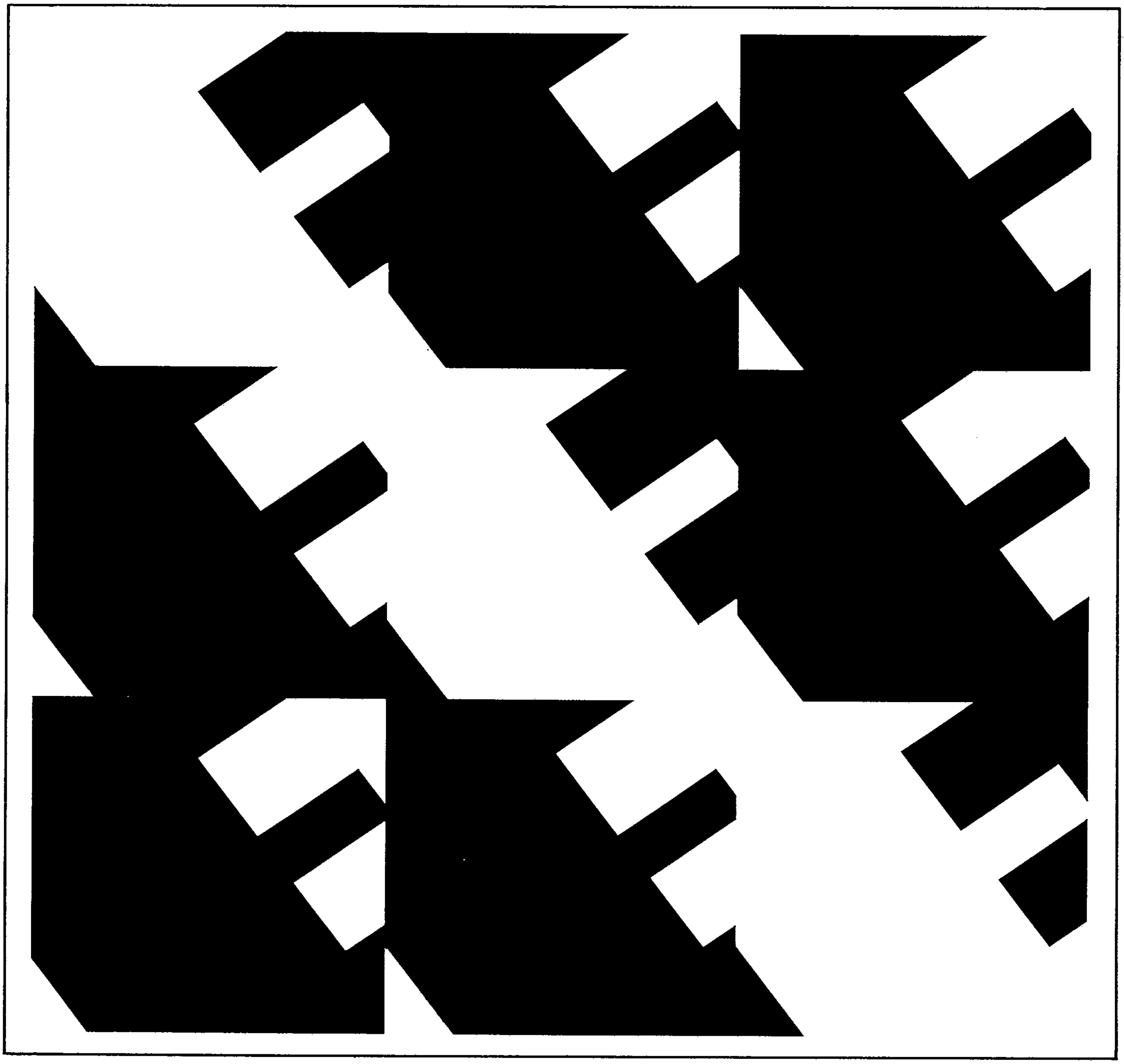
E-34-19

IEEE Std 323-1983
(Revision of IEEE
Std 323-1974)

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



IEEE Std 323-1983

Published by The Institute of Electrical and Electronics Engineers, Inc 345 East 47th Street, New York, New York 10017
September 30, 1983
SH09266

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

Sponsor

Nuclear Power Engineering Committee of the IEEE Power Engineering Society

The Institute of Electrical and Electronics Engineers, Inc
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Foreword

(This Foreword is not a part of IEEE Std 323-1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.)

The requirements for qualification of Class 1E equipment are included in the Code of Federal Regulations. Among them are the following:

(1) 10 CFR Part 50, Appendix B, Quality Assurance Criteria, III *Design Control.* This requires that design control measures be established and that such measures provide for verifying or checking the adequacy of design. One of the methods of design verification is *by the performance of a suitable testing program.*

(2) 10 CFR Part 50, Appendix B, Quality Assurance Criteria, XI *Test Control.* This requires that a test program be established and that testing be performed under suitable environmental conditions. These requirements, at least in part, can be met by suitable qualifications.

(3) 10 CFR Part 50.55 Codes and Standards, Protection System. This requires that the protection system meet the requirements set forth in ANSI/IEEE Std 279-1971 (R 1978), Criteria for Protection Systems for Nuclear Power Generating Stations, (see section 4.4).

Information pertinent to developing designs and their qualification requirements may be found in the above mentioned documents and in 10 CFR Part 50, Appendix A, General Design Criteria 1, 2, 4, and 23.

Qualification is addressed by other IEEE standards for nuclear power generating stations, for example: ANSI/IEEE Std 497-1981, Standard Criteria for Post Accident Monitoring Instrumentation for Nuclear Power Generating Stations, (see section 6.1.8), ANSI/IEEE Std 308-1980, Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, 5.9, and IEEE Std 603-1980, Criteria for Safety Systems for Nuclear Power Generating Stations, (see section 4.4).

This standard is written to serve as a general standard for qualification of all types of Class 1E equipment in nuclear power generating stations. Additional guidance for qualifying specific types of equipment may be found in various equipment qualification standards that are now available or being prepared. This standard gives generic requirements and methods for qualifying Class 1E equipment. Daughter standards may include unique test requirements or methods that are not specifically discussed in this standard, but that fall within the generic requirements of this standard. The unique requirements, determined by applicable experience for the equipment covered by daughter standards, should not be construed to apply to all equipment. For example, IEEE Project 572 for Class 1E connection assemblies discusses qualification methods such as generic qualification, pacing, and ongoing qualification. These methods are not specifically discussed in this standard, but do fall within its generic requirements.

Adherence to this standard may not assure public health and safety because it is the integrated performance of the structures, fluid systems, instrumentation systems, and electrical systems of the station that limits the consequence of accidents. Each user is responsible for assuring that this standard, if used, is pertinent to his application.

Class 1E equipment in nuclear power generating stations must meet its safety functional requirements throughout its installed life. This is accomplished by a thorough program of quality assurance, design, qualification, production, transportation, storage, installation, maintenance, periodic testing, and surveillance. This standard is for the qualification portion of the program.

The user should note that while this standard covers Class 1E equipment qualification, other documents such as ANSI/IEEE Std 279-1971 (R1978) and IEEE Std 603-1980 also require *system integrity*. Therefore, attention needs to be given to equipment performance specifications and interfaces to ensure their adequate performance in a system.

The nuclear power generating station safety analysis, in part, considers the station and its safety system design in terms of postulated service conditions including events such as submersion, hydrogen burn, radiation plate-out, etc. Inherent to each such analysis are two presumptions that must be evaluated. First, designs must be such that equipment can actually perform designated safety functions in postulated service environments. Second, in-service aging must not degrade Class 1E equipment to the point where it cannot perform designated safety functions when required.

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 in-service time and environment because of the special environmental stresses associated with some postulated service conditions included in the station safety analysis. Under these circumstances, common cause failure of redundant Class 1E equipment might occur just at the time its safety function(s) is required. It is the fundamental role of qualification to provide reasonable assurance, with due recognition given to the established technology, that design, manufacture, and age related common cause failures do not exist and that the design and manufacture are adequate to permit the equipment to perform its safety function(s) during postulated service conditions.

Synergistic effects and ionizing radiation dose-rate effects have become a concern within the industry. Preliminary results indicate that synergistic effects can be either positive or negative. Some limited work, Underwriters Laboratories (UL) and Sandia Laboratories, has been done, however, synergistic and ionizing radiation dose-rate effects remain the subject of research programs. Where known, such effects should be considered in developing a qualification program but are not, at this time, part of the requirements of this standard.

IEEE Std 323 was issued on a *Trial Use* basis in 1971 as the first of a series of qualification documents for electric equipment in nuclear power generating stations. It was revised and reissued as an IEEE standard in 1974. A supplement to the Foreword was issued in 1975. In late 1975 the ANSI/Nuclear Standards Management Board requested that a joint IEEE/ASME group prepare a general qualification document for electrical and mechanical equipment. This initiated IEEE Project 627. In 1977 a joint ASME/IEEE agreement established responsibility for qualification and quality assurance standards preparation. The agreement reaffirmed that IEEE (in conjunction with ASME) was to prepare a generic qualification standard. That document is IEEE Std 627-1980, Standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations. IEEE Std 323-1983 is the overall qualification standard for Class 1E equipment.

Electrical equipment qualified in accordance with either IEEE Std 323-1974 or IEEE Std 323-1983 will meet the requirements of IEEE Std 627-1980 which provides the basic principles for design qualification for all safety systems equipment for use in Nuclear Power Generating Stations. This revision to IEEE Std 323-1974 was made to clarify its requirements and imposes no additional requirements for qualifying Class 1E equipment.

This standard defines requirements that are adequate to qualify Class 1E equipment located in all areas of the Nuclear Power Generating Station including *harsh* and *mild* environmental areas. At this time, it appears that the seismic event is the only design basis event with potential for common cause failure in otherwise mild environments; however, other environmental service conditions may also be contributors.

The user of this standard should be aware that other methods to demonstrate qualification may be valid and more cost-effective than the above. Methodology should be reviewed at the time the qualification program is established to determine the most effective manner to demonstrate qualification.

The working group will continue to evaluate the results of on-going research and knowledge gained from operating experience.

This standard was prepared by Working Group 2.0 of Subcommittee 2 (Qualification) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society. The members of the working group were as follows:

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

1. Scope and Purpose

1.1 Scope. This standard describes the basic requirements for qualifying Class 1E equipment with interfaces that are to be used in nuclear power generating stations. The requirements presented include the principles, procedures, and methods of qualification. These qualification requirements, when met, will confirm the adequacy of the equipment design under normal, abnormal, design basis event, post design basis event, and in-service test conditions for the performance of safety function(s).

1.2 Purpose. The purpose of this standard is to identify requirements for the qualification of Class 1E equipment, including those interfaces whose failure could adversely affect the performance of Class 1E equipment and systems.

The methods described shall be used for qualifying equipment, extending qualification, and updating qualification if the equipment is modified. Other issued IEEE standards which present qualification methods for specific equipment or components, or both, and those that deal with parts of the qualification program, may be used to supplement this standard, as applicable.

2. References

[1] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms.[1]

[2] ANSI/IEEE Std 279-1971 (R1978), IEEE Standard Criteria for Protection Systems for Nuclear Power Generating Stations.

[3] ANSI/IEEE Std 308-1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

[4] ANSI/IEEE Std 338-1977, IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Safety Systems.

[5] ANSI/IEEE Std 344-1975 (R1980), IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

[6] ANSI/IEEE Std 497-1981, IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations.

[7] IEEE Std 603-1980, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.[2]

[8] IEEE Std 627-1980, IEEE Standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations.

3. Definitions

These definitions apply to key words as used in this standard only and which are not included in ANSI/IEEE Std 100-1977[1].[3]

aging. The effect of operational, environmental, and system conditions on equipment during a period of time up to, but not including design basis events, or the process of simulating these events.

[1] ANSI publications are available from the Sales Department, American National Standard Institute, 1430 Broadway, New York, NY 10018.

[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08854.

[3] The numbers in brackets correspond to the references listed in Section 2 of this standard.

components. Items from which the equipment is assembled, for example, resistors, capacitors, wires, connectors, transistors, tubes, switches, springs, etc.

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

NOTE: The life may be specified in calendar time. However, operating time, number of operating cycles or other performance interval, as appropriate, may be used to determine the time.

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

NOTE: Examples of equipment are motors, transformers, valve operators, and instrumentation and control devices.

harsh environment. An environment expected as the result of the postulated service conditions appropriate for the design basis and post-design basis accidents of the station.[4] Harsh environments are the result of a loss of cooling accident (LOCA)/high energy line break (HELB) inside containment and post-LOCA or HELB outside containment.

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.

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

mild environment. An environment expected as a result of normal service conditions and extremes (abnormal) in service conditions where seismic is the only design basis event (DBE) of consequence.

qualification. The generation and maintenance of evidence to ensure that the equipment will operate on demand to meet the system performance requirements.

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

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

[4] A design basis accident is that subset of a design basis event which requires safety function performance.

service conditions. Environmental, loading, power and signal conditons 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.

4. Introduction

It is required that Class 1E equipment [5], with its interfaces, meets or exceeds the specification requirements throughout its installed life. This is accomplished through a program that includes, but is not limited to, design control, qualification, production quality control, installation, maintenance, periodic testing, and surveillance. This standard deals with the qualification portion of the program.

It is the primary role of qualification to ensure that Class 1E equipment can perform its safety function(s) with no failure mechanism that could lead to common cause failures under postulated service conditions.

It is degradation with time (aging), followed by exposure to the environmental extremes of temperature, pressure, humidity, radiation, vibration, or chemical spray resulting from design basis events which presents a potential for causing common cause failures of Class 1E equipment. For this reason it is necessary to establish a qualified life for equipment with significant aging mechanisms unless aging is adequately addressed by periodic surveillance/maintenance. The qualified life determination shall be accomplished using the qualification methods described in the remainder of this standard. These methods include type testing, operating experience, analysis, or any combination thereof.

For equipment located in mild environments and which has no significant aging mechanisms, a qualified life is not required. This equipment shall be selected for application to the specific service conditions based on sound engineering practices and manufacturer's recommendations.

With regard to seismic testing of equipment located in mild environments, preaging prior to seismic tests is required only where significant aging mechanisms exist.

[5] Throughout this standard, qualification of *equipment* includes addressing its interfaces as part of the qualification program. When an interface includes components covered by ASME codes, adherence to the appropriate ASME code is outside the scope of this standard (see IEEE Std 627-1980[8].

For all qualification programs, the end result must be documentation that demonstrates the equipment's adequacy to perform its safety function(s). The documentation must be in a form that allows verification by competent personnel, other than the qualifiers, and shall contain, as appropriate, the equipment specification requirements, the applicable qualification methods, qualification plan, qualification data, justifications, and acceptance criteria.

5. Qualification Methods

Methods for qualifying equipment are listed below:

5.1 Type Testing. Type testing of equipment satisfies qualification if it accounts for significant aging mechanisms (see 6.2.1), subjects the equipment to specified service conditions, and demonstrates that such equipment can subsequently perform its intended safety function(s) for at least the required operating time.

5.2 Operating Experience. Data from equipment of similar generic design that has successfully operated under known service conditions may be used as the basis for qualifying other equipment to equal or less severe service conditions. The validity of this qualification method depends on the adequacy of documentation establishing the past service conditions, equipment performance, maintenance, and similarity between the equipment to be qualified and that for which the operating experience exists. Operating experience can provide information on limits of extrapolation, aging characteristics, failure modes, and failure rates.

5.3 Analysis. Qualification by analysis requires a logical assessment or a valid mathematical model of the equipment to be qualified. Qualification shall consist of quantitative analysis supported by test data, operating experience or physical laws of nature to demonstrate that the equipment can perform its safety function(s) under specified service conditions. Aging effects shall be considered.

The analysis, including logical bases and data used to support it, shall be presented in a step by step manner for one complete set of computations so a person reasonably skilled in the type of analysis used can follow the reasoning and computations.

5.4 Combined Methods. Equipment may be qualified by any combination(s) of type test, operating experience, and analysis. For example, where size, application, time or other limitations preclude the use of a type test on the complete equipment assembly, type testing of components supplemented by analysis may be used in the qualification process.

6. Qualification Procedures

6.1 Specification Requirements. The basis for qualification is a complete specification from which a qualification program can be formulated and implemented. For the purpose of qualification, the equipment specification, which contains the design performance requirements and provides the technical basis for the equipment, shall identify the safety function(s) and the service conditions during which the function(s) is required. As a minimum, the following items shall be included:

6.1.1 Equipment 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 (that is, physical attachments, mounting, auxiliary devices, connectors to the equipment at the equipment boundary) shall be specified for each operating mode. Motive power or control signal inputs and outputs, and the physical manner by which they are supplied (for example, connectors, terminals blocks) shall be specified. Control, indicating, and other auxiliary devices mounted internal or externally to the equipment and required for proper operation shall be included.

NOTE: Material incompatibilities at interfaces should be considered and evaluated.

6.1.3 Qualified Life Objective. Where applicable, the desired qualified life objective of the equipment shall be stated.

6.1.4 Safety Function(s). The equipment specification shall identify the equipment's safety function(s) which includes 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 shown, through a documented means such as an analysis that assumed failures, including spurious operation, to have no adverse effect on the stated safety function(s) or, by way of interfaces, on the safety function(s) of other equipment.

6.1.5 Service Conditions

6.1.5.1 **Normal and Abnormal Service Conditions.**[6] The service conditions for the equipment shall be specified. These shall include the nominal values and their expected durations, and the extremes and their expected durations. Examples include but are not limited to:

(1) Ambient pressure and temperature
(2) Relative humidity
(3) Radiation environment
(4) Seismic operating basis earthquake (OBE) and nonseismic vibration
(5) Operating cycles
(6) Electrical loading and signals
(7) Submergence.

6.1.5.2 **Design Basis Accident and Seismic Service Conditions.** The postulated service conditions for the design basis accidents and post design basis accidents and the seismic events during or after which the equipment is required to perform its safety function(s) shall be specified. The margin, if included, shall be identified.

The curves of Figs 1 and 2, Section 7, illustrate typical forms for the specification of some environmental parameters for a postulated high energy line break (HELB), loss of coolant accident (LOCA), and the post-LOCA events. The chemical composition and duration of in-containment spray, if applicable, shall also be specified.

For equipment with safety function times less than the duration of the event, qualification to the safety function time (based on system analysis) rather than event time is acceptable if such equipment is not subsequently applied to, and considered qualified for, longer times.

6.1.5.3 **Margin.** If the equipment specification identifies qualification margins as defined in Section 3, their values shall be stated.

6.2 Qualification Program Requirements. A qualification program plan shall be prepared based on the equipment specification. The qualification program consists of an equipment performance evaluation to demonstrate that the equipment can perform its specified safety function(s). As a minimum, the required elements of the program shall include:

6.2.1 **Aging Considerations.** The ability of Class 1E equipment to perform its safety function(s) might be affected by changes due to natural, operational, and environmental phenomena over time (aging). It is not the intent that age conditioning (see 6.3.3.2) be applied to all Class 1E equipment, but rather that the effect of aging be addressed.

The techniques available to address the effects of aging include testing, analysis, and in-service surveillance/maintenance. One of these techniques shall be selected based on an evaluation of the specific design and application of the equipment.

Equipment shall be reviewed in terms of design, function, materials, and environment for its specified application to identify potential aging mechanisms. An aging mechanism is significant if in the normal and abnormal service environment, it causes degradation during the installed life of the equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) under DBE conditions.

If the equipment is determined not to have significant aging mechanisms, then preconditioning prior to qualification testing is not required if the type test method is being employed.

If the equipment is determined to have a significant aging mechanism, then the mechanism shall be accounted for in the qualification program. If the qualification method is type testing, then preconditioning prior to qualification testing is required unless the effects of the significant aging mechanism can be accounted for by periodic inservice surveillance/maintenance. In the latter case, instead of qualified life, the periodic surveillance/maintenance interval becomes its operational limitation.

If age conditioning is required, a further determination shall be made as to whether accelerated aging techniques can be applied to the equipment and yield valid results that may be correlated to real time. It is acknowledged that the state-of-the-art regarding aging for some Class 1E equipment is more advanced than others. It is expected that established technology will be utilized in any aging program. Optionally (and particularly where the state-of-the-art is limiting), aging as part of the qualification program may be addressed by operating experience, analysis, or combined qualification.

6.2.2 **Qualified Life Objective.** Where applicable, a qualified life objective shall be determined consistent with the specification requirements, the anticipated capabilities of the

[6]NOTE: These conditions should be derived from the station environmental design basis.

equipment, and any limitations imposed by the specified aging program. Any components with a design life shorter than the equipment's qualified life objective shall be identified.

Periodic surveillance/maintenance, test and replacement/refurbishment recommendations based on documented data, combined with the equipment service conditions and application criteria may be used as the basis for establishing the qualified life objective or periodic surveillance/maintenance interval. (See ANSI/IEEE Std 338-1977 [4] for guidance on establishing and performing surveillance/maintenance.)

6.2.3 Margin. Margin is required in qualification test programs to account for reasonable uncertainties in demonstrating satisfactory performance and normal variations in commercial production, thereby providing assurance that the equipment can perform under the most adverse service condition specified. Increasing test parameter values, number of tests, transients, operability time, or test duration (but not necessarily all at the same time) are acceptable methods of ensuring that adequate margin does exist. If it can be demonstrated that sufficient margin exists in the equipment performance characteristics or in the specified service conditions, then additional margin need not be added.

6.2.4 Maintenance. Periodic maintenance/replacement required during the aging portion of the qualification program shall be identified.

6.2.5 Documentation. The qualification of the equipment shall be documented as specified in Section 8.

6.2.6 Qualification Method. The qualification method, selected from Section 5, shall be identified.

6.2.7 Acceptance Criteria. The value(s) of performance parameters to be used to demonstrate that the equipment can perform its safety function(s) shall be identified for applicable service conditions.

6.3 Type Testing

6.3.1 General. The type test shall demonstrate that the equipment performance meets or exceeds its safety function requirements. The type test conditions shall meet or exceed the specified service conditions. Margin shall be added if not included in the specified service conditions.

6.3.1.1 Test Plan. The test plan shall describe the required tests and provide an auditable link between the specifications and the test results. As a minimum, the following requirements shall be met:

(1) 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
(2) Listing of equipment safety function(s) to be demonstrated
(3) Mounting, connection, and other interface requirements
(4) Test sequence
(5) Aging conditioning procedure, if required
(6) The specified service conditions and margins or test levels
(7) Performance and environmental variables to be measured, including measurement accuracy
(8) Environmental, operating, and measurement sequence in detail including monitoring requirements
(9) Acceptance criteria
(10) Maintenance/replacement during aging, if required
(11) Provisions for control of modifications during tests
(12) Required documentation
(13) A description of any conditions peculiar to the equipment which are not listed but which would probably affect said equipment during testing.

6.3.1.2 Mounting. Equipment shall be mounted in a manner and a position that simulates its expected installation when in actual use unless an analysis can be performed and justified to show that the equipment's performance is not altered by other means of mounting. By manner is meant the means to be used such as bolts, rivets, welds, clamps, etc. By position is meant the spatial orientation with respect to the gravitational field of the earth. The effect of any interposing structures which are required for installation, such as control boards, stands, legs, pedestals, etc, shall be taken into account in the test mounting.

6.3.1.3 Connections. Equipment shall be connected in a manner that simulates its expected installation when in actual use unless an analysis can be performed to show that the equipment's ability to perform its safety function(s) would not be altered by other means of connection. By manner is meant the means such as wiring, connectors, cables, conduit, terminal blocks, service loops, piping, tubing, etc.

6.3.1.4 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, and mechanical characteristics, radiological features, and any auxiliary features such as the functions of any switches and feedback devices which provide input to other Class 1E equipment. Data acquisition equipment, as appropriate, shall be calibrated against standards traceable to nationally recognized standards and shall have documentation to support such calibration. Measurement intervals shall be chosen to obtain the time dependence of each parameter.

6.3.1.5 Margin. Margin shall be applied to the type test parameters for DBE testing. Specific equipment qualification standards provide guidelines on margin. However, for cases where no margins are given, the following suggested factors may be used. These are only suggested factors and should be reviewed for each application. In some cases, lesser values will be adequate while in others larger values may be necessary. In all cases, engineering judgment should be used to determine the adequacy.

(1) Peak temperature: + 15 °F (8 °C). When qualification testing is conducted under saturated steam conditions, the temperature margin shall be such that test pressure will not exceed saturated steam pressure corresponding to peak service temperature by more than 10 lbf/in^2.

(2) Peak pressure: + 10% of gage, but not more than 10 lbf/in^2, 7.03 (10^{-1})kg/cm^2, or at a gage pressure of 68.948 kPa

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

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

(5) Line frequency: ± 5% of rated value

(6) Equipment operating time: + 10% of the period of time the equipment is required to be operational following the start of the DBE

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

For environmental transients, two methods which may be used to apply margin are: (1) temperature and pressure margin may be added or (2) the peak transient without temperature and pressure margin may be applied twice. Combinations of these or other methods may also be used.

Margin may be positive or negative in accordance with what increases the severity of the test. For example, it will generally be necessary to increase temperature, while in the case of equipment supply voltage given as a nominal value, it may be necessary to use either increasing or decreasing values.

The margin factors suggested above are not meant to be applied to aging. Natural aging (see 6.3.3.1) by its nature, does not require margin. For age conditioning (see 6.3.3.2), use conservative practices in simulating aging effects; that is, age conditioning shall be performed on the basis of conservative estimates of service conditions and conservative accelerated aging techniques.

6.3.2 Test Sequence. The steps in type testing shall be run in a specified sequence appropriate to the postulated set of service conditions for each equipment application. 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 and applications, the following steps and sequence are acceptable. However, other steps and sequences are acceptable if justified. For example, all steps in the test sequence below need not be performed if it can be justified that one or more steps can be exempted and the remainder are adequate to verify qualification.

(1) Inspection shall be performed to identify the test sample and ensure that it has not been damaged due to handling since manufacture.

(2) The test sample shall be subjected to specified baseline functional tests under normal conditions.

(3) The test sample shall be operated to the extremes of all performance 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 (for example, design verification tests) on identical or similar equipment.

(4) When required, the test sample shall be put in a condition which simulates its expected end-of-qualified-life. Design basis event radiation may be included. Appropriate measurements should be made following aging to determine if the test sample is performing satisfactorily prior to subsequent testing.

Where it is practical and applicable, the functional capability should be demonstrated during the DBE radiation exposure unless it can be shown, by analysis or engineering judgement that the safety function(s) is not affected during the exposure to DBE radiation.

(5) The test sample shall be subjected to specified non-seismic mechanical vibration.

(6) The test sample shall be subjected to simulated operating basis earthquake (OBE) and safe shutdown earthquake (SSE) seismic vibration in accordance with ANSI/IEEE Std 344-1975 (R 1980)[5].

(7) For equipment located in harsh environments, the test sample shall perform its required safety function(s) while exposed to the simulated design basis accident. DBA radiation may be excluded if incorporated in (4). The functions which must be performed during the design basis accident shall be monitored.

(8) The test sample shall perform its required safety function(s) while exposed to the simulated post-DBA conditions as applicable. The functions which must be performed following the simulated design basis event shall be monitored during this post-DBE simulation.

(9) Post-test inspection. Record findings.

NOTE: The user of this standard should not infer that the sequence used implies a coupling among the various DBEs postulated for any given plant.

6.3.3 Aging. The assessment of equipment aging effects is required to determine if aging has a significant effect on operability. The types of aging include thermal, radiation, wear, and vibration. The assessment shall include an analysis of the equipment to determine any significant aging mechanisms for the DBEs under consideration. Where these mechanisms are identified, a suitable aging subprogram shall be included in the type test unless excluded in 6.2.1. When natural aging is used in the qualification program it is not necessary to identify significant aging mechanisms.

6.3.3.1 Natural Aging. Natural aging is the most technically justified method. Naturally aged equipment may be used for type testing provided that:

(1) The equipment has been aged in an environment at least as severe as the normal one for the intended application

(2) Operating and maintenance/replacement records are available to verify the service conditions

(3) The aged equipment was operated under load at least as severe as that specified for the equipment to be qualified.

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.

6.3.3.2 Age Conditioning. If naturally-aged equipment is not available with proper documentation and significant aging mechanism(s) have been identified, the equipment shall be age conditioned in the typetest program unless the effects of the significant aging mechanism can be accounted for by in-service surveillance/maintenance. Age conditioning is a process whereby the effects of significant aging mechanisms are simulated in the test sample. For example, electromechanical equipment shall be operated to simulate the expected mechanical wear and electrical contact degradation (that is, contact pitting) of the device to be type tested.

An accelerated cycle rate for the number required during the design life may be utilized provided the rate is not accelerated to any value which results in effects that are not present at normal rates.

Age conditioning generally involves applying simulated in-service stresses (for example, thermal, radiation, wear, and vibration) at magnitudes or rates that are greater than expected in-service levels but less than the material property limitations. These stresses may be applied sequentially.

6.3.4 Radiation. All material or components, which may be degraded to a degree which adversely affects performance of the equipment's safety function(s) by the radiation exposure expected to occur during normal service and postulated accidents, shall be irradiated to simulate this exposure. Radiation shall be applied as a part of the sequence of environments representative of service conditions. The equipment shall be subjected to the significant type of radiation equivalent to or greater than that expected in service. However, if more than one type of radiation is significant, each type can be applied separately. With an accelerated exposure rate, a greater total dose than the service lifetime dose may be needed to simulate long-term effects.

If it can be shown that the combined normal and accident radiation dose and dose rate do not affect the safety function(s) and there are no adverse affects if radiation is done sequentially, either before or after thermal or wear cycling, then radiation testing may be excluded. If it can be shown that the radiation effect is restricted to the heating effects of energy absorption, the effect may be taken into account during accelerated thermal aging.

A gamma radiation source may be used to simulate the expected effects of the radiation environment.

6.3.5 Seismic and Nonseismic Vibration. The equipment shall be qualified for expected seismic events in accordance with ANSI/IEEE Std 344-1975 (R 1980)[5] following any required aging. Equipment subject to nonseismic vibration which produces significant effects (fatigue, wear) during normal and abnormal use shall be subjected to vibration testing prior to the seismic tests. Vibration to be simulated includes self-induced vibration or vibration from piping. Other vibration such as hydrodynamic loadings may be simulated, where applicable, and may be included with the seismic qualification.

6.3.6 Operation Under Normal and DBE Conditions. It shall be demonstrated that equipment can adequately perform its safety function(s) under all applicable service conditions (that is, where practical, the test sample shall be electrically energized and exposed to simulated environmental conditions during DBE testing).

6.3.7 Inspection. Upon completion of type testing, the equipment shall be visually inspected and a description of its physical condition included in the qualification documentation.

6.4 Operating Experience

6.4.1 General. Portions or all of an equipment qualification program may be satisfied by documented operating experience. Equipment can be considered qualified if the same or similar equipment has functioned successfully under service conditions that are more severe than those postulated for the new application. 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 conditions plus appropriate DBE margin. Any differences shall be justified.

If the equipment used as a basis for qualification by operating experience has not been subjected to the full range of postulated service conditions which are significant and not qualified by analysis, it shall be removed from service and tested so as to evaluate its capabilities under these conditions. Subsequently, it shall not be returned to safety service if it has been subjected to conditions which exceeded those due to normal or abnormal operating requirements (non-DBE conditions). Any modifications to the equipment shall conform to the restrictions of 6.8.

The safety function(s) shall be demonstrated by testing, analysis of past performance, or both. Documentation shall include measurement or determination of performance characteristics required in the equipment qualification program, 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 also be included.

The documentation shall include physical locations and mounting arrangements of the equipment in the operating facilities.

6.4.2 Operating History. The auditable data to be used to establish the equipment qualification shall consist of the following:

(1) Justification that the equipment with operating experience is the same as or similar to the equipment to be qualified. Alternatively, analysis or tests shall be performed to demonstrate that the differences between the two do not affect the ability of the equipment being qualified to perform its safety function(s).

(2) A record or auditable data showing that equipment similar to that being qualified has been exposed to levels of environment at least as severe as those expected from all service conditions for which the equipment being qualified is required to function and that the equipment satisfactorily performed the function(s) required of the equipment being qualified. Those elements of required exposure not covered by operating history may be accounted for by testing.

6.4.3 Determination of Qualification. Operating experience may be the basis for all qualification when the qualification documentation includes auditable data demonstrating the equipment has satisfactorily performed its safety function(s) during conditions at least as severe as the specified service conditions plus appropriate margin. The qualified life determined shall not exceed the amount of time the equipment operated under normal and abnormal service condition levels prior to the occurrence of an actual or simulated design basis event.

6.5 Analysis

6.5.1 General. Qualification by analysis shall consist of a mathematical or logical assessment to establish that the equipment to be qualified can perform its safety function(s) when subjected to the specified service conditions. This assessment may be based exclusively on quantitative analysis; however, analytical techniques may be limited and analysis supplemented by test data or operating experience may be needed in a qualification program. Justification is required for the technique used.

6.5.2 Mathematical Modeling. Quantitative analysis may be used to qualify the equipment by construction of a valid mathematical model to demonstrate that the equipment can perform its safety function(s) under actual service conditions. Such an analysis shall account for all time dependent environmental parameters originating from the qualification criteria.

6.5.3 Extrapolation and Interpolation. Extrapolation and interpolation are analytical techniques which may be used to qualify equipment by extending the application of test data. Two types of extrapolation and interpolation are possible:

(1) Extrapolation or interpolation of successful performance at a specific service condition to a different service condition.

(2) 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 are met:

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

6.5.3.2 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.

6.5.3.3 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 the safety function(s).

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

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

6.5.3.6 Function. The safety function(s) as evaluated shall be the same (for example, activate to operate or de-activate to operate).

6.5.4 Determination of Qualification. The equipment shall be considered qualified through demonstration that its performance meets or exceeds that required under the specified service conditions during its qualified life or that the operation limitations of periodic inspection or surveillance have been identified.

6.6 Combined Qualification. Equipment may be qualified by a combination of test, analysis, or previous operating experience. Combined qualification shall be developed on a case-by-case basis applying the procedures of the foregoing sections. The qualification shall provide auditable data by which the combined methods can be shown to constitute a complete qualification program.

6.7 Acceptance Criteria. In the evaluation of the qualification-program results, the equipment is considered to have passed when it meets the requirements of 6.2.7. Acceptance criteria shall be defined so that all failures to perform the specified safety function(s) for the service conditions for which the equipment is being qualified can be identified. Any failure to meet the acceptance criteria shall be analyzed to determine the modification of the equipment or the limitation that shall be imposed on its use. Failures shall be documented as described in 8.1.

Any failures or abnormalities occurring during testing shall be documented according to their cause and the overall effects on the equipment's qualification. If the failure or abnormality is completely spurious (not induced by the qualification test) or due to a deficiency in the test equipment (that is subsequently eliminated) corrective action is not required. However, if the failure is induced by the test or due to a cause that affected or potentially could affect multiple components operating in redundancy (such as a design deficiency), the document shall indicate the corrective actions required (material change or replacement schedule) and all or portions of the test may have to be repeated, depending on the significance of the test deficiency.

6.8 Modifications. Any modification to the equipment or to the qualification bases 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, or postulated service conditions.

If the evaluation concludes that additional qualification steps are not required, the evaluation, including supporting information, shall be added to the qualification documentation. Otherwise, the indicated additional qualification steps shall be conducted and documented.

6.9 Extension of Qualified Life. There are several methods of extending qualified life which include age conditioning, natural aging, or surveillance/maintenance as described below. These methods may be employed in situations where significant aging mechanisms have been identified and the established qualified life is less than the anticipated installed life or where periodic surveillance/maintenance provides a basis for mild environment qualification.

(1) The qualified life of a piece of equipment may be extended by type testing a piece of equipment of the same or similar design and construction which has been age conditioned for a period equivalent to a longer time than the qualified life of the installed equipment. This process may be repeated as required to extend the qualified life to equal the anticipated installed life.

(2) The qualified life of a piece of equipment may be extended by type testing a piece of equipment of the same or similar design and construction which has been naturally aged in an environment equal to or more severe than the non-DBE service conditions for the intended application. The qualified life will be extended by the amount of time that the period of natural aging exceeds the initially established qualified life.

(3) The qualified life of a piece of equipment may be extended by testing a piece of equipment of the same or similar design and construction which has undergone a combination of natural aging and age conditioning for a period equivalent to a longer time than the qualified life of the installed equipment. The natural aging and age conditioning may be done in any order.

(4) Periodic surveillance/maintenance, testing, and replacement/refurbishment programs based on manufacturers' recommendations and sound engineering practices may be used to extend the equipment's qualified life, where justified.

(5) If it can be shown that the evaluation in the original qualification program was conservative with respect to the equipment's specified service conditions and performance specifications, then the original qualification program may be re-evaluated with the objective of increasing the qualified life.

(6) Qualified life may be extended if it can be shown through subsequently developed data that an age-conditioning procedure, which limited the qualified life of Class 1E equipment, is in fact conservative. To be acceptable for extending qualified life, the subsequently developed data shall contain quantitative evidence justifying the extended qualified life.

(7) Qualified life may be extended if it can be shown that the service or environmental conditions originally assumed were overly conservative with respect to those that apply at the equipment's locations, in its installed configuration.

The use of extension methods requires documentation of the program to be followed and auditable records of the results.

7. Simulated Test Profiles

The user shall furnish sufficient environmental data to allow the simulation of the postulated environmental service conditions profile for the equipment being qualified. To this shall be added margins to derive the appropriate simulated service condition test profile (Figs 1 and 2). Although only typical, Figs 1 and 2 show two acceptable methods of including margin in LOCA/HELB profiles for many equipment locations.

It should be recognized, however, that other possibilities exist to address margin in the test profile. Accelerated thermal testing may be used to simulate the temperature/time profile following the major temperature transients.

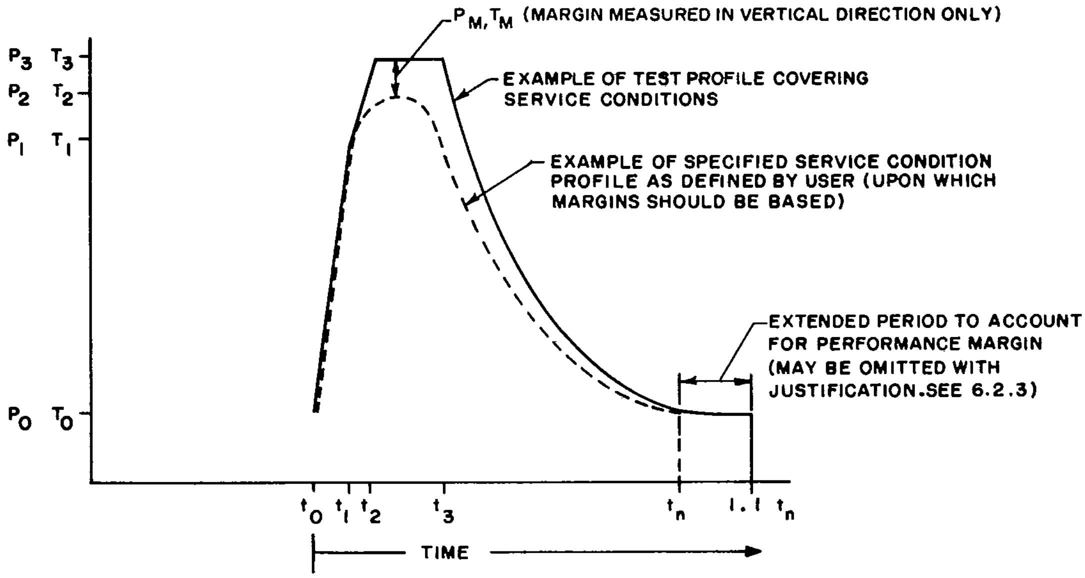

Fig 1
Typical LOCA/HELB Temperature and Pressure Illustrating Application of Time, Temperature, and Pressure Margins

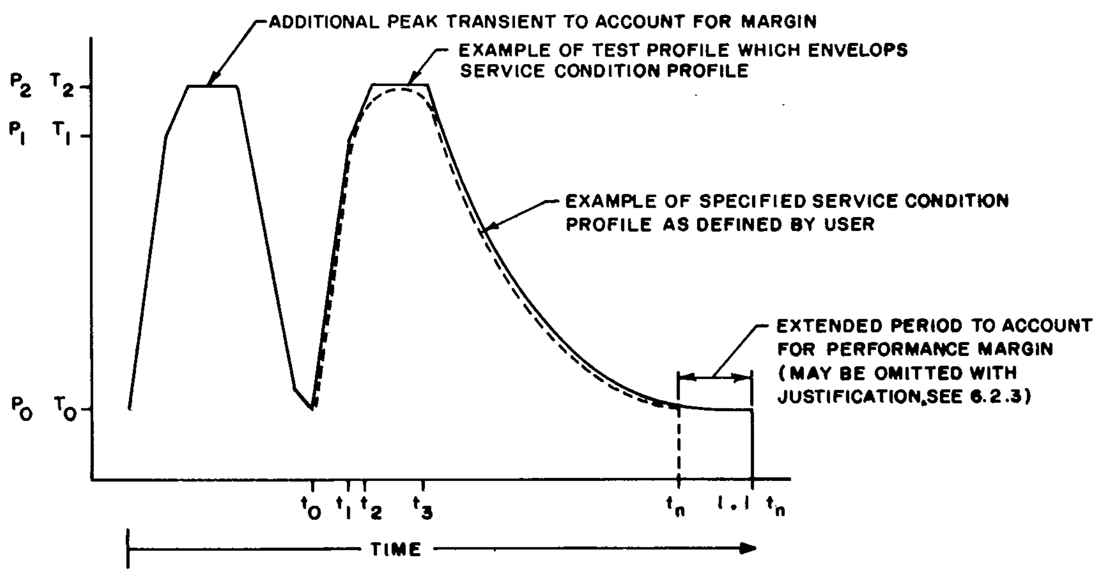

Fig 2
Typical LOCA/HELB Temperature and Pressure Illustrating Additional Peak Transient to Account for Margin

8. Documentation

8.1 General. 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 or periodic surveillance/maintenance interval established. Data used to demonstrate the qualification of the equipment shall be pertinent to the application and be organized in a readily understandable and traceable manner that permits independent auditing of the conclusion presented.

8.2 Documentation Files. The user shall maintain a qualification file (not necessarily at the plant site). The file shall contain, as appropriate, information as listed in 8.3, 8.4, 8.5, and 8.6 depending upon the qualification method used.

8.3 Type Test Data

(1) Identification of the equipment qualified

(2) The equipment specification (see 6.1)

(3) The qualification program (see 6.2)

(4) Identification of any scheduled surveillance/maintenance, periodic testing, and any parts replacement required to maintain qualification

(5) Identification of safety function(s) to be demonstrated by test data

(6) Test plan (see 6.3.1.1)

(7) The report of test results shall include:

(a) Test objective

(b) Detailed description of test sample

(c) Description of test setup, instrumentation and calibration data

(d) Test procedure

(e) Summary of test data, accuracy, and anomalies.

(8) Summary and conclusions, including limitations and qualifed life or periodic surveillance/maintenance interval determination

(9) Approval signature and date.

8.4 Operating Experience Data

(1) Identification of equipment qualified

(2) The equipment specification (see 6.1)

(3) The qualification program (see 6.2)

(4) Identification of any scheduled surveillance/maintenance, periodic testing, and any parts replacement required to maintain qualification

(5) Identification of the safety function(s) to be demonstrated by operating experience

(6) The specification of the equipment for which operating experience is available

(7) Comparison of specfications and functions of equipment with operating experience and new equipment to be qualified

(8) Summary of operating experience data, including service conditions, maintenance records, operating history, etc.

(9) Conclusions, including limitations and qualified life or periodic surveillance/maintenance interval determination

(10) Approval signature and date.

8.5 Analysis

(1) Identification of the equipment qualified

(2) The equipment specification (see 6.1)

(3) The qualification program (see 6.2)

(4) Identification of any scheduled surveillance/maintenance, periodic testing, and any parts replacement required to maintain qualification.

(5) The specific safety function(s), postulated failure modes, or the failure effects to be demonstrated by analysis

(6) Description of analytical methods, computer program or mathematical model used, and the method of verification

(7) The assumptions and empirically derived values used, with appropriate justification

(8) Summary of analytically established performance characteristics and their acceptability

(9) Conclusions, including limitations and qualified life or periodic surveillance/maintenance interval determination

(10) Approval signature and date.

8.6 Equipment for Mild Environment

(1) Identification of the equipment qualified

(2) The equipment specification (see 6.1)

(3) Identification of any scheduled surveillance/maintenance, periodic testing, and any parts replacement required to maintain qualification

(4) Identification of the equipment's safety function(s)

(5) Certificate of compliance that the equipment supplied meets the requirements of the equipment specification with approval signature and date.

8.7 Combined Qualification. When combined qualification is used, the documentation files shall contain the applicable data of the methods specified in 8.3, 8.4, 8.5, and 8.6.

8.8 Extrapolation. Where the test data or operating experience data have been extrapolated or interpolated, the bases shall be included.

IEEE Standards of Particular Interest to Nuclear Engineers and Scientists

IEEE Std	Title
279-1971	Criteria for Protection Systems for Nuclear Power Generating Stations (ANSI/IEEE) (Reaff 1978)
300-1982	Test Procedure for Semiconductor Charged-Particle Detectors (ANSI/IEEE)
301-1976	Test Procedure for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation (ANSI/IEEE) (Reaff 1982)
308-1980	Criteria for Class 1E Power Systems for Nuclear Power Generating Stations (Revision of IEEE Std 308-1978) (ANSI/IEEE)
309-1970	Test Procedure for Geiger-Muller Counters (ANSI/IEEE) (Reaff 1980)
317-1983	Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations
323-1983	Qualifying Class 1E Equipment for Nuclear Power Generating Stations
325-1971	Test Procedure for Germanium Gamma-Ray Detectors (ANSI/IEEE) (Reaff 1982)
334-1974	Standard for Type Test of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations (ANSI/IEEE) (Reaff 1980)
336-1980	Installation, Inspection, and Testing Requirements for Class 1E Instrumentation and Electric Equipment at Nuclear Power Generating Stations (ANSI/IEEE)
338-1977	Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Class 1E Power and Protection Systems (ANSI/IEEE)
344-1975	Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (ANSI/IEEE) (Reaff 1980)
352-1975	Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems (ANSI/IEEE) (Reaff 1980)
379-1977	Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Class 1E Systems (ANSI/IEEE)
381-1977	Standard Criteria for Type Tests of Class 1 Modules Used in Nuclear Power Generating Stations
382-1980	Standard for Qualification of Safety-Related Valve Actuators (Revision of IEEE Std 382-1972)
383-1974	Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Station (ANSI/IEEE) (Reaff 1980)
384-1981	Standard Criteria for Independence of Class 1E Equipment and Circuits (Revision of IEEE Std 384-1977) (ANSI/IEEE)
387-1983	Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations (IEEE) (Revision of ANSI/IEEE Std 387-1977)
398-1972	Test Procedures for Photomultipliers for Scintillation Counting and Glossary for Scintillation Counting Field (ANSI/IEEE) (Reaff 1982)
420-1982	Standard for the Design and Qualification of Class 1E Control Boards, Panels and Racks Used in Nuclear Power Generating Stations
450-1980	Recommended Practice for Large Lead Storage Batteries for Generating Stations and Substations (ANSI/IEEE)
467-1980	Standard Quality Assurance Program Requirements for the Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations

(Continued on the back page of the standard)

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IEEE Std	Title
484-1981	Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations (Revision of ANSI/IEEE Std 484-1975)
494-1974	Standard Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations (ANSI/IEEE)
497-1981	Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations (ANSI/IEEE)
498-1980	Standard Requirements for the Calibration and Control of Measuring and Test Equipment Used in the Construction and Maintenance of Nuclear Power Generating Stations
500-1977	Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability Data for Nuclear-Power Generating Stations
535-1979	Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations (ANSI/IEEE)
566-1977	Recommended Practice for the Design of Display and Control Facilities for Central Control Rooms of Nuclear Power Generating Stations
567	Trial-Use Standard Criteria for the Design of the Control Room Complex for a Nuclear Power Generating Station (ANSI/IEEE)
577-1976	Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations (ANSI/IEEE)
600	Trial-Use Standard Requirements for Organizations that Conduct Qualification Testing of Safety Systems Equipment for Use in Nuclear Power Generating Stations
603-1980	Standard Criteria for Safety Systems for Nuclear Power Generating Stations (Revision of IEEE Std 603-1977)
622-1979	Recommended Practice for the Design and Installation of Electric Pipe Heating Systems for Nuclear Power Generating Stations (ANSI/IEEE)
627-1980	Standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations
649-1980	Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations
650-1979	Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations (ANSI/IEEE)
749-1983	Standard Periodic Testing of Diesel-Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations
765-1983	Standard for Preferred Power Supply for Nuclear Power Generating Stations
7-4.3.2-1982	Application Criteria for Programmable Digital Computer Systems in Safety Systems of Nuclear Power Generating Stations (ANSI/IEEE-ANS)
ANSI N13.4-1971	Specifications of Portable X- or Gamma-Radiation Survey Instruments (Reaff 1977)
ANSI N42.4-1971	High Voltage Connectors for Nuclear Instruments (Reaff 1978)
ANSI N42.5-1965	Bases for GM Counter Tubes (Reaffirmed 1977)
ANSI N42.6-1980	Interrelationship of Quartz-Fiber Electrometer Type Exposure Meters and Companion Exposure Meter Charges
ANSI N42.12-1980	Calibration and Usage of Sodium Iodide Detector Systems
ANSI N42.15-1980	Performance Verification of Liquid-Scintillation Counting Systems
ANSI N42.18-1980	Specification and Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents (Reaff and redesignation of ANSI N13.10-1974)
ANSI N317-1980	Performance Criteria for Instrumentation used for Inplant Plutonium Monitoring
ANSI N320-1979	Performance Specifications for Reeactor Emergency Radiological Monitoring Instrumentation