32

WCAP 8587, Rev. 5

Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment

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0764A

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

FOREWORD

Historically, safety related electrical equipment has been tested under the severe environmental conditions expected to occur in the event of a design basis accident. This testing provided a high degree of confidence in the safety system performance under the limiting environmental conditions. However, in keeping with the advancing state of the art, qualification criteria were revised in 1974 by revision of IEEE-323-1974 and by Regulatory Guide 1.89 which endorses this IEEE Standard. The concept of aging was highlighted in IEEE-323-1974 and interpretation of the scope of aging and implementation methods were soon urgently required. Some guidance on the scope of applicability of aging considerations was subsequently provided by the NPEC-7-24-75 "Nuclear Power Engineering Committee Position Statement to Foreword of IEEE Standard 323-1974".

Shortly after IEEE-323-1974 was issued, Westinghouse WRD formed an engineering task group to interpret new requirements and to recommend implementation methods. The qualification procedures described throughout this topical report are the result of this task group's efforts and subsequent evolution. The task group members were also assisted greatly by discussions with experts from other divisions of the company and the nuclear industry as well as from NRC Staff and IEEE committee personnel. The Westinghouse WRD program for qualification to IEEE-323-1974 is consistent with the interpretation set forth by the NPEC position mentioned above. In general, if any conflict exists between IEEE-323-1974 and other IEEE standards addressing qualification of electrical equipment, IEEE-323-1974 takes precedence in the Westinghouse interpretation of requirements. 5

Meetings with the NRC staff have been held to discuss qualification methods since Revision 0 of this report was issued in September, 1975. Revision 0 was written to respond to NRC Staff concerns on environmental qualification to IEEE-323-1974 relative to the Westinghouse RESAR-41 application. In the last three years, the program has been revised based on evolution of the state-of-the-art and interaction with NRC and industry representatives. The topical report's title has been changed to reflect the fact that the report, in its present from, represents general qualification methods to be utilized for qualification and not the qualification results themselves. Also, it was desirable to define the title in terms of Westinghouse's WRD Supplied NSSS scope equipment so that no mistake could be made that the contents of the topical report represent any other sister division's BOP qualification methods.

3

Revisions 2 and 3 of the topical have been made to include additional detail now available as a result of general program development and some reformating of the report has been introduced to allow the discussion contained in this report to follow the format headings of the Equipment Qualification Data Packages (EQDP's) now issued as Supplement 1 to this report. This reformatting permits easy cross reference between the methodology defined in this report and the detailed plans contained in the Supplement.

Revision 4 of this WCAP includes an update of Appendix A, which is the format used for the Equipment Qualification Data Package (EQDP), and the initial submittal of Appendix C, "Effects of Gamma Radiation Doses Below 10^4 Rads on the Mechanical Properties of Materials". Appendix C provides the basis that radiation aging below 10^4 Rads is not significant and will not be addressed in Westinghouse test programs for equipment subject to lifetime doses of less than 10^4 Rads.

5

Appendix D, "Accelerated Thermal Aging Parameters" was added to WCAP 8587 but not as a revision. This appendix describes the methodology employed by Westinghouse in calculating the accelerated thermal aging parameters used in this program.

Revision 5 of this WCAP includes the resolution of comments resulting from the independent utility review of the Westinghouse qualification program, plus some general updating by Westinghouse.

1.0 PURPOSE

The basic aim of equipment qualification of safety related equipment is:

- to reduce the potential for common mode failures due to environmental effects.

- to demonstrate that safety electrical equipment is capable of performing its designated safety related functions.

The purpose of WCAP-8587 is to describe the methodology that Westinghouse WRD has adopted to qualify equipment to IEEE-323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations." This methodology represents the Westinghouse WRD interpretation of this standard and defines the basis on which the detailed qualification program plans, contained in Supplement 1 to this report, have been established together with the intended methods of documenting the results.

2.0 SCOPE

The qualification criteria, methods, and environmental conditions described herein constitute the methodology that Westinghouse has adopted to comply with the above mentioned standard. This methodology applies to the NSSS scope safety related electrical equipment (e.g. equipment required to perform reactor trip, engineered safeguard features, or post-accident monitoring) supplied by Westinghouse WRD. Table 2-1 is a typical list of safety related electrical equipment, that has been supplied by Westinghouse WRD by its name, system, location (inside or outside containment) and the corresponding Equipment Qualification Data Package reference contained in Supplement 1 to this report. As additional qualification testing is completed and the scope of the program 5
expanded to include other safety related electrical equipment, the index of qualified equipment, contained in WCAP-8587 Supplement 1 and WCAP-8687 Supplement 2, will be updated. It is important to note that there may be plant to plant variations in Westinghouse WRD supplied NSSS equipment. Thus, not all of the equipment listed in Table 2-1 would be in Westinghouse WRD scope for any one plant. The actual listing of Westinghouse WRD supplied safety related electrical equipment is found in the applicant's SAR. If advancements in technology or substantial change in equipment type cause the methods for qualifying equipment to differ from those documented in this report, Westinghouse will supplement WCAP-8587 to identify and/or clarify these changes.

TABLE 2-1

TYPICAL SAFETY RELATED EQUIPMENT IN W WRD SCOPE OF SUPPLY 5

EQUIPMENT	SYSTEM	PLANT LOCATION**	EQDP REFERENCE	3
Safety Related Valve Electric Motor Operators	CVCS	i/0	HE-1 and 4	
	SIS	i/0		
	CSS	0		
	RHR	i/0		
Safety Related Solenoid Valve	CVCS	i/0	HE-2/5 (combined)	
	SIS	i/0		
	RCS*	i/0		5
	WPS*	0		
	SS*	i/0		
	SGBP*	0		
	RHR	i/0		
Safety Related Externally Mounted Limit Switches	CVCS	i/0	HE-3/6 (combined)	
	SIS	i/0		
	CSS	0		
	RHR	i/0		
	RCS*	i/0		
	WPS*	0		
	SS*	i/0		
	SGBP*	0		
Pressure Transmitters	RPS/PAM	i/0	ESE-1 and 2	
Differential Pressure Transmitters	RPS/PAM	i/0	ESE-3 and 4	
Resistance Temperature Detectors	RPS/PAM	i	ESE-5, 6 and 7	
Excore Neutron Detectors	RPS	i	ESE-8 and 9	
Nuclear Instrumentation System (NIS)	RPS	0	ESE-10	
Source Range Preamplifier	RPS	i/0	ESE-11 and 36	
Main Control Board Switch Modules	RPS/ESF	0	ESE-12	

TABLE 2-1 (Continued)

TYPICAL SAFETY RELATED EQUIPMENT IN W WRD SCOPE OF SUPPLY

EQUIPMENT	SYSTEM	PLANT LOCATION**	EQDP REFERENCE
Process Protection Sets	RPS	0	ESE-13
Indicators and Recorders	PAM	0	ESE-14 and 15
Solid State Protection Systm. Logic and actuation Trains - (Auxiliary Safeguards cabinets where Applied) and ESF on-Line Test Cabinet	RPS/ESF	0	ESE-16 and 17
Instrument Power Supply (Static Invertor)	Electrical Power Supply	0	ESE-18 and 35
Instrument Bus Distribution Panel	Electrical Power Supply	0	ESE-19, 33 and 34
Reactor Trip Switchgear	RPS	0	ESE-20 and 26
Pressure Sensor	RPS	i	ESE-21
4 Section Excore Neutron Detector	RPS	i	ESE-22
Loop Stop Valve Cabinet	RPS	0	ESE-23
RCP Speed Sensor	RPS	0	ESE-24
Main Control Board Primary Control Console Secondary Control Console Safety Center	RPS/ESF/PAM	0	ESE-25
Nitrogen-16 Detector	RPS	i	ESE-27
Rod Position Detector	RPS	i	ESE-28
Rod Position Data Cabinet	RPS	i	ESE-29
Integrated Protection Cabinet	RPS	0	ESE-30
Integrated Logic Cabinet	RPS	0	ESE-31
Field Termination Cabinet	RPS	0	ESE-32
PAMS Demultiplexer	PAM	0	ESE-37
Control Board Multiplexer	RPS/ESF	0	ESE-38

TABLE 2-1 (Continued)

TYPICAL SAFETY RELATED EQUIPMENT IN W WRD SCOPE OF SUPPLY 5

EQUIPMENT	SYSTEM	PLANT LOCATION**	EQDP REFERENCE	
				3
Fiber Optic Cable	RPS/ESF	0	ESE-39	
Hydrogen Recombiner	ESF	i	SP-1	
Safety Related Pump Motors	CVCS	0	AE-1 thru 4	
	SIS	0		
	EBS	i		
	RHRS	0		
	CCWS	0		

NOTES:

0 = Outside containment

i = Inside containment

* = Containment Isolation valves only

** = For the Equipment listed below, the Applicant will be responsible for locating this equipment in a plant area which has environmental conditions within the equipment's normal, abnormal, and accident environments (specified in each EQDP). 3

CVCS = Chemical Volume Control System

SIS = Safety Injection System

WPS = Waste Processing System

SGBP = Steam Generator Blowdown (Waste) Processing System)

RHR = Residual Heat Removal (System)

PAM = Post Accident Monitoring

RPS = Reactor Protection System

ESF = Engineered Safeguard Feature

N/A = Not Applicable

EBS = Emergency Boration System

CCWS = Component Cooling Water System

CSS = Containment Spray System

SS = Sampling System

RCS = Reactor Coolant System 3

3.0 INTRODUCTION

As mentioned in Section 1, the purpose of WCAP 8587 is to describe the methodology which will be applied in qualifying Westinghouse WRD supplied NSSS safety related electrical equipment. Section 4 describes WCAP 8587's inter-relationship between the actual qualification of equipment, licensing documentation of the qualification, and application to individual Safety Analysis Reports (SARs). Section 5 identifies the various industry and regulatory criteria upon which the program is based. Section 6 defines the methodology employed in defining the Performance Specification, including functional requirements and applicable environments, provided in Section 1 of the individual Equipment Qualification Data Packages (EQDP's) contained in Supplement 1 to this report. Section 7 defines the basis on which the qualification program plans have been established, whether by test (EQDP Section 2), experience (EQDP Section 3), analysis (EQDP Section 4) or a combination of these methods. The discussion in Sections 6 and 7 follows the section headings of the standard EQDP (Appendix A).

4.0 DOCUMENTATION PLAN

The overall equipment qualification documentation plan consists of three sets of documents:

1. WCAP-8587 "Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment" which is a Westinghouse Class 3 (Non-Proprietary) report and represents the generic program parent document and describes the basis methodology on which the Westinghouse qualification program is based. 5

2. WCAP-8587, Supplement 1 "Equipment Qualification Data Packages" (EQDP) is also a Westinghouse Class 3 (Non-Proprietary) report which represents a summary of the program testing, this document is revised to include a summary of test results and identifies defining the equipment performance specifications and qualification plan. Upon completion of testing, this document is revised to include a summary of test results and identifies the supporting test reports.

3. WCAP-8687, Supplement 2 "Equipment Qualification Test Reports," (EQTR) is a Westinghouse Class 2 (Proprietary) report and presents specific methods used during testing and results of those tests. All test reports are coded to the appropriate EQDP reference number.

Each EQDP follows the format outlined in Appendix A. Figure 4-1 graphically demonstrates how WCAP-8587 acts as the parent methodology document for the daughter EQDP's that are separately documented in Supplement 1 to WCAP 8587 and test reports documented in Supplement 2 to WCAP 8687. All information necessary to demonstrate the equipments ability to perform its intended safety function(s) under normal, abnormal, accident and post accident environments will 5 be provided. All support test data will be maintained available for audit by Westinghouse for the life of the plant. If maintenance, refurbishment or replacement of the equipment is necessary to ensure the ability to perform the equipments safety function, then this information will also be included in the EQDP. The completed EQDP will be made available to the NRC staff for audit. Westinghouse WRD will provide, as input to the applicant's SAR, references to the applicable qualification documentation.

The performance specification, contained in Section 1 of each EQDP, constitutes interface requirements to the applicant who references the EQDP in his license application. The Owner/AE will be responsible for demonstrating that qualified equipment is utilized and located such as not to prejudice the performance specification contained in Section 1 of the EQDP. The NRC review of the SAR will ensure that the equipment qualification is satisfactory when compared to the plant specific environment and functional requirements. This entire process, described above, is graphically presented in Figure 4-2.

4.1 TRACEABILITY

Westinghouse has instituted a system of Baseline Design Documentation (BDD) to control the design, procurement and manufacturing of all Class 1E products. As part of this quality control program critical parts are identified and assigned a level of control to reflect the Westinghouse estimate of potential qualification and/or procurement problems. For example, Westinghouse employed a lot control program on some initial purchases of equipment for harsh environments until confidence in the specification could be assured. In addition, levels of quality
5 inspection are also assigned to each part. The Baseline Design documentation provided describes the equipment in sufficient detail (drawing number, part number, manufacturer, etc) to establish traceability between equipment shipped and that tested in the qualification program.

4.2 AUDITABLE LINK DOCUMENT

The purchaser of equipment referencing this program will require an auditable link document, designated EQAL-XXX, which provides a tie between the plant specific equipment and this program. This auditable link document will include one or more of the following sections:

4.2.1 EQUIPMENT LINK

This documentation certifies that the plant specific equipment is covered by the applicable equipment test reports in WCAP-8687, Supplement 2. This link will reflect a comparison of the as-built drawings, baseline design document or other documentation of the tested equipment to the plant specific equipment.

4.2.2 COMPONENT LINK

This documentation certifies that the components utilized in the plant specific
equipment is represented in the Component Aging Program, WCAP-8586, Appendix 5
B, Subprogram C. This link would only apply to equipment whose EQDP references
the W Component Aging Program. This link will reflect a comparison of the
as-built drawings, baseline design document or other documentation of the plant
specific equipment to the component program listing.

4.2.3 MATERIALS LINK

This documentation certifies that the materials utilized in the plant equipment is represented in the Materials Aging Analysis, WCAP-8587, Appendix B, Subprogram B. This link would only apply to equipment whose EQDP references the W Materials Aging Analysis and will reflect a comparison of the as-built drawings, baseline design document or other documentation of the plant specific equipment to the materials aging analysis listing.

14.050-1

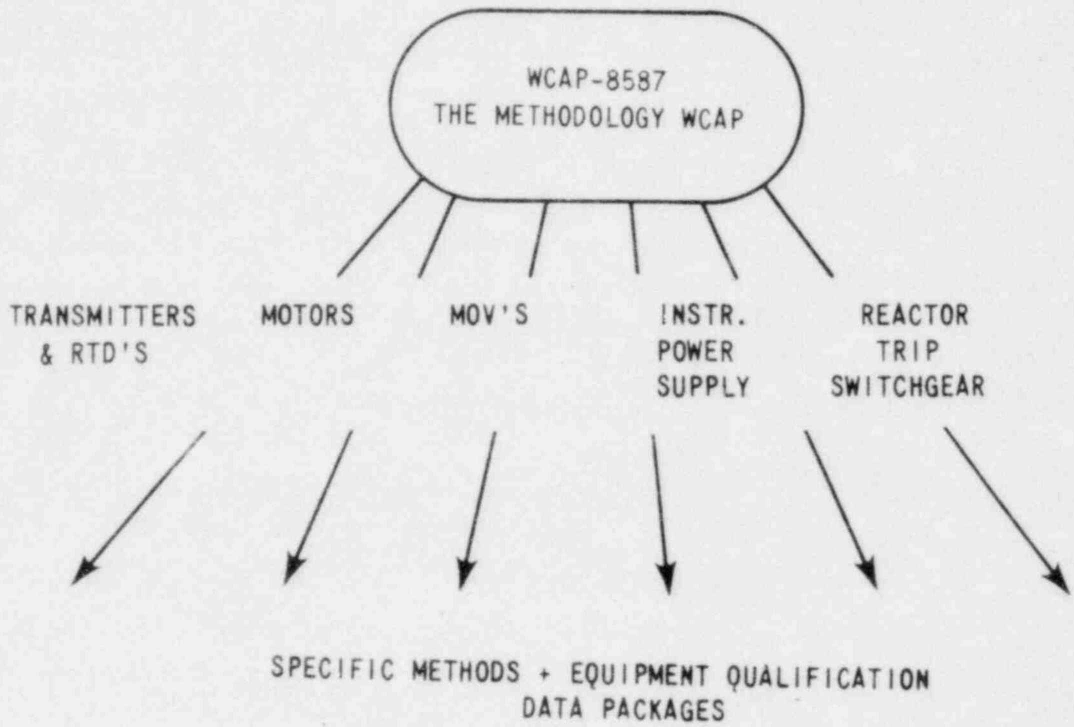

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Figure 4-1 Equipment Qualification Documentation

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WESTINGHOUSE CLASS 3

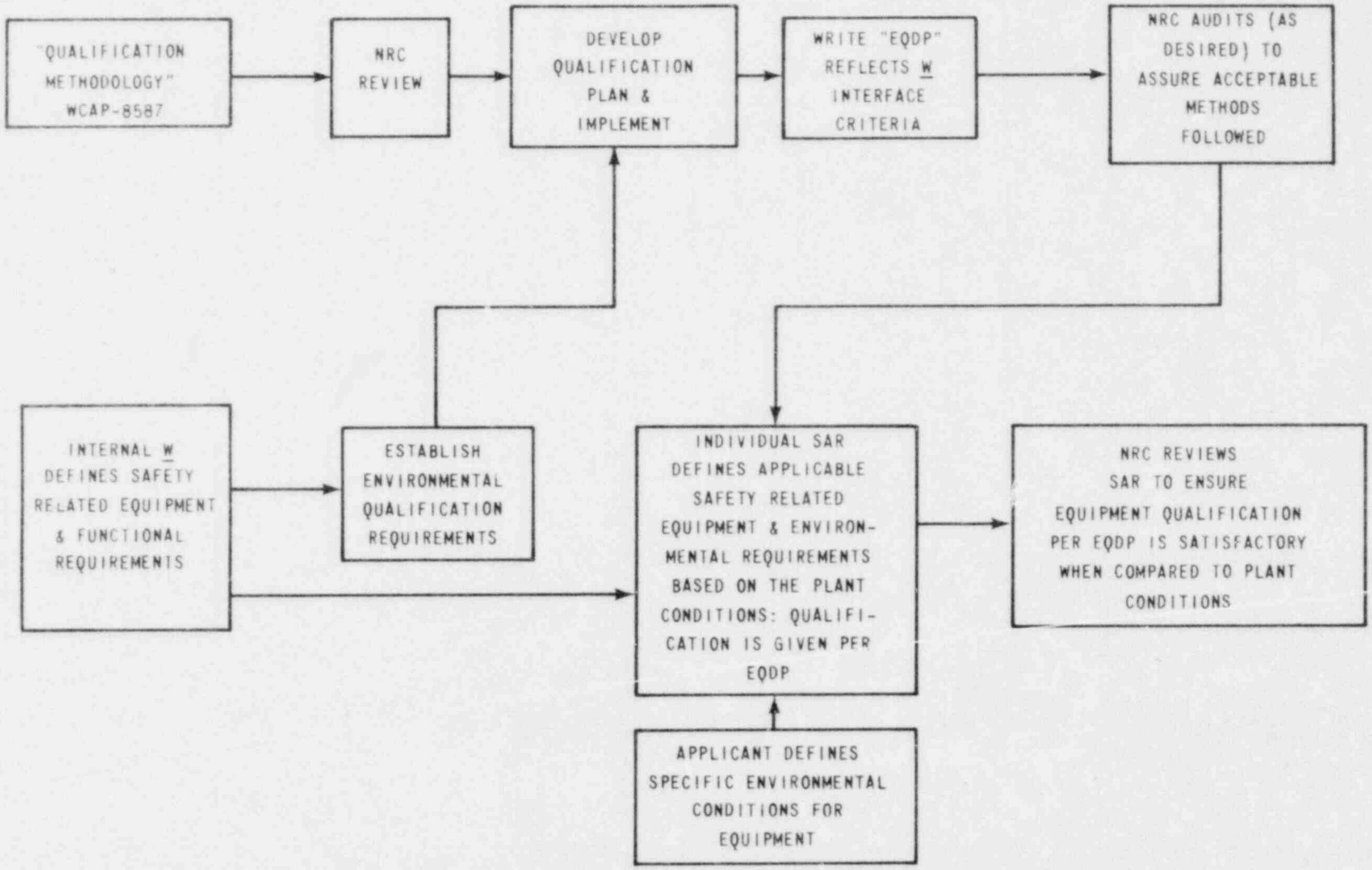

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Figure 4-2 Safety Related Electrical Equipment Qualification Process

5.0 QUALIFICATION CRITERIA

5.1 QUALIFICATION BASIS

The environmental requirements to be considered in the design of safety related equipment are embodied in Title 10 Code of Federal Regulations (10CFR), Appendix A to Part 50, "General Design Criteria" and specifically General Design Criterion 2 "Design Bases for Protection Against Natural Phenomena", General Design Criterion 4 "Environmental and Missile Design Bases" and General Design Criterion 23 "Protection System Failure Modes." That the environmental design of the safety related equipment is verified, documented and controlled is required by General Design Criterion 1 "Quality Standards and Records" and Section III "Design Control" of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" to 10CFR Part 50.

The qualification methods described in this topical report will be utilized to verify the environmental design basis and capability of the Nuclear Steam Supply System safety related electrical equipment supplied by Westinghouse WRD. The results of the verification, as well as the design basis for each equipment, will be documented in an "Equipment Qualification Data Package" (EQDP), (See Appendix A for sample format). Design control will be performed via the Westinghouse Quality Assurance Program.

5.2 QUALIFICATION GUIDES

The need for safety related electrical equipment qualification to verify its operational capability was identified in Section 4.4 of the "Proposed IEEE Criteria for Nuclear Power Plant Protection System" (IEEE279-1968) which evolved into IEEE Standard 279-1971 "Criteria for Protection Systems for Nuclear Power Generating Stations" and Section 4.7 of IEEE 308-1970 "IEEE Standard Criteria for Class 1E Electrical Systems for Nuclear Power Generating Stations. IEEE 323-1971, "IEEE Trial-Use Standard: General Guide for Qualifying Class 1E Electric Equipment for Nuclear Power Generating Stations" was issued ... "to provide guidance for demonstrating the qualifications of electrical equipment as required..." in the before mentioned IEEE Standards. IEEE 344-1971 "IEEE Guide for Seismic Qualification of Class 1 Electric Equipment for Nuclear Power Generating Stations" was issued to provide guidance relating to seismic qualification and to supplement IEEE 323-1971.

IEEE-323 and IEEE-344 have been revised and reissued as IEEE-323-1974 (Endorsed by Regulatory Guide 1.89, November, 1974) and IEEE-344-1975 (Endorsed by Regulatory Guide 1.100, March, 1976). These two documents serve as the basis upon which the qualification methodology is developed, supplemented by the standards listed above and guided by IEEE-323A-1975, "Nuclear Power Engineering Committee Position Statement to Foreword of IEEE-323-1974".

The Institue of Electrical and Electronics Engineers, Inc., has issued additional standards for qualification of specific types of electrical equipment. The individual daughter standards that Westinghouse will employ, either in whole or in part are:

1. IEEE 382-1972 "IEEE Trial Use Guide for Type Test of Class 1E Electric Valve Operators for Nuclear Power Generating Stations" (Endorsed by Regulatory Guide 1.73, (January, 1974)).

2. IEEE-383-1974 "IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations."

3. IEEE-117-1974 "Test Procedure for Evaluation of Systems of Insulating Materials for Random Wound AC Electric Machinery."

4. IEEE-275-1966 (Reaff 1972) "Test Procedure for Evaluation of Systems of Insulating Materials for AC Electric Machinery Employing Form-Wound Preinsulated Stator Coils."

Other standards will be evaluated for acceptability by Westinghouse as they are developed.

5.3 QUALIFICATION TEST PROCEDURE CRITERIA

In establishing the qualification procedures, methods and documentation, Section 6 of IEEE-323-1974 was utilized. The following provides an outline of the implementation of Section 6 IEEE-323-1974 into the Westinghouse program (parenthesis refer to Sections of the Standard):

Identification of the Class IE Equipment Being Qualified (Section 6.1) - The Equipment will be identified on the cover sheet and Section 2.1 of the EQDP.

Equipment Performance Specifications (Section 6.2) - The equipment performance specifications will be delineated in Section 1 of the EQDP.

Type Test Procedures - General (Section 6.3.1) - The general type test procedures will be identified in Sections 2.1 through 2.7 of the EQDP.

Test Sequence (6.3.2) - The test sequence to be utilized in qualifying the various equipment types is delineated, in general terms, in Section 7 of this report. The specific test sequence to be employed will be documented in Section 2.9 of the EQDP.

Aging (6.3.3) - The methods utilized to address aging in the qualification of the various equipment types are discussed in Section 7 and Appendix B to this report. The aging considerations will also be documented in Sections 2.5 and 4.0 (where applicable) of the EQDP.

Radiation (6.3.4) - The specific radiation test requirements and actual radiation dose employed for qualification will be delineated in Sections 1.8.4 and 2.6.4 respectively of the EQDP. Radiation conditions are also addressed in Section 6.7 of this report.

Vibration (6.3.5) - The procedures utilized in performing seismic qualification will be in accordance with IEEE-344-1975 and will employ either multi-axis, multi-frequency testing; single axis sine beat testing; dynamic or static analysis or a combination of these methods. The specific option to be employed in the qualification of the equipment type is identified in Section 2.9 and 4.0 (where applicable) of the EQDP. Sections 1.8.7 and 2.6.7 or 4.0 of the EQDP will document the performance specification and the seismic levels assumed for qualification purposes respectively. Consideration of ambient vibration as an aging factor for electrical equipment is addressed in Section 7 and Appendix B. Requirements and qualification specifications with respect to
5 vibration will be documented in Sections 1.8.6, and 2.6.6 of the EQDP, where applicable.

Operation Under Normal and Accident Conditions (6.3.6) - Where operation is required under normal, abnormal accident, and/or post accident conditions, means will be provided to obtain the necessary information during type
5 testing. These "means" will be described under Section 2.10 of the EQDP.

Inspection (6.3.7) - Post type test visual inspection will be performed and the condition of the equipment noted. A summary, conclusions and recommendations resulting from the inspection will be included in Section 2.10 of the EQDP.

Operating Experience (6.4) - Where operating experience is chosen as a supplementary method of qualification, Westinghouse WRD will demonstrate that the experience is applicable to the functional requirements for which the equipment is being qualified. This applicability determination will include an evaluation of operating environments, mountings, performance requirements and performance history. Documentation of qualification by experience will be provided in Section 3.0 of the EQDP.

Analysis (6.5) - Qualification by analysis alone is not employed by Westinghouse WRD. Analysis is employed to supplement testing or to provide verification that the test results are applicable. The assumptions and models utilized will be described and with the results of the analysis and conclusions will be documented in Section 4.0 of the EQDP.

On-Going Qualification (6.6) - On going qualification as described in Section 6.6 of IEEE 323-1974 is not employed by Westinghouse WRD as a method for qualification.

Criteria of Failure (6.7) - The equipment will be judged unsuitable when the qualification results fail to demonstrate that the equipment will perform the safety function required by the particular functional requirements as specified in Section 1.7 of the EQDP. It is possible for equipment to be suitable and qualified to perform some safety functions but unsuitable for others. The suitability to perform a safety function for a particular plant will be demonstrated in individual plant Safety Analysis Reports by comparing the qualification demonstrated by the Equipment Qualification Data Package to the plant specific requirements of the function for which the equipment is used (See Figure 4-2).

Modifications (6.8) - The criteria for modification, if applicable, will be delineated in the individual test procedures.

Documentation (6.9) - Documentation of specific equipment qualification will be provided via the Equipment Qualification Data Packages (See Appendix A).

5.4 REGULATORY GUIDE CONFORMANCE

Regulatory Guides describe methods acceptable to the NRC staff for implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents or to provide guidance to applicants. In the area of seismic and environmental qualification of safety related electrical equipment, the NRC has issued the following Regulatory Guides:

Regulatory Guide 1.40, "Qualification Tests of Continuous-Duty Motors Installed Inside the Containment of Water Cooled Nuclear Power Plants" - This guide endorses, with certain modifications, IEEE 334-1971. Westinghouse WRD does not currently supply equipment within the scope of this guide.

Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Water-Cooled Nuclear Power Plants - This Regulatory Guide endorses, with certain qualifications, IEEE 317-1972. However, since Westinghouse WRD does not supply containment penetrations, this guide is not applicable.

Regulatory Guide 1.73, "Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants" - Regulatory Guide 1.73 endorses, with certain qualifications, IEEE 382-1972. Westinghouse employs the recommendations of the Regulatory Guide in part in specifying the qualification
3 program plans contained in Supplement 1 to this report and specifies additional requirements to ensure conformance with IEEE 323-1974.

Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Power Plants" - This guide endorses IEEE 323-1974 with certain qualifications, i.e. the use of IEEE 344-1971 (see below) and source terms. Westinghouse employs the recommendations of Regulatory Guide 1.89 by the following:

1. The recommendations of IEEE 323-1974 are met by the methods discussed in Sections 6, 7 and Appendix A of this WCAP.

2. The radiation source terms used in qualification are described in Section 6 of this WCAP and meet the recommendations of Regulatory Guide 1.89.

3. The seismic qualification requirements employ the recommendations of IEEE-344-1975 as described in Section 7 of this WCAP.

Regulatory Guide 1.100, "Seismic Qualification of Electrical Equipment for Nuclear Power Plants" - This guide endorses, with certain qualifications, IEEE 344-1975. Westinghouse employs the recommendations of by Regulatory Guide 1.100 as described in Section 7 of this topical report.

6.0 PERFORMANCE SPECIFICATIONS

Section 1.0 of the Equipment Qualification Data Packages (Appendix A) contains the performance specification of the equipment. This specification establishes the necessary parameters against which qualification shall be demonstrated. The basic acceptance criteria for qualification is that the safety related functional requirements defined in EQDP Section 1 are successfully demonstrated, with margin, under the specified environmental conditions. The Owner/AE will be responsible for ensuring the qualified equipment is utilized and located such as not to prejudice the performance specification contained in Section 1 of the EQDP.

The following sections, define the basis on which the parameters contained in EQDP Section 1; Performance Specifications, are selected.

6.1 ELECTRICAL REQUIREMENTS

The pertinent electrical requirements are specified (i.e. voltage, frequency, etc.) in Section 1.1 of the EQDP together with the variation in the defined parameters for which the equipment is required to perform its specified functions.

6.2 INSTALLATION REQUIREMENTS

In order to ensure that the qualification represents the in-plant condition the method of installation, as specified in Section 1.2 of the EQDP, is in accordance with the supplier's installation instructions.

6.3 AUXILIARY DEVICES

Where the equipment to be qualified relies upon the operation of any auxiliary device(s) in order to perform the specified safety related functions, such devices are identified in EQDP Section 1.3. The applicable EQDP for the auxiliary device(s) is specified, if within the Westinghouse scope of supply.

6.4 PREVENTATIVE MAINTENANCE SCHEDULE

The details of any preventative maintenance schedule implicit in establishing the qualified life of the equipment, will be specified in EQDP Section 1.4 on completion of the qualification program.

6.5 DESIGN LIFE

The specified value listed in EQDP Section 1.5 for the design life is the period of time for which satisfactory performance of the equipment is anticipated. Due to limitations in current technology regarding the simulation and consequent effects of aging, it may be necessary in some instances, to specify a qualified life less than the design life.

6.6 OPERATING CYCLES

Where applicable, a conservative estimate of the number of cycles (i.e. start-up and shutdown) that the equipment will experience during the design life is specified in EQDP Section 1.6. This estimate includes an allowance for periodic testing of the equipment.

6.7 ENVIRONMENTAL CONDITIONS

The environmental conditions considered in the qualification of NSSS safety related equipment can be separated into three categories: normal, abnormal, and accident conditions. "Normal Conditions" are those sets and ranges of plant conditions that are expected to occur regularly and for which plant equipment is expected to perform its safety function, as required, on a continuous, steady-state basis. "Abnormal" refers to the operating range in which the equipment is designed to operate for a period of time without any special calibration or maintenance effort. "Accident conditions" refers to an operating limit to which the equipment may be subjected without impairment of its operating characteristics. Equipment operated within the accident condition operating limit may require that tests, inspections, and maintenance to be performed on the equipment, prior to return to normal operating conditions.

The following sections define the basis for the normal, abnormal, accident and post accident environmental conditions specified in EQDP Section 1.8 and to be assumed by Westinghouse for qualification of safety related electrical equipment. These conditions have been conservatively derived to allow for possible alternative locations of equipment within the plant.

6.7.1 NORMAL OPERATING CONDITIONS 5

Pressure, Temperature, Humidity

In defining the normal operating environmental parameters to be employed, maximum use has been made of available Architect Engineering interface information and the draft recommendations of the IEEE concerning environmental parameters (Reference 1). The assumed values for temperature, pressure and humidity during normal operation are specified in Table 6-1 as a function of in-plant location.

Radiation Dose

The normal operating dose rates, and consequent 40 year doses, assumed at various locations inside containment are specified in Table 6-2. These values have been derived from theoretical calculations assuming 40 years of continuous operation with a reactor power of 4100 MWth and steady state operating conditions. Equivalent data at various locations outside containment are specified in Table 6-3. The 40 year doses quoted are consistent with the draft IEEE recommended environmental parameters (Reference 1).

6.7.2 ABNORMAL OPERATING CONDITIONS 5

Abnormal environments are defined to recognize possible plant service abnormalities which could lead to short-term changes in equipment environments.

Figure 6-1 presents the assumptions made in defining potential abnormal environments due to loss of air conditioning or ventilation systems. The specified values are consistent with available Architect Engineering interface information and the draft recommendations of the IEEE (Reference 1). Table 6-1 defines the abnormal environments as a function of equipment location. The assumed duration of the abnormal conditions specified in Table 6-1 are consistent with current operating practices and Technical Specification limits. For certain plant applications, qualification for abnormal environments will not be necessary when equipment is located in an air conditioned environment controlled by a class IE system.

3, 5 6.7.3 CONTAINMENT TEST ENVIRONMENT

Reg. Guide 1.18 specifies that containment integrity shall be demonstrated at 1.15 times design pressure. The maximum design pressure of containments employed with PWR system designs is of the order of 60 psig. Consequently, the assumed pressure for the containment test, as specified in Section 1.8 of the EQDP, is 1.15 x 60 psig $\simeq$ 70 psig. Other environmental parameters (temperature, humidity, etc.) obtaining during the test are adequately enveloped by other aspects of the qualification program and will therefore be assumed to be the normal operating values.

5 6.7.4 ACCIDENT AND POST ACCIDENT ENVIRONMENTS

Section 1.7 of the EQDP separately specifies the performance requirements for those accidents for which the equipment is claimed to perform a safety related function and which have a potential for changing its equipment environment due to increased temperature, pressure, humidity, radiation or seismic effects. The consequent environmental conditions for those design basis events are defined in EQDP Section 1.8 on the basis of the assumptions described in the following discussion:

High Energy Line Break Accidents (HELB) - In Containment

1. The accidents to be addressed are the Loss of Coolant Accident (LOCA), Steamline Break (SLB) and Feedline Break (FLB). In order to retain the option of qualifying equipment for separate applicable HELB conditions, separate in-containment environmental design envelopes have been specified for the higher irradiation/lower saturated temperature conditions of LOCA (Figure 6-2) as against the lower irradiation/short term superheated temperature conditions associated with the steamline break (Figure 6-3). In order to limit the number of basic envelopes to be employed, this latter envelope is conservatively employed to define the incontainment envelope following a feedline break.

   Since Westinghouse is conducting generic testing, the environmental envelopes specified in Figures 6-2 and 6-3 for HELB accidents have been defined to encompass the results of available preliminary containment analyses, in many cases completed by the Architect Engineer, for Westinghouse NSSS plants committed to qualifying equipment to IEEE Std 323-1974. Current indications are that the specified envelope for the steamline break (Figure 6-3), which 5 defines the limiting short-term temperature peak, is highly conservative. Analyses completed by Westinghouse to-date employing the NRC interim proposed containment analysis model yield peak temperatures no greater than $370^{\circ}F$. Furthermore, equivalent analyses employing the Westinghouse containment analysis model described in References 5 through 11 yield peak temperatures no greater than $350^{\circ}F$. When final calculations for these plants become available, should the envelope conditions described in Figures 6-2 and 6-3 prove to be excessively conservative in either magnitude or duration, the envelope(s) may be reduced to bound the final calculations in order to avoid unnecessary penalty in equipment design and procurement.

3 2. The specification for chemical spray solution is 2500 ppm boron buffered with 0.88% dissolved sodium hydroxide to maintain a pH of 10.5.

3. For LOCA, the radiation sources associated with an equivalent core meltdown accident are consistent with those set forth in TID-14844, "Calculation of Distance Factors for Power and Test Reactor Sites", and are conservative estimates of the recommendations of Regulatory Guide 1.89, November, 1974. The exposure inside the containment is estimated by considering the dose in the middle of a PWR containment based on the following analytical assumptions:

Core Thermal Power	4100 MWt
Equivalent Core Meltdown Sources	
Fraction of Core Activity Released to Containment Atmosphere	
Noble Gases	1.0
Halogens	.5
Remaining Inventory	.01
Gap Activity Sources	
Fraction of Core Activity	
Kr-85	.3
Other Noble Gases	.10
Halogens	.10

a) Based on these assumptions, the instantaneous and integrated gamma and beta doses for the containment atmosphere following a LOCA are shown in Figures 6-4 and 6-5 respectively.

b) Also using these assumptions and further postulating that the radiation source is released from the core to the reactor coolant system coincident with reactor shutdown, but without subsequent release to the containment 5 and no credit taken for cleanup, the instantaneous and integrated gamma doses are shown in Figure 6-8.

4. For safety related equipment required after a steamline break (SLB), the exposures have been estimated by conservatively assuming 1% clad damage and considering the fraction of the core activity in the RCS as 0.003 Kr-85, 0.001 halogens and 0.001 of other noble gases. It was also conservatively assumed that all of the reactor coolant system inventory was instantaneously released into the containment atmosphere at the initiation of the incident. Based on these assumptions, the instantaneous and integrated gamma and beta doses for the containment atmosphere following a SLB are shown in Figures 6-6 and 6-7, respectively.

5. For convenience and simplicity, it has been conservatively assumed that the radiation doses resulting from a feedline break are equal to the values specified in Figures 6-6 and 6-7 for steamline break.

6. The applicable accident doses specified in EQDP Section 1.8.4 have been derived based upon the time required to perform the specified safety function in the accident environment (EQDP Section 1.7.1) and the dose calculations described above, subject to the following modifications:

   a. In the general area between the loop compartment wall and containment annulus, the gamma dose levels have been calculated to be a factor of 2.7 5 less to allow for the effects of shielding in this area.

   b. For equipment only required to function after accidents involving no release of radioactive material (e.g. loss of flow), the radiation dose is based on the normal dose rates (Table 6-2).

High Energy Line Break Accidents - Outside Containment

1. For the majority of equipment located outside containment, the normal operating environment will remain unchanged by a HELB accident. As a consequence, qualification for such events is covered by qualification for normal conditions.

2. It is recognized that a limited amount of equipment located outside containment, near high energy lines, could be subject to local hostile environmental conditions due to a high energy line break outside containment. In this case, the equipment will be qualified to the environmental conditions specified for equipment located in-containment described above.

3. Certain pumps and valves outside containment are utilized to recirculate sump
5 water post accident. The gamma dose to a motor/operator located outside the pipe boundary has been calculated to be a factor of 5 less than the unshielded dose at the pipe center (Figure 6-8). The dose calculations presented in Figure 6-8 are based on the LOCA source terms presented in Para. 3 for in-containment, assuming a recirculating water volume of 60,000 ft^3 and the following fraction of core activity in the sump water:

Noble gases	0.0
Halogens	0.50
Remaining inventory	0.01

Seismic Events

The seismic parameters defined in EQDP Section 1.8.7 have been established for generic qualification purposes and have been conservatively selected to envelope all anticipated plant applications, including high seismic applications for the west coast. The synthetically generated earthquake input to the test table employed by Westinghouse results in simultaneous acceleration of the test equipment in all three perpendicular directions. The specified required response spectra (RRS) in each of these three directions are identical. Figure 6-9 defines the RRS (floor) for generic testing of equipment to be located at the operating deck elevation and in Figure 6-10 for equipment at the control room elevation. Where undue conservatism may result from employing these generic spectra, due to limited plant application or location at a lower level, an equipment specific RRS may be defined such as the one shown in Figure 6-12 for the reactor trip switchgear. The RRS (device) for generic testing of control board mounted equipment is shown in Figure 6-11.

6.8 PERFORMANCE REQUIREMENTS 5

Some items of safety related equipment (e.g. ΔP transmitters) may be employed to perform more than one safety related function (e.g. steam flow, pressurizer level, etc.). A separate set of performance requirements, and applicable environmental conditions, are defined for each safety related function for which the equipment may be employed. The performance requirements (e.g. accuracy, response time, etc.), together with the duration of the requirement, are separately specified in Section 1.7 of the EQDP for normal and abnormal conditions and for all accident and post accident conditions for which the equipment is claimed to perform a safety related function. Time response is only measured as part of the test sequence when the equipment is subjected to an environment that could potentially cause a common mode failure (i.e., time response degradation). An example of this would be an increase in the viscosity of the oil in a transmitter due to exposure to high level radiation. On major electronic systems, the equipment is cycled during the test and any change in time response performance would be detected as a change in accuracy, therefore, there is no need to make a special time response measurement. All equipment is evaluated for potential time response degradation and this measurement is included if necessary. 5

1. Normal/Abnormal - the specifications for accuracy and response times are the same for both these conditions with the difference being that the specs under normal conditions are met by periodic calibration and maintenance while a time restriction is specified for operation under abnormal conditions (where the specs must be met without any special calibration or maintenance effort).

2. Containment Test - Westinghouse does not suppy equipment that is located
inside containment and required to function during a containment pressure
5 test. Nevertheless, for equipment located inside containment, the
requirement is specified that the equipment shall not sustain any damage as a
result of exposure to the high pressure conditions existing during this test.

3. Accident - Performance specifications include the effects of both radiation and steam/temperature conditions that exist after a high energy line break (HELB). The addition of errors at the same point in time from the radiation test and the steam/temperature test must not exceed the performance requirements for that point in time after the event.

4. Seismic - Performance specifications include the deviation allowed from normal specifications due to seismic events only and are plant and location dependent. Since high energy lines inside containment are designed for seismic events, seismic and environmental errors are not additive for breaks in these lines.

6.9 QUALIFIED LIFE

The demonstrated qualified life will be specified in EQDP Section 1.9, based upon the results of the finally completed qualification program.

It may be possible to extend the qualified life of a particular piece of equipment
by, at some future date, comparing the actual in-plant environments that existed
during the equipment life to the values assumed by Westinghouse in establishing the 5
qualified life or by performing an analysis of internal temperatures (e.g., motors)
based on actual service conditions.

TABLE 6-1

NORMAL AND ABNORMAL OPERATING ENVIRONMENTS

General Area	Zone Description	Zone Code	Typical Areas	Range	Normal Operation Temp (°F)	Normal Operation RH (%)	Normal Operation Press. (psig)	Abnormal Operation Time Limit	Abnormal Operation Temp (°F)	Abnormal Operation RH (%)	Abnormal Operation Press. (psig)
In-Containment	Inaccessible	IC/I	Inside Sec.	Max	135	70	+0.3	8 hours	150	95	Atmos
			Shield	Min	65	20	-0.1		50	0	Atmos
	Accessible	IC/O	Outside Sec.	Max	120	70	+0.3	∞	120	95	Atmos
			Shield	Min	65	20	-0.1		50	0	Atmos
									82	95	
Out of	Air[a]	OC/A.C.	Control room,	Max	80	50	Atmos	12 hrs	120	35	Atmos
Containment	Conditioned		Aux Equip Room	Min	60	30	Atmos		40	0	Atmos
									82	95	
	Ventilated	OC/V	Aux building,	Max	104	70	Atmos	12 hrs	120	35	Atmos
			Safeguards	Min	60	20	Atmos		40	0	Atmos
									82	95	
	Non-	OC/NV	Turbine-	Max	104	70	Atmos	∞	120	35	Atmos
	Ventilated		Hall	Min	60	20	Atmos		40	0	Atmos

Note a: Abnormal operating parameters only apply for applications where Class 1E air conditioning systems are not supplied.

TABLE 6-2

40 YEAR NORMAL OPERATING DOSES - INSIDE CONTAINMENT

Location	γ Dose rate R/hr	40 yr γ dose (R)
RCL pipe center	820	3.0×10^{8}
RCL pipe ID	470	1.6×10^{8}
RCL pipe OD (contact)	165	5.8×10^{7}
RCL - general area	50	$<2.0 \times 10^{7}$
Outside loop compartment wall	<0.1	$<3.5 \times 10^{4}$
Detectors located next to R.V.	5×10^{4}	1.8×10^{10} (a)

3

(a) 40 year dose from neutrons > 1 Mev is 5×10^{18} n/cm^2.

TABLE 6-3

40 YEAR NORMAL OPERATING DOSES - OUTSIDE CONTAINMENT

Location	40 yr γ dose (R)
Penetration Area	$<1 \times 10^6$
Pump Cubicles	
Radioactive Waste Area	
Radwaste Tank Cubicles	$<$[illegible] $\times 10^7$
Other general areas	$<4 \times 10^2$

14,050-3

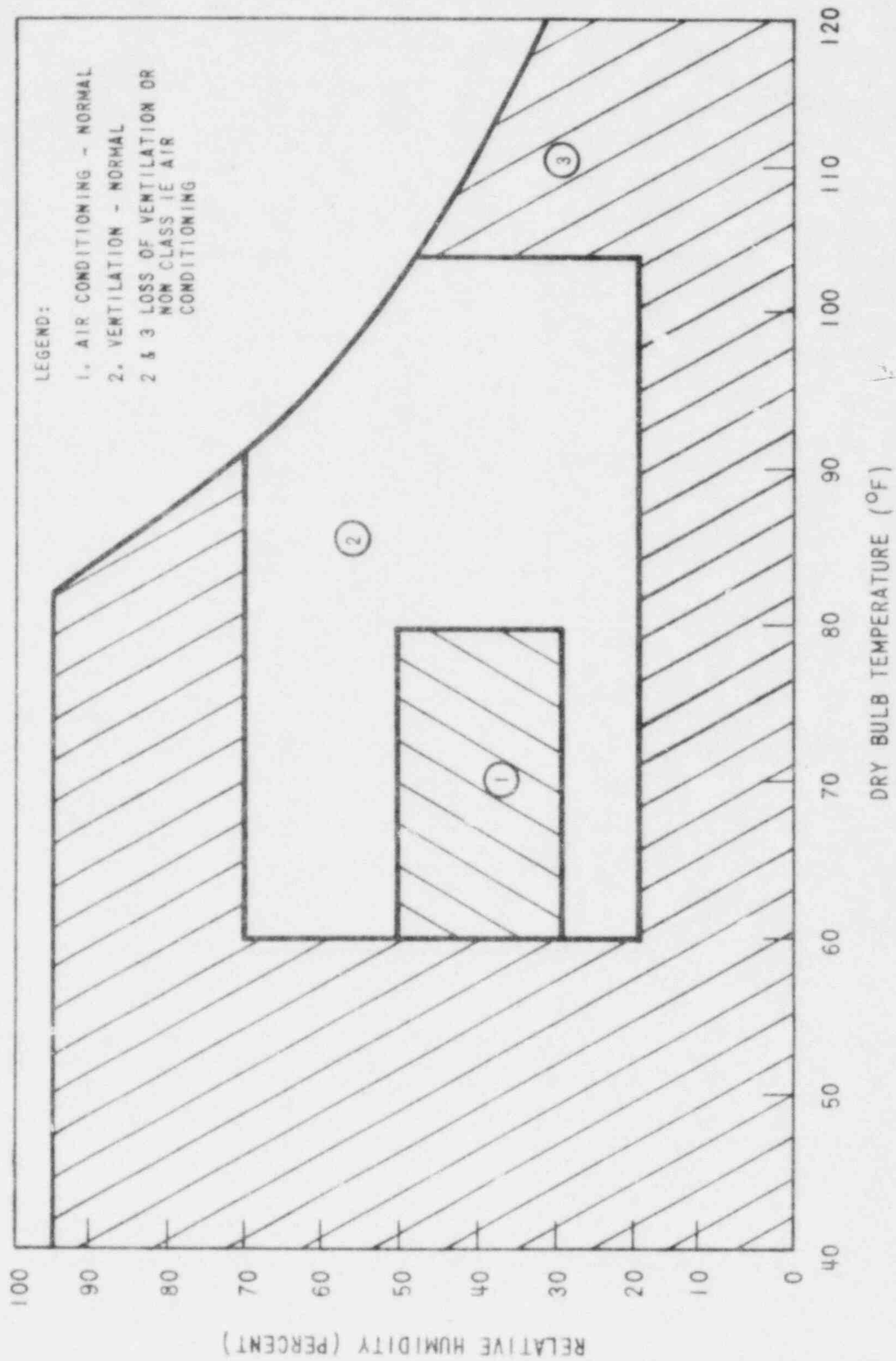
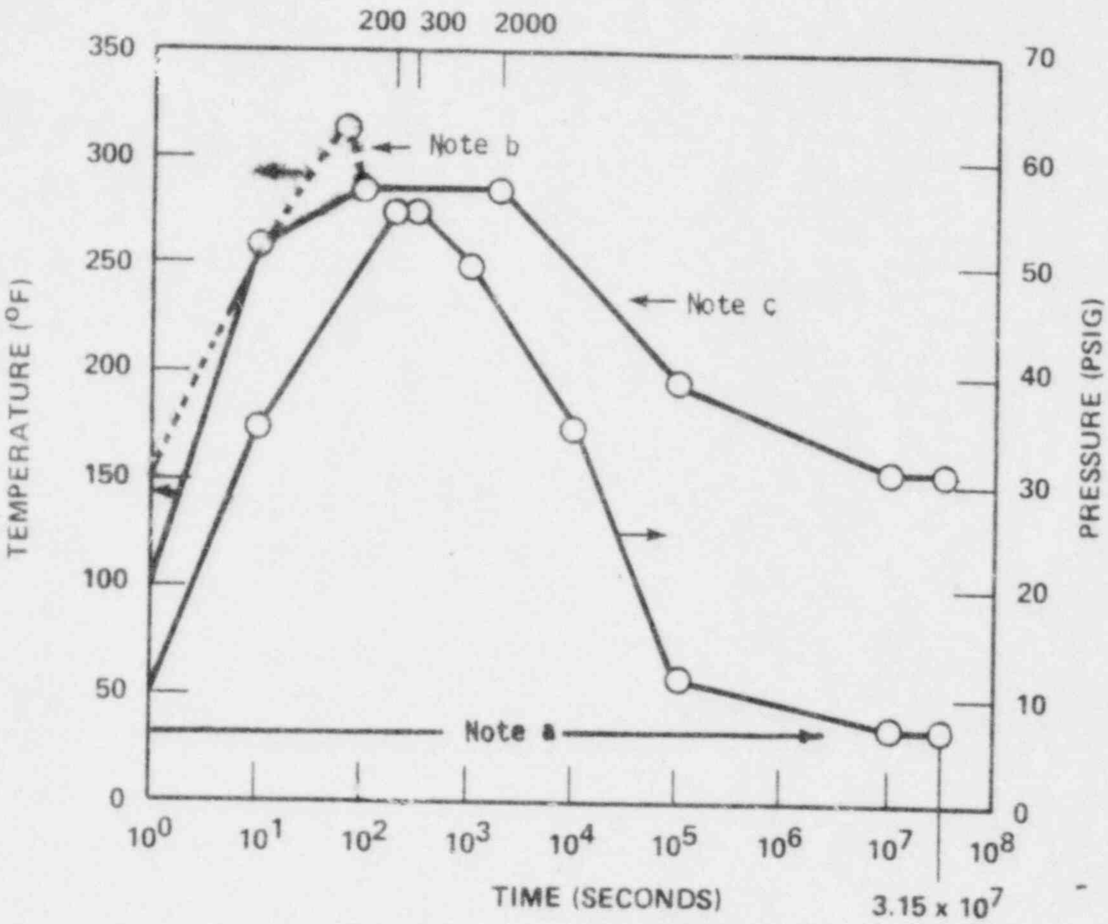


Figure 6-1 Temperature Versus Humidity - Enclosed Environments Outside Containment



Note a: Initial 24 hour containment spray solution of 2500 ppm boron with 0.24% NaOH

Note b: Represents plants whose analysis predicts super heated conditions

Note c: Represents plants whose analysis does not predict super heated conditions

Figure 6-2 Containment Environmental Design Conditions —LOCA—

5

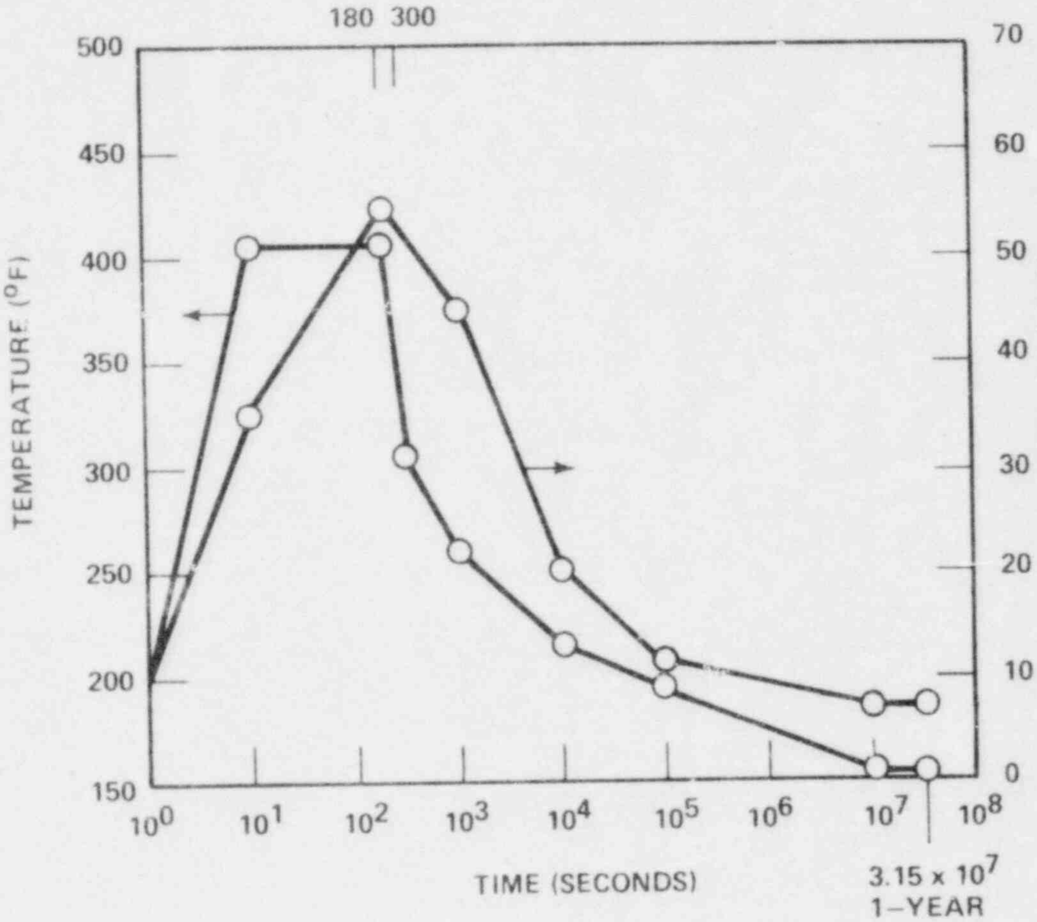


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Figure 6-3 Containment Environmental Design Conditions
– Main Steam Line Break and Feedline Break –

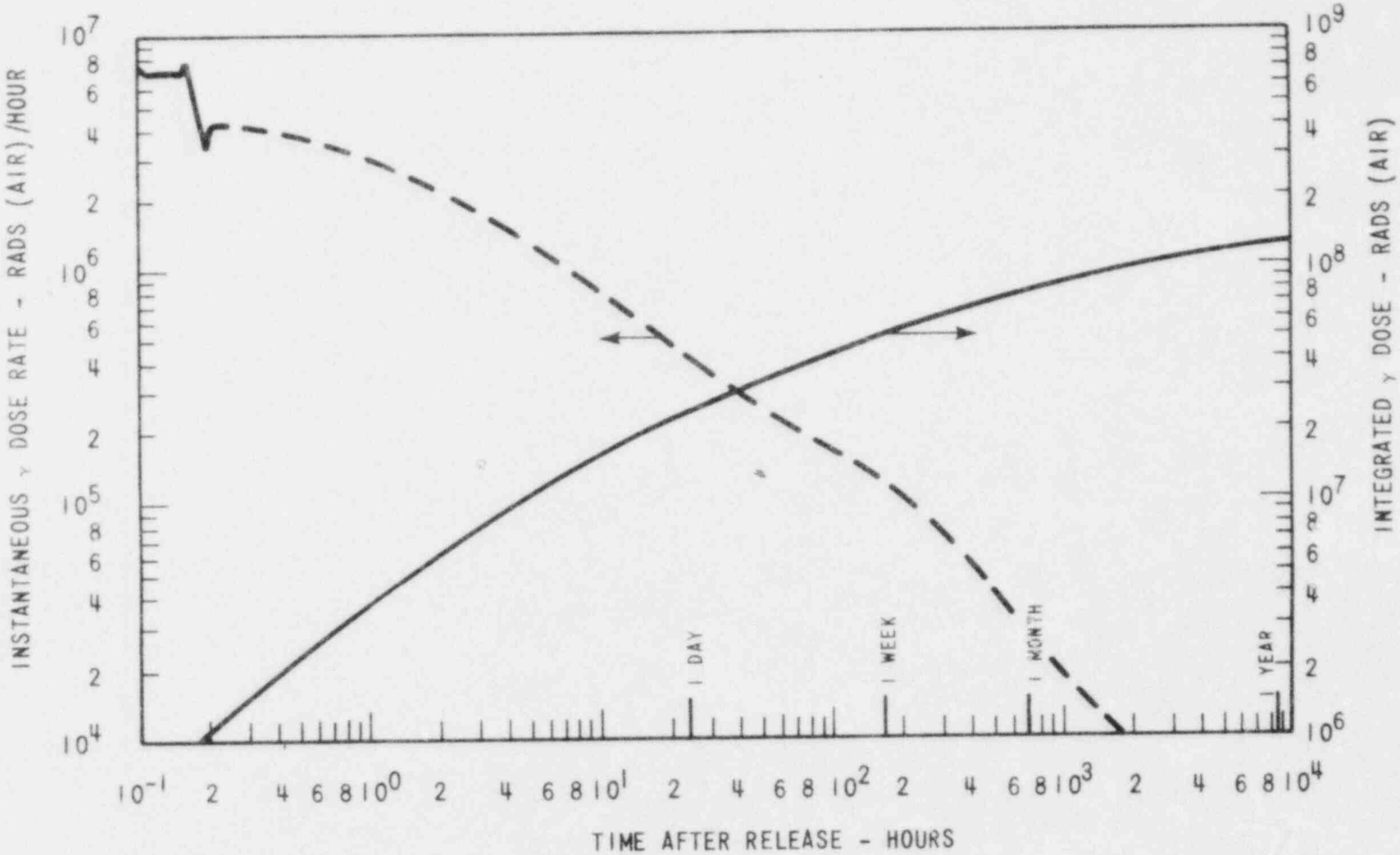


Figure 6-4 Gamma Dose and Dose Rate Inside the Containment as a Function of Time After LOCA

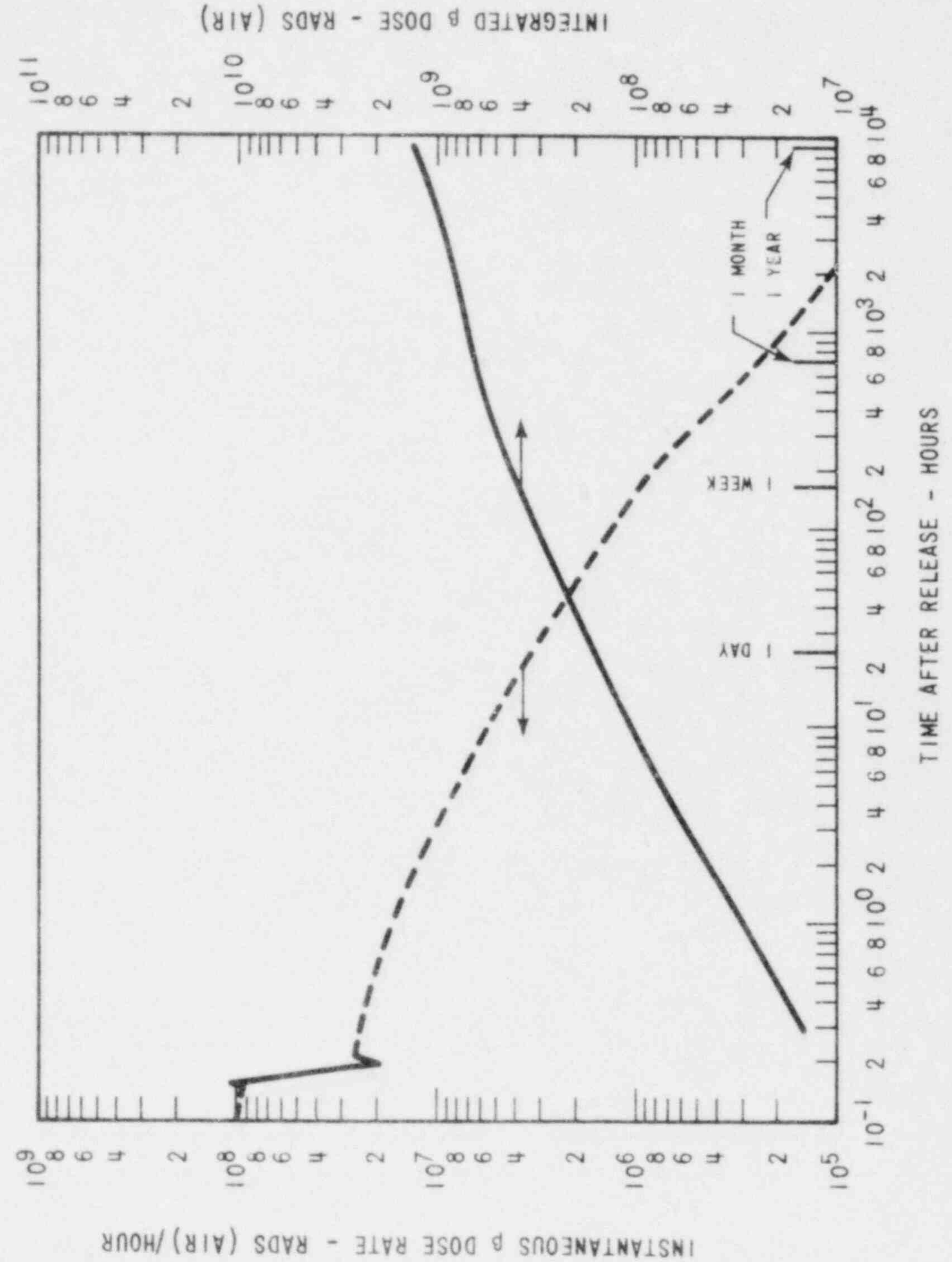


Figure 6-5 Beta Dose and Dose Rate Inside the Containment as a Function of Time After LOCA

3

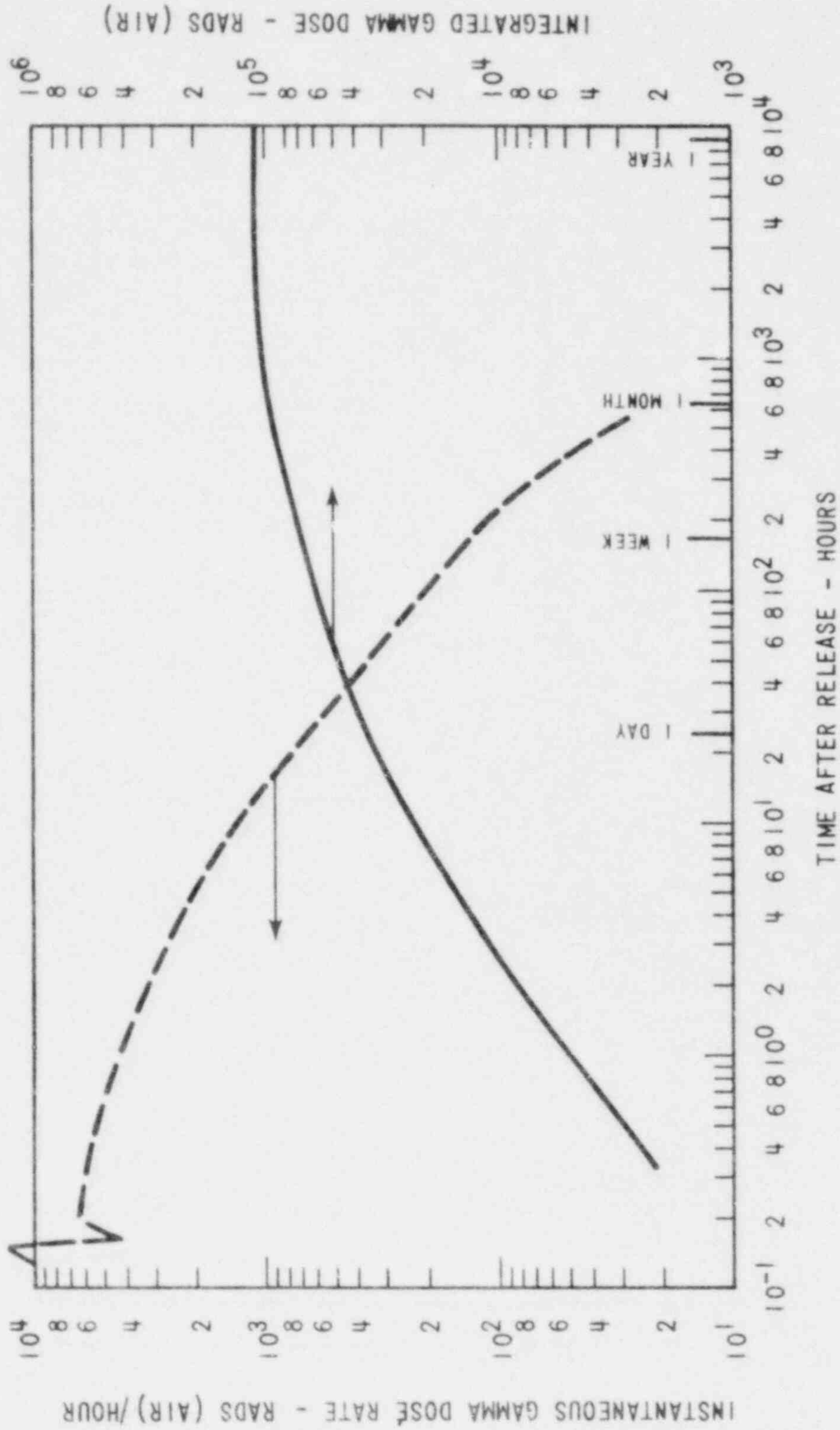


Figure 6-6 Gamma Dose and Dose Rate Inside the Containment as a Function of Time After a Steam Line Break Accident.

3

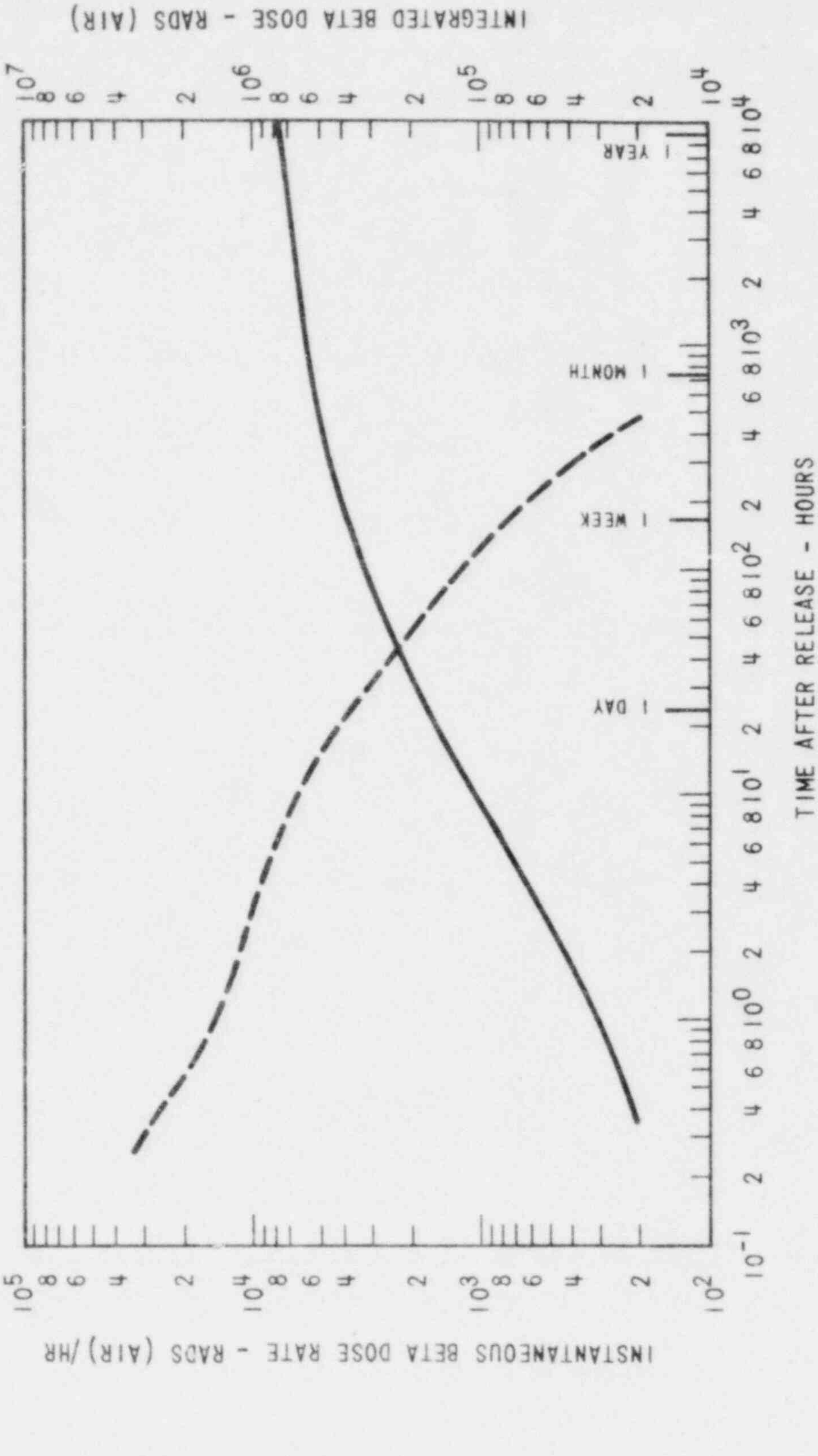


Figure 6-7 Beta Dose and Dose Rate Inside the Containment as a Function of Time After a Steam Line Break Accident

3

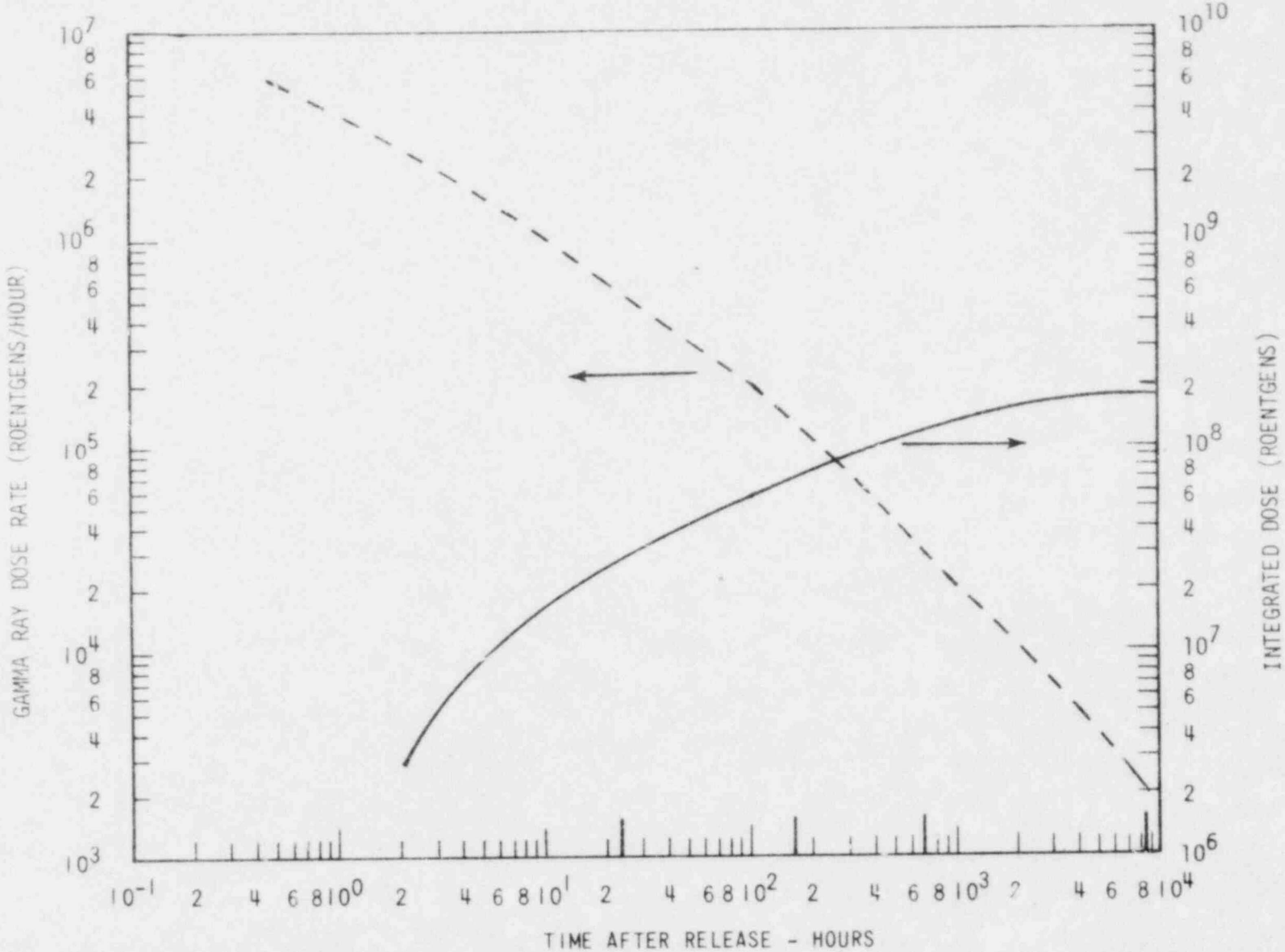
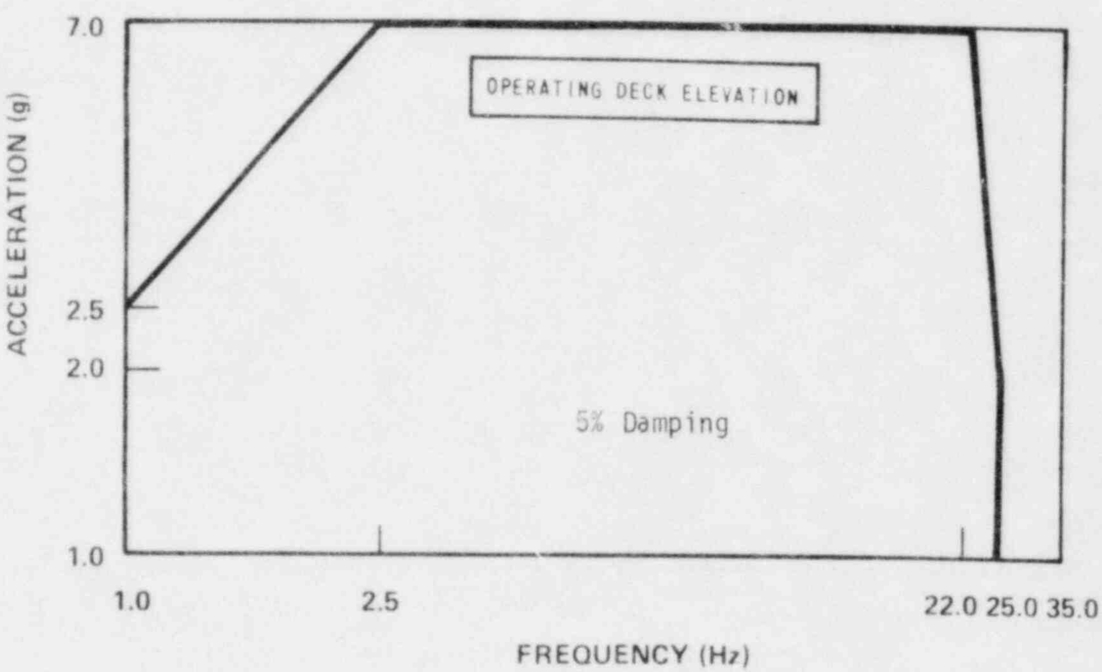


Figure 6-8 Gamma Ray Dose and Dose Rate at the Center of a Primary Loop Pipe as a Function of Time Following a TID 14844 Release to the RCS



(NOTE: OBE REQUIRED RESPONSE SPECTRUM = 0.5 SSE RRS) 5

Figure 6-9 Required Response Spectrum (RRS) for Safe Shutdown Earthquake (SSE)

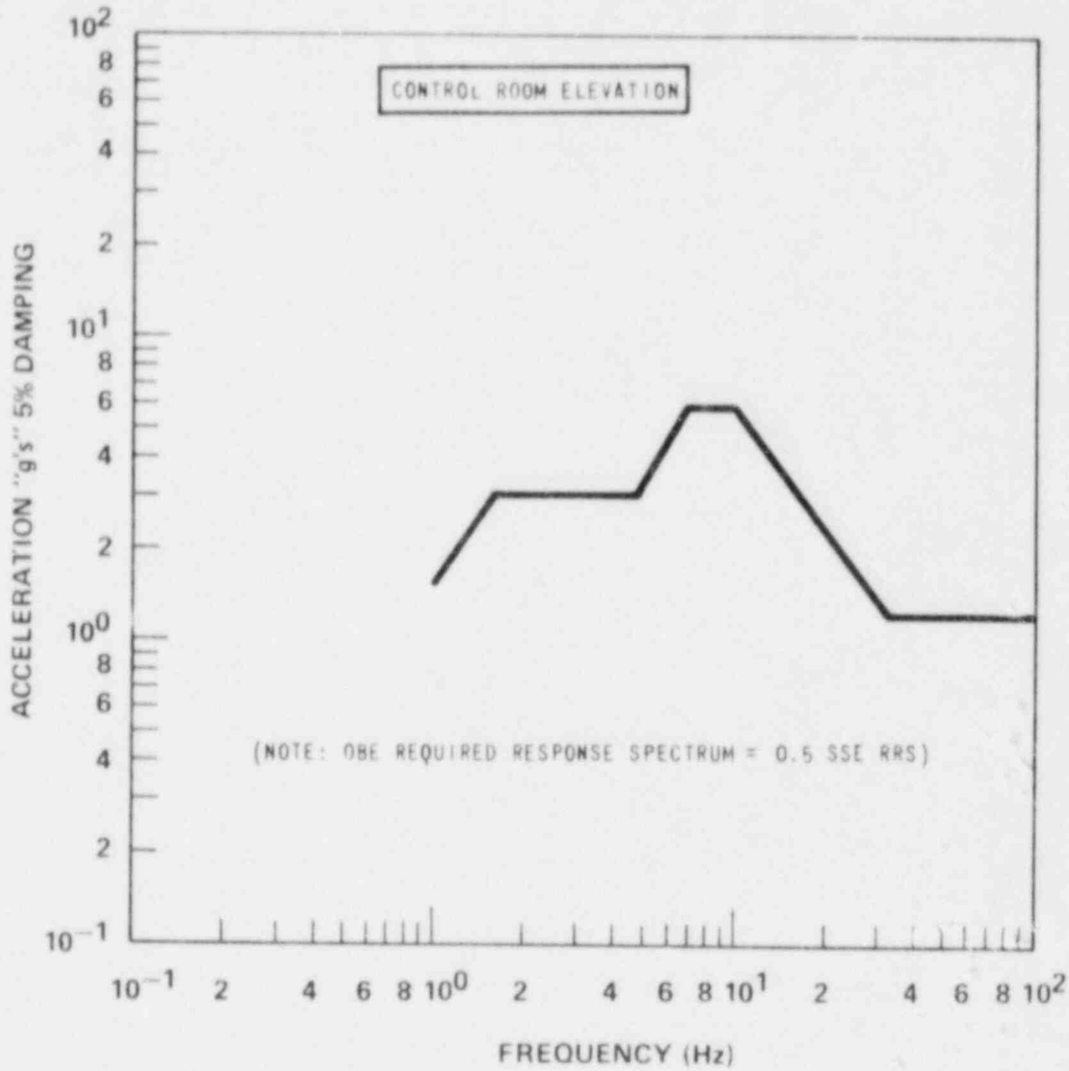


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Figure 6-10 Required Response Spectrum (RRS) for Safe Shutdown Earthquake (SSE)

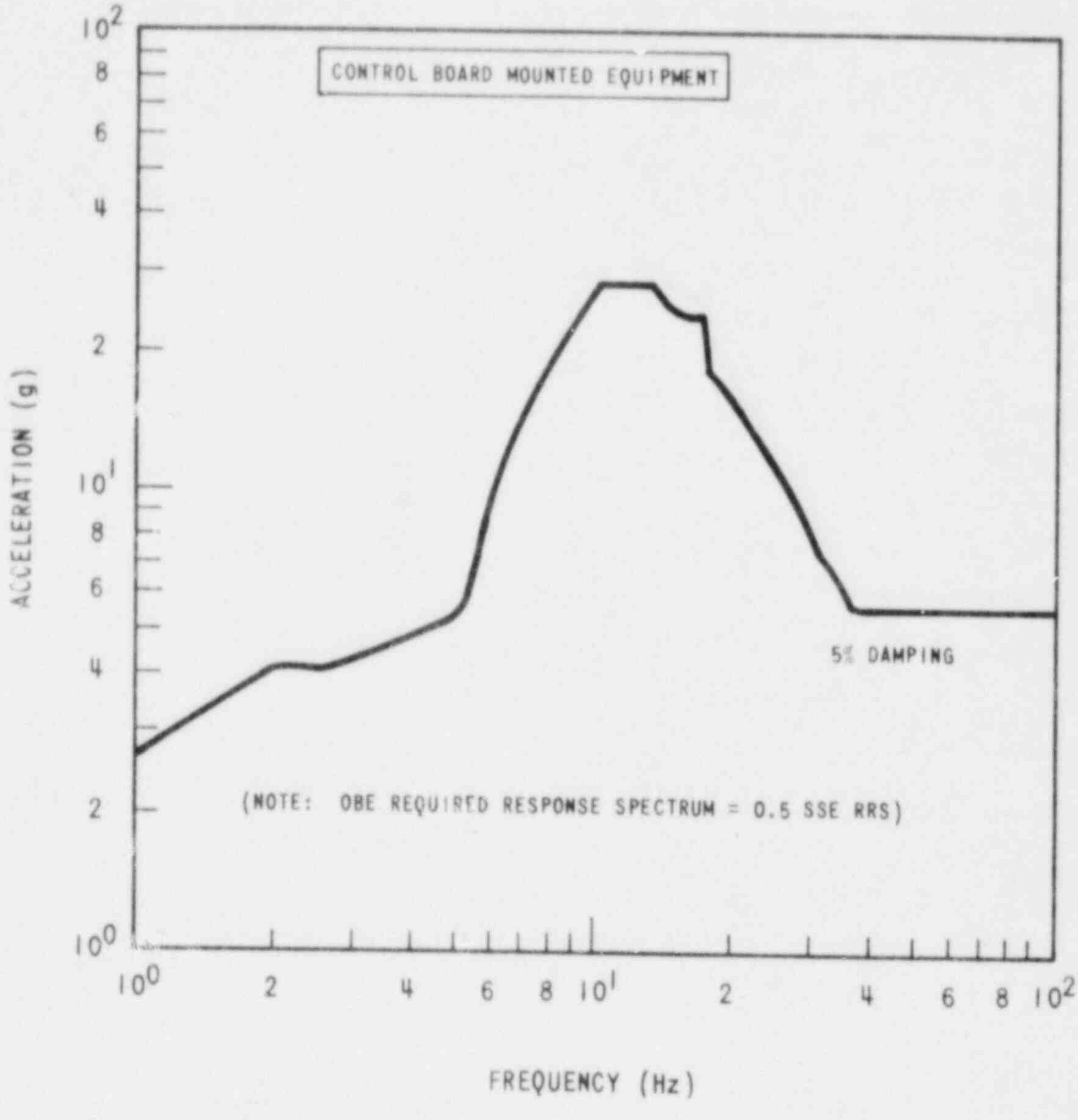

Figure 6-11 Required Response Spectrum (RRS) for Safe Shutdown Earthquake (SSE)

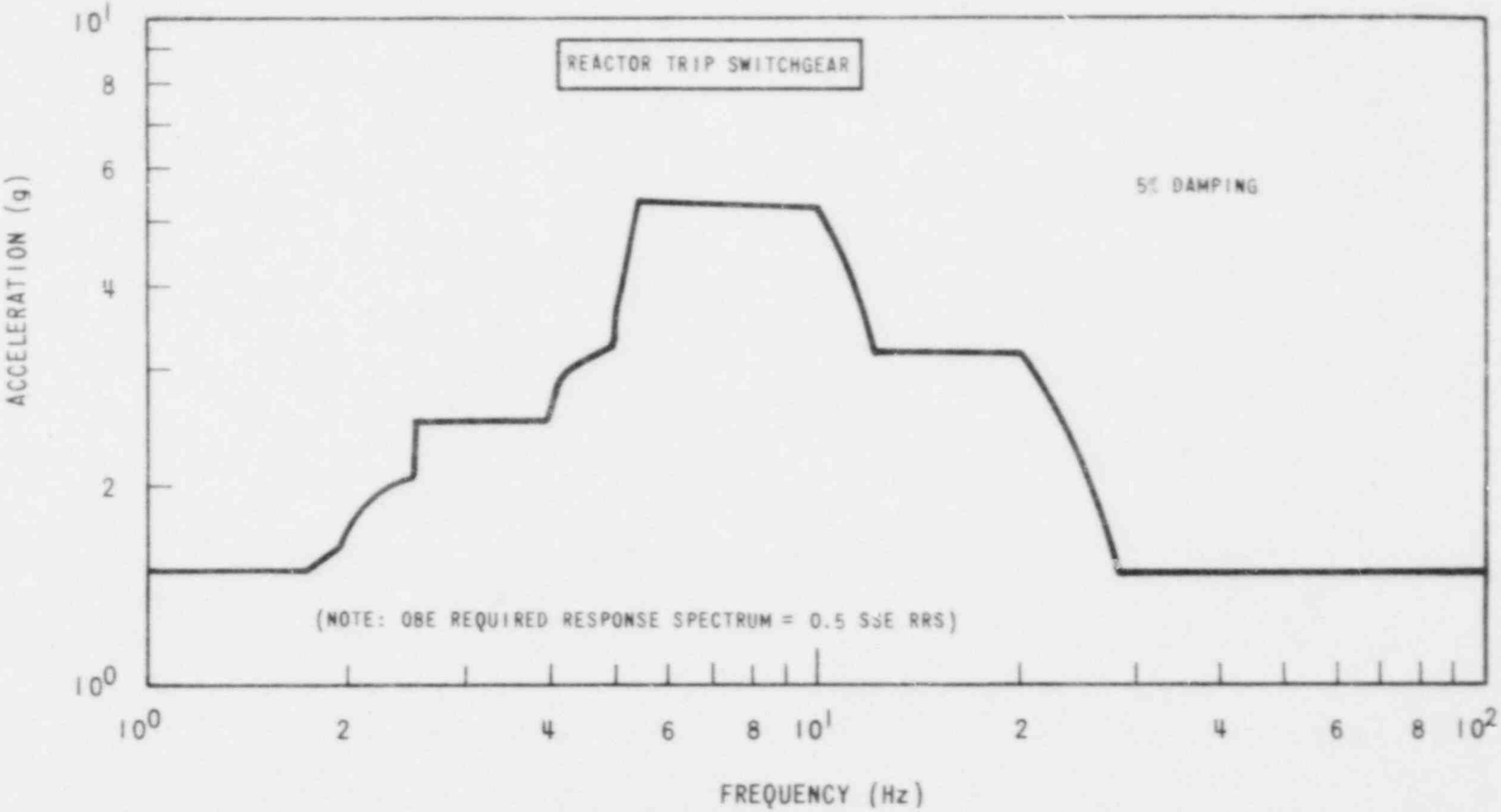

Figure 6-12 Required Response Spectrum (RRS) for Safe Shutdown Earthquake (SSE)

7.0 QUALIFICATION METHODS

The recognized methods available for qualifying safety-related electrical equipment are established in IEEE-323 as being; type testing, operating experience, analysis, on-going or a combination of these methods. The choice of qualification method to be employed by Westinghouse, for a particular item of equipment, is based upon many factors including; practicability, complexity of equipment, economics, availability of previous qualification to earlier standards, etc. The qualification method to be employed for this program is identified in the individual Equipment Qualification Data Packages (EQDP's); whether by test (Section 2), experience (Section 3), analysis (Section 4) or by some combination of these methods. The Westinghouse WRD program does not currently employ on-going qualification and only utilizes experience as supportive to analysis and/or test.

7.1 MARGIN

IEEE 323-1974 (Section 6.3.1.5) recommends that margin be applied to the most severe specified service conditions in order to establish the conditions for qualification. This margin is required to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance. Westinghouse incorporates margin, in defining qualification parameters, as follows:

7.1.1 NORMAL AND ABNORMAL EXTREMES 3

As indicated in Section 7 of IEEE 323-1974, the application of margin is directed at specifying adequate qualification requirements for the most severe service conditions represented by the design basis event accidents (i.e. HELB accidents and seismic events). As a consequence, Westinghouse does not apply any systematic margin to the normal and abnormal service conditions in defining the qualification conditions. However, for equipment to be qualified to operate in a high energy line break (HELB) environment, qualification to the severe HELB conditions demonstrates ample margin for acceptable performance under any specified normal and abnormal service conditions. For electronic equipment not qualified to operate in a HELB environment, additional margin is included by requiring that the equipment be operated through a double cycle of normal and abnormal service condition extremes, as indicated in Figure 7-1, which at least equals the specified range of service condition parameters. An exception occurs for transmitters where a performance verification is completed at 130°F to encompass the specified maximum abnormal conditions.

7.1.2 AGING

No specific margin is applied to the time component in deriving appropriate aging
3 parameters. Rather, margin is included in deriving the accelerated aging parameters to be employed for simulating each applicable aging mechanism, as described in Appendix B.

7.1.3 RADIATION

5 As discussed in Sections 6.7.1 and 6.7.4 Westinghouse bases its calculations on a 4100 MWth plant and TID-14844 which results in a very conservative generic design condition. Therefore, no additional margin is added in specifying the test requirements. When requested by the applicant, Westinghouse will identify the margin available on a particular plant application.

7.1.4 SEISMIC CONDITIONS

The seismic parameters specified for this program are designed to encompass all plants referencing this program, including a number of high seismic plants, with a
5 10% margin on amplitude and a 15% margin on frequency. As a consequence, for most applications, considerable margin exists with respect to the acceleration levels employed on a plant specific basis and the width of the response spectra. In the Westinghouse generic program no additional margin is included in the test requirements, i.e. the TRS equals the RRS. When requested by the applicant, Westinghouse will identify the margin available on a particular plant application with respect to the plant specific response spectra and equipment configuration.

7.1.5 HIGH ENERGY LINE BREAK (HELB) CONDITIONS

The envelopes specified for high energy line breaks, in Figures 6-2 and 6-3, have been
selected to encompass the transients resulting from a spectrum of reactor models,
break sizes and locations and differing containment designs. As a consequence, these
design envelopes already contain significant margin with respect to any transient
corresponding to a single break on a specific plant application. Nevertheless,
Westinghouse requires that the qualification envelopes be derived with a margin of
15°F on temperature and 10 psi on pressure with respect to the design envelopes in 3
Figures 6-2 and 6-3. No additional margin is specified in defining the radiation doses
to be employed for qualification since the assumptions employed in establishing the
dose requirements in Sections 6.7.1 and 6.7.4 already contain extreme conservatism.
The margin on dose will be identified in the applicants FSAR by comparision of the
plant specific dose requirements and the Westinghouse qualification parameters. The 5
alkalinity of the caustic spray is increased by 10% with respect to the peak value
identified for any plant originally referencing this program.

7.2 QUALIFICATION BY TEST (EQDP SECTION 2)

Qualification by test is, in general, selected as the primary method of qualification for complex equipment, not readily ameanable to analysis, and/or for equipment required to perform a safety related function in a high energy line break (HELB) environment. The proposed test plan is identified in EQDP Section 2.0 and, where supportive experience and/or analysis is claimed as an integral part of the qualification program, cross reference is provided to Section 3.0 (Experience) and/or Section 4 (Analysis) for those aspects of the qualification not covered by the test plan. The following sections establish the basis on which the information specified in EQDP Section 2.0 (Test) is selected.

7.2.1 EQUIPMENT DESCRIPTION

The equipment to be qualified is identified including, where applicable, the type and model number, in EQDP Section 2.1.

7.2.2 NUMBER TESTED

The number of identical items of equipment, as described under the equipment description, to be tested is defined in EQDP Section 2.2.

7.2.3 MOUNTING

The method of mounting the equipment for the test is identified in EQDP Section 2.3. Care is taken to ensure that the in-plant installation requirements, as specified by the supplier under EQDP Section 1.2, are fully represented.

7.2.4 CONNECTIONS

The equipment connections necessary to be able to demonstrate safety related functional operability during testing, are identified in EQDP Section 2.4.

7.2.5 AGING SIMULATION PROCEDURE

Potential aging mechanisms resulting from any significant in-service thermal, electrical, mechanical, radiation and vibration sources are identified in EQDP Section 2.5. When aging is addressed as part of the test sequence, the method to be employed for aging the equipment is indicated and is chosen to conservatively simulate the potential aging effects resulting from the operating cycles and environmental conditions specified in EQDP Section 1, Performance Specification. A detailed description of the methods employed by Westinghouse WRD to address potential aging mechanisms is provided in Appendix B to this report.

7.2.6 SIMULATED SERVICE CONDITIONS

The service conditions to be simulated by the test plan are identified in EQDP Section 2.6. In general, the parameters employed are selected to be equal to (normal and abnormal) or have margin (accident and post accident) with respect to the specified service conditions of EQDP Section 1.0 as recommended by IEEE 323-1974.

Pressure, Temperature, Humidity and Chemical Spray

Equipment not subject to high energy line break (HELB) environments is qualified against normal and abnormal (where applicable) conditions employing a cyclic test sequence at environmental and electrical extremes. A typical test profile, including voltage and frequency cycling, is shown in Figure 7-1.

Qualification tests to HELB conditions are designed to address the applicable specified environment(s) (Figure 6-2 and/or Figure 6-3) with a margin of 15^{o} on temperature and 10 psi on pressure. Separate envelopes (Figure 6-2 and/or Figure 6-3) with margin may be employed or a combined LOCA/SLB/FLB envelope (Figure 7-2) may be employed for equipment qualification tests. The simulated post accident aging time-temperature profile (Figure 7-2 from 24 hours to test conclusion) will be defined consistent with the smallest value of activation energy applicable to the thermal aging sensitive components comprising the test equipment or will be a demonstrably conservative activation energy, as described in Appendix D. 5

The HELB testing will employ a chemical spray, for the first 24 hours of test, consisting of 2500 ppm boron buffered with 0.9% dissolved sodium hydroxide to maintain a pH of approximately 10.7. This spray concentration results in an increase in alkalinity of at least 10% compared to the concentration defined in the Specification (Section 6.7.4). 3

Radiation

The total integrated dose (TID) employed for testing is a combination of normal and accident doses (where applicable) and is defined to equal or exceed the maximum radiation dose contained in the Specification (EQDP Section 1.8.4). Margin is implicitly included in defining the integrated doses for testing, since the calculation methods, described in Sections 6.7.1 and 6.7.4, already contain extreme conservatism. Normal operating and accident gamma doses are simulated using a cobalt-60 source. The test dose is applied at a rate approximate to the initial phase of the accident dose rate shown in Figure 6-4 (i.e., typically 2 to 2.5 MR/hr). Where exposed organic material is to be evaluated by test for the effect of (accident) beta radiation, a beta source will be employed or, alternatively, a cobalt-60 source to impart the same dose using gamma radiation.

Vibration and Seismic Acceleration

In service vibration as a potential aging mechanism is discussed in Appendix B. Test requirements to simulate vibration, if significant, will be specified in EQDP Section 2.6.

Seismic qualification will be demonstrated by one of the following:

1. For equipment which has been previously qualified by the single axis sine beat method and included in the NRC seismic audit of Westinghouse safety related electrical equipment and, where required by the NRC audit, the Seismic Demonstration Program (Ref: NS-CE-692), no additional qualification testing will be required to demonstrate acceptability to IEEE 344-1975 provided that:

    a. The Westinghouse aging evaluation program for aging effects on complex electronic equipment located outside containment demonstrates there are no deleterious aging phenomena. In the event the aging evaluation program identifies materials that are marginal, either the materials will be replaced or the projected qualified life will be adjusted.

    b. Any changes made to the equipment due to a. above or due to design modifications does not significantly affect the seismic characteristics of the equipment.

    c. The previously employed test inputs can be shown to be conservative with respect to applicable plant specific response spectra.

2. For new equipment (i.e., new design, equipment not previously qualified or previously qualified equipment that does not meet a, b, and c above) seismic qualification will be performed in accordance with IEEE 344-1975. Where testing is utilized, multifrequency multiaxis inputs will be developed by the general procedures outlined in Reference 2. The test results will demonstrate that the measured Test Response Spectrum envelopes the Required Response Spectrum of the Specification (Section 6.7.4). Alternative test methods, such as single frequency, single axis inputs, will be used in selected cases as permitted by IEEE-344-1975 and Regulatory Guide 1.100.

7.2.7 MEASURED VARIABLES

... parameters that must be measured during the specified test sequence, in order to demonstrate qualification against the performance specification (EQDP Section 1), are individually listed in EQDP Section 2.7.

7.2.8 TEST SEQUENCE PREFERRED

The preferred test sequence specified in EQDP Section 2.8 is that recommended by IEEE 323-1974.

7.2.9 TEST SEQUENCE ACTUAL

The test sequence actually employed is specified in EQDP Section 2.9. Where the test sequence deviates from that recommended by IEEE 323-1974, the deviation is indicated and justified. Clarifications to the IEEE 323-1974 recommended test sequence, to be employed by Westinghouse, are discussed below. 5

1. Burn-In Test

   For electronic equipment, a burn in test is completed, prior to operational testing of the equipment, to eliminate infant failures. The test consists of energizing the equipment for a minimum of 50 hours at nominal voltage and frequency under ambient temperature conditions. Any malfunction observed during these tests will be repaired and the 50 hour burn-in repeated for the repaired portion of the equipment.

2. Performance Extremes Test

   For equipment where seismic testing has previously been completed (Table 7-1) employing the recommended methods of IEEE 344-1975, seismic testing will not be repeated. Testing of the equipment to demonstrate qualification at performance extremes will be separately performed as permitted by IEEE 323-1974 Section 6.3.2(3).

3. Aging Simulation and Testing

For equipment not required to perform a safety related function under environmental conditions associated with a High Energy Line Break (Table 7-2) aging will be addressed, as described in Section 7.3 and Appendix B, by separate testing and/or analysis to demonstrate either that aging of components is not significant during the qualified life of the equipment and therefore, testing of unaged equipment is valid or, that aged components/modules are still capable of performing the specified safety related function(s) under applicable service conditions.

4. Visual Inspections/Disassembly

Westinghouse does not document the result of visual inspections unless problems are discovered. Disassembly is only performed when test results or visual inspections require further investigation.

5

7.2.10 TYPE TEST DATA

On completion of the qualification tests, Section 2.10 of the EQDP will be completed to provide a summary of the qualification tests and results. The applicable test reports are provided as referenced in the EQDP Section 2.10 with the test data maintained available by Westinghouse for audit.

7.2.11 ACCEPTANCE CRITERIA

The basic acceptance criteria is that the qualification test program shall demonstrate the ability of the equipment to meet with appropriate margin the safety related functional requirements defined in EQDP Section 1.7 while subjected to the environmental conditions specified in EQDP Section 1.8.

7.2.12 TREATMENT OF FAILURES

The primary purpose of equipment qualification is to reduce the potential for common mode failures due to anticipated environmental conditions. The redundancy, diversity and periodic testing of nuclear power plant safety related equipment are designed to accommodate random failures of individual components. Where an adequate test sample is available, the failure of one component/device together with a successful test of two identical components/devices will be taken to indicate a random failure mechanism, subject to an investigation concluding the observed failure is not common mode. Where insufficient test samples prevent such a conclusion being reached, any failures will be investigated to ascertain whether the failure mechanism is of common mode origin. Should a common mode failure mechanism be identified as having caused the failure, a design change will be implemented to eliminate the problem and supplemental or repeat tests completed to demonstrate compliance with the acceptance criteria.

7.3 QUALIFICATION BY EXPERIENCE (EQDP SECTION 3.0)

Qualification by experience is not employed by Westinghouse WRD as a prime method of qualification. Operating experience may be provided as supportive evidence to the prime method of qualification. Where such information is provided, Westinghouse will demonstrate that the experience is applicable to the functional requirements for which the equipment is being qualified. This applicability determination will include an evaluation of operating environments, mountings, performance requirements and performance history. Documentation of supportive information based on operating experience is provided in EQDP Section 3.0.

7.4 QUALIFICATION BY ANALYSIS (EQDP SECTION 4.0)

Qualification by analysis alone is not employed by Westinghouse WRD. Analysis is employed to supplement testing or to provide verification that the test results are applicable. The following sections outline the primary analytical methods to be employed as described in EQDP Section 4.0.

7.4.1 SAFETY RELATED PUMP MOTORS (EQDP-AE-1 THROUGH 4)

The structural integrity of the motor will be established by a static seismic analysis in accordance with IEEE 344-1975, with justification. Should analysis fail to show the resonant frequency to be significantly greater than 33Hz, a test will be performed to establish the motor resonant frequency. Motor operability during a seismic event will be demonstrated by calculating critical deflections, loads, and stresses under various combinations of seismic, gravitational, and operating loads. The worst case (maximum) values calculated are tabulated against the allowable values. In combining these stresses, the most unfavorable possibilities are considered for the following areas: 1) maximum rotor deflection, 2) maximum shaft stresses, 3) maximum bearing load and shaft slope at the bearings, 4) maximum stress in stator core welds, 5) maximum stress in stator core bar to frame welds, 6) maximum stress in motor mounting bolts, and 7) maximum stress in motor feet. The qualified life for
5 the pump motors can be extended by performing an analysis of internal temperatures based on actual plant specific conditions.

7.4.2 QUALIFICATION BY DEMONSTRATION OF SIMILARITY (EQDP-ESE-23 AND 25)

Where minor differences exist between items of equipment, analysis may be employed to demonstrate that the test results obtained for one piece of equipment are equally applicable to a similar piece of equipment.

7.4.3 DIFFERENCES BETWEEN TEST AND QUALIFICATION TEMPERATURE LEVELS

The qualification test envelope for HELB conditions may, in some cases, not encompass the short term temperature peak defined by the specification (Figure 6-3), in which case the superheated steam transient will be addressed by analysis. The analysis will employ a thermal response model of the equipment derived from the physical characteristics of the equipment and measurements taken during the qualification test. This model will then be employed to demonstrate that the equipment is insensitive to the short term superheated temperature peak defined by the specification (Figure 6-3). The analytical procedures and models to be employed are consistent with those discussed in References 3 and 4.

7.4.4 AGING

A detailed description of the Westinghouse Aging Evaluation Program is provided in Appendix B. Analysis will be employed in this program to define, from available test data, accelerated aging parameters, where employed. In addition, analytical methods will be utilized to demonstrate that the results of any separate component/module testing are conservative with respect to anticipated performance at the component/module location within the equipment.

TABLE 7-1

EQUIPMENT FOR WHICH PREVIOUS SEISMIC TESTS DEMONSTRATE CAPABILITY TO IEEE 344-1975

Equipment	EQDP Reference
Nuclear Instrumentation System (NIS)	EQDP-ESE-10
Process Protection Sets	EQDP-ESE-13
Solid State Protection System and Safeguards Test Cabinets (2 Train)	EQDP-ESE-16
Instrument Bus Power Supply (Static Inverter) - 7.5 KVA	EQDP-ESE-18
Instrument Bus Distribution Panel - 7.5 KVA	EQDP-ESE-19

TABLE 7-2

EQUIPMENT NOT REQUIRED TO OPERATE IN A HIGH ENERGY LINE BREAK ENVIRONMENT

Equipment	EQDP Reference
Pressure Transmitters: Qualification Group B	ESE-2
ΔP Transmitters: Qualification Group B	ESE-4
Excore Neutron Detectors	ESE-8 & 9
Nuclear Instrumentation System (NIS)	ESE-10
Source Range Preamplifier	ESE-11 & 36
Main Control Board Switch Modules	ESE-12
Process Protection Sets	ESE-13
Indicators and Recorders	ESE-14 & 15
Solid State Protector System & Safeguards Cabinets	ESE-16 & 17
Instrument Bus Power Supply (Static Inverter)	ESE-18 & 25
Instrument Bus Distribution Panel	ESE-19, 33 & 34
Reactor Trip Switchgear	ESE-20 & 26
4 Section Excore Neutron Detector (Power Range)	ESE-22
Loop Stop Valve Cabinet	ESE-23
RCP Speed Sensor	ESE-24
Main Control Board, Primary Control Console, Secondary Control Console and Safety Center	ESE-25
Nitrogen - 16 Detector	ESE-27
Rod Position Detector	ESE-28
Rod Position Data Cabinet	ESE-29
Integrated Protection Cabinet	ESE-30
Integrated Logic Cabinet	ESE-31
Field Termination Cabinet	ESE-32
PAMS Demultiplexer	ESE-37
Control Board Demultiplexer	ESE-38
Fiber Optic Cable	ESE-39

3

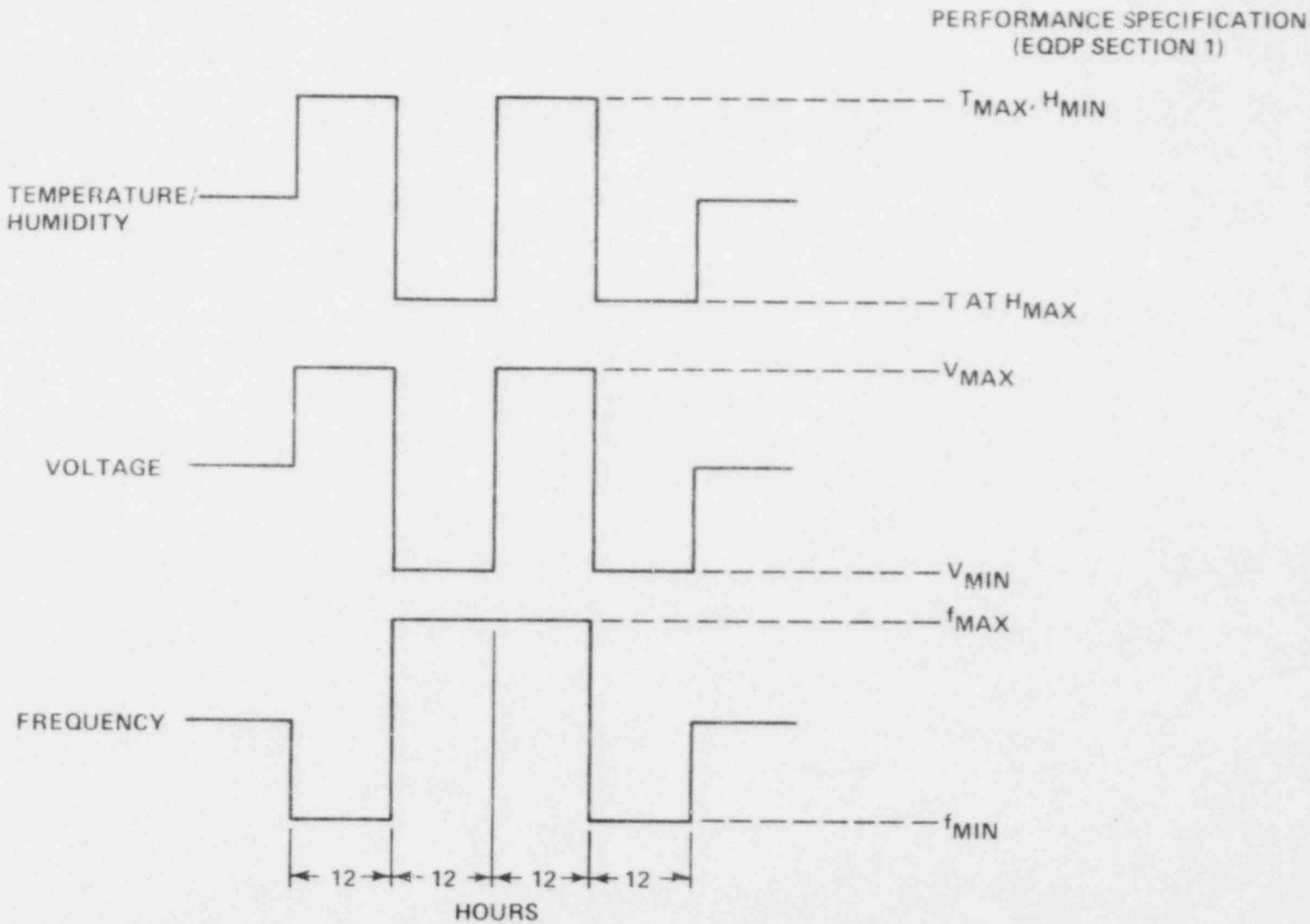

Figure 7-1 Typical Verification Test Profile

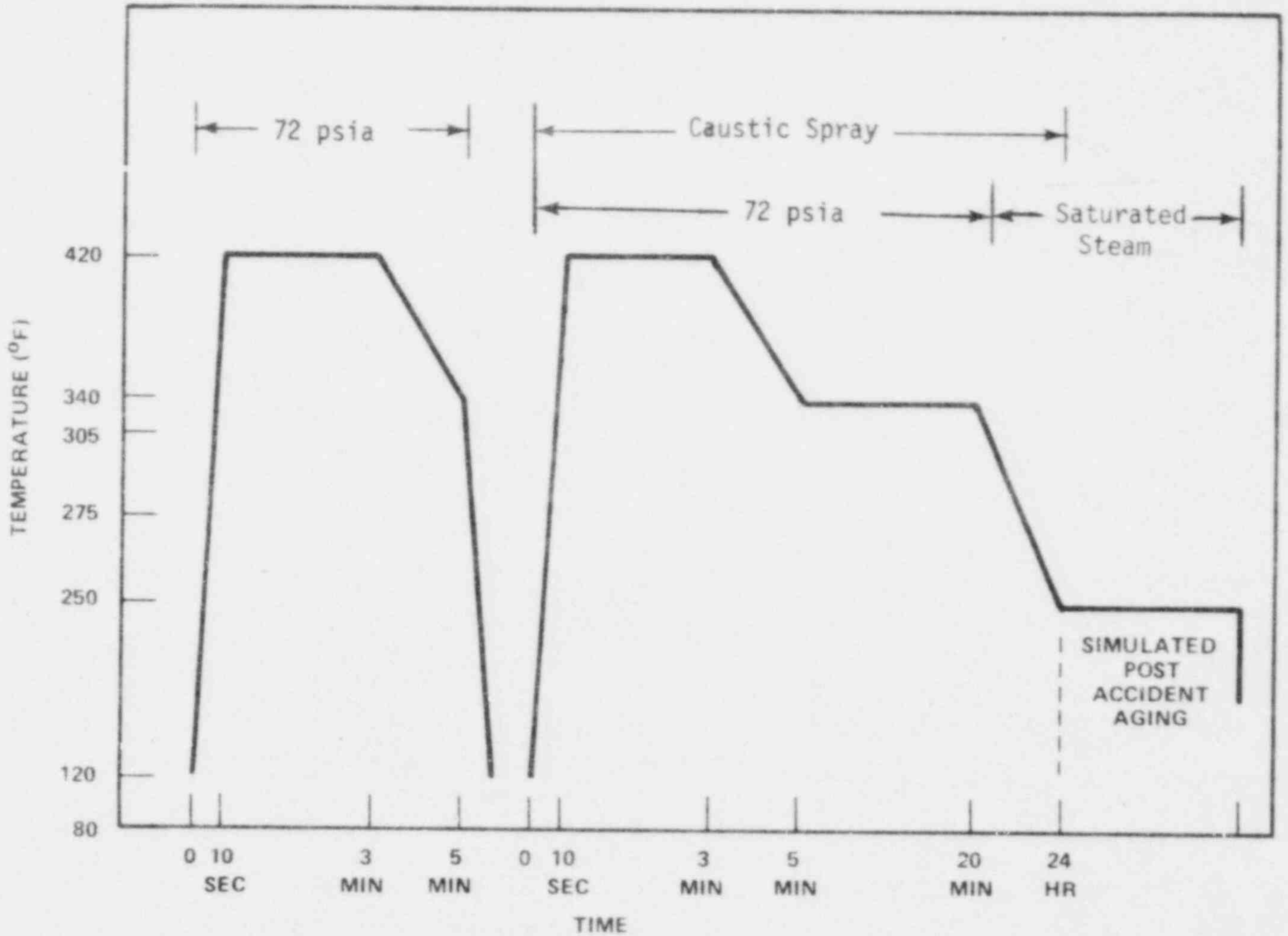

Figure 7-2 Typical Combined LOCA/SLB/FLB Test Envelope

8.0 REFERENCES

1. IEEE NPEC SC2 WG 2.6 Environmental Qualification - Draft Environmental Qualification Parameters, 1978. 4

2. Jarecki, S. J., "General Method of Developing Multifrequency Biaxial Test Inputs for Bistables," WCAP-8695 (Non-Proprietary), WCAP-8624 (Proprietary), September 1975.

3. Hsieh, T., Barlow, R. T. and Julian, H. V., Environmental Qualification Instrument Transmittor Temperature Transient Analysis WCAP-8936 (Proprietary) WCAP-8937 (Non-Proprietary) February 1977.

4. NRC Report - "Short Term Safety Assessment on the Environmental Qualification of Safety Related Electrical Equipment of SEP Operating Reactors," NUREG-0458, May 1978.

5. Bordelon, F. M., Murphy, E. T., WCAP-8327, Containment Pressure Analysis Code (COCO) July 1974.

6. Letter to Mr. D. B. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated March 17, 1976 (NS-CE-992).

7. Letter to Mr. D. V. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated July 10, 1975 (NS-CE-692).

8. Letter to Mr. D. V. Vassallo, Chief, Light Water Reactors Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated April 7, 1976 (NS-CE-1021).

9. Letter to Mr. J. F. Stolz, Chief, Light Water Reactor Project Branch 6, USNRC from Mr. C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated August 27, 1976 (NS-CE-1183).

10. T. Hsieh, et. al., WCAP-8936, "Environmental Qualification Instrument Transmitter Temperature Transient Analysis," February 1977.

11. Letter to John F. Stolz, Chief, Light Water Reactors Project, Branch 6, USNRC from C. Eicheldinger, Manager, Nuclear Safety, Westinghouse Electric Corporation, Dated June 14, 1977 (NS-CE-1453).

APPENDIX A

EQUIPMENT QUALIFICATION DATA PACKAGE

This document contains information, relative to the qualification of the equipment identified below, in accordance with the methodology of WCAP 8587. The Specification section (Section 1) defines the assumed limits for the equipment qualification and constitute interface requirements to the user. 4

APPROVED: ______________________________
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SECTION 1 - SPECIFICATIONS

1.0 PERFORMANCE SPECIFICATIONS

1.1 Electrical Requirements

1.1.1 Voltage:

1.1.2 Frequency:

1.1.3 Load:

1.1.4 Electromagnetic Interference:

1.1.5 Other:

1.2 Installation Requirements: 4

1.3 Auxiliary Devices:

1.4 Preventative Maintenance Schedule: The details of any preventative maintenance schedule, assumed in establishing the qualified life, will be specified in this section on completion of the Westinghouse Aging Evaluation Program.

1.5 Design Life:

1.6 Operating Cycles (Expected number of cycles during design life, including test):

1.7 Performance Requirements for[b]:

Parameter	Normal Conditions	Abnormal Conditions	Containment Test Conditions	DBE Conditions(a) FLB/SLB	DBE Conditions(a) LOCA	DBE Conditions(a) Seismic	Post DBE Conditions(a) FLB/SLB	Post DBE Conditions(a) LOCA	Post DBE Conditions(a) Seismic
1.7.1 Time requirement									
1.7.2 Performance requirement									

1.8 Environmental Conditions for Same Function[b]

1.8.1 Temperature(°F)									
1.8.2 Pressure (psig)									
1.8.3 Humidity (% RH)									
1.8.4 Radiation (R)									
1.8.5 Chemicals									
1.8.6 Vibration									
1.8.7 Acceleration (g)									

Notes: a: DBE is the Design Basis Event.
b: Margin is not included in the parameters of this section.

1.9 Qualified Life: The demonstrated qualified life will be specified in this section on completion of Subprogram C of the Westinghouse Aging Evaluation Program. (Appendix B to WCAP-8587) 4

1.10 Remarks: None

SECTION 2 - QUALIFICATION BY TEST

2.0 TEST PLAN

2.1 Equipment Description:

4 2.2 Number Tested:

2.3 Mounting:

2.4 Connections:

2.5 Aging Simulation Procedure

5

2.6 Service Conditions to be Simulated by Test (1)

	Normal	Abnormal	Containment Test	Seismic	HELB	Post-HELB
2.6.1 Temp. (°F)						
2.6.2 Pressure (psig)						
2.6.3 Humidity (% RH)						
2.6.4 Radiation (R)						
2.6.5 Chemicals						
2.6.6 Vibration						
2.6.7 Acceleration (g)						

2.7 Measured Variables

This section identifies the parameters required to be measured during the test sequence(s).

		Required	Not Required
2.7.1	Category I - Environment		
2.7.1.1	Temperature		
2.7.1.2	Pressure		
2.7.1.3	Moisture		
2.7.1.4	Composition		
2.7.1.5	Seismic Acceleration		
2.7.1.6	Time		
2.7.2	Category II - Input Electrical Characteristics		
2.7.2.1	Voltage		
2.7.2.2	Current		
2.7.2.3	Frequency		
2.7.2.4	Power		
2.7.2.5	Other		
2.7.3	Category III - Fluid Characteristics		
2.7.3.1	Chemical Composition		
2.7.3.2	Flow Rate		
2.7.3.3	Spray		
2.7.3.4	Temperature		
2.7.4	Category IV - Radiological Features		
2.7.4.1	Energy Type		
2.7.4.2	Energy Level		
2.7.4.3	Dose Rate		
2.7.4.4	Integrated Dose		

4

		Required	Not Required
2.7.5	Category V - Electrical Characteristics		
2.7.5.1	Insulation Resistance		
2.7.5.2	Output Voltage		
2.7.5.3	Output Current		
2.7.5.4	Output Power		
2.7.5.5	Response Time		
2.7.5.6	Frequency Characteristics		
2.7.5.7	Simulated Load		
2.7.6	Category VI - Mechanical Characteristics		
2.7.6.1	Thrust		
2.7.6.2	Torque		
2.7.6.3	Time		
2.7.6.4	Load Profile		
2.7.7	Category VII - Auxiliary Equipment		

4

2.8 Test Sequence Preferred

This section identifies the preferred test sequences as specified in IEEE-323-74

2.8.1 Inspection of Test Item
2.8.2 Operation (Normal Condition)
2.8.3 Operation (Perfomance Specifications Extremes, Section 1)
2.8.4 Simulated Aging
2.8.5 Vibration
2.8.6 Operation (Simulated High Energy Line Break Conditions)
5 2.8.7 Operation (Simulated Post HELB Conditions)
2.8.8 Inspection

4 2.9 Test Sequence Actual

This section identifies the actual test sequence(s) which, in total, constitutes the overall qualification program for this equipment. The separate subsections indicate the separate test sequences completed on differing, but essentially identical, equipment and/or components. The justification for employing anything other than the preferred sequence is as follows;

Step	Notes

5

2.10 Type Test Data

2.10.1 Objective

The objective of this test program is to demonstrate, employing
the recommended practices of Reg. Guide 1.89 (IEEE-323-1974)
and Reg. Guide 1.100 (IEEE 344-1975), the capability of 4
the ____ to complete it's/their safety-related function(s)
described in EQDP Section 1.7 while exposed to the applicable
environments defined in EQDP Section 1.8.

2.10.2 Equipment Tested

2.10.3 Test Summary 5

2.10.4 Conclusion

2.11 Section 2 Notes

4 (1) The generic tests completed by Westinghouse employ parameters designed to envelope a number of plant applications. Margin is a plant specific parameter and will be established by the applicant.

2.12 References

SECTIONS 3 & 4 QUALIFICATION BY EXPERIENCE AND/OR ANALYSIS

Westinghouse does not employ operating experience or analysis in support of the qualification program for ____. 4

Appendix B

Westinghouse Aging Evaluation Program

Introduction

1. IEEE-323-1974 requires that aging of Class 1E equipment during normal
service be considered as an integral part of the qualification program. The 3
objective is not to address random age induced failures that occur in-service,
which are detected by periodic testing and maintenance programs, but to
address the concern that some aging mechanisms, when considered in
conjunction with the specified Design Basis Events (DBE), may have the
potential for common mode failure.

2. Since the endorsement of IEEE-323-1974 by the NRC in November of that year by Reg. Guide 1.89, industry reaction, particularly over the question of aging, has reflected the lack of established methods to comprehensively address this issue with the current state of technology. There has been a reluctance to embark on extensive qualification programs due to the consequent exposure from trying to interpret what is an adequate, state-of-the-art address to aging that would be acceptable to the NRC.

3. A program aimed at establishing the necessary data base to address this issue,
in a correct scientific manner in all aspects, would not provide the requisite
address to this issue in the short-term and would be outside the financial
capabilities of any single supplier having a large scope of supply of safety
related electrical equipment. Nevertheless, the issue of potential common 5
mode failures must be addressed.

4. The Westinghouse approach to addressing this issue described below represents a genuine state-of-the-art address to the aging concern and makes maximum use of available data and experience on aging mechanisms. In addition, it takes account of the recommendations, of the various IEEE committees currently involved in developing qualification related standards, as to what constitutes an acceptable, state-of-the-art, address to the aging issue.

5 5. The Westinghouse approach places primary emphasis on common mode failures due to severe Design Basis Events. For example, reasonable assurance against common mode failures being induced due to a loss of HVAC can be provided by adequate design normal maintenance and calibration procedures.

Objectives

6. The objectives of the Westinghouse Aging Evaluation Program are:

- To establish, where possible, the effects of the degradation due to aging mechanisms that can occur prior to the occurrence of an accident, when safety related equipment is called upon to function.

- To provide increased assurance that safety related equipment can perform its safety related function under the specified service conditions.

Basic Approach

7. The general approach to addressing aging, as employed by Westinghouse Water Reactor Divisions, allocates equipment to one of three subprograms:

3 - Subprogram A includes electrical equipment required to perform a safety related function in a high energy line break (HELB) environment. For this equipment an aging simulation will be included as part of the equipment
5 qualification test sequence. The equipment will be energized during the aging simulation.

- Subprogram B encompasses structural components and simple equipment for which information is available that demonstrates a lack of pronounced property degradation due to aging mechanisms. The limited effect of aging mechanisms on such materials and equipment permits qualification by evaluation of available test data. (eg., equipment which is primarily of metal construction, etc.)

- Subprogram C includes equipment which is not required to perform a safety related function in a HELB environment. Equipment is included that is required to mitigate HELB's but which, due to its location, is isolated from any adverse external environment resulting from the accident. For equipment in Subprogram C the single Design Basis Event (DBE) that is capable of producing an adverse environment at the equipment location is the seismic event. Aging, for Subprogram C, will not be included in the equipment qualification test sequence. Aging will be addressed by a separate program that demonstrates that aged components continue to meet manufacturer's performance specifications under applicable seismic DBE conditions and this seismic testing of unaged equipment is not invalidated by any anticipated aging mechanisms. This approach provides several distinct benefits: 3

  - Avoidance of unnecessary retesting of equipment previously seismically tested employing IEEE-344 1975 methodology.

  - Seismic and environmental testing of equipment can be completed on schedule for the lead plant without undue delays due to lack of comprehensive knowledge on component aging characteristics.

  - Complete seismic retesting of equipment, as a result of future developments in aging technology for individual components or simple design modifications to specific components, is avoided. Component requalification is possible.

  - Families of similar components may be qualified by qualification of a representative sample.

- Duplicate aging and testing of identical components, employed in different equipment is avoided.

- Component qualification continues to be applicable for future designed safety related equipment.

- Problems arising due to future unavailability of qualified spare parts can be avoided by qualification of new replacement components. This is especially important since the industry constantly seeks improvements in design and performance of components and avoids the necessity of complete retest and NRC approval.

- Employment of this approach introduces the possibility of optimizing industry wide application of resources, leading to an ever-expanding knowledge of aging effects at the component level (i.e. future data bank of qualified components).

Subprogram C is divided into two phases. The objective of the initial short-term phase of the program is to demonstrate a qualified life of at least 5 years. The second phase of the program will be defined based on the experience acquired during the initial phase. The objective of the second phase is to extend the demonstrated qualified life to the maximum attainable (not more than 40 years) and to include additional Westinghouse Class 1E equipment to be supplied to later plants. It is the short term program which is specifically addressed in this appendix.

8. Table B-1 identifies the typical Class 1E equipment to be supplied by Westinghouse to the lead plants committed to IEEE 323-1974 and indicates the aging subprogram to which the equipment has been allocated.

Subprogram A

9. Electrical equipment which is required to perform a safety related function in a HELB (i.e., LOCA, feedline break or steamline break) environment is included in subprogram A. This subprogram specifically provides for an aging simulation to be included in the equipment's qualification test sequence.

Scope

10. The equipment scope and aging mechanisms applied under Subprogram A are shown in Tables B-1 and B-2 respectively. As additional qualification testing is completed and the scope of the program expanded to include other safety related electrical equipment, the index of qualified equipment, contained in 5
WCAP-8587 Supplement 1 and WCAP-8687 Supplement 2, will be updated. The equipment selected is that Class IE equipment which is to be qualified to operate in a HELB environment. The aging mechanisms discussed below are those to which the equipment may be potentially sensitive in its installed location.

Aging Mechanisms 3

11. The aging mechanisms that could potentially affect electrical equipment in Subprogram A are discussed under the following headings:

time in conjunction with:

- operational stresses
  - current, voltage, operating cycles, Joulean heating
- external stresses
  - thermal, vibration, radiation, humidity, seismic

The aging mechanisms considered potentially significant and to be simulated are identified in Table B-2 for each item of equipment in Subprogram A. Where applied, the aging mechanisms will be simulated as described below.

Time

12. For equipment subject to high energy line break conditions, the most significant in-service aging mechanisms (i.e., radiation and thermal) come into effect during reactor operation. Consequently, it can be assumed that the "aging clock" starts on plant start-up.

Operational Stresses

Electrical Cycling

13. Electrical supplies to safety related equipment are, in general, highly stable, and aging effects due to supply cycling during running service is not anticipated. Where the equipment is anticipated to experience multiple startup and shutdown cycles, the equipment will be elect ically cycled to simulate the number of anticipated startup and shutdown cycles plus 10%.

3 Mechanical Cycling

14. Aging effects resulting from any anticipated mechanical cycling of the equipment will be simulated by applying, as a minimum, the number of cycles estimated to occur during the target qualified life plus 10%. Mechanical cycling covers such operations as switching, relay actuation, etc.

Joulean Self-heating

15. Where the equipment is not aged in a live condition, the aging effects resulting
from Joulean self-heating will be recognized by employing the equipment
5 operating temperature as the datum temperature (To) for assessing the
accelerated thermal aging parameters to be employed.
(Paragraph 16)

External Stresses

Thermal Effects

16. Thermal effects are considered to be one of the most significant aging mechanisms to be addressed. The equipment will be thermally aged to

simulate an end-of-qualified-life condition using the Arrhenius Model to establish the appropriate conditioning period at elevated temperature. Where data is not available to establish the model parameters for the materials employed, a verifiably (Appendix D) conservative value of 0.5 ev will be used for activation energy. For each piece of equipment an appropriate normal and abnormal operating temperature (To) and an associated time history are 5
determined for inclusion in the Arrhenius Model. The equipment temperature is determined by the addition of an appropriate equipment specific ΔT to the external ambient temperature. Appendix D also provides information concerning the determination of appropriate ambient temperatures and time temperature histories for use in thermal aging evaluation of equipment. Post accident thermal aging is included by recognizing the higher post accident ambient temperatures in determining the parameters to be employed for the post-accident accelerated thermal aging simulation.

<u>In-Service Vibration</u> 3

17. The majority of Westinghouse safety related electrical equipment has a well proven history of in-plant service. Thus, it is unlikely that a significant, undetected, failure mechanism exists due to low level in-plant vibration. In addition, although not strictly equitable, 5 OBE's employed during equipment and component seismic testing gives added assurance that this potential aging mechanism is covered. For pipe-mounted equipment, in-service vibration may be significant and as a consequence an additional vibration aging step will be included in the aging sequence as indicated for certain items of equipment in Table B-2.

<u>Radiation</u>

18. Radiation during normal operation will not be considered an aging mechanism for equipment that is subject to in-service integrated doses less than 10^4 rads. Research has established that no aging mechanisms are measurable

5 below 10^4 rads (Appendix C) for materials and components employed in Westinghouse supplied safety related electrical equipment. For radiation doses in excess of 10^4 rads, the equipment will be irradiated using a γ source, to a dose equivalent to the estimated dose to be incurred during normal operation for the target qualified life. The estimated doses to be employed are specified in EQDP Section 1.8.4 and are based on 100% load factor, thus including appropriate margin. It should be additionally noted that in general, for Subprogram A equipment, the equivalent accident dose is also applied prior to DBE testing.

Humidity

19. The use of materials significantly affected by humidity will be avoided. For equipment that is subject to High Energy Line Break (HELB) environments, the
3 aging effects due to humidity during normal operation are judged to be insignificant compared to the effects of the high temperature steam accident simulation and therefore no additional humidity aging simulation is required.

Seismic Aging

20. The potential aging effects of low level seismic activity, and some low level in-plant vibration, is addressed by employing 5 OBE's, as recommended by IEEE-344-75, prior to seismic testing of the aged equipment.

Synergism

21. An important consideration in aging is the possible existence of synergistic effects when multiple stress environments are applied simultaneously. Westinghouse will not attempt to simulate synergistic effects. The potential for significant synergistic effects will be addressed by the conservatisms inherent in utilization of the "worst-case" aging sequence (paragraphs 23 and

24), utilization of conservative accelerated aging parameters (paragraphs 12-20), and conservative, design basis event test levels (paragraph 22) all of which provide assurance that any synergistic effects have been enveloped. A continuing review of developments related to synergistic effects will be conducted to determine whether modification of the Westinghouse approach is required.

DBE Testing

22. Design Basis Event testing subsequent to equipment aging is discussed in Section 6.7.4 of WCAP-8587 as to guidelines for defining HELB environments and seismic conditions and in EQDP Section 2.0 for equipment specific test environments and seismic parameters.

Aging Sequence

23. The aging mechanisms to be applied to equipment subject to HELB environments are determined by definition of the aging environments at the equipment location and a subsequent evaluation of the sensitivity of the equipment to these environments. If the sensitivity of the equipment is not known, aging mechanisms will be simulated by conservative methods as described above. Those aging mechanisms which will be simulated for equipment subject to HELB environments are shown in Table B-2. 3

24. The order in which each of the aging mechanisms is applied is as shown in Table B-2. This order is considered to be conservative as no aging mechanism is anticipated to be capable of reducing the impact of the previously applied mechanisms. As an example, thermal aging is applied prior to radiation aging to preclude the annealing out of any radiation induced defects. Similarly, the effects of mechanical aging are considered to be more significant when applied to equipment that has already been preaged to address thermal and radiation phenomena.

Acceptance Criteria

25. The basic acceptance criteria is that the qualification tests shall demonstrate the capability of the aged equipment to perform prespecified safety related functions consistent with meeting the performance specification of Section 1.7 of the applicable EQDP(s) while exposed to the associated environmental conditions defined in EQDP Section 1.8.

Failure Treatment

26. When thermal aging is simulated at an equipment level, a conservative value for the activation energy is assumed for the components comprising the equipment. As a consequence, many components will be grossly over-aged and failure of some of the components can be expected during the aging simulation. Where three test units are being preaged, in the event of such failure(s), one of the following options will be selected.

3

- where a particular component fails in one of the three test units, the failure will be considered random and the failed component replaced by a new component and the test continued.

- where a particular component fails in more than one of the three test units, either;

  the failed components will be replaced by new identical components and the aging simulation continued. The claimed qualified life of the unit will be consistent with the minimum aging period simulated by at least two of the three units.

  or the failed components will be replaced by identical components specifically aged to the qualified life by assuming for thermal aging a less conservative activation energy specifically determined for the component.

<u>or</u> the failed components will be replaced by a different type of component which has been aged for a period equal to the test units.

5

27. Where less than three (3) test samples prevent such a conclusion being reached, any failures will be investigated to ascertain whether the failure mechanism is of common mode origin. 3 Should a common mode failure mechanism be identified as having caused the failure, a design change will be implemented to eliminate the problem and supplemental or repeat tests completed to demonstrate compliance with the acceptance criteria.

Subprogram B

28. Certain types of structural components and simple equipment are known from experience not to be subject to pronounced property degradation due to aging mechanisms. The limited effect of aging mechanisms on such materials and equipment can be justified and supported by an evaluation of available test data.

Scope

5

29. Equipment in Subprogram B for which aging is to be addressed by an evaluation of available test data is listed in Table B-1 and the appropriate aging mechanisms to be considered in Table B-2. As additional qualification testing is completed and the scope of the program expanded to include other safety related electrical equipment, the index of qualified equipment contained in WCAP-8587, Supplement 1 and WCAP-8687, Supplement 2 will be updated.

Aging Mechanisms

3

30. The aging mechanisms that have potential impact on the equipment and components in Subprogram B are the same categories noted and discussed under Subprogram A. Mechanisms which are applicable to items under Subprogram B are addressed by consideration of available test data concerning aging mechanisms. This data is compared with the expected operating conditions for the equipment, and a conservative qualified operating life is determined for those aging mechanisms identified as being applicable.

DBE Testing

31. Design Basis Event testing is discussed in Section 6.7.4 of WCAP-8587 as to guidelines for DBE test environments and seismic conditions and in EQDP Section 2.0 for equipment specific test environments and seismic test parameters. For equipment allocated to Subprogram B, DBE testing will be conducted on non-aged equipment since the subprogram will establish the information necessary to demonstrate that there is no in-service aging mechanism capable of degrading the equipment performance under DBE conditions.

Acceptance Criteria

32. For equipment and components for which aging is addressed by evaluation of appropriate mechanisms, the basic acceptance criteria is that the evaluation of test data shall demonstrate the effect of aging is minor and will not affect the capability of the aged equipment to perform prespecified functions consistent with meeting the performance specification of Section 1.7 of the applicable EQDP(s) while exposed to the associated environmental conditions defined in EQDP Section 1.8.

Failure Treatment

3

33. In the event of failure to demonstrate conformance to acceptance criteria for items applicable under Subprogram B, several options are available for resolution of qualification with respect to aging. These options are:

    - reduce qualified life,

    - replace with components or materials of known acceptable characteristics,

    - qualify the item in question by inclusion in Subprogram A or Subprogram C for testing.

Subprogram C

34. Subprogram C includes Class 1E equipment not required to perform a safety related function in a HELB environment and where insufficient information is available to demonstrate the absence of significant in-service aging mechanisms. For equipment allocated to this subprogram, the single Design Basis Event (DBE) capable of producing an adverse environment at the equipment location is the seismic event. Previously completed seismic testing on unaged equipment will be verified as valid by demonstrating via this subprogram that aged components continue to meet their design specification during a seismic event.

Scope

3 35. Subprogram C includes equipment which is not required to perform a safety
related function in a HELB environment. Equipment is included that is
required to mitigate HELB's but which, due to the equipment location, is
isolated from any adverse environment resulting from the accident.
Equipment allocated to Subprogram C is identified in Table B-1. As additional
5 qualification testing is completed and the scope of the program expanded to
include other safety related electrical equipment the index of equipment
contained in WCAP-8587 Supplement 1 WCAP-8687 Supplement 2 will be
updated.

Aging Mechanisms

36. The aging mechanisms considered potentially significant for equipment within
the scope of this subprogram are identified in Table B-2. The methods of
simulating these aging mechanisms are as described in Subprogram A. For this
5 equipment, the most significant aging mechanisms come into effect when the
ambient environment for the components increases. Consequently, it can be
assumed that the "aging clock" starts when the equipment is energized.

Synergism

37. For Subprogram C, Westinghouse will not attempt to simulate synergistic effects. The conservatisms provided in the short-term program by utilization of the "worst-case" aging sequence (paragraphs 23 and 24), utilization of conservative accelerated aging parameters (paragraphs 12-20), and conservative, design basis event test levels (paragraph 22) provide assurance that any synergistic effects have been enveloped. A continuing review of developments related to synergistic effects will be conducted to determine whether any modification of the Westinghouse approach is required for the second phase of Subprogram C.

DBE Testing

38. For equipment allocated to Subprogram C, the single DBE that is capable of producing an adverse environment at the equipment location is the seismic event. The object of this subprogram is to demonstrate, by seismic testing of aged components, that previously completed seismic testing of unaged equipment is not prejudiced by any in-service aging mechanism. Aged critical components will be seismically tested employing a specially developed required response spectra which envelopes all anticipated locations of the tested components in the equipment. This spectra includes an allowance for potential amplification from the support structure. In general, components will be card mounted with provisions for testing of components live during the seismic event simulation. 3

Test Samples

39. By employing the decision tree outlined in Figure B-1, a complete list of critical components will be established for all equipment allocated to Subprogram C (Table B-1). For the initial phase of the aging program, the component classification will not be as sophisticated as implied by Figure B-1 due to lack of information on the aging characteristics of components. As a result, all non-metallic or non-ceramic components of a piece of Class 1E equipment will be classified as "critical" unless it can be shown that a component's failure will not affect the safety related performance of the equipment. Any such decisions will be justified and documented. Critical components will be sorted into:

Groups - i.e., Resistors
Families - Carbon resistors
3 Family Members - Different types of carbon resistors

From this total listing of critical components, a sample of components will be defined for Subprogram C. The sample will be selected in such a way that it can be shown to be representative of the total list of critical components.

The component list will be generated through a review of the baseline design document or the as-built drawings for the equipment. The list will define the components, component family and vendor. The components selected for the short term program were those with short lead time. The short term program
5 covered roughly half of the component families and one-third of the components. The long term program will cover about 200 additional line items. As new systems and equipment are added to the program, their baseline design document or their as-built drawings will be reviewed against the existing component list and additional components added to the list as necessary.

40. Within a particular family of components, the major variable is the vendor. There may be major differences in materials and methods of manufacture for a carbon resistor, for instance, but it is unlikely that a single vendor would manufacture different sizes of carbon resistors with completely different materials and techniques. Consequently, a representative sample of the total list of critical components will be defined to be one that includes no less than
3 10% of the component members supplied by each vendor to each family of components. An estimate of the size of the representative sample for the equipment allocated to Subprogram C is:

$$\text{No. of Groups} \times \frac{\text{No. of Families}}{\text{Group}} \times \frac{\text{No. of Vendors}}{\text{Family}} \times \frac{\text{Members}}{\text{Vendor}} \times \frac{1}{10}$$

$$\simeq 25 \times 4 \times 3 \times (<10) \times \frac{1}{10}$$

$$\simeq 300$$

Assuming an adequate test sample is 9 identical components then ~2700-components are required for a representative aging test. The minimum acceptable number of samples will be at least 1 per family (i.e., 100 samples). A minimum target of 100 samples (900 components) will therefore be established for the short-term program.

The test sample will be employed as follows:

- 3 component samples at typically 130^oC for 2125 hrs. (≅5 yrs at 60^oC for a 0.5 ev activation energy),
- 3 component samples at higher temperature/shorter duration (≅5 yrs.),
- 3 spares.

The higher temperature will be selected based on limiting material properties. This higher temperature will be used to 3

- Provide advanced warning of potential problems on the lower temperature samples, thereby giving the option to remove the lower temperature samples early,
- Duplicate qualified life tests by accelerated aging at two temperatures.

Aging Sequence

41. The order in which each of the aging mechanisms is applied is as shown in Table B-2. This order has been defined to ensure that no aging mechanism significantly reduces the impact of the previously applied mechanisms. As an example, thermal aging is applied prior to radiation aging to preclude the annealing out of any radiation induced defects. Similarly, the effects of mechanical aging are considered to be more significant when applied to materials that have already been preaged to address thermal and radiation phenomena. Westinghouse will review any information which would suggest that the sequence of applying aging mechanism proposed in Table B-2 is non-conservative and will consider whether any modification of the Westinghouse approach is required for the second phase of Subprogram C.

Acceptance Criteria

42. Random component failure or unacceptable performance due to aging is detected by routine maintenance and equipment calibration during service. The objective of Subprogram C is to demonstrate that a seismic event does not constitute a common mode failure mechanism capable of inducing unacceptable performance characteristics in aged components. Consequently, the single acceptance criteria for the aging portion of the qualification sequence requires that the component not fail to perform its general function, but not that the component meet the original design and procurement specifications. For the seismic event simulation, the component will be considered acceptable if during and after the simulation it does not exhibit any temporary or permanent step change in performance characteristics. Conversely, any such change will be investigated with respect to tolerable
3 limits of performance characteristics within the equipment. Failure of one of three components being tested will be considered to be a random failure, while failure of more than one component to meet the acceptance criterion will constitute failure to meet qualification requirements.

Failure Treatment

43. In the event of failure to demonstrate conformance to acceptance criteria, several options are available for resolution of qualification with respect to age. The options are:

- reduce qualified life,

- replace the components with those constructed of materials of known acceptable characteristics.

TABLE B-1

TYPICAL CLASS IE EQUIPMENT SCOPE AND SUBPROGRAM ALLOCATION 5

Aging Method	Equipment	Equipment Qualifiction Data Package	
Subprogram A	Valve Motor Operators	EQDP-HE-1 and 4	
	Pilot Solenoid Valves	EQDP-HE-2/5	
	Externally Mounted Limit Switches	EQDP-HE-3/6	5
	Pressure Transmitter (Group A)	EQDP-ESE-1	
	Differential Pressure Transmitter (Group A)	EQDP-ESE-3	
	Resistance Temperature Detectors	EQDP-ESE-5, 6 and 7	
	Neutron Detectors (Power Range)	EQDP-ESE-8 and 22	
	Nitrogen-16 Detector	EQDP-ESE-27	
Subprogram B	Indicators (Post-Accident Monitoring)	EQDP-ESE-14	3
	Instrument Bus Distribution Panels	EQDP-ESE-19 and 34	
	Pressure Sensor	EQDP-ESE-21	
Subprogram C	Pressure Transmitter (Group B)	EQDP-ESE-2	
	Differential Pressure Transmitter (Group B)	EQDP-ESE-4	
	Nuclear Instrumentation System (NIS)	EQDP-ESE-10	
	Main Control Board Switch Modules	EQDP-ESE-12	
	Process Protection System	EQDP-ESE-13	
	Recorders (Post-Accident Monitoring)	EQDP-ESE-15	
	Solid-State Protection System and Safeguards Test Cabinet	EQDP-ESE-16 and 17	
	Instrument Bus Power Supply (Static Inverter)	EQDP-ESE-18 and 35	
	Reactor Trip Switchgear	EQDP-ESE-20	
	Class IE Pump Motors	EQDP-AE-2 and 3	

0764A

WESTINGHOUSE CLASS 3

TABLE B-2 (1 of 2)

Equipment	EQDP Ref.	Location	Sub-program	Aging Mechanisms: Burn-in	Thermal	Radiation	Mechanical	Vibration	Electrical	Seismic	DBE: Seismic	HELB
Safety Related Valve,	EQDP-HE-1	I/C	A		X	X	X	X		X	X	X
Elec. Motor Operators	EQDP-HE-4	O/C	A		X	X	X	X		X	X	
Safety Related Pilot	EQDP-HE-2/5	I/C	A		X	X	X	X		X	X	X
Solenoid Valves		O/C	A		X	X	X	X		X	X	
Safety Related Externally	EQDP-HE-3/6	I/C	A		X	X	X	X		X	X	X
Mounted Limit Switches		O/C	A		X	X	X	X		X	X	
Large Pump Motors (outside containment)	EQDP-AE-2	O/C	C		X	X	X	X	X	X	X	
Canned Pump Motors (outside containment)	EQDP-AE-3	O/C	C		X	X	X	X	X	X	X	
Pressure Transmitters	EQDP-ESE-1	I/C&O/C	A	X	X	X				X	X	X
	EQDP-ESE-2	I/C&O/C	C	X	X					X	X	
Differential Pressure	EQDP-ESE-3	I/C&O/C	A	X	X	X				X	X	X
Transmitters	EQDP-ESE-4	I/C&O/C	C	X	X					X	X	
Resistance Temperature	EQDP-ESE-5	I/C	A		X	X		X		X	X	X
Detectors: Well Mounted	EQDP-ESE-6	I/C	A		X	X		X		X	X	X
	EQDP-ESE-7	I/C	A		X	X		X		X	X	X
Excore Neutron Detectors:	EQDP-ESE-8	I/C	A		X	X				X	X	X
Power Range	EQDP-ESE-22	I/C	A		X	X				X	X	X
Nuclear Instrumentation System (NIS)	EQDP-ESE-10	O/C	C	X	X					X	X	
Main Control Board Switch Modules	EQDP-ESE-12	O/C	C	X	X					X	X	
Process Protection System	EQDP-ESE-13	O/C	C	X	X					X	X	

5 3 5

TABLE B-2 (2 of 2)

Equipment	EQDP Ref.	Location	Sub-program	Aging Mechanisms: Burn-in	Thermal	Radiation	Mechanical	Vibration	Electrical	Seismic	DBE: Seismic	HELB
Indicators, Post-Accident Monitoring	EQDP-ESE-14	O/C	B		X					X	X	
Recorders, Post-Accident Monitoring	EQDP-ESE-15	O/C	C	X	X					X	X	
Solid-State Protection System and Safeguard Test Cabinet	EQDP-ESE-16	O/C	C	X	X		X			X	X	
	EQDP-ESE-17	O/C	C	X	X		X			X	X	
Instrument Bus Power Supply (Static Inverter)	EQDP-ESE-18	O/C	C	X	X		X			X	X	
	EQDP-ESE-35	O/C	C	X	X		X			X	X	
Instrument Bus Distribution Panel	EQDP-ESE-19	O/C	B		X					X	X	
	EQDP-ESE-34	O/C	B		X					X	X	
Reactor Trip Switchgear	EQDP-ESE-20	O/C	C	X	X		X			X	X	
Pressure Sensor	EQDP-ESE-21	I/C	A							X	X	X
Nitrogen-16 Detector	EQDP-ESE-27	I/C	A		X	X		X		X	X	X

3

5 5

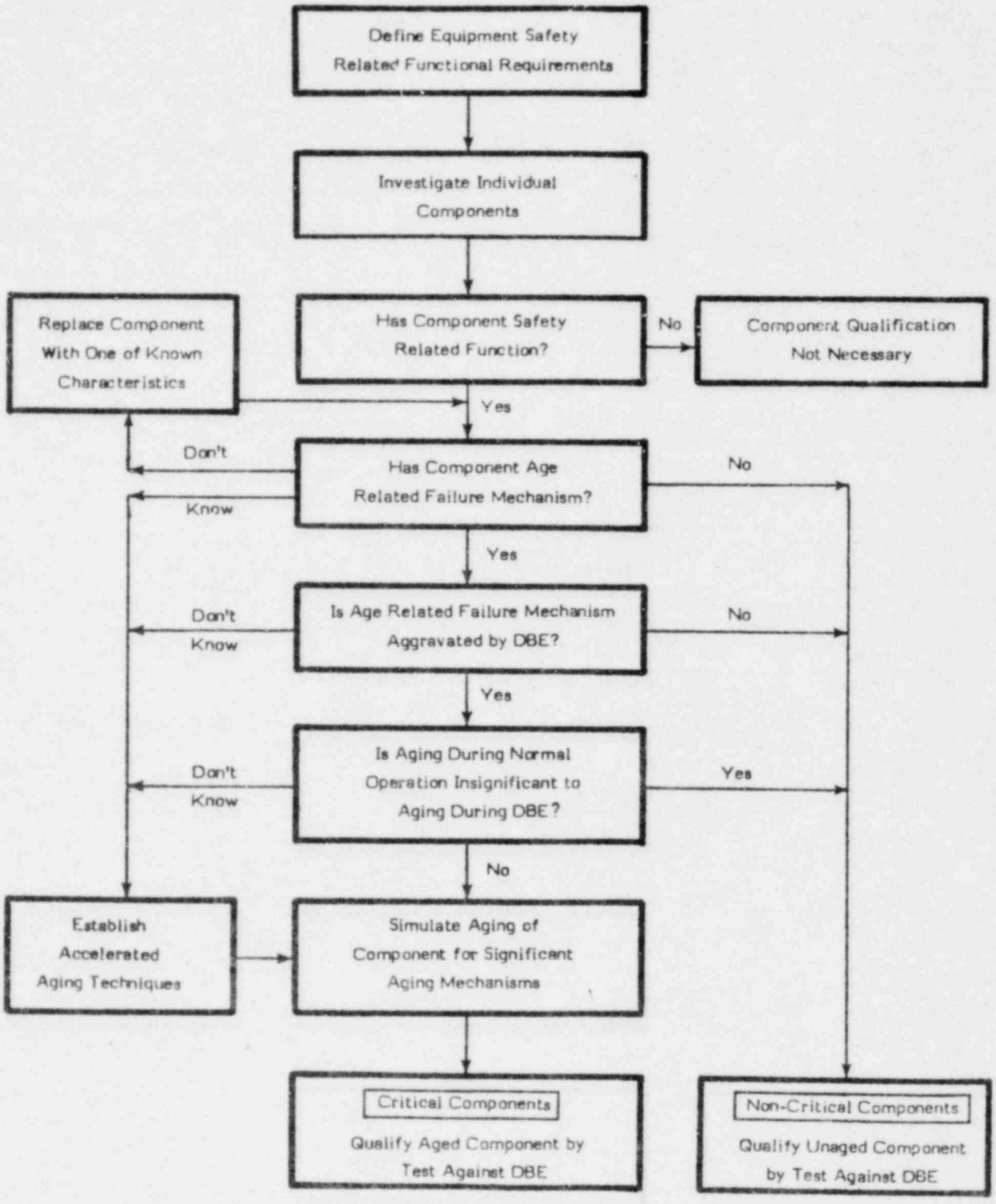

Figure B-1 Component Classification

Appendix C

Effects of Gamma Radiation Doses Below 10^4 Rads On the Mechanical Properties of Materials

Introduction

One potential common mode failure mechanism to be considered in the qualification of safety related equipment is gamma radiation. As part of a qualification program, the effect of gamma radiation dose is considered for two purposes: as a component of the High Energy Line Break (HELB) environment and as a potential aging mechanism which could reduce the capability of Class 1E equipment to perform safety related functions under Design Basis Event (DBE) conditions (HELB or seismic). The scope of this report is limited to consideration of the effect of radiation for that substantial portion of equipment outside containment which does not experience an adverse change in external environment 4
as a result of a HELB and for which, therefore, the only gamma radiation concern is as an in-service aging mechanism. This report could be applied to equipment which must perform its function in a HELB if the applicability of the report can be demonstrated, however the information in this report is not adequate to make this determination.

The primary purpose of equipment qualification is to reduce the potential for common-mode failures due to environmental effects during the qualified life. Random failures that inevitably occur in-service are accommodated by the redundancy and diversity of the design of safety systems. Furthermore, in-service maintenance and testing programs are designed to detect such random failures. 5
The chances of two identical components that perform identical functions failing during the same limited time period in between routine tests is considered insignificant due to:

- the general low failure rate of components used in nuclear equipment,

- the minor differences in component material or geometric tolerances or both, and

- the minor differences in operating environment.

5 Therefore, failures that may be induced in components by normal background gamma radiation below 10^4 rads alone are considered to be random in nature. Thus the only gamma radiation concern to be addressed for equipment not subject to an adverse HELB environment is the potential for an aging mechanism resulting in a deterioration in component properties such that, when subject to seismic stress, a common mode failure results. Clearly, when considering such a failure mode, the aging mechanism of concern is not one that affects the electrical properties of components, but one that reduces the mechanical strength and flexibility of components.

Scope

4

This report summarizes available information concerning the effects of gamma radiation on material mechanical properties and justifies that for a gamma dose of less than 10^4 rads, there are no observable radiation effects which impact material mechanical properties. Of the materials investigated only Teflon TFE is subject to an alteration of mechanical properties for a gamma dose of less than 10^5 rads. Information has been drawn from several sources listed as references on page C-5, they include: various texts concerning radiation effects and damage, and pertinent reports from the Radiation Effects Information Center at the Battelle Memorial Institute in Columbus, Ohio.

Discussion

The primary effects of gamma photons on materials are ionization, material heating (primarily at high dose rates which is of negligible significance here), and some displacement damage caused by high energy photons. Some other types of radiation can have effects similar to those induced by gamma radiation. This allows the use of data obtained from exposure of material to an alternate radiation to provide some limited information concerning the effects of exposure to gamma radiation. For example, the primary consequence of fast neutron bombardment of material is atom displacement. Therefore, if the effect of radiation on a material property is primarily dependent on atom displacement, it can be inferred that for an equivalent dose (rads) of gamma and fast neutron radiation, data obtained from neutron irradiation will provide a conservative estimate of the effect of gamma irradiation in producing displacements. The same type of inference can be drawn for the ionization effect of charged particle (e.g., electron, proton, alpha particle, etc.) irradiation. However, it should be understood that charged particles do not have the penetration capability that gamma or neutron radiations exhibit as a result of extensive interaction between charged particles and atomic charge centers.

Table C-1 summarizes information derived from the listed references which relates to the effect of gamma radiation on material mechanical properties. The table presents either the threshold dose (that dose at which an effect on any mechanical property can first be detected) or, if so indicated, the dose which will result in the identified effect. This provides a general indication of the susceptibility of material mechanical properties to gamma radiation.

From an evaluation of the information available on inorganic materials, as summarized in Table C-1, it can be deduced that the mechanical damage threshold for gamma radiation is many orders of magnitude greater than 10^4 rads. For the organic materials listed in Table C-1, a histogram comparing threshold dose level and frequency of material susceptibility is provided in Figure C-1. In instances for which a material threshold dose is not indicated in Table C-1, a threshold value has been assumed which is one order of magnitude lower than the indicated damage dose. Where information is available, referenced documents indicate that the difference between threshold dose and 25% damage dose is in general, approximately a factor of three, thus a factor of ten supplies substantial margin in estimating the threshold dose level. It can be seen in Figure C-1 that any indications of mechanical property, damage thresholds below 10^4 rads would be extremely unusual. 4

Conclusions

The references listed do not identify the existence of materials whose mechanical properties are deteriorated when exposed to a gamma-radiation dose up to 10^4 rads. As a consequence it can be concluded that common mode failures will not arise in electrical equipment during or after a seismic event as a result of radiation induced degradation up to 10^4 rads.

This conclusion is supported by Nuclear Regulatory Commission (NRC) documentation, available as an attachment to "Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors," which provides further justification for the use of 10^4 rads as a threshold for mechanical damage. In comparisons with Table C-1 the NRC information appears to be consistent, thereby raising the confidence level concerning the correctness of both sources.

Recommendations

4 For Class 1E equipment subject to a lifetime gamma dose of up to 10^4 rads, it is not necessary to address radiation aging for qualification purposes provided that the equipment is not required to perform a safety function in a HELB environment. This conclusion is supported by the text of this report, as no materials reviewed have indicated a degradation of mechanical properties for gamma radiation exposures of up to 10^4 rads. Westinghouse will continue to review information related to the effect of gamma radiation on material mechancial properties. If a material in Westinghouse supplied Class 1E equipment is identified as subject to a significant degradation of mechanical properties as a result of exposure to gamma radiation doses below 10^4 rads, its effect on equipment qualified life will be evaluated on an individual basis and the results reported to the affected customers.

References

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9. L. W. Ricketts, "Fundamentals of Nuclear Hardening of Electronic Equipment," Wiley-Interscience, New York, 1972.

10. J. F. Kircher and Richard E. Bowman, "Effect of Radiation on Materials and Components," Reinhold Publishing Corp., New York, 1964.

4 11. R. O. Bolt and J. G. Carroll, "Radiation Effects on Organic Materials," Academic Press, New York, 1963.

12. Irving Kaplan, "Nuclear Physics," Addison-Wesley, 1962.

TABLE C-1

RADIATION INDUCED DEGRADATION OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS
Structural Metals	10^{19} n/cm^2 (fast neutron spectrum)	Similar to cold work ($\sim 10^{10}$ rads)
Inorganic Materials	$\sim 10^{17}$ n/cm^2 (fast neutron spectrum)	Borated materials will have lower threshold values for neutron irradiation.
Elastomers		
Natural Rubber	2×10^6 rads(C)	
Polyurethane Rubber	9×10^5 rads(C)	
Styrene-Butadiene Rubber	2×10^6 rads(C)	
Nitrile Rubber	7×10^6 rads(C)	Compression Set is 25% degraded
Neoprene Rubber	7×10^6 rads(C)	
Hypalon	$\sim 10^7$ rads(C)	Variable
Acrylic Rubber	9×10^7 rads(C)	Variable
Silicone Rubber	10^7 rads(C)	$\sim$25% damage
Fluorocarbon Rubber	9×10^7 rads(C)	$\sim$25% Hardness, 80% Elongation
Polysulfate Rubber	10^8 rads(C)	
Butyl Rubber	10^7 rads(C)	$\sim$25% damage

4

1 Rad (C) is the field of radiation which will produce 100 ergs/gm in carbon.

TABLE C-1 (Continued)

RADIATION INDUCED DEGRADATION
OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS
Plastic		
Teflon TFE	1.7×10^4 rads(C)	
Kel-F	1.3×10^6 rads(C)	
Polyethylene	$>10^7$ rads(C)	
Polystyrene	10^8 rads	
Mylar	10^6 rads(C)	Conservative
Polyamide (Nylon)	8.6×10^5 rads(C)	
Diallyl Phthalate	10^8 rads(C)	
Polypropylene	10^7 rads(C)	
Polyurethane	7×10^8 rads(C)	
Kynar (400)	10^7 rads(C)	
Acrylics	8.2×10^5 rads	
Amino Resins	10^6 rads	
Aromatic Amide-Imide Resins	10^7 rads	
Cellulose Derivatives	3×10^7 rads	25% damage
Polyester, Glass Filled	8.7×10^8 rads	
Phenolics	3×10^8 rads(C)	25% damage
Silcones	10^8 rads(C)	
Polycarbonate Resins	5×10^7 rads	25% damage to elongation

4

TABLE C-1 (Continued)

RADIATION INDUCED DEGRADATION
OF MATERIAL MECHANICAL PROPERTIES

MATERIAL	THRESHOLD DOSE FOR MECHANICAL DAMAGE	COMMENTS	
<u>Plastic (Cont.)</u>			
Polyesters	$\sim 10^5 - 10^6$ rads		4
Styrene Polymers	4×10^7 rads		
Styrene Copolymers	4×10^7 rads	25% damage	
Vinyl Polymers	$1.4 \times 10^6 - 8.8 \times 10^7$ rads		
Vinyl Copolymers	$1.4 \times 10^6 - 8.8 \times 10^7$ rads		
<u>Encapsulating Compounds</u>			
RTV 501	2×10^6 rads		
Sylgard 182	2×10^6 rads		
Sylgard 1383	2×10^6 rads		
Polyurethane Foam	2×10^6 rads		
Epoxies	10^9 rads(C)		

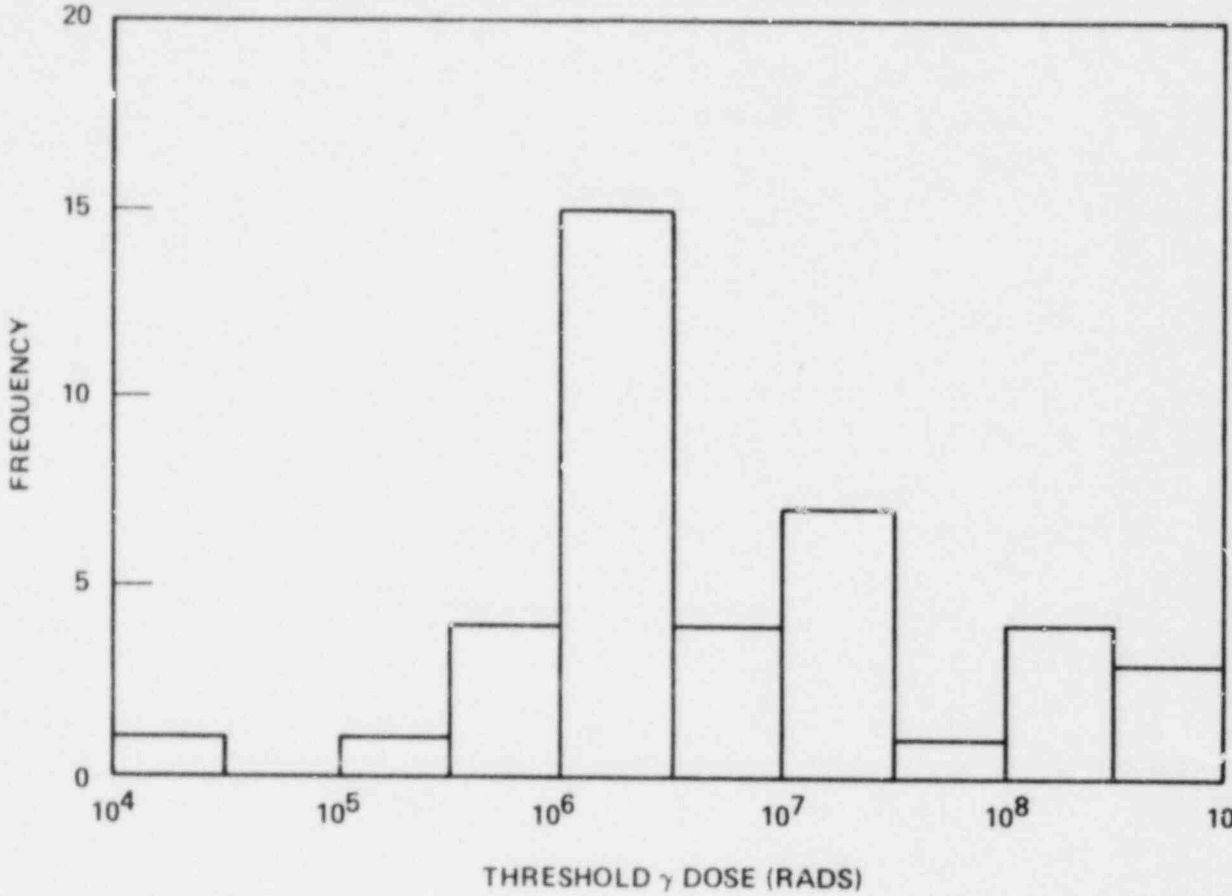

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Figure C-1 Histogram of Threshold γ-Dose for Mechanical Damage to Elastomers, Plastics and Encapsulating Compounds

WESTINGHOUSE CLASS 3

APPENDIX D

ACCELERATED THERMAL AGING PARAMETERS

1.0 INTRODUCTION

Appendix B of this report describes the approach employed by Westinghouse to address the aging requirement of IEEE-323-1974. In general, for equipment required to perform a safety related function in a high energy line break (HELB) environment, Westinghouse committed to an aging simulation as part of its qualification test sequence (Subprogram A of Appendix B). For equipment not required to perform a safety related function in a HELB environment the single Design Basis Event (DBE) considered is a seismic event. Aging, in this case (Subprogram C of Appendix B) will not usually be included in the test sequence. Aging, where significant, is addressed by separate qualification of aged components using conservative testing under applicable seismic DBE conditions.

Thermal effects are one of the primary aging mechanisms addressed by the Westinghouse program described in Appendix B for equipment containing non-metallic or non-ceramic materials. When thermal aging effects are established as being potentially significant to the component/equipment capability to perform its safety related function under DBE conditions, or in the absence of evidence to the contrary, the component/equipment is thermally aged to simulate an end-of-qualified-life condition prior to DBE testing. Equipment required to operate in a HELB environment is also thermally aged to simulate the post-accident conditions, consistent with its established functional requirements (Reference 1).

This appendix defines the appropriate thermal environments considered for each item of equipment in the WRD NSSS scope of supply and establishes consequent accelerated thermal aging parameters for use in the qualification programs.

2.0 ARRHENIUS MODEL

If an aging mechanism is governed by a single chemical reaction, the rate of which is dependent on temperature alone the Arrhenius equation can be used as the basis for establishing the accelerated aging parameters;

$$\frac{dR}{dt} = Ae^{\frac{-E}{kT}} \qquad (1)$$

where

E = Activation energy (eV)

k = Boltzmann's constant (8.62×10^{-5} eV/°K)

A = Constant factor

T = Material temperature (°K)

$\frac{dR}{dt}$ = Reaction rate = aging rate

Integration gives;

$$\Delta R = Be^{\frac{-E}{kT}} \Delta t \qquad (2)$$ 5

where

ΔR = change in measured property due to aging

Δt = time for aging effect ΔR to occur

If the accelerated aging process employed correctly simulates the change in properties due to aging under normal operating or post-accident temperature conditions then;

$$\Delta R_1 = \Delta R_0$$

and

$$B\, t_1\, e^{\frac{-E}{kT_1}} = B\, t_0\, e^{\frac{-E}{kT_0}}$$

and

$$\mathrm{Ln}\ t_1 = \frac{-E}{k}\left[\frac{T_1 - T_0}{T_1 T_0}\right] + \mathrm{Ln}\ t_0 \qquad (3)$$

where

T_1 = accelerated aging material temperature (°K)

t_1 = time at temperature T_1

T_0 = material temperature under normal operating or post accident conditions (°K)

t_0 = time at temperature T_0

From equation 3, given an activation energy (E) for the material, the time required at any selected elevated temperature can be calculated to simulate the ambient aging effects.

This model has been verified to represent the thermal aging characteristics of non-metallic and non-ceramic materials and is employed by Westinghouse to derive accelerated thermal aging parameters. The only material dependent parameter input into this model, when establishing the accelerated aging parameters, is the activation energy. This parameter is a direct measure of the chemical reaction rate governing the thermal degradation of the material.

3.0 ACTIVATION ENERGY

A single material may have more than one physical property that thermally degrades (i.e., dielectric strength, flexural strength etc.) and as a consequence exhibit different activation energies with respect to each property. The activation energy that should be selected is the one that reflects the physical property most significant to the safety related function performed or the stresses applied to the material by the design basis event(s) being considered.

In actual practice, however, rarely is the choice so simple. Electrical components are invariably made up of more than one material and in many cases either the materials employed are not known in any chemical detail, but just by a general organic or industrial trade name, or the appropriate activation energy is not known. A program to establish the necessary data base to address this issue, in a correct scientific manner in all aspects, would not provide the requisite address to this issue in the short-term and would be outside the financial capabilities of any single supplier having a large scope of supply of safety related equipment. In the absence of adequate information, Westinghouse adopted a conservative approach. A single conservative activation energy was selected to establish the accelerated thermal aging parameters used throughout this program.

A distribution of activation energies (Figure D-1) was produced by EPRI (Reference 2) based on 170 materials. An independent review of materials used in Westinghouse supplied equipment is summarized in Table D-1 and plotted in similar form in Figure D-2. A statistical analysis indicates that 95 percent of the activation energies exceed approximately 0.4 eV from the EPRI data and 0.6 eV from the Westinghouse data. Based on this information, a value of 0.5 eV was selected for use throughout the Westinghouse program, whenever specific activation energies were not available. Employing a low value of activation energy in deriving the accelerated aging parameters causes all materials having a higher activation energy to be over-aged with respect to the simulated conditions.

4.0 THERMAL AGING (NORMAL/ABNORMAL OPERATING CONDITIONS)

Table B-2 of Appendix B identifies equipment and components where the effects of in-service thermal aging is simulated as part of the qualification test procedure. This section establishes the methodology employed and derives a typical set of accelerated aging parameters for equipment in various plant locations.

4.1 NORMAL OPERATING TEMPERATURE (T_O)

One of the parameters input into the Arrhenius equation, when deriving accelerated aging parameters, is the ambient operating temperature of the component/material/equipment under investigation. The operating temperature could be dependent on a number of factors;

- Self heating (I^2R effects)
- External ambient temperature
- Ventilation/air conditioning etc.

The accelerated aging parameters of equipment having significant self heating (i.e., pump motors etc.) and other items which are located in areas having unusually high ambient temperatures (i.e., neutron detectors etc.) require special treatment. However, for the majority of equipment supplied by Westinghouse, a generic set of accelerated thermal aging parameters can be derived. Two basic sets of accelerated thermal aging parameters are generated in this Appendix reflecting the location dependent environments presented in Table B-2 of Appendix B.

Base 1: For equipment located in areas supplied by a Class 1E air conditioning system a conservative mean external ambient temperature of 75°F is assumed throughout the qualified life. For non-class 1E air conditioning systems, two excursions per year to 120°F, each lasting 12 hours, will also be assumed to reflect the potential for loss of the non-Class 1E system.

Base 2: For equipment located in general areas inside the containment and for equipment located outside containment in areas with ventilation, a conservative mean external ambient temperature approaching 104°F is assumed. In addition two excursions per year to 120°F, each lasting 12 hours, is assumed to reflect the potential for loss of the ventilation system.

In estimating the component or material operating temperature, consideration must be given to such phenomena as localized ambient hot spots within electronic cabinets and component self-heating (I^2R) effects. The value of T_0 employed depends on whether the component/system to be aged is energized or deenergized during the simulation:

a) Energized - The ambient temperature is used for T_0. However, if the components or material is enclosed in a confined space, a value representing the increase in temperature (typically 15°F) from outside to inside the enclosure is added to the external ambient temperature.

b) Deenergized - In order to adequately simulate the component internal temperature under energized conditions, a 50 percent stress factor is assumed as standard design practice employed when selecting components. A review of electronic components has indicated that a temperature of 60°C (140°F) is a good average value for T_0.

4.2 ACCELERATED THERMAL AGING PARAMETERS FOR NORMAL/ABNORMAL CONDITIONS

The accelerated thermal aging parameters vary significantly with the system or component to be aged. In general for systems that contain electronic components (transmitter, etc) and for the component aging program (Appendix B, Subprogram C) the conservative activation energy of 0.5 eV is used in the Arrhenius equation. The assumed ambient temperatures are determined by location and energized/deenergized test conditions e.g. 40°C (104°F) for transmitters which are powered during the aging process and 60°C (140°F) for components that are not powered.

Temperatures used for actual accelerated simulated thermal aging tests are selected based on component specifications and could range from 100°C (212°F) to 200°C (393°F). A system that contains a variety of components is typically aged at 125°C (257°F). If the limiting temperature cannot be determined, 130°C is generally used.

Based on the above data and the targeted qualified life, the thermal aging program was established. For example, to obtain a 10 year qualified life for a transmitter requires thermal aging at 125°C for 70 days assuming an activation energy of 0.5 eV. Figures D-3, D-4 and D-5 show accelerated aging factors for a variety of aging temperatures and activation energies for 40°C (104°F), 50°C (122°F) and 60°C (140°F) ambient temperatures.

The excursions to 120°F have a negligible additional aging effect on the equipment and are easily absorbed in the conservative aging simulation.

5.0 POST ACCIDENT THERMAL AGING

Table B-2 of Appendix B indentifies equipment which will be qualified to operate in a high energy line break (HELB) environment. In the majority of cases, some safety-related post-accident performance capability is specified by the functional requirements (Reference 1). As a consequence, in order to qualify this equipment to IEEE 323-1974, the effects of post-accident thermal aging must be simulated after the HELB test. This section establishes the accelerated thermal aging parameters employed in performing this simulation.

5.1 POST ACCIDENT OPERATING TEMPERATURES

Assuming continuous operation of containment safeguards systems post-accident the containment environment temperature would be reduced to the external ambient temperature well within 1 year for any postulated HELB. However, in order to allow for possible variations in plant operations post-accident, the design HELB envelopes presented in Figures 6-2 and 6-3 of WCAP 8587, repeated here as Figures D-6 and D-7, have been assumed to remain constant at 155°F between 4 months and 1 year. As indicated in Figures D-6 and D-7 the limiting design profile post-accident is therefore defined by the LOCA envelope starting at 24 hours.

For Westinghouse supplied safety-related equipment located inside containment either; the self-heating effects of the operating unit, under post-accident conditions, are insignificant compared to the heat input from the external environment (i.e., transmitters, RTD's, etc) or the unit is not in continuous operation during this phase (i.e., valve operators, etc). As a consequence, no specific temperature increment is added to account for self-heating of these devices post-accident. The LOCA profile reproduced here as Figure D-6 is therefore input as T_0 into the Arrhenius equation to calculate appropriate accelerated aging parameters for post-accident conditions.

5.2 ACCELERATED THERMAL AGING PARAMETERS FOR POST-ACCIDENT CONDITIONS

The aging temperature most often used by Westinghouse for post-accident simulation is 250°F. This temperature was selected as a maximum for electronic components and is generally used for all tests. Using this value and the conservative activation energy of 0.5 eV the Arrhenius equation can be applied to the curve in Figure D-8 from 24 hours to 4 months or to 1 year in small increments of time. The required aging times to simulate these small increments are then summed to yield a total test time of 15 days to simulate 4 months and 29 days to simulate 1 year post accident operation.

REFERENCES

1. "Equipment Qualification Data Packages," Supplement 1 to WCAP 8587.

2. "A Review of Equipment Aging Theory and Technology," EPRI NP-1558, Project 890-1, September 1980.

TABLE D-1 (1 of 3)

ACTIVATION ENERGIES FROM WESTINGHOUSE REPORTS

Material	Electron Volts
Melamine-Glass, G5	0.29
Epoxy B-725	0.48
Ester-Glass, GPO-3	0.57
RTV Silicone	0.60
Phenolic-Asbestos, A	0.61
Nylon 33% GF	0.70
Acetal	0.73
Mineral Phenolic	0.74
Silicone Varnish	0.74
Polypropylene	0.81
Polysulfone	0.83
Phenolic-Cotton, C	0.84
Formvar	0.85
Epoxy	0.88
Epoxy Adhes.	0.89
Nylon	0.90
Pressboard	0.91
Kapton	0.93
Silicone	0.94
Phenolic-Asbestos, A	0.94
Cast Epoxy	0.98
Urethane-Nylon	0.99
Phenolic-Glass, G-3	1.01
Polycarbonate	1.01
Phenolic-Paper, X	1.02
Epoxy Wire	1.05
Epoxy-Glass, FR-4	1.05
Varn. Cotton	1.06
PVC	1.08

TABLE D-1 (2 of 3)

ACTIVATION ENERGIES FROM WESTINGHOUSE REPORTS

Material	Electron Volts
Ester-Glass, GPO-1	1.09
Cell. Phenolic	1.10
X-Link Ethylene	1.11
Urethane	1.12
Ester-Glass, GPO-2	1.13
Ester-Nylon	1.14
Ester-Glass, GPO-1	1.16
32102BK Varn.	1.16
Vulc. Fiber	1.16
Cell. & Min. Phen.	1.17
Mylar	1.18
Cast Epoxy	1.18
32101EV Varn.	1.18
Epoxy	1.18
Silicone	1.18
Phenolic-Paper, XX	1.20
Vulc. Fiber	1.21
Cell. Phenolic	1.24
Phenolic-Glass, G-3	1.24
Kraft Phenolic	1.25
Neoprene	1.26
Amide-Imide Varn.	1.31
Loctite 75	1.38
Acetyl. Cotton	1.39
Silicone-Asbestos	1.41
Epoxy-Glass, FR-4	1.50
Mylar	1.58
Nomex	1.59
Omega Varn.	1.59
Epoxy-Glass, G-11	1.64

TABLE D-1 (3 of 3)

ACTIVATION ENERGIES FROM WESTINGHOUSE REPORTS

Material	Electron Volts
Polythermaleze	1.64
Kraft Paper	1.67
Valox 310SE-0	1.75
Varn. Kraft	1.86
Nomex	1.91
Ester-Glass, GPO-3	2.03
Phenolic-Cotton, C	2.12
Melamine-Glass, G-5	2.18

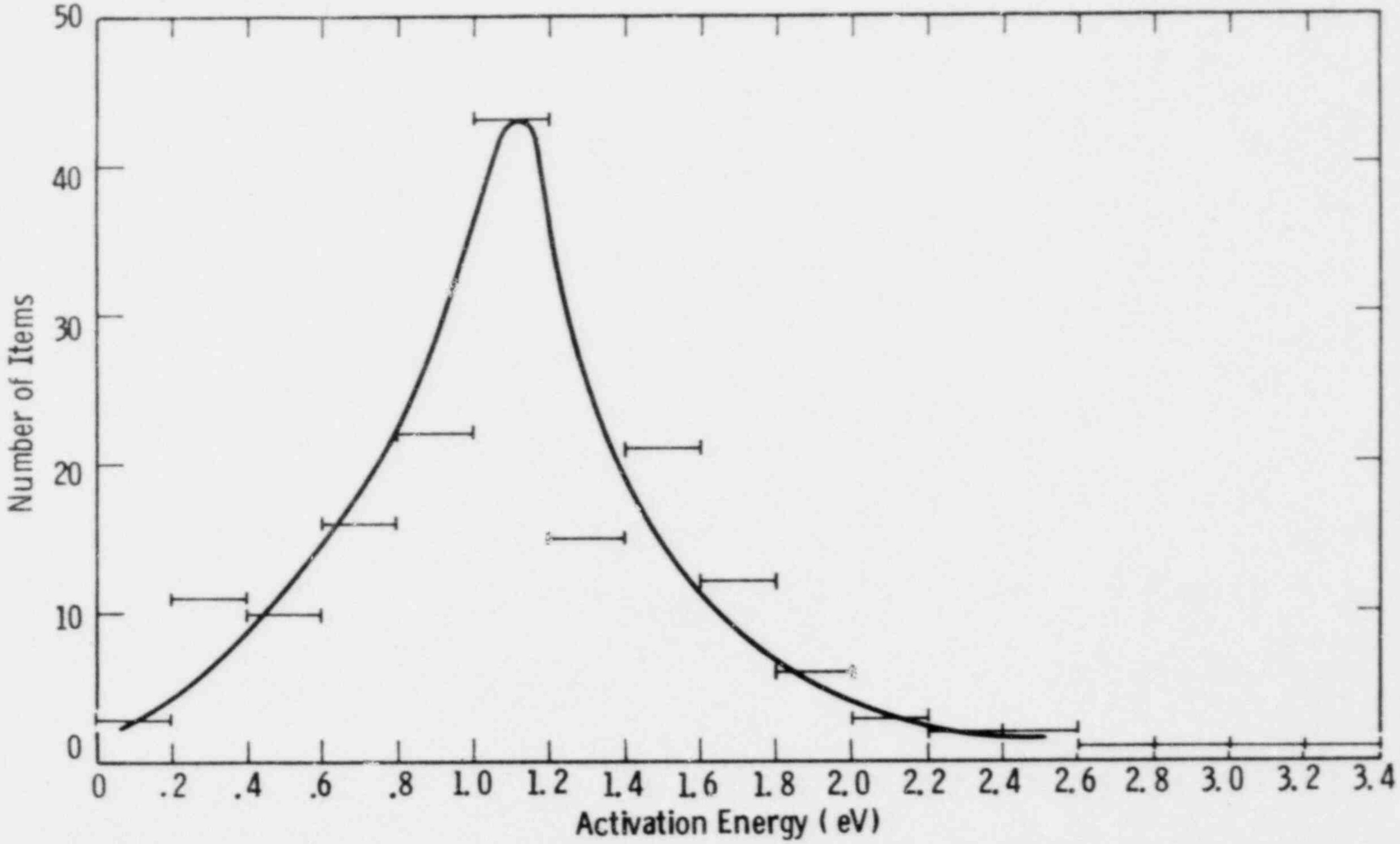

Figure D-1. Frequency Distribution of Activation Energies of Various Components/ Materials (EPRI Data)

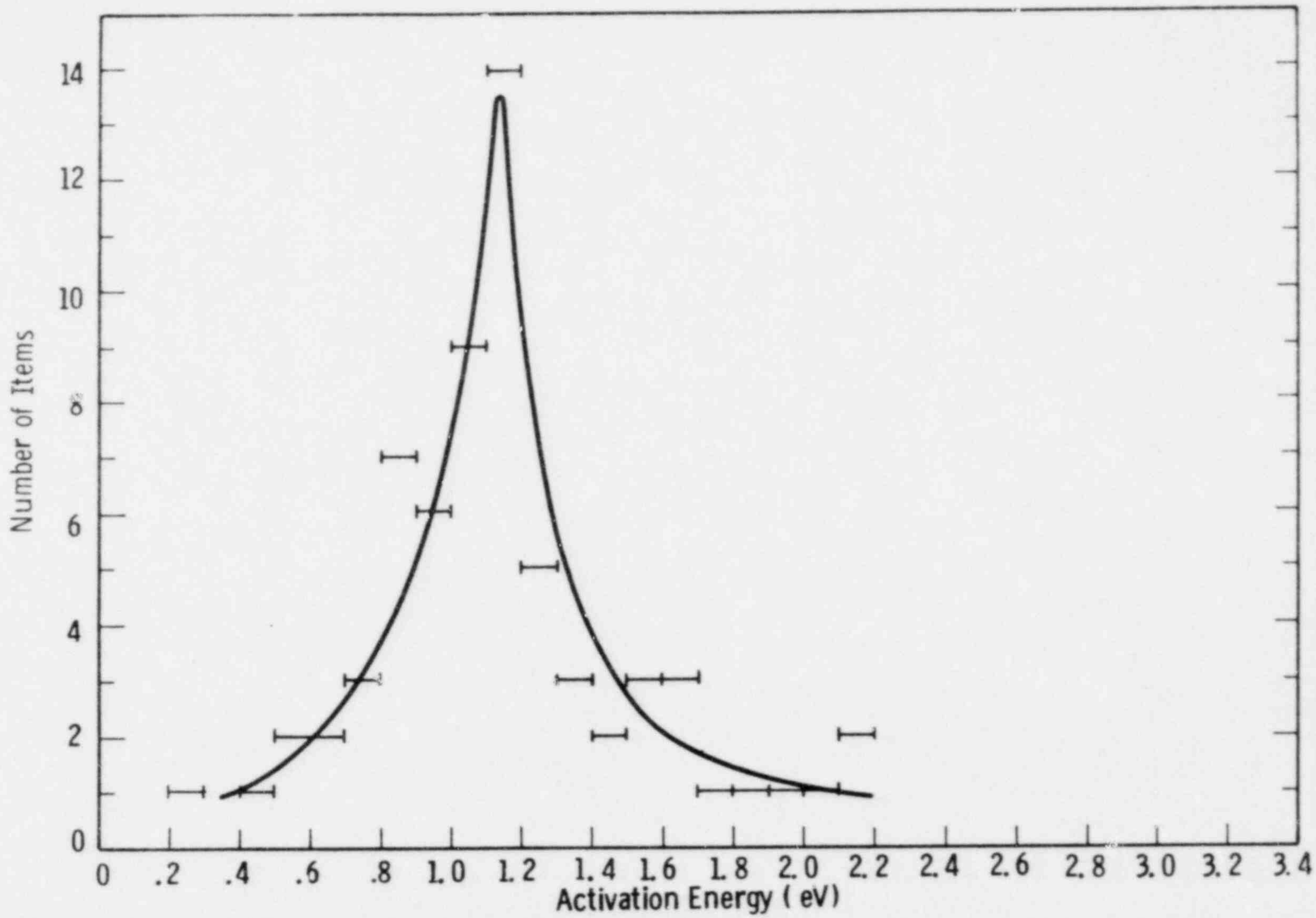

Figure D-2. Frequency Distribution of Activation Energies of Various Materials (Westinghouse Data)

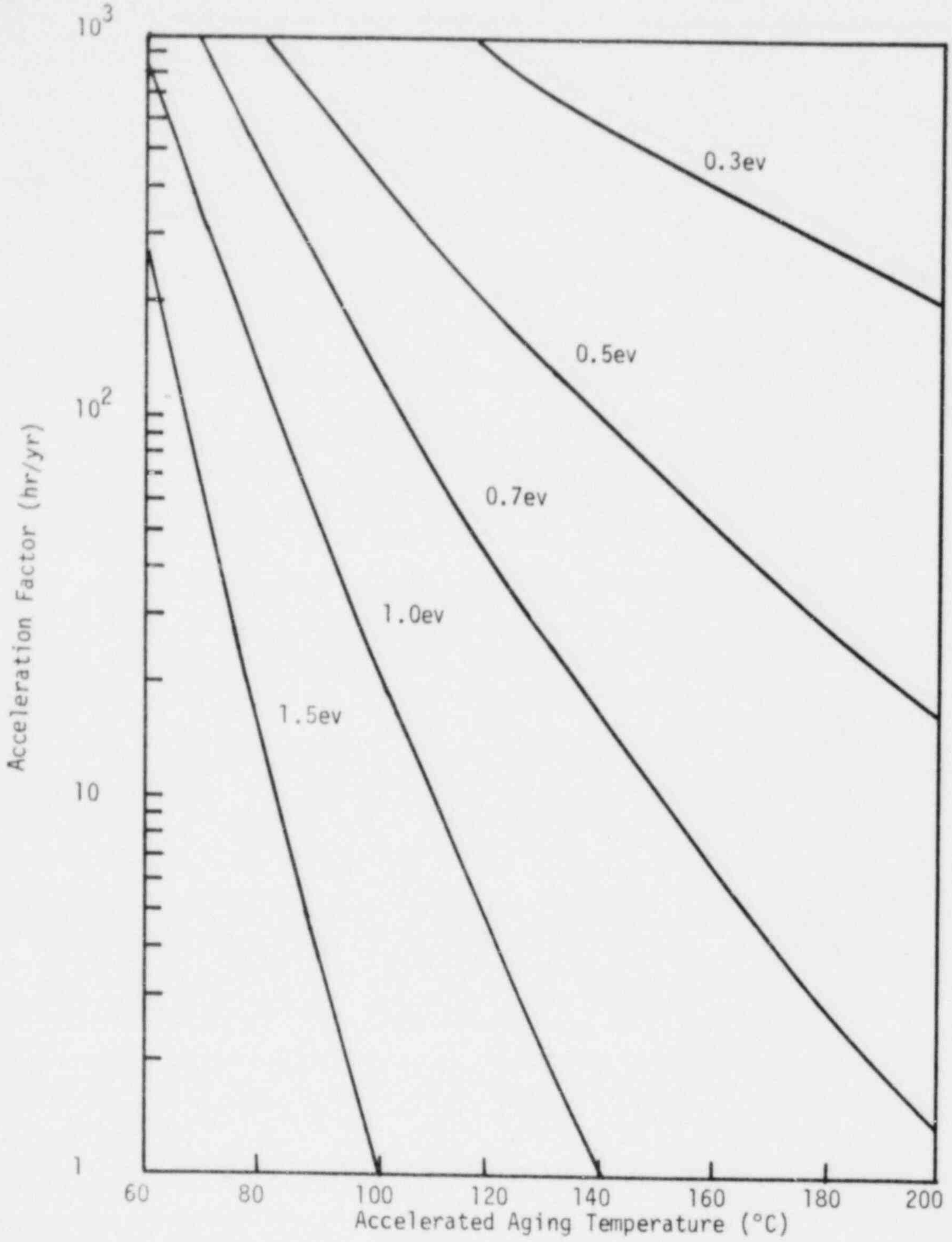

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Figure D-3. Acceleration Factor vs Acceleration Aging Temperature Material Ambient Temperature 40°C 5

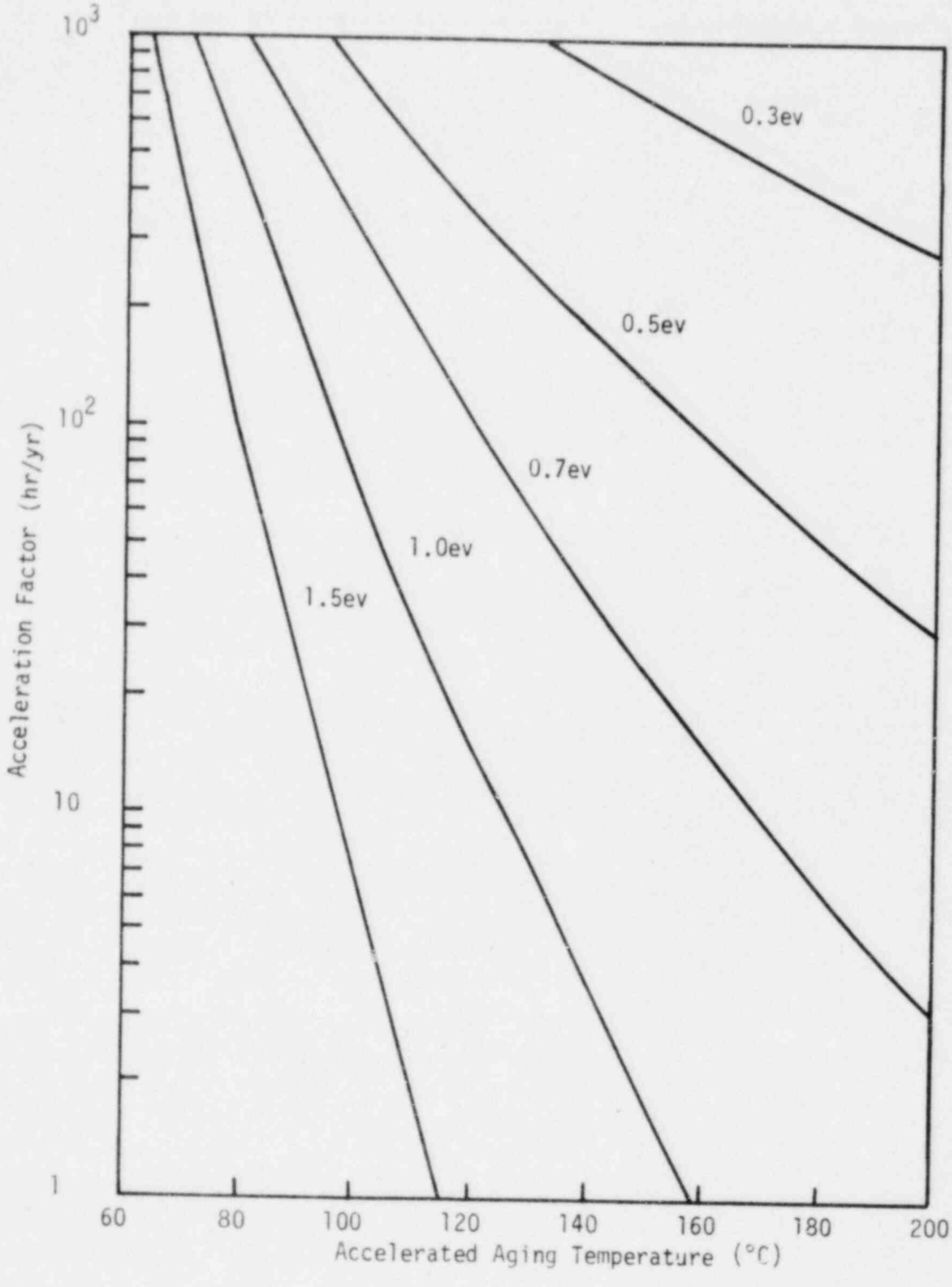


Figure D-4. Acceleration Factor vs Acceleration Aging Temperature Material Ambient Temperature 50°C 5

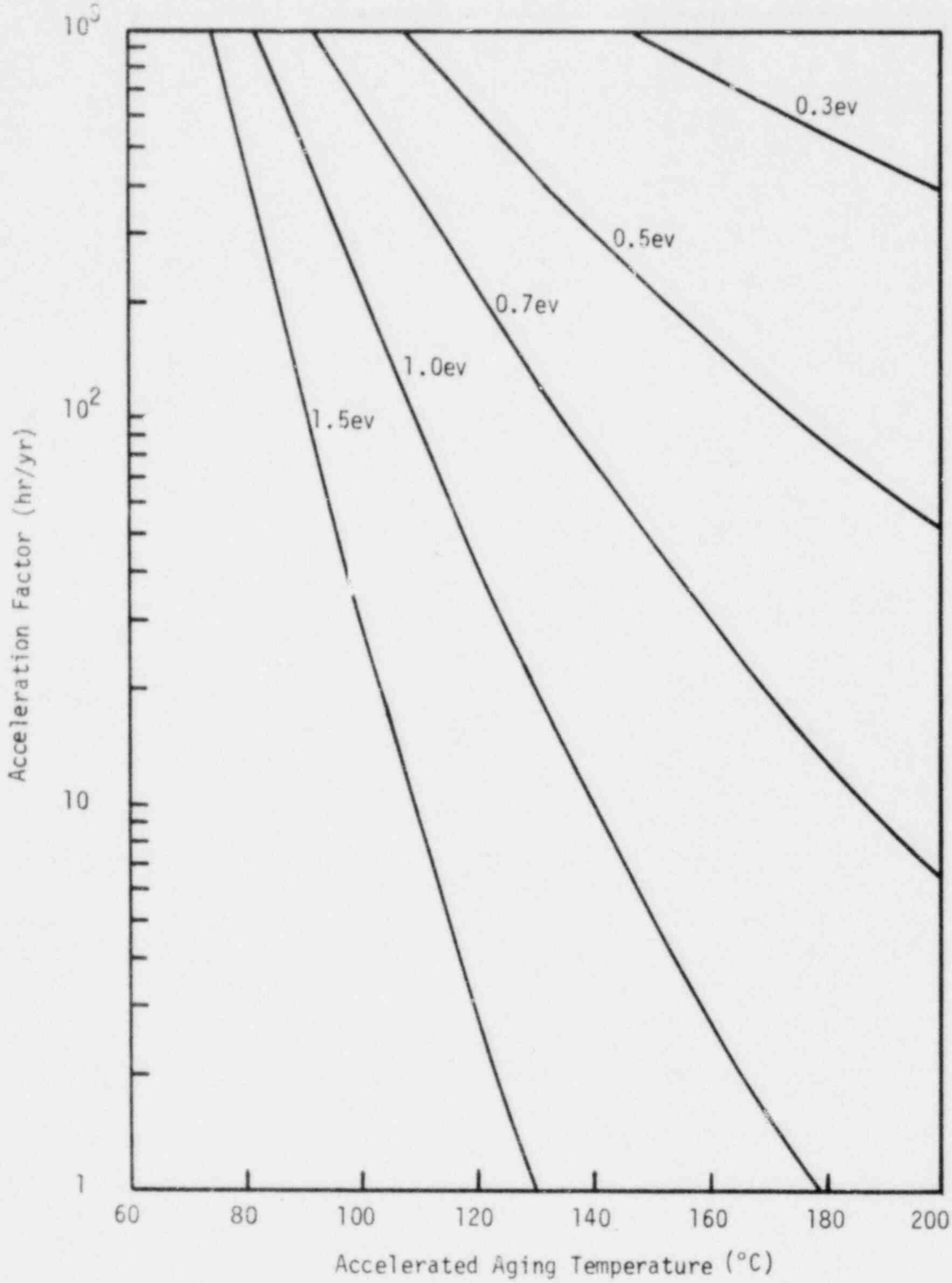
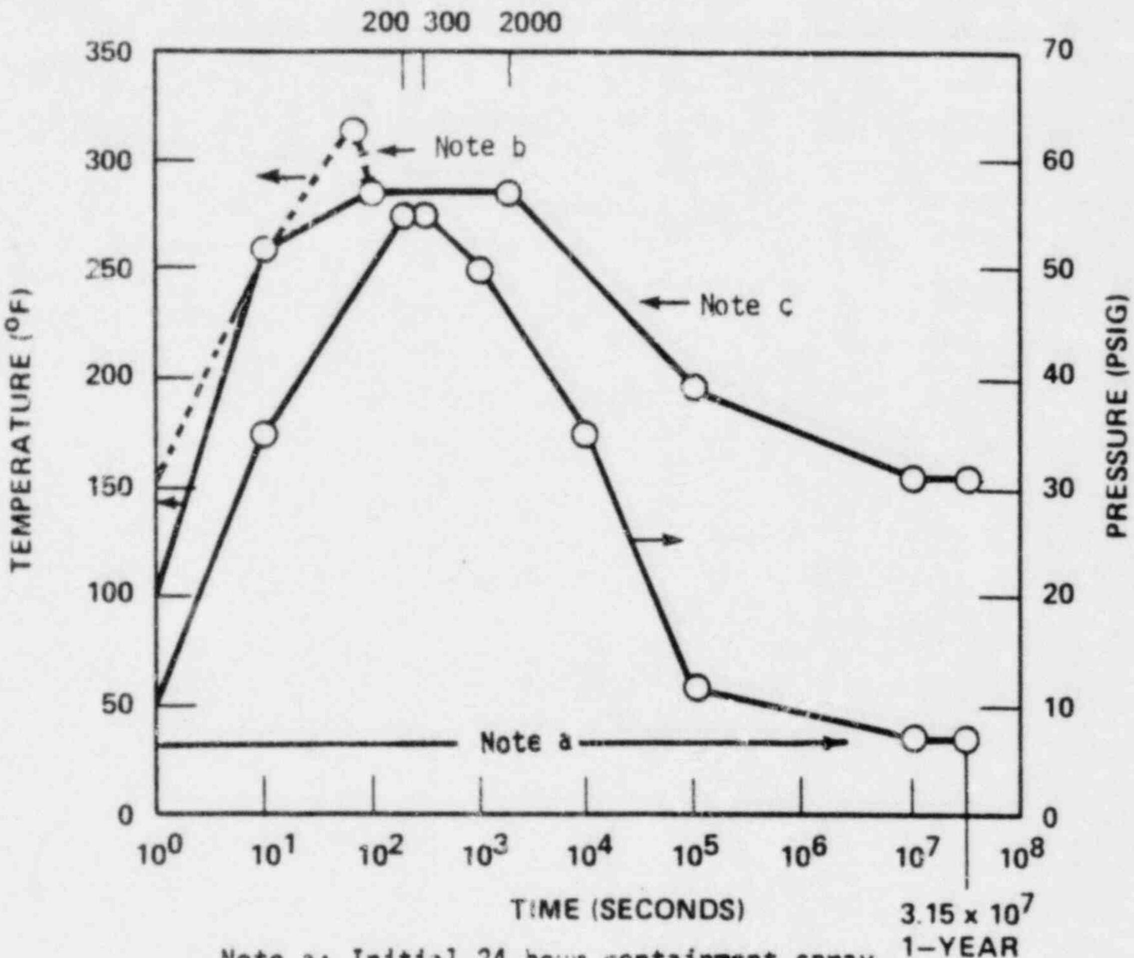


Figure D-5. Acceleration Factor vs Acceleration Aging Temperature Material Ambient Temperature 60°C 5

5



Note a: Initial 24 hour containment spray solution of 2500 ppm boron with 0.24% NaOH

Note b: Represents plants whose analysis predicts super heated conditions

Note c: Represents plants whose analysis does not predict super heated conditions

Figure D-6. Containment Environmental Design Conditions - LOCA

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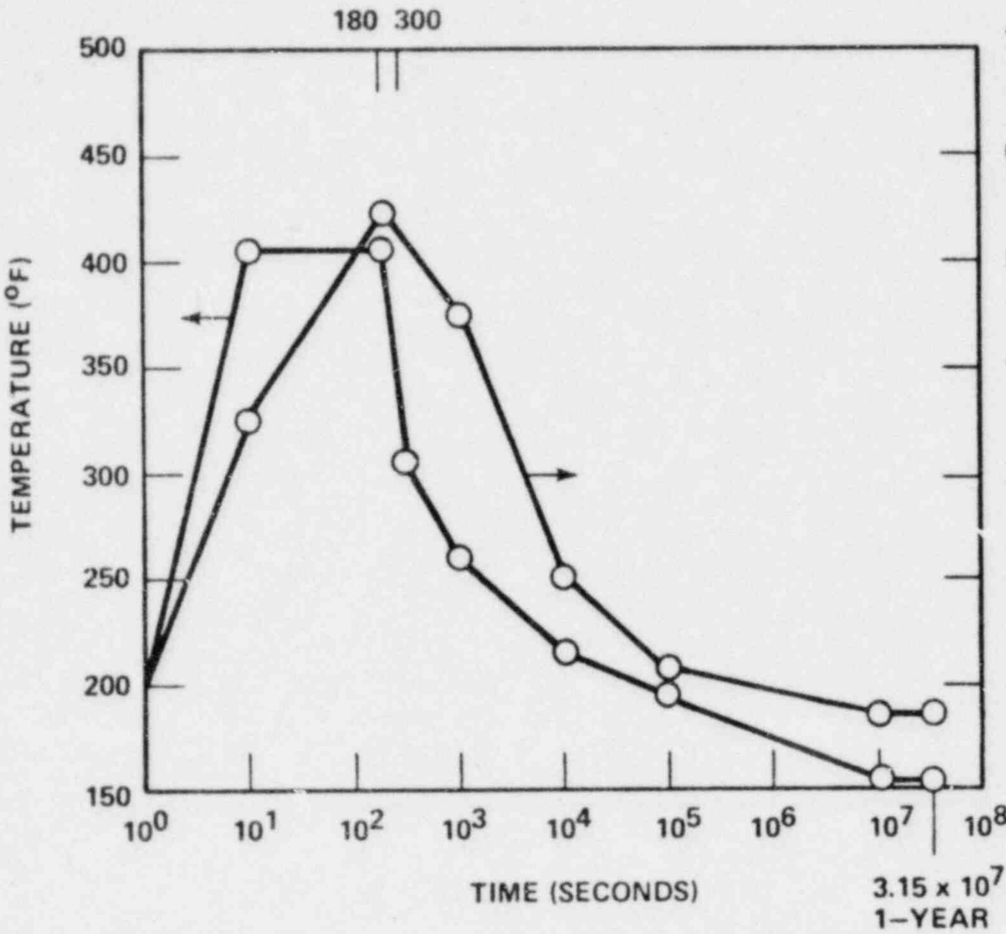

Figure D-7. Containment Environmental Design Conditions - Main Steam Line Break and Feedline Break

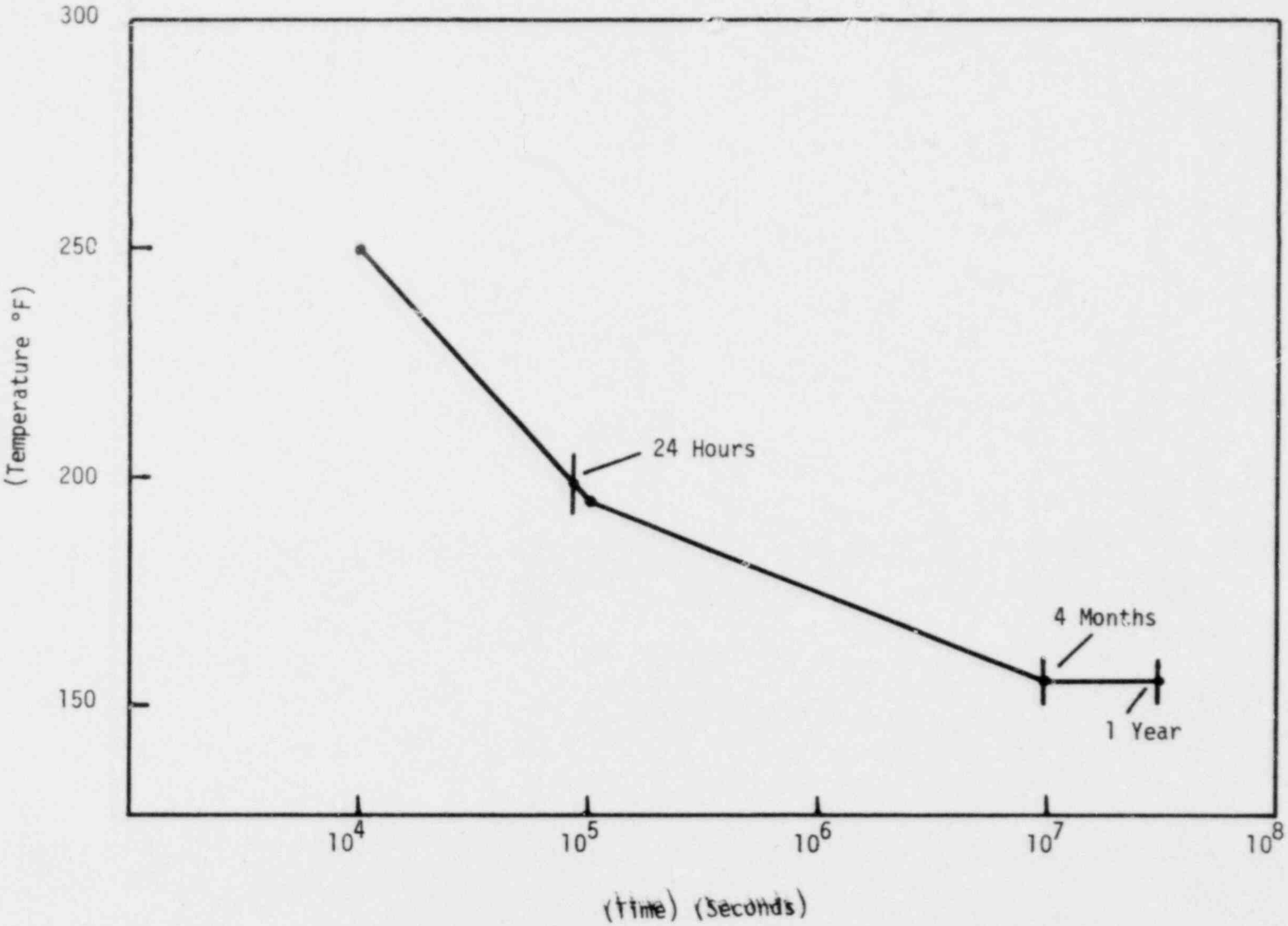

Figure D-8. Post-Accident Temperature Profile