



Earthquake Instrumentation Criteria for Nuclear Power Plants

An American National Standard

Published by the
American Nuclear Society
555 N. Kensington Ave
La Grange Park, IL 60526



ANSI/ANS-2.2-2016

**American National Standard
Earthquake Instrumentation
Criteria for Nuclear Power Plants**

Secretariat
American Nuclear Society

Prepared by the
**American Nuclear Society
Standards Committee
Working Group ANS-2.2**

Published by the
**American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA**

Approved July 14, 2016
by the
American National Standards Institute, Inc.

American National Standard

Designation of this document as an American National Standard attests that the principles of openness and due process have been followed in the approval procedure and that a consensus of those directly and materially affected by the standard has been achieved.

This standard was developed under the procedures of the Standards Committee of the American Nuclear Society; these procedures are accredited by the American National Standards Institute, Inc., as meeting the criteria for American National Standards. The consensus committee that approved the standard was balanced to ensure that competent, concerned, and varied interests have had an opportunity to participate.

An American National Standard is intended to aid industry, consumers, governmental agencies, and general interest groups. Its use is entirely voluntary. The existence of an American National Standard, in and of itself, does not preclude anyone from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

By publication of this standard, the American Nuclear Society does not insure anyone utilizing the standard against liability allegedly arising from or after its use. The content of this standard reflects acceptable practice at the time of its approval and publication. Changes, if any, occurring through developments in the state of the art, may be considered at the time that the standard is subjected to periodic review. It may be reaffirmed, revised, or withdrawn at any time in accordance with established procedures. Users of this standard are cautioned to determine the validity of copies in their possession and to establish that they are of the latest issue.

The American Nuclear Society accepts no responsibility for interpretations of this standard made by any individual or by any ad hoc group of individuals. Inquiries about requirements, recommendations, and/or permissive statements (i.e., “shall,” “should,” and “may,” respectively) should be sent to the Scientific Publications and Standards Department at Society Headquarters. Action will be taken to provide appropriate response in accordance with established procedures that ensure consensus.

Comments on this standard are encouraged and should be sent to Society Headquarters.

Published by the

**American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60526 USA**



This document is copyright protected.

Copyright © 2016 by American Nuclear Society. All rights reserved.

Any part of this standard may be quoted. Credit lines should read “Extracted from American National Standard ANSI/ANS-2.2-2016 with permission of the publisher, the American Nuclear Society.” Reproduction prohibited under copyright convention unless written permission is granted by the American Nuclear Society.

Printed in the United States of America

Inquiry Requests

The American Nuclear Society (ANS) Standards Committee will provide responses to inquiries about requirements, recommendations, and/or permissive statements (i.e., “shall,” “should,” and “may,” respectively) in American National Standards that are developed and approved by ANS. Responses to inquiries will be provided according to the Policy Manual for the ANS Standards Committee. Nonrelevant inquiries or those concerning unrelated subjects will be returned with appropriate explanation. ANS does not develop case interpretations of requirements in a standard that are applicable to a specific design, operation, facility, or other unique situation only and therefore is not intended for generic application.

Responses to inquiries on standards are published in ANS’s magazine, *Nuclear News*, and are available publicly on the ANS Web site or by contacting the ANS Scientific Publications and Standards Department.

Inquiry Format

Inquiry requests shall include the following:

- (1) the name, company name if applicable, mailing address, and telephone number of the inquirer;
- (2) reference to the applicable standard edition, section, paragraph, figure, and/or table;
- (3) the purpose(s) of the inquiry;
- (4) the inquiry stated in a clear, concise manner;
- (5) a proposed reply, if the inquirer is in a position to offer one.

Inquiries should be addressed to:

American Nuclear Society
ATTN: Scientific Publications and Standards Department
555 N. Kensington Avenue
La Grange Park, IL 60526

or standards@ans.org

Foreword

(This foreword is not a part of American National Standard “Earthquake Instrumentation Criteria for Nuclear Power Plants,” ANSI/ANS-2.2-2016.)

The purpose of this standard is to specify for water-cooled nuclear power plants the minimum requirements for earthquake instrumentation. Should an earthquake occur, the instrumentation provides information on the vibratory ground motion and resultant vibratory responses of representative Category I structures (defined in U.S. Nuclear Regulatory Commission Regulatory Guide 1.29, “Seismic Design Classification for Nuclear Power Plants”) so that an evaluation can be made as to

- (1) whether or not the design response spectra have been exceeded;
- (2) whether or not the motion was damaging through determination of its standardized cumulative absolute velocity (CAV) as incorporated in ANSI/ANS-2.23-2016, “Nuclear Power Plant Response to an Earthquake”;
- (3) whether or not the calculated vibratory responses used in the design of the representative Category I structures and equipment have been exceeded at instrumented locations;
- (4) the degree of applicability of the mathematical models used in the seismic analysis of the building and equipment.

In addition, instrumentation could be provided to furnish specific information that would increase knowledge and understanding of seismic design. The problem of determining what additional instrumentation is needed to perform this function should be the basis of research and development programs and is not addressed in this standard.

The seismic design of nuclear power facilities requires, in part,

- (1) the determination of (a) site-specific earthquake ground motion response spectra, and (b) site-independent certified broadband smooth response spectra, referred to as certified seismic design response spectra (CSDRS);
- (2) the construction of mathematical models for dynamic analysis from which the vibratory response of structures and equipment to the input vibratory ground motion can be calculated.

Seismic designs for nuclear power plants utilize advanced analytical and design techniques. Therefore, evidence that the earthquake ground motion response spectra, developed from actual instrumental measurements, did not exceed the design basis spectral values, or that the CAV from the free-field instrument showed that the motion was not damaging, in accordance with ANSI/ANS-2.23-2016, “Nuclear Power Plant Response to an Earthquake,” would give reasonable assurance that plant structures and equipment were not damaged or made inoperable. In addition, the determination by actual instrument data of (a) the resultant vibratory responses of representative structures, (b) the input to supported equipment, and (c) the check of the applicability of mathematical models used in the dynamic analysis would give further assurance that plant structures or equipment was not damaged.

When an earthquake occurs, it is important to determine as soon as possible (within 4 hours) whether or not the free-field motion exceeded predetermined conditions in accordance with ANSI/ANS-2.23-2016. An acceptable instrumentation system would provide necessary data in a conveniently usable form for making this determination in a timely manner. Through the use of commercially available instruments, and by specifying their functional and operational requirements, an acceptable instrumentation system can be assembled, procured, installed, and operated. This standard provides the minimum requirements for an acceptable seismic instrumentation system.

The basic and most important instrument for measuring vibratory motion is the data acquisition unit (DAU), a subsystem of the seismic monitoring system (time-history accelerograph in previous versions of this standard), that acquires, stores, and transmits digital data from one or more sensors. A DAU consists of amplifiers, analog-to-digital converter, storage, telemetry, and timing source (for instance, global positioning system or network time protocol). From the resulting time-history records, the peak accelerations and duration can be determined, and the response spectra and CAV can be derived by computation.

This standard references documents and other standards that may have been, or become, superseded or withdrawn at the time the standard is applied. A statement has been included in the reference section that provides guidance on the use of such references.

This standard does not explicitly incorporate the concepts of generating risk-informed insights, performance-based requirements, or a graded approach to quality assurance. The user is advised that one or more of these techniques could enhance the application of this standard.

This standard was prepared by Working Group ANS-2.2 of the American Nuclear Society Standards Committee. This is a major revision to the ANSI/ANS-2.2-2002 standard. All comments received were reviewed and, where possible, were incorporated. Working Group ANS-2.2 had the following membership during its work on this standard:

F. Ostadan (Chair), *Bechtel Corporation*

J. Ake, *U.S. Nuclear Regulatory Commission*

M. Ciudad-Real, *Kinematics, Inc.*

V. Graizer, *U.S. Nuclear Regulatory Commission*

R. J. Hunt, *Consolidated Nuclear Security LLC*

J. J. Johnson, *James J. Johnson and Associates*

R. M. Kenneally, *Individual*

R. Lee, *Los Alamos National Laboratory*

M. Lewis, *Bechtel Corporation*

J. Marrone, *Bechtel Corporation*

R. Nigbor, *University of California, Los Angeles*

This standard was prepared under the guidance of the Siting: Seismic Subcommittee, which had the following membership at the time of its approval:

Q. Hossain (Chair), *Lawrence Livermore National Laboratory*

J. Xu (Vice Chair), *U.S. Nuclear Regulatory Commission*

E. Gibson, *Defense Nuclear Facilities Safety Board*

K. Hanson, *Individual*

R. Kassawara, *Electric Power Research Institute*

F. Ostadan, *Bechtel Corporation*

J. Savy, *Individual*

I. Wong, *URS Professional Solutions LLC (an AECOM Company)*

The Environmental and Siting Consensus Committee (ESCC) had the following membership at the time of its approval of this standard:

C. A. Mazzola (Chair), *CB&I Federal Services*

Y. Gao (Vice Chair), *Westinghouse Electric Company, LLC*

T. Bellinger, *Consolidated Nuclear Solutions, LLC*
D. Bruggeman, *Los Alamos National Laboratory*
(Alt. J. Dewart, *Los Alamos National Laboratory*)
K. Bryson, *Individual*
J. Call, *OASYS, Inc.*
P. Doub, *U.S. Nuclear Regulatory Commission*
Q. Hossain, *Lawrence Livermore National Laboratory*
R. J. Hunt, *Consolidated Nuclear Solutions, LLC*
A. L. Miracle, *Pacific Northwest National Laboratory*
J. O'Brien, *U.S. Department of Energy*
L. Spradley Parks, *U.S. Nuclear Regulatory Commission*
T. C. Rasmussen, *University of Georgia*
J. Savy, *Individual*
S. A. Vigeant, *CB&I Federal Services*
J. Xu, *U.S. Nuclear Regulatory Commission*

ESCC Observer:

B. Harvey, *U.S. Nuclear Regulatory Commission*

Contents

Section	Page
1 Scope	1
2 Purpose	1
3 Acronyms and definitions.....	1
3.1 Shall, should, and may	1
3.2 List of acronyms	1
3.3 Definitions.....	2
4 General information and requirements	5
4.1 Instrument description.....	5
4.2 Data analysis	5
4.3 Instrument location from design verification and ALARA considerations.....	6
4.4 Required sensor locations	6
4.5 Instrumentation at multiunit sites.....	13
4.6 Interconnection of instruments.....	13
4.7 Timeliness of data evaluation	13
5 Instrument requirements	13
5.1 General.....	13
5.1.1 Accuracy	13
5.1.2 Operating range	13
5.1.3 Data capacity	14
5.1.4 Connectivity.....	14
5.1.5 Backup power.....	14
5.1.6 Reliability	14
5.1.7 In-Service testing and maintenance	14
5.2 Acceleration sensor(s).....	15
5.2.1 Amplitude range	15
5.2.2 Frequency range.....	15
5.2.3 Spurious resonances.....	15
5.2.4 Cross axis sensitivity	15
5.3 Data acquisition unit	15
5.3.1 Data type and format.....	15
5.3.2 Sampling.....	15
5.3.3 Bandwidth.....	15
5.3.4 Timing	15
5.3.5 Triggering and alarming	16
5.3.6 Recording sequence	16
5.3.7 State-of-health monitoring	16
6 Instrumentation station installation.....	16
6.1 Mechanical rigidity	16
6.2 Accessibility.....	16
6.3 Orientation	17
6.4 Actuation.....	17
6.4.1 General.....	17
6.4.2 Actuating levels	17
6.5 Remote indication	17
6.6 Instrumentation station environment.....	17
6.7 Installation.....	17

7	Accompanying materials	18
8	Other instruments	18
9	Surveillance	18
9.1	General.....	18
9.1.1	Technical procedures	18
9.1.2	Testing procedures.....	18
9.1.3	Administrative procedures.....	18
9.2	Schedule.....	19
9.2.1	General.....	19
9.2.2	Specific surveillance tasks	19
9.3	Test requirements.....	19
9.3.1	State-of-health check	19
9.3.2	Channel calibration	20
10	References	20

Figures

Figure 1	Seismic Category I structures supported on independent foundations	9
Figure 2	All Seismic Category I structures supported on containment foundation	10
Figure 3	Several Seismic Category I structures supported on containment foundation (nuclear island) and other Seismic Category I structures supported on independent foundations	11
Figure 4	Several Seismic Category I structures supported on containment foundation (nuclear island) and other Seismic Category I structures designed with site-independent and site-specific response spectra	12

Table

Table 1	Sensor locations and numbers for various nuclear power plant design configurations.....	8
---------	-----------------------------------------------------------------------------------------	---

Appendices

Appendix A	Overview of Criteria, Guidance, and Terminology Pertaining to Issuing Early Site Permits and Combined Licenses	21
Appendix B	Guidance and Commentary	24
Appendix C	Soil-Structure-Interaction Analyses to Locate Nuclear Power Plant Free-Field Seismic Instrumentation	30

Earthquake Instrumentation Criteria for Nuclear Power Plants

1 Scope

This standard specifies the required earthquake instrumentation at the site and on Seismic Category I structures of light-water-cooled, land-based nuclear power plants. It may be used for guidance at other types of nuclear facilities. This standard does not address the following:

- (1) instrumentation to shut down a nuclear power plant automatically at a predetermined parameter of the ground motion or the in-structure response;
- (2) procedures for evaluating records obtained from seismic instrumentation and instructions for the treatment of data. These procedures and instructions are specified in ANSI/ANS-2.23-2016 [1]¹⁾;
- (3) instrumentation for nuclear power plant designs incorporating base isolation techniques.

2 Purpose

This standard defines the minimum requirements for an earthquake instrumentation system to be installed at nuclear power plants. These instruments are intended to provide timely (within 4 hours) information on the earthquake ground motion at the site and the corresponding response vibratory motion of Seismic Category I structures, when subjected to earthquake ground motion. By comparing this information with the vibratory motions used in the facility's seismic design,²⁾ an evaluation can be made as to whether or not the design basis vibratory motions have been exceeded.

3 Acronyms and definitions

3.1 Shall, should, and may

shall, should, and may: The word “shall” is used to denote a requirement; the word “should” is used to denote a recommendation; and the word “may” is used to denote permission, neither a requirement nor a recommendation.

3.2 List of acronyms

ADC: analog-to-digital converter

ALARA: as low as reasonably achievable

CSDRS: certified seismic design response spectra

CAV: cumulative absolute velocity

¹⁾Numbers in brackets refer to corresponding numbers in Sec. 10, “References.”

²⁾Appendix A provides an overview of applicable licensing practices used in the issuance of early site permits and combined licenses.