U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE 1.61, REVISION 2

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DAMPING VALUES FOR SEISMIC DESIGN OF NUCLEAR POWER PLANTS

A. INTRODUCTION

Purpose

This regulatory guide (RG) provides guidance on damping values that the staff of the U.S. Nuclear Regulatory Commission (NRC) finds acceptable for use in the seismic response analysis of seismic Category I nuclear power plant structures, systems, and components (SSCs). The specified damping values are intended for elastic dynamic seismic analysis where energy dissipation is accounted for by viscous damping.

Applicability

This RG applies to applicants for a construction permit or operating license for a nuclear power plant under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1), or a design certification, combined license, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2).

Applicable Regulations

- 10 CFR Part 50 provides regulations for licensing production and utilization facilities.
    - General Design Criterion 2, "Design bases for protection against natural phenomena," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes without losing the ability to perform their safety functions. Such SSCs must also be designed to accommodate the effects of and be compatible with the environmental conditions associated with normal operation and postulated accidents.
    - 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," specifies the requirements for the implementation of General Design Criterion 2 with respect to earthquakes.

Written suggestions regarding this guide may be submitted through the NRC's public website in the NRC Library at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html., under Document Collections, in Regulatory Guides, at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/contactus.html, and will be considered in future updates and enhancements to the "Regulatory Guide" series. During the development process of new guides suggestions should be submitted within the comment period for immediate consideration. Suggestions received outside of the comment period will be considered if practical to do so or may be considered for future updates.

Electronic copies of this RG, previous versions of RGs, and other recently issued guides are also available through the NRC's public website in the NRC Library at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html/under Document Collections, in Regulatory Guides. This RG is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession Number (No.) ML23284A272. The regulatory analysis may be found in ADAMS under Accession No. ML22273A041. The associated draft guide DG-1364 may be found in ADAMS under Accession No. ML22273A040, and the staff responses to the public comments on DG-1364 may be found under ML23284A274.

- 10 CFR Part 52 governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities.

  - 10 CFR 52.47, "Contents of applications; technical information," contains requirements on the technical content of applications for standard design certifications submitted under 10 CFR Part 52.

  - 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," contains requirements on the technical content of combined license applications.

- Appendix A to 10 CFR Part 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," (Ref. 3) provides in Section VI earthquake engineering criteria for nuclear power plants applicable to an operating license applicant or holder whose construction permit was issued prior to January 10, 1997.

Related Guidance

- RG 1.243, "Safety-Related Steel Structures and Steel-Plate Composite Walls for Other than Reactor Vessels and Containments," (Ref. 4) describes a method that the NRC staff considers acceptable for compliance with NRC regulations for the design, fabrication, and erection of safety-related steel structures and steel-plate composite (SC) walls for other than nuclear power plant containments.

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (Ref. 5), which provides guidance to the NRC staff in its review of safety analysis reports submitted as part of a nuclear power plant license application.

Purpose of Regulatory Guides

The NRC issues RGs to describe methods that are acceptable to the staff for implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. Regulatory guides are not NRC regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50, 52, and 100 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.). These information collections were approved by the Office of Management and Budget (OMB), under control number 3150-0011, 3150-0151, and 3150-0093, respectively. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch ((T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by email to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0011, 3150-0151, and 3150-0093), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW, Washington, DC 20503; e-mail: oira_submission@omb.eop.gov.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

RG 1.61, Revision 1, specifies the damping values that the NRC staff considers acceptable for complying with the agency's regulations for seismic analysis. This revision of the RG (Revision 2) provides additional guidance related to concrete properties and damping values for use in the development of in-structure response spectra (ISRS). It also includes guidance on damping for steel-plate composite walls. In addition, it updates the guidance for piping damping in RG 1.61, Revision 1.

Background

The NRC published Revision 1 of RG 1.61 in March 2007 to provide acceptable damping values for use in the seismic response analysis of Seismic Category I nuclear power plant structures, systems, and components (SSCs). Since the issuance of Revision 1 of RG 1.61, updated criteria related to the concrete properties and damping values for use in the development of in-structure response spectra has become available. Additionally, new construction technologies for nuclear plants, namely, steel plate composite structures have been proposed and used by the industry. This revision of RG 1.61 updates regulatory position C.1.2 for consistency with NUREG-0800 Section 3.7.2 (Revision 4), subsection II.3.C which includes additional acceptance criteria related to the concrete properties and damping values for use in the development of in-structure response spectra (ISRS). This revision also includes guidance on damping for steel plate composite structures for use with the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE). Additionally, the revision also considers updates in the codes and standards for design and analysis of nuclear power plant structures and equipment including piping.

Damping

Damping is a measure of the energy dissipation of a material or structural system as it responds to dynamic excitation. It is a term used to assist in mathematically modeling and solving dynamic equations of motion for a vibratory system in which energy is dissipated. When performing an elastic dynamic analysis, one can account for the energy dissipated by specifying the amount of viscous damping (i.e., damping force proportional to the velocity) in the analytical model. This RG, first issued in October 1973 (Ref. 6), presents current NRC guidance on damping values to be used in the elastic design of nuclear power plants.

Structural Damping

In August 2021, the NRC issued RG 1.243, which endorses, with exceptions and clarifications, the 2018 edition of American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC) N690, "Specification for Safety-Related Steel Structures for Nuclear Facilities" (Ref. 7). ANSI/AISC N690 includes damping values for steel-plate composite walls for the SSE and operating-basis earthquake OBE seismic analyses. Section C of this revised RG includes such values. Except for the damping values for steel-plate composite walls, which are new to this revision, the structural damping values in this RG are the same as those in Revision 1, issued March 2007 (Ref. 8), and follow the recommendations and reported results in NUREG/CR-6011, "Review of Structure Damping Values for Elastic Seismic Analysis of Nuclear Power Plants," issued March 1993 (Ref. 9).

Piping Damping

The damping values specified for SSE and OBE analyses of piping systems in section C, Table 3, of this RG are the same as those for Revision 1. NUREG/CR-6919, "Recommendations for Revision of Seismic Damping Values in Regulatory Guide 1.61," issued November 2006 (Ref. 10), provides the technical justification for the piping damping values in Table 3 in Regulatory Position 2. Since frequency dependent damping is no longer in the applicable design codes and standards, this revision (Revision 2) of RG 1.61 is updated to remove the guidance for its use.

Electrical Distribution System Damping

Regulatory Position 3 in section C of this RG provides the damping values that resulted from the review of cable tray test data in A.G. Ware, and C.B. Slaughterbeck, "A Survey of Cable Tray and Conduit Damping Research," Idaho National Engineering Laboratory, Report No. EGG-EA-7346, Revision 1 (Ref. 11), and results of NRC staff safety evaluation reports of the Comanche Peak Steam Electric Station and Watts Bar Nuclear Plant (NUREG-0797, "Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2," Supplement No. 16 [Ref 12], and NUREG-0847, "Safety Evaluation Report Related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2," Supplement No. 8, [Ref. 13]).

Heating, Ventilation, and Air Conditioning Duct Damping

The damping values for heating, ventilation, and air conditioning (HVAC) systems are consistent with the guidance provided for bolted steel structures. Because no tests of welded duct construction have been identified, the damping values provided in Regulatory Position 4 in section C are the same as those for welded steel structures. NUREG/CR-6919 contains related information on the selection of HVAC duct damping values.

Mechanical and Electrical Component Damping

The mechanical and electrical component damping values in Regulatory Position 5 are identical to those in Revision 1 of RG 1.61. The damping values in this RG apply to passive subcomponents that are amenable to qualification by analysis. Seismic qualification by analysis is not readily applicable to active components, which require qualification by testing. NUREG-0800, section 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment," addresses seismic qualification by testing. NUREG/CR-6919 comments further on the characteristics and types of passive and active components.

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety Requirements and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports, reflects an international perspective on what constitutes a high level of safety. To inform its development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides pursuant to the Commission's International Policy Statement (Ref. 14) and Management Directive and Handbook 6.6, "Regulatory Guides" (Ref. 15).

The following IAEA Safety Requirements and Guides were considered in the update of the Regulatory Guide:

- IAEA Safety Guide NS-G-1.6, “Seismic Design and Qualification for Nuclear Power Plants,” issued 2003 (Ref. 16)

C. STAFF REGULATORY GUIDANCE

The following regulatory positions provide acceptable damping values to be used in the elastic dynamic seismic analysis and design of SSCs, where energy dissipation is approximated by viscous damping unless otherwise specified. Damping values higher than those provided may be used if documented test data support the higher values. Damping values associated with soil-structure interaction analysis are beyond the scope of this RG.

1. Structural Damping

1.1 Acceptable Structural Damping Values for Containment Structures, Containment Internal Structures, and Other Seismic Category I Structures

1.1.1 *Safe-Shutdown Earthquake*

Table 1 provides acceptable damping values for the SSE analysis.

Table 1 SSE Damping Values

Structural Material	**Damping** (% of Critical Damping)
Reinforced Concrete	7%
Reinforced Masonry	7%
Prestressed Concrete	5%
Steel-Plate Composite Walls	5%
Welded Steel or Bolted Steel with Friction Connections	4%
Bolted Steel with Bearing Connections	7%

Note: For steel structures with a combination of different connection types, use the lowest specified damping value, or as an alternative, use a "weighted average" damping value based on the number of connections of each type present in the structure.

1.1.2 *Operating-Basis Earthquake*

If the design-basis OBE ground acceleration is selected to be less than or equal to one-third of the design-basis SSE ground acceleration, then a separate OBE analysis is not required. However, if the design-basis OBE ground acceleration is selected to be greater than one-third of the design-basis SSE ground acceleration, then a separate OBE analysis should be conducted. Table 2 provides acceptable damping values for the OBE analysis.

Table 2 OBE Damping Values

Structural Material	**Damping** (% of Critical Damping)
Reinforced Concrete	4%
Reinforced Masonry	4%
Prestressed Concrete	3%
Steel-Plate Composite Walls	3%

Structural Material	Damping (% of Critical Damping)
Welded Steel or Bolted Steel with Friction Connections	3%
Bolted Steel with Bearing Connections	5%

1.2 Special Consideration for Generation of In-Structure Response Spectra

The SSE damping values specified in Table 1 for linear dynamic analysis of structures have been selected based on the expectation that the structural response attributed to load combinations that include the SSE will be close to the applicable code stress limits, as defined in Chapter 3, "Design of Structures, Components, Equipment, and Systems," of NUREG-0800.

However, in some cases, the predicted structural response to load combinations that include the SSE may be significantly below the applicable code stress limits. Because equivalent viscous damping ratios have been shown to depend on the structural response level, the SSE damping values in Table 1 may be inconsistent with the predicted structural response level.

For structural evaluation, this is not a concern, because the stresses resulting from the use of the damping-compatible structural response will still be less than the applicable code stress limits. However, for ISRS generation, it is necessary to use damping compatible with the structural response stress levels. Consequently, the following additional guidance is provided for analyses used to determine ISRS:

(1) Use the OBE damping values specified in Table 2, which are acceptable to the staff without further review.

(2) In general, for certified standard plant designs where the design-basis ISRS represent the envelope of the in-structure responses obtained from multiple analyses conducted to account for a range of expected site soil conditions associated with the certified seismic design response spectra (CSDRS), the SSE damping values in Table 1 of this RG and cracked concrete properties may be used. Combined license applicants referencing these certified standard plant design cases do not need to address this issue. However, if plant-specific seismic analyses are conducted for Category I structures or for structures not included in the standard plant design, then the applicant should address this issue accordingly.

(3) If a CSDRS is associated with a single site condition, such as the hard-rock high-frequency spectra for a specific site, then the OBE damping values in Table 2 of this RG should be used.

2. Piping Damping

Table 3 presents the damping values specified for SSE and OBE (where required) analyses of piping systems. These values are applicable in time-history analysis, response spectrum analysis, and equivalent static analysis procedures for structural qualification.

Table 3 SSE and OBE Damping Values for Piping Systems

Category	Damping Value	
	SSE	OBE > SSE/3
Piping Systems	4%	3%

3. Electrical Distribution System Damping

Table 4 presents the constant damping values to be used for SSE and OBE (where required) analyses of cable tray and conduit systems. These values are applicable in response spectrum analysis and equivalent static analysis procedures for structural qualification. The damping values specified in Table 4 are applicable to all types of supports, including welded supports.

The analysis methodology should consider the flexibility of supports in determining the system response to seismic excitation.

Table 4 Damping Values for Electrical Distribution Systems

Category	Damping Value	
	SSE	**OBE > SSE/3**
Cable Tray System[1]		
Maximum Cable Loading[2]	10%	7%
Empty[3]	7%	5%
Sprayed-On Fire Retardant or Other Cable-Restraining Mechanism[4]	7%	5%
Conduit Systems[1]		
Maximum Cable Fill[2]	7%	5%
Empty[3]	5%	3%

Notes:

1. When design calculations specify less than the maximum cable loadings, the applicant or licensee should justify the selected damping values for NRC staff review.
2. Maximum cable loadings, in accordance with the plant design specification should be used in conjunction with these damping values.
3. Spare cable tray and conduit, initially empty, may be analyzed with zero cable load and these damping values. (Note: Reanalysis should be performed when the system is put into service.)
4. Restraint of the free relative movement of the cables inside a tray reduces the system damping.

4. Heating, Ventilation, and Air Conditioning Duct Damping

Table 5 presents the constant damping values specified for SSE and OBE (when required) analyses of HVAC duct systems. These values are applicable in response spectrum analysis and equivalent static analysis procedures for structural qualification.

The analysis methodology should consider the flexibility of supports in determining system response to seismic excitation.

Table 5 Damping Values for HVAC Duct Systems

Type of Duct Construction	Damping Value	
	SSE	OBE > SSE/3
Pocket Lock	10%	7%
Companion Angle	7%	5%
Welded	4%	3%

5. Mechanical and Electrical Component Damping

Table 6 presents the damping values for mechanical and electrical components, which are applicable to passive subcomponents that can be seismically qualified by analysis. Active subcomponents do not readily lend themselves to seismic qualification by analysis, and require qualification by test, as described in section 3.10 of NUREG-0800.

Table 6 Damping Values for Mechanical and Electrical Components

Component Type	Damping Value	
	SSE	OBE > SSE/3
Motor, Fan, and Compressor Housings (Protection, Structural Support)	3%	2%
Pressure Vessels, Heat Exchangers, and Pump and Valve Bodies (Pressure Boundary)	3%	2%
Welded Instrument Racks (Structural Support)	3%	2%
Electrical Cabinets, Panels, and Motor Control Centers (Protection, Structural Support)	3%	2%
Metal Atmospheric Storage Tanks (Containment, Protection) — Impulsive Mode — Sloshing Mode	 3% 0.5%	 2% 0.5%

D. IMPLEMENTATION

The NRC staff may use this regulatory guide as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this regulatory guide to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, "Backfitting," and as described in NRC Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests" (Ref. 17), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

REFERENCES [1]

1. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."

2. *U.S. Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter I, Title 10, "Energy."

3. *U.S. Code of Federal Regulations*, "Reactor Site Criteria," Part 100, Appendix A, Section VI, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

4. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.243, "Safety-Related Steel Structures and Steel-Plate Composite Walls for Other than Reactor Vessels and Containments," August 2021.

5. NRC, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants."

6. U.S. Atomic Energy Commission, RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Washington, DC, October 1973.

7. American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC), ANSI/AISC N690-18, "Specification for Steel-Related Steel Structures for Nuclear Facilities," Chicago, IL, June 2018.

8. NRC, RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants," March 2007.

9. NRC, NUREG/CR-6011, "Review of Structure Damping Values for Elastic Seismic Analysis of Nuclear Power Plants," March 1993.

10. NRC, NUREG/CR-6919, "Recommendations for Revision of Seismic Damping Values in Regulatory Guide 1.61," November 2006.

11. Ware, A.G., and C.B. Slaughterbeck, "A Survey of Cable Tray and Conduit Damping Research," Idaho National Engineering Laboratory, Report No. EGG-EA-7346, Revision 1, prepared for the NRC, Washington, DC, August 1986.

12. NRC, NUREG-0797, "Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2," Supplement No. 16, July 1988.

1 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public website at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. For problems with ADAMS, contact the Public Document Room staff at 301-415-4737 or (800) 397-4209, or email pdr.resource@nrc.gov. The NRC Public Document Room (PDR), where you may also examine and order copies of publicly available documents, is open by appointment. To make an appointment to visit the PDR, please send an email to PDR.Resource@nrc.gov or call 1-800-397-4209 or 301-415-4737, between 8 a.m. and 4 p.m. eastern time (ET), Monday through Friday, except Federal holidays.

13. NRC, NUREG-0847, "Safety Evaluation Report Related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2," Supplement No. 8, January 1992.

14. NRC, "Nuclear Regulatory Commission International Policy Statement," *Federal Register*, Vol. 79, No. 132, July 10, 2014, pp. 39415–39418.

15. NRC, Management Directive (MD) 6.6, "Regulatory Guides."

16. International Atomic Energy Agency, Safety Guide NS-G-1.6, "Seismic Design and Qualification for Nuclear Power Plants," Vienna, Austria, 2003.[2]

17. NRC, MD 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests."

2 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: WWW.IAEA.Org/ or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria.