IEEE Std 344™-2004
(Revision of
IEEE Std 344-1987)

IEEE Standards

344™

IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

8 June 2005

Print: SH95327
PDF: SS95327

IEEE Std 344™-2004
(Revision of
IEEE Std 344-1987)

IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

Sponsor

Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society

Approved 8 December 2004

IEEE-SA Standards Board

Abstract: Recommended practices are provided for establishing procedures that will yield data to demonstrate that the Class 1E equipment can meet its performance requirements during and/or following one safe shutdown earthquake event preceded by a number of operating basis earthquake events. This recommended practice may be used to establish tests, analyses, or experienced-based evaluations that will yield data to demonstrate Class 1E equipment performance claims or to evaluate and verify performance of devices and assemblies as part of an overall qualification effort. Common methods currently in use for seismic qualification by test are presented. Two approaches to seismic analysis are described, one based on dynamic analysis and the other on static coefficient analysis. Two approaches to experienced-based seismic evaluation are described, one based on earthquake experience and the other based on test experience.
Keywords: Class 1E, earthquake, earthquake experience, equipment qualification, inclusion rules, nuclear, operating basis earthquake, prohibited features, qualification methods, required response spectrum, response spectra, safe shutdown earthquake, safety function, seismic, seismic analysis, test response spectrum, test experience, type testing

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-4678-1 SH95327
PDF: ISBN 0-7381-4679-X SS95327

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "**AS IS**."

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

NOTE—Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Introduction

This introduction is not part of IEEE Std 344-2004, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

This revision of IEEE Std 344-1987 was developed to expand and clarify guidance for developing programs to seismically qualify Class 1E equipment for nuclear power generating stations. Specific areas of amplification included are based on experience gained since 1987.

The Class 1E equipment to be qualified by procedures or standards based upon this revised recommended practice can be of many forms; therefore, this recommended practice presents the guidelines for many acceptable seismic qualification methods with the intent of permitting the user to make a judicious selection from the options offered. This revised recommended practice attempts to define more fully the procedures by which Class 1E equipment can be seismically qualified. It presents the methods that are known by the working group to be practices that are acceptable to the nuclear power generation industry, its equipment suppliers, and the industrial test and analysis facilities utilized by the industry. The clarification and update of methods in this recommended practice reflect an effort to recommend state-of-the-art techniques at the time of publication.

The methods and definitions presented in this revision are not intended to limit other seismic qualification techniques. Exceptions to these recommended practices may be made at any time where it can be shown that the substituted procedure verifies that the equipment can perform its safety function with justifiable methodology. The basis for a technical justification may be, but is not limited to, partial analysis, tests on similar equipment, experience data, or a combination thereof. Engineering judgment may be used in conjunction with these methods. Exceptions to these guidelines, which are founded on a broad base of actual test, analysis, and earthquake experience, supplemented by engineering judgment, may be used to meet the intent of this standard, provided the methods are justified.

The Foreword of the 1987 revision of this standard noted that experience-based methods for seismic qualification of equipment were under development and Clause 9 of the 1987 revision contained interim guidance for the use of experience data for this purpose. Since then, development of the experience-based approach has been furthered by the Seismic Qualification Utility Group (SQUG). The SQUG approach was used at many nuclear power plants to resolve USI A-46. It has also been adopted, in part, and used by other governmental and industrial organizations. Accordingly, Clause 10 and relevant parts of Clause 11 of this revision of the standard have been rewritten to incorporate the results of this development. Use of the experience-based approach in this recommended practice is acceptable for use in nuclear plants if it is consistent with the plant's licensing/regulatory design basis.

Issues related to use of median-centered in-structure response spectra for the earthquake experience-based method, operating basis earthquake (OBE) requirements associated with the test experience method, and generation of the test experience spectrum were considered at length by the working group in the preparation of this document.

Further guidance for qualification of replacement components and devices within an existing, previously qualified larger equipment assembly by the earthquake experience-based method is deferred to the next revision of the standard. Special consideration could be added to determine how to extend earthquake experience data to replacement of components and devices in a previously qualified equipment assembly so that there is sufficient detail and traceability in the areas of equipment performance (physical configuration, operational, and dynamic), installation, excitation, and demonstration of safety function.

Adherence to this recommended practice to obtain equipment seismic qualification alone will not suffice for assurance of public health and safety since it is the integrated performance of structures, fluid systems,

instrumentation systems, electrical systems, and man/machine interface systems of a nuclear power generating station that establishes totally safe operating conditions.

This standard was prepared by Subcommittee 2 Working Group 2.5 (Seismic) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: http://standards.ieee.org/reading/ieee/updates/errata/index.html. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents or patent applications for which a license may be required to implement an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Participants

At the time this standard was balloted, Working Group SC 2.5 (Seismic) of Subcommittee 2 (Qualification) of the Nuclear Power Engineering Committee had the following membership:

James Parello,[a] *Chair*

Mostafa A. Ahmed[a]	Gregory Hardy	Donald P. Moore[a]
Paul D. Baughman[a]	Paul Ibanez	Karur S. Parthasarathy
Suresh Channarasappa[a]	Johnny Jenkins	Daniel J. Pomerening
Garry V. Chapman[a]	Robert Kassawara	John M. Richards[a]
Pei-Ying Chen[a]	Mohsin Khan	William Schmidt[a]
Walter Lojdlievic[a]	Bruce M. Lory[a]	K. M. Skreiner[b]
Robert Lyons	William LaPay[b]	Donald Smith
Gregory Ferguson	Darren Martin	Richard G. Starck[a]

[a] Member of the Writing Group
[b] Past Chair of the Working Group

At the time this standard was balloted, Subcommittee 2 (Qualification) under the Nuclear Power Engineering Committee had the following membership:

Satish K. Aggarwal, *Chair*
Robert Lofaro, *Secretary*

Bohumil Bartonicek
Paul D. Baughman
Anup K. Behera
Brij M. Bharteey
Thomas Brewington
Nissen M. Burstein
Craig R. Butcher
Steve Casadevall
Suresh Channarasappa
Garry V. Chapman
Javier Alonso Chicote
Marty Chipkin
Jeff Chivers
Sun Yeong Choi
James M. Dean
Liviu Nicolae Delcea
Dennis E. Dellinger
Philip DiBenedetto
Quang H. Duong
Frank Drumm
Wells D. Fargo
Artur J. Faya
Robert Francis
James F. Gleason
Patrick Gove
William L. Hadovski
Peter Helander
Thomas R. Hencey III
Jerrell C. Henley
David A. Horvath
Craig S. Irish
Serena A. Jagtiani-Krause
Sushant Kapur
Mohsin Khan
Henry Leung
Bruce M. Lory
Darin R. Martin
P. G. McQuillan
Daniel R. Mikow
Todd Mitton
Asif Mohiuddin
Edward Mohtashemi
Carole Monchy-Leroy
Bill Newell
James Parello
Janez Pavsek
Daniel J. Pomerening
Robert Queenan
John M. Richards
Fredrick Roy
Steve Sandberg
Glen E Schinzel
Roderick Simms
Kjell Spang
Richard G. [illegible]rck
Marek Tengler
Marco [illegible]n Uffelen
Lasz[illegible] Varga
Ca[illegible] Webe
John [illegible]hel[illegible]ss
Jo[illegible] White
Toni Wittamore
Richard T. Wood
Toshio Yamamoto

At the time this standard was balloted, the Nuclear Power Engineering Committee had the following membership:

John P. Carter, *Chair*
John J. Dis[illegible]sway, *Vice Chair*
David A. [illegible]o[illegible]vath, *Secretary*

Satish K. Aggarwal
Ijaz Ahmad
George Attarian
Farouk D. Baxter
Brij M. Bharteey
Wesley W. Bowers
Daniel F. Brosnan
Nissen M. Burstein
Robert C. Carru[illegible]
Surin K. Dure[illegible]
Stephen A. Flege[illegible]
[illegible]rt Fletcher
Robert B. Fuld
James F. Gleason
Dale Goodney
Britton P. Grim
Paul R. Johnson
Harvey C. Leake
John D. MacDonald
J. Scott Malcolm
Alexander Marion
Michael H. Miller
Gerald L. Nicely
Roger D. Parker
Glen E. Schinzel
Neil P. Smith
James E. Stoner
John Taylor
James E. Thomas
Terence J. Voss
John Waclo
John White
Paul L. Yanosy, Sr.
David J. Zaprazny

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Satish K. Aggarwal
Faropuk D. Baxter
Wesley W. Bowers
Thomas Brewington
Daniel F. Brosnan
Nissen M. Burstein
Salvatore Carfagno
John P. Carter
Suresh Channarasappa
Garry V. Chapman
Dr. Guru Dutt Dhingra
Philip DiBenedetto
John J. Disosway
Surin Dureja
Amir El-Sheikh
Jay Forster
James F. Gleason
Lawrence Gradin
Britton P. Grim
Randall Groves
Ajit Gwal
Paul R. Johnson
Harvey C. Leake
John D. MacDonald
G. Michel
William Mindick
James Parello
Roger D. Parker
Fredrick Roy
James Ruggieri
Neil P. Smith
Richard G. Starck
James E. Stoner
James E. Thomas
John Ullo
Terence J. Voss
John White
Paul L. Yanosy, Sr.
Li Zhang

When the IEEE-SA Standards Board approved this standard on 8 December 2004, it had the following membership:

Don Wright, *Chair*
Steve M. Mills, *Vice Chair*
Judith Gorman, *Secretary*

Chuck Adams
Stephen Berger
Mark D. Bowman
Joseph A. Bruder
Bob Davis
Roberto de Marca Boisson
Julian Forster*
Arnold M. Greenspan
Mark S. Halpin
Raymond Hapeman
Richard J. Holleman
Richard H. Hulett
Lowell G. Johnson
Joseph L. Koepfinger*
Hermann Koch
Thomas J. McGean
Daleep C. Mohla
Paul Nikolich
T. W. Olsen
Ronald C. Petersen
Gary S. Robinson
Frank Stone
Malcolm V. Thaden
Doug Topping
Joe D. Watson

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Alan Cookson, *NIST Representative*

Don Messina
IEEE Standards Project Editor

Contents

IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

1. Overview

This recommended practice is divided into 11 clauses. Clause 1 provides the scope of this recommended practice. Clause 2 lists normative references to other standards that are useful in applying this recommended practice. Clause 3 provides definitions that are either not found in other standards or have been modified for use with this recommended practice. Clause 4 provides background information on earthquake behavior and on the performance of equipment during simulated seismic events. Clause 5 defines the most commonly used methods for seismic qualification of equipment contained in this recommended practice. Clause 6 provides guidance on the measurement and application of damping in the seismic qualification of equipment. Clause 7 provides procedures for two approaches most commonly used to seismically qualify equipment by analysis. Clause 8 provides procedures for the commonly used methods for seismic qualification of equipment by test. Clause 9 provides guidelines for seismic qualification of equipment that cannot be practically qualified by analysis or testing alone. Clause 10 provides guidelines for two approaches to seismically qualify equipment using experience data for a reference equipment class. Clause 11 provides documentation guidelines for the seismic qualification of equipment.

This recommended practice also contains six annexes. Annex A explains how to measure the zero period acceleration (ZPA) from seismic test data. Annex B explains frequency content and stationarity of the input waveform. Annex C provides guidance on fragility testing. Annex D explains the use of test duration and response cycles in ensuring adequate equipment response relative to low-cycle fatigue capability. Annex E provides guidance in establishing statistically independent simulated simultaneous multiaxis motions for seismic testing and analysis. Annex F provides bibliographic references.

1.1 Scope

This document describes recommended practices for establishing seismic qualification procedures that will yield quantitative data to demonstrate that the Class 1E equipment can meet its performance requirements during and/or following one safe shutdown earthquake (SSE) event preceded by a number of operating basis earthquake (OBE) events. The test, analysis, or experienced-based evaluation methods described herein may be used to yield data to demonstrate Class 1E equipment performance claims or to evaluate and verify performance of devices and assemblies as part of an overall qualification effort.