IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations

Sponsor
Power Systems Relaying Committee
of the
IEEE Power Engineering Society

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Foreword

(This foreword is not a part of IEEE C37.105-1987, IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations.)

ANSI/IEEE Std 323-1983 provides general guidance for demonstrating and documenting the adequacy of electrical equipment used in all Class 1E and interface systems. IEEE C37.105-1987 has been prepared to deal specifically with protective relays and auxiliary equipment, using ANSI/IEEE Std 323-1983 as the parent document for guidance.

Safety systems equipment in nuclear power generating stations must meet or exceed its performance requirements throughout its installed life. This is accomplished by a program of design qualification and quality assurance of design, production, installation, maintenance and surveillance. This standard is for the design qualification portion of the program only.

The nuclear power generating station safety analysis, in part, considers the station and its safety system design in terms of a set of postulated service conditions. Inherent to each such analysis are two requirements that must be evaluated to assure overall technical validity. First, designs must be such that equipment is capable of actually performing designated safety functions in postulated service environments. Second, in-service aging must not degrade safety systems equipment from its original design condition to the point where it cannot perform designated safety functions, when required.

The special environmental stresses associated with some postulated service conditions promote the possibility that production testing, normal service testing and surveillance may not be able to determine whether the equipment is vulnerable to failure, either as a result of inadequate design or aging. Under these circumstances, simultaneous failure of redundant safety equipment might occur just at the time safety functions are required. It is the fundamental role of qualification to provide reasonable assurance that design and age related common failure modes do not exist and that the equipment design is adequate to permit the equipment to perform its safety function during postulated service conditions.

Adherence to this standard alone may not suffice for assuring public health and safety since it is the integrated performance of the structures, fluid systems, instrumentation systems, and electric systems of the generating station that establishes safe operating conditions. Each applicant has the responsibility to establish that this standard, if used, is pertinent to the particular requirements of the generating station of concern and that the integrated performance of the station is adequate.

This standard was prepared by Working Group II (Relay Qualified Life) of Subcommittee I (Relay Practices) of the Power Systems Relaying Committee. The members of the working group are

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IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations

1. Scope and References

1.1 Scope

This standard describes the basic principles, requirements, and methods for qualifying Class 1E protective relays and auxiliaries such as test and control switches, terminal blocks, and indicating lamps for applications in nuclear power generating stations. When properly employed it can be used to demonstrate the design adequacy of such equipment under normal, abnormal, design basis event and post design basis event conditions in accordance with ANSI/IEEE Std 323-1983 [5].[1] When protective relays and auxiliaries are located in areas not subject to harsh environments, environmental qualification is not required.

Protective relays and auxiliaries located inside primary containment in a nuclear power generating station present special conditions beyond the scope of this document.

The qualification procedure presented is generic in nature. Other methods may be used at the discretion of the qualifier, provided the basic precepts of ANSI/IEEE Std 323-1983 [5] are satisfied.

1.2 References

The following publications shall be used in conjunction with this standard:

[1] ANSI/IEEE C37.90-1978 (R1983), IEEE Standard Relays and Relay Systems Associated with Electric Power Apparatus.[2]

[2] ANSI/IEEE C37.98-1978, IEEE Standard Seismic Testing of Relays.

[1]The numbers in brackets correspond to those of the references listed in 1.2.
[2]ANSI/IEEE publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

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[3] ANSI/IEEE Std 43-1974 (R1985), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

[4] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.

[5] ANSI/IEEE Std 323-1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

[6] ANSI/IEEE Std 344-1975 (R1982), IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

[7] ANSI/IEEE Std 381-1977 (R1984), IEEE Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations.

[8] ANSI/IEEE Std 494-1974 (R1983), IEEE Standard Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations.

[9] ANSI/IEEE Std 650-1979, IEEE Class 1E Battery Chargers and Inverters for Nuclear Power Generating Stations.

[10] ANSI/NEMA ICS-1 1983, General Standards for Industrial Controls and Systems.[3]

[11] ANSI/NEMA ICS-4 1983, Terminal Blocks For Industrial Use.

[12] ANSI/UL 508-1983, Standard for Industrial Control Equipment.

[13] IEEE Std 101-1972, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

[14] IEEE Std 467-1980, IEEE Standard Quality Assurance Program Requirements for the Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations.

[15] U/L 1059-1975 (R1986), Electrical Terminal Blocks.[4]

2. Purpose

The purpose of this standard is to

1) Define specific qualification methods for Class 1E protective relays and auxiliaries in accordance with the more general qualification requirements of ANSI/IEEE Std 323-1983 [5].
2) Provide guidance in establishing a program for demonstrating the design adequacy of Class 1E protective relays and auxiliaries in nuclear power generating stations applications.

Related standards such as ANSI/IEEE C37.98-1978 [2], shall be used to supplement this document.

3. Definitions

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 effects.

[3]NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW Washington, DC 20037.
[4]UL publications are available from the Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60020.

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ambient temperature: The average of air temperature readings at several locations in the immediate neighborhood of the equipment.

auxiliaries: Auxiliary relays, control switches, terminal blocks, indicating lights, test blocks, and other devices associated with the protective relay scheme.

base line data: Initial data needed to show acceptable functioning of the equipment during qualification testing.

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 are essential in preventing significant release of radioactive material to the environment (ANSI/IEEE Std 100-1984 [4]).

common mode failure: A multiple failure attributable to a common cause.

component: Item from which a system is assembled (for example, as used in this document, a component is a resistor, capacitor, wire, connector, spring, terminal block, bus support, etc).

design basis events (DBEs): 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 (ANSI/IEEE Std 323-1983 [5]).

design life: The time during which satisfactory performance can be expected for a specific set of service conditions (ANSI/IEEE Std 323-1983 [5]).

duty cycle: The percentage of time that heat producing electrical currents flows in equipment over a specific period of time.

equipment qualification: The generation and maintenance of evidence to assure that the equipment will operate on demand to meet the system performance requirements (ANSI/IEEE Std 323-1983 [5]).

generic environment: A set of environmental conditions intended to envelop the range of expected environments.

generic equipment: A family of equipment units having similar materials, manufacturing processes, limiting stresses, design and operating principles, that can be represented for qualification purposes by a representative unit(s).

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 (ANSI/IEEE Std 323-1983 [5]).

NOTE — Equipment may have an installed life of 40 years with certain components changed periodically; thus, the installed life of the components would be less than 40 years.

malfunction: The loss of capability of Class 1E equipment to initiate or sustain a required function, or the initiation of undesired spurious action which might result in consequences adverse to safety (ANSI/IEEE Std 344-1975 (R1982) [6]).

margin: Margin is the difference between the most severe specified service conditions and the conditions used in qualification of the equipment.

operating basis earthquake (OBE): That 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 (ANSI/IEEE Std 344-1975 (R1982) [6]).

operational tests: Tests conducted in a qualification program to demonstrate operational capability. These tests are either as specified in Table I of Section 11 of this document or as specified by the user.

qualified life: The period of time for which satisfactory performance can be demonstrated for a specific set of service conditions (ANSI/IEEE Std 323-1983 [5]).

NOTE — The qualified life of a particular equipment item may be changed during its installed life where justified.

random failure: Any failure whose cause and/or mechanism makes its time of occurrence unpredictable (ANSI/IEEE Std 100-1984 [4]).

representative sample: Production/prototype equipment used in a qualification program which is equivalent to that for which qualification is sought in terms of design, function, materials, and manufacturing techniques and processes.

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

4. Introduction

The manufacturers and users of Class 1E protective relays and auxiliaries are required to provide assurance that such equipment will meet or exceed its specific performance requirements throughout its installed life. This is accomplished through a quality assurance program that includes, but is not limited to, design, qualification, production quality control, installation, maintenance and periodic testing. This document treats only the qualification portion of this program.

The purpose of the qualification program is to provide assurance, by demonstration, that the protective relays and auxiliaries are capable of performing their required Class 1E function(s) before, during and after the postulated design basis event(s) specified for that equipment.

Qualification may be accomplished in several ways: testing, analysis, previous operating experience, or a combination of these. This document provides qualification procedures for both testing and analysis. Ongoing qualification may be used to extend the qualified life.

With all qualification methods, the end result is the demonstration and documentation that verifies that the protective relay or auxiliary is capable of performing its required function. The documentation shall be in a form that allows auditing by competent personnel other than the qualifiers. It should contain the performance requirements, the qualification method and procedure, the results, and justification for assumptions used in the qualification program.

5. Principles of Qualification

5.1 General

The qualification principles of Class 1E equipment for nuclear power generating stations are specified in ANSI/IEEE Std 323-1983 [5]. These principles shall be observed for the qualification of Class 1E, protective relays and auxiliaries.

The fundamental requirement inherent to these principles is to provide assurance, by demonstration, that the equipment is capable of performing its required Class 1E functions(s) before, during, and after the postulated design basis event(s) specified for that equipment. Such demonstration requires a qualification program which includes both an aging evaluation and a performance evaluation. The aging evaluation must first include identification of potential aging failure mechanisms of that equipment. When potential aging failure mechanisms are present, the qualification program must include both aging and performance evaluations coupled to show safety function performance capability for the specified DBE(s). A qualified life, as defined in ANSI/IEEE Std 323-1983 [5], must be assigned.[5] When potential aging failure mechanisms are not present, the qualified life may be taken as equal to the plant design life The qualification requirements are then reduced to demonstration of capability to perform Class 1E functions before, during, and after the specified DBE's. The test plan for Class 1E relays and auxiliaries should contain the following explanation:

1) Identification of Equipment and Its Application
2) Qualification Program
3) Documentation

[5]Because the typical life of a nuclear power plant is forty years, a desired but not required qualified life is in excess of forty years.

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5.2 Application to Protective Relays and Auxiliaries

This standard establishes a standard set of equipment operational and environmental condition[6] (Table I, Table IV) and then presents qualification alternatives (test or analysis) for these conditions. The test alternative involves accelerated aging of the equipment at the device (or component) level. The analysis alternative consists of a detailed comparison of a device to a previously qualified test device of similar function and construction. The comparison includes such items as mechanical construction, stress analysis (mechanical or electrical, or both), basic materials application, and operating levels. In either case, where a specific set of requirements (or equipment, or both) is not encompassed by the standard set of conditions assumed in this document, the qualification program shall be revised or extrapolated providing suitable justification can be provided.

5.2.1 Identification of Equipment and Its Application

For a specific application, as differentiated from generic qualification, identification of equipment and its application shall be contained in the equipment specification. (See Section 10, Documentation.) The specification shall contain the following:

1) Type — protective relay or auxiliary
2) Class 1E Performance Requirements — during normal, abnormal, DBE, and post-DBE conditions.
3) Environment — during normal, abnormal, DBE, and post-DBE conditions.

5.2.2 Qualification Program

The capability of Class 1E protective relays and auxiliaries to perform their required function shall be determined by the qualification program outlined in this section (See Fig 1 for flowchart.)

1) *Identification of Aging Failure Mechanisms*. Protective relay and auxiliary devices are composed of components having significant variety in materials, design and function. Each component should therefore, be reviewed in terms of its materials, design, function and environment to identify aging failure mechanisms which could limit the equipment's ability to perform its required safety function(s). The most likely aging failure mechanisms for protective relay and auxiliary devices (and those which are therefore considered in this document) are
   1) Operational cycles
   2) Time/temperature effects
   3) Radiation

   Other aging mechanisms[7] are not considered detrimental to the life of the equipment for usual applications. When unusual conditions exist, they shall be so specified by the user and addressed in the qualification program. For protective relay and auxiliary application, the time/temperature and radiation effects apply primarily to plastics and other organic materials. Certain electronic components, such as semi-conductors, resistors and capacitors which could be classified as a quasi-organic material, may not react to the effects of time/temperature and radiation aging within the limits defined in Table IV.

   When it can be demonstrated and documented that these or other effects are not significant, they need not be included in the test portion of the qualification program.
2) *Development of Qualification Plan*. A documented qualification plan which provides an audit table link between the specifications and the qualification program results is required. It shall describe the required qualification program (including a statement of the qualified life objective) as determined from the

[6]Though it cannot be presumed that the standard set of equipment operational and environmental conditions presented herein envelope all applications, both today and in the future, it does provide a basis for development of both generic qualification programs and user specifications.

[7]Other aging mechanisms addressed in the preparation of this standard, but considered to be relatively insignificant in view of operating experience, are

1. Humidity—Providing the protective relay and auxiliary device enclosure internal air temperatures exceed surrounding ambient air temperatures by 5 °C minimum. See ANSI/ IEEE Std 43-1974 (R1985) [3].
2. Contamination—Based on expected application in nuclear power plants where ambient air quality is controlled to habitable levels.
3. Altitude—When below 5,000 feet. See ANSI/IEEE C37.90-1978 (R1983) [l].
4. Vibration—Seismic levels (both five OBE's and one SSE) to be addressed in seismic testing. There is no history evidencing sensitivity of this equipment to normal in-plant vibration levels.

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identification of the potential aging mechanisms, the specified DBE(s) and other requirements, such as post DBE(s). It shall contain other information as specified in Section 10, Documentation.

3) *Implementation of Qualification Plan.* When the equipment, its specified performance requirements, environments, interface conditions and aging mechanisms fall within the bounds of those considered in this document, qualification procedures following the general principles of those described herein (see Section 6, Qualification Procedures) may then be used to qualify the equipment. Variations from these conditions require alteration of the procedure or extrapolation therefrom and appropriate justification. The qualification sequence shall be as follows:
    1) Device Qualification
        a) Inspection
        b) Base Line Data
        c) Aging
        d) Inspection and Data Measurement
        e) Seismic Test (DBE)
        f) Post DBE Conditions (if different than normal)
        g) Operational Tests and Inspection
4) *Determination of Qualification.* Such determination shall be as specified in Section 6.9, Determination of Qualification.

5.2.3 Documentation

Documentation shall be as specified in Section 10, Documentation.

5.3 Alternative Methods

Methods other than those presented in this document may be used at the discretion of the qualifier providing the method chosen can be shown to satisfy the basic precepts of ANSI/IEEE Std 323-1983 [5].

6. Qualification Procedure

6.1 General

Section 6 presents qualification procedures for the two recommended alternatives of testing and analysis. Section 6.2 treats the testing alternative and 6.3 treats the analysis alternative. These two subsections present qualification procedures which are generic in nature and are generally applicable to all relays and associated devices. Sections 6.4, 6.5, 6.6, and 6.7, respectively, present procedures for electromechanical relays, static relays, switches, and auxiliary devices. These subsections identify exceptions to the general procedure and describe procedures which are specific for particular subsections.

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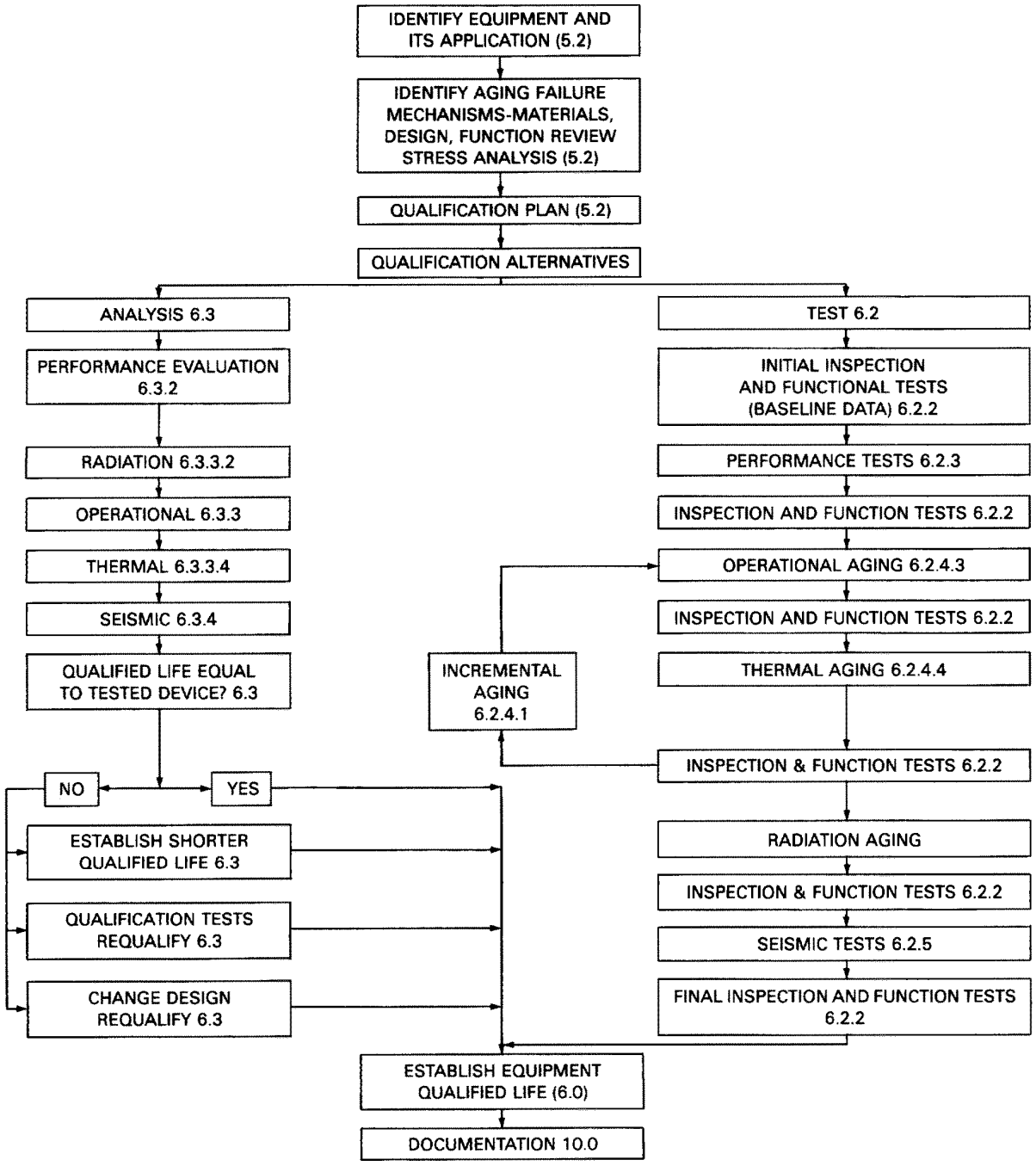

Figure 1—Flowchart for Qualification of Class 1E Devices

6.2 Testing Alternative

Qualification of relays and auxiliary devices by the testing alternative is achieved by performing baseline measurements and inspection followed by performance testing, aging, seismic testing, and other testing, when specified. The test sample shall contain at least three fully aged and tested specimens of each type of device.

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6.2.1 Testing Sequence

The testing sequence shall be as follows:

1) Inspection and Baseline Data Measurement
2) Performance Evaluation with respect to ANSI/IEEE C37.90-1978 (R1983) [1]
3) Aging
4) Seismic Test
5) Final Operation Tests

Changes in the test sequence or omission of any step, (1) through (5), or of a portion of these steps shall be justified.

6.2.2 Inspection and Baseline Data Measurement

Each device specified in the qualification plan shall be inspected to assure that there is no apparent initial damage and to establish basic parameters as appropriate.

Before testing, the essential function of each device shall be determined from its application. Parameters shall be identified which show acceptable functioning and provide reference data for subsequent tests. For example, the measurement parameters for an auxiliary relay may be “minimum pickup voltage” and the “dropout time from rated voltage.”

Inspection and subsequent data parameter measurements shall be made and repeated after performance, aging, and seismic tests and compared with baseline data.

6.2.3 Performance Evaluation

Devices shall be operated to applicable portions of ANSI/IEEE C37.90-1978 (R1983) [1] as follows:

1) Allowable variation from rated voltage for protective relays (6.2)
2) Range of operating voltage for auxiliary relays (6.4)
3) Test for operation at minimum voltage for auxiliary relays (6.5)
4) Make and carry ratings for tripping contacts (6.6)
5) Limits of temperature rise for coils (7.1)
6) Dielectric tests (Section 8)
7) Surge withstand capability (Section 9)
8) Each device shall be shown to be functionally operable through ambient temperatures of –20 °C through +55 °C.

6.2.4 Aging

6.2.4.1 General

The aging mechanisms addressed in this procedure are radiation, operational cycles and time/temperature effects. The sequence in which the aging mechanisms are applied is optional. The test plan for each aging mechanism must be designed with the objective of placing the device in an end of life condition. At the outset, a target qualified life shall be chosen for each device. This is necessary to establish a time/temperature relationship for accelerated aging. This determination shall be made only after a review of each device, its design, materials and available operating history for possible indications of limits on life. In addition to establishing the target number of years of qualified life, additional targets in terms of number of operations or cycles may also be necessary. Failures, whether of random or of common mode nature, could have the effect of seriously delaying a qualification program. Ways to minimize this effect include:

1) Aging of an adequate number of each device for assistance in the identification of, and use in the event of a random failure.
2) Aging of alternative devices with a deliberately introduced age difference for backup use.

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3) Accumulation of the thermal aging or operational cycling on an incremental basis, or both. A typical combined operational and thermal aging sequence follows:
   a) Accumulate an equivalent of five years of operational cycles as specified in Table II at an accelerated rate and at nominal room temperature.
   b) Thermally age device in a high temperature environment for an equivalent of five year real time (five years of operational cycles and thermal aging equivalent are nominal values which may be varied at the discretion of the qualifier).
   c) Repeat the base line measurements and compare results to the original baseline data.
   d) Return device to the operational cycle environment and repeat the above sequence the necessary number of times until an equivalent of the qualified life has been accumulated.

6.2.4.2 Radiation Aging Tests

Subject device to gamma radiation to simulate exposure to the specified total integrated dose due to beta and gamma radiations combined. The reduction in dose from beta rays due to absorption in the surrounding media should be considered. This test may be omitted when justification is provided. The dose rate shall be such not to introduce an abnormal failure.

6.2.4.3 Operational Aging Test

Each device shall be subjected to the total number of operational cycles specified in Table II at an accelerated rate and at nominal room temperature.

6.2.4.4 Thermal Aging Tests

Successful thermal aging of equipment is possible only through careful review, at the outset, of the equipment, its application and the desired aging conditions. Particular considerations for this qualification program are:

1) *The Aging Model.* Where applicable, thermal aging conditions and qualified life values shall be established by use of the Arrhenius relationship (IEEE 101-1972 [13]). Acceleration factors and test conditions shall be conservatively chosen based on the time/ temperature sensitivity of elements in the device. Where specific thermal aging acceleration factors are not available, they can be estimated by an appropriate consideration of the minimum activation energies for the generic class of materials used and of the temperatures involved.
2) *Temperatures.* Selection of aging temperature depends upon the upper practical temperature limit of the materials involved, the desired aging time, and the average in-service ambient air temperature of the equipment. For relays and auxiliary devices, the in-service device ambient air temperature shall be taken as the average room ambient air temperature. This value, as well as a typical aging temperature is given in Tables III and IV. When temperatures differ from those given in Table III, the user shall so specify and they shall be accounted for in the qualification program by the qualifier.
3) *Choice of Qualified Life Goal.* A target qualified life goal should be established at the outset as described in the second paragraph of 6.2.4.
4) *Self-Heating Effects.* Device self-heating effects may be a significant factor in the life of the equipment depending upon the degree of self-heating, the in-service operating duty cycle and other factors. Each device should therefore be reviewed in terms of these factors—and their effects shall be accounted for.

6.2.5 Seismic Testing

6.2.5.1 General

Seismic qualification of Class 1E relays and auxiliary devices shall meet the requirements of ANSI/IEEE C37.98-1978 [2]. The procedures and guidelines of that document shall be followed in demonstrating that the Class 1E relays and auxiliary devices can meet their qualification requirements. In addition, some specific areas which are peculiar to switches and auxiliary devices are covered in 6.6 and 6.7. These procedures are intended to supplement those

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described in ANSI/IEEE Std 344-1975 (R1982) [6] and ANSI/IEEE C37.98-1978 [2], and provide additional guidance for qualifying these kinds of equipment.

6.2.5.2 Specific Requirements

1) *Input Motion.* The test input motions shall be in accordance with ANSI/IEEE C37.98-1978 [2].
2) *Monitoring Equipment.* The monitoring equipment used during testing shall be in accordance with Standard ANSI/IEEE C37.98-1978 [2].
3) *Number of Tests*. There shall be five or more OBE tests to satisfy the seismic requirements of ANSI/IEEE C37.98-1978 [2], followed by at least one SSE test in each direction. Credit may be taken for any test preceding the SSE test, if the severity is shown to be greater than or equal to the required OBE.
4) *Mounting.* The method of mounting devices should be rigid such that no additional amplification will be introduced. The method and procedures used during testing shall be documented.
5) *Damping Factor.* The recommended values of damping to be used is five (5) percent unless other values are determined from test data. For that reason, the preferred damping value of the required response spectrum (RRS) curves is five percent.
6) *Contact Chatter* (Unwanted change of circuit conditions). All contacts between external terminals (ANSI/ IEEE C37.98-1978 [2]) of each device tested shall be monitored for contact chatter during the operations specified in 6.3.2.8. The maximum permissible time for contact chatter of any contact due to seismic input during testing is two (2) milliseconds, unless the user ascertains that other values are permissible.
7) *Electrical Loading.* All testing shall include contact loading and energization in accordance with ANSI/IEEE C37.98-1978 [2]. A representative sample of all devices shall be tested in both the energized and de-energized state.
8) *Operation of Devices*. Seismic testing shall include operation of devices as follows:
   a) Devices which are required to change state (energized to deenergized or vice versa) shall be operated in a similar manner during testing at the SSE level.
   b) Contacts whose positions are governed by the state of the devices with which they are associated, shall be tested with contacts both open and closed; and with devices both energized and de-energized.
   c) Each device must experience the seismic input in each state (that is, energized or deenergized) for the duration specified by ANSI/IEEE C37.98-1978 [2]. The transfer from one state to the other may be performed at any time once the specified duration has been exceeded.

6.2.5.3 Documentation

The documentation requirements shall be in accordance with ANSI/ IEEE C37.98-1978 [2] and Section 10, Documentation.

6.2.6 Final Operational Test

The inspection and baseline data measurements of 6.2.2 shall be repeated to demonstrate operational capability within twice manufacturer's published tolerances. Operational capability beyond twice manufacturer's published tolerances shall be considered a failure.

6.3 Analysis Alternative

6.3.1 General

Qualification of relays and auxiliary devices by the analysis alternative is achieved by a detailed comparison of a device to a previously tested device of similar function and construction. This detailed comparison must take into consideration performance requirements, aging mechanisms, and seismic capability.

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6.3.2 Performance Evaluation Analysis

The applicable performance requirements, such as limits of temperature rise of a relay coil (ANSI/IEEE C37.90-1978 (R1983) [1], must first be identified. The analysis must then identify the significant features such as coil insulation, wire size and number of turns, rating information and duty cycle and show by comparison that performance of the device for which the analysis is made will be as good or better than that of the previously tested device. This process must be repeated for each performance requirement.

6.3.3 Aging Analysis

6.3.3.1 General

The aging mechanisms addressed by analysis are radiation, operational cycles and time/temperature effects. The analysis shall consider the anticipated environmental and operational conditions experienced by equipment and determine whether degradation will result which will prevent the equipment from performing its required function. If a given material cannot withstand the effects of the desired qualified life of forty (40) years, it shall be determined whether the device containing that material can be replaced periodically and still maintain proper operation of the equipment. If not, the equipment shall be redesigned or a shorter qualified life assigned.

6.3.3.2 Radiation Aging Analysis

Metals are unaffected by outside of containment levels of radiation. Thus, radiation aging analysis must be provided only for nonmetallic materials.

The radiation aging effects of materials, components or systems are evaluated by consideration of the aging characteristics of the nonmetallic materials and total integrated radiation dosage to which they are subjected. To accomplish this:

1) Identify all nonmetallic materials used in the equipment.
2) Conduct a literature search for radiation effects based on the threshold damage level of the parts.
3) Compare the resulting capabilities of the equipment at these degraded levels with their design requirements. Each material shall have retained a sufficient amount of its design properties to ensure proper operation of the equipment for specified environmental and operating conditions.
4) Where a literature search fails to disclose adequate radiation-effect information for a specific material, a radiation test to determine such effects shall be conducted.

6.3.3.3 Operational Aging Analysis

Operational aging analysis may apply to either metallic or nonmetallic materials. Determine the applicable operating modes and number of operational cycles from Table II. Identify metallic and/or nonmetallic materials and components subject to operational aging and perform a detailed comparison of aging effects with the previously tested device of similar function and design. This detailed comparison should establish the qualified life with respect to operational aging for the device for which the analysis is performed.

6.3.3.4 Thermal Aging Analysis

Metals, when applied within their temperature limits, will not experience degradation while exposed to anticipated thermal conditions. Therefore, the thermal aging effects on equipment shall be evaluated by considering the aging characteristics of the nonmetallic materials and the environmental and operating conditions to which they are expected to be subjected. A typical sequence is as follows:

1) Identify all nonmetallic materials used in the equipment.

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2) Obtain Arrhenius type data and/or other applicable time/temperature curves for each nonmetallic material. Verify that the criteria (properties) used to develop the data (curves) pertain to the design requirements of the equipment (for example, dielectric strength, flexural strength, etc).
3) Determine the extent of degradation of each material due to the specified environmental and operating conditions for the desired period of time. The thermal degradation shall be based on the material operating temperature expected for each nonmetallic material. It is required that thermal data from prior tests on these same materials be used in determining these material operating temperatures.
4) Compare the resulting capabilities of the equipment at these degraded levels with their design requirements (for example, required flexural strength, etc). Each material shall have retained a sufficient amount of its design properties to ensure proper operation of the equipment for the specified environmental and operating conditions.
5) Results of the analysis shall be documented.

6.3.4 Seismic Analysis

Seismic analysis is performed by comparing seismic capability with a previously tested device(s) of similar function and design. Items which shall be considered include

1) Types of fasteners and consideration of their ability to maintain secure assemblies.
2) Weight and weight distribution of parts and assemblies.
3) Strength of materials with respect to applied stresses.
4) Types of electrical contacts employed and consideration of contact wipe, gaps, contact pressure, and spring properties.
5) Type of control springs used and spring force, torque, and gradients employed.
6) Results of the analysis shall be documented.

6.4 Electromechanical Relays

The generic procedures described by 6.2, Testing Alternatives, and 6.3, Analysis Alternatives, apply to electromechanical relay qualification with the exception of 6.2.3, (7) SWC (surge withstand capability).

6.5 Static Relays

The generic procedures described by 6.2, Testing Alternatives, and 6.3, Analysis Alternatives, apply to static relay qualifications.

6.6 Switches

The generic procedures described by 6.2, Testing Alternatives, and 6.3, Analysis Alternatives, apply to switch qualification. Exceptions are noted in 6.6.1; additional exceptions, if any, should be documented and justification given.

The essential function(s), contact voltage, current ratings, and methods of operation for performance of switching functions, should be documented prior to testing or analysis.

6.6.1 Not Applicable to Switches

1) ANSI/IEEE C37.90-1978 (R1983) [1] requirements which specify protective or auxiliary relays
2) SWC (Surge Withstand Capability)

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6.6.2 Applicable to Switches

1) Mechanical Operation
2) Electrical considerations: Dielectric (hi-pot), contact resistance and continuity
3) Temperature rise of contacts and connectors
4) Radiation, operational and thermal aging
5) Seismic capability

6.7 Auxiliary Devices

The generic procedures described by 6.2, Testing Alternative, and 6.3, Analysis Alternative, generally apply to auxiliary devices. However, because of the variety of devices and functions, the essential functions(s) and design of each device should be reviewed to identify procedures applicable to each device.

As an example, auxiliary devices include passive devices such as terminal boards which have no moving parts and no static components. For such devices, operational aging and surge withstand capability and are not applicable. Contact and connector temperature rise, dielectric (hi-pot) capability, radiation and thermal aging withstand capability, circuit integrity, and seismic capability do apply to terminal boards and should be covered in the qualification procedure.

6.8 Other Events

For relays and auxiliary devices, the seismic event is the design basis event of major concern. However, other design basis events, post-design basis events or abnormal conditions, or both, such as elevated temperature, humidity and radiation are sometimes specified. When this occurs, such specified events or conditions shall be addressed in the qualification program. The acceptable methods for demonstrating equipment capability for these events or conditions are testing, operating experience, analysis, ongoing qualification, or combinations thereof. Such demonstration shall be coordinated with the rest of the qualification program to satisfy the basic qualification precepts of Class 1E equipment.

6.9 Determination of Qualification

The relay or auxiliary device shall be considered to be qualified when three devices have successfully completed the specified qualification sequence including the requirements of 6.9.

6.9.1 Failure During Qualification

Failure during the qualification testing process does not mean that the equipment is disqualified for its intended safety application, if it can be shown that the failure was random in nature or if the failure does not affect the device's Class 1E function. When random failure of a device or component occurs. it may be replaced by an equivalently aged identical device or component and the qualification process continued, providing the effect on interface connections can be shown to be insignificant.

Nonrandom failures may be rectified either by design changes to eliminate the cause of the failure(s) or by justifiably reducing the qualified life.

Equipment modification during the qualification procedure may affect the equipment qualification. Refer to Section 9 regarding modifications.

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7. Environmental Conditions

The environmental parameters listed in Table IV are considered to affect the qualification of a protective relay or auxiliary. The values given in Table IV for these parameters represent the anticipated conditions of current nuclear power plant designs and are the recommended values to be used for generic qualification of protective relays and auxiliary equipment.

When the protective relay and auxiliary is to be installed in an environment whose parameters exceed the values listed in Table IV, the user shall provide to the qualifier the normal and abnormal environmental conditions that the equipment will experience. The protective relay or auxiliary and its components shall then be qualified for these conditions in accordance with Section 6 of this standard. The specific environmental parameters shall be clearly identified in the test plan description (See 10.2.3.5).

8. Margin

The purpose of applying margin in the qualification program is to account for reasonable variabilities in establishing satisfactory performance and in experimental measurements, thereby providing greater assurance that the equipment can perform under the worst application conditions for which it is designed.

Margin shall be considered in the following manner:

1) *Baseline Data Operational Tests.* Standard industry limits on the performance of the equipment shall be considered to include margin to account for variabilities in the manufacturing process. Additional margin shall be applied by the system designer to account for variations in service conditions. When specified limits exceed standard industry limits, margin shall be included by the specifier.
2) *Aging.* Margin considerations do not apply to the aging portion of this qualification program.
3) *Seismic Test.* The response spectra, as shown in ANSI/IEEE C37.98-1978 [2], shall be considered to include margin to account for variabilities in the manufacturing process. Additional margin shall be applied by structure designer to account for variations in structural mounting.

9. Modifications

9.1 Modifications During Qualification

Each modification made to the equipment or to the equipment test specification after the start of the qualification program shall be evaluated to determine its effect on the equipment qualification. This evaluation shall indicate whether or not requalification is necessary.

Requalification is not necessary if the modification is fully justified and documented as

1) Having no bearing on the validity of the tests, or equipment qualification, or
2) A modification in the nature of equipment replacement, servicing, or adjustment that is included in a prescribed maintenance program for that equipment.

Where the modification or change does affect equipment qualification, the change in qualification shall be identified (materials of construction, lubricant, clearances, dielectric stress levels, etc), and the equipment requalified with supporting justification. Necessity shall be based on the effect(s) on the equipment's ability to perform its Class 1E

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function(s). Components of the equipment which can be shown to be unaffected by the modification need not be requalified.

9.2 Modifications After Qualification

During the qualified life of the installed equipment, additions and/or changes may become necessary. Such modifications to protective relays and auxiliaries require evaluation and requalifications, as necessary.

10. Documentation

10.1 General

The documentation shall be sufficient to provide justification that the protective relays and auxiliaries and their subcomponents can meet their specified Class 1E performance requirements for normal service conditions, extreme service conditions, design basis events, and post-design basis conditions. The documentation shall be presented in an organized and auditable form.

10.2 Equipment Qualification Data

10.2.1 Service Conditions

The documentation shall include a tabulation of all normal and abnormal specified service conditions and equipment qualified service conditions identified in Table IV.

10.2.2 Specific Feature(s)

Specific feature(s), in addition to those identified in Tables I and IV that are also to be demonstrated by the equipment qualification program, shall be identified.

10.2.3 Qualification Plan

The qualification plan shall contain sufficient details to identify the acceptance criteria, describe the required procedures and correlate the qualification methods and results to the equipment specification. The qualification plan shall contain the following:

1) Equipment description and specification
2) Number (quantity) of units to be tested
3) Mounting, connection and other interface requirements
4) Aging simulation procedures, including the target qualified life
5) The service conditions to be simulated
6) Performance and environmental variables to be measured
7) Test equipment requirements, including accuracies
8) Environmental, operating and measurement sequence in step-by-step detail
9) Acceptance criteria
10) Type test data
11) Statement of nonapplicable portions of the specification
12) A description of any conditions peculiar to the protective relay or auxiliaries which are not covered above, but which could affect the said equipment during testing.

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10.2.4 Report Formal

The qualification report shall conform to the following format:

1) Objective (acceptance criteria)
2) Detailed description of equipment tested
3) Test facility and instrumentation
4) Test procedures
5) Test data
6) Maintenance and replacement schedule, or both
7) Summary and conclusions
8) Supporting documentation
9) Approval, signature, and date.

10.3 Supporting Documentation

Partial type tests of protective relays or auxiliaries that are augmented by operating experience, analysis, extrapolation or combinations of these shall include the following:

10.3.1 Operating Experience Data

1) The equipment performance specifications identified in Table I.
2) The interface and boundary conditions of the equipment
3) The specifications of equipment for which operating experience is available
4) Identification of the specific features to be demonstrated by operating experiences
5) Comparison of past application and specifications with the new equipment specifications for each feature identified in item 4
6) Summary and source of operating experience applicable to equipment qualification
7) The basis on which the data have been determined to be suitable and the equipment qualified
8) Approval, signature, and date.

10.3.2 Analysis

1) The equipment performance specifications identified in Table I
2) The interface boundary conditions of the equipment
3) The specific features, postulated failure modes, or failure effects to be analyzed
4) The assumptions, empirically derived values, and the mathematical models used together with justification for their use
5) Description of analytical methods or computer programs used
6) A summary of analytically established performance characteristics and their acceptability
7) Approval, signature and date.

10.3.3 Extrapolation

Where the test data or operating experience data have been extrapolated, the basis and justification of the validity for the extrapolation shall be provided.

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Table I—Operational Tests

1. Nondirectional Current Relays

A. Instantaneous

(1) Pickup—At minimum calibration point

(2) Dropout—At or above minimum specified by manufacturer

(3) Operate time—Manufacturer's time curve at 3 times pickup (minimum)

B. Time Delay

(1) Pickup—At minimum calibration point

(2) Dropout—At or above minimim specified by manufacturer

(3) Operate time—Manufacturer's time curve at 5 times pickup and approximate midpoint of time range

2. Directional Current Relays

A. Overcurrent Element—Same as single function relays

B. Directional Unit—50% rated voltage and overcurrent unit current level at maximum sensitivity of current-voltage phase relationship

3. Power or Angle Directional Relays A.

A. Pickup—Manufacturers’ specification at rated voltage

B. Dropout—At or above minimum specified by manufacturer

4. Voltage Relays

A. Undervoltage

(1) Dropout with setting at approximately 90% of rating

(2) Pickup—At or below minimum specified by manufacturer

(3) Operate time—Refer to manufacturers’ time curve at 80% of setting

B. Overvoltage

(1) Pickup—With setting at approximately 110% of rating

(2) Dropout—At or below minimum specified by manufacturer

(3) Operate time—Refer to manufacturers’ time curve at 200% of setting

5. Differential Relays

A. Pickup—Nominal differential pickup

B. Operate time—Refer to manufacturers’ time curve at 200% pickup

6. Temperature Relays

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Table I—Operational Tests (Continued)

A. Pickup—Operating temperature

7. Reclosing Relays

8. Synchronizing and Synchrocheck Relays

A. Pickup—Minimum angular setting

B. Operate time—Refer to manufacturers' time curve for an in-phase condition

9. Timing Relays

A. Operate time—Minimum time setting

10. Frequency Relays

A. Pickup—With setting at one Hz deviation from normal system frequency

B. Operate time—Minimum setting recommended by manufacturer

11. Impedance Measuring Relays

A. Pickup—Minimum reach at angle of maximum sensitivity and 15 amperes

12. Auxiliary Relays

A. Pickup

(1) DC—Minimum recommended by manufacturer

(2) AC—Minimum recommended by manufacturer

Above to be when coils are stabilized at operating temperature.

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Table II —Operating Aging Parameters

To approximate a 40 year life, nominal 2000 operations shall be considered as an adequate operational aging cycle. Since most protective relays have as their output function the tripping of a circuit breaker, the contact load shall be 30 amperes "make" at a L/R time constant of 0.04 seconds or less. The cycle shall be made for 200 ms, break by an external means, off for 30 seconds, and then repeat.

The input quantities for the various relay types for both "non contact make" and "contact make" are listed below:

	Input Conditions	
Relay Type	**Non-Contact Make**	**Contact Make**
1. Nondirectional Current		
a. Instantaneous	0 A	200% of pickup or more
b. Time delay	0 A	200% of pickup or more
2. Directional Current Relays Same as 1 above		
3. Power of Angle Directional	0 A	200% of pickup or more
	Rated V	Rated V
4. Voltage Relays		
a. Undervoltage	Rated V	0 V
b. Overvoltage	0 V	120% of pickup or more
5. Differential Relays	0	200% of pickup or more
6. Temperature Relays	0	120% of pickup or more
7. Reclosing Relays	0	Rated V
8. Synchronizing Relays	0	In-phase rated V
9. Timing Relays	0	Rated V minimum time
10. Underfrequency Relays	rated system frequency	One Hz below pickup
11. Impedance Relays	rated current and voltage	50% of relay reach at 50% rated V at angle of maximum sensitivity
12. Auxiliary Relays		
a. Latching Relays	0	Rated V
b. Contactors	0	Rated V
c. Contact multipliers		
(1) Energized	Rated V	0
(2) De-energized	0	Rated V

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Table III —Typical Thermal Aging Conditions

Temperatures	
Thermal Aging Temperature	100 °C
In-Service External Ambient Temperature	30 °C
Average External to Internal Air Temperature Difference due to Enclosure	10 °C
Average In-Service Device Ambient Temperature	40 °C
Resultant Thermal Aging Accelerating Delta	60 °C

In order to thermally age all materials of the device in the same time period, it is permissible to energize the coils, thus resulting in a coil temperature higher than that of the remainder of the device.

Table IV —Environmental Conditions

The values given as average service conditions represent anticipated conditions for protective relays and associated devices in nuclear power generating stations and are recommended for use in generic qualification programs.

The values given in allowable excursions are those that might be expected for short periods of time and would not affect the qualification.

	Average	**Allowable Excursions**
Temperature (in service external ambient)	30 °C	10 °C–40 °C
Relative Humidity	60%	10%–90%
Radiation	$1 \cdot 10^4$ Rads (total integrated dose)	—
Control Voltage		
DC	Rated	80%–112%
AC	Rated	75%–120%
Frequency	Rated	±0.1 Hz
Altitude	5000 ft (maximum)	—

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