

A-36
50-348/364-CIVP
2/20/92

0065938

IEEE Std 323-1974
(Revision of IEEE Std 323-1971)

'92 MAR 13 P4:25

OFFICE OF SECRETARY
DOCKETING & COMPLIANCE
BRANCH

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

323

Sponsor

Nuclear Power Engineering Committee of the
IEEE Power Engineering Society

© Copyright 1974 by

The Institute of Electrical and Electronics Engineers, Inc.

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

9204080063 920220
PDR ADOCK 0500034E
G PDR

NUCLEAR REGULATORY COMMISSION

Case No. 50-348/364-CivP Official File No. 36
In the matter of Alabama Power Company

Staff _____ IDENTIFIED 3:40 pm 2/20/92
Applicant RECEIVED 3:41 pm 2/20/92
Intervenor _____ REJECTED _____

Cost's Offr _____
Contractor _____ DATE 2/20/92
Other _____ WITNESS _____

Reporter L. Estep

Foreword

(This foreword is not part of IEEE Std 323-1974, Qualifying Class IE Equipment for Nuclear Power Generating Stations.)

The following IEEE Standards establish basic requirements that equipment within their scope must be adequately qualified:

IEEE Std 279-1971 (ANSI N42.7-1972), Criteria for Protection Systems for Nuclear Power Generating Stations.

IEEE Std 308-1974, Criteria for Class IE Power Systems for Nuclear Power Generating Stations.

The Institute of Electrical and Electronics Engineers has developed this document to provide guidance for demonstrating and documenting the adequacy of electric equipment used in all Class IE and interface systems.

Adherence to this guide may not suffice for assuring 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 consequences of accidents. Each applicant has the responsibility to assure himself and others that this guide, if used, is pertinent to his application and that the integrated performance of his station is adequate.

Representative in-containment design basis event conditions for the principal reactor types are included in the appendixes for guidance in environmental simulation. These conditions may not be acceptable for all specific applications and the user should confirm the suitability of these data and modify them as appropriate for qualification in any given Nuclear Power Generating Station.

Guidance for demonstrating the capability of specific electric equipment may be found in the following documents which are in various stages of preparation or issue.

Project P-381, Guide for Type Tests of Modules Used in Nuclear Power Generating Station Protection Systems.

IEEE Std 334-1971, Trial-Use Guide for Type Tests of Continuous Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations.

IEEE Std 382-1972 (ANSI N41.6-1972), Trial-Use Guide for Type Test of Class I Electric Valve Operators for Nuclear Power Generating Stations.

IEEE Std 383-1974 Guide for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

IEEE Std 344-1971, Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations.

This standard was prepared by a working group of Subcommittee 2 (Qualification) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society. Members of this group were:

J. T. Bauer, Chairman	C. V. Fields, Past Chairman
S. Carfagno	A. Kaplan
J. B. Gardner	D. G. Woodward
C. F. Miller	A. J. Simmons
L. D. Test	J. T. Keiper

At the time it approved this standard, Subcommittee 2 (Qualification) had the following membership:

A. J. Simmons, Chairman	L. D. Test, Vice Chairman
A. Kaplan, Secretary	

J. F. Bates	D. J. Meraner	D. G. Woodward
J. T. Bauer	F. W. Chandler	G. T. Dowd, Jr
L. J. Blasiak	H. E. McConnell	W. J. Denkowski
J. T. Keiper	C. E. Corley	R. F. Edwards
F. Campbell	W. Dalce	C. F. Miller
W. J. Foley	E. P. Donegan	A. S. Hintze
J. B. Gardner	W. D. Loftus	W. G. Stiffler
T. H. Ling	W. H. Steigelmann	B. Gregory
T. R. Beans	S. Carfagno	A. Garshick
G. W. Hammond	W. A. Szelistowski	E. E. McIlveen
	F. Trunzo	

At the time it approved this standard, The Nuclear Power Engineering Committee had the following membership:

	J. C. Russ, <i>Chairman</i>	T. J. Martin, <i>Vice Chairman</i>	
	L. M. Johnson, <i>Secretary</i>	J. T. Boettger, <i>Coordinator</i>	
R. E. Allen	E. F. Chelotti	E. S. Patterson	C. E. Stine
J. F. Bates	C. M. Chiappetta	D. G. Pitcher	H. K. Stolt
R. G. Benham	R. J. Cooney	W. F. Sailer	D. F. Sullivan
K. J. Brockwell	D. G. Fitzgerald	R. A. Sava	W. A. Szelistowski
D. F. Brosman	J. M. Gallagher	A. J. Simmons	L. D. Test
O. K. Brown	A. Kaplan	J. H. Smith	J. L. Voyles
S. G. Caslake	T. A. Ippolito	A. J. Spurgin	E. C. Wenzinger
F. W. Chandler	M. I. Oiken	L. Stanley	C. J. Wylie

IEEE
Std 323A-1975
(Supplement to
IEEE Std 323-1974)

Supplement to the Foreword of IEEE Std 323-1974
IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

(This Supplement is provided to amplify the information in the Foreword; it is not a part of IEEE Std 323-1974.)

The concept of aging was addressed explicitly for the first time in IEEE Std 323-1974. The aging guidance therein reflects the requirement of IEEE Std 279-1971 (ANSI N42.7-1972) Section 4.4. It is based on an awareness by the IEEE that the ability of Class 1E equipment to perform its safety related function might be affected by changes due to natural, operational, and environmental phenomena over time (aging). It was not the intent that aging must be applied to all Class 1E equipment, but rather that aging must be considered in the same manner as environmental parameters. The need for aging of particular equipment should be determined based on an evaluation of the specific design and application. If aging is needed a further determination must 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, ongoing qualification.

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 known 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, combined, or ongoing qualification as detailed in Section 5.2, 5.3, 5.4 and 5.5.

Further clarification of aging as it applies to specific types of equipment will be provided in individual IEEE Class 1E equipment qualification documents. For example, an IEEE Standard is being prepared to establish criteria for Class 1E modules. IEEE Standards 334-1974, 382-1972 (ANSI N41.6), and 383-1974 (ANSI N41.10-1975) presently provide guidance for motors, valve operators, and cables respectively.

0065941

Approved December 13, 1973

IEFE Standards Board

Robert D. Briskman, *Chairman*

Sava I. Sherr, *Secretary*

Stephen J. Angello
Saul Aronow
James E. Beehler
Richard Brereton
Warren H. Cook
Louis Costrell
Jay Forster

Joseph L. Koepfneer
William R. Kruesi
Benjamin J. Leon
Donald T. Michael
Voss A. Moore
J. David M. Phelps
Saul W. Rosenthal
Gustave Shapiro

Ralph M. Showers
Robert A. Soderman
Frederick G. Timmel
Leendert van Rooij
Robert V. Wachter
Bruno O. Weinschel
William T. Wintringham

Contents

SECTION	PAGE
1. Scope	7
2. Purpose	7
3. Definitions	7
4. Introduction	8
5. Principles of Qualification	9
5.1 Type Testing	9
5.2 Operating Experience	8
5.3 Qualification by Analysis	9
5.4 Combined Qualification	10
5.5 On-Going Qualification	10
6. Qualification Procedures and Methods	10
6.1 Identification of the Class IE Equipment Being Qualified	10
6.2 Equipment Performance Specifications	10
6.3 Type Test Procedures	11
6.4 Operating Experience	13
6.5 Analysis	14
6.6 On-Going Qualification	15
6.7 Criteria of Failure	15
6.8 Modifications	15
6.9 Documentation	15
7. Simulated Service Condition Test Profile	15
8. Documentation	16
8.1 General	16
8.2 Documentation Files	16
8.3 Type Test Data	16
8.4 Operating Experience Data	16
8.5 Analysis	17
8.6 Extrapolation	17
FIGURES	
Fig 1 Simulated Service Environment Test Profile	16
APPENDIXES	
Appendix A In-Containment Design Basis Event Environment Simulation for PWR and BWR ..	18
A1 General	18
A2 Simulation Sequence	20
Appendix B In-Containment Design Basis Event Environment Simulation for a High Temperature Gas Cooled Reactor (HTGR)	20
Appendix C Test Chamber Moisture Content	23
FIGURES	
Fig A1 Test Chamber Profile for Accident Environment Simulation	18
Fig B1 Typical Temperature and Pressure History for Environment Simulation of HTGR Containment Atmosphere Response Following a Hot Helium Blowdown into Containment	21
Fig B2 Typical Temperature and Pressure History for Environment Simulation of HTGR Containment Atmosphere Response Following a Steam Line Rupture Inside the Containment	22

0065943

TABLES

Table A1	Test Conditions for Pressurized Water Reactors	19
Table A2	Test Conditions for Boiling Water Reactors	19
Table B1	Test Conditions for High Temperature Gas Cooled Reactors	21
Table B2	HTGR Containment Building	23

IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations

1. Scope

This document describes the basic requirements for qualifying Class IE equipment and 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 containment test conditions for the performance of Class IE functions.

2. Purpose

The purpose of this document is to provide guidance for demonstrating the qualification of Class IE equipment including components or equipment of any interface whose failure could adversely affect the performance of Class IE systems and electric equipment. Qualification required in IEEE Std 279-1971 (ANSI N42.7-1972), Criteria for Protection Systems for Nuclear Power Generating Stations and IEEE Std 308-1974, Criteria for Class IE Power Systems for Nuclear Power Generating Stations can be demonstrated by using the guidance provided in this document.

The qualification methods described shall be used for qualifying equipment and for updating qualification following modifications. Other qualification guides for specific electric equipment or test methods (for example, IEEE Std 344-1971, Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations) will present specific requirements and should be used to supplement this document.

3. Definitions

These definitions establish the meanings of

words in the context of their use in this guide.

analysis. A process of mathematical or other logical reasoning that leads from stated premises to the conclusion concerning specific capabilities of equipment and its adequacy for a particular application.

auditable data. Technical information which is documented and organized in a readily understandable and traceable manner that permits independent auditing of the inferences or conclusions based on the information.

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

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

containment. That portion of the engineered safety features designed to act as the principal barrier, after the reactor system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive material beyond a controlled zone.

demonstration. A course of reasoning showing that a certain result is a consequence of assumed premises; an explanation or illustration, as in teaching by use of examples.

design basis events. 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.

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

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

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.

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

interface. A junction or junctions between a Class IE equipment and another equipment or device. Examples: connection boxes, splices, terminal boards, electrical connections, grommets, gaskets, cables, conduits, enclosures, etc.)

nuclear generating station. A plant wherein electric energy is produced from nuclear energy by means of suitable apparatus. The station may consist of one or more units which may or may not share some common auxiliaries.

operating experience. Accumulation of verifiable service data for conditions equivalent to those for which particular equipment is to be qualified.

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

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

sample equipment. Production equipment tested to obtain data that are valid over a range of ratings and for specific services.

service conditions. Environmental, power, and signal conditions expected as a result of normal operating requirements, expected extremes in operating requirements, and postulated conditions appropriate for the design basis events of the station.

type tests. Tests made on one or more sample equipments to verify adequacy of design and the manufacturing processes.

That such equipment will meet or exceed its performance requirements throughout its installed life. This is accomplished through a disciplined program of quality assurance that includes but is not limited to design, qualification, production quality control, installation, maintenance, and periodic testing. This document will treat only the qualification portion of the program.

It is the primary role of qualification to assure that for each type of Class IE equipment the design and the manufacturing processes are such that there is a high degree of confidence that future equipment of the same type will perform as required. The other steps in the quality assurance program require strict control to assure that subsequent equipment of the same type matches that which was qualified and is suitably applied, installed, maintained, and periodically tested. Margins used during type testing provide additional assurance that the equipment will perform as required.

Qualification may be accomplished in several ways: type testing, operating experience, or analysis. These may be used individually or in any combination depending upon the particular situation. In the first, it is expected that the equipment will be subjected to the environments and operating conditions for which it was designed and its performance measured. In a test program, it is usually practical only to simulate environments and operating conditions. The limitations in such simulations, the abbreviation of exposures permitted by increasing the severity of the environment, and the validity of data extrapolations must be taken into account in the design of the test. These points will be covered in greater detail in this and other guides. A representative test profile is given in Section 7.¹

Operating experience is a method of limited use as a sole means of qualification but of great use for the supplementation of testing in that it may provide an insight into the change in behavior of materials and equipment with time

4. Introduction

The manufacturers and users of Class IE equipment are required to provide assurance

¹Representative in-containment design basis event conditions for the principal reactor types are included in the appendixes for guidance in environmental simulation. These conditions may not be applicable for all specific applications and the user should confirm the suitability of these data and modify them as appropriate for qualification for any given Nuclear Power Generating Station.

under actual service and maintenance conditions. Operating experience is typically of particular use in qualification of equipment outside of the containment.

Qualification by analysis must include justification of methods, theories, and assumptions used. In general, electric equipment is too complex to be qualified by analysis alone, although it may be effective in the extrapolation of test data and determination of the effects of minor design changes to equipment that was previously tested.

With all qualification methods, the end result must be the documentation that must demonstrate the equipment's adequacy to perform its required function. The documentation must be in a form that allows verification by competent personnel other than the qualifiers and should contain the performance requirements, the qualification method, results, and the justifications.

5. Principles of Qualification

The capability of all Class IE equipment, including interfaces, of a nuclear power generating station for performing its required function shall be demonstrated. It is preferred that the demonstration be done by type tests on actual equipment. Operating experience and analysis may be used to supplement type tests.

Principles and procedures for demonstrating the qualification of Class IE equipment include:

- (1) Assurance that the severity of the qualification methods equal or exceed the maximum anticipated service requirements and conditions
- (2) Assurance that any extrapolation or inference be justified by allowances for known potential failure modes and the mechanism leading to them
- (3) On-going qualification testing of installed equipment whose qualified life is less than the design life of the equipment
- (4) Documentation files which provide the basis for qualification
- (5) Qualification test data as required for on-going qualification testing
- (6) Qualification of any interfaces associated with Class IE equipment

Several demonstration methods are acceptable. Service conditions, size, and aging are factors which determine the demonstration

method to be used to assure proper qualification. Each method (see below) requires justification to assure acceptability.

5.1 Type Testing. Type testing of actual equipment using simulated service conditions is the preferred method. This method should be used for qualifying the greater portion of equipment. However, a type test alone satisfies qualification only if the equipment to be tested is aged, subjected to all environmental influences, and operated under post-event conditions to provide assurance that all such equipment will be able to perform their intended function for at least the required operating time. When size or other practical requirements limit or preclude type tests, this part of the demonstration may be completed by methods described in Sections 5.2, 5.3, and 5.4.

5.2 Operating Experience. Electric equipment that has operated successfully can be considered qualified for equal or less severe service. Operating experience can provide information on limits of extrapolation, failure modes, and failures rates. The validity of operating experience as a means of qualification shall be determined from the type and amount of documentation supporting the service conditions and equipment performance.

5.3 Qualification by Analysis. Qualification by analysis shall require the construction of a valid mathematical model of the electric equipment to be qualified, in which the performance characteristics of the equipment are the dependent variables and the environmental influences are the independent variables. The validity of the mathematical model shall be justified by test data, operating experience, or physical laws of nature. Qualification shall consist of a quantitative analysis of the mathematical model of the electric equipment that shall logically prove that the performance characteristics of the equipment meet or exceed the equipment design specifications when the equipment is subjected to the design basis event environment.

Qualified life shall be determined from the time dependent effects of the environmental influences by quantitatively demonstrating that the performance characteristics of the equipment meet or exceed the design specifications of the equipment after a design basis event, preceded by a time period during which the equipment is subjected to its normal design environment. The maximum time period of

normal environment for which the quantitative analysis is valid shall be the maximum life for which the equipment can be qualified by analysis.

In general, mathematical models which can simultaneously quantify all the performance characteristics of electric equipment as functions of time and environment are unavailable. Because of this, analysis is generally used in the qualification process to quantify electric equipment performance as a function of the magnitude of a single environmental factor, such as seismic excitation, with aging and all other independent environment factors held constant or to quantify the performance of electric equipment as a function of the time history of a single environmental factor with all independent environmental influences held constant. This single variable analysis is then used for justification and augmentation of partial type tests and for providing the necessary logical link between the various factors of a test in which two or more environmental parameters are simulated.

The data used to support the qualification of equipment by analysis shall be pertinent to the application and in an auditable form. The data shall be presented as a step-by-step description for one complete set of computations, so persons reasonably skilled in this type of analysis can follow both the reasoning and the computations.

5.4 Combined Qualification. Equipment may be qualified by type test, previous operating experience, analysis, or any combination of these three methods. Partial type test may be augmented by tests of components where size, applications, time, or other test limitations preclude the use of a full type test.

Partial type tests with extrapolation or analysis, operating experience with extrapolation or analysis, and type tests supplemented with tests of components and analysis are examples of the use of combined qualification.

5.5 On-Going Qualification. The qualification methods described thus far may yield a qualified life of equipment that is less than the anticipated installed life of the equipment. When this occurs, an on-going qualification program may be implemented. Two methods for achieving this are:

- (1) aging and testing of identical equipment

or components may continue during the qualified life period of the installed equipment

- (2) additional equipment could be installed beside the required equipment, removed before the end of the qualified life period, and be type tested to determine its additional qualified life

Either of these methods would be considered on-going qualification. Other methods with proper justification may be found equivalent.

5. Qualification Procedures and Method

The qualification of Class IE equipment² shall include the following.

6.1 Identification of the Class IE Equipment Being Qualified.

6.2 Equipment Performance Specifications. Electric equipment specifications shall define the equipment's Class IE requirements and shall include as applicable:

- (1) Performance characteristics under defined normal, abnormal, containment test, design basis event, and post design basis event conditions

- (2) The range of voltage, frequency, load, electromagnetic interference, and other electrical characteristics

- (3) The installation requirements including mounting method and configuration(s)

- (4) Preventive maintenance schedule for the installed life of the equipment, (including lubricants and seals)

- (5) The design life of the equipment and the design life of any components which may have a life shorter than that of the complete equipment

- (6) Control, indicating, and other auxiliary devices contained in the equipment or external to the equipment and required for proper operation

- (7) The range, type, and duration of environmental conditions including temperature, pressure, humidity, radiation, chemicals, and seismic forces

- (8) Complete description and number of operating cycles including periodic testing

- (9) Qualified life. (This Performance Specification entry may be established during the qualification testing)

²Throughout this document the use of the term Class IE equipment also includes appropriate interfaces.

6.3 Type Test Procedures

6.3.1 *General*. The type test shall be designed to demonstrate that the equipment performance meets or exceeds the requirements of the equipment specifications for the plant. The type test shall consist of a planned sequence of test conditions that meet or exceed the expected or specified service conditions, including performance margin, and shall take account of both normal and abnormal operation.

6.3.1.1 *Test Plan*. The first step in the test procedure is the preparation of the test plan. The plan should be compatible with the equipment specification and should contain sufficient detail to describe the required tests and provide an auditable link between the specifications and the test results. *Auditable link* means that the plan should provide proof that the test method used was adequate, as this is not always discernible from the test results.

The test plan should contain the following information:

- (1) Equipment descriptions
- (2) Number (quantity) of units to be tested
- (3) Mounting and connection requirements
- (4) Aging simulation procedure
- (5) The service conditions to be simulated
- (6) Performance and environmental variables to be measured
- (7) Test equipment requirements including accuracies
- (8) Environmental, operating, and measurement sequence in step-by-step detail
- (9) Performance limits or failure definition
- (10) Documentation (Section 8.3)
- (11) Statement of nonapplicable portions of the specification
- (12) A description of any conditions peculiar to the equipment which are not covered above, but which would probably affect said equipment during testing

6.3.1.2 *Mounting*. Equipment shall be mounted in a manner and 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 would not be 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 specifying 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 and justified to show that the equipment's performance would not be altered by other means of connection. By *manner* is meant the means to be used in connection to equipment such as wiring, connectors, cables, conduit, terminal blocks, service loops, piping, tubing, etc.

6.3.1.4 *Monitoring*. The test shall be monitored using equipment that provides resolution for detecting meaningful changes in the variables. The test equipment shall be calibrated against auditable calibration standards and shall have documentation to support such calibration. The time interval between measurements shall be such as to obtain the time dependence of each variable. In describing test sequences, the measured variables may be classified into general categories as follows.

6.3.1.4.1 *Category I — Environment*. Temperature, pressure, moisture content,³ gas composition, vibration, and time.

6.3.1.4.2 *Category II — Input Electrical Characteristics*. Frequency, current, voltage, power to the equipment, and time duration of the input.

6.3.1.4.3 *Category III — Fluid Characteristics*. Concentration of chemical constituents in fluid injected into the test chamber plus the flow rate and spray disposition and temperature of such fluids.

6.3.1.4.4 *Category IV — Radiological Features*. Nuclear radiation data including energy type, energy level, exposure rate, and integrated dose.

6.3.1.4.5 *Category V — Electrical Characteristics*. Insulation resistance of electrical components; voltage, current and power output; response time; frequency characteristics and simulated load.

6.3.1.4.6 *Category VI — Mechanical Characteristics*. Thrust, torque, time, and load profile.

6.3.1.4.7 *Category VII — Auxiliary Function Measurements*. Function measurements related to Class IE equipments which

³Appendix C contains a preferred method for assuring saturated steam conditions in a test environment.

are included in the equipment but not necessary for its own operation; that is items which are required to provide a signal to control other Class IE equipment. Included under this heading would be auxiliary switches and position feedback potentiometers. Measurements shall be taken which confirm the capability of the equipment to handle rated or specified load and to provide rated or specified accuracy. Relevant measurements would include: current carrying and current interrupting capability of switches; contact resistance of limit switches with contacts closed; and potentiometer resistance and linearity.

6.3.1.5 *Margin*. Margin is the difference between the most severe specified service conditions of the plant and the conditions used in type testing to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance. The qualification type testing shall include provisions to verify that adequate margin exists. In defining the type test, increasing levels of testing, number of test cycles, and test duration shall be considered as methods of assuring adequate margin does exist.

Suggested factors to be applied to service conditions for type testing are as follows:

- (1) 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 lb_f/in²
- (2) Pressure: + 10 percent of gauge, but not more than 10 lb_f/in² [7.03(10⁻¹) kg/cm²]
- (3) Radiation: + 10 percent (on accident dose)
- (4) Voltage: ± 10 percent of rated value unless otherwise specified
- (5) Frequency: ± 5 percent of rated value unless otherwise specified
- (6) Time: + 10 percent of the period of time the equipment is required to be operational following the design basis event
- (7) Environmental Transients: The initial transient and the dwell at peak temperature shall be applied at least twice
- (8) Vibration: + 10 percent added to the acceleration of the response spectrum at the mounting point of the equipment

NOTE: Negative factors shall be applied when lowering the value of the service conditions increases the severity of the test.

6.3.2 *Test Sequence*. The type tests shall be run on the equipment in a specified order. For most equipment and applications, the following constitutes the most severe sequence; however, the sequence used shall be justified as the most severe for the item being tested.

(1) Inspection may be performed to assure that a test unit has not been damaged due to handling since manufacture and to determine basic dimensions. This inspection shall not be directed to select a specific unit for type testing

(2) The equipment shall be operated under normal conditions to provide a data base for comparison with performance under more highly stressed conditions. Certain measurements such as drift (rate of change with time) of a parameter may be made at this time

(3) The equipment 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 on identical or essentially similar equipment

(4) Equipment shall be aged in accordance with Section 6.3.3 to put it in a condition which simulates its expected end-of-qualified-life condition including the effect of radiation (design basis event radiation may be included). If the required radiation level can be shown to produce less effect than that which would cause loss of the equipment's Class IE function, radiation need not be included as part of aging. Certain key measurements should be made following aging to determine if the equipment is performing satisfactorily prior to subsequent testing

(5) The aged equipment shall be subjected to such mechanical vibration as will be seen in service. This should include simulated seismic vibration (see IEEE Std 344-1971), self-induced vibration (see IEEE Std 334-1971, Trial-Use Guide for Type Tests of Continuous Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations (ANSI N41.9)

(6) The aged equipment shall next be operated while exposed to the simulated design basis event (Section 7) [radiation may be excluded if incorporated in (4) above]. Those functions which must be performed during the simulated design basis event shall be monitored

(7) The equipment shall then be operated while exposed to the simulated post accident conditions (following exposure to accident conditions). Those functions which must be performed following the simulated design basis event shall be monitored during this simulation.

(8) Disassemble, to the extent necessary for the inspection of the status and condition of the equipment and record the findings.

6.3.3 Aging. The objective of aging is to put samples in a condition equivalent to the end-of-life condition. If previous aging of various devices exists, it can be utilized provided these data are applicable and justifiable in regard to the service conditions that are required by the performance specifications of the device to be type tested.

A short period of accelerated thermal aging merely simulates service life; however, it produces some deterioration and, when followed by vibration may produce realistic failure modes.⁴ Radiation shall be added to other known degrading influences where appropriate. Margins over that expected in the qualified life shall be provided in the application of each influence. Electromechanical equipment (motors, relays, etc) shall be operated to simulate the expected mechanical wear and electrical contact degradation (for example, contact pitting) of the device to be type tested.

An accelerated rate for the number of cycles equal to the required number during the design life may be utilized provided the rate shall not be accelerated to any value which results in effects that would not be present at normal rates.

For insulating materials, a regression line (see IEEE Std 101-1972, Guide for Statistical Analysis of Thermal Life Test Data) may be used as a basis for selecting the aging time and temperature. Sample aging times of less than 100 hours shall not be permitted.

6.3.4 Radiation. All materials or components which may be degraded to a degree which would adversely affect performance of Class IE functions by the radiation exposure expected to occur during normal service and postulated accidents shall be irradiated to simulate this exposure. Radiation shall be ap-

plied 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 that expected in service. However, if more than one type of radiation is significant, each type can be applied separately. In determining the total required test radiation equivalent to that of service life, consideration shall be given to oxidation gas-diffusion effects. To facilitate the use of a reasonable test time, an accelerated exposure rate may be necessary. Thus, to allow margin for these effects, a greater total dose than the service lifetime dose should be applied. Formulas for approximating the test dose equivalent to service are given in IEEE Std 278-1967 (ANSI N4.1-1967), Guide for Classifying Electrical Insulating Materials Exposed to Neutron and Gamma Radiation and ASTM D 2953-71, Classification System for Polymeric Materials for Service in Ionizing Radiation.

6.3.5 Vibration. The aged equipment shall be qualified for expected seismic events in accordance with IEEE Std 344-1971. In addition, equipment subject to nonseismic vibration during normal and abnormal use shall be subjected to such typical vibration following the aging and seismic procedures. Vibration to be simulated shall include self-induced vibration (such as the starting and running of a motor, vibration from nearby equipment, or vibration from equipment) which produces the mounting support for the Class IE equipment being qualified (such as pumps, generators, motors, etc).

6.3.6 Operation Under Normal and Accident Conditions. Means shall be provided during the type test for electrically energizing the equipment, applying simulated loads, applying input signals, and exposing it to simulated environmental conditions (for example, temperature, pressure, moisture, vibration, nuclear radiations, chemical solutions, jet forces, and chemical composition of the ambient environment).

6.3.7 Inspection. Upon completion of type testing, the equipment shall be dismantled to permit all parts to be appropriately tested and visually inspected. The condition of electrical insulation, mechanical parts, bearings, lubricants, electrical contacts, wiring, gear drive trains, linkages, and other related components shall be recorded.

6.4 Operating Experience

6.4.1 General Qualification of electric

⁴See IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment.

equipment by operating experience shall consist of determining the past history of performance and service conditions of the equipment type to be qualified, correlating operating service conditions with design service conditions, and proving that the Class IE performance characteristics of the equipment will meet or exceed the equipment specification under design service conditions.

6.4.2 *Operating History.*

6.4.2.1 The operating environment of the electric equipment to be qualified shall be determined and shall be justified by analysis of the effects of noncontinuous measurements. The documentation of the operating environment shall include physical locations and mounting arrangements of the equipments in the operating facilities.

6.4.2.2 The performance of the electric equipment type to be qualified shall be determined from measured data or analysis of failures that may have occurred or both. Documentation of all Class IE performance shall include measurement or determination of all performance characteristics in the equipment specifications, recording and analysis of all failures and trends that occurred during the operating period, and a log of all periodic maintenance (including adjustments and calibrations) and inspections.

6.4.3 *Determination of Qualification.* It shall be documented that the equipment whose operational history becomes a basis for qualification is typical of equipment bearing the same designation.

The electric equipment type shall be considered to be qualified by demonstrating that the recorded operating environment equals or exceeds the design environment in severity, and that the performance of the in service equipment equaled or exceeded the specified user requirements. The period of time for which the above requirements can be shown to be met with reasonable margin shall be the qualified life.

It should be noted that if the design environment includes seismic accelerations followed by a design basis event environment that is more severe than the recorded in service environment, then the installed equipment must, in general, be removed from service and subjected to a partial type test to include the seismic and design basis event effects before the equipment can be considered fully qualified.

6.5 Analysis

6.5.1 *General.* Qualification by analysis shall consist of a mathematical or logical proof that the Class IE performance of the equipment to be qualified meets or exceeds its specified performance when subjected to its specified normal and design basis event environments. In general, this proof must be based on established principles, operating experience data, partial type test data, or combinations of these. All assumptions, including extrapolations that are made in proof, shall be justified by establishing principles or verifiable test data; and the analysis shall be of a form that can be readily understood and verified by people qualified in the pertinent discipline of engineering or science.

6.5.2 *Mathematical Modeling.* The first step in the qualification by analysis is generally the construction of a valid mathematical model of the electric equipment to be qualified. The mathematical model shall be based upon established principles, verifiable test data, or operating experience data. The mathematical model shall be such that the performance of the electric equipment is a function of time and the pertinent environmental parameters. All environmental parameters listed in the equipment specification must be accounted for in the construction of the mathematical model unless it can be shown that the effects of the parameter of interest are dependent on the effects of the remaining environmental parameters.

6.5.3 *Extrapolation.* Extrapolation is an analytical technique which may be used to augment testing. However, in order to be considered valid for qualifying Class IE equipment certain guidelines must be met.

6.5.3.1 *Failure Modes.* The modes of failure produced under intensified or accelerated environmental or other influences shall be the same as those predicted under the required service conditions. If not, the intensity of the accelerating variable shall be reduced until failure modes and mechanisms produced are consistent with those known or predicted for required service conditions.

6.5.3.2 *Characterization of Effects.* The life (or other attribute) being extrapolated shall be characterized as a function of the environmental variable to provide a basis to forecast changes of the equipment performance with time (or other domain).

6.5.3.3 *Extrapolation Basis.* To establish

the basis for extrapolation, equipment or components shall be subjected to a comparable environment for a time or level necessary to justify the extrapolation of the test results to the total time or level to be qualified.

6.5.4 Determination of Qualification. The electric equipment type shall be considered to be qualified by demonstrating that the equipment performance will meet or exceed its specified values for the most severe environment or sequence of environments in the equipment specification during its qualified life. The severity of the environmental parameters shall be based upon knowledge of the failure modes and failure mechanisms of the equipment which may be determined by test. The qualified life shall be based upon the known limits of extrapolation of the time dependent environmental effects if an accelerated aging test was used to determine the mathematical model.

6.6 On-Going Qualification. Some equipment may have a qualified life less than the required design life of a nuclear power generating station. There are two recommended methods of long term qualification (see Section 5.5):

(1) Equipment of the same type as that which has been type tested and installed in a station shall be placed in an environment that accelerates the aging under controlled conditions. When it is determined that the equipment has reached the required design life of the station, it shall be removed from the accelerated life environment and type tested. The installed equipment may be considered adequate for the design life of the station if the equipment that was subjected to the accelerated life environment passes the type test.

(2) Additional identical equipment shall be installed in a nuclear generating station in locations where service conditions equal or exceed those of the equipment to be qualified. This equipment shall be removed after a planned period less than the previously qualified life and subjected to a qualification test similar to that performed prior to its installation. This test must include additional accelerated aging. Successful completion of this type test extends the qualified life of the installed equipment. This procedure shall be repeated until the qualified life equals the required installed life of the equipment.

Should the above methods demonstrate that the qualified life is less than the required life, a

periodic replacement plan shall be instituted.

6.7 Criteria of Failure. In the evaluation of the qualification test results, any sample equipment is considered to have failed when the equipment does not perform the Class IE functions required by the equipment specifications.

6.8 Modifications. Modifications should not be made to the equipment, or to the equipment or test specifications, after the start of the type test or beginning of the operating experience reporting period since such modification will normally render the test and experience results inconclusive. Modifications may be made only if full justification is documented and it is determined that such modifications have no bearing on the validity of the test.

Each modification to the equipment specifications shall be subjected to a type test or beginning of the operating experience reporting period to determine its effect on the equipment qualification. This evaluation shall indicate whether or not complete requalification is required. If not, the analysis or data and evaluation that demonstrates the effect of the modification on equipment performance shall be added to the original qualification documentation.

Components of the equipment which can be shown to be unaffected by the change need not be type tested again, as previous operating experience and type test data along with complete qualifications for portions affected by the modification shall constitute qualification of the entire equipment.

Any changes in qualification basis, materials of construction, lubricant, mechanical stresses, clearances, manufacturing process, dielectric stress levels, etc, shall be identified and the equipment requalified if necessary. Necessity shall be based on effect of the change on the equipment's Class IE functions.

6.9 Documentation. Files which provide documentation of the qualification procedures, methods, and results shall be maintained to provide a current basis for qualification and permit comparisons if future tests are conducted.

7. Simulated Service Condition Test Profile

The user shall furnish sufficient environmental data to allow the simulation of the

postulated design basis event profile. To this shall be added performance margins (see Section 6.3.1.5) to derive the appropriate simulated service condition test profile (Fig 1).

8. Documentation

8.1 General. The qualification documentation shall verify that each type of electric equipment is qualified for its application and meets its specified performance requirements. The basis of qualification shall be explained to show the relationship of all facets of proof needed to support adequacy of the complete equipment. Data used to demonstrate the qualification of the equipment shall be pertinent to the application and organized in an auditable form.

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

8.3 Type Test Data. The type test data shall contain:

- (1) The equipment performance specifications (Section 6.2)
- (2) Identification of the specific feature(s) to be demonstrated by the test
- (3) Test plan (Section 6.3.1.1)
- (4) Report of test results

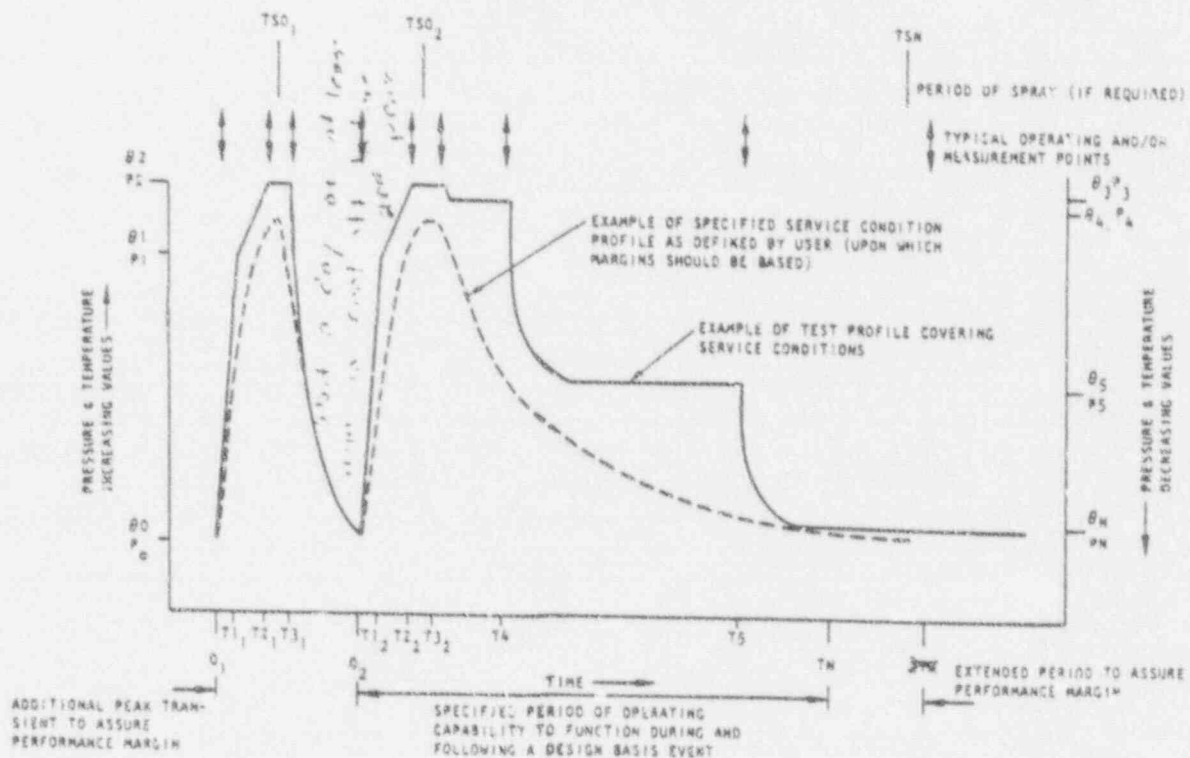
The report shall include:

- (a) Objective
- (b) Equipment tested
- (c) Description of test facility (test setup) and instrumentation used including calibration records reference
- (d) Test procedures
- (e) Test data and accuracy (results)
- (f) Summary, conclusions, and recommendations
- (g) Supporting data
- (h) Approval signature and date

8.4 Operating Experience Data. The operating experience data shall contain:

- (1) The equipment performance specifications (Section 6.2)
- (2) The interface or boundary conditions of the equipment

Fig 1
Simulated Service Condition Test Profile



(3) The specifications of equipment for which operating experience is available

(4) Identification of the specific features to be demonstrated by operating experience

(5) Comparison of past application and specifications with the new equipment specifications for each feature identified above

(6) Summary and source of operating experience applicable to equipment qualification

(7) The basis on which the data have been determined to be suitable and the equipment qualified

(8) Approval signature and date

8.5 Analysis. The analysis data shall contain:

(1) The equipment performance specifications (Section 6.2)

(2) The interface or boundary conditions of the equipment

(3) The specific features, postulated failure modes, or the failure effects to be analyzed

(4) The assumptions, empirically derived values, and mathematical models used together with appropriate justification for their use

(5) Description of analytical methods or computer programs used

(6) A summary of analytically established performance characteristics and their acceptability

(7) Approval signature and date

8.6 Extrapolation. Where the test data or operating experience data have been extrapolated, the basis for the extrapolation shall be included.

Appendix A

In-Containment Design Basis Event Environment Simulation For Pressurized
Water Reactors and Boiling Water Reactors

(These appendices are not part of IEEE Std 323-1974, Qualifying Class IE Equipment for Nuclear Power Generating Stations.)

NOTE: All the conditions presented are representative and may need modification to assure their suitability to any specific equipment application.

A1 General. The design basis event environment conditions to be simulated for a Pressurized Water Reactor (PWR) or Boiling Water Reactor (BWR) resulting from a postulated loss-of-coolant accident (LOCA) which are to be simulated generally consist of exposure to hot gases or vapors (for example, steam) and a spray or jet of water, chemical solution, or

other fluids. These environmental conditions differ markedly among different types of reactors, and also vary significantly from location to location in the plant. In most locations outside of the primary containment there will be no special environmental conditions resulting from a design basis event. There are other locations, such as within the reactor building in some BWR plants, where there will be special environmental conditions, but these may be less severe than those within the primary con-

Fig A1
Test Chamber Temperature Profile for Environment Simulation (Combined PWR/BWR)

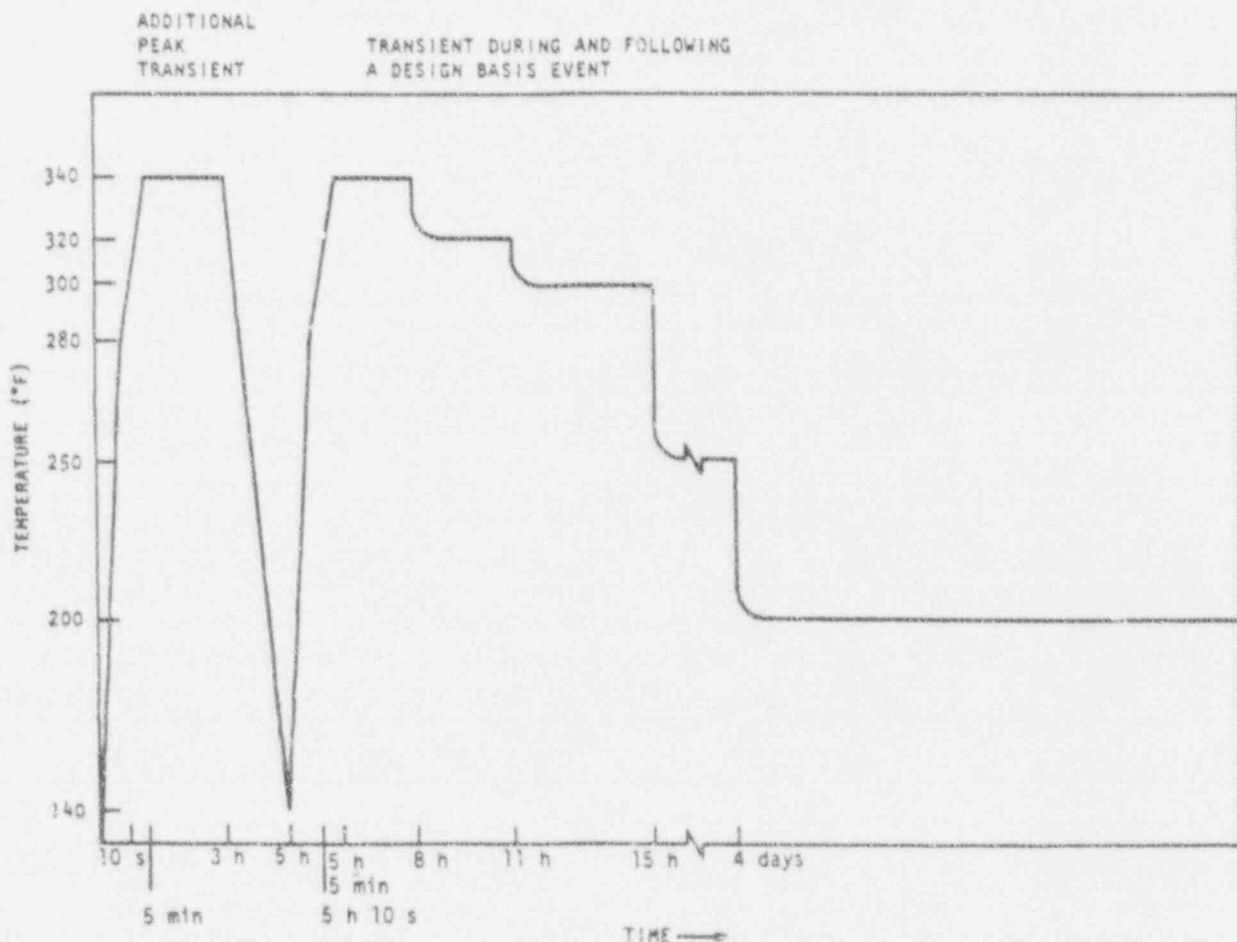


Table A1
Test Conditions for Pressurized Water Reactors*
(Typical In-Containment Design Basis Event Test Conditions)

(1) Exposure to Nuclear Radiation†

4 megarads after 1 hour
20 megarads after 12 hours
24 megarads after 1 day
40 megarads after 10 days
55 megarads after 1 month
110 megarads after 6 months
150 megarads after 1 year

(2) Exposure to Steam and Chemicals

(a) Steam Exposure

Time	Temperature		Pressure	
	(°F)	(°C)	(lb _f /in ² , gauge)	(kPa)
0 to 10 seconds	120 to 300	48.9 to 148.9	0 to 70	0 to 482.6
10 seconds to 10 hours	300	148.9	70	482.6
10 hours to 4 days	210	98.9	40	275.8
4 days to 1 year	167	75.0	5	34.5

(b) Spray Exposure. Continuously spray vertically downward for first 24 hours with a solution of the following composition at a rate of 0.15 (gal/min)/ft² (6.1 (ml/min)/m²) of area of the test chamber projected on to a horizontal plane.

0.28 molar H₃BO₃ (3000 parts per million boron)
 0.064 molar Na₂S₂O₃
 NaOH to make a pH of 10.5 at 77°F (about 0.59 percent)
 Dissolve chemicals, on a one-liter basis, in the following order:

- (i) 600 ml potable water
- (ii) H₃BO₃
- (iii) NaOH
- (iv) Na₂S₂O₃
- (v) Add remainder of water to volume of one liter
- (vi) Add NaOH to make a pH of 10.5 at 77°F, as required for the initial spray solution.

*The values given in this table may vary from plant to plant and may or may not contain adequate margin.

†Conservative calculation of radiation dose to containment atmosphere resulting from beta and gamma radiation emitters released from the primary system and at a location within the primary containment.

Table A2
Test Conditions for Boiling Water Reactors*
(Typical In-Containment Design Basis Event Test Conditions)

(1) Exposure to Nuclear Radiations†

26 megarads integrated over the accident

(2) Exposure to Steam and Spray

(a) Steam Exposure

Time	Temperature		Pressure	
	(°F)	(°C)	(lb _f /in ² , gauge)	(kPa)
0 to 20 seconds	135 to 280	57.2 to 137.8	0 to 62	0 to 427.5
20 seconds to 5 min	280 to 340	137.8 to 171.1	62	427.5
5 min to 3 hours	340	171.1	40	275.8
3 hours to 6 hours	320	160.0	40	275.8
6 hours to 4 days	250	121.1	25	172.4
4 to 100 days	200	93.3	10	68.9

If it is not practical to reproduce the specified pressure and temperature profiles combined, it is acceptable during the first four days to follow the temperature profile and allow the pressure to conform to saturated conditions (100 percent relative humidity). This procedure is justified by the fact that temperature is the more important parameter and increasing the pressure (to maintain saturated conditions) will increase the severity of the test, if anything.

(b) Spray Exposure. Continuously spray vertically downward with demineralized water at a rate of 0.15 (gal/min)/ft² (6.1 (ml/min)/m²) of area of the test chamber projected onto a horizontal plane.

*See 1st footnote to Table A1.

†See 2nd footnote to Table A1.

tainment. The equipment specification shall define the actual environment in detail.

The test profile to simulate the environmental conditions anticipated within the primary containment in current plants with Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) are shown in Tables A1 and A2. If it is desired to qualify equipment for in-containment service for both PWRs and BWRs, the test conditions may be chosen to encompass both test profiles, including the chemical spray specified for PWRs and the temperature/pressure profile specified for BWRs. Fig A1 shows a representative test chamber profile for a combined PWR/BWR test. If the actual conditions are different from these curves, the parameters may be adjusted accordingly. As noted above for out-of-containment service, the conditions may be less severe and generally are not different from the normal operating conditions.

Although the equipment is expected to experience at most only one severe environmental transient as a result of a LOCA event during its installed life, it is recommended that it be exposed to two initial steam/chemical transients in the Accident Environment Simulation, as

shown in the profiles (Fig A1).

A2 Simulation Sequence. Suggested sequences include:

- (1) Expose sample equipment to simulated
 - (a) Aging
 - (b) Radiation (if size permits and if warranted by radiation tolerance limits and effects on Class IE performance)
 - (c) Vibration
- (2) Stabilize operation in normal environment to establish reference conditions
- (3) Inject steam and chemical sprays at rates simulating service conditions, raising the temperature and pressure to test profile levels required
- (4) Maintain these conditions for three hours. De-energize for static readings including insulation resistance to ground. Re-energize one additional hour
- (5) Reduce the environmental conditions to the normal operating conditions within two hours
- (6) Repeat first cycle; but at the end of three hours, lower pressure in steps as required to simulate post-event profile for which equipment is to be qualified

Appendix B

In-Containment Design Basis Event Environment Simulation For A High Temperature Gas Cooled Reactor (HTGR)

NOTE: All the conditions presented are representative and may need modification to assure their suitability to any specific equipment application.

The design basis event (DBE) environments to be simulated for a high temperature gas cooled reactor (HTGR) typically consist of exposure to helium or steam. Table B1 in conjunction with Figs B1 and B2 present the anticipated pressure and temperature history of the containment atmosphere for design basis event environments; hot helium blowdown and hot reheat steam line rupture. Shown with the helium and steam exposure profiles is a representative equipment surface temperature profile. It is the responsibility of the equipment manufacturer to determine which of the conditions will present the most severe environment for his equipment and to specify the

criteria he used in selecting this condition. If doubt exists in identifying which condition is the most severe, consideration should be given to testing the equipment under both conditions.

Various test profiles may be used to produce the same equipment conditions provided this is adequately demonstrated by analysis or other means. The helium blowdown DBE profile assumes helium is used, however, nitrogen, air, or other gas can be used provided the exposure profile is appropriately modified.

The qualification testing shall assure adequate margin of survival. Although the equipment is expected to experience at most only one severe environmental transient as the result of a DBE during its installed life, it is suggested that it be exposed to at least two DBE

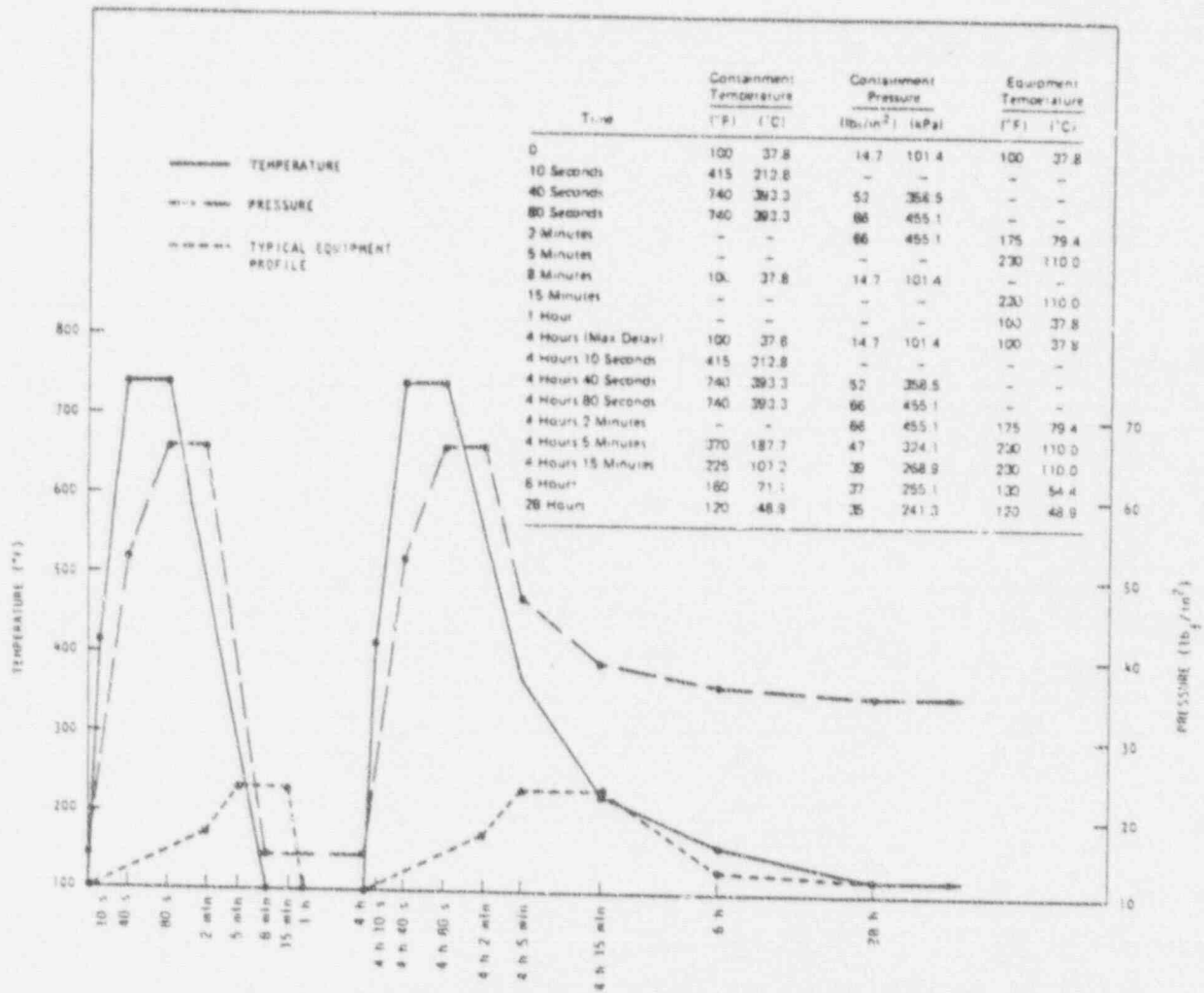


Fig B1
Typical Temperature and Pressure History for Environment Simulation of HTGR Containment Atmosphere Response Following a Hot Helium Blowdown into Containment ($T_o = 100^\circ\text{F}$, $P_o = 14.7 \text{ lb}_f/\text{in}^2$. Note: For Long-Term Testing, Assume Equilibrium Conditions at $T = 120^\circ\text{F}$ and $35 \text{ lb}_f/\text{in}^2$.)

Table B1
Test Conditions for High-Temperature Gas-Cooled Reactors
(Typical In-Containment Design Basis Accident Conditions)

- (1) Exposure to Nuclear Radiation
 - 2 megarads after 1 hour
 - 12 megarads after 1 day
 - 75 megarads after 1 year
- (2) Exposure to Steam and Gases
 - (a) Hot helium exposure -- see Fig B1
 - (b) Superheated steam exposure -- see Fig B2

transients as a method of demonstrating this margin. This method is shown in Figs B1 and B2.

As an aid in preparing for an environment simulation, the typical normal operating conditions for an HTGR are presented in Table

Fig B2
Typical Temperature and Pressure History for Environment Simulation of HTGR Containment Atmosphere Response Following a Steam Line Rupture Inside the Containment ($T_o = 100^\circ\text{F}$, $P_o = 14.7\text{ lb}_f/\text{in}^2$. Note: For Long-Term Testing, Assume Equilibrium Conditions at $T = 120^\circ\text{F}$ and $P = 16\text{ lb}_f/\text{in}^2$.)

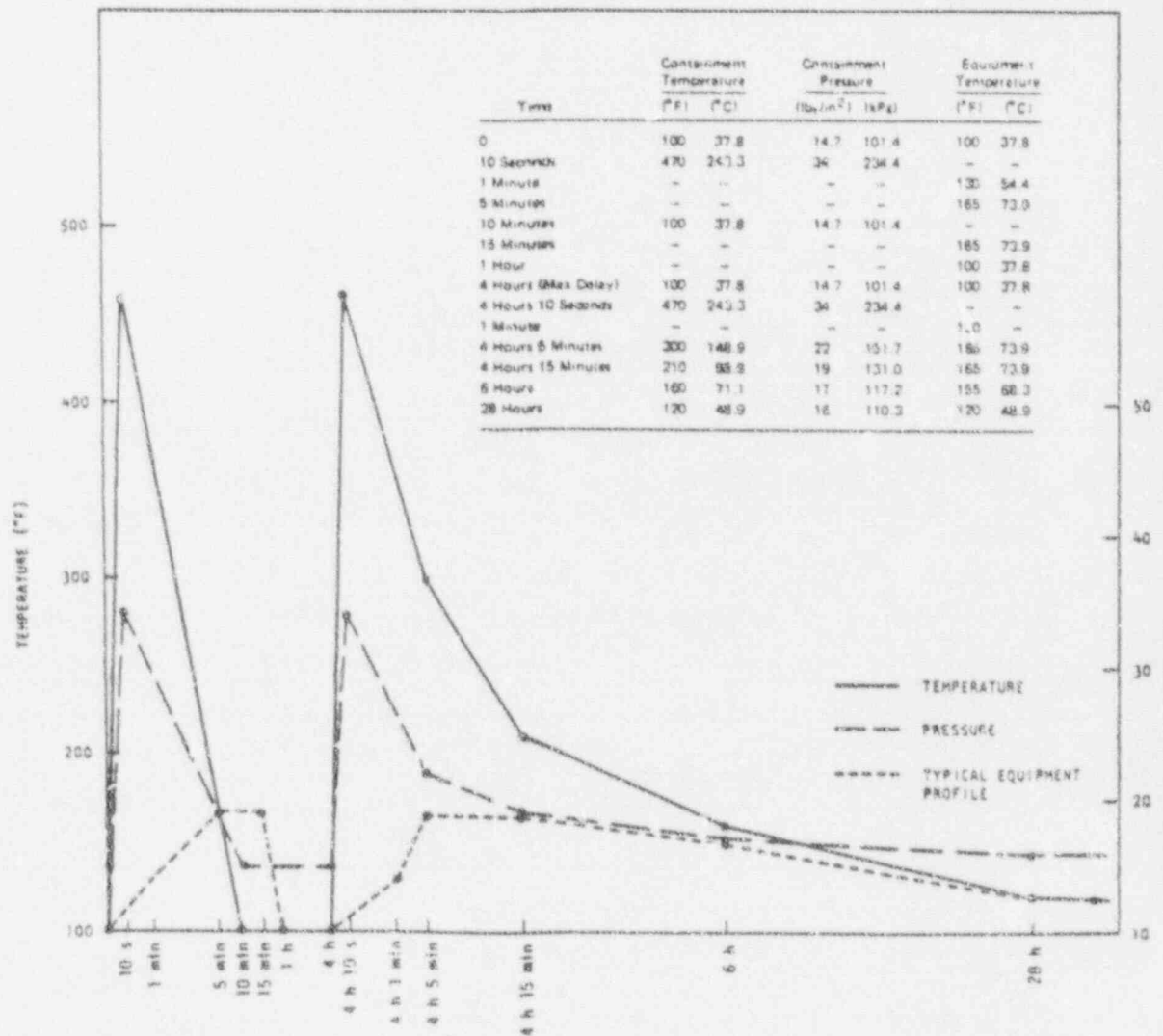


Table B2
HTGR Containment Building
(Normal Operating Conditions)

0065960

	Top Head Area		Bottom Support Area	
	Average Ambient	Maximum	Average Ambient	Maximum
Temperature	70-100°F (21.1-37.8°C)	170°F (54.4°C)	70-130°F (21.1-54.4°C)	160°F (71.1°C)
Pressure	-0.5 to 0.5 lb _f /in ² , gauge (-3.4 to 3.4 kPa)	-0.5 to 0.5 lb _f /in ² , gauge (-3.4 to 3.4 kPa)	-0.5 to 0.5 lb _f /in ² , gauge (-3.4 to 3.4 kPa)	-0.5 to 0.5 lb _f /in ² , gauge (-3.4 to 3.4 kPa)
Relative humidity	10-80 percent	80 percent	10-80 percent	80 percent
Radiation dose rate	2.5 to 25 mrd/hour	< 100 mrd/hour	2.5 to 25 mrd/hour	< 100 mrd/hour
Radiation dose for 40 year plant life	8.8 × 10 ³ rd		8.8 × 10 ³ rd	

Appendix C

Test Chamber Moisture Content

The simulation of Design Basis Event (DBE) conditions in qualification tests sometimes requires that a moisture-saturated environment be maintained at temperatures exceeding the highest temperatures at which commercially available relative humidity and dewpoint sensors are capable of functioning. This appendix suggests one way in which the existence of a saturated atmosphere can be assured in such cases.

Generally, the chamber that contains the equipment under test is initially full of air, and steam is injected into the chamber to execute the specified temperature profile. The analysis of moisture concentration inside the test chamber would be quite straight-forward if the air initially in the chamber were to remain trapped inside it, or if the air were driven out completely by the introduction of steam. But the situation is generally intermediate between these extremes, and there is no convenient way of determining the exact state. This is illustrated by the following.

Consider a mixture of air and steam at temperature T and pressure P . The pressure of the mixture is equal to the sum of the partial pressures of steam (P_{steam}) and air (P_{air}):

$$P = P_{steam} + P_{air}$$

and at equilibrium, we have

$$T = T_{steam} = T_{air}$$

For 100 percent relative humidity (RH), or saturated conditions, it is necessary that the partial steam pressure be equal to the pressure of saturated steam (P_{sat}) at the temperature T . If one knew the partial pressure of steam in the mixture, steam tables could be used to verify whether P_{steam} and T correspond to saturated steam conditions and, therefore, whether the RH of the mixture is 100 percent. However, the difficulty of measuring the partial pressure of steam makes this impractical. One way to avoid this problem is to introduce moisture into the test chamber in a way that assures saturation of the environment, as is described below.

The gas in a test chamber will be saturated with water vapor, that is, have a relative humidity of 100 percent, if thermal equilibrium exists between the water vapor and liquid water inside the chamber. Therefore, one way to guarantee saturated conditions is to place a container of water inside the chamber and keep its temperature at a value equal to the temperature of the gas in the chamber. It is also required that water vapor be evaporated from the heated water at a rate capable of saturating the chamber volume in a time that is short by comparison with the duration of con-

stant-temperature dwells in the test profile. To facilitate this, the water should be heated to boiling prior to the start of the test. A further requirement is that the chamber atmosphere be stirred at a rate adequate to maintain uniform conditions.

As an example, this can be done by sparging steam through water in a vessel that is inside the test chamber. The temperature of the water must equal or exceed the temperature of the steam/air mixture in the test chamber. The steam flow rate must be adjusted to meet this requirement as well as to satisfy the requirements of the preceding paragraph, and a fan or

other means of mixing must be provided to assure uniformity of the chamber atmosphere.

The method described above will provide a saturated atmosphere essentially throughout the test. The only exception is the short period required to reestablish equilibrium following a temperature rise. Since the amount of water vapor needed to saturate an environment decreases with a drop in temperature, there should be no lag in maintaining saturated conditions following temperature drops. Other methods of maintaining saturated conditions may be used provided their adequacy is demonstrated.