

IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies With Safety-Related Functions for Nuclear Power Plants

Sponsor

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Abstract: The qualification of all types of power-driven valve actuators, including damper actuators, for safety-related functions in nuclear power generating stations, is described. This standard may also be used to separately qualify actuator components. The minimum requirements for, and guidance regarding, the methods and procedures for qualification of power-driven valve actuators with safety-related functions are provided.

Keywords: Class 1E safety equipment, nuclear power plants, qualification

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Introduction

(This introduction is not part of IEEE Std 382-1996, IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies With Safety-Related Functions for Nuclear Power Plants.)

Applicants for a construction permit or operating license for a nuclear generating station are required to provide assurance that systems, components, and structures are adequate for their service conditions to comply with the Code of Federal Regulations 10 CFR 50, Appendix B *Quality Assurance Criteria*, and Criterion III *Design Control*. Each applicant has the responsibility to ensure that this or any other standard, if used, is pertinent to the application and that the integrated performance of the station is acceptable. Implementation of this standard requires the applicant to produce documentary evidence to ensure that the valve actuator can perform its intended function.

Typical design basis event conditions for principal reactor types are presented as one source of parameters for generic-type tests. If the actual conditions of a specific application differ, it will be the obligation of the user to specify these actual conditions.

The numerical values presented in this standard envelop current industry design with respect to radiation types and levels; seismic levels; temperature, pressure, and humidity levels; post-accident periods of operability; spray initiation, and duration. Composition of environment may change in the future, so the user is cautioned to verify the suitability of these values for each application.

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Contents

CLAUSE	PAGE
Part I—Process.....	1
1. Overview.....	1
1.1 Scope.....	1
1.2 Purpose.....	1
2. References.....	1
3. Definitions.....	1
4. Introduction.....	3
4.1 General.....	3
4.2 Requirements	4
5. Identification of the generic actuator group.....	4
5.1 Generic actuator group identification	4
5.2 Selection of actuator units for type testing	5
6. Qualification testing of selected actuators in generic actuator group	5
6.1 Type test parameter values.....	5
6.2 Type test plan	6
6.3 Type test procedure.....	7
6.4 Inspection	7
6.5 Acceptance criteria.....	8
6.6 Generic actuator group design modification.....	8
7. Qualification of actuator for specific application	8
7.1 General.....	8
7.2 Valve actuator specification.....	9
7.3 Relationship to generic actuator group	9
7.4 Relationship to specification.....	10
8. Documentation	10
8.1 General.....	10
8.2 Documentation for qualification of generic actuator group.....	10
8.3 Documentation for qualification for a specific application	11
Part II—Qualification cases.....	12
1. Scope.....	12
2. Multiple operations	12

CLAUSE	PAGE
3. Single operation	13
Part III—Tests.....	24
1. Baseline operability test.....	24
1.1 Scope.....	24
1.2 Test setup requirements	24
1.3 Test conduct	24
2. Normal thermal aging test.....	25
2.1 Scope.....	25
2.2 Test setup requirements	25
2.3 Test conduct	25
2.4 Deviation.....	25
3. Normal pressurization cycle test.....	26
3.1 Scope.....	26
3.2 Test setup requirements	26
3.3 Test conduct	26
4. Normal radiation aging test.....	26
4.1 Scope.....	26
4.2 Test setup requirements	26
4.3 Test conduct	26
5. Vibration aging test.....	27
5.1 Scope.....	27
5.2 Test setup requirements	27
5.3 Test conduct	27
6. Seismic simulation test	27
6.1 Scope.....	27
6.2 Test setup requirements	27
6.3 Test conduct	28
7. DBE radiation exposure test	30
7.1 Scope.....	30
7.2 Test setup requirements	30
7.3 Test conduct	30
8. DBE environment test.....	30
8.1 Scope.....	30
8.2 Test setup requirements	30
8.3 Test conduct	32

ANNEX	PAGE
Annex A (informative) Method of selection of representative actuator(s) for type testing.....	33
Annex B (informative) Representative normal and design basis event environmental conditions	36
Annex C (informative) Rationale for normal thermal aging	43
Annex D (informative) Rational for vibration and seismic test methods	45
Annex E (informative) Performance verification test.....	47

IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies With Safety-Related Functions for Nuclear Power Plants

Part I—Process

1. Overview

1.1 Scope

This standard describes the qualification of all types of power-driven valve actuators, including damper actuators, for safety-related functions in nuclear power generating stations. This standard may also be used to separately qualify actuator components.

1.2 Purpose

This standard establishes the minimum requirements for, and guidance regarding, the methods and procedures for qualification of power-driven valve actuators with safety-related functions. Part I describes the qualification process.

2. References

This standard shall be used in conjunction with the following publications:

IEEE Std 323-1983 (Reaff 1990), IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations (ANSI).¹

IEEE Std 344-1987 (Reaff 1993), IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (ANSI).

Code of Federal Regulations, Title 10, Energy—Nuclear Regulatory Commission, Part 100, Jan. 1996.²

3. Definitions

3.1 aging: The 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 events.

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

²CFR publications are available from Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA.

3.2 air equivalent radiation dose: The energy that is absorbed per unit mass of air at the geometric center of the volume occupied by the specimen if it were replaced with air and a uniform flux were incident at the boundary of the volume, directed toward the center.

3.3 analysis: A course of reasoning showing that a certain result is a consequence of assumed premises.

3.4 auditable data: Information which is documented and organized in a readily understandable and traceable manner that permits independent verification of inferences or conclusions based on the information.

NOTE—Examples of information include product catalog information, dimensional drawings, bills of material, engineering specifications, performance specifications, installation and calibration instructions and manuals, maintenance manuals, test reports, and analyses.

3.5 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 otherwise essential in preventing significant release of radioactive material to the environment.

3.6 containment: The portion of the engineered safety features designed to act as the principal barrier, after the reactor system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive material beyond a controlled zone.

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

3.8 design life: The time during which satisfactory performance can be expected for a specific set of service conditions.

NOTE—The time may be specified in real time, operating time, number of operating cycles, or other performance intervals, as appropriate.

3.9 generic actuator group: The actuator or family of actuators within a range of sizes with similar design principles, materials, manufacturing processes, limiting stresses, operating principles and design margins.

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

3.11 margin: The difference between service conditions and the conditions used for equipment qualification.

3.12 motive power: The electric, fluid, air, nitrogen, or mechanical energy required to operate the actuator.

3.13 operating basis earthquake (OBE): The earthquake which could reasonably be expected to affect the plant site during the operating life of the plant. It is that earthquake which produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.

3.14 qualified life: The period of time, prior to the start of a design basis event, for which equipment was demonstrated to meet the design requirements for the specified service conditions.

NOTE—At the end of the qualified life, the equipment shall be capable of performing the safety function(s) required for the postulated-design basis and post-design basis events.

3.15 ratio set: A set of performance parameter values described by a range of numerical values whose boundaries have been established by doubling and halving the numerical mean value of a selected physical performance parameter.

3.16 required input motion (RIM): The input motion in terms of acceleration, velocity, and displacement expressed as a function of frequency that a device being tested shall withstand and still perform its intended function.

3.17 required response spectrum (RRS): The required response spectrum issued by the user or his agent as part of his specifications for proof testing, or artificially created to cover future applications. The RRS constitutes a requirement to be met.

3.18 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.

3.19 safe shutdown earthquake (SSE): That earthquake which produces the maximum vibratory ground motion for which certain structural systems and components are designed to remain functional. These structures, systems, and components are those necessary to ensure

- a) The integrity of the reactor coolant pressure boundary
- b) The capability to shut down the reactor and maintain it in a safe shutdown condition
- c) The capability to prevent or mitigate the consequences of an accident which could result in potential offsite exposures comparable to the exposure guideline of CFR 10 Energy,³ Part 100 (Jan. 1996).

3.20 service conditions: Environmental, loading, power, and signal conditions expected as a result of normal operating requirements, expected extremes (abnormal) in operating requirements, and postulated conditions appropriate for the design basis events of the station.

3.21 test operating cycle: The movement of an actuator through its required operations travel under specified loading conditions, terminating with a return to the starting position.

3.22 test response spectrum (TRS): The response spectrum that is constructed using analysis or derived using spectrum analysis equipment based on the actual input test table motion to the device.

3.23 type test: Tests made on one or more sample actuators to verify adequacy of design and the manufacturing processes.

3.24 valve actuator: An electric, pneumatic, hydraulic, or electrohydraulic power-driven mechanism for positioning two-position or modulating valves, and dampers. Included are those components required to control valve action and to provide valve position output signals, as defined in the actuator specification.

3.25 zero period acceleration (ZPA): The acceleration which appears as a constant portion of a response spectrum in the highest frequency range. It is the maximum acceleration in the time history from which that response spectrum was developed.

4. Introduction

4.1 General

Safety-system equipment in nuclear power stations shall be capable of performing satisfactorily under defined conditions, including postulated design basis events (DBE). It is necessary to provide assurance that such equipment meets its performance requirements throughout its installed life. This is accomplished

³Information about references can be found in clause 2.

through a disciplined program of design, qualification, production quality control, installation, maintenance, and surveillance testing.

This standard applies only to the qualification portion of the above mentioned program.

Most actuators are designed and manufactured in generic design groups (families) that, although varying considerably in size, are made of similar materials and have similar design and manufacture. Individual actuators from these design groups can be applied to a wide range of applications. An independent qualification of each possible variation of design within each generic group is not practical. When a specific purchase request does exist, qualification shall be demonstrated with regard to that specific application.

Specific qualification requires demonstration that each actuator is a member of a generically qualified family and further that it will, when manufactured to meet an actuator specification, function as required for a particular application. However, if a particular actuator for which qualification is required cannot be related to a generically qualified actuator, the qualification test procedure shall be performed on a sample of that particular actuator.

It is not the intent of this standard that a manufacturer shall perform generic qualification prior to receipt of an order for specific application.

This standard divides the qualification process for actuators into the following three sequential steps:

- a) Identification of the generic actuator group
- b) Qualification testing of selected actuators in generic actuator group
- c) Qualification of actuator for specific application

4.2 Requirements

Methods used for qualification includes type testing, operating experience and analysis. This standard requires that

- a) Qualification of a generic actuator group shall be accomplished by type testing, supplemented as needed by analysis.
- b) Specific qualification for each application shall be accomplished by testing or analysis of generic group qualification data, operating experience, and additional testing when necessary.

In type testing sample actuators, a representative unit(s) manufactured in accordance with the manufacturer's quality control system and specifications for production units shall be subjected to environmental and operating cycles that simulate the intended service conditions and safety-related function for which they are to be qualified.

Documentation shall be provided as described in this standard.

5. Identification of the generic actuator group

5.1 Generic actuator group identification

A generic actuator group from which sample actuators will be selected for type test shall be established and identified. Consideration shall be given to details including but not limited to design, materials, manufacturing processes, limiting stresses, deformation, deflections, operating principles, and design margin.

Generic actuator group designs shall have the following common characteristics:

- a) Identical type actuator (electromechanical, pneumatic, hydraulic, mechanical, electrical, or any combination)
- b) Functionally and geometrically similar structural arrangements with the principal differences being overall size, weight, and ratings
- c) Similar actuator mounting configuration and output drive method
- d) Similar mounting of functional accessories
- e) Similar internal control devices

5.2 Selection of actuator units for type testing

Due to the variation in types, sizes, and configurations of valve actuators, it is not practical for this standard to establish a fixed number of actuators to be tested in order to establish qualification. It is also impractical to require all actuators to be tested.

All actuators within a generic group will be qualified by analysis provided an appropriate number of units are type tested and a comparison by analysis is made between tested units and others. The number of units to be tested shall be based on an evaluation of the variations in physical and performance parameters that exist within the generic group; for example, thrust, torque, power, speed, materials, pressure, weight, dimension, inertia, and seismic moment.

NOTE—The relationship between generic actuator group and the specific application of an actuator is given in Part I, 7.3.

Annex A describes a suggested procedure for selection of test units.

6. Qualification testing of selected actuators in generic actuator group

6.1 Type test parameter values

6.1.1 Test parameter values

Parameter values to be used in qualification of generic actuator group shall be obtained from one of the two sources described in 6.1.2 and 6.1.3.

6.1.2 Standard sources

The standard qualification cases are defined in Part II. The test parameter values to be used in Part III, clause 8, are also shown in Part II. These values include environmental margins as stated in IEEE Std 323-1983. In Part II, the values for the figures are based on composite service conditions, shown in annex B. These are a compilation of data obtained from the nuclear community at the time this standard was written. The thermal aging values for Part III, clause 2 are based on the rationale described in annex C. The vibration testing and seismic simulation values for Part III, clauses 5 and 6, are based on the rationale described in annex D.

6.1.3 Other sources

Test parameters other than (but in form comparable to) those in Part II may be developed. Margins, as required by IEEE Std 323-1983, shall be applied to service conditions to obtain parameter values.

6.2 Type test plan

A type test plan shall be prepared based on the requirements of this standard. The test plan shall contain the following information as a minimum:

- a) Reference to this standard
- b) Identification of the actuator(s) to be tested including the manufacturer, catalog identifications, and parts list and drawings for each actuator
- c) Range and quality requirements of motive power source and control signal requirements, including quality of the actuating medium (such as cleanliness of an air supply or voltage ripple) that are critical to the proper functioning of the actuator
- d) Mounting, connection, special orientation and interface requirements, cable and conduit entry points including pressure-seal type, and installation when required
- e) Maintenance to be performed during the type test as related to the installed life maintenance program
- f) The normal or rated performance specifications for the actuators(s) and accessory parts to be tested. These specifications shall include output characteristics and all the capabilities for which the actuator is to be qualified. For example, if it is intended to demonstrate that a limit switch in electric actuator or solenoid valve in pneumatic actuator functions, this should be included in the listing
- g) Qualified life objective
- h) Safety-function capability to be demonstrated
- i) Acceptable performance limits
- j) Conditions which constitute test failure
- k) Method of load simulation
- l) Test procedure
- m) A listing of environmental test parameters (see Part II). The variation of these parameters with time is to be specified by a table or graph similar to those shown in Part II. The listing shall indicate the variables to be measured and recorded and the frequency and accuracy of each measurement. These parameters may be classified as follows:
 - 1) *Thermodynamic environment*. Temperature, pressure, moisture content (relative humidity)
 - 2) *Fluid jet or spray environment*. Flow rate and duration jet or spray pattern, temperature, and chemical composition and pH of fluids injected into the test chamber
 - 3) *Seismic and nonseismic vibration environment*. Frequency and amplitude or acceleration characteristics of vibration
 - 4) *Radiological environment*. Nuclear radiation type(s), energy spectra, exposure rates, and integrated dose levels
 - 5) *Input power source*. Electrical frequency, voltage, and current; hydraulic and pneumatic fluid type, quality, pressure, and flow rate
 - 6) *Electrical characteristics*. Insulation resistance of electrical components
 - 7) *Mechanical characteristics*. Torque, thrust, position, time and load profile from receipt of signal until stop of motion, and actuator fluid leakage
 - 8) *Auxiliary function measurement*. Function measurements confirming the capability of equipment included with the actuator but not necessary for its own operation. Measurements shall be

taken that confirm the capability of the auxiliary equipment to handle rated load and provide the accuracy required by the test plan (for example, position-indicating devices)

- 9) Any special requirements or conditions such as steam air mixture that may affect performance of the actuator during the test

6.3 Type test procedure

6.3.1 Installation for tests

The test actuators(s) shall be selected as representative of production actuators and means shall be provided as required to permit testing in accordance with Part III. Electric, pneumatic, or hydraulic connections for motive power shall be provided as required. The same actuator(s) shall be used throughout the test. Orientation(s) shall be as required by the type test plan.

6.3.2 Test sequence and requirements

As applicable, the qualification type test shall be performed in sequence as follows:

- a) Baseline operability test. (See Part III, clause 1.)
- b) Normal thermal aging test. (See Part III, clause 2.)
- c) Normal pressurization cycle test. (See Part III, clause 3.)
- d) Normal radiation aging test. (See Part III, clause 4.)
- e) Vibration aging test. (See Part III, clause 5.)
- f) Seismic simulation test. (See Part III, clause 6.)
- g) DBE radiation exposure test. (See Part III, clause 7.) [Can be included in step d).]
- h) DBE environment test. (See Part III, clause 8.)
- i) Operability test as in a).

6.4 Inspection

6.4.1 Inspection of the test actuator(s)

Inspection of the test actuator(s) shall be performed prior to and upon completion of the qualification test series in accordance with a written test plan (see Part I, 6.2).

6.4.2 Pretest inspection

Pretest inspection shall be performed according to the test plan prepared by the actuator manufacturer for such items as

- a) Control settings
- b) Securing of fasteners
- c) Motive power-drive system
- d) Test equipment calibration

6.4.3 Intermediate inspection

To assist in evaluation of the test actuator, inspections including operability testing may be made at intermediate times during the qualification testing program.

Aside from any adjustments or other changes that are required to perform the various tests, no alterations, adjustments, or maintenance without suitable justification will be allowed other than those stipulated in the

test plan without the qualification tests being reinitiated. Any such maintenance or adjustments shall be fully described and evaluated in the qualification report.

6.4.4 Post-test inspection

The test actuator shall be disassembled and inspected and the condition of the actuator parts shall be recorded.

6.5 Acceptance criteria

The actuator will have passed the type test if it performs the functions required by the type test plan described in 6.2.

6.6 Generic actuator group design modification

Any design modification made to a generically qualified group of actuators is cause for requalification. In this event requalification may be performed by analysis, or test, or a combination of both. The actuator manufacturer is responsible for determining the type of qualification by evaluation of any possible synergistic effects which may result from the modification. If it can be proven that the modification has negligible effect on the generic qualifications no further type testing is necessary. Any analysis or test shall be appended to and become part of the original generic qualification report.

Examples of modifications that may require requalification by type test are

- a) Change in materials of construction that may have an effect on qualified life, for example, seals and lubricants
- b) Change in materials of construction that affect deflection or strength
- c) Changes in manufacturing processes or specifications
- d) Changes in mechanical and electrical stress levels
- e) Changes in the actuator design affecting components

NOTE—Components or accessories required for control or indication, whether safety related or not, that are required as a result of a user's valve actuator specification shall be evaluated in the specific qualification process of this standard.

7. Qualification of actuator for specific application

7.1 General

The steps necessary to accomplish qualification for specific actuator application are as follows:

- a) Verification that the valve actuator is a member of a qualified generic actuator group.
- b) Evaluation of the valve actuator specification for the specific application and verification that the environmental test conditions used to qualify the generic actuator group include the specific service conditions plus margin.

Those actuators from a generic family that were not seismically qualified by type test shall be analyzed for seismic stresses in critical sections.

- c) If the valve actuator considered for specific application is not a member of an established generic actuator group, a qualification type test shall be performed, as described in Part I, clause 6, to encompass specific service conditions.

NOTE—Performance verification test, while not a part of qualification, is recommended and is presented in annex E for guidance.

7.2 Valve actuator specification

The actuator specification, a document to be provided to the valve actuator manufacturer, shall include at least

- a) The requirement that the actuator is to be qualified in accordance with this standard.
- b) Identification of the safety-related functions and the service conditions including normal DBE environments.
- c) The range of electrical voltage, current and frequency, pneumatic or hydraulic pressure, type of hydraulic or pneumatic actuating fluid (unless provided by actuator manufacturer), cleanliness (amount of solid contaminants), and the filtration to be provided.
- d) The actuator performance requirements in the normal, abnormal, and accident environments under the extremes of the above ranges. The requirements to be addressed shall include at least the output torque or thrust, speed in both directions, number of operating cycles, design life, and position upon loss of actuating power.
- e) The installation requirements at the plant site such as mounting method, orientation with respect to gravity, configuration, and space envelope.
- f) The requirement that the manufacturer will provide the following information for the installed life of the actuator: a preventive maintenance schedule for lubrication and hydraulic fluids, a replacement schedule for parts subject to wear or environmental deterioration, and inspection of filters. Any restrictions on maintenance accessibility shall be stated.
- g) The requirements for control, indicating devices, or other components and accessories to be mounted on the actuator or external to the actuator, and any special features such as mechanical or electrical separation between redundant components used in different safety channels. Items that are considered to be safety related shall be identified and their performance requirements shall be stated.

7.3 Relationship to generic actuator group

Analytical comparison shall be made between a generic actuator qualified by test and the actuator for a specific application. Such comparison shall show that

- a) Ratios of the specific actuator design dimensions are similar to those of the test actuator. Any difference shall be shown to be conservative in favor of the specific actuator with regard to any stress-related dimensional aspect.⁴
- b) The elevated stresses in the driving parts of the actuator, due to stall thrust or torque, are within the allowable stress limits for the material.
- c) The static and dynamic loading section fiber stresses, bearing and drive element contact stresses, fluid/gas pressures and other design loading, and strength-related parameters in the specific actuator are similar to those of the test actuator. Any differences shall be shown to be conservative in favor of the specific actuator.
- d) In addition, similarity shall be shown between the specific actuator and the tested actuator for

⁴If this comparison is not favorable to the specific actuator,

- a) Calculations shall show that the stresses in the materials of construction are within the allowable limits, or
- b) Qualification tests shall be performed as outlined in Part I, clause 6.