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IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

IEEE Power Engineering Society

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IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

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Nuclear Power Engineering Committee
of the
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Approved 11 September 2003

IEEE-SA Standards Board

Abstract: The basic requirements for qualifying Class 1E equipment and interfaces that are to be used in nuclear power generating stations are described in this standard. The principles, methods, and procedures described are intended to be used for qualifying equipment, maintaining and extending qualification, and updating qualification, as required, if the equipment is modified. The qualification requirements in this standard, when met, demonstrate and document the ability of equipment to perform safety function(s) under applicable service conditions including design basis events, reducing the risk of common-cause equipment failure.
Keywords: age conditioning, aging, condition monitoring, design basis events, equipment qualification, harsh environment, margin, mild environment, qualification methods, qualified life, radiation, safety related function, significant aging mechanism, test plan, test sequence, type testing

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Introduction

(This introduction is not part of IEEE Std 323-2003, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.)

IEEE Std 323-2003, a revision of IEEE Std 323-1983, is the result of a review of IEEE Std 323-1983 and present practices in equipment qualification. This revision incorporates current practices and lessons learned from the implementation of previous versions of this standard by the nuclear industry.

Several issues are clarified or changed in this revision:

- This standard defines the methods for equipment qualification when it is desired to qualify equipment for the applications and the environments to which it may be exposed. This standard is generally utilized for qualification of Class 1E (safety-related electric) equipment located in harsh environments, and for certain post-accident monitoring equipment, but it may also be utilized for the qualification of equipment in mild environments. The documentation requirements are, however, more rigorous for equipment located in a harsh environment.
- The term *design basis event* has been generally used instead of the acronyms DBE, DBA, LOCA, and HELB, and the term *design basis accident* in order to reduce the complexity of the text.
- Seismic events are identified as design basis events.
- The test margins have been updated to better identify the parameters that achieve test margin on design basis event profiles. Since quantitative margin can be adequately identified by increases in temperature, pressure, radiation, and operating time, the performance of two transients is no longer recommended.
- New digital systems and new advanced analog systems may require susceptibility testing for EMI/RFI and power surges, if the environments are significant to the equipment being qualified. Since existing instrument and control (I&C) systems were less vulnerable and have the benefit of successful operation under nuclear power plant EMI/RFI and power surge environments, qualification to EMI/RFI and power surges was not previously significant enough to be considered in environmental equipment qualification. As existing I&C equipment in nuclear power plants may be replaced with computer-based digital I&C systems or advanced analog systems, these new technologies may exhibit greater vulnerability to the nuclear power plant EMI/RFI and power surges environments. Documents such as NUREG/CR-5700-1992 [B32],[a] NUREG/CR-5904-1994 [B33], NUREG/CR-6384-1996, Volumes 1 and 2 ([B34], [B35]), NUREG/CR-6406-1996 [B36], NUREG/CR-6579-1998 [37], and NRC IN 94-20 [B31] have documented the environmental influence of EMI/RFI and power surges on safety-related electric equipment. Guidelines for ensuring electromagnetic compatibility of safety systems can be found in IEEE Std 603™-1998 and IEEE Std 7-4.3.2™-2003.[b]
- An important concept in equipment qualification is the recognition that significant degradation could be caused by aging mechanisms occurring from the environments during the service life, and therefore safety-related electric equipment should be in a state of degradation prior to imposing design basis event simulations. Previous versions recognized that the period of time for which acceptable performance was demonstrated is the qualified life. The concept of qualified life continues in this revision. This revision also recognizes that the condition of the equipment for which acceptable performance was demonstrated is the qualified condition. Thus, new license renewal and life extension options are available by assuring that qualified equipment continues to remain in a qualified condition.

Industry research in the area of equipment qualification and decades of its application have greatly benefited this standard. Future activities of the working group to update this standard will consider the following:

[a]The numbers in brackets correspond to those of the bibliography in Annex A.

[b]Information on references can be found in Clause 2.

— Risk-informed approaches and impact of condition monitoring, performance, safety function assessment, and qualified life precision.

— Significance of refinements in aging mechanisms, equipment sealing, interfaces, extrapolation, similarity, test sequence and parameters (such as ramp rates, time duration, timing of spray initiation and its duration), and qualification documentation.

Participants

This standard was prepared by Working Group (SC 2.1) of the Subcommittee on Qualification (SC 2) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society. At the time of completion, SC 2.1 had the following membership:

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Contents

IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

1. Scope

This standard describes the basic requirements for qualifying Class 1E equipment and interfaces that are to be used in nuclear power generating stations. The principles, methods, and procedures described are intended to be used for qualifying equipment, maintaining and extending qualification, and updating qualification, as required, if the equipment is modified. The qualification requirements in this standard, when met, demonstrate and document the ability of equipment to perform safety function(s) under applicable service conditions including design basis events, reducing the risk of common-cause equipment failure. This standard does not provide environmental stress levels and performance requirements.

NOTE—Other IEEE standards that present qualification methods for specific equipment, specific environments, or specific parts of the qualification program may be used to supplement this standard, as applicable. Annex A lists other standards related to equipment qualification.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved version, the revision shall apply.

IEEE Std 344™-1987 (Reaff 1993), IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.[1,2]

IEEE Std 603™-1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

IEEE Std 7-4.3.2™-2003, IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations.

[1]The IEEE standards or products referred to in Clause 2 are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

3. Definitions

The following terms are considered important for accurate interpretation of this standard. Definitions of terms are given in *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition [B3][3], and are repeated here for convenience in using this standard.

3.1 age conditioning: Exposure of sample equipment to environmental, operational, and system conditions to simulate these conditions for a period of time; design basis events are not included.

3.2 Class 1E: The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment.

NOTE—The terms *Class 1E equipment* and *safety-related electric equipment* are synonymous.

3.3 components: Items from which the equipment is assembled, e.g., resistors, capacitors, wires, connectors, transistors, tubes, switches, and springs.

3.4 condition-based qualification: Qualification based on measurement of one or more condition indicators of equipment, its components, or materials for which an acceptance criterion can be correlated to the equipment's ability to function as specified during an applicable design basis event.

3.5 condition indicator: A measurable physical property of equipment, its components, or materials that changes monotonically with time and can be correlated with its safety function performance under design basis event conditions.

3.6 design basis events: Postulated events used in the design to establish the acceptable performance requirements for the structures, systems, and components.

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

3.8 end condition: Value(s) of equipment condition indicator(s) at the conclusion of age conditioning.

3.9 equipment: An assembly of components designed and manufactured to perform specific functions.

3.10 equipment qualification: The generation and maintenance of evidence to ensure that equipment will operate on demand to meet system performance requirements during normal and abnormal service conditions and postulated design basis events.

NOTE—Equipment qualification includes environmental and seismic qualification.

3.11 harsh environment: An environment resulting from a design basis event, i.e., loss-of-coolant accident (LOCA), high-energy line break (HELB), and main steam line break (MSLB).

3.12 interfaces: Physical attachments, mounting, auxiliary components, and connectors (electrical and mechanical) to the equipment at the equipment boundary.

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

3.14 mild environment: An environment that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences.

[3]The numbers in brackets correspond to those of the bibliography in Annex A.

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

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

3.17 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.

3.18 service life: The time period from initial operation to removal from service.

3.19 significant aging mechanism: An aging mechanism that, under normal and abnormal service conditions, causes degradation of equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) during the design basis event conditions.

4. Principles of equipment qualification

4.1 Qualification objective

The primary objective of qualification is to demonstrate with reasonable assurance that Class 1E equipment for which a qualified life or condition has been established can perform its safety function(s) without experiencing common-cause failures before, during, and after applicable design basis events. Class 1E equipment, with its interfaces, must meet or exceed the equipment specification requirements. This continued capability is ensured through a program that includes, but is not limited to, design control, quality control, qualification, installation, maintenance, periodic testing, and surveillance. The focus of this standard is on qualification, although it affects the other parts of the program.

For equipment located in a mild environment for meeting its functional requirements during normal environmental conditions and anticipated operational occurrences, the requirements shall be specified in the design/purchase specifications. A qualified life is not required for equipment located in a mild environment and which has no significant aging mechanisms. When seismic testing is used to qualify equipment located in a mild environment, pre-aging prior to the seismic tests is required only where significant aging mechanisms exist (see 6.2.1.1). A maintenance/surveillance program based on a vendor's recommendations, which may be supplemented with operating experience, should ensure that equipment meets the specified requirements.

4.2 Qualified life and qualified condition

Degradation with time followed by exposure to environmental extremes of temperature, pressure, humidity, radiation, vibration and, if applicable, chemical spray and submergence resulting from a design basis event condition can precipitate common-cause failures of Class 1E equipment. For this reason, it is necessary to establish a qualified life for equipment with significant aging mechanisms. The qualified life determination must consider degradation of equipment capability prior to and during service. Inherent in establishing a qualified life is that a qualified condition is also established. This qualified condition is the state of degradation for which successful performance during a subsequent design basis event was demonstrated.

4.3 Qualification elements

The essential elements of equipment qualification include the following:

a) Equipment specification including definition of the safety function(s)

b) Acceptance criteria

c) Description of the service conditions, including applicable design basis events and their duration

d) Qualification program plan

e) Implementation of the plan

f) Documentation demonstrating successful qualification, including maintenance activities required to maintain qualification. The equipment user is responsible for specifying performance requirements and verifying that the documentation demonstrates that the requirements have been satisfied.

4.4 Qualification documentation

The result of a qualification program shall be documented to demonstrate the equipment's ability to perform its safety function(s) during its qualified life and applicable design basis events. The documentation shall allow verification by competent personnel, other than the qualifier, that the equipment is qualified.

5. Qualification methods

Methods for acquiring data in support of equipment qualification are listed in 5.1.1, 5.1.2, 5.1.3, and 5.1.4. Equipment is generally qualified by a combination of methods.

5.1 Initial qualification

5.1.1 Type testing

A type test subjects a representative sample of equipment, including interfaces, to a series of tests, simulating the effects of significant aging mechanisms during normal operation. The sample is subsequently subjected to design basis event testing that simulates and thereby establishes the tested configuration for installed equipment service, including mounting, orientation, interfaces, conduit sealing, and expected environments. A successful type test demonstrates that the equipment can perform the intended safety function(s) for the required operating time before, during, and/or following the design basis event, as appropriate.

5.1.2 Operating experience

Performance data from equipment of similar design that has successfully operated under known service conditions may be used in qualifying other equipment to equal or less severe conditions. Applicability of this data depends on the adequacy of documentation establishing past service conditions, equipment performance, and similarity against the equipment to be qualified and upon which operating experience exists. A demonstration of required operability during applicable design basis event(s) shall be included in equipment qualification programs based on operating experience, when design basis event qualification is required.

5.1.3 Analysis

Qualification by analysis requires a logical assessment or a valid mathematical model of the equipment to be qualified. The bases for analysis typically include physical laws of nature, results of test data, operating experience, and condition indicators. Analysis of data and tests for material properties, equipment rating, and environmental tolerance can be used to demonstrate qualification. However, analysis alone cannot be used to demonstrate qualification.

5.1.4 Combined methods

Equipment may be qualified by combinations of type test, operating experience, and analysis. For example, where type test of a complete assembly is not possible, component testing supplemented by analysis may be used.

5.2 Extension of qualified life

Initial environmental qualification may yield a qualified life that is less than the anticipated service life of the equipment. For example, the qualified life may be limited due to the use of moderate aging acceleration factors to achieve more realistic simulation of degradation in service during available testing time. Such moderate aging acceleration factors could result in the equipment's condition being excessively far from its end-of-life condition. The methods for extension of the qualified life are as follows:

a) Retain and continue aging the test sample from the initial program or begin aging a new sample while the qualified equipment is in service. Subsequent demonstration of equipment safety function performance during applicable design basis event(s) increases the qualified life by the additional life simulated.

b) Install additional equipment in identical service conditions, remove before the end of the qualified life of equipment in service, and type test with further age conditioning to establish additional qualified life.

c) Evaluation of conservatisms in original assumptions for environmental conditions, failure criteria, and acceleration factors may identify that actual conditions are less severe, and the qualified life may be adjusted accordingly.

d) Identify age-sensitive components and replace them with new, like components.

5.3 Condition monitoring

Condition monitoring may be used in place of a qualified life to determine if qualified equipment is suitable for further service. Condition monitoring for equipment qualification purposes monitors one or more condition indicators to determine whether equipment remains in a qualified condition. The trend of the condition indicator is determined during the performance of age conditioning of the test specimen during qualification testing. The condition indicator must be measurable, linked to the functional degradation of the qualified equipment, and have a consistent trend from unaged through the limit of the qualified pre-accident condition. Condition monitoring may be used with or independently from the concept of qualified life. As the qualified equipment approaches the end of its theoretical qualified life, periodic condition monitoring may be implemented to determine if actual aging is occurring at a slower rate, and if further qualified service is possible based on the condition monitoring results.

6. Qualification program

The major elements of a qualification program are described in 4.3. Clause 6 provides additional details for these elements.

6.1 Equipment specification

Documentation in this category provides essential information about the equipment to be qualified. At a minimum, it shall contain the items specified in 6.1.1, 6.1.2, 6.1.3, 6.1.4, and 6.1.5.

6.1.1 Identification

A technical description of the equipment to be qualified, including applicable performance and qualification standards, shall be provided.

6.1.2 Interfaces

Loadings at interfaces [i.e., physical attachments, mounting, auxiliary components, connectors (electrical and mechanical) to the equipment at the equipment boundary] shall be specified. Motive power or control signal inputs and outputs, and the physical manner by which they are supplied (e.g., connectors, terminal blocks), shall be specified. Control, indicating, and other auxiliary components mounted internal or external to the equipment and required for proper operation shall be included. Material incompatibilities at interfaces shall be considered and evaluated.

6.1.3 Qualified life objective

Where applicable, the equipment qualified life objective of the program shall be stated.

6.1.4 Safety function(s)

The equipment specification shall identify the equipment's safety function(s) including the required operating times.

NOTE—Components not involved in the equipment's safety function(s) may be excluded from the qualification process if it can be demonstrated and documented that assumed failures, including spurious operation, have no adverse effect on any and all safety functions, have no adverse effect on the safety function of interfaced equipment, would not mislead an operator, and shall not fail in a manner as to fail other safety-related electric equipment.

6.1.5 Service conditions

6.1.5.1 Normal and abnormal service conditions

The service conditions for the equipment shall be specified. These conditions shall include the nominal values and their expected durations, as well as extreme values and their expected durations. Examples include, but are not limited to, the following:

a) Ambient pressure and temperature
b) Relative humidity
c) Radiation environment
d) Seismic operating basis earthquake (OBE) and nonseismic vibration
e) Operating cycles
f) Electrical loading and signals
g) Condensation, chemical spray, and submergence
h) EMI/RFI and power surges

6.1.5.2 Design basis event conditions

The postulated design basis event conditions including specified high-energy line break, loss-of-coolant accident, main steam line break, and/or safe shutdown seismic events, during or after which the equipment is required to perform its safety function(s), shall be specified. Equipment shall be qualified for the duration of its operational performance requirement for each applicable design basis event condition, including any required post design basis event operability period.

6.1.5.3 Margin

If the equipment specification identifies qualification margins (see 3.13 for the definition of margin), their values shall be stated.

6.2 Qualification program plan

A qualification program plan shall define tests, inspections, performance evaluation, acceptance criteria, and required analysis to demonstrate that, when called upon, the equipment can perform its specified safety function(s). The required elements of the program plan are provided in 6.2.1, 6.2.2, 6.2.3, 6.2.4, and 6.2.5.

6.2.1 Aging

The ability of Class 1E equipment to perform its safety function(s) might be affected by changes due to environmental and operational conditions over time. The qualification program shall specifically address effects of aging to evaluate their significance. The techniques available to address the effects of aging include operating experience, testing, analysis, in-service surveillance, condition monitoring, and maintenance activities.

6.2.1.1 Significant aging mechanisms

Equipment shall be reviewed in terms of design, function, materials, and environment for its specified application to identify potentially significant aging mechanisms. An aging mechanism is significant if subsequent to manufacture, while in storage, and/or in the normal and abnormal service environment, it results in degradation of the equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) under design basis event conditions. Examples of significant aging mechanisms include wear and tear, oxidation, and loss of material strength. Additional information on potentially significant aging mechanisms can be found in IEEE Std 1205™-2000 [B23].

6.2.1.2 Aging considerations

If the equipment is determined to have a significant aging mechanism, then the mechanism shall be accounted for in the qualification program. Aging, as part of the qualification program, may be addressed by age conditioning of a test sample prior to design basis event testing. Age conditioning is not required for equipment without significant aging mechanisms. The technique used to address aging may affect ongoing requirements to maintain equipment in a qualified condition.

6.2.2 Qualified life objective

The qualified life objective shall be based on a specified set of service conditions. Pre-service conditions shall be considered if significant aging occurs before equipment is placed into service. Qualified life can be demonstrated by age conditioning a test sample to simulate effects of significant aging mechanisms during a time equal to the qualified life objective. An adjunct to establishing a qualified life objective is to establish an end-condition objective (as described in 6.3.5) of equipment condition indicators that correlate to the ability of equipment to perform its safety function. In this case, the end condition is the basis of qualification, and the time to reach that end condition in service may be more or less than the qualified life established by age conditioning.

6.2.3 Margin

Margin shall be included in qualification programs. This will account for reasonable uncertainties in demonstrating satisfactory performance and normal variations in commercial production and uncertainties in measurement and test equipment, thereby providing assurance that the equipment can perform under adverse service conditions. Increasing the severity of test parameter values, number of tests, or test duration (but not necessarily all at the same time) are acceptable methods of adding margin in testing, where necessary. If the specified service conditions contain the requisite margins, no additional margin is needed. Guidance for margin in design basis event testing is provided in 6.3.1.6.

6.2.4 Maintenance

Periodic maintenance/replacements required during the aging portion of the qualification program shall be identified.

NOTE—Maintenance may contribute to aging if it is necessary to exercise equipment during maintenance activity.

6.2.5 Acceptance criteria

The value(s) of performance parameters and other criteria to demonstrate that equipment can perform the safety function(s) shall be identified.

6.3 Qualification program implementation

6.3.1 Type testing

The type test shall demonstrate that Class 1E equipment performance meets or exceeds the safety function requirements. Type test conditions shall meet or exceed specified service conditions. Appropriate margin shall be added to design basis event parameters (see 6.3.1.3) if not otherwise included in the specified service conditions.

6.3.1.1 Test plan

The test plan describes the required tests and shall include the following:

a) Identification, description, and quantity of the samples to be tested including significant information—such as manufacturer, model(s), and serial numbers—to uniquely identify the sample
b) Equipment safety function(s) to be demonstrated and qualified life objective
c) Mounting, connection, and other interface requirements
d) Test sequence
e) Age conditioning procedure, if required
f) Specified service conditions and margins or test levels
g) Performance and environmental conditions to be measured, including measurement accuracy
h) Operating conditions and measurement sequence in detail, including monitoring requirements
i) General acceptance criteria (ultimate acceptance criteria are plant-specific based on application of the equipment)
j) Maintenance/replacement during age conditioning, if required
k) Provisions for control of modifications during tests
l) Required documentation
m) Quality assurance requirements

6.3.1.2 Simulated test profiles

The user shall furnish sufficient environmental data to allow the simulation of the design basis event environmental qualification profile for the equipment being qualified. The test profile may be a single event or a profile that envelops multiple design basis events. If not included in the service environmental conditions, margin shall be added (see 6.3.1.6) to derive a test profile. Although only a simplified example, Figure 1 illustrates typical methods of including margin in design basis event environmental qualification profiles.

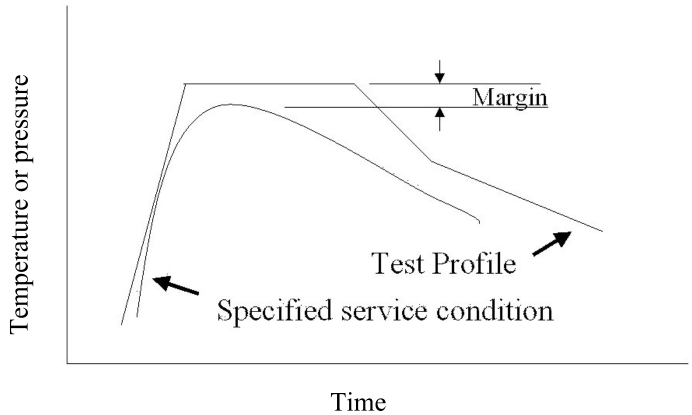

Figure 1—Example of test profile enveloping a specified service condition profile with amplitude margin

6.3.1.3 Mounting

Equipment shall be mounted in a manner and a position that simulates its expected installation. Any mounting limitations, e.g., orientation, shall be specified in the test report. Qualification of equipment mounted in other than the tested configuration requires analysis showing that equipment performance is not degraded by the differing configuration.

6.3.1.4 Connections

Equipment shall be connected (both mechanically and electrically) in a manner that simulates its expected installation. Qualification of equipment connected in other than the tested manner requires analysis showing that performance is not degraded by the differing connections.

6.3.1.5 Monitoring

During testing, both the test environment and the equipment's safety function(s) shall be monitored using equipment that provides resolution for detecting meaningful changes in the parameters. Where applicable, measurements to be included are environment, electrical, fluid, mechanical characteristics, radiological features, and any auxiliary features, such as the functions of any switches and feedback components, which provide input to other Class 1E equipment. Data acquisition equipment, as appropriate, shall be calibrated against standards traceable to nationally and/or internationally recognized standards and shall have documentation to support such calibration. Measurement intervals shall be chosen to obtain the time dependence of each parameter.

6.3.1.6 Margin

The following suggested margins apply to design basis event service conditions and do not apply to age conditioning. Alternate margin values may be acceptable if properly justified.

a) Peak temperature: +8 ºC

b) Peak pressure: +10% of gauge

c) Radiation: +10% (on accident dose)

d) Power supply voltage: ±10% but not to exceed equipment design limits

e) Equipment operating time: +10% of the period of time the equipment is required to operate following the start of the design basis event

f) Seismic vibration: +10% added to the acceleration requirements at the mounting point of the equipment

g) Line frequency: ±5% of rated value

Margin may be positive or negative to increase the severity of the test. For example, generally it is necessary to use higher temperatures; while in the case of equipment supply voltage, higher or lower values that cause the most degradation should be chosen. Based on factors such as product design control, test sample size, and test measurement accuracy, lesser values may be adequate.

6.3.1.7 Test sequence

The steps in type testing shall be completed in a sequence that places the sample in the worst state of degradation that can occur in service during the qualified life, prior to application of design basis events. All steps in the sequence shall be performed on the same test sample. The test sample shall be representative of the same design, materials, and manufacturing process as the installed equipment. For most equipment, the following steps and sequence are acceptable:

a) Inspection shall identify the test sample and ensure that it is not damaged.

b) Specified baseline functional tests shall be performed under normal conditions.

c) The test sample shall be operated to the extremes of all performance, operating, surge voltages, and electrical characteristics given in the equipment specifications, excluding design basis event and post-design basis event conditions, unless these data are available from other tests (e.g., design verification tests) on identical or similar equipment.

NOTE—Information on susceptibility testing for EMI/RFI and surge voltages is given in Annex B of IEEE Std 603-1998 and Annex C of IEEE Std 7-4.3.2-2003.[4] EMI/RFI susceptibility testing may be performed on a separate test specimen.

d) When required, the test sample shall be age conditioned to simulate its functional capability at the end of its qualified life. Measurements made during, or baseline tests following, age conditioning can verify that the test sample is performing satisfactorily prior to subsequent testing. If condition monitoring is to be used in service, measurements after age conditioning would establish the qualified end condition.

NOTE—If the qualification program is establishing a qualified life only, normal and design basis event radiation may be combined in age conditioning. However, if condition monitoring is contemplated, an accurate end condition is needed before design basis event simulation.

e) The test sample shall be subjected to specified nonseismic mechanical vibration.

f) The test sample shall be subjected to simulated OBE and safe shutdown earthquake (SSE) seismic vibration in accordance with IEEE Std 344-1987.

NOTE—A seismic event is not assumed to occur in conjunction with a loss-of-coolant accident. Rather, the sequence described previously has been developed as the basis of a conservative qualification, not one indicative of a sequence of expected plant events.

g) The test sample shall perform its required safety function(s) while exposed to simulated accident conditions, including conditions following the accident for the period of required equipment operability, as applicable. Accident radiation may have been included in step d). Safety function performance during testing shall be monitored. Note that safety function can be different in different stages of an accident.

h) Post-test inspection shall be performed on the test sample, and all findings shall be recorded.

[4]Information on references can be found in Clause 2.

6.3.1.8 Aging

The assessment of equipment aging effects in connection with a type test program is required to determine if aging has a significant effect on operability. The types of aging include, but are not necessarily limited to, thermal, radiation, wear, and vibration. The assessment shall identify potentially significant aging mechanisms related to equipment performance for the design basis events under consideration. Where significant aging mechanisms are identified, suitable age conditioning shall be included in the type test.

6.3.1.8.1 Natural aging

Use of a naturally aged test sample is an age conditioning method which avoids the need to identify significant aging mechanisms. Naturally aged equipment may be used for type testing provided that

a) Equipment has been operated under service, loading, and environmental conditions at least as severe as those that apply to the intended application, and sufficient documentation exists.
b) Operating and maintenance/replacement records are available.

Natural aging may be supplemented by analysis or age conditioning, or both, to account for differences between the specified service and the natural aging conditions to justify the qualified life of the sample.

6.3.1.8.2 Age conditioning

Age conditioning is a process that replicates in a test sample, as accurately as possible, the degradation of equipment over a period of time due to significant aging mechanisms. This process generally involves applying simulated in-service stresses, typically thermal, radiation, wear, and vibration, as appropriate, at magnitudes or rates that are more severe than expected in-service levels, but less severe than levels that cause aging mechanisms not present in normal service. It is the intent of the age conditioning process to put the test sample in the worst state of degradation that it would experience during the qualified life, prior to the design basis event. The sequence of age conditioning should consider sequential, simultaneous, and synergistic effects in order to achieve the worst state of degradation. When condition-based qualification is employed, condition indicator measurements should be performed at the beginning, during, and the end of age conditioning in order to document that the trend of the condition indicator is monotonically changing. Arrhenius methodology is an acceptable method for accelerating time-temperature aging effects during type testing. Sample thermal aging times of a minimum of 100 h are recommended. Dose rate acceleration, within equipment limits, is an acceptable method for accelerating radiation degradation effects. The dose rate for radiation aging should be as low as can be accommodated within reasonable cost and schedule. Information on condition monitoring and aging assessment can be found in IEEE Std 1205-2000 [B23].

6.3.1.9 Radiation

In the type test, all materials or components, for which radiation causes significant aging, shall be irradiated to simulate the effects of the radiation exposure. If normal and accident radiation doses and dose rate are demonstrated to have no effect on the safety function(s) of the equipment, then radiation testing may be excluded, and the justification should be documented. A gamma radiation source may be used to simulate the expected effects of the radiation environment.

6.3.1.10 Seismic and nonseismic vibration

The equipment shall be qualified for expected seismic events in accordance with IEEE Std 344-1987 following any required aging. Nonseismic vibration, which may produce significant degradation (fatigue, wear) during normal and abnormal use, shall be simulated prior to the seismic tests. Vibration to be simulated includes self-induced vibration and vibration from piping, pumps, and motors. Other vibration such as hydrodynamic loadings should be simulated, where applicable, and should be included with the seismic qualification.

6.3.1.11 Operation under normal and design basis event conditions

It shall be demonstrated that equipment can adequately perform its safety function(s) under the identified service conditions.

6.3.1.12 Inspection

Upon completion of type testing, the equipment shall be visually inspected, including disassembly when required, and a description of its physical condition shall be included in the qualification documentation.

6.3.2 Operating experience

Portions or all of an equipment qualification program may be satisfied by documented operating experience. Equipment can be considered for qualification if the same or similar equipment has functioned successfully under service conditions at least as severe as those postulated for the new application. If the operating experience data do not encompass the entire qualified life objective and a design basis event, additional testing of the equipment is required. The similarity of the equipment in service to the equipment designated for a new application shall be established. Service conditions established from operating experience shall envelop the proposed service condition, plus appropriate design basis event margin. Differences shall be evaluated and justified. Documentation shall include the results of measurement or determination of performance characteristics required in the equipment qualification program, test records, and analyses of failures. Trends that have occurred during the operating period and a description of periodic maintenance (including adjustments, modifications, and calibration) and inspections shall be included. The documentation shall also include physical locations and mounting arrangements of the equipment in the operating facilities.

6.3.2.1 Operating history

The auditable data to be used to establish the equipment qualification shall consist of the following:

a) Verification that equipment with operating experience is the same as the equipment to be qualified, or that the differences do not unacceptably reduce equipment capability to perform the safety function(s).
b) A record establishing that equipment with operating experience has been exposed to levels of environment and service conditions at least as severe as those for which the equipment being qualified is required to function and that the equipment satisfactorily performed the function(s) required.

6.3.2.2 Determination of qualification

Operating experience may be the primary basis for qualification only if the qualification documentation includes auditable data demonstrating that the equipment has satisfactorily performed its safety function(s) during conditions at least as severe as the specified service conditions plus appropriate margin. Use of operating experience data from equipment performing nonsafety functions may also be acceptable if adequately justified. The qualified life determination shall evaluate the time that the equipment operated under normal and abnormal service condition levels prior to the occurrence of the design basis event (if the design basis event is simulated, type test requirements apply to the testing). The duration of the qualified life for the equipment being qualified shall be based on the analysis of the conditions of the operating history equipment in relation to the conditions of service for the qualified equipment.

6.3.3 Analysis

Qualification by analysis requires a logical assessment, similarity evaluations, or a valid mathematical model to establish that the equipment to be qualified can perform its safety function(s) when subjected to the specified service conditions. Such an analysis shall account for all time-dependent environmental parameters originating from the qualification criteria. Analytical techniques are limited for many types of equipment, and analysis supplemented by test data or operating experience is usually needed for a comprehensive qualification program. Justification is required for the technique used.

6.3.4 Extrapolation and interpolation

Extrapolation and interpolation are analytical techniques that may be used to qualify equipment by extending the application of test data. The following two types of extrapolation and interpolation are possible:

a) Extrapolation or interpolation of successful performance at a specified service condition to a different service condition
b) Extrapolation or interpolation of successful performance of a specific piece of equipment to similar equipment

Extrapolation or interpolation of a service condition requires analysis using established physical principles. Extrapolation or interpolation to other equipment by similarity can be used when the following criteria in 6.3.4.1, 6.3.4.2, 6.3.4.3, 6.3.4.4, 6.3.4.5, and 6.3.4.6 are met.

6.3.4.1 Material

Materials of construction shall either be the same or equivalent. Any identified differences shall be shown to not adversely affect performance of the safety function(s).

6.3.4.2 Size

Size may vary if the basic configuration remains the same and dimensions are related by known scale factors. Consideration shall be taken of such factors as thermal effects of different surface areas and seismic effects of different masses and modes.

6.3.4.3 Shape

The shape shall be the same or similar (subject to restrictions of size), and any differences shown shall not adversely affect the performance of safety function(s).

6.3.4.4 Stress

Operating and environmental stresses on the new equipment shall be equal or less than those experienced on the qualified equipment under normal and abnormal conditions.

6.3.4.5 Aging mechanisms

The aging mechanisms that apply to the tested equipment encompass those that apply to the similar equipment.

6.3.4.6 Function

The safety function(s) as evaluated shall be the same (e.g., activate to operate or deactivate to operate).

6.3.5 Extension of qualified life

The qualified life of a piece of equipment may be extended by

a) An evaluation of the conservatisms in the environments to which the equipment is actually exposed.
b) An evaluation of the conservatisms utilized to determine qualified life, such as Arrhenius activation energies.

c) Verification that the actual condition of equipment in service is less severe than the condition demonstrated during qualification prior to the application of design basis events.

d) Similarity to qualified equipment, which has a longer qualified life.

e) Type testing a piece of equipment of the same or similar design and construction that has been age conditioned for a period longer than the qualified life of the installed equipment.

f) Type testing a piece of equipment of the same or similar design and construction that has been naturally aged in an environment more severe than the installed equipment. The qualified life will be extended by the amount of time that the period of natural aging exceeds the initially established qualified life.

g) Testing a piece of equipment of the same or similar design and construction that has undergone a combination of natural aging and age conditioning for a period longer than the qualified life of the installed equipment. The natural aging and age conditioning may be done in any order.

6.3.6 Condition-based qualification

Condition-based qualification is an adjunct to type testing described in 6.3.1. To use condition-based qualification, age conditioning is performed incrementally and condition indicators are measured at each increment to establish data for comparison with observations of the same indicators during service. In particular, it is required to establish an end condition of the condition indicator(s) at the conclusion of age conditioning, prior to design basis event testing. If the qualification program has been completed, age conditioning may be replicated on another sample with incremental condition indicator measurements. Condition indicators must be leading indicators of adverse change in condition, either directly related to equipment ability to function or directly related to the degree of aging performed in the program. Measured changes must be large enough to distinguish the degree of aging and be consistent enough to establish a qualified condition. If condition data is taken during conventional qualification, the user may choose whether to base qualification on qualified life from the traditional methodology or on condition-based results, or a combination of the two. When condition-based qualification is used, the equipment remains qualified until it reaches the end condition. If trending of condition indicators proves to be impractical, the basis for qualification may be reverted to qualified life. The documentation for condition-based qualification must contain a full description of the test methods, limitations on use of the results, and the age conditioning methods used.

6.3.7 Acceptance criteria

The equipment being qualified shall demonstrate that it can perform the safety-related function specified in the acceptance criteria. Any failure to meet the acceptance criteria shall be analyzed to determine the modification needed to the equipment or the limitation that shall be imposed on its use.

6.4 Modifications

Modifications to the equipment or to the qualification basis made during or after completion of the qualification program shall be evaluated to determine whether additional qualification steps are required. Modifications to the equipment include changes in its design, materials, manufacturing process, clearances, lubricant, or mounting conditions. Modifications to the qualification bases include changes in the equipment's safety function(s), acceptance criteria, dielectric stress levels, mechanical stresses, postulated service conditions, or plant life extensions. If the evaluation concludes that additional qualification steps are not required, the evaluation, including supporting information, shall be included in the qualification documentation. Otherwise, steps shall be taken to verify and document that modified equipment is qualified.

7. Documentation

The documentation shall be retained throughout the qualified life of the equipment or its installed life.

7.1 Mild environment documentation

The documents required to demonstrate the qualification of Class 1E equipment located in a mild environment are the design/purchase specifications, seismic test reports (if applicable), and an evaluation and/or certificate of conformance. The design/purchase specifications, shall contain a description of the functional requirements for a specific environmental zone during normal environmental conditions and anticipated operational occurrences.

7.2 Harsh environment documentation

The qualification documentation shall provide evidence that the Class 1E equipment is qualified for its application, meets its specification requirements, and has its qualified life and periodic surveillance, maintenance, and/or condition monitoring interval established. Data used to demonstrate the qualification of the equipment shall be pertinent to the application and shall be organized in a readily understandable and traceable manner that permits independent auditing of the conclusions presented.

The harsh environment documentation requirements are as follows:

a) Identification of the equipment being qualified, including manufacturer, model, and model family, if applicable
b) Identification of the safety-related function(s)
c) Identification and description of the qualification method utilized
d) Identification of test sample equipment, if applicable
e) Identification of normal environmental conditions, including those resulting from anticipated operational occurrences, as applicable, for temperature, pressure, radiation, relative humidity, EMI/RFI, power surge environment, and operational cycling, and design basis events to which the equipment is qualified
f) Identification of the acceptance criteria and performance results
g) Identification of the test sequence, if applicable
h) Identification of installation considerations and requirements for mounting, orientation, interfaces, and conduit sealing
i) Identification of tested configuration (whether any connections within the test chamber are exposed to simulated accident effects)
j) Justification of how test sample equipment is representative of the qualified equipment
k) Evaluation of significant aging mechanisms and the method for addressing these in the qualification program
l) Identification of the qualified life of the equipment and its basis
m) Identification of age conditioning test results, as applicable
n) Identification of the design basis event test results, as applicable, including temperature versus time curve, pressure versus time curve, humidity, chemical spray, water spray, electrical loading, mechanical loading, applied voltage, applied frequency, and submergence
o) Identification of radiation test results, as applicable, including radiation type, dose rate, and total dose
p) Identification of seismic test results, as applicable

q) Identification of margin, as applicable, for peak temperature, peak pressure, radiation, power supply voltage, operating time, and seismic level

r) Identification of any scheduled surveillance, maintenance, periodic testing, or component replacement required to maintain qualification

s) Evaluation of test anomalies, including effect on qualification

t) Summary and conclusions, including limitations or caveats, and qualified life, and any periodic surveillance/maintenance interval determination

Annex A

(informative)

Bibliography

Other standards and documents related to equipment qualification are as follows:

[B1] IAEA TECDOC-932, Pilot Study on the Management of Aging of Instrumentation and Control Cables, Results of a Co-coordinated Research Program 1993–1995.[5]

[B2] IEC 60780 1998-10, Nuclear Power Plants—Electrical Equipment of the Safety System—Qualification.

[B3] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition.

[B4] IEEE Std 99™-1980 (Reaff 2000), IEEE Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment.[6]

[B5] IEEE Std 101™-1987 (Reaff 1995), IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

[B6] IEEE Std 308™-2001, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

[B7] IEEE Std 317™-1983 (Reaff 1996), IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.

[B8] IEEE Std 334™-1999, IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations.

[B9] IEEE Std 338™-1987 (Reaff 2000), IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.

[B10] IEEE Std 382™-1996, IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants.

[B11] IEEE Std 383™-1974 (Reaff 1992), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

[B12] IEEE Std 387™-1995 (Reaff 2001), IEEE Standard Criteria for Diesel-Generator Units Applied as Power Standby Supplies for Nuclear Power Generating Stations.

[B13] IEEE Std 420™-2001, IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations.

[B14] IEEE Std 535™-1986 (Reaff 1994), IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations.

[5]IAEA publications are available from the INIS Clearinghouse, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria, tel +43 1 2600 22880 (http:\\www.iaea.org\inis\dd_srv.htm).

[6]The IEEE standards or products referred to in Annex A are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

[B15] IEEE Std 572™-1985 (Reaff 1992), IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations.

[B16] IEEE Std 628™-2001, IEEE Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations.

[B17] IEEE Std 638™-1992 (Reaff 1999), IEEE Standard for Qualification of Class 1E Transformers for Nuclear Power Generating Stations.

[B18] IEEE Std 649™-1991 (Reaff 1999), IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations.

[B19] IEEE Std 650™-1990 (Reaff 1998), IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations.

[B20] IEEE Std 775™-1993 (W 2000), IEEE Guide for Designing Multistress Aging Tests of Electrical Insulation in a Radiation Environment.[7]

[B21] IEEE Std 943™-1986 (Reaff 1992), IEEE Guide for Aging Mechanisms and Diagnostic Procedures in Evaluating Electrical Insulation Systems.

[B22] IEEE Std 1064™-1991, IEEE Guide for Multifactor Stress Functional Testing of Electrical Insulation Systems.

[B23] IEEE Std 1205-2000, IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.

[B24] IEEE Std C37.81™-1989 (Reaff 1994), IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies.

[B25] IEEE Std C37.82™-1987 (Reaff 1998), IEEE Standard for the Qualification of Switchgear Assemblies for Class 1E Applications in Nuclear Power Generating Stations.

[B26] IEEE Std C37.98™-1987 (Reaff 1999), IEEE Standard Seismic Testing of Relays.

[B27] IEEE Std C37.105™-1987 (Reaff 1999), IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations.

[B28] IEEE Std C57.114™-1990 (W 1996), IEEE Seismic Guide for Power Transformers and Reactors.[8]

[B29] IEEE Std C62.41™-1991 (Reaff 1995), IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

[B30] IEEE Std C62.45™-2002, IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits.

[7]IEEE Std 775-1993 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel +1 303 792 2181 (http://global.ihs.com).

[8]IEEE Std C57.114-1990 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel +1 303 792 2181 (http://global.ihs.com).

[B31] NRC IN 94-20, Common-Cause Failures Due to Inadequate Design Control and Dedication, March 1994.[9]

[B32] NUREG/CR-5700, Aging Assessment of Reactor Instrumentation and Protection System Components, July 1992.[10]

[B33] NUREG/CR-5904, Functional Issues and Environmental Qualification of Digital Protection Systems of Advanced Light-Water Nuclear Reactors, April 1994.

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[9]NRC Information Notices can be obtained from the U.S. Regulatory Commission, Office of Public Affairs (OPA), Washington, DC 20555, USA, tel +1 301 415 8200 (http://www.nrc.gov).

[10]NUREG publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37802, Washington, DC 20013-7082, USA (http://www.access.gpo.gov/).