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# REGULATORY GUIDE

**OFFICE OF NUCLEAR REGULATORY RESEARCH**

## REGULATORY GUIDE 1.100

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# SEISMIC QUALIFICATION OF ELECTRICAL AND ACTIVE MECHANICAL EQUIPMENT AND FUNCTIONAL QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT FOR NUCLEAR POWER PLANTS

## A. INTRODUCTION

This guide describes methods that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in the seismic qualification of electrical and active mechanical equipment and the functional qualification of active mechanical equipment for nuclear power plants (NPPs).

The general requirements for the seismic design of electrical and active mechanical equipment appear in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1), and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2). The primary sections include General Design Criterion (GDC) 1, "Quality Standards and Records"; GDC 2, "Design Bases for Protection Against Natural Phenomena"; of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50; Criterion III, "Design Control"; Criterion XI, "Test Control"; and Criterion XVII, "Quality Assurance Records," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50; and Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50.

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Section III, "Definitions," of Appendix S to 10 CFR Part 50 states that the structures, systems, and components (SSCs) required to withstand the effects of the safe-shutdown earthquake (SSE) ground motion or surface deformation are those necessary to assure (1) the integrity of the reactor coolant pressure boundary; (2) the capability to shut down the reactor and maintain it in a safe-shutdown condition; or (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR 50.34(a)(1).
Section IV(a)(1)(ii) of Appendix S to 10 CFR Part 50 requires the NPP to be designed so that, if the SSE ground motion occurs, certain SSCs will remain functional and within applicable stress, strain, and deformation limits.  In addition to seismic loads, the design of these safety-related SSCs must take into account applicable concurrent normal operating, functional, and accident-induced loads.
Section IV(a)(1)(iii) of Appendix S to 10 CFR Part 50 requires the safety functions of SSCs to be assured during and after the vibratory ground motion associated with the SSE ground motion through design, testing, or qualification methods.[1]

The general requirements for the functional design of active mechanical equipment also appear in 10 CFR Part 50 and 10 CFR Part 52.  In 10 CFR Part 50, particular sections include GDC 1, GDC 2, GDC 14, "Reactor Coolant Pressure Boundary," GDC 15, "Reactor Coolant System Design," GDC 30, "Quality of Reactor Pressure Boundary," GDC 37, "Testing of Emergency Core Cooling System," GDC 40, "Testing of Containment Heat Removal System," GDC 43, "Testing of Containment Atmosphere Cleanup Systems," GDC 46, "Testing of Cooling Water System," and GDC 54, "Systems Penetrating Containment," of Appendix A to 10 CFR Part 50, as well as Criteria III, XI, and XVII of Appendix B to 10 CFR Part 50.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 and 10 CFR Part 52 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0011 and 3150-0151.  The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays currently valid OMB control numbers.

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[1] Appendix S to 10 CFR Part 50 applies to applicants for a design certification or combined license pursuant to 10 CFR Part 52 or a construction permit or operating license pursuant to 10 CFR Part 50 after January 10, 1997. However, the earthquake engineering criteria in Section VI, "Application to Engineering Design," of Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3), continue to apply to either an operating license applicant or holder with a construction permit issued before January 10, 1997.

# B. DISCUSSION

## Background

The NRC issued Revision 2 of Regulatory Guide (RG) 1.100, “Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants” (Ref. 4), in June 1988. With a few exceptions and clarifications, it endorsed the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 344-1987, “IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations” (Ref. 5), issued January 1987, and extended the application of that standard to the seismic qualification of mechanical equipment. In extending the application of IEEE Std. 344-1987 to mechanical equipment, the NRC staff recognized differences in seismic qualification methods for electrical equipment[2] (including instrumentation and control (I&C) components) and mechanical equipment. Specifically, Revision 2 of this regulatory guide stated that the seismic qualification of mechanical equipment by analysis is permitted when such equipment can be modeled to adequately predict its response. Revision 2 also stated that the American Society of Mechanical Engineers (ASME) was developing a standard for the seismic qualification of mechanical equipment and, upon its publication; the NRC staff would review it for suitability for endorsement by a revision of this regulatory guide.

In March 1981, the NRC issued Revision 0 of RG 1.148, “Functional Specification for Active Valve Assemblies in Systems Important to Safety in Nuclear Power Plants” (Ref. 6). With a few exceptions and clarifications, this guide endorsed American National Standards Institute (ANSI) N278.1-1975, “Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard” (Ref. 7).

In 1994, ASME issued a standard, ASME QME-1-1994, “Qualification of Active Mechanical Equipment Used in Nuclear Power Plants” (Ref. 8). This ASME standard eventually replaced the ANSI N278.1 standard. The ASME QME-1 standard covers both the seismic qualification and the functional qualification of active mechanical equipment. ASME subsequently revised and reissued the standard in 1997, 2000, and 2002, with the last revision issued in November 2007 as ASME QME-1-2007 (Ref. 9). Furthermore, the IEEE updated IEEE Std. 344-1987 and issued it as IEEE Std. 344-2004 (Ref. 10) in June 2005.

The NRC is revising this RG (i.e., Revision 3 of RG 1.100) to endorse, with exceptions and clarifications, IEEE Std. 344-2004 and ASME QME-1-2007. (This is the first time the NRC has endorsed ASME QME-1.) This revision of the RG will also subsume RG 1.148. Specifically, Sections B.1 and C.1 of this RG endorse, with exceptions and clarifications, the entire IEEE Std. 344-2004 and Section QR, "General Requirements," and Non-mandatory Appendix QR-A, "Seismic Qualification of Active Mechanical Equipment," to ASME QME-1-2007 for the seismic qualification of electrical and active mechanical equipment. Sections B.2 and C.2 of this RG endorse, with exceptions and clarifications, Section QR and the remaining sections of ASME QME-1-2007 (except Non-mandatory Appendix QR-A) for the functional qualification of active mechanical equipment. The ASME QME-1 standard defines active mechanical equipment as “Mechanical equipment containing moving parts, which, in order to accomplish its required function as defined in the Qualification Specification, must undergo or

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2 Hereafter in this RG, the term “electrical equipment” means an assembly of electrical and electronic components designed and manufactured to perform specific functions, and the term “electrical component” or “electronic component” means items from which the equipment is assembled (e.g., resistors, capacitors, wires, connectors, microprocessors, switches, springs, and instrumentation and control items).

prevent mechanical movement. This includes any internal components or appurtenances whose failure degrades the required function of the equipment."

## 1. Seismic Qualification of Electrical and Active Mechanical Equipment

The major change from IEEE Std. 344-1987 to IEEE Std. 344-2004 is the update and expansion of Clause 10, "Experience," which describes the use of experience data as a method for seismic qualification of Class 1E electrical equipment (including I&C components). Experience data include earthquake experience data and test experience data. Non-mandatory Appendix QR-A to ASME QME-1-2007, which has been updated and expanded from Non-mandatory Appendix QR-A to ASME QME-1-2002, also includes the use of experience data as a method for the seismic qualification of active mechanical equipment.

The use of earthquake experience data for the seismic qualification of electrical and mechanical equipment has its origin in the NRC research program associated with Unresolved Safety Issue (USI) A-46, "Seismic Qualification of Mechanical and Electrical Equipment in Operating Nuclear Power Plants." In 1980, the NRC staff raised a safety concern that licensees had not conducted the seismic qualification of electrical and mechanical equipment in some older NPPs (i.e., plants with construction permit applications docketed before about 1972), in accordance with the licensing criteria for the seismic qualification of equipment acceptable at that time (i.e., IEEE Std. 344-1975 (Ref. 11) and RG 1.100, Revision 1 (Ref. 12), issued August 1977). Therefore, equipment in the older NPPs may not have been adequately qualified to ensure its structural integrity or proper functionality in the event of an SSE ground motion. As a result, the NRC established the USI A-46 program in December 1980 and, in February 1987, issued Generic Letter (GL) 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46" (Ref. 13), to address this safety concern. The NRC staff categorized approximately 70 NPP units in the United States as "USI A-46 plants."

In 1982, the Seismic Qualification Utility Group (SQUG) developed a database using earthquake experience and test experience to address USI A-46. Because of the scarcity of data on equipment that was subjected to strong earthquake motion in U.S. NPPs, the SQUG and its contractors performed a pilot study to determine the feasibility of using actual earthquake experience data from nonnuclear plants located worldwide (e.g., fossil-fueled power plants, substations, petrochemical plants) and existing test experience data from domestic NPPs to evaluate the performance of electrical and mechanical equipment in those facilities to infer the susceptibility of similar NPP equipment to seismic loads. The SQUG concluded, and the NRC agreed, that the use of experience data was feasible for the purpose of verifying the seismic adequacy of equipment in the older, USI A-46 plants. The staff does not accept the use of SQUG guidelines for the seismic qualification of equipment in non-USI A-46 plants licensed under 10 CFR Part 50 or in plants licensed under 10 CFR Part 52.

Large uncertainties exist in the seismic qualification of equipment, as a class, on the basis of earthquake experience data, because (1) it is difficult to compile a credible earthquake experience database (e.g., estimation of ground and floor earthquake excitations used in the earthquake experience database), (2) the inclusion and exclusion rules (termed "prohibited features" in IEEE Std. 344-2004) of equipment in the database may not be complete, (3) the similarity between equipment in fossil or petrochemical plants in the database and the equipment in NPPs is difficult to establish; and, most importantly, (4) generally, there is not sufficient credible information from the earthquake experience database to provide assurance that certain active electrical equipment will function properly during earthquakes.

In using the test experience data for the seismic qualification of electrical equipment, quantifying the damage potential of equipment under testing should capture the combination of input motion and the equipment item exhibiting a particular malfunction. Given the likelihood that the resonant frequency for items of equipment of the same class may differ significantly, multiple malfunction mechanisms for components and subcomponents should be considered in comparing the test response spectra (TRS) and the required response spectra (RRS).

The technologies and designs of certain electrical components (such as certain types of relays and microprocessor-based components) have undergone significant changes since the NRC issued Revision 2 of this RG, as a result of the more prevalent use of digital rather than analog I&C components. Some solid-state relays and microprocessor-based components may be sensitive to earthquake excitations. The staff considers the use of test experience data from the older electrical components of this type to be inappropriate and unacceptable for the seismic qualification of the new generation of such electrical components. Furthermore, since no new NPPs have been built in the United States since the early 1980s, a number of manufacturers of electrical or active mechanical equipment are no longer in business, and the appropriateness of using the test experience of old equipment made by manufacturers no longer in business for the seismic qualification of modern equipment designs made by different manufacturers is highly questionable.

Recent studies related to applications for early site permits at certain hard-rock-based plants along the east coast of the United States indicated that the site-specific spectra may exceed the certified design spectra of those new plants in the high-frequency range (20 hertz (Hz) and above). This exceedance cannot always be eliminated, even with incoherency added to the soil-structure interaction analyses. As a result of the high-frequency ground motion, the seismic input to SSCs may also contain high-frequency excitations. For operating boiling-water reactor (BWR) plants, the seismic qualifications of some safety-related electrical and active mechanical equipment were performed using IEEE Std. 344-type tests with intentional high-frequency contents to account for concurrent BWR hydrodynamic loads. However, the vast majority of existing seismic qualification tests used input frequencies up to only 33 Hz, although the TRS may have shown a zero period acceleration (nonamplified frequency range) up to 100 Hz. Ball joints and kinematics linkages of the shake tables generated these inadvertent high frequencies that may not have the proper frequency content with sufficient energy to be compatible with the amplified region of the RRS at high frequencies. Therefore, any attempt to use such past test experience data for the seismic qualification of high-frequency-sensitive equipment or components in such a plant is not appropriate unless the frequency content of the power spectral density (PSD) of the test waveform has been evaluated in accordance with Annex B, "Frequency Content and Stationarity," to IEEE Std. 344-2004. When licensees plan new seismic qualification tests for equipment in such plants, the formulation of the test input waveforms should properly consider this high-frequency excitation.

## 2. Functional Qualification of Active Mechanical Equipment

The ASME QME-1-2007 standard describes requirements and guidelines for qualifying active mechanical equipment used in NPPs. The foreword to the standard indicates that it may be applied to future NPPs or existing operating NPP component replacements, modifications, or additions, as determined by regulators and the licensees. ASME QME-1-2007 provides functional qualification guidance for nonmetallic parts, dynamic restraints, pumps, and valves. The following sections and appendices of ASME QME-1-2007 provide the functional qualification guidance for this active mechanical equipment: (1) Section QR, (2) Non-mandatory Appendix QR-B, "Guide for Qualification of Nonmetallic Parts," (3) Section QDR, "Qualification of Dynamic Restraints," and its Non-mandatory Appendices QDR-A, "Functional Specification for Dynamic Restraints," QDR-B, "Restraint Similarity," and QDR-C, "Typical Values of Restraint Functional Parameters," (4) Section QP, "Qualification of

Active Pump Assemblies," and its Non-mandatory Appendices QP-A, "Pump Specification Checklist," QP-B, "Pump Shaft-Seal System Specification Checklist," QP-C, "Pump Turbine Driver Specification Checklist," QP-D, "Pump Similarity Checklist," and QP-E, "Guidelines for Shaft-Seal System Material and Design Consideration," (5) Section QV, "Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants," its Mandatory Appendix QV-I, "Qualification Specification for Active Valves," and its Non-mandatory Appendix QV-A, "Functional Specification for Active Valves for Nuclear Power Plants," and (6) Section QV-G, "Guide to Section QV: Determination of Valve Assembly Performance Characteristics." The major change from ASME QME-1-2002 to ASME QME-1-2007, in terms of the functional qualification of mechanical equipment, is a complete rewrite of Section QV and the new Mandatory Appendix QV-I.

In the 1980s and 1990s, operating experience at NPPs revealed a number of weaknesses in the initial design, qualification, testing, and performance of motor-operated valves (MOVs). For example, some engineering analyses used in the original sizing and setting of MOVs inadequately predicted the thrust and torque for opening and closing valves under design-basis conditions. Similarly, some testing methods used to measure valve stroke times under zero differential-pressure and flow conditions did not detect deficiencies that could prevent MOVs from performing their safety functions under design-basis conditions. Both regulatory and industry research programs later confirmed weaknesses in the performance of MOVs. Such programs included extensive NRC research to study the performance of MOVs under various flow, temperature, and voltage conditions, and a nuclear-industry-sponsored program by the Electrical Power Research Institute (EPRI) to develop a computer methodology to predict the performance of MOVs under a wide range of operating conditions.

Responding to weaknesses found in the initial design, qualification, testing, and performance of MOVs, the NRC issued GL 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance" (Ref. 14), in June 1989, which requested licensees to (1) ensure the capability of MOVs in safety-related systems to perform their intended functions by reviewing MOV design bases, (2) verify MOV switch settings initially and periodically, (3) test MOVs under design-basis conditions when practicable, (4) improve evaluations of MOV failures and necessary corrective action, and (5) trend MOV problems. The NRC staff evaluated various MOV NPP programs through onsite inspections of the design-basis capability of safety-related MOVs.

In support of the regulatory activities to ensure MOV design-basis capability, the NRC conducted a research program to test several MOVs under normal flow and blowdown conditions. The NRC summarized the results of this MOV research program in Information Notice (IN) 90-40, "Results of NRC-Sponsored Testing of Motor-Operated Valves" (Ref. 15), dated June 5, 1990. The tests revealed that (1) more thrust was needed to operate gate valves than predicted by standard industry methods, (2) some valves were internally damaged under blowdown conditions and how they would operate was unpredictable, (3) static and low-flow testing might not predict valve performance under design-basis flow conditions, (4) during valve opening strokes, the highest thrust might be needed at unseating or in the flow stream, (5) partial valve stroking did not reveal the total thrust needed to operate the valve, (6) torque, thrust, and motor operating parameters were needed to fully characterize MOV performance, and (7) reliable use of MOV diagnostic data requires accurate equipment and trained personnel.

To assist NPP licensees in responding to GL 89-10, EPRI developed the MOV performance prediction methodology (PPM) to determine the minimum dynamic thrust and torque requirements for gate, globe, and butterfly valves, based on first principles of MOV design and operation. EPRI described the methodology in Topical Report (TR) -103237, Revision 2, "EPRI MOV Performance Prediction Program" (Ref. 16), issued April 1997. The EPRI program included the development of improved methods for the prediction and evaluation of system flow parameters; gate, globe, and butterfly valve performance; and motor-actuator rate-of-loading effects (load-sensitive behavior). EPRI conducted numerous valve tests to provide data for the development and validation of the valve performance models and methods, including flow loop testing, parametric flow loop testing of butterfly valve disk designs, and in situ MOV testing. The NRC staff issued a safety evaluation (SE) in March 1996, "Safety Evaluation on EPRI MOV Performance Prediction Methodology" (Ref. 17), accepting the EPRI program with certain conditions and limitations. The NRC staff also issued supplements to the SE in February 1997 (Ref. 18), April 2001 (Ref. 19), September 2002 (Ref.20), and February 2009 (Ref. 21), to address updates to the EPRI MOV program. The NRC staff alerted licensees to lessons learned from the EPRI program in IN 96-48, "Motor-Operated Valve Performance Issues" (Ref. 22), dated August 21, 1996.

In September 1996, the NRC issued GL 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves" (Ref. 23), to provide recommendations for ensuring the capability of safety-related MOVs to perform their design-basis functions over the long term. In response to GL 96-05, the NPP owners groups developed an industry wide Joint Owners Group (JOG) program on MOV periodic verification to obtain benefits from sharing information among licensees on MOV performance. Following an interim MOV program and extensive dynamic MOV testing at NPPs, in February 2004, the JOG submitted to the NRC the Topical Report MPR-2524, Revision 0, "Joint Owners' Group Motor-Operated Valve Periodic Verification Program Summary" (Ref. 24), providing long-term recommendations for the periodic verification of MOVs to be implemented by licensees as part of their commitments to GL 96-05. The NRC staff issued its "Final Safety Evaluation on Joint Owners' Group Program on Motor-Operated Valve Periodic Verification" in September 2006 (Ref. 25).

In the late 1990s, the NRC conducted research to study the performance of alternating current (ac)-powered MOV motor actuators manufactured by Limitorque Corporation under various temperature and voltage conditions. For the Limitorque ac-powered motor-actuator combinations tested, the research indicated that (1) actuator efficiency might not be maintained at the "run" efficiency published by the manufacturer, (2) degraded voltage effects can be more severe than predicted by the square of the ratio of actual-to-rated motor voltage, (3) some motors produce more torque output than predicted by their nameplate rating, and (4) temperature effects on motor performance appeared consistent with the Limitorque guidance. The NRC documented its study of ac-powered MOV output in NUREG/CR-6478, "Motor-Operated Valve (MOV) Actuator Motor and Gearbox Testing" (Ref. 26), issued July 1997. The nuclear industry also evaluated the output capability of ac-powered MOVs at several plants. In response to the new information on ac-powered MOV performance, Limitorque provided updated guidance in its Technical Update 98-01, "Actuator Output Torque Calculation" (Ref. 27), issued May 1998, and Supplement 1, issued in July 1998, for the prediction of ac-powered MOV motor actuator output. The NRC alerted licensees to the new information on ac-powered MOV output in Supplement 1 to IN 96-48 (Ref. 28), dated July 24, 1998.

Following its review of ac-powered MOV performance, the NRC conducted research to study the performance of Limitorque direct current (dc)-powered MOV motor actuators under various temperature and voltage conditions. For the Limitorque dc-powered motor-actuator combinations tested, the research indicated that (1) the ambient temperature effects were more significant than predicted, (2) the use of a linear voltage factor needs to consider reduced speed, increased motor temperature, and reduced motor output, (3) the stroke-time increase is significant for some dc-powered MOVs under loaded conditions, and (4) the actuator efficiency may fall below the published "pullout" efficiency at low-speed and high-load conditions. The NRC documented this research in NUREG/CR-6620, "Testing of dc-Powered Actuators for Motor-Operated Valves" (Ref. 29), issued May 1999. In June 2000, the BWR Owners Group forwarded to the NRC its TR NEDC-32958, "BWR Owners Group dc Motor Performance Methodology—Predicting Capability and Stroke Time in dc Motor-Operated Valves" (Ref. 30), issued March 2000. In August 2001, the NRC issued Regulatory Issue Summary 2001-15, "Performance of dc-

Powered Motor-Operated Valve Actuators" (Ref. 31), to inform licensees of the availability of improved industry guidance for predicting dc-powered MOV actuator performance.

Through an extensive effort spanning many years, the ASME QME Standards Committee revised Section QV in ASME QME-1 to incorporate the lessons learned from the MOV operating experience and research programs for the functional qualification of all power-operated valves. The staff presents its regulatory positions on ASME QME-1-2007 in Section C of this RG.

# C. REGULATORY POSITION

## 1. Seismic Qualification of Electrical and Active Mechanical Equipment

### 1.1 Regulatory Positions on IEEE Std. 344-2004

1.1.1 General NRC Staff Positions

The IEEE Std. 344-2004 is, in general, acceptable to the NRC staff for the seismic qualification of (1) electrical equipment in new NPPs and (2) new or replacement electrical equipment in operating NPPs, subject to the following provisions:

a. Rigorous seismic qualification by analysis, testing, or combined analysis and testing, as described in Clauses 7, 8, and 9 of IEEE Std. 344-2004, are acceptable methods for the seismic qualification of electrical equipment.

b. The use of experience data (earthquake or test experience data) for the seismic qualification of electrical equipment is subject to review by the NRC staff. Topical reports may be submitted to the NRC for approval. The staff's review will include areas such as (1) the credibility and completeness of the compilation of the experience database, (2) the inclusion and exclusion rules (termed "prohibited features" in IEEE Std. 344-2004) for electrical equipment in the experience database, (3) the justification used to demonstrate the similarity among the member items in a reference equipment class, (4) the justification used to demonstrate the similarity between electrical equipment in the experience database and equipment in the NPP for seismic qualification purposes, and (5) the justification used to demonstrate the functionality of candidate equipment and the member items in a reference equipment class during and after an earthquake.

c. The NRC staff concurs with the limitations given in IEEE Std. 344-2004, Section 10.4.2, for the use of experience data (earthquake or test experience data) for the seismic qualification of certain active electrical components that may inadvertently change state or chatter during an earthquake and thus may not consistently perform their intended safety functions during and/or after an earthquake (e.g., certain types of relays, contactors, circuit breakers, switches, sensors, microprocessor-based components, and potentiometers). A seismic test may be needed to confirm that a component is not sensitive to high-frequency ground motion, if applicable.

d. If the licensee/applicant[3] proposes to use test experience data for seismic qualification in accordance with IEEE Std. 344-2004, Clause 10.3, the licensee should submit, for staff review and approval, the details of the test experience database, including applicable implementation procedures, to ensure the structural integrity and functionality of the in-scope electrical equipment.

Supporting documentation for equipment identified in the database should confirm that such equipment will remain functional during and after the equivalent effect of five postulated

3 This regulatory guide applies to operating NPPs licensed under 10 CFR Part 50 and to plants that have applied or will apply for a license under 10 CFR Part 52. The term' licensee' and 'applicant' are interchangeable in this regulatory guide.

occurrences of an operating-basis earthquake (OBE) and one SSE, in combination with other relevant static and dynamic loads, consistent with the licensing basis[4] for the facility.

e. The NRC staff does not generally find it acceptable to restrict the frequency range of testing up to 33 Hz. The frequency range should be consistent with the RRS of the specific plant equipment. Although 1/3 octave spacing is referred to in different sections of this RG and IEEE Std. 344-2004, this is for use with low frequency excitation. For high-frequency sensitive equipment, an interval of 1/6 octave spacing should be used extending up to the frequency of interest shown in the RRS.

f. For certain hard-rock-based plants, the site-specific spectra may exceed the certified design spectra in the high-frequency range. As a result of the high-frequency ground motion, the seismic input to SSCs may also contain high-frequency excitations. The vast majority of prior existing seismic qualification tests used input frequencies up to only 33 Hz. The use of these prior testing results should be justified by demonstrating that the frequency content of the PSD of the test waveform is sufficient, in accordance with Annex B to IEEE Std. 344-2004.

g. If licensees plan new seismic qualification tests for equipment in plants with high-frequency ground motion, the tests should demonstrate the adequacy of the frequency content and the stationarity of the frequency content of the synthesized input waveforms. The frequency content of the Fourier transform of the test waveform or the frequency content of the PSD of the test waveform must be compatible with the amplified portion of the RRS. Annex B to IEEE Std. 344-2004 provides acceptable guidelines on frequency content and stationarity.

h. For NPPs that were licensed with the elimination of the OBE, electrical equipment qualified by testing should be qualified with five one-half SSE events followed by one full SSE event or, alternatively, a number of fractional peak cycles equivalent to the maximum peak cycles for five one-half SSE events, in accordance with Annex D to IEEE Std. 344-2004, when followed by one full SSE (SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," issued April 1993) (Ref. 32), even if the OBE of a plant is defined to be one-third of SSE or less. For other reactors, the staff will review the seismic qualification based on the OBE level, in accordance with the licensing basis.

i. The damping values used in the analysis should be in accordance with the damping values listed in Table 6 of RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants" (Ref. 33), issued March 2007, or as approved in the plant design basis.

1.1.2 Specific NRC Staff Positions

The following are specific NRC staff positions, including exceptions and clarifications, on IEEE Std. 344-2004:

a. Clause 10.2.3.1 and Clause 10.3.3.1 (Earthquake and Test Experience Data—Attributes of Equipment Class)

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4 In the context of this RG, the licensing basis refers to the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance to those requirements, including modifications and additions to those commitments that are docketed and in effect over the life of the license.

The NRC staff will review, in detail, the attributes of the equipment for establishing the inclusion rules that constitute the reference equipment class for earthquake or test experience, as described in Clause 10.2.3.1 or Clause 10.3.3.1, respectively, to determine the acceptability of similarity arguments to define a reference equipment class.

Fatigue failure at low-cycle loads must be addressed. Clause 10.2.3.1(b) does not demonstrate adequate equipment functionality under OBEs as required by the NRC regulations delineated in Appendix B and Appendix S to 10 CFR Part 50, or 10 CFR Part 52. Earthquake experience data or test data are needed to demonstrate that all electrical equipment in the reference equipment class, including the enclosed or attached devices or subassemblies, performed successfully (structural integrity and specified functionality) under the equivalent of five OBE and one SSE loadings.

b. Clause 10.2.3.3 (Earthquake Experience Data—Reference Equipment Class Functionality)

Licensees should submit, for NRC review and approval, detailed information on the justification used to demonstrate the reference equipment class functionality during and after an earthquake.

c. Clause 10.2.4 (Earthquake Experience Data—Qualification of Candidate Equipment)

Licensees should ensure that in-structure response spectra used as the RRS for the qualification of candidate equipment is in accordance with the licensing or design basis or NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (SRP)" (Ref. 34), Section 3.7.2, as applicable. The use of a RRS less conservative than that described in the design basis should be submitted for NRC review and approval.

d. Clause 10.3.2 (Test Experience Data—Test Experience Spectra)

(1) The use of the frequency-by-frequency mean of the successful TRS may not be adequate to define test experience spectra (TES).

Therefore, the NRC takes exception to the existing second sentence in the first paragraph of Clause 10.3.2. Instead, the following is acceptable to the NRC:

> The TES shall be the frequency-by-frequency mean of the response spectra from successful tests without malfunction. When using test experience data, both the mean and the standard deviation of the data leading to the TES curve should be provided for review and approval.

(2) The second paragraph of Clause 10.3.2 is not appropriate. The position acceptable to the NRC staff is the one stated in Section C.1.1.1.h of this regulatory guide.

e. Clause 10.3.3 (Test Experience Data—Characterization of Reference Equipment Class)

Clause 10.3.3 cites an example that significant natural frequencies of the reference equipment class would lie within approximately a one-third octave. This will not provide an adequate range of significant natural frequencies in the high frequency range of the reference equipment in a class. Instead of one-third octave, one-sixth octave should be used.

f. Clause 10.3.3.2 (Test Experience Data—Number of Independent Items for Reference Equipment Class)

Licensees should provide justification to show the adequacy of using a minimum of five independent items to define a reference equipment class for test experience.

g. Clause 10.4.2 (Special Considerations—Limitations)

The list of limitations for the use of earthquake- or test-experience-based methods for the seismic qualification of equipment, as described in Clause 10.4.2, may not be complete. The list should be expanded to include additional limitations as a result of new findings from testing new equipment or new studies.

h. Annex C (Fragility Testing)

An example of determining the fragility level to single-frequency transient excitation of the equipment is to subject it to any single-frequency excitation such as sine-beat motion. The frequency range of the test excitation should be continued beyond 33 Hz, in accordance with the RRS of a specific plant.

i. Annex D (Test Duration and Number of Cycles)

Figure D.2 is used to determine the equivalent number of fatigue cycles for a given filtered frequency and duration. Currently, IEEE Std. 344-2004 does not develop guidance beyond 40 Hz. Therefore, licensees should provide justification for applications beyond 40 Hz.

## 1.2 Regulatory Positions on ASME QME-1-2007

### 1.2.1 General NRC Staff Positions

In the discussion of the seismic qualification of some active mechanical equipment, ASME QME-1-2007 references IEEE Std. 344-1987 (as addressed in RG 1.100, Revision 2) or Non-mandatory Appendix QR-A. Such references appear in several sections of ASME QME-1-2007, such as Section QP-6400 for pumps and Sections QV-7450 and QV-7650 for valves. The NRC finds these acceptable if their application is consistent with the NRC staff positions delineated in this RG (Revision 3) and other relevant NRC regulatory documents.

The NRC staff finds Non-mandatory Appendix QR-A to ASME QME-1-2007 acceptable, in general, for the seismic qualification of (1) active mechanical equipment in new NPPs, and (2) new or replacement active mechanical equipment in operating NPPs. However, the NRC staff acknowledges the statement in Section QR-A7500 that the section on test-experience-based qualification is currently not available in ASME QME-1-2007 and will be added in a later issue of the standard. In addition, the NRC has the following regulatory positions, including exceptions and clarifications, on Non-mandatory Appendix QR-A to ASME QME-1-2007:

a. In endorsing the use of ASME QME-1-2007, the staff noticed that several appendices are designated as either non-mandatory or mandatory (e.g., Non-mandatory Appendix QR-A; Non-mandatory Appendix QR-B; Non-mandatory Appendices QDR-A, QDR-B, and QDR-C; Non-mandatory Appendices QP-A, QP-B, QP-C, QP-D, and QP-E; and Mandatory Appendix QV-I and Non-mandatory Appendix QV-A). The staff position is that, if a licensee commits to the use of non-mandatory appendices in ASME QME-1-2007 for its qualification of active mechanical equipment in NPPs, then the criteria and procedures delineated in those non-mandatory appendices become part of the basis for its qualification program, unless specific deviations are requested and justified.

b. Rigorous seismic` qualification by analysis or testing, as described in Sections QR-A7100, QR-A7200, and QR-A7300 of ASME QME-1-2007, is an acceptable method for the seismic qualification of active mechanical equipment.

c. ASME Class 1, 2, and 3 active mechanical equipment is subject to and must meet the requirements in the ASME Boiler and Pressure Vessel Code (ASME Code), Section III (Ref. 35). The NRC staff recommends that a future revision of ASME QME-1 add this position to (1) Section QR-6000, "Qualification Specification," as item (j), and (2) Section QR-A7440, "Qualification of Candidate Equipment," as item (g).

d. The NRC staff will review the use of earthquake experience data for the seismic qualification of active mechanical equipment, as described in Section QR-A7400 of ASME QME-1-2007.Topical reports may be submitted to the NRC for approval. The staff's review will include areas such as (1) the credibility and completeness of the compilation of the experience database, (2) the inclusion and exclusion rules for active mechanical equipment in the experience database, (3) the justification used to demonstrate the similarity among the member items in a reference equipment class, (4) the justification used to demonstrate the similarity between active mechanical equipment in the experience database and equipment in the NPP, for seismic qualification purposes, and (5) the justification used to demonstrate the functionality of candidate equipment and the member items in a reference equipment class during and after an earthquake.

e. If the licensee proposes to use test experience data for seismic qualification, the licensee should submit, for NRC review and approval, the details of the test experience database, including applicable implementation procedures, to ensure the structural integrity and functionality of the in-scope mechanical equipment. Supporting documentation for equipment identified in the database should confirm that such equipment will remain functional during and after the equivalent effect of five postulated occurrences of an OBE and one SSE, in combination with other relevant static and dynamic loads, consistent with the design basis.

f. The NRC staff does not generally find it acceptable to restrict the frequency range of testing up to 33 Hz. The frequency range should be consistent with the RRS of specific plant equipment. Although 1/3 octave spacing is referred to in different sections of this RG, ASME QME-1-2007 and IEEE Std. 344-2004, this is for use with low frequency excitation. For high-frequency sensitive equipment, an interval of 1/6 octave spacing should be used extending up to the frequency of interest shown in the RRS.

g. For certain hard-rock-based plants, the site-specific spectra may exceed the certified design spectra in the high-frequency range. As a result of the high-frequency ground motion, the seismic input to SSCs may also contain high-frequency excitations. The vast majority of existing seismic qualification tests used input frequencies up to only 33 Hz. The use of these prior testing results should be justified by demonstrating that the frequency content of the PSD of the test waveform is sufficient, in accordance with Annex B to IEEE Std. 344-2004.

h. If licensees plan new seismic qualification tests for active mechanical equipment in plants with high-frequency ground motion, the tests should demonstrate the adequacy of the frequency content and the stationarity of the frequency content of the synthesized input waveforms. The frequency content of the Fourier transform of the test waveform or the frequency content of the PSD of the test waveform should be compatible with the amplified portion of the RRS. Annex B to IEEE Std. 344-2004 provides guidelines on frequency content and stationarity.

i. For NPPs that were licensed with the elimination of the OBE, active mechanical equipment qualified by testing should be qualified with five one-half SSE events followed by one full SSE event or, alternatively, a number of fractional peak cycles equivalent to the maximum peak cycles for five one-half SSE events, in accordance with Annex D to IEEE Std. 344-2004, when followed by one full SSE (SECY-93-087) even if the OBE of a plant is defined to be one-third of SSE or less. For other reactors, the staff will review the seismic qualification based on the OBE level, in accordance with the design basis.

1.2.2 Specific NRC Staff Positions

The following are specific NRC staff positions, including exceptions and clarifications, on ASME QME-1-2007:

a. Section QR-A6200 (Seismic Qualification Requirements—Damping)

The damping values used in analysis should be in accordance with the damping values listed in Table 6 of RG 1.61, Revision 1, or as approved in the plant design basis.

b. Section QR-A6300 (Seismic Qualification Requirements—Required Response Spectrum)

Section QR-A6300 states: "For in-line active mechanical equipment qualified in accordance with QR-A7400 (Earthquake Experience-Based Qualification), the RRS is typically the building filtered response spectrum at the distribution system support attachments to the building." The use of the building filtered response spectrum at the distribution system support attachments to the building as the RRS for the in-line equipment may not be adequate. The RRS for in-line active mechanical equipment should account for the potential motion amplification of the distribution system.

c. Section QR-A7331 (Qualification by Similarity—Excitation)

Section QR-A7331 states that; "a conservative composite excitation may be generated by extrapolations or interpolations of data whose parameters are not identical but are justifiable." Likewise, excitation whose spectral content are significantly different may be used to generate lower-level composite estimates, providing that an account is taken of possible multi-axis response or cross-axis coupling, or both." The licensee should provide, for NRC review and approval, detailed information justifying this statement.

d. Section QR-A7421 (Earthquake Experience-Based Qualification—Attributes of Equipment Class)

The NRC staff will review, in detail, the attributes of the equipment for establishing the inclusion rules that constitute the reference equipment class for earthquake experience, as described in Section QR-A7421, to determine the acceptability of similarity arguments to define a reference equipment class.

Section QR-A7421 also states the following:

Prohibited features should include any attributes that would contribute to fatigue failure from low cycle loads. The rules of this section apply to active mechanical equipment that may undergo 5 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 (less than 60 full range stress cycles), it shall be evaluated in accordance with Section QR-A6800.

The NRC regulations delineated in 10 CFR Part 100, Appendix S to 10 CFR Part 50, and 10 CFR Part 52 require the demonstration of successful equipment functionality under OBEs.

e. Section QR-A7423 (Earthquake Experience-Based Qualification—Functionality During Earthquake)

Licensees should submit, for NRC review and approval, detailed information about the justification used to demonstrate the functionality of the reference equipment class during and after an earthquake.

f. Section QR-A7431 (Earthquake Experience-Based Qualification—Inherently Rugged Active Mechanical Equipment)

To justify the active mechanical equipment class as an "inherently rugged active mechanical equipment" class, the licensee should provide, for NRC review, information regarding the operational or shipping loads as compared to the expected seismic loads that the equipment could be subjected to, and the explicit design standards applied to this equipment class. Licensees should also provide, for NRC review, detailed information regarding the simplified and reduced rules, including the technical justification and data for characterizing the inherently rugged active mechanical equipment class and the procedure for defining the seismic capacity for this equipment class (i.e., the earthquake experience spectrum).

g. Section QR-A7432 (Earthquake Experience-Based Qualification—Limitations)

The limitations for the use of an earthquake-experience-based method of seismic qualification of equipment, as described in Section QR-A7432, may not be a complete list. The list should be expanded to include additional limitations as a result of new findings from testing new equipment or new studies.

h. Section QR-A7440 (Earthquake Experience-Based Qualification—Qualification of Candidate Equipment)

In-structure response spectra used as the RRS for the qualification of candidate equipment should be in accordance with the licensing or design basis or SRP Section 3.7.2, as applicable. The use of a RRS less conservative than that described in the design basis should be submitted for NRC review and approval.

i. Section QR-A8330 (Qualification Report—Earthquake Experience-Based Qualification Documentation)

All ASME Class 1, 2, and 3 active mechanical equipment should comply with the ASME Code Section III requirements. The NRC staff recommends adding the following item to a future revision of ASME QME-1:

(f) compliance with the ASME Code, Section III, requirements for ASME Class 1, 2, and 3 active mechanical equipment.

j. Attachment C to Non-mandatory Appendix QR-A (Qualification of Pumps and Valves Using Natural Earthquake Experience Data)

Attachment C to Non-mandatory Appendix QR-A is based on the guidelines developed by the SQUG for USI A-46 plants. The provisions in the SQUG guidelines rely heavily on earthquake experience data that the staff considered reasonable to verify the seismic adequacy of existing equipment, and the qualification of new and replacement equipment in older, USI A-46 plants only. The NRC staff has not accepted these SQUG guidelines for the seismic qualification of equipment in plants other than USI A-46 plants. The provisions outlined in Section QR-A7400, including the NRC staff's positions noted in Sections C.1.2.1 and C.1.2.2 of this RG, are acceptable for the seismic qualification of active mechanical components. In addition, contrary to the provisions in Section QR-A7400, the introduction to Attachment C states that the data have not been developed to conclusively demonstrate that pumps and valves function properly during earthquakes. Therefore, Attachment C in its current form does not fully comply with the requirements in 10 CFR Part 100. Attachment C also contains an error in Section C-2. The equipment frequency restriction should be greater than 8 Hz instead of less than 8 Hz.

## 2. Functional Qualification of Active Mechanical Equipment

### 2.1 <u>Regulatory Positions on ASME QME-1-2007</u>

2.1.1 General NRC Staff Positions

In general, the NRC staff finds ASME QME-1-2007 acceptable for the functional qualification of (1) active mechanical equipment in new NPPs and (2) new or replacement active mechanical equipment in operating NPPs, subject to the following provisions:

a. Appendices

In endorsing the use of ASME QME-1-2007, the staff acknowledged that several appendices are designated as either non-mandatory or mandatory (e.g., Non-mandatory Appendix QR-A; Non-mandatory Appendix QR-B; Non-mandatory Appendices QDR-A, QDR-B, and QDR-C; Non-mandatory Appendices QP-A, QP-B, QP-C, QP-D, and QP-E; and Mandatory Appendix QV-I and Non-mandatory Appendix QV-A). The staff position is that, if a licensee commits to the use of non-mandatory appendices in ASME QME-1-2007 for its qualification of active mechanical equipment in NPPs, then the criteria and procedures delineated in those non-mandatory appendices become part of the requirements for its qualification program, unless specific deviations are requested and justified.

b. Non-mandatory Appendix QR-B

This appendix recommends a methodology and describes the documentation that should be available in a user's files to demonstrate the qualification of nonmetallic parts, materials, or lubricants. It addresses the steps for the user of the active mechanical equipment to follow to qualify and maintain the qualification of the nonmetallic material that is part of the active mechanical equipment. The NRC staff considers Non-mandatory Appendix QR-B to provide a reasonable approach to the qualification of nonmetallic material in active mechanical equipment.

c. Sections QDR and QP

The NRC staff considers Sections QDR and QP to provide a reasonable approach to the qualification of dynamic restraints and active pump assemblies, respectively. These sections have not changed from those in ASME QME-1-2002, and they still adequately document the state of the art of the nuclear industry in the qualification of dynamic restraints and active pump assemblies.

d. Section QV

The revision to ASME QME-1 reflects valve performance information obtained from nuclear industry programs and the NRC's research since the development of ASME QME-1 in the 1980s. With the active involvement of industry personnel and the NRC staff in the development of ASME QME-1-2007, only a few NRC staff exceptions and clarifications are necessary for Section QV, as described in Section C.2.1.2 below.

2.1.2 Specific NRC Staff Positions

a. The definition of "valve assembly" in Section QV-4000, "Definitions," refers to power-operated valves. The NRC staff considers the power actuators for valve assemblies to include all types of power actuators, such as motor, pneumatic, hydraulic, solenoid, and other drivers.[5]

b. Section QV-6000, "Qualification Specification," states that the owner or owner's designee is responsible for identifying the functional requirements for a valve assembly, and that these requirements shall be provided in a qualification specification prepared in accordance with Mandatory Appendix QV-I. The NRC staff considers Mandatory Appendix QV-I to be a necessary part of the implementation of Section QV of ASME QME-1-2007. For example, Mandatory Appendix QV-I provides the definitions of QV Category A and B valve assemblies used in Section QV of ASME QME-1-2007.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

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5 The guidance in ASME QME-1-2007 may also be used, where applicable, in the qualification of manually operated valves.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

# REFERENCES[6]


1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.

2. 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

3. 10 CFR Part 100, "Reactor Site Criteria," U.S. Nuclear Regulatory Commission, Washington, DC.

4. Regulatory Guide 1.100, Revision 2, "Seismic Qualification of Electrical and Mechanical Equipment for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, June 1988.

5. IEEE Std. 344-1987, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Inc., New York, NY, January 1987.[7]

6. Regulatory Guide 1.148, "Functional Specification for Active Valve Assemblies in Systems Important to Safety in Nuclear Power Plants," U. S. Nuclear Regulatory Commission, Washington, DC, March 1981.

7. American National Standards Institute (ANSI) N278.1-1975, "Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard" American Society of Mechanical Engineers, New York, NY, 1975.

8. ASME QME-1-1994, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," American Society of Mechanical Engineers, New York, NY, June 1994.

9. ASME QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," American Society of Mechanical Engineers, New York, NY, November 2007.

10. IEEE Std. 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Inc., New York, NY, June 2005.

11. IEEE Std. 344-1975, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1975.


6 Publicly available NRC published documents such as Regulations, Regulatory Guides, NUREGs, and Generic Letters listed herein are available electronically through the Electronic Reading room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

7 Copies of the non-NRC documents included in these references may be obtained directly from the publishing organization.

12. Regulatory Guide 1.100, Revision 1, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, August 1977.

13. Generic Letter 87-02, "Verification of Seismic Adequacy of Mechanical and Electric Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46," U.S. Nuclear Regulatory Commission, Washington, DC, February 1987.

14. Generic Letter 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," U.S. Nuclear Regulatory Commission, Washington, DC, June 1989.

15. Information Notice 90-40, "Result of NRC-Sponsored Testing of Motor-Operated Valves," U.S. Nuclear Regulatory Commission, Washington, DC, June 1990.

16. Topical Report TR-103237, Revision 2, "EPRI MOV Performance Prediction Program," and Addenda 1 and 2, nonproprietary versions, Electric Power Research Institute, Palo Alto, CA, April 1997

17. Safety Evaluation, "Safety Evaluation on EPRI MOV Performance Prediction Methodology," U.S. Nuclear Regulatory Commission, Washington, DC, March 1996, [ADAMS Accession Number ML9608070288].

18. Safety Evaluation Supplement, "Supplement to Safety Evaluation on EPRI MOV Performance Prediction Methodology," U.S. Nuclear Regulatory Commission, Washington, DC, February 1997, [ADAMS Accession Number ML9704300106].

19. Safety Evaluation Supplement, "Supplement 2 to Safety Evaluation on EPRI MOV Performance Prediction Methodology," U.S. Nuclear Regulatory Commission, Washington, DC, April 2001, [ADAMS Accession Number ML011100121].

20. Safety Evaluation Supplement, "Supplement 3 to Safety Evaluation on EPRI MOV Performance Prediction Methodology," U.S. Nuclear Regulatory Commission, Washington, DC, September 2002, [ADAMS Accession Number ML022410364].

21. Safety Evaluation Supplement, "Supplement 4 to Final Safety Evaluation on Addenda 3, 4, 5, 6, and 7 to EPRI Topical Report (TR)-103237, "EPRI MOV Performance Prediction Program, Revision 2," U.S. Nuclear Regulatory Commission, Washington, DC, February 2009, [ADAMS Accession Number ML090400621].

22. Information Notice 96-48, "Motor-Operated Valve Performance Issues," U.S. Nuclear Regulatory Commission, Washington, DC, August 1996.

23. Generic Letter 96-05, "Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves," U.S. Nuclear Regulatory Commission, Washington, DC, September 1996.

24. Topical Report MPR-2524, "Joint Owners' Group Motor Operated Valve Periodic Verification Program Summary," Joint Owners Group, February 2004, [ADAMS Accession Number ML040720092].

25. Final Safety Evaluation, "Final Safety Evaluation on Joint Owners' Group Program on Motor-Operated Valve Periodic Verification," U.S. Nuclear Regulatory Commission, Washington, DC, September 2006.

26. NUREG/CR-6478, "Motor-Operated Valve (MOV) Actuator Motor and Gearbox Testing," U.S. Nuclear Regulatory Commission, Washington, DC, July 1997.

27. Technical Update 98-01, "Actuator Output Torque Calculation," Limitorque Corporation, Lynchburg, VA, May 1998, and Supplement 1, July 1998, [ADAMS Accession Number ML9905060175].

28. Information Notice 96-48, Supplement 1, "Motor-Operated Valve Performance Issues," U.S. Nuclear Regulatory Commission, Washington, DC, July 24, 1998.

29. NUREG/CR-6620, "Testing of DC-Powered Actuators for Motor-Operated Valves," U.S. Nuclear Regulatory Commission, Washington, DC, May 1999.

30. Topical Report NEDC-32958, "BWR Owners' Group DC Motor Performance Methodology—Predicting Capability and Stroke Time in DC Motor-Operated Valves," Boiling Water Reactor Owners' Group, March 2000, [ADAMS Accession Number ML003733225].

31. Regulatory Issue Summary 2001-15, "Performance of DC-Powered Motor-Operated Valve Actuators," U.S. Nuclear Regulatory Commission, Washington, DC, August 2001.

32. SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," ADAMS ML No: ML003708021, U.S. Nuclear Regulatory Commission, Washington, DC, April 1993.

33. Regulatory Guide 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

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