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Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment

Office of Nuclear
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Commission

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ABSTRACT

This document provides the NRC staff positions regarding selected areas of environmental qualification of safety-related electrical equipment. The positions herein are applicable to plants that are or will be in the construction permit (CP) or operating license (OL) review process and that are required to satisfy the requirements set forth in either the 1971 or the 1974 version of IEEE-323 standard. These positions were developed prior to the Three Mile Island Unit 2 event. Any recommendations resulting from the ~~event~~ ~~pending~~ staff's ~~completion of the~~ review of that event, will be provided ~~in a~~ later ~~supplemental report~~. The seismic qualification requirements are addressed elsewere and are not included in the scope of this document.

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INTERIM STAFF POSITION ON ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED ELECTRICAL EQUIPMENT

INTRODUCTION

Equipment that is used to perform a necessary safety function must be capable of maintaining functional operability under all service conditions ~~expected~~ postulated to occur during the installed life for the time it is required to operate. This requirement, which is embodied in General Design Criteria 1, 2, 4 and 23 of Appendix A and Sections III and XI of Appendix B to 10 CFR Part 50, is applicable to equipment located inside as well as outside containment. More detailed guidance related to the methods, procedures and guidelines for demonstrating this capability has been set forth by industry in IEEE Std. ~~323~~ 323 and ancillary standards (e.g., IEEE Stds. 317, 334, 382, 383) and has been endorsed, as noted in Regulatory Guides, by the NRC.

Pursuant to ~~the Standard Review Plan (Section 3.11) and~~ Regulatory Guide 1.89, the staff requires that, for plants for which a construction permit (CP) safety evaluation report (SER) was issued after July 1, 1974, ~~the methodology developed to qualify the~~ safety-related equipment should be qualified in accordance with ~~conform~~ to the requirements of ~~as described in~~ IEEE Std. 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," ~~and that this standard be used as a guide in evaluating these qualification programs. For those construction permit applications for which an SER was issued prior to July 1, 1974, the staff may, subsequent to issuance of the construction permit or operating license (OL), have allowed the Safety Analysis Report of a user to~~

basis to assure that these methods have been specified in purchase orders for safety-related equipment dated on or after November 15, 1974.

For plants for which a construction permit SER was issued prior to July 1, 1974, and whose equipment purchase orders were executed prior to November 15, 1974, the staff requires that the qualification programs for safety-related equipment be developed and evaluated on the basis for conformance to the requirements established in IEEE Std. 323-1971, "IEEE Trial-Use Standard: General Guide for Qualifying Class 1E Electric Equipment for Nuclear Power Generating Stations." This requirement has been applied on a case-by-case basis, ~~to~~ on the older plants that have been and are currently undergoing ~~a CP or~~ an OL review.

As part of the operating license review for each plant, the staff evaluates the applicant's equipment qualification program by reviewing the qualification documentation on selected safety-related equipment. The objective of this review is to provide reasonable assurance that the equipment can perform its intended function in the most limiting environment in which it is expected to function.

The staff review of the documentation submitted by both equipment suppliers and license applicants indicate that some have developed generally acceptable qualification programs. The efforts of others, as compared with the "state of the art," need improvements. This is due in part to the fact that the qualification requirements contained in industry standards and other guidance related to equipment qualification have been evolutionary in nature and subject to diverse interpretation.

To promote more orderly and systematic implementation of equipment qualification programs in industry and to provide guidance ~~within~~ the NRC staff ~~for use~~ in the ongoing licensing reviews, the staff has developed a number of positions on selected areas of the qualification issue ~~that~~ are presented in this report. These positions provide guidance on the establishment of service conditions, methods for qualifying equipment, and other related matters. They do not address in detail all areas of qualification, since certain areas are not yet well understood and are the subjects of research studies conducted by the NRC and by the industry. For example, the effects of aging, sequential versus synergistic testing, and the potential combustible gas and chloride formation in equipment containing organic materials are being evaluated. It is expected that these studies will lead to the development of more detailed guidance in the future, and may require changes to these positions.

These positions ~~have been~~ developed prior to the staff completion of the TMI-2 event evaluation, and any additional requirements or modifications to these positions as a result of ~~the events~~ will be identified ~~in a supplemental report.~~ Seismic qualification~~, which~~ is being pursued ~~generically, and~~ on a case-by-case basis by the Seismic Qualification Review Team (SQRT) is ~~also~~ outside the scope of this document.

These positions are applicable only to plants that are or will be in the construction permit or operating license review process ~~that are required to satisfy the requirements set forth in either the 1971 or 1974 version of the IEEE 323 Standard.~~ These positions do not apply to operating plants. Operating plant licensees have been required by the NRC Office of Inspection and Enforcement to reassess the qualification of safety-related equipment used in those facilities (see IE Bulletin 79-01). Licensee responses are to be evaluated using criteria being developed specifically for that effort.

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INTERIM STAFF POSITION ON ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED ~~EQUIPMENT~~ ELECTRICAL EQUIPMENT

CATEGORY I	CATEGORY II
Applicable to equipment qualified in accordance with IEEE-323-1971	*Applicable to equipment qualified in accordance with IEEE-323-[illegible]*
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
1. <u>ESTABLISHMENT OF THE QUALIFICATION PARAMETERS FOR DESIGN BASIS EVENTS</u>	1. <u>ESTABLISHMENT OF THE QUALIFICATION PARAMETERS FOR DESIGN BASIS EVENTS</u>
1.1 <u>Temperature and Pressure Conditions Inside Containment - Loss-of-Coolant Accident (LOCA)</u>	1.1 <u>Temperature and Pressure Conditions Inside Containment - Loss-of-Coolant Accident (LOCA)</u>
(1) The *time dependent* temperature and pressure ~~as a function of time~~ established for the design of the containment structure and found acceptable by the staff, may be used for environmental qualification of equipment.	(1) Same as Category I.
(2) Acceptable methods for calculating and establishing the containment pressure and temperature envelopes to which equipment should be qualified are summarized below. Acceptable methods for calculating mass and energy release rates are summarized in Appendix A.	(2) Same as Category I.
<u>Pressurized Water Reactors (PWRs)</u>	<u>Pressurized Water Reactors</u>
<u>Dry Containment</u> - Calculate LOCA containment environment using CONTEMPT-LT or equivalent industry codes. Additional guidance is provided in Standard Review Plan (SRP) Section 6.2.1.1.A, NUREG-75/087.	<u>Dry Containment</u> - Use the same containment models as in Category I. The assumption of partial revaporization will be allowed. Other assumptions that reduce the temperature response of the containment will be evaluated on a case-by-case basis.
<u>Ice Condenser Containment</u> - Calculate LOCA containment environment using LOTIC or equivalent industry codes. Additional guidance is provided in SRP Section 6.2.1.1.B, NUREG-75/087.	<u>Ice Condenser Containment</u> - Same as Category I.
<u>Boiling Water Reactors (BWRs)</u>	<u>Boiling Water Reactors</u>
<u>Mark I, II and III Containment</u> - Calculate LOCA environment using methods of GESSAR Appendix 3B or equivalent industry codes. Additional guidance is provided in SRP Section 6.2.1.1.C, NUREG-75/087.	Same as Category I.
(3) In lieu of using the plant-specific containment temperature and pressure design profiles for BWR and ice condenser types of plants, the generic envelope shown in Appendix C may be used for qualification testing.	(3) Same as Category I.

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
(4) The test profiles included in Appendix A to IEEE Std. 323-1974 should not be considered an acceptable alternative in lieu of using plant-specific containment temperature and pressure design profiles unless plant-specific analysis is provided to verify the adequacy of those profiles.	(4) Same as Category I.
1.2 <u>Temperature and Pressure Conditions Inside Containment - Main Steam Line Break (MSLB)</u>	1.2 <u>Temperature and Pressure Conditions Inside Containment - Main Steam Line Break (MSLB)</u>
(1) The environmental parameters used for equipment qualification should be calculated with a plant-specific model reviewed and approved by the staff.	(1) Where qualification has not been completed ~~or has been completed with consideration for MSLB conditions,~~ the environmental parameters used for equipment qualification should be calculated using a plant-specific model based on the staff-approved assumptions discussed in item 1 of Appendix B.
(2) Models that are acceptable for calculating containment parameters are listed in Section 1.1(2).	(2) Other models that are acceptable for calculating containment parameters are listed in Section 1.1(2).
(3) In lieu of using the plant-specific containment temperature and pressure design profiles for BWR and ice condenser ~~[illegible]~~ plants, the generic envelope shown in Appendix C may be used ~~for qualification testing~~.	(3) Same as Category I.
(4) The test profiles included in Appendix A to IEEE Std. 323-1974 should not be considered an acceptable alternative in lieu of using plant-specific containment temperature and pressure design profiles unless plant-specific analysis is provided to verify the adequacy of those profiles.	(4) Same as Category I.
(5) Where qualification has been completed but only LOCA conditions were considered, it must be demonstrated that the LOCA qualification conditions exceed or are equivalent to the maximum calculated MSLB conditions. The following technique is acceptable:	(5) Where qualification has been completed but only LOCA conditions were considered, ~~then~~ it must be demonstrated that the LOCA qualification conditions exceed or are equivalent to the maximum calculated MSLB conditions. The following technique is acceptable:
(a) Calculate the peak temperature envelope from an MSLB using a model based on the staff's approved assumptions defined in Section 1.1(2).	(a) Calculate the peak temperature from an MSLB using a model based on the staff's approved assumptions discussed in item 1 of Appendix B.
(b) Show that the peak surface temperature of the component to be qualified does not exceed the LOCA qualification temperature by the method discussed in item 2 of Appendix B.	(b) Same as Category I Section 1.2(5)(b).

CATEGORY I Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	CATEGORY II Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
(c) If the calculated surface temperature exceeds the ~~actual~~ qualification temperature, the staff requires that (i) requalification testing be performed with appropriate margins, or (ii) qualified physical protection be provided to assure that the surface temperature will not exceed the actual qualification temperature. For plants that are currently being reviewed, or will be submitted for an operating license review within six months from issue date of this report, ~~where~~ compliance with items (i) or (ii) above represents a substantial impact, the staff will consider additional ~~qualification~~ submitted by the applicant ~~of their equipment adequacy in some defined basis.~~	(c) If the calculated surface temperature exceeds the ~~actual~~ qualification temperature, the staff requires that (i) additional justification be provided to demonstrate that the ~~component~~ can maintain its required functional operability ~~in the environments associated with the calculated peak~~ surface temperature, or (ii) requalification testing be performed with appropriate margins, or (iii) qualified physical protection be provided to assure that the surface temperature will not exceed the actual qualification temperature.
1.3 Effects of Chemical Spray The effects of caustic spray should be addressed for the equipment qualification. The concentration of caustics used for qualification should be equivalent to or more severe than those used in the plant containment spray system. If the chemical composition of the caustic spray can be affected by equipment malfunctions, the most severe caustic spray environment that results from a single failure in the spray system should be assumed. See SRP Section 6.5.2 (NUREG-75/0879), paragraph II, item (e) for caustic spray solution guidelines.	1.3 Effects of Chemical Spray Same as Category I.
1.4 Radiation Conditions Inside and Outside Containment The radiation environment for qualification of equipment should be based on the normally expected radiation environment over the equipment qualified life, plus that associated with the most severe design basis accident (DBA) during or following which that equipment must remain functional. It should be assumed that the DBA related environmental conditions occur at the end of the equipment qualified life. The sample calculations in Appendix D and the following positions provide an acceptable approach for establishing radiation limits for qualification. Additional radiation margins identified in Section 6.3.1.5 of IEEE Std. 323-1974 for qualification type testing are not required if these methods are used.	1.4 Radiation Conditions Inside and Outside Containment Same as Category I.

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
(1) The source term to be used in determining the radiation environment associated with the design basis LOCA should be taken as an instantaneous release from the fuel to the atmosphere of 100 percent of the noble gases, 50 percent of the iodines, and 1 percent of the remaining fission products. For all other non-LOCA design basis accident conditions, a source term involving an instantaneous release from the fuel to the atmosphere of 10 percent of the noble gases (except Kr-85 for which a release of 30 percent should be assumed) and 10 percent of the iodines is acceptable. (2) The calculation of the radiation environment associated with design basis accidents should take into account the time-dependent transport of released fission products within various regions of containment and auxiliary structures. (3) The initial distribution of activity within the containment should be based on a mechanistically rational assumption. Hence, for compartmented containments, such as in a BWR, a large portion of the source should be assumed to be initially contained in the drywell. The assumption of uniform distribution of activity throughout the containment at time zero is not appropriate. (4) Effects of ESF systems, such as containment sprays and containment ventilation and filtration systems, which act to remove airborne activity and redistribute activity within containment, should be calculated using the same assumptions used in the calculation of offsite dose. See SRP Section 15.6.5 (NUREG-75/087) and the related ~~SRPs~~ referenced in the Appendices to that section. (5) Natural deposition (i.e., plate-out) of airborne activity should be ~~calculated~~ determined using a mechanistic model and best estimates for the model parameters. The assumption of 50 percent instantaneous plate-out of the iodine released from the core should not be made. Removal of iodine from surfaces by steam condensate flow or washoff by the containment spray may be assumed if such effects can be justified and quantified by analysis or experiment.	

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974

(5) The radiation environment should be based on factors such as the location and concentration of radioactive material, local and structural shielding, attenuation in air, water, and encapsulating materials (such as sheathing of cables).

6 For unshielded equipment located in the containment, the gamma dose and dose rate should be equal to the dose and dose rate at the centerpoint of the containment unless it can be shown by analyses that location and shielding of the equipment reduces the dose and dose rate.

7 For unshielded equipment, the beta doses at the surface of the equipment should be the sum of the airborne and plate-out sources. The airborne beta dose should be taken as the beta dose calculated for a point at the containment center.

8 Shielded components need be qualified only to the gamma radiation levels required, provided an analysis or test shows that the sensitive portions of the component or equipment are not exposed to beta radiation or that the effects of beta radiation heating and ionization have no deleterious effects on component performance.

9 ~~[illegible]~~ Cables arranged in cable trays in the containment should be assumed to be exposed to half the beta radiation ~~environment~~ calculated for a point at the center of the containment plus the gamma ray ~~environment~~ calculated in accordance with Section 1.4(7). This reduction in beta dose is allowed because of the localized shielding by other cables plus the cable tray itself.

10 Paints and coatings should be assumed to be exposed to both beta and gamma rays in assessing their resistance to radiation. Plate-out activity should be assumed to remain on the equipment surface unless the effects of the removal mechanisms, such as spray wash-off or steam condensate flow, can be justified and quantified by analysis or experiment.

Components of the emergency core cooling system (ECCS) located outside containment (e.g., pumps, valves, seals and electrical equipment) should be qualified to withstand the radiation

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974

equivalent to that penetrating the containment, plus the exposure from the sump fluid using assumptions consistent with the requirements stated in Appendix K to 10 CFR Part 50.

(13) Equipment that may be exposed to radiation doses below 10^4 rads should not be considered to be exempt from radiation qualification, unless analysis supported by test data is provided to verify that these levels will not degrade the operability of the equipment below acceptable values.

(14) The staff will accept a given component to be qualified provided ~~the applicant~~ can ~~show~~ be shown that the component has been qualified to integrated beta and gamma doses which are equal to or higher than those levels resulting from an analysis similar in nature and scope to that included in Appendix D (which uses the source term given in item (1) above), and that the component incorporates appropriate factors pertinent to the plant design and operating characteristics, as given in these general guidelines.

(15) When a conservative analysis has not been provided by the applicant for staff review, the staff will use the radiation environment estimates contained in Appendix D, suitably corrected for the differences in reactor power level, type, containment size, and other appropriate factors.

1.3 <u>Environmental Conditions for Outside Containment</u>

(1) Equipment located in general plant areas outside containment where equipment is not subjected to a design basis accident environment should be qualified to the normal and abnormal range of environmental conditions ~~expected~~ to occur at the ~~postulated~~ location.

(2) Equipment not served by Class IE environmental support systems, or served by Class IE support systems that may be secured during plant operation or shutdown, should be qualified to the limiting environmental conditions that are ~~expected to occur in~~ that location, assuming a loss of the environmental support system.

Category II:

1.3 <u>Environmental Conditions for Outside Containment</u>

(1) Same as Category I.

(2) Same as Category I, or, there may be designs where a loss of the environmental support system may expose some equipment to environments that exceed the qualified limits. For these designs, appropriate monitoring devices should be provided to alert the operator that abnormal conditions exist and to permit an assessment of the conditions that occurred in order to determine if corrective action, such as replacing any affected equipment, is warranted.

CATEGORY I

Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974

(2) Equipment located outside containment that could be subjected to high-energy pipe breaks should be qualified to ~~meet~~ the conditions resulting from the accident for the duration required. The techniques to calculate the environmental parameters described in Sections 1.1 through 1.4 above should be applied.

2. QUALIFICATION METHODS

2.1 Selection of Methods

(1) Qualification methods should conform to the requirements defined in IEEE Std. 323-1974.

(2) The choice of the methods selected is largely a matter of technical judgment and availability of information that supports the conclusions reached. Experience has shown that qualification of equipment subjected to an accident environment without test data is not adequate to demonstrate functional operability. In general, the staff will not accept analysis in lieu of test data unless (a) testing of the component is impractical due to size limitations, and (b) partial type test data is provided to support the analytical assumptions and conclusions reached.

(3) The environmental qualification of equipment exposed to DBA environments should conform to the following positions: The bases should be provided for the time interval required for operability of this equipment. The operability criteria should be specified and the safety margins defined.

(a) Equipment that must function in order to mitigate any accident should be qualified by test to demonstrate its operability for the time required in the environmental conditions resulting from that accident.

(b) Any equipment (safety-related or nonsafety-related) that need not function in order to mitigate any accident, but that must not fail in a manner detrimental to plant safety ~~or accident mitigation requirements~~ should be qualified by test to demonstrate its capability to withstand any accident environment for the time during which it must not fail.

CATEGORY II

Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974

(3) Equipment located outside containment that could be subjected to high-energy pipe breaks should be qualified to ~~meet~~ the conditions resulting from the accident for the duration required. The techniques to calculate the environmental parameters described in Sections 1.1 through 1.4 above should be applied.

2. QUALIFICATION METHODS

2.1 Selection of Methods

(1) Qualification methods should conform to the requirements defined in IEEE Std. 323-1971.

(2) Same as Category I.

(3) Same as Category I.

CATEGORY I Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	CATEGORY II Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
(c) Equipment that need not function in order to mitigate any accident and whose failure in any mode in any accident environment is not detrimental to plant safety need only be qualified for its non-accident service environment. Although actual type testing is preferred, other methods when justified may be found acceptable. The bases should be provided for concluding that such equipment is not required to function in order to mitigate any accident, and that its failure in any mode in any accident environment is not detrimental to plant safety ~~(or accident mitigation)~~.	
(4) For environmental qualification of equipment subject to events other than a DBA, which result in abnormal environmental conditions, actual type testing is preferred. However, analysis or operating history, or any applicable combination thereof, coupled with partial type test may be found acceptable, subject to the applicability and detail of information provided.	(4) Same as Category I.
2.2 Qualification by Test	2.2 Qualification by Test
(1) Test results should demonstrate that the equipment can perform its required function for all service conditions ~~expected~~ (with margin) during its installed life.	(1) Same as Category I.
(2) The items described in Section 6.3 of IEEE Std. 323-1974 supplemented by items (3) through ~~(10)~~ below constitute acceptable guidelines for establishing test procedures.	(2) The items described in Section 5.2 of IEEE Std. 323-1971 supplemented by items (3) through ~~(10)~~ below constitute acceptable guidelines for establishing test procedures.
(3) When establishing the simulated environmental profile for qualifying equipment located inside containment, it is preferred that a single profile be used that envelopes the environmental conditions resulting from any design basis event during any mode of plant operation (e.g., a profile that envelopes the conditions produced by the main steamline break and loss-of-coolant accidents).	(3) Same as Category I.
(4) Equipment should be located above flood level or protected against submergence by locating the equipment in qualified watertight enclosures. Where equipment is located in watertight enclosures, qualification by test or analysis should	(4) Same as Category I.

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
be used to demonstrate the adequacy of such protection. Where equipment could be submerged, it should be identified and demonstrated to be qualified by test for the duration required.	
(5) The temperature to which equipment is qualified, when exposed to the simulated ~~test~~ environment, should be defined by thermocouple readings on or as close as practical to the surface of the component being qualified.	(5) Same as Category I. If thermocouples ~~(at or as close as practical to the~~ ~~component) were not used~~ during the tests, heat transfer analysis should be used to determine the ~~actual~~ temperature ~~environment~~ at the component. (Acceptable heat transfer analysis methods are provided in Appendix B.)
(6) Performance characteristics of equipment should be verified before, after, and periodically during testing throughout its range of required operability.	(6) Same as Category I.
(7) Caustic spray should be incorporated during simulated ~~LOCA~~ testing.	(7) Same as Category I.
(8) The operability status of equipment should be monitored continuously during testing. For long-term testing, however, monitoring at discrete intervals should be justified if used.	(8) Same as Category I.
(9) Expected extremes in power supply voltage range and frequency should be applied during simulated event environmental testing.	(9) Same as Category I.
(10) Dust environments should be addressed when establishing qualification service conditions.	(10) Same as Category I.
(11) Cobalt-60 is an acceptable gamma radiation source for environmental qualification.	(11) Same as Category I.
2.3 Test Sequence	2.3 Test Sequence
(1) The test sequence should conform fully to the guidelines established in Section 6.3.2 of IEEE Std. 323-1974. The test procedures should insure that the same piece of equipment is used throughout the test sequence, and that the test simulates as closely as practicable the ~~expected steam~~ environment.	(1) Justification of the adequacy of the test sequence selected should be provided.
	(2) The test should as closely as practicable the ~~expected~~ environment.
	(3) The test procedures should conform to the guidelines described in Section 6 of IEEE Std. 323-1971.

CATEGORY I

Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974

2.4 Other Qualification Methods

Qualification by analysis or operating experience implemented as described in IEEE Std. 323-1974 and other ancillary standards, may be found acceptable. The adequacy of these methods will be evaluated on the basis of the quality and detail of the information submitted in support of the assumptions made and the specific function and location of the equipment. These methods are most suitable for equipment where testing is precluded by physical size of the equipment being qualified. It is required that, when these methods are employed, some partial type tests on vital components of the equipment be provided in support of these methods.

3. MARGINS

(1) Quantified margins should be applied to the design parameters discussed in Section 1) to assure that these parameters have been enveloped during testing. These margins should be applied in addition to any margins (conservatism) applied during the derivation of the specified plant parameters.

(2) In lieu of other proposed margins that may be found acceptable, the suggested values indicated in IEEE Std. 323-1974, Section 6.3.1.5, should be used as a guide. (Note exceptions stated in Section 1.4.)

(3) When the qualification envelope in Appendix C is used, the only required margins are those accounting for the inaccuracies in the test equipment. Sufficient conservatism has already been [illegible] to

CATEGORY II

Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974

(4) The suggested sequence described in the 1974 revision of the standard is considered a severe sequence for equipment inside containment and may be used in lieu of others proposed and found acceptable.

The staff considers that, for vital electrical equipment such as penetrations, connectors, cables, valves and motors, and transmitters located inside containment or exposed to hostile steam environments outside containment, separate effects testing for the most part is not an acceptable qualification method. The testing of such equipment should be conducted in a manner that subjects the same piece of equipment to radiation and the hostile steam environment sequentially.

2.4 Other Qualification Methods

Same as Category I (except that IEEE Std. 323-1971 and ancillary standards endorsed at the time the CP SER was issued may be used).

3. MARGINS

(1) Same as Category I.

(2) The margins provided in the design will be evaluated on a case-by-case basis. Factors that should be considered in quantifying margins are (a) the environmental stress levels induced during testing, (b) the duration of the stress level, (c) the number of items tested and the number of tests performed in the hostile environment, (d) the performance characteristics of the equipment while subjected to the environmental stresses, and (e) the specified function of the equipment.

(3) Same as Category I.

CATEGORY I Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	CATEGORY II Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
account for uncertainties such as production errors and errors associated with defining satisfactory performance (e.g., when only a small number of units are tested).	
(4) Some equipment may be required by the design to only perform its safety function within a short time period into the event (i.e., within seconds or minutes), and, once its function is complete, subsequent failures are shown not to be detrimental to plant safety. Other equipment may not be required to perform a safety function but must not fail within a short time period into the event, and subsequent failures are also shown not to be detrimental to plant safety. Equipment in these categories is required to remain functional in the accident environment for a period of at least 1 hour in excess of the time assumed in the accident analysis. For all other equipment (e.g., post-accident monitoring, recombiners, etc.), the 10 percent time margin identified in Section 6.3.1.5 of IEEE Std. 323-1974 may be used.	(4) Same as Category I, ~~or, for equipment that has been qualified, a technical basis should be provided for the adequacy of the margins specified~~.
4. AGING	4. AGING
(1) Aging effects on all equipment, regardless of its location in the plant, should be considered and included in the qualification program.	(1) Qualification programs that are committed to conform to the requirements of IEEE Std. 382-1972 (for valve operators) and IEEE Std. 334-1971 (for motors) should consider the effects of aging. For this equipment, the Category I positions of Section 4 are applicable.
(2) The degrading influences discussed in Sections 6.3.3, 6.3.4 and 6.3.5 of IEEE Std. 323-1974 and the electrical and mechanical stresses associated with cyclic operation of equipment should be considered and included as part of the aging programs.	(2) For other equipment, the qualification programs need ~~not~~ specifically address aging. ~~However,~~ During individual case reviews, the staff ~~may~~ require that the effects of aging be accounted for on selected equipment if operating experience or testing indicates that the equipment may exhibit deleterious aging mechanisms. [illegible]
(3) Synergistic effects should be considered in the accelerated aging programs. Investigation should be performed to assure that no known synergistic effects have been identified on materials that are included in the equipment being qualified. Where synergistic effects have been identified, they should be accounted for in the qualification programs. Refer to NUREG/CR-0276 (SAND 78-0799) and NUREG/CR-0401 (SAND 78-1452), "Qualification Testing Evaluation Quarterly Reports," for additional information.	

CATEGORY I	CATEGORY II
Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974

CATEGORY I

(4) The Arrhenius methodology is considered an acceptable method of addressing accelerated aging. Other aging methods that can be supported by type tests will be evaluated on a case-by-case basis.

(5) Known material phase changes and reactions should be defined to insure that no known changes occur within the extrapolation limits.

(6) The aging acceleration rate used during qualification testing and the basis upon which the rate was established should be described and justified.

(7) Periodic surveillance testing under normal service conditions is not considered an acceptable method for on-going qualification, unless the plant design includes provisions for subjecting the equipment to the limiting ~~design environments it is expected to experience~~ (specified in Section 3(7) of IEEE Std. 279-1971) during such testing.

(8) Effects of relative humidity need not be considered in the aging of electrical cable insulation.

(9) The qualified life of the equipment (and/or component as applicable) and the basis for its selection should be defined.

(9) Qualified life ~~is considered a best-estimate approach and~~ should be established based on the severity of the testing performed, the conservatisms employed in the extrapolation of data, the operating history, and in other methods that may be reasonably assumed, coupled with good engineering judgment.

5. QUALIFICATION DOCUMENTATION

(1) The staff endorses the requirements stated in IEEE Std 323-1974 that, "The qualification documentation shall verify that each type of electrical equipment is qualified for its application and meets its specified performance requirements. The basis of qualification shall be explained to show the relationship of all facets of proof needed to support adequacy of the complete equipment. Data used to demonstrate the

CATEGORY II

5. QUALIFICATION DOCUMENTATION

(1) Same as Category I.

CATEGORY I Plants with CP SERs Issued After July 1, 1974, and Equipment Purchased After November 15, 1974	CATEGORY II Plants With OL Applications Currently Under Staff Review and CP SERs Issued Prior to July 1, 1974, and Equipment Purchased Before November 15, 1974
qualification of the equipment shall be pertinent to the application and organized in an auditable form." (2) The guidelines for documentation in IEEE Std. 323-1974 when fully implemented are acceptable. The documentation should include sufficient information to address the required information identified in Appendix E.	(2) Same as Category I, except the guidelines of IEEE Std. 323-1971 may be used.

APPENDIX A

METHODS FOR CALCULATING MASS AND ENERGY RELEASE

APPENDIX A

METHODS FOR CALCULATING MASS AND ENERGY RELEASE

Acceptable methods for calculating the mass and energy release to determine the loss-of-coolant accident (LOCA) environment for PWR and BWR plants are described in the following:

(1) Topical Report WCAP-8312A for Westinghouse plants.

(2) Section 6.2.1 of CESSAR System 80 PSAR for Combustion Engineering plants.

(3) Appendix 6A of B-SAR-205 for Babcock & Wilcox plants.

(4) NEDO-10320 and Supplements 1 & 2 for General Electric plants.

Acceptable methods for calculating the mass and energy release to determine the main steam line break (MSLB) environment are described in the following:

(1) Appendix 6B of CESSAR System 80 PSAR for Combustion Engineering plants.

(2) Section 15.1.14 of B-SAR-205 for Babcock & Wilcox plants.

(3) Same as item (4) above for General Electric plants.

(4) Topical Report WCAP-8822 for Westinghouse plants. (Although this Topical Report is currently under review, the use of this method is acceptable in the interim if no entrainment is assumed. Reanalysis may be required following the NRC staff review of the entrainment model as presently described.)

APPENDIX B

MODEL FOR ENVIRONMENTAL QUALIFICATION FOR LOSS-OF-COOLANT ACCIDENT AND MAIN STEAM LINE BREAK INSIDE PWR AND BWR DRY TYPE OF CONTAINMENT

APPENDIX B

MODEL FOR ENVIRONMENTAL QUALIFICATION FOR LOSS-OF-COOLANT ACCIDENT AND MAIN STEAM LINE BREAK INSIDE PWR AND BWR DRY TYPE OF CONTAINMENT

1. Methodology to Determine the Containment Environmental Response

a. Heat Transfer Coefficient

For heat transfer coefficient to the heat sinks, the Tagami condensing heat transfer correlation should be used for a LOCA with the maximum heat transfer rate determined at the time of peak pressure or the end of primary system blowdown. A rapid transition to a natural convection, condensing heat transfer correlation should follow. The Uchida heat transfer correlation should be used for MSLB accidents while in the condensing mode. A natural convection heat transfer coefficient should be used at all other times when not in the condensing heat trasfer mode for both LOCAs and MSLB accidents. The application of these correlations should be as follows:

(1) Condensing heat transfer

$$q/A = h_{cond} * (T_s - T_w)$$

where q/A = the surface heat flux

h_{cond} = the condensing heat transfer coefficient

T_s = the steam saturation (dew point) temperature

T_w = surface temperature of the heat sink

(2) Convective heat transfer

$$q/A = h_c (T_v - T_w)$$

where h_c = convective heat transfer coefficient

T_v = the bulk vapor temperature

All other parameters are the same as for the condensing mode.

b. Heat Sink Condensate Treatment

When the containment atmosphere is at or below the saturation temperature, all condensate formed on the heat sinks should be transferred directly to the sump. When the atmosphere is superheated, a maximum of 8 percent of the condensate may be assumed to remain in the vapor region. The condensed mass should be calculated as follows:

$$M_{cond} = K q / (h_v - h_L)$$

where M_{cond} = mass condensation rate

K = mass condensation fraction (0.92)

q = surface heat transfer rate

h_v = enthalphy of the superheated steam

h_L = enthalphy of the liquid condensate entering the sump region (i.e., average enthalpy of the heat sink condensate boundary layer)

c. Heat Sink - Surface Area

The surface area of the heat sinks should correspond to that used for the containment design pressure evaluation.

d. Single Active Failure Evaluation

Single active failures should be evaluated for those containment safety systems and components relied upon to limit the containment temperature/pressure response to a LOCA or MSLB accident. This evaluation should include, but not necessarily be limited to, the loss or availability of offsite power (whichever is worse), diesel generator failure when loss of offsite power is evaluated, and loss of containment heat removal systems (either partial or total, whichever is worse).

e. Containment Heat Removal System Actuation

The time determined at which active containment heat removal systems become effective should include consideration of actuation sensors and setpoints, actuation delay time, and system delay time (i.e., time required to come into operation).

f. Identification of Most Severe Environment

The worst case for environmental qualification should be selected considering time duration at elevated temperatures as well as the maximum temperature. In particular, consider the spectrum of break sizes analyzed and single failures evaluated.

2. Acceptable Methodology for Safety-Related Component Thermal Analysis

Component thermal analyses may be performed to justify environmental qualification test conditions that are found to be less than those calculated during the containment environmental response calculation.

The heat transfer rate to component should be calculated as follows:

a. Condensing Heat Transfer Rate

$$q/A = h_{cond} \odot (T_s - T_w)$$

where q/A = component surface heat flux

h_{cond} = condensing heat transfer coefficient

= the larger of 4x Tagami correlation or 4x Uchida correlation

T_s = saturation temperature (dew point)

T_w = component surface temperature

b. Convective Heat Transfer

A convective heat transfer coefficient should be used when the condensing heat flux is calculated to be less than the convective heat flux. During the blowdown period, a forced convection heat transfer correlation should be used. For example:

$$NU = C\ (Re)^{n}$$

where Nu = Nusselt number

Re = Reynolds number

C,n = empirical constants dependent on geometry and Reynolds number

The velocity used in the evaluation of Reynolds number may be determined as follows:

$$V = 25\ \frac{M_{BD}}{V_{CONT}}$$

where V = velocity in ft/sec

M_{BD} = the blowdown rate in lbs/hr

V_{CONT} = containment volume in ft^3

After the blowdown has ceased or reduced to a negligibly low value, a natural convection heat transfer correlation is acceptable.

However, use of a natural convection heat transfer coefficient must be fully justified whenever used.

APPENDIX C

QUALIFICATION PROFILES FOR

BWR AND ICE CONDENSER CONTAINMENTS

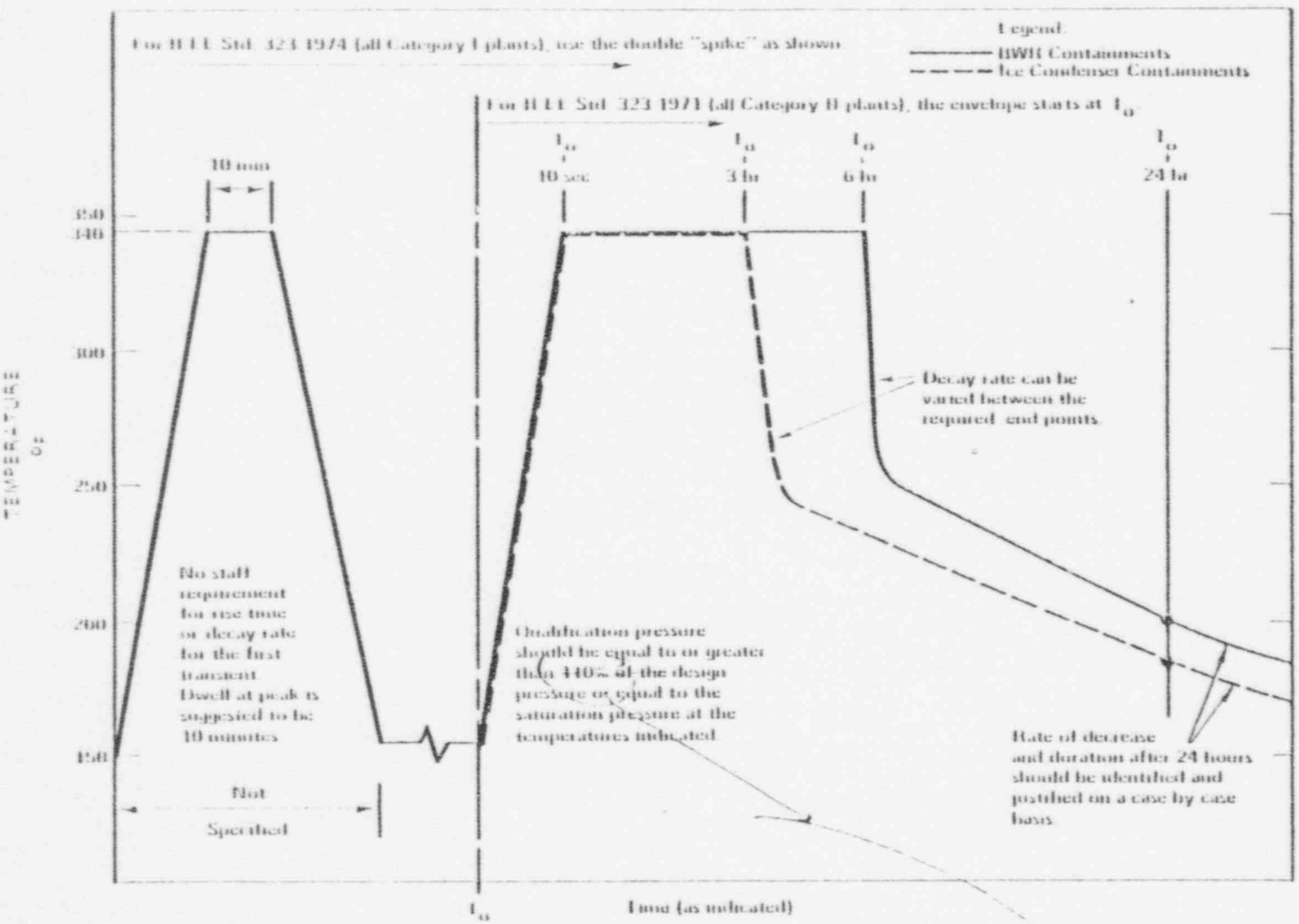

Figure C-1. Qualification Profiles for BWR and Ice Condenser Containments

CSB
SHOULD BE AS MARKED OUT
110% IS IN ERROR

APPENDIX D

SAMPLE CALCULATION AND TYPE METHODOLOGY
FOR RADIATION QUALIFICATION DOSE

APPENDIX D

SAMPLE CALCULATION AND TYPE METHODOLOGY
FOR RADIATION QUALIFICATION DOSE

This appendix illustrates the proposed staff model for calculating dose rates and integrated doses for equipment qualification purposes. The example doses shown below include contributions from several dose point locations in the containment and cover a period of only thirty days following the postulated fission product release. The values shown are not intended for use as appropriate equipment qualification levels. The dose levels intended for qualification purposes should be determined using the maximum time the equipment is intended to function which, for the design basis LOCA event, may well exceed thirty days.

The beta and gamma integrated doses presented in the tables below have been estimated using models and assumptions consistent with those of Regulatory Guides 1.7 and 1.89. This analysis is conservative, but it does not ignore important time-dependent phenomena related to the action of engineered safety features (ESFs) and natural phenomena, such as plateout, as done in previous staff analyses.

Doses were calculated for points within the containment atmosphere, at the containment surface (taking sprays and plateout mechanisms into account), and near the sump water.

THIRTY-DAY INTEGRATED DOSES

Location	Integrated Dose (Rad) Beta	Gamma
Containment Atmosphere	1.4×10^8	1.5×10^7
Containment Surface	1.1×10^7	9.1×10^6
Near Sump Water	7.2×10^7	4.4×10^6

1. General Summary of the LOCA Scenario

The accident considered in this report for determining the radiation environment for qualification of safety-related equipment is a design basis LOCA. The following is a description of the events that are postulated to occur. At the time t=0, the pipe break occurs and results in rapid blowdown of the reactor coolant system (RCS). The blowdown of the RCS ends approximately 20 to 40 seconds after the break. Flashing and escape of the coolant during blowdown removes heat rapidly from the primary system and causes the fuel rod cladding temperature to drop. Consequently, only a few fuel rods are expected to fail during the blowdown period.

Following the end of blowdown, the fuel rods are uncovered and the stored heat in the fuel and the decay heat are transferred to the cladding, thus raising the cladding temperature. Some fuel rods may experience cladding failure during this period. The ECCS refills the lower reactor vessel and then refloods the core region within 100 to 300 seconds, causing cladding temperature turnaround. During the initial blowdown, only the radioactive material contained in the coolant from steady-state operation would be released to the containment. During reflood/refill when fuel rod cladding failure may occur, the noble gases would be transported out of the primary system by steam flow and would become airborne within the primary containment of a PWR (or within the drywell of a BWR). Some fraction of the iodines and less volatile fission products that are released as a result of fuel rod failure would also be transported out of the primary system by the steam flow and become airborne, and some fraction would remain in solution in the sump water or would be deposited on surfaces within the primary system. The amount that becomes airborne outside the primary system would be strongly dependent on the time of fuel rod failure and the transport phenomenon for each species within the primary system.

Following the release from the primary system, the fission products would be distributed within the containment. For a PWR containment, the released airborne activity would rapidly disperse and become uniformly distributed within the primary containment. For a BWR, the released activity would be airborne within the drywell. Following initial release to the containment atmosphere, the action of natural convection currents and ESF equipment, such as cooling fans, will cause time-dependent redistribution of the activity within the containment. Natural removal processes, such as deposition on containment surfaces and washout from the containment atmosphere by the containment spray systems, would reduce the airborne activity concentration and would redistribute this activity to the containment surfaces and to the containment sump water.

During the same period of time, leakage of radioactivity from the containment to the atmosphere could take place. This would be processed to some extent, by ESF filters if present, causing a buildup of activity on these filters. In addition, there could be some deposition and plateout of radioactivity (iodine and daughters of noble gases) on surfaces of ductwork or on the walls of secondary containment.

During the longer term, contaminated primary coolant could be circulated through pipes outside of containment (PWR residual heat removal model). The staff usually assumes a failure of a seal in the ECCS equipment, such that significant quantities of coolant could leak into compartments outside of containment. The leaked fluid is either retained in a sealed room or transported to the radwaste system. Some portion of this leaked fluid is volatilized and also transported in the air of these compartments. These sources would be processed to some extent by ESF filters.

2. Basic Assumptions Used in the Analysis

Gamma and beta doses and dose rates were determined for three types of radioactive source distributions: isotopes suspended in the containment atmosphere, plated-out on containment surfaces, or mixed in the containment sump water. Thus, a given piece of equipment may receive a dose contribution from any or all of these sources. The amount of dose contributed by each of these sources is determined by the location of the equipment, the time-dependent and location-dependent distribution of the source, and effects of shielding.

Previous guidance issued by the staff regarding the source term for equipment qualification was general in nature. Recognizing that implementation of that guidance required a number of assumptions to be made regarding the time-dependent behavior of material within and outside of containment, the staff, in this report, has performed an analysis of the radiation environment that is associated with the source term of position C.2 of Regulation Guide 1.89, using assumptions and methods which were intended to be consistent with staff practices in analyzing the radiological consequences of a design basis LOCA. Position C.2 of Regulatory Guide 1.89 assumes a source term condition associated with a core meltdown. To get a feel for the degree of conservatism in this assumption, calculations using the RELAP-EM (Evaluation Model) program, which uses the conservative assumptions given in Appendix K to 10 CFR Part 50, predict that the peak cladding temperature attained by the hottest fuel rod will be less than 2200°F. Based on the predicted distribution of cladding temperature throughout the core, it is estimated that between 20 and 30 percent of the fuel rods could experience cladding failure for a PWR with a lesser fraction for a BWR. Calculations performed using the more realistic RELAP-BE (Best Estimate) program predicted much lower cladding temperatures than RELAP-EM. Based on the RELAP-BE predictions, the number of fuel rod cladding failures is estimated to be less than 10 percent.

A Sandia Laboratories report (SAND 76-0740, "Radiation Signature Following the Hypothesized LOCA") also analyzed the radiation environment associated with the conditions of position C.2 of Regulatory Guide 1.89. But as noted in the text of that report (cf. Table 1.1, for example), those analyses are based upon calculational assumptions that are not consistent (are overly conservative) with respect to staff recommended practices. Therefore, the results in that report should <u>not</u> be directly applied.

Table D-1 compares the source terms of position C.2 of Regulatory Guide 1.89 to source terms used for other design basis events.

3. <u>Analysis of the Concentration of Fission Products in Air</u>

This section discusses the physical model used to simulate the PWR containment and to determine the time-dependent and location-dependent distribution of noble gases and iodines airborne within the containment atmosphere and plated-out on containment surfaces.

The staff has developed a computer program (TACT) to be published that is used to model the time-dependent behavior of iodine and noble gases within a nuclear power plant. The TACT code is used routinely by the staff for the calculation of the offsite radiological consequences of a LOCA, and is an acceptable method for modeling the transfer of activity from one containment region to another and in modeling the reduction of activity due to the action of ESFs. Another staff code, SPIRT (Ref. 1), is used to estimate the removal rates of elemental iodine by plate-out and sprays, and is a needed input to TACT. These codes were used to develop the source term estimates.

The source terms used in the analysis assumed that 50 percent of the core iodines and 100 percent of the core noble gases were released instantaneously to the containment atmosphere. The following assumptions were also used to calculate the distribution of radioactivity within the containment:

1. The representative containment free volume was taken as 2.52×10^6 ft^3. Of this volume, 74 percent or 1.86×10^6 ft^3 is assumed to be directly covered by the containment sprays.

b. 6.6×10^5 ft^3 of the containment free volume is assumed unsprayed, which includes regions within the main containment room near the containment dome and compartments below the operating floor level. Good mixing of the containment activity between the sprayed and unsprayed regions is assured by natural convection currents and ESF fans.

c. The ESF fans are assumed to have a design flow rate of 220,000 cfm in the post-LOCA environment. Since mixing between all major unsprayed regions and compartments and the main sprayed region will occur, the containment was modeled with TACT nodes.

d. Air exchange between the sprayed and unsprayed region was taken as one-half of the design flow rate of ESF fans plus the effect of natural convection.

e. The containment spray system was assumed to have two equal capacity trains, each designed to inject 3000 gpm of boric acid solution into the containment.

f. Trace levels of hydrazine was assumed added to enhance the removal of iodine.

g. The spray removal rate constant (lambda) was calculated using the staff's SPIRT program, conservatively assuming only one spray train operation and an elemental iodine instantaneous partition coefficient

(H) of 5000. The calculated value of the elemental iodine spray removal constant was 27.2 hr^{-1}, which represents an elemental iodine residence half-life in the sprayed region of approximately 1.5 minutes.

h. Plate-out of iodine on containment internal surfaces was modeled as a first-order rate removal process and best estimates for model parameters were assumed. Based on an assumed total surface area within containment of approximately 5.0×10^5 ft^2, the calculated value for the overall elemental iodine plate-out constant was 1.23 hr^{-1}.

i. The spray removal and plate-out process were modeled as competing iodine removal mechanisms.

4. Departure from Past Practices

Computing the radiological consequences at the exclusion radius and the low population zone, the staff usually assumed that an instantaneous release of 100 percent of the noble gases and 25 percent of the core iodines is available for leakage from the containment. Recognizing that it would take some time before a release of this magnitude could occur, even assuming degraded emergency core cooling system (ECCS) operation, the staff has also assumed, for purposes of estimating offsite dose consequences, that the source is uniformly distributed and that containment sprays activate at the time the large source is available for release (both of which would also take time to occur). Also implicit in the 25 percent release of iodines was the assumption that 50 percent of a 50 percent release of iodine from the fuel is plated-out in a very short period of time.

The staff usually limits credit for element iodine spray removal to no more than 10 hr^{-1}, for an assumed release of 25 percent of the halogens to compensate for the artical assumption of instantaneous plate-out. If a release of 50 percent were assumed (as is implied by Regulatory Guide 1.7 and TID-14844), the actual conservatively calculated spray lambdas would be appropriate. In any event, removal of elemental iodine from the containment atmosphere by spray and plate-out is assumed to cease when the concentration in the sprayed region is reduced by a factor of 200 (when the initial concentration of iodine in the containment is calculated assuming 50 percent of the core inventory of iodines is initially airborne). This reduction factor is obtained by doubling the reduction factor used in the LOCA dose analysis. The intent is to achieve an equilibrium airborne iodine concentration that is consistent with the LOCA analysis. Since the initial (t=0) concentration is assumed to be twice that of the LOCA analysis (50 versus 25 percent), the reduction factor has been doubled.

The staff assumes that more than one species of iodine is present, or will be formed, in a design basis LOCA (see Regulatory Guides 1.3 and 1.4). For our analysis, it is assumed that 2.5 percent of the core inventory of iodine released is associated with airborne particulate material and 2 percent of the core inventory of iodine released forms organic compounds. Even though these values would not be obtained until several hours after the LOCA, it is the staff assumption that the aforementioned composition is present at t=0.

A removal rate constant for particulate iodine was calculated to be 0.43 hr^{-1}. The organic iodine concentration in the containment atmosphere was assumed to be unaffected by containment sprays or plate-out. The action of sprays would not commence at t=0 (e.g., some time would elapse between the onset of the LOCA and the delivery of spray solution to the spray nozzles). Similarly, the assumed large source would not be immediately released from the fuel, and some time would pass before any airborne iodine would be distributed throughout containment.

The assumption of a large release, uniformly distributed in containment (or in the sump water as will be discussed later) is a convenient simplification for purpose of the dose assessment in a PWR containment, and is conservative in terms of specifying the time-dependent radiation environment. Accurate coupling of the various time sequences is beyond the scope of this analysis.

The calculated values of noble gas and airborne iodine activity in the containment as a function of time following the LOCA are presented in Table D-2.

5. Analysis of the Concentration of Fission Products on Surface

The air dose model assumed that only one spray train and one ventilation system train were operable. If both trains of both systems were operable, spray washout would progress more rapidly in the sprayed regions and the "equilibrium" of concentrations between sprayed and unsprayed regions would be reached more quickly. The result would be lower dose rates due to plate-out activity on surfaces or suspended in the air in sprayed regions, and in unsprayed regions during the early phases of the accident.

It has been suggested that the plate-out source used in estimating the radiation environment should assume that 50 percent of the released elemental iodine is instantaneously plated-out on containment and equipment surfaces. This assumption is inconsistent with the time-dependent model used to characterize the concentration of iodines in the air. It is the staff's view that the estimates should be mechanistically consistent. A large margin of conservatism already exists by virtue of the assumed large source term. In any event, the subsequent removal of deposited material by washoff (by sprays or condensate flow) may be important. Ignoring this factor (as was done for this short-term effort) introduces conservatism. Current staff guidelines do not include an acceptable method for estimating this effect. In the absence of such methods, it has been assumed that all plated-out material is retained by the containment surfaces. Table D-3 gives the values calculated for the iodine activity buildup on the plate-out surfaces of the containment.

6. <u>Analysis of the Concentration of Fission Products in the Sump</u>

Regulatory Guide 1.7 (Table D-1) recommends that 50 percent of the iodines and 1 percent of the remaining fission products present in the core are assumed to be intimately mixed with the coolant water. These values stem directly from TID-14844 (and we presume that the 1 percent solids refer to fission products other than halogens and noble gases). No specification of the time dependencies for this source are given. However, for a PWR with containment sprays, the elemental iodine (constituting about 95 percent of released iodine) is rapidly washed out of the containment atmosphere and transported to the containment sump (over 90 percent in less than 15 minutes is a typical result). Table D-4 presents an estimate of buildup of iodine in the sump fluid. There is little difference in the estimated integrated dose from the sump water between these values and values resulting from an assumed instantaneous release of 50 percent of the core iodines into the sump.

The inclusion of solid fission products in the sump source seems to be an artifact from the source of TID-14844. Although it may have applicability to the estimates of hydrogen production per Regulatory Guide 1.7, its applicability to radiation dose estimates has not been fully resolved. Pending this resolution, it should be assumed that the sump fluid contains 1 percent of the solid fission products and that the solid fission products are released and uniformly distributed in the sump fluid at t=0.

7. Estimates of the Radiation Environment Dose and Dose Rates

Previous staff estimates did not take into account the important time-dependent and spatially dependent phenomena. The calculated radiation environment was generally taken as a point on a surface or in the center of containment.

The activities within the containment regions were used as input to calculate the beta and gamma dose rates and integrated doses. One typical location was assumed to be a point located in the center of the main containment region. A second location was assumed to be a point on a containment inner surface. A third location would be adjacent to the sump water. Doses for representative points outside containment were taken from Reference 2 and are also listed for completeness.

The gamma transport calculations were performed in cylindrical geometry. Containment internal geometry was not modeled because this was considered to involve a degree of complexity beyond the scope of the present work. The calculations of both References 3 and 4 indicate that the specific internal shielding and structure would be expected to reduce the gamma doses and dose rates by factors of two or more, depending upon the specific location and geometry.

The beta doses were calculated using the infinite medium approximation. Because of the short range of the betas, this was shown in Reference 5 to result in only small error. The beta doses are not expected to be significantly reduced by the presence of containment internal structures.

Finally, the doses were multiplied by a correction factor of 1.3 as suggested by Reference 5 to account for the neglect of the decay chains with subsequent growing-in of additional daughter products.

a. <u>Containment Atmosphere Doses and Integrated Dose</u>

The beta and gamma dose rates and integrated doses for a point detector on the containment centerline exposed to the airborne activity within the containment atmosphere was calculated. The containment was modeled as an air-filled cylinder whose height equaled the diameter. Containment internal structure and shielding were neglected. The gamma dose rate contribution for the plate-out iodine on containment surfaces to the detector was also modeled and included as a contributor. The gamma dose rates and integrated doses are shown in Table D-5, whereas the beta dose rates and integrated doses are shown in Table D-6. The increased pressure effects in a post-LOCA containment have little shielding importance and therefore was not considered. This results in a small conservatism in the calculated dose.

b. Surface Dose and Dose Rates

The beta and gamma dose rates and integrated doses were computed for containment coatings on which iodine fisssion products were presumed to be plated-out. The containment coatings were assumed to have a thickness of 10 mils (0.0254 cm) with an average density of 1 gms/cm^3.

Removal of plated-out activity with time is expected to be a complex phenomenon dependent upon such conditions as whether the surface is exposed to the sprays and whether moisture condensation and runoff can be expected to remove surface activity. Assuming complete retention of plate-out activity, half of the beta energy from plated-out iodine is assumed directed toward the coated surface. The airborne contribution was added to the plate-out contribution, and all the betas directed toward the coating were assumed to be absorbed in the coating. This is conservative since the maximum range for betas is greater than the coating thickness. Hence, this assumption may overestimate the beta dose for a specific coating.

but may be appropriate for a cable insulation layer. The airborne contribution was taken to be one-half the dose rate from an infinite cloud.

The gamma dose rate at the plated-out surface exposed to airborne activity was calculated to be one-half of the dose rate for a detector at the containment centerline. Although half of the gamma energy from plated-out iodine is also directed toward the coating, the coating is calculated to be relatively permeable to gammas with only about 1 percent of the plated-out gammas absorbed by the coating, and this contribution is considered negligible.

The gamma dose rates and integrated doses are therefore half of the centerpoint values for an airborne detector. The gamma dose rates are not significantly affected by the radioactive decay of plated-out activity with time.

The beta dose rates and integrated doses for "well-washed" and "unwashed" surface, respectively, are shown in Table D-7. Note that a plate-out "washoff" model was not used for the "well-washed" example, the plate-out dose rate component was set equal to zero.

c. Dose Near Sump Water

The activity in the sump water was assumed to vary with time, and to be initially free of any iodine fission products. Ultimately, essentially all of the iodine released appears in the sump water.

Table D-4 shows the iodine activity in the sump as a function of time. Note that the maximum is reached in about 0.2 hour with radioactive decay reducing the activity afterwards. The beta and gamma dose rates and integrated doses were computed for a detector located at the surface of a large pool of sump water contaminated by iodine and solid fission products. There was 44,200 cubic feet of water that was assumed to cover the bottom of the containment. The containment geometry was simplified to assume a uniform depth of water of about 2.5 feet, and the dose rates were calculated at the sump water surface. The gamma dose rate and integrated dose from the sump water source are given in Table D-8.

d. Equipment Outside Containment

Although not specifically calculated in this study, several values of dose rates and doses at points outside of containment were taken from Reference 2 for completeness. The method used in this report in arriving at these results are acceptable for plant-specific determination.

The gamma dose rates and integrated doses at a point outside of containment are shown in Table D-9 (taken from Reference 2). The containment source was assumed to be a Regulatory Guide 1.4 source (with a power level of 4000 MWt) and was shielded by 3 feet of concrete. The dose rates at the beginning of recirculation near a pipe containing water contaminated by iodine fission products was also calculated in Reference 2 and the dose rates are shown in Table D-10.

8. Comparison of a PWR and a BWR

A detailed model for a BWR equivalent to the PWR model is not presented in this report. Doses to equipment inside a BWR containment (primarily considering a BWR with a MARK III type of containment structure) would not be expected to differ greatly from the doses calculated for PWR equipment. However, some differences in equipment doses will result due to the compartmented design of BWR containments, and the fact that most BWRs do not have containment sprays designed for rapid iodine removal.

Several of the models and assumptions used in the PWR analysis would not be appropriate for an equivalent analysis for a BWR. Specifically:

a. The assumption of an initial uniformly distributed airborne concentration of activity throughout the containment is not appropriate for a BWR containment.

b. Following the blowdown portion of the LOCA, the air exchange rates between the drywell region and the remainder of the containment free volume will be relatively small.

c. Since any major releases of activity would be initially into the drywell and would occur following the blowdown period, only relatively slow transport would occur to the main containment volume. Consequently, an appropriate model for a BWR containment should consider that all (or most) of the activity is initially released into the drywell region.

d. It is important to correctly estimate the atmospheric mixing rates between the drywell and the main containment regions (including sprayed and unsprayed regions) to adequately estimate the time-dependent and location-dependent distribution of activity. This should include an estimate of the flow between the drywell and the main containment that bypasses the suppression pool. This suggests a relatively detailed multi-node containment model, if overly conservative estimates of the radiation environment are to be avoided.

e. Removal of iodines from the main containment region and from the drywell, by operation of ESF systems such as containment sprays, should be modeled in a manner similar to that used in calculating offsite doses (i.e., single failure etc.).

f. Time-dependent deposition of iodines on surfaces by natural processes should be evaluated using mechanistic models and best estimates for model parameters; this will require a relatively detailed evaluation of potential deposition surfaces within the main containment and drywell.

g. Capture of iodines in the suppression pool, although not currently assumed, may be important and should be evaluated.

Table D-1. Source Terms: Activity Released from the Fuel as a Percentage of the Total Core Inventory

Source Terms	Activity Released (percent) Noble Gases	Iodines	Solids
1. Source term based on TID-14844 required by Reg. Guides 1.3 and 1.4)	100	50	0
2. Source term as required by Regulatory Guides 1.7 and 1.89 Rev. 0 (base case)*	100	50	1
3. Source term based on conservative gap release (Reg. Guide 1.25)	10 (30 of Kr-185)	10	0
4. Best estimates of total activity gap:			
WASH-1400	3	5	
NUREG/CR-0091**	1.27	2.79	

*Case 2 was used in the calculations presented in this appendix.
**Calculated for stable and long-half-life isotopes.

Table D-2. PWR Airborne Activity Distribution Within Containment Versus Time - Base Case, Ci

Time (hours)	Noble Gases	Elemental Iodine	Organic Iodine	Particulate Iodine	Total Iodine	Total Airborne
0.0	1.31 + 9	4.37 + 8	9.15 + 6	1.14 + 7	4.58 + 8	1.77 + 9
0.03	1.19 + 9	4.17 + 8	9.07 + 6	1.13 + 7	4.37 + 8	1.63 + 9
0.50	7.36 + 8	3.56 + 6	7.98 + 6	8.58 + 6	2.01 + 7	7.56 + 8
0.75	6.30 + 8	3.35 + 6	7.51 + 6	7.46 + 6	1.83 + 7	6.98 + 8
1.00	6.41 + 8	3.17 + 6	7.11 + 6	6.52 + 6	1.68 + 7	6.58 + 8
2.00	5.54 + 8	2.66 + 6	5.95 + 6	3.96 + 6	1.26 + 7	5.67 + 8
3.00	3.62 + 8	1.62 + 6	3.62 + 6	3.56 + 5	5.60 + 6	3.68 + 8
24.00	2.33 + 8	9.11 + 5	2.04 + 6	1.21 + 3	2.95 + 6	2.36 + 8
60.00	1.64 + 8	4.84 + 5	1.09 + 6	--	1.57 + 6	1.66 + 8
96.00	1.33 + 8	3.47 + 5	7.78 + 5	--	1.13 + 6	1.34 + 8
192.00	7.34 + 7	2.19 + 5	4.92 + 5	--	7.11 + 5	7.31 + 7
298.00	4.49 + 7	1.48 + 5	3.34 + 5	--	4.82 + 5	4.54 + 7
394.00	2.73 + 7	1.05 + 5	2.37 + 5	--	3.42 + 5	2.76 + 7
560.00	1.20 + 7	5.76 + 4	1.31 + 5	--	1.89 + 5	1.22 + 7
720.00	6.01 + 6	3.23 + 4	7.36 + 4	--	1.06 + 5	6.12 + 6

Table D-3. Total Plate-out Surface Activity in the Containment Versus Time for the Base Case

Time (hours)	Iodine Activity Deposited on Surfaces, Ci
0.0	0.0
0.03	1.57 + 7
0.07	2.96 + 7
0.14	3.92 + 7
0.20	4.23 + 7
0.40	--
0.50	4.23 + 7
0.75	3.98 + 7
1.00	3.77 + 7
2.00	3.15 + 7
8.00	1.92 + 7
24.00	1.08 + 7
60.00	5.76 + 6
96.00	4.13 + 6
192.00	2.61 + 6
298.00	1.77 + 6
394.00	1.25 + 6
560.00	6.91 + 5
720.00	3.90 + 5

Table D-4. Iodine Activity in Containment Sump Versus Time
Iodine Activity in Containment Sump, Ci

Time (hours)	Elemental Iodine	Particulate* Iodine	Total Iodine in Sump
0.0	0.0	0.0	0.0
0.03	0.0	0.0	0.0
0.07	2.04 + 3	- -	2.04 + 3
0.14	3.04 + 3	- -	3.04 + 3
0.20	3.35 + 3	- -	3.35 + 3
0.25	3.44 + 3	- -	3.44 + 3
0.50	3.34 + 3	1.39 + 6	3.35 + 3
0.75	3.15 + 3	1.93 + 6	3.17 + 3
1.00	2.98 + 3	2.36 + 6	3.00 + 3
2.00	2.49 + 3	3.48 + 6	2.52 + 3
3.00	1.52 + 3	4.18 + 6	1.56 + 3
24.00	8.38 + 7	2.54 + 6	8.33 + 7
60.00	4.56 + 7	1.36 + 6	4.70 + 7
96.00	3.27 + 7	9.75 + 6	3.37 + 7
192.00	2.06 + 7	6.15 + 5	2.12 + 7
.98.00	1.40 + 7	4.13 + 5	1.44 + 7
394.00	9.43 + 6	2.96 + 5	9.73 + 6
360.00	5.48 + 6	1.63 + 5	5.64 + 6
720.00	3.09 + 6	9.30 + 4	3.18 + 6

*Particulate iodine activity in the containment sump for times less than 0.5 hours is small and, when added to the elemental iodine activity, does not significantly affect the total magnitude of the iodine activity in the sump.

Table D-5. Total Gamma Dose Rates and Integrated Doses at the Containment Center in Air Versus Time - Base Case Unwashed

Time (hours)	Gamma Dose Rate From Airborne (R/hr)	Gamma Dose Rate in Air From Plate-out Source (R/hr)	Total Gamma Dose Rate in Air (R/hr)	Total Integrated Gamma Dose in the Containment Air (R)
0.0	4.92 + 6	1.56 + 4	4.92 + 6	--
0.03	4.43 + 6	5.59 + 4	4.49 + 6	2.06 + 5
0.50	1.33 + 6	1.[illegible]4 + 5	1.47 + 6	1.18 + 6
0.75	1.16 + 6	1.33 + 5	1.29 + 6	1.55 + 6
1.00	1.05 - 6	1.23 + 5	1.17 + 6	1.82 - 6
2.00	7.75 - 6	9.44 - 4	8.69 + 5	2.80 - 6
8.00	2.37 + 5	4.14 + 4	2.78 + 5	6.0 + 6
24.00	5.19 + 4	1.58 + 4	6.77 + 4	7.1 + 6
60.00	1.70 - 4	6.36 - 3	2.34 - 4	9.2 - 6
96.00	1.30 + 4	4.36 - 3	1.74 - 4	1.0 - 7
192.00	7.66 - 3	2.66 - 3	1.03 + 4	1.15 - 7
298.00	4.38 - 3	1.80 - 3	6.18 - 3	1.20 - 7
394.00	2.67 + 3	1.28 + 3	3.95 - 3	1.25 - 7
580.00	1.14 - 3	[illegible]04 + 2	1.34 - 3	1.30 - 7
720.00	5.14 + 2	1.[illegible]8 + 2	9.12 - 2	1.36 - 7

Table D-6. Beta Dose Rates and Integrated Doses at the Containment Center Versus Time in Air

Time (hours)	Dose Rate in Containment Air (R/hr)	Integrated Dose in Containment Air (R)
0.0	2.373 + 7	--
0.03	1.951 + 7	8.39 + 5
0.25	5.356 + 6	3.55 + 6
0.5	4.198 + 6	4.93 + 6
0.75	3.671 + 6	6.0 + 6
1.0	3.369 + 6	7.13 + 6
2.0	2.758 + 6	1.03 + 7
8.0	1.538 + 6	2.21 + 7
24.0	7.068 + 5	4.1 + 7
60.0	3.919 + 5	6.1 + 7
96.0	3.117 + 5	7.2 + 7
192.0	1.371 + 5	8.9 + 7
298.0	1.083 + 5	1.03 + 8
394.0	6.307 + 4	1.08 + 8
560.0	3.278 + 4	1.17 + 8
720.0	1.901 + 4	1.26 + 8

Table D-7. Beta Dose Rates and Integrated Doses for Paint on Containment Wall - Washed and Unwashed Cases

Time (hours)	Dose Rate* Unwashed (R/hr)	Dose Rate** Washed (R/hr)	Dose Unwashed (R)	Dose Washed (R)
0.0	1.19 + 7	1.19 + 7	0.0	0.0
0.03	1.01 + 7	9.76 + 6	4.99 + 5	6.46 + 5
0.25	3.79 + 6	2.93 + 6	1.81 + 6	1.69 + 6
0.5	2.92 + 6	2.10 + 6	2.70 + 6	2.32 + 6
0.75	2.60 + 6	1.84 + 6	3.65 + 6	3.0 + 6
1.0	2.39 + 6	1.68 + 6	4.20 + 6	3.25 + 6
2.0	1.94 + 6	1.38 + 6	6.39 + 6	4.77 + 6
8.0	1.07 + 6	7.69 + 5	1.42 + 7	9.9 + 6
24.0	5.05 + 5	3.53 + 5	2.55 + 7	1.77 + 7
60.0	2.60 + 5	1.96 + 5	3.90 + 7	2.73 + 7
96.0	1.96 + 5	1.56 + 5	4.6 + 7	3.3 + 7
192.0	1.16 + 5	9.36 + 4	6.0 + 7	4.4 + 7
298.0	6.90 + 4	5.42 + 4	7.0 + 7	5.2 + 7
394.0	4.45 + 4	3.40 + 4	7.6 + 7	5.6 + 7
560.0	2.22 + 4	1.64 + 4	8.2 + 7	6.1 + 7
720.0	1.28 + 4	9.51 + 3	8.29 + 7	6.33 + 7

*Includes both the containment airborne and plate-out contributions.
**Includes only the containment airborne contribution.

Table D-8. Containment Sump Gamma Dose Rates and Integrated Doses Versus Time

Time (hours)	(Mev) $\bar{E}$	Dose Rate at the Sump Surface From Iodine in Sump (R/hr)	Dose Rate at the Sump Surface From 1% Solids in Sump (R/hr)	Total Dose Rate at the Sump Surface (R/hr)	Total Integrated Gamma Dose at the Surface (R)
0.0	0.887	0.0	5.90 + 4	5.90 + 4	--
0.03	0.887	0.0	3.09 + 4	3.09 + 4	4.65 + 2
0.07	0.886	1.18 + 5	--	--	--
0.14	0.884	1.79 + 5	2.21 + 4	2.01 + 5	1.23 + 4
0.20	0.882	1.94 + 5	--	--	--
0.25	0.880	1.99 + 5	1.90 + 4	2.18 + 5	2.32 + 4
0.50	0.873	1.83 + 5	1.59 + 4	1.99 + 5	7.89 + 4
0.75	0.866	1.71 + 5	--	--	--
1.00	0.860	1.56 + 5	1.25 + 4	1.68 + 5	1.68 + 5
2.00	0.839	1.19 + 5	1.01 + 4	1.29 + 5	3.00 + 5
8.00	0.763	5.08 + 4	--	--	--
24.00	0.569	1.61 + 4	4.99 + 3	2.11 + 4	1.15 + 6
60.00	0.401	6.04 + 3	--	--	--
96.00	0.357	3.81 + 3	3.09 + 3	6.90 + 3	1.95 + 6
192.00	0.332	2.20 + 3	--	--	--
298.00	0.330	1.50 + 3	2.14 + 3	3.64 + 3	2.95 + 6
394.00	0.330	1.06 + 3	--	--	--
560.00	0.330	5.86 + 2	1.61 + 3	2.20 + 3	3.65 + 6
720.0	0.330	3.30 + 2	1.42 + 3	1.75 + 3	3.96 + 6

Table D-9. Gamma Dose Rates Outside Shielded Containment (3-foot Concrete Shield)

Time After Release (hours)	Dose Rate (R/hr)	Integrated Dose (Rads)
0	4.0×10^{2}	0
1	2.5×10^{2}	3.2×10^{2}
3	1.2×10^{2}	6.9×10^{2}
10	2.3×10^{1}	1.2×10^{3}
30	2.4×10^{0}	1.5×10^{3}
100	2.3×10^{-2}	1.6×10^{3}

Table D-10. Gamma Dose Rates at Beginning of Recirculation Near Pipe Containing Iodine Fission Products

Distance	Dose Rate (R/hr)
4 inches	1.6×10^5
1 foot	5.3×10^4
3 feet	1.8×10^4

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APPENDIX E

STANDARD QUESTION ON ENVIRONMENTAL QUALIFICATION OF CLASS 1E EQUIPMENT

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STANDARD QUESTION ON ENVIRONMENTAL QUALIFICATION OF CLASS 1E EQUIPMENT

In order to ensure that your environmental qualification program conforms with General Design Criteria 1, 2, 4 and 23 of Appendix A and Sections III and XI of Appendix B to 10 CFR Part 50, and to the national standards mentioned in Part II "Acceptance Criteria" (which includes IEEE Std. 323) contained in Standard Review Plan Section 3.11, the following information on the qualification program is required for all Class 1E equipment.

1. Identify all Class 1E equipment, and provide the following:
   a. Type (functional designation)
   b. Manufacturer
   c. Manufacturer's type number and model number
   d. The equipment should include the following, as applicable:
      (1) Switchgear
      (2) Motor control centers
      (3) Valve operators
      (4) Motors
      (5) Logic equipment
      (6) Cable
      (7) Diesel generator control equipment
      (8) Sensors (pressure, pressure differential, temperature and neutron)

(9) Limit switches

(10) Heaters

(11) Fans

(12) Control boards

(13) Instrument racks and panels

(14) Connectors

(15) Electrical penetrations

(16) Splices

(17) Terminal blocks

2. Categorize the equipment identified in item 1 above into one of the following categories:

a. Equipment that will experience the environmental conditions of design basis accidents for which it must function to mitigate said accidents, and that will be qualified to demonstrate operability in the accident environment for the time required for accident mitigation with safety margin to failure.

b. Equipment that will experience environmental conditions of design basis accidents through which it need not function for mitigation of said accidents, but through which it must not fail in a manner detrimental to plant safety or accident mitigation, and that will be qualified to demonstrate the capability to withstand any accident environment for the time during which it must not fail with safety margin to failure.

c. Equipment that will experience environmental conditions of design basis accidents through which it need not function for mitigation of said accidents, and whose failure (in any mode) is deemed not detrimental to plant safety or accident mitigation, and need not be qualified for any accident environment, but will be qualified for its non-accident service environment.

d. Equipment that will not experience environmental conditions of design basis accidents and that will be qualified to demonstrate operability under the expected extremes of its non-accident service environment. This equipment would normally be located outside the reactor containment.

3. For each type of equipment in the categories of equipment listed in item 2 above, provide separately the equipment design specification requirements, including:

a. The system safety function requirements.

b. An environmental envelope as a function of time that includes all extreme parameters, both maximum and minimum values, expected to occur during plant shutdown, normal operation, abnormal operation, and any design basis event (including LOCA and MSLB), including post-event conditions.

c. Time required to fulfill its safety function when subjected to any of the extremes of the environment envelope specified above.

d. Technical bases should be provided to justify the placement of each type equipment in the categories 2.b and 2.c listed above.

4. Provide the qualification test plan, test setup, test procedures, and acceptance criteria for at least one of each group of equipment of item 1.d as appropriate to the category identified in item 2 above. If any method other than type testing was used for qualification (operating experience, analysis, combined qualification, or ongoing qualification), describe the method in sufficient detail to permit evaluation of its adequacy.

5. For each category of equipment identified in item 2 above, state the actual qualification envelope simulated during testing (defining the duration of the hostile environment and the margin in excess of the design requirements). If any method other than type testing was used for qualification, identify the method and define the equivalent "qualification envelope" so derived.

*6. A summary of test results that demonstrates the adequacy of the qualification program. If analysis is used for qualification, justification of all analysis assumptions must be provided.

*7. Identification of the qualification documents which contain detailed supporting information, including test data, for items 4, 5 and 6.

*For applications for construction permits, it is acceptable to state that items 6 and 7 will be supplied in the initial application for an operating license.

In addition, in accordance with the requirements of Appendix B of 10 CFR 50, the staff requires a statement verifying that (1) all Class 1E equipment has been qualified for an operating license (OL) or will be qualified for a construction permit (CP) to the program described above, and (2) the detailed qualification information and test results are (or will be) available for an NRC audit.