ASME QME-1–2002

(Revision of ASME QME-1–2000)

Qualification of Active Mechanical Equipment Used in Nuclear Power Plants

The American Society of Mechanical Engineers

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AN AMERICAN NATIONAL STANDARD

QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT USED IN NUCLEAR POWER PLANTS

ASME QME-1–2002

(Revision of ASME QME-1–2000)

Date of Issuance: February 20, 2003

The next edition of this Standard is scheduled for publication in 2004. There will be no addenda issued to this edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

CONTENTS

Nonmandatory Appendices to Section QP

FOREWORD

Federal regulations applicable to nuclear power plants require that measures be established to ensure that certain equipment operates as specified. This Standard sets forth requirements and guidelines that may be used to ensure that active mechanical equipment is qualified for specified service conditions. As determined by federal regulators and/or nuclear power plant licensees, this Standard may be applied to future nuclear power plants, or existing operating nuclear power plant component replacements, modifications, or additions.

In the early 1970s, initial development of qualification standards was assigned to the ANSI N45 Committee. The N45 Committee in turn established a task force to prepare two series of standards to ensure that pumps and valves used in nuclear plant systems would function as specified.

The N45 Committee's valve task force (N278) was reassigned in 1974 to the American National Standards Committee B16 and designated Subcommittee H. The first qualification standard to be issued for valves was ANSI N278.1-1975, which covered the preparation of functional specifications. In 1982, the task force was reassigned to the ASME Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants (QME) and designated the Subcommittee on Qualification of Valve Assemblies. As an interim measure, in 1983, ANSI B16.41 was issued to cover functional qualification requirements for power-operated active valve assemblies for nuclear power plants.

The N45 Committee's pump task force (N551), established in 1973, was assigned to ASME Nuclear Power Codes and Standards along with N278 as part of the Subcommittee QNPE, Qualification of Nuclear Plant Equipment. Both N551 and N278 operated as Subcommittee QNPE until 1982, when they were reassigned to the ASME Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants (QME) and designated as the Subcommittee on Qualification of Valve Assemblies and the Subcommittee on Qualification of Pump Assemblies.

In June 1977, an IEEE/ASME agreement was formulated giving primary responsibility for qualification standards to IEEE and quality assurance standards to ASME. This arrangement remained in effect until ASME established the current Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants.

During 1985, the Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants researched the various formats this Standard could take. Based on the wide acceptance of ASME Section III's format for multiple classes, the Committee adopted a similar organizational format to accommodate multiple equipment types covered by this Standard. As IEEE Standards 323 and 627 had already been in use many years for electrical equipment, these standards were also studied for appropriate content that should be addressed for mechanical equipment. Subsequently, the following Organization Guide was developed for this Standard and submitted to the ASME Board on Nuclear Codes and Standards for approval. On January 16, 1986, the Board on Nuclear Codes and Standards approved QME's approach and outline for this Standard.

Consistent with the guidance in ASME SI-9, [ASME Guide for Metrication of Codes and Standards SI (Metric Units)] regarding metrication, SI units have been provided in narrative portions of QME-1 for general information only, and the U.S. Customary units are the standard. Either U.S. Customary units or SI units may be used, but one system shall be used consistently throughout construction of the component. Should the owner or his agent desire metric units, it sill be set forth in the design specifications.

The various parts of ASME QME-1–1994 were approved by the American National Standards Institute (ANSI) on the following dates: Section QP, September 22, 1992; Section QR, June 8, 1993; Section QR, Appendix A, October 7, 1993; Section QR, Appendix B, May 14, 1993; and Section QV and its Appendix A, February 17, 1994. Section QV is a revision and redesignation of ANSI B16.41-1983.

Requests for interpretation or suggestions for improvement of this Standard should be addressed to the Secretary of the ASME Committee on Qualification of Mechanical Equipment

Used in Nuclear Power Plants, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

In 1996 the Board of Nuclear Codes and Standards requested all committees reporting to it to add SI (metric) units to all documents by replacing Customary (English) units with SI units or by showing SI units in a dual format with Customary units. The decision as to the extent of the conversion and format was left to the various committees. The Committee on Qualification of Mechanical Equipment for Nuclear Power Plants voted in 1996 to present SI units in the QME document, with Customary units in parentheses. A group of proposed changes was prepared at that time. The changes encountered a good deal of opposition. The Committee on Qualification of Mechanical Equipment for Nuclear Power Plants revisited this decision at its February 29, 2000 meeting and voted to publish QME-1 with dual units, Customary as the primary units, with SI units in parentheses. This decision was further modified by the Committee to make the change apply to textual material only. Tables and figures were not to be modified. The changes made herein confirm with those decisions. The changes apply to the text as it appeared in the 1997 edition of QME-1.

This Standard was approved as an American National Standard on October 31, 2002.

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(The following is the roster of the Committee at the time of approval of this Standard.)

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SUBGROUP ON QDR DEVELOPMENT

ORGANIZATION OF QME-1

1 GENERAL

ASME QME-1 is divided into sections that are designated by capital letters: the letter Q, which stands for qualification, followed by a second letter that generally indicates the subject matter of the section. This Standard consists of three major sections as follows:

(a) Section QR: General Requirements
(b) Section QP: Qualification of Pump Assemblies
(c) Section QV: Qualification of Valve Assemblies

2 SECTIONS

Sections are divided into articles, subarticles, paragraphs, and, where necessary, subparagraphs and subsubparagraphs.

3 ARTICLES

Articles are designated by the applicable letters indicated above for the sections, followed by Arabic numbers, such as QR-1000, QP-2000, and QV-6000. Whenever possible, articles dealing with the same topics are given the same number in each section in accordance with the following general scheme:

Article Number	Title
1000	Scope
2000	Purpose
3000	References
4000	Definitions
5000	Qualification Principles and Philosophy
6000	Qualification Specification Criteria
7000	Qualification Program
8000	Documentation

The numbering of the articles and the material contained in the articles may not, however, be consecutive. Due to the fact that the complete outline may cover phases not applicable to a particular section or article, the rules have been prepared allowing some gaps in the numbering. In Section QV of this Standard, subarticles QV-1200, QV-1300, and QV-1400 describe exceptions to this general numbering system, which may apply to paras. 4 through 8.

4 SUBARTICLES

Subarticles are numbered in units of 100, such as QR-7100 or QV-7200. When more than nine subarticles are required, numbering is done by paragraph and units of 1 starting with 10.

5 SUBSUBARTICLES

Subsubarticles are numbered in units of 10, such as QR-8310, and generally have no text. When a number such as QR-8320 is followed by text, it is considered a paragraph. When more than nine subsubarticles are required, numbering is done by paragraph and units of 1 starting with 10.

6 PARAGRAPHS

Paragraphs are numbered in units of 1, such as QR-8321 or QV-8322.

7 SUBPARAGRAPHS

Subparagraphs, when they are major subdivisions of a paragraph, are designated by adding a decimal followed by one or more digits to the paragraph number, such as QR-8321.1 or QV-8321.2. When they are minor subdivisions of a paragraph, subparagraphs may be designated by lowercase letters in parentheses, such as QR-8321(a) and QV-8321(b).

8 SUBSUBPARAGRAPHS

Subsubparagraphs are designated by adding lowercase letters in parentheses to the major subparagraph numbers, such as QR-8321.1(a) and QV-8321.1(b). When further subdivisions of minor subparagraphs are necessary, subsubsubparagraphs are designated by adding Arabic numbers in parentheses to the subsubparagraph designation, such as QR-8321.1(a)(1) and QV-8321.1(a)(2).

9 REFERENCES

References used within this Standard generally fall into one of the following three categories:

(a) References to Other Portions of This Standard. When a reference is made to another article, subarticle, or paragraph, all numbers subsidiary to that reference shall be included. For example, reference to QR-5000 includes all material in Article QR-5000; reference to QR-7300 includes all material in Subarticle QR-7300; reference to QR-7320 includes all material in Subsubarticle QR-7320.

(b) References to the Boiler and Pressure Vessel Code and to Other Standards. When a reference is made to any Section of the BPVC, or to other standards, it shall be understood to mean the designated article, paragraph, figure, or table in the designated document. All such

references shall be identified in the text of this Standard by the document's issuing source and the document's unique identification number, e.g., ASME III Subsection NF, IEEE Std 627, or 10CFR50 Part A. If required, further reference to unique articles or paragraphs of the referenced document may also be described, e.g., ASME III Subsection NF paragraph NF-3211.1(a). Each short reference made in the text shall be described in more complete detail in Article 3000 by issuing source, unique identification number, year of publication being referenced, and full title, e.g., IEEE Std 382-1980, Standard for Qualification of Safety Related Valve Operators. References listed without year of publication suggest that the latest version of the reference was utilized in the development of this Standard. It should be noted by users of this Standard that regulatory requirements and Codes of Record for a particular nuclear power plant may take precedence over references used within this Standard. Section QR references applicable for both pumps and valves shall be described in Article QR-3000, while references unique to Section QP or QV only will be described in Article QP- or QV-3000, as applicable.

(c) *References to Appendices.* Two types of appendices may be used in this Standard, designated Mandatory and Nonmandatory. Both types of appendices are designated by the prefix Q. This is followed by a letter, which is the same one used by the section to which the appendix applies, e.g., QR. Mandatory appendices contain requirements that must be followed in qualification; such references are then uniquely identified by a roman numeral, e.g., Appendix QR-I and its specific title. Nonmandatory appendices provide information or guidance; such references are designated by a capital letter, e.g., Appendix QR-A, and its specific title.

ASME QME-1–2002
SUMMARY OF CHANGES

Following approval by the ASME Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants and ASME, and after public review, QME-1–2002 was approved by the American National Standards Institute on October 31, 2002.

QME-1–2002 includes the following changes identified by a margin note, **(02)**.

Page	*Location*	*Change*
14	Table QR-A6210-1	Revised
52–66	Section QDR	Added
77	Appendix QP-D I(a)(1)	Revised
	Appendix QP-D I(b)(1)	Revised
	Appendix QP-D I(b)(2)	Revised
79	Table QP-E1	Revised
80	QP-E5300(c)	Revised
	QP-E5400(a)	Revised
	Table QP-E2	Revised
81	QV Introduction	Third paragraph revised
94	QVP-7370.1(g)	Nomenclature revised
96	QVP-7381.1(c)	Nomenclature revised
99	QVP-7393.3(a)	Revised
99	QVP-7394.3(a)	Revised
100	QVP-7394.3(c)	Revised
103	QVC-7420.1(a)(2)(a)	Revised
	QVC-7420.1(a)(2)(b)	Revised
	QVC-7420.1(a)(2)(c)	Revised
108	QV-A4000	Definitions of *valves, low leakage* and *valves, nominal leakage* revised
111–119	Section QV-G	Added

SPECIAL NOTE:

The Code Cases to ASME QME-1 follow the last page of this edition as a separate section.

QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT USED IN NUCLEAR POWER PLANTS

Section QR: General Requirements

QR-1000 SCOPE

This Standard describes the requirements and guidelines for qualifying active mechanical equipment used in nuclear power plants. The requirements and guidelines presented include the principles, procedures, and methods of qualification. Requirements are specifically denoted throughout this Standard and are generally recognized by the accompanying word *shall*, while guidelines are accompanied by the word *should*.

This Standard does not apply to electric components such as motors, electric valve actuators, instrumentation, and control devices, which are qualified by conformance with appropriate IEEE standards. It should be recognized that some qualification aspects are performed when the mechanical/electrical component interface is addressed, e.g., Section QV provides qualification guidance for valve assemblies using electric actuators and Section QP provides qualification guidance for pump assemblies using electric motor drivers that have been previously qualified per the appropriate IEEE standards.

Qualification of active mechanical equipment in accordance with this Standard is the responsibility of the Owner or the Owner's designee. It is also the responsibility of the Owner or the Owner's designee to define specifically any other equipment to which this Standard will be applied. The Owner or the Owner's designee is further responsible for program(s) and associated documentation required to ensure continuation of initial qualification of active mechanical equipment that is beyond the scope of this Standard.

Qualification of mechanical equipment in accordance with this Standard requires utilization of two sections and applicable appendices as a minimum, e.g., Section QR must be used jointly with other sections of the Standard.

QR-2000 PURPOSE

The purpose of this Standard is to provide basic principles and guidance to demonstrate the qualification of active mechanical equipment used in nuclear power plants. Qualification is intended to confirm the adequacy of the equipment to function over the expected range of service conditions, including design basis event and postdesign basis event conditions, as well as in-service inspection and test conditions. Qualification is not intended to confirm adequacy of the equipment to function beyond its specified service conditions even though qualification margins should ensure additional capability.

QR-3000 REFERENCES

The references listed below have provided guidance on concepts, principles, practices, criteria, and parameters in the preparation of this Standard.

ANS 51.1-1988, Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants
ANS 52.1-1988, Nuclear Safety Criteria for the Design of Stationary Boiling Water Reactor Plants
Publisher: American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60526

ASME NQA-1 and NQA-2 (1989), Quality Assurance Program Requirements for Nuclear Facilities
Publisher: The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900

IEEE Std 323-1983 (Reaffirmed), Qualifying Class 1E Equipment for Nuclear Power Generating Stations
IEEE Std 334-1974 (Reaffirmed), Standard for Type Test of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations
IEEE Std 344-1987, Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
IEEE Std 627-1980 (Reaffirmed), Standard for Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations

Publisher: Institute of Electrical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854

Further reference to any of the above throughout this Standard is by standard or document number only (e.g., IEEE Std 627).

QR-4000 DEFINITIONS

These definitions establish the meanings of words in the context of their use in this Standard. Definitions in this Article apply generically to all mechanical equipment within the scope of this Standard. This Standard attempts to ensure consistency with established definitions and terms within ASME, IEEE, and regulatory agencies.

aging: the cumulative effects of operational, environmental, and system conditions on equipment during a period of time up to, but not including, design basis events, or the process of simulating these effects.

aging, natural: aging that occurs within normal service environments as opposed to simulated service environments at magnitudes or rates that are greater than expected in-service levels.

Application Report: documentation for a specific application showing that the required pressure ratings, qualification loading levels, and operating condition capabilities are equaled or exceeded by the corresponding pressure ratings, qualification loadings, and operating condition capabilities shown in the Functional Qualification Report.

Class 1E: the 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 are otherwise essential in preventing significant release of radioactive material to the environment.

component, mechanical: those items of a nuclear power plant such as pumps, valves, vessels, piping, and supports (see also *equipment, mechanical*).

component supports: structural elements that transmit loads between nuclear power plant components and the building structure (includes hangers and snubbers, but does not include intervening elements in the component support load path such as electric motors and valve operators).

demonstration: the provision of evidence to support the conclusion derived from assumed premises.

design basis event (DBE): postulated events (specified by the safety analysis of the station) used in the design to establish the acceptable performance requirements of the structures and systems.

design life: the time during which satisfactory performance can be expected for a specific set of service conditions (the time may be specified in real time, number of operating cycles, or other performance intervals, as appropriate).

Earthquake Ground Motion, Operating Basis (OBE): the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation will remain functional without undue risk to the health and safety of the public.

Earthquake Ground Motion, Safe Shutdown (SSE): the vibratory ground motion for which certain structures, systems, and components are designed, pursuant to Appendix S to 10 CFR Part 50, to remain functional.

equipment, active: equipment containing moving parts, which in order to accomplish its function, must undergo mechanical movement of those parts, or must prevent a movement of those parts to ensure that the equipment will remain in its last position.

equipment, candidate (sometimes referred to as *test equipment*): equipment representative of the prototype to be qualified by:

(a) a combination of test, analysis, or experience; or

(b) analysis that demonstrates design similarity with another qualified candidate or parent equipment; or

(c) analysis as described in (b) above with appropriate testing.

equipment, mechanical: for the purpose of this Standard, mechanical equipment may be used interchangeably with *mechanical component* or *assembly.*

equipment, production: equipment fabricated with the same manufacturing techniques, materials, production testing, and quality assurance that were used for prototype or parent equipment.

equipment, prototype: production equipment representing the first model/type or original design/pattern. Prototype equipment may be used for qualification testing; when selected for qualification testing, the equipment may also be called *candidate equipment.*

equipment, qualified candidate: equipment that has been qualified primarily by methods described in the *candidate equipment* definition above.

equipment, qualified parent: equipment that has been qualified primarily by testing.

equipment, test: equipment selected for qualification testing.

essential-to-function parts/components: those parts or components of the assembly that are essential to cause, permit, or enable the assembly to perform the specified accident-condition function, or whose failure could prevent the performance of this function.

Functional Qualification Report: documentation of tests or analyses (or both) performed in accordance with this Standard.

installed life: the interval from installation to removal during which the equipment or component thereof may be subject to design service condition and system demands.

NOTE: When equipment may have an installed life of 40 years with certain components changed periodically, the installed life of the changed components would be less than 40 years.

maintenance: work performed on an item to keep it operable or to restore it to an operable condition.

malfunction: the loss of capability of equipment to initiate or sustain its specified function, or the initiation of undesired actions that might result in adverse consequences.

margin: the amount by which the qualification condition levels exceed the service condition levels.

NOTE: Qualification margins may or may not be addressed by ASME Code design margins.

may: an expression of permission.

modification: a change to an item made necessary by, or resulting in, a change in design requirements.

operability: ability of an active component to remain in its last position, or to perform the mechanical motion required to fulfill its specified function when subjected to the prescribed service conditions.

qualification: the generation and maintenance of evidence to ensure/demonstrate that the equipment can meet its specified service conditions in accordance with the qualification specification.

qualification criteria: criteria developed from those specific service conditions for which the equipment is to be qualified.

qualification life: the period of time, 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: At the end of the qualified life, the equipment shall be capable of performing the function required for the postulated design basis and postdesign basis events.

qualification program: the overall cumulative process of specifying, conducting, and documenting the results of those activities required to qualify active mechanical equipment to perform its function in accordance with the qualification specification.

Qualification Report: documentation of tests, analyses, operating experience, or any combination of these performed in accordance with this Standard or the qualification specification that demonstrates operability of the equipment.

service conditions: postulated conditions specified for environmental, dynamic/static/pressure loadings, material degradation, etc., for normal operation, abnormal operation, and design basis events.

shall: an expression of a requirement.

should: an expression of a recommendation.

Specification, Design: a document prepared by the Owner or the Owner's designee that provides a basis for design.

specification, qualification: that specification or portion of the Design Specification that describes the qualification requirements to be met in the qualification of the equipment.

tests: those testing activities conducted to specified service conditions to demonstrate that such equipment can subsequently perform its intended function.

QR-5000 QUALIFICATION PRINCIPLES AND PHILOSOPHY

The fundamental principles and philosophy pertinent to equipment qualification are provided in subarticles QR-5100, QR-5200, and QR-5300. Subarticles QR-5100 and QR-5200 outline the fundamental requirements and approaches for active mechanical equipment qualification programs. Subarticle QR-5300 then establishes the general requirements for the qualification program.

QR-5100 Fundamental Qualification Requirement

To establish equipment qualification, it shall be demonstrated that the equipment can perform its specified required function when operational and environmental conditions are imposed on the equipment in accordance with the equipment qualification specification.

QR-5200 Approaches to Qualification

Equipment shall be qualified by one or more or a combination of the methods described in Article QR-7000 to verify that the qualification requirements are satisfied. The requirements generally address a single equipment application, but they may envelop the service conditions for more than one application. In addition, a family of equipment may be qualified by using one or more of the qualification methods described in QR-7300 or further described in a qualification specification. Such extension of qualification requires consideration of significant design parameters to establish the similarity of the qualified member to the family of equipment.

The pressure containment integrity and passive structural requirements of mechanical equipment covered by ASME, AISC, or ACI codes are considered qualified by adherence to the requirements of these codes.

QR-5300 General Requirements for a Qualification Program

A qualification program for active mechanical equipment used in a nuclear power plant shall include the following:

(a) qualification requirements;

(b) a process to demonstrate that the equipment satisfies the qualification requirements by analysis, test, operating experience, or a combination of these;

(c) evidence of successful completion of qualification;

(d) a documentation file containing QR-5300(a), (b), and (c).

The requirements to satisfy QR-5300(a), (b), (c), and (d) should be contained in the equipment qualification specification.

In a qualification program, aging, qualified life, and margin shall be considered as described in QR-5310, QR-5320, and QR-5330.

QR-5310 Aging. Mechanical equipment covered by this Standard is primarily characterized by the use of metal components. The use of properly specified metal in mechanical components provides basic assurance against environmental and aging effects on equipment performance. The use of nonmetallic materials is primarily confined to applications involving substantially total confinement in compressive loadings, as in stem seal packing and in joint sealing gaskets.

The assessment of equipment aging effects is an essential part of the qualification process to determine if aging has a significant effect on performance. The assessment shall include an analysis and/or evaluation of the equipment to determine any significant aging mechanisms on items that are readily susceptible to thermal, radiation, corrosion, erosion, or wear type aging. When one or more mechanisms are identified as significant, the assessment shall be developed as part of the overall qualification program. When natural (actual) aging results are used in the qualification program, it may not be necessary to conduct a detailed analysis and/or evaluation to determine significant aging mechanisms.

An aging mechanism is considered significant if it satisfies one or more of the following criteria:

(a) in normal service environments, the aging mechanism promotes the same malfunction as that which may result from exposure to abnormal or design basis event service conditions;

(b) the aging mechanism adversely affects the ability of the equipment to perform its function in accordance with its specification requirements;

(c) the deterioration caused by the aging mechanism is not amenable to assessment by in-service test/inspection or surveillance activities that provide confidence in the equipment's ability to function during the intervals between surveillance in accordance with its specification requirements;

(d) in normal service environments, the aging mechanism causes degradation during the design life of the equipment that is appreciable compared to degradation caused by the design basis event.

Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts. Industry research/reports provide additional guidance on viable contributors to aging of mechanical equipment.

QR-5320 Determination of Qualified Life. For equipment with significant aging mechanisms, a qualified life shall be established. For equipment with no significant aging mechanisms, its qualified life is equal to its design life.

The determination of qualified life depends upon the method employed for addressing aging effects. Where naturally aged equipment is available for use in qualification, the qualified life determination and justification is straightforward. The determination of qualified life shall be based upon conservative engineering analysis and/or evaluation in these instances. The analysis and/or evaluation may take into account, if available:

(a) results of age conditioning used in qualification (aging may be natural, artificial, or a combination thereof);

(b) equipment operating data;

(c) previous test results for the same material and the same type of design service;

(d) understanding of significant aging mechanisms that have been identified;

(e) margins in excess of those required for the most adverse service conditions for which the equipment is qualified.

The qualified life of a particular equipment item may be changed during its installed life where justified. For example, the qualified life of equipment may be limited by certain components that have a qualified life shorter than the installed life of the equipment. By periodic replacement of those components, the qualified life of the equipment may be extended.

QR-5330 Margin. Margin shall be considered in the qualification program to account for variation in performance, errors in experimental measurements, and variations in commercial production, thereby providing a level of confidence that the equipment can perform under the most adverse service conditions for which it is qualified.

Other sections and Appendix QR-A provide additional guidelines on margins as required for metallic components. Additional guidelines on margins for nonmetallic components are provided in Appendix QR-B.

In identifying margin, it is necessary to consider not only the accuracy of the design data, but also the dimensional tolerances for the parts and the accuracy of the instrumentation. In all cases, engineering judgment should be used to determine the adequacy of qualification margins. This determination shall be appropriately documented.

Examples of parameters that should be considered for appropriate margins are maximum or minimum external temperatures and pressures, radiation levels, electrical voltages and frequencies, operating time periods, dynamic excitation (including vibration), and accuracy of data and calculation methods.

QR-6000 QUALIFICATION SPECIFICATION

Qualification specification for active mechanical equipment shall describe the requirements to be met to qualify the equipment for its intended application. This forms the basis for development of an equipment qualification program. As a minimum, QR-6000(a) through (j) shall be included in the qualification specification.

(a) Equipment performance requirements, both normal and design basis event, including a description of the basis for its classification as active mechanical equipment, and a description of the required function, including the time period it must remain operable, shall be specified.

(b) Equipment description and boundary, including components that are inside the boundary, and the physical orientation/location of the equipment, shall be specified. Attachments, motive power connection, seals, and control circuitry that cross this boundary shall be described.

(c) Interface loadings via physical attachments of the equipment at the equipment boundary shall be specified for each operating mode. In the same manner, motive power or control signal inputs must be specified, including those that deviate from normal.

(d) The qualification specifications for equipment within the scope of this Standard shall reference specifically invoked codes and standards. Other standards applicable to equipment or component qualification shall also be referenced.

(e) Specific equipment qualification standards that are applicable to the equipment shall be referenced and applied as pertinent to the equipment. For example, Section QP (Qualification of Active Pump Assemblies) may furnish a substantial part of the qualification program for a complete pump assembly.

(f) Definition of the service conditions for the equipment shall be specified. A range of values and appropriate time histories for local environmental and equipment operational parameters shall be specified, reflecting expected service conditions for the particular application. Examples of such parameters are internal and external pressures/temperatures, relative humidity, radi-ation, vibration, corrosion effects, and transients.

(g) Required margin in the qualification parameters shall be specified. As discussed in QR-5330, any margin included in the specified value of qualification parameters shall be indicated.

(h) Significant aging mechanisms, where known, shall be identified. Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts.

(i) Acceptance criteria for qualification shall be specified to ensure satisfaction of the fundamental qualification requirement. The acceptance criteria shall include limiting values of input to and performance required from the equipment under the required operating conditions, as well as environmental parameter levels.

(j) Required equipment qualification documentation shall be included as described in QR-8000.

Specific qualification criteria for different types of mechanical equipment are provided in subsequent sections of this Standard. Appendix QR-A provides supplementary details associated with the dynamic qualification of mechanical equipment, and Appendix QR-B provides supplementary details for the qualification of nonmetallic parts of mechanical equipment.

QR-7000 QUALIFICATION PROGRAM

QR-7100 General Requirements

A qualification program shall be established based on the equipment's qualification specification. The qualification program should include and address qualification principles, mandatory requirements, aging, and qualified life as described in QR-5000. The program shall ensure that qualification specification/acceptance criteria are properly addressed as described in QR-6000. In addition, the program shall ensure that qualification is properly addressed by testing, analysis, operating experience, or combined methods.

QR-7200 Review for Potential Malfunctions

The selection of methods for qualifying active mechanical equipment should be based on a review of potential malfunctions that could result from specified service conditions. Potential malfunctions shall be reviewed comprehensively by all parties involved in the development, implementation, and documentation of the qualification program; however, the overall responsibility is that of the Owner.

Components and subassemblies that are not involved in the equipment's function may be excluded from the qualification process if it can be shown that their malfunction has no effect on the specified function or, via interfaces, on the function of other equipment.

QR-7300 Selection of Qualification Methods

During the development of the qualification program, alternative methods of qualification should be considered and addressed. Qualification shall be accomplished by test, analysis, operating experience, or some combination of these methods. Regardless of the qualification method, rationale shall be provided to show that the operability of the equipment cannot be degraded to such a point that it cannot perform its specified function.

QR-7310 Qualification by Test. Tests shall demonstrate that the equipment performance meets or exceeds the requirements of the equipment design and the applicable qualification specifications. Testing of equipment satisfies qualification requirements if it accounts for significant aging mechanisms, subjects the equipment to specified service conditions, and demonstrates that such equipment can perform its specified function during and/or subsequently for the specified operating time.

The testing shall consist of a planned sequence of test conditions that meet or exceed the expected service conditions. Testing shall include all specified service condition functional tests, radiation exposure, aging, abnormal or special operation, seismic, accident (design basis event), and posttest inspection when they are included in the qualification specification. Sequence of testing and acceptance criteria shall be established prior to testing.

QR-7311 Aging. In general, aging is not a significant concern for metallic components, but aging may influence the functional performance of active components. For nonmetallic materials, a component aging process designed to emulate postulated modes of material degradation shall be considered. Significant aging mechanisms shall be identified and accounted for in an aging program using such methods as overstress and time compression for accelerated aging. The aging acceleration rate and the basis upon which the rate was established shall be described and justified. If natural aging is used, determination of significant aging mechanisms is not necessary. Components subject to different aging mechanisms of wear or environmental degradation may be separately aged.

QR-7312 Dynamic Loading. Qualification of equipment for dynamic loadings, such as but not limited to vibration and seismic loadings, shall consider the requirements and general approaches outlined in Appendix QR-A and IEEE Std 344. Equipment must be demonstrated capable of performing its defined function at all specified conditions before, during, and after a design basis event. If specified, operability of equipment to perform its required function during a dynamic transient shall use the normal system fluid. Use of an alternative fluid is acceptable, if justified.

QR-7313 Determination of Qualification. An individual component test (or other qualification methods) may be conducted only if interfaces and interrelationships between components can be accommodated in a manner reflecting in-plant configuration. Otherwise, equipment must be tested as an assembled unit. Equipment shall be considered to be qualified by test if it can be successfully demonstrated as being able to meet or exceed its specified functions for applicable design basis and postdesign basis events at the end of its qualified life. Equipment qualified life shall be equal to the equivalent age of the tested unit prior to undergoing design basis event simulation.

QR-7320 Qualification by Analysis. Qualification by analysis shall consist of mathematical or other logical methods for qualification. Bases for assumptions and extrapolations shall be documented. Test data, operating data, or physical laws of nature may be used to demonstrate that the equipment can perform its function under specified service conditions. Qualification by analysis may be used when testing is not practical and other supporting data are available to support the analytical assumptions and conclusions reached. Qualification by analysis may also be used when only partial test and other supporting data are available to support the analytical assumptions and conclusions reached.

QR-7321 Aging. As described in QR-7311, aging is not normally a significant concern for metallic components; however, it should be one of the items considered:

(*a*) analysis may be used to eliminate consideration of environmental stresses or aging effects that have an insignificant impact upon equipment functional integrity;

(*b*) analysis may be used to extrapolate or otherwise account for the effect of equipment design modifications as well as verification of aging or environmental parameters in instances when intended application exceeds prior qualification constraints.

When analysis is used to simplify or extend equipment qualification, the analysis shall consider significant aging mechanisms for the item, such as thermal, radiation, wear, and chemical. Analysis methods may be used in conjunction with supportive empirical data to simplify or supplant the test aging exercise for nonmetallic items.

QR-7322 Dynamic Loading. Equipment qualification for dynamic loadings, such as but not limited to vibration and seismic, shall consider analytical procedures detailed in Appendix QR-A, IEEE Std 344, or other acceptable industry practices.

QR-7323 Determination of Qualification. The equipment shall be considered to be qualified by analysis if the equipment can be demonstrated as being able to meet or exceed its specified function for design basis events and postdesign basis events at the end of its qualified life. The equipment qualified life shall be equal to the age of the equipment assumed when performing the design basis event analysis.

QR-7330 Qualification by Experience. Data from equipment of similar design that has successfully operated under known service conditions may be used as the basis for qualification. Qualification by experience is applicable only for those service conditions that have actually been experienced without adverse results on the equipment's ability to perform its function. The validity of this qualification method depends on demonstrating similarity between the equipment to be qualified and the equipment for which there is operating experience, including similarity between the service conditions and equipment performance. Operating experience can provide information on limits of extrapolation, aging characteristics, malfunction modes and rates, equipment performance, and maintenance requirements.

QR-7340 Combined Methods. Equipment may be qualified by a combination of test, analysis, and operating experience, provided partial qualification achieved under multiple procedures can be articulated in a logical fashion to justify the overall equipment qualification. For example, when size, application, time, or other limitations preclude the use of a test on the complete equipment assembly, testing of components supplemented by analysis may be used in the qualification process. This method must ensure that pertinent parameters and the effects of interfaces are addressed.

QR-8000 DOCUMENTATION

QR-8100 General

The qualification documentation shall establish that the active mechanical equipment is qualified for its application and meets its qualification specification requirements. Documentation shall demonstrate that:

(a) the qualification requirements are satisfied; and

(b) the qualified life is determined and the basis established.

Data used to demonstrate the qualification of the equipment shall be pertinent to the in-plant application. In addition, any aging processes not treated during initial qualification, but addressed by in-service surveillance monitoring, shall be specifically identified.

QR-8200 Documentation Files

Equipment qualification documentation shall be maintained in a qualification file. The file shall contain the equipment qualification specification and supporting qualification documentation similar to, but not limited to, the following:

(a) evidence that the specified design requirements were addressed;

(b) evidence that the functional qualification requirements were addressed;

(c) evidence of extent of qualification determined, including a description of the process followed;

(d) supporting qualification documentation or reference to same, such as qualification and production test reports, certificates of compliance, material certifications, and installation/operation/maintenance manual;

(e) summary and conclusions; and

(f) approval signature and date.

Qualification file shall be prepared and maintained in accordance with ASME NQA-1.

NONMANDATORY APPENDIX QR-A
DYNAMIC QUALIFICATION OF MECHANICAL EQUIPMENT

QR-A1000 SCOPE

This Appendix identifies the procedures and guidelines by which ASME Class 1, 2, and 3 pumps and valves may be seismically qualified for operability when subjected to dynamic effects. This initial publication addresses qualification for seismic loadings only. The methods and definitions presented in this Standard are not intended to limit other qualification techniques. In particular, this Standard permits the testing methods presented in IEEE Std 344-87 by direct reference to it (see QR-A3000).

One significant difference between this Appendix and IEEE Std 344-87 is the deletion of the explicit Operating Basis Earthquake (OBE) seismic functionality qualification requirement by provisions of this Appendix, provided certain caveats are met.

Mechanical equipment specified as ASME Code Classes 1, 2, and 3 (unlike electrical equipment) require ASME Boiler and Pressure Vessel Code (BPVC) Section III evaluation of leak tightness and structural integrity of pressure-retaining components. Within the Service Level B category normally used to evaluate the OBE loading case, linear elastic response is usually required for all primary loads. When stresses and deformations induced by the OBE are limited to the elastic range, deformations are small and predictable, and therefore ASME Boiler and Pressure Vessel Code analysis for the OBE loading case can provide functional or operability qualification.

With the caveat that operability failure modes be identified and evaluated for the OBE, including fatigue evaluations within the limitations of the ASME BPVC, there is no requirement that such components be further evaluated by this Appendix for operability under the OBE loading condition.

The mechanical equipment to be qualified by procedures based upon this document can be of many forms; therefore, this document 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. Exceptions to these recommended practices may be made when it can be shown that the substituted procedure verifies that the equipment can perform its specified function. The basis for a technical justification is:

(a) directly by analysis or tests of equipment or prototype equipment being qualified; or

(b) indirectly by demonstrated similarity of candidate equipment to parent equipment that has been qualified by analysis, test, or experience data.

QR-A2000 PURPOSE

The purpose of this Appendix is to provide recommended practices to demonstrate that pumps and valves constructed to ASME BPVC Section III can meet specified function or operability requirements during and following Design Basis Earthquakes. This Appendix is nonmandatory and provides various recommended practices for seismic qualification performance of mechanical equipment. As a nonmandatory document, it contains wording such as *shall, should* and *may.* The word *shall* denotes a suggested requirement; *should* denotes a suggested recommendation; and *may* denotes permission, neither a requirement nor a recommendation.

QR-A3000 REFERENCES

The references listed below have provided guidance on concepts, principles, practices, and criteria in the preparation of this Appendix and are cited throughout this Appendix.

ASCE Standard 4-86, Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures, American Society of Civil Engineers, September 1986

Publisher: American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400

ANSI/ASME OME3-1982, Requirements for Preoperational and Initial Start-up Test of Nuclear Power Plant Piping Systems, The American Society of Mechanical Engineers, September 4, 1981

ASME Boiler and Pressure Vessel Code (BPVC), Section III, Appendix I, Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves, The American Society of Mechanical Engineers, 1986

ASME Boiler and Pressure Vessel Code (BPVC), Section III, Appendix N, Dynamic Analysis Methods, The American Society of Mechanical Engineers, 1986

ASME Paper 74-NE-8, Equivalent Static Load From Amplification Response Curves; J. M. Gwinn and Goldstein; PV&P Conference, 1974

ASME Paper 74-NE-9, Amplification Factors to Be Used in Simplified Seismic Dynamic Analysis of Piping Systems; J. D. Stevenson and W. S. Lapay; PV&P Conference, June 1971

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007

EQE Inc., Vol. 1: Pilot Program Report, Program for the Development of an Alternate Approach to Seismic Equipment Qualification, September 1982

EQE Inc., Vol. 2: Pilot Program Report Appendices, Program for the Development of an Alternative Approach to Seismic Equipment Qualification, September 1982

EQE Report, Summary of the Seismic Adequacy of Twenty Classes of Equipment Required for Safe Shutdown of Nuclear Plants, EQE Inc., San Francisco, California, February 1987 draft

Publisher: Stevenson & Associates, 9217 Midwest Avenue, Cleveland, OH 44125-2415

IEEE Std 344-87, Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations, Institute of Electrical and Electronics Engineers, 1987

IEEE Std 382-85, Type Test of Class 1E Electrical Valve Operators for Nuclear Power Generating Stations, Institute of Electrical and Electronics Engineers, 1985

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NUREG/CR-5012, Similarity Principles for Equipment Qualification by Experience; D. J. Kana and D. J. Pomerening; July 1988

Regulatory Guide 1.60, Design Response Spectra for Nuclear Power Plants, U.S. Atomic Energy Commission, Washington, D.C., 1973

Regulatory Guide 1.61, Damping Valves for Seismic Design of Nuclear Power Plants, U.S. Atomic Energy Commission, Washington, D.C., 1973

Regulatory Guide 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components, Rev. 1, U.S. Nuclear Regulatory Commission, February 1978

Senior Seismic Review and Advisory Panel (SSRAP), Use of Seismic Experience and Test Data to Show Ruggedness of Equipment in Nuclear Power Plants, prepared for Seismic Qualification Utility Group in Cooperation with the U.S. Nuclear Regulatory Commission, April 1990

Publisher: U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

User's Manual, COMPAR-Access Program to Seismic Qualification Data Bank Based on Analysis and Testing, Stevenson and Associates, January 1985

Publisher: Stevenson & Associates, 9217 Midwest Avenue, Cleveland, OH 44125-2415

User's Manual, EPRI/NUS Equipment Qualification Data Bank, Rev. 9, NUS Corp., Clearwater, Florida, October 1987

Publisher: Electric Power Research Institute (EPRI), 3412 Hillview Avenue, Palo Alto, CA 94304

WRC Bulletin 300, (1) Technical Positions on Criteria Establishment; (2) Technical Position on Damping Values—Interim Summary Report; (3) Technical Position on Response Spectra Broadening; (4) Technical Position on Industry Practice, December 1984

Publisher: Welding Research Council (WRC), 3 Park Avenue, 27th Floor, New York, NY 10016-5902

QR-A4000 DEFINITIONS

These definitions establish the meanings of words in the context of their use in this Appendix.

acceleration design value: acceleration value that may be used as an alternative response spectrum or time history to define seismic input for design of equipment.

assembly: two or more connected components that may be qualified as a unit.

attachment: an item that is appended to a device, component, or assembly.

bounding spectra: ground response spectra for a site for which items of equipment are considered seismically qualified by experience.

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

Classes 1, 2, 3, MC: ASME Boiler and Pressure Vessel Code Section III definitions of classes of equipment.

coherence: the coherence function defines a comparative relationship between two time histories. It provides a statistical estimate of how much two motions are related as a function of frequency. The numerical range is from zero, for unrelated, to one, for perfectly correlated motions.

correlation coefficient: the correlation coefficient function defines a comparative relationship between two time histories. It provides a statistical estimate of how much two motions are related as a function of time delay. The numerical range is from zero for unrelated, to ±1.0 for related motions.

cutoff frequency: the frequency in the response spectrum where the Zero Period Acceleration asymptote essentially begins. This is the frequency beyond which the single-degree-of-freedom oscillators exhibit very little or no amplification of motion, and indicates the upper limit of the frequency content of the waveform being analyzed.

cycle: one complete sequence of values of an alternating quantity.

damping: a generic name ascribed to the energy dissipation mechanisms or small, otherwise unrepresented nonlinearities that reduce the amplification and broaden the vibratory response in the region of resonance. One hundred percent critical damping is defined as the least amount of equivalent viscous damping that causes a single-degree-of-freedom system to return to its original position without oscillation after initial disturbance.

device: an item that is used in connection with, or as an auxiliary to, other items of equipment on which it may be mounted.

effective mass: the mass of the structure or equipment that participates in determining the dynamic response of the structure or equipment.

effective mass ratio: the ratio of the effective mass considered in the response to the total effective mass for the equipment or structure.

equipment: see definition in QR-4000.

equipment, candidate: see definition in QR-4000.

equipment, flexible: equipment, including the effects of the equipment supports, the lowest natural frequency of which is less than the frequency value at the start of the Zero Period Acceleration (ZPA) or the cutoff frequency of the applicable response spectrum.

equipment, parent: see definition in QR-4000.

equipment, rigid: equipment, including the effects of the equipment supports, the lowest natural frequency of which is greater than the frequency value at the start of the Zero Period Acceleration (ZPA) or the cutoff frequency of the applicable response spectrum.

equivalent static load: an equivalent statically applied load or acceleration based on a function of the peak of the applicable response spectrum that may be used as an alternative to response spectrum or time history to define seismic input for design of equipment.

floor acceleration: the acceleration of a particular building floor (or equipment mounting) resulting from the motion of a given earthquake. The maximum floor acceleration is the ZPA of the floor response spectrum.

foundation: a structure that supports or otherwise provides restraint to equipment and buildings.

Fourier spectrum: a complex valued function that provides amplitude and phase information as a function of frequency for a time domain waveform.

fragility: susceptibility of equipment to malfunction as a result of structural or operational limitations or both when subjected to dynamic excitation.

fragility level: the highest level of excitation parameters that equipment can withstand and still perform the specified functions (note that the fragility level may include the interdependence of amplitude, frequency, and time).

fragility response spectrum: a test response spectrum (TRS) that defines the fragility level of the equipment.

generic equipment ruggedness spectrum: a composite response spectrum based on experience for which a class of similar equipment has been demonstrated to have sufficient ruggedness to perform its specified function.

generic response spectrum: a response spectrum that defines an envelope for which specific equipment including its supports has been found to be able to perform its specified function.

ground acceleration: the acceleration time history of the ground resulting from the motion of a given earthquake. The maximum amplitude ground acceleration is the ZPA of the ground response spectrum.

groups (supports): one or more supports that are assumed to undergo the same seismic motion (i.e., a single response spectrum is applicable to a group of supports).

low-cycle fatigue: a progressive fracture or cumulative fatigue damage of the material, which may be inflicted by less than 1,000 cycles of load because of localized stress concentration at high strains under fluctuating loads.

mass ratio: the ratio of the equipment mass (secondary) to the building mass (primary) participating in the response.

narrow band response spectrum: a response spectrum that describes motion in which amplified response occurs over a limited (narrow) range of frequencies.

natural frequency: the frequency or frequencies 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.

octave: the interval between two frequencies that have a frequency ratio of two.

power spectral density (PSD): the mean squared amplitude per unit frequency of a waveform. PSD is expressed in g^2/Hz versus frequency for acceleration waveforms.

qualification life: see definition in QR-4000.

required input motion (RIM): the input motion in terms of either acceleration, velocity, or displacement expressed as a function of frequency, for which the equipment or component shall be qualified for its acceptance criteria.

required response spectrum (RRS): the response spectrum issued by the Owner or his agent as part of the specification for seismically qualifying equipment. The RRS constitutes a requirement to be met in qualifying equipment.

resonance frequency: a frequency at which peak response occurs in a system subject to forced vibration.

response spectrum: a 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.

ruggedness: ability of equipment to perform its specified function when subjected to dynamic excitation.

sine beats: a continuous sinusoid, of one frequency, with its amplitude modulated by a sinusoid of a lower frequency.

stationarity: a waveform is stationary if its amplitude distribution, frequency content, and other descriptive parameters are statistically constant with time.

structure: a combination of physical members that make an item, such as a building or a support, that is designed to sustain a load.

structural integrity: a condition describing an assembly or grouping of equipment relative to their ability to carry applicable loads within the limits of acceptable structural behavior.

system: an assembly or grouping of equipment that performs a specific plant function.

test response spectrum (TRS): the response spectrum that is developed from the actual time history motion of the shake table or other dynamic input device.

transfer function: a complex frequency response function that defines the dynamic characteristics of a constant parameter linear system. For an ideal system, the transfer function is the ratio of the Fourier transform of the output to that of a given input. The output/input ratio function versus frequency is called a *transmissibility function.*

Zero Period Acceleration (ZPA): the high-frequency acceleration level of the nonamplified portion of the response spectrum. This acceleration corresponds to the maximum acceleration amplitude of the time history used to derive the spectrum.

QR-A5000 GENERAL DISCUSSION OF EARTHQUAKE ENVIRONMENT AND EQUIPMENT RESPONSE

This Article provides background on earthquake behavior and on methods for simulating seismic events.

QR-A5100 Earthquake Environment

Earthquakes produce six degrees of freedom (three translational and three rotational) random ground motions. These motions, for design purposes, are characterized by simultaneous but statistically independent components, two horizontal and one vertical. The strong-motion portion of the earthquake normally considered in design may last 10 sec to 15 sec, although the measurable earthquake motion duration may be considerably longer. For earthquakes with zero period ground accelerations in excess of about 0.35 g, the strong-motion durations often exceed 15 sec. Ground motion is typically broadbanded and random, and it is generally accepted that amplified response can occur over a frequency range of 1 Hz to 33 Hz.

QR-A5200 Equipment on Foundations

The vibratory nature of ground motion (both horizontal and vertical) can be amplified or attenuated in structure-mounted equipment. For any given ground motion, the alteration depends on the system's natural frequencies of vibration (soil, equipment support, and equipment) and the mechanisms of damping and mass ratio between the equipment and the foundation. The response spectra that describe ground motion are typically broadband, indicating that multiple frequency excitation predominates.

QR-A5300 Equipment on Structures

Ground motion (horizontal and vertical) may be filtered by intervening building structures to produce either amplified or attenuated narrow band motions within the structure. The dynamic response of equipment on structures may be further amplified or attenuated to an acceleration level many times more or, in some instances, less than that of the maximum ground acceleration, depending upon the structure and equipment damping, effective mass ratios, and natural frequencies. The narrow band response spectra that typically describe a building floor response motion indicate that single-frequency excitation of equipment subcomponents can predominate.

QR-A5400 Equipment on Systems (in Line)

Similar filtering of in-structure motion may occur in flexible distribution (piping and ducting) systems. For components mounted away from system supports, the resultant motion may be predominantly single frequency in nature and centered near or at the local resonance frequency of the distribution (piping) system. This resonance condition may produce the most critical seismic load on components mounted in the system line. Mass ratio effects or dynamic coupling that typically reduce the response of the in-line equipment are often conservatively neglected. The seismic input motions for components mounted on flexible systems may be defined in terms of required input motion (RIM), and procedures defined in IEEE 382-85 (see QR-A3000) may be used to seismically qualify such components. In addition to inertia effects, the potential for relative motion between a distribution system and its supporting building structure, or between a branch and main line, may be a significant earthquake effect.

QR-A5500 Nonlinear Equipment Response

Nonlinearity in equipment response may exist in addition to the minor nonlinear effects typically associated with damping. These nonlinearities may be of a geometric nature, such as rocking or sliding, a working of connections and rattling of components, or of a material behavior source, such as yielding. These effects may result in a significant change in stiffness as a function of load. If a system exhibits significant nonlinearity, such behavior is recognized and accounted for in order to accurately predict or bound the equipment response. If the nonlinearities cannot be adequately analyzed, testing is required.

Nonlinearity may also occur as a result of local vibrations, contact, or impact of equipment. Such examples include the closing of gaps between the equipment and its supports or restraints and the high-frequency rattling of valves subject to piping interaction with supporting or adjacent equipment on structures. When such nonlinear response conditions exist, the qualification procedure shall account for such behavior and shall be properly validated.

QR-A5600 Simulating the Earthquake

The goal of seismic simulation is to reproduce the postulated earthquake environment in a realistic manner that is amenable for use in equipment qualification. The form of the simulated seismic input used for the qualification of equipment by analysis or testing can be described by one of the following functions: required input motion, response spectrum, time history, power spectral density, acceleration, or equivalent static load design value. This input may be generated for the foundation, floor of the building, or system upon which the equipment is to be mounted. It is supplied by the Owner or agent to the manufacturer as a part of the specifications for that equipment, or it is generated by the manufacturer to generically cover future applications.

Because of the directional nature of seismic motion, as well as the filtered response motion of structures and in-line systems on which equipment may be mounted, the directional components of the motion and their application to the equipment shall be specified.

Due to eccentricity of supporting structures (center of shear and center of gravity do not coincide) or due to the finite time passage of seismic wave motion across the building foundation, additional torsional motion (depending on the type of building model used) may be applicable to equipment as a function of its distance from the shear center of the supporting building. Procedures for determining this torsional effect, if applicable, shall be specified.

QR-A5610 Required Input Motion. The required input motion is defined in terms of accelerations, velocity, or displacement as a function of frequency and is applied in the form of a continuous series of sine beats or sinusoids over the frequency range of interest (1–33 Hz) when testing is used to qualify the components. See IEEE Std 382-85 (QR-A3000) for more details.

QR-A5620 Response Spectrum. The response spectrum provides information on the maximum response of single-degree-of-freedom oscillators as a function of oscillator frequency and damping when subjected to an input time history motion. The frequency content as well as the peak amplitude (Zero Period Acceleration) of the input motion are also indicated.

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

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

(b) the duration of motion (this must be given separately in specifications);

(c) the response of any particular equipment during a test.

QR-A5630 Time History. The expected form of the motion is generally obtained from existing or artificially generated earthquake records. It may also be generated so that its response spectrum will essentially match a given response spectrum. 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.

QR-A5640 Power Spectral Density Function. The mean squared amplitude per unit frequency of the vibratory motion is characterized in terms of the PSD, a function of frequency.

NOTE: Although response spectrum and PSD function, unlike time history, do not define the unique waveform or duration of the excitation, they are still valuable tools. They enable significant frequency-dependent properties of the motion to be seen at a glance from one curve.

QR-A5650 Acceleration or Equivalent Static Load Design Values. Components or equipment may be qualified analytically by applying a limiting acceleration design value (ADV) to the mass distribution of the component or equipment in order to determine limiting equivalent static forces in all three orthogonal directions. This ADV is determined by use of the peak of the applicable RRS or the ZPA if the component can be shown to be rigid. A coefficient of 1.5 times these peak or ZPA values is often used to define the ADV in those instances in which the component is supported at more than two points. However, values less than 1.5 may be used if justified (see NUREG-75/087 in QR-A3000).

QR-A6000 GENERAL SEISMIC QUALIFICATION REQUIREMENTS

The seismic qualification of ASME Class 1, 2, and 3 equipment should demonstrate ability of the equipment to perform its specified function during and after the time it is subjected to the loadings resulting from one Safe Shutdown Earthquake (SSE). Meeting the ASME Boiler and Pressure Vessel Code (BPVC) Section III analysis requirements within elastic limits for the Operating Basis Earthquake (OBE) provides assurance of specified function for that level of earthquake as discussed in QR-A1000. The most commonly used methods for seismic qualification are described in this document. The methods are grouped into the following four general categories:

(a) predict and evaluate the equipment's performance by analysis;

(b) test the equipment under simulated seismic conditions;

(c) qualify the equipment by use of experience data;

(d) perform evaluations by combined analysis, test, and/or experience data.

Each of the preceding methods may be used to verify the ability of the equipment to meet the seismic qualification requirements. The choice should be based on the practicality of the method for the type, size, shape, and complexity of the equipment, the available database, whether the required safety function can be assessed in terms of structural integrity alone, and the reliability of the conclusions. When the specified function of equipment requires a demonstration of operability during the earthquake, the equipment specified function shall be demonstrated during the strong-motion portion of the earthquake.

Design margins specified in ASME BPVC Section III shall be employed where required or applicable.

Seismic testing, as part of an overall qualification program, should be performed in its proper sequence as indicated in the overall equipment qualification program.

The effects of equipment repair and parts replacement on the performance of equipment in the qualification programs shall also be considered.

QR-A6100 Design Basis Earthquake

The Design Basis Earthquake for which equipment shall be qualified is the SSE identified for the site. Seismic qualification for operability for the OBE shall be in accordance with ASME BPVC Section III requirements for pressure-retaining and leak-tight integrity. In some instances, a smaller OBE may also be specified by the Owner or agent for seismic qualification of the equipment. In such instances, the methods and procedures contained in this Appendix may also be used to qualify equipment for the OBE. However, margins to be used to qualify equipment for either the SSE or the OBE are beyond the scope of this Standard. Guidance for the establishment of such margins may be found in ASME BPVC Section III and various ANS system standards, as well as applicable NRC regulatory procedures and guides. The acceptance criteria, which include consideration of specified margin, shall be established as described in QR-A7240 and QR-A7340.

QR-A6200 Damping

QR-A6210 Introduction. Structural damping is the generic name ascribed to the numerous energy dissipation mechanisms in a system. It also accounts for small nonlinear response effects not otherwise considered in the evaluation. In practice, structural damping depends on many parameters, such as structural system support configurations and types, modes of vibration, strain levels, velocity, material properties, and joint slippage. In linear vibration theory, the simplifying assumption is made that damping is purely viscous, or dependent on 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 viscous. This is a convenient way of relating real-world hardware behavior, which is usually nonlinear to some degree, with theoretical concepts, which normally use linear methods of analysis.

For equipment composed of an assembly of components, there is usually no single damping value. Damping is associated with types of connections used, ranging from bolted to welded construction, and is strongly affected by boundary conditions, including gaps and joint slippage. The value of structural damping may vary from place to place depending on the numerous other factors previously mentioned and can be termed local damping. The structural damping that is typically defined for use in seismic evaluations is called *global damping* and is a composite of the local damping values of the system. In such instances, it is recommended that best estimate values of structural damping be used in equipment qualification, rather than some lower bound value. In the absence of specific damping criteria, the values contained in Table QR-A6210-1 should be used.

Since each mode of vibration of a structure can and often does have a different value of damping as a function of modal mass and stiffness, 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. Furthermore, damping may also be defined as a function of modal frequency, which is the case for piping when ASME BPVC Code Case N-411-1 applies.

QR-A6220 Measurement of Damping. Linear vibration theory indicates that there are numerous methods

(02) **Table QR-A6210-1 Damping Values: Percent of Critical Damping**

	Earthquake Magnitude	
Structure or Component	Operating Basis Earthquake	Safe Shutdown Earthquake
Equipment and large diameter piping systems [Note (1)], > NPS 12 (DN 300)	2	3
Small diameter piping systems, ≤ NPS 12 (DN300)	1	2
Welded steel structures	2	4
Bolted steel structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

NOTE:
(1) Includes both material and structural damping. If the piping system consists of only one or two spans, with little structural damping, use values for small diameter piping.

available to measure damping. Considerable care must be exercised in making the transition from an idealized model to a practical system. The following methods for evaluating damping are commonly used. The methods assume that a single mode of vibration can be excited in the equipment and that motion transducers are mounted at positions other than at a stationary node of zero motion. In all cases, care should be exercised to determine whether damping changes with response amplitude are significant.

QR-A6221 Damping by Measuring the Decay Rate. The equivalent viscous damping can be calculated by recording the decay rate of the particular mode of vibration. This procedure is often referred to as the *logarithmic decrement method.*

QR-A6222 Damping by Measuring the Half-Power Bandwidth. Equipment is typically excited with a slow sine sweep test. The response of any desired location in equipment is measured and plotted as a function of frequency. The damping associated with each mode can be calculated by measurements of the width of the respective resonance peak at the half-power point. This procedure is often referred to as the *half-power bandwidth method.*

QR-A6223 Damping by Curve Fitting Methods. Equipment is typically excited by swept sine, random, or transient excitation, and a response transfer function is developed. The resulting curve is matched by adjusting the individual modal damping values to a best fit of the multiple mode response of the equipment.

QR-A6230 The Application of Damping. Damping is used differently in testing and analysis in equipment qualification as described below. The damping factor used in verification by analysis is recommended as the best estimate, rather than lower bound values, for getting the most realistic dynamic response of the component.

In analysis, a mathematical model is made of the equipment in order to predict the response to the seismic motion. The value of damping used in this model shall correspond to the actual energy dissipation in the equipment, plus the nonlinear effects that reduce response not otherwise included in the analysis, to enable the response to be accurately predicted. There is a need to know the ranges of damping for the specific equipment and the nature of nonlinearities and their effect on the response. It is recommended that appropriate values of damping be obtained from tests.

In most equipment, damping is a function of response amplitude, due to such factors as internal friction within material or at connections between components, degree of cracking of composite members, or Coulomb-type sliding friction. For analytical purposes, these energy dissipation damping mechanisms may often be dealt with in terms of linear viscous damping approximations if proper consideration is given to the fact that they vary, sometimes significantly, with increasing response. Damping shall be used with caution when determined by low impedance testing, for damping values thus determined may not indicate strong-motion excitation.

In general, damping increases with excitation level. However, at very low levels of excitation, apparent damping levels can be quite high due to nonlinear effects associated with small gaps in the supports. At levels of excitation where operability of the equipment would be a concern, damping is expected to remain constant or increase with increases in excitation level.

Most analysis of structural systems assumes linear behavior and viscous damping. Certain components may exhibit nonviscous damping or nonlinear behavior. The treatment of this problem is analytically complex, but may be performed using time history techniques.

In testing, the equipment may be qualified by being subjected to a simulated seismic motion as defined by the RRS. The response spectrum defines the seismic motion via the peak response of an array of single-degree-of-freedom damped oscillators. Since the oscillators are hypothetical, any practical value of damping, e.g., 5%, may be employed in the RRS for testing, and it need not correspond to the actual equipment damping. (Note the distinction from the use of the RRS in analysis, where the value of damping must be related to the equipment being qualified.) The application of the RRS and TRS in selecting acceptable test motions is referenced in QR-A7300.

In comparing the RRS and TRS, it is preferred that the damping in each be the same. When the RRS and TRS damping are different, the following applies:

(a) if the damping for the enveloping TRS is greater than that for the RRS and the criteria referenced in QR-A7300 are satisfied, then the qualification is acceptable since under these circumstances the TRS is conservative;

(b) if the damping for the enveloping TRS is less than that for the RRS, a conclusive statement is not possible without further evaluation. One possibility is to reanalyze the test motions to produce a TRS for an acceptable damping value equal to or greater than the RRS damping value.

QR-A6300 Response Spectrum

Basic spectra used in seismic qualification of equipment are contained in NRC Regulatory Guide 1.60 (see QR-A3000) and are reproduced in this Appendix as Figs. QR-A6300-1 and QR-A6300-2. On a case-by-case basis acceptable to regulatory authorities, site specific spectra may be substituted for spectra shown in Figs. QR-A6300-1 and QR-A6300-2. RRS may be generated from the basic spectra of Figs. QR-A6300-1 and QR-A6300-2 or other site-specific spectra using either the time history or the direct method. A description of an acceptable time history and application of the direct method can be found in NUREG-75/087 Standard Review Plan 3.7.2, Rev. 2 (QR-A3000). Response spectra are used directly to develop inertial seismic loading on equipment and may be used indirectly to determine relative support motion seismic loads on equipment.

QR-A6400 Required Input Motion

Required input motion (RIM) in seismic evaluations is normally associated with components mounted in distribution system (piping or duct) lines where the single mode seismic input to the component is dominated by the seismic response of the distribution system (line) and qualification is performed by test for generic application to a wide range of line frequencies.

The input to a distribution system is typically a random excitation with broad frequency content. The dynamic characteristics of the system amplify the excitation at the system resonance frequencies and suppress the other frequencies. The maximum response occurs at the predominant distribution system frequencies.

A method that meets the above seismic input simulation criteria for a component mounted in the distribution system is either a sine beat test or a relatively short duration sine dwell test at several frequencies. The minimum peak test amplitude shall be that which the distribution system is expected to experience.

A series of continuous sine beats or sinusoids at varying amplitudes as defined in Fig. QR-A6400-1 is recommended for qualification by test. To ensure the excitation of all predominant resonance frequencies, the sine beats shall be applied at one-third octave intervals over the frequency range of 1 Hz to 33 Hz. The test amplitude shall correspond to the levels specified for response of the distribution system. This amplitude shall be independent of direction. Hence, single-axis excitation is permitted, with the axes corresponding to the apparent most critical direction of the component.

When a component in a distribution system is closely restrained by a support back to the building or other supporting structure, RRS or response spectra techniques are recommended for qualification rather than the RIM test procedure just described, unless the RIM has been conservatively established with regard to the RRS.

QR-A6500 Acceleration or Equivalent Static Load Design Values

Equipment can be analytically seismically qualified by applying acceleration design values (ADV) used to develop equivalent static loads. These are single value accelerations that may be applied statically to the equipment in accordance with the mass distribution simultaneously along the two principal horizontal and vertical directions. Resultant limiting stresses, deflections, and reactions are combined with other applicable load phenomena and evaluated against the applicable acceptance criteria to demonstrate design adequacy. The ADV are determined as a function of the peak of the applicable RRS, or from the ZPA of the RRS, if rigidity can be demonstrated. The response spectral peak value or the ZPA should be multiplied by a suitable coefficient that accounts for the potential effects of higher modes or incomplete or missing modes associated with static versus dynamic mode shapes. For equipment supported at more than two points, a coefficient of 1.5 is recommended. Coefficients less than 1.5 may be used if adequately justified.

QR-A6600 Differential Support Motion

In addition to the inertial loading on equipment developed from seismic accelerations applied to the mass of the equipment, additional loads may be induced on equipment supported at two or more points that are undergoing relative support motion associated with the motion of the supporting structures. In general, most equipment is supported at a single point. Because of the relatively high stiffness and required elastic response to earthquake motions of nuclear power plant structures, differential support motions are usually negligible and have little effect on the seismic induced forces on equipment. Therefore, differential support motions are not normally considered in the seismic evaluation of equipment, except for equipment or a component that is supported at three or more points on the same structure, or at two or more points on different structures, or between in-line components and the supporting structure (see NUREG-75/085 in QR-A3000). In these cases,

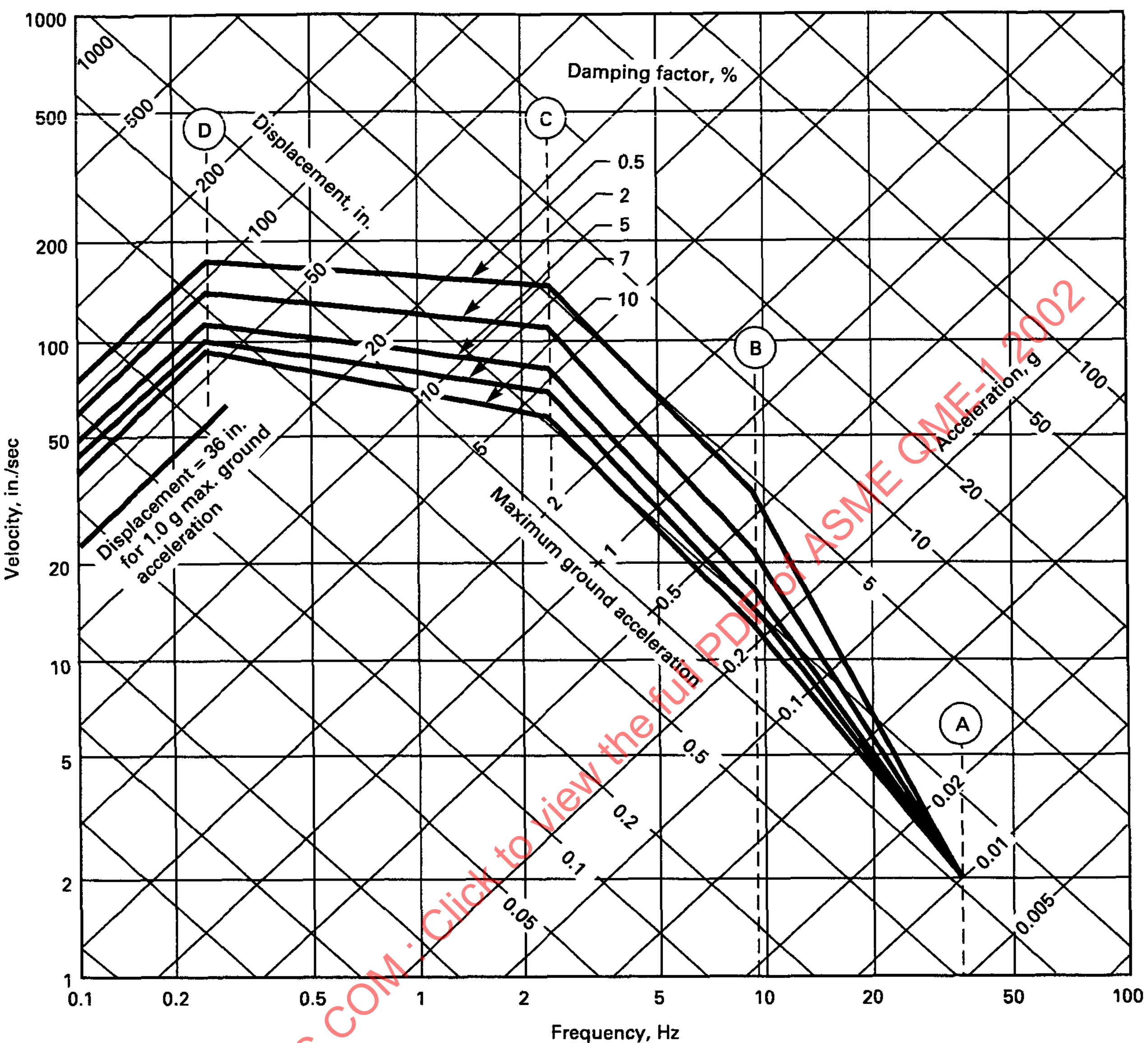


Fig. QR-A6300-1 Horizontal Design Response Spectra Scaled to 1 g Horizontal Ground Acceleration

the equipment qualifier shall consider the effects of distinct multiple support inputs in analysis.

QR-A6610 Evaluation for Differential Support Motions. The maximum relative support displacements can be obtained from the supporting structure structural response calculations or by using the applicable floor response spectra. For the latter option, the maximum displacement of each support is predicted by the relationship $Z_d = Z_a g/w^2$, where Z_a is the spectral acceleration in g's at the ZPA end of the spectrum curve, w is equal to the predominant frequency of the primary support structure in radians per second, and g is the gravitational constant.

The support displacements shall be imposed on the supported item. The responses due to the inertia effect and relative displacements should be combined as follows:

(a) For equipment supported by a common or different supporting structure, the relative displacements may be determined by using the square root sum of squares method if it is demonstrated that they are uncorrelated. Otherwise, they shall be determined by the absolute sum method.

(b) For in-line components (e.g., valves) supported by both the line and the primary structure, relative displacements shall be determined by the absolute sum method.

In lieu of the response spectrum approach, time histories of support motions may also be used as excitations to the systems.

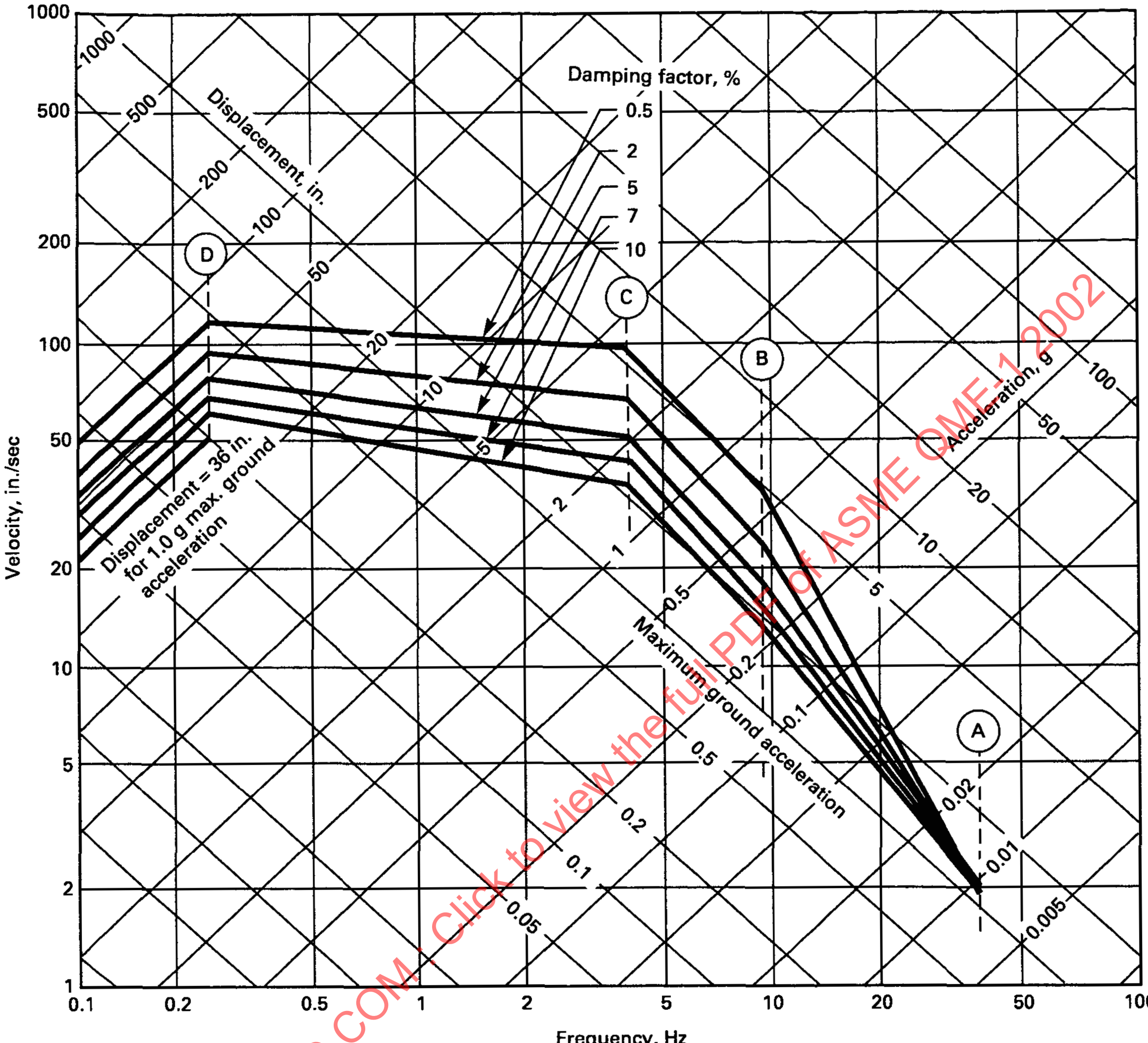


Fig. QR-A6300-2 Vertical Design Response Spectra Scaled to 1 g Horizontal Ground Acceleration

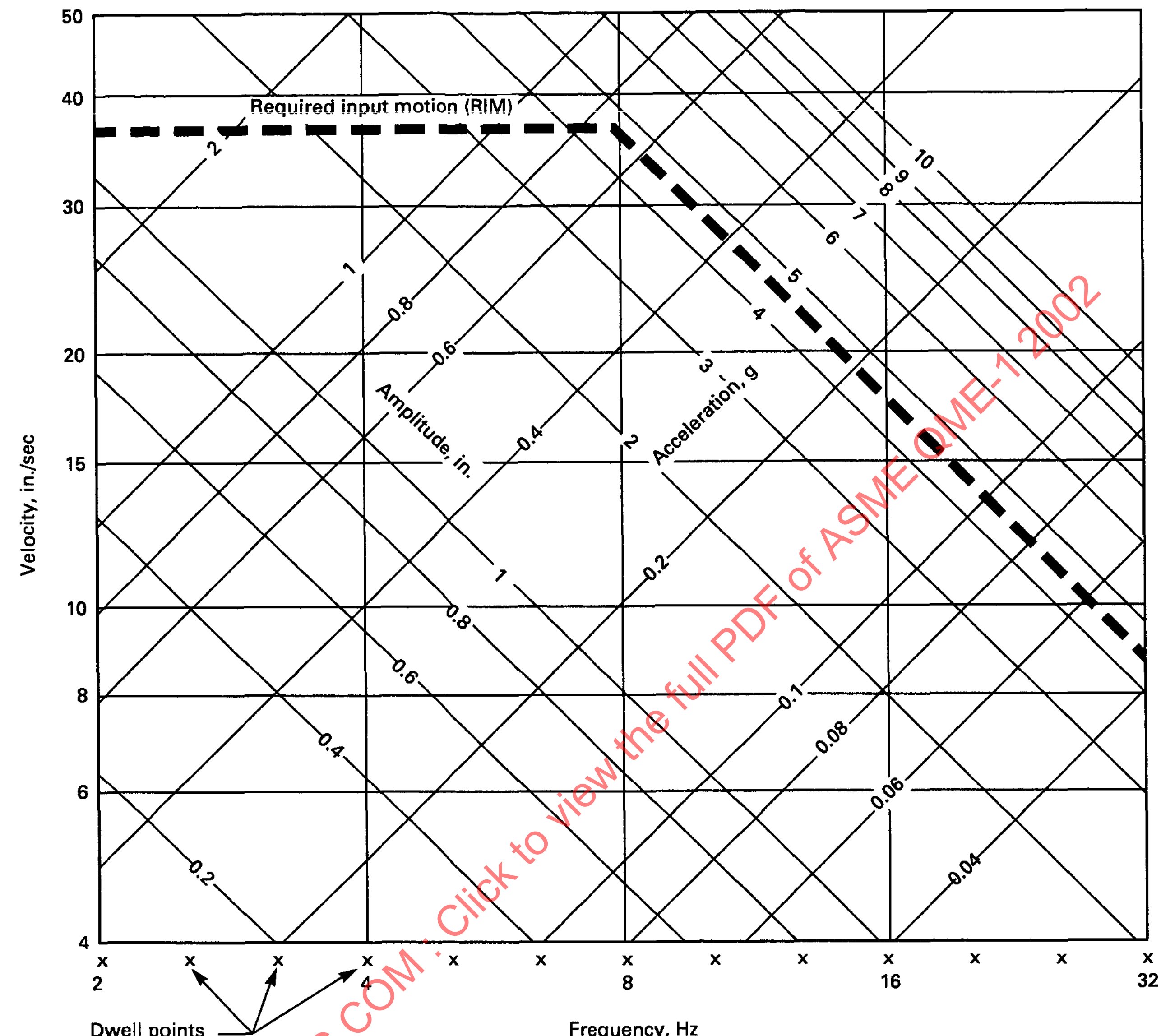
QR-A6700 Loads to Be Considered in Qualification

The loads to be considered in the seismic qualification of mechanical equipment for nuclear power stations are defined in the Design Specification required by ASME BPVC Section III. They will be made part of the Seismic Input Specification required to seismically qualify the required function or performance of the component.

QR-A6800 Fatigue and Aging Considerations

QR-A6810 Fatigue. Seismic loads, being vibratory in nature, give rise to cyclic loading of components; hence, there is a potential for fatigue-type failures. However, the number of maximum stress cycles from a given earthquake is quite limited. Paragraph N-1214 of Appendix N to ASME BPVC Section III suggests ten cycles per earthquake. This Appendix assumes in the limit that there are 60 full stress cycles during the plant life. This cyclic input assumes the potential of five OBE or aftershocks and one SSE.

The minimum value of S_a for all Code materials from the Appendix I-9.1 curves of ASME BPVC Section III (see QR-A3000) is 230 ksi for 60 cycles. Inertia-induced earthquake stresses are considered primary in nature and in all cases are limited in design to less than $3S_m$, where S_m is no greater than $0.33S_u$. In the limit, earthquake stresses may be equal to S_u computed on an elastic basis. Independent of other loads, the S_u of the material used would have to equal or exceed 230 ksi before fatigue induced by earthquake stresses could govern



GENERAL NOTES:

(a) Values may not envelop all plants. User shall verify adequacy.

(b) Figure reprinted with permission from IEEE Std 382-1985*, "IEEE Standard for Qualification of Actuators for Power Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants," Copyright 1985*, by IEEE. The IEEE disclaims any responsibility or liability resulting from the placement and use in the described manner.

Fig. QR-A6400-1 Seismic Qualification Required Input Motion (RIM)

design. Code materials used to design mechanical components typically do not exceed an ultimate strength of 100 ksi, so earthquake-induced failure in ASME BPVC Section III materials is not considered credible. When functionality or operability of equipment is determined by behavior of Code materials having specified minimum ultimate strengths of less than 230 ksi, no cyclic or fatigue evaluation is required.

Non-ASME Boiler and Pressure Vessel Code materials, such as gaskets or seals, or Code materials having an ultimate strength in excess of 230 ksi may not have been qualified to preclude fatigue failure for low-cycle loading up to 60 cycles. In such instances, it is recommended that these materials be qualified by separate effects tests or, alternatively, it would be necessary as part of the functionality or operability seismic qualifications to subject the equipment to 60 cycles of loading.

Other cyclic loads induced on the mechanical equipment by valve operation, equipment start or stop, flow, or rotating equipment vibration and temperature ranges shall be considered in evaluating the overall fatigue life of the component or otherwise be limited to such a low magnitude (e.g., see ANSI/ASME OM3-1982 in QR-A3000) that they do not exceed the endurance limit for the material used in the equipment.

QR-A6820 Aging. Aging in mechanical components is associated with corrosion, erosion, wear, particle deposits, and embrittlement. In new construction, corrosion and erosion are considered by providing additional material thickness as a corrosion or erosion allowance above that required in design. Aging phenomena are considered during in-service inspections of operating components as contained in plant technical specifications in Section XI of the ASME Boiler and Pressure Vessel Code, and in this Standard. Aging qualification of metallic parts of equipment shall be in compliance with ASME Section XI requirements. Aging qualification of nonmetallic parts of equipment shall be in compliance with the specific standard for the mechanical equipment under consideration.

QR-A7000 QUALIFICATION METHODS

There are two basic methods for seismic functional qualification of mechanical equipment, direct and indirect. The indirect method is also referred to as *parent equipment extension*. The direct method involves qualification of the actual or prototype equipment by analysis or test. The indirect method qualifies equipment by similarity to equipment that has been qualified previously by analysis, test, or the use of experience data. QR-A7100 covers qualification by experience data and similarity associated with the indirect method. QR-A7200 addresses qualification by analysis, QR-A7300 addresses qualification by testing, and QR-A7400 addresses combination of testing and analysis using either the direct or the indirect method.

QR-A7100 Qualification by Indirect Method

QR-A7110 Introduction. There are many types of equipment that were qualified by prior testing, by analysis, or by a combination of both methods. In addition, there is equipment that is similar to equipment that has been in service for various periods of time and has been exposed to in-plant vibration and natural seismic disturbances. Therefore, qualification of equipment may be accomplished by demonstrating its similarity with previously qualified equipment or with equipment that has been exposed to other more severe seismic environments. Similarity of excitation environment and of equipment characteristics must be established by techniques that can be technically justified. Due consideration to changes in design and manufacturing techniques must be considered as part of the technical justification supporting similarity.

Similarity guidelines are contained in Attachment A to this Appendix. Because similarity comparisons are dependent upon the type of equipment being qualified, specific equipment qualification articles in the individual QV and QP Sections of this Standard should be consulted in order to establish similarity between parent and candidate components.

QR-A7120 Experience Data. Experience data may be derived from a variety of sources such as:

(a) analysis or test data from previous qualification programs (EQE Vols. 1 and 2; and User's Manual, EPRI/NUS in QR-A3000);

(b) documented data from equipment in facilities that have experienced natural strong-motion earthquakes (User's Manual, COMPAR; EQE Report; and NUREG-1211 in QR-A3000); or

(c) data from operating dynamic loading or other dynamic environments.

Depending on the source and the level of documentation detail available, various approaches are appropriate. QR-A7121, QR-A7122, and QR-A7123 provide additional detail specific to each case.

QR-A7121 Previous Qualifications. Many seismic and dynamic qualification programs have been conducted for various ASME Class 1, 2, and 3 equipment by the nuclear industry and can be used to develop an experience database. Some of these equipment items may have been qualified by incorporating a full test program along with preliminary exploratory (resonance search) tests as referenced in QR-A7300. Others have been qualified using analysis techniques as described in QR-A7200 or by using a combined test and analysis technique as described in QR-A7400. In order to use this experience database, the input motions, to which the equipment was previously qualified, must be clearly documented, together with pertinent qualification parameters, such as resonance frequencies, damping, and responses of the equipment.

QR-A7122 Natural Earthquakes. Another type of experience database consists of the documented performance of equipment in facilities that have been subjected to an earthquake. The database equipment shall be identical, or similar (in construction, dynamic response, etc.), to the equipment being qualified. It is preferable that the earthquake be quantified by recorded measurement of the earthquake-induced motion at, or near, the equipment mounting location. However, it is recognized that this information is not generally available from natural earthquake data; therefore, alternatively, a documented conservative estimate of input motion may be generated by extrapolation or interpolation of measurements elsewhere (see QR-A7131). Based on the observed response to natural earthquake, bounding ground response spectra can be developed that may be used to qualify equipment, as discussed in Attachment C.

QR-A7123 Other Experience. The approach described above for natural earthquake data may also be applied to the use of operating dynamic loading or other documented dynamic environments as a basis for qualification. In such a case, the principle of similarity as discussed in QR-A7130 must be used to justify the approach.

QR-A7130 Similarity. Qualification by the use of extrapolation from experience data must be based on the concept of similarity. This concept recognizes that the qualification process for equipment is composed of the following basic factors:

(a) excitation;

(b) physical system (dynamic properties and operability); and

(c) dynamic response.

Generally, establishment of similarity for the excitation and physical system will allow a successful qualification to be established by extrapolation from experience data. For example, assume that a given equipment component has been qualified to a specified excitation. Then, a second equipment component, whose physical system similarity can be established, is also qualified to the same excitation. Another example would be when two or more identical or at least dynamically similar components have each been qualified to different excitations. They may both be demonstrated to be qualified to another composite excitation, which can be shown to be similar to the original different excitations. Guidelines for similarity determination are contained in Attachment A to this Appendix.

QR-A7131 Excitation. Similarity of excitation constitutes likeness of parameters such as spectral characteristics, duration, directions of excitation axes, and location of measurement for the motions relative to the equipment mounting. Ideally, the generic response spectra (GRS) or generic equipment ruggedness spectra (GERS) should be as alike as is practicable for different excitations whose similarity is to be established. However, a conservative composite excitation can be derived by extrapolations or interpolations of data whose parameters are not identical but are comparable. For example, estimates may be based on measurements taken elsewhere on the structure or on other structures in the vicinity of the given equipment, if the estimates can be justified by conservative calculations based on sound engineering methods using geophysical models, structural models, or both, as applicable. Likewise, excitations whose spectral content are significantly different may be used to generate lower-level composite estimates, providing that approximations for multimode response and/or cross axis coupling are taken into account. Justification for such approximations must consider the absence of modal excitation caused by mismatch of spectral content in the composite RRS. Thus, the interaction of excitation characteristics and dynamic properties for the specimen must be considered. Duration of a composite excitation must be similar to those from which it is derived. Furthermore, to provide for proper vibration buildup and low-cycle fatigue effects, as with qualification by testing, any constituent experience data must be based on a minimum of 15 sec of strong-motion duration. The qualification must also account for exposure to the required normal and abnormal conditions, such as normal plant vibrations anticipated and abnormal thermal and pressure transients.

QR-A7132 Physical Systems. Physical system similarity must be established for an equipment assembly, and/or a device or subassembly (including mounting), depending on the configuration of the new equipment to be qualified. For a complete assembly, similarity may be demonstrated through comparison of make, model, and serial numbers, and consideration of dynamic properties, construction, and operating characteristics.

Since the objective of qualification by the similarity and past experience method includes a consideration of the expected dynamic response, a rational approach can be used to establish similarity of dynamic structural properties by an investigation of physical parameters of equipment systems. This can be done by comparing the predominant resonant frequencies, mode shapes, and damping, or alternatively establishing similarity of transfer functions at locations where critical devices are installed. This can be covered by dynamic characteristics. These dynamic characteristics are dependent on parameters such as:

(a) equipment physical dimensions;

(b) equipment weight, its distribution, and center of gravity;

(c) equipment structural load transferring characteristics and stiffness to resist seismic excitation;

(d) equipment base anchorage strength and stiffness to ensure both structural integrity and adequate boundary conditions; and

(e) equipment interfaces with adjacent items or connecting accessories.

The relative difference, or dissimilarity, of all the above physical parameters needs to be bounded to ensure that adequate similarity exists between equipment assemblies. In addition, assurance should be obtained that changes from the original database equipment do not result in the formation of previously nonexistent resonances and do not introduce new mechanisms for malfunction.

For equipment for which seismic qualification can be demonstrated by showing that individual devices are performing their specified function during the earthquake, a device or subassembly similarity evaluation approach may be considered. Similarity of physical systems shall be addressed for the individual devices. In this case, similarity in device-operating principle shall be addressed. Physical system parameters, as applicable to equipment assemblies discussed above, may not be obvious or may be difficult to define, such as in an analysis or engineering judgment justification. Therefore, the justification for similarity lies in the careful examination of the dynamic properties, anchorage, and operating principles applicable to the device. In any case, an appropriate physical parameter database shall be used to demonstrate that similar equipment behavior results between the database equipment and the equipment under investigation. For complex devices, a test and/or analysis may be required to show proper justification.

QR-A7133 Dynamic Response. A physical system response can be described by the same quantities as excitation (e.g., duration, frequency content, amplitude), or through a physical system description such as failure modes, and excitation level and/or failure criteria acceptance and/or rejection. When physical system characteristics are known through the experience data (by any one of the previously mentioned methods of QR-A7121 through QR-A7123) and when excitation characteristics are also available, then system response can be evaluated and extended toward similar systems. On the other hand, there are occasions for which only response and physical system characteristics are available. For these situations, the excitation requirement can be conservatively evaluated in light of known response quantities and physical system characteristics (obtained by the methods of QR-A7121 through QR-A7123). Such information for input excitation may then be used to qualify similar equipment.

QR-A7134 Operability. Equipment being qualified shall be capable of performing its specified function during and after an earthquake. The specified function during the earthquake may or may not be the same as that after the earthquake. Therefore, for each qualification, the specified function shall be defined for both during and after the earthquake. The experience data shall provide the documented evidence to support the demonstration of proper operability, as defined, for each application. Where an operation is required during the earthquake, the experience data shall provide evidence that the equipment performed as required in a similar system.

QR-A7200 Qualification by Analysis

QR-A7210 Introduction. Analytical procedures are summarized and referenced in this subarticle, which can be used to demonstrate that ASME BPVC Section III mechanical equipment can meet their operability requirement during and following one SSE (Safe Shutdown Earthquake). Design limits as specified in ASME BPVC Section III are used to provide assurance of pressure-retaining and leak-tight integrity of individual mechanical equipment. The analysis method shall not be used to demonstrate operability for complex equipment that cannot be modeled to adequately predict its behavior. Analysis without testing or experience data is acceptable only if structural integrity as defined in QR-A4000 can ensure the design-intended function. Operability analysis is limited to applications that can be quantified in terms of a parameter that can be calculated and a margin to loss of operability can be established.

Two approaches to seismic analysis are described. One approach is based on dynamic analysis, the other on static analysis. Although the methods described are most commonly used, other methods may be used if they are justified. The general procedure is first to review the equipment to assess the dynamic characteristics; second, determine the response using one or more of several methods described in the following sections; third, determine the behavior (stresses, deformation, displacements, rotations, loads, loss or initiation of contact at interface, etc.) that results from the response; and finally, compare the calculated behavior with behavior that would ensure compliance with specified function requirements.

The review stage should take into account the complexity of the equipment and the adequacy of analytical techniques to properly predict the equipment's operability while subjected to seismic excitation. The response determination phase of the analysis can take several paths, the first of which is determined by the choice between the dynamic analysis method (QR-A7220) and static coefficient method (QR-A7230). In general, the choice is based on the perceived margin of strength of the equipment, since the static coefficient method, though easier and more economical to perform, is generally more conservative. The RRS used to analyze equipment should be peak broadened ±15% in accordance with the requirements of Regulatory Guide 1.122 (see QR-A3000) to account for uncertainty in modeling associated with mass and stiffness definitions.

The mathematical models used for analysis may be based on structural parameters that are calculated or on parameters established by test, or a combination of these. They shall also represent the stiffness properties and boundary conditions of the equipment. The model shall be sufficiently refined to ensure mathematical representation of all significant modes of vibration and allow the evaluation of all pertinent failure modes. Sufficient detail to illustrate relative motion of key points, coupling and load transfer, etc., shall be obtained. All significant equipment interfaces with other equipment, components, assemblies, or systems shall be considered. These interfaces shall include all significant eccentricity and torsion-producing phenomena, such as the effects of equipment attachments.

The boundary condition of the mathematical model and its interface with other equipment and systems shall be effectively coordinated with the characterization of the seismic input. If not previously considered in the load definition, the mathematical model should incorporate the effects of equipment mounting and location (floor, wall, etc.), intervening elements and structures (supports, platforms, etc.), intervening systems (pipe, duct, etc.), and differential support motion, as discussed in QR-A6600. The damping that is used in the analysis shall have a reference basis. Such reference bases include Appendix N of ASME BPVC Section III, Regulatory Guide 1.61, WRC Bulletin 300 (see QR-A3000), and the applicable safety analysis report or by test. If no damping value has been established in the Seismic Input Specification, justifiable means shall be used to support the damping value used in the Seismic Qualification Report.

Using the calculated response, one determines the behavior of the equipment in terms of structure integrity as related to the functional requirements of the equipment, including operating loads. Such loads include internal pressure, operator thrust, dynamic transients, flow-induced vibration, reciprocating and rotating equipment vibrations, and nozzle loadings. Applicable combinations of these loads are typically required in the analytical qualification process and their effects shall be combined, as appropriate, with seismic effects, as defined in the equipment qualification specification.

Typically, analytical methods of equipment seismic qualification for functionality and operability are limited to applications in which all safety-related strength, displacement, and operability features can be effectively modeled and evaluated by analysis.

The analysis procedures used in this Standard are intended to be consistent with the seismic analysis procedures described in more detail in Appendix N of ASME BPVC Section III and ASCE Standard 4-86, seismic analysis criteria (see QR-A3000).

QR-A7220 Dynamic Analysis

QR-A7221 Introduction. The equipment and supports shall be modeled to adequately represent their mass distribution and stiffness characteristics. This model may be used to perform a modal (eigenvalue) analysis to determine the equipment's dynamic characteristics (frequency and mode shapes). Alternatively, an incremented time step solution of the equations of motion may be used to determine dynamic response. The time step integration procedure, while relatively costly, has the ability for direct determination of multiple independent support motions and nonlinear response.

QR-A7222 Response Spectrum. The response spectrum analysis allows the response of interest (deformations, deflections, rotations, loads, stresses, strains, and initiation or loss of contact at interface) to be determined by combining all significant modes of vibrations. A sufficient number of modes should be included to ensure an adequate representation of the equipment dynamic response and reaction forces at supports. An acceptable criterion for adequacy is that the inclusion of additional modes does not result in more than a 10% increase in total response. The response is determined by combining each modal response by the square root of the sum of the squares (SRSS) criterion, except where closely spaced modes are encountered. In these situations, the modal and spatial combination procedures identified in Regulatory Guides 1.60 and 1.92 shall be used.

QR-A7223 Time Histories. When three components of the statistically independent time histories are input simultaneously for a time history analysis, the responses can be combined algebraically at each time increment. To ensure statistical independence, artificially generated time histories should have coherence values of less than 0.5 when computed with at least 12 data samples. Alternatively, a correlation coefficient with an absolute value of less than 0.3 for all time lags may be used as discussed in IEEE Std 344-87.

QR-A7230 Static Coefficient Analysis. This method of analysis allows a simpler technique that usually results in added conservatism. No dynamic analysis is required. The acceleration response of the equipment is assumed to be defined by the acceleration design value (QR-A6500). The resultant inertial force, when the acceleration design value is applied to the mass distribution of the equipment, is applied in the three principal directions with a plus or minus sensing to determine the worse resultant.

QR-A7240 Acceptance Criteria. Acceptance criteria to be used in qualification by analysis shall be applied to the computed parameters associated with the identified failure modes that determine functional adequacy of the equipment. Acceptance criteria shall be established in the input specification requirement. Compliance with the acceptance criteria shall be demonstrated in the Seismic Qualification Report. In general, for active equipment qualified by analysis, behavior of the equipment is limited to elastic response due to primary loads.

QR-A7300 Qualification by Testing

QR-A7310 Introduction. Seismic qualification by testing requires that the equipment be subjected to a simulated earthquake motion that is anticipated to occur at the equipment mounting. The test shall demonstrate that the equipment will perform its specified function during and after the seismic event. The nature of the simulated motion can vary significantly, depending on whether the equipment is to be installed at ground level or at some floor level within a building structure. Procedures necessary to carry out such tests with a reasonable degree of conservatism are in most cases quite complex. Detailed guidelines for typical test procedures for electrical equipment have been provided by IEEE Std 344 since 1975. Since those guidelines were applicable to equipment in general, they have also been used for mechanical equipment. The policy of this Standard is generally to endorse the continued use of IEEE Std 344, so Section 7.0 of that document shall provide the detailed requirements for qualification of mechanical equipment by testing except as modified by this Standard in QR-A7340. For the sake of continuity, some general statements will be included herein.

QR-A7320 Types of Tests

QR-A7321 Exploratory Tests. Exploratory tests consist of the measurements of equipment dynamic characteristics by some form of modal identification procedures. The equipment is mounted in close simulation to that anticipated in the field, with the required instruments. Measurements are taken at various locations anticipated to be important to interior functioning devices or at locations that provide a good indication of structural modal characteristics. It is then subjected to a suitable excitation and the responses are recorded. In particular, care shall be taken to ensure that the mounting of equipment during the test is similar to the mounting in the field. Components that may in themselves be rigid if flexibly mounted or attached in the field shall have this flexibility represented during the test. In the past, a sine sweep resonance search has been widely used for these tests. However, random excitation or even simulated earthquake events are now often used, and equipment transfer functions are subsequently developed by fast Fourier transform processing of the response and excitation data. Exploratory tests are not a requirement for qualification directly, but their results may be used in further development of procedures or in justification for qualification tests, or these results may be part of a combined analysis experience and test approach, as described in QR-A7400.

QR-A7322 Proof Tests. In the past, most equipment qualification has been performed by proof test methods. This approach requires that the simulated earthquake motion at the equipment mounting represents that anticipated from the specified Safe Shutdown Earthquake (SSE). Simulated motion usually is required to demonstrate that the test response spectrum (TRS) conservatively envelops the required response spectrum (RRS) that was generated for the equipment mounting location as part of the test specification. The result of a proof test is a demonstration that the equipment performs its specified function, both during and after the simulated SSE event. In view of the tendency of building structures to filter ground motion differently from one site to another, such qualifications may be site-specific. However, this limitation may be reduced by broadening the frequency content of a specified response spectrum and enveloping response to represent a more generic simulation.

QR-A7323 Fragility Tests. Fragility tests are conducted to determine the peak amplitude level of a specified excitation waveform for which the equipment can perform its specified function. A sequence of test runs is performed with increasing amplitudes of the specified waveform until malfunction is observed in the equipment. When the specified motion is compared to that anticipated for the SSE at the equipment mounting, a measure of margin is established.

In addition to the response spectrum type of input loading, in-line equipment may also be qualified by RIM testing as described in IEEE Std 382-85.

QR-A7330 General Approach to Testing

QR-A7331 Preliminary Tests. Exploratory tests described in QR-A7320 are usually performed prior to conducting the actual qualification test or qualification by a combination of testing and other methods. Other preliminary tests, such as thermal or operational aging, or any other required environmental test, should be performed prior to the seismic test. This sequence ensures that the equipment is at the end of the qualified life state at the time of the seismic qualification.

QR-A7332 Development of Simulated Seismic Motion. The simulated seismic motion shall conservatively represent that which can be expected at the equipment mounting for the SSE event. The general nature of earthquake motion can be represented by a nonstationary random process having broad frequency content (i.e., 1 Hz to 33 Hz) at ground level, but with much narrower frequency content near building natural frequencies, when representing filtered motion at building floor levels. Several characteristics of seismic motion must be noted when simulated waveforms are developed for testing purposes. These characteristics are understood to describe the motion that occurs at the equipment mounting.

(a) The general character of earthquake motion is a random process that builds to a relatively stationary level (called the *strong motion*), which holds at that level for some duration and then decays to a negligible value.

(b) Approximately stationary random motion occurs during the strong motion. It is this part of the excitation that causes most damage to equipment. It must be sustained a minimum of the larger of 15 sec or the duration of strong motion during a qualification test.

(c) Frequency content of the required motion and actual test motion is indicated by the amplified region of a response spectrum. Thus, a TRS shall closely envelop the RRS to ensure proper frequency content.

(d) Stationarity of the waveform during the simulated strong motion shall be demonstrated. This ensures that all required frequencies are present to a sufficient amount during the strong motion.

(e) Multiaxis motions shall have an appropriate degree of statistical independence. This is determined by examining the coherence or cross correlation between the waveforms for different axes.

Test waveforms that have the above characteristics may be generated by superimposing a variety of component signals, such as sine dwells, sine beats, narrow band, and broadband random signals.

QR-A7333 Conduct of Test and Operability. Detailed procedures for preparing and conducting seismic qualification tests shall be obtained from IEEE Std 344-87, Section 7.0, and IEEE Std 382-85, Section 5.5.8. Details for preparing and conducting functional tests for equipment shall be obtained from the manufacturers' operability manuals and equipment specifications.

QR-A7340 Acceptance Criteria. Acceptance criteria for seismic tests shall be based on the functional requirements for the individual item of equipment. Acceptable ranges for performance variations must further be evaluated in light of the consequences of these variations on the specified function of that equipment and any other with which it may interact. Such interactions with other equipment that affect acceptance criteria shall be identified in the Seismic Input Specification. Numerical ranges for these variations shall be established and compared with observed test values. Inability of an item to function within acceptable limits during and after seismic testing shall be noted as an anomaly. Thereafter, evaluation of the consequences of the anomaly may or may not lead to a conclusion that the item has malfunctioned. It may be noted that, contrary to qualification by analysis, failure of an item to qualify by test can be determined without ever establishing the exact source of the failure within the item.

QR-A7400 Combined Qualification Methods

Each qualification method—experience data, analysis, and testing—has its advantages and limitations. For example, to qualify the component in question, it is necessary to show that the like component(s) in the experience database has experienced seismic inputs equal to or greater than the design basis of the component being qualified. In general, this can best be examined by analysis to develop the input seismic motion applicable to the experience database.

Results of a given particular component qualification test may become a part of an experience database. Strictly speaking, this qualification is applicable only to the component tested. To extend qualification to similar components, it is necessary to consider potential differences in material properties, sizes, manufacturing tolerances, clearances, and mounting characteristics. When these differences exceed the limits of similarity (Attachment A), their effects on qualification shall be evaluated directly by means of analysis or test.

Analysis in general is limited to determination of loads, reactions, stresses, strains, deflections, and clearances, which are then compared with acceptable limits. However, loss of function of components cannot always be explained in terms of such computed quantities. In these cases, experience data or testing must be relied upon to demonstrate operability or to otherwise establish acceptable limits for those quantities that can be evaluated by analysis.

In general, all three methods or combinations thereof may be used to seismically qualify operability or functionality of mechanical components. The decision regarding which methods to use to qualify a particular mechanical component should be left to the Professional Engineer or the officer of the qualifying organization who approves and signs the Seismic Qualification Report (QR-A8300).

However, nothing in this Appendix shall be interpreted as preventing the author of the Seismic Input Specification (SIS) from specifying in detail (in the SIS) the method(s) or combinations of methods to be used in seismically qualifying the equipment covered by the SIS.

QR-A8000 DOCUMENTATION

QR-A8100 General

The documentation for qualification of each equipment type shall demonstrate that the equipment performs its specified function when subjected to the seismic motions for which it is to be qualified, including any required margin. Therefore, proper documentation requires a clear statement of the specific requirements and an accurate recording of the procedures and results of the analysis, test, experience data, or any combination of these methods.

In general, two documents are required to demonstrate functional seismic qualification of equipment, a Seismic Input Specification and a Seismic Qualification Report. The preparation of the Seismic Input Specification is the responsibility of the Owner of the equipment. The preparation of the Seismic Qualification Report is the responsibility of the organization that performs the equipment seismic qualification and evaluates the results as applicable to the qualification of the equipment. In the event that a manufacturer of the equipment performs a generic seismic equipment qualification, the preparation of both the Seismic Input Specification (as the Owner's agent) and Seismic Qualification Report are the responsibility of the manufacturer. It is the responsibility of the Owner to review and accept the Seismic Qualification Report.

QR-A8200 Input Specification Requirements

Directions for the preparation of specification information required for evaluation of the equipment are as follows:

(a) If RRS are furnished, the RRS for the location on which the equipment is to be mounted shall contain the data for the two horizontal and one vertical axes as a minimum. The RRS shall have been broadened as recommended in Regulatory Guide 1.122 (see QR-A3000) and shall include damping values for which the RRS are calculated.

(b) If RRS are not furnished, acceleration design values, load coefficients, simplified waveforms such as sine beats or sine sweep, or a time history shall be provided.

(c) The earthquake's strong-motion time duration shall be specified, in seconds, as well as the total number of cycles and cyclic profile.

(d) Equipment mounting or support details, including all interface connections, shall be described.

(e) A physical description of equipment shall be provided.

(f) A clear description of the functional requirements for which the equipment is to be seismically qualified shall be provided. This description shall include typical operational settings (or ranges) for adjustable devices.

(g) Identification of ASME Class 1, 2, and 3 devices and components shall be provided.

(h) Other loading requirements and interface requirements to be accounted for shall be specified.

(i) Acceptance criteria shall be specified.

QR-A8300 Seismic Qualification Report

The Seismic Qualification Report shall present a clear, logical explanation of how the data contained in the Seismic Input Specification and resultant experience, analysis, tests, or combinations thereof have been used to achieve seismic qualification of particular equipment. Toward this end, it shall contain the following information:

(a) Equipment being qualified shall be clearly identified.

(b) RRS, ADV, time histories, RIM, or load coefficients levels for which equipment is being qualified shall be shown.

(c) A detailed summary of the analysis, test, past experience used, and results (including pertinent anomalies) shall be presented. Details defining a test fixture if used during testing shall also be provided. If a component or device of the equipment is tested or analyzed separately, the procedure used shall also be summarized. If an anomaly is experienced during any test, it shall be documented in the report. If the equipment is not modified to eliminate the anomaly, then the final user shall justify the use of the equipment and file this justification with the Seismic Qualification Report. Any equipment refurbishment that is performed during seismic testing shall be documented in the test report and reconciled by the equipment supplier. This data may become part of the postearthquake field maintenance checks and procedures for that equipment.

(d) If analysis is used to qualify the equipment, the failure modes used to determine functional adequacy shall be clearly identified and computed margins to failure presented.

(e) All documents used in generating the Seismic Qualification Report shall be identified and referenced.

(f) A dated approval signature of a Professional Engineer or an officer of the qualification organization shall be included.

QR-A8310 Analytical Data. If analysis is performed as the qualification method, the method and data used and the failure modes considered shall be presented in a step-by-step form that can be audited by persons skilled in such analysis. Boundary conditions, including anchoring and any other interfaces, shall be clearly defined. Input/output data required to support performance claims shall be included in the report. The reaction force(s) at the interface connection(s) to the support structure shall also be included.

A statement shall be made verifying that the computer programs were validated on the computer hardware on which the program was executed. Computer programs, options, version numbers, dates, and systems used shall be identified and documented.

QR-A8320 Test Data. If testing is used as the qualification method, the test data shall contain the following information:

(a) equipment being qualified:

(1) tested equipment identification (including devices)

(2) tested equipment functional specification

(3) tested equipment settings and limitations when appropriate;

(b) test facility:

(1) location

(2) testing equipment and calibration;

(c) test method and procedures, including monitoring for operability, and acceptance criteria;

(d) equipment mounting details, including all interface connections;

(e) test data (including proof of performance, TRS plots, RIM plots, time histories, and PSD coherence checks as necessary). Whatever the type of multifrequency testing employed, the acceleration time history of the input table motion shall be provided in the test report in addition to the TRS. As a minimum, a time history of the table motion shall be provided for one test in each of the three directions of excitation from the SSE testing.

(f) test results, including measured natural frequencies and conclusions (including statement of any anomalies).

QR-A8330 Past Experience Data

QR-A8331 Strong-Motion Earthquake Data. If a comparison to past experience in real strong-motion earthquake or other tests is used as the qualification method, the qualification data shall contain:

(a) a description of original equipment that is past experience qualified, including, as a minimum, actual nameplate data and anchorage or support of the equipment;

(b) a description of new equipment being qualified;

(c) a description of the service or use of the original equipment past experience qualified;

(d) a description of the service or use of the new equipment being qualified;

(e) a discussion of similarities or lack thereof between the candidate equipment being qualified and the reference equipment in the past experience database (see Attachment A);

(f) a description of the past experience strong-motion earthquake, including the basis for any seismic loading estimation or bounding;

(g) a description of the excitation for which the new equipment is to be qualified;

(h) a description of the response and behavior of the original equipment based on the past experience strong-motion earthquake;

(i) justification of the results.

QR-A8332 Generic Response Spectra Enveloping Data. In this method, generic response spectra (GRS) or generic equipment ruggedness spectra (GERS) are developed from analysis or tests of various types of equipment. These GRS or GERS are compared to the RRS.[1] If the GRS or GERS envelop the RRS, the equipment is qualified provided it can be demonstrated that the type of equipment for which the GRS or GERS is generated has similar functional and dynamic characteristics as the equipment being qualified. This demonstration requires the following documentation:

(a) a description of original equipment past experience qualified, including, as a minimum, actual nameplate data and anchorage or support of the equipment;

(b) a description of new equipment being qualified;

(c) a description of the service or use of the original equipment past experience qualified;

(d) a description of the service or use of the new equipment being qualified;

(e) a discussion of similarities or lack thereof between the candidate equipment being qualified and the reference equipment in the past experience database (see Attachment A);

(f) a description of the past experience, including the basis for any seismic loading estimation, GRS, or GERS. It may be necessary to scale down the GERS by an uncertainty factor as a function of the data used to develop the GERS;

(g) justification of the results.

QR-A8340 Combined Methods of Qualification. If proof of performance is by a combination of methods described in QR-A8100 to QR-A8300, the report shall contain reference to the specific combined qualification method used and the appropriate information contained in each method as described therein. When extrapolation of data is made from similar equipment, a description of the differences between the equipment involved is required. Justification that the differences do not degrade the seismic adequacy below acceptable limits (additional analyses or testing may be required) shall be included.

[1] As discussed in the Senior Seismic Review (see QR-A3000), if the RRS is not computed equivalent to the Regulatory Guides 1.60 and 1.122 derived spectrum (see QR-A3000), a multiplier of 1.5 shall be applied to the shape of the RRS.

ATTACHMENT A
GUIDELINES FOR QUALIFICATION BY SIMILARITY (Indirect Method)

A1 GENERAL

This Attachment presents guidelines to achieve the qualification of candidate equipment by establishing its similarity to parent equipment. Much of the guidance provided herein is summarized from the User's Manual prepared by COMPAR-Access (see QR-A3000), which can be consulted for more details. The guidance provided herein is also an expansion of general concepts defined in IEEE Std 344-87, Section 9.0. A valid qualification by similarity requires consideration of each of the following four items:

(a) functional characteristics
(b) excitation characteristics
(c) physical characteristics
(d) concurrence of excitation and physical characteristics.

A2 FUNCTIONAL CHARACTERISTICS

Candidate equipment considered for qualification by similarity shall have function/malfunction characteristics similar to those of the parent equipment for which a database is available.

A2.1 Specified Function

The specific function of the candidate equipment to be qualified shall be the same or enveloped by the specified function defined in the qualification document of the parent equipment.

A2.2 Failure/Malfunction Modes

The most probable mode or modes of failure/malfunction of the candidate equipment shall be stated and justified to be common with that of the parent equipment. Furthermore, the physical location on the equipment of any critical device/mechanism that precipitates the failure/malfunction is to be noted.

A2.3 Design Parameters

List the appropriate parameters for the candidate and parent equipment, as shown in Table A1.

A2.4 Acceptance Criteria

A comparison of the design parameters for both the parent and the candidate component shall be made. If any one of the listed parameters for the candidate component deviates by more than 10% from the corresponding parameter for the parent component, an assessment of the effect of increment(s) shall be made in terms of quantities impacting the qualification status, such as stresses and deformations.

A3 EXCITATION CHARACTERISTICS

The excitation for the candidate equipment shall be shown to be similar to that for the parent equipment. The parent data may include a composite spectrum that was generated from qualification of several parent equipment items. Specific excitation characteristics to be considered include (but are not necessarily limited to):

(a) frequency distribution: indicated by amplified region of response spectrum or by power spectral density;
(b) peak amplitude of time history, i.e., excitation ZPA;
(c) maximum amplification factor: ratio of maximum response spectrum value to ZPA;
(d) time duration: strong-motion portion must be at least 10 sec;
(e) axes of orientation: must be common for candidate and parent equipment, i.e., careful examination of supports at excitation location is required;
(f) excitation location.

A4 PHYSICAL CHARACTERISTICS

Physical similarity is determined by those equipment properties that influence its dynamic response. Physical similarity between candidate and parent equipment can be shown by one of several methods (which include A4.1 through A4.4).

A4.1 Essentially Identical Equipment

Equipment can be compared by make, model, and serial number, and found to be identical (within deviations associated with manufacturing tolerances) or found to have differences that are so slight that the dynamic response can be argued to be essentially unaffected.

A4.2 Similar Modal Properties

This is equipment whose mass, stiffness, and damping properties can be shown to be similar. Justification

Table A1 List of Input Parameters

Parameters	Parent Equipment	Candidate Equipment
1. Temperature		
2. Design pressure		
3. Operating pressure		
4. Hydrostatic pressure		
5. Process medium		
6. Maximum leakage rate		
7. Torque		
8. Thrust		
9. Nozzle loads		
10. Other parameters (list as applicable)		

Resolution of any significant differences:

includes providing comparative data as shown in Table A2.

A4.3 Acceptance Criteria

For acceptance criteria, provide comparison of items 1 through 7 of Table A2 for both the parent and candidate equipment. If there are significant differences (more than ±15%) in any one of the items (or subitems), the effect of the difference shall be evaluated in terms of the following:

(a) stiffness
(b) mass distribution
(c) boundary conditions
(d) natural frequencies
(e) damping

The different effect on the stresses, deformations, and load capacities (such as stem or shaft buckling capacity and bearing load capacity) at critical locations shall also be evaluated and shown to be within the allowable criteria limits.

Table A2 Comparative List of Physical Parameters

Parameters	Parent Equipment	Candidate Equipment
1. Component physical dimensions		
2. Component weight, its distribution, and center of gravity		
3. Bill of materials		
4. Cross-sectional and length data to characterize stiffness and load-transferring capacity		
5. Mounting with respect to:		
Mounting description		
Type of support		
Support details		
Structural members		
Size		
Location		
Material		
Welding details		
Rod (material)		
Location		
Size and length		
Type		
Bolting details		
Bolts and nuts material, grade		
Number and size		
Geometry (bolt circle or pattern info.)		
Washers		
Holes in baseplates (circular or oval)		
Pretorque values		
6. Nozzles:		
Locations		
Sizes		
7. Other interfaces with adjacent items such as cables, conduits, tubes, etc.		

Resolution of any significant differences:

A4.4 Similar Critical Transfer Function

The critical transfer function establishes a direct dynamic relationship between the excitation and the critical location where failure or malfunction is being evaluated. It can be established from typical exploratory resonance search data, if available, for a response point near a critical location. When the critical transfer function plot can be established for both candidate and parent equipment, and where this can be shown to be within 20% in amplitude within a designated frequency bandwidth, no further modal characteristics need to be determined. As a result, the equipment is physically similar within the designated frequency bandwidth.

A5 CONCURRENCE OF EXCITATION AND PHYSICAL SIMILARITY

A valid qualification by similarity requires that the frequency bandwidth within which physical similarity exists for both candidate and parent items shall be concurrent within the frequency band for which the candidate's required excitation spectrum is enveloped by the parent equipment excitation spectrum. Enveloping outside this frequency band is not essential, but cannot be unlimited, as discussed in NUREG/CR-5012 (see QR-A3000).

ATTACHMENT B EXAMPLES OF QUALIFICATION OF PUMPS AND VALVES BY ANALYSIS[1, 2]

B1 EXAMPLE 1: VERTICAL PUMP/MOTOR ASSEMBLY

B1.1 Introduction

Example 1 identifies and presents the model, analysis method, and results associated with the seismic evaluation of a vertical pump/motor assembly when subjected to static and dynamic loads. The analysis is performed to assess the design adequacy of the pump/motor assembly design when subjected to earthquake-induced static and dynamic loads, as well as other loads defined in the Design Specification.

A three-dimensional lumped mass beam finite element model of the pump/motor assembly and its support is developed and dynamically analyzed using the response spectrum analysis method. The same model is analyzed due to static nozzle loads, pump thrust loads, and deadweight and temperature effects. Critical location stresses are evaluated and compared with the allowable stress criteria to determine structural and leak-tight integrity, and critical location deflections and bearing loads are compared to evaluate operability.

B1.2 Model Description

A finite element model is developed for the pump/motor assembly as shown in Fig. B1 and used in the analysis. The merits of using this approach are threefold:

(a) It represents the distribution of mass and stiffness for the determination of natural frequencies, including higher modes.

(b) A complete dynamic analysis may be performed to determine the loads and resultant stresses and displacements using this model.

(c) It determines how the loads are distributed through each load path in the statically indeterminate portions of the structure.

The finite element model in this instance is used to verify the structural integrity as well as the operability of this active pump. In general, however, there is no requirement that a dynamic model be used to compute resultant stress in the pump/motor assembly. Often, dynamic external forces in each mode are determined from the response spectrum analysis of a dynamic model and applied to a more detailed static model of the pump/motor assembly to determine such things as resultant stress, deformations, and bearing loads.

The pump/motor assembly and some details of the pump are shown in Fig. B1. The schematic representation of the model is provided in Fig. B2. Essentially, the model is a three-dimensional lumped mass beam element model, capable of accepting loads from the postulated vertical and two horizontal directions of earthquake simultaneously. The three parallel beams of the lower portion represent the centerlines of the pump shaft, bowl casings, and suction barrel shell. The discharge head, discharge nozzle, motor stator, and rotor are also modeled with equivalent beams and lumped masses as defined and located on the appropriate outline drawings and other references. This model has a total of 105 nodes, 97 beam elements, and 16 boundary elements.

B1.3 Method of Analysis

The analysis is performed in two distinct steps. First, a modal analysis is performed using the subspace iteration technique and all eigenvectors are saved on a permanent file for subsequent analysis with various dynamic loading conditions. In this instance, 25 modes were considered in the analysis, with a highest frequency of 140.5 Hz. This frequency is high enough to cover the ZPA of all applicable response spectra (both earthquake and hydrodynamic effects). It should be noted that earthquake-induced excitations seldom have input energies above 33 Hz and hydrodynamic effects above about 100 Hz. It should also be noted that damage due to dynamic excitations above about 15 Hz is usually controlled by velocity or displacement, not acceleration. Therefore, use of equivalent static loads based on accelerations at frequencies above 15 Hz may result in overly conservative design requirements. Table B1 gives the first 14 frequencies of the model up to 84.1 Hz. As Table B1 shows, the fundamental frequency of the equipment is 7.82 Hz, which is in the potential resonant region

[1] Examples 1 and 2 contain an OBE design requirement because the analysis performed is to determine structural and leak-tight integrity in accordance with ASME BPVC Section III requirements, as well as to determine functional adequacy.

[2] Examples 1 and 2 are for rough illustrative purposes only, to define the type of analysis performed. In general, current design control procedures, as described in 10CFR50 Appendix B and implemented by organizational quality assurance and ASME NQA procedures, would require a more detailed documentation of qualification by analysis than is illustrated by these examples.

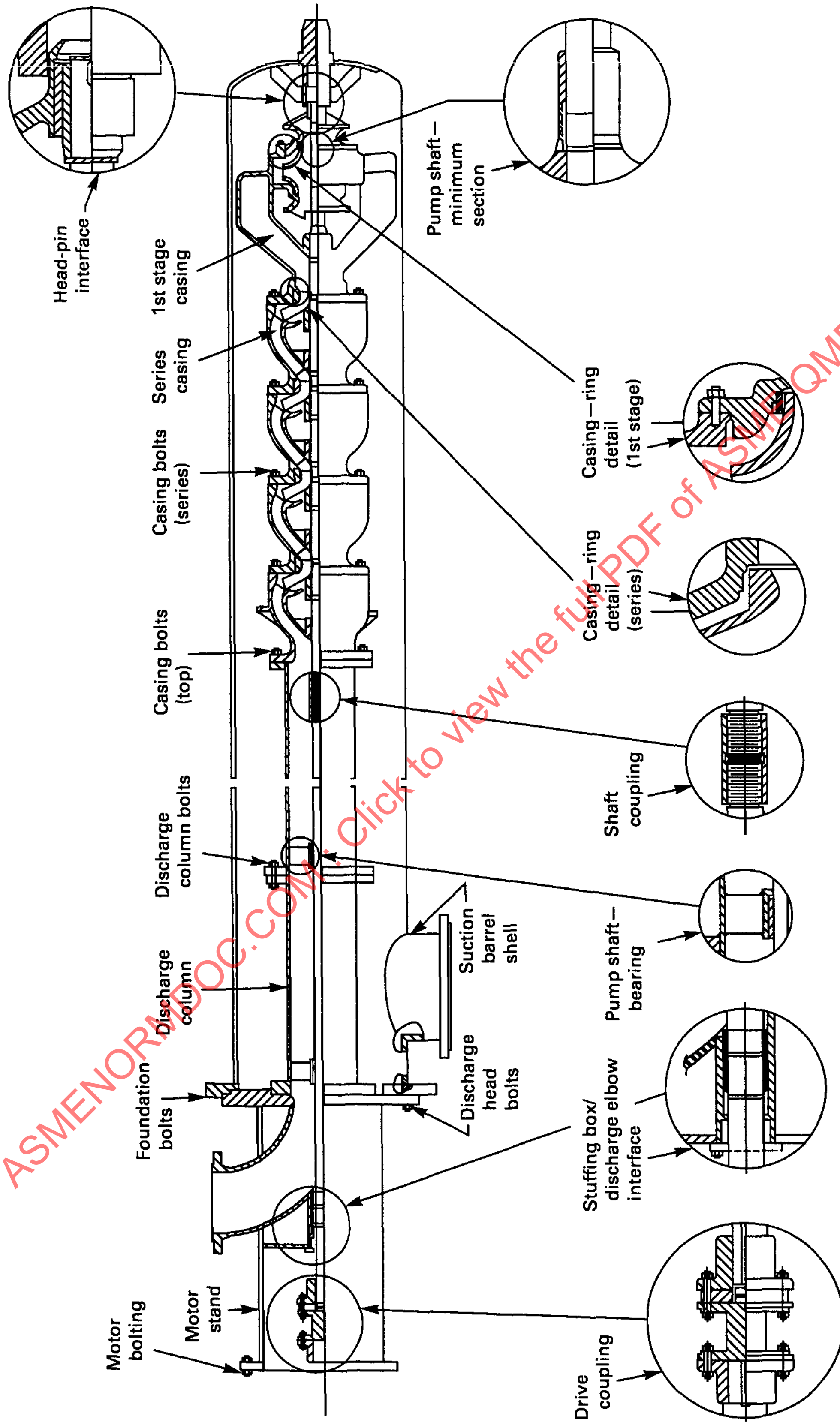


Fig. B1 Pump Assembly

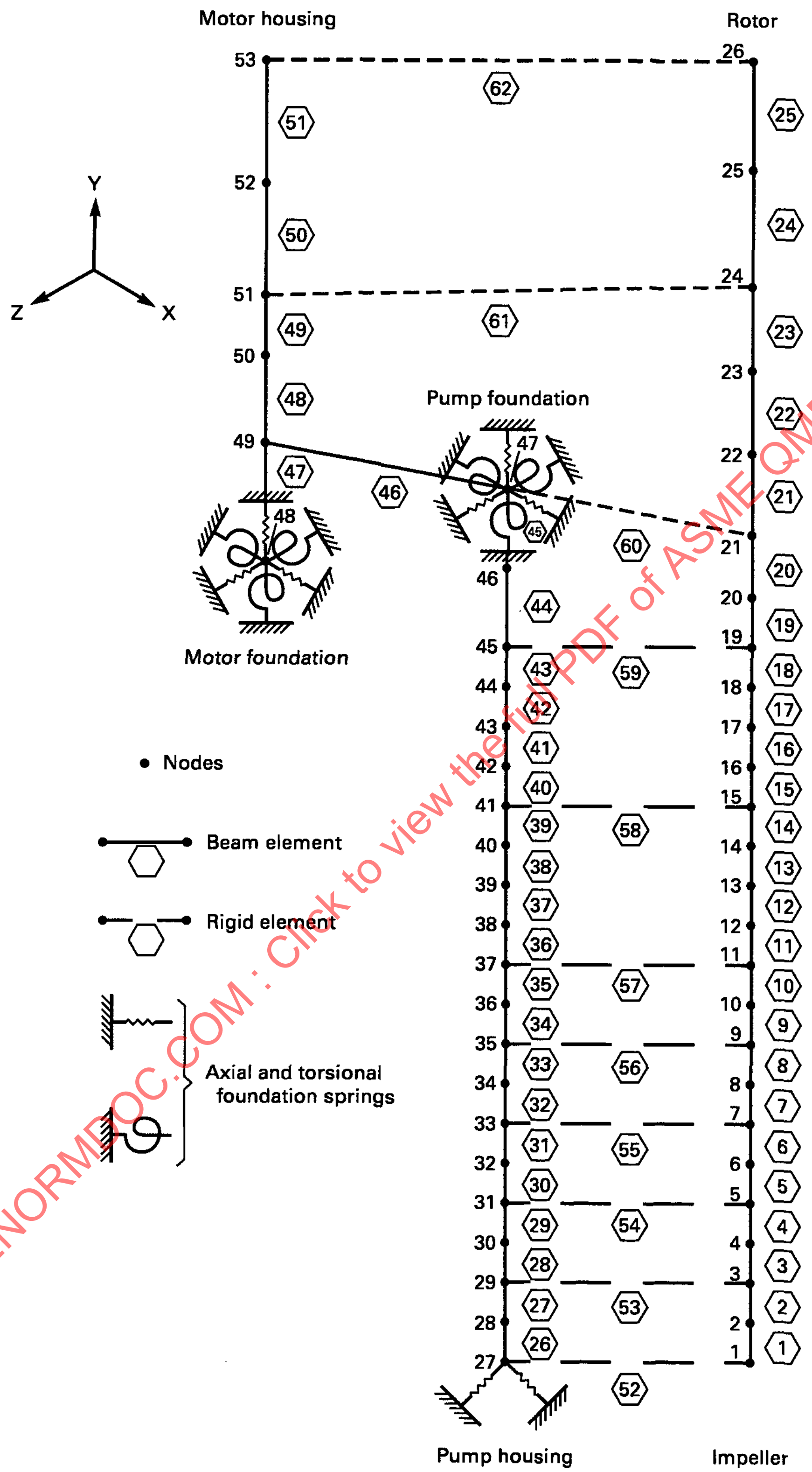


Fig. B2 Finite Element Formulation of Pump Assembly

Table B1 Calculated Frequencies for Pump/Motor Assembly: Print of Frequencies

Mode Number	Frequency, Hz (Cycles/sec)
1	0.7818+01
2	0.8518+01
3	0.1163+02
4	0.1211+02
5	0.3450+02
6	0.3458+02
7	0.3717+02
8	0.4122+02
9	0.5935+02
10	0.6421+02
11	0.7330+02
12	0.7679+02
13	0.7835+02
14	0.8409+02

of earthquake-induced response, thereby justifying the need for a dynamic analysis for this relatively flexible equipment.

In general, it is necessary only to include a sufficient number of frequencies and mode shapes such that 85% to 90% of the effective mass of the equipment being evaluated has been included. The second step of the analysis consists of applying various dynamic and static loads to the model and investigating the structural behavior of the pump/motor assembly.

As discussed above, the response spectra analysis method is selected for the dynamic analysis of the assembly. However, other methods such as time history analysis, simplified dynamic, or equivalent static analysis as defined in Standard Review Plan 3.7.2 and ASME BPVC Section III Appendix N may also be used. The response spectra used are developed from the seismic response spectra curves and other applicable dynamic loads as defined in the Design Specifications.

Conservative damping values of 2% for ASME Code Level C conditions and 1% for Level B conditions are adopted in this example. The following additional loads are also included in the analyses performed in this example:

(a) pump nozzle loads, obtained from the analysis of the piping subsystems attached to the suction and discharge nozzles;

(b) weight of all the parts of the pump and motor and the water inside the pump;

(c) internal design pressure acting on pressure boundary components;

(d) pump thrust and torque loads;

(e) motor electromagnetic forces.

B1.4 Load Combinations

The pressure boundary components of this pump/motor assembly are classified as ASME BPVC Section III Class 2 equipment and therefore must comply with the rules of Subsection NC of ASME BPVC Section III. Structural and leak-tight integrity are addressed in terms of these Code rules wherever applicable. At locations where the ASME Code does not apply, general methods of stress analysis and principles of mechanics are used with behavior limits consistent with those defined in the ASME Code.

In Example 1, the following load combinations were identified in the Design Specification and are calculated using the results of static and dynamic analysis.[3]

ASME Service Level B Condition:

N + OBE + SRV

ASME Service Level C Condition:

SSE + CO
N + Envelope of SSE + CO + SRV
SSE + CHUG + SRV

where

N = normal conditions
CO = condensation oscillation loads
SRV = safety relief valve loads
CHUG = chugging load
OBE = Operation Basis Earthquake Load
SSE = Safe Shutdown Earthquake Load

The internal forces and moments obtained for each beam element are combined according to the load combinations identified above using appropriate methods as defined in Regulatory Guides 1.60, 1.61, and 1.92, and Standard Review Plans 3.7, 3.8, and 3.9, and with the overall guidance of ANS Standards 51.1 for BWR and 52.1 for PWR systems. These combined loads are then used to calculate the component stresses at critical locations. Evaluation of stresses is in accordance with NC-3400 of ASME BPVC Section III for Service Levels B, C, or D as defined in the Design Specification for the component.

B1.5 Stress Analysis, Leak-tight and Structural Integrity

In order to ensure the adequacy of the equipment, the following analytical efforts and considerations are undertaken:

(a) Perform a detailed dynamic/static analysis on a three-dimensional finite element model that represents the mass, stiffness, and boundary conditions of the pump/motor assembly.

(b) Consider the loading combinations that are stipulated in the Design Specification.

[3] CO, SRV, and CHUG loads are applicable to BWR pressure suppression systems.

(c) Comply with the design requirements of the Design Specification and ASME BPVC Section III for Service Levels B, C, or D, whichever are applicable; also, use other methods of mechanics and stress analysis when needed.

In Example 1, foundation bolt stresses are calculated from forces developed in the model elements representing the anchor bolts at the foundation level, assuming that shear on the equipment is carried by the anchor bolts. Depending on the size, configuration, and magnitude of load on the equipment, shear may also be assumed to be transferred by friction between the base of the equipment and the supporting structure.

In the example, for all critical locations, the stresses evaluated using Service Level C criteria are higher than stresses produced by other load combinations. Highest stress levels at all locations are compared to the allowables and the resultant safety factor determined as shown in Table B2. It is also common to express design adequacy in terms of design margins. Design margins are determined as follows:

$$\text{design margin} = \text{safety factor} - 1.0$$

B1.6 Deformations, Bearing Loads, and Operability

In Service Level C, in Example 1, the computed deflections or deformations are limited to 75% of those that are expected to cause malfunction of the pump. Verify the operability analytically by checking relative displacements and bearing load capacities at the critical locations. This is accomplished by combination of the following steps:

(a) Failure mode analysis dictates critical locations.

(b) Model analysis yields relative displacements at these critical locations between moving and stationary parts.

(c) Calculated relative displacements and bearing loads are compared with allowable or minimum clearances and bearing loads supplied by the manufacturer.

(d) In order to support the analytical approach indicated by (a) through (c) above, various test results such as in-situ low impedance test results of the equipment to verify dynamic characteristics or start-up and in-service vibration test results (ASME OM3) are compared to analysis results. These comparisons are used to substantiate the validity of analytical models used for the computation or alternatively to provide a basis for better analytical definition of the equipment.

B1.7 Summary and Concluding Remarks

Example 1 presents the results of an analytical assessment and design qualification for a vertical pump/motor assembly. Based on the results of the analyses presented, the pump is considered seismically qualified for the load combinations specified in para. B1.4.[4]

B2 EXAMPLE 2: FOUR-INCH BUTTERFLY VALVE

B2.1 Purpose

The purpose of Example 2 is to present the seismic qualification of a 4 in. butterfly valve used in a nuclear power generating station This example describes the analysis required to perform this qualification.

B2.2 Model Description

The analysis is performed using a finite element model. In the finite element model, the valve, bracket, shaft, wafer, and actuator are modeled in considerable structural detail using beam and plate elements to mathematically describe the mass and stiffness distribution of the system. In general, these elements are terminated at nodal points wherever structural discontinuities occurred (i.e., corners, changes in moments of inertia, etc.). See Figs. B3 and B4.

B2.3 Method of Analysis

The fundamental natural frequencies of the valves are determined. The units have their lowest natural frequency above 33 Hz.

Once the frequency requirements are satisfied, the valve is analyzed for the following static equivalent loads:

(a) seismic g loads

(b) deadweight (1.0 g)

(c) pressure on the wafer

(d) torque on the shaft

The following seismic acceleration design value (ADV) g loads are considered:

Earthquake	Horizontal	Vertical
OBE	3.3	2.0
SSE	4.5	3.0

Each orthogonal direction is evaluated separately and the three results are combined by the SRSS method. These combined results are added to the absolute value of the results of the deadweight, pressure, and torque load evaluations.

Unit load cases are input and the results are factored by the appropriate values to obtain the correct seismic, deadweight, pressure, and torque loadings.

B2.4 Stress Analysis, Leak-tight and Structural Integrity

The results of various analyses performed are presented in this section. Table B3 provides the materials

[4] Further detailed treatment of the similar qualification effort for similar pumps is in "Structural Integrity and Operability Analysis of Vertical Pump-Motor Assemblies," J.S. Mokri and W.H. Fleming, General Electric Co., Paper #84-PVP-108, ASME.

Table B2 Evaluation of Behavior at Critical Locations

Description	Calculated	Allowable	Safety Factor
Leak-tight and Structural Integrity			
Motor stand stress	5,221 psi	19,250 psi	3.70
Motor bolting tensile stress Motor bolting shear stress	5,587 psi 2,281 psi	37,500 psi 15,500 psi	6.67 6.67
Suction barrel shell at inlet nozzle stress	8,195 psi	16,500 psi	2.0
Suction barrel head/pin interface stress	5,024 psi	16,500 psi	3.33
Pump first stage casing min. section stress	2,446 psi	8,250 psi	3.33
Pump series casing min. section stress	3,000 psi	8,250 psi	2.78
Pump series casing bolts req. area	$A_m = 7.73$ in.^{2} (req.)	$A_b = 11.02$ in.^{2} (avail.)	1.43
Pump top casing bolts req. area	$A_m = 7.65$ in.^{2} (req.)	$A_b = 11.02$ in.^{2} (avail.)	1.45
Stuffing box discharge elbow interface stress	17,725 psi 24,170 psi	28,875 psi (Level B) 31,500 psi (Level C)	1.64 1.30
Discharge head bolts req. area	$A_m = 19.60$ in.^{2} (req.)	$A_b = 19.84$ in.^{2} (avail.)	1.01
Foundation bolts tensile stress Foundation bolts shear stress	12,730 psi 4,129 psi	29,000 psi 11,950 psi	2.27 2.86
Discharge column stress	6,101 psi	16,500 psi	2.70
Discharge column bolts req. area	$A_m = 8.73$ in.^{2} (req.)	$A_b = 11.02$ in.^{2} (avail.)	1.27
Pump shaft at min. section stress	5,838 psi	15,000 psi	2.56
Operability			
Pump shaft bearing (max. load location)	11 psi	20 psi	1.82
Pump pin to support reaction load	9,789 lb	14,650 lb	1.49
Motor upthrust load	0 [Note (1)]	2,287 lb	0
Motor down thrust load	4,380 lb	22,500 lb	5.0
Relative displacement between shaft and throttle bushing	0.008 in.	0.009 in.	1.12
Relative displacement between shaft and mechanical seal	0.0006 in.	0.030 in.	50.0

NOTE:
(1) Actual valve is less than weight.

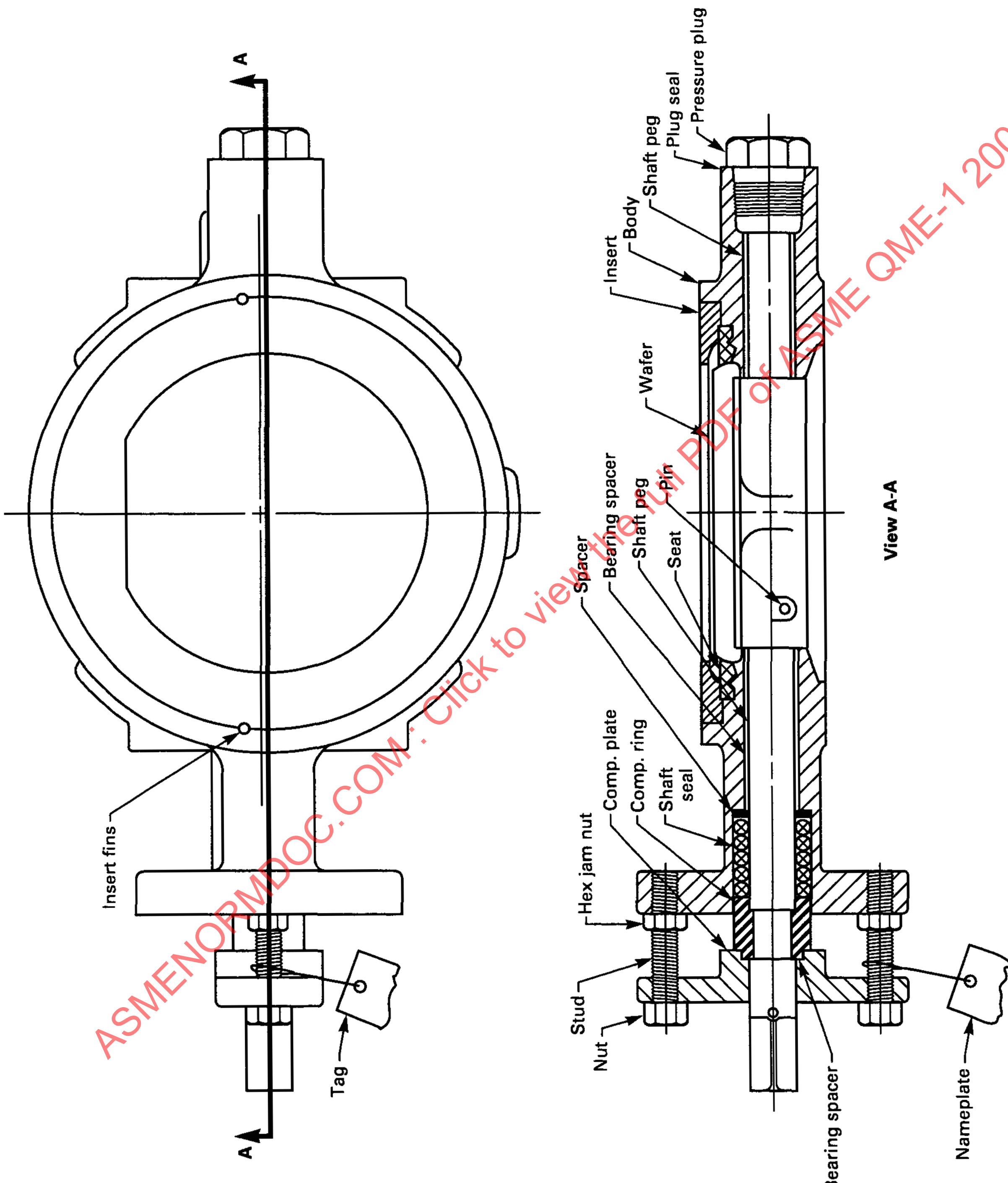


Fig. B3 Butterfly Valve Assembly

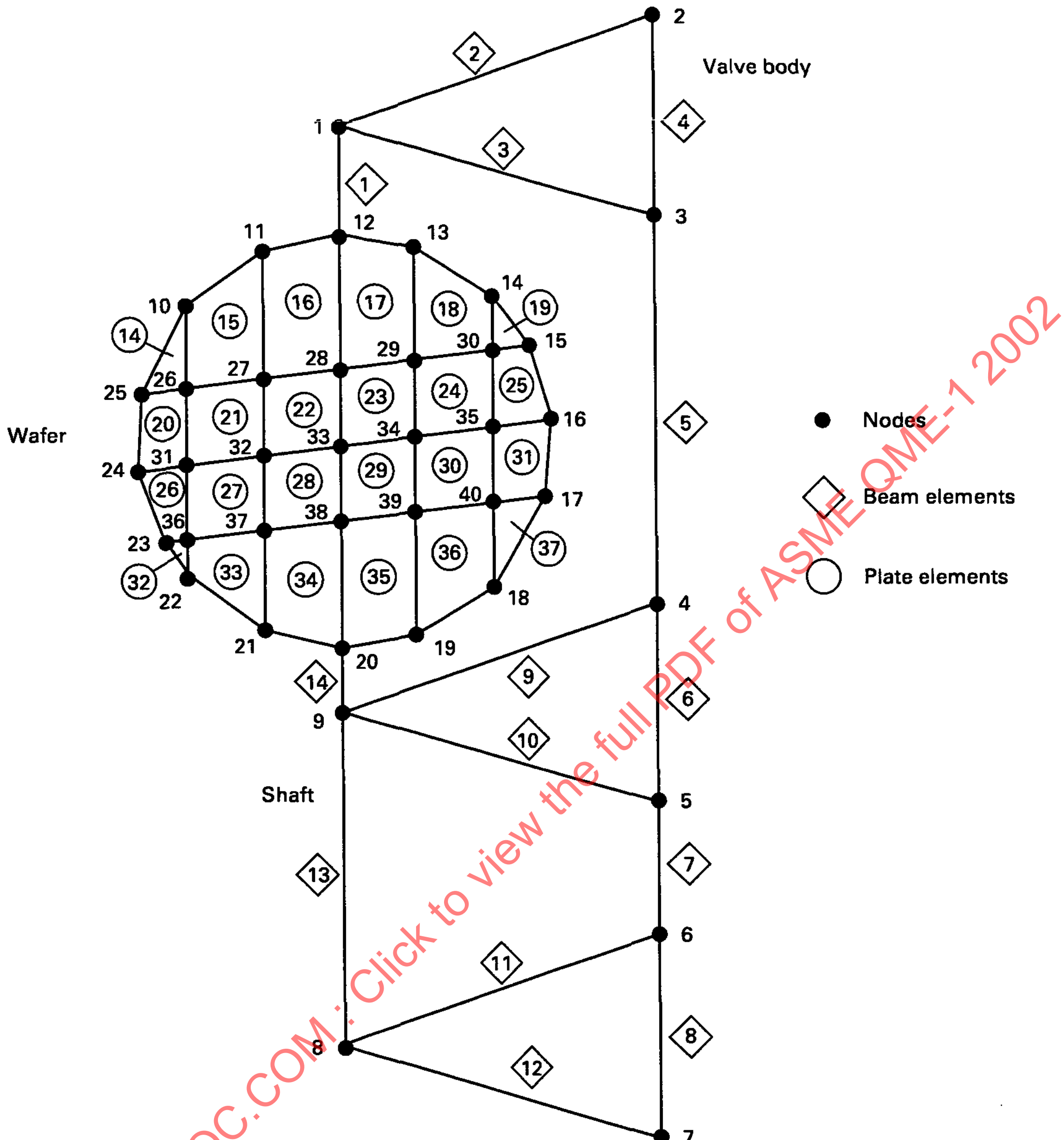


Fig. B4 Finite Element Formulation of Butterfly Valve Assembly

and allowable stress values for the valve parts analyzed. Stresses for ASME Level B and Level C Service Conditions are summarized on Tables B4 through B8. At critical locations identified through failure mode-effect analyses, the model displacements are obtained as the result of the same finite element model analysis.

B2.5 Deformations and Operability

Computed displacements are given in Table B9. Also provided are the allowable clearances obtained from the valve manufacturer.

B2.6 Summary and Concluding Remarks

(a) The valve had its lowest natural frequency above 33 Hz and therefore can be considered rigid.

(b) The membrane (σ_m), membrane plus bending (σ_{m+b}), and shear (σ_v) stresses developed under the combined loadings specified are all within the appropriate allowable values.

(c) The displacements calculated are well below the limits that could cause valve leakage or shaft binding.

It is therefore assured that the seismic acceleration design values given in para. B2.3 do not adversely affect the leak-tight, structural integrity, and function or subsequent operation of the valve.

Table B3 Allowable Stresses at 200°F for 4 in. Valve

Material	Body SA-216 WCB	Shaft A 564 630	Wafer SA-351 CF8M	Bracket A 36	Bolts A 449 Gr. 5
ASME S_h	17,500	...	17,500	...	...
ASME S	...	115,600	...	36,000	...
Upset					
Allowable σ_m	17,500	84,000	17,500	28,800	53,300
Allowable σ_{m+b}	17,500	84,000	17,500	28,000	...
Allowable σ_v	9,450	62,424	9,450	19,440	20,000
Faulted					
Allowable σ_m	17,500	84,000	17,500	28,800	53,300
Allowable σ_{m+b}	28,875	84,000	28,875	28,800	...
Allowable σ_v	9,450	62,424	9,450	19,440	20,000

Table B4 Beam Stresses, psi, for ASME Service Level B

	Body Neck (BP-1)	Shaft (BP-2, 3)
Beam	105	112
σ_m	9	39
Allowable	17,500	92,480
Beam	105	110
σ_{m+b}	582	15,365
Allowable	17,500	92,480
Beam	105	112
σ_v	134	51,139
Allowable	9,450	62,424

Table B5 Beam Stresses, psi, for ASME Service Level C

	Body Neck (BP-1)	Shaft (BP-2, 3)
Beam	105	112
σ_m	12	52
Allowable	17,500	92,480
Beam	105	110
σ_{m+b}	648	15,395
Allowable	28,875	92,480
Beam	105	112
σ_v	139	51,139
Allowable	9,450	62,424

Table B6 Plate Stresses, psi, for ASME Service Level B

	Wafer	Bracket
Plate	...	367
σ_m	< 13	18
Allowable	17,500	21,600
Plate	309	...
σ_{m+b}	11,071	< 3,851
Allowable	17,500	28,800
Plate	...	367
σ_v	< 9	13
Allowable	9,450	19,440

Table B7 Plate Stresses, psi, for ASME Service Level C

	Wafer	Bracket
Plate	...	367
σ_m	< 16	21
Allowable	17,500	21,600
Plate	309	...
σ_{m+b}	11,078	< 3,854
Allowable	28,875	28,800
Plate	...	367
σ_v	< 11	15
Allowable	9,450	19,440

Table B8 Other Locations

Wedge Pin

$$\sigma_p = 11{,}293 \text{ psi} < \sigma_{all} = 92{,}480 \text{ psi}$$

Wafer Hub

$$\sigma_t = 10{,}492 \text{ psi} < \sigma_{all} = 17{,}500 \text{ psi}$$

Bolts (bracket to neck)

$$\sigma_t = \text{small}$$

Table B9 4 in. Valve Nodal Displacements, in., for ASME Service Level C

Location	Node	ΔG_1	ΔG_2	ΔG_3	SRSS	Allowable [Note (1)]	Safety Factor
Wafer	23	0.003166	0.00000125	0.0000182	0.003166	0.010	3.16
Shaft bearing	6	0.00000824	0.00000227	0.000000476	0.00000856	0.010	1000.00
Bracket	57	0.0000296	0.0000104	0.0000315	0.0000444	0.020	450.00

NOTE:
(1) Supplied by manufacturer.

ATTACHMENT C
QUALIFICATION OF PUMPS AND VALVES USING NATURAL EARTHQUAKE EXPERIENCE DATA

C1 INTRODUCTION

This Attachment illustrates an approach using a natural earthquake experience database in establishing the functional qualification of certain classes of mechanical equipment in nuclear power plants, specifically pumps and valves. This Attachment draws heavily on procedures developed by the Seismic Qualification Utility Group (SQUG) as discussed in NUREG-1211 (see QR-A3000). Formal development of an earthquake database sponsored by SQUG began in 1982 and the available natural earthquake experience database expands with each new major seismic event. New data have consistently led to increased confidence in the use of this technique to describe behavior of mechanical equipment in earthquakes and for evaluating and qualifying equipment for functional adequacy in earthquakes. This has established the technical basis for the use of natural earthquake experience data for postearthquake functional qualification purposes.

Pumps and valves demonstrate significant inherent seismic resistance when properly anchored and not subjected to impacting forces from seismic spatial interactions. The functional qualification for pumps and valves identified herein is for operability following the earthquake. Data have not yet been developed that conclusively demonstrate that pumps and valves function properly during the earthquake; however, there are no data to suggest that pump and valve operability during an earthquake is a significant issue, except where there has been earthquake-induced damage.

The requirements of this Attachment in no way reduce or modify the ASME BPVC Section III requirements applicable to construction of pumps and valves, nor do they ensure generic acceptance by regulatory authorities.

C2 APPLICATION

With certain caveats and exclusions that are described in C3, it is possible to demonstrate seismic ruggedness for many classes of equipment at a nuclear power plant through use of a seismic bounding spectrum. An example of such a bounding spectrum applicable to pumps and valves is shown in Fig. C1. The purpose of the bounding spectrum is to allow a comparison of the potential seismic exposure of equipment in the plant being evaluated with the estimated ground motion that similar equipment in the database actually resisted in natural earthquakes. To simplify this comparison, the bounding spectrum is normally expressed in terms of the ground response at the site rather than floor response or equipment response.

The bounding spectrum shown in Fig. C1 is intended for comparison with the 5% damped design horizontal *ground* response spectrum at a given nuclear power plant site. In other words, if the horizontal ground response spectrum for the nuclear plant site is less than a bounding spectrum at the approximate frequency of vibration of the equipment and at all greater frequencies (also referred to as the frequency range of interest), then the equipment class associated with that spectrum is considered to be included within the scope of this method. Alternatively, 1.5 times the bounding spectra may be compared with the applicable 5% building and 5% equipment damped horizontal floor spectrum in the nuclear plant.

The comparison of the bounding spectrum with design horizontal ground response spectra is acceptable for pumps and valves mounted at less than approximately 40 ft above grade (the top of the ground surrounding the building). It should be noted that, in general, this procedure of direct comparison of a bounding spectrum with ground spectrum applies only to equipment with as-anchored frequencies of less than 8 Hz. However, for both valves and pumps, the 8 Hz lower-bound frequency requirement is unnecessary. For equipment mounted at more than approximately 40 ft above grade, comparisons of 1.5 times the bounding spectra with horizontal floor spectra are necessary.

Based on the review of data from a large number of earthquakes, it was judged that the vertical component is not any more significant relative to the horizontal components for nuclear plants than it was for the database plants. Therefore, it was concluded that seismic bounds could be defined purely in terms of horizontal motion levels.

The criteria are met when the 5% damped design horizontal spectrum lies below the bounding spectrum at frequencies greater than or equal to the fundamental frequency range of the equipment. This estimate can be made by experienced engineers using their own judgment without the need for equipment-specific analysis or testing.

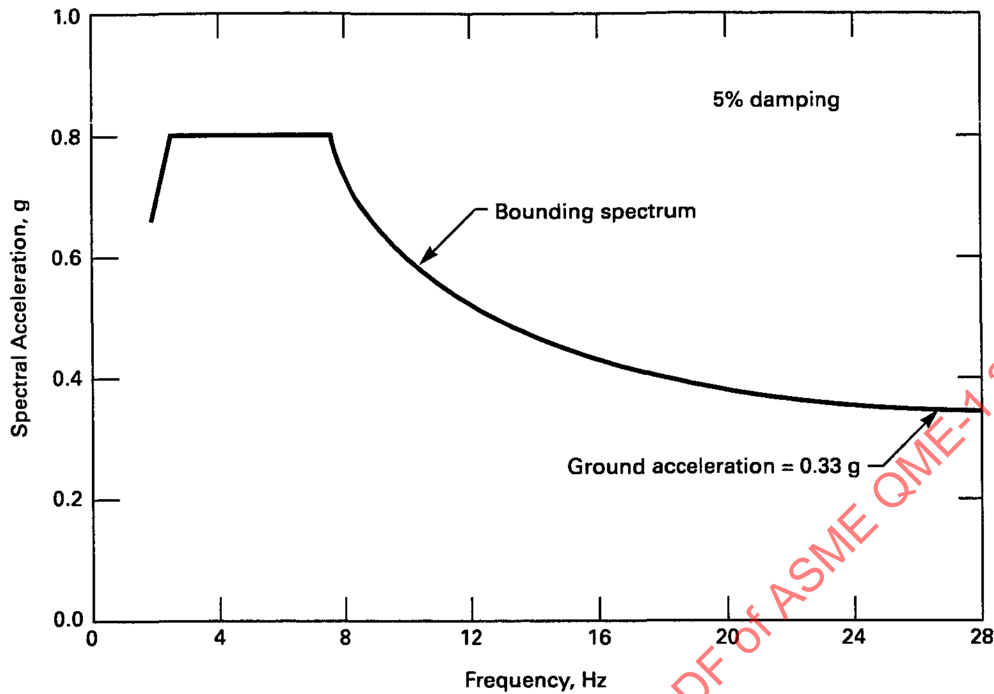


Fig. C1 Seismic Motion Bounding Spectrum Horizontal Ground Motion

C3 CAVEATS AND EXCEPTIONS

C3.1 Pumps

Pumps are relatively stiff and very rugged devices due to their inherent design and operating requirements. Motors for this class of equipment are also included for functional qualification of the assembly, but not for the motor itself. Subject to the limitations described in C3.1.1 and C3.1.2, the equipment meets the criteria for seismic qualification for operability using the bounding spectrum.

C3.1.1 Horizontal Pumps. Horizontal pumps include rotary impeller and positive displacement pumps. They may be driven by electric motors, reciprocating piston engines, or steam turbines. Peripheral systems are included if they are mounted directly on the pump. The database is sufficiently broad so that horizontal pumps of all capacities are included.

For horizontal pumps, all such units are very rugged and need no further evaluation except as noted in the following caveats:

(a) The unit is properly anchored. Expansion anchors are generally not acceptable unless the safety factor on the anchor can be shown to exceed 4.0 for loads that include the dynamic cyclic characteristics of design basis earthquake load.

(b) Any vibration isolation system must be evaluated.

(c) The driver and pump must be connected by a rigid base or skid. If not, the potential for differential displacement must be evaluated.

(d) Thrust restraint of the shaft in both axial directions should exist.

(e) Any relays used to control operability of horizontal pumps must be separately evaluated.

(f) Sufficient slack and flexibility must be present in cooling, fuel, and electrical lines.

(g) Consideration should be given to identify situations in which horizontal pumps may be affected by gross pipe motion, differential displacement, and excessive nozzle loads. This is an issue associated with excessive force on pump nozzles, which could potentially break the pump nozzle, cause pump body distortion sufficient to cause binding, or fail the pump anchorage.

These excessive forces are uncommon and need only be considered if there is a long section of unsupported pipe, significant restraint of free end displacement of the attached pipe, or a heavy valve attached to the pipe near the pump. An experienced engineer can assess whether further evaluation is required beyond that identified herein.

C3.1.2 Vertical Pumps. Vertical pumps include an electric motor drive attached to a base flange with a centrifugal or a deep well pump below the flange. Peripheral equipment attached to the pump is included. The database is sufficiently broad so that vertical pumps of all capacities are included. Vertical pumps above the flange are very rigid and need no further analysis except as noted below.

The variety of vertical pump configurations and shaft lengths below the flange, and the relatively small number of database points in several categories preclude the use of the database to screen all vertical pumps. Vertical turbine pumps, i.e., deep well submerged pumps with cantilevered shafts up to 20 ft in length and with bottom-bearing support of the shaft to the casing are well enough represented to meet the bounding criteria below the flange as well. Either individual analysis or use of another method is required as a means of evaluating other vertical pumps below the flange. The chief concerns would be damage to bearings due to excessive loads, damage to the impeller due to excessive displacement, and damage due to interfloor displacement on multifloor supported pumps. There is evidence of increased wear and maintenance required on vertical pumps after earthquakes.

The caveats for vertical pumps are as follows:

(a) The unit is properly anchored. Expansion anchors are not acceptable unless the safety factor on the anchor can be shown to exceed 4.0 for loads that include the dynamic cyclic characteristics of the design basis earthquake load.

(b) Vertical pumps with shaft lengths in excess of 20 ft must be evaluated separately. The impeller drive shaft must be supported within the casing.

(c) Brief consideration should be given to avoid situations in which vertical pumps may be affected by gross pipe motion, differential displacement, and nozzle loads (see C3.1.1 discussion for horizontal pumps).

(d) Any relays on the vertical pumps and motors must be separately evaluated to determine possible effects of seismically induced vibration.

(e) Sufficient slack and flexibility must be present in cooling and in electrical instrument, power, and control lines.

C3.2 Valves

Valves of many different types that are present on piping in nuclear power plants are covered in this section, including air-operated diaphragm valves, piston-operated valves, spring-operated pressure relief valves, and motor-operated valves. Not included in the database in sufficient quantities and not covered in this section are liquid-operated piston valves such as hydraulic piston-operated valves.

Air-operated diaphragm valves consist of a valve operated by a rod actuated by air pressure against a diaphragm attached to the rod. The actuator is supported by the valve body through a cantilevered yoke. Piston-operated valves or spring-operated pressure relief valves contain air or liquid in a cylinder or chamber that actuates the valve with control provided by a spring. Motor-operated valves consist of an electric motor and gear box cantilevered from the valve body by a yoke and interconnected by a drive shaft. The motor and gear box serve as an actuator to operate the valve.

Based on a review of the database and anticipated variations in conditions, valves are sufficiently rugged to survive a seismic event generating ground motion within the bounding spectrum and remain operational thereafter, provided that the following conditions exist in the nuclear facility:

(a) The valve body is not cast iron.

(b) The valve yoke construction is not cast iron in motor-operated valves, piston-operated valves, and spring-operated pressure relief valves.

(c) The valve is mounted on a pipe of 1 in. diameter or greater.

(d) For air-operated diaphragm valves, piston-operated valves that are lightweight similar to air-operated diaphragm valves, and spring-operated pressure relief valves, the distance from the centerline of the pipe to the top of the operator or cylinder shall not exceed the distance indicated in Fig. C2 corresponding to the diameter of the pipe.

(e) For motor-operated valves and piston-operated valves that are of substantial weight, the distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator shall not exceed the values indicated in Fig. C3 corresponding to the diameter of the pipe.

(f) The actuator and yoke are supported by the pipe, and neither is independently braced to the structure or supported by the structure unless the pipe is also braced immediately adjacent to the valves to a common structure.

(g) Sufficient slack and flexibility is provided in the tubing, conduits, or piping that supply the air or power needed to operate the valve.

Figure C3 for motor-operated valves and substantial piston-operated valves may not cover all combinations of operator weight and eccentricity from the pipe centerline due to limits in the database. Some extrapolation of the values in Fig. C3 may be done provided that the engineer making the extrapolation uses sound engineering judgment. For example, for a given pipe diameter, the values of operator weight and distance to the top of the operator from centerline of pipe may be varied provided that their product, a measure of the cantilever moment applied to the pipe, does not exceed the value calculated from Fig. C3. The distance to the top of the operator may not be increased by the procedure by more than approximately 30%. Likewise, if the ground motion spectra for the site is below the bounding spectrum in the entire frequency range possible for the piping and valve network, the operator weight or distance to the top of the operator can be increased by the ratio of the spectra. Either of these values may not be increased by more than approximately 30% by this procedure.

The operator weights given in Fig. C3 are from the database and may have been estimated slightly low from available catalogs. Thus, if an actual operator is slightly

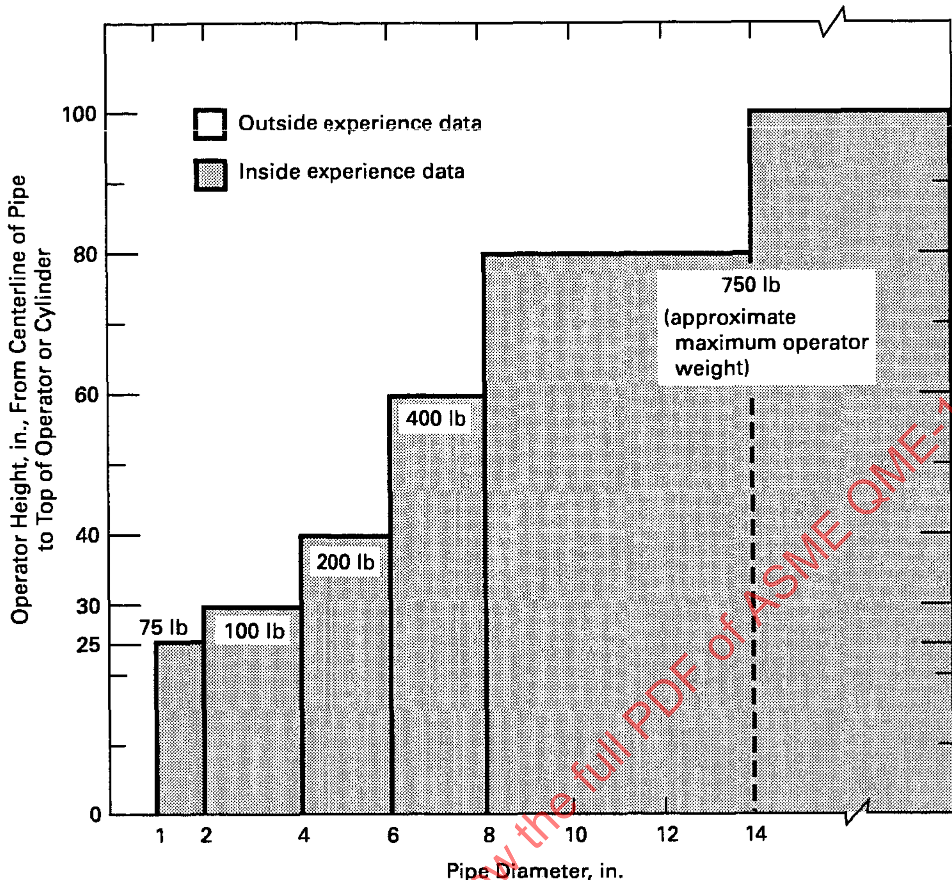


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Fig. C2 Limits of Experience Data for Motor-Operated Valves and Substantial Piston-Operated Valves

heavier than the value in Fig. C3, the engineer evaluating the valve can use some engineering judgment in assigning similarity.

For air-operated and liquid-operated valves not complying with the above limitations, the seismic ruggedness may be demonstrated by static test. In these tests, a static force equal to three times the approximate operator weight shall be applied approximately at the center of gravity of the operator nonconcurrently in each of the three orthogonal principal axes of the yoke. Such tests should include demonstration of operability following the application of the static loads. The limitations other than those related to the distance of the top of the operator to the centerline of the pipe, given above, shall remain in effect. Similarly, static tests can be performed on a mock-up test stand provided that the valve details are very similar to those in the plant. If there are numerous valves, a rational test program can be developed to envelop the valve configurations in the plant. Alternatively, an analytical evaluation can be made.

If the valve body is cast iron, the valve can be qualified, provided that stress analysis of the valve and associated piping reveals that total maximum stress from all sources of load in the cast iron material does not exceed 3,000 psi. It may be necessary to add braces to the piping near the valve to obtain these low stresses in the valve body.

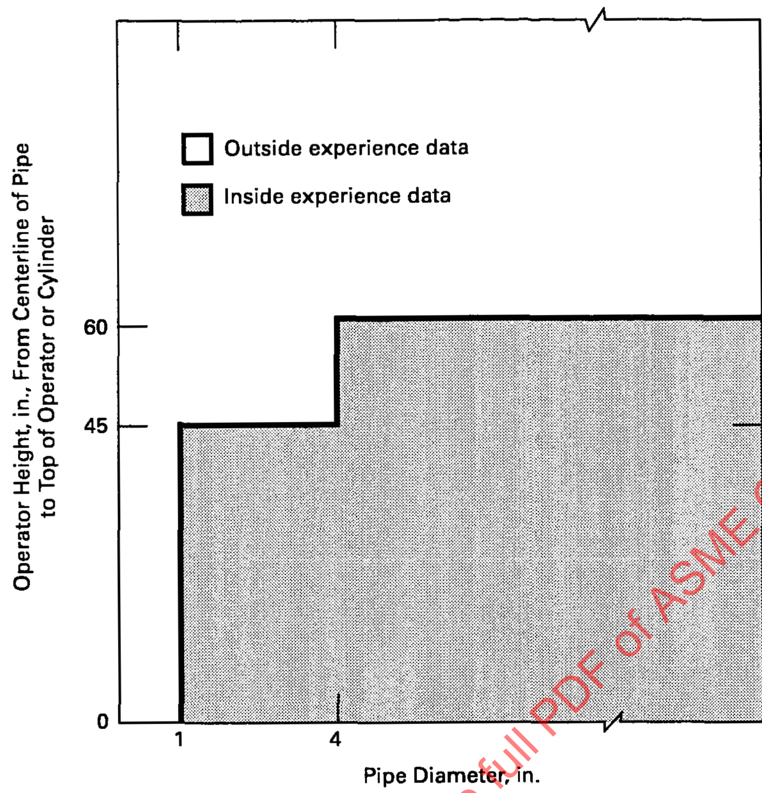

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Fig. C3 Limits of Experience Data for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves, and Piston-Operated Valves of Lightweight Construction

NONMANDATORY APPENDIX QR-B GUIDE FOR QUALIFICATION OF NONMETALLIC PARTS

QR-B1000 SCOPE

This Appendix recommends a methodology and describes the documentation that should be available in a user's (generally a utility's) files to demonstrate the qualification of nonmetallic parts, materials, or lubricants (nonmetallics). It covers the qualification of nonmetallics in new equipment and in existing equipment that is within the scope of the user's mechanical equipment qualification program.

It provides guidance for the utilization of nonmetallics test data, documented service life information, analysis as a means of qualification, qualification testing of nonmetallics, and the establishment of limitations on the use of certain nonmetallics to ensure their acceptable performance. It provides guidance on the factors to be considered in qualifying equipment utilizing these nonmetallics for service in nuclear power plant environments.

This Appendix addresses the steps for the user of the mechanical equipment to follow in order to qualify and to maintain the qualification of the nonmetallics that are a part of the mechanical equipment.

QR-B2000 PURPOSE

The purpose of this Appendix is to provide guidance for demonstrating and maintaining the environmental qualification of nonmetallics. It provides guidance for the use of nonmetallic test data, documented service life information, analysis, and qualification testing as means of demonstrating the environmental qualification of nonmetallics.

This Appendix is nonmandatory. It provides recommended methods for the demonstration and maintenance of the environmental qualification of nonmetallics. As a nonmandatory recommended guide, it contains wording such as *shall, should,* and *may.* The word *shall* is used to denote a suggested requirement, the word *should* to denote a suggested recommendation, and the word *may* to denote permission, neither a requirement nor a recommendation.

This Appendix provides guidance on the necessary documentation requirements that are specific to nonmetallics to ensure the existence of accurate and complete records of qualification. It provides the user with those factors that should be considered when preparing a qualification maintenance program for the equipment in which the nonmetallics are used.

QR-B3000 REFERENCES

IEEE Std 101-1987, Guide for the Statistical Analysis of Thermal Life Test Data
IEEE Std 323-1983, Qualification of 1E Equipment for Nuclear Power Generating Stations
IEEE Std 627-1980, Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations
Publisher: Institute of Electrical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854

QR-B4000 DEFINITIONS

All definitions are contained in Section QR-4000.

QR-B5000 REQUIREMENTS

QR-B5100 General

Normally, nonmetallics in mechanical equipment are more susceptible to degradation resulting from normal, abnormal, and accident environmental and service conditions than are metallic parts. The qualification of the nonmetallics in mechanical equipment shall be demonstrated for the applicable postulated service and environmental conditions to ensure that the equipment can perform its intended safety function.

The nonmetallics shall be identified by their specific material name, manufacturer, manufacturer's specific compound, configuration, and their safety function(s). All of the environmental service conditions at the location of the nonmetallic shall be clearly defined. The effect of the process medium temperature on the life of the nonmetallic should be evaluated for any process medium whose temperature is higher than the highest external environmental temperature. Temperature rise within the mechanical equipment during operation of the equipment should also be included when defining the environment for a nonmetallic.

When qualification is by analysis, it is important that the combined effects of the environmental parameters be fully considered in the analysis. The combined effects of time–temperature and radiation degradation should be considered. The effect that exceeding the radiation threshold could have on the time–temperature analysis should be included in the analysis.

The effects of environmental and service conditions should be evaluated, and all failure mechanisms associated with these conditions should be identified. This evaluation should be used in selecting an appropriate qualification method.

QR-B5200 Identification and Specification of Qualification Requirements

Each nonmetallic shall be identified by material type. It is important to be as specific as possible, since there may be variations in degradation properties of nonmetallics within the same generic material family. The following are necessary to properly identify nonmetallics:

(a) commercial name/trade name of the material
(b) manufacturer
(c) generic name/chemical name of the material
(d) dimensions of the part(s) composed of the material
(e) chemical composition of the material
(f) manufacturer's compound identification for the material
(g) material's activation energy (in conjunction with one of the above identification methods only, and which is based on the material's critical failure mechanism in the intended service)

NOTE: When properties for a specific material are not available, the qualifier should choose data for materials of the same family and the same failure mechanism as the materials in question. The qualifier shall provide a basis as to why these properties are conservative.

The safety functions of each nonmetallic should be specified. Its location and function in the equipment should be identified. The effects of failure modes (the component's manufacturer should be consulted for advice/assistance in making this determination) for the nonmetallic should be evaluated with respect to its safety function. Nonmetallics having no failure modes under the specified environmental and service conditions that affect the safety function of the mechanical equipment may be excluded from qualification. However, the evaluation leading to their exclusion should be recorded in the mechanical equipment's qualification documentation.

QR-B5210 External Conditions. The external service conditions should be specified separately from the conditions at the location of the nonmetallic (internal to the mechanical equipment). The specification for the external conditions should include normal, abnormal, and postulated design basis event (DBE) parameters. These parameters may include, but are not limited to, the following:

(a) temperature
(b) pressure
(c) relative humidity
(d) radiation: gamma, beta, neutron (doses and rates, under normal and accident conditions)
(e) cycling/operability: wear, make/break
(f) duration: normal, DBE, post-DBE
(g) spray: chemical, demineralized water
(h) submergence.

QR-B5220 Internal Conditions. The internal conditions depend upon the application of the mechanical equipment and vary accordingly. These parameters may include:

(a) process fluid media type and chemistry
(b) process temperature
(c) process pressure
(d) process relative humidity
(e) process radiation
(f) mechanical stress.

QR-B5300 Selection of Qualification Methods

Acceptable methods of qualification are testing, analysis, use of operating experience, and combinations thereof. The choice of qualification method will depend upon the severity of the environmental and service conditions, and the resulting failure mechanisms for the nonmetallics. In some instances, it may also depend on the data available to document qualification.

Analysis may be used when a well-defined model exists for evaluating the effect of the environmental and service conditions on the nonmetallics. The use of analysis is simplified when the number of influences on the nonmetallics is limited to one or at most two parameters. Operating experience may be used if it can be adequately documented and can be shown to envelop the specified normal, accident, and post-accident environmental and service conditions of the nonmetallic. Testing to simulated conditions may be used when applicable analytical models do not exist, or when the number of influences to be considered makes their use difficult. Any of the methods may be used in conjunction with another. For example, operating experience could be used to limit or eliminate the need for normal life simulation. The reasoning for the choice of methods should be documented in the qualification record.

Following qualification, it may be necessary to use alternate nonmetallics or change the configuration of nonmetallics in the course of equipment evolution. The effects of these changes and/or substitutions should be evaluated to determine if the nonmetallic's qualification has been affected. The evaluation should be documented and should become part of the qualification record for the associated mechanical equipment. If the evaluation determines that qualification has been affected, the nonmetallics shall be qualified in accordance with all of the requirements of this Appendix. Analysis may be used provided it is documented; it demonstrates that the substituted nonmetallics are equal or superior to the qualified nonmetallics in materials, design, and application; and it demonstrates that they do not compromise the performance of the mechanical equipment under any postulated normal, abnormal, and/or accident condition.

The qualified life, replacement schedule, and replacement procedures for the qualified nonmetallics should be determined and recorded in the qualification documentation. Reference to another appropriate document containing the data may be made in lieu of repeating the contents of that document.

The shelf life of all nonmetallics, and any applicable storage limitations, should be determined and recorded in the qualification documentation.

QR-B5400 Preservation of Qualification

Once qualified mechanical equipment is installed, its qualified condition should be preserved through appropriate preventive maintenance, testing, and monitoring. Care should be taken to ensure that nonmetallics are exposed to conditions that are no more severe than those for which they have been qualified.

If during the course of their service life, nonmetallics are exposed to conditions not bounded by the qualification, their ability to withstand these conditions shall be evaluated and, as appropriate, further qualification shall be performed. This additional qualification may result in shorter qualified life, increased surveillance requirements, or the need for the use of another material.

The preventive maintenance that was assumed or simulated under the qualification program should be performed upon the installed component to preserve the qualification of the component. Nonmetallics should be replaced prior to the end of their qualified lives. Any time that the nonmetallic is disturbed, such as during corrective maintenance, it shall be returned to the condition assumed or simulated in the qualification. For example, disturbing crush seal O-rings will require their replacement. The maintenance program for the overall component should ensure that all covers, seals, etc., that protect nonmetallics from the environment or inadvertent physical damage are restored following maintenance.

Failure or unexpected wear out of nonmetallics during the service life of the associated component should be evaluated to determine whether the condition resulted from a random defect or from a stress that was not fully considered during the qualification. If the condition resulted from such a stress, appropriate action, such as eliminating the stress, limiting the life of the nonmetallic, or requalification, should be taken.

Where uncertainties exist in qualification models or in accurately defining environmental or service conditions at the location of the nonmetallic, condition monitoring may be used to establish replacement and refurbishment schedules. Intervals between monitoring the condition of the nonmetallic should be set such that wear out or failure does not occur prior to observation of the condition.

QR-B5500 Documentation

The qualification of nonmetallics shall be documented. The equipment user should maintain the record of qualification. The documentation should, as a minimum, include:

(a) identification of each of the nonmetallics in the equipment;

(b) description of its application/function in the mechanical equipment;

(c) the equipment's postulated internal and external service conditions;

(d) the Qualification Report;

(e) the qualified life of each nonmetallic;

(f) the qualification for replacement nonmetallics that were not part of the original qualification;

(g) schedules and requirements for maintenance/surveillance;

(h) shelf life preservation requirements.

Qualification documentation should include as much detail as possible concerning assumptions and considerations made during the performance of the qualification. Such details are of great use during the service life of mechanical equipment when further analysis and evaluation of the qualification of nonmetallics is necessary. It should also establish traceability and similarity to the tested/analyzed materials for the nonmetallics that are installed in the qualified component.

Article QR-B7000 describes the details of the documentation procedure requirements of this Appendix.

QR-B6000 METHODS OF QUALIFICATION

QR-B6100 General

This Article provides guidance on the application of testing, experience data, and analysis to qualify nonmetallics for their safety functions. Each of these methods has certain strengths and weaknesses that the qualification engineer should consider in selecting the most appropriate method, or combination of methods, for a specific component. It is the qualifier's responsibility to ensure that any qualification of nonmetallics is done to the same margins as is required by QME-1 Sections QP and QV, as applicable.

Testing at the actual conditions desired for qualification will normally provide the most assurance that the nonmetallic will perform acceptably. However, it may be necessary to approximate the anticipated conditions as a result of limited time and test facility capabilities. The qualifier shall consider the effects of these approximations on the qualification results.

The application of experience from actual service of a similar nature to that desired for qualification may provide information from applicable environments, but adequate documentation of that experience may be difficult to maintain and retrieve. The qualifier shall exercise care in extrapolating this data for use in environments other than those for which actual data is available.

Analysis can be an effective method of demonstrating the applicability of information for one nonmetallic to the qualification of another. However, great care should be taken to ensure that the methods used for the comparison are validated and appropriate for the specific qualification activity.

In most cases, a combination of the three methods will provide the most accurate and reliable qualification.

Prior to selecting the method(s) to be used in a particular qualification application, the qualifier should evaluate the potential failure modes of the nonmetallic(s) and the consequences of that failure. Formalized approaches to this analysis, such as failure modes and effects analysis, should be considered. Such an analysis can assist the qualifier in predicting the most probable failure mode (such as tensile failure, compression set, and others) and the degree to which the degraded part can perform its safety function.

In order to be qualified to the criteria of this Article, the nonmetallic shall demonstrate that after exposure to its normal and/or accident environment, it will retain sufficient properties to perform its intended safety function. It shall have at least the specified minimum elasticity, tensile or compressive strength, or other pertinent property that the mechanical equipment manufacturer deems necessary for it to perform its safety function.

QR-B6200 Arrhenius Model

A recognized method of characterizing accelerated thermal aging effects and estimating equivalent damage at specific time–temperature points is the application of the Arrhenius Model. This methodology is described below.

It has been generally demonstrated that for many nonmetallics, the time–temperature degradation process can be described in a single temperature-dependent reaction that follows the Arrhenius equation:

$$k = A \exp [-(E_a/k_B T)]$$

where

k = reaction rate
A = frequency factor (assumed constant)
exp = exponent to base e
E_a = activation energy, eV
k_B = Boltzmann's constant
= 0.8617×10^{-4} eV/K
T = absolute temperature, K

This equation can be rearranged into the following form, which is more useful:

$$t_2 = t_1 \exp E_a/k_B [1/T_2 - 1/T_1]$$

where

t_1 = accelerated aging time, units of time (usually days)
t_2 = qualified service duration, same units of time as t_1
T_1 = accelerated aging temperature, K
T_2 = qualified service temperature, K
E_a = activation energy of the nonmetallic, eV
k_B = Boltzmann's constant
= 0.8617×10^{-4} eV/K

One of the most important assumptions on which the Arrhenius Model is based is that the activation energy of the reaction remains constant over the temperature range of interest. Activation energies for most elastomeric materials are typically in the range of 0.75 eV to 0.85 eV. However, there is a great deal of data available to the qualifier with higher and with lower eVs. It is the qualifier's responsibility to review the available literature and databases to determine the eV most applicable to the material and the specific usage for which it is being qualified.

It is the responsibility of the qualifier to determine the activation energy of the material being qualified. The manufacturer of the nonmetallic is normally the primary source for this information. If the manufacturer is unable to provide the required information and the qualifier uses data for similar materials, it shall be demonstrated that the value selected is conservative for the material being qualified, for the intended use/configuration of the material, and for the environmental conditions for which the qualification is intended.

NOTE: Lower values of activation energy produce conservative results when predicting lifetimes from accelerated aging tests. The reasonableness of these results should be considered in the determination of the qualified life of the nonmetallic.

The Arrhenius Model is presented here because of its wide acceptance in the determination of thermal aging effects. However, other models have also been developed, especially by material manufacturers. It is recommended that the Arrhenius Model be used.

QR-B6300 Testing

Testing a nonmetallic at conditions similar to those for which it is to be qualified can provide a high level of confidence in its ability to perform its safety function. Testing shall subject the nonmetallic to load conditions, durations, and sequences that have been shown to be at least as severe as the conditions for which the nonmetallic is to be qualified. Except as described in QR-B6310 and QR-B6320, the sequence of applied loads should duplicate, to the extent practicable, the environment for which the nonmetallic is to be qualified. A typical sequence includes thermal aging, radiation exposure, and operation under the qualification conditions of temperature, pressure, humidity, and chemical environment. The test sequence, whether as described above or some other, shall be justified and documented as appropriate for the qualification application.

It is preferred that the nonmetallic be tested when installed in the actual equipment in which it performs its safety-related function. If this is not practical, the fixture used should accurately simulate the actual installation of the nonmetallic.

During the qualification testing, typical conditions of static and mechanical loads (including operating cycles), chemical environment, radiation environment, temperature, and pressure shall be applied. The operating cycles during aging (end of life conditions) should simulate expected operation for the same interval as the accelerated normal life. Separate operating cycles should be imposed during simulated accident exposure for equipment that is expected to operate during and/or following exposure to an accident or postaccident environment(s). The test conditions and the duration of testing shall be as severe as the conditions for which the nonmetallic is to be qualified.

Considerable data exist as a result of testing performed by manufacturers and users of nonmetallics. With proper verification of the validity and applicability, this data can be used in the qualification process. This verification should include a consideration of the physical and chemical properties, test sequences, loads and load combinations applied, durations of loads, and potential synergistic effects. A sound basis shall be provided for accepting testing sequences other than those stated above.

Other factors to consider include the size and shape of the nonmetallic being tested, the amount of the nonmetallic exposed to the test environment, and the variation of the material properties within the specific material compound. The effect of a given environment on one property of the material shall not be used to infer the effect of that environment on other properties unless the appropriate correlation is justified.

The uncertainties inherent in the test methods, test facilities, assumptions, and judgments concerning sequences of loads applied and other factors should be considered when establishing qualification margins.

QR-B6310 Thermal Aging. Thermal aging is imposed on nonmetallics to approximate, during qualification testing, the thermal degradation expected over the life of the nonmetallic. This testing can be performed at the temperatures expected during the life of the nonmetallic or can be accelerated to some extent by subjecting the nonmetallic to higher than expected temperatures for a shorter time than anticipated in service. If accelerated aging is used in the qualification process, extreme care shall be taken to ensure that atypical material changes resulting from the elevated temperature do not invalidate the test data. A method of showing a correlation between the long-term thermally induced degradation at one temperature and the accelerated degradation that occurs at elevated temperatures is described in QR-B6200.

During the thermal aging process, the nonmetallic shall be mounted or contained in its normal configuration, either as installed in the mechanical equipment or in a test fixture.

QR-B6320 Radiation Aging. Radiation aging is used in the qualification process to cause material degradation that is at least as severe as that which is anticipated to occur in the service for which the nonmetallic is to be qualified. Since it is frequently impractical to expose the nonmetallic to its end of life condition at normal exposure rates, it is permissible to accelerate the radiation aging by exposing the nonmetallic to a higher dose rate for a shorter length of time than anticipated in service. The maximum exposure rate should be limited to a level that prevents excessive temperature rise in the material and subsequent nontypical material property changes. The effects of self-shielding and the location of the source(s) should also be evaluated and justified. The possibility that low dose rates experienced in actual service may be more damaging than the higher rates applied during qualification should also be considered.

Consideration should be given to the types of radiation (beta, gamma, etc.) that the equipment and its nonmetallics will see in service. These types of radiation shall be addressed in any testing program and the appropriate exposure requirements established by the qualifier.

QR-B6330 Mechanical Wear Aging. Mechanical wear resulting from operating cycles is an important qualification consideration. It is desirable to perform the wear cycles during the accelerated thermal and radiation aging process to account for any transitory property changes. The qualifier should consider the fact that accelerated aging (thermal and radiation) may impose different loadings and material property characteristics on the nonmetallic. If it is determined that this is the case, mechanical wear aging should be performed under conditions that more accurately reflect actual operating conditions. Wear aging testing should address any lubrication requirements for the nonmetallic being tested. The wear cycles should be imposed in combination with the other loads anticipated in actual service. However, if this is impractical, the wear aging cycles may be applied during another part of the qualification process, provided that the deviations from the anticipated operating sequences are justified.

QR-B6400 Use of Experience

Data obtained from operating experience are considered comparable to test data, provided the total environment in which the nonmetallic was used is well characterized. Appropriate conservatism shall be used to account for the unknowns associated with the reduced control on actual operating environments compared to typical test environments.

Since qualification testing usually requires the imposition of DBE conditions following aging of the nonmetallic, a common application of experience data in qualification is the testing at DBE conditions of the nonmetallic previously used in the actual environment of interest.

Without further testing, the experience data shall adequately demonstrate that the criteria stated in QR-B6100 for demonstration of qualification can be met.

QR-B6500 Qualification by Analysis

Nonmetallics may also be qualified through the use of analysis. Analysis may be used to show that test or experience conditions are more severe than those to which the candidate nonmetallic is to be qualified. Analysis is also used to determine the loads that are to be applied in the qualification process. It can also be used to demonstrate that specific load combinations are appropriate for a given qualification activity. The analytical techniques used should be based on sound engineering principles and should have been verified by independent means to demonstrate their validity for the functional characteristic being analyzed. All assumptions and approximations included in the analyses shall be clearly defined and justified.

Without further testing, the analysis should adequately demonstrate that the criteria stated in QR-B6100 for demonstration of qualification can be met.

QR-B7000 DOCUMENTATION

In addition to the documentation requirements contained in QR-7000, the requirements in QR-B7100 through QR-B7400 shall be met when one of the stated methods is used to qualify nonmetallics.

QR-B7100 Documentation for Qualification by Operating Experience

(a) Identification of the specification for the nonmetallics for which operating experience is available;

(b) comparison of specifications and functions of the nonmetallics to be qualified with those having operating experience data;

(c) summary of operating experience data including operating conditions, maintenance records, and operating history;

(d) the logic used to qualify the nonmetallic for its intended service based on the available experience data;

(e) limitations on the qualification.

QR-B7200 Documentation for Qualification by Analysis

(a) Description of the analytical methods, computer codes, or mathematical model used and the method of verification;

(b) description of the assumptions and empirical data used, along with the appropriate justifications;

(c) description of the analytically established performance characteristics and/or the sources of the test data used to perform the analysis, along with justification of the data's applicability to the specific qualification program;

(d) conclusions including any limitations on qualification.

QR-B7300 Documentation for Qualification by Combined Methods

When combined methods of qualification are used, the appropriate requirements of QR-B7100 and QR-B7200 shall be complied with.

QR-B7400 Documentation of Modifications or Changes That Can Affect Qualification of Nonmetallics

All modifications to qualified nonmetallics made during the installed life of the component should be documented by the component user. The evaluation of the effect of the modification to the nonmetallic should be documented, as should any requalification that is determined to be necessary.

(02)

Section QDR: Qualification of Dynamic Restraints

QDR-1000 SCOPE

Section QDR contains the qualification requirements and guidelines for ASME Code qualified dynamic restraint assemblies. Restraint assembly items may be qualified as part of a restraint assembly or may be qualified separately. It is the responsibility of the Owner or the Owner's designee, hereafter referred to as the Owner, to specify those restraint assemblies to which this Section will be applied.

The scope of this Standard is limited to hydraulic snubbers, mechanical snubbers, and gap restraints. Restraint assemblies and restraint assembly items qualified in accordance with this Section shall meet the requirements of Section QR. Where the requirements of Section QDR conflict with the requirements of Section QR, the requirements of Section QDR take precedence.

QDR-1100 Boundaries of Jurisdiction

All elements of a restraint within the Boundaries of Jurisdiction are within the scope of Section QDR. The Boundaries of Jurisdiction are defined as pin-to-pin of the restraint.

This qualification standard augments, but does not replace, the requirements of ASME Boiler and Pressure Vessel Code (BPVC) Section III, Subsection NF.

QDR-2000 PURPOSE

The purpose of Section QDR is to define requirements and provide guidelines for the qualification of the design of the dynamic restraint assembly. Initial qualification shall be achieved by testing and analysis in order to provide assurance that the restraint in service shall function as required under all specified design conditions.

A functional specification for dynamic restraints that specifies the functional parameters and general performance requirements provides the basis for qualification.

QDR-3000 DEFINITIONS

These definitions establish the meaning of words in the context of their use in this Section and supplement those listed in Section QR.

activation: the change of condition from passive to active, in which a snubber resists rapid displacement of the attached pipe or component.

break away: the force required to initiate movement in one direction.

candidate restraint: those components qualified through extension of parent qualification.

dead band: the free axial movement of the restraint between the two activation levels in opposite directions.

drag: the load required to maintain restraint movement at a specific velocity.

dynamic restraint: any restraint that, by design, has a primary purpose of controlling dynamic movement of a pipe or component.

gap: the physical distance the pipe or component will travel along the restraint axis before movement is restricted.

parent restraint: components used to initially qualify a given design.

rated load: the design load capacity for the restraint based on the use of Level A Service Limits defined by ASME Boiler and Pressure Vessel Code Section III.

release rate: the rate of the restraint axial movement after the activation of the restraint under a specified load.

spring rate: the linear approximation of the relationship of the load displacement characteristics of the restraint.

stroke: the maximum available axial movement of the device.

QDR-4000 QUALIFICATION PRINCIPLES AND PHILOSOPHY

The fundamental principles and philosophy pertaining to equipment qualification are provided in Section QR, Article QR-5000 and apply to mechanical equipment in general. Qualification requirements specific to the restraint assembly or restraint assembly items are contained in Articles QDR-5000 through QDR-7000 of this section.

Restraints are used to control dynamic system responses. Ideally, under a steady or continuing force, the system or component supported by restraints will move freely, as if the restraints did not exist. However, when a force is applied suddenly, restraints will control dynamic responses so that the stresses in the supported system will not exceed allowable Code limits.

The basic characteristic of a dynamic restraint is its ability to develop a force-displacement relationship during dynamic loading that will restrain the movement of the component. The qualification program for dynamic restraints will adequately define the level of this force-displacement relationship at various operating frequencies. Additionally, the qualification program may predict the degradation of these force-displacement relationships when subjected to operational and severe environmental conditions, such as high cycle fatigue, humidity, dirt, dust, spray, radiation, or other environmental conditions. Each restraint device will have different functional parameters that will be specific to its operation and that will govern the level and degree of qualification needed to define this force-displacement relationship. The qualification program shall identify the key functional parameters to be qualified for the specific restraint type identified. Some typical values of the more common functional parameters requiring qualification for identified devices are contained in Nonmandatory Appendix QDR-C.

Vibration of piping systems has a detrimental effect on the long-term performance of a restraint. System vibrations may result in reduced fatigue life and possibly increased restraint aging.

The load-displacement relationship is used by designers for the modeling of restraints in a system analysis and, in turn, adds to the validity of the system analysis. The spring rate is a simplified expression of the force-displacement relationship of the restraint under the action of a cyclically applied load equal to the magnitude of the rated load in both tension and compression. The spring rate may vary as a function of the frequency and the magnitude of the applied load.

Section QR-7340 describes qualification by similarity analysis. Nonmandatory Appendix QDR-B of this Section contains typical parameters to be considered when qualification is to be established by similarity.

QDR-4100 Hydraulic Snubbers

Hydraulic snubbers are component standard supports used to mitigate the effects of a dynamic event. These devices allow for relatively unrestricted movement at low velocities, typical of thermal growth rates. They control displacement velocities by passing a fluid medium through some form of controlled passage or orifice from the high-pressure portion of the fluid system to a lower pressure portion of the device. The controlled flow rate determines the linear displacement of the piston/piston rod. These devices typically provide some means of accommodating fluid expansion/contraction due to ambient temperature changes, and may accommodate fluid volume differences associated with single piston rod designs.

QDR-4110 Functional Parameters. The functional parameters of snubbers are essential for the users to design their systems. These parameters are activation level, release rate, break away, drag, dead band, load rating, and spring rate, as applicable to the individual design.

(*a*) Activation of the restraint is triggered when the design characteristic (a velocity or an acceleration) reaches a predetermined value in either direction. The activation level is determined by rapid application of a single direction load of increasing velocity. Only a small fraction of the rated load is normally required to activate a restraint. Some restraint designs may not have an active triggering characteristic, but instead rely on passive inherent nonlinear response. In such cases, this test, and the determination of the dead band, would not be applicable.

(*b*) Release rate is the velocity at which restraint motion occurs after activation has taken place. It can be measured during the activation test of the restraint. The release rate magnitude depends upon the loading magnitude and is an indication of the recovery rate of the restraint as it returns to the inactivated condition. The release rate magnitude needs to be determined for several levels up to the faulted load in both directions, all at a specific temperature.

(*c*) Break away can be determined using a load cell to measure the force required to initiate movement. True break away can only be determined in one direction per test sequence. Note that in laboratory environments this test can be performed with adequate controls, but it is not intended to be performed as any part of an in-service operability testing program.

(*d*) Drag can be determined using a load cell to measure the force required to move the restraint at a specific velocity. Testing shall be performed in both directions.

(*e*) Dead band can be determined by measuring the distances traveled by the restraint before it activates in opposite directions. The dead band can have a significant effect on performance at all load levels. It is therefore prudent to measure it with the associated loading at several levels, up to the rated load.

(*f*) Load rating may be determined by test or analysis, in accordance with ASME BPVC Section III, Subsection NF.

(*g*) Spring rate shall be determined dynamically. Additionally, a static spring rate may be determined if required. The applied loads in tension and compression divided by the recorded displacements in tension and compression describe the spring rate, including dead band. Methods of spring rate determination shall be identified in the Functional Qualification Report (QDR-7310).

(*h*) The amount of stroke is typically dictated by the amount of thermal movement (in the restraint's axial direction) experienced at the location where the restraint is to be used. The amount of stroke is predicated on what the pipe analysis indicates is appropriate. The stroke is the physical distance the pipe will travel along the restraint axis.

(i) While the rate of fluid loss in hydraulic restraints is not strictly a functional parameter, it is important because hydraulic restraints will not function properly without hydraulic fluid. An acceptable limit for the fluid loss rate is important to the qualification of a restraint and therefore shall be considered in the functional specification and the subsequent testing.

QDR-4200 Mechanical Snubbers

Mechanical snubbers are component standard supports used to mitigate the effects of a dynamic event. These devices allow for relatively unrestricted movement at low velocities, typical of thermal growth rates. They control displacements, displacement velocities, or acceleration levels by mechanical means.

QDR-4210 Functional Parameters. The functional parameters of snubbers are essential for the users to design their systems. These parameters are activation level, break away, drag, dead band, load rating, and spring rate, as applicable to the individual design.

(a) Activation of the restraint is triggered when the design characteristic (a velocity or an acceleration) reaches a predetermined value in either direction. The activation level is determined by rapid application of a single direction load of increasing velocity. Only a small fraction of the rated load is normally required to activate a restraint. Some restraint designs may not have an active triggering characteristic but instead rely on passive inherent nonlinear response. In such cases, this test and the determination of the dead band would not be applicable.

(b) Release rate is the velocity at which restraint motion occurs after activation has taken place. It can be measured during the activation test of the restraint. The release rate magnitude depends on the loading magnitude and is an indication of the recovery rate of the restraint as it returns to the inactivated condition. The release rate magnitude needs to be determined for several levels up to the faulted load in both directions, all at a specific temperature.

(c) Break away can be determined using a load cell to measure the force required to initiate movement. True break away can only be determined in one direction per test sequence.

NOTE: In laboratory environments this test can be performed with adequate controls, but this test is not intended to be performed as any part of in-service operability testing program.

(d) Drag can be determined using a load cell to measure the force required to move the restraint at a specific velocity. Testing shall be performed in both directions.

(e) Dead band can be determined by measuring the distances traveled by the restraint before it activates in opposite directions. The dead band can have a significant effect on performance at all load levels. Dead band should be measured with the associated loading at several levels, up to the rated load.

(f) Load rating may be determined by test or analysis, in accordance with ASME BPVC Section III, Subsection NF.

(g) Spring rate shall be determined dynamically. Additionally, a static spring rate may be determined if required. The applied loads in tension and compression divided by the recorded displacements in tension and compression describe the spring rate, including dead band. Methods of spring rate determination shall be identified in the Functional Qualification Report (QDR-7310).

(h) The amount of stroke is typically dictated by the amount of thermal movement (in the restraint's axial direction) experienced at the location where the restraint is to be used. The amount of stroke is predicated on what the pipe analysis indicates is appropriate. The stroke is the physical distance the pipe will travel along the restraint axis.

(i) The effects on the above functional parameters due to any form of lubricant used shall be considered in the functional specification and subsequent testing.

QDR-4300 Gap Restraints

Gap restraints are nonlinear devices. The restraint provides a gap, which can be set for the predicted thermal movements of the piping at the installed location. This gap will allow free thermal expansion, or the device can be set so that there is a compromise between thermal movement and dynamic gap (i.e., some thermal movement is restrained to lessen the amount of dynamic deflection allowed). After the gap is closed, a force is generated when the contact surfaces engage. When the dynamic movement of the pipe is reversed, the pipe moves back through the gap until the gap closes in the opposite direction. The opposite contact surfaces then engage and a force is generated.

QDR-4310 Functional Parameters. The functional parameters pertinent to gapped restraints are gap size, spring rate, fatigue of springs, friction, and load rating.

(a) Gap size is typically dictated by the amount of thermal movement (in the restraint's axial direction) experienced at the location where the restraint is to be used. The intent is to allow free thermal movement (i.e., impose no normal loading on the piping) while still restricting dynamic movement. The amount of gap is predicated on what the pipe analysis indicates is appropriate and can be smaller or greater than the predicted thermal movement. The gap size is the physical distance the pipe will travel along the restraint axis before movement is restricted. The gap is analogous to the dead band of a snubber.

(b) Deflections will be imposed on the device as a result of the transmission of static and/or dynamic loads. Spring rate is typically determined by analysis requirements. Spring rate in a gapped device is defined by its characteristics after the gap is closed and loading begins. Spring rates may differ in tension and compression and shall be noted. Through testing, the manufacturer shall establish the spring rates. Methods of spring rate determination shall be identified in resulting report. For gap restraints that have load-limiting capability, the spring rate may change at a predetermined load. For these restraints, there is no increase in load with additional displacement.

(c) An evaluation shall be made to determine fatigue life of springs used in the device. Testing and/or analytical evaluations can be used.

(d) Friction could be developed as the device moves through its gap. Friction loads shall be determined through testing.

(e) Load rating may be determined by test or analysis, in accordance with ASME BPVC Section III, Subsection NF.

QDR-5000 FUNCTIONAL SPECIFICATION

(a) The owner shall provide a functional specification to define the required performance characteristics. The performance characteristics shall include the acceptable values and ranges of restraint functional parameters and anticipated environments. Typical content of a functional specification is shown in Nonmandatory Appendix QDR-A. The functional specification shall be reconciled with the Design Specification in accordance with ASME BPVC Section III, Subsection NF.

(b) A restraint design's suitability to meet the requirements of the functional specification for a specific application is required to be documented in an Application Report as described in QDR-7320.

QDR-6000 QUALIFICATION PROGRAM

QDR-6100 General Requirements

Section QDR provides two basic methods for qualification of a restraint assembly. A restraint may be qualified by a program of testing and analysis to become a qualified parent restraint assembly, or it may be qualified by an extension of a qualification program that has been previously performed on a similar parent restraint assembly.

(a) QDR-6200 may be used to provide functional qualification of a parent restraint assembly through a testing program. The testing is intended to demonstrate that a restraint assembly can perform its required function under conditions specified in the functional specification.

(b) QDR-6300 may be used to provide functional qualification of a wide range for candidate restraint sizes by extension of the parent restraint qualification. This is accomplished through demonstration of design similarity and analysis.

The procedure of QDR-6300 is based on the application of a comprehensive analytical modeling procedure that must be verified by the results of the parent restraint testing program. The program must show applicability to the selected candidate restraints. This extension of qualification is based upon the conditions that both the parent and candidate restraints use the same design concept, and that the rules of QDR-6300 are fully satisfied. The use of QDR-6300 is not obligatory in the sense that all restraints may be qualified by testing as parent restraint assemblies; however, if QDR-6300 is used for the extension of parent restraint qualification to a candidate restraint qualification, all provisions of QDR-6300 must be complied with for the candidate restraint.

QDR-6200 Parent Restraint Qualification

QDR-6210 Approach to Qualification. The intent of parent restraint qualification is to provide generic qualification of a given restraint assembly design. An Application Report, as described in QDR-7320, is required to provide documentation that each of the production restraints is qualified for a specific application.

In any qualification program there is a concern that the unit selected for testing is exceptional. Testing multiple units, randomly selected if possible, may reduce this concern. The Owner shall establish the number of units required for satisfactory qualification. Testing of multiple units provides increased confidence in repeatability of the test results. Additional conservatism may be added to the anticipated service requirements to add further confidence in the component. If one or more units fail to meet the requirements, an analysis to determine the reason for failure is required to provide data for design changes. Since the test program could result in considerable usage of the restraints, tested units shall be inspected and appropriately refurbished prior to actual service.

Overloading of restraints could take place under some accident conditions. The restraint should fail in a manner that would not result in undesirable stress or strain on the piping system. The margin to failure due to overloading conditions is designated as the ultimate load and shall be furnished by the manufacturer. Ultimate load capability shall be determined analytically and/or by testing as permitted by the governing codes and design specifications.

There may be special requirements specified for restraints subject to unique conditions or applications. Such requirements shall be defined in the functional specification. Tests or evaluations shall be conducted to verify the ability of the restraint to endure or satisfy these conditions.

QDR-6220 Testing. The qualification program shall specify the functional parameters and environmental variables to be measured. The functional parameters shall include those specified in Article QDR-4000. The environmental variables shall include temperature, humidity or steam-water condition, special thermal transients, external pressure, and radiation as applicable. The application of a low amplitude, high frequency vibration shall be included as an environmental requirement. Testing shall include all loading conditions defined in the functional specifications.

The spring rate is a function of the load direction, the extension of restraint travel, and the amplitude and frequency of the dynamic loading, as well as environmental conditions. The spring rate is determined by subjecting the test unit to dynamic cyclic tests over an appropriate frequency range. The temperature extremes anticipated in service shall be reproduced for testing.

QDR-6221 Installation and Orientation. The parent test restraint shall be supported by its normal mounting points to permit testing in accordance with QDR-6222. The qualification program shall specify the way the restraint is to be mounted for testing.

If spherical bearings are utilized for connection, the tolerance between the inner bearing hole diameter and the diameter of the pin shall be specified by the restraint manufacturer. The connection of the restraint is not designed to transmit moments and must allow for erection misalignment, in service pipe movement, or both. There shall be no binding or interference between the mating connection parts within the specified angular cone. The design of the connection shall be such that movement of the pipe attachment in the direction of the load is minimized in the connection.

The program shall require that the restraint unit be mounted in a manner that simulates its expected service application. The test restraint assembly may be mounted in a conservative worst-case orientation, provided that a satisfactory justification for the worst-case orientation decision is documented in the Functional Qualification Report.

The provisions of QDR-6300 shall be used to extend parent restraint qualification to various candidate restraint sizes. The parent restraint test program shall include measurement instrumentation as necessary to satisfy all the requirements of that sub-article.

QDR-6222 Test and Monitoring Equipment. The test shall be conducted and monitored using equipment adequate for detecting changes in the variables. The qualification program shall specify the test and monitoring equipment to be used for the qualification and describe the accuracy within the anticipated range. The test and monitoring equipment shall be calibrated and documented against auditable calibration standards. The data-recording equipment shall have sufficient speed, sensitivity, and capacity to permit measurement of the time dependence of each variable.

QDR-6223 Test Sequence. Qualification testing shall be in accordance with QDR-6200 and shall include tests QDR-6223(a) through (f) in the described sequential order. Any deviations shall be justified in the Functional Qualification Report. Additional testing may be inserted within this sequence as appropriate. The testing sequence, except as noted in the previous sentence, shall be:

(a) pretest inspection;

(b) pre-aging functional parameter testing;

(c) aging and service condition simulation;

(d) intermediate inspection without disassembly, maintenance, or modifications;

(e) post-aging functional parameter testing;

(f) posttest inspection.

Pretest inspection shall include, but is not limited to, a thorough dimensional inspection of all components. These dimensions shall be recorded for comparison with the posttest dimensional inspection.

Intermediate inspection shall consist of visual inspection for loose, broken, or corroded components, fittings, fasteners, etc. Signs of fluid loss should be noted, where applicable. No activities that could repair or mitigate any degradation shall be performed.

QDR-6223.1 Functional Parameter Testing for Hydraulic Snubbers. All parameters described in QDR-4100 shall be determined at the recorded room temperature and at a temperature of 200°F (93°C) or at the specified maximum design temperature, whichever is higher. Temperature correction factors for higher or lower temperatures shall be documented where appropriate. Temperature shall be recorded at the beginning and end of each of the tests. The tests shall be performed with the restraint at the mid-stroke position unless otherwise required.

(a) The activation level (where applicable) shall be tested in each direction. The acceleration or velocity shall be recorded as a function of time. The activation level shall be determined from this data.

(b) The release rate shall be tested and recorded in each direction at 5%, 10%, 25%, 50%, and 100% of rated load and at the emergency load.

(c) The break away drag shall be determined at the initiation of the drag test in each direction or during a test performed specifically to determine break away drag. The force corresponding with the initiation of movement shall be recorded.

(d) The drag shall be determined in each direction. The values of the drag and the velocity shall be recorded. Drag shall be performed throughout the entire range of travel to demonstrate drag characteristics.

(e) The dead band shall be recorded during the activation level testing described in this Article or during a separate test performed specifically for determination of dead band.

(f) Where it is impracticable to perform multicycle dual-direction faulted-load dynamic testing, one-cycle dynamic loading tests shall be performed subsequent to all other tests. The restraint shall be centered about the $\frac{1}{2}$ stroke location, and at each end of the manufacturer-recommended useable stroke. A loading amplitude equal to the faulted loading shall be performed to demonstrate adequacy of the response. The force, displacement, and velocity (or acceleration as appropriate) shall be recorded. Any damage or other anomalies shall be noted and evaluated to determine the effects of faulted loads on the operability of the restraint.

(g) The spring rate shall be tested by a dynamic cyclic loading equal to the rated load (or other specified load). The peak displacement range, including the dead band, shall be obtained during the dynamic cyclic test through the peak force range. The peak force range shall include load applied in opposite directions. Restraint movement shall be centered about the $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ stroke locations according to the requirements of the functional specification. The testing frequency shall be from 3 Hz to 33 Hz at intervals of approximately 3 Hz. Each frequency shall last not less than 10 sec. Response at each frequency shall be recorded as load-displacement traces. No extreme change in displacement should be observed from one frequency to the next, as this could indicate that the fundamental frequency (natural frequency) resides in the 3 to 33 Hz range.

(h) The stroke is a parameter to be dimensionally verified, but no further testing need be performed.

(i) Hydraulic fluid loss during the testing shall be recorded.

QDR-6223.2 Functional Parameter Testing for Mechanical Snubbers. All parameters described in QDR-4200 shall be determined at the recorded room temperature and at a temperature of 200°F (93°C) or the specified maximum design temperature, whichever is higher. Temperature correction factors for higher or lower temperatures shall be documented where appropriate. Temperature shall be recorded at the beginning and end of each of the tests. The tests shall be performed with the restraint at the mid-stroke position unless otherwise required.

(a) The activation level (where applicable) shall be tested in each direction. The acceleration or velocity shall be recorded as a function of time. The activation level shall be determined from this data.

(b) The release rate shall be tested and recorded in each direction at 5%, 10%, 25%, 50%, and 100% of rated load and at the emergency load.

(c) The break away drag shall be determined at the initiation of the drag test in each direction, or during a separate test performed specifically for determination of break away drag. The force corresponding with the initiation of movement shall be recorded.

(d) The drag shall be determined in each direction. The values of the drag and the velocity shall be recorded. Drag shall be performed throughout the entire range of travel to demonstrate drag characteristics.

(e) The dead band shall be recorded during the activation level testing described in this Article, or during a separate test performed specifically for determination of dead band.

(f) Where it is impracticable to perform multicycle dual-direction faulted-load dynamic testing, one-cycle dynamic loading tests shall be performed subsequent to all other tests. The restraint shall be centered about the $\frac{1}{2}$ stroke location, and at each end of the manufacturer recommended useable stroke. A loading amplitude equal to the faulted loading, shall be performed to demonstrate adequacy of the response. The force, displacement, and velocity (or acceleration, as appropriate) shall be recorded. Any damage or other anomalies shall be noted and evaluated to determine the effects of faulted loads on the operability of the restraint.

(g) The spring rate shall be tested by a dynamic cyclic loading equal to the rated load (or other specified load). The peak displacement range, including the dead band, shall be obtained during the dynamic cyclic test through the peak force range. The peak force range shall include load applied in opposite directions. Restraint movement shall be centered about the $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ stroke locations according to the requirements of the functional specification. The testing frequency shall be from 3 Hz to 33 Hz at intervals of approximately 3 Hz. Each frequency shall last not less than 10 seconds. Response at each frequency shall be recorded as load-displacement traces. No extreme change in displacement should be observed from one frequency to the next, as this could indicate that the fundamental frequency (natural frequency) resides in the 3 to 33 Hz range.

(h) The stroke is a parameter to be dimensionally verified, but no further testing need be performed.

(i) Degradation of any lubrication shall be monitored and documented during testing.

QDR-6223.3 Functional Parameter Testing for GAP Restraints. All parameters described in QDR-4300 shall be determined at the recorded room temperature. The tests shall be performed with the restraint at the mid-stroke position unless otherwise required.

(a) The gap is a parameter to be dimensionally verified, but no further testing need be performed.

(b) The spring rate shall be verified through testing by a dynamic cyclic loading equal to the rated load (or other specified load). No extreme change in displacement should be observed from one frequency to the next, as this could indicate that the fundamental frequency (natural frequency) resides in the 3 to 33 Hz range.

(c) If fatigue life of springs is to be verified through test, the spring shall be exercised through its entire working range for sufficient cycles to simulate the expected or predicted design life exposure.

(d) The drag shall be determined in each direction. The value of the drag shall be recorded. Drag shall be performed throughout the entire range of travel (gap) to demonstrate drag characteristics.

(e) A loading amplitude equal to the faulted loading shall be performed to demonstrate adequacy of the response. The force, displacement, and velocity shall be recorded. Any damage or other anomalies shall be noted and evaluated to determine the effects of faulted loads on the operability of the restraint.

QDR-6224 Aging and Service Condition Simulation

QDR-6224.1 Aging. The qualification program shall specify the aging simulation based on requirements in the functional specification. Aging simulation equivalent to full service life conditions shall be conducted. These shall include sand and dust simulation and a salt spray test if specified as an environmental condition in the functional specification.

The manufacturer shall specify the level of low amplitude, high frequency vibration (axial and/or transverse) that the restraint design can withstand without adversely impacting the operating parameters of the restraint.

QDR-6224.2 Service Condition. The qualification program shall specify the service condition simulation (steam, humidity, temperature, wetted, etc.) to which the restraint will be subjected. Vibration aging, testing for Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE), exposure to Design Basis Event (DBE) such as Loss Of Coolant Accident (LOCA) and High Energy Line Break (HELB) environments, as applicable, shall be considered. This shall correspond to the service conditions defined in the functional specification.

QDR-6225 Special Tests. The qualification plan shall specify special tests for the restraint design as required by the functional specification. These are the tests demonstrating the ability of the restraints to meet special requirements such as load-sharing arrangements or an in situ in-service activation test. Test setup and equipment used shall closely simulate the required condition so that feasibility can be illustrated and correlation between results can be established.

QDR-6226 Material Data Requirements. The following material data shall be included to ensure that the restraint is manufactured according to the specification:

(a) The data from or reference to tests conducted to prove the adequacy of the basic material selection. An example of this would be tests for compatibility between the seal material and the hydraulic fluid and between the seal material and the working environment. Special consideration shall be given to the combined effects of temperature and radiation on material performance.

(b) Data on material and process tractability shall be included to demonstrate that the material of the tested restraint and the materials designated in the manufacturing specification meet the same requirements as the material selection justified in QDR-6226(a).

QDR-6227 Limits or Failure Definition. The dynamic restraint shall be considered to have failed the qualification testing requirements if any of the following occurs:

(a) failure to meet any of the functional parameters (e.g., activation, release rate, drag force, dead band, spring rate) specified for the dynamic restraint in the functional specification, while being loaded to its specified load ratings for all loading conditions;

(b) failure to meet any of the functional parameters during/after being subjected to the environmental conditions specified in the functional specification;

(c) failure to meet any of the special testing requirements of the Functional Specification;

(d) failure to pass a posttest inspection and analysis after all testing and exposure to the environmental conditions specified in the functional specification.

QDR-6228 Ultimate Load Capacity. The ultimate load capacity of a restraint design shall be determined by test or analysis. The analysis report shall follow the stress report requirements described by the ASME BPVC Section III, Subsection NF. The mode of failure shall be determined by the test or analysis.

QDR-6229 Posttest Inspection and Analysis. Upon completion of the qualification tests, the tested assembly shall be disassembled, inspected, and subjected to a posttest analysis. The results of this analysis shall be documented in the Functional Qualification Report and shall contain the following information:

(a) identification of the restraint tested;

(b) the last test conducted on the restraint in the test sequence;

(c) analysis of the posttest restraint condition;

(d) summary, conclusions, and recommendation;

(e) approval signature and date (certification by a Registered Professional Engineer competent in the field of functional and environmental testing);

(f) disposition of restraint.

QDR-6300 Candidate Qualification

QDR-6310 General Requirements. Candidate restraint assemblies that are identical in construction (same manufacturer, type, size, rating, etc.) to a parent restraint assembly may be qualified by preparing an Application Report in accordance with QDR-7320 and referencing the appropriate parent restraint Functional Qualification Report.

Candidate restraint assemblies that are not identical in construction to a parent restraint assembly may be qualified by extension through appropriate analysis and/or testing.

QDR-6310 is not intended to be a stand-alone qualification-by-analysis technique. It contains guidelines for the functional qualification of a candidate restraint assembly based on the extension of parent restraint qualification by analysis. The analysis techniques and procedures shall have been validated through correlation of analytical predictions with the parent test results. As such, qualification of a candidate restraint by QDR-6300 cannot be broader in scope than that for the parent restraint, tested in accordance with the requirements of QDR-6200.

The procedure is based on a high degree of similarity between the candidate restraint and the parent restraint assemblies. Where sufficient design similarity exists (in accordance with QDR-6320), qualification of the candidate restraint can be demonstrated by a test-verified analysis procedure designed to ensure that the mechanical strength, rigidity, and critical design tolerances of the candidate restraint compare favorably with the qualified parent restraint. Where inadequate design similarity occurs, the analysis procedure must be supplemented with additional analytical evaluations or tests.

In order to provide reasonable validation, the test-verified analysis procedure is based on comparison of analytical predictions with two or more parent restraints as established in QDR-6340.

QDR-6320 Design Similarity

QDR-6321 Allowance for Differences. Any analysis must make allowances for differences in dimensions, performance characteristics, working fluid, orientation, and other parameters. In order to address these allowances, the test-verified analysis procedure shall be based on the similarity between the parent restraint assembly and the candidate restraint assembly. The similarity must be sufficient to justify the applicability of the analysis procedure to these parameters. The establishment of certain design similarity criteria will also provide qualification assurance for those parameters that are difficult to address in an analysis procedure.

QDR-6322 Similarity Requirements. For qualification of a candidate restraint assembly by the test-verified analysis methods, the requirements for design similarity and evaluation of differences shall include, where applicable, but not be limited to those parameters addressed in Section QR, Nonmandatory Appendix A.

QDR-6330 Analysis Procedure

QDR-6331 Selection and Documentation

(a) The extension of qualification by test-verified analysis requires selection of an appropriate analysis procedure. Analysis procedure, as used herein, is defined as any combination of algorithms, finite-element analyses, or other appropriate analytical techniques.

(b) The analysis procedure shall be documented in the Application Report in a form that provides adequate revision control, and that permits reviewing, checking, or verifying its applicability by personnel who are experienced in this area of activity.

QDR-6332 Procedure Requirements

(a) A detailed analytical model shall be prepared to address each characteristic of the restraint assembly, such as those listed in QDR-6332(b). The term shall be loosely interpreted to mean any analytical form which can be used to provide consistent analysis results. The model can range in complexity from a simple handbook formula to an elaborate finite-element analysis algorithm, or even a specified analytical procedure composed of various combinations of analytical forms. The same analytical models shall be capable of analyzing all similar restraints to be qualified without alterations or arbitrary adjustment of constants. The models, once established and verified, must be consistently applied to all restraint assemblies to be analyzed. All finite-element analysis models shall maintain consistency in the application of elements, the element types, and the boundary conditions at all interfaces for all similar restraint assemblies that are analyzed.

(b) The analysis procedure models shall be sufficiently detailed to include, but not be limited to, an analysis of the following:

(1) stresses and deflection data for all critical points in the restraint assembly based on the maximum specified dynamic loading;

(2) stress calculations on all essential-to-function parts based on the maximum load capability of the restraint;

(3) stresses and deflections for all critical points in the restraint based on the maximum specified angular misalignment of the specified load;

(4) relative deflections that affect clearances between all essential-to-function parts that undergo relative motion during operation of the restraint;

(5) fatigue usage on the restraint assembly as applicable;

(6) fundamental resonant frequency of the restraint assembly;

(7) rigidity of the mounting brackets used to attach accessories to the restraint assembly;

(8) other functional parameters as designated in QDR-4000.

QDR-6340 Analysis Procedure Verification

QDR-6341 Verification Methods

(a) Verification of the analytical procedure shall be accomplished through correlation of the analytical results with data obtained from testing.

(b) Verification methods may take any combination of the following forms:

(1) tests conducted on parent restraint assemblies performed in accordance with QDR-6200. The parent restraint test program shall include additional measurements or testing as necessary to satisfy the requirements of QDR-6300.

(2) supplemental tests performed outside the scope of the parent restraint test program, but which address specific portions of the overall analysis procedure, e.g., tests performed by the manufacturer to verify restraint sizing calculations, dead band calculations, restraint break away force calculations, etc. It is incumbent upon the restraint supplier to demonstrate applicability of these tests to the restraints being qualified.

(3) reference to standard textbook calculation procedures that have been extensively verified, are widely used, and are accepted throughout the industry without recourse to further verification tests.

QDR-6400 Extension of Qualification

QDR-6410 Applicability of Qualification Extension. Provided that the allowable stresses predicted by the test-verified analysis are within the elastic range, the analysis procedure is applicable in its entirety, without further verification, to candidate restraint sizes and ratings that:

(a) fall within the range of restraint sizes established in QDR-6300, and

(b) satisfy the design similarity requirements of QDR-6320.

QDR-6420 Qualification Extension Requirements. The qualification analysis procedure may be applied without further verification by testing to candidate restraint sizes and ratings that meet the design similarity requirements listed below (See also Nonmandatory Appendix QDR-B, Restraint Similarity). Design similarity must be established based on the lack of potential effect on performance with regard to all functional parameters, (e.g., activation, release rate, drag force, dead band, spring rate). Environmental conditions identified in the functional specification must be considered. The following specific parameters shall be considered in establishing similarity of design:

(a) Design/Configuration. Applicable candidate restraint parts shall be similar in design and configuration, the principal difference being overall size and/or weight.

(b) Materials. Differences in materials of restraint assembly components need to be accounted for. Material differences are acceptable provided that

(1) appropriate adjustments in qualification rating parameters are made based on the relative yield strengths of the materials;

(2) due consideration is given to functional performance capabilities of materials and combinations of materials.

(c) Dimensions/Tolerances. Physical dimensions and tolerances of applicable candidate restraint parts shall be considered.

(d) Surface Finish. Surface finishes of applicable candidate restraint parts shall be considered where applicable.

(e) Fabrication/Assembly Method. Fabrication and assembly method (e.g., welding, bolting) shall be considered.

(f) Coatings/Plating. Coatings and plating of applicable candidate restraint parts shall be considered where applicable.

(g) Production Testing. Methods used in production testing during manufacturing shall be considered.

QDR-7000 DOCUMENTATION REQUIREMENTS

QDR-7100 Scope

(a) Qualification documentation is intended to verify that each restraint assembly is qualified to perform its designated function when used for its intended service. Qualification is substantiated by demonstrating the relationship between the service requirements and the testing and/or analysis, which is done in the qualification program.

(b) A qualification plan, as described in QDR-7200, is required to translate the functional specification into a step-by-step qualification program.

(c) A Functional Qualification Report, as described in QDR-7310, is required to document parent restraint compliance with Section QDR.

(d) An Application Report, as described in QDR-7320, is required to document qualification of a particular candidate restraint assembly for a specific application.

QDR-7200 Qualification Plan

A qualification plan (which may be part of the Functional Qualification Report) shall be prepared with appropriate inspection and test record forms. These shall define test objectives, test instrumentation, conditions of the test, orientation, permissible maintenance or adjustments, and acceptance criteria. In addition, the plan shall define specific analytical techniques and acceptance criteria to be used for the extension of parent restraint qualification to candidate restraints using QDR-7300.

QDR-7300 Reports

QDR-7310 Functional Qualification Report

(a) A Functional Qualification Report shall be prepared for each parent restraint assembly qualified in

accordance with this Standard. This Functional Qualification Report shall provide complete identification of the restraint by type, size, rating, and other data as appropriate, including the qualification plan, test results, and inspection data. The Functional Qualification Report shall also contain a summary of the methodologies used and the parameters established by the functional qualification testing and analysis. Any specific limitations that restrict qualification shall be stated.

(b) Where prequalified components of the restraint assembly (e.g., brackets, solenoid restraints) are used as part of the restraint assembly qualification, the Functional Qualification Report shall reference the report(s) upon which such prequalification is based. In addition, it must be shown that the mounting and integration of this prequalified component on the restraint assembly does not degrade or otherwise interfere with the prequalification of the component.

(c) Each Functional Qualification Report shall be certified to be correct and complete and to be in compliance with this Standard, by one or more Registered Professional Engineers representing the organization responsible for the functional qualification.

QDR-7320 Application Report

(a) An Application Report is required to demonstrate the suitability of any candidate restraint assembly to meet the requirements of a specific application. An Application Report is required for each serial-numbered restraint assembly; however, restraint assemblies that have identical construction and service conditions, differing only in serial numbers and tag numbers, may be combined into one Application Report.

(b) Candidate restraint assemblies that are identical in construction to a parent restraint assembly may be qualified simply by preparing an Application Report and referencing the appropriate parent restraint Functional Qualification Report. Candidate restraint assemblies, which are not identical in construction to a parent restraint assembly, may have qualification extended to them through appropriate analysis and/or testing as outlined in QDR-6000. In addition, the Application Report shall reference the appropriate parent restraint Functional Qualification Report and shall further show how each of the specific application requirements of the functional specification are appropriately addressed by the parent restraint report or other tests and analysis.

(c) Qualification of a candidate restraint is based on the individual test conditions for a parent restraint and the guidance for extension of qualification to candidate restraint assemblies given in QDR-6300. It is the objective of the Application Report to verify that the candidate restraint will perform its intended function and that it qualifies for the operating conditions shown in the Functional Qualification Report. This may be accomplished by direct comparison with an identical parent restraint assembly, or by supplementary analysis and/or testing. Any supplementary analysis and/or testing shall conform to the requirements of QDR-6300 and shall show that the qualification of a given parent restraint assembly constitutes a valid basis for conclusion that the design of the candidate restraint assembly is of at least an equivalent adequacy for its intended function.

(d) Where prequalified parts of the restraint assembly (e.g., brackets, solenoids) are used as part of the restraint assembly qualification, the Application Report shall reference the report(s) upon which such prequalification is based. In addition, it shall be shown that the mounting and integration of this prequalified part on the restraint assembly does not degrade or otherwise interfere with the prequalification of the part.

(e) The Application Report for a qualified candidate restraint assembly shall contain the following, as applicable:

(1) serial number, tag number, or other unique identification of the candidate restraint assembly;

(2) complete description of the candidate restraint assembly construction configuration, including an assembly drawing. This description shall include a complete identification of the restraint by type, size, and rating.

(3) a summary of the functional parameters and how they are met by the candidate restraint assembly;

(4) reference to the parent restraint Functional Qualification Report(s) upon which the candidate restraint qualification is based;

(5) inspection reports, as applicable, for both the parent restraint and candidate restraint assemblies;

(6) all test results and analyses used to show that the candidate restraint assembly satisfies the requirements of QDR-6300;

(7) reference to the Qualification Reports for all prequalified components used per (d) above;

(8) any specific limitations that restrict qualification.

(f) Each Application Report shall be certified by one or more Registered Professional Engineers to be correct and complete and to be in compliance with this Standard.

NONMANDATORY APPENDIX QDR-A FUNCTIONAL SPECIFICATION FOR DYNAMIC RESTRAINTS

QDR-A1000 SCOPE

This Nonmandatory Appendix provides guidance for a functional specification for Dynamic Restraints for applications in systems important to the safety of nuclear facilities.

QDR-A2000 PURPOSE

The functional specification provides detailed definition of functional requirements applicable to restraints for components and piping systems important to safety. The requirements of the functional specification may be provided as part of the restraint design specification or as part of an equipment or purchase specification that also includes the design specification. If this functional specification is prepared by the restraint manufacturer, an application report prepared for the Owner shall be made part of the design specification. The Application Report shall be reviewed and certified by one or more Registered Professional Engineers to be correct and complete and in accordance with the functional specification prepared by the manufacturer. Compliance with these requirements for this functional specification is intended to ensure that the operating conditions and functions of the restraint have been adequately defined. This will permit the restraint manufacturer to demonstrate the adequacy of both the design of the restraint and the materials used in its construction for the intended service.

QDR-A3000 REFERENCES

To be identified by the Owner.

QDR-A4000 DEFINITIONS

See QDR-3000.

QDR-A5000 FUNCTIONAL SPECIFICATION CONTENTS

It is the responsibility of the owner or the owner's agent to identify the functional requirements of the restraint and provide for the delineation of the following:

(a) application characteristics (see QDR-A5100);
(b) aesign requirements (see QDR-A5200);
(c) operational requirements (see QDR-A5300);
(d) functional parameters (see QDR-A5400);
(e) specific material requirements (see QDR-A5500);
(f) installation requirements (see QDR-A5600);
(g) maintenance and inspection requirements (see QDR-A5700);
(h) other requirements (see QDR-A5800).

QDR-A5100 Application Characteristics

The application characteristics of each restraint should be identified by listing which of the following descriptive terms are appropriate:

(a) seismic restraint;
(b) dynamic force restraint;
(c) vibration restraint;
(d) pipe whip restraint;
(e) relief valve restraint;
(f) others, including combinations of the above.

QDR-A5200 Design Requirements

The following information should be specified:

(a) design operating temperature;
(b) time-temperature data for design thermal transients with the number of cycles indicated;
(c) seismic acceleration and dynamic loading that the restraints must be capable of withstanding transverse to the line of action without loss of functional capability;
(d) seismic acceleration and dynamic loading that the restraints must be capable of withstanding along the line of action without loss of functional capability;
(e) limits on the acceptable range of the fundamental frequency of the restraint assembly;
(f) limits on acceptable angular offset from the line of action of load.

QDR-A5300 Operational Requirements

Anticipated modes of restraint operation, including those related to seismic events and water hammer, should be specified. The operating conditions and environmental conditions should be identified.

QDR-A5310 Operating Conditions. The number of operational cycles, the imposed loading or movement (number, amplitude and direction), and the environment (including temperature) for each of the following operational categories, as a minimum, should include:

(a) installation testing;
(b) system hydrostatic testing;
(c) pre-operational testing;
(d) start-up testing;

(e) normal and abnormal plant operations (including postulated accident conditions, shock, or pulsating loads);

(f) in-service testing;

(g) vibration.

QDR-A5320 Environmental Conditions. A histogram of the environmental conditions that are postulated to exist should be provided.

The need of restraints to survive normal and abnormal environmental conditions with or without maintenance should be stated. Since the attaching hardware can influence the survival of the restraint, it should also be considered. The following factors are considered relevant:

(a) atmosphere, including chemistry, temperature, humidity, and radioactivity, in which the restraints will be installed and must operate under normal plant conditions.

(b) atmosphere, including chemistry, temperature, humidity, and radioactivity, in which the restraints must operate under upset, emergency, and faulted plant conditions. The duration of these conditions should be specified.

(c) vibration environment under normal, upset, emergency, and faulted conditions.

QDR-A5400 Functional Parameters

The functional parameters defined in QDR-5000 should be specified and should include QDR-A5400(a) through QDR-A5400(c).

(a) Hydraulic Snubbers

(1) activation level (when applicable) and tolerance at rated load at the maximum and minimum working temperatures;

(2) release rate and tolerance at 5%, 10%, 25%, 50%, and 100% of rated load at emergency load for the maximum and minimum working temperatures;

(3) acceptable limits for the break away force at the maximum and minimum working temperatures;

(4) acceptable limits for drag force associated with moving under a specified velocity at the maximum and minimum working temperatures;

(5) acceptable limits for the dead band at the maximum and minimum working temperatures for the range of working loads and restraint locations;

(6) load ratings for all service levels;

(7) acceptable range of spring rates at the maximum and minimum working temperature at the frequency, the load range, and the classification of the load (i.e., normal or emergency) at which the spring rate is to be determined with restraint locations at $1/4$, $1/2$, and $3/4$ stroke locations;

(8) verification of availability of full design stroke;

(9) fluid loss rate not exceeding that which would empty the reservoir during the expected service life of the component.

(b) Mechanical Snubbers

(1) activation level (when applicable) and tolerance at rated load at the maximum and minimum working temperatures;

(2) release rate and tolerance at 5%, 10%, 25%, 50%, and 100% of rated load at emergency load for the maximum and minimum working temperatures;

(3) acceptable limits for the break away force at the maximum and minimum working temperatures;

(4) acceptable limits for drag force associated with moving under a specified velocity at the maximum and minimum working temperatures;

(5) acceptable limits for the dead band at the maximum and minimum working temperatures for the range of working loads and restraint locations;

(6) load ratings for all service levels;

(7) acceptable range of spring rates at the maximum and minimum working temperature at the frequency, the load range, and the classification of the load (i.e., normal or emergency) at which the spring rate is to be determined with restraint locations at $1/4$, $1/2$ and $3/4$ stroke locations;

(8) verify availability of full design stroke;

(9) any lubrication degradation may affect other parameters such a drag.

(c) Gap Devices

(1) acceptable limits for the drag force;

(2) inclusion of the range of available gap adjustment;

(3) acceptable range of spring rates, the load range, and the classification of the load (i.e., normal or emergency) at which the spring rate is to be determined;

(4) acceptable number of cycles for spring fatigue testing.

QDR-A5500 Special Material Requirements

Special material requirements of the restraint should be specified. Items to be considered should include, but not be limited to, the following:

(a) hydraulic fluid (including its potential for electrolytic corrosion)

(b) seals

(c) springs

(d) special surface preparations or coatings

(e) lubricants.

QDR-A5600 Installation Requirements

The following requirements for the installation of the restraint should be specified:

(a) orientation of the hydraulic restraint and relative position of the hydraulic reservoir to the restraint if any limitations exist;

(b) orientation of the mechanical restraints installation if any limitations exist;

(c) the available space for installation and removal if any limitations exist;

(d) travel location in the restraint as installed;

(e) the range of transverse movement provided;

(f) any special mounting provided or required.

QDR-A5700 Maintenance and Inspection Requirements

An acceptable hydraulic fluid leakage rate should be specified for hydraulic restraints. Special provisions for restraint maintenance should be specified, if required. Where requirements are established for in situ inservice testing, requirements should be included for demonstrating the feasibility of performing the required inservice tests (i.e., drag test, activation level test, and release rate test) with specific testing equipment.

QDR-A5800 Special Performance Requirements

Other requirements for special performance or loading, conditions, as applicable, should be specified.

QDR-A6000 FILING REQUIREMENTS

A copy of the functional specification should be filed at the location of the installation and shall be available to the enforcement authorities having jurisdiction over the plant installation.

NONMANDATORY APPENDIX QDR-B RESTRAINT SIMILARITY

QDR-B1000 SCOPE

This Nonmandatory Appendix provides guidance in determining whether design similarity exists such that the qualification analysis procedure may be applied to candidate restraint sizes and ratings without further verification by testing. Examples are included that illustrate how design similarity may be established, in terms of specific similarity parameters defined in QDR-7420.

QDR-B2000 EXAMPLES OF DESIGN SIMILARITY

Examples of design similarity in terms of specific parameters are listed below. These are limited, selected examples and are not intended to be all-inclusive. It should be noted, however, that all similarity parameters defined in QDR-7420 must be considered when determining the acceptability of applying a qualification analysis procedure without further verification by testing.

QDR-B2100 Similarity of Design Configuration

With hydraulic snubbers, activation level and release rate may be defined in terms of flow rate and pressure. For hydraulic snubbers that use the same control valve or a similar configuration, the effect of temperature on these parameters should be determined by extrapolation or interpolation of data obtained by testing one snubber size.

QDR-B2200 Similarity of Materials

Wear or aging data obtained by testing a selected restraint model or size should be applied to other models or sizes provided that the same or similar materials, (i.e., mechanical, physical and chemical properties), are used. Justification of differences should be provided.

QDR-B2300 Similarity of Dimensions/Tolerances

Seal aging data obtained by testing o-rings of a specific size should be applied to other o-ring sizes that have the same cross-section thickness. Tolerances for mating parts should be the same or the differences should be justified.

QDR-B2400 Similarity of Surface Finish

Wear or aging data obtained by testing restraints of a given model should be applied to other models provided that surface finishes between mating parts for which relative motion exists are representative of the restraints to which the data are to be applied.

QDR-B2500 Similarity of Fabrication/Assembly Method

Life cycle test data (e.g., data obtained from cyclic loading tests or vibration tests) obtained by testing a specific restraint model should be applied to other models, provided that both models were fabricated and assembled in the same or a similar manner. Application of data obtained using a model that is assembled by welding to a model that is assembled by bolting would normally not be acceptable.

QDR-B2600 Similarity of Coatings/Plating

Corrosion resistance data obtained by testing a selected restraint model should be applied to other models or sizes provided that the same or similar plating or coatings are used.

QDR-B2700 Similarity of Production Testing

Production tests for some snubber models may involve quasi-static testing in which activation parameters such as activation level, release rate, or acceleration threshold are measured. For other restraint models, dynamic testing methods may be used for production tests. Qualification testing, on the other hand, generally involves dynamic testing. Similarity of production test methods should be considered when applying qualification test data from one restraint model to another.

NONMANDATORY APPENDIX QDR-C TYPICAL VALUES OF RESTRAINT FUNCTIONAL PARAMETERS

QDR-C1000 SCOPE

This Nonmandatory Appendix is provided to aid both the restraint designer and the specification writer. It identifies the qualification functional parameter values that may be considered when establishing a qualification program. The selection of applicable items, either the ones identified herein or others specified as required, is the option of the owner.

QDR-C2000 FUNCTIONAL PARAMETERS

QDR-C2100 Hydraulic Snubbers

Typical values for hydraulic snubber functional parameters are as follows:

(a) activation level 4 in. per minute (IPM) to 20 IPM

(b) release rate 0 IPM to 6 IPM

(c) break away for less than 1 kip rated load, 5% maximum; for 1 kip and above, 3% maximum

(d) drag for less than 1 kip rated load, 5% maximum; for 1 kip and above, 3% maximum

(e) dead band (lost motion) generally should not exceed 0.040 in. when measured across the snubber excluding end fittings

(f) load rating, see QDR-4110(f)

(g) spring rate is the peak-to-peak displacement under load, excluding end attachments, and should not exceed 0.12 in. when the input frequency is in the 3 to 33 Hz range

(h) the stroke should be able to accommodate the thermal and dynamic movements plus one additional inch of travel on each end (inclusive of installation tolerances)

(i) fluid loss rate should not exceed that which would empty the reservoir during the expected service life of the component.

QDR-C2200 Mechanical Snubbers

Typical values for mechanical snubber functional parameters are as follows:

(a) Activation level—acceleration-limiting snubbers are generally designed to a maximum value of 0.02 g.

(b) Release rate for a snubber that does not have an active/passive mode should be within 25% of the theoretical performance curves (unless specifically designed, neither acceleration or velocity limiting snubbers should have a release rate of zero).

(c) Break away/drag is the force required to initiate and maintain axial movement of mechanical snubbers and is typically restricted to less than 2% or 3% of the rated load.

(d) Drag for less than 1 kip rated load, 5% maximum; for 1 kip and above, 3% maximum.

(e) Dead band (lost motion) generally should not exceed 0.040 in. when measured across the snubber excluding end fittings.

(f) For load rating, see QDR-4210(f).

(g) Spring rate is the peak-to-peak displacement under load, excluding end attachments, and should not exceed 0.12 inches when the input frequency is in the 3 Hz to 33 Hz range.

(h) The stroke should be able to accommodate the thermal and dynamic movements plus an additional 1 in. of travel on each end (inclusive of installation tolerances).

(i) Any lubrication degradation should not affect other parameters such a drag.

QDR-C2300 Gap Restraints

(a) Gap (see QDR-6223).

(b) Spring rate tolerances should be kept to a plus or minus of 20% if no specific value is given from the analysis of the piping system.

(c) Fatigue life of springs should be greater than the service life of the component.

(d) Friction developed should be kept to 2% of rated load of the device.

(e) Load ratings are the minimum load that the device will restrain under the given loading condition. However, for a load-limiting device, the load rating is a maximum load and the device should be within 10% of the rated load.

QDR-C3000 AGING AND SERVICE CONDITION SIMULATION QUALIFICATION PROGRAM

The qualification program should specify a steam humidity simulation of 350°F (177°C) saturated steam for 72 hr if the restraint service area is inside the containment. It should specify submergence in 200°F (93°C) water for 72 hr if the restraint service is in a water environment.

Section QP: Qualification of Active Pump Assemblies

INTRODUCTION

Qualification of pumps that must perform a specified function is an integration of numerous steps that involve many disciplines and authorities. Section QP is to be used to develop a qualification program designed specifically for the intended application of equipment and the operational requirements of the system in which it resides. The objective is to provide confidence in the design, engineering, testing, installation, operation, and maintenance of pumps in nuclear systems, including performance of function for a design basis event.

Section QP supplements General Requirements Section QR, which provides general qualification guidance. Specific requirements applicable to pumps that are not addressed in QR are identified in this Section in a format that is cross-referenced to QR. Consequently, articles on definitions, qualification principles, qualification specification criteria, and program and documentation requirements are covered similarly by QR, QP, and QV.

Mandatory requirements as well as nonmandatory guidance are included in this Section to provide a guide and framework for pump qualification. Qualification requirements are provided for the following:

(a) pump assembly/pump
(b) shaft-seal system
(c) turbine driver
(d) power transmission device
(e) auxiliary equipment

QP-1000 SCOPE

Section QP contains the qualification requirements and guidelines for active pump assemblies used in nuclear power plants and that must function for design basis events. Pump assembly items may be qualified as part of a single pump assembly or may be qualified separately. It is the responsibility of the Owner or the Owner's designee to specify those pump assemblies to which this Section will be applied.

Pump assemblies and pump assembly items qualified in accordance with this Section shall meet the requirements of Section QR. Wherever the requirements of Section QP conflict with the requirements of Section QR, the requirements of Section QP take precedence.

Section QP is applicable to all pump types, as defined in Section III of the ASME Boiler and Pressure Vessel Code (BPVC). Specifically, pumps that operate on velocity or displacement principles, regardless of the arrangement, are included. Additionally, shaft-sealing systems, drivers, power transmission devices, and auxiliary equipment are also included. Section QP does not apply to electrical equipment such as motors, valve actuators, instruments, and control devices that are qualified by conformance with appropriate IEEE standards. However, qualification of the motor driver mechanical effects on the pump assembly is included in Section QP.

Detailed design considerations for shaft-seal systems are provided in Nonmandatory Appendix QP-E. These guidelines are provided as an aid to the qualification specification writer and are not part of this Standard.

QP-2000 PURPOSE

The purpose of Section QP is to provide qualification requirements and guidelines specific to pump assemblies to ensure the adequacy of the pump assembly to perform its specified function.

QP-3000 REFERENCES

This Article documents reference documents of significance from which guidance, concepts, principles, practices, criteria, and parameters, have been carried forward into Section QP. These references include:

API Standard 610, Centrifugal Pumps for Petroleum, Heavy Duty Chemicals, and Gas Industry Services, Feb. 1995, 8th Edition
API Standard 611, Steam Turbines for General Refinery Service, Aug. 1988, Reaffirmed May 1991, 3rd Edition
API Standard 682, Shaft Sealing Systems for Centrifugal and Rotary Pumps, Oct. 1994
Publisher: American Petroleum Institute (API), 1220 L Street, N.W., Washington, DC 20005

ASME B73.1M, Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process, 1991
ASME B73.2M, Specification for Vertical In-Line Centrifugal Pumps for Chemical Process, 1991
ASME OM Code-1995, Subsection ISTB, Inservice Testing of Pumps in Light-Water Reactor Power Plants
ASME PTC 8.2-1990, Performance Test Codes—Centrifugal Pumps
Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY

10016-5990; Order Department: 22 Lawn Drive, Fairfield, NJ 07007-2900

Hydraulic Institute Pump Standards, 1994

Publisher: Hydraulic Institute, 9 Sylvan Way, Parsippany, NJ 07054

SM 23-1979, Steam Turbines for Mechanical Drive Service

Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Rosslyn, VA 22209

SP-1, Glossary of Seal Terms, March 1995

SP-30, Guidelines for Meeting Emission Regulations for Rotating Machinery with Mechanical Seals, April 1994

Publisher: Society of Tribologists and Lubrication Engineers (STLE), 840 Busse Highway Park, IL 60068-2376

QP-4000 DEFINITIONS

The following definitions establish the meanings of words in the context of their use in this Section and supplement those definitions listed in Section QR.

auxiliary equipment: items necessary to support the operation of the pump, shaft-seal system, driver, or power transmission device, including any appurtenances as defined in ASME Boiler and Pressure Vessel Code, Section III, NCA-1260.

best efficiency point: the hydraulic flow at which the pump assembly achieves its highest efficiency, i.e., the reference point for which the specific speed is calculated for similitude comparisons.

component coolant: a fluid used as a heat removal medium and separated from the process fluid by a barrier.

injection fluid: a fluid injected into the seal area at a pressure higher than the process fluid to lubricate and cool the seal, and in some instances to prevent leakage of process fluid along the shaft.

motor driver: a class of machines that converts electrical energy into rotary motion.

operating point(s): any hydraulic point at which the pump is expected to operate, under the various operating conditions of the plant. Multiple operating points may be specified for a pump, within the flow range from minimum flow to the maximum runout condition.

power transmission device: an item that transmits the rotary motion from the turbine driver or motor driver to the pump.

process fluid: the fluid pumped.

pump: the basic component of the pump assembly that transfers the process fluid.

pump assembly: the pump and the grouping of items needed to ensure the operation of the pump.

shaft seal: a device designed to prevent or limit the leakage of fluid between two surfaces of relative motion. This includes mechanical end face seals and packing.

shaft-seal system: a system of shaft seals and directly associated appurtenances as required that limits the process fluid leakage to the atmosphere or to low-pressure systems and collects and directs the leakage.

turbine driver: a class of machines that converts energy in a fluid stream to rotary motion.

QP-5000 QUALIFICATION PRINCIPLES AND PHILOSOPHY

The fundamental principles and philosophy pertaining to equipment qualification are provided in Article QR-5000 and apply to mechanical equipment in general. Qualification requirements specific to the pump assembly or pump assembly items are contained in Articles QP-6000 through QP-8000.

QR-7000 describes qualification by similarity analysis. Nonmandatory Appendix QP-D contains typical parameters to be considered when qualification is to be established by similarity.

QP-6000 QUALIFICATION SPECIFICATION

The qualification specification for pump assemblies and pump assembly items shall be provided in accordance with QR-6000 and the additional requirements of this Article. Nonmandatory Appendices QP-A, QP-B, and QP-C provide checklists of items for guidance in the preparation of the qualification specification.

It is the responsibility of the Owner or the Owner's designee to provide the qualification specification and to approve the qualification program used to demonstrate that the acceptance criteria established in the qualification specification have been met.

For a pump assembly qualified to a generic environment, the manufacturer is responsible for the development of both the specification and the qualification program.

QP-6100 Equipment Specified Function

Pump assembly specified function shall be in accordance with QR-6000(a).

Items may be excluded from the qualification process if it can be shown that their malfunctions have no effect on the pump assembly's specified function. For example, when the pumping function is not a requirement but the pressure retention function is, motive power to the pump need not be qualified but the shaft-sealing system shall be qualified.

QP-6200 Equipment Description and Boundary

The qualification specification shall identify those items that are part of the pump assembly. The qualification specification shall also define the interfaces between the pump assembly and the external attachments and supports. When pump assembly items are qualified separately, the qualification specification shall also define interfaces between the pump and the driver, shaft-seal system, power transmission device, and auxiliary equipment.

QP-6210 Pump Assembly/Pump. The pump assembly includes the pump and its shaft-seal system, driver, transmission device, and auxiliary equipment.

The pump pressure boundary is defined in ASME BPVC Section III. The pump includes items that:

(a) contain the process fluid, such as the casing or barrel, including nozzles, thermal barrier, and closure members;

(b) propel the process fluid, such as the impeller;

(c) are an integral part of the pump, such as the diffuser or bowl including the pump shaft, pump bearings, and bearing supports; and

(d) are auxiliary equipment.

QP-6220 Shaft-Seal System. The shaft-seal system includes the seal assembly, seal system piping, seal water cooling, filtering devices, and auxiliary equipment.

QP-6230 Turbine Driver. The turbine driver includes the casing, shaft, blades, wheel, jets, governor, stop valves, shaft seals, bearings, and auxiliary equipment.

QP-6240 Power Transmission Device. Power transmission devices include shaft couplings, belt drives, fluid drives, gear drives, and auxiliary equipment.

QP-6250 Auxiliary Equipment. Examples of auxiliary equipment are cooling water systems, lubricating systems, control valves, instrumentation, and external supports, which are supplied as part of the pump assembly.

QP-6300 Description of Interface Attachments and Loads

Location, nature, and magnitude of externally applied loads and structural characteristics for interface attachments shall be specified.

QP-6400 Service Conditions

Service conditions defining the application of the pump assembly shall be specified. Service conditions are of two types:

(a) operating conditions that tend to stress the pump assembly;

(b) environmental conditions that define the surroundings.

Nonmandatory Appendix QR-A provides supplementary details associated with dynamic qualification of mechanical equipment.

QP-6500 Margins

Required margin for QP-6700 acceptance criteria shall be specified.

QP-6600 Aging

The qualification specification shall require that significant aging mechanisms along with components and/or materials subject to aging be identified. The effects of the identified aging mechanisms shall be assessed and shown to be acceptable during the qualification process. Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts.

QP-6700 Acceptance Criteria

The required acceptance criteria shall be specified in accordance with the requirements of QR-6000(i) and QP-6710 through QP-6750. The types of performance items listed in QP-6710 through QP-6750 shall be included in, but may not be limited to, the types of required acceptance criteria listed.

QP-6710 Pump Assembly/Pump. The qualification specification shall specify the performance required from the pump assembly/pump during specified service conditions. Acceptance criteria shall be specified for:

(a) capacity (flow)

(b) total developed head (or pressure)

(c) required net positive suction head (NPSHR)

(d) start-up and operating time based upon plant conditions

(e) transients such as thermal or pressure

(f) priming time

(g) process fluid conditions

(h) environmental parameters

(i) minimum flow rates and associated time limitations

(j) vibration limits

Instrument accuracy for pressure, flow rate, speed, vibration, and differential pressure, and vibration acceptance criteria, shall not be less than that prescribed in ASME OM, Subsection ISTB.

QP-6720 Shaft-Seal System. The qualification specification shall specify the performance required from the shaft-seal system during specified service conditions. Acceptance criteria shall be specified for:

(a) flow rate of coolant through cooling jacket or seal cavity;

(b) start-up and running torque requirements;

(c) seal leakage rates under static and dynamic operating conditions.

QP-6730 Turbine Driver. The qualification specification shall specify the performance required from the turbine driver during specified service conditions. Acceptance criteria shall be specified for:

(a) speed/output torque at operating steam conditions (pressure, temperature, flow, and quality);

(b) required start-up and operating time based upon plant conditions;
(c) capability of the governor system to regulate steam flow within specified limits;
(d) vibration limits.

QP-6740 Power Transmission Device. The qualification specification shall specify the performance required from the power transmission device during specified service conditions. Acceptance criteria shall be specified for:
(a) torque and horsepower capacities
(b) input/output speeds
(c) vibration limits
(d) total indicated runout
(e) cooling requirements

QP-6750 Auxiliary Equipment. The qualification specification shall specify the performance required from any uniquely identified auxiliary equipment during specified service conditions.

QP-7000 QUALIFICATION PROGRAM

QP-7100 General Requirements

The qualification program shall be established in accordance with the requirements of QR-7000 and as modified below.

QP-7200 Review for Potential Malfunctions

Potential malfunctions shall be identified in accordance with the requirements of QR-7200. Examples of potential malfunctions in pump assemblies that shall be reviewed include loss of rated flow/head, rotating element seizure, or rotating element clearance/drag/leakage. The effects of wear of critical components shall be part of this review.

QP-7300 Selection of Qualification Methods

Methods for qualification of pump assemblies and pump assembly items shall be in accordance with the requirements of QR-7300.

QP-7310 Pump
(a) Pump qualification shall consider significant hydraulic and mechanical design factors that can degrade and impact the ability of the pump to perform its specified function.

In addition to aging effects, qualification techniques shall address and incorporate, as necessary, the impact of periodic testing, maintenance, overhaul, and replacement of essential parts of the pump assembly.

The qualification method shall identify the service conditions for which the pump is being qualified as described in QP-7310(b).

The pump qualification program shall include the following:

(1) testing over the full range of normal and DBE operating points for hydraulic performance, leak tightness, and structural integrity. Testing in the vendor shop or a suitable test facility is preferred in order to reduce test variables and provide controlled results. If such testing is not physically practicable due to size or configuration, in-situ testing as part of ASME OM, Subsection ISTB preservice test provided with suitably accurate instrumentation is acceptable.
(2) The test assembly shall include the pump, its auxiliary equipment, and the baseplate if one is provided.
(3) visual and dimensional inspections at appropriate intervals to identify excessive wear or degradation of pump parts

(b) Service aspects that shall be considered in formulating a qualification program are:
(1) pump functional conditions (flow capacities, developed head requirements, suction head provided, system fluid conditions including transients, operating time, and operating frequency anticipated over the life of the plant, etc.). Functional conditions are to include periodic in-service testing and anticipated inoperative periods.
(2) environmental conditions;
(3) starting requirements;
(4) normal operating loads;
(5) externally applied loads (seismic, nozzle, etc.);
(6) aging of nonmetallic materials (Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts and may or may not be part of the in-situ testing above);
(7) maintaining design life (maintenance, overhaul, replacement, etc.).

QP-7320 Shaft-Seal System. A shaft-seal system normally should not be functionally qualified by analysis alone. However, analysis may be used to extend previous testing or previous experience to the specified design service conditions, provided the analytical techniques have been validated through comparison to measured performance of comparable shaft-seal system. Types of permitted analysis include heat generation and removal, mechanical stress, thermal stress, wear rate, interface velocity, axial movement, radial movement, angular movement, torsional deflection, and natural frequency.

In qualification by test, a plan shall be prepared with appropriate inspection and test record forms to define test objectives, test fluids, conditions of the test, permissible maintenance or adjustments, and acceptance criteria. A shaft-seal system test facility shall be used that provides rotation, appropriate means for pressurization, fluid thermal control, and seal leakage measurement. Prior to start of a test sequence, all system conditions shall be recorded as applicable to the test shaft-seal assembly and test installation according to the plan. Test data shall include face surface finish and flatness, face loads at installation length, shaft-seal system leakage, temperature, pressure, and seal face power requirements. Testing sequence shall include all service conditions.

Qualification on the basis of experience or analysis requires that documentation be provided which demonstrates that the performance of a similar shaft-seal system equals or exceeds the specified design service conditions, both normal and DBE, of the proposed application. Areas that shall be evaluated when determining applicability of experience are similarity of application, environment, performance data, maintenance, and inspection records.

Environmental and aging effects on the materials of construction may be evaluated on the basis of generic testing that adequately encompasses the process and environmental effects on the material properties. Qualification need not be based on the actual shaft-seal system components. However, any qualification not based on actual tests shall demonstrate that the data used are appropriate and applicable to the configuration and to the material used for the application.

The manufacturer shall demonstrate the adequacy of the shaft-seal system in either or both of the following ways:

(a) by supplying documentation that the proposed system had proved itself through a comprehensive testing program. The testing program shall have included full-scale tests at normal and DBE operating conditions. The documentation shall include a detailed description of the tests, test equipment, and actual test results.

(b) by providing documentation showing that the proposed system is similar and has been used successfully for a stated length of time in similar service. This method shall not be used if the proposed system, or the environment in which it is to be used, differs significantly from the one to which it is being compared or if service conditions vary significantly from normal operating service conditions.

QP-7330 Turbine Driver

(a) Turbine driver qualification shall consider significant hydraulic and mechanical design factors that can degrade and impact the ability of the turbine driver to perform its specified function.

In addition to aging effects, qualification techniques shall address and incorporate, as necessary, the impact of periodic testing, maintenance, overhaul, and replacement of essential parts of the turbine driver.

The qualification method shall identify the service conditions for which the turbine driver is being qualified as described in QP-7330(b).

The turbine driver qualification program shall include the following:

(1) testing over the full range of normal and DBE operating conditions for steam performance, leak tightness, and structural integrity;

(2) the test assembly shall include the turbine and its auxiliary equipment;

(3) visual and dimensional inspections at appropriate intervals to identify excessive wear or degradation of turbine parts.

(b) Service aspects considered in formulating a test qualification program shall include:

(1) turbine functional conditions (turbine horsepower/speed including transients, operating time, and operating frequency anticipated over the life of the plant, etc.). Functional conditions are to include periodic inservice testing and anticipated inoperative periods.

(2) environmental conditions;

(3) starting requirements;

(4) normal operating loads;

(5) externally applied loads (seismic, nozzle, etc.);

(6) aging of nonmetallic materials (Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts and may or may not be part of the in-situ testing above);

(7) maintaining design life (maintenance, overhaul, replacement, etc.).

(c) Any electrical controls associated with the turbine shall be qualified in accordance with the requirements of IEEE Std 323 and IEEE Std 344. Qualification of any motor-operated control or block valve actuators in the steam supply systems shall be in accordance with the requirements of IEEE Std 382.

QP-7340 Power Transmission Device

(a) Power transmission device qualification shall consider significant hydraulic and mechanical design factors that can degrade and impact the ability of the device to perform its specified function.

Qualification shall consider the full range of speed and horsepower requirements. In addition to aging effects, qualification techniques shall address and incorporate, as necessary, the impact of periodic testing, maintenance, overhaul, and replacement of essential parts of the power transmission device.

The qualification program shall include the following:

(1) The power transmission device shall be tested at the design conditions of speed and horsepower (torque) over the full range of normal and DBE operating conditions for both mechanical performance and structural integrity.

(2) Visual and dimensional inspections shall be performed at appropriate intervals to identify excessive wear or degradation.

(b) Service aspects considered in formulating a test qualification program shall include:

(1) power transmission device functional conditions (speed, horsepower, operating time, and operating

frequency anticipated over the life of the plant). Functional conditions are to include periodic in-service testing and anticipated inoperative periods.

(2) environmental conditions;

(3) starting requirements;

(4) normal operating loads;

(5) externally applied loads (seismic);

(6) aging of nonmetallic materials (Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts and may or may not be part of the in-situ testing above);

(7) maintaining design life (maintenance, overhaul, replacement, etc.).

(c) Any electrical controls associated with speed changing devices shall be qualified in accordance with the requirements of IEEE Std 323 and IEEE Std 344.

QP-7350 Auxiliary Equipment. When auxiliary equipment is qualified separately from the pump assembly, pump, shaft-seal system, driver, and transmission device, its qualification shall consider significant hydraulic and mechanical design factors that can degrade and impact performance of specified function. The approach to qualification shall identify the service conditions and interfaces with pump assembly items.

QP-7400 Aging

Pump assemblies and pump assembly items shall be qualified in accordance with QR-7311 or QR-7321. Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts.

QP-7500 Dynamic Loading

Pump assemblies and pump assembly items shall be qualified in accordance with QR-7312 or QR-7322. Nonmandatory Appendix QR-A provides supplementary details associated with the dynamic qualification of mechanical equipment.

QP-8000 DOCUMENTATION

The documentation requirements shall be in accordance with QR-8000 and the additional requirements of this Article. In addition to original qualification documentation, special installation requirements and maintenance required to maintain qualification shall be documented.

QP-8100 Pump Assembly/Pump

Documentation shall include, but is not limited to, dimension of mechanical fits and clearances.

QP-8200 Shaft-Seal System

Documentation shall include, but is not limited to, shaft-seal assembly drawing with appropriate bill of materials, service conditions, and precautions noted that would preclude malfunction.

QP-8300 Turbine Driver

Documentation shall include, but is not limited to, dimension of mechanical fits and clearances. The documentation for the turbine driver shall also be as specified in IEEE Std 323, IEEE Std 344, and IEEE Std 382 where these standards are invoked.

QP-8400 Power Transmission Device

Documentation shall include, but is not limited to, dimensions of mechanical fits and clearances. The documentation for the power transmission device shall also be as specified in IEEE Std 323, IEEE Std 344, and IEEE Std 382 where these standards are invoked.

QP-8500 Auxiliary Equipment

Documentation shall include, but is not limited to, dimension of mechanical fits and clearances.

NONMANDATORY APPENDIX QP-A
PUMP SPECIFICATION CHECKLIST

This Nonmandatory Appendix is provided to aid the specification writer. It lists items that may be considered when developing the qualification specification for pump assembly items.

I APPLICABLE DOCUMENTS, CODES, AND STANDARDS

(a) ASME Boiler and Pressure Vessel Code (BPVC), Section III (Code) construction class, applicable edition and addenda

(b) Design Specification.

II DESIGN AND CONSTRUCTION REQUIREMENTS

(a) pump type

(b) design life

(c) functional, operating, environmental, and service conditions under which the pump must operate

(d) operational modes including time limit for recirculating flow testing

(e) fluid pumped, specific gravity at given temperatures

(f) design pressure

(g) design temperature

(h) rated flow, maximum required flow (runout flow)

(i) head at rated flow, maximum required flow, and shutoff conditions

(j) suction temperature: minimum, normal, maximum

(k) suction pressure: maximum and normal

(l) NPSH available at rated and maximum required flows

(m) ambient temperature, humidity, and radiation

(n) water chemical content (pump and/or seal cooling water)

(o) minimum operating flow limitations

(p) use of mechanical seals and type of seal cooler, if applicable

(q) flow restrictor from seal cavity, if applicable

(r) vent and drain from pump casing and types of connections

(s) type of pump nozzle connections and details

(t) connection requirements to other ancillary piping

(u) support and anchorage requirements, and configuration

(v) cooling water piping code requirements

(w) maximum input driver horsepower for diesel generator loading

(x) cooling water; temperature, minimum and maximum; pressure; and maximum pressure drop

(y) entrained material for which the pump is designed; dirt, debris, insulation, molten fuel, diesel oil, fish, etc., under normal and abnormal service conditions

(z) separation of running frequency from shaft natural frequency and pump assembly torsional natural frequency

(aa) start-up and operating time

(bb) coupling; flexibility, alignment, service life, bearing load, balance

(cc) specific location at plant site (inside or outside containment).

III STRUCTURAL, SEISMIC, AND ENVIRONMENTAL QUALIFICATION REQUIREMENTS

(a) requirements for dynamic analysis or testing

(b) designation of loads, load combinations, and related Code service conditions

(c) demonstration of operability by analysis or test under all applicable loading conditions

(d) seismic loading OBE and SSE

(e) stress limits

(f) seismic design criteria

(g) minimum acceptable force and moment carrying capability of the pump nozzles, the pump casing, and the pump support attachments

(h) seismic acceleration, both horizontal (two orthogonal directions) and vertical.

IV MATERIAL AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards).

V TESTING REQUIREMENTS

(a) shop performance test and measurements to be taken, including capacity, total head, power input, efficiency, NPSH, and vibration at the bearing or on the shaft

(b) prequalification transient test requirements and acceptance criteria.

VI DOCUMENTATION, INSTRUCTIONS, AND LIMITATIONS

(a) documentation requirements

(b) requirement for manufacturer's provision of values of maximum allowable forces and moments

(c) operational limits for pump recirculation or operation without cooling water

(d) requirement for manufacturer's provision of values for minimum flow capability and time limitations

(e) requirements for manufacturer's provision of bolting material requirements, torque values, and washer configuration

(f) quantified acceptable limits for wear of bearings to establish minimum service life.

NONMANDATORY APPENDIX QP-B
PUMP SHAFT-SEAL SYSTEM SPECIFICATION CHECKLIST

This Nonmandatory Appendix is provided to aid the specification writer. It lists items that may be considered when developing the qualification specification for pump shaft-seal system items.

I APPLICABLE DOCUMENTS, CODES, AND STANDARDS

(a) ASME Boiler and Pressure Vessel Code (BPVC), Section III (Code) construction class, applicable edition, and addenda

(b) Design Specification

(c) ASME B73.1M, ASME B73.2M, API 610, API 682, and STLE SP-30.

II DESIGN AND CONSTRUCTION REQUIREMENTS

(a) type of seal or seal system to be provided

(b) design life

(1) static

(2) dynamic

(c) post-design basis event design life

(1) number of cycles

(2) duration of cycles

(d) conditions at seal cavity

(1) fluid pumped, specific gravity at given temperature

(2) design pressures

(3) design temperature

(4) thermal and pressure transient (rate, range, direction)

(5) thermal and pressure transient duration (minutes)

(6) allowable leakage

(7) radiation

(8) shaft speed

(9) maximum entrained material size under normal and abnormal service conditions

(e) component coolant conditions

(1) pressure

(2) temperature

(3) flow rate

(4) chemistry

(5) pressure drop

(f) availability of seal injection, including the quantity, temperature, chemistry, and solids particle size

(g) possible inaccessibility of pump during operation that restricts opportunities for visual inspection and preventive maintenance to the seal system

(h) the need for assembly and maintenance features to limit personnel exposure time in radiation fields

(i) shaft direction or rotation as viewed from the drive end

(j) specific location at plant site (inside or outside containment).

III STRUCTURAL, SEISMIC, AND ENVIRONMENTAL QUALIFICATION REQUIREMENTS

(a) qualification acceptance criteria

(b) environmental qualification requirements.

IV MATERIALS AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards).

V TESTING REQUIREMENTS

VI DOCUMENTATION, INSTRUCTIONS, AND LIMITATIONS

(a) documentation requirements

(b) requirements for manufacturer's provision of bolting material requirements, torque values, and washer configuration.

NONMANDATORY APPENDIX QP-C
PUMP TURBINE DRIVER SPECIFICATION CHECKLIST

This Nonmandatory Appendix is provided to aid the specification writer. It lists items that may be considered when developing the qualification specification for pump turbine driver items.

I APPLICABLE DOCUMENTS, CODES, AND STANDARDS

(a) applicable turbine design standard: NEMA, API, etc.

(b) Design Specification.

II DESIGN AND CONSTRUCTION REQUIREMENTS

(a) required design life of major components (nonconsumables)

(b) functional, operating, environmental, and design conditions under which the turbine must operate

(1) design pressures and temperatures (maximum, normal, minimum) for inlet and exhaust

(2) operating pressures and temperatures (maximum, normal, minimum) for inlet and exhaust

(3) operating conditions (bhp, rpm) at corresponding design/operating conditions

(4) ambient temperature, pressure, humidity, and radiation

(5) maximum horsepower

(6) cooling water: minimum, normal, and maximum temperature and pressure

(7) process fluid analysis (chlorides, etc.)

(c) operational modes including operating and design process fluid conditions, and duration and frequency of operation

(d) interface requirements (control system, utilities available, flanged connections, etc.)

(e) shaft vibration limits

(f) specific location at plant site (inside or outside containment).

III STRUCTURAL, SEISMIC, AND ENVIRONMENTAL QUALIFICATION REQUIREMENTS

(a) seismic qualification requirements (specification must include definition of seismic environment)

(b) environmental qualification requirements

(c) design qualification requirements (i.e., pressure vessel analysis, low-cycle fatigue analysis, etc.)

(d) qualification acceptance criteria.

IV MATERIAL AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards).

V TESTING REQUIREMENTS

(a) requirement for demonstration that the unit will operate through all modes of operation for duration specified (i.e., shop or field test, analysis, and/or experience).

VI DOCUMENTATION, INSTRUCTIONS, AND LIMITATIONS

(a) document requirements

(b) requirements for manufacturer's provisions of bolting material requirements, torque values, and washer configuration.

NONMANDATORY APPENDIX QP-D PUMP SIMILARITY CHECKLIST

This Nonmandatory Appendix is provided to aid both the pump designer and the specification writer. It lists items that may be considered when establishing rules of similarity between either pump designs or process conditions. The selection of applicable items, either the ones identified herein or others specified as required, is at the option of the Owner.

I PUMP DESIGN

(*a*) hydraulic capability

(02) (*1*) rating of pump, discharge size, NPS (DN)

(*2*) best efficiency point as percentage of condition

(*3*) rise-to-shutoff from condition

(*4*) NPSHR at condition

(*5*) specific speed

(*6*) suction specific speed

(*7*) speed(s) of rotation

(*8*) tip speed

(*9*) number of vanes

(*b*) mechanical capability

(02) (*1*) size of suction and discharge nozzles, NPS (DN)

(02) (*2*) impeller diameter, in. (mm)

(*3*) vane treatment, finish and filing (over and under)

(*4*) stationary to rotating fit clearances

(*5*) rotation

(*6*) method of support (frame, foot, centerline)

(*7*) speed control (constant/variable)

(*8*) type and size of bearing system

(*9*) type and size of drive coupling

(*10*) stiffness of *pump* and *driver* support on base

(*11*) arrangement (vertical or horizontal)

(*12*) open or closed impeller

(*13*) single or multistage

(*14*) metallurgy of wetted parts.

II PROCESS DESIGN

(*a*) pumped fluid

(*1*) start-up conditions

(*2*) normal and abnormal conditions

(*3*) transient conditions of flow, temperature, fluid chemistry, and pressure

(*4*) test conditions

(*b*) external conditions

(*1*) start-up conditions

(*2*) normal and abnormal conditions

(*3*) transient conditions of flow, temperature, fluid chemistry, and pressure

(*4*) amplitude and duration of seismic excitation

(*5*) transient piping interaction

(*6*) cooling water for seal or bearing cooling.

Similarity can be undertaken only within pumps of the same class and type.

The collection of the above parameters provides a means of narrowing the differences between pumps. To establish similarity, it must be shown that when exposed to like internal and external loads, expressed as casing stress and assembly strain in response to normal and abnormal loads, similar pumps will exhibit congruent performance—hydraulic and mechanical. They will equally be expected to withstand like aging effects and will retain their ability to perform their specified design function.

Exceptions will be considered if documentation demonstrates similarity of performance notwithstanding the above criteria.

NONMANDATORY APPENDIX QP-E GUIDELINES FOR SHAFT-SEAL SYSTEM MATERIAL AND DESIGN CONSIDERATION

QP-E1000 SCOPE

This Nonmandatory Appendix contains guidelines for the special material and design considerations for shaft-seal systems that are intended to be qualified in accordance with the requirements of Section QP.

QP-E2000 PURPOSE

This Appendix provides material and design guidance to the qualification specification writer.

QP-E3000 DEFINITIONS

The following definition establishes the meaning of a term in the context of its use in this Appendix and supplements those found in Sections QR and QP:

stress index: the ratio of the design stress to the minimum ultimate strength of the material (S/S_u).

QP-E4000 MATERIAL CONSIDERATIONS

QP-E4100 Pressure-Retaining Material

Gland plates and associated bolting are defined as pressure-retaining material by the ASME Boiler and Pressure Vessel Code (BPVC), Section III. Requirements to be included in the qualification specification for material used in pressure-retaining applications are to be in accordance with the appropriate ASME BPVC Section III classification and its associated material requirements.

QP-E4200 Nonpressure-Retaining Material

(a) Considerations to be included in the qualification specification for material used for seal-mating faces applications are:

(1) no detrimental physical property changes occurring when subjected to the seal cavity fluids for the times listed in Table QP-E1;

(2) no detrimental physical property changes occurring when subjected to the maximum seal cavity temperature listed in Table QP-E1;

(3) no detrimental wear rate when subjected to the conditions listed in Table QP-E1.

(b) Material with a stress index less than 0.1, used for retainers, bolts, pins, bushings, and other parts, may be manufactured from any material suitable for the intended service.

(c) Material with a stress index greater than 0.1, used for springs, bolts, pins, and other metallic or brittle parts, should meet an ASME, ASTM, or AMS specification that controls the quality of the material.

(d) Proprietary material with a stress index greater than 0.1, used for springs, bolts, pins, and other metallic or brittle parts that do not have a suitable national specification available, should be qualified by testing in accordance with Section QP. Such proprietary materials are designated by a specific identification number by the material manufacturer and certified to meet all the quality assurance requirements of the originally qualified material.

QP-E5000 DESIGN CONSIDERATIONS

QP-E5100 General

For normal operating conditions, the shaft-seal system is designed to operate without maintenance for the design life listed in Table QP-E1.

For service conditions other than normal, the shaft-seal system is designed to operate without maintenance for a specified duration and a specified number of cycles. If only one cycle of a specific operating condition is specified, then it is understood that replacement or maintenence may occur before resuming normal operation unless other design considerations are specified in the qualification specification.

Special shaft-seal systems such as double seals, tandem seals, bellows, and/or cartridged seals are to be specified in the qualification specification.

QP-E5200 Design Input

(a) The pump manufacturer will supply the seal manufacturer with the following general design criteria:

(1) applicable edition and addenda of Section III of the ASME Boiler and Pressure Vessel Code;

(2) service conditions and associated duty cycles as listed in Table QP-E1.

(b) The pump manufacturer will supply the seal manufacturer with the following arrangement and interface conditions:

(1) type of seal to be provided (i.e., packing, mechanical, bellows, double tandems, cartridged, etc.);

Table QP-E1 Shaft-Seal System Specification (02)

		Normal [Note (1)]	Design Basis Condition: Design Basis Events	In-Service Tests	Hydrostatic [Note (2)]	Other [Note (3)]
Conditions at Seal Cavity	Fluid [Note (4)]					
	Pressure, psia (MPa)					
	Temperature, °F (°C)				NA	
	Thermal transient rate, range, and direction, °F/min (°C/s)				NA	
	Thermal transient duration, min				NA	
	Allowable leakage [Note (5)]					
	Radiation, rads				NA	
	Speed, rpm				NA	
Abnormal Condition Info (Design Life)	Number of cycles	NA				
	Duration of cycles, hr	NA				
Component Coolant Conditions	Pressure, psia (MPa)				NA	
	Temperature, °F (°C)				NA	
	Flow rate, gpm (mm^3/s)				NA	
Design Life	Static, hr		NA	NA	NA	
	Dynamic, hr		NA	NA	NA	

GENERAL NOTE: NA indicates not applicable.

NOTES:
(1) Normal conditions refer to seal conditions in pump that are required to function during normal plant operation.
(2) Include this information if seal is to be used during hydrostatic tests.
(3) Other refers to conditions that may affect the seal cavity environment such as external loads, loss of component coolant or injection, and to conditions that are not covered in the other categories.
(4) If fluid is water, specify quantity of chemicals present as additives or impurities and solids particle size.
(5) Allowable leakage refers to that leakage which can be collected as liquid at the seal operating conditions.

(2) shaft or sleeve diameter at seal;
(3) shaft or sleeve material;
(4) shaft orientation (i.e., vertical or horizontal);
(5) direction of rotation;
(6) seal cavity maximum diameter at seal;
(7) seal cavity length;
(8) shaft to seal cavity misalignment conditions (i.e., static eccentricity, static angularity, range of axial travel, etc.); and
(9) shaft motions (i.e., radial, axial, and angular) relative to the seal cavity during seismic and design basis conditions as listed in Table QP-E1.

(c) The pump manufacturer will supply the seal manufacturer with the following shaft-seal system external conditions:

(1) seal system piping arrangements and seal flushing systems shall conform to ASME B73.1M, ASME B73.2M, API 610, API 682, and STLE SP-30;
(2) availability of component coolant, including the quantity, maximum temperature, pressure, available pressure drop, and chemistry; and
(3) availability of seal injection, including the quantity, temperature, chemistry, and solids particle size.

(d) The pump manufacturer will supply the seal manufacturer with the following special provisions:

(1) maintenance provisions;
(2) inaccessibility of the pump during operation that would restrict visual inspection and preventive maintenance; and

(3) necessary assembly and maintenance features that limit personnel exposure time in radiation fields.

QP-E5300 Mechanical Face Seals

(a) Mechanical face seals should be of the hydraulically balanced type, except as provided for in Table QP-E2.

(b) Either a sliding gasket (i.e., O-ring, V-ring, or U-ring) or a metal or rubber bellows should be used between the axially moving seal face and shaft sleeve or housing.

(02) *(c)* For applications involving seal face velocities over 5,000 fpm (25 m/s), it is preferred that the axially movable seal face be mounted on the stationary housing rather than on the shaft.

QP-E5400 Packings

(02) *(a)* Stuffing boxes on all pumps should be packed with a sufficient amount of packing as recommended by the packing manufacturer. The minimum packing size is $\frac{1}{4}$ sq in. (160 mm^2); however, a packing size of $\frac{3}{8}$ sq in. (240 mm^2) or greater is preferred.

(b) Pump stuffing boxes are to be provided with a lantern ring for fluid injection directly into the packing. Inlet and outlet connections must be provided for the lantern ring.

(c) Sufficient space is to be provided for the packing to be replaced without removing or dismantling any part other than the gland and the lantern ring if split.

Table QP-E2 Limits for Unbalanced Seals (02)

Seal Diameter, in. (mm)	Max. Shaft Speed, rpm	Max. Sealing Pressure, psig (MPa)
$\frac{1}{2}$ to 2 (13 to 51)	Up to 1,800	100 (0.69)
	1,801 to 3,600	50 (0.35)
Over 2 to 4 (51 to 102)	Up to 1,800	50 (0.35)
	1,801 to 3,600	25 (0.17)

(d) If the stuffing box of a vertical pump is subjected to discharge pressure and a bleedoff to suction is used, the bleedoff should be by means of internal rather than external piping.

(e) Adequate seal draining is to be provided so that no liquid can collect in the driver support piece.

QP-E5500 Shaft Sleeves

(a) Shaft sleeves, when used, are to be sealed to prevent leakage between the sleeve and the shaft, and machined for concentric rotation.

(b) Ends of shaft sleeve assemblies or nuts, when used on pumps arranged for packing, are to extend beyond the outer face of the packing gland.

(c) Shaft sleeves are to extend beyond the external seal gland plate on pumps employing an auxiliary seal other than a throttle bushing.

Section QV: Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants

(02) ## INTRODUCTION

This Section of ASME QME-1 is provided to ensure that active valve assemblies for nuclear power plants will function as specified and was developed under sponsorship of The American Society of Mechanical Engineers. Its development was initiated by the American National Standards Committee N45 on Reactor Plants and Their Maintenance. In October 1972, the N45 Committee established a task force to prepare a series of standards to ensure that valves would function as specified. In 1974, the task force was reassigned to American National Standards Committee B16 and designated Subcommittee H. In 1982, the task force was again reassigned to ASME Main Committee on Qualification of Mechanical Equipment Used in Nuclear Power Plants and designated Subcommittee QV. The first standard to be issued by Subcommittee H was ANSI N278.1-1975, which covers the preparation of functional specifications.

Section QV provides a method for qualification of active valve assemblies that will provide an acceptable level of assurance of functional operability. This qualification is based on tests and analysis demonstrating the ability of the valve assembly to perform its function under extreme adverse conditions of pressure, mechanical loading, flow dynamics, temperature, and vibration. The testing involves imposition of certain of these conditions in combination, and others individually, all equaling or exceeding maximum levels expected in service. It is recognized that in the extremity of certain adverse plant events involving need for valve operation, loading combinations not specifically addressed by this qualification standard may be imposed on valves. The adverse effects of such combinations have been considered by the Committee, and it has been concluded that this qualification standard will provide a high degree of assurance of functional operability for all such combinations.

It is recognized that in testing a complete series of valves, for example NPS 6, 8, 10, 12, 14, 16, 18, 20, 24, 28, 32, and 36 (DN 150 to 900) valves, all being Class 600 valves of the same type, much of the test time, work, and expense will be unproductive because no useful information will be produced by the later tests. If the various sizes are uniformly designed and proportioned, it will be expected that all valves in the series will perform uniformly in the tests. Conversely, if on the test of the first valve, a specific design weakness is discovered, then a similar weakness will be expected in all the other valve sizes.

It has been proposed that in such cases, if a representative number of valve sizes test successfully, it should be possible by similarity analysis to infer that the qualification of design acceptability can be extended to all remaining valve sizes of similar design.

Such generic qualification is considered to be potentially acceptable, subject to due consideration of the degrees of variation from exact geometric similarity of two valves of different size, and considering the possibility of scale factors having some unanticipated adverse effect on functional performance.

In Section QV, provision has been made for analytical extension of parent valve qualification to candidate valves, with the expectation that generic qualification will be a practical way to maximize the cost-effectiveness of the design qualification process. References in this Standard to parent and candidate assemblies address this undertaking. The term *parent* is intended to mean the elder in a family of generic offspring having strong resemblance to the parent.

The *candidate* is the nominee for family membership until it is shown that specific rules have been satisfied for analytical extension of parent qualification, and the candidate is accepted as qualified by the Owner or Owner's designee.

Article QVC-7000 provides guidance for extending parent valve qualification to a wide range of candidate valve sizes, provided that both the parent and candidate valves use the same basic concept, and that the rules of Article QVC-7000 are satisfied. The intent is to ensure that the candidate valve structure has substantially the same or greater mechanical strength and rigidity as the parent valve structure, relative to their respective load ratings. The procedure of Article QVC-7000 is based on the application of a comprehensive analytical modeling procedure that must be rigorously verified by the results of the parent valve testing program.

Over the past several years, results of NRC-sponsored testing of active type valves have identified technical considerations requiring future evaluation beyond that leading up to this version of QME-1, Section QV. The overall development of ASME QME-1 represents many years of work and is needed by industry. ASME QME-1 is now suitable for publication, including Section QV, which represents a current-day version of ANSI B16.41 and ANSI N278.1. It is the considered opinion of QME's Main Committee that many of industry's problems and subsequent associated valve testing results are due to lack of proper mechanical equipment qualification as opposed to product quality. Many of the industry's valve problems would have been precluded if adequate qualification requirements such as those documented in this Standard had been implemented in the past. The application of valve assembly performance characteristics developed through parent valve testing, as required in this Standard, will lead to the development of data required for implementation of meaningful O&M procedures, and is expected to contribute to the elimination of plant operating problems. Once published, it is the intent of QME to pursue more recently identified active valve technical considerations requiring resolution and to revise this Standard as required.

QV-1000 SCOPE

QV-1100 General Information

(a) Section QV establishes the requirements and guidelines for functional qualification of active valve assemblies for nuclear power plants. These active valves can be classified as either active power-operated valve assemblies, active self-operated check valve assemblies, or active pressure relief valve assemblies. The scope of Section QV as it relates to the qualification requirements of each of these classifications is outlined in QV-1200 through QV-1400, respectively.

(b) It is especially important for the plant Owner or Owner's designee to identify any external load conditions, other than seismic loads, that may fall into the category of dynamic loads on the valve assembly. Work is under way regarding the qualification requirements for special dynamic load conditions other than seismic; however, until that work is complete, the scope of this Standard is limited to valve qualification that demonstrates valve operability under dynamic load situations represented by seismic (earthquake) conditions (including process flow/dynamic conditions). All other special dynamic load conditions currently fall outside the scope of this Standard and are to be addressed separately in accordance with the Owner's specifications. Also, to ensure proper functional qualification, it is the responsibility of the Owner or Owner's designee to identify those active valves that require qualification under Section QV, identify the valve functional classification as outlined in QV-1100(a), identify the ASME nuclear valve classification, and specify the functional qualification requirements (due to process flow conditions and externally applied loads arising from installation of the valve assembly in the pipeline) and all acceptance criteria that shall be met.

(c) Section QV considers all the conditions affecting operability qualification of the complete valve assembly, as opposed to attempting to qualify either the valve or actuator as separate units. In case of conflicts, Section QV takes precedence over Section QR for specific valve qualification requirements. Integrity of the pressure-retaining boundary of the valve, covered by the code developed by the ASME Boiler and Pressure Vessel Committee, is excluded from the scope of Section QV.

(d) Functional qualification of a parent valve assembly consists of testing and analysis, as specified in this Section, to demonstrate that a valve assembly can perform its required function under specified conditions.

(e) Article QVC-7000 can be used to provide functional qualification of a candidate valve assembly by extension of parent valve qualification through demonstration of design similarity and rigorous analysis. The use of Article QVC-7000 is not obligatory in the sense that all valves could be qualified by testing as parent valves; however, if Article QVC-7000 is used for the analytical extension of parent valve qualification to a candidate valve assembly, then all provisions of that Article shall apply.

QV-1200 Active Power-Operated Valve Requirements

(a) Where appropriate, each numbered article and its subarticles in Section QV is substructured using decimal numbers to differentiate between active power-operated valves, active self-operated check valves, and active pressure relief valves. When there is no difference in the qualification requirements for the three types of valves, the subarticle decimal substructuring is eliminated. All numbered articles, subarticles, etc., that outline the requirements for active power-operated valves are substructured using the decimal .1 (i.e., QV-xxxx.1). Active power-operated valve assemblies seeking operability qualification under Section QV shall meet all provisions of this Section as outlined in this paragraph.

(b) It is not intended that this subarticle be applied to power-operated relief valves that are qualified per the requirements of QV-1400, nor is this subarticle intended to be applied to self-operated check valves that are qualified per the requirements of QV-1300.

QV-1300 Active Self-Operated Check Valve Requirements

(a) Where appropriate, each numbered article and its subarticles in Section QV is substructured using decimal numbers to differentiate between active power-operated valves, active self-operated check valves, and active pressure relief valves. When there is no difference in the qualification requirements for the three types of valves, the subarticle decimal substructuring is eliminated. All numbered articles, subarticles, etc., that outline the

requirements for active self-operated check valves are substructured using the decimal .2 (i.e., QV-xxxx.2). Active self-operated check valve assemblies to be qualified for operability under Section QV shall meet all provisions of this Section as outlined in this paragraph.

(b) It is not intended that this subarticle be applied to power-operated valves that are qualified per the requirements of QV-1200, nor is this Section intended to be applied to active pressure relief valves that are qualified per the requirements of QV-1400.

(c) Check valves with an external actuating device whose sole purpose is to provide a means for in-service testing of operability are considered within the scope of QV-1300. Check valves with a simple weight or spring device are also considered to be within the scope of QV-1300. Check valves with an external actuator whose purpose is to provide positive closure or to assist in closure are considered within the scope of QV-1200 in addition to QV-1300.

QV-1400 Active Pressure Relief Valve Requirements

(a) When appropriate, each numbered article and its subarticles in Section QV is substructured using decimal numbers to differentiate between active power-operated valves, active self-operated check valves, and active pressure relief valves. When there is no difference in the qualification requirements for the three types of valves, the subarticle decimal substructuring is eliminated. All numbered articles, subarticles, etc., that outline the requirements for active pressure relief valves are substructured using the decimal .3 (i.e., QV-xxxx.3). Active pressure relief valve assemblies to be qualified for operability under Section QV shall meet all provisions of this Section as outlined in this paragraph.

(b) It is not intended that this subarticle be applied to self-operated check valves that are qualified per the requirements of QV-1300, nor is this subarticle intended to be applied to power-operated valves that are qualified per the requirements of QV-1200.

QV-2000 PURPOSE

It is the purpose of Section QV on active valves to provide requirements for the qualification of the design of valves, actuators, and the combination thereof (valve assemblies). This qualification is achieved by test, analysis, or a combination thereof, in order to provide assurance that the valve assemblies in service will func-tion as required under all specified operating conditions.

QV-3000 REFERENCES

To avoid inconsistency and duplication, all standards or codes referenced in this Standard are described in QR-3000.

QV-4000 DEFINITIONS

QV-4000.1 Active Power Operated Valves

The following definitions apply only to active valves. Other definitions pertinent to valves, but which also apply to other types of mechanical equipment, can be found in QR-4000.

cold working pressure: the valve pressure rating at 100°F (38°C).

extended structure: that portion of a valve assembly that extends outward from the centerline of the pipeline, as measured from the mating surface on the valve body; e.g., on a sliding-stem valve assembly, the extended structure would include, as a minimum, the valve bonnet, yoke, actuator, and all accessories mounted on the actuator assembly.

maximum motive power: the electrical, fluid, or mechanical power provided when voltage or actuator pressure is at the highest value for which the valve assembly is to be qualified.

minimum motive power: the electrical, fluid, or mechanical power provided when voltage or actuator pressure is at the lowest value for which the valve assembly is to be qualified.

motive power: the electrical, fluid, or mechanical power required to operate the valve assembly.

normal motive power: the electrical, fluid, or mechanical power provided when voltage or actuator pressure is at its normal or nominal value.

operating cycle: the movement of a valve closure member through its full stroke under defined operating conditions, terminating with a return to the starting position.

valve assembly: a valve–actuator combination including those functional accessories that are directly mounted thereon. The term *valve assembly* should be broadly interpreted to include power-operated valves, self-operated check valves, and pressure relief valves.

(a) test valve assembly: a valve assembly selected for qualification testing.

(b) parent valve assembly: a test valve assembly that has been qualified by all appropriate testing and analysis as required by QVP-7000.

(c) candidate valve assembly: a valve assembly to be qualified by extension of parent valve assembly qualification through the application of the rules contained in QVC-7000.

(d) qualified candidate valve assembly: a candidate valve assembly that has completed the qualification requirements of QVC-7000.

QV-4000.2 Active Self-Operated Check Valves

See QV-4000.1.

QV-4000.3 Active Pressure Relief Valves

All definitions from QV-4000.1 apply, with the following additions: the terminology for pressure relief valves shall be as defined in ASME PTC 25.3-1988. In addition, the following definitions are provided to ensure a uniform understanding of selected terms as they are used in this Standard.

pressure relief valve: a valve that is designed to open to prevent a rise of internal fluid pressure in excess of a specified value due to exposure to emergency or abnormal conditions, and to reclose and prevent the further flow of fluid after normal conditions have been restored (it may also be designed to prevent excessive internal vacuum). The valve consists of all functional accessories mounted directly thereon. Pressure relief valves may be further classified as follows:

(a) *self-actuated valve:* a valve that is actuated by inlet static pressure.

(b) *externally actuated valve:* a valve that is actuated by external motive power.

(c) *combined self- and externally actuated valve:* a valve that is actuated by external motive power and, in the event of failure of the external motive power, will open automatically at the set pressure due to inlet static pressure.

QV-5000 QUALIFICATION REQUIREMENTS

QV-5000.1 Active Power-Operated Valves

(a) Functional qualification shall be demonstrated by tests, by analyses, or by a suitable combination thereof, based on the requirements provided in this Standard.

(b) As applicable, the functional qualification shall demonstrate the following:

(1) valve sealing capability

(2) cold cyclic operability

(3) hot cyclic operability

(4) operability under maximum pipe-reaction end loading

(5) operability during and after loading representative of the maximum seismic or vibratory incident [see QV-5000.1(e)]

(6) flow interruption and functional capability

(7) adequacy of the materials of construction to survive environmental and aging effects

(c) Qualification of a parent valve assembly in accordance with this Standard demonstrates that the parent valve assembly will perform its function for the specified test conditions and qualifies the parent valve assembly design for operating conditions shown in the Functional Qualification Report described in QV-8310. The functional qualification program qualifies the valve assembly only for the orientation used in the qualification test program, unless that test orientation can be shown to be the worst-case orientation for the assembly.

(d) A qualification plan (which may be part of the Functional Qualification Report) shall be prepared in accordance with QV-8200. A Functional Qualification Report shall be prepared for each parent valve assembly in accordance with QV-8310, and an Application Report shall be prepared for each qualified candidate valve in accordance with QV-8320.

(e) Appendix QR-A is a nonmandatory appendix for reference only. Compliance with the requirements of this Section QV fully meets the intent of Appendix QR-A and no further consideration of that Appendix is required for the qualification of any valves under this Standard; however, upon agreement with the Owner, Appendix QR-A may be used to supplement portions of Section QV.

QV-5000.2 Active Self-Operated Check Valves

Article QV-5000.1 applies, with the exception of items QV-5000.1(b)(2) and QV-5000.1(b)(3), which are not applicable for active self-operated check valves.

QV-5000.3 Active Pressure Relief Valves

Article QV-5000.1 applies with the following modification of QV-5000.3(b):

(b) As applicable, the functional qualification shall demonstrate the following:

(1) valve sealing capability

(2) operability under maximum pipe-reaction end loading

(3) operability during and after loading representative of the maximum seismic incident [see QV-5000.1(e)]

(4) flow interruption capability

(5) adequacy of the materials of construction to survive environmental and aging effects

(6) set point verification

(7) blowdown verification

(8) thermal shock capability.

QV-6000 FUNCTIONAL QUALIFICATION SPECIFICATION

It is the responsibility of the plant Owner or Owner's designee to identify the functional requirements for a valve assembly. These requirements shall be provided in a specification document prepared in accordance with Appendix QV-A.

QV-7000 QUALIFICATION PROGRAM

(a) Section QV provides two basic methods for qualification of a valve assembly. A valve assembly that is a candidate for qualification may be qualified by a thorough program of testing and analysis to become a qualified parent valve assembly, or it may be qualified by a rigorous extension of a qualification program that has

been previously performed on a similar qualified parent valve assembly.

(b) Article QVP-7000 may be used to provide functional qualification of a parent valve assembly through a rigorous program consisting of testing intended to demonstrate that a valve assembly can perform its required function under conditions specified in the functional specification.

(c) Article QVC-7000 may be used to provide functional qualification of a wide range of candidate valve sizes by extension of parent valve qualification through demonstration of design similarity and rigorous analysis. The procedure of Article QVC-7000 is based on the application of a comprehensive analytical modeling procedure that must be rigorously verified by the results of the parent valve testing program, which shows applicability to the selected candidate valves. This extension of qualification is based upon the conditions that both the parent and candidate valves use the same design concept, and that the rules of Article QVC-7000 are fully satisfied. The use of Article QVC-7000 is not obligatory in the sense that all valves could be qualified by testing as parent valve assemblies; however, if Article QVC-7000 is used for the extension of parent valve qualification to a candidate valve assembly, then all provisions of that Article must be complied with for the candidate valve in question.

QVP-7000 PARENT VALVE QUALIFICATION

QVP-7100 Approach to Qualification

The intent of parent valve qualification is to provide generic qualification of a given valve assembly design, not necessarily to qualify a specific valve assembly for use in a specific nuclear power plant. Compliance with the quality assurance provisions of ASME NQA-1 then provides assurance of qualification for all production valves that are built to that identical design construction. An Application Report, as described in QV-8320, is then required to provide documentation that each of the production valves is qualified for a specific nuclear plant application.

QVP-7200 Methods of Qualification

Although analysis, per Article QVC-7000, is used extensively in the extension of parent valve qualification to candidate valves that are similar in construction to the parent valve, testing as outlined in this Article is the primary method for qualification of parent valve assemblies. Certain limited analysis, however, is permissible as outlined in QVP-7400.1.

QVP-7300 Testing

QVP-7310 Installation and Orientation

(a) A parent valve assembly or assemblies shall be selected as representative of the production valves to be qualified. To ensure that the parent valve assembly to be tested is representative of the candidate valves to be qualified, the manufacturer shall assure that subsequent candidate valves to be qualified are constructed to quality levels that are equal to or better than those used for the parent valve; i.e., all candidate valve materials and methods of manufacture shall be rigorously controlled and shall compare favorably with those of the parent valve. This may be accomplished by conformance with the appropriate provisions of ASME BPVC Section III, Division 1 and ASME NQA-1.

(b) The parent test valve shall be supported by its normal mounting points in such a manner as to permit testing in accordance with each of the tests outlined in QVP-7320.

(c) The orientation of the test valve assembly shall be as required by the functional specification; however, the test valve assembly may be mounted in a more conservative, worst-case orientation, provided that a satisfactory justification for the worst-case orientation decision is presented in the Functional Qualification Report.

(d) When it is anticipated that the provisions of QVC-7000 will be used to extend parent valve qualification to various candidate valve sizes, the parent valve test program may include measurement instrumentation as necessary to satisfy all the requirements of that Article.

QVP-7320 Test Sequence

QVP-7320.1 Active Power-Operated Valves

(a) All testing per QVP-7300 shall be performed on the same parent valve test assembly in the sequence listed below except for permissible deviations listed in QVP-7320.1(b). Any other deviations must be thoroughly justified in the Functional Qualification Report.

(1) pretest inspection
(2) fundamental frequency determination
(3) environmental and aging simulation
(4) intermediate inspection
(5) cycle test
(6) intermediate inspection
(7) end-loading test
(8) intermediate inspection
(9) seismic test
(10) intermediate inspection
(11) flow interruption and functional capability demonstration
(12) posttest inspection

(b) In the test sequence above, it may be desirable to group certain tests or to change the sequence. The following deviations to the above sequence are permissible:

(1) the fundamental frequency determination may be combined with the seismic test;

(2) the end-loading test may be combined with the seismic test [see QVP-7370.1(c)];

(3) additional testing as required to satisfy the provisions of QVC-7000 may be performed at any point in the sequence.

QVP-7320.2 Active Self-Operated Check Valves. QVP-7320.1 applies with the exception of items QVP-7320.1(a)(2), (a)(5), and (a)(9), which are not required for active self-operated check valves. In addition, the following paragraph applies:

(c) Those check valves with actuating means involving external weights, springs, or a power actuator whose purpose is to provide positive closure or to assist in closure, and those check valves with an external actuating device whose sole purpose is to provide a means for in-service testing of operability, may be tested or qualified by analysis which verifies that the actuating device cannot degrade the function or operability during and after a seismic event.

QVP-7320.3 Active Pressure Relief Valves

(a) All testing per QVP-7300 shall be performed on the same parent valve test assembly in the group sequence listed below. Individual tests within Group 2 may be conducted in any sequence or in any combination with other tests within that group. Any deviations must be thoroughly justified in the Functional Qualification Report.

(1) Group 1

(a) pretest inspection

(b) performance and leakage (baseline)

(2) Group 2

(a) fundamental frequency determination

(b) seismic test

(c) discharge-pipe and reaction-loading qualification test

(d) combined seismic and end-loading test

(e) external environment test

(f) thermal effects test

(3) Group 3

(a) performance and leakage (final)

(b) posttest inspection.

QVP-7330 Inspection

QVP-7330.1 Active Power-Operated Valves

(a) A pretest inspection per QVP-7331 shall be performed on the test valve assembly as the first step in the test sequence outlined in QVP-7320. The purpose of this pretest inspection is to ensure the appropriateness of the test valve assembly and to establish baseline values for the functional performance of the assembly. These baseline functional values will then be compared with the post-test inspection values upon completion of the test sequence.

(b) Intermediate inspections per QVP-7332 should be performed on the test valve assembly at intermediate points throughout the test program as outlined in QVP-7320. The purpose of these intermediate inspections is to assist in the evaluation of the test valve assembly and provide data relating the functional performance of the assembly to the various test environments.

(c) A posttest inspection per QVP-7333 shall be performed on the test valve assembly as the last step in the test sequence outlined in QVP-7320. The purpose of this posttest inspection is to obtain data for comparison with the pretest inspection in order to determine what effect, if any, the sequence of qualification tests has had upon the functional performance of the assembly.

QVP-7330.2 Active Self-Operated Check Valves. See QVP-7330.1.

QVP-7330.3 Active Pressure Relief Valves

(a) See QVP-7330.1(a).

(b) Intermediate inspection per QVP-7332 to assist in evaluation of the test valve may be made at intermediate times during the qualification testing program. If some condition is exhibited during the sequence of the testing that requires maintenance or adjustment of a part, acceptance of the test must be evaluated according to the limitations of the test plan. No alterations, adjustments, or maintenance is allowed other than that stipulated in the test plan without qualification tests being reinitiated. Any maintenance or adjustments shall be fully described and evaluated in the Functional Qualification Report.

(c) See QVP-7330.1(c).

QVP-7331 Pretest Inspection

QVP-7331.1 Active Power-Operated Valves

(a) The first step in the pretest inspection is to determine the suitability of the test valve assembly prior to beginning the actual test program. This inspection, as a minimum, shall include a thorough visual examination of the assembly to ensure correct assembly of all the components, proper calibration of the assembly, proper calibration of all test equipment, security of fasteners, adequacy of the motive power supply, and appropriateness of all control settings, packing preload, etc.

(b) In order to establish baseline functional values for the test valve assembly, pretest functional tests shall be performed according to the qualification plan. As a minimum, leakage tests and stroking time cycle tests shall be performed as specified in QVP-7331.1(e), (f), and (h). The initial valve leakage and stroking time tests establish the base performance of the valve being tested. Leakage rates and stroking times measured following the other tests in the qualification test series shall be recorded in the Functional Qualification Report for comparison with the initial test values in order to establish a basis for verification of the valve application. In the event that the user of this Standard intends to use the rules of QVC-7000 for the extension of qualification to various candidate valve assemblies, the pretest inspection should also include the measurement of all critical

operating clearances as required in QVC-7220.1(h).

(c) The test valve assembly shall be installed in a test fixture assembly that simulates the actual installation of the valve assembly as closely as possible. In addition, the following requirements shall be met:

(1) the test fixture shall permit control of the pressurization of both the upstream and downstream flow ports;

(2) motive power connections shall be functionally equivalent to an actual installation;

(3) orientation of the valve assembly shall be as required to satisfy the provisions of QVP-7310;

(4) provision shall be made to measure main-seat leakage as stipulated in QVP-7331.1(e);

(5) provision shall be made to observe primary stem/shaft-seal leakage as stipulated in QVP-7331.1(f);

(6) provision shall be made to measure valve cycle stroking time in both the opening and closing directions as required in QVP-7331.1(h);

(7) the test working fluid may be water (that may contain a corrosion inhibitor), steam, air, or an inert gas, whichever is appropriate to simulate worst-case application conditions.

(d) Both the test pressure for the valve and the maximum test seat-sealing differential pressure shall be defined in the qualification plan and documented in the Functional Qualification Report. In addition, the valve is to be identified as bidirectional or unidirectional, in which case the direction of pressurization must be defined. The valve-body test pressure and the seat-sealing test pressure used in this test may be equal to or less than the rated pressure of the valve, but in any event these test pressures determine the qualification pressure rating for the parent valve test assembly. The selected test pressures may be established with sufficient margin to allow for the qualification of other candidate valves that are similar to the parent valve being tested. For this reason, the selected test pressures may be conservatively chosen to be equal to the rated pressure of the valve.

(e) For measurement of main-seat leakage, a valve closure shall be effected by the actuator using minimum motive power, and the maximum seat-sealing differential test pressure shall be established. Pressure on one side of the closure shall be relieved to establish a differential pressure in the specified flow direction, or in the most adverse direction for bidirectional valves. For example, a globe valve with an unbalanced disk, when the design is such that flow tends to open the valve disk, shall be seat-leak tested with pressure applied on the upstream side of the disk. Leakage shall be collected from the low pressure side of the closure or otherwise measured by appropriate means. The test period shall be a minimum of 5 min or longer as deemed adequate to establish the leakage rate. For double-disk gate valves, the selected seat-sealing test pressure may be applied to the bonnet cavity, the leakage rates being measured for each main seat.

(f) The primary stem/shaft-seal leakage shall be observed at the rated cold working pressure with the valve in the partially open position to ensure pressurization of the valve in the area of the primary stem/shaft seal. For valves without leak-off connections, primary stem/shaft-seal leakage shall be observed and the leak rate estimated. For valves with leak-off connections, leakage at the leak-off connections shall be measured and recorded. For valves utilizing diaphragms or bellows to achieve zero stem/shaft-seal leakage, the test shall be performed so as to demonstrate the pressure integrity of the bellows or diaphragm seal. In all cases, regardless of the stem/shaft-seal construction, the intent of this test is to demonstrate the pressure integrity of the primary stem/shaft-seal arrangement. The initial primary stem/shaft-seal leakage test shall be performed after fully cycling the test valve assembly ten times. The leakage rate test duration shall be adequate to determine the leakage rate, but no less than 5 min.

(g) An initial baseline cold-cycle stroking time test shall be performed in order to provide a basis for comparison with stroking time tests conducted throughout the test sequence. The actual value of the stroking time for the test valve is not important here because:

(1) the design stroking time will be evaluated as a production test at the time of valve manufacture for specific candidate valve assemblies; and

(2) the test valve is not being qualified for a specific stroking time.

Stroking time can be varied for many valve assembly styles by control system changes, and therefore should be checked for a particular application by test on the specific production valve assembly at the time of manufacture. It should be realized, however, that the stroking time in an actual application may also vary as a function of the installation. The stroking time test performed here is to be used simply as a basis for determining whether the qualification tests performed in the remainder of the test sequence have any deleterious effects upon the stroking capability of the valve assembly. It is common for a valve assembly to have quite different stroking times for each direction of travel. The most important parameter to evaluate for the basis of qualification is the stroking time in the direction of the defined function (i.e., whether the valve is expected to stroke closed or stroke open during postulated accident conditions).

(h) The baseline cold-cycle stroking time test described in QVP-7331.1(g) shall consist of one full operating cycle using normal motive power and one full operating cycle using minimum motive power. Both cycles are to be performed at normal room temperature, not to exceed 100°F (38°C). With the valve fully open,

the valve body is pressurized at the selected test pressure, and a valve closure is initiated and timed. One side of the closure is then depressurized to establish the test differential operating pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. An opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated.

QVP-7331.2 Active Self-Operated Check Valves

(a) The first step in the pretest inspection is to determine the suitability of the test valve assembly prior to beginning the actual test program. This inspection, as a minimum, shall include a thorough visual examination of the assembly to ensure correct assembly of all the components, proper calibration of the assembly, proper calibration of all test equipment, security of fasteners, adequacy of the motive power supply, and appropriateness of all control settings.

(b) In order to establish baseline functional values for the test valve assembly, pretest functional tests shall be performed according to the qualification plan. The initial valve leakage establishes the base performance of the valve being tested. Leakage rates measured following the other tests in the qualification test series shall be recorded in the Functional Qualification Report for comparison with the initial test values in order to establish a basis for verification of the valve application.

(c) The test valve assembly shall be installed in a test fixture assembly that simulates the actual installation of the valve assembly as closely as possible. In addition, the following requirements shall be met:

(1) The test fixture shall permit control of the pressurization of both the upstream and downstream flow ports.

(2) Motive power connections shall be functionally equivalent to an actual installation.

(3) Orientation of the valve assembly shall be as required to satisfy the provisions of QVP-7310.

(4) Provision shall be made to measure main-seat leakage as stipulated in QVP-7331.2(e).

(5) Provision shall be made to observe primary stem/shaft-seal leakage as stipulated in QVP-7331.2(f).

(6) The test working fluid may be water (that may contain a corrosion inhibitor), steam, air, or an inert gas, whichever is appropriate to the test.

(d) Both the test pressure for the valve and the maximum test seat-sealing differential pressure shall be defined in the qualification plan and documented in the Functional Qualification Report. The valve-body test pressure and the seat-sealing test pressure used in this test may be equal to or less than the rated pressure of the valve, but in any event, these test pressures determine the qualification pressure rating for the parent valve test assembly. The selected test pressures may be established with sufficient margin to allow for the qualification of other candidate valves that are similar to the parent valve being tested. For this reason, the selected test pressures may be conservatively chosen to be equal to the rated pressure of the valve.

(e) The valve shall be pressurized in a direction tending to seat the disk. Leakage shall be collected from the opposite side of the closure or otherwise measured by appropriate means. The test shall be a minimum of 5 min or a longer period deemed adequate to measure the leakage rate.

(f) For check valves having sealed shafts, shaft-seal leakage shall be observed at cold working pressure with the valve in the partially open position. For valves without leak-off connections, shaft-seal leakage shall be observed and the leak rate estimated. For valves with leak-off connections, leakage at the leak-off connection shall be measured and recorded. If the sealed shaft is a moving part, the initial shaft-seal leakage test shall be performed after fully cycling the test valve assembly ten times. The leakage rate test duration shall be adequate to measure the leakage rate, but no less than 5 min.

QVP-7331.3 Active Pressure Relief Valves

(a) The first step in the pretest inspection is to determine the suitability of the test valve assembly prior to beginning the actual test program. This inspection, as a minimum, shall include a thorough visual examination of the assembly to ensure correct assembly of all the components, proper calibration of the assembly, proper calibration of all test equipment, security of fasteners, adequacy of the motive power supply, and appropriateness of all control settings.

(b) In order to establish baseline functional values for the test valve assembly, pretest functional tests shall be performed according to the qualification plan.

QVP-7332 Intermediate Inspections

QVP-7332.1 Active Power-Operated Valves. At each of the intermediate inspection test points specified in the test sequence of QVP-7320.1, the valve assembly shall be fixtured according to QVP-7331.1(c), followed by the main-seat leakage test of QVP-7331.1(e), the primary stem/shaft-seal leakage test of QVP-7331.1(f), and the cold-cycle stroking time test of QVP-7331.1(h). Test data for these intermediate inspection tests shall be recorded in the Functional Qualification Report for comparison with the baseline data from QVP-7331.1.

QVP-7332.2 Active Self-Operated Check Valves. QVP-7332.1 applies with the exception of the reference to the stroking time test of QVP-7331.1(h).

QVP-7332.3 Active Pressure Relief Valves. Data for intermediate inspections as required by the qualification plan shall be recorded in the Functional Qualification Report for comparison with the baseline data from QVP-7331.3.

QVP-7333 Posttest Inspection

QVP-7333.1 Active Power-Operated Valves

(a) Upon completion of the complete test program, the valve assembly shall be fixtured according to QVP-7331.1(c), followed by the main-seat leakage test of QVP-7331.1(e), the primary stem/shaft-seal leakage test of QVP-7331.1(f), and the cold-cycle stroking time test of QVP-7331.1(h). Test data for these posttest inspection tests shall be recorded in the Functional Qualification Report for comparison with the baseline data from QVP-7331.1. The basis for qualification shall include conformance to the functional performance criteria for main-seat leakage, primary stem/shaft-seal leakage, and stroking time, following completion of the qualification test program.

(b) Upon completion of the tests in QVP-7333.1(a), the test valve assembly shall be disassembled and thoroughly inspected. Any significant damage or changes shall be recorded and evaluated in the Functional Qualification Report described in QV-8310.

QVP-7333.2 Active Self-Operated Check Valves. QVP-7333.1 applies, except for the references to QVP-7331.1(f) and (h), which are not applicable to active self-operated check valves.

QVP-7333.3 Active Pressure Relief Valves. Upon completion of the complete test program, the valve assembly shall be disassembled and thoroughly inspected. Any significant damage or changes shall be recorded and evaluated in the Functional Qualification Report described in QV-8310.

QVP-7340 Fundamental Frequency Determination

QVP-7340.1 Active Power-Operated Valves

(a) Resonance of a structure occurs when the frequency of the disturbing input is such that the inertial forces of the structure are exactly balanced by the restorative, spring-type forces. This leaves only the internal damping forces to overcome the input-disturbing force and can result in large amplification of the resulting structure motion.

(b) The objective of QVP-7340 is to determine the fundamental frequency, i.e., the lowest frequency at which resonance occurs. For vibratory disturbances below this frequency, no resonant amplification of the motion will result. The results of this fundamental frequency determination are used to classify the valve assembly as flexible or rigid per the requirements of QVP-7380.1.

(c) The fundamental frequency determination for any candidate valve assembly or component can be made by analysis per the requirements of QVC-7300, or by test using the methods of QVP-7341.1; however, the fundamental frequency determination for all parent valve test assemblies shall be made using the test methods of QVP-7341.1.

QVP-7340.2 Active Self-Operated Check Valves. See QVP-7340.1 except as noted in QVP-7320.2(c).

QVP-7340.3 Active Pressure Relief Valves. See QVP-7340.1.

QVP-7341 Test Methods

QVP-7341.1 Active Power-Operated Valves

(a) Test Method Selection. If a structure is temporarily disturbed in some way, it will respond in a vibratory manner at its fundamental frequency until the internal damping dissipates the energy of the input disturbance and brings the structure to rest. If the structure is continuously disturbed in a cyclic manner, the structure will exhibit an increase in its motion when the frequency of the driving input matches the fundamental frequency of the structure. There are a number of techniques using one or both of these facts to determine the fundamental frequency of a valve assembly. Acceptable methods are described below. As applicable, the valve stroke position shall be determined by experimentation so that the lowest possible fundamental frequency is obtained, and the valve assembly shall be tested independently in each of three mutually perpendicular directions along each of the major axes of the valve assembly.

(b) Snap-Release Method

(1) This technique involves rigidly mounting the valve assembly by its normal mounting points (usually the valve body ends), and then applying a side loading force to the valve extended structure using a steel wire and turnbuckle arrangement, or some similar apparatus.

(2) This restraining apparatus shall then be cut or rapidly released to allow the valve assembly to vibrate at its fundamental frequency. A suitable recording device shall be used to record the output of an accelerometer attached to the extended structure of the valve assembly.

(3) Counting the average number of cycles in 1 sec on this accelerometer recording will determine the fundamental frequency of the valve assembly.

(4) This method of testing will work well in most instances; however, the recording may be difficult to interpret when several higher frequency modes are superimposed on the fundamental frequency.

(5) To implement this method, the valve assembly must be rigidly mounted by its normal mounting points (usually the valve body ends) to a large inertial mass that can effectively provide inertial isolation from the surrounding environment.

(c) Vibration Table Method

(1) This technique involves rigidly mounting the valve assembly by its normal mounting points (usually the valve body ends) to a vibration shake table capable of providing pure sinusoidal motion in a single direction.

(2) Vibrate the valve assembly using a sinusoidal frequency sweep from 5 Hz to the maximum qualification frequency, and an input amplitude sufficiently high to excite resonance of the structure.

(3) In no case shall the maximum vibration frequency be less than 40 Hz, nor shall the input amplitude be less than 0.2 g. In addition, the input frequency sweep rate shall not exceed one octave per minute.

(4) One input accelerometer shall be mounted on the test valve mounting fixture at a location where it interfaces with the test valve assembly, and a response accelerometer shall be mounted centrally on the test valve assembly, preferably near the center of gravity of the valve extended structure. These accelerometers shall be aligned with each other and oriented so as to measure motion along the input axis.

(5) The fundamental frequency of the valve assembly is defined as the lowest frequency at which the output acceleration response value exceeds the input acceleration value by a factor of three or more.

(d) Fast Fourier Transform Method

(1) The fast Fourier transform method, otherwise known as the FFT method, uses a digital signal-processing device to collect vibration input and response data and then transform this data from the real time domain to the frequency domain in order to allow easier interpretation.

(2) Most FFT devices can then display the data as a Bode diagram (amplification and phase shift versus frequency), co-quad diagram (real and imaginary components versus frequency), or Nyquist diagram (real component versus imaginary component), as well as displaying the original input and output data versus time.

(3) Although all of these displays can be useful for different purposes, the co-quad diagram or the Bode diagram are the most useful for determining the fundamental resonant frequency of the valve assembly.

(4) To implement this method, the valve assembly must be rigidly mounted by its normal mounting points (usually the valve body ends) to a large inertial mass that can effectively provide inertial isolation from the surrounding environment.

(5) The valve assembly is then given a measured input excitation and the resulting valve assembly response is measured with a centrally located accelerometer, preferably near the center of gravity of the extended structure.

(6) The input excitation can take several forms. It can be a measured force impulse using a specially instrumented hammer with built-in force transducer or, alternatively, it can be a random vibration input provided by a small vibration machine attached to the valve assembly or provided by mounting the valve rigidly on a large vibration shake table. The measured input can be either force or acceleration measured at the point of input to the valve assembly. The FFT machine collects the input and response data, transforms it into the frequency domain, and displays it in any of the diagrams previously mentioned.

(7) The fundamental frequency of the test valve assembly is the lowest frequency when:

(a) the co-quad diagram shows a definite peak response on one component display coinciding with a definite zero-crossing on the other component display, and/or

(b) the Bode diagram shows a peak in the amplitude-versus-frequency display coinciding with a 90 deg phase shift in the phase-versus-frequency display.

(e) Constant Force Method

(1) There is an alternate method that is similar to the FFT method, but that does not require an FFT device. This method depends upon a vibration machine that is specially equipped with a feedback system so as to produce a constant-amplitude sinusoidal force that can be used to excite the valve assembly.

(2) To implement this method, the valve assembly must be rigidly mounted by its normal mounting points (usually the valve body ends) to a large inertial mass that can effectively provide inertial isolation from the surrounding environment.

(3) The constant-force vibration drive mechanism shall be attached as close as possible to the center of gravity of the valve assembly extended structure.

(4) A response accelerometer shall be mounted centrally on the test valve assembly, preferably near the center of gravity of the valve extended structure, and as close as possible to the point of attachment of the driving force, or on the side of the assembly directly opposite from the driving force. This accelerometer shall be aligned so as to measure motion along the input axis.

(5) Vibrate the valve assembly using a constant-amplitude sinusoidal frequency sweep from 5 Hz to the maximum qualification frequency, with an input force amplitude sufficiently high to excite resonance of the structure.

(6) In no case shall the maximum vibration frequency be less than 40 Hz. In addition, the input frequency sweep rate shall not exceed one octave per minute.

(7) Since the input force is being maintained at a constant amplitude, the fundamental frequency of the valve assembly is defined as the lowest frequency at which the output acceleration experiences a significant and sharply defined increase in amplitude.

(8) Because of the unknown inertial properties of the valve assembly being tested, it is impossible to establish an exact amplitude criterion, as was done in QVP-7341.1(c)(5); however, by monitoring both the force input signal and the acceleration response on a two-channel oscilloscope, it is possible to determine the resonant frequency by observing the 90 deg change in input/output phase relationship from the Lissajous pattern on the oscilloscope.

(9) Since the accuracy of this method is dependent upon the ability of the vibration system to maintain a

constant input force, it is extremely important to monitor the force input to ensure that it remains constant throughout the frequency sweep range.

QVP-7341.2 Active Self-Operated Check Valves. See QVP-7341.1 except as noted in QVP-7320.2(c).

QVP-7341.3 Active Pressure Relief Valves. See QVP-7341.1.

QVP-7350 Environmental and Aging Simulation

(a) Valve assemblies generally covered by this Section are characterized by the use of metal for all components that provide the pressure-containing boundaries and operating load bearing or transmitting functions. The use of metal in valve components provides basic assurance against loss of operability from environmental and aging effects, such as radiation, elevated temperature, and impinging chemical sprays; however, due consideration must be given to the aging mechanisms associated with the effects of corrosion, erosion, and fatigue. These aging effects on metal components are addressed in QVP-7350(b).

(b) Since the aging effects of corrosion, erosion, and fatigue on metal components are primarily related to the mechanical strength of the components, these effects can be addressed quite adequately through the use of analysis or test margins. The aging effects of fatigue are most practically addressed through analysis as prescribed in QVP-7360. Since the aging effects of erosion are confined to the internal surfaces of the pressure-retaining parts that are in contact with the process fluid, this aging phenomenon is adequately addressed through the design provisions prescribed in ASME BPVC Section III. Likewise, the aging effects of corrosion on the internal surfaces of the pressure-retaining parts are also accounted for by the design provisions of ASME BPVC Section III; therefore, the main concern of this Standard should be toward the aging effects of corrosion on the structural integrity of any essential-to-function parts other than the pressure-retaining components. Since nuclear power plants have relatively clean ambient environments during normal operation, the long-term aging effect due to corrosion of structural members is relatively insignificant. In addition, normal good design practice incorporates some margin in the initial design of the components. These considerations, coupled with the fact that the seismic loading tests of this Standard (see QVP-7381) require adjustments to compensate for variability in material and geometric properties, provide reasonable assurance against loss of operability due to corrosion.

(c) The use of nonmetallic materials is frequently confined to nonessential-to-function components or components involving substantially total confinement in compressive loadings, as in stem/shaft-seal packing and in joint sealing gaskets when there is little concern for environmental effects, and when normal in-service testing practices prescribed by ASME Section XI provide adequate corrective action to compensate for any degradation due to environmental or aging effects.

(d) Qualification of plastic or elastomeric materials that are used in essential-to-function parts requires exposure to radiation and thermal aging environments that are equivalent to the maximum for which the valve is to be qualified. This radiation and thermal aging qualification shall be performed as specified in Appendix QR-B, followed by functional tests of the valve assemblies per QVP-7320. It is preferred that the radiation and thermal aging tests be performed with the nonmetallic materials installed in their normal manner in the valve assembly or in a fixture that simulates this normal installation.

(e) If electric actuators are used, whose performance may be degraded when exposed to various environmental conditions, these electric actuators must first be qualified per the appropriate requirements of IEEE Std 382 prior to beginning the qualification tests outlined in this Section. Pneumatic actuators, whose defined function during postulated accident conditions is achieved by essential-to-function parts that are made of metal, need not undergo prior testing per IEEE Std 382. In addition, valve accessories that are not essential-to-function components need not undergo prior testing per IEEE Std 382.

(f) In addition to the hot- and cold-cycle functional tests described in QVP-7360, test and/or analysis techniques shall be used to address the effects of fatigue on the design life of any essential-to-function parts, such as springs or gears, that experience cyclic stresses in their normal operation (see QVP-7400.1).

QVP-7360 Cycle Testing

QVP-7360.1 Active Power-Operated Valves. Cycle testing demonstrates the capability of the test valve assembly to open and close under adverse combinations of motive power, system pressure, and temperature. Cycle testing is performed at both hot and cold conditions.

QVP-7360.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7360.3 Active Pressure Relief Valves. Not applicable to active pressure relief valves.

QVP-7361 Cold Cycle Functional Test

QVP-7361.1 Active Power-Operated Valves

(a) The cold cycle functional test shall be performed at room temperature conditions not exceeding 100°F (38°C).

(b) The test valve shall be placed in a fixture per QVP-7331.1(c).

(c) Three full operating cycles shall be performed with the test valve depressurized and utilizing the maximum

motive power for actuation. Stroking time shall be measured separately for each half of the cycle for comparison with the baseline measurement of QVP-7331.1(h).

(d) Three full operating cycles shall also be performed utilizing minimum motive power. With the valve fully open, the valve body is pressurized at the selected test pressure, and a valve closure is initiated and timed. One side of the closure is then depressurized to establish the test differential operating pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. An opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated. Stroking time measurements for each half of the cycle shall be recorded for comparison with the baseline measurement of QVP-7331.1(h).

QVP-7361.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7361.3 Active Pressure Relief Valves. Not applicable to active pressure relief valves.

QVP-7362 Hot Cycle Functional Test

QVP-7362.1 Active Power-Operated Valves

(a) The hot cycle functional test is only required when either of the following two conditions exist:

(1) if the valve is to be qualified for fluid temperature in excess of 200°F (93°C); or

(2) if the test valve has essential-to-function components made of plastic or elastomeric materials that will operate in service at temperatures in excess of 100°F (38°C).

(b) The hot cycle functional test shall be performed at a qualification temperature such that all portions of the entire valve assembly are subjected to temperatures that are at least as great as expected when the valve assembly is operating at the specified service temperatures. In no case shall the test temperature be less than the appropriate temperatures from QVP-7362.1(a).

(c) The test valve shall be installed in a test fixture as specified in QVP-7331.1(c). Provision shall also be made for regulating the working fluid temperature and/or the temperature of the test valve assembly.

(d) An initial test run shall be made consisting of one full operating cycle utilizing normal motive power. With the valve fully open, the valve body is pressurized at the selected test pressure. When it is ensured that all portions of the entire valve assembly, including the working fluid, are subjected to temperatures that are at least as great as expected when the valve assembly is operating at the specified service temperatures, a valve closure shall be initiated and timed. One side of the closure is then depressurized to establish the test differential operating pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. An opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated. Stroking time measurements for each half of the cycle shall be recorded for comparison with the baseline measurement of QVP-7331.1(h).

(e) Three full operating cycles shall be performed utilizing minimum motive power for valve actuation. With the valve fully open, the valve body is pressurized at the selected test pressure. When it is ensured that all portions of the entire valve assembly, including the working fluid, are subjected to temperatures that are at least as great as expected when the valve assembly is operating at the specified service temperatures, a valve closure is initiated and timed. One side of the closure is then depressurized to establish the test differential operating pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. An opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated. Stroking time measurements for each half of the cycle shall be recorded for comparison with the baseline measurement of QVP-7331.1(h).

(f) A final test run is begun with the valve open, the test valve pressurized at the selected test pressure, and all portions of the entire valve assembly, including the working fluid, subjected to temperatures that are at least as great as expected when the valve assembly is operating at the specified service temperatures. A valve closure is then initiated using the maximum motive power and the closure timed. With the valve closed, the test valve and fixture shall be allowed to cool to steady state equilibrium with ambient air, no higher than 100°F (38°C). One side of the closure is then depressurized to establish the test differential operating pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. An opening is then performed using minimum motive power for actuation, and the opening timed. Differential pressure need not be maintained after the test valve assembly is unseated. Stroking time measurements for each half of the cycle shall be recorded for comparison with the baseline measurement of QVP-7331.1(h).

QVP-7362.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7362.3 Active Pressure Relief Valves. Not applicable to active pressure relief valves.

QVP-7363 Performance and Leakage Test (Self-Actuated)

QVP-7363.1 Active Power-Operated Valves. Not applicable to active power-operated valves.

QVP-7363.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7363.3 Active Pressure Relief Valves

(a) The performance and leakage test is intended to establish an operability baseline that will be used throughout the functional qualification test program to demonstrate acceptability of the test valve assembly during and after exposure to the qualification loading tests. For the initial performance and leakage test series, it is intended that valve setup adjustments may be made to bring valve performance in line with the functional specification requirements. No further adjustment shall be allowed during or following qualification testing unless specifically allowed by the test plan.

(b) The test valve assembly shall be installed in a test facility having the capability of providing pressurized test fluid as required per the test plan to the valve inlet with sufficient flow capability to adequately test the valve. Instrumentation shall be provided to record, as a minimum, pressures, ambient and fluid temperatures, valve seat leakage rate, and valve lift.

(c) Appropriate valve thermal stabilization shall be achieved. Adjust valve set pressure and blowdown pressure as specified in the test plan. Test media shall be as defined in the test plan. Following valve setup, the test valve assembly shall be cycled through a minimum of three complete cycles, recording applicable data.

(d) Unless otherwise specified in the test plan, conduct of the seat leakage test shall be performed as noted below.

(1) Appropriate valve thermal stabilization shall have been achieved.

(2) Leakage measurement shall be performed with the specified differential pressure applied for the specified period to establish and record the seat leakage.

QVP-7364 Performance and Leakage Test (Externally Actuated)

QVP-7364.1 Active Power-Operated Valves. Not applicable to active power-operated valves.

QVP-7364.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7364.3 Active Pressure Relief Valves

(a) The performance and leakage test is intended to establish an operability baseline that will be used throughout the functional qualification test program to demonstrate acceptability of the test valve assembly during and after exposure to the qualification loading tests. For the initial performance and leakage test series, it is intended that valve setup adjustments may be made to bring valve performance in line with the functional specification requirements. No further adjustments shall be allowed during or following qualification testing unless specifically allowed by the test plan.

(b) The test valve assembly shall be installed in a test facility having the capability of providing pressurized test fluid as required per the test plan to the valve inlet with sufficient flow capability to adequately test the valve. The facility shall also provide the appropriate motive power for actuation. Instrumentation shall be provided as applicable to record pressures, ambient and fluid temperatures, valve position, valve travel time, input power (i.e., volts, amps, air pressure, hydraulic pressure, etc.), and valve stem and seat leakage.

(c) The test valve assembly shall be operated (open and closed) at the specified inlet pressure, and static and/or dynamic backpressure. Cycle the valve a minimum of three times for each motive power condition, recording the applicable data. The power failure mode shall be tested, if applicable.

(d) With the test valve assembly in the closed position (for valves using external motive power for closure, minimum motive power shall be used), increase inlet pressure until the specified pressure differential is achieved. Maintain this condition until thermal stabilization is established. Record seat leakage for the specified period.

(e) Packing leakage, if applicable, shall be observed with the valve and packing subjected to the specified differential pressure. For valves without leak-off connections, packing leakage shall be observed and the leak rate estimated. For valves with leak-off connections, leakage at the leak-off connections shall be measured and recorded.

QVP-7370 End-Loading Test

QVP-7370.1 Active Power-Operated Valves

(a) The pipe-reaction end-loading test is intended to demonstrate operability of the test valve assembly while being subjected to all pipe end-loading forces for which the valve is to be qualified, along with the normal service loads, which include pressure and deadweight.

(b) The end-loading test is not required if:

(1) the intended application for the valve does not impose significant end-load reactions (e.g., a drain valve with piping attached to one end of the valve does not impose significant loading); or

(2) the valve is designed to be installed in piping by bolting the valve between pipe flanges, and the valve body has a generally cylindrical cross section (except for through bolting holes and a provision for actuator mounting and entrance of the valve stem/shaft) of such proportions that the length of the valve body parallel to the pipe run is equal to or less than the inside diameter of the valve (e.g., a wafer-style butterfly valve).

(c) The end-loading test may be combined with the seismic test of QVP-7380.1 or it may be conducted separately, depending upon which option represents the worst-case operability condition. The Functional Qualification Report must contain justification for the option chosen for each test valve.

(d) The test valve assembly shall be installed in a test fixture as specified in QVP-7331.1(c), with end pieces capable of transmitting the test end loading. The test

arrangement may be such that a constant moment is applied over the entire length of the valve body, and that the valve body is subjected to at least the normal axial tensile forces produced in the end closures by the simultaneous application of full test pressure in the valve and connecting piping. Alternative arrangements that impose shear loadings and variable moments over the length of the valve body are acceptable, provided that the moment is at least equal to the minimum required at any point in the valve body. The test moment shall be applied in the plane and mode most likely to adversely affect test valve assembly operability. For most gate and globe valves, this is normally considered to be in the plane of the valve stem and pipe centerlines, and tending to close the bonnet bore.

(e) Initially, the test operating pressure should be at least equal to the 100°F (38°C) cold-working pressure rating for the valve assembly being qualified; however, a higher test pressure may be selected in order to cover qualification of candidate valve bodies of the same type, but higher pressure rating classifications. In order to ensure the worst-case pressure condition during the initial test loading, the initial test operating pressure shall be greater than that for which the test valve assembly is to be qualified by a factor equal to the ratio of the actual test bar yield strength of the tested body material divided by the specified minimum yield strength of the body material.

(f) The initial test load end moment M to be applied shall be at least equal to the maximum possible moment that the specified piping can apply to the valve without yielding the pipe. For convenience in describing this initial moment, reference is made to NB-3545 in ASME Section III; however, it should be emphasized that this method applies to valves of all ASME classes for purposes of this end-loading test. The initial moment M shall be at least equal to $F_b S$, as defined in NB-3545.

(02) *(g)* Due to tolerances and material variations, the test valve body may be stronger than the minimum allowable design conditions. Therefore, the initial loading moment M determined in QVP-7370.1(f) shall be further increased by a factor K_1 determined by the following ratio:

$$K_1 = \frac{S_y G_{bm}}{(SMYS) G_{bd}}$$

such that the initial loading moment $M = K_1 F_b S$, where

S_y = actual test bar yield strength of the body material, psi (MPa)

G_{bm} = valve body section bending modulus at the valve crotch region (defined as G_b in NB-3500, ASME BPVC Section III) based on the actual measured dimensions, in.^{3} (mm^3)

G_{bd} = valve body section bending modulus at the valve crotch region (defined as G_b in NB-3500) based on minimum drawing dimensions, in.^{3} (mm^3)

$SMYS$ = specified minimum yield strength for the valve body material, psi

(h) With the valve in the open position, the initial test operating pressure from QVP-7370.1(e) is established in the valve assembly, and while this pressure is maintained, the initial test loading moment from QVP-7370.1(f) and (g) is applied to the valve assembly. This test, using the largest possible loading moment and pressure, is intended to simulate any deformation of the valve body that might result from an accidental simultaneous application of the maximum pressure and maximum possible loading moment that the attached piping can impart to a valve of minimum material properties and minimum dimensions.

(i) In order to provide a more realistic loading condition on the valve during the valve closure test, the end-loading moment is reduced to the maximum value that the attached piping could impart to the valve and still remain within the ASME Code allowable stresses for the piping. For simplicity, this reduced loading moment is approximated by reducing the end-loading moment to two-thirds of the initial moment obtained in QVP-7370.1(f) and (g). In order to provide a more realistic pressure condition for which the valve actuator is designed to operate against, the test pressure from QVP-7370.1(e) is then reduced to the maximum design pressure for which the valve is to be qualified. A valve closure cycle is then effected using minimum motive power for the actuator. The closure time shall be observed and recorded for comparison with the baseline measurement of QVP-7331.1(h). Following closure, a valve main-seat leakage test shall be conducted in accordance with QVP-7331.1(e).

(j) With the test loading moment at the same value as in QVP-7370.1(i), a valve opening is made utilizing minimum motive power with maximum closure differential pressure for which the test valve assembly is to be qualified. This pressure differential shall be applied in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. Differential pressure need not be maintained after the test valve assembly is unseated. During this operation, the opening time shall be observed and recorded for comparison with the baseline measurement of QVP-7331.1(h).

QVP-7370.2 Active Self-Operated Check Valves

(a) See QVP-7370.1(a).

(b) See QVP-7370.1(b).

(c) See QVP-7370.1(c).

(d) See QVP-7370.1(d).

(e) See QVP-7370.1(e).

(f) See QVP-7370.1(f).

(g) See QVP-7370.1(g).

(h) See QVP-7370.1(h).

(i) In order to provide a more realistic loading condition on the valve during the valve closure test, the end-loading moment is reduced to the maximum value that the attached piping could impart to the valve and still remain within the ASME Code allowable stresses for the piping. For simplicity, this reduced loading moment is approximated by reducing the end-loading moment to two-thirds of the initial moment obtained in QVP-7370.2(f) and (g). In order to provide a more realistic pressure condition for which the valve actuator is designed to operate against, the test pressure from QVP-7370.2(e) is then reduced to the maximum design pressure for which the valve is to be qualified. A valve closure cycle is then effected. Normal valve movement is required. Following closure, a valve main-seat leakage test shall be conducted in accordance with QVP-7331.1(e). Finally, with the test loading moment at the same reduced value, a valve opening is made.

(j) Performance of this test requires that a test exercising mechanism be provided to enable the cycling of the disk from fully closed to fully open to fully closed again. The exercising mechanism shall be designed so that it imparts minimal additional loads to the valve, allowing normal valve movement to be observed, and so it can therefore be determined that the valve is free of any binding.

QVP-7370.3 Active Pressure Relief Valves

(a) For active pressure relief valves, the end-loading test is commonly known as the *discharge-pipe and reaction-loading qualification test.* This discharge and reaction-loading test demonstrates the operability of the valve when subjected to discharge-pipe, end-load forces for which the test valve assembly is to be qualified.

(b) The magnitude and direction of the discharge-pipe loading force shall be as specified in the test plan.

(c) The test valve shall be installed in a test facility as specified in QVP-7363.3(b) or QVP-7364.3(b) as applicable, with provisions for applying the test loading. Loads shall be verified through instrument readout or recording.

(d) The test shall be conducted as follows:

(1) *Self-Actuated.* With the discharge-pipe static test load applied to the valve, the test pressure shall be applied to the valve inlet for seat leakage testing as specified in QVP-7363.3(d). Record the results. The test valve shall then be operationally tested as specified in QVP-7363.3(c). Record all applicable data. Repeat the seat leakage test as specified in QVP-7363.3(d).

(2) *Externally Actuated.* With the discharge-pipe static load test applied to the valve, the test pressure shall be applied to the valve inlet for seat leakage testing as specified in QVP-7364.3(d). Record the results. The test valve shall then be operationally tested at minimum motive power as specified in QVP-7364.3(c). Record all applicable data. Repeat the seat leakage test as specified in QVP-7364.3(d).

QVP-7380 Seismic Test

QVP-7380.1 Active Power-Operated Valves

(a) The seismic test is intended to demonstrate the operability of a test valve assembly when subjected to a loading that is representative of the specified seismic load qualification level.

(b) The qualification test method shall be determined by whether the test valve assembly is flexible (i.e., has a fundamental frequency less than 33 Hz) or rigid (i.e., has a fundamental frequency greater than or equal to 33 Hz) in its least rigid axis. If the test valve assembly has a fundamental frequency of 33 Hz or greater, as determined by QVP-7340.1, it shall be seismically qualified by testing in accordance with QVP-7381.1. If the test valve assembly has a fundamental frequency less than 33 Hz, as determined by QVP-7340.1, it shall be seismically qualified by testing in accordance with QVP-7382.

(c) Complex actuators, such as electric actuators, hydraulic actuators, or large pneumatic piston rotary actuators, etc., whose operability depends to a high degree upon the interdependence of many internal parts, shall have undergone seismic qualification testing in accordance with the applicable portions of IEEE Std 344 prior to meeting the requirements of this Section. Simpler actuators, such as spring-return diaphragm/piston types, which have a minimum of internal parts and whose operability is more dependent upon its structural characteristics, are exempt from the IEEE Std 344 prequalification if the test valve assembly is rigid per the definition of QVP-7380.1(b).

(d) All essential-to-function accessories shall be attached to the valve assembly to satisfy the rigidity requirements of QVP-7380.1(b). The essential-to-function accessories that have not been previously qualified in accordance with IEEE Std 344 as part of the actuator assembly shall be seismically qualified by test in accordance with the test section of IEEE Std 344.

QVP-7380.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7380.3 Active Pressure Relief Valves. See QVP-7380.1.

QVP-7381 Rigid Valve Assemblies

QVP-7381.1 Active Power-Operated Valves

(a) The valve manufacturer is responsible for determining the magnitude of the loading required to simulate the effect of the specified triaxial acceleration g-levels for which the valve is to be qualified. Since the valve assembly is considered to be rigid, the specified seismic g-loads may be simulated by a single uniaxial force concentrated at the center of gravity of the valve extended structure, and applied in the least rigid axis as determined in QVP-7380.1(b), unless a more critical axis can be determined. If desired, the seismic g-levels

may be increased to facilitate later candidate valve qualification of similar valves.

(b) The first step in calculating the seismic test load force F_t is to convert the triaxial acceleration g-level components, acting on the installed valve assembly, into a single resultant uniaxial acceleration g-level by using the square-root-sum-of-squares (SRSS) method. This uniaxial g-level is then multiplied by the weight of the valve extended structure to obtain a qualification load force F_q. This qualification load force may need to be further adjusted to compensate for the effects of gravity on the test valve, depending upon the orientation of the valve assembly during the test.

(02) *(c)* A higher test load force F_t may be selected to ensure adequate margin to meet the candidate valve extension requirements of QVC-7520(a) or QVC-7620(b)(3)(a), and to account for any dimensional or material tolerance differences between the parent valve assembly and any candidate valve assemblies. Unless it can be shown conclusively by analysis or other methods that a lesser adjustment is adequate to account for dimensional and material tolerances, the following relationship should be used to determine the test load force:

$$F_t \geq 1.1F_q$$

where

F_t = test load force, lb_f (N)

F_q = required qualification load force, lb_f (N)

(d) the test operating pressure should be at least equal to the 100°F (38°C) cold-working pressure rating for the valve assembly being qualified; however, a higher test pressure may be selected in order to cover qualification of candidate valve bodies of the same type, but higher pressure rating classifications. In order to ensure the worst-case pressure condition during the seismic test, the test operating pressure shall be greater than that for which the test valve assembly is to be qualified by a factor equal to the ratio of the actual test bar yield strength of the tested body material divided by the specified minimum yield strength of the body material.

(e) The valve assembly shall be installed in a test fixture with suitable provision for imposing the static test load, and such that the valve assembly is mounted by its normal mounting points (usually the valve body ends). The valve mounting shall be sufficiently rigid to resist the applied seismic load and ensure that the load force remains essentially perpendicular to the centerline of the valve extended structure. The test load force F_t shall be applied along the least rigid axis of the valve assembly as determined in QVP-7380.1(b), and shall be concentrated as close to the center of gravity of the valve extended structure as can safely be applied, such that the resulting forces, moments, and torque acting on the yoke-actuator structure in the region from the actuator mounting flange to the valve body are at least equal to the calculated forces and moments that would result from the application of uniform seismic acceleration to the valve assembly.

(f) With the valve in the open position, test operating pressure, as defined in QVP-7381.1(d), shall be established in the valve, and while pressure is maintained, the test load force F_t shall be applied as specified in QVP-7381.1(e).

(g) While maintaining the test load force F_t from QVP-7381.1(c), reduce the pressure in the valve to the designated test pressure for which the valve assembly is to be qualified. A seismic operability test shall then be performed in accordance with QVP-7381.1(h), (i), and (j) below.

(h) The seismic operability test shall be made starting with one full operating cycle utilizing normal motive power at normal room temperature, not to exceed 100°F (38°C). With the valve fully open, the valve body is maintained at the designated test pressure and a valve closure is initiated and timed. One side of the closure is then depressurized to establish the test differential pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. A valve opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated.

(i) Three full operating cycles shall then be performed with the test valve depressurized and utilizing the maximum motive power for actuation. Stroking time shall be measured separately for each half of the cycle for comparison with the baseline measurement of QVP-7331.1(h).

(j) Three full operating cycles shall also be performed utilizing minimum motive power. With the valve fully open, the valve is pressurized at the designated test pressure and a valve closure initiated and timed. One side of the closure is then depressurized to establish the test differential pressure in the specified flow direction, or in the most adverse direction for bidirectional valves [see QVP-7331.1(e)]. A valve opening is then initiated and timed. Differential pressure need not be maintained after the test valve assembly is unseated. Stroking time measurements for each half of the cycle shall be recorded for comparison with the baseline measurement of QVP-7331.1(h).

QVP-7381.2 Active Self-Operated Check Valves. QVP-7381.1 applies with the exception of QVP-7381.1(h), (i), and (j). In addition, the following subsubparagraph applies:

(h) The seismic operability test shall be made starting with one full operating cycle utilizing normal motive power at normal room temperature, not to exceed 100°F (38°C). With the valve fully open, the valve body is pressurized at the designated test pressure. The valve is permitted to close to confirm free movement of the disk.

QVP-7381.3 Active Pressure Relief Valves

(a) See QVP-7381.1(a).

(b) See QVP-7381.1(b).

(c) See QVP-7381.1(c).

(d) QVP-7381.1(d) is not applicable to active pressure relief valves.

(e) See QVP-7381.1(e).

(f) The test shall be conducted as follows:

(1) *Self-Actuated.* With the load applied, conduct the performance tests defined in QVP-7363.3(c) and record all applicable results. The deflection of the center of gravity of the upper structure in the direction of the application of the load relative to the valve body shall be measured and recorded.

(2) *Externally Actuated.* With the load applied, conduct the minimum motive power performance tests defined in QVP-7364.3(c) and record all applicable results. The deflection of the center of gravity of the upper structure in the direction of the application of the load relative to the valve body shall be measured and recorded.

QVP-7382 Flexible Valve Assemblies. Test valve assemblies that are classified as flexible per the definition of QVP-7380.1(b) shall be seismically qualified by test in accordance with the test section of IEEE Std 344.

QVP-7383 Combined Seismic and Discharge-Pipe Loading Test

QVP-7383.1 Active Power-Operated Valves. Not applicable to active power-operated valves.

QVP-7383.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7383.3 Active Pressure Relief Valves

(a) This loading test demonstrates the operability of the test valve assembly when subjected to a combination of seismic and discharge-pipe loading forces.

(b) The test valve assembly shall be installed in a test facility as specified in QVP-7381.1(e).

(c) The test shall be conducted as follows:

(1) *Self-Actuated.* Apply test loads specified in QVP-7381.1(c); then apply test loads specified in QVP-7370.3(b) such that the load combination simulates the most severe condition. Perform the tests and record the results specified in QVP-7370.3(d)(1).

(2) *Externally Actuated.* Apply test loads specified in QVP-7381.1(c); then apply test loads and perform the tests specified in QVP-7370.3(d)(2).

QVP-7390 Flow Interruption and Functional Capability Demonstration

QVP-7390.1 Active Power-Operated Valves. The flow interruption capability demonstration is intended to verify the ability of the valve assembly to open or close against substantial flow that can cause large dynamic fluid forces on the valve disk, which the actuator must overcome. This capability can be demonstrated by test as described in QVP-7391.1, or by analysis as described in QVP-7392.1, provided that sufficient test verification exists to justify the analysis methods used, over the qualification conditions involved. As a minimum, verification of the analysis used in QVP-7392 shall meet all the requirements of QVC-7300 and QVC-7400.

QVP-7390.2 Active Self-Operated Check Valves

(a) The valve functional test is a procedure developed to establish key performance parameters necessary for the evaluation of valve adequacy for service applications involving flow reversal and resulting pressure surge produced by valve closure, the evaluation of valve tendency to wedge-lock the disk in the seat following a maximum differential pressure closure, and the evaluation of proper valve sizing to maintain the valve disk in the fully open position under normal flow conditions.

(b) For the evaluation of valve adequacy to handle flow reversals, it is required that a math model or the equivalent be developed and demonstrated, by the representative dynamic flow reversal tests, as conservatively adequate for the prediction of pressure surge levels.

QVP-7390.3 Active Pressure Relief Valves. Flow interruption is inherently demonstrated on pressure relief valves during all cycle or operational performance tests. No other individual tests are required to demonstrate this capability.

QVP-7391 Test Method

QVP-7391.1 Active Power-Operated Valves

(a) The test valve assembly shall be installed in a pipe run connected to a reservoir sufficient to supply the required flow and to simulate the desired operating conditions. Instrumentation shall be provided to simultaneously record the valve disk travel, upstream pressure, and downstream pressure. Supplementary instrumentation shall be provided to measure the flow or to permit calculation of the flow during the closure part of the test cycle.

(b) Prior to the initiation of the test, the valve will be closed and the working fluid upstream of the valve shall be raised to and maintained at the pressure for which the valve is to be qualified. The pressure downstream of the valve shall be at ambient pressure.

(c) The test will be initiated by opening the valve against the full inlet pressure. Once fully open flow condition has been established, the valve will again be closed. To the extent practical, the pressure differential across the valve for the entire valve travel cycle should be maintained at the maximum pressure differential for which the valve is to be qualified. For rotating-stem/shaft type valves, such as butterfly or ball valves, where the maximum torque has the potential for occurring at

larger angles of opening, or for balanced-disk designs of sliding-stem valves where the maximum thrust requirements may not occur near the closed position, the analysis methods of QVP-7392.1 should be used to qualify the valve when the test facility is unable to maintain the appropriate pressure differential throughout the full closure range. Significant deviations from this procedure must be thoroughly justified.

(d) The valve cycle shall be effected using the minimum motive power of the actuator. Following completion of the final valve closure, an observation shall be made of the seat leakage using the maximum seat-sealing differential test pressure as defined in QVP-7331.1(d).

(e) The requirements of QVP-7392.1(b) and (c) shall also be met with regard to actuator stall condition loads.

(f) During this test sequence, functional test measurements shall be established as appropriate for the particular valve-actuator assembly to be qualified. The functional measurements shall include measurement of the torques and/or thrusts required to operate the valve for the entire range of pressure differential and flow conditions for which the valve is to be qualified, and the torque and/or thrust delivered by the valve actuator. For electric-motor-driven actuators, the delivered torque and/or thrust shall be measured at minimum, normal, and maximum input voltage. In addition, the functional performance characteristics of the valve-actuator assembly shall be established by measurement of the appropriate input signal and resulting valve disk position over the complete stroking range of the valve. The valve operating conditions, including upstream pressure, downstream pressure, pressure differential across the valve disk, stroking time, fluid flow, and fluid temperature, shall be measured and recorded.

(g) In order to demonstrate that no physical damage to the valve has occurred that will interfere with subsequent cycling of the valve, the valve shall be cycled open and closed a second time per the requirements of QVP-7391.1(b) and (c). The maximum motive power of the actuator shall be used during this test.

QVP-7391.2 Active Self-Operated Check Valves

(a) Flow Reversal Test

(1) The test valve assembly shall be installed in a piping system for water flow testing suitable for production of flow reversal at controlled rates of acceleration, from an initial velocity adequate to hold the test valve closure element in its fully open position.

The downstream pipe section shall be the same nominal size as the valve, and shall have a wall thickness adequate for service at the maximum pressure for which the valve is rated. The length of the upstream and downstream piping shall be reasonably representative of practical service conditions. Instrumentation shall be capable of recording time charts or digital equivalent of flow velocity, upstream pressure, and downstream pressure as a function of time.

(2) Tests shall be performed by establishing full forward flow or full opening of the valve, initiating flow reversal, and observing the behavior of the valve and the upstream and downstream pressures, and verifying that the valve disk closes as specified in the functional specification.

(3) Tests at varying rates of flow reversal shall be made to demonstrate the validity of the math model prediction of surge pressure.

(4) Free closing valves, in which there is no quantifiable restraint on the closure element as it approaches the seated position other than its inertia, will produce significant pressure surge as a function of the reverse velocity of the test fluid at the instant-of-closure seat contact. Tests of free closing valves shall include at least:

(a) one test that produces an instant-of-closure velocity at least equal to the corresponding highest instant-of-closure velocity for which the valve is to be qualified; or

(b) three tests at significantly different instant-of-closure velocities, to provide math model data adequate to establish credibility of extrapolations of performance at reverse velocities exceeding the test values.

(5) Controlled closure valves, in which closure element approach to the seated position is forcefully restrained, shall be tested for at least three significantly different rates of flow reversal to permit verification of the math model for subsequent use in applications analysis.

(6) As soon as conditions permit, following completion of the valve closure, an observation shall be made of the seat leakage under differential pressure.

(b) Disk-to-Seat Wedge-Lock Evaluation Test

(1) For valves requiring this test, it will be necessary to install the test valve assembly in a piping system capable of applying a static pressure differential across the closed valve equal to the maximum total static-plus-dynamic differential pressure for which the valve is to be qualified.

(2) If valve design is to be qualified for applications at elevated temperature [above 212°F (100°C)], provision will be required for heating the assembly to the desired qualification temperature for an additional test.

(3) Valves having a body and/or disk seating taper angle greater than 29 deg (cone angle greater than 58 deg) are not required to be tested.

(4) For this test it is important that the body and disk seating surfaces are chemically clean and that there is no contaminant in the test fluid that would produce lubricity greater than that of potable water.

(5) Valves shall be subjected to a static closed pressure differential equal to the maximum static-plus-dynamic pressure differential for which the valve is to be qualified. The pressure shall then be removed, and

a determination made that the valve can open normally with a minimum of fluid pressure in the flow direction.

(6) If the valve is to be qualified for elevated temperature [above 212°F (100°C)], repeat as in the sequence above after raising the temperature of the contained test fluid to the desired qualification temperature. Both the test pressure and temperature will determine the conditions for which the test will qualify the valve, and the pressure need not be the same as for the cold opening test.

(c) Fully Open Valve Disk Flow Test

(1) The test valve assembly shall be installed in a piping system capable of incremental increasing of forward flow until the valve disk reaches its fully open and stable position. The valve shall be protected against system turbulence. A typical method would be to provide a straight section of pipe at least ten diameters in length upstream of the valve inlet.

(2) The test fluid shall be of equal or less density than the fluid of the valve application.

(3) The test valve shall include a means to verify the valve disk position. Instrumentation of the test system shall be capable of determining the flow velocity and fluid conditions.

(4) The mass flow rate required to ensure full travel of the disk to stable contact with a stop shall be determined. At the fully open, stable flow condition, the flow velocity and fluid condition (data to determine the mass flow rates) shall be recorded. Three test runs shall be performed to verify the fully open, stable characteristics of the valve.

QVP-7391.3 Active Pressure Relief Valves. Not applicable to active pressure relief valves.

QVP-7392 Analysis Method

QVP-7392.1 Active Power-Operated Valves

(a) The analysis method must demonstrate that the force or torque produced by all the possible loading effects on the valve disk must not over-stress the valve disk, valve stem/shaft, or any connecting linkages to the valve actuator. It must also show that the clearances (including manufacturing tolerances) in the valve disk-to-body guide will not permit sufficient disk movement to cause excessive bearing loads. In addition, it must be demonstrated that the minimum force or torque produced by the actuator is capable of overcoming all the applied loads on the valve.

(b) Calculate, as a function of valve opening, the maximum force or torque produced on the valve disk and stem/shaft due to dynamic flow loads, pressure unbalance loads, bearing and packing friction loads, seat loads, unbalanced weight loads, seismic loads, actuator stall condition loads, and any other loads appropriate for the given application. For some valve designs it may be possible to justify that maximum force or torque conditions occur near the closed position of the valve, and calculations need only be made at this condition; however, for many rotary valves or some balanced-disk design sliding-stem valves, it may be necessary to perform these calculations considering each major increment of valve opening.

(c) Determine the capability of all essential-to-function parts to withstand the applied force or torque that is calculated in QVP-7392.1(b).

(d) Demonstrate that the minimum force or torque capable of being developed by the actuator exceeds the applied loads from QVP-7392.1(b).

QVP-7392.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7392.3 Active Pressure Relief Valves. Not applicable to active pressure relief valves.

QVP-7393 External Environment Effects Test (Self-Actuated Only)

QVP-7393.1 Active Power-Operated Valves. Not applicable to active power-operated valves.

QVP-7393.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7393.3 Active Pressure Relief Valves

(a) The external environment effects test demonstrates the effects of the external environment on the test valve assembly. The test is intended to induce normal external environmental conditions (temperature, pressure, etc.) that exceed standard design ambient conditions of 40°F (4°C) to 100°F (38°C), and when external pressure can affect pressure relief valve performance, and to determine their effect on valve performance and seat leakage. (02)

(b) The test valve shall be installed for test in the same manner as specified in QVP-7363.3(b).

(c) Provisions for producing the external environment, as defined in the test plan, shall be provided.

(d) With the specified external environment conditions applied to the test valve, perform the tests and record the results specified in QVP-7363.3(c) and (d).

QVP-7394 Thermal Effects Test

QVP-7394.1 Active Power-Operated Valves. Not applicable to active power-operated valves.

QVP-7394.2 Active Self-Operated Check Valves. Not applicable to active self-operated check valves.

QVP-7394.3 Active Pressure Relief Valves

(a) Active pressure relief valves that are required to withstand fluid temperature transients equal to or greater than a temperature change of 500°F (260°C) in 10 sec shall be subject to a thermal shock test to demonstrate that sudden application of hot fluid is not detrimental to the test valve. (02)

(b) The test valve assembly shall be installed in a test facility having the capability of inducing a fast thermal