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(Revision of IEEE Std 382-1985)

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

Sponsor
Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society

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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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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.

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

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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.

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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

[3]Information about references can be found in clause 2.

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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.

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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.

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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

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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 that those stipulated in the

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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.

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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

[4]If 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.

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1) Operating principles
2) Structural arrangement is functionally and geometrically similar, with the principal differences being overall size, weight, and ratings
3) Materials, manufacturing process, finishes, and tolerances
4) Operating characteristics including time and load
5) Auxiliary components
6) Qualification parameters
7) Design margins
8) Mounting requirements
9) Power supply

Substitution of functional parts of a type different from those used in the qualification is permissible, provided that such parts or components are individually qualified for the appropriate conditions.

Examples are torque switches on motor actuators and solenoid-actuated control valves which form part of a pneumatic actuator. Type testing shall be used to establish the qualification of the substituted component and an analysis shall be provided to justify the use of the component in the specific application.

Simple substitution of different materials is permissible provided material testing and analysis demonstrates that the substitute materials are satisfactory for the appropriate conditions. Examples are bolting material and gasket material. The test results of materials shall be used to establish properties of the material under the appropriate conditions. An analysis shall be provided to demonstrate conclusively that the properties are satisfactory for the specific application.

7.4 Relationship to specification

Comparison shall be made between the performance characteristics of the actuator selected for specific application and those required by the user's specification.

8. Documentation

8.1 General

The qualification documentation is ultimately intended to verify that each actuator is qualified for its intended service. Documentation for generic and specific qualification as described in 8.2 and 8.3 comprise the documentation package. The substantiation for qualification shall be explained by showing the relationship among the requirement, test reports, and analysis.

8.2 Documentation for qualification of generic actuator group

The generic qualification documents shall include quantitative information pertinent to

a) The basis for identification of the generic actuator group

b) The basis for selection of units for type testing

c) The equipment type test plan for the unit selected for testing

d) The equipment type test sequence used to test the actuator(s)

e) Test facility, instrumentation, and instrumentation calibration records

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f) Justification of any adjustment, disassembly, or alteration to the sample actuator other than that identified in the type test specification

g) Test results and supportive data

h) Substituted component or material qualification data

i) Summary, conclusion, and recommendation required to support qualification

j) Date and signature of person(s) responsible for the generic qualification

The documentation shall be arranged and maintained in an auditable form.

8.3 Documentation for qualification for a specific application

The specific qualification documents shall identify the conditions outlined in the actuator specification that enable the particular actuator design, rating, and performance to be selected and proposed for the duty and environment required and that further enable the manufacturer to verify in an auditable form that the specific requirements have been met.

The documentation shall include

a) Identification of equipment being specifically qualified, including assembly drawings and list of materials

b) Summary of method used to select the specific valve actuator to meet the operating conditions and valve characteristics required

c) Demonstration that the specific actuator is a member of a generically qualified family

d) Requirements for periodic maintenance and a schedule for replacement of parts

e) Other technical information such as reference to installation, calibration, maintenance and operation instruction manuals

f) Substituted component or material qualification data

All documents shall bear the date and signature of person(s) responsible for the specific qualification.

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Part II—Qualification cases

1. Scope

Qualification cases describe various levels of qualification. The environmental test parameters for each case are presented. These cases are typical only and are based upon data from the industry for those plant types addressed. It is the user's responsibility to assure that the qualification test parameters meet the specific plant conditions with margins.

Part II describes the standard qualification cases and their environmental parameters for the usual locations of safety-related equipment in a nuclear generating station.

2. Multiple operations

a) *Case I.* Locations inside drywell and steam tunnel of plants using a boiling water reactor (BWR) Mark III containment and intended to operate following the start of the DBE and on demand for an extended period.

   Figure 1 describes qualification parameter values and time profile for actuators that are to be qualified for Case I.

b) *Case II.* Locations inside containment (outside the drywell and steam tunnel) of plants using a BWR and intended to operate following the start of the DBE and on demand for extended period.

   Figure 2 describes qualification parameter values and time profile for actuators that are to be qualified for Case II.

c) *Case III.* Locations inside containment of plants using a pressurized water reactor (PWR) and intended to operate following the start of loss of coolant accident (LOCA) event and on demand for extended periods.

   Figure 3 describes qualification parameter values and time profile for actuators that are to be qualified for Case III.

d) *Case IV.* Locations inside containment of plants using a PWR and intended to operate following the start of main steam line break (MSLB) event and on demand for an extended period.

   Figure 4 describes qualification parameter values and time profile for actuators that are to be qualified for Case IV.

e) *Case V.* Locations outside PWR and BWR containment subject to steam exposure and intended to operate following the start of the DBE and on demand for an extended period.

   Figure 5 describes qualification parameter values and time profile for actuators that are to be qualified for Case V.

f) *Case VI.* Locations outside PWR and BWR containment not subject to steam exposure and intended to operate following the start of the DBE and on demand for an extended period. No DBE radiation or steam/temperature simulation test is required. Normal service aging qualification is accomplished by either demonstration of prior use or analysis.

Actuators qualified for Case III are considered to be qualified for Cases I and II.

Actuators qualified for Cases I, II, or III are considered to be qualified for Cases V and VI.

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Actuators qualified for Case IV are considered to be qualified for Cases I, II, and III except for DBE radiation levels.

Actuators qualified for Case V are considered to be qualified for Case VI.

NOTE—The above recommendations are satisfactory for actuators not required to operate beyond 30 days following the start of a DBE. If specific conditions of use require need for operation beyond 30 days the specific qualification process should satisfactorily extrapolate the results of the generic qualification tests or additional testing may be necessary.

3. Single operation

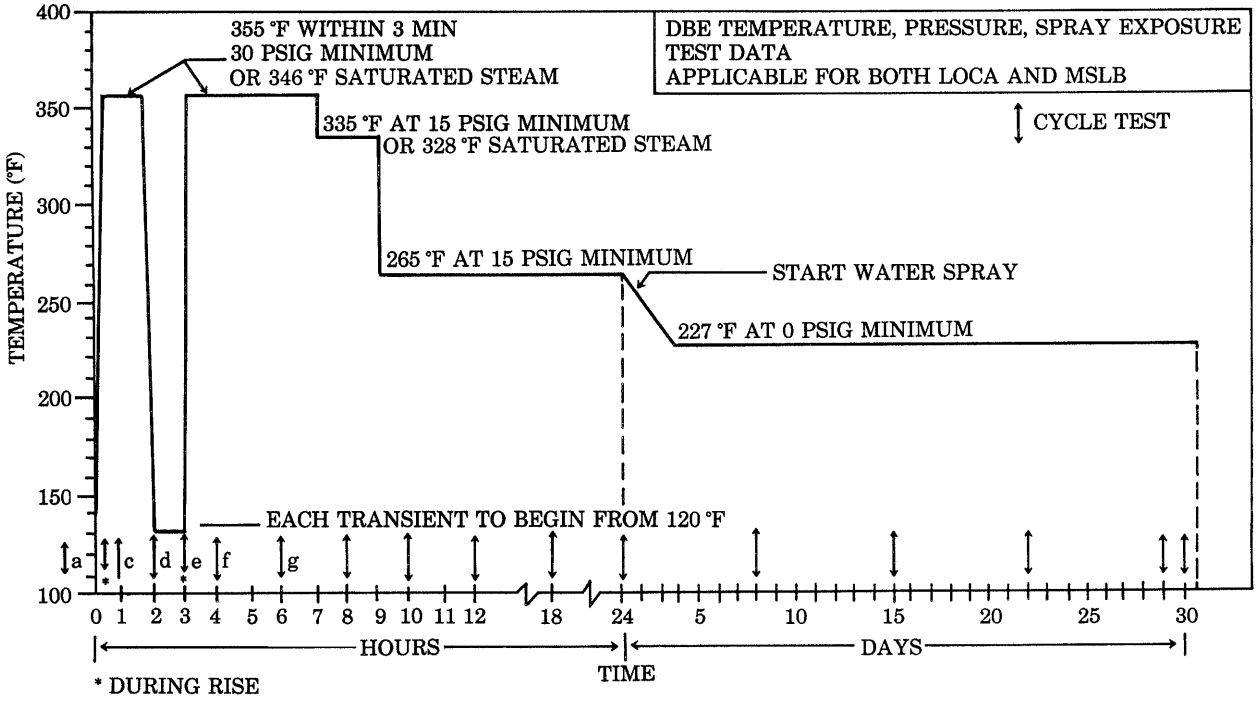
If the intended qualification goal is for the circumstances where the safety-related function of the actuator involves only one operation in one direction, or maintenance of the position without operation, the following procedure is permissible during the DBE environmental simulation. This may apply to any of the six cases.

Operate the actuator in the critical direction during the first dwell at peak temperature at a time that imposes the most severe conditions on the actuator. (This may be at the start of the dwell for a pneumatic actuator and after thermal equilibrium has been attained for electric or hydraulic actuators.)

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NORMAL SERVICE AGING TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$45 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurizations:	To 65 PSIG for 3 min each

DBE RADIATION EXPOSURE TEST DATA
$10 \cdot 10^6$ RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 250 °F. Relative humidity (rh) shall be ≥95% when temperature is below 212 °F.

4—Water spray for not less than 6 h at a rate of approximately 0.3 gal/min · ft^2 of actuator projected horizontal cross-sectional area.

5—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

6—Temperature and pressure for Marks I and II containment are higher.

7—Values may not envelope all plants. User shall verify adequacy.

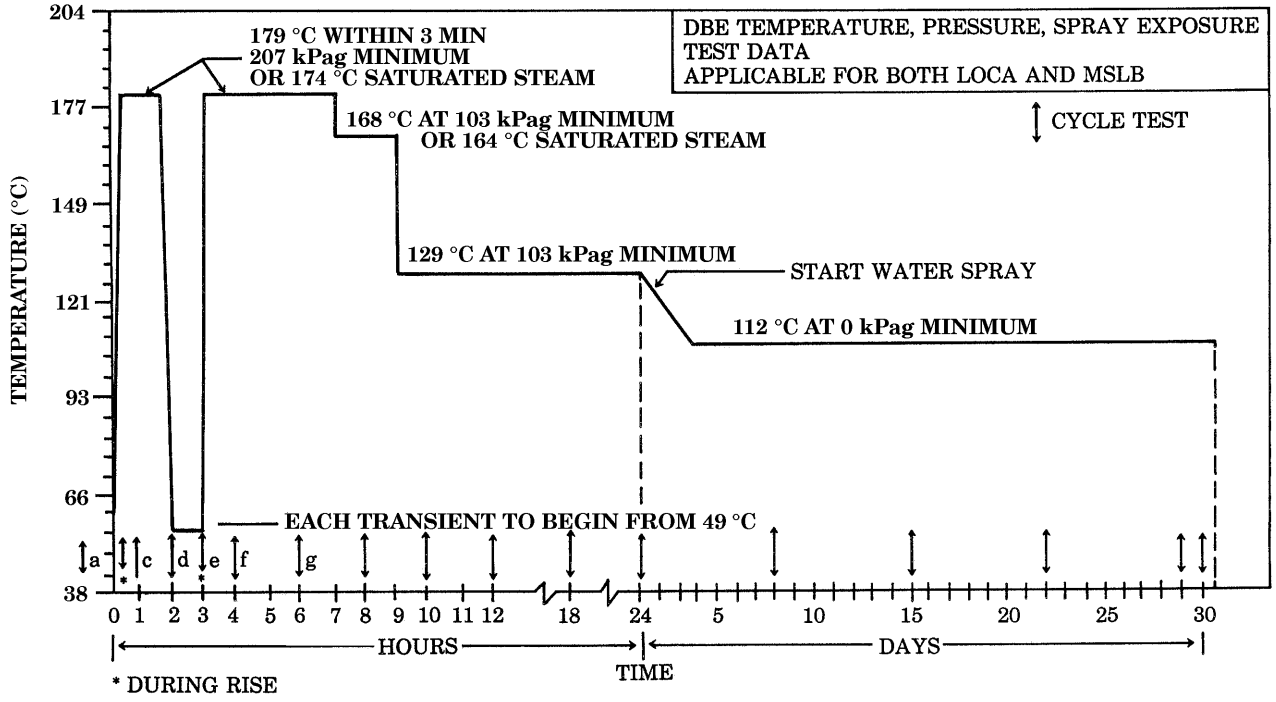
a) English

Figure 1—Qualification type test parameters inside BWR (Mark III containment) drywell and steam tunnel, Case I

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NORMAL SERVICE AGING TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$45 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurizations:	To 448 kPag for 3 min each

DBE RADIATION EXPOSURE TEST DATA
$10 \cdot 10^6$ RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 121 °C. Relative humidity (rh) shall be ≥95% when temperature is below 100 °C.

4—Water spray for not less than 6 h at a rate of approximately12.2 L/min · m^2 of actuator projected horizontal cross-sectional area.

5—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

6—Temperature and pressure for Marks I and II containment are higher.

7—Values may not envelope all plants. User shall verify adequacy.

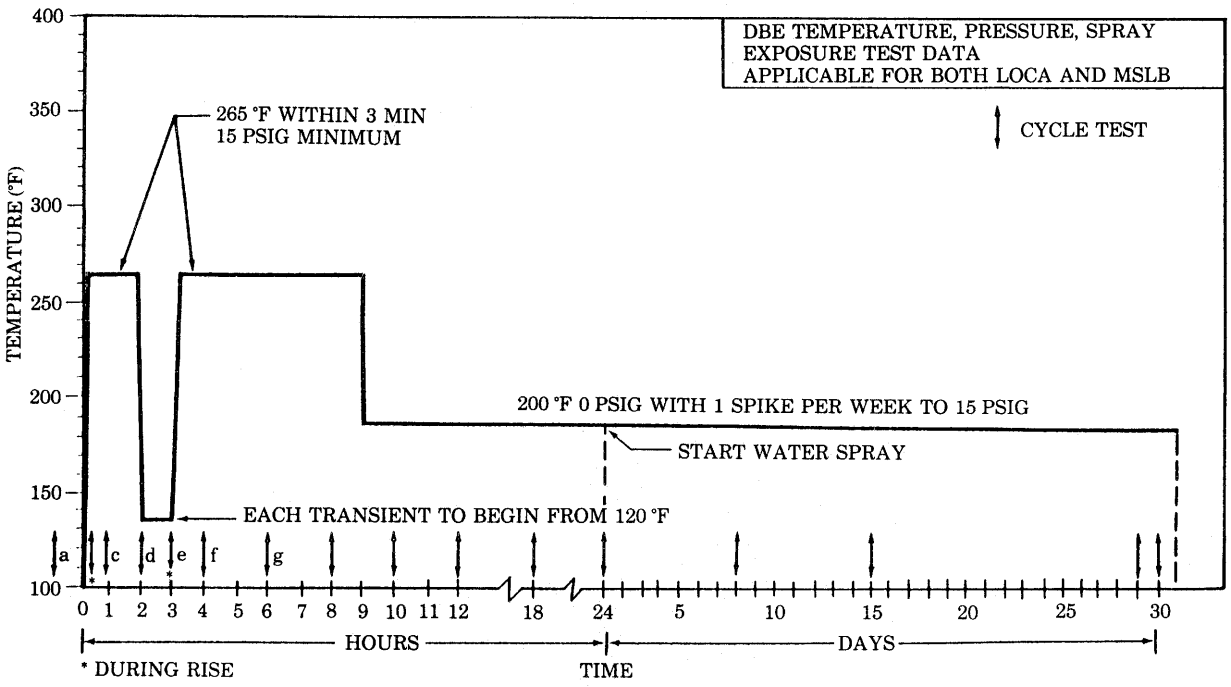
b) Metric

Figure 1—Qualification type test parameters inside BWR (Mark III containment) drywell and steam tunnel, Case I *(Continued)*

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NORMAL SERVICE AGING TEST DATE	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$5 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurizations:	To 65 PSIG for 3 min

DBE RADIATION EXPOSURE TEST DATA
$20 \cdot 10^6$ RAD



NOTES
1—The actual qualification levels are those obtained by subtracting margins from the test data.
2—Descending temperature changes shall be concluded before conducting the next identified cycle test.
3—All steam environment during DBE simulation for temperature above 250 °F. Relative humidity (rh) shall be ≥95% when temperature is below 212 °F.
4—Water spray for not less than 6 h at a rate of approximately 0.3 gal/min · ft^2 of actuator projected horizontal cross-sectional area.
5—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.
6—Temperature and pressure for Marks I and II containment are higher.
7—Values may not envelope all plants. User shall verify adequacy.

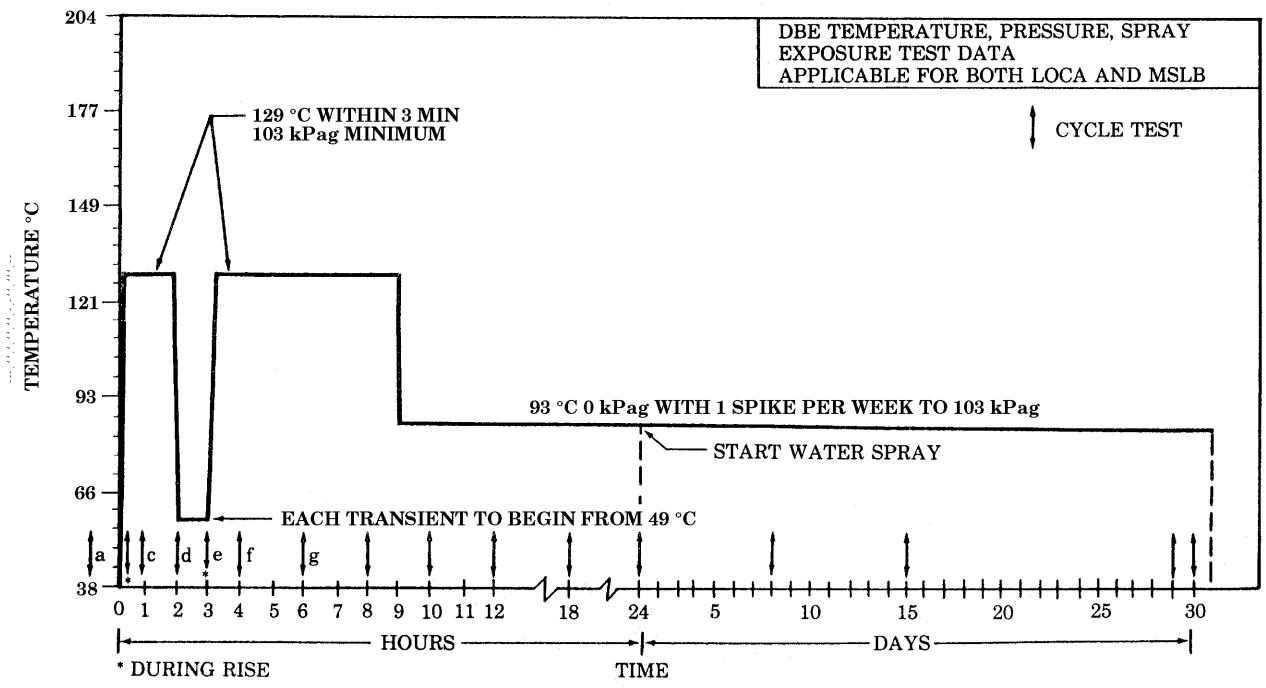
a) English

Figure 2—Qualification type test parameters inside containment outside BWR drywell and steam tunnel, Case II

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NORMAL SERVICE AGING TEST DATE	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$5 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurizations:	To 448 kPag for 3 min

DBE RADIATION EXPOSURE TEST DATA
$20 \cdot 10^6$ RAD



NOTES
1—The actual qualification levels are those obtained by subtracting margins from the test data.
2—Descending temperature changes shall be concluded before conducting the next identified cycle test.
3—All steam environment during DBE simulation for temperature above 121 °C. Relative humidity (rh) shall be ≥95% when temperature is below 100 °C.
4—Water spray for not less than 6 h at a rate of approximately12.2 L/min · m^2 of actuator projected horizontal cross-sectional area.
5—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.
6—Temperature and pressure for Marks I and II containment are higher.
7—Values may not envelope all plants. User shall verify adequacy.

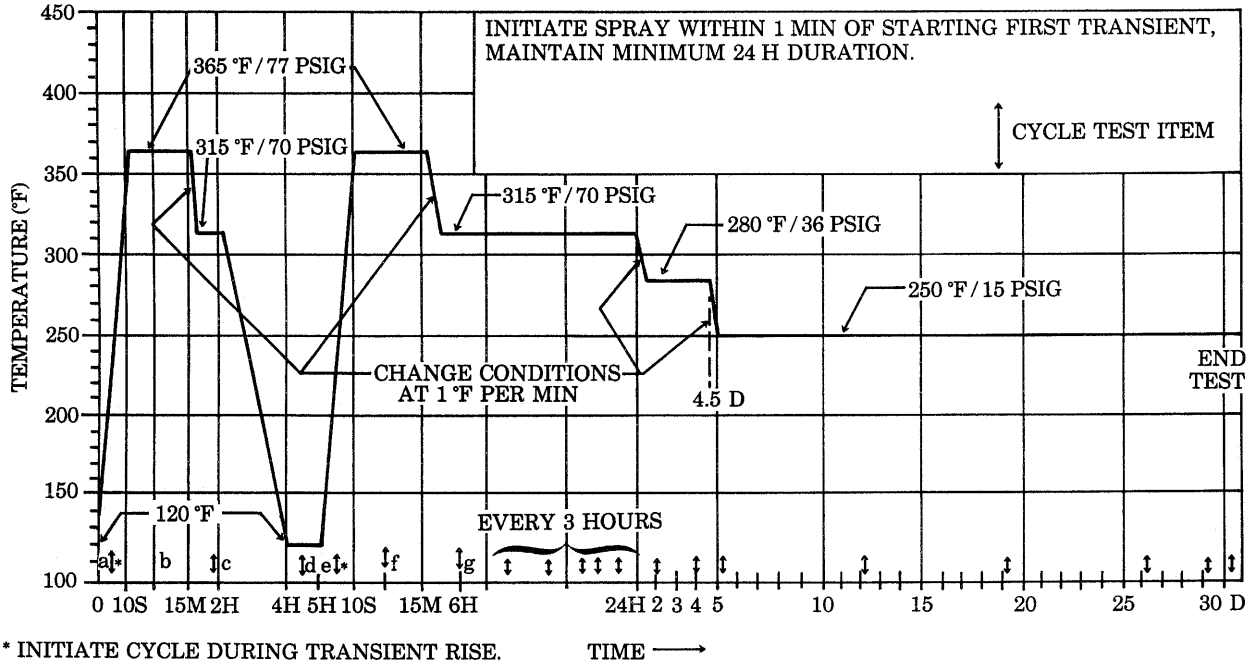
b) Metric

Figure 2—Qualification type test parameters inside containment outside BWR drywell and steam tunnel, Case II *(Continued)*

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NORMAL SERVICE TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$70 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurization:	To 65 PSIG for 3 min

DBE RADIATION EXPOSURE TEST DATA
$1.2 \cdot 10^8$ RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 250 °F. Relative humidity (rh) shall be ≥95% when temperature is below 212 °F.

4—Chemical spray solutions:

a) 1.5% by weight boric acid with sodium hydroxide to pH of 10.5 at room temperature.

b) 6200 ppm boron as H_3BO_3, 50–100 ppm hydrazine sodium phosphate solution, pH 4–10.

c) 1.146% boric acid by weight and 0.17% sodium hydroxide dissolved in water.

5—Superheated steam conditions are required for first 12 min of each transient followed by saturated steam at initiation of spray. Spray shall be terminated at end of first transient and not reinitiated until after 12 min of second transient. If superheat steam environment is maintained, adjust temperature and pressure accordingly.

6—The user should be advised that no single chemical spray solution is recommended during PWR testing. Therefore, he shall assure himself that the solution selected will be acceptable for the desired qualification being sought.

7—Use a source having average gamma energy ≥ 1.0 MeV. For qualification of an installed life less than 40 yr, the normal service radiation may be proportionately reduced, if suitably justified.

8—Chemical spray rate approximately 0.7 gal/min · ft^2 of actuator projected horizontal cross-sectional area.

9—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

10—Values may not envelope all plants. User shall verify adequacy.

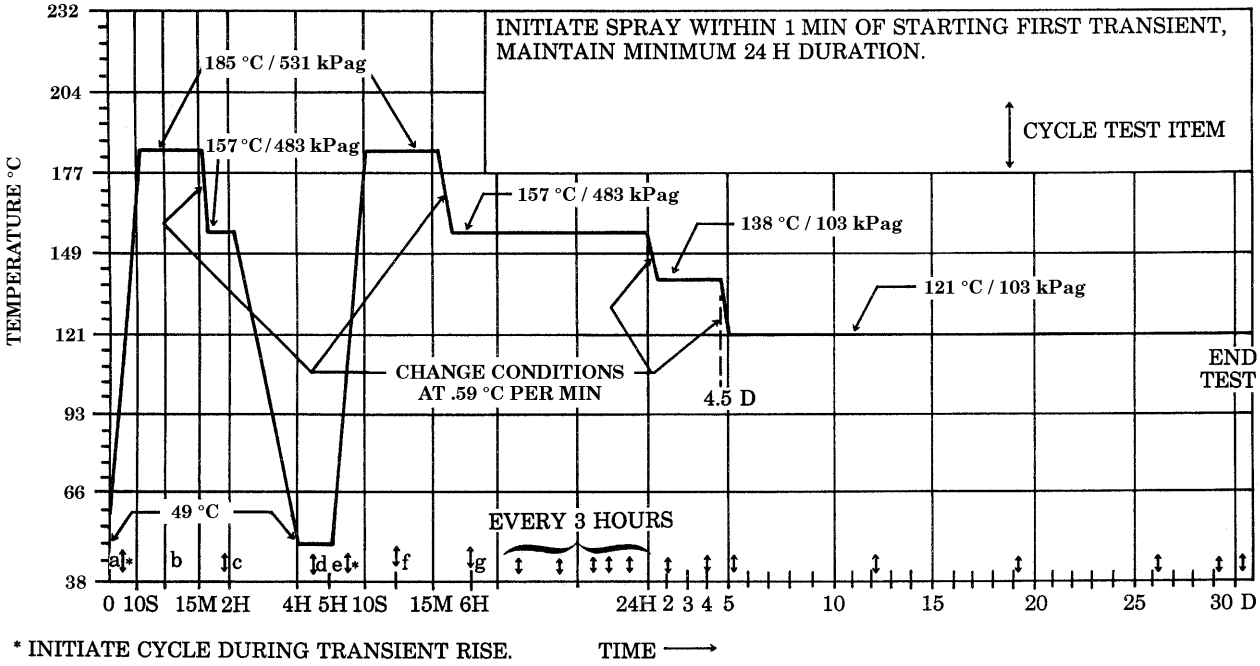
a) English

Figure 3—Qualification type test parameters LOCA inside (PWR) containment, Case III

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NORMAL SERVICE TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$70 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurization:	To 448 kPag for 3 min each

DBE RADIATION EXPOSURE TEST DATA
$1.2 \cdot 10^8$ RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 121 °C. Relative humidity (rh) shall be ≥95% when temperature is below 100 °C.

4—Chemical spray solutions:

a) 1.5% by weight boric acid with sodium hydroxide to pH of 10.5 at room temperature.

b) 6200 ppm boron as H_3BO_3, 50–100 ppm hydrazine sodium phosphate solution, pH 4–10.

c) 1.146% boric acid by weight and 0.17% sodium hydroxide dissolved in water.

5—Superheated steam conditions are required for first 12 min of each transient followed by saturated steam at initiation of spray. Spray shall be terminated at end of first transient and not reinitiated until after 12 min of second transient. If superheat steam environment is maintained, adjust temperature and pressure accordingly.

6—The user should be advised that no single chemical spray solution is recommended during PWR testing. Therefore, he shall assure himself that the solution selected will be acceptable for the desired qualification being sought.

7—Use a source having average gamma energy ≥ 1.0 MeV. For qualification of an installed life less than 40 yr, the normal service radiation may be proportionately reduced, if suitably justified.

8—Chemical spray rate approximately 28.5 L/min · m^2 of actuator projected horizontal cross-sectional area.

9—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

10—Values may not envelope all plants. User shall verify adequacy.

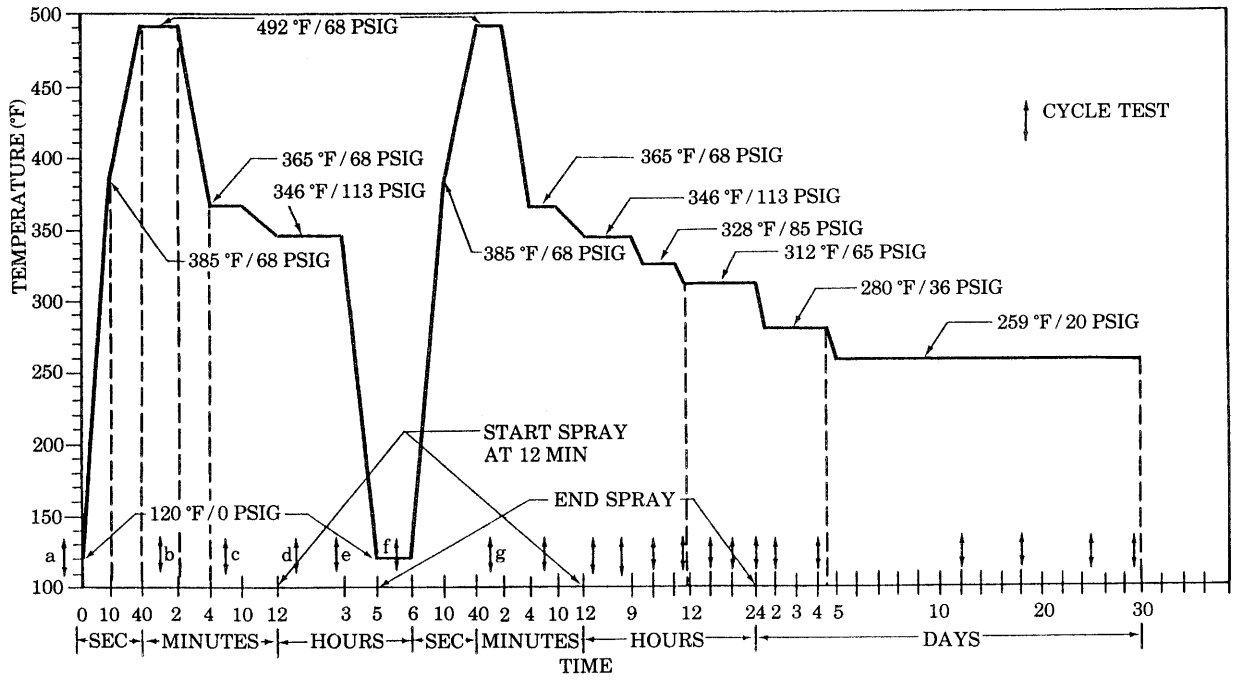
b) Metric

Figure 3—Qualification type test parameters LOCA inside (PWR) containment, Case III *(Continued)*

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NORMAL SERVICE TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$70 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurization:	To 65 PSIG for 3 min

DBE RADIATION EXPOSURE TEST DATA
$30 \cdot 10^6$ RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 250 °F. Relative humidity (rh) shall be ≥95% when temperature is below 212 °F.

4—Chemical spray solutions:

a) 1.5% by weight boric acid with sodium hydroxide to pH of 10.5 at room temperature.

b) 6200 ppm boron as H_3BO_3, 50–100 ppm hydrazine sodium phosphate solution, pH 4–10.

c) 1.146% boric acid by weight and 0.17% sodium hydroxide dissolved in water.

5—Superheated steam conditions are required for first 12 min of each transient followed by saturated steam at initiation of spray. Spray shall be terminated at end of first transient and not reinitiated until after 12 min of second transient. If superheat steam environment is maintained, adjust temperature and pressure accordingly.

6—The user should be advised that no single chemical spray solution is recommended during PWR testing. Therefore, he shall assure himself that the solution selected will be acceptable for the desired qualification being sought.

7—Use a source having average gamma energy ≥1.0 MeV. For qualification of an installed life less than 40 yr, the normal service radiation may be proportionately reduced, if suitably justified.

8—Chemical spray rate approximately 0.7 gal/min · ft^2 of actuator projected horizontal cross-sectional area.

9—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

10—Values may not envelope all plants. User shall verify adequacy.

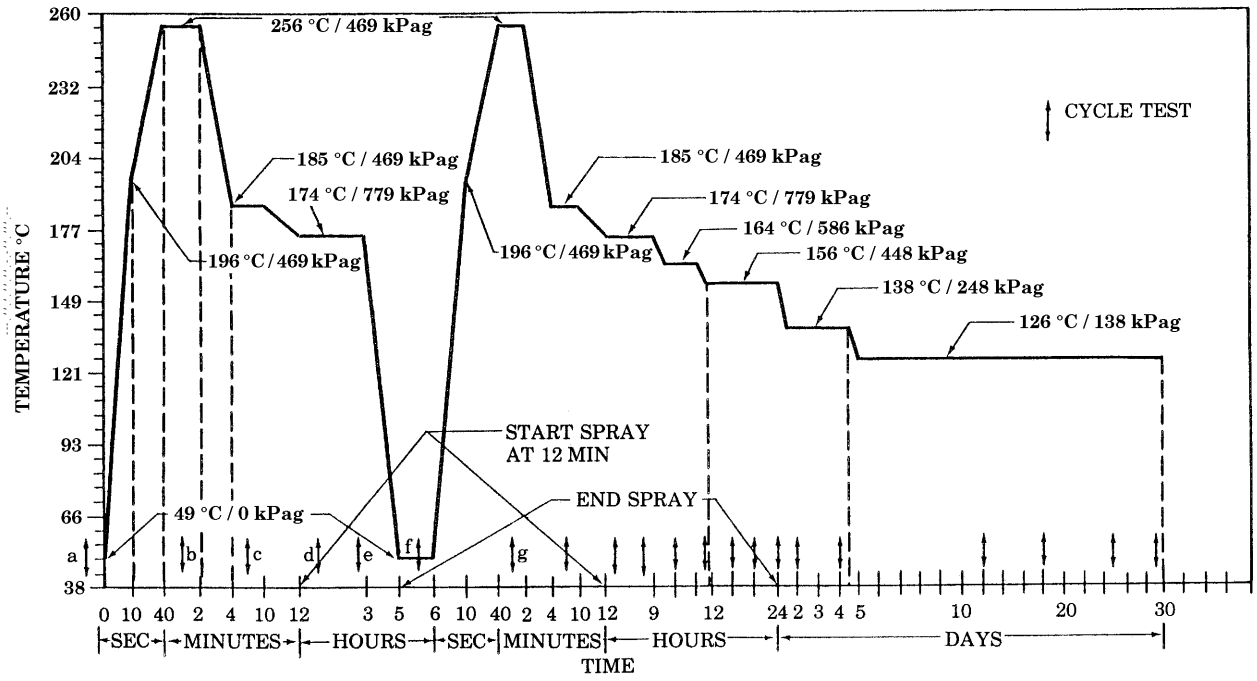
a) English

Figure 4—Qualification type test parameters MSLB inside (PWR) containment, Case IV

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NORMAL SERVICE TEST DATA	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	70 · 10^6 RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
15 External Pressurization:	To 448 kPag for 3 min

DBE RADIATION EXPOSURE TEST DATA
30 · 10^6 RAD



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Descending temperature changes shall be concluded before conducting the next identified cycle test.

3—All steam environment during DBE simulation for temperature above 121 °C. Relative humidity (rh) shall be ≥95% when temperature is below 100 °C.

4—Chemical spray solutions:

a) 1.5% by weight boric acid with sodium hydroxide to pH of 10.5 at room temperature.

b) 6200 ppm boron as H_3BO_3, 50–100 ppm hydrazine sodium phosphate solution, pH 4–10.

c) 1.146% boric acid by weight and 0.17% sodium hydroxide dissolved in water.

5—Superheated steam conditions are required for first 12 min of each transient followed by saturated steam at initiation of spray. Spray shall be terminated at end of first transient and not reinitiated until after 12 min of second transient. If superheat steam environment is maintained, adjust temperature and pressure accordingly.

6—The user should be advised that no single chemical spray solution is recommended during PWR testing. Therefore, he shall assure himself that the solution selected will be acceptable for the desired qualification being sought.

7—Use a source having average gamma energy ≥ 1.0 MeV. For qualification of an installed life less than 40 yr, the normal service radiation may be proportionately reduced, if suitably justified.

8—Chemical spray rate approximately 28.5 L/min · m^2 of actuator projected horizontal cross-sectional area.

9—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power values, and cycle g is performed at maximum input power value.

10—Values may not envelope all plants. User shall verify adequacy.

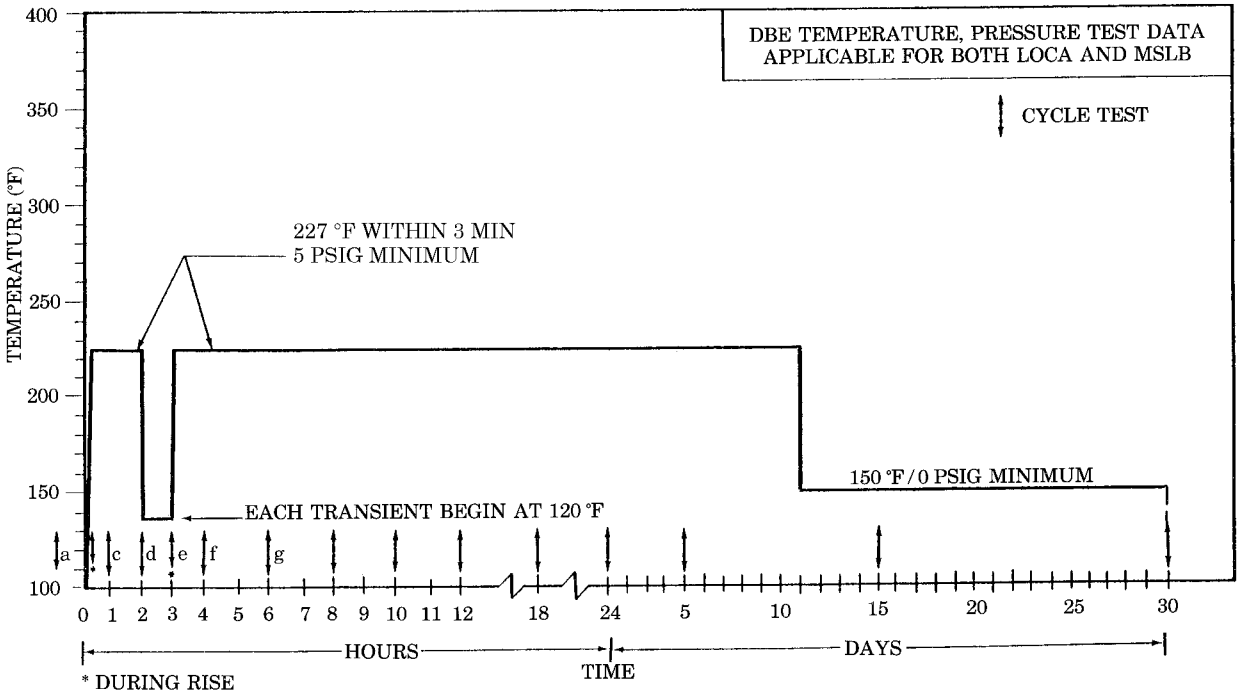
b) Metric

Figure 4—Qualification type test parameters MSLB inside (PWR) containment, Case IV *(Continued)*

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NORMAL SERVICE AGING SIMULATION	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$2 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
External Pressurization:	None

DBE RADIATION EXPOSURE TEST DATA
0



NOTES

1—The actual qualification levels are those obtained by subtracting margins from the test data.

2—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power value, and cycle g is performed at maximum input power value.

3—Values may not envelop all plants. User shall verify adequacy.

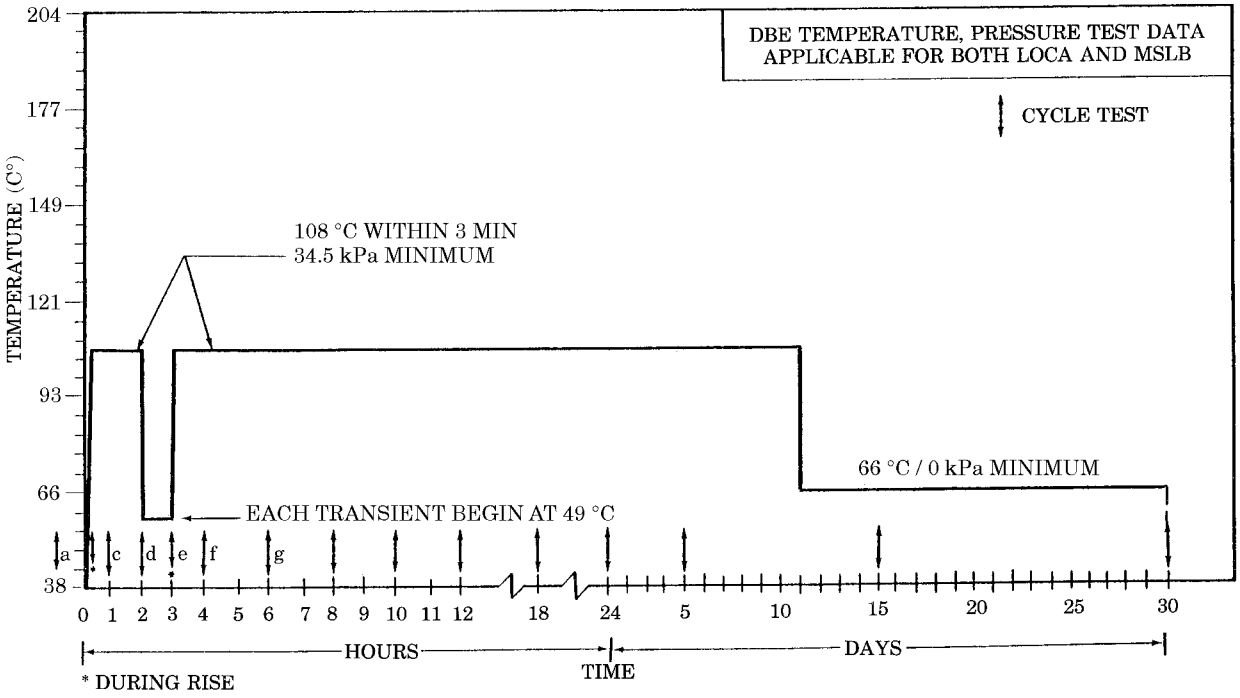
a) English

Figure 5—Qualification type test parameters outside containment (BWR and PWR), Case V

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NORMAL SERVICE AGING SIMULATION	
Operating Cycles Under Load:	
Modulating Valves:	2000 at full and 100 000 at 20% stroke
Two Position Valves:	2000
Nuclear Radiation:	$2 \cdot 10^6$ RAD (40 yr)
Thermal Aging:	See Part III, Clause 2
External Pressurization:	None

DBE RADIATION EXPOSURE TEST DATA
0



NOTES
1—The actual qualification levels are those obtained by subtracting margins from the test data.
2—Sample actuator is to be operated under simulated load through one complete cycle (on-off actuators) or 10 cycles at 20% stroke (modulating actuators) at times shown. All cycles are performed using nominal input power values, except that cycles c and f are performed at minimum input power value, and cycle g is performed at maximum input power value.
3—Values may not envelop all plants. User shall verify adequacy.

b) Metric

Figure 5—Qualification type test parameters outside containment (BWR and PWR), Case V *(Continued)*

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Part III—Tests

1. Baseline operability test

Part III describes the qualification tests outlined in 6.3.2 of Part I.

1.1 Scope

The baseline operability test establishes reference actuator performance data for comparison with performance at other stages of the qualification test program.

1.2 Test setup requirements

a) Attach electrical, hydraulic, or pneumatic connections to the actuator in accordance with the manufacturer's recommended method.

b) Ensure source of variable motive power so that maximum, nominal, and minimum input conditions can be provided.

c) Sufficient instrumentation shall be provided to record actuator performance.

1.3 Test conduct

Operate the actuator and record the following data as a minimum:

1.3.1 For electrical, pneumatic motor, or hydraulic-motor actuators

a) Output speed in each direction under no-load conditions at nominal input supply (voltage pressure)

b) Operating time in each direction under simulated load conditions

c) The operating output torque or thrust characteristics under the minimum specified input supply (voltage pressure)

d) Confirmation of proper torque, limit, and auxiliary switch action

1.3.2 For pneumatic, electrohydraulic, and hydraulic actuators (cylinder, rams, rotary vanes, and diaphragm double acting or spring return)

a) The no-load and rated output speeds

b) Operating time in each direction under simulated load conditions

c) The operating output thrust and torque characteristics at minimum specified pneumatic or hydraulic pressure

d) The maximum thrust or torque capability in each direction at maximum specified pneumatic or hydraulic pressure

e) Rate of leakage of piston, diaphragm, and vane seals at maximum specified input pressure

1.3.3 For integral valve—solenoid type actuators

a) Pull-in voltage at maximum specified operating pressure drop

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b) Drop-out voltage at maximum specified differential pressure and at zero pressure
c) Minimum specified operating pressure at nominal voltage

NOTE—This information is to be recorded once only during this test and not repeated for subsequent tests.

d) Internal leakage at rated pressure
e) External leakage at 1.5 times the rate pressure
f) Test fluid and its quality characteristics
g) Special application requirements (such as response time, duty cycle, and flow rate)

2. Normal thermal aging test

2.1 Scope

The thermal aging simulation test demonstrates the operability of the test actuator during and after exposure to accelerated thermal aging environment, which is equivalent to the normal thermal aging expected over the installed life of the equipment.

2.2 Test setup requirements

a) The actuator shall be mounted in a test chamber with interfaces such as cables and seals, as described in the test plan.

b) Electrical, hydraulic, or pneumatic connection shall be in accordance with manufacturer's recommended method.

2.3 Test conduct

Perform normal thermal aging simulation by heating the actuator to a temperature of 280 °F (138 °C) and maintaining it at that level for a time selected from the following table:

Desired qualified life at 104 °F (40 °C) (years)	Accelerated aging time at 280 °F (138 °C) (hours)
10	100
20	150
40	300

This table applies if the ambient temperature during expected normal service is 104 °F (40 °C). For other ambient temperatures, refer to annex C for guidance in calculating the thermal aging conditions.

2.4 Deviation

The table in 2.3.1 is based on a test temperature of 280 °F (138 °C) and on an activation energy of 0.8 eV, and rounded off from the values given in annex C with the value for 10 yr set at 100 h. If 0.8 eV is not sufficiently conservative for the material in the actuator being qualified, a smaller value shall be used.

Additionally, test temperature deviation is permitted, provided the combination of test temperature and test time is based on the Arrhenius equation 2 in annex C. Documentation shall be provided demonstrating the conservatism in choice of ϕ, temperature, and time.

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3. Normal pressurization cycle test

3.1 Scope

The normal pressurization cycle test demonstrates the ability of the test actuator to operate during and after exposure to a series of pressurization cycles expected during normal operation.

3.2 Test setup requirements

a) Attach electrical, hydraulic or pneumatic connections to the actuator in accordance with the manufacturer's recommended method.

b) The orientation of the actuator shall be determined by the intended application or on the most critical orientation determined for pressurization cycles. The rationale for selecting the most critical orientation shall be included in the qualification report.

3.3 Test conduct

a) For qualification for application inside containment, the actuator shall be exposed to 15 external pressurizations to 65 psig (448 kPag.) The 65 psig (448 kPag) shall be held for a minimum of 3 min for each pressurization cycle.

b) For qualification for application outside containment, no pressurization cycle testing is required.

4. Normal radiation aging test

4.1 Scope

The radiation aging test demonstrates the operability of the test actuator after normal radiation aging.

4.2 Test setup requirements

a) The actuator shall be mounted in a test chamber with interfaces such as cables and seals, as described in the test plan.

b) Electrical, hydraulic, or pneumatic connections shall be in accordance with manufacturer's recommended method.

4.3 Test conduct

a) Perform one half of the operating cycles under load.

b) Expose the actuator to a source of gamma radiation simulating the normal background integrated dose expected over the installed life of the actuator (figures 1 through 5).

c) The actuator performance characteristics shall be measured before and after the radiation. Components that are known to exhibit transitory characteristics during radiation shall be monitored during irradiation.

d) The specified irradiation dose shall be considered an air equivalent dose and the exposure shall be conducted so that no part of the air equivalent volume will receive a dose less than minimum speci-

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fied value (this may result in an overdose to those portions within the volume nearest the radiation source).

e) Perform the remaining operating cycles under load.

5. Vibration aging test

5.1 Scope

The vibration aging test provides a vibratory environment that is representative of normal plant induced vibration including system operating transients and other dynamic vibratory environments. The test is intended to induce an arbitrary but reasonable amount of vibratory aging prior to the DBE testing. It is not intended to be a qualification test in itself nor a test to any specific plant environment.

5.2 Test setup requirements

a) Mount the actuator to the shake table fixture in the same manner as it would be attached to a valve.

b) Attach electrical, hydraulic, or pneumatic connections to the actuator in accordance with the manufacturer's recommended method.

c) Ensure suitable means of inducing vibration and measurement of vibration frequency and acceleration.

5.3 Test conduct

a) Apply sinusoidal motion by exposing the actuator to 0.75 g or such reduced acceleration necessary at low frequencies to not exceed 0.025 in double amplitude with the frequency sweeping from 5 Hz to 100 Hz to 5 Hz at a rate of two octaves per minute. Ninety minutes of vibration shall be applied along each orthogonal axis. Operate on-off actuators under simulated load every 15 min. Operate modulating actuators under load continuously at between 20% and 80% stroke. Refer to annex D for rationale applying to the above procedure.

b) Monitor and control the input motion to the actuator using accelerometers located on the test fixture adjacent to the mounting surface of the actuator.

c) Operate the actuator under load before and after the tests with sufficient monitoring equipment to verify functional operability. Instrumentation shall be attached to the actuator and its appendages so that malfunction can be adequately detected.

6. Seismic simulation test

6.1 Scope

The seismic simulation test demonstrates the operability of a test actuator during and after exposure to the equivalent dynamic effect of five qualification OBEs followed by the qualification SSE.

6.2 Test setup requirements

a) Mount the actuator to the shake table fixture in the same manner as it would be attached to a valve. The orientation of the actuator should be such that one of the axes of vibratory excitation is in the

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line with the apparent most critical direction of the actuator. The rationale for selecting the most critical direction should be included in the qualification report. The rationale for selecting the test orientation with respect to gravity should also be included in the qualification report.

b) Attach electrical, hydraulic, or pneumatic connections to the actuator in accordance with the manufacturer's recommended method.

c) Monitor and control the input motion to the actuator using accelerometers located on the test fixture adjacent to the mounting surface of the actuator.

d) Provide sufficient monitoring equipment to verify functional operability to provide resonance search data. Instrumentation shall be attached to the actuator and its appendages so that malfunction can be adequately detected.

6.3 Test conduct

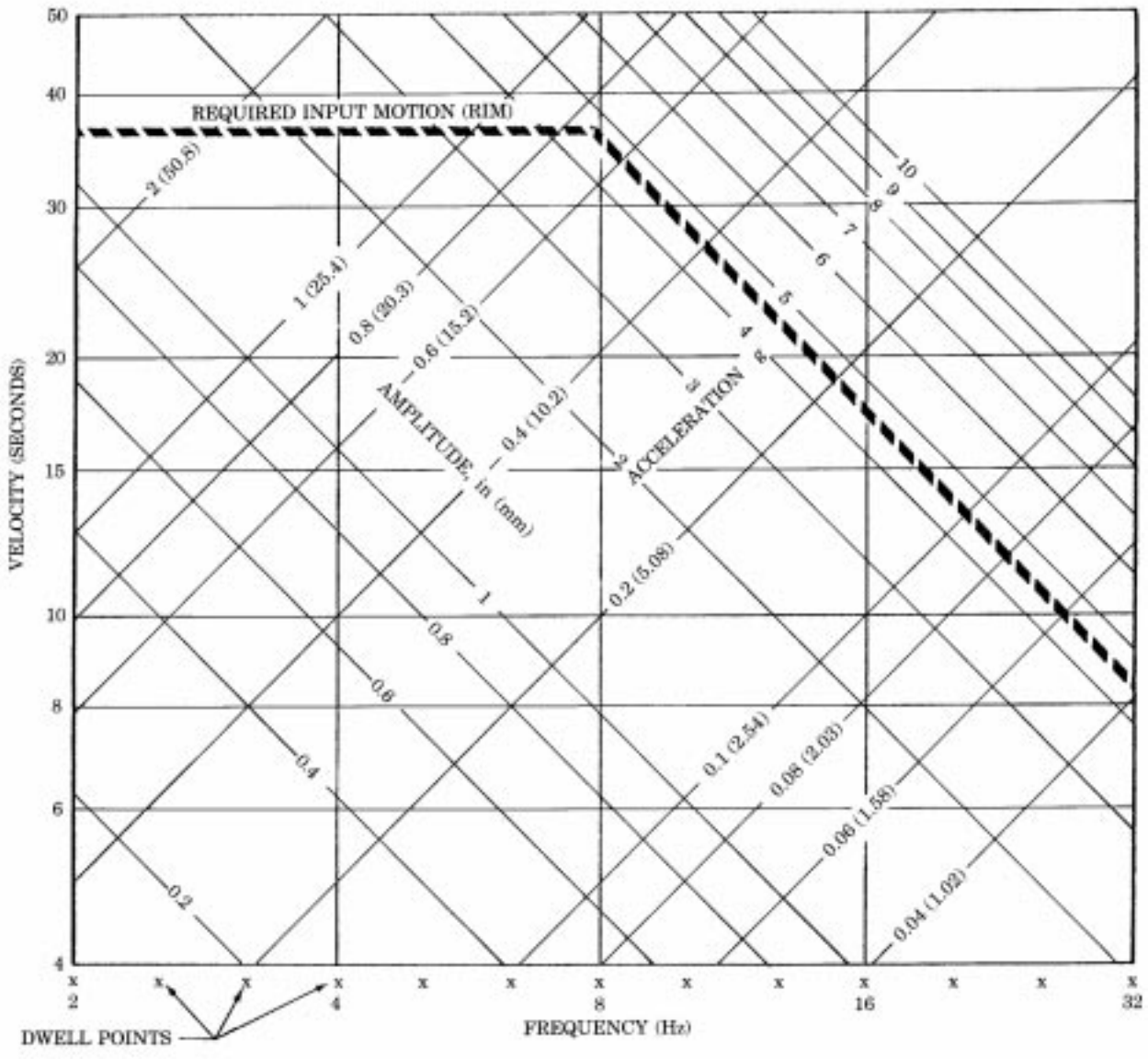
a) Since a valve actuator may be line mounted or hard mounted, it is recommended that both single frequency and multifrequency tests be performed.

b) For actuator qualification for both line mounted and hard mounted configurations, OBE vibratory motion shall be simulated by exposing the actuator to two sinusoidal sweeps at two-thirds of the required input motion (RIM) levels shown in figure 6 in each orthogonal axis. Each sweep shall be from 2 Hz to 35 Hz to 21 Hz at a rate of not more than one octave per minute. One sweep shall be performed with the valve actuator open and one with the actuator closed. The OBE sweeps in each axis may be followed by the SSE test in the same axis [see c) and d)]. The OBE sweeps may also provide resonance search data unless test table and fixtures adversely affect the results.

c) For actuator SSE qualification for line mounted application, perform a single frequency test by exposing the actuator to a series of single frequency sine-beat tests at the one-third octave interval test frequencies indicated on figure 6 (see IEEE Std 344-1987 for further definitions and detailed descriptions of test methods). The excitation at each frequency shall be in the form of a continuous series of sine beats of 12–15 oscillations per beat for the duration required. The successive beats shall be phased so that any superposition of response motion will be additive. At each test frequency the peak acceleration shall be the RIM value shown in figure 6. The duration of each test shall be 15 s minimum. If the operating cycle duration is greater that 15 s. the vibration may be interrupted during a part of the cycle provided the open and close operation takes place during vibration at the specified level. Actuators whose open/close cycle time is less than 5 s shall be cycled at least twice during the test at each frequency. Operate modulating actuators, under load, at 20% stroke. Apply motion at the same frequencies and accelerations in each of the three orthogonal axes separately or biaxially, in which case the test is to be performed both in phase and out of phase in each of the two orientations. See d) for guidance in biaxial testing (a single frequency sinusoidal dwell test of 15 s duration at each frequency may be used in lieu of the sine-beat tests if desired).

d) For actuator SSE qualification for hard-mounted application, perform a multifrequency test by exposing the actuator to biaxial multifrequency test motion which, when analyzed for each axis, produces a test response spectrum (TRS) that envelopes the required response spectrum (RRS) shown in figure 7 (see IEEE Std 344-1987 for further definitions and detailed descriptions of test methods). The test shall be performed with one horizontal axis combined with the vertical axis and then repeated with the orthogonal horizontal axis combined with the vertical. Independent (nonphase coherent) multifrequency motions for the two axes are preferred. If phase-coherent motions are used the test shall be performed four times, that is, in each of the four horizontal directions (90° apart), each one combined in phase with the vertical. The duration of each test shall be 30 s minimum. If the operating cycle duration is greater than 30 s, the vibration may be interrupted during a part of the cycle provided the open and close operations take place during vibration at the specified level. Operate modulating actuators, under load, at 20% stroke. The results of the test may be presented in terms of the TRS at 5% damping for comparison to the RRS (figure 7). The results of the test shall also be

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NOTE—Values may not envelop all plants. User shall verify adequacy.

Figure 6—Seismic qualification required input motion (RIM)

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presented in terms of the TRS at two additional values of damping, for example, 1% and 3%. Refer to annex D for rationale to the above procedure.

7. DBE radiation exposure test

7.1 Scope

The DBE radiation exposure test demonstrates the operability of the test actuator after DBE radiation exposure. It is permissible to combine this exposure with the simulation called for in Part III, clause 4.

7.2 Test setup requirements

a) The actuator shall be mounted in a test chamber with interfaces such as cables and seals, as described in the test plan.

b) Electrical, hydraulic, or pneumatic connections shall be in accordance with the manufacturer's recommended method.

7.3 Test conduct

a) Expose the actuator to a source of gamma radiation simulating the dose the actuator is expected to receive during and following a DBE up through the time when there is no longer a need to perform safety-related functions (see figures 1 through 5).

b) The actuator performance characteristics shall be measured before and after the radiation. Actuators that contain any components that exhibit transitory characteristics during radiation shall be monitored during irradiation.

c) The specified radiation dose shall be considered an air equivalent dose and the exposure shall be conducted so that no part of the air equivalent volume will receive a dose less than the minimum specified value (this may result in an overdose to those portions within the volume nearest the radiation source).

8. DBE environment test

8.1 Scope

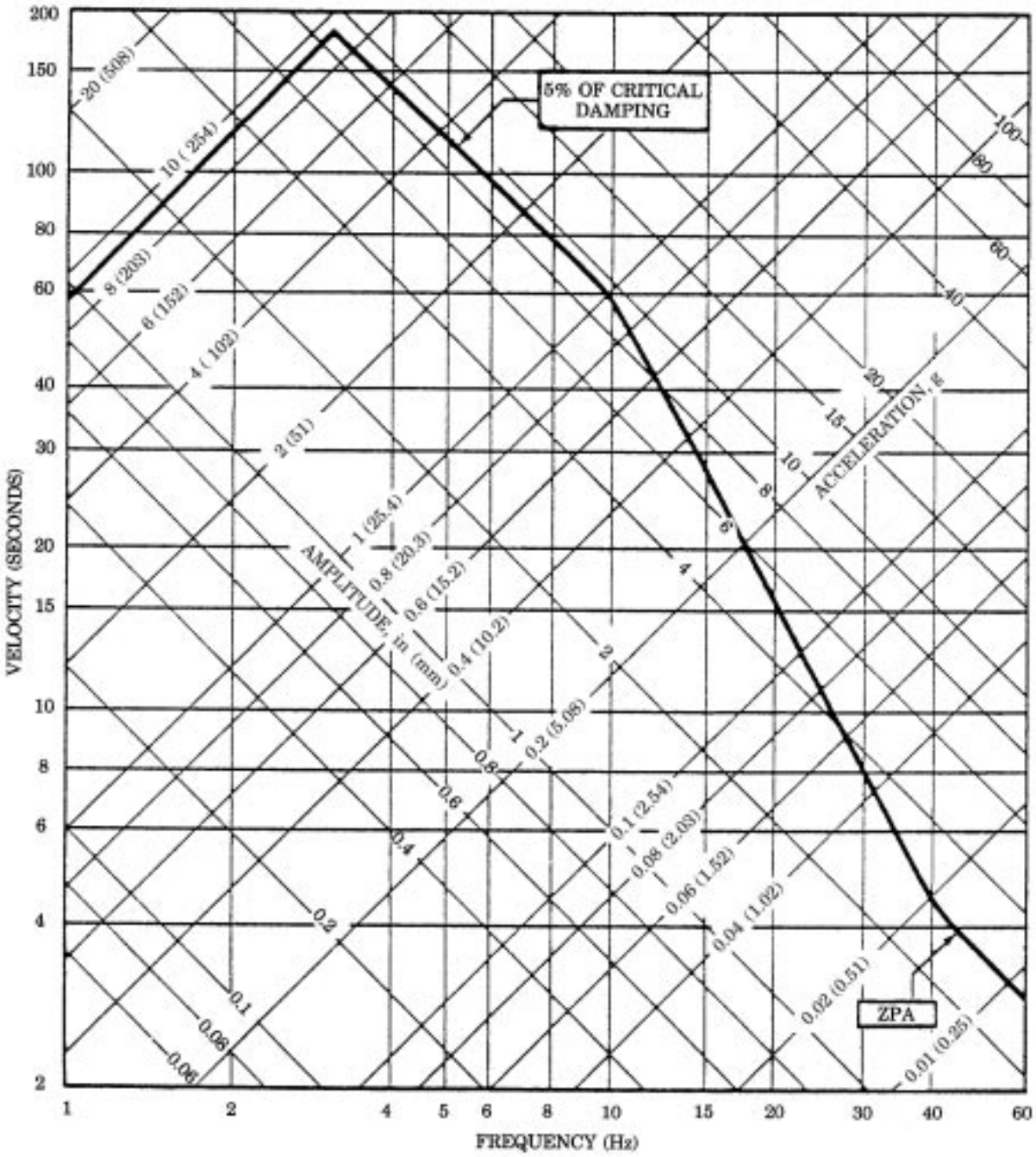
The DBE environment test demonstrates the operability of the test actuator during exposure to DBE temperature, pressure, moisture, or spray environment.

8.2 Test setup requirements

a) The actuator shall be mounted in a test chamber with interfaces such as cables, seals, and unique routing, as described in the test plan.

b) Prior to initiating the exposure to temperature/pressure transients, the normal environmental conditions which exist prior to a DBE shall be established in the test chamber and the actuator shall be operated to provide DBE simulation baseline data.

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NOTE—Values may not envelop all plants. User shall verify adequacy.

Figure 7—Seismic qualification required response spectrum (RRS)

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8.3 Test conduct

a) The actuator shall be operated through complete test operating cycles under rated-load conditions.

b) If the actuator is to be qualified for the application where multiple operation is required, then the test parameters vary depending upon the level of qualification desired. See Part II for the description of the various levels.

c) If the actuator is to be qualified for the application where the requirement is for only one operation in one direction or the maintenance of one position without operation, the actuator shall be operated in the critical direction during the peak conditions of the first transient (former requirement) or not operated at all (latter requirement for maintenance position). No other actuations are required during the DBE environmental simulation.

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Annex A

(informative)

Method of selection of representative actuator(s) for type testing

A.1 Introduction

The validity of this method for selection of test actuators required in Part I, 5.2 represents a consensus of the working group for this standard. The method is based on an existing extrapolation concept in which variation from a mean value, of 50% smaller to 100% larger, defines the extrapolation limits. The method, if applied in a technically responsible manner, will result in a representative and reasonable number of test units within a generic actuator group.

The method has been investigated by several electric motor and hydraulic cylinder actuator manufacturers and results were found to be acceptable to the manufacturers and to the working group of this standard.

A suggested procedure for selecting units for type testing of a generic actuator group is as follows:

a) Identify the actuators intended to comprise a generic actuator group.

b) Select the technically significant design parameters (a minimum of four shall be chosen for completeness).

c) Tabulate the significant parameter values for each actuator in the group.

d) Calculate the mean value of one parameter using the complete range (smallest to largest).

e) Double and halve the numerical mean value for this parameter. This forms the bounds for one ration set within extrapolation limits for the parameter.

f) Form as many additional sets for this parameter as necessary, by selecting different real parameter value ranges and by repeating d) and e) until all units are included in at least one ratio set.

g) Repeat d) through f) for the remaining tabulated parameters (at least three).

h) Tabulate the ratio sets and the models within those sets for each parameter. Any one model within each ratio set is eligible for type test.

i) Tabulate the eligible models and select the test models so that each ratio set from each parameter is represented.

A.2 Example

Pneumatic cylinder actuator family, all with similar materials, design stresses, pressure rating, and manufacturing process.

a) Identity family and significant parameters A.1a) and A.1b).

b) The models for the generic actuator group are A through X. See table A.1.

c) The parameters chosen for comparison and selection of the number of actuators to be tested within the generic group are

   1) Bore diameter
   2) Stroke

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Table A.1—Significant parameter values [step c)]

Model	Bore diameter		Stroke		Weight		Center of gravity distance	
	in	mm	in	mm	lb	kg	in	mm
A	6	152.4	0.5	12.7	105	47.6	2.3	58.4
B	6	152.4	3	76	120	54.4	3.3	83.8
C	6	152.4	6	152	135	61.2	4.8	121.9
D	8	203.2	0.5	12.7	160	72.6	2.9	73.7
E	8	203.2	4	102	180	81.6	4.4	111.8
F	8	203.2	8	203	200	90.7	6.4	162.6
G	10	254	0.5	12.7	210	95.3	3.3	83.8
H	10	254	5	127	250	113.4	5.5	139.7
I	10	254	10	254	290	131.5	8.0	203.2
J	12	305	0.5	12.7	320	145.2	3.9	99.1
K	12	305	6	152	380	172.3	6.6	167.6
L	12	305	12	305	440	199.6	9.6	243.8
M	14	356	0.5	12.7	485	220.0	4.5	114.3
N	14	356	7	178	575	260.8	7.7	195.6
O	14	356	14	356	665	301.6	11.2	284.5
P	16	406	0.5	12.7	760	344.7	5.1	129.5
Q	16	406	8	203	880	399.2	8.8	223.5
R	16	406	16	406	1000	453.6	12.8	325.1
S	18	457	0.5	12.7	1150	521.6	5.9	149.9
T	18	457	9	229	1300	589.7	9.9	251.5
U	18	457	18	457	1450	657.7	15.4	391.2
V	20	508	0.5	12.7	1400	635.0	6.3	160.0
W	20	508	10	254	1600	725.8	11.1	281.9
X	20	508	20	508	1800	816.5	16.0	406.4

3) Weight
4) Center of gravity distance from mounting surface.

d) Tabulate parameter values A.1c). See table A1.

e) Establish ratio set—A.1d) through A.1g)

1) Bore diameter
Range A1: (6 to 20); mean 13, ratio set A1: 6.5 to 26
Range A2: (6 to 6); mean 6, ratio set A2: 3 to 12

2) Stroke
Range B1: (0.5 to 20); mean 10.3, ratio set B1: 5.2 to 20.6
Range B2: (0.5 to 5); mean 2.8, ratio set B2: 1.4 to 5.6
Range B3: (0.5 to 0.5); mean 0.5, ratio set B3: 0.25 to 1.0

3) Weight
Range C1: (105 to 1800); mean 953, ratio set C1: 476 to 1906
Range C2: (105 to 380); mean 243, ratio set C2: 122 to 486
Range C3: 105 to 120); mean 113, ratio set C3: 57 to 226

4) Center of gravity distance
Range D1: (2.3 to 16); mean 9.2, ratio set D1: 4.6 to 18.4
Range D2: (2.3 to 4.5); mean 3.4, ratio set D2: 1.7 to 6.8

f) Tabulate ratio sets and identify eligible models—A.1h). See table A.2.

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Table A.2—Identification of eligible models

Parameter	Ratio set	Eligible models
Bore	A1, 6.5 to 26 A2, 3 to 12	DEFGHIKLMNOPQRSTUVWX ABCDEFGHIJKL
Eligible: All in ratio set A2, and M through X of ratio set A1.		
Stroke	B1, 5.2 to 20.6 B2, 1.4 to 5.6 B3, 0.25 to 1.0	CFIKLNOQRTUWX BEH ADGJMPSV
Eligible: All in each ratio set.		
Weight	C1, 476 to 1906 C2, 122 to 486 C3, 53 to 226	MNOPQRSTUVWX CDEFGHIJKLM ABCDEFG
Eligible: All in ratio set C3, H I J K L of ratio set C2, and all in ratio set C1.		
Center of gravity distance	D1, 4.6 to 18.4 D2, 1.6 to 6.8	CFHIKLNOPQRSTUVWX ABCDEFGHIJKMPV
Eligible: A through H, J, and M of ratio group D2; I through X of ratio group D1.		

g) Tabulate eligible models and select test model(s)—A.1i). See table A.3.

Table A.3—Selection of test models

Parameter	Ratio set	Eligible models from each ratio set
Bore	A1	_ _ _ _ _ _ _ _ _ _ _ _ M N O P Q R S T U V W X
	A2	A B C D E F G H I J K L _ _ _ _ _ _ _ _ _ _ _ _
Stroke	B1	_ _ C _ _ F _ _ I _ K L _ N O _ Q R _ T U _ W X
	B2	_ B _ _ E _ _ H _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
	B3	A _ _ D _ _ G _ _ J _ _ M _ _ P _ _ S _ _ V _ _
Weight	C1	_ _ _ _ _ _ _ _ _ _ _ _ M N O P Q R S T U V W X
	C2	_ _ _ _ _ _ _ H I J K L _ _ _ _ _ _ _ _ _ _ _ _
	C3	A B C D E F G _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
Center of gravity distance	D1	_ _ _ _ _ _ _ _ I _ K L _ N O P Q R S T U V W X
	D2	A B C D E F G H _ J _ _ M _ _ _ _ _ _ _ _ _ _ _

Each ratio set in each parameter shall be represented by the selected test models. For example, a test to the three models A, H, and T is acceptable. No two models could be selected.

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Annex B

(informative)

Representative normal and design basis event environmental conditions

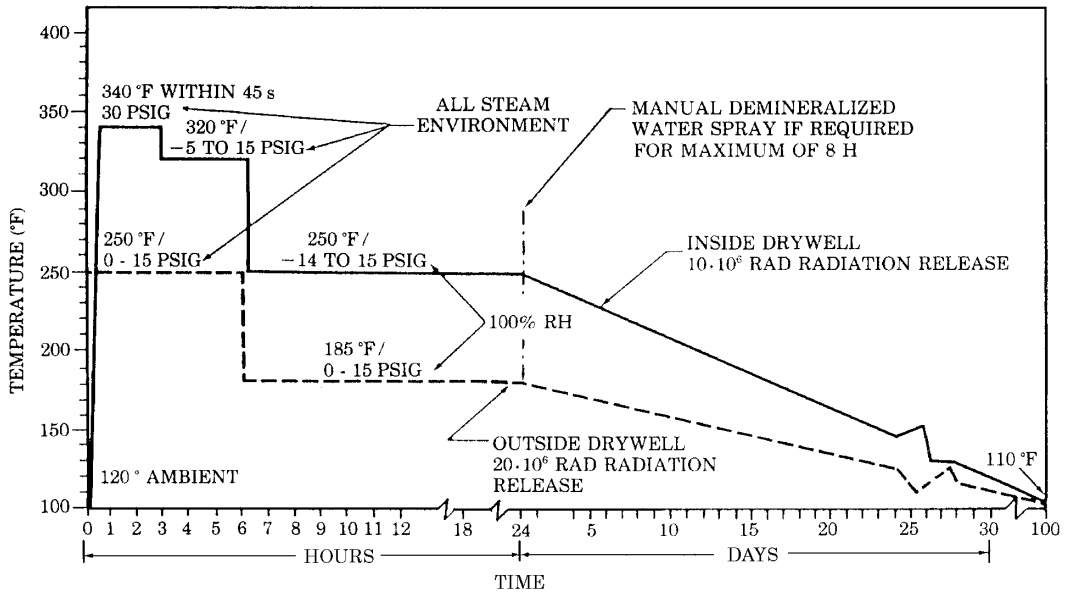
B.1 General

This annex presents a discussion of conditions to which valve actuators may be subjected in a nuclear power generating station that used either pressurized water reactor (PWR) or boiling water reactor (BWR) in its nuclear steam supply system (NSSS). The environmental conditions described in this annex cover those which occur

a) During normal plant operation (including the testing of various safety systems and minor earthquake)

b) During design basis event (DBE) conditions

The environmental conditions differ markedly from plant to plant, location to location within a plant, and from system to system, depending on the use of the equipment under consideration. Environmental conditions of testing for plant service stated by nuclear plant designers are represented by figures B.1, B.2, and B.3. Information for the preparation of these figures was obtained from specifications prepared by suppliers and engineers in the industry.

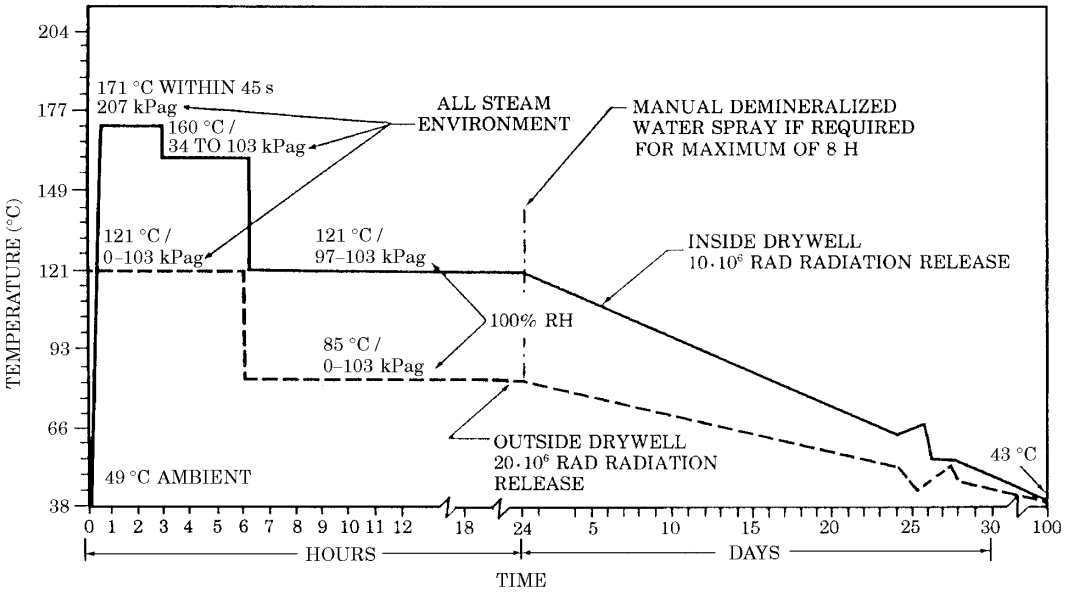


NOTE—Pressure and temperature for Marks I and II containment are higher.

a) English

Figure B.1—Reference service conditions DBE parameters inside containment (BWR, Mark III)

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NOTE—Pressure and temperature for Marks I and II containment are higher.

b) Metric

Figure B.1—Reference service conditions DBE parameters inside containment (BWR, Mark III) *(Continued)*

Combination of the PWR and BWR/LOCA cases into one case was not considered because of the variance between the two cases of composition and duration of the spray liquid and test pressure.

The containment system used with large boiling water reactors in the U.S. is the pressure suppression type. This containment system consists of two structures; a *drywell*, in which the reactor vessels and associated piping are located and a *suppression chamber*, which is partially filled with water. A system of large-diameter pipes connects the drywell with the suppression chamber, entering the latter below the water surface. Any sizable leakage of steam or water (which would flash into steam) from the reactor or associated piping within the drywell will, therefore, pass through the water in the suppression chamber, and in this way some of the steam will be condensed and the pressure is thereby *suppressed* over what it would be in the absence of the suppression feature. Various embodiments of this containment concept have been used with BWR plants, and the environmental conditions that may occur in the event of an LOCA are a function of the configuration. The environmental conditions presented in this annex are based upon the configuration used in most of the more recently designed BWR plants. In this configuration, called the *Mark III Containment*, the drywell is within the suppression chamber, which is called the *containment.*

The containment system used with most PWR plants consists of a single shell, usually cylindrical in form and constructed of steel, reinforced concrete, or prestressed concrete. There are radiation shielding walls and subcompartments within the containment, but these are not pressure tight. A few PWR plants employ a pressure-suppression type of design feature, but have beds of small ice pieces to absorb the steam energy, rather than a pool of water.

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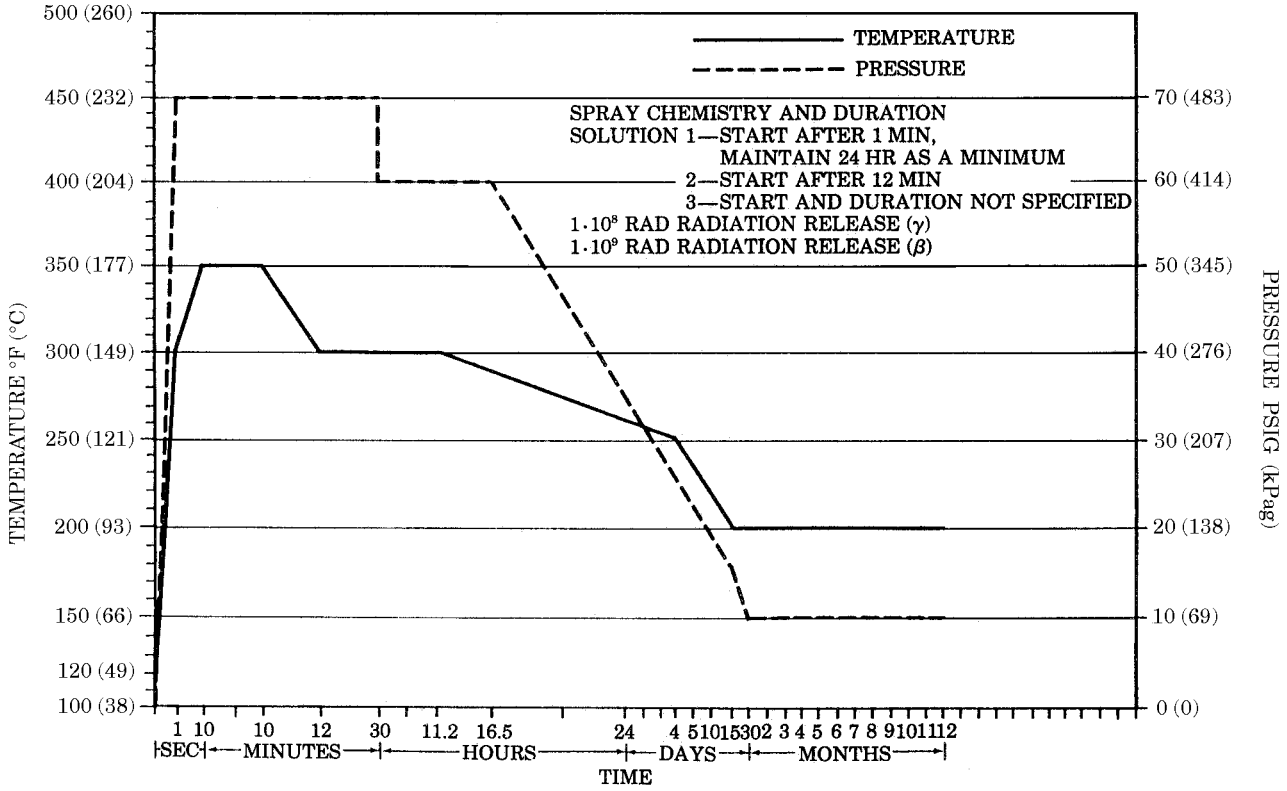


Figure B.2—Reference service conditions local environmental parameters inside containment (PWR)

B.2 Normal service conditions

A nuclear power generating station is expected to operate for a period of approximately 40 yr and survive a design basis event should one occur. Hence, equipment installed in the plant is expected to function adequately for an extended period of time without being subjected to the severe DBE environmental conditions. Because the DBE could occur at any time, however, and because the prolonged exposure to the relatively less severe normal operation conditions may produce significant degradation of important physical or electrical properties of materials, it is necessary to properly simulate these normal operation conditions in the qualification program. See annex C for further explanation regarding aging tests.

B.2.1 Temperature/Pressure/Humidity/Environments

a) *Outside containment* (fuel building, auxiliary building):

PWR and BWR Plants	Avg	Max	Min
Temperature °F (°C)	105 (41)	135 (57)	40 (4)
Humidity (% rh)	55	95	20
Pressure psig (kPag)	0 (0)	0 (0)	0 (0)

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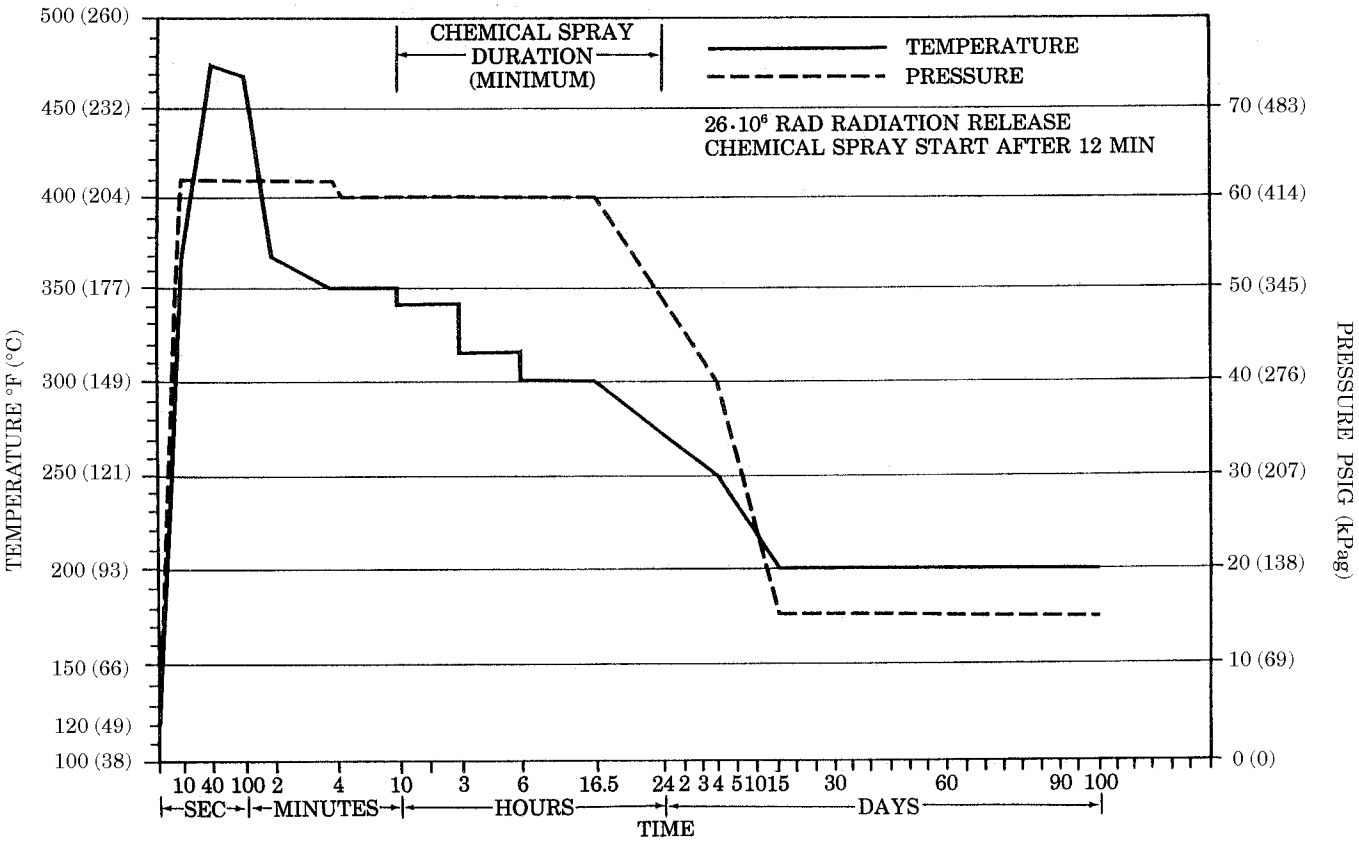


Figure B.3—Reference service conditions MSLB environmental inside containment (PWR)

b) *Inside containment*

PWR Plants	Avg	Max	Min
Temperature °F (°C)	112 (44)	150 (66)	40 (4)
Humidity (% rh)	80	100	10
Pressure psig (kPag)	0 (0)	60 (414)[a]	0 (0)

BWR Plants	Containment			Drywell		
	Avg	Max	Min	Avg	Max	Min
Temperature °F (°C)	90 (32)	120 (49)	40 (4)	135 (57)	180 (82)	180 (82)
Humidity (% rh)	45	90	20	45	90	20
Pressure psig (kPag)	0	50 (344)[a]	0	0	50 (344)[a]	0

[a]Value actuators located within the containment will be subjected to approximately 15 pressurization cycles during the life of the plant when the containment is leak tested. In these tests, the pressure of the air within the containment is increased to a nominal value of 60 psig (414 kPag) (varies from plant to plant).

B.2.2 Radiation environment

a) *Outside containment.* If the valve actuator is not near a source of nuclear radiation, the radiation dose will be essentially zero. In some cases, such as a pipe carrying radioactive fluid, the gamma

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dose rates[5] may be as high as 15 rad/h (this could result in an integrated dose over the life of the plant of 5.10^6 rads).

b) *Inside containment.* In both PWR and BWR plants, equipment within the containment may be exposed to radiation during normal plant operation. The exposure rates will vary with location, and typical values range between 0.10–100 rad/h for gamma[6] and $1–2.10^5$ n/cm^2-s for neutrons. In the areas where most valve actuators are located, the gamma dose rate is typically 100 rad/h with neutron exposure negligible.

B.2.3 Seismic and nonseismic vibration environments

Valve actuators located either outside or within the containment will be subjected to small amplitude vibration from the plant structures and piping systems due to the operation of other equipment and machinery, flow effects in the piping, etc. The amplitude and spectral characteristics of this vibration will be a strong function of

a) Location within the plant
b) Rigidity of the piping system and valve actuator mounting.

In addition, the plant may be subjected to one or more seismic events during its operating life. The plant is designed to continue to operate normally if these seismic events are of smaller magnitude than the value at which some plant damage may occur [termed the operating basis earthquake (OBE)].

B.3 Design basis event conditions

B.3.1 Temperature/Pressure/Chemical Spray/Humidity/Environments

a) *Outside containment.* Valve actuators located outside of containment may be exposed to a cloud of steam at 212 °F (100 °C), 0–2 psig (0–14 kPag) should there be a break in a line carrying steam or water under pressure. Also, ambient temperature may increase to 150 °F (66 °C) with high humidity for an extended period (see figure B.4).

b) *Inside containment.* There are four key time-varying environmental parameters for the pressure-suppression type of containment used with BWR plants (see figures B.1, B.2, B.3, and B.5).

   1) Containment pressure
   2) Containment temperature
   3) Drywell pressure
   4) Drywell temperature

There is no single postulated accident that results in the simultaneous occurrence of the maximum values of these parameters; thus there is no single design basis accident for this containment concept.

The maximum containment pressure and temperature occur during the long-term suppression pool and containment heat-up transient that follows the reactor blowdown phase of an LOCA. Since this long-term transient is insensitive to the rate at which the reactor blows down, the temperature and pressure environment within the containment are not dependent upon the break size of the primary system rupture.

The maximum drywell pressure occurs very early during the reactor blowdown phase of an LOCA and is dependent upon the rate at which primary system energy and fluid enter the drywell. The largest pipe in the

[5]The gamma dose rate is expressed on an air equivalent basis.
[6]See footnote 5.

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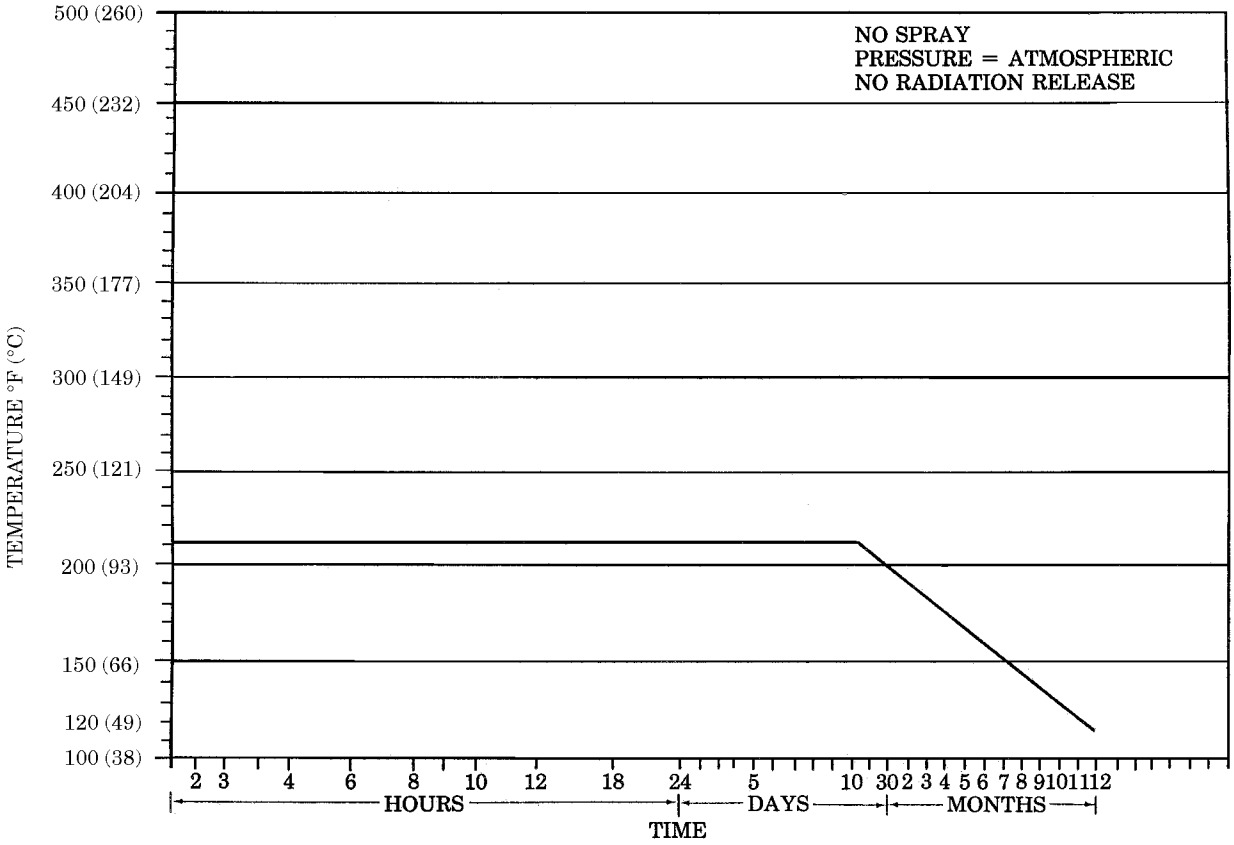


Figure B.4—Reference service conditions line-break parameters outside containment (BWR and PWR)

primary coolant system is the main steam line (28 in (711 mm) diameter). The instantaneous guillotine rupture of this pipe is the design basis accident for the drywell. The most severe drywell temperature condition occurs as a result of a small primary system rupture above the reactor water level which results in the blowdown of reactor steam to the drywell. Because of the nature of the blowdown process, this produces high-temperature, superheated steam in the drywell. The pressure developed within the drywell by this type of accident is quite small [less than 10 psig (69 kPag)].

In a PWR plant, the maximum temperature and maximum pressure also do not result from the same postulated accident, with the break of a primary, coolant pipe resulting in the highest pressure and a steam-line break giving the highest temperature.

In most PWR plants, a chemical solution containing boric acid and sodium hydroxide is sprayed throughout the containment from suspended spray headers. The mean droplet size is 0.039 in (1 mm) initially, and the spray-rate density is typically 0.1 (gal/min)ft^2 (4.07 L/min-m^2) of area in horizontal plane.

The boron content is typically 6300 ppm, and the pH in the range of 8–10. In some PWR plants a small amount of sodium thiosulfate is also included in the spray. The spray commences approximately 40 s after the LOCA begins, and lasts approximately one week. For approximately the first hour, spray solution is taken from a storage tank and has a temperature of approximately 100 °F (37.8 °C). For the remainder of the time, the solution is recirculated (along with spilled reactor coolant). In some BWR plants, demineralized

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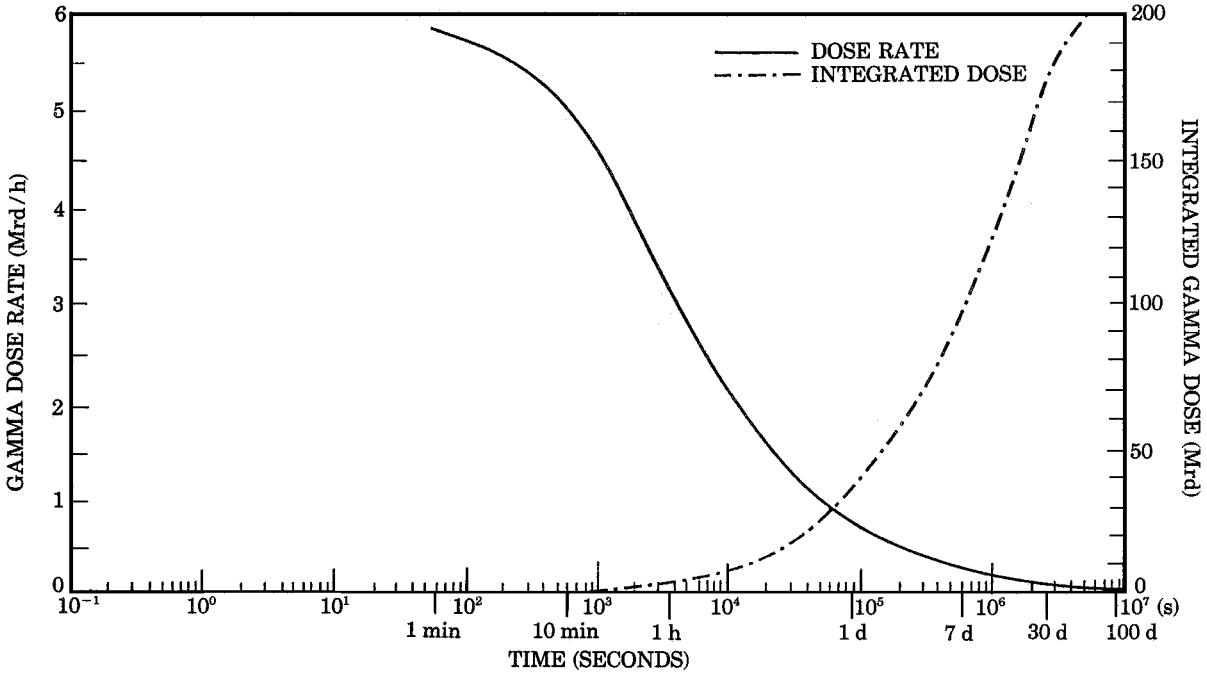


Figure B.5—Gamma dose rate and integrated dose within containment of BWR or PWR plant

water is sprayed into the suppression chamber portion of the containment. The demineralized water has the following typical specifications:

Conductivity	5 µNmho/cm
Chlorides	0.5 ppm at 25 °C
Silicon	1 ppm
pH	Neutral

B.3.2 Radiation environments

Inside containment. The gamma dose rate and integrated doses that may occur are shown in figures B.1, B.2, B.3, and B.5. The integrated dose values shown are considered to be very conservative and are the subject of further considerations.

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Annex C

(informative)

Rationale for normal thermal aging

If thermal degradation is determined by a single temperature-dependent reaction that follows the Arrhenius law, this law can be used as a basis for accelerated thermal aging. This law is expressed mathematically by the following equation:

$$\frac{dq}{dt} = A \cdot e^{-\phi/kT} \tag{1}$$

where

$\frac{dq}{dt}$ = reaction rate
k = Boltzman constant $0.8617 \cdot 10^{-4}$, eV/K
q = quantity of material reacted
A = constant determined by experiment
T = absolute reaction of temperature, K
ϕ = activation energy of the reaction, eV

If it is assumed that ϕ is independent of temperature, equation 1 can be integrated with respect to time and transformed into the following form:

$$\frac{t_1}{t_2} = e^{\left[\frac{\phi}{k}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)\right]} \tag{2}$$

An interpretation of equation 2 is that t_2 is the time at temperature T_2 required to produce the same amount of reaction (thermal degradation) that takes place in a longer time t_1 at lower temperature T_1. For example, we can choose

T_1 = 104 °F (40 °C), temperature of materials in actuator in normal service
T_2 = 280 °F (138 °C), accelerated thermal aging temperature
t_1 = 40 yr, 350 000 h, desired qualified life

Then, for different values of ϕ, equation 2 yields the following values for t_2:

ϕ(eV)	t_2 (hours)
0.5	4218
0.8	297
1.0	51
1.2	8.7

These numbers illustrate the fact that, with respect to accelerated thermal aging, choosing small values of ϕ is the conservative procedure when one does not know all the values that apply to the materials and compo-

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nents in the actuator. If $\phi = 0.8$ eV is adequately conservative, the values of accelerated aging time at 280 °F (138 °C) given by equation 2 for different qualified lifetime are as follows:

Desired qualified life at 104 °F (40 °C) (years)	Accelerated aging time at 280 °F (138 °C) (hours)
10	74
20	149
40	297

The temperature of 280 °F (138 °C) was used in the foregoing calculations because this is the maximum temperature that materials and components of most actuators can withstand without incurring degradation of a type that does not take place in normal service. The user of this annex should verify the suitability of this aging temperature for each application.

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Annex D

(informative)

Rationale for vibration and seismic test methods

D.1 Vibration aging

The vibration aging test provides a vibratory environment, which is representative of normal plant-induced vibration. The test is intended to induce an arbitrary but reasonable amount of vibratory aging for the actuator prior to the DBE testing. It is not intended to be a qualification test in itself nor a test to any specific plant environment. The level of acceleration 0.75 g at a frequency range of 5 Hz to 100 Hz is considered to be conservative. For example, for shipboard service where vibration could be much more severe than for land based plants, test frequency is 5 Hz to 50 Hz at 0.27 g acceleration.

D.2 Seismic aging

Valve actuators are subjected to a variety of seismic environments, depending on the details of their mounting. The actuator may be *hard mounted* and subjected to a multifrequency excitation with a frequency content from 1 Hz to 35 Hz. The actuator is more likely to be mounted in a piping system and be subjected to an excitation which is the result of the dynamic response of the piping system. The objective then is to define a test method(s) which will qualify actuators to either or both situations.

The input to the piping system will typically be a random excitation with broad frequency content. The dynamic characteristics of the system will amplify the excitation at the system resonance frequency and will suppress the other frequencies. The maximum response will occur at the predominant piping system frequency and will be excited each time that frequency occurs with sufficient amplitude. The actuator will be subjected to a series of sine beats with varying amplitudes and with relatively long durations, for example, 15–20 oscillations per beat. The predominant frequency may be anywhere in the range of 5 Hz to 35 Hz.

The best test method to meet the above simulation criteria is either a sine-beat test or a relatively short duration or a sine-dwell test at several frequencies. The minimum, peak-test amplitude should be that which the piping-system designers are not expected to exceed in their system design.

Most actuators shall demonstrate operability during seismic excitation. The sine sweep is not a practical technique because it is not conclusive to demonstrate operability with the continuously changing frequency of excitation. A single sine beat, or sine beats spaced apart in time, is not a practical technique because of the difficulty of synchronizing the excitation and the operability. However, a continuous series of sine beats applies continuous excitation, albeit at varying amplitudes, during which time operability may be demonstrated. Actuators with short cycle times are required to cycle at least two times during the test for better assurance of operability.

To ensure the excitation of all resonance and critical frequencies, the sine beats are applied at one-third octave intervals over the frequency range of 2 Hz to 33 Hz. The test amplitude should correspond to the levels specified by pipe-system designers for high seismic zones. This amplitude shall be independent of direction. Hence, single-axis excitation is recommended, with one of the axes corresponding to the apparent most critical direction of the actuator. If the actuator is to be mounted in various orientations, it may be necessary to test the actuator in more than one orientation.

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The general requirement to perform five OBE tests prior to the SSE is met by performing the two sine sweeps which will provide equivalent dynamic effect of five OBEs.

For the cases where an actuator is to be hard mounted and subjected to a multifrequency environment specified by an RRS for the structure, there are two ways to show qualification. One is to show that a TRS from any one of the sine-beat or sine-dwell tests will envelop the entire RRS. A second more widely applicable and preferred method is to show that a TRS from the multifrequency test envelops the RRS.

Since a valve actuator may be line mounted or hard mounted, it is recommended that both the single frequency and multifrequency tests be performed.

The test levels show in figures 6 and 7 of this standard are selected to envelop the requirements of most of the power plants in the U.S.[7]

Some users request resonance search data. The actuator manufacturer may elect to conduct a resonance search to make these data available. The resonance search shall be performed separately in each of the three orthogonal axes. Alternatively, the actuator may be instrumented during the two OBE sine sweep tests to identify resonance frequencies.

[7]The actuator manufacturer is cautioned that specifications exist that require testing to RIM requirements as high as 12 g.

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Annex E

(informative)

Performance verification test

If an operating performance verification test (see Part I, 7.1) is specified, the user shall establish the performance verification test requirements. The test procedure shall be prepared by the actuator manufacturer with the user concurrence. Minimum performance data to be taken for different types of actuators and recorded during the test are listed below.

A performance verification record shall be prepared based on listed requirements. This record shall include positive identification of the actuator tested: actuator designation, serial number, safety-related function, location, and valve identification number if applicable. All operating performance data obtained during the verification test shall be recorded.

E.1 Electric pneumatic-motor, or hydraulic-motor actuators

At least the following operating performance data shall be taken and recorded during the test:

a) Output speed in each direction under no-load conditions at nominal power supply.

b) The operating output torque or thrust characteristics under the minimum specified power supply

c) The stall torque or thrust in seating direction bypassing limit-control devices (electric motor locked-rotor input at maximum specified power supply or at maximum specified pneumatic or hydraulic pressure for pneumatic and hydraulic motors)

d) Confirmation of proper torque, limit, and auxiliary-switch action

E.2 Pneumatic, electro-hydraulic, and hydraulic actuators (cylinders, rams, rotary vanes, and diaphragm double acting or spring return)

At least the following operating performance data shall be taken and recorded during the test:

a) The no-load and rated-load output speeds
b) The operating output thrust and torque characteristics at minimum pneumatic or hydraulic pressure
c) The maximum thrust or torque capability in each direction at maximum pneumatic or hydraulic pressures
d) Rate of leakage of piston, diaphragm, and vane seals at maximum differential pressure

E.3 Integral valve—Solenoid type actuators

At least the following operating performance data shall be taken and recorded during the test:

a) Pull-in voltage at maximum operating pressure drop
b) Drop-out voltage at maximum differential operating pressure and at zero pressure.
c) Minimum operating pressure at nominal voltage
d) Internal leakage at rated pressure
e) External leakage at 1.5 times the rated pressure
f) Test fluid and its quality characteristics
g) Special application requirements, such as response time, duty cycle, and flow rate

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