3D Methodology for Qualifying Safety-Related Electrical and Mechanical Equipment

3D.1 Purpose

The purpose of this appendix is to describe the U.S. EPR environmental qualification (EQ) program for qualifying electrical equipment (See Section 3D.4) and mechanical equipment (See Section 3D.6.2.3) in accordance with the applicable requirements. In addition, the qualification of electrical and mechanical equipment is also addressed in Sections 3.11 and 3.10, respectively.

Mechanical and electrical equipment covered by this section includes equipment associated with systems that are essential to emergency reactor shutdown; containment isolation; core cooling and containment; and reactor heat removal, or are otherwise essential to preventing significant release of radioactive material to the environment.

Included in this equipment scope is:

- Equipment that performs these functions automatically.
- Equipment that is used by the operators to perform these functions manually.
- Equipment whose failure can prevent the satisfactory accomplishment of one or more of the above safety functions.
- Safety-related and important to safety electrical equipment, including instrumentation and controls (I&C), as described in 10 CFR 50.49 (b)(1) and (b)(2).
- Certain post-accident monitoring equipment as described in 10 CFR 50.49(b)(3).

3D.2 Scope

This appendix presents the methods and procedures for qualifying electrical and mechanical equipment to a range of environments to which the equipment could be exposed during plant operation or design basis events (DBE).

3D.3 Introduction

This section provides background for the U.S. EPR equipment qualification program and presents a summary of the program objectives, a program outline, and definitions for terms used in this document. Section 3D.4 identifies qualification criteria. Section 3D.5 presents design specifications. Section 3D.6 presents the equipment qualification methods, which includes: type-testing, analyses, operating experience, a combination of methods, and supplemental methods to aid qualification. Sections 3D.7 and 3D.8 describe the documentation, including data packages, test

reports, and maintenance records, needed to support the equipment qualification program.

3D.4 Qualification Criteria

General Design Criteria 1, 2, 4, and 23 of 10 CFR 50, Appendix A; Quality Assurance Criteria III, XI, and XVII of 10 CFR 50, Appendix B; and 10 CFR 50.49 establish the regulatory requirements for this program.

3D.4.1 Qualification Guides

The following documents are used in the equipment qualification process:

- NUREG-0588 (Category 1 guidance if relevant guidance is not provided in Regulatory Guide 1.89).
- Section 3.11 provides a list of IEEE standards and Regulatory Guides that are used in the equipment qualification process.

3D.4.2 Definitions

The definitions of the terms used in this section are as follows.

1. Abnormal conditions—Possible plant service conditions that lead to short-term changes in environments at various equipment locations. The assumed duration of the abnormal conditions are consistent with operating practices and the technical specification limits.
2. Age conditioning—Exposure of sample equipment to environmental, operational, and system conditions to simulate these conditions for a period of time; DBEs are not included.
3. Aging—The effect of operational, environmental, and system conditions on equipment during a period of time up to, but not including, DBEs, or the process of simulating these events.
4. Common mode failure—Multiple failures attributable to a common cause.
5. Containment—That portion of the engineered safety features designed to act as the principal barrier, after the reactor coolant system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive material beyond a controlled zone.
6. Design basis event—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.
7. Design life—The time during which satisfactory performance can be expected for a specific set of service conditions. (The life may be specified in calendar time,

operating time, number of operating cycles, or other performance interval, as appropriate).

8. Environmental qualification specification—A document that prescribes, in a complete, precise, and verifiable manner, the environmental qualification requirements that must be met to verify that the equipment will operate on demand to meet the system performance requirements.

9. Equipment qualification—The generation and maintenance of evidence to determine that the equipment will operate on demand, to meet the system performance requirements.

10. Equipment specification—A document that prescribes, in a complete, precise, and verifiable manner, the requirements, design, behavior, or characteristics of a system or system component.

11. Equipment supports—Any structure whose primary function is structural integrity (e.g., cabinets, panels, consoles, or instrument racks).

12. Installed life—The interval from installation to removal, during which the equipment or component thereof may be subject to design service conditions and demands. Equipment may have an installed life equal to the plant design life, even though certain components may be changed periodically. Thus, the installed life of the changed components would be less than the plant design life.

13. Margin—The difference between service conditions and the conditions used for equipment qualification.

14. Module—Any assembly of interconnected components that constitutes an identifiable device, instrument, or piece of equipment. A module can be disconnected, removed as a unit, and replaced with a spare. It has definable performance characteristics that permit it to be tested as a unit. A module could be a card, a drawout circuit breaker, or other subassembly of a larger device, provided it meets the requirements of this definition.

15. Period of operability—The amount of time after an accident that the plant safety analysis requires equipment be available to perform its safety function.

16. Qualified life—The period of time for which a satisfactory performance can be demonstrated for a specific set of service conditions.

17. Random failure—Any failure whose cause or mechanism makes its time of occurrence unpredictable.

18. Safety function—One of the processes or conditions (e.g., emergency negative reactivity insertion, postaccident heat removal, emergency core cooling, postaccident radioactivity removal, containment isolation) that are essential to maintain plant parameters within acceptable limits for a DBE. A safety function is achieved by the completion of required protective actions by the reactor trip

system or the engineered safety features concurrent with the completion of required protective actions by the auxiliary supporting features, or both.

19. Service conditions—Environmental, loading, power, and signal conditions expected as a result of normal operating requirements, expected extremes (abnormal) in operating requirements, and postulated conditions appropriate for the DBEs of the station.

3D.4.3 Mild versus Harsh Environments

Section 3.11.1.2 provides a description of mild and harsh environments.

3D.4.4 Test Sequence

Type testing is generally done in the following sequence:

1. Inspections identify the test sample and verify that it is not damaged.

2. Specified baseline functional tests are performed on the test sample under normal conditions.

3. The test sample is operated to the extremes of performance, operating environments, surge voltages, and electrical characteristics in the equipment specifications, unless these data are available from other tests (e.g., design verification tests) on identical or similar equipment. These tests exclude DBE and post-DBE conditions. Electromagnetic interference (EMI) and radio frequency interference (RFI) susceptibility are a service condition for electromagnetic compatibility (EMC) as addressed in Table 3.11-1.

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

5. The test sample is subjected to specified non-seismic mechanical vibration.

6. The test sample is subjected to simulated OBE and SSE seismic vibration in accordance with IEEE Std 344-2004[1].

7. The test sample performs its required safety function(s) while exposed to simulated accident conditions, including conditions following the accident for the period of required equipment operability, as applicable. Accident radiation may have been included in Step 4 and need not be repeated here. Safety function performance, which can be different in different stages of an accident, is monitored during the testing.

8. Post-test inspection is performed on the test sample and findings are recorded.

Loss of coolant accident (LOCA) and steam line break (SLB) testing will normally be a single steam and spray test preceded by exposure to radiation. Analysis will be used to identify the LOCA and SLB service conditions required for testing.

The steps in the test sequence are performed on the same test sample, except as allowed under Step 3.

3D.4.5 Aging

Age conditioning is a process of controlled physical deterioration that provides a qualitative evaluation of the equipment's vulnerability to aging effects that may affect its ability to perform its safety functions. Age conditioning stresses are intended to produce equipment degradation levels that equal or exceed the expected inservice degradation. Age conditioning addresses the effects of temperature, humidity, pressure, radiation, vibration, chemical atmosphere, power supply, monitored processes, and operational cycles as follows:

- Temperature generally affects aging by determining the rate of the chemical reactions that deteriorate the materials, as described by the Arrhenius equation:

  $\text{Ln } t = E_A/(kT) + C$

  Where:

  t = time to failure

  T = temperature, °Kelvin

  k = Boltzman's constant

  E_A = activation energy

  C = scaling constant

  When Ln t is plotted against the inverse of temperature, the slope of the resultant straight line is a measure of the activation energy, E_A, for the unit being tested. Extrapolation of this line will result in sets of times and temperatures that may be used to accelerate the chemical reactions in order to simulate aging. A more complete discussion of the basis for and use of this method of thermal aging are found in IEEE Std 101-87. This method is widely used for insulating materials, resistors, and semiconductors.

- Humidity can cause component failure by corrosion or metallic migration (i.e., dendritic growth). Conditioning at elevated relative humidity levels may be used to simulate these effects because published data indicate that moisture induced failures occur early in the component's life.

- When the vibration levels seen in normal service may affect performance, vibration conditioning is conducted by additional seismic testing after an exploratory resonance search but before OBE testing. The additional testing typically may consist of 90 minutes of sinusoidal vibration in each orientation at 5 to 100 Hz (linear sweep). Vibration levels are one-half the OBE level but do not exceed 0.025 in double amplitude, as detailed in IEEE Std 382-2006.

- Chemical atmosphere corrosion effects depend largely on the concentration of the chemicals. For conditioning, increased concentrations of chemicals may be used to achieve the anticipated levels of degradation.

- Test specimens may be irradiated to the total integrated dose expected during the qualified life (QL). Otherwise, suitable justification is provided to demonstrate that radiation effects are negligible. For conservative purposes, the accident radiation dose may be added to the aging dose.

- Effects of loss of power may be simulated by subjecting the test specimen to the number of on and off cycles anticipated in service. In some cases, increased voltage levels may also be applied to promote degradation.

- Operational cycling effects may be simulated by subjecting the test specimen to the number of cycles anticipated in service. The cycling exercises electromechanical components (e.g., switches, relays) whose failure could affect the safety function performance.

- Process effects on modules are both steady state and cyclic.

Other methods of age conditioning are detailed in the specific equipment qualification data package (EQDP).

The basis for implementing the above conditioning methods consists of at least one of the following approaches:

- Component Approach—Each component of the module is conditioned separately and then the module is assembled. Justifying this approach requires showing that each component's significant aging mechanisms are not amplified or accelerated by the surrounding components, and that no significant aging mechanism involves more than one component at a time.

- Critical Component Approach—The module is examined for a component with a clearly dominant age-related failure mode at the various service conditions to which the module will be subjected. The conditioning determined for the critical component will be applied to the entire assembled module. The critical component selection will be supported by handbooks, vendor test results, literature on test results of similar components, or testing samples at the various environmental levels required. The requirements to justify this approach include a determination of the amount of conditioning given to the balance of the components.

- Split-Phase Approach—Components are individually conditioned with respect to significant aging mechanisms and at acceleration rates and durations applicable to each component. This is done in "Phase I" so that each component reaches a prespecified apparent advanced age, which varies from component to component. These individual ages are selected so that when the components are assembled into the module at the end of Phase I and further advanced conditioning is done on the module itself, the components in the module arrive at the desired advanced life condition.

- Module Level Approach—The entire module is conditioned to a point where some of the components are conditioned to the end of QL and the remainder is conditioned to a point of known or estimated life.

3D.4.5.1 Design Life

Equipment in mild environment locations is expected to perform satisfactorily during the design life for the specified set of mild environmental service conditions. The design life of equipment is obtained from manufacturer's literature. Surveillance or trending programs also assist in verifying the design life or the need for re-evaluation.

3D.4.5.2 Shelf Life

The equipment and material controlled storage program complies with the requirements of 10 CFR 50, Appendix B. This program verifies that equipment is handled and stored in accordance with the manufacturer's or vendor's recommendations, the engineering requirements, or general industry practices. In addition, the shelf life of non-metallic materials is considered and used in specifying the maximum allowable time a component or material can be stored. Materials are removed and replaced when they reach their established shelf life.

3D.4.5.3 Qualified Life

Methods used to establish the QL for equipment include:

- Analyzing available qualification test data for actual or similar equipment to support a conservative equivalent life.

- Contacting manufacturers and vendors to obtain bills of material and technical data that identify age sensitive materials.

- Review and engineering evaluation of industry references and technical literature to determine material radiation threshold or thermal withstand capabilities.

- Performing engineering analyses to establish QLs and justifiable replacement schedules.

The calculations, assumptions, technical data, and references used to establish QLs are incorporated into the qualification documentation file for the equipment. The results

of these evaluations and analyses are also incorporated into the plant maintenance and surveillance programs to preserve the qualification of the equipment.

When no aging mechanisms have been found, a QL equal to the plant life is assigned. When similarity is used, a QL is assigned equal to the age-conditioned similar unit. When natural aging is used, the QL does not exceed the actual age of the unit. When age conditioning is used, the QL is based on conservative engineering analysis, which takes into account, as available and applicable, the following:

- Results of age conditioning.
- Equipment operating data.
- Existing test results.
- Reliability data.
- Physical understanding of the significant aging mechanisms that have been identified.
- Equipment's expected in-service duty cycle.
- Estimated rate of aging, based on the results of the conditioning process.
- Expected in-service maintenance procedure and schedules.

The QL is expressed in the most meaningful terms for the particular application, and the justification of the means used to estimate the QL is provided in the qualification documentation.

3D.4.5.4 Qualified Life Reevaluation

If the original QL of certain equipment is less than the plant design life, methods are developed which can extend the QL to meet the plant design life. This may be a replacement program, additional testing, further analysis of operating experience, or other demonstration that the equipment can perform its safety function for an additional specified period of time. Modules are usually replaced when they have components with a QL that limits the overall equipment QL, or when experience determines that the chance of successful extension is low.

Additional testing is used when the original demonstrated QL is limited by the state-of-the-art aging techniques, and experience determines that the equipment has a high probability of successful life extension. Retests are done on either a sample that is age conditioned by more advanced techniques to a longer life, or by age conditioning a natural aged sample to demonstrate a QL equal to the sum of the conditioned age and natural age. This latter approach may be repeated to further extend the QL.

Analysis may be performed when physically measurable parameters are identified that accurately reflect the state of deterioration. Periodic examination of these parameters may yield a more accurate determination of the actual aging rate, with a correspondingly more accurate evaluation of the QL when the revised rates are factored into the analysis.

Other methods for extension of QL may be used if they meet the requirement of demonstrating that the equipment will perform its safety functions for an additional specific period of time.

3D.4.6 Operability Time

Equipment required to be environmentally qualified has one or more of the following safety functions: reactor trip, engineered safeguards actuation, postaccident monitoring, or containment isolation. For each safety function, a period of operability is assigned that ranges from two hours to one year. These operability designations and durations are summarized in Table 3D-2—Equipment Post-Accident Operability Times.

3D.4.6.1 Shorter Operability Times

Equipment that performs its safety function prior to significant changes in its environment may be qualified for shorter durations. Per Regulatory Guide 1.89, justification for shorter duration includes:

- The consideration of a spectrum of pipe break sizes.
- The potential need for the equipment later in an event or during recovery operations.

Subsequent failure of the equipment is shown to not be detrimental to plant safety or to mislead the operator.

The determination that the margin applied to the minimum operability time, when combined with other test margins, accounts for uncertainties associated with the use of analytical techniques used to derive environmental parameters, the number of units tested, the production tolerances, and the test equipment inaccuracies.

3D.4.7 Performance Criterion

The qualification test program demonstrates the capability of the equipment to meet the safety-related performance requirements defined in the equipment qualification data package (see Section 3D.8.1). The primary objective of qualification is to demonstrate that equipment, for which a qualified life or condition has been established, can perform its safety functions without experiencing common-cause failures before, during, and after applicable DBEs. The continued capability for this

equipment and its interfaces to meet or exceed its specification requirements is provided through a program that includes, but is not limited to, design control, quality control, qualification, installation, maintenance, periodic testing, and surveillance.

3D.4.8 Margin

The purpose of using margin in the qualification program is to account for commercial production variability, errors in establishing satisfactory performance, and errors in experimental measurements, thereby providing greater assurance that the equipment can perform under the specified service conditions. Table 3D-3—EQ Program Margin Requirements presents the margins for various environmental parameters. The margins shown in the table are those recommended in IEEE Std 323-1974. The operability time margin may be different as allowed by Section 3D.4.6.1 above.

3D.4.9 Treatment of Failures

Any failure to meet the acceptance criteria is analyzed to determine the cause. Equipment modifications, equipment retesting, or equipment use limitations are imposed as necessary to address the failure.

3D.4.10 Traceability

The installed equipment is compared to the qualified equipment to verify the test sample is representative of the qualified equipment. The tested and installed equipment are considered the same if the manufacturer, model number, and the specifications, including materials of constructions, are the same. Differences between the installed and tested equipment are evaluated to determine the impact on qualification.

3D.5 Design Specifications

The equipment design specification identifies the performance requirements, safety functions, environmental service conditions, accepted methods of qualification, and acceptance criteria. The design specification also provides the basis for establishing the EQ of the specific equipment or the family of equipment.

3D.5.1 Normal Operating Conditions

Normal operating conditions are summarized in Table 3D-4—Normal Operating Environments. Pressure requirements of controlled buildings are summarized in Table 3D-5—Pressure Requirements of Controlled Buildings. Operating temperature ranges for selected components are shown in Table 3D-6—Operating Temperature Ranges for Selected Components. For qualification under normal operating conditions, the equipment is mounted, connected, interfaced, and operated in a manner that simulates its normal inservice conditions, and the equipment's safety

functions are demonstrated during exposure to normal service conditions. Data are recorded for later reference.

3D.5.1.1 Normal Radiation Dose

The normal dose rates and cumulative doses for equipment are based on the maximum normal reactor coolant system radionuclide activities and system parameters to determine bounding normal dose rates and cumulative doses both inside and outside of the containment, as shown in Table 3D-8—Bounding Normal EQ Radiation Dose. These values were determined based on 60 years of continuous operation and steady-state operating conditions, and take into account radiation exposure because of recirculatory fluid for equipment outside the containment.

The dose rates and cumulative doses shown in Table 3D-8 represent the direct dose to equipment and bound any additional air submersion doses.

3D.5.2 Abnormal Operating Conditions

Abnormal operating conditions are identified in Table 3D-7—Abnormal Room Conditions.

3D.5.3 Seismic

The methods, including applicable seismic loads, used for the seismic qualification of mechanical, electrical, and I&C equipment for the U.S. EPR are addressed in Sections 3.7, 3.10, and Appendix 3D Attach F.

3D.5.4 Containment Test Environment

The design pressure of the Containment Building is 62 psig, though it is initially tested at 1.15 times this value. The building is then tested periodically at the design pressure. The equipment in the containment building that is required to be environmentally qualified is tested to these containment conditions.

3D.5.5 Design Basis Event Conditions

The environmental conditions for the various DBEs are noted in the following figures. Equipment that is required to perform a safety-related function, and could potentially be subjected to the design basis environments, is qualified to these conditions for the required operability time.

- Figure 3D-1—Typical Combined LOCA/SLB Inside Containment Temperature Service Conditions Envelope.
- Figure 3D-2—Typical Combined LOCA/SLB Inside Containment Pressure Service Conditions Envelope.

- Figure 3D-3—Outside Containment Temperature Service Conditions Envelope (Feedwater Valve Compartment).
- Figure 3D-4—Outside Containment Pressure Service Conditions Envelope (Feedwater Valve Compartment).
- Figure 3D-5—Outside Containment Temperature Service Conditions Envelope (Main Steam Valve Compartment).
- Figure 3D-6—Outside Containment Pressure Service Conditions Envelope (Main Steam Valve Compartment).

3D.5.5.1 Design Basis Event Radiation Doses

The accident cumulative doses are based on the guidance provided in Regulatory Guide 1.183 for equipment following design basis events. The doses resulting from a LOCA event bound those from a main steam line break accident.

The accident conditions cumulative doses within the reactor building and the annulus were determined using the maximum normal core radionuclide inventory. The maximum normal core inventory (5-41 GWD/MTU for 5% enrichment) bounds the equilibrium cycle burnup (27 GWD/MTU) for the U.S. EPR and is representative of operating cycle characteristics for environmental qualification purposes.

Based on the above, the cumulative doses following a design basis event are shown in Table 3D-9—Accident EQ Radiation Dose and represent the summation of the direct and air submersion doses.

For discussion on beta radiation, refer to Section 3.11.5.

3D.6 Qualification Methods

This section describes the methodologies used to qualify equipment. Alternative approaches are available; however, the equipment vendor selects the methods best applied to the equipment. The result is an auditable record demonstrating that the equipment can perform its safety functions, under the specified service conditions, during its QL.

IEEE Std 323-2003 (as endorsed by RG 1.209 for computer-based digital I&C equipment in a mild environment) and IEEE Std 323-1974 allow various qualification methods (e.g., testing, analysis, operating experience, or a combination of methods) as applicable to the equipment scope. Although type testing is the preferred method of qualification, a qualification program usually involves some combination of these methods. The qualification methods used depend on factors such as the:

- Materials used in construction of the equipment.

- Applicable normal, abnormal, and DBE service conditions.
- Operational requirements during and after accidents.
- Nature of the required safety function(s).
- Size of the equipment.
- Dynamic characteristics of the expected failure modes (e.g., structural or functional).

In general, analysis may be used to supplement test data; although simple structures may lend themselves to seismic analysis in lieu of full-scale testing. The role of operating experience is generally limited to aiding in determining realistic performance goals.

3D.6.1 Type Test

The type test program is designed to demonstrate that the equipment can perform its safety functions within the accuracy and response time requirements applicable for normal, abnormal, and DBE service conditions. The type test consists of a demonstration of safety functions under a planned sequence of environmental tests both before and after age conditioning. The type test program is implemented by the AREVA NP EQ specification, which provides detailed instructions to vendors on program implementation.

A test plan is prepared at the beginning of the test program, which includes the qualification methodology, its intent and purpose, and a description of the tests in sufficient detail to demonstrate compatibility with AREVA NP requirements. As a minimum, the plan includes:

- Equipment description.
- Number of test specimens.
- Acceptance criteria.
- Failure definition.
- Testing sequence.
- Aging technique with justification.
- Test levels that envelope or equal the service conditions.
- Parameters to be monitored.
- Test equipment to be used.

- Mounting and connection methods.
- Qualified life goal and design life.
- Documentation to be maintained.

3D.6.2 Analysis

Analysis can be used to demonstrate that equipment suffers no appreciable change in its ability to perform because of the environmental conditions associated with high stress events at any time in its QL. This method is generally limited to the following classes of equipment:

- Equipment that is simple in design and construction (e.g., cabinets, panels, instrument racks).
- Equipment where the DBE does not impose stresses additive to those imposed during normal operation in such a manner as to cause a common mode failure.
- Equipment that is similar to existing qualified equipment and where any differences are minor.
- Equipment that has no significant aging mechanisms over its QL.

3D.6.2.1 Similarity

Similarity is employed to optimize equipment qualification. Representative samples of the model family being qualified are employed in the test sample. Supporting analysis is used to demonstrate that the results of the tests can be appropriately used to demonstrate the qualification of installed equipment.

For example, the aging mechanisms of carbon resistors, printed circuits, junctions, solder joints, and wiring may not differ from one module to a similar module. If the QL of one module can be established, then modules of similar types will have an equivalent QL if modules have similar failure mechanisms. For the modules to be qualified, various types of equipment can be compared for similarity or grouping by comparing the following items:

- Type of technology used to design and manufacture the module.
- Type of critical components.
- Packaging, mounting, and type of connections.
- Service conditions.
- Safety functions.

For such a group, modules are type tested excluding aging. Some representative modules have an additional specimen type tested including aging. If the representative modules show no change in test results, whether aged or not aged, aging had no effect on safety function performance. Therefore, aging would have no effect on the safety function performance of the remainder of the similar group. However, if significant differences in performance between aged and unaged modules are found, similarity may not be used.

In summary, the analysis to extrapolate QL for similar equipment includes the following:

- Group modules by similarity and justify the grouping.
- Type test modules, excluding aging.
- Type test one duplicate module from each similar group with aging.
- Determine if differences in results are acceptable for extending aging results to similar units.

3D.6.2.2 Substitution

Substitution of parts or materials is acceptable if a comparison or analysis of their fit, form, and function supports the conclusion that the equipment performance is equal to or better than the originally qualified equipment.

3D.6.2.3 Analysis of Safety-Related Mechanical Equipment

Section 3.11.2.2 describes the qualification of mechanical equipment. Engineering design specifications are generated and used to procure equipment, components, and parts. Under the procurement program, compliance with GDC 4 through the evaluation of non-metallic parts in mechanical components is based on material evaluations and the form, fit, and function methodology used in an item equivalency evaluation. Table 3D-10—Mechanical Equipment Components Requiring Environmental Qualification provides a summary of the types of non-metallic or consumable parts in mechanical components that will be screened for EQ. The list of specific non-metallic components by tag number screened in the EQ program is provided in Section 3.10, Table 3.10-1—List of Seismically and Dynamically Qualified Mechanical and Electrical Equipment.

3D.7 Equipment Qualification Maintenance Requirements

The equipment qualification maintenance requirements serve a dual function. They identify the specific maintenance requirements for EQ, and the condition monitoring and preventive maintenance activities required based on vendor requirements and engineering judgment.

These maintenance requirements documents typically consist of the following sections:

1.0 Equipment Description

Tag numbers, equipment numbers, description of function, location, manufacturer, and model number—general information for completing maintenance orders.

2.0 Technical References

Reference information useful for preparing for or conducting maintenance.

3.0 Installation and Maintenance Requirements

3.1 Installation Requirements

Tasks essential to achieving installations that conform to EQ requirements—derived from vendor technical manuals and equipment EQ test reports.

3.2 Electrical Connection Interface and Data Requirements

The requirements for environmentally qualified connections—the information represents the current physical configuration.

3.3 Maintenance Requirements

Tasks and their frequencies necessary to maintaining the equipment's EQ—derived from vendor technical manuals and equipment EQ test reports; to be incorporated into the plant surveillance test procedures or preventive maintenance program, as applicable.

3.4 Post-Maintenance Test Requirements

Testing to be performed after EQ maintenance is completed.

3.5 Condition Monitoring Requirements

Monitoring required to detect and assess degradation of materials or performance—derived from review of qualification documentation, evaluation of degrading mechanisms, and engineering judgment.

4.0 Replacement Parts

The description, manufacturer, and model number of parts needed to maintain EQ equipment—includes items routinely used in the maintenance activity.

5.0 Design Changes/Modifications

Information on design changes and modifications and their reasons—adequate to identify the equipment's original configuration.

3D.7.1 Operating Experience

Operating experience can serve as a basis for determining the QL of equipment, including systems, elements, components, modules, and other constituent parts. Auditable data are maintained for environmental qualification of equipment qualified on the basis of operating experience that addresses the following criteria:

- The equipment cited for operating experience is identical or justifiably similar to the equipment to be qualified.
- The equipment cited for operating experience has operated under service conditions that equal, or exceed in severity, service conditions for which the equipment is to be qualified, and has performed its safety function under these conditions.
- The normal and abnormal service condition requirements were satisfied prior to the occurrence of the DBE conditions.
- Margin has been considered in determining the service conditions for the equipment to be qualified.

When the above auditable documentation criteria are met, the equipment is considered qualified because of operating experience for a time no longer than the length of time from the start of operation until the DBE.

Operating experience is a limited method of qualifying equipment. However, when the above criteria are met the equipment may be qualified per Section 3D.7.3.

3D.7.2 On-Going Qualification

The U.S. EPR equipment qualification program may employ on-going qualification, though this method is not acceptable as a sole means for qualifying equipment for DBE conditions. Its use is generally limited to areas subjected to mild environment conditions. Supplemental test, analysis, or experience data to address equipment operability and performance during and after a seismic DBE is also required.

3D.7.3 Combinations of Methods

Equipment may be qualified by test, analysis, previous operating experience, or any combination of these three methods. Using a combination of methods may be appropriate under a variety of circumstances, such as:

- Equipment is too complex for analysis alone or too large for testing alone.
- Test data are available on samples of similar design and materials that are of different sizes, so extrapolation may be possible.

- Verification of a mathematical model using partial type test to determine mode shapes and resonant frequencies.
- Operating experience provides the basis for developing simulated aging techniques.
- Analysis of an assembly to determine the environment to which components are to be tested.
- Two subassemblies that have been tested and qualified separately are combined into a module, and analysis of certain parameters (e.g., individual subassemblies' error rates and response times) demonstrates that the combination is also qualified.

The combined qualification demonstrates that the equipment can perform its safety function under normal, abnormal, and DBE service conditions throughout its QL. Certain portions of the qualification (e.g., operation during normal and abnormal service conditions) may be demonstrated by operating experience. Other portions (e.g., seismic and LOCA operability) may be demonstrated by testing. Combined qualification provides auditable data by which the various primary qualification methods may be brought together to satisfy the qualification program requirements.

3D.8 Documentation

The U.S. EPR equipment qualification program documentation consists of equipment qualification data packages, equipment qualification test reports, and qualification maintenance requirements.

3D.8.1 Equipment Qualification Data Package

The EQDP for each equipment item contains the documentation that demonstrates that the equipment or system is environmentally qualified for its application, and can accomplish its specified safety functions. An equipment item refers to electrical equipment categorized by manufacturer and model, which is representative of identical or similar equipment in plant areas potentially exposed to the same bounding environmental conditions during and after a design basis event. Documentation that supports EQ for the equipment is compiled in the EQDP or referenced therein. The elements of the EQDP include: equipment identification, interfaces, qualified life, safety functions, service conditions (e.g., normal, abnormal, DBE), qualification program plan, and qualification program implementation following the guidance of IEEE Std 323-1974. Refer also to Appendix 3D, Attachment A.

3D.8.2 Equipment Qualification Test Reports

The equipment qualification test report is prepared by the equipment vendor or an independent testing laboratory. This report documents the tests that demonstrate the capability to meet specified functional requirements under specified environmental conditions and operational parameters. These tests subject one or more equipment

samples to conditions designed to simulate normal, abnormal, containment test, DBE, and post-DBE conditions, as applicable.

3D.8.3 Qualification Maintenance Requirements

The qualification maintenance requirements document identifies the specific EQ-related maintenance activities, condition monitoring activities, and preventive maintenance activities required to maintain equipment qualification. These form part of the EQDP described in Section 3D.8.1, and the document is described in greater detail in Section 3D.7.

3D.9 References

1. IEEE Standard 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Inc., 2003.

2. IEEE Standard 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Inc., 2005.

3. IEEE Standard 101-1987 (R2004) "IEEE Guide for the Statistical Analysis of Thermal Life Test Data," Institute of Electrical and Electronics Engineers, Inc.

4. IEEE Std 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," Institute fof Electrical and Electronic Engineers, 1974.

Table 3D-1—Typical Mild Environment Parameter Limits

Description	Limit	Comments
Temperature	≤115°F	Outside Containment Building
	≤122°F	Inside Containment Building
Pressure	atmospheric	nominal
Humidity	20%–80%	Outside Containment Building (unless noted otherwise)
	Non-Condensing	Outside Containment Building (main steam and feedwater valve compartment, diesel buildings, Turbine Building)
	Non-Condensing	Inside containment
Radiation	$\leq 10^3$ rads gamma	Electronic devices and components
	$\leq 10^4$ rads gamma	Non-electronic devices and components
Chemical Spray	Not applicable	Refer to Sections 3.11.5
Submergence	-5 ft–4 in Elev.	Inside containment

Table 3D-2—Equipment Post-Accident Operability Times

Description	Required Post-Accident Operability Duration	Notes
Immediate Operability	2 hours	1
Short-Term	24 hours	2
Medium-Term	4 months	3
Long-Term	1 year	4

Notes:

1. Immediate operability includes components that must remain operational for a maximum of two hours after the onset of the event. Equipment automatically triggered by the protection system is qualified according to this category, except if it is also required for operating the reactor to the cold shutdown conditions or for the long-term plant operation. The qualification time is established based on a conservative estimate consistent with the analyses of when and for how long the component is required to function, plus margin, per IEEE Std 323-1974.

2. Short-term operability includes components that must remain operational for a maximum of 24 hours after onset of the event. Equipment operated to reach the cold shutdown conditions is qualified according to this category, except if it is also required for the long-term plant operation. Per IEEE Std 323-1974 margin is also included.

3. Medium-term operability includes replacement, repair, or recalibration of equipment accessible outside containment or inaccessible instrumentation inside containment required for post-accident monitoring. In the event of post-accident monitoring, the period of operability allows for identification of an alternate indication for the affected instrument. The four months is assumed to include the margin, as required by IEEE Std 323-1974.

4. Long-term operability includes equipment needed to operate for the entire duration of the accident as well as into the start of the recovery phase. The qualification time for individual components is based on an evaluation of alternate methods that can be used to perform the function, or when replacement components can be installed. The one-year duration is assumed to include the margin, as required by IEEE Std 323-1974.

Table 3D-3—EQ Program Margin Requirements

Parameter	Required Margin	Notes
Peak Temperature	+15°F	For accident profile.
Peak Pressure	+10% of gauge	For accident profile.
Radiation	+10%	On accident dose only.
Power Supply Voltage	±10%	Not to exceed equipment design limits.
Equipment Operating Time	+10%	For the period of time the equipment is required to operate following the start of a DBE. See also Section 3D.4.6 and Table 3D-2.
Seismic Vibration	+10%	Margin added to acceleration requirements at the mounting point of the equipment.
Line Frequency	±5%	Of rated value, not to exceed design limits.

Table 3D-4—Normal Operating Environments[1, 2]

Sheet 1 of 5

Location/Parameter	Normal Range	Notes
Containment Building (30UJA)		
Non-accessible areas		
• Temperature	59–122°F	
• Pressure	See Table 3D-5	
• Humidity	Non-Condensing	
• Radiation	See Table 3D-8	
• Chemistry	None	
Accessible Areas (during access)		
• Temperature	59–86°F	
• Pressure	See Table 3D-5	
• Humidity	30–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Annulus Building (30UJB)		
• Temperature	45–113°F	
• Pressure	See Table 3D-5	
• Humidity	Non-Condensing	
• Radiation	See Table 3D-8	
• Chemistry	None	
Electrical Areas of Safeguards Building (32UJK)		
Main Control Room		
• Temperature	65–76°F	
• Pressure	See Table 3D-5	
• Humidity	40–60%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Electrical Areas of Safeguards Building (32UJK, 33UJK)		
I&C and computer rooms and Remote Shutdown Station		
• Temperature	68–79°F	
• Pressure	See Table 3D-5	
• Humidity	30–60%	
• Radiation	See Table 3D-8	

Table 3D-4—Normal Operating Environments[1, 2]

Sheet 2 of 5

Location/Parameter	Normal Range	Notes
• Chemistry	None	
Electrical Areas of Safeguards Building (31UJK, 32UJK, 33UJK, 34UJK)		
Switchgear Rooms		
• Temperature	59–86°F	
• Pressure	See Table 3D-5	
• Humidity	35–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Cable Floor Rooms		
• Temperature	41–95°F	
• Pressure	See Table 3D-5	
• Humidity	20–80%	
• Radiation	See Table 3D-8	
• Chemistry	None	
I&C Equipment Rooms		
• Temperature	68–82°F	
• Pressure	See Table 3D-5	
• Humidity	35–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Electrical Areas of Safeguards Building (31UJK, 32UJK, 33UJK, 34UJK)		
Battery Rooms		
• Temperature	65–77°F	
• Pressure	See Table 3D-5	
• Humidity	35–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
HVAC Rooms		
• Temperature	50–95°F	
• Pressure	See Table 3D-5	
• Humidity	20–80%	
• Radiation	See Table 3D-8	

Table 3D-4—Normal Operating Environments[1, 2]

Sheet 3 of 5

Location/Parameter	Normal Range	Notes
• Chemistry	None	
All other rooms		
• Temperature	41–104°F	
• Pressure	See Table 3D-5	
• Humidity	20–80%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Mechanical Area of Safeguards Building: (Part of Building 31UJK, 32UJK, 33UJK, 34UJK)		
Main Steam Valve and Feedwater Valve Rooms		
• Temperature	50–104°F	
• Pressure	See Table 3D-5	
• Humidity	Non-Condensing	
• Radiation	See Table 3D-8	
• Chemistry	None	
Mechanical Area of Safeguards Building: (31UJH, 32UJH, 33UJH, 34UJH)		
All other rooms		
• Temperature	50–113°F	
• Pressure	See Table 3D-5	
• Humidity	25–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Fuel Building (30UFA)		
All other rooms		
• Temperature	50–113°F	
• Pressure	See Table 3D-5	
• Humidity	25–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Fuel Pool Rooms		
• Temperature	68–96°F	
• Pressure	See Table 3D-5	
• Humidity	30–70%	

Table 3D-4—Normal Operating Environments[1, 2]

Sheet 4 of 5

Location/Parameter	Normal Range	Notes
• Radiation	See Table 3D-8	
• Chemistry	None	
Boric Acid Rooms		
• Temperature	68–113°F	
• Pressure	See Table 3D-5	
• Humidity	30–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Nuclear Auxiliary Building (30UKA)		
All other rooms (except Laboratory Rooms)		
• Temperature	50–113°F	
• Pressure	See Table 3D-5	
• Humidity	25–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Laboratory Rooms		
• Temperature	65–79°F	
• Pressure	See Table 3D-5	
• Humidity	30–70%	
• Radiation	See Table 3D-8	
• Chemistry	None	
Emergency Power Generating Buildings (31UBP, 32UBP, 33UBP, 34UBP)		
Diesel Hall		
• Temperature	59–140°F[3]	
• Pressure	See Table 3D-5	
• Humidity	Non-Condensing	
• Radiation	Mild	
• Chemistry	None	
Electrical Room		
• Temperature	59–95°F	
• Pressure	See Table 3D-5	
• Humidity	35–70%	

Table 3D-4—Normal Operating Environments[1, 2]

Sheet 5 of 5

Location/Parameter	Normal Range	Notes
• Radiation	Mild	
• Chemistry	None	

Notes:

1. The U.S. EPR subscribes to the Kraftwerks Kennzeichen System (KKS) for coding and nomenclature of structures, systems, and components.

2. The minimum temperatures are expected during winter design conditions; the maximum temperatures are expected during summer design conditions.

3. The maximum temperature is based on 115°F ambient temperature with an assumed 25°F heat rise.

Table 3D-5—Pressure Requirements of Controlled Buildings

Location	Pressure (Inches of Water)
Reactor Building	
• Equipment compartments	-1.2 in wg
• Service compartments	- 0.8 in wg
Annulus (normal operation)	- 0.8 in wg
Annulus (accident operation)	- 2.5 in wg
Fuel Building	
• Normal operation	- 0.6 in wg
• Fuel handling hall during fuel handling accident	- 2.5 in wg
Auxiliary Building	- 0.4 i. wg
Safeguard Building mechanical areas	
• Normal operation	- 0.4 in wg
• Under accident conditions	- 2.5 in wg
Safeguard Building electrical areas	0 in wg[4]
Main Control Room Envelope	+ 0.125 in wg[1]
Waste Building	- 0.4 in wg
Access Building controlled area	- 0.4 in wg
Diesel Hall	+ 0.01 in wg[2]
Emergency Power Generating Building Ventilation System Building Electrical Room	+ 0.01 in wg[3]

Notes:

1. Relative to all adjacent spaces to the Control Room envelope.
2. Relative to outside.
3. Relative to Diesel Hall.
4. There is no pressure requirement for these areas; therefore, these areas are considered to be at atmospheric pressure.

Table 3D-6—Operating Temperature Ranges for Selected Components

Type of Equipment	Minimum Temperature	Maximum Temperature
Raw water system	>32˚F	None Specified[1]
Borated water system 2200 ppm	45˚F	113˚F
Borated water system 7000 ppm	65˚F	113˚F
I&C equipment	41˚F	104˚F
Electrical Components (e.g., Transformers, Switchgear)	41˚F	104°F
Computers and associated peripherals	50°F	95˚F
Battery	66˚F	88˚F

Notes:

1. There is no EQ equipment within this system.

Table 3D-7—Abnormal Room Conditions

Rooms	Maximum Temperature	Humidity
Reactor Building		
Non-accessible area	131˚F	Non-condensing
Localized hot spots	140˚F	Non-condensing
Electrical Division of Safeguard Building Ventilation System		
All Locations	104˚F	20%-80%

Table 3D-8—Bounding Normal EQ Radiation Dose

Location		Dose Rate (rad_{air}/h)	Radiation Zone	Cumulative Dose (rad_{air})
UJH	All Equipment[1]	8.0E-01	6	4.21E+05
UJK	Other than MCR/TSC, Filter Rooms	2.5E-04	2	1.31E+02
	MCR/TSC	2.5E-04	2	1.31E+02
	MCR Filter Rooms	2.5E-04	2	1.31E+02
UJE	All Equipment	2.5E-04	2	1.31E+02
UFA	All Equipment [2]	1.2E+01	7	6.31E+06
UKA	KBE/FAL Mixed Bed Filters—All Equipment[3]	2.0E+04	8	1.05E+10
	Other than KBE/FAL Mixed Bed Filters [4]	1.2E+01	7	6.31E+06
UJB	All Equipment <+17 ft level	3.0E+01	7	1.45E+07
	All Equipment ≥17 ft level	5.0E-03	4	2.42E+03
UJA	UJA above RPV	5.3E+01	7	2.78E+07
	Equipment Area—All Equipment	5.0E+01	7	2.42E+07
	Service Area—All Equipment <+17 ft level	3.0E+01	7	1.45E+07
	Service Area—All Equipment ≥17 ft level	5.0E-03	4	2.42E+03
	IRWST—12 in above water surface	1.0E-01	5	5.26E+04
UJA Reactor Vessel wall: 60-year integrated neutron dose for E > 1 MeV = 2.85E17 n/cm^2				

Notes:

1. Based on bounding condition from the residual heat removal system equipment.
2. Based on bounding condition from the volume control tank.
3. The mixed bed filters (KBE and FAL) provide the highest dose rate for all rooms within the Nuclear Auxiliary Building (UKA) for normal conditions.
4. Based on bounding condition from the coolant storage tank (KPL) delay beds.

Table 3D-9—Accident EQ Radiation Dose

Location		Accident Cumulative Dose (rad_{air})			
		2 hours	24 hours	4 months	1 year
UJH	All Equipment	6.0E+04	2.9E+05	4.4E+06	9.0E+06
UJK	Other than MCR/TSC, Filter Rooms	1.1E-03	1.4E-02	5.0E-01	5.0E-01
	MCR/TSC	1.1E-03	5.6E-02	5.0E-01	5.0E-01
	MCR Filter Rooms	2.3E-01	1.2E+02	1.0E+03	1.0E+03
UJE	All Equipment	2.4E+03	9.6E+04	4.0E+05	6.8E+05
UFA	All Other Equipment	4.0E+03	1.2E+05	9.3E+05	1.1E+06
	KLB/KLC Filter rooms & Rooms immediately above/ below KLB/KLC Filter rooms	1.6E+04	1.2E+06	5.3E+07	1.2E+08
UKA	KBE/FAL Mixed Bed Filters—All Equipment	4.00E+04	4.80E+05	5.76E+07	1.75E+08
	Other than KBE/FAL Mixed Bed Filters—All Equipment	2.40E+01	2.88E+02	3.46E+04	1.05E+05
UJB	All Equipment <+17 ft level	2.06E+02 (1.7E+03)[1]	1.42E+04 (1.3E+05)[1]	2.52E+05 (1.5E+06)[1]	4.76E+05 (2.3E+06)[1]
	All Equipment ≥17 ft level	2.06E+02 (1.7E+03)[1]	1.42E+04 (1.3E+05)[1]	2.52E+05 (1.5E+06)[1]	4.76E+05 (2.3E+06)[1]
UJA	UJA above RPV	1.40E+06 (6.9E+06)[1]	9.07E+06 (5.3E+07)[1]	8.56E+07 (3.3E+08)[1]	1.58E+08 (4.9E+08)[1]
	Equipment Area—All Equipment	1.40E+06 (6.9E+06)[1]	9.07E+06 (5.3E+07)[1]	8.56E+07 (3.3E+08)[1]	1.58E+08 (4.9E+08)[1]
	Service Area—All Equipment <+17 ft level	1.40E+06 (6.9E+06)[1]	9.07E+06 (5.3E+07)[1]	8.56E+07 (3.3E+08)[1]	1.58E+08 (4.9E+08)[1]
	Service Area—All Equipment ≥17 ft level	1.40E+06 (6.9E+06)[1]	9.07E+06 (5.3E+07)[1]	8.56E+07 (3.3E+08)[1]	1.58E+08 (4.9E+08)[1]
	IRWST—12 in above water surface	8.39E+05	3.10E+06	5.44E+07	1.21E+08

Notes:

1. Indicates Beta Dose.

Table 3D-10—Mechanical Equipment Components Requiring Environmental Qualification[1,2]

Component	Material Property
Gaskets	Compression set/elongation
O-rings	Compression set/elongation
Diaphragms	Elongation/tensile strength
Diaphragm support sheets	Elongation/tensile strength
Lubricant	Viscosity/penetration
Worm gear	Flexural strength

Notes:

1. The list of specific non-metallic or consumable components by tag number screened in the EQ program is listed in Section 3.10, Table 3.10-1.

2. Typical radiation doses for non-metallic/consumable components will be provided on the basis of the All Equipment doses shown in Table 3D-8 and 3D-9.

Figure 3D-1—Typical Combined LOCA/SLB Inside Containment Temperature Service Conditions Envelope

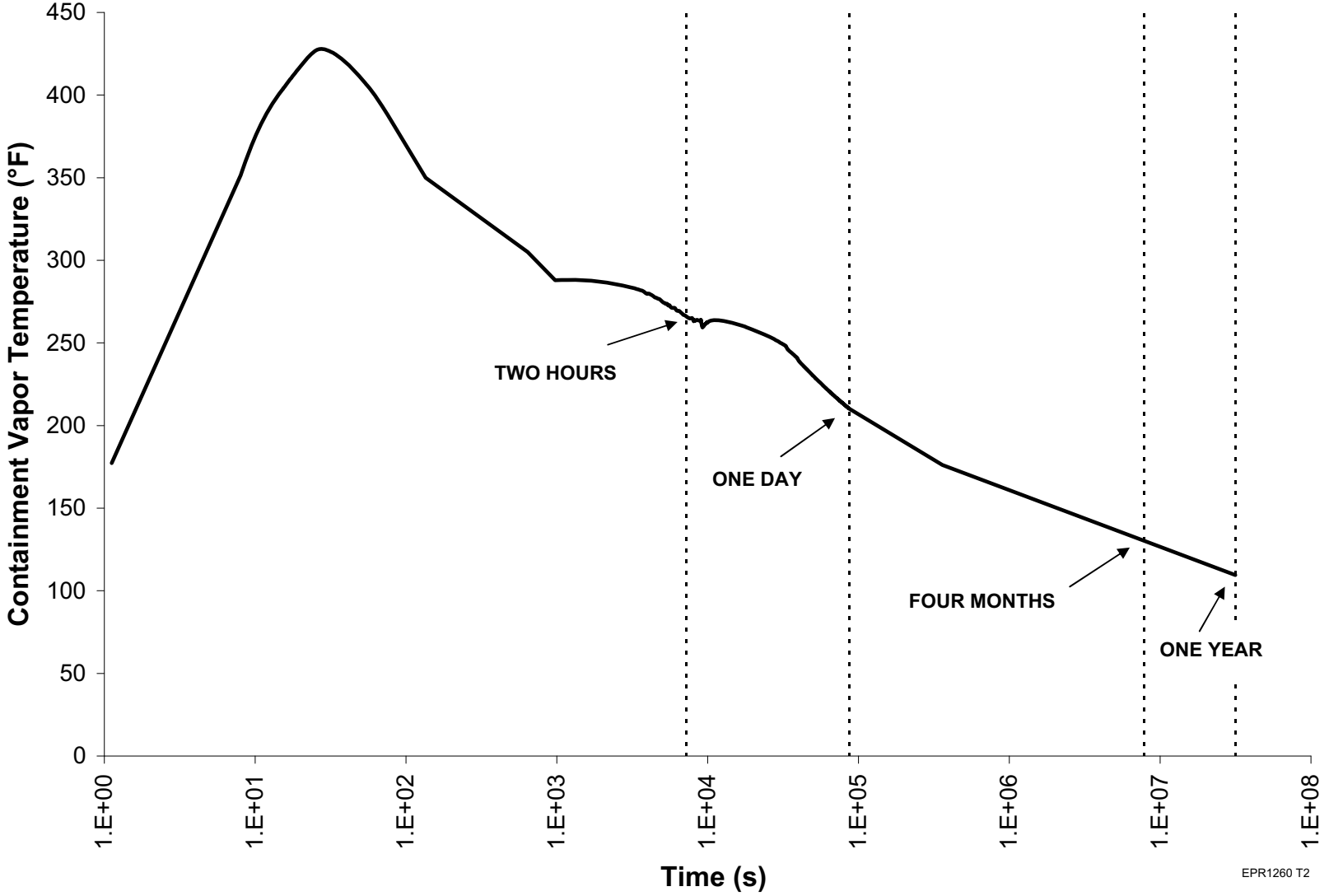


Figure 3D-2—Typical Combined LOCA/SLB Inside Containment Pressure Service Conditions Envelope

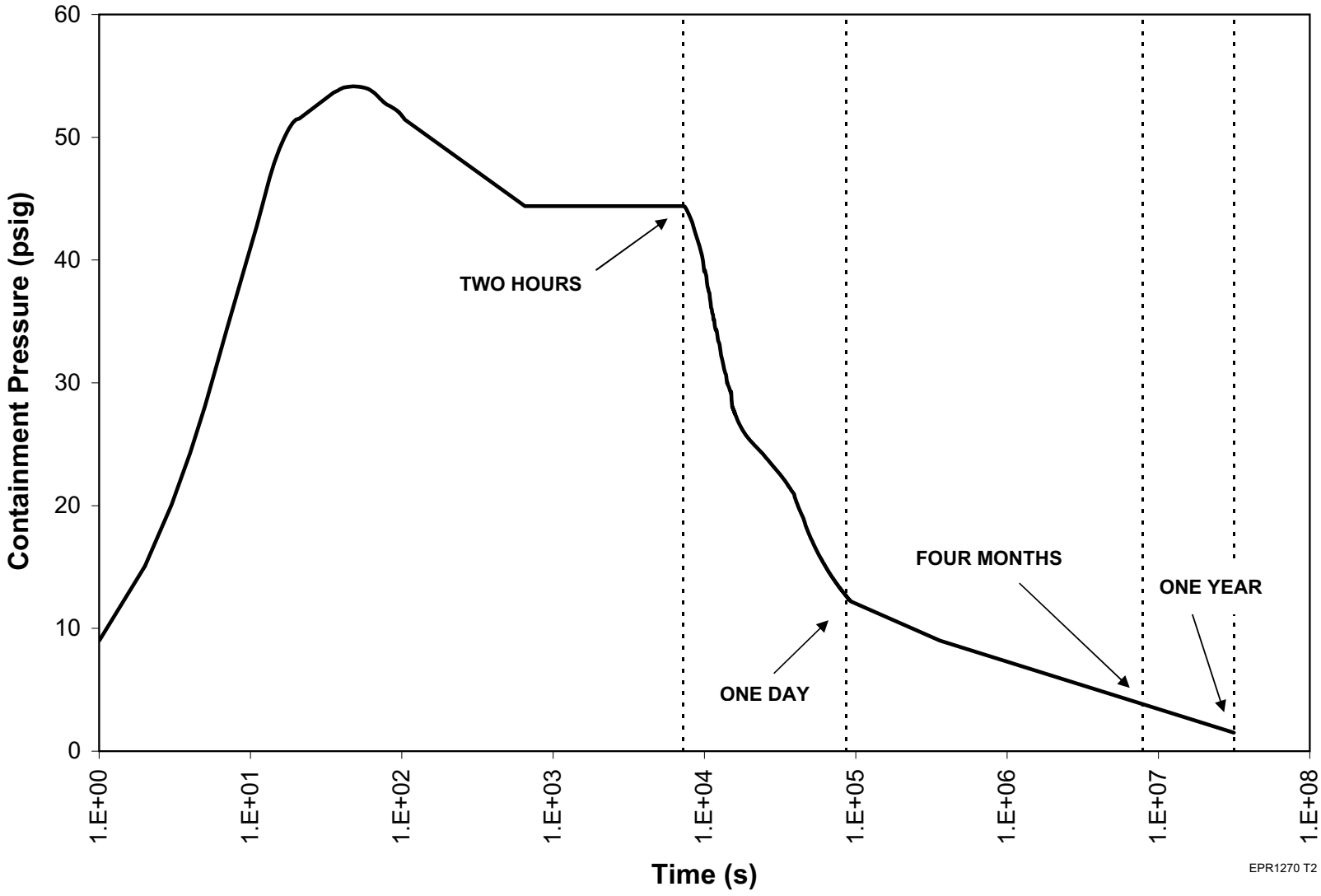


Figure 3D-3—Outside Containment Temperature Service Conditions Envelope (Feedwater Valve Compartment)

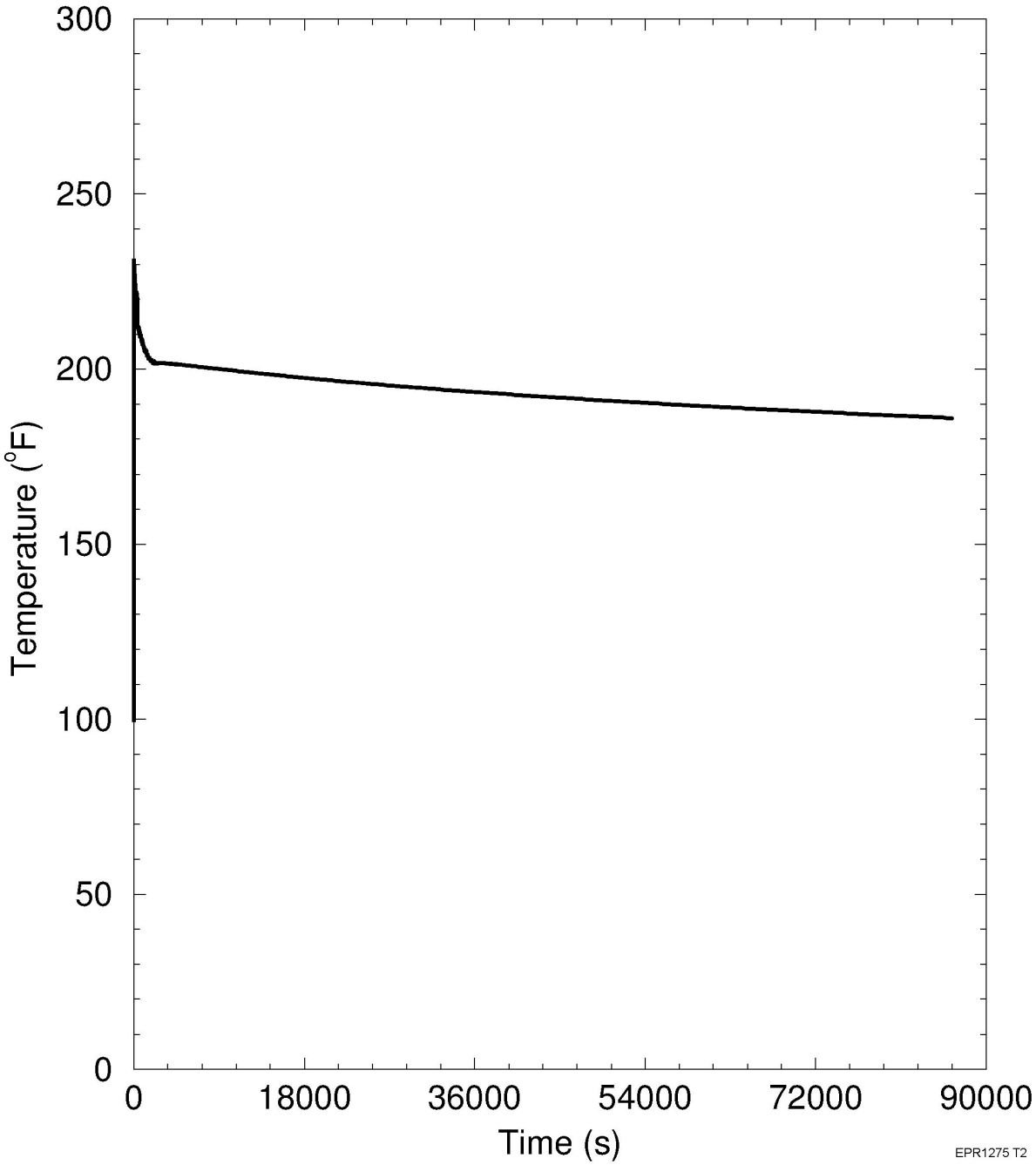


Figure 3D-4—Outside Containment Pressure Service Conditions Envelope (Feedwater Valve Compartment)

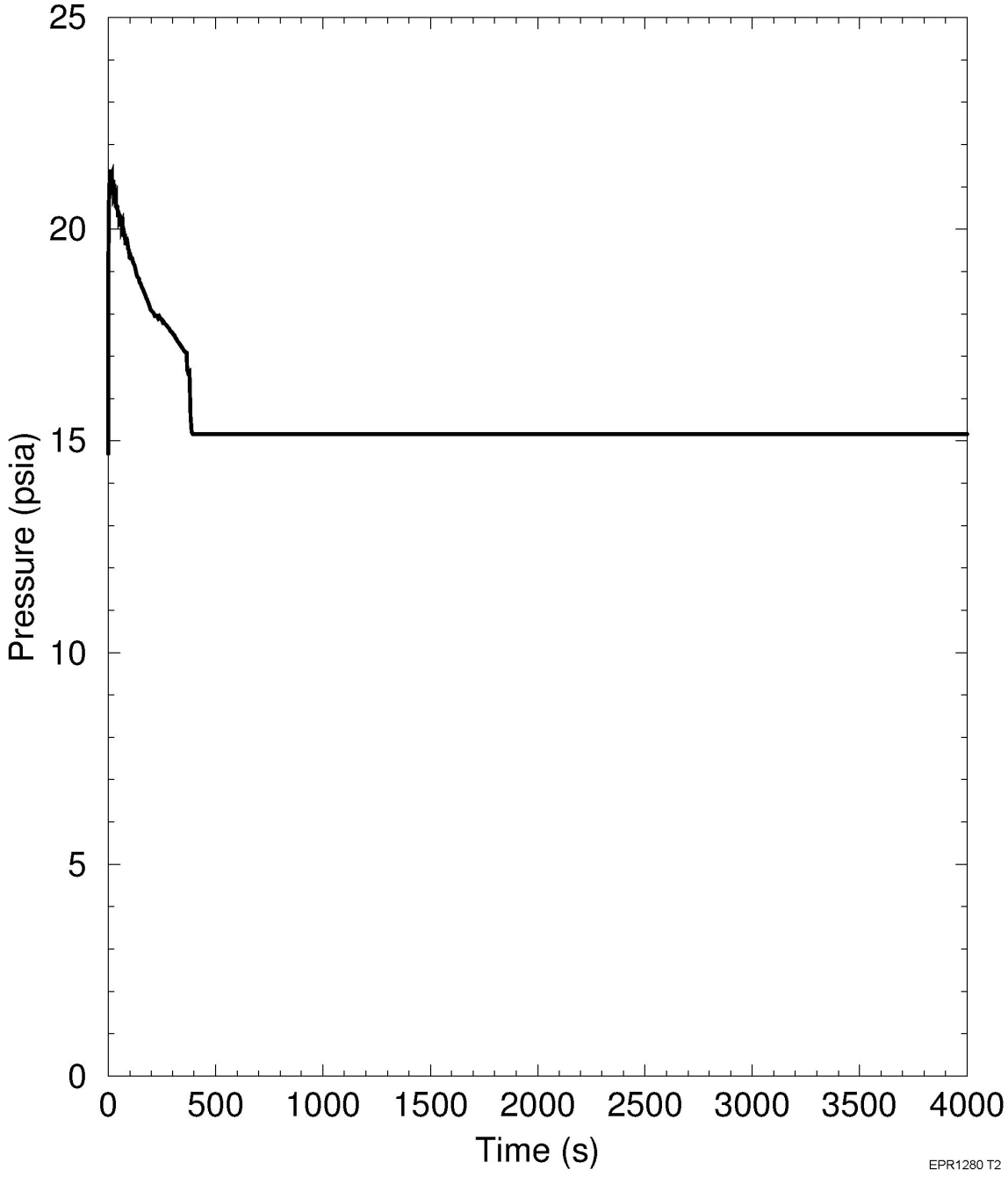


Figure 3D-5—Outside Containment Temperature Service Conditions Envelope (Main Steam Valve Compartment)

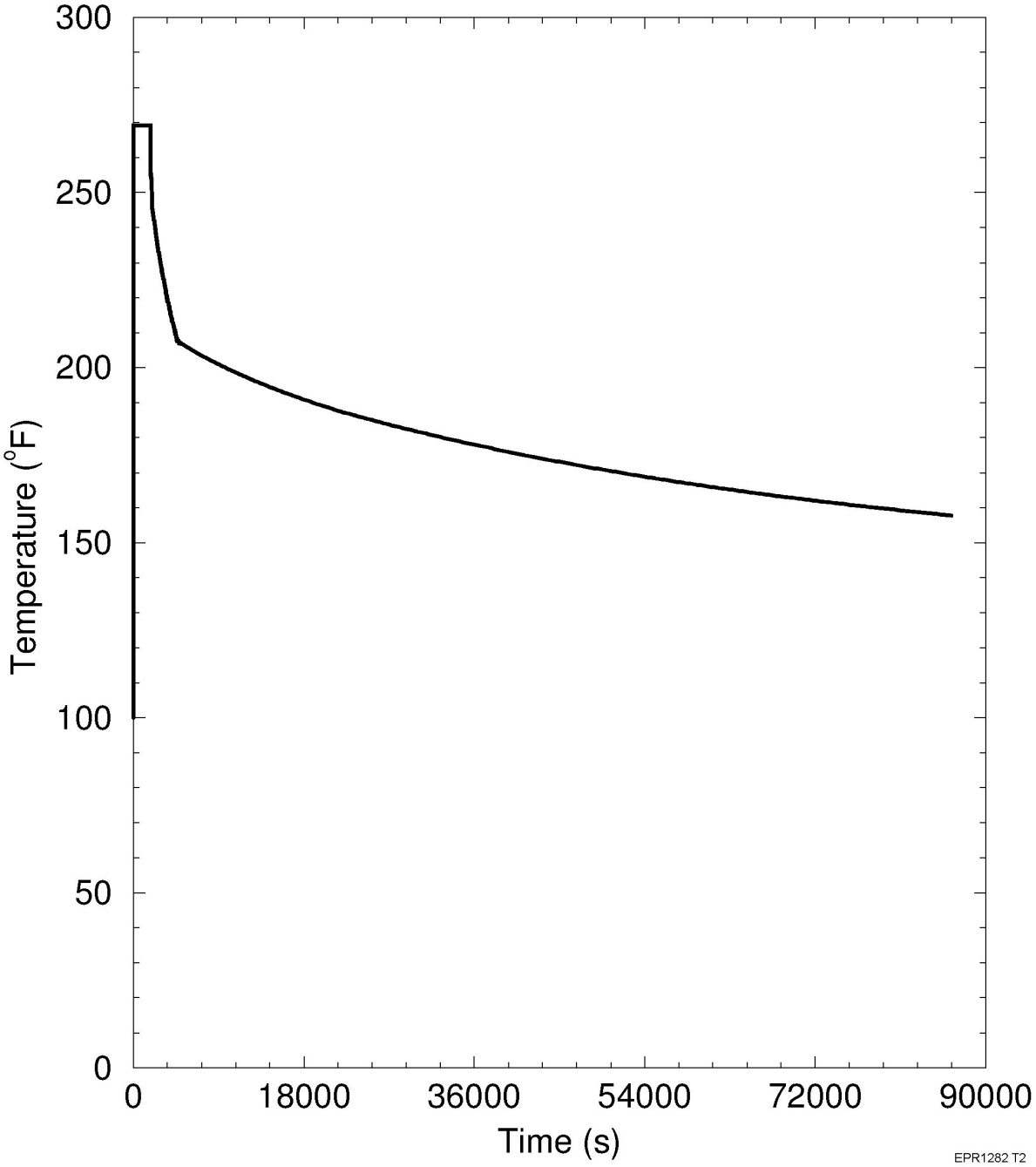
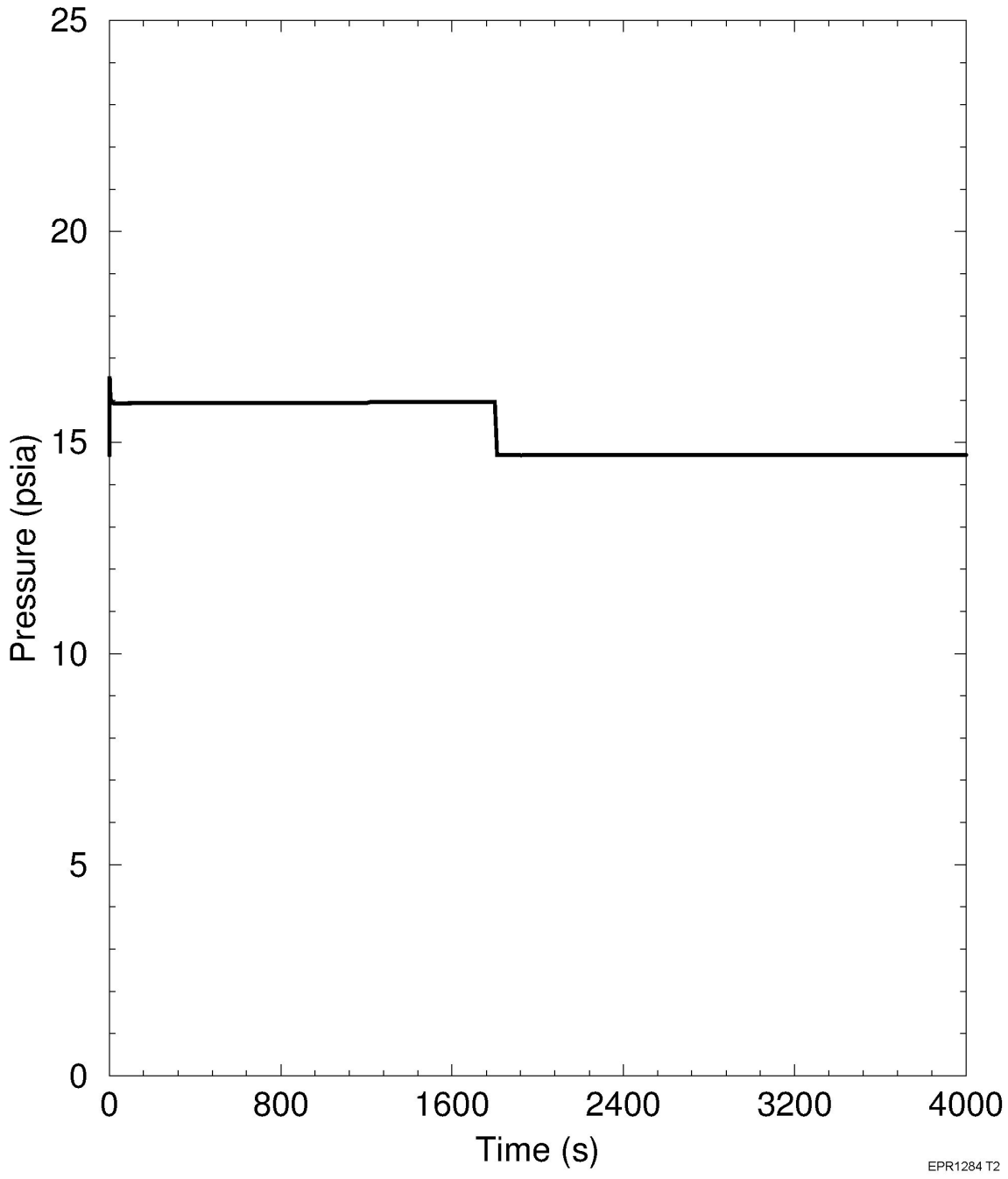


Figure 3D-6—Outside Containment Pressure Service Conditions Envelope (Main Steam Valve Compartment)



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