ASME QME-1–2007

(Revision of ASME QME-1–2002)

Qualification of Active Mechanical Equipment Used in Nuclear Power Plants

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers

Three Park Avenue • New York, NY 10016

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The next edition of this Standard is scheduled for publication in 2010. There will be no addenda issued to this edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Interpretations are published on the ASME Web site under the Committee Pages at http://cstools.asme.org as they are issued.

The American Society of Mechanical Engineers
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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.

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.

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.

The 2002 edition of this Standard was approved as an American National Standard on October 31, 2002.

This Standard was approved as an American National Standard on June 25, 2007.

COMMITTEE ON QUALIFICATION OF MECHANICAL EQUIPMENT USED IN NUCLEAR FACILITIES

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

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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-1–2007
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-1–2007 was approved by the American National Standards Institute on June 25, 2007.

QME-1–2007 includes the following changes identified by a margin note, **(07)**.

Page	*Location*	*Change*
1–6	Section QR	Revised in its entirety
7–23	Nonmandatory Appendix QR-A	Revised in its entirety
78–89	Section QV	Revised in its entirety
90–103	Mandatory Appendix QV-I	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

(07)

QR-1000 SCOPE

This Standard provides the requirements and guidelines for the qualification of active mechanical equipment whose function is required to ensure the safe operation or safe shutdown of a nuclear power plant. In addition to requirements and guidelines put forth in this Standard, the active mechanical equipment shall comply with the requirements of the applicable design and construction codes and standards.

This Standard does not apply to electric components such as motors, electric valve actuators, instrumentation, and controls, which are qualified by conformance with appropriate IEEE standards.

QR-2000 PURPOSE

The purpose of this Standard is to provide the requirements and recommended practices to qualify active mechanical equipment to meet specified functional requirements during operation and during or after any postulated abnormal or accident conditions.

QR-3000 REFERENCES

This Section lists reference documents from which guidance, concepts, principles, practices, criteria, and parameters have been carried forward into 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 (ANS), 555 North Kensington Avenue, LaGrange Park, IL 60526

IEEE Standard 334-1974 (Reaffirmed), Standard for Type Test of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations

IEEE Standard 344-1987, Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854-1331

QR-4000 DEFINITIONS

active mechanical equipment: mechanical equipment containing moving parts, which, in order to accomplish its required function as defined in the Qualification Specification, must undergo or prevent mechanical movement. This includes any internal components or appurtenances whose failure degrades the required function of the equipment.

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.

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.

candidate equipment: active mechanical equipment to be qualified in accordance with the rules of this Standard.

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 supports: structural elements that transmit loads between the components and building structure 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 plant) 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).

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

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.

functionality: ability of an active component to perform the mechanical motion required to fulfill its specified function when subjected to the prescribed service conditions.

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.

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.

may: an expression of permission.

mechanical component: those items of a plant such as pumps, valves, vessels, and piping.

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

modification: a change in a system component or equipment configuration.

natural aging: aging that occurs within normal service environments as opposed to simulated service environments.

operability: see *functionality* for the definition of this term for use in this Standard.

operating basis earthquake (OBE): the vibratory seismic motion associated with the plant shutdown and inspection, which may be identified as a design input as specified by the safety analysis of the plant.

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

prototype equipment: 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*.

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 active mechanical equipment was demonstrated to meet the design requirements for the specified service conditions. (Note that at the end of the qualified life, the active mechanical 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 functionality of the active mechanical equipment.

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

qualified candidate equipment: equipment that has been qualified primarily by methods described in the candidate equipment definition above met in the qualification of the active mechanical equipment.

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

safe shutdown earthquake (SSE): the vibratory seismic motion (greater than the OBE) for which certain structures, systems, and components in a plant are designed to remain functional as specified by the safety analysis of the plant.

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

shake table system: an assembly that is able to induce and control seismic type motion into a test specimen and measure the vibratory responses that are to be documented.

shall: an expression of a requirement.

should: an expression of a recommendation.

test equipment: active mechanical equipment selected for qualification testing.

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

QR-5000 QUALIFICATION PRINCIPLES

The principles pertinent to active mechanical equipment qualification are provided in the following subarticles. 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 Qualification Requirement

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

QR-5200 Approaches to Qualification

Active mechanical equipment shall be qualified by one or a combination of the methods described in Article QR-7000. The requirements generally address a single active mechanical equipment application, but they may envelop the service conditions for more than one application. In addition, a family of active mechanical 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 candidate active mechanical equipment to the reference active mechanical equipment.

The pressure boundary integrity and structural supports of active mechanical equipment shall be qualified in accordance with the applicable design codes and standards.

QR-5300 General Requirements for a Qualification Program

A qualification program for active mechanical equipment shall include the following:

(a) qualification requirements

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

(c) evidence of successful completion of a qualification

(d) documentation containing (a) through (c) above.

The requirements to satisfy (a) through (d) above should be contained in the active mechanical equipment qualification specification.

In a qualification program, aging and qualified life shall be considered as described in the following paragraphs.

QR-5310 Aging. Assessment of active mechanical equipment shall include an analysis and/or evaluation of the active mechanical equipment to determine any significant aging mechanisms, such as thermal, radiation, corrosion, erosion, vibration, aggressive chemical attack, or wear. When one or more mechanisms are identified as significant, the assessment shall be developed as part of the overall qualification program. When natural aging results are utilized in the qualification program, it may not be necessary to conduct a detailed analysis or evaluation to determine significant aging mechanisms.

An aging mechanism is considered significant if it satisfies any 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 active mechanical 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

(d) in the normal service environment, the aging mechanism causes degradation during the design life of the active mechanical equipment that is significant compared with degradation caused by the design basis event

Nonmandatory Appendix QR-B provides supplementary details associated with the qualification of nonmetallic parts.

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

The determination of qualified life shall be based upon engineering analysis and/or evaluation in these instances. The analysis and/or evaluation should take into account, if available, the following:

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

(b) active mechanical equipment operating data

(c) previous test results for the same material and the same type of 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 active mechanical equipment item may be changed during its installed life where justified. For example, the qualified life of active mechanical equipment may be limited by certain internal components or appurtenances that have a shorter qualified life than the installed life of the equipment. By periodic replacement of those internal components or appurtenances, the qualified life of the active mechanical equipment may be extended.

QR-6000 QUALIFICATION SPECIFICATION

The qualification specification for active mechanical equipment shall describe the requirements to be met to qualify the active mechanical equipment for its intended application. This forms the basis for development of an active mechanical equipment qualification program. As a minimum, the following shall be included in the qualification specification. The qualification specification shall state whether function is required during, after, or during and after the design basis event.

(a) Active mechanical 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 shall remain operable, shall be specified.

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

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

(d) The qualification specifications for active mechanical equipment within the scope of this Standard shall reference specifically invoked Codes and Standards. For example, Section QP (Qualification of Active Pump Assemblies) may furnish a substantial part of the qualification program for a complete pump assembly.

(e) The service conditions and concurrent loads for the active mechanical equipment shall be specified. Examples of such parameters are earthquakes, internal and external pressures/temperatures, relative humidity, radiation, vibration, corrosion effects, transients, etc.

(f) Required margin in the qualification parameters shall be specified to account for a variation in performance, errors in experimental measurements, and variations in production, thereby providing a level of confidence that the active mechanical equipment will perform under the most adverse service conditions for which it is qualified.

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

(h) 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.

(i) Active mechanical equipment qualification documentation shall be included as described in Article QR-8000.

QR-7000 QUALIFICATION PROGRAM

QR-7100 General Requirements

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

QR-7200 Review for Potential Malfunctions

The selection of methods for qualifying active mechanical equipment shall consider potential malfunctions that would degrade the required functions as defined in the Qualification Specification (QR-6000).

Components and subassemblies that are not involved in the active mechanical equipment's function may be excluded from the qualification process if it can be shown that their malfunctions have no effect on the specified function of the active mechanical equipment.

QR-7300 Selection of Qualification Methods

Qualification shall be accomplished by test, analysis, use of earthquake experience data, similarity, or some combination of these methods. Regardless of the qualification method, rationale shall be provided to show that the functionality of the active mechanical equipment cannot be degraded to the point that it cannot perform its specified function. In addition, the method selected shall account for the pertinent interface parameters.

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

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

QR-7311 Aging. Significant aging mechanisms shall be identified and accounted for in an aging program using such methods as cycling, damage due to erosion or corrosion, overstress, and time compression for accelerated aging. The aging acceleration rate and basis upon which the rate was established shall be described and justified. If natural aging is utilized, determination of significant aging mechanisms is not necessary. Components subject to different aging mechanisms of wear or environmental degradation can be separately aged.

QR-7312 Dynamic Loading. Qualification of active mechanical equipment for dynamic loadings, such as but not limited to vibration and seismic loadings, should consider the requirements and general approaches outlined in Nonmandatory Appendix QR-A and IEEE Standard 344. Active mechanical equipment shall be demonstrated capable of performing its defined function before, during, or after a design basis event as specified in the qualification specification. If specified, functionality of equipment during a dynamic transient shall utilize the normal system fluid. Use of an alternative fluid is acceptable, if justified.

QR-7313 Qualification. Interfaces and interrelationships between components shall reflect the in-plant configuration. Otherwise, active mechanical equipment shall be tested as an assembled unit. Active mechanical equipment shall be considered to be qualified by test if it can be demonstrated to meet or exceed its specified functions for applicable design basis and postdesign basis events at the end of its qualified life. Active mechanical 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 the assessment of stresses, strains, loads, or displacements against allowable capacity limits. The basis for assumptions and extrapolations shall be documented. 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. Aging can be a concern for metallic and nonmetallic components. Analysis may be used for aging in a supporting capability to simplify or extend active mechanical equipment qualifications in special circumstances.

(a) Analysis may be used to eliminate consideration of environmental stresses or aging effects which have an insignificant impact upon active mechanical equipment functional integrity.

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

When analysis is utilized to simplify or extend active mechanical equipment qualification, the analysis shall consider significant aging mechanisms for the item. Analysis methods can be used in conjunction with supportive empirical data to simplify or supplement the test aging exercise for nonmetallic items.

QR-7322 Dynamic Loading. Active mechanical equipment qualification for dynamic loadings, such as but not limited to vibration and seismic, should consider analytical procedures detailed in Nonmandatory Appendix QR-A, IEEE Standard 344, or other acceptable industry practices, as documented in the Qualification Report.

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

QR-7330 Qualification by Earthquake Experience. Data from the earthquake performance of active mechanical equipment may be used as the basis for seismic qualification. Qualification of active mechanical equipment by use of earthquake experience should consider the requirements in Nonmandatory Appendix QR-A.

QR-7331 Aging. Significant aging mechanisms shall be identified. If aging mechanisms are anticipated in the candidate equipment, which are not represented in the earthquake experience, then qualification methods other than earthquake experience may be required.

QR-7332 Dynamic Loading. Significant dynamic loads not represented in the earthquake experience that act concurrently with seismic loads for the candidate equipment shall be addressed by supplemental qualification methods.

QR-7333 Qualification. The candidate equipment shall be considered to be qualified by earthquake experience if demonstrated to be bounded by the body of documented equipment performance from facilities that experienced natural earthquakes.

QR-7340 Qualification by Similarity. There are many instances of active mechanical equipment similar to a type that was previously qualified, which differs only in size or in the assembly or structure. The candidate active mechanical equipment may be qualified by demonstrating that it is similar in excitation and physical and dynamic characteristics to the previously qualified active mechanical equipment. The validity of this method depends on demonstrating similarity of the candidate active mechanical equipment and the previously qualified active mechanical equipment [QR-3000(b)].

QR-7350 Combined Methods. Active mechanical equipment may be qualified by a combination of test, analysis, and earthquake experience or similarity provided partial qualification achieved under multiple procedures can be articulated in a logical fashion to justify the overall equipment qualification. For example, where size, application, time, or other limitations preclude the use of a test on the complete active mechanical equipment assembly, testing of components supplemented by analysis may be used in the qualification process.

QR-8000 DOCUMENTATION

A Qualification Report shall be prepared. The Qualification Report shall establish that the active mechanical equipment is qualified for its application and meets its qualification specification requirements as defined in QR-6000. Documentation shall demonstrate that

(a) the qualification requirements are satisfied

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

In addition, any aging processes not treated during initial qualification, but addressed by in-service surveillance monitoring, shall be specifically identified.

Qualification documentation shall be prepared and maintained in accordance with the Owner's applicable Quality Assurance Program.

Nonmandatory Appendix QR-A Seismic Qualification of Active Mechanical Equipment

(07)

QR-A1000 SCOPE

This Nonmandatory Appendix applies to active mechanical equipment in nuclear power plants that must be qualified to function when subjected to earthquake (seismic) loads.

QR-A2000 PURPOSE

The purpose of this Nonmandatory Appendix is to provide the requirements and recommended practices to demonstrate that active mechanical equipment in nuclear power plants can function during or following design basis earthquake.

QR-A3000 REFERENCES

The references listed below have been used to obtain guidance, concepts, principles, practices, and criteria in the preparation of this Nonmandatory Appendix.

ANSI/ASME OM-S/G-2000, "Standards and Guides for Operation and Maintenance of Nuclear Power Plants," Part 3 "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems"

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036

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

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

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

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2300, Fairfield, NJ 07007-2300

EPRI NP-5228-SL, Seismic Verification of Nuclear Plant Equipment Anchorage (Revision 1), Volume 1: Development of Anchorage Guidelines, June 1991

Publisher: Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304

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

Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854-1331

Advanced Light Water Reactor (ALWR) First-of-a-Kind Engineering Project on Equipment Seismic Qualification, Advanced Reactor Corporation (ARC), April 1995

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

NRC Supplemental Safety Evaluation Reports on the GIP, Revision 2, Corrected 2/14/92 (SSER No. 2) and the GIP, Revision 3, Updated 5/16/97 (SSER No. 3), U.S. Nuclear Regulatory Commission

NUREG/CR-6464, "An Evaluation of Methodology for Seismic Qualification of Equipment, Cable Trays, and Ducts in ALWR Plants by Use of Experience Data." USNRC, 1997

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 Values for Seismic Design of Nuclear Power Plants, U.S. Atomic Energy Commission, Washington, D.C., 1973

Regulatory Guide 1.100, Revision 2, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants, June 1988

SQUG Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, Revision 3, Updated May 16, 1997, Seismic Qualification Utility Group (SQUG)

Standard Review Plan Section 3.7.2, Seismic Systems Analysis, NUREG-0800 1987

Standard Review Plan Section 3.7.3, Seismic Subsystem Analysis, Rev. 2, NUREG-0800, August 1989

Standard Review Plan Section 3.10, Seismic and Dynamic Qualification of Mechanical and Electrical Equipment, NUREG-0800, 1987

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

QR-A4000 DEFINITIONS

The definitions below establish the meanings of words in the context of their use in this Appendix. The definitions in Section QR are also applicable for use in this Appendix.

acceleration design value (ADV): acceleration value that may be used as an alternative response spectrum or time history to define seismic input for design of active mechanical 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.

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

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 0, for unrelated, to 1, 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 0, for unrelated, to 1, 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 which 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.

earthquake experience spectrum (EES): the earthquake-based response spectrum that defines the seismic capacity of a reference equipment class.

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.

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 active mechanical equipment.

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

foundation: the structure that supports or otherwise provides restraint to active mechanical equipment and buildings.

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

fragility: susceptibility of active mechanical 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).

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.

inclusion rules: the physical and operational characteristics that define an acceptable range of equipment physical characteristics, dynamic characteristics, and functions for ensuring seismic ruggedness and defining the bounds of active mechanical equipment included in a reference equipment class (see QR-A7421).

independent items: items of equipment which have different physical characteristics or experience different seismic motion characteristics, e.g., different earthquakes, sites, buildings, or orientations/locations in the same building.

in-line active mechanical equipment: active mechanical equipment whose loads are caused by the distribution system in which it is installed.

load path: structural path necessary to transmit the seismic forces from the active mechanical equipment centers of mass through to the anchorage.

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

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

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

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 2.

power spectral density (PSD): the mean squared amplitude per unit frequency of a waveform. PSD is expressed in grams squared per Hertz versus frequency for acceleration waveforms.

prohibited features: design details, materials, construction features, or installation characteristics that have resulted in seismic-induced failure or malfunction of active mechanical equipment at earthquake excitations up to and including the defined seismic capacity level.

qualification life: see definition in Section QR.

reference equipment class: a group of active mechanical equipment sharing common attributes as defined by a set of inclusion rules and prohibited features.

reference site: a site containing active mechanical equipment or items used to establish a reference equipment class.

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

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

resonance frequency: a frequency at which peak response occurs in a structure, component, or 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.

rigid equipment: active mechanical equipment, including the effects of the active mechanical equipment supports, whose lowest natural frequency is greater than the frequency value at the start of the zero period acceleration (ZPA) or the cutoff frequency of the applicable response spectrum.

ruggedness: ability of active mechanical equipment to maintain its structural integrity and perform its specified function when subjected to dynamic excitation.

seismic proof test: a seismic test conducted to a specified required response spectrum level.

Seismic Qualification Specification (SQS): the document that describes the seismic qualification requirements to be met in the qualification of the active mechanical equipment.

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 makes an item, such as a building or support, designed to sustain a load.

structural diameter: the diameter of a circle having the equivalent area of the facility foundation.

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

system: an assembly or grouping of active mechanical 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: the transfer function is 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 is referred to as zero period acceleration or generally called ZPA. This acceleration corresponds to the maximum acceleration amplitude of the time history used to derive the spectrum.

QR-A5000 EARTHQUAKE ENVIRONMENT AND EQUIPMENT RESPONSE

This Section provides background on earthquake behavior and 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. The ground motion is typically broadbanded and random, and amplified response can occur over a frequency range of 1 Hz to 33 Hz.

QR-A5200 Active Mechanical Equipment on Foundations

The vibratory nature of the ground motion (both horizontal and vertical) can be amplified or attenuated for in-structure, mounted active mechanical 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 foundation. The response spectra, which describe ground motion, are typically broadband, indicating that multiple frequency excitation predominates.

QR-A5300 Active Mechanical Equipment on Structures

The 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 active mechanical 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 indicates that single frequency excitation of active mechanical equipment subcomponents can predominate.

QR-A5400 Active Mechanical 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, which typically reduces the response of the in-line equipment, is often conservatively neglected. The seismic input motions for components mounted on flexible systems may be defined in terms of required input motion (RIM). 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 active mechanical 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 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 should be recognized and accounted for to accurately predict or bound the active mechanical 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 active mechanical equipment. Such examples include the closing of gaps between the active mechanical equipment and its supports or restraints and the high-frequency rattling of valves subject to piping interaction with supporting or adjacent active mechanical equipment on structures. When such nonlinear response conditions exist, the qualification procedure shall account for such behavior.

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 active mechanical equipment qualification. The form of the simulated seismic input used for qualification of equipment by analysis or testing may 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 active mechanical equipment is to be mounted. It is supplied by the Owner or designee to the manufacturer as a part of the Seismic Qualification Specification (SQS) 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 active mechanical equipment may be mounted, the directional components of the motion and their application to the active mechanical equipment shall be specified. Active mechanical equipment can be mounted at varying locations. In addition, the mounting or anchorage of the active mechanical equipment can affect the seismic response of the active mechanical equipment. In generation of the postulated earthquake environment, these factors should be considered and incorporated as required.

QR-A5610 Required Input Motion. The test input motion in terms of accelerations, velocities, or displacements is expressed as a function of frequency, which is applied in the form of a continuous series of sine beats or sinusoids at defined amplitudes and durations over the frequency range of interest (typically 1 Hz to 33 Hz) and shall be consistent with the requirements of IEEE Standard 344-1987 [QR-A3000(a)].

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 ZPA 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 shall be given separately in the SQS)

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

The application of different waveforms shall meet the requirements of IEEE Standard 344-1987 [QR-A3000(a)].

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 such 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.

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

Although, unlike the time history, the PSD function does not define the unique waveform or duration of the excitation, it is a valuable tool. It enables significant frequency-dependent properties of the motion to be seen at a glance from one curve. If only one time history is used to match a given required response spectrum, the PSD should be used to ensure proper frequency content of the time history.

QR-A5640 Acceleration or Equivalent Static Load Design Values. Components or active mechanical 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. The ADV shall be provided in the Seismic Qualification Specification (QR-A8200). When a response spectrum is specified, the ADV is determined by use of the peak spectral acceleration of the applicable required response spectrum or the ZPA if the component can be shown to be rigid. A coefficient of 1.5 times these peak values is often used to account for multimode and multiple frequency response. However, values less than 1.5 may be used if justified [see QR-A3000(c) and (j)].

QR-A6000 SEISMIC QUALIFICATION REQUIREMENTS

The seismic qualification of active mechanical equipment should demonstrate the ability of the active mechanical equipment to perform its specified function during and/or after the time it is subjected to the earthquake loadings defined in the seismic qualification specification. The most commonly used methods for seismic qualification of active mechanical equipment are described in this document. The methods are grouped into the following five general categories:

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

(b) test the active mechanical equipment under simulated seismic conditions

(c) qualification of the active mechanical equipment by extrapolation of tests or analysis results from similar equipment (similarity)

(d) qualify the active mechanical equipment by use of earthquake experience data

(e) perform evaluations of the active mechanical equipment by combined analysis, test, and/or experience data

Each of the preceding methods may be used to verify the ability of the active mechanical 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 functions of active mechanical equipment require a demonstration of functionality during the earthquake, the active mechanical equipment specified function shall be demonstrated during the strong-motion portion of the earthquake.

The effects of active mechanical equipment repairs and part replacements on the performance of active mechanical equipment in the qualification programs shall also be considered.

QR-A6100 Design Basis Earthquake

The Design Basis Earthquake for which active mechanical equipment shall be qualified is the SSE. Seismic qualification for functionality for the OBE shall be conducted if required in the Seismic Qualification Specification by the Owner or designee. In such instances, the methods and procedures contained in this Appendix

Table QR-A6210-1 Damping Values: Percent of Critical Damping

Structure or Component	Earthquake Magnitude: Operating Basis Earthquake	Earthquake Magnitude: Safe Shutdown Earthquake
Equipment	2	3
Piping systems	5	5
Welded steel structures	2	4
Bolted steel structures	4	7

may also be used to qualify active mechanical equipment for the OBE.

QR-A6200 Damping

QR-A6210 Introduction. Damping is the generic name ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends on many parameters, such as the structural system, modes of vibration, strain levels, velocity, material properties, joint slippage, etc. In linear vibration theory, the simplifying assumption is made that damping is purely viscous or proportional to the relative velocity of moving parts. Therefore, when a value of damping is associated with a practical system, it is usually assumed to be equivalent viscous or linear. This is a convenient way of relating real-world hardware behavior, which is usually nonlinear to some degree, with theoretical concepts, which normally utilize linear methods of analysis.

For active mechanical 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 damping may vary from place to place depending on the numerous other factors previously mentioned and may 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. For such instances, it is recommended that the best estimate values of structural damping be used in active mechanical 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 for Response Spectrum Modal analysis.

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.

QR-A6220 Measurement of Damping. Linear vibration theory indicates that there are numerous methods available to measure damping. Considerable care shall be exercised in making the transition from an idealized model to a practical system. For example, it is rarely possible to locate precise points in active mechanical equipment that have exact correspondence with the lumped mass elements in a model. Some methods of calculating modal damping, such as the Q method, rely purely on single-degree-of-freedom assumptions.

Damping is calculated directly from the maximum response at the resonance peak measure at any point in the active mechanical equipment and the magnitude of the sine sweep input excitation. These methods are not generally acceptable since the response of points in active mechanical equipment is usually determined by the mode shape vector and participation factor for each vibration mode. The following methods for evaluating the damping are commonly used, but other justifiable methods may be used. These methods assume that a single mode of vibration can be excited in the active mechanical equipment and that motion transducers are mounted at positions other than at a point of zero motion. In all cases, care should be exercised to determine whether damping nonlinearity with responses amplitude is 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. The active mechanical equipment is typically excited with a slow sine sweep test. The response of any desired location in the equipment is measured and plotted as a function of frequency. The damping associated with each mode may 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. The active mechanical equipment is typically excited by swept sine, random, or transient excitation, and a response transfer function is developed. The modal damping to the actual frequency is obtained by fitting a mathematical model to the actual frequency response data (transfer function). This curve fitting will smooth out any noise or small experimental errors.

QR-A6230 The Application of Damping. Ranges of damping, measured as described in QR-A6220, are valuable data for the active mechanical equipment designer. Damping is used differently in analysis and testing in active mechanical equipment qualification as described in QR-A6231 and QR-A6232.

QR-A6231 The Application of Damping in Analysis. In analysis, a mathematical model is made of the active mechanical equipment so as 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 active mechanical equipment to enable the response to be accurately predicted. An alternative approach is to use a conservative value of linear damping, such as shown in Table QR-A6210-1, to obtain a conservative estimate of response. In any case, there is need to know the ranges of damping for the specific equipment and nature of nonlinearities and their effect on the response. Appropriate values of damping shall be obtained from tests or other justifiable sources.

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

Generally, most treatment of structural systems assumes viscous damping; however, certain cabinets or housings may exhibit nonviscous damping. The treatment of such a problem is analytically complex and shall be performed using appropriate techniques.

QR-A6232 The Application of Damping in Testing. In testing, the active mechanical equipment may be qualified by subjecting it to a simulated seismic motion as defined by the required response spectrum (RRS). The response spectrum defines the seismic motion by way of 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 active mechanical equipment damping (Note the distinction from the use of the RRS in analysis where the value of damping shall be related to the actual active mechanical equipment). The application of the RRS and the test response spectrum (TRS) in selecting acceptable test motions is given in QR-A7200. The following relationships exist for the values of damping in the response spectra:

(a) In comparing the RRS with the TRS, the damping in the two should be the same.

(b) In some cases, however, when past test data are used for a new RRS, the damping in the two cases may be different, and the following circumstances apply:

(1) When the damping for the TRS is greater than that for the RRS and the criteria in QR-A7200 are satisfied, then the qualification is acceptable since under this circumstance, it is conservative.

(2) When the damping in the TRS is less than that in 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 and apply the criteria given in either (a) or (b)(1) above.

QR-A6300 Required Response Spectrum

The response spectrum to be used in seismic qualification of active mechanical equipment is the required response spectrum (RRS) as provided in the Seismic Qualification Specification by the Owner or designee. The RRS is typically the building filtered response spectrum at mounting location of the active mechanical equipment. For in-line active mechanical equipment qualified in accordance with QR-A7400, the RRS is typically the building filtered response spectrum at the distribution system support attachments to the building.

QR-A6400 Required Input Motion

Required input motion (RIM) in seismic evaluations is normally associated with active mechanical equipment 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 active mechanical equipment 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 by the RIM 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 active mechanical equipment.

For the cases where 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, as provided in QR-A6300, 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

Active mechanical equipment may be seismically qualified analytically by use of acceleration design values (ADV) used to develop equivalent static loads. These are single value accelerations which shall be applied statically to the active mechanical 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 required response spectrum or from the ZPA of the required response spectrum if rigidity can be demonstrated. The response spectral peak value 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 active mechanical equipment supported at more than two points, a coefficient of 1.5 shall be used unless adequate justification for a lower value is provided.

QR-A6600 Differential Support Motion

In addition to the inertial loading developed from seismic accelerations, additional loads may be induced on active mechanical equipment supported at two or more points which are undergoing relative support motion associated with the motion of the supporting structures. In general, most active mechanical equipment is supported at a single point or 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 active mechanical equipment, except for active mechanical equipment or a component that is supported at three or more points on the same structure, at two or more points on different structures, or between in-line components and the supporting structure. In these cases, the active mechanical equipment qualification shall consider the effects of differential support motions.

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 shall be predicted by the relationship

$$Z_d = Z_a g/w^2$$

where

g = gravitational constant

w = equal to the predominant frequency of the primary support structure in radians per second

Z_a = spectral acceleration in g at the ZPA end of the spectrum curve

The relative displacements between supports shall 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.

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

QR-A6700 Loads to Be Considered in Qualification

The loads to be considered in the seismic qualification of active mechanical equipment are defined in the Qualification Specification. They shall be made part of the Seismic Qualification Specification required to seismically qualify the required function or performance of the active mechanical equipment.

QR-A6800 Fatigue and Aging Considerations

QR-A6810 Fatigue. Equipment qualification for multiple seismic events of lower levels than the required response spectrum, such as five OBEs, is achieved when applying the methods of this Section to the evaluation of the single enveloping required response spectrum, provided the equipment is shown to have no credible, low-cycle fatigue failure modes considering the number of specified earthquake cycles. For applications that involve fatigue-sensitive features, supplementary analysis is required.

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 limited. This Appendix assumes for ASME Class 1 components that there are 60 full-stress cycles during the plant life. This cyclic input assumes the potential of five OBEs or aftershocks and one SSE.

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 that they do not exceed the endurance limit for the material used in the equipment [e.g., ANSI/ASME OM-S/G-2000; see QR-A3000].

The use of this Standard for the qualification of equipment fabricated from nonmetallic materials might not preclude fatigue failure for low cycle loading up to 60 cycles. If such fatigue failure is possible, it is recommended that such materials be qualified by separate tests or use of acceptable alternative techniques to ensure no fatigue failure.

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 effects for active mechanical equipment shall be addressed to ensure functionality for the life of the equipment.

QR-A6900 Installation of Active Mechanical Equipment in the Nuclear Power Plant

It is the responsibility of the Owner or his designee to ensure that the method used to support the active mechanical equipment when installed in the plant is consistent with the support method used in the equipment qualification and meets the plant design basis requirements.

QR-A7000 QUALIFICATION METHODS

There are five methods, listed below, that may be applied for the seismic qualification of active mechanical equipment.

(a) qualification by analysis
(b) qualification by testing
(c) qualification by similarity
(d) qualification by earthquake experience data
(e) qualification by a combination of the above methods

QR-A7100 Qualification by Analysis

QR-A7110 Introduction. Analytical procedures are summarized and referenced in this subarticle, which may be used to demonstrate that active mechanical equipment meet the specified structural integrity and functionality requirements during and/or following the earthquake loadings defined in the Seismic Qualification Specification (QR-A8200). Analysis without testing or earthquake experience data is acceptable only if structural integrity as defined in QR-A4000 can ensure the design-intended function. Functionality analysis is limited to applications which can be quantified in terms of a parameter (e.g., gap clearance) that can be calculated and a margin to loss of functionality can be established.

Two approaches to seismic analysis are described. One approach is based on dynamic analysis, the other on static analysis. The methods described are most commonly used, but other methods may be used if they are justified. The general procedure is to

(a) review the active mechanical equipment to assess the dynamic characteristics

(b) determine the response using one or more of several methods described in the following sections

(c) determine the behavior (stresses, deformation, displacements, rotations, loads, loss or initiation of contact at interface, etc.) that results from the response

(d) compare the calculated behavior with those which would ensure compliance with specified function requirements

The review stage shall take into account the complexity of the active mechanical equipment and the adequacy of analytical techniques to properly predict the equipment's functionality while subjected to seismic excitation. The response determination phase of the analysis may take several paths, the first of which is determined by the choice between the dynamic analysis method (QR-A7120) and static coefficient method (QR-A7130). In general, the choice is based on the perceived strength margin of the active mechanical equipment, since the static coefficient method, while easier and more economical to perform, is generally more conservative.

The mathematical models used for analysis shall be based on structural parameters which 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 active mechanical 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. This shall entail sufficient detail to illustrate relative motion of key points, coupling and load transfer, etc. All significant active mechanical equipment that 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 active mechanical 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 shall incorporate the effects of active mechanical equipment mounting and location (floor, wall, etc.), intervening elements and structures (supports, platforms, etc.), intervening systems (pipe, duct, etc.), differential support motion as discussed in QR-A6600, and excitation from other sources. The damping, which is used in the analysis, shall be provided in the Seismic Qualification Specification.

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

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

QR-A7120 Dynamic Analysis

QR-A7121 Introduction. The active mechanical 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 active mechanical 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-A7122 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 shall 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. Closely spaced modes shall be appropriately considered in the response evaluation. Closely spaced modes are those with frequencies differing by 10% or less of the next lower frequency.

QR-A7123 Time Histories. When three components of the statistically independent time histories are input simultaneously for a time history analysis, the responses may 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 Appendix E of IEEE Standard 344.

QR-A7130 Static Analysis. This method of analysis allows a simpler technique, which 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 active mechanical equipment, is applied in the three principal directions with a plus or minus sensing to determine the worse resultant.

QR-A7140 Acceptance Criteria. Acceptance criteria to be used in qualification by analysis shall be applied to the computed parameters associated with the identified failure modes, which determine functional adequacy of the active mechanical equipment. Acceptance criteria shall be established in the input specification requirement. Compliance with the acceptance criteria shall be demonstrated in the Qualification Report.

QR-A7200 Qualification by Analysis

QR-A7210 Introduction. Seismic qualification by testing requires that the active mechanical equipment be subjected to a simulated earthquake motion that is anticipated to occur at the active mechanical equipment mounting. The test shall demonstrate that the active mechanical equipment will perform its specified function during and/or after the seismic event. The nature of the simulated motion can vary significantly, depending on whether the active mechanical 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 Standard 344 since 1975. Since those guidelines were applicable to equipment in general, they have also been used for active mechanical equipment. The policy of this Standard is to generally endorse the continued use of IEEE Standard 344, so Section 7.0 of that document shall provide the detailed requirements for qualification of active mechanical equipment by testing, except as modified by this Standard in QR-A7240. Only some general statements will be included herein, for the sake of continuity.

QR-A7220 Types of Tests

QR-A7221 Exploratory Tests. Exploratory tests consist of the measurements of active mechanical equipment dynamic characteristics by some form of modal identification procedures. The active mechanical equipment is mounted in a close simulation of that anticipated in the field. The active mechanical equipment is instrumented for measurement of responses at various locations anticipated to be important to interior functioning devices or at locations which provide a good indication of structural modal characteristics. It is then subjected to a suitable excitation, and responses are recorded. Components which may in themselves be rigid if flexibly mounted or attached in the field shall have this flexibility represented during the test. In the past, sine sweep resonance tests have been widely used for these tests. However, random excitation or even simulated earthquake events may be used. Exploratory tests are not a requirement for qualification directly and do not serve as the basis for even partial seismic qualification, 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-A7600.

QR-A7222 Seismic Proof Tests. In the past, most active mechanical equipment qualification has been performed by proof test methods. This approach requires that the simulated earthquake motion at the active mechanical equipment mounting represents that anticipated from the specified SSE. The simulated motion usually is required to demonstrate that the test response spectrum (TRS) conservatively envelops the required response spectrum (RRS), which was generated for the active mechanical equipment mounting location as part of the test specification. The result of a proof test is a demonstration that the active mechanical equipment performs its specified function, during and/or after the simulated SSE event.

QR-A7223 Fragility Tests. Fragility tests are conducted to determine the peak amplitude level of a specified excitation waveform for which the active mechanical 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 active mechanical equipment. When the specified motion is compared with that anticipated for the SSE at the active mechanical equipment mounting, a measure of margin is established.

In addition to the response spectrum type of input loading, in-line active mechanical equipment may also be qualified by required input motion (RIM) testing as described in IEEE Standard 382.

QR-A7230 General Approach to Testing

QR-A7231 Preliminary Tests. Exploratory tests described in QR-A7221 are usually performed prior to conduct of 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 shall be performed prior to the seismic test. This sequence ensures that the active mechanical equipment is in the end of the qualified life state at the time of the seismic qualification.

QR-A7232 Development of Simulated Seismic Motion. The simulated seismic motion shall conservatively represent that which can be expected at the active mechanical 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 shall 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 which 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 active mechanical equipment. It shall 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 test response spectrum shall closely envelop the required response spectrum 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-A7233 Conduct of Test and Functionality. Detailed procedures for preparing Seismic Qualification Specifications and conducting seismic qualification tests shall be obtained from IEEE Standard 344. Details for conducting functional tests for the active mechanical equipment shall be obtained from the manufacturers' operating manuals and active mechanical equipment specifications.

QR-A7240 Acceptance Criteria. Acceptance criteria for seismic tests shall be based on the functional requirements for the individual item of active mechanical equipment. Acceptable ranges for performance variations shall 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 active mechanical equipment which affect acceptance criteria shall be identified in the Seismic Qualification 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 or 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.

QR-A7300 Qualification by Similarity

There are many instances of active mechanical equipment, similar to a type that was qualified, which differs only in size or in the specific qualified devices located in the assembly or structure. In such cases, it is neither practical nor necessary to test every variation of the basic qualified version. Furthermore, it may be shown that the active mechanical equipment to be qualified is similar to another that has experienced actual documented earthquake conditions. Qualification by combined test and analysis applies in these situations.

QR-A7310 Test Method. A full test program, as described in QR-A7200 and preliminary exploratory tests (resonance search), as described in QR-A7221 are conducted on a typical piece of active mechanical equipment. Data on modal frequencies, damping, and responses throughout the active mechanical equipment shall be taken and recorded.

QR-A7320 Analysis. When it can be shown that no resonances exist in the frequency range of the amplified response, the active mechanical equipment may be analyzed as a rigid active mechanical equipment. When a resonance search is utilized, assurance should be obtained that adequate test methodologies are followed to verify the absence of resonant frequencies. In addition, assurance should be obtained that changes from the originally tested active mechanical equipment did not result in the formation of previously nonexistent resonances. This may be done by simple testing or analysis.

When the active mechanical equipment is not rigid, the effects of the changes shall be analyzed using the techniques of QR-A7100 or other justifiable means. For very complex active mechanical equipment, this requires sufficient knowledge of the active mechanical equipment to include the significant structural parameters to enable the responses at all points of interest to be calculated.

The test results combined with the preceding analysis allow the model of similar active mechanical equipment to be adjusted to take into consideration the parametric quantities affected and allow revision of the analysis for the modal frequencies of the similar active mechanical equipment. The result is a verified analytical model that may be used to qualify the similar active mechanical equipment.

QR-A7330 Active Mechanical Equipment Similarity for Comparison With Single Reference Active Mechanical Equipment. Where qualification of an active mechanical equipment item is achieved by extrapolation of qualification results from a single similar reference active mechanical equipment item, the extrapolation shall be based on similarity of excitation, physical system, and function.

QR-A7331 Excitation. Similarity of excitation constitutes likeness of the following parameters: spectral characteristics, duration, directions of excitation axes, and location of measurement for the motions relative to the equipment mounting. Ideally, these parameters should be as alike as is practical for excitations whose similarity is to be established. However, a conservative composite excitation may be generated by extrapolations or interpolations of data whose parameters are not identical but are justifiable. For example, estimates may be based on measurements elsewhere on the structure or on other structures in the vicinity of the given active mechanical equipment, when the estimates can be justified by calculations based on sound engineering methods using geophysical models, structural models, or both, as applicable. Likewise, excitation whose spectral content are significantly different may be used to generate lower level composite estimates, provided that an account is taken of possible multiaxis response, cross-axis coupling, or both. Justification for such approximations shall consider all modes of the active mechanical equipment response that are significant in determining its structural integrity and functionality. A sufficient justification is that active mechanical equipment is stressed, excited, or both to at least as high a level by each one of the component spectra used to create the lower level composite spectrum estimate.

The qualification shall account for the fatigue effects of exposure to the required normal and abnormal conditions, such as normal operating vibrations and the OBE, if required.

QR-A7332 Physical Systems. Active mechanical equipment similarity shall be established for an active mechanical equipment assembly, a device, or both, or subassembly (including mounting), depending on the configuration of the new active mechanical equipment to be qualified. For a complete assembly, similarity may be demonstrated through comparison of make, model, and serial numbers, and consideration of dynamic response characteristics and construction.

Similarity of dynamic response characteristics may be established by comparing the physical parameters of the active mechanical equipment. This may be done by comparing the predominant resonant frequencies and mode shapes. These dynamic characteristics are dependent on parameters such as the following:

(a) active mechanical equipment physical dimensions

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

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

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

(e) active mechanical equipment interfaces with adjacent items or connecting accessories, such as cables and conduits

Assurance shall be obtained that active mechanical equipment modifications from previously qualified active mechanical equipment do not effect a change in the dynamic response characteristics of the item being qualified compared with the item used for similarity.

QR-A7333 Function. Active mechanical equipment being qualified may be required to perform a safety function during and/or after an earthquake. The required function during the earthquake may, or may not, be the same as after the earthquake. Therefore, for each qualification, the required function shall be defined during and/or after the earthquake. The available qualification data shall provide documented evidence to support the demonstration of proper functionality, as defined, for each application. Where an active function, or absence of a spurious function, is required during the earthquake, the available qualification data shall provide sound evidence that the candidate active mechanical equipment will perform as required in the system for which it is being qualified.

QR-A7400 Earthquake Experience-Based Qualification

Procedures are presented in this Section to seismically qualify active mechanical equipment by comparison with the body of documented equipment performance from facilities that have experienced natural earthquakes.

Qualification based on earthquake performance involves five steps that will be covered in the following sections:

(a) characterization of earthquake motions by a response spectrum

(b) establishment of the earthquake experience-based capacity for a reference equipment class

(c) characterization of the reference active mechanical equipment class

(d) qualification of the candidate active mechanical equipment by comparison with the reference active mechanical equipment class

(e) documentation of the qualification process

QR-A7410 Characterization of Earthquake Experience Motions

QR-A7411 Earthquake Motions. The earthquake experience ground motions shall be characterized as follows:

(a) Ground motion recordings or conservative estimates from a minimum of four reference sites containing reference active mechanical equipment are required to establish a reference active mechanical equipment class. The four reference sites should be selected from at least four earthquakes.

(b) The free field ground motion of each reference site should be established by recorded data within two structural diameters of the site structure location. The recording location should have the same geological/geotechnical conditions as the reference site structure location. The measurement of two structural diameters starts at the perimeter of the foundation. Estimates of free field ground motion for a reference site more distant than two structural diameters from the recording location or where there are no nearby recorded data may be made, provided that the estimates are conservatively derived and justified. To make the ground motion estimates for these two cases, multiple attenuation relationships developed using strong-motion recordings from earthquakes with similar tectonic environments, crustal properties, and seismological parameters are to be used. The range of parameters used to develop the attenuation relationship shall encompass those of the reference site and earthquake. The appropriate level of conservatism is the average of the 5% critically damped response spectrum estimate obtained from each attenuation relationship.

(c) The ground response spectrum assigned to a reference site shall be the average of two orthogonal horizontal components of the 5% critically damped response spectra at the reference site.

(d) The free field motion shall be considered an estimate of the seismic excitation experienced by the active mechanical equipment at the reference site.

QR-A7412 Experience-Based Seismic Capacity. The earthquake experience spectrum (EES) is a response spectrum that defines the seismic capacity of a reference active mechanical equipment class. The EES shall be the weighed average of the spectrum at each reference site. The weight factor as provided below shall be the ratio of the number of independent items at each reference site to the total number of independent items at all reference sites.

$$A_{EES,i} = \frac{\sum_{n=1}^{m} N_n A_{n,i}}{\sum_{n=1}^{m} N_n}$$

where

$A_{EES,i}$ = spectral acceleration of the EES, at 5% critical damping, at frequency i

$A_{n,i}$ = spectral acceleration, at 5% critical damping, at reference site n and frequency i

m = number of reference sites, a minimum of four

N_n = number of independent equipment items at reference site n

QR-A7420 Characterization of the Reference Active Mechanical Equipment Class. A reference active mechanical equipment class is a group of active mechanical equipment that shares a range of physical, operational, and dynamic characteristics whose performance in earthquakes has been documented. The attributes of the active mechanical equipment that constitute the reference active mechanical equipment class shall be defined such that those features important to seismic ruggedness can be ensured, and any seismic vulnerabilities can be identified and precluded in the candidate active mechanical equipment. These active mechanical equipment ruggedness and vulnerability attributes of the reference active mechanical equipment class shall be defined in terms of inclusion rules and prohibited features, respectively.

QR-A7421 Attributes of Equipment Class. Inclusion rules are the physical and operational characteristics that define an acceptable range of equipment physical characteristics, dynamic characteristics, and functions for ensuring seismic ruggedness and defining the bounds of active mechanical equipment included in a reference equipment class.

The following factors shall also be considered and evaluated when developing inclusion rules: active mechanical equipment type, weight, features, size and shape, function, capacity rating, load path, governing industry standards, materials, natural frequencies, moveable subassemblies, attached items or components, and modifications necessary to achieve the defined seismic capacity. Not all these attributes may be applicable to a particular class of equipment.

The diversity of features represented in the reference active mechanical equipment shall be described in the inclusion rules. In those cases where diversity is limited, the reference active mechanical equipment class shall be narrowed to the specific features represented in the reference active mechanical equipment. In developing a reference equipment class for in-line components, if more than half of the items are judged not to have experienced distribution system amplification (i.e., the in-line component is located immediately adjacent to a distribution system support providing seismic restraint), a limitation shall be applied in terms of an inclusion rule for the reference equipment class.

Prohibited features are design details, materials, construction features, or installation characteristics that have resulted in seismic-induced failure of the active mechanical equipment to maintain its structural integrity and perform its specified function at earthquake excitations up to and including the defined seismic capacity level.

Prohibited features should include any attributes that would contribute to fatigue failure from low cycle loads.

Table QR-A7422-1 Reduction Factors

Number of Independent Items	EES Reduction Factor
30	1.0
25	0.9
20	0.8
15	0.7

The rules of this Section apply to active mechanical equipment that may undergo five OBEs or aftershocks and one SSE, resulting in 60 full-range stress cycles during plant life. If a component contains items which could experience a fatigue failure from low cycle loads (fewer than 60 full-range stress cycles), it shall be evaluated in accordance with QR-A6800.

QR-A7422 Number of Independent Items. The reference active mechanical equipment class should include a minimum of 30 independent items that performed satisfactorily. Independent items are components and equipment which have different physical characteristics or experience different seismic motion characteristics, e.g., different earthquakes, sites, buildings, or orientations/locations in the same building.

Where fewer than 30 independent items constitute the reference equipment class, the EES shall be reduced by the factors given in Table QR-A7422-1 to produce the same statistical confidence level as a reference active mechanical equipment class comprising 30 independent items. The number of independent items shall not be fewer than 15.

QR-A7423 Functionality During Earthquake. Where functionality during the earthquake is required of a candidate equipment, an appropriate justification shall exist in the definition of the reference equipment class for this functionality. This justification shall demonstrate one of the following:

(a) All of the equipment defining the reference equipment class performed the required functions during the earthquake.

(b) All of the equipment defining the reference equipment class was functional after the earthquake, and a quantitative assessment of functionality during the earthquake is established based on knowledge of the required operation of the equipment during the earthquake and consideration of credible seismic failure modes (e.g., shaft binding) that may prevent equipment operation. Experience gained from analysis or testing of similar equipment may be used to establish this quantitative assessment.

QR-A7430 Special Considerations

QR-A7431 Inherently Rugged Active Mechanical Equipment. Earthquake experience shows that certain types of active mechanical equipment possess high resistance to seismic inertia loads. This may be the result of inherent characteristics required to accommodate operational or shipping loads and the application of explicit design standards. Such active mechanical equipment is inherently rugged. Where inherent seismic ruggedness can be established through analysis, testing, or earthquake experience, or where the seismic loads are but a small fraction of the operating loads, the rules for characterizing the reference equipment class (i.e., the attributes and number of independent items defined in QR-A7421 and QR-A7422) and the procedure for defining the seismic capacity of the reference active mechanical equipment class (i.e., the EES defined in QR-A7412) may be simplified and reduced. In this case, the characteristics of the reference active mechanical equipment class and the technical justification for the assigned capacity level (EES) shall be developed and documented as the reference data for this special case.

QR-A7432 Limitations. Earthquake experience-based qualification is limited by the following considerations:

(a) Some types of active mechanical equipment have complex features, and their design varies significantly with time. These applications require more detailed considerations of design variability, which may render the application of experience data impractical. In these cases, other methods of qualification shall be used.

(b) In certain cases, functions such as operation during an earthquake or chatter of relays and contact devices may be difficult to establish from the experience data. In these cases, other methods of qualification shall be used.

(c) If there is insufficient sample size, diversity in the sample, or insufficient reference sites to adequately define an equipment class, other methods of qualification shall be used.

(d) Use of earthquake experience data ensures active mechanical equipment seismic qualification in combination with normal operating loads. For active mechanical equipment subject to other concurrent loads, including applied nozzle loads from distribution systems, the effect of the loads shall be addressed by supplemental qualification methods, such as analysis, testing, etc.

(e) Applications that require active mechanical equipment be exposed to harsh environments or aging prior to or during an earthquake require special consideration. In such cases, qualification methods other than experience-based methods may be required.

QR-A7440 Qualification of Candidate Equipment. The requirements for qualifying candidate equipment using earthquake experience data are as follows:

(a) The 5% critically damped required response spectra (RRS) should be enveloped by the EES of the reference active mechanical equipment class over the frequency range of interest, typically 1 Hz to 33 Hz. Failure of the EES to envelop the RRS shall be justified.

(b) The RRS, as defined in the Seismic Qualification Specification, shall be derived from the Design Basis Earthquake (QR-A6100). The minimum RRS used in earthquake experience-based seismic qualification shall be a median-centered in-structure response spectrum.

(c) The candidate equipment shall be verified to be within the inclusion rules of the reference active mechanical equipment class.

(d) The candidate equipment shall be verified to exclude the prohibited features of the reference active mechanical equipment class.

(e) Candidate equipment of a newer vintage than the reference active mechanical equipment class shall be evaluated for any significant changes in design, material, or fabrication that could reduce its seismic capacity compared with the reference active mechanical equipment class.

(f) The qualification of a candidate equipment shall be documented as specified in QR-A8330.

QR-A7500 Test Experience-Based Qualification

(to be added in a later edition)

QR-A7600 Combined Qualification Methods

All of the qualification methods — experience data, analysis, and testing — have their advantages and limitations. For example, to qualify the active mechanical equipment in question, it is necessary to show that the like active mechanical equipment 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 active mechanical equipment qualification test may become a part of an experience database. Strictly speaking, this qualification is applicable only to the active mechanical equipment tested. To extend qualification to similar active mechanical equipment, 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 as provided in QR-A7300, 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. Loss of function of active mechanical equipment, however, cannot always be explained in terms of such computed quantities. In such cases, experience data or testing shall be relied upon to demonstrate functionality or otherwise establish acceptable limits on those quantities which can be evaluated by analysis.

All three methods or combinations thereof may be used to seismically qualify functionality of active mechanical equipment. The decision as to the methods to be used to qualify a given piece of active mechanical equipment shall be left to the professional engineer or 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 Qualification Specification (SQS) from specifying in detail (in the SQS) the method(s) or combinations of methods to be used in seismically qualifying the active mechanical equipment covered by the SQS.

QR-A8000 DOCUMENTATION

QR-A8100 General

The documentation for qualification of each active mechanical equipment type shall demonstrate that the active mechanical 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.

Two documents are required to demonstrate functional seismic qualification of active mechanical equipment: a Seismic Qualification Specification and Seismic Qualification Report. The preparation of the Seismic Qualification Specification is the responsibility of the active mechanical equipment Owner or his designee. The preparation of the Seismic Qualification Report is the responsibility of the organization that performs the active mechanical equipment seismic qualification and evaluates the results as applicable to the qualification of the active mechanical equipment. In the event that a manufacturer of the active mechanical equipment performs a generic seismic equipment qualification, the preparation of both the Seismic Qualification Specification (as the Owner's designee) and Seismic Qualification Report is the responsibility of the manufacturer. It is the responsibility of the Owner to review and accept the Seismic Qualification Report.

QR-A8200 Seismic Qualification Specification Requirements

The following gives directions in the preparation of Seismic Qualification Specification required for evaluation of the active mechanical equipment:

(a) The required response spectrum (RRS) for the location on which the active mechanical equipment is to be mounted shall contain the data for the two horizontal and one vertical axes as a minimum. The RRS shall be appropriately broadened or based upon a building in-structure response spectrum that was appropriately broadened. The RRS shall include the damping values for which it was calculated.

(b) If RRSs 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) Active mechanical equipment mounting or support details, including all interface connections, shall be described.

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

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

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

(h) The environment in which the equipment is designed to function shall be described.

(i) Acceptance criteria shall be specified.

(j) ASME Class 1, 2, and 3 components shall be identified.

QR-A8300 Qualification Report

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

(a) Active mechanical equipment being qualified shall be clearly identified.

(b) Required response spectrum (RRS), acceleration design value (ADV), time histories, required input motion (RIM), or load coefficient levels for which active mechanical 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 active mechanical 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 active mechanical equipment is not modified to eliminate the anomaly, then the final user shall justify the use of the active mechanical equipment and file this justification with the Seismic Qualification Report. Any active mechanical equipment refurbishment that is performed during seismic testing shall be documented in the test report and reconciled by the active mechanical equipment supplier. These data may become part of the postearthquake field maintenance checks and procedures for that active mechanical equipment.

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

(e) Integrity of equipment supports and component or device mountings shall be demonstrated and described.

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

(g) A dated approval signature shall be included.

QR-A8310 Analytical Data. If analysis is performed as the qualification method, the method and data used, and failure modes considered, shall be presented in a step-by-step form that is readily auditable 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 utilized 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) active mechanical equipment being qualified

(1) tested active mechanical equipment identification (including devices)

(2) tested active mechanical equipment functional specification

(3) tested active mechanical equipment settings and limitations when appropriate

(b) test facility

(1) location

(2) testing equipment and calibration

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

(d) active mechanical equipment mounting details, including all interface connections

(e) test data, including proof of performance, test response spectrum (TRS) plots, required input motion (RIM) plots, time histories, and power spectral density (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 Earthquake Experience-Based Qualification Documentation. The qualification report shall include

(a) a detailed description of the active mechanical equipment to be qualified, including the essential internal components and devices.

(b) the required response spectrum at 5% critical damping.

(c) a detailed description of the reference active mechanical equipment class, including

(1) characterization of the reference motions in terms of a response spectrum

(2) development of the EES for the specific equipment class

(3) characteristics of the reference active mechanical equipment class

(4) inclusion rules and prohibited features

(5) function of the reference active mechanical equipment class

(6) compliance to the requirements of this Standard

(d) compliance of the active mechanical equipment to be qualified to the inclusion rules and prohibited features of the reference active mechanical equipment class.

(e) demonstration of integrity of equipment supports, load path, mounting, and anchorage shall be demonstrated and described.

QR-A8340 Combined Methods of Qualification. If proof of performance is by a combination of methods described in QR-A7100 to QR-A7400, the report shall contain reference to the specific combined qualification method used and appropriate information contained in each method as described therein. When extrapolation of data is made from similar active mechanical equipment, a description of the differences between the active mechanical equipment involved shall be provided. Justification that the differences do not degrade the seismic adequacy below acceptable limits, which may require some additional analyses or testing, shall be included.

Attachment A
Guidelines for Qualification by Similarity (Indirect Method)

A-1 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, which can be consulted for more details. The guidance provided herein is also an expansion of general concepts defined in IEEE Standard 344-1987, 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

A-2 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.

A-2.1 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.

A-2.2 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.

A-2.3 Design Parameters

List the appropriate parameters for the candidate and parent equipment, as shown in Table A-1.

A-2.4 Acceptance Criteria

A comparison of the design parameters for both the parent and 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.

A-3 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 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

A-4 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 A-4.1 through A-4.4.

A-4.1 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 to have differences that are so slight that the dynamic response can be argued to be essentially unaffected.

A-4.2 Similar Modal Properties

This is equipment whose mass, stiffness, and damping properties can be shown to be similar. Justification includes providing comparative data as shown in Table A-2.

A-4.3 Acceptance Criteria

For acceptance criteria, provide comparison of items 1 through 7 of Table A-2 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.

A-4.4 Similar Critical Transfer Function

The critical transfer function establishes a direct dynamic relationship between the excitation and 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.

A-5 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).

Table A-1 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:

Table A-2 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:

Attachment B
Examples of Qualification of Pumps and Valves by Analysis[1, 2]

B-1 EXAMPLE 1: VERTICAL PUMP/MOTOR ASSEMBLY

B-1.1 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.

B-1.2 Model Description

A finite element model is developed for the pump/motor assembly as shown in Fig. B-1 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. B-1. The schematic representation of the model is provided in Fig. B-2. 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.

B-1.3 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 B-1 gives the first 14 frequencies of the model up to 84.1 Hz. As Table B-1 shows, the fundamental frequency of the equipment is 7.82 Hz, which is in the potential resonant region of earthquake-induced response, thereby justifying the need for a dynamic analysis for this relatively flexible equipment.

[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. B-1 Pump Assembly

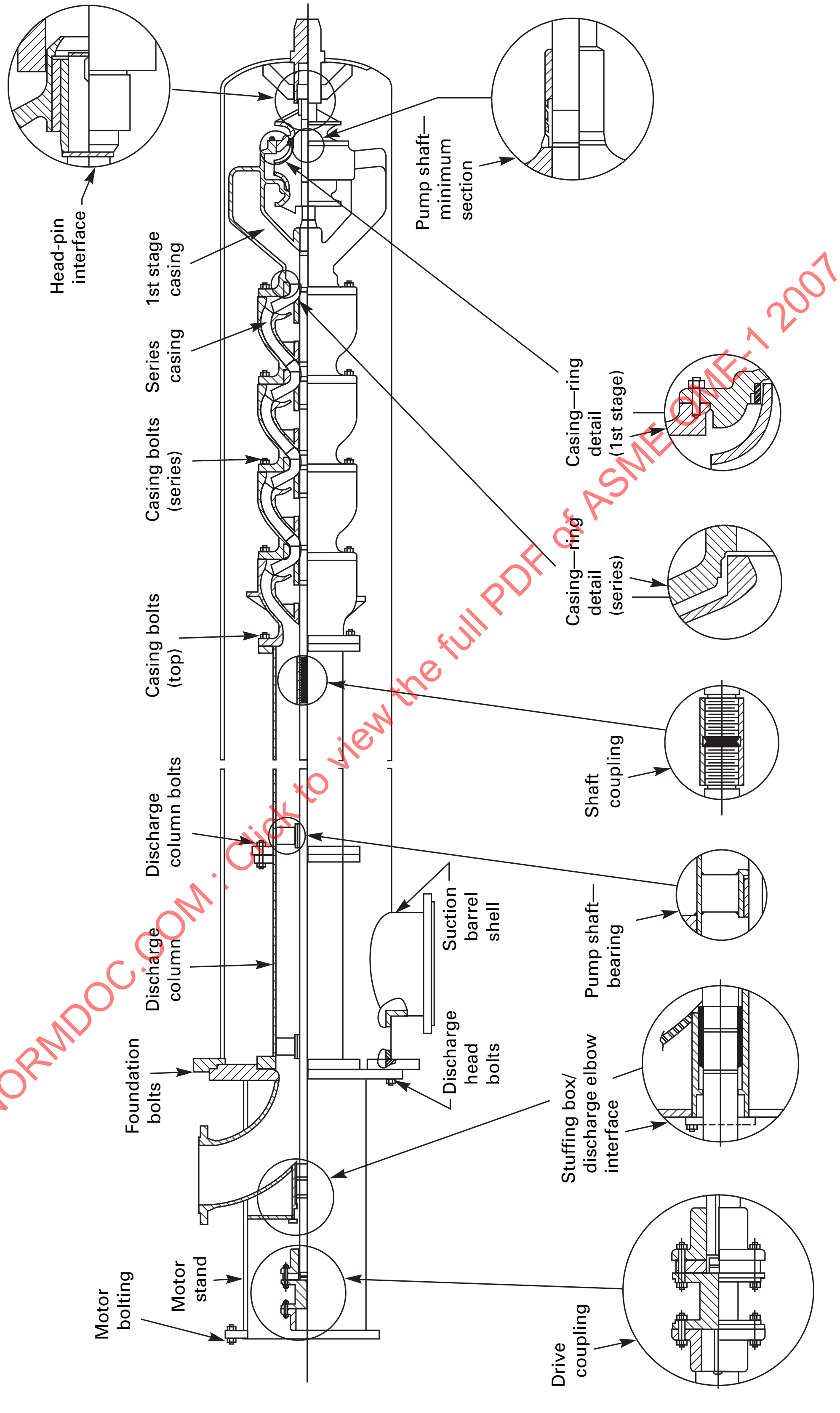


Fig. B-2 Finite Element Formulation of Pump Assembly

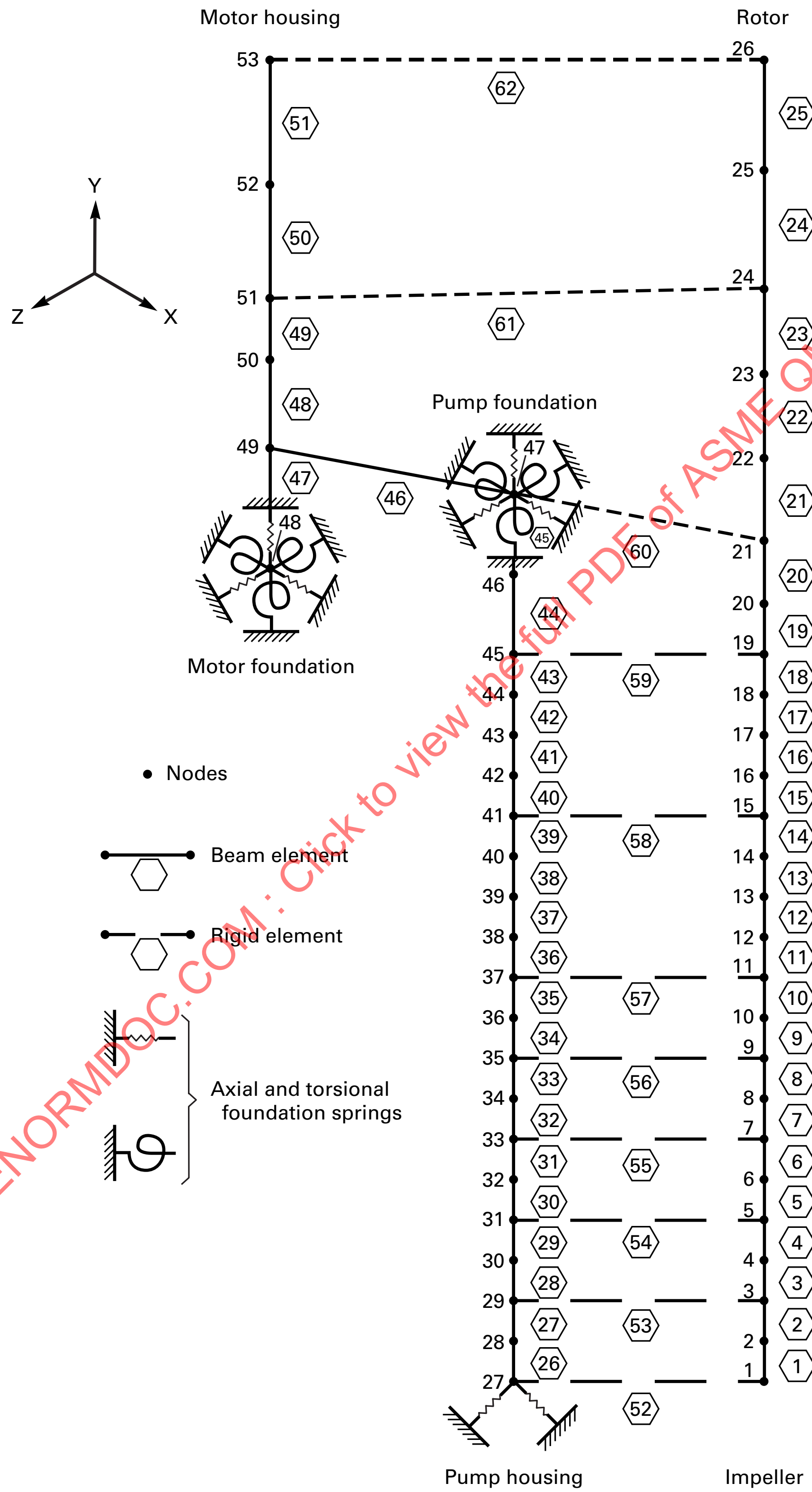


Table B-1 Calculated Frequencies for Pump/Motor Assembly: Print of Frequencies

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

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

B-1.4 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:

$$N + \text{Envelope of} \begin{cases} SSE + CO \\ SSE + CO + SRV \\ SSE + CHUG + SRV \end{cases}$$

where

CHUG = chugging load
CO = condensation oscillation loads
N = normal conditions
OBE = operation basis earthquake load
SRV = safety relief valve loads
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; 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.

B-1.5 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.

(c) Comply with the design requirements of the Design Specification and ASME BPVC Section III for Service Level B, C, or D, whichever are applicable; also,

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

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 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 B-2. It is also common to express design adequacy in terms of design margins. Design margins are determined as follows:

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

B-1.6 Deformations, Bearing Loads, and Operability

In Service Level C, 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 with 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.

B-1.7 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. B-1.4.[4]

[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.

B-2 EXAMPLE 2: 4-in. BUTTERFLY VALVE

B-2.1 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.

B-2.2 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. B-3 and B-4.

B-2.3 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.

B-2.4 Stress Analysis, Leak-Tight and Structural Integrity

The results of various analyses performed are presented in this Section. Table B-3 provides the materials and allowable stress values for the valve parts analyzed. Stresses for ASME Levels B and C Service Conditions are summarized on Tables B-4 through B-8. At critical locations identified through failure mode-effect analyses, the model displacements are obtained as the result of the same finite element model analysis.

Table B-2 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	5,587 psi	37,500 psi	6.67
Motor bolting shear stress	2,281 psi	15,500 psi	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	12,730 psi	29,000 psi	2.27
Foundation bolts shear stress	4,129 psi	11,950 psi	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. B-3 Butterfly Valve Assembly

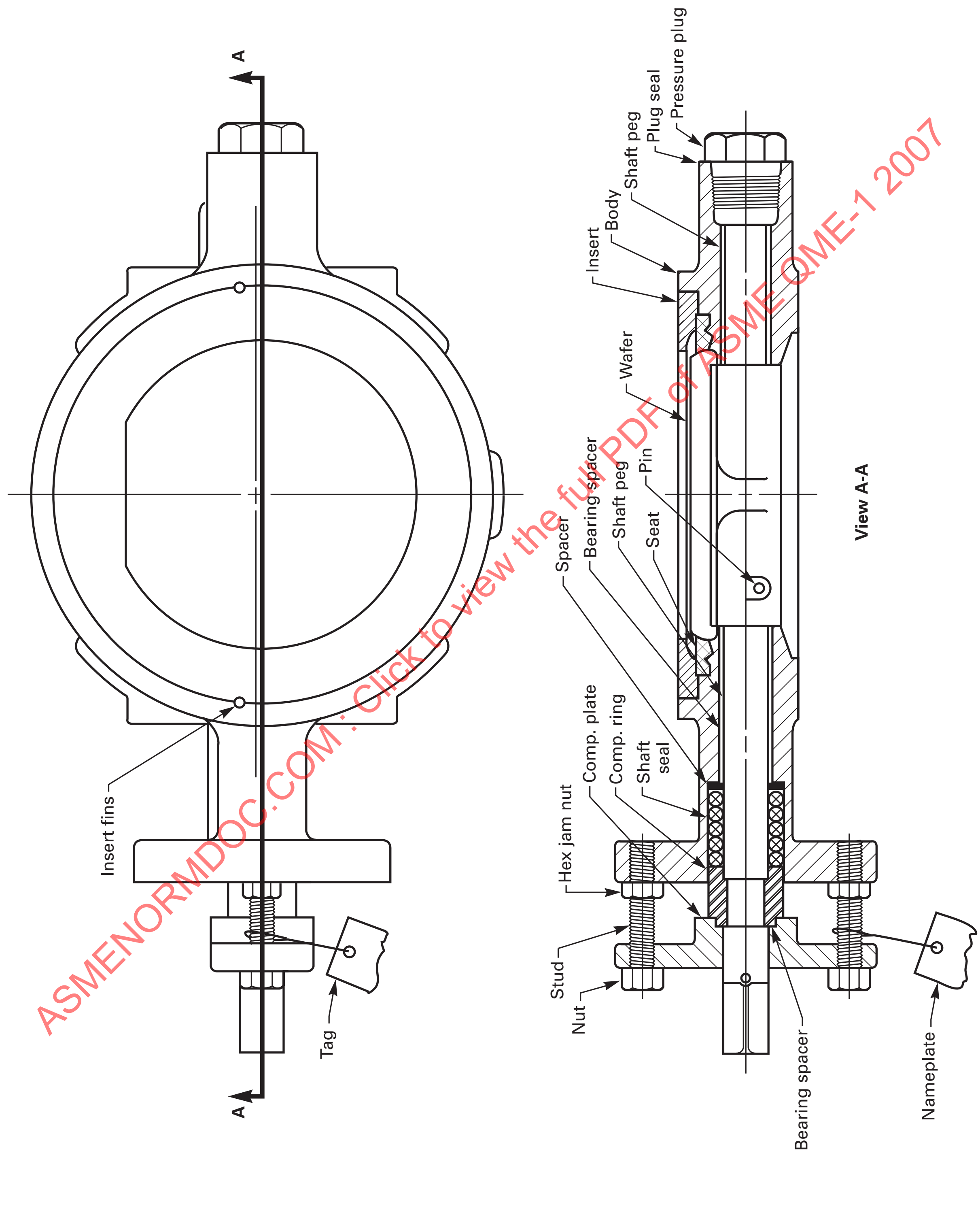


Fig. B-4 Finite Element Formulation of Butterfly Valve Assembly

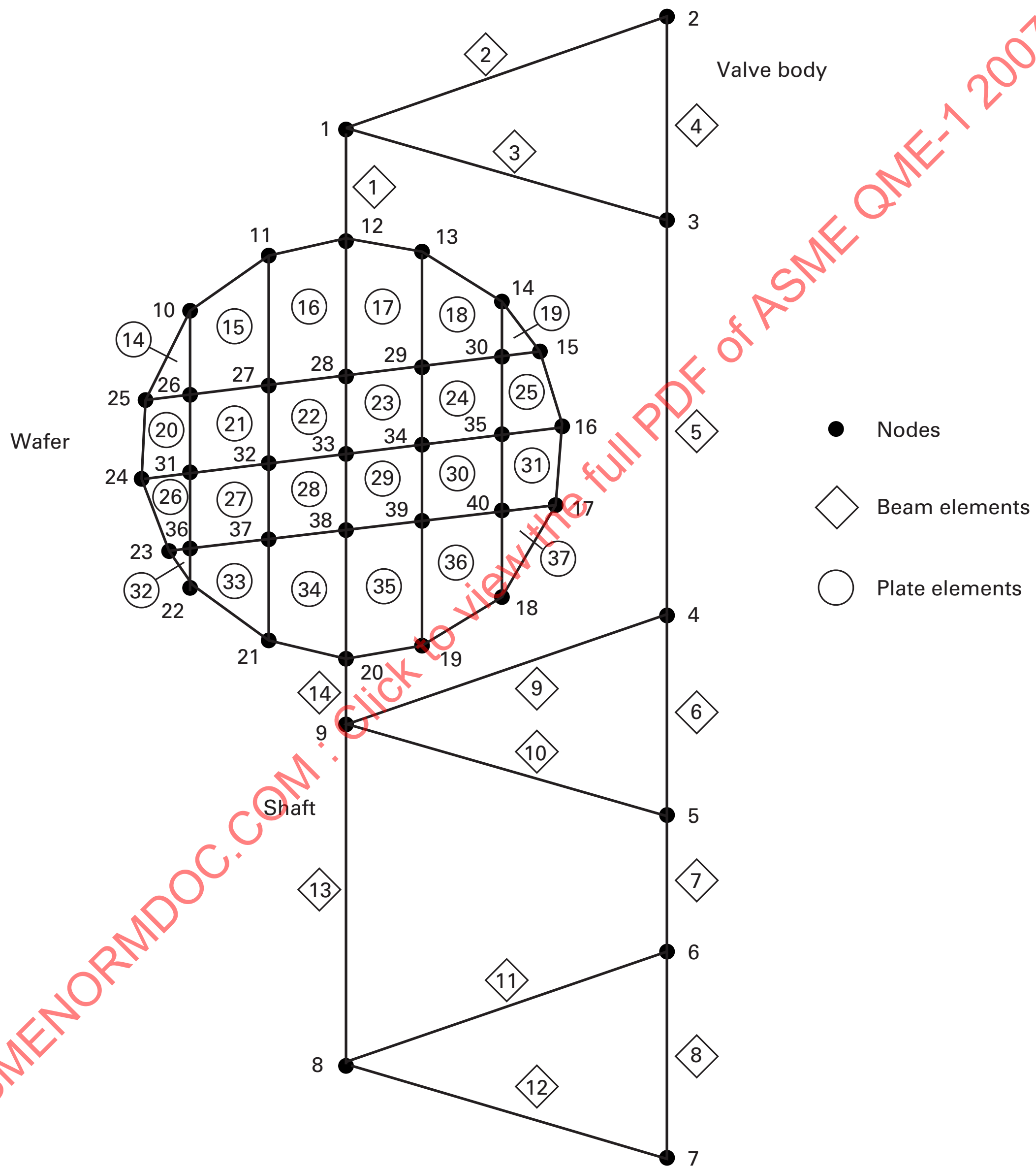


Table B-3 Allowable Stresses at 200°F for 4-in. Valve

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 B-4 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 B-5 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 B-6 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 B-7 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 B-8 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)
σ_t = small

Table B-9 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.

B-2.5 Deformations and Operability

Computed displacements are given in Table B-9. Also provided are the allowable clearances obtained from the valve manufacturer.

B-2.6 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 ensured that the seismic acceleration design values given in para. B-2.3 do not adversely affect the leak-tight, structural integrity, and function or subsequent operation of the valve.

Attachment C
Qualification of Pumps and Valves Using Natural Earthquake Experience Data

C-1 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. 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.

C-2 APPLICATION

With certain caveats and exclusions that are described in C-3, 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. C-1. 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 or equipment response.

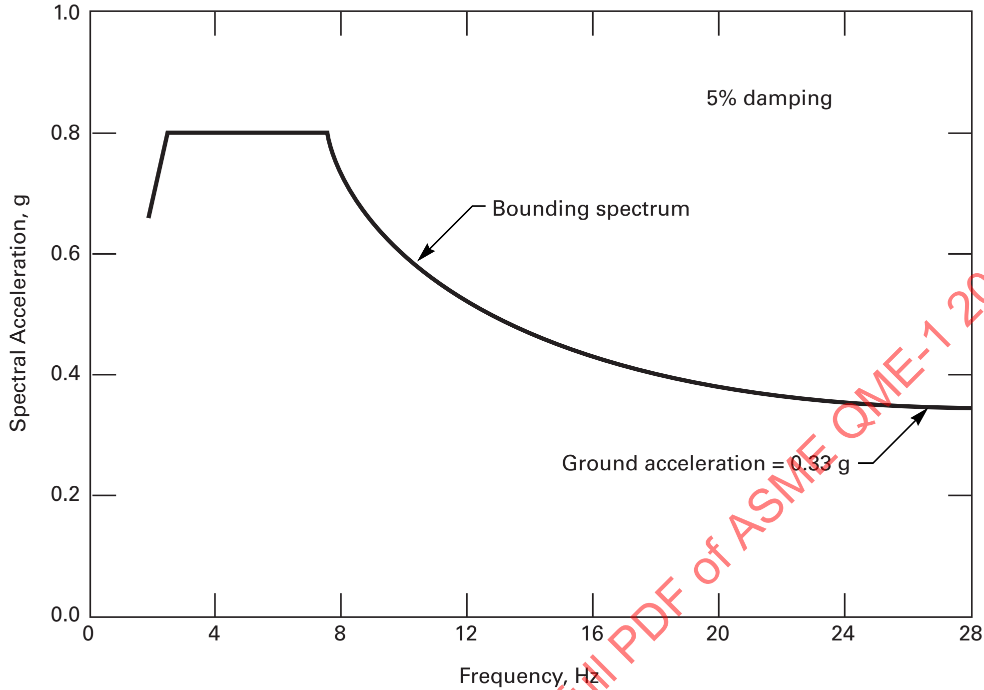
The bounding spectrum shown in Fig. C-1 is intended for comparison with the 5% damped design horizontal ground response spectrum at a given nuclear power plant site. In other words, if the horizontal ground response spectrum for the nuclear plant site is less than a bounding spectrum at the approximate 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. C-1 Seismic Motion Bounding Spectrum Horizontal Ground Motion



C-3 CAVEATS AND EXCEPTIONS

C-3.1 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 C-3.1.1 and C-3.1.2, the equipment meets the criteria for seismic qualification for operability using the bounding spectrum.

C-3.1.1 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.

C-3.1.2 Vertical Pumps. Vertical pumps include an electric motor drive attached to a base flange with a centrifugal or 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 C-3.1.1 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 electrical instrument, power, and control lines.

C-3.2 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. C-2 corresponding to the diameter of the pipe.

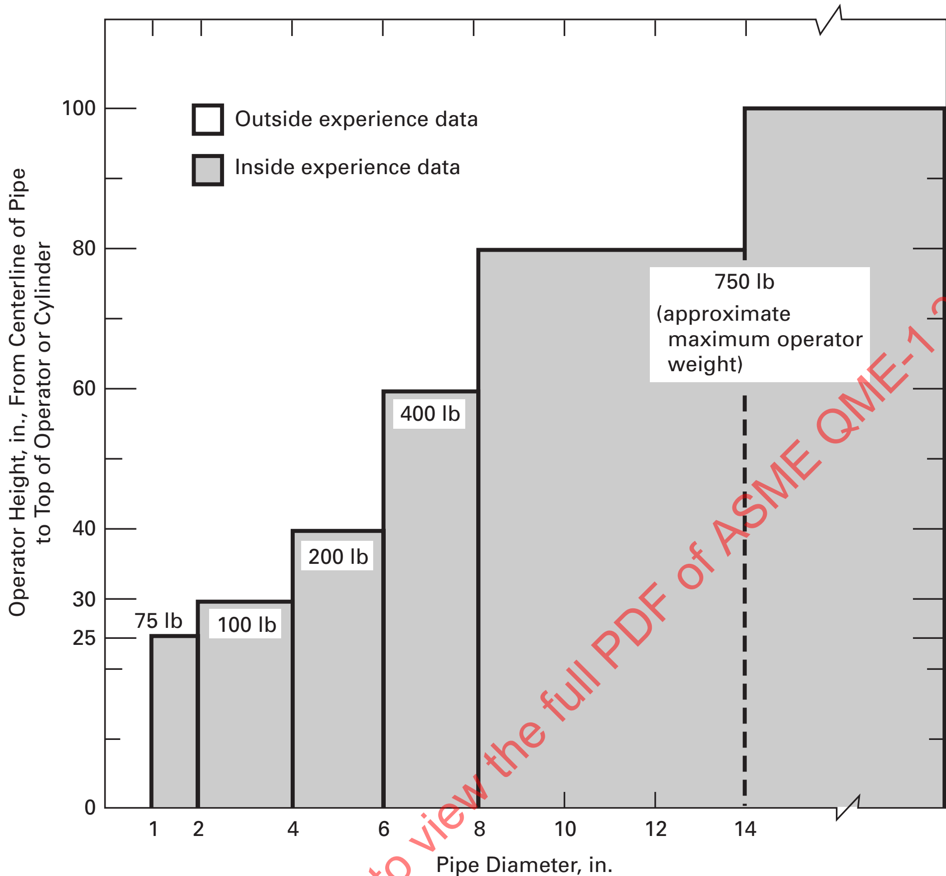
(e) For motor- and piston-operated valves that are of substantial weight, the distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator shall not exceed the values indicated in Fig. C-3 corresponding to the diameter of the pipe.

(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 C-3 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. C-3 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. C-3. 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.

Fig. C-2 Limits of Experience Data for Motor-Operated Valves and Substantial Piston-Operated Valves



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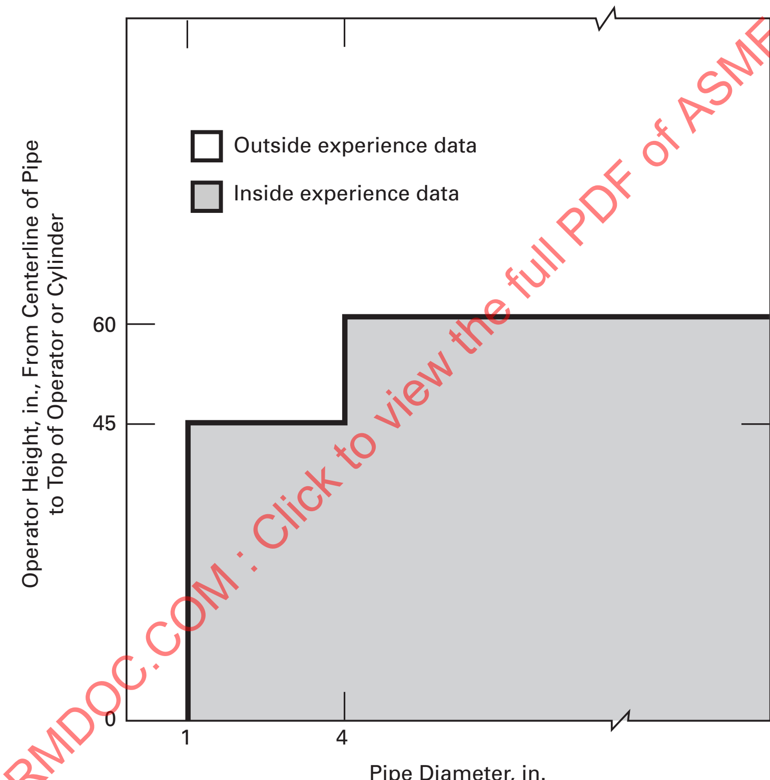
The operator weights given in Fig. C-3 are from the database and may have been estimated slightly low from available catalogs. Thus, if an actual operator is slightly heavier than the value in Fig. C-3, the engineer evaluating the valve can use some engineering judgment in assigning similarity.

For air- 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.

Fig. C-3 Limits of Experience Data for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves, and Piston-Operated Valves of Lightweight Construction



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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 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 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, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854-1331

QR-B4000 DEFINITIONS

All definitions are contained in 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 that 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 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 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 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 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 these data for use in environments other than those for which actual data are 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

A = frequency factor (assumed constant)
E_a = activation energy, eV
exp = exponent to base e
k = reaction rate
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

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

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 lower electronvolts. It is the qualifier's responsibility to review the available literature and databases to determine the electronvolt 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, intended use/configuration of the material, and 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 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, these 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, amount of the nonmetallic exposed to the test environment, and 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 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 with 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 with 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 modification's effect to the nonmetallic should be documented, as should any requalification that is determined to be necessary.

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 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 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 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, extension of restraint travel, and 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 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 subarticle.

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 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) postaging functional parameter testing
(f) post-test 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 post-test 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 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 these 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 Section 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 ½ 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 ¼, ½, and ¾ 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 Hz 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 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 these 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 Section, 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 ½ 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 ¼, ½, and ¾ 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 Hz 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 Hz 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) These 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 hydraulic fluid and between the seal material and 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 post-test 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 Post-Test Inspection and Analysis. Upon completion of the qualification tests, the tested assembly shall be disassembled, inspected, and subjected to a post-test analysis. The results of this analysis shall be documented in the Functional Qualification Report and 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 post-test 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.

Paragraph 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 and 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 and candidate restraint assemblies. 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 that 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

(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, and 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 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, complete, and 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 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 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 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 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, complete, and in compliance with this Standard.

Nonmandatory Appendix QDR-A
Functional Specification for Dynamic Restraints

QDR-A1000 SCOPE

This 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) design 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 load action.

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 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 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, load range, and 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, load range, and 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 as 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 in-service testing, requirements should be included for demonstrating the feasibility of performing the required inservice tests (i.e., drag, activation level, and release rate tests) 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 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 not intended to be all inclusive. It should be noted, however, that all similarity parameters defined in QDR-6420 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 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 Appendix is provided to aid both the restraint designer and 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 0.04 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 Hz 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 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 0.04 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 in. 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 as 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, NW, Washington, DC 20005-4070

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 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900

Hydraulic Institute Pump Standards, 1994

Publisher: Hydraulic Institute (HI), 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 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 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 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 through 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 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 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 external attachments and supports. When pump assembly items are qualified separately, the qualification specification shall also define interfaces between the pump and 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

(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, 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 experience to the specified design service conditions, provided the analytical techniques have been validated through comparison with 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 sequences shall include all service conditions.

Qualification on the basis of experience or analysis requires that documentation be provided that demonstrates 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 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.).

(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

QP-A1000 SCOPE

This Appendix is provided to aid the specification writer. It lists items that may be considered when developing the qualification specification for pump assembly items.

QP-A2000 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

QP-A3000 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, and 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)

QP-A4000 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, casing, and support attachments
(h) seismic acceleration, both horizontal (two orthogonal directions) and vertical

QP-A5000 MATERIAL AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards)

QP-A6000 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

QP-A7000 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

QP-B1000 SCOPE

This 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.

QP-B2000 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

QP-B3000 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)

QP-B4000 STRUCTURAL, SEISMIC, AND ENVIRONMENTAL QUALIFICATION REQUIREMENTS

(a) qualification acceptance criteria

(b) environmental qualification requirements

QP-B5000 MATERIALS AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards)

QP-B6000 TESTING REQUIREMENTS

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QP-B7000 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

QP-C1000 SCOPE

This 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.

QP-C2000 APPLICABLE DOCUMENTS, CODES, AND STANDARDS

(a) applicable turbine design standard: NEMA, API, etc.
(b) Design Specification

QP-C3000 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, and minimum) for inlet and exhaust
(2) operating pressures and temperatures (maximum, normal, and 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)

QP-C4000 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

QP-C5000 MATERIAL AND MANUFACTURING REQUIREMENTS

(a) specific material requirements (if differing from the manufacturer's standards)

QP-C6000 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)

QP-C7000 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

QP-D1000 SCOPE

This Appendix is provided to aid both the pump designer and 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.

QP-D2000 PUMP DESIGN

(a) hydraulic capability
(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
(1) size of suction and discharge nozzles, NPS (DN)
(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, and 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

QP-D3000 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 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 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 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.)

(2) shaft or sleeve diameter at seal

(3) shaft or sleeve material

Table QP-E1 Shaft-Seal System Specification

			Design Basis Condition			
		Normal [Note (1)]	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 and 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.

(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.)

(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

(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

(3) necessary assembly and maintenance features that limit personnel exposure time in radiation fields

Table QP-E2 Limits for Unbalanced Seals

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)

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.

(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

(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 $\frac{1}{4}$ in.^{2} (160 mm^2); however, a packing size of $\frac{3}{8}$ in.^{2} (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 lantern ring if split.

(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 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.

(07)

Section QV
Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants

QV-1000 SCOPE

Section QV contains the qualification requirements and guidelines for active valve assemblies that perform a nuclear safety function used in nuclear power plants. Valve assembly items may be qualified as part of a single assembly or may be qualified separately, provided their combination into a single unit is addressed. It is the responsibility of the Owner to specify those valve assemblies that require qualification to this Section.

Section QV provides a number of ways to qualify a valve assembly. The Qualification Specification that has been generated (QV-6000) is required to specify those parameters for which the assembly is to be qualified.

In case of conflicts, Section QV takes precedence over Section QR for specific valve assembly qualification requirements. Design of the pressure-retaining boundary of the valve is addressed by the Owner-specified code of record and is excluded from the scope of Section QV.

QV-2000 PURPOSE

It is the purpose of Section QV to provide requirements for the qualification of the design of valves, actuators, and the combination thereof (valve assemblies) to perform in service as required under all specified operating and design-basis conditions.

QV-3000 REFERENCES

References are as listed in QR-3000.

QV-4000 DEFINITIONS

The following definitions apply specifically to valve assemblies. Other definitions pertinent to valves will be found in Mandatory Appendix QV-I. Definitions that also apply to other types of mechanical equipment can be found in Section QR. Where there are conflicting definitions between QR and QV, the definitions in QV take precedence with regard to application of Section QV.

active check valve assembly: a valve assembly that is self-actuating in response to system conditions to allow flow in only one direction.

active valve assembly: a valve assembly that is required to change obturator position to perform its Nuclear Safety Function.

bending stress (P_b): the variable component of normal stress.

cold working pressure: the valve pressure rating at 100°F (38°C).

diagnostic test: a test of a valve assembly where valve and actuator performance parameters, fluid system conditions, ambient environmental conditions, and motive power supply parameters are obtained from calibrated instrumentation.

expansion stress (P_e): stresses resulting from the restraint of free end displacement of the piping system. In a piping system, this is commonly considered to be the stress resulting from constraint of the free thermal expansion of the piping system (thermal expansion stress). However, it may also include various types of piping system anchor movement effects, such as seismic anchor motions, equipment or building thermal anchor movements, etc.

extended structure: the 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.

local primary membrane stress (P_L): a membrane stress produced by pressure or other mechanical load and associated with a discontinuity, if not limited, would produce excessive distortion in the transfer of the load to other portions of the structure.

membrane stress: the component of normal stress, which is uniformly distributed and equal to the average value of stress across the thickness of the section under consideration.

motive power: the electrical, fluid, or mechanical power or system flow required to operate the valve assembly.

normal stress: component of stress normal to the plane of reference.

obturator: valve closure element (e.g., disk, plug, ball, etc.).

operating cycle: the movement of a valve assembly through its full stroke under defined operating conditions, terminating with a return to the starting position.

power-operated valve assembly: a valve assembly that requires external power such as provided by a motor, air piston or diaphragm, solenoid, or electro hydraulic operator to perform its safety function.

pressure relief valve assembly: a valve assembly that is designed to open to prevent a rise of internal fluid pressure, in excess of a specified value, and re-close. Pressure relief valve assemblies may be further classified as follows:

self-actuated: one that is actuated by inlet static pressure.

externally actuated: one that is actuated by external motive power.

combined self- and externally actuated: one 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.

primary membrane stress (P_M): the component of primary normal stress that is uniformly distributed and equal to the average value of stress across the thickness of the section under consideration.

primary stress: any normal or shear stress developed by an imposed loading that is necessary to satisfy the laws of equilibrium of external and internal forces and moments.

shear stress: component of stress tangent to the plane of reference.

stress intensity: the difference between the algebraically largest principal stress and the algebraically smallest principal stress.

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, self-operated, and pressure relief valve assemblies.

production valve assembly: a valve assembly that is manufactured with the intent of being identical within allowed manufacturing tolerances and clearances to the qualified valve assembly to which its qualification is based. A production valve assembly consists of a production valve and production actuator.

qualified valve assembly: a valve assembly consisting of a specific valve (e.g., including type, size, rating, material, and drawing) and a specific actuator (e.g., including type, size, rating, gear ratio, voltage, speed, and stem nut, as applicable), which has been qualified by all appropriate testing and analysis as required by QV-7000. A qualified valve assembly consists of a qualified valve and qualified actuator.

test valve assembly: a valve assembly selected for qualification testing.

QV-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 valve assembles are contained in the Guide to ASME QME-1 Standard, Section QV-G, "Determination of Valve Assembly Performance Characteristics." This Guide is included with this Standard.

QV-6000 QUALIFICATION SPECIFICATION

It is the responsibility of the Owner or Owner's designee to identify the functional requirements for a valve assembly. These requirements shall be provided in a Qualification Specification prepared in accordance with Mandatory Appendix QV-I.

The manufacturer has the option to qualify the valve assembly for more stringent parameters than provided in the Qualification Specification but shall ensure that the parameters to which the valve assembly is qualified envelop those in the Qualification Specification.

QV-7000 QUALIFICATION PROGRAM

QV-7100 General Requirements

An Application Report, as described in QV-8320, is required to provide documentation and additional requirements as necessary to ensure that each of the production valve assemblies is qualified for the application specified in the Qualification Specification required by QV-6000. The qualification program shall account for dimensional variations of critical clearances of essential-to-function parts. Further, any analytical techniques applied in the qualification of valve assemblies require verification to ensure that the analysis techniques are valid for the variations of the design being qualified. This program shall demonstrate that the performance of valve assemblies, predicted by these analytical techniques, is applicable to all allowable variations of the valve clearances being qualified for the flow conditions specified by the valve Qualification Specification. Even though valve assemblies may satisfy the requirements of the manufacturer's Quality Assurance Program (during the normal manufacturing process), the qualification program shall demonstrate that the design limiting allowable variation in the critical clearances between essential-to-function parts during the manufacturing phase shall not render a valve assembly incapable of consistent performance due to binding, blockage, etc.

Section QV provides for qualification of a valve assembly by a combination of testing and analysis. The functional qualification of a qualified valve assembly may be extended to another valve assembly through limited testing and demonstration of design similarity. This

Table QV-7300 Valve Assembly Qualification Requirement Matrix

Parameter	Power Actuated: QV Category A	Power Actuated: QV Category B	Self Actuated: QV Category A	Self Actuated: QV Category B	Relief: QV Category A	Relief: QV Category B
Seismic	QV-7450	QV-7450	NR [Note (1)]	NR [Note (1)]	NA [Note (2)]	QV-7650
End load	QV-7440	NR [Note (3)]	QV-7540	NR [Note (1)]	NA [Note (2)]	NR [Note (3)]
Functional	QV-7460	QV-7460	QV-7560 [Note (4)]	QV-7560 [Note (4)]	NA [Note (2)]	QV-7660
Environmental	QV-7420	QV-7420	QV-7520	QV-7520	NA [Note (2)]	QV-7620
Sealing capability	QV-7430	QV-7430	QV-7530 [Note (4)]	QV-7530 [Note (4)]	NA [Note (2)]	QV-7630

GENERAL NOTES:
(a) NA = not applicable
(b) NR = not required

NOTES:
(1) Seismic evaluation of self-actuated valves is not required due to the lack of an extended structure.
(2) Relief valves, by function of their purpose (i.e., pressure relief), cannot be QV Category A.
(3) End-load testing is not required by the definition of QV Category B.
(4) Self-actuated valves that are closed in normal operation and remain closed in an accident scenario due to pressure forces acting on the obturator need only show proof of sealing capability by way of a production seat leak test.

extension of qualification is based upon the condition that both the valve assemblies utilize the same design concept and that critical dimensional clearances are maintained. Diagnostic testing shall be performed during the qualification testing covered by this Standard.

QV-7200 Analysis Guidelines

(a) Analysis is permissible provided that sufficient test verification exists to justify the analysis used over the qualification conditions involved.

(b) Analysis methods may be used for ensuring accessories and associated attachments are rigid (see QR-A6500).

(c) Analysis methods based on extensive valve assembly testing programs may be used in conjunction with focused flow testing to demonstrate functional capability. The user should be cautioned that, because of difficulties associated with identifying and predicting factors that affect operating loads for certain types of valves (e.g., flexible wedge gate valves), even when those valve assemblies are identical, it may be necessary to limit the use of analysis in functional capability qualification. Analysis methods may be used in the accelerated environmental aging process per the requirements of Nonmandatory Appendix QR-B.

QV-7300 Specific Qualification Requirements for Valve Assemblies

Valve requirements are based on the valve assembly type and category as delineated by Table QV-7300.

QV-7400 Qualification Requirements for Power-Operated Valve Assemblies

QV-7410 Initial Considerations. The ranges of the pressure, temperature, and flow for the valve and the maximum seat-sealing differential pressure shall be defined in the Qualification Plan and documented in the Functional Qualification Report (see QV-8310). 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 pressure and the seat-sealing test pressure used for qualification may be equal to or less than the rated pressure of the valve, but these test pressures shall determine the qualification pressure rating for the valve assembly. Pressure locking and thermal binding should also be addressed. Where production valve assemblies may have different operating requirements, the qualification plan shall envelop the requirements for the production valve assemblies.

The orientation of the valve assembly shall be as required by the Qualification Specification; however, the 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. Design limiting orientation may be different based on various qualification attributes, e.g., seismic capability versus functional capability.

Throughout the following sections of QV, it should be noted that the actuator used when testing the performance of the valve does not need to be the actuator that was tested for the actuator portions of the testing. Use of other than a qualified actuator for valve testing does, however, require special attention be paid to the valve and actuator interface as discussed below in QV-7461.3, QV-7462.3, and QV-7463.3.

QV-7420 Environmental and Aging. Friction of valve internal sliding surfaces can increase with age until a plateau is reached. Further, inspections and disassembly/reassembly of valves that expose valve internal surfaces to air can result in a temporary reduction in friction coefficients. Qualification of functional capability must address these phenomena when establishing valve operating requirements.

Environmental Qualification of actuators is performed in accordance with IEEE Std 323 and IEEE Std 382. Qualification of other nonmetallic parts, critical to valve assembly performance, may be performed in accordance with Nonmandatory Appendix QR-B.

QV-7430 Sealing Capability

QV-7431 Main-Seat Leakage. 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 (e.g., a globe valve with an unbalanced disk, where 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 shall be as long as required to determine the leakage rate but not fewer than 5 min. For double-disk gate valves, the selected seat-sealing test pressure may be applied to the bonnet cavity with the leakage rates being measured for each main seat. Document the relationship between seat leakage and applied thrust and/or torque and differential pressure. The qualification plan shall consider whether temperature and fluid conditions for the application of the valve assembly result in the need for further qualification testing.

QV-7432 Stem-Seal Leakage. 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 valve assembly ten times. The test shall be as long as required to determine the leakage rate but not fewer than 5 min. Document the relationship between stem-seal leakage and pressure. The qualification plan shall consider whether temperature and fluid conditions for the application of the valve assembly result in the need for further qualification testing.

QV-7440 End Loading. The pressure-containing portions of valves that are to be qualified to this document shall be designed to the applicable code selected by the plant Owner.

End-loading qualification is not required if

(a) 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

(b) 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)

QV-7441 End-Loading Qualification for QV Category A Valve Assemblies. For QV Category A valve assemblies, one of the following is required:

(a) Qualify analytically the maximum load (forces and moments) that can be placed on the valve body such that operation is not adversely affected. In turn, this load is to be supplied to the piping system designer who must design his system such that the load cannot be exceeded.

(b) Qualify by test for the maximum load that can be placed on the valve body such that operation is not adversely affected. In turn, this load is to be supplied to the piping system designer who must design his system such that the load cannot be exceeded.

(c) Require that the maximum stress intensity in the attached piping at the pipe to valve junction resulting from the combination of the primary or local membrane stress (P_M or P_L) plus the bending stress (P_b) plus the expansion stress (P_e) shall be limited to a value of $(G_b/F_b) \times S_y$ (G_b, S_b defined below). That is,

$$(P_M \text{ or } P_L) + P_b + P_e \leq \frac{G_b}{F_b} S_y$$

If G_b is unknown, then $\left(\frac{G_b}{F_b}\right)$ may be taken as 1.

where

F_b = bending modulus of connecting pipe
G_b = valve body section modulus at the crotch region
P_b = bending stress
P_e = expansion stress
P_L = local primary membrane stress
P_M = primary membrane stress

The determination of the maximum stress intensity shall be based on the highest combination of concurrent loads considering all concurrent loads defined in the Qualification Specification. The value of S_y shall be taken at the highest metal temperature of the attached piping for the concurrent load combination under consideration.

QV-7442 End-Loading Qualification for QV Category B Valve Assemblies. End-loading qualification is not required for QV Category B valve assemblies.

QV-7450 Seismic Qualification

(a) Seismic qualification is intended to demonstrate the ability of a valve assembly to withstand a loading that is representative of the specified seismic load qualification level.

(b) Qualification of valve assemblies shall be in accordance with IEEE Std 344 as addressed in NRC Regulatory Guide 1.100 (Revision 2) or Nonmandatory Appendix QR-A.

(c) All essential-to-function accessories shall be attached to the valve assembly. 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 in accordance with IEEE Std 344 or Nonmandatory Appendix QR-A.

QV-7460 Functional Qualification. The functional qualification of a valve assembly is made up of several different activities.

(a) Establish a qualified valve assembly by qualifying a valve assembly to function under a specified set of conditions. This is discussed below in QV-7461.

(b) Develop a methodology to extrapolate the qualification to another valve assembly. (It is desirable to not have to individually qualify each specific valve for its individual operating conditions.) This effort involves the analysis of the critical characteristics of how the valve assembly under consideration compares with the qualified valve assembly. This is described below in QV-7462.

(c) Ensure the production valve assembly performs in the manner predicted by the qualified valve assembly. This is described below in QV-7463.

QV-7461 Qualified Valve Assembly. The qualification of the functional capability of a valve assembly shall be justified using a combination of analysis and diagnostic test data. Test-based methodologies that have been demonstrated to reliably predict valve assembly performance may be used to supplement the testing in order to minimize the amount of testing needed to qualify the valve assembly. The following activities shall be performed to justify the qualification of the functional capability of the qualified valve assembly.

QV-7461.1 Qualified Valve

(a) Identify the manufacturer, type, size, materials (including internal parts), and rating; stem packing; and corrosion inhibitor (as applicable) for the valve to be qualified.

(b) Perform an internal inspection of the valve for material, surface condition, and critical internal dimensions (including valve internal clearances and edge radii). Evaluate design limiting tolerance combinations in the manufacturing process, and verify that the valve will behave predictably during the evaluation described in the following:

(1) Establish any orientation requirements and any system piping constraints that are applicable to the qualification of the valve.

(2) Establish fluid conditions (including blowdown) and stroke time requirements for which the valve is being qualified.

(3) Determine the seat leakage limitations (including directional sealing) of the valve.

(4) Determine the stem leakage limitations of the valve.

(5) While collecting diagnostic test data (including valve stem thrust and/or torque, fluid pressure and temperature, and stroke time), cycle the valve under static fluid conditions throughout the valve stroke in both the opening (including unseating) and closing (including seating) directions, and verify proper valve assembly.

(6) While collecting diagnostic test data (including valve stem thrust and/or torque, fluid pressure and temperature, and stroke time), cycle the valve in both the opening and closing directions until the coefficient of friction has stabilized and baseline performance parameters have been established.

(7) While collecting diagnostic test data (including stem thrust and/or torque, fluid pressure and temperature, and stroke time), cycle the valve under applicable fluid temperature, pressure, and flow conditions (from ambient to hot water and steam conditions); environmental conditions; and stroke-time requirements throughout the valve stroke (including seating and unseating), and verify the functional capability of the valve under design-basis conditions.

(8) Determine whether the valve is susceptible to pressure locking and/or thermal binding. If so, establish design limitations to prevent pressure locking and/or thermal binding.

QV-7461.2 Qualified Actuator

(a) Identify actuator manufacturer, type, size, and rating; lubricants used for gearboxes and sliding friction

points; and corrosion inhibitor (as applicable) for the power actuator to be qualified.

(b) Perform an internal inspection of the actuator for material, surface condition, and critical internal dimensions. Evaluate design limiting tolerance combinations in the manufacturing process, and verify that the actuator will behave predictably during the evaluation in the following:

(1) Establish any orientation requirements that are applicable to the qualification of the actuator.

(2) Establish the output thrust and/or torque versus stem position, environmental conditions, and motive power sources for which the actuator is being qualified.

(3) While collecting diagnostic test data (including actuator output thrust and/or torque; environmental conditions; stroke time; gearbox efficiency; motor torque, voltage, and current for motor-powered actuators; and operating air pressures and current signals for air-powered actuators, as applicable), cycle the actuator under nominal motive power source conditions throughout the actuator stroke in both the opening and closing directions, verify proper assembly, and establish baseline performance parameters.

(4) While collecting diagnostic test data (including actuator output thrust and/or torque; environmental conditions; stroke time; gearbox efficiency and motor torque, voltage, and current for motor-powered actuators; and operating air pressures and current signals for air-powered actuators, as applicable), cycle the actuator under applicable thrust and/or torque loads, environmental conditions, stroke-time requirements, and motive-power conditions throughout the actuator stroke in both the opening and closing directions, and verify the functional capability of the actuator under design-basis conditions.

QV-7461.3 Valve and Actuator Interface

(a) Identify the interface between the valve and actuator for the valve assembly to be qualified.

(b) Verify that the qualified thrust and/or torque output of the actuator equals or exceeds the required thrust and/or torque demands of the valve throughout the valve assembly stroke.

(c) For a motor-powered actuator with a rising stem valve, do the following:

(1) Identify any lubricants used on the valve stem.

(2) While collecting diagnostic test data (including valve stem thrust and/or torque), cycle the valve assembly throughout the valve assembly stroke until the friction between the stem and the stem-nut has stabilized.

(3) While collecting diagnostic test data (including valve stem thrust and/or torque), cycle the valve assembly throughout the valve assembly stroke under representative fluid and environmental conditions and determine the stem-to-stem-nut coefficient of friction and load sensitive behavior. Refer to Section QV-G, Guide to Section QV: Determination of Valve Assembly Performance Characteristics for Guidance.

QV-7462 Extrapolation of Qualification to Another Valve Assembly. The extrapolation of the qualification of the functional capability of a qualified valve assembly to another valve assembly shall be justified using a combination of analytical comparison of physical attributes and diagnostic test data. Test-based methodologies that have been demonstrated to reliably predict valve assembly performance may be used in lieu of the testing needed to extrapolate the qualification to another valve assembly. The following activities shall be performed to justify the extrapolation of the qualification to another valve assembly.

QV-7462.1 Valve

(a) Establish applicability of valve type, size, material (including internal parts), and rating; orientation; system piping constraints; stem packing; and any corrosion inhibitor of the valve being qualified to the qualified valve.

(b) Perform an internal inspection of the valve for material, surface condition, and critical internal dimensions (including valve internal clearances and edge radii) in order to establish applicability of construction to the qualified valve (see QV-7461.1) and to evaluate design-limiting tolerance combinations in the manufacturing process, and verify that the valve will behave predictably.

(c) Establish applicability of fluid conditions and stroke-time requirements for the valve to be qualified to the qualified valve.

(d) Determine the seat leakage limitations (including directional sealing) of the valve.

(e) Determine the stem leakage limitations of the valve.

(f) While collecting diagnostic test data (including valve stem thrust and/or torque; fluid pressure and temperature; and stroke time), cycle the valve under static fluid conditions throughout the valve stroke in both the opening (including unseating) and closing (including seating) directions, and verify proper valve assembly.

(g) Applying the qualification and test information obtained under QV-7461.1, with supplemental testing as necessary, collect diagnostic data (including stem thrust and/or torque, fluid pressure and temperature, and stroke time) for applicable fluid temperature, pressure, and flow conditions (from ambient to hot water and steam conditions) and stroke time throughout the valve stroke (including seating and unseating), and verify the functional capability of the valve under design-basis conditions.

(h) Determine whether the valve is susceptible to pressure locking and/or thermal binding. If so, establish

design limitations to prevent pressure locking and/or thermal binding.

QV-7462.2 Actuator

(a) Establish applicability of actuator type, size, and rating (including internal parts and material); orientation; lubricants; and any corrosion inhibitor of the actuator being qualified to the qualified actuator.

(b) Perform an internal inspection of the actuator for material, surface condition, and critical internal dimensions. Evaluate design-limiting tolerance combinations in the manufacturing process, and verify that the actuator will behave predictability.

(c) Establish the output thrust and/or torque-versus-stem position for which the actuator is being qualified.

(d) Establish applicability of environmental conditions, stroke-time requirements, and motive power source conditions (such as air pressures for air-powered actuators and motor current and voltage for motor-powered actuators, as applicable) for the actuator to be qualified to conditions applicable to the qualified actuator.

(e) While collecting diagnostic test data (including actuator output thrust and/or torque; environmental conditions; stroke time; gearbox efficiency; motor torque, voltage, and current for motor-powered actuators; and operating air pressures and current signals for air-powered actuators, as applicable), cycle the actuator under nominal motive power source conditions throughout the actuator stroke in both the opening and closing directions, verify proper assembly, and establish baseline performance parameters.

(f) Applying the qualification and test information obtained under QV-7461.2, with supplemental testing as necessary, establish diagnostic data (including actuator output thrust and/or torque; environmental conditions; stroke time; gearbox efficiency and motor torque, voltage, and current for motor-powered actuators; and operating air pressures and current signals for air-powered actuators, as applicable) for applicable thrust and/or torque loads, stroke time, and motive-power conditions throughout the actuator stroke in both the opening and closing directions, and verify the functional capability of the actuator under design-basis conditions.

QV-7462.3 Valve and Actuator Interface

(a) Identify the interface between the valve and actuator for the valve assembly to be qualified.

(b) Verify that the qualified thrust and/or torque output of the actuator equals or exceeds the required thrust and/or torque demands of the valve throughout the valve assembly stroke.

(c) For a motor-powered actuator with a rising stem valve, do the following:

(1) Identify any lubricants, and establish the applicability under environmental conditions of the lubricants, used on the valve stem.

(2) Applying the qualification and test information obtained under QV-7461.3, with supplemental testing as necessary, collect diagnostic data (including valve stem thrust and/or torque) for the valve assembly throughout the valve assembly stroke at representative fluid conditions, and determine the stem-to-stem-nut coefficient of friction and load sensitive behavior. Refer to Section QV-G, Guide to Section QV: Determination of Valve Assembly Performance Characteristics for Guidance.

QV-7463 Demonstration of Functional Capability of Production Valve Assemblies. The functional capability of the production valve assembly shall be demonstrated by verification of the physical attributes, application, and diagnostic test data of the production valve assembly to its qualified valve assembly. At the discretion of the Owner, the production valve assembly testing may be performed following final installation of the valve assembly. The following activities shall be performed to demonstrate the functional capability of production valve assembly.

QV-7463.1 Production Valve

(a) Verify applicability of the production valve type, size, material (including internal parts), and rating; orientation; piping system constraints; stem packing; and any corrosion inhibitor to the qualified valve.

(b) Perform an internal inspection of the production valve for material, surface condition, and critical internal dimensions (including verifying that valve internal dimensions, clearances, and edge radii are within manufacturing tolerances) to establish applicability to the qualified valve.

(c) Verify applicability of fluid conditions and stroke-time requirements for the production valve to the qualified valve.

(d) Verify that the seat leakage limitations (including directional sealing) of the qualified valve are applicable to the production valve.

(e) Verify that the stem leakage limitations of the qualified valve are applicable to the production valve.

(f) While collecting diagnostic test data (including valve stem thrust and/or torque, fluid pressure and temperature, and stroke time), cycle the production valve under static fluid conditions throughout the valve stroke in both the opening (including unseating) and closing (including seating) directions in order to verify proper assembly.

(g) Verify applicability of the functional capability (including stroke time) of the production valve for opening and closing under fluid conditions to the qualified valve through the use of specific test data or a test-based qualification methodology.

(h) Verify that the production valve addresses any pressure locking and/or thermal binding limitations of the qualified valve.

QV-7463.2 Production Actuator

(a) Verify applicability of the production actuator type, size, and rating (including internal parts and materials); orientation; lubricants; and any corrosion inhibitor to the qualified actuator.

(b) Perform an internal inspection of the Production Actuator for material, surface condition, and critical internal dimensions (including verifying that internal dimensions, clearances, and edge radii are within manufacturing tolerances) to establish applicability to the qualified actuator.

(c) Verify applicability of environmental conditions, stroke-time requirements, and motive power source conditions (such as air pressures for air-powered actuators and motor current and voltage for motor-powered actuators) of the production actuator to the qualified actuator.

(d) While collecting diagnostic test data (including stem thrust and/or torque; environmental conditions; stroke time; motor torque, voltage, and current for motor-powered actuators; and operating air pressures and current signals for air-powered actuators, as applicable), cycle the production actuator under nominal motive power source conditions throughout the actuator stroke to verify proper assembly.

(e) Verify applicability of the functional capability (including stroke time) of the production actuator for opening and closing under environmental and power conditions to the qualified actuator through the use of specific test data or a test-based qualification methodology.

QV-7463.3 Production Valve and Actuator Interface

(a) Verify applicability of the production valve and production actuator interface to the qualified valve assembly.

(b) Verify that the thrust and/or torque output of the production actuator equals or exceeds the required thrust and/or torque demands of the production valve throughout the valve assembly stroke.

(c) For a motor-powered actuator with a rising stem valve, do the following:

(1) Verify that the lubricants used are applicable to the qualified valve assembly.

(2) Verify applicability of the stem-to-stem-nut coefficient of friction and the load sensitive behavior of the production valve assembly to the qualified valve assembly through the use of specific test data or a test-based qualification methodology.

(3) Cycle the production valve assembly under static conditions throughout the valve stroke to verify proper assembly.

QV-7470 Post-Installation Verification and IST Baseline After the production valve assembly has been installed in the plant, it shall be cycled under representative fluid conditions as necessary to collect diagnostic data (including valve stem thrust and torque; fluid pressure and temperature; stroke time; MOV motor torque, voltage, and current; and AOV operating air pressures and current signals, as applicable) throughout the valve stroke to verify the production valve assembly meets the functional requirements of the Qualification Specification. The requirements of QV-7470 are the responsibility of the Owner.

QV-7500 Qualification Requirements for Self-Actuated Check Valve Assemblies

QV-7510 Initial Considerations. The ranges of the test pressure, temperature, and flow 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 and seat-sealing test pressures 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 valve assembly. Where production valve assemblies may have different operating pressure requirements, the qualification of the qualified valve assembly must include a range of test pressures encompassing the requirements for the production valve assemblies.

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 may be qualified by analysis that verifies that the actuating device cannot degrade the function or operability during and after a seismic event. Additionally, those check valves with an external actuating device whose sole purpose is to provide a means for in-service testing of operability may be qualified by analysis that verifies the actuating device cannot degrade the function or operability during and after a seismic event.

QV-7520 Environmental and Aging. The qualification of nonmetallic parts that are critical to valve assembly performance may be performed in accordance with Nonmandatory Appendix QR-B.

QV-7530 Sealing Capability

QV-7531 Main-Seat Leakage. The valve shall be pressurized in the flow 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.

QV-7532 Shaft-Seal Leakage. For check valves having sealed shafts, shaft-seal leakage shall be observed at cold working pressure applied to the seal. For valves with leak-off connections, leakage at the leak-off connection shall be measured and recorded. For valves without leak-off connections, shaft-seal leakage shall be observed and the leak rate estimated. If the sealed shaft is a moving part, the initial shaft-seal leakage test shall be performed after fully cycling the valve assembly ten times. The leakage rate test duration shall be adequate to measure the leakage rate but not fewer than 5 min.

QV-7540 End Loading. The pressure-containing portions of valves that are to be qualified to this document shall be designed to the applicable code selected by the plant Owner.

The end-loading test is not required if

(a) 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

(b) 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)

QV-7541 End Loading for QV Category A Valve Assemblies. For QV Category A valve assemblies, one of the following is required:

(a) Qualify analytically the maximum load (forces and moments) that can be placed on the valve body such that operation is not adversely affected. In turn, this load is to be supplied to the piping system designer who must design his system such that the load cannot be exceeded.

(b) Qualify by test for the maximum load (forces and moments) that can be placed on the valve body such that operation is not adversely affected. In turn, this load is to be supplied to the piping system designer who must design his system such that the load cannot be exceeded.

(c) Require that the maximum stress intensity in the attached piping, at the pipe-to-valve junction resulting from the combination of the primary or local membrane stress (P_M or P_L) plus the bending stress (P_b) plus the expansion stress (P_e), shall be limited to a value of $(G_b/F_b) \times S_y$ (G_b, S_y defined below). That is,

$$(P_M \text{ or } P_L) + P_b + P_e \leq \frac{G_b}{F_b} S_y$$

If G_b is unknown, then $\left(\frac{G_b}{F_b}\right)$ may be taken as 1.0

when

F_b = bending modulus of connecting pipe
G_b = valve body section modulus at the crotch region
P_b = bending stress
P_e = expansion stress
P_L = local primary membrane stress
P_M = primary membrane stress

The determination of the maximum stress intensity shall be based on the highest combination of concurrent loads considering all concurrent loads defined in the Qualification Specification. The value of S_y shall be taken at the highest metal temperature of the attached piping for the concurrent load combination under consideration.

QV-7542 End Loading for QV Category B Valve Assemblies. End-loading qualification is not required for QV Category B valve assemblies.

QV-7550 Seismic Qualification. Seismic qualification of check valves is not required under this Standard and may be covered by applicable design codes.

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 may be qualified by analysis that verifies the actuating device cannot degrade the function or operability during and after a seismic event. Additionally, those check valves with an external actuating device whose sole purpose is to provide a means for in-service testing of operability may be qualified by analysis that verifies the actuating device cannot degrade the function or operability during and after a seismic event.

QV-7560 Functional Qualification

QV-7561 Valve Assembly to Be Qualified. The valve functional qualification establishes key performance parameters necessary for the evaluation of proper valve sizing to maintain the valve disk in the full open position under normal flow conditions and the evaluation of valve adequacy for service applications involving flow reversal and resulting pressure surge produced by valve closure. The following activities shall be performed to justify the qualification for functional capability of the valve assembly:

(a) Identify manufacturer, type, size, material (including internal parts), and rating; stem packing; and corrosion inhibitor (as applicable).

(b) Establish orientation and system piping application.

(c) Establish applicable fluid and system flow conditions.

(d) Establish sealing capability requirements for valve.

(e) Establish stem shaft leakage limitations for valve.

Test-based methodologies that have been demonstrated to reliably predict valve assembly performance may be used to supplement valve-specific testing to minimize the range of flow testing in qualifying the valve assembly.

QV-7561.1 Valve Qualification for Forward Flow. Perform internal inspection of the valve assembly to be qualified for material and surface condition and critical internal dimensions (including valve internal clearances), and evaluate design-limiting tolerance combination in manufacturing process to assess valve predictable behavior.

The valve assembly shall be installed in a piping system capable of incrementally increasing volumetric and mass flow rates to determine valve disk position at various flows, including the full open, stable position against a stop. A sufficient number of test runs shall be performed to verify the full open, stable characteristics of the valve. The valve shall be protected against system turbulence. The test fluid shall be of equal or less density than the fluid of the valve application, or appropriate momentum corrections shall be made.

The test valve shall include a means to verify the valve disk position. The valve shall be protected against unstable flow conditions.

The mass flow rate required ensuring full travel of the disk to stable contact with a stop shall be determined. At the full open, stable flow condition, the flow velocity and fluid condition (data to determine the mass flow rates) shall be recorded. A sufficient number of test runs shall be performed to verify the full open, stable characteristics of the valve.

QV-7561.2 Valve Qualification for Closing. The test valve assembly shall be installed in a piping system for water flow testing. Tests shall be performed by establishing full forward flow or full opening of the valve, stopping forward flow at various rates, and observing the valve closure.

If flow reversal can occur prior to valve closure, a test shall be performed to simulate the reverse flow and the valve open position to verify that sealing parts remain intact and that seat wedging cannot occur. Typically, flow reversal can occur prior to valve closure when the check valve closes to isolate a line break or when one of a group of parallel pumps trips and a check valve closes to prevent pump short circuiting.

NOTE: 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 during a reverse flow test.

As soon as conditions permit, following completion of the valve closure, an observation shall be made of the seat leakage under differential pressure.

Valves having a body and/or disk seating taper angle greater than 29 deg (cone angle greater than 58 deg) are not susceptible to seat wedging and need not be qualified for seat wedging.

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 the minimum differential pressure in the normal flowing direction.

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 this testing.

For the evaluation of valve adequacy to handle flow reversals, it is required that an analytical model, a test, or a combination of both be developed and demonstrated.

QV-7562 Extrapolation of Qualification for Functional Capability. The extrapolation of the qualification of the functional capability of a qualified valve assembly to another valve assembly shall be justified using a combination of analytical comparison of physical attributes and diagnostic test data. The following activities shall be performed to justify the extrapolation of the qualification for functional capability:

(a) Establish applicability of valve type, size, and rating (including internal parts and seat material); orientation; and any corrosion inhibitor of the valve assembly being qualified to the applicable qualified valve assembly.

(b) Perform internal inspection of valve assembly for material and surface condition and critical internal dimensions, and evaluate design-limiting tolerance combination to assess valve predictable behavior and to establish applicability of construction to the qualified valve assembly.

(c) Establish applicability of fluid and environmental conditions for the valve assembly to be qualified to conditions applicable to the qualified valve assembly.

(d) Determine applicability of sealing capability requirements.

(e) Cycle the valve assembly to be qualified under static conditions with collection of diagnostic data to verify proper assembly and establish baseline parameters.

(f) Establish applicability of functional capability of the valve assembly to be qualified for opening and closing under fluid flow and environmental conditions to the qualified valve assembly through use of specific test data or a test-based qualification methodology.

QV-7563 Demonstration of Functional Capability of Production Valve Assemblies. The functional capability of production valve assemblies shall be demonstrated based on verification of the physical attributes, application, and diagnostic data for the production valve assemblies consistent within manufacturing tolerances to its qualified valve assembly. The following activities shall be performed in demonstrating the functional capability of production valve assemblies:

(a) Verify applicability of the production valve assembly, e.g., including valve type, size, and rating; internal parts; seat material; orientation; and any corrosion inhibitor, to its qualified valve assembly.

(b) Perform internal inspection of production valve assembly for material and surface condition and critical