BS EN IEC/IEEE 60980-344:2021



BSI Standards Publication

Nuclear facilities – Equipment important to safety – Seismic qualification

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National foreword

This British Standard is the UK implementation of EN IEC/IEEE 60980-344:2021. It is identical to IEC/IEEE 60980-344:2020. It supersedes BS IEC/IEEE 60980-344:2020, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/8, Instrumentation, Control & Electrical Systems of Nuclear Facilities.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Amendments/corrigenda issued since publication

Date	Text affected
31 May 2021	This corrigendum renumbers BS IEC/IEEE 60980-344:2020 as BS EN IEC/IEEE 60980-344:2021

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC/IEEE 60980-344

April 2021

ICS 27.120.10; 27.120.20

English Version

Nuclear facilities - Equipment important to safety - Seismic qualification (IEC/IEEE 60980-344:2020)

Installations nucléaires - Equipements importants pour la sûreté - Qualification sismique (IEC/IEEE 60980-344:2020)

Kerntechnische Anlagen - Gerät mit sicherheitstechnischer Bedeutung - Seismische Qualifizierung (IEC/IEEE 60980-344:2020)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

The text of document 45A/1323/FDIS, future edition 1 of IEC/IEEE 60980-344, prepared by SC 45A "Instrumentation, control and electrical power systems of nuclear facilities" of IEC/TC 45 "Nuclear instrumentation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC/IEEE 60980-344:2021.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2022-01-19
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2024-04-19

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As stated in the nuclear safety directive 2009/71/EURATOM, Chapter 1, Article 2, item 2, Member States are not prevented from taking more stringent safety measures in the subject-matter covered by the Directive, in compliance with Community law.

In a similar manner, this European standard does not prevent Member States from taking more stringent nuclear safety and/or security measures in the subject-matter covered by this standard.

Endorsement notice

The text of the International Standard IEC/IEEE 60980-344:2020 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-3-3	NOTE	Harmonized as EN IEC 60068-3-3
IEC 60068-2-81	NOTE	Harmonized as EN 60068-2-81
IEC 60068-2-47	NOTE	Harmonized as EN 60068-2-47
IEC 60068-2-57	NOTE	Harmonized as EN 60068-2-57

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC/IEEE 60780-323	-	Nuclear facilities - Electrical equipment important to safety - Qualification	EN 60780-323	-

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NUCLEAR FACILITIES – EQUIPMENT IMPORTANT TO SAFETY – SEISMIC QUALIFICATION

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

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8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

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International Standard IEC/IEEE 60980-344 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with Nuclear Power Engineering Committee of the IEEE, under the IEC/IEEE Dual Logo Agreement.

It is published as an IEC/IEEE dual logo standard.

This new edition cancels and replaces the first edition of IEC 60980, published in 1989, and constitutes a technical revision. It also supersedes IEEE Std 344™-2013.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
45A/1323/FDIS	45A/1334/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

a) Technical background, main issues and organisation of the Standard

This standard is applicable to electrical equipment important to safety and its interfaces that are necessary to perform a safety function, or whose failure could adversely affect the safety functions of other equipment.

Electrical equipment in nuclear facilities shall meet its safety function requirements throughout its installed life. This is accomplished by a thorough programme of quality assurance, design control, quality control, qualification, production, transportation, storage, installation, maintenance, periodic testing, and surveillance. This IEC/IEEE standard specifically focuses on seismic qualification. This standard shall be used in conjunction with IEC/IEEE 60780-323.

Other aspects, relating to quality assurance, reliability, selection and use of electronic devices, design and modification of digital systems including Verification and Validation (V&V) activities are not part of this standard.

Industry research in the area of equipment qualification and decades of its application have greatly benefited this standard. Future activities of the working group to update this standard will consider the following:

- Experience and knowledge gained by using condition monitoring techniques,
- Knowledge gained on ageing mechanisms and kinetics,
- Improvement in the use of methods (test and analysis) described throughout the standard,
- Improvement of computation tools and modalities of use.

It is intended that the Standard be used by operators of NPPs (utilities), systems evaluators, equipment manufacturers, test facilities, qualification laboratories and by licensors.

b) Situation of the current standard in the structure of the IEC SC 45A standard series

IEC 61513 and IEC 63046 are first level IEC SC 45A documents that give guidance applicable to Instrumentation and Control (I&C) system and electrical power systems (at system level). They are completed by guidance relative to functional classification (IEC 61226).

These documents are supplemented by second level IEC SC 45A documents. Second level IEC SC 45A documents give guidance on hardware design (IEC 60987), software (IEC 60880 and IEC 62138), selection and use of HDL programmed integrated circuits (IEC 62566), requirements in order to reduce the possibility and limit the impact of common cause failure of category A functions (IEC 62340), qualification (IEC/IEEE 60780-323, IEC/IEEE 60980-344 and IEC 62003), control room design (IEC 62342) and cybersecurity (IEC 62645).

IEC/IEEE 60980-344 is a second level IEC SC 45A document which focuses on seismic qualification of electrical equipment important to safety.

For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

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c) Recommendations and limitations regarding the application of this standard

This dual logo standard applies to all electrical equipment important to safety in accordance with IAEA terminology. If using IEEE standards, this standard applies to systems, structures, and components classified as safety or safety-related. If using the IEC 61226 and IEC 61513 classification guidance, this standard applies to all Class 1, 2 and 3 equipment. This document shall only be applied in accordance with the single selected classification scheme, either IEC or IEEE.

To ensure that the Standard will continue to be relevant in future years, the emphasis has been placed on issues of principle, rather than specific technologies.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply systems of the I&C systems. IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45 standard series, corresponds to the Technical Reports which are not normative.

The IEC SC 45A standards series consistently implements and details the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA requirements SSR-2/1, establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs and the implementing guide NSS 17 for computer security at nuclear facilities. The safety and security terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

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IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 and IEC 63046 refer to ISO as well as to IAEA GS-R part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA). At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC/SC 45A security standards. It builds upon the valid high level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards and IEC 62342 is the entry document for the ageing management standards.

NOTE 1 It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, process energy hazards) international or national standards would be applied.

NOTE 2 IEC/SC 45A domain was extended in 2013 to cover electrical systems. In 2014 and 2015 discussions were held in IEC/SC 45A to decide how and where general requirements for the design of electrical systems were to be considered. IEC/SC 45A experts recommended that an independent standard be developed at the same level as IEC 61513 to establish general requirements for electrical systems. Project IEC 63046 is now launched to cover this objective. When IEC 63046 is published, this Note 2 of the introduction of IEC/SC 45A standards will be suppressed.

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NUCLEAR FACILITIES – EQUIPMENT IMPORTANT TO SAFETY – SEISMIC QUALIFICATION

1 Scope

This International Standard describes methods for establishing seismic qualification procedures that will yield quantitative data to demonstrate that the equipment can meet its performance requirements. This document is applicable to electrical, mechanical, instrumentation and control equipment/components that are used in nuclear facilities. This document provides methods and documentation requirements for seismic qualification of equipment to verify the equipment's ability to perform its specified performance requirements during and/or after specified seismic demands. This document does not specify seismic demand or performance requirements. Other aspects, relating to quality assurance, selection of equipment, and design and modification of systems, are not part of this document. As seismic qualification is only a part of equipment qualification, this document is used in conjunction with IEC/IEEE 60780-323.

The seismic qualification demonstrates equipment's ability to perform its safety function(s) during and/or after the time it is subjected to the forces resulting from at least one safe shutdown earthquake (SSE/S2). This ability is demonstrated by taking into account, prior to the SSE/S2, the ageing of equipment and the postulated occurrences of a given number of lower intensity operating basis earthquake (OBE/S1). Ageing phenomena to be considered, if specified in the design specification, are those which could increase the vulnerability of equipment to vibrations caused by an SSE/S2.

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.

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC/IEEE 60780-323, *Nuclear facilities – Electrical equipment important to safety – Qualification*[1,2]

IEEE Std 382™, *IEEE Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations*

3 Terms and definitions

The terminology and definitions used in this document are consistent with IAEA Safety Glossary[3].

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1 IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).

2 The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

3 IAEA safety glossary is available at https://www.iaea.org/publications/11098/iaea-safety-glossary-2019-edition

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For the purposes of this document, the following terms and definitions apply.

ISO, IEC, and IEEE maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp
- IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

The *IEEE Standards Dictionary Online* should be consulted for terms not defined in these databases.[4]

3.1
acceptance criteria
specified bounds on the value of a functional indicator or condition indicator used to assess the ability of a structure, system or component to perform its design function

Note 1 to entry: Value(s) of performance parameters and other criteria to demonstrate that equipment can perform the safety function(s) shall be identified.

[SOURCE: IAEA Safety Glossary, 2018]

3.2
assembly
comprising all electrical, mechanical, and structural components of the equipment including a common mounting and supporting structure

3.3
broadband response spectrum
response spectrum that describes motion in which amplified response occurs over a wide (broad) range of frequencies

3.4
Class 1E
safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment

Note 1 to entry: Users of this standard are advised that “Class 1E” is a functional term. Equipment and systems are to be classified Class 1E only if they fulfill the functions listed in the definition. Identification of systems or equipment as Class 1E based on anything other than their function is an improper use of the term and should be avoided.

[SOURCE: IEEE Standards Dictionary Online]

3.5
components
one of the parts that make up an equipment. A component may be a hardware component (e.g., wires, transistors, integrated circuits, motors, relays, solenoids, pipes, fittings, pumps, tanks and valve or a software component). A component may be made up of other components

Note 1 to entry: Components are items from which equipment is assembled.

Note 2 to entry: The terms component and device are interchangeable.

[SOURCE: IAEA Safety Glossary, 2018]

4 *IEEE Standards Dictionary Online subscription* is available at: http://dictionary.ieee.org

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3.6
coherence function
comparative relationship between two time histories as a function of frequency

Note 1 to entry: It provides a statistical estimate of how much two motions are related, as a function of frequency.

Note 2 to entry: The numerical range is from zero for unrelated to +1,0 for related motions.

3.7
correlation coefficient function
comparative relationship between two time histories, as a function of time delay

Note 1 to entry: It provides a statistical estimate of how much two motions are related, as a function of time delay.

Note 2 to entry: The numerical range is from −1,0 for inversely related motions, zero for unrelated, to +1,0 for related motions.

3.8
critical damping
least amount of viscous damping that causes a single-degree-of-freedom (SDOF) system to return to its original position without oscillation after initial disturbance

[SOURCE: IEEE Standards Dictionary Online]

3.9
critical seismic characteristics
design, material, and performance characteristics of an equipment item that provide reasonable assurance that the item will perform its required function under seismic loads

3.10
cutoff frequency
frequency in the response spectrum where the zero period acceleration (ZPA) asymptote begins

Note 1 to entry: This is the frequency beyond which the single-degree-of-freedom (SDOF) oscillators exhibit no amplification of motion and indicates the upper limit of the frequency content of the waveform being analysed.

3.11
damping
energy dissipation mechanism that reduces the amplification and broadens the vibratory response in the region of resonance

Note 1 to entry: It is usually expressed as a percentage of critical damping.

3.12
design basis events
postulated events used in the design to establish the acceptable performance requirements for the structures, systems, and components

Note 1 to entry: The postulated design basis event (DBE) conditions including specified high-energy line break, loss-of-coolant accident, main steam line break, and/or seismic events to be taken into account for plant design, during or after which the equipment is required to perform its safety function(s), shall be specified.

Note 2 to entry: Equipment shall be qualified for the duration of its operational performance requirement for each applicable DBE condition, including any required post-DBE operation period.

[SOURCE: IEEE Standards Dictionary Online]

3.13
earthquake experience spectrum
response spectrum that defines the seismic capacity of a reference equipment class based on earthquake experience data

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3.14
equipment important to safety
equipment that is part of a safety group and/or whose malfunction or failure could lead to undue radiation exposure of the site personnel or members of the public. Equipment including:

- Those structures, systems and components whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public;
- Those structures, systems and components that prevent anticipated operational occurrences from leading to accident conditions;
- Safety features for design extension conditions;
- Those features that are provided to mitigate the consequences of malfunction or failure of structures, systems and components.

Note 1 to entry: For usage consistent with IEC 61226, equipment important to safety are as follows:

- all I&C equipment performing Category A to Category C functions (in accordance with the IEC 61226 categorisation scheme),
- all electrical equipment needed to ensure emergency energy supply to this equipment in case of a loss of normal power supply,
- all electrical equipment needed to ensure ultimate energy supply in case of total loss of on-site power (if selected as design extension condition to be mitigated).

Note 2 to entry: For usage consistent with other IEEE documents and a Class 1E categorization; for equipment important to safety, qualification is essential for the following:

- equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or
- equipment that are otherwise essential in preventing significant release of radioactive material to the environment.

[SOURCE: IAEA Safety Glossary, 2018]

3.15
flexible equipment
equipment, structures, and components whose lowest resonant frequency is less than the cutoff frequency on the response spectrum

3.16
floor acceleration
acceleration of a particular building floor (or equipment mounting) resulting from the motion of a given earthquake

Note 1 to entry: The maximum floor acceleration is the zero period acceleration (ZPA) of the floor response spectrum.

3.17
fragility level
highest level of input excitation, expressed as a function of input frequency, acceleration and test duration, under which equipment remains able to fulfill its performance requirements

3.18
fragility response spectrum
response spectrum that defines the ultimate seismic capability of the equipment under test based upon fragility data

3.19
ground acceleration
acceleration of the ground resulting from the motion of a given earthquake

Note 1 to entry: The maximum ground acceleration is the zero period acceleration (ZPA) of the ground response spectrum.

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3.20
inclusion rules
rules that define the bounds of equipment included in a reference equipment class based on an acceptable range of equipment physical characteristics, dynamic characteristics, and functions for which seismic ruggedness has been demonstrated by experience data

Note 1 to entry: See A.2.4.2 and A.3.4.2.

3.21
independent items
components and equipment that:

a) have different physical characteristics, or

b) experience different seismic motion characteristics, e.g., different earthquakes, different sites, different buildings, or different orientations/locations in the same building

3.22
median-centered in-structure response spectrum
in-structure response spectrum developed using realistic damping and best estimate modeling parameters to obtain the most probable structural amplification that could realistically occur for the level of the specified earthquake ground motion

3.23
narrowband response spectrum
response spectrum that describes the motion in which amplified response occurs over a limited (narrow) range of frequencies

3.24
natural frequency
frequency(ies) at which a body vibrates due to its own physical characteristics (mass and stiffness) when the body is distorted in a specific direction and then released

3.25
operating basis earthquake
earthquake that could reasonably be expected to occur at the plant site during the operating life of the plant considering the regional and local geology and seismology and specific characteristics of local subsurface material

Note 1 to entry: It is that earthquake that produces the vibratory ground motion for which those features of the nuclear power plant, necessary for continued operation without undue risk to the health and safety of the public, are designed to remain functional.

3.26
performance requirement
requirement that imposes performance characteristics (conditions) on the functional and structural requirements of the equipment or system

3.27
power spectral density
mean squared amplitude per unit frequency of a waveform

Note 1 to entry: Expressed in acceleration spectral density versus frequency $[m/s^2]^2$ /Hz (g^2 /Hz) for acceleration waveforms.

Note 2 to entry: The characterization of random vibration typically results in a frequency spectrum of power spectral density (PSD), or Acceleration Spectral Density (ASD).

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3.28
prohibited features
design details, materials, construction features, or installation characteristics that have resulted in seismic induced failure or malfunction of the equipment to maintain its structural integrity and perform its specified function at earthquake or test excitations up to and including the defined seismic capacity level

3.29
proof testing
test used to qualify equipment for a particular application or to a particular requirement

[SOURCE: IEEE Standards Dictionary Online]

3.30
qualified condition
condition of equipment, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions

Note 1 to entry: This could include certain post-accident cooling and monitoring systems that are expected to remain operational.

3.31
qualified life
period for which a structure, system or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in accident conditions or earthquake

Note 1 to entry: At the end of the qualified life, the equipment shall be capable of performing the safety function(s) required for the postulated design basis and post design basis events.

[SOURCE: IAEA Safety Glossary, 2018]

3.32
reference equipment
equipment used to establish a reference equipment class

3.33
reference equipment class
group of equipment sharing common attributes as defined by a set of inclusion rules and prohibited features

3.34
reference site
site containing equipment or items used to establish a reference equipment class

3.35
required response spectrum
response spectrum issued by the user or the user's agent as part of the specifications for qualification or artificially created to cover future applications

Note 1 to entry: The required response spectrum (RRS) constitutes a requirement to be met and includes the test margin required by IEC/IEEE 60780-323.

3.36
resonant frequency
frequency at which a response peak occurs in a system subjected to forced vibration. This frequency is accompanied by a phase shift of response relative to the excitation

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3.37
response spectrum
plot of the maximum response, as a function of oscillator frequency, of an array of single-degree-of-freedom (SDOF) damped oscillators subjected to the same base excitation

3.38
rigid equipment
equipment, structures, and components whose lowest resonant frequency is greater than the cutoff frequency on the response spectrum

3.39
safe shutdown earthquake
earthquake that is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake that produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional. These structures, systems, and components are those necessary to provide reasonable assurance of the following:

a) Integrity of the reactor coolant pressure boundary;

b) Capability to shut down the reactor and maintain it in a safe shutdown condition;

c) Capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to applicable regulatory requirements.

3.40
safety function
a specific purpose that must be accomplished for safety of a facility to prevent or to mitigate radiological consequences in normal operation, anticipated operational occurrences and accident conditions

[SOURCE: IAEA Safety Glossary, 2018]

3.41
seismic capacity
highest seismic level for which required adequacy of performance has been verified

3.42
service conditions
actual physical states or influences during the service life of equipment, including normal operating conditions, abnormal operating conditions, design basis event conditions and design extension conditions

Note 1 to entry: In 2007 edition of IAEA safety glossary, accident conditions include both design basis accident and beyond design basis accident. This second notion has been replaced within IAEA by the notion of design extension conditions (DEC) [IAEA, SSR-2/1]. Equipment needed in case of DEC shall be qualified accordingly. It explains the need of changing the definition.

[SOURCE: IAEA Safety Glossary, 2007, modified: see Note 1 to entry.]

3.43
service life
period from initial operation to final withdrawal from service of a structure, system or component

[SOURCE: IAEA Safety Glossary, 2018]

3.44
Seismic Category I equipment
equipment designed to withstand the effects of the safe shutdown earthquake (SSE/S2) and perform its safety function during and/or after the SSE/S2 while maintaining structural integrity

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3.45
Seismic Category II equipment
equipment that is not required to function but whose failure could adversely affect the safety function of other equipment

Note 1 to entry: It should be designed to mitigate against failure that could adversely affect the performance of any Seismic Category I equipment or could result in incapacitating injury to occupants of the facility (e.g., control room) that could impact the safe operation of the plant.

3.46
seismic ruggedness
ability to resist the damaging effects of an earthquake imparted by robust design and manufacture

3.47
seismic vulnerability
physical and/or electrical characteristic that renders an equipment item susceptible to structural damage or malfunction from the effects of an earthquake

3.48
sine beats
continuous sinusoid of one frequency, amplitude modulated by a sinusoid of a lower frequency

3.49
sine dwell
continuous sinusoid at a single-frequency

3.50
stationarity
condition that exists when a waveform's amplitude distribution, frequency content, and other descriptive parameters are statistically constant with time

3.51
strong motion
time portions of the test acceleration time history where the first acceleration peak reaches and exceeds 25 % of the maximum peak value to the time when it falls for the last time below the 25 % of maximum peak value

3.52
structure diameter
diameter of a circle having the equivalent area of the facility's foundation

3.53
test experience spectra
test-based response spectra that define the seismic capacity of a reference equipment class

3.54
test frequency
frequency of the applied force by which equipment is excited during the test

3.55
test response spectrum
response spectrum that is developed from the actual time history of the motion of a seismic test table (commonly called a shake table)

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3.56
transfer function
complex frequency response function that defines the dynamic characteristics of a constant parameter linear system

Note 1 to entry: For an ideal system, the transfer function is the ratio of the Fourier transform of the output to that of a given input.

3.57
zero period acceleration
acceleration level of the high-frequency, nonamplified portion of the response spectrum

Note 1 to entry: This acceleration corresponds to the maximum peak acceleration of the time history used to derive the spectrum.

4 Abbreviated terms

ASCE	American Society of Civil Engineers
ASD	Acceleration Spectral Density
ASME	American Society of Mechanical Engineers
DBE	Design Basis Event
DEC	Design Extension Conditions
EES	Earthquake Experience Spectrum
FFT	Fast Fourier Transform
HELB	High Energy Line Break
HVAC	Heating, Ventilation, and Air Conditioning
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LOCA	Loss-of-Coolant Accident
OBE/S1	Operating Basis Earthquake
PSD	Power Spectral Density
QA	Quality Assurance
RMS	Root Mean Square
RRS	Required Response Spectrum
RSA	Response Spectrum Analysis
SC-I	Seismic Category I
SC-II	Seismic Category II
SC-II/I	Seismic Category II over I
SDOF	Single-degree-of-freedom
SRSS	Square Root of the Sum of the Squares
SRV	Safety Relief Valve
SSE/S2	Safe Shutdown Earthquake
TES	Test Experience Spectrum
TRS	Test Response Spectrum
U.S. NRC	United States Nuclear Regulatory Commission

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V&V Verification and Validation

ZPA Zero Period Acceleration

3D Three-dimensional

5 General discussion of earthquake environment and equipment response

5.1 General

This clause provides background information on earthquake behaviour and on the performance of equipment during simulated seismic events. Numerical values provided are typical and illustrative and should not be considered as standards. The flowchart provided in Figure G.1 illustrates the establishment of the seismic conditions from the earthquake to the equipment being qualified.

5.2 Earthquake environment

Earthquakes are initiated by rupture and slippage along geologic faults. Earthquakes produce three-dimensional (3D) random ground motions that are characterized by simultaneous but statistically independent horizontal and vertical components. The ground motion is typically broadband random and produces potentially damaging effects over a frequency range of 1 Hz to the cutoff frequency of the response spectra. The cutoff frequency is generally between 32 Hz and 50 Hz for a building structure subjected to an earthquake with the exception of hard rock regions of the Central and Eastern U.S. and other parts of the world which may experience energy content up to 100 Hz. The cutoff frequency may be greater if additional vibration induced loads are combined with seismic loads.

The strong motion portion of the earthquake may last from 10 s to 15 s, although the complete event may be considerably longer and produce a horizontal ground acceleration from 0,1 g to 0,6 g or higher. Duration of strong motion is dependent upon ground soil type, distance from the fault, energy released by the rupture, and slippage along a geological fault.

5.3 Equipment on foundations

The vibratory level of the ground motion (both horizontal and vertical) can be amplified or attenuated in foundation-mounted equipment. For any given ground motion, the alteration depends on the natural frequencies of vibration (soil, foundation, intermediate structure and equipment), the stiffness, the mass and the geometry of the building and intermediate structures and the damping mechanisms (damping coefficient may depend on frequencies considered). The broadband response spectra that typically describe the ground motion indicate that multiple-frequency excitation predominates.

5.4 Equipment on structures

The ground motion (horizontal and vertical) can be filtered by intervening building structures to produce amplified or attenuated narrowband motions within the structure. The dynamic response of equipment on structures can be further amplified or attenuated to an acceleration level many times more or less than that of the maximum ground acceleration, depending upon the equipment damping and natural frequencies. The narrowband response spectra that typically describe a building floor motion indicate that single-frequency excitation can be predominant. Filtering of in-structure motion can occur in flexible piping systems. For components mounted away from piping supports, the resultant motion can be predominantly single frequency in nature and centered near or at the resonant frequency of the piping system. This resonance condition can produce the most critical seismic load on components mounted on the pipe line.

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5.5 Interfaces and adverse interactions

Some equipment may have interfaces in an electrical or mechanical way or located in close proximity to each other. Seismic qualification of equipment shall consider installation features (e.g., support assembly and anchorage) and the potential for adverse seismic interactions (such as falling of overhead components, proximity impacts, differential displacements, spray, flood, or fire). If two pieces of equipment have mechanical or electrical interfaces, the effect of differential relative displacement of both equipment induced by earthquake shall be evaluated by considering resulting constraints at interface level and by proving (through analysis and/or test) there is no impact to performance function(s) required during and/or after seismic conditions. This demonstration may rely on specific test modalities (methods and procedures).

5.6 Simulating vibration induced by an earthquake

5.6.1 General

The main damaging potential of equipment caused by an earthquake is dependent on the ground motion excitation intensity (ZPA), the number of peak amplitude cycles, duration of excitation, and the excitation amplification caused by the structural response of the building and/or system upon which the equipment is installed. The goal of seismic simulation is to replicate the postulated earthquake environment in a realistic manner. The form of the simulated seismic motion used for the qualification of equipment by analysis or testing can be described by one of the following functions:

a) Response spectrum;

b) Time history;

c) Power spectral density (PSD).

The simulated seismic motion may be generated for the foundation, floor of the building, or substructure upon which the equipment is to be mounted. It is supplied by the user or the user's agent as a part of the specifications for that equipment (see Clause 6) or generated by others for generic applications.

Because of the directional nature of seismic motion and the filtered output motion of building and equipment structures, the directional components of the motion and their application to the equipment should be specified or accounted for in some other appropriate manner.

5.6.2 Response spectrum

The response spectrum provides information on the maximum response of single-degree-of-freedom (SDOF) oscillators as a function of oscillator frequency and damping when subjected to an input motion. The frequency content and the peak value of the input motion, that is, the ZPA, are indicated.

It is important to recognize that the response spectrum does not supply the following information:

a) The waveform or time history of the excitation that produced it;

b) The duration of motion (shall be defined in the qualification specification);

c) The dynamic response of any particular equipment.

The waveform of the excitation is generally determined by considering existing earthquake records and specificities of the site. The total duration of motion as well as the duration of strong motion shall be defined in the procurement or design specification. If strong motion duration is not specified, or no other site-specific information/requirement is specified, then the duration of strong motion for seismic testing should be a minimum of 15 s. Dynamic response of equipment is determined by considering its natural frequency and damping characteristics. If the equipment exhibits no amplification below the cutoff frequency, the equipment is considered to be rigid.

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5.6.3 Time history

A time history is a form of earthquake-induced motion defined in terms of acceleration as a function of time. The simulated motion is derived from existing or artificially generated earthquake records. For application at any floor, the time history record generated includes the dynamic filtering and amplification effects of the building and other intervening support structures. It is possible by knowing time history displays to determine, through discrete Fast Fourier Transform (FFT) analysis, acceleration as a function of frequency. There is no one-to-one relationship between a response spectrum and a time history, since a given response spectrum can be fulfilled by several different time histories.

5.6.4 PSD function

The Power Spectral Density (PSD) is the mean squared acceleration of the vibratory motion and is characterized in terms of the PSD as a function of frequency. PSD gives an indication of the frequency distribution of power in the acceleration signal (measure of signal power over the frequency range) and is typically used to characterize broadband stationary random vibration motion. For vibration data, PSD amplitude is in units of $[m/s^2]^2$ /Hz or g^2 /Hz. According to Parseval's theorem the square root of the total area under the PSD-curve is equal to the root mean square (RMS) acceleration calculated in the time domain. The PSD provides information regarding the excitation directly without including the effects on an array of SDOF oscillators as is done for the response spectrum. The PSD function does not define the exact waveform or duration of the excitation but enables significant frequency-dependent properties of the motion to be seen at a glance from one curve. The PSD allows application of relationships between excitation and response by way of the transfer functions for linear systems.

5.7 Damping

5.7.1 General

Damping is the generic name ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends on many parameters, such as the structural system, mode of vibration, strain, normal force, velocity, materials, joint, and slippage. In linear vibration theory, the simplifying assumption is made that damping is purely viscous or proportional to the relative velocity of moving parts. Therefore, when a value of damping is associated with a practical system, it is usually assumed to be equivalent to viscous or linear. This is a convenient simplification relating real-world hardware behaviour, which may be nonlinear to some degree, with theoretical concepts that normally utilize linear methods of analysis.

It is reasonable to state that actual damping is nonlinear by nature. In most equipment, it is a function of response amplitude owing to such factors as internal friction within material, or at connections between components, or Coulomb-type sliding friction. For analytical purposes, these energy dissipation damping mechanisms may often be treated in terms of linear damping approximations if proper consideration is given to the fact that these approximations vary, sometimes significantly, with increasing response. As an example, the use of low-impedance testing to determine damping shall be exercised with caution since at strong motion shaking, indicative of significant earthquakes, the aforementioned factors may cause the real damping to be quite different and higher than that measured at low levels.

For equipment composed of an assembly of components, there is usually no single value of damping. Damping is associated with every part of the equipment, ranging from bolted or welded construction to uniform material. The value of damping may vary from place to place, depending on numerous factors. Therefore, when a value of damping is ascribed to equipment, it is common to give a range of typical values. Since each mode of vibration of a structure can, and most often does, have a different value of damping, a useful practice in analysis is to associate a value of damping to each mode of vibration of the equipment that is in the frequency range of interest.

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