US-APWR Equipment Qualification Program

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Revision History

Revision	Page	Description
0	All	Original issued
1	-	Changed the title “Equipment Environmental Qualification Program” to “Equipment Qualification Program”
	-	Made grammatical and typo corrections
	1 through 5	Added Definitions
	9	Added Section 1.3 “Important to Safety vs. Safety-Related Nomenclature
	10	Revised Scope
	25, 26	Revised ASME QME-1 description content including the tests and analysis of components located in harsh environments according to the Responses to RAI No. 444, Question 3.11-7, 15
	28	Added Section 3.8 “Quality Assurance”
	30 through 38	Changed Section 4.2 including the tests and analysis of components located in harsh environments according to the Responses to RAI No. 444, Question 3.11-7
	42 through 47	Updated Subsection 5.5.1 according to the Responses to RAI No. 358, Question 3.11-1
	50	Changed the pressure “-0.2 - +.0 psig” to “-0.3 - +2.0 psig”
	54 through 62	Changed Table 5-4 and Added Table 5-5 according to the Responses to RAI No. 358, Question 3.11-2
	63, 64	Changed Figure 5.1 and 5.2 incorporated the mass and energy release analysis methodology for LOCA, MUAP 07012 P-A Rev. 2 and NP-A Rev. 2
	71	Added Chapter 7.0 “THE EQUIPMENT QUALIFICATION PROCESS” including the Equipment Qualification Process according to the Responses to RAI No. 358, Question 3.11-6
	71	Added the description about the process of design/purchase specifications in Section 7.1
	76	Added Section 7.7 “Development of Aging Program, and Spare or Replacement Parts according to the Responses to RAI No. 444, Question 3.11-8
	78	Added Chapter 8.0 “MHI US-APWR EQP”

Revision	Page	Description
	84	Added Chapter 9.0 “EQUIPMENT QUALIFICATION IMPLEMENTATION”
	92	Added Chapter 10.0 “EQ PROGRAM TRANSFER TO U.S. UTILITY (LICENSEE) AND CLOSEOUT”
	92	Added the description about the consideration of synergistic effects according to the Responses to RAI No. 444, Question 3.11-10
	92	Added the description about the process for verifying electric motor output under high temperature conditions according to the Responses to RAI No. 444, Question 3.11-11
	92	Added the description about the EQ process for dynamic restraints (snubbers) according to the Responses to RAI No. 444, Question 3.11-12
	92	Identified maintenance/surveillance and preventive maintenance program for equipment according to the Responses to RAI No. 444, Question 3.11-13
	94, 95	Added Section 10.3 “ITAAC” according to the Responses to RAI No. 444, Question 3.11-14
	97	Added Chapter 11.0 “GENERAL DESCRIPTION OF UTILITY (LICENSEE) OPERATING EQUIPMENT QUALIFICATION PROGRAM
	99	Added Chapter 12.0 “SUMMARY”
	113	Revised Attachment B “Description of the US-APWR Equipment Seismic Qualification Program”
	119, 120	Added the description of OBE ISRS and high frequency exceedances in Section B.7
	134	Added Attachment C “List of Implementing Directives and Procedures”
2	General	Editorial correction.
	General	Revised to follow the responses to RAI 805-5915 Question 03.11-41.
	General	Revised to follow the responses to RAI 1034-7055 Question 03.11-68.
	General	Updated reference document to latest version.
	Abstract, 1 through 4, 6, 7, 38, 70, 94, 97	Revised Abstract, Definitions, Sections 1.0, 4.2.13, 4.3, 4.4, 7.1, 10.5 and 12.0 to follow the responses to RAI 1034-7055 Question 03.11-64.
	xii	Added the description of Table 5-5 to “List of Tables”.
	xv, 9 through 12, 88, 95, 96	Revised List of Acronyms, Sections 2.0, 2.1, 9.14, 11.0 and Figure 2-1 to follow the responses to RAI 880-6142 Question 03.11-46.

Revision	Page	Description
	4, 9, 13, 29, 32, 30, 34, 36, 71	Revised Definitions, Sections 2.0, 3.1.1, 4.0, 4.1.1, 4.2, 4.2.8, 4.2.9.2 and 7.3 to follow the responses to RAI 1034-7055 Question 03.11-63.
	7	Revised Section 1.0 to follow the responses to RAI 1034-7055 Question 03.11-65.
	13, 14	Revised Section 3.1.1 to follow the responses to RAI 511-3739 Question 03.11-19.
	14, 72, 73, 75	Revised Sections 3.1.1, 7.7 and deleted Figure 7-1 to follow the responses to RAI 650-5093 Question 03.11-39.
	21, 24, 25, 92	Revised Sections 3.3, 3.4 and 10.3.2 to follow the responses to RAI 901-6257 Question 03.11-48.
	30	Revised Section 4.1.1 to be consistent with DCD Tier 2 Subsection 3.11.1.2.
	30, 95	Revised Sections 4.1.1 and 11.0 to follow the responses to RAI 901-6257 Questions 03.11-49 and 03.11-54.
	31, 36, 38, 92	Revised Sections 4.2, 10.3.1 and added Section 4.2.14 and deleted 4.2.10.1 to follow the responses to RAI 880-6142 Question 03.11-45.
	31	Revised Section 4.2.1 to follow the responses to RAI 511-3739 Question 03.11-20.
	33	Revised the description of Indoor chemical environment in Section 4.2.6.
	33	Revised Section 4.2.6 to be consistent with DCD Tier 2 Subsection 3.11.5.1.
	38	Revised Section 4.2.14 to clarify EMC qualification requirement.
	41	Revised Table 4-2 to follow the responses to RAI 880-6142 Question 03.11-44.
	43, 54, 55, 57, 58, 150 through 208	Revised Section 5.5.1.1, Table 5-5 and added Attachment E to follow the responses to RAI 589-4536 Question 03.11-36.
	45	Revised Section 5.5.1.3 to be consistent with Section 5.5.1.4.
	52, 60	Revised Tables 5-4 and 5-5 to follow the responses to RAI 512-3893 Question 03.11-34.
	55	Revised accident cumulative dose for Zones 1-5 and 1-6 in Table 5-5.
	65 through 68	Revised Section 6.2.1 to follow the responses to RAI 511-3739 Question 03.11-18.
	67, 68	Revised Section 6.2.2 to follow the responses to RAI 511-3739 Question 03.11-17.
	68	Revised Section 6.2.2 to follow the responses to RAI 901-6257 Question 03.11-50.

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	68, 69	Moved Section 6.2.3 to Section 6.6.
	69	Revised Section 6.6 to follow the responses to RAI 901-6257 Question 03.11-51.
	86, 140 through 149	Revised Section 9.9 and added Attachment D to follow the responses to RAI 880-6142 Question 03.11-42.
	92	Revised Section 10.3.2 to follow the responses to RAI 901-6257 Question 03.11-53.
	106, 115, 122, 128, 131	Replaced RG 1.148 with RG 1.100 Rev. 3 due to RG 1.148 withdrawn.
	115	Revised Attachment B.4 to follow the responses to RAI 901-6257 Question 03.11-57.
	117, 121	Updated document information.
	117, 118	Revised Attachment B.6 to be consistent with DCD Tier 2 Subsection 3.10.2.
	118	Revised Attachment B.7 to follow the responses to RAI 1019-7043 Question 03.10-20.
	122	Revised Attachment B.11 to be consistent with DCD Tier 2 Subsection 3.10.2.1.1.
	127	Revised Equipment Qualification Summary Data Sheet (EQSDS), Environmental Qualification Report (EQR) and Seismic Qualification Report (SQR) formats in Attachment B to be consistent with DCD Tier 2 Section 3.10.
	131	Revised Section 1.a of ESQ summary data sheet in Attachment B to be consisntent with DCD Tier 2 Subsection 3.10.4.
	131	Revised Section 1.b of ESQ summary data sheet in Attachment B to be consistent with DCD Tier 2 Section 3.10.1.2.
	137	Revised Attachment C to follow the responses to RAI 880-6142 Question 03.11-47.
	137	Revised Attachment C to follow the responses to RAI 901-6257 Question 03.11-59.
	209 through 216	Added Attachment F to follow the responses to RAI 1034-7055 Question 03.11-68.

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Abstract

Structures, systems and components (SSCs) that are used to construct the US-APWR need to function in all anticipated environments associated with normal and accident conditions. Good engineering practices, as well as adherence to applicable regulations and standards establishes the need to demonstrate that the SSCs requiring environmental, seismic and functional qualification are capable of fulfilling their design functions in design basis environmental conditions, including seismic events.

Equipment qualification is defined as a systematic approach to verify, demonstrate and document, by one or more defined methods, that an SSC addressed by the program is qualified for use in all anticipated environmental conditions (including seismic) such that the SSC can fulfill its intended safety function during normal, testing, accident and post accident conditions including postulated design basis events. The Design Control Document (DCD) is the basic document for licensing of the US-APWR standard plant for the US market. A specific plant is constructed and operated using a combined license (COL) application. The DCD follows the process established by the U.S. Nuclear Regulatory Commission (NRC) pursuant to Title 10, Code of Federal Regulations (CFR), Sections 50.34 and 52.47 (10 CFR 50.34 & 52.47), which requires that the means and methods for equipment qualification be properly identified and established. This licensing process requires that the equipment manufacturer, Mitsubishi Heavy Industries (MHI) and the COL applicant identify and establish means and methods for equipment qualification during the design, procurement, construction, testing, turnover and operational phases of each US-APWR project, respectively.

MHI will supply a standard plant to utilities (licensees) who will obtain a license by submitting a COL application to the NRC using the licensing process delineated in 10 CFR 52.79. The actual design, procurement, construction, testing, turnover and early operation of a facility are collectively referred to as a US-APWR Project. The US-APWR Equipment Qualification Program is implemented on a Project basis and addresses both environmental and seismic qualification of SSCs.

This Technical Report describes the Equipment Qualification Program, procedures and policies that MHI will implement during the design, procurement, construction, testing, turnover and operational phases of a Project. The standard Equipment Qualification Program provides the requirements and guidance needed to develop a specific Project Equipment Qualification Program (PEQP). This is accomplished by establishing and defining a Project Organization. The Project Organization is responsible for the actual design, procurement, construction, testing and early operation of the specific US-APWR project. The Project Organization is expected to be comprised of MHI, Mitsubishi Nuclear Energy Systems, Inc. (MNES), one or more Architect/Engineers, key suppliers, one or more Constructors, the plant licensee (utility), and other key project support organizations. MHI/MNES is responsible for establishing a Project Equipment Qualification Organization (PEQO) within the Project Organization. The PEQO is responsible for preparing project specific equipment qualification procedures following the guidance provided in the US-APWR Equipment Qualification Program. In addition to this Technical Report, the US-APWR Equipment Qualification Program also consists of Directives and Procedures. The Directives can be viewed as broad policy guidelines which implement the commitments identified in the US-APWR DCD. The Procedures provide direction to the PEQO in implementing a PEQP which complies with the commitments made in the DCD.

This Technical Report first identifies the regulatory basis and supporting industry standards applicable to the equipment qualification process including the equipment qualification criteria and methodology. It then provides applicable equipment qualification parameters of the US-APWR. The Technical Report also describes the generic Equipment Qualification Program and then describes the implementation of a PEQP.

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List of Acronyms

A/E	Architect/Engineer
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
AST	Alternative Source Term
AWS	American Welding Society
CCASSI	Critical Characteristics for Acceptance of Seismically Sensitive Items
CFR	Code of Federal Regulations
CMTR	Certified Mill Test Report
COL	Combined License
COLA	Combined License Application
CSDRS	Certified Seismic Design Response Spectra
CV	Containment Vessel
DBA	Design Basis Accident
DBE	Design Basis Event
DCD	Design Control Document
DG	Draft Regulator Guide
EEQR	Equipment Environmental Qualification Report
EFW	Emergency Feedwater
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Fielf
EMI	Electromagnetic Interference
EPC	Engineering, Procurement and Construction
EPRI	Electric Power Research Institute
Deleted	
Deleted	
EQDP	Equipment Qualification Data Package
EQDSR	Equipment Qualification Data Summary Report
EQSDS	Equipment Qualification Summary Data Sheet
ESQR	Eqipment Seismic Qualificdation Report
FIRS	Foundation Input Response Spectra
FLB	Feedwater Line Break
FSAR	Final Safety Analysis Report

GDC	General Design Criteria
GMRS	Ground Motion Response Spectra
HELB	High-Energy Line Break
HVAC	Heating, Ventilation and Air Conditioning
HX	Heat Exchanger
I&C	Instrumentation and Control
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
ILRT	Integrated Leak Rate Test
INPO	Institute of Nuclear Power Operations
IP	Inspection Procedure
ISI	Inservice Inspection
ISO	International Organization for Standardization
IST	Inservice Testing
ISRS	In-Structure Response Spectra
ITAAC	Inspections, Tests, Analysis, and Acceptance Criteria
ITP	Initial Test Program
LOCA	Loss-of-coolant Accident
MELCO	Mitsubishi Electric Corporation
MHI	Mitsubishi Heavy Industries, Ltd.
MNES	Mitsubishi Nuclear Energy Systems, Inc.
MOV	Motor-Operated Valve
MFLB	Main Feedwater Line Break
MSLB	Main Steam Line Break
MS/MF	Main Steam/Feedwater
NEMA	National Electrical Manufacturers Association
NIAC	Nuclear Industry Assessment Committee
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NUPIC	Nuclear Procurement Issues Committee
OBE	Operating-basis Earthquake
OEQP	Operational Equipment Qualification Program
OL	Operating License (a portion of a Construction and Operating License COL)
PCCV	Pre-stressed Concrete Containment Vessel
PEQO	Project Equipment Qualification Organization
PEQP	Project Equipment Qualification Program
PS/BS	East/West Power Source Buildings
QA	Quality Assurance

QAP	Quality Assurance Program
QAPD	Quality Assurance Program Description
QC	Quality Control
QV&V	Quality Assurance Verification and Validation
R/B	Reactor Building
RCS	Reactor Coolant System
RFI	Radio Frequency Interface
RG	Regulatory Guide
RRS	Required Response Spectra
RV	Reactor Vessel
SG	Steam Generator
SLB	Steam Line Break
SQUG	Seismic Qualification Utility Group
SRP	Standard Review Plan
SRSS	Square Root Sum of the Squares
SSC	Structure, System and Component
SSE	Safe-shutdown Earthquake
T/B	Turbine Building
T/D	Turbine Driven
TEDE	Total Effective Dose Equivalent
TID	Technical Information Document or Total Integrated Dose
TMI	Three Mile Island
TRS	Test Response Spectrum
UPS	Uninteruptible Power Supply
ZPA	Zero Period Accelerations

Definitions

Architect / Engineer (A/E) – A licensed business organization responsible for the detailed design engineering for a US-APWR Project or portion thereof. The A/E may also provide procurement, construction, startup and other services to the Project. A Project may have more than one A/E, each responsible for some aspect of the Project.

Class 1E – The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or that are otherwise essential in preventing significant release of radioactive material to the environment. Class 1E equipment is safety-related equipment.

Construction Phase – As used in this Report, the Construction Phase refers to work performed on the project site to construct the US-APWR. This phase normally is initiated while detailed design is being completed and while initial procurement activities are commencing. The construction phase is completed prior to fuel load but some construction forces will remain to support initial power ascension testing activities. Construction can not begin until the licensee has received a Combined License or a Limited Work Authorization or Early Site Permit.

Constructor – The business organization(s) responsible for the actual construction of a US-APWR plant. The Constructor typically operates as a General Contractor (normally licensed as such) and subcontracts some construction activities.

Design Control Document (DCD) – A multi-chapter document that describes, in detail, how the design of the standard US-APWR complies with U.S. NRC regulatory requirements. The DCD is part of the documentation submitted to obtain approval from the NRC to manufacture and sell the US-APWR to U.S. utilities.

Design Phase – A time period when detailed analysis and engineering design is performed as part of a US-APWR project.

Engineering, Procurement and Construction (EPC) – A project milestone associated with the plant owner contracting for the engineering design, procurement and construction activities associated with an US-APWR project.

Environmental Condition – The expected temperature, pressure, humidity (including submergence or impingement), chemical, radiation, seismic, EMI/RFI, aging and synergistic effects that an SSC may experience during normal, accident, testing and post accident conditions at the location within the facility at which the SSC is installed.

Equipment Qualification – Systematic approach to verify, demonstrate and document, by one or more defined methods, that structures, systems and components (SSCs) addressed by the equipment qualification program are qualified for use in all anticipated environmental conditions (including seismic) such that the SSC can fulfill its intended safety function during normal, testing, accident and post accident conditions including postulated design basis events.

Equipment Qualification Program – A program to provide for the generation and maintenance of evidence (records) to demonstrate that SSCs requiring environmental, seismic or functional qualification are qualified for use in plant environments associated with normal, abnormal, accident and post accident environmental conditions including postulated design basis events (DBE). An Equipment Qualification Program generates and maintains equipment qualification records in accordance with established program procedures and quality assurance requirements. For the US-APWR, the Equipment Qualification Program is defined by the US-APWR Equipment Qualification Directives and Procedures.

Equipment Qualification Data Summary Report (EQDSR) – A report (documentation, also called equipment qualification data package) prepared for an SSC, demonstrating compliance with equipment qualification requirements (also known as a Qualification Specification).

Equipment Environmental Qualification Report (EEQR) – A report (documentation, also called EEQ data package) prepared for an SSC, demonstrating compliance with environmental qualification requirements (also known as an Environmental Qualification Specification). An EEQR is a subset of an EQDSR.

Equipment Seismic Qualification Report (ESQR) – A report (documentation, also called SEQ data package) prepared for an SSC, demonstrating compliance with seismic qualification requirements (also known as a Seismic Qualification Specification). An ESQR is a subset of an EQDSR.

Equipment Vendor – The manufacturer or supplier responsible for providing an SSC to the Project. Normally, the equipment vendor is responsible for demonstrating that the SSC meets the Equipment Qualification Specification for SSCs requiring environmental, seismic or functional qualification.

Harsh Environment – An environment expected as a result of the postulated service conditions appropriate for the design basis and post-design basis accidents (DBA) of the station. (A design basis accident is that subset of a design basis event (DBE) which requires safety function performance). Harsh environments are the result of a loss of cooling accident (LOCA) / high-energy line break (HELB) inside containment and post-LOCA or HELB outside containment. (This definition from IEEE Std 100-2000, *"IEEE 100 The Authoritative Dictionary of IEEE Standard Terms Seventh Edition*")

MHI – Mitsubishi Heavy Industries, Ltd., the designer and manufacturer of the US-APWR nuclear power plant. MHI is headquartered in Tokyo, Japan.

Mild Environment – An environment that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences. From IEEE Std 100, the definition for *Mild Environment* is:

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

MNES - Mitsubishi Nuclear Energy Systems, Inc. – U.S. representative and subsidiary of Mitsubishi Heavy Industries, Ltd.

MELCO - Mitsubishi Electric Corporation – MHI subsidiary supplier for electrical, Instrumentation and Control (I&C), and digital control system for the US-APWR.

Nuclear Steam Supply System (NSSS) – The Reactor Coolant System (RCS), components and supporting equipment for the US-APWR. The NSSS includes the steam generators and all systems connected to the primary loop.

Personnel Qualification – The minimum level of qualification, knowledge, familiarity, understanding, education, experience and/or expertise required for development, specifying, procuring, testing, analysis, implementation, maintenance, documentation, record keeping and/or administration process of the entire equipment qualification program.

Project Phases – As used in this Report, a project phase defines and divides (in time) various aspects of an overall project. For any project, and in particular a US-APWR project, the project follows a distinct sequence of events that can be referred to as phases of the project. For example, at the beginning, the project is in the conceptualization phase, this phase would transition to an evaluation phase (can it be done?), and so on. From an equipment qualification standpoint, the Equipment Qualification Program is invoked when the project moves into the detailed design and procurement phase and remains operational throughout the life of the plant.

Project – The work associated with all aspects of licensing, design, procurement, construction startup and early operation of a US-APWR for a utility client (plant licensee). See Project Phases.

Project Equipment Qualification Organization (PEQO) – An organization established within the Project Organization responsible for the implementation of the Project Equipment Qualification Program.

Project Equipment Qualification Program (PEQP) – A project-specific Equipment Qualification Program, defined by the US-APWR equipment qualification Directives and Procedures, to provide for the preparation and maintenance of records that demonstrate evidence that SSCs requiring environmental, seismic or functional qualification will operate to fulfill its intended safety function during normal, abnormal, accident, and post accident conditions, including postulated DBEs.

Project Organization – The organization contractually established by MNES/MHI to deliver a US-APWR(s) to a U.S. utility client (plant Licensee). The Project Organization includes companies and organizations responsible for the licensing, design, manufacture, supply, construction, testing, and related services needed to deliver a US-APWR to a plant licensee. At aminimum Project Organization will include MHI, MNES, Architect/Engineer (s), Constructors (s), equipment vendor, and the Licensee.

Qualification Specification – The definition of all environmental conditions (parameters) that a specific SSC must meet in order to be accepted for inclusion in the Project.

Quality Assurance Record – A completed document that furnishes evidence of the quality of items and/or activities affecting quality. Records may also include specially processed documents such as radiographs, photographs, negatives or microforms.

Restricted Material – Confidential or proprietary information, including aspects of national security withheld from general circulation for reasons of security, non-disclosure agreements, company privacy, or other distribution restrictions.

Safety Function – An action relied upon during and following a design basis event to provide for:

- Integrity of the reactor coolant system
- The capability to shut down and maintain the reactor in a safe-shutdown condition
- The capability to prevent or mitigate the consequences of an accident that could result in the potential for offsite exposures comparable to the guideline exposures of Title10 Energy, Code of Federal Regulations (CFR): 10 CFR 50.34(a)(1) or 10 CFR 100.11

Safety-related Structures, Systems and Components (SSC) – The definition from 10 CFR 50.49 is for electric equipment (SSC) that are relied upon to remain functional during, and following, design basis events to ensure:

- The integrity of the reactor coolant pressure boundary
- The capability to shut down the reactor and maintain it in a safe shutdown condition or
- The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the applicable guideline exposures set forth in 10 CFR 50.34(a)(1) or 10 CFR 100.11 of Title 10 of the Code of Federal Regulations, as applicable

Structures, Systems and Components (SSCs) – terminology used to reflect that the items used to construct the US-APWR can be evaluated as portions of a structure (building), a system (e.g. feed water), or as individual components.

Structures, Systems and Components (SSCs) That Require Environmental, Seismic or Functional Qualification (or Equipment Qualification) –SSCs that meet one or more of the following criteria:

- Equipment important to safety within the scope described in DCD Section 3.11, *Introduction*, that is qualified by the Environmental Qualification Program
- Mechanical and electric equipment with special seismic qualification requirements such as seismic categories I and II
- Active mechanical components required to be functionally qualified

Operating-basis Earthquake (OBE) – The vibratory seismic motion associated with the plant shutdown and inspection during normal operation of the nuclear plant.

Procurement Phase – The period of time (usually years) in which the components and materials used to construct the US-APWR for a specific project are ordered and delivered to the project site. The Procurement Phase of a Project is normally initiated following detailed project design phases and some procurement will continue through the early Operational Phase as various items are delivered to the project site.

Safe Shutdown Earthquake (SSE) – The vibratory seismic motion (greater than the OBE) for which certain SSCs in a plant are designed to remain functional as specified by safety analysis of plant.

System – A system consists of all components and related equipment needed to fulfill a task or action that is built into a US-APWR (e.g., feed water system, safety injection system).

Test Phase – As used in this report, the test phase of a project encompasses both construction, pre-operational (including Containment Integrated Leak Rate Testing and Plant Hot Functional Testing) and power ascension testing. These tests are sequenced so as to 1) verify SSCs are properly constructed (construction tests), SSCs will operate as designed (preoperational tests), and the plant as a whole will operate as designed (power ascension testing). Construction and Pre-operational testing occur prior to fuel load, power ascension testing occurs after fuel load (low power operational license obtained). Some of these tests are used to verify certain aspects of a SSC's equipment qualification requirements are acceptable.

Turnover phase – A time period when construction/installation is complete and associated SSCs are ready for functional testing and subsequent turnover to the Licensee (U.S. Utility).

UPS – An acronym for an uninterruptible power supply.

U.S. Utility – The organization obtaining a construction and operating license for a US-APWR(s) from the U.S. Nuclear Regulatory Commission (NRC).

Vendor – see Equipment Vendor.

Note: As used in this Technical Report, the phrases shown in this section have the meaning defined herein unless modified in a specific section of the Technical Report by either direct definition or the context in which they are used.

1.0 PURPOSE

The purpose of this technical report is to describe the Equipment Qualification Program applicable to structures, systems and components (SSCs) used to construct a Mitsubishi Heavy Industries, Ltd. (MHI), US-APWR nuclear power plant that require environmental, seismic, or functional qualification.

The purpose of the US-APWR Equipment Qualification Program is to both enhance the quality of the US-APWR and to comply with the requirements of Title 10 Energy, Code of Federal Regulations (CFR) and in particular Parts 50.49 and Appendix A of 10 CFR 50, General Design Criteria (GDC) 2 and 4. The Introduction to 10 CFR 50, Appendix A includes the following wording (emphasis added in bold):

> "Under the provisions of 10 CFR 50.34, an application for a construction permit must include the principal design criteria for a proposed facility. Under the provisions of 10 CFR 52.47, 52.79, 52.137, and 52.157, an application for a **design certification**, **combined license**, **design approval, or manufacturing license**, respectively, must include the principal design criteria for a proposed facility. The principal design criteria establish the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components **important to safety**; that is, structures, systems, and components that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public. …"

There are 64 GDCs applicable to power reactors, however, GDCs 1, 2 and 4 are the primary criteria dealing with equipment qualification requirements. GDC No.1 requires quality assurance programs and records applicable to a power reactor project. GDCs 2 and 4 are quoted below.

GDC No. 2 states:

> "*Criterion 2--Design bases for protection against natural phenomena*. **Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.** The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed."

GDC No. 4 states:

> "*Criterion 4--Environmental and dynamic effects design bases*. Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be **compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.** These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic

effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."

These requirements are partially codified in 10 CFR 50.49 which states, in part:

> "Each holder of or an applicant for an operating license issued under this part, or a combined license or manufacturing license issued under part 52 of this chapter, other than a nuclear power plant for which the certifications required under 10 CFR 50.82(a)(1) or 10 CFR 52.110(a)(1) of this chapter have been submitted, **shall establish a program for qualifying the electric equipment defined in paragraph (b) of this section.** For a manufacturing license, only electric equipment defined in paragraph (b) which is within the scope of the manufactured reactor must be included in the program."

> [Note that American Society of Mechanical Engineers (ASME) QME-1 provides guidance on the qualification of active mechanical components (e.g., valves) and has been endorsed by the NRC in lieu of a direct statutory reference.]

These regulations require that the US-APWR be designed and constructed using SSCs that will withstand both normal (mild) and potentially harsh environments associated with accident conditions. The US-APWR Equipment Qualification Program provides a structured approach to complying with these requirements as an integrated US-APWR equipment qualification program that includes an environmental qualification program. Equipment qualification is defined in part as a systematic approach to generating documentation, by one or more defined methods, to demonstrate that SSCs, which require environmental, seismic, or functional qualification, are qualified for operation in all anticipated environmental conditions. This qualification provides assurance that the SSC can fulfill its intended safety function during normal, testing, accident and post accident conditions, including postulated Design Basis Accidents (DBA). Anticipated environmental conditions are the expected temperature, pressure, humidity (including submergence or impingement), chemical, radiation, seismic, aging and synergistic effects that an SSC may experience during normal, accident, testing and post accident conditions at the location within the facility at which the SSC is installed.

The scope of SSCs qualified by the Equipment Qualification Program is defined in Section 2.0.

1.1 Applicable Codes and Standards

Questions arise concerning which version of various guidance documents including Regulatory Guides (RGs), industry standards and industry practices (NUPIC, EPRI) apply to a certain element of the Equipment Qualification Program. There are cases where one version (revision) may be referenced in one area of this Technical Report and another revision referenced somewhere else. This occurs because the guidance documents are not fully synchronized to the ongoing revision process that occurs with these documents. NUREG 0800, the Standard Review Plan (SRP) for licensing documentation discusses this and indicates that the licensing documents should reference the versions that are in effect approximately 6 months from the date of submission of a licensing document.

In the case of this Technical Report, which describes the generic US-APWR Equipment Qualification Program, various current guidance documents have endorsed different versions of the same national standard. It should be recognized that these irregularities will be resolved

when a specific Equipment Qualification Program is established for a specific US-APWR project. For a specific project, the applicable Combined Operating License (COL) application will be the controlling licensing document for the project. The implementation of a Project Specific Equipment Qualification Program will address these irregularities. The guidance documents are not mandatory, but instead only provide general direction on how statutory requirements are to be met. As such, as long as the established programs address statutory requirements, the NRC has indicated that this is an acceptable methodology. In summary, various revisions of equipment qualification guidance documents may be referenced primarily because that aspect of the equipment qualification program is based on the version of the guidance document presently published by the NRC. As an example, RG 1.89s (Rev. 0, 1974 & Rev. 1, 1984) are directed primarily at qualifying electrical equipment in harsh environments. They both endorse IEEE Std 323-1974. RG 1.209 (Rev. 0, 2007), which addresses safety-related computer-based I&C systems, primarily located in mild environments, endorses IEEE Std 323-2003. Similar examples exist with other elements of the Equipment Qualification Program.

1.2 References to the US-APWR Design Control Document and Combined License Applications

The US-APWR Design Control Document (DCD) as well as Combined License (COL) Application is referenced in various places in this Technical Report. This Technical Report as well as the DCD and specific COL applications are separate documents subject to independent revision. As such, hard or specific references to various tables, sections and attachments in these documents have been explicitly excluded from this Technical Report to preclude the possibility of a revision to one document potentially impacting another document. When references are made to the DCD or COL documents, the intent is to indicate that the information needed to implement a project specific Equipment Qualification Program is contained in these documents and will used at the time a specific Equipment Qualification Program developed.

1.3 Deleted

2.0 SCOPE

This technical report describes the US-APWR Equipment Qualification Program. The Equipment Qualification Program is presented and discussed in the US-APWR Design Control Document (DCD). The equipment qualification process is required for the life of the facility (i.e., ~60 years). However, the US-APWR Equipment Qualification Program covered by this Technical Report only addresses the period from plant licensing (DCD and COL) submittal for a project through the point the Operating License (OL) is received. Figure 2-1 illustrates the various phases for equipment qualification and the US-APWR Equipment Qualification Program. The roles and responsibilities for an Equipment Qualification Program change, depending on the phase of a project being considered. At the DCD phase, Mitsubishi Heavy Industries, Ltd. (MHI) is responsible for establishing a generic Equipment Qualification Program. The Equipment Qualification Program addresses:

- Equipment important to safety within the scope described in DCD Section 3.11, *Introduction*, that is qualified by the Environmental Qualification Program
- Active mechanical components required to be functionally qualified
- Mechanical and electrical equipment with special seismic qualification requirements such as seismic categories I and II

Plant piping systems are analyzed under ASME requirements and are, therefore, not directly covered by the Equipment Qualification Program (active components such as valves in these piping systems are covered by the Equipment Qualification Program).

MHI is represented in the U.S. by Mitsubishi Nuclear Energy Systems (MNES). MNES is the primary interface between U.S. utilities, the NRC and MHI. The Equipment Qualification Program has been formulated under the basic assumption that MHI/MNES will be contracted to deliver a US-APWR to a U.S. utility (MHI is the reactor vendor pursuant to 10 CFR 52). Under this arrangement, MHI/MNES will most likely contract with a qualified Architect/Engineer (A/E) and others (equipment suppliers) to deliver the plant to a U.S. utility. MHI/MNES is responsible for establishing the contractual relationships between the organizations supporting the delivery of a US-APWR. These contractual relationships, with designated roles and responsibilities, are collectively referred to as the Project Organization. The Project Equipment Qualification Program (PEQP) is a project-specific Equipment Qualification Program. MHI/MNES is responsible for establishing a project equipment qualification organization (PEQO) within the Project Organization to implement the PEQP. The PEQO is responsible for preparing Project equipment qualification Implementing Procedure(s) following the guidance given in the US-APWR Equipment Qualification Program. These procedures shall be prepared, reviewed, and approved pursuant to the project Quality Assurance Program (QAP) requirements.

For each US-APWR project contracted for delivery to a U.S. utility, the PEQP shall be established in such a way that it applies to all project activities, including those associated with the design, procurement, construction, testing, turnover and operational phases of the project. At the completion of the Equipment Qualification Program, equipment qualification records will be turned over to the utility as the basis for the utility's Operational Equipment Qualification Program. The Scope of this Technical Report is to provide a description of:

1. The basis for equipment qualification
2. The US-APWR positions relative to the applicable governing rules, regulations, standards and industry practices

3. The US-APWR Equipment Qualification Program directives and procedures
4. Equipment qualification parameters for a generic plant
5. The Equipment Qualification Program generic policies and procedures (that implement a PEQP).
6. The Equipment Qualification Program implementation requirements for a specific project
7. Application of the Equipment Qualification Program to the design, procurement, construction, testing, turnover and operational phases of a project.
8. Turnover of the Equipment Qualification Program /records to the operating utility
9. A description of the equipment qualification process including both environmental and seismic programs.
10. A brief discussion of the implementation of equipment qualification by the operating utility in support of the 60 year design life.

Table F-1 provides a roadmap describing the applicability of various sections on this report to the environmental qualification, seismic qualification, and functional qualification programs for SSCs.

2.1 Equipment Qualification Program Technical Report Layout

Sections 1.0 and 2.0 of this Report provide the basis for the formal adaptation of an Equipment Qualification Program. Section 3.0 describes the applicable statutory (Title 10, Energy Code of Federal Regulation) requirements, the regulatory guidance (RGs and NUREGs), industry codes and standards, and industry practices applicable to the US-APWR Equipment Qualification Program. Section 4.0 describes the Qualification Criteria for mild and harsh environment definitions, aging, operability time, performance criterion, margin, treatment of failures and traceability. Section 5.0 discusses the normal, abnormal and DBA conditions. Section 6.0 describes the equipment qualification Methods including type test, analysis, operating experience, on-going qualification and combination of methods. Section 7 describes the equipment qualification process. Section 8 describes the generic MHI US-APWR Equipment Qualification Program. Section 9 describes implementation of the Equipment Qualification Program from the licensing phase through turnover to the Utility (licensee) for a specific project. Section 10 describes the process for turning the Project Equipment Qualification Program over to the Utility (licensee) for a specific project and becoming the Operational Equipment Qualification Program. Section 11 briefly describes the content and scope of the licensee's Equipment Qualification Program and Section 11 provides a Summary of the MHI US-APWR Equipment Qualification Program.

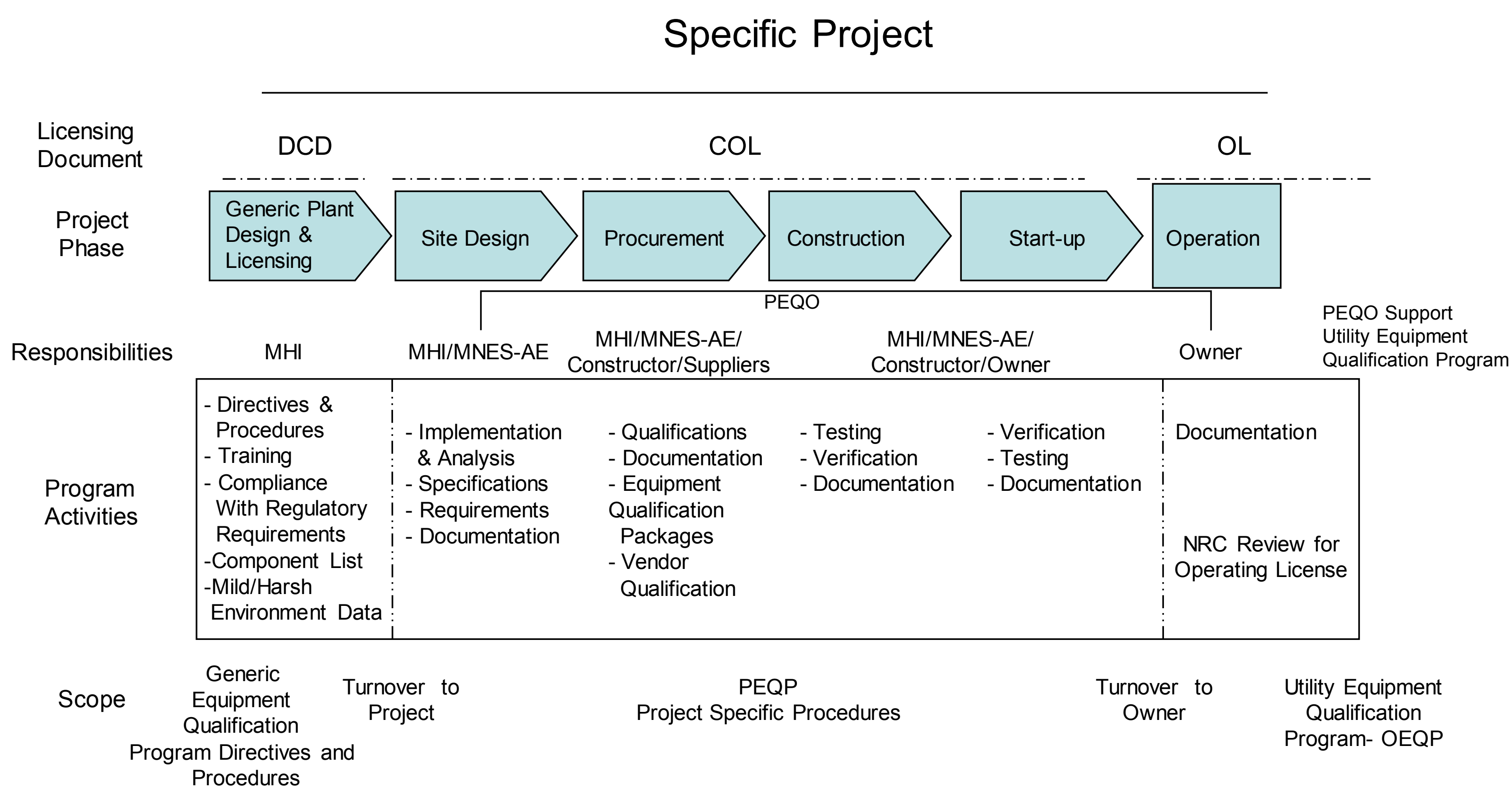
Figure 2-1 illustrates the scope of a project-specific Equipment Qualification Program. Projects can be divided into phases, and although the distinctions between these phases are in practice not sharp, from a planning or management perspective, they are unique. The DCD process licenses a standardized US-APWR, including the generic Equipment Qualification Program. When a plant is sold, an application is normally submitted for a COL that covers the time period associated with site-specific design, procurement, construction and startup phases of the project. Site design phase in COL also includes development of site-specific environmental data that is used to verify the standard design, and evaluate site-specific portions of the plant, including input design parameters for equipment qualification. Prior to and during the initial power ascension testing, the COL transitions to a full Operating License (OL). The PEQP covers the time period and phases associated with the COL up to

the point when a full OL is authorized. At the point that the plant is complete, and the project transitions to the owner and the PEQP transitions to the owner's (plant licensee's) Equipment Qualification Program. The licensee's Equipment Qualification Program is an operational program primarily designed to assure qualified replacement parts are used during the life of the plant. The PEQP is a design, procure, construct and test Equipment Qualification Program. Thus, for each US-APWR, there are three applicable and distinct Equipment Qualification Programs. They are:

1. **Generic Equipment Qualification Program:** The program that provides the foundation for the project-specific Equipment Qualification Program. This program and the associated commitments to the NRC are addressed in the DCD and in this Technical Report.
2. **Project Equipment Qualification Program (PEQP):** An Equipment Qualification Program that is implemented under, and governed by, the MHI/MNES equipment qualification Directives and Procedures for a specific project. A PEQP generates and maintains equipment qualification records in accordance with established project program procedures and quality assurance requirements. This program is implemented under a COL (or associated limited work authorizations). That is, it is implemented when a project transitions from the early licensing phase to the actual implementation phase.
3. **Licensee's Operational Equipment Qualification Program (OEQP):** The plant owner's long-term Operational Equipment Qualification Program. The OEQP is based on the records and results of the PEQP. The transition from the PEQP to OEQP occurs at the time of initial plant licensure (OL or as a condition of licensure, e.g. at or before fuel load). The plant Equipment Qualification Program covers the life of the plant (~60 yrs) and is discussed in the licensee's COL application (Ch 13 of the COL).

The Technical Report is primarily concerned with the generic US-APWR Equipment Qualification Program and its implementation as a PEQP. The next section describes the statutory and regulatory basis for equipment qualification.

Figure 2-1 Project Equipment Qualification Program (PEQP) Implementation Framework



DCD – Design Control Document – Generic to all US-APWRs

COL – Combined Operating License – Specific to each plant/site

OL - Operating License – Issued to plant owner/operator

PEQO – Project Equipment Qualification Organization

PEQP – Project Equipment Qualification Program

OEQP – Operational Equipment Qualification Program

3.0 REGULATORY STATUTES, REGULATORY GUIDES, INDUSTRY CODES AND STANDARDS APPLICABLE TO EQUIPMENT QUALIFICATION

The regulatory basis for the US-APWR Equipment Qualification Program is briefly described in Section 1.0 of this Technical Report. This section expands on the initial regulatory basis and identifies additional guidance documents applicable to the implementation of the Equipment Qualification Program. The requirements and guidance provided in these documents form the basis for the equipment qualification procedures for the US-APWR Equipment Qualification Program as described in the DCD.

This section first identifies the major applicable federal statutes and the associated guidance documents (RGs). RGs are issued by the NRC as guidance to addressing regulatory requirements. RGs usually endorse one or more industry codes and standards. For equipment qualification, these are, for the most part, issued by the Institute of Electrical and Electronic Engineers (IEEE) and the American Society of Mechanical Engineers (ASME). Finally, industry groups such as the Electric Power Research Institute (EPRI), Nuclear Procurement Issues Committee (NUPIC) and Nuclear Industry Assessment Committee (NIAC) provide additional guidance and direction to various elements of an effective Equipment Qualification Program.

Attachment A summarizes identified regulations, codes, standards and industry documents applicable to the US-APWR Equipment Qualification Program. This section discusses the major statutory (10 CFR), regulatory (RGs), standards (industry, e.g., IEEE) and other documents that form the foundation for the US-APWR Equipment Qualification Program. There are additional RGs, industry codes and standards applicable to certain elements of the Equipment Qualification Program that are not listed in this section but are listed in the References section (Section 13.0) of this Technical Report.

3.1 Code of Federal Regulations and General Design Criteria

The design, construction and operation of a power reactor are governed by general requirements, or design criteria, by which each type of power reactor must comply. These general requirements assure that, regardless of reactor type, adherence to the principles of these criteria will result in a facility that minimizes the risk to workers and the public. These regulations are invoked in Title 10, Energy in the Code of Federal Regulations (CFR), Parts 34, 50 and 52, and particularly in 10 CFR 50, Appendix A. Adherence to the General Design Criteria (GDC) contained in Appendix A is a condition of licensure and is, in part, the basis for the need for an Equipment Qualification Program. As such, the GDCs form the basis for standards promulgated by IEEE and ASME pertaining to the equipment qualification. The applicable GDCs, along with a brief explanation, are listed below.

3.1.1 10 CFR 50.49 Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants

This is the key statute regarding equipment qualification for electrical equipment. It should be noted that this statute defines which equipment needs to be qualified and the specifications to which it needs to be qualified. 10 CFR 50.49 requirements are clarified in RG 1.89 and together they reference IEEE Std 323 as an acceptable methodology to follow in qualifying electrical equipment. In 10 CFR 50.49 and IEEE Std 323, a distinction is made between Harsh and Mild environments. In general,equipment important to safety within the scope described in DCD Section 3.11, *Introduction*, located in harsh environments are qualified

pursuant to IEEE Std 323 (and other applicable IEEE standards) while mild environment SSCs can be considered qualified provided the environmental conditions are specified in a purchase specification and the vendor provides appropriate documentation for the equipment demonstrating that it complies with the purchase specification requirements. When appropriate, environmental qualification and procurement of mechanical and electrical equipment will be performed using a combination of qualification testing as described in Section 6.0 of this report, supplemented with an acceptable commercial grade dedication program and documentation as detailed in EPRI and NRC approved EPRI topical reports. This procurement method uses commercial grade dedication when the supplier lacks a 10 CFR 50, Appendix B QA program.

Commercial grade dedication is based on nuclear industry documents (standards, codes, etc.) as outlined in NRC Inspection Procedures (IP) 38703, “Commercial-Grade Dedication” and IP 43004, “Inspection of Commercial Grade Dedication Programs”, the EPRI reports referenced or endorsed therein and NQA-1a-2009, PART II, SUBPART 2.14. Of particular importance is the critical parameter characteristics definition for equipment requiring environmental qualification and the verification of these critical characteristics during the Environmental Qualification Program’s harsh environment evaluation.

The purpose of commercial grade dedication acceptance is to provide reasonable assurance that an item meets specified requirements. Therefore, for applications which have environmental qualification requirements, these environmental qualification requirements will become an input to the commercial grade acceptance process when the selection of critical characteristics for acceptance is performed.

Non-destructive methods will be used to verify the critical characteristics of the item to provide reasonable assurance that each individual commercial-grade item will perform in the design basis accident/event (e.g., loss of coolant accident, high-energy line break). The critical characteristics which relate to the environmental qualification requirements will be weighted heavily in selection of critical characteristics for acceptance and will become part of the Critical Characteristics.

3.1.2 10 CFR 50 Appendix A: General Design Criteria for Nuclear Power Plants

GDC 1: QUALITY STANDARDS AND RECORDS
This GDC requires that:

“Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.”

The US-APWR Equipment Qualification Program encompasses the above criteria including requirements that all records associated with the Equipment Qualification

Program be maintained in accordance with the Quality Assurance Program Description (QAPD).

GDC 2: DESIGN BASES FOR PROTECTION AGAINST NATURAL PHENOMENA
This GDC requires that:

"Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed."

The US-APWR Equipment Qualification Program encompasses the above criteria. Safety-related SSCs must be qualified to withstand the effects of a seismic event or are designed such that their response or failure will be in a safe condition. The seismic category I and II equipment must be qualified to withstand anticipated seismic events for a specific plant (project). Thus the seismic qualification requirements are based on both plant-specific seismic criteria as well as the location within the facility.

GDC 4: ENVIRONMENTAL AND DYNAMIC EFFECTS DESIGN BASES.
This GDC requires that:

"Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."

The US-APWR Equipment Qualification Program encompasses the above criteria. Safety-related equipment located within the containment or support structures must be qualified to withstand anticipated conditions associated with a Loss-of-coolant Accident (LOCA, a harsh environment), unless the location in the plant will not change before or after a postulated accident (e.g., control room, also known as a mild environment).

GDC 19 CONTROL ROOM
This GDC requires that:

"A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions, including loss-of-coolant accidents. Adequate radiation

protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident. Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.

Applicants for and holders of construction permits and operating licenses under this part who apply on or after January 10, 1997, applicants for design approvals or certifications under part 52 of this chapter who apply on or after January 10, 1997, applicants for and holders of combined licenses or manufacturing licenses under part 52 of this chapter who do not reference a standard design approval or certification, or holders of operating licenses using an alternative source term under 10 CFR 50.67, shall meet the requirements of this criterion, except that with regard to control room access and occupancy, adequate radiation protection shall be provided to ensure that radiation exposures shall not exceed 0.05 Sv (5 rem) total effective dose equivalent (TEDE) as defined in 10 CFR 50.2 for the duration of the accident."

The US-APWR Equipment Qualification Program encompasses the above criteria. The control room design is required to allow safe operation during normal and accident (including post accident) conditions and to prevent radiation exposure (above a certain threshold) to the control room or personnel within it. Control room equipment must therefore be qualified for operation for both seismic and environmental conditions.

GDC 20 PROTECTION SYSTEM FUNCTIONS
This GDC requires that:

"The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety."

The US-APWR Equipment Qualification Program encompasses the above criteria. Thus, the plant protection systems shall be designed for all anticipated environmental and seismic conditions, and as such, the protection system components must be qualified.

GDC 21 PROTECTION SYSTEM RELIABILITY AND TESTABILITY
This GDC requires that:

"The protection system shall be designed for high functional reliability and inservice testability commensurate with the safety functions to be performed. Redundancy and independence designed into the protection system shall be sufficient to assure that (1) no single failure results in loss of the protection function and (2) removal from service of any component or channel does not result in loss of the required minimum redundancy unless the acceptable reliability of operation of the protection system can be otherwise demonstrated. The protection system shall be designed to permit periodic testing of its functioning when the reactor is in operation, including a capability to test

channels independently to determine failures and losses of redundancy that may have occurred."

The US-APWR Equipment Qualification Program encompasses the above criteria. Thus, the protection system design criteria for equipment qualification should include accomplishing these requirements under the environmental parameters for its location. This would indicate that testing a part of the protection system would not alter the equipment qualification environment protection for the remainder of the protection system. An example of this would be if a protection system instrument cabinet had to be opened to perform a test thus exposing the remainder of the protection system to an environment outside of the equipment qualification.

GDC 23 PROTECTION SYSTEM FAILURE MODES
This GDC requires that:

"The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis if conditions such as disconnection of the system, loss of energy (e.g., electric power, instrument air), or postulated adverse environments (e.g., extreme heat or cold, fire, pressure, steam, water, and radiation) are experienced."

The US-APWR Equipment Qualification Program encompasses the above criteria and therefore must identify possible extreme environmental conditions.

GDC 24 SEPARATION OF PROTECTION AND CONTROL SYSTEMS
This GDC is related to GDC 19 and 20, and therefore, aspects of the Equipment Qualification Program are invoked. This GDC requires that:

"The protection system shall be separated from control systems to the extent that failure of any single control system component or channel, or failure or removal from service of any single protection system component or channel which is common to the control and protection systems leaves intact a system satisfying all reliability, redundancy, and independence requirements of the protection system. Interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired."

The Equipment Qualification Program aspects of this GDC are in the physical isolation of the various components, systems and structures of the protection system. The US-APWR Equipment Qualification Program encompasses the above criteria.

GDC 29 PROTECTION AGAINST ANTICIPATED OPERATIONAL OCCURRENCES
This GDC is related to GDC 19 and 20, and therefore, aspects of the Equipment Qualification Program are invoked. This GDC requires that:
"The protection and reactivity control systems shall be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences."

The US-APWR Equipment Qualification Program encompasses the above criteria. These events include those that would have an outside environmental cause. These environmental parameters can be plant-specific and are described in general in Section 4.0 of this Report.

Other GDC's (e.g., 14, 22, 30 and 60) have elements of equipment qualification within them but are not as prominent as these cited in this Section but do have impact on the PEQP and are addressed when the PEQP procedures are implemented. Section 4.0 of this Technical Report provides additional discussions on GDC 14, 22, and 30.

3.2 NRC Staff Requirements Memoranda

10 CFR 50.34 (f) Post-TMI Requirements. These memoranda primarily concern the need for post-accident monitoring and recovery equipment to be qualified for post-accident conditions.

3.3 NRC Regulatory Guides

Regulatory Guides (RG) are issued to clarify statutory requirements and to advise licensees of the NRC's acceptance of using certain professional society codes and standards to meet these requirements. RGs will often point out differences acceptable to the staff in certain aspects of the codes and standards that the NRC believes should be followed to meet statutory requirements. The RGs listed below apply to the US-APWR Equipment Qualification Program in the areas identified.

RG 1.22, "PERIODIC TESTING OF PROTECTION SYSTEM ACTUATION FUNCTIONS"

This RG addresses the requirements for periodic automatic and manual tests.

The US-APWR Equipment Qualification Program function encompasses performance of the automatic and manual tests. See Section 3.1, (1), GDC 21 for additional information

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.29, REVISION 4, "SEISMIC DESIGN CLASSIFICATION"

In some cases, a Seismic Category I (safety-related) SSC will also include Seismic Category II (non-safety-related) equipment. However, Seismic Category II equipment is designed so that a Safe Shutdown Earthquake (SSE) will not result in a seismic induced failure that would impede the Category I safety related SSC from performing its intended design safety function.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.40, REVISION 1, "QUALIFICATION OF CONTINUOUS DUTY SAFETY-RELATED MOTORS FOR NUCLEAR POWER PLANTS"

IEEE Std 334-2006, "IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations," was prepared by Subcommittee 2 of the Joint Committee on Nuclear Power Standards of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and was subsequently approved by the IEEE Standards Committee on January 31, 2007.

The Standard delineates specific procedures for the qualification testing of Class I motors to demonstrate adequacy of design for service within the containment of nuclear power plants. These procedures provide for testing under conditions which simulate those imposed during normal operation in addition to those resulting from a design basis LOCA.

The Standard specifies procedures for accomplishing accelerated aging of components to simulate the effects of long-term operation, including radiation effects, and for subjecting a prototype aged motor to combined (steam) pressure, temperature, and chemical environments approximating those of the design basis LOCA.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.63, REVISION 3, "ELECTRIC PENETRATION ASSEMBLIES IN CONTAINMENT STRUCTURES FOR NUCLEAR POWER PLANTS"

IEEE Std 317-1983, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations," was prepared by a working group of Subcommittee 1, General Plant Criteria, of the Nuclear Power Engineering Committee of the Institute of Electrical and Electronics Engineers (IEEE) and was subsequently approved by the IEEE Standards Board on September 23, 1982. This standard prescribes requirements for the design, construction, testing, qualification, and installation of electric penetration assemblies in containment structures for stationary nuclear power generating stations.

Section 6.2.8(5) of IEEE Std 317-1983 requires that the duration of maximum short circuit current flow in test specimens of electric penetration assemblies be no less than 0.033 second.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.73, REVISION 0, JANUARY 1974, "QUALIFICATION TESTS OF ELECTRIC VALVE OPERATORS INSTALLED INSIDE THE CONTAINMENT OF NUCLEAR POWER PLANTS"

Provides guidance for electric valve operators installed inside the Containment of Nuclear Power Plants.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.89, REVISION 1, "ENVIRONMENTAL QUALIFICATION OF CERTAIN ELECTRIC EQUIPMENT IMPORTANT TO SAFETY FOR NUCLEAR POWER PLANTS"

This RG was issued in 1974 and was revised in 1984. The DCD and NUREG-0800 reference the 1984 version. The 1984 version of RG 1.89 endorses IEEE Std 323-1974. RG 1.89 provides the principal guidance for implementing the requirements and criteria of 10 CFR 50.49 for environmental qualification of electric equipment. However, certain NUREG-0588 Category I guidance may be used where relevant guidance is not provided in RG 1.89. The 1984 version provided additional guidance in addressing items

associated with environmental conditions caused by chemicals, radiation, high-energy line breaks (HELB), pressure changes, humidity and synergistic effects. This guidance is incorporated in the Equipment Qualification Program. The following describes how the US-APWR Equipment Qualification Program meets the guidance in RG 1.89 regarding environmental qualification of equipment.

Section 50.49 requires that three categories of electric equipment be qualified for their application and specified performance and provides requirements for establishing environmental qualification methods and qualification parameters. These three categories are (1) safety-related electric equipment (Class 1E), (2) non-Safety-Related electric equipment (non-Class 1E) whose failure under postulated environmental conditions could prevent satisfactory accomplishment of safety functions by safety-related equipment, and (3) certain post accident monitoring equipment. RG 1.89 applies only to these three categories of electric equipment.

This RG describes a methodology acceptable to the NRC staff for complying with Section 50.49 of 10 CFR 50 with regard to qualification of electric equipment for service in nuclear power plants to ensure that the equipment can perform its safety function during and after a DBA.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

The environmental qualification of the equipment covered by this RG is by an appropriate combination of testing and analysis. This RG addresses equipment that is located in both harsh and mild environments. Equipment that is located in harsh environments is qualified following the guidance provided in this RG and IEEE Std 323, and other documents as listed in this section of the Technical Report. Mild environments include those that are not adversely affected by plant accidents. Therefore, qualification of equipment in mild environments for temperature, humidity and radiation is normally done by analysis of component vendor specifications, room ambient conditions and heat rise calculations for the installed configuration. The vendors will normally test this equipment (in most cases using nationally recognized testing agencies such as Underwriters Laboratory) and certify its use in mild environments by industry recognized ratings (e.g., National Electric Manufacturers Association (NEMA), NEMA 1 – indoor locations, NEMA 3R outdoor subject to rain). As part of the vendor qualification, the vendor's test programs and manufacturing processes are audited. Seismic qualification and Electromagnetic Interference (EMI) qualification are normally done by type testing (for seismic, see RG 1.100 and IEEE Std 344-2004, and for EMI, see RG 1.180). This type of equipment generally has no known aging failure mechanisms and usually has an expected long service life. However, random failures and other long term issues are normally detected by an operating plant's periodic surveillance, calibration and testing programs. These types of failures, if they were to occur, are anticipated by the defenses-in-depth approach (i.e., single failure criteria) of multiple safety-related system divisions and associated separation criteria. Other environmental qualification requirements (e.g., synergistic effects) for equipment in mild environments are normally covered by analysis, as installed inspections or various forms of vendor certifications.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.97, REVISION 4, "CRITERIA FOR ACCIDENT MONITORING INSTRUMENTATION FOR NUCLEAR POWER PLANTS" - ENDORSES IEEE STD 497-2002

The equipment regulated by this RG is used to process and display signals from accident monitoring instrumentation of all variable types.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.100, REVISION 3, "SEISMIC QUALIFICATION OF ELECTRICAL AND ACTIVE MECHANICAL EQUIPMENT AND FUNCTIONAL QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT FOR NUCLEAR POWER PLANTS"

This RG endorses, with some exceptions and clarifications IEEE Std 344-2004, "*Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*", and ASME QME-1 2007, "*Qualification of Active Mechanical Equipment in Nuclear Power Plants,*" as the basis for seismic qualification of mechanical and electrical equipment. QME-1, as endorsed by RG 1.100 Rev 3, describes methods that the staff of the NRC considers acceptable for the qualification of components and non-metallic parts. The nuclear safety-related equipment governed by the US-APWR Equipment Qualification Program is designated Seismic Category I. It is designed and qualified to withstand the cumulative effects of a minimum of five (5) OBEs and one (1) SSE without loss of safety function or physical integrity. The input spectrum is selected to envelope all anticipated applications. Conformance to this envelope for specific applications is discussed in DCD Section 3.10.

ASME Code generally invokes American Institute of Steel Construction (AISC) for support design. However, for non-ASME supports and structures, such as those for electrical equipment, AISC N690 Code for safety-related steel structures is applicable. The US-APWR is committed to AISC N690, including Supplement 2, and specifies to apply N690 stress coefficients to the allowable stresses of AISC and American Iron and Steel Institute (AISI) in order to determine allowable stresses to be used.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.211, "QUALIFICATION OF SAFETY-RELATED CABLES AND FIELD SPLICES, FOR NUCLEAR POWER PLANTS"

This RG endorses IEEE Std 383, "IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations," 2003.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.156, "ENVIRONMENTAL QUALIFICATION OF CONNECTION ASSEMBLIES FOR NUCLEARPOWER PLANTS"

This RG endorses IEEE 572-1985. The US-APWR Equipment Qualification

Program employs the recommendations of RG 1.156 in specifying the qualification program plans where this guide supplements the guidance of IEEE 572 to demonstrate conformance with the guidance of IEEE 323.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG

RG 1.158, "QUALIFICATION OF SAFETY-RELATED LEAD STORAGE BATTERIES FOR NUCLEAR POWER PLANTS"

This RG endorses IEEE 535-1986. Thes US-APWR Equipment Qualification Program employs the recommendations of RG 1.158 in specifying the qualification program plans where this guide supplements the guidance of IEEE 535 to demonstrate conformance with the guidance of IEEE 323.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG

RG 1.180, REVISION 1, 2003, “GUIDELINES FOR EVALUATING ELECTROMAGNETIC AND RADIO-FREQUENCY INTERFERENCE IN SAFETY-RELATED INSTRUMENTATION AND CONTROL SYSTEMS”

This RG endorses Military Standard MIL-STD-461E and the International Electrotechnical Commission (IEC) 61000 series of EMI/ Radio Frequency Interface (RFI) test methods. Section 50.55a(h) of 10 CFR Part 50 requires that protection systems meet the requirements of the Institute of Electrical and Electronics Engineers (IEEE) standard (Std) IEEE Std 603-1991, “Criteria for Safety Systems for Nuclear Power Generating Stations.” 10 CFR 52.47(a)(vi) requires that an application for design certification must state the tests, inspections, analyses, and acceptance criteria that are necessary and sufficient to provide reasonable assurance that a plant will operate within the design certification. Methods for addressing electromagnetic compatibility (EMC) constitute Tier 2 information under the 10 CFR Part 52 requirements. The RG also endorses design and installation practices described in IEEE Std 1050-1996, “IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.”

Safety-related electronic equipment subject to potential EMI/RFI caused malfunctions is evaluated in the Equipment Qualification Program to verify acceptable operation using the guidance provided in this RG.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.209, “GUIDELINES FOR ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED COMPUTER-BASED INSTRUMENTATION AND CONTROL SYSTEMS IN NUCLEAR POWER PLANTS” - ENDORSES IEEE STD 323-2003

This referenced Equipment, which consists of safety-related computer-based I&C systems, is located in a mild environment. There is no change in the environment due to plant accidents. This equipment is tested and analyzed to satisfy the mild environmental qualification requirements.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

RG 1.183, "ALTERNATIVE RADIOLOGICAL SOURCE TERMS FOR EVALUATING DESIGN BASIS ACCIDENTS AT NUCLEAR POWER REACTORS"

This RG provides the basis for the radiation source term for evaluating DBAs and the resulting radiation doses input into the Equipment Qualification Program. This input is a critical characteristic of equipment requiring environmental qualification and these radiation doses are to be used in the purchase specification for this equipment. With respect to the RG, it provides the basis for the radiation source term as found in the introduction to the guide:

This guide provides guidance to licensees of operating power reactors on acceptable applications of alternative source terms; the scope, nature, and documentation of associated analyses and evaluations; consideration of impacts on analyzed risk; and content of submittals. This guide establishes an acceptable alternative source term (AST) and identifies the significant attributes of other ASTs that may be found acceptable by the NRC staff. This guide also identifies acceptable radiological analysis assumptions for use in conjunction with the accepted AST.

In 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Section 50.34, "Contents of Applications; Technical Information," requires that each applicant for a construction permit or operating license provide an analysis and evaluation of the design and performance of SSCs of the facility with the objective of assessing the risk to public health and safety resulting from operation of the facility. Applicants are also required by 10 CFR 50.34 to provide an analysis of the proposed site. In 10 CFR Part 100, "Reactor Site Criteria," Section 100.11 "Determination of Exclusion Area, Low Population Zone, and Population Center Distance," provides criteria for evaluating the radiological aspects of the proposed site. A footnote to 10 CFR 100.11 states that the fission product release assumed in these evaluations should be based upon a major accident involving substantial meltdown of the core with subsequent release of appreciable quantities of fission products.

Technical Information Document (TID) 14844, "Calculation of Distance Factors for Power and Test Reactor Sites" is cited in 10 CFR Part 100 as a source of further guidance on these analyses. Although initially used only for siting evaluations, the TID-14844 source term has been used in other design basis applications, such as environmental qualification of equipment under 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," and in some requirements related to Three Mile Island (TMI) as stated in NUREG-0737, "Clarification of TMI Action Plan Requirements." The analyses and evaluations required by 10 CFR 50.34 for an operating license are documented in the facility Final Safety Analysis Report (FSAR). Fundamental assumptions that are design inputs, including the source term, are to be included in the FSAR and become part of the facility design basis.

The US-APWR Equipment Qualification Program encompasses the requirements specified in this RG.

3.4 ASME and Other Industry Standards Codes

The following ASME codes and industry codes are applicable to the US-APWR during the design, procurement, and construction phases.

ASME Section III addresses safety-related mechanical components and systems and the qualification needed to meet the mechanical requirements of that code. This also includes the material specifications of those ASME Code Section III components and piping systems especially for the piping systems and components, including pipe, valves and other fittings that make up these systems. Seismic analysis criteria and methods for the mechanical and piping systems for the US-APWR follow this code. These requirements extend to the support systems and structures for the ASME Code Section III components and piping systems. Individual portions of the support structures are qualified by referring to the American Institute of Steel Construction (AISC) manual and accompanying analysis for steel structures (see below).

Active support components such as springs and snubbers are also covered under ASME codes. The equipment qualification requirements for ASME extend beyond confirmation of appropriate material specification via the Certified Mill Test Report (CMTR) or Certificate of Compliance in the case of items such as valves, pipe support spring hangers, or snubbers. This includes pressure testing of valves, chemical and environmental qualification for the material selection, painting of components, and other equipment qualification factors, as each design requires.

ASME NQA-1-1994 provides the Quality Assurance requirements needed for the above mechanical systems and components. ASME NQA-1-1994 also includes the documentation requirements necessary to meet this code. ASME NQA-1a-2009, PART II, SUBPART 2.14, Quality Assurance Requirements for Commercial Grade Items and Services, further defines commercial grade dedication process.

ASME QME-1, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants, 2007, describes methods that the staff of the NRC considers acceptable for use in the qualification of active mechanical equipment such as pumps, valves, dynamic restraints, and non-metallic parts. When a licensee commits to use ASME QME-1-2007 for its qualification of mechanical equipment, then the criteria and procedures delineated in ASME QME-1-2007 become part of the requirements for its qualification program.

ASME QME-1-2007, Nonmandatory Appendices to Section QR along with the Appendix QR-A to QR-E, QDR (QDR-A to QDR-C), and QV and QV-1 provide guidance on qualifying active mechanical equipment such as pumps, valves and dynamic restraints particularly their nonmetallic parts. These Sections are intended as a guide in the absence of project specific procedures to direct the PEQO in developing related equipment qualification procedures for the qualifying active mechanical equipment such as pumps, valves, dynamic restraints and non-metallic parts. However, if a licensee commits to use the non-mandatory appendix, then the criteria and procedures delineated in the non-mandatory appendix become part of the requirements for its qualification program. For example, if the licensee commits to use of QME-1-2007 Appendix QR-B for the qualification of non-metallic parts, then the criteria and procedures delineated in the non-mandatory appendix become part of the requirements for its qualification program. Qualification of non-metallic parts of mechanical equipment shall be performed in accordance with ASME QME-1-2007 Appendix QR-B as endorsed by RG 1.100

Rev 3. The following list from ASME QME-1-2007 Table of Contents indicates what items should be addressed by the PEQP:

- QR-A Seismic Qualification of Active Mechanical Equipment
  - Appendix QR-A Figures
  - Appendix QR-A Table
- QR-B Guide for Qualification of Nonmetallic Parts
- QDR Qualification of Dynamic Restraints
  - QDR-A Functional Specification for Dynamic Restraints
  - QDR-B Restraint Similarity
  - QDR-C Typical Values of Restraint Functional Parameters
- QP Qualification of Active Pump Assemblies
- QP-A Pump Specification Checklist
- QP-B Pump Shaft-Seal System Specification Checklist
- QP-C Pump Turbine Driver Specification Checklist
- QP-D Pump Similarity Checklist
- QP-E Guidelines for Shaft-Seal System Material and Design Considerations
- QV Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants
- QV-1 Qualification Specification for Active Valves
- QV-A Functional Specification for Active Valves for Nuclear Power Plants
- QV-G Guide to Section QV

The project specific equipment qualification procedures for Active Mechanical Equipment must be established to determine the suitability of materials, parts, and equipment needed for safety functions, and to verify that the design of such materials, parts, and equipment is adequate. The verification of design (i.e., qualification) for components located in harsh environments shall be demonstrated by appropriate testing and analysis. Testing at the actual conditions desired for qualification will normally be provided to assure that the nonmetallic will perform acceptably. Analysis can be an alternate method of demonstrating the information for one nonmetallic to the qualification of another. Details of the material analysis such as description of analytical methods, assumptions, justifications, supporting test data, conclusions, and limitations shall be recorded in the qualification documentation for each component. The test/analysis shall establish a qualification life or replacement schedule for the nonmetallic which shall be recorded in the qualification documentation.

The AISC manual and material specifications are used in design, engineering and fabrication of individual portions of the support structures. This includes fasteners, steel shapes, and welding specifications invoked from the American Welding Society (AWS) D1.1 code for prequalified welds. These prequalified welds of steel structures allow for support fabrication and are from the AWS code.

AWS standards are used for welding of metallic components under both ASME and AISC codes and will be addressed on a project-specific basis to allow inclusion of site-specific welding procedures at the time of construction for a US-APWR project.

See References (Section 13) for additional Industry Codes applicable to the US-APWR Equipment Qualification Program.

The US-APWR Equipment Qualification Program encompasses the above codes and standards.

3.5 NUREG-Series Publications (NRC Guidance Document for SRP for DCD)

NUREG 0800 addresses the preparation of the US-APWR DCD and an associated Combined License Application (COLA) FSAR, and the licensing requirements therein. NUREG 0800, *Standard Review Plan (SRP)* Section 3.10 addresses “Seismic and Dynamic Qualification of Mechanical and Electrical Equipment”. Section 3.11 addresses “Environmental Qualification of Mechanical and Electrical Equipment.” Refer to the US-APWR DCD and project COLA FSAR for the response to NUREG 0800, Section 3.10 and 3.11. The US-APWR DCD can be found as a public document filed with the U.S. Nuclear Regulatory Commission. The DCD provides the licensing basis and plant description for the standard US-APWR. The DCD and its Appendix 3D includes engineering and design details for the components and systems addressed by the Equipment Qualification Program and added details for the Equipment Qualification Program. Appendix 3D is the listing of the equipment and environmental requirements for the components and systems requiring environmental, seismic or functional qualification for the standard US-APWR. The COLA FSAR for a specific US-APWR plant project will include any site-specific items to be included in its Equipment Qualification Program.

3.6 IEEE and Other Standards

IEEE Std 344-2004, “IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations”

IEEE Std 323-2003, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations” (see discussion under RG 1.89 for IEEE Std 323-1974).

For additional standards, see Section 13.0, References.

The US-APWR Equipment Qualification Program encompasses the above codes and standards.

3.7 NSSS Industry Standards

Equipment qualification activities are addressed by other NSSS industry organizations, including the Electric Power Research Institute (EPRI), the Nuclear Procurement Issues Committee (NUPIC) and Nuclear Industry Assessment Committee (NIAC). The following is a list of equipment qualification relevant documents issued by these organizations.

<u>EPRI</u>

EPRI Commercial Grade Dedication methodologies, as approved by the NRC, are encompassed in the US-APWR Equipment Qualification Program. The following EPRI documents address commercial dedication.

> EPRI NP 5652 Guideline for the Utilization of Commercial Grade Items in Nuclear Safety-related Applications (NCIG-07), 1988
>
> EPRI TR-102260 Supplemental Guidance for the Application of EPRI NP5652 on the Utilization of Commercial Grade Items, 1994

EPRI TR-106439 Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications, 1996

EPRI TR-1001452 Generic Qualification of Commercial Grade Digital Devices, 2001

EPRI TR-1001468 Generic Qualification of Rosemount 3051N Pressure Transmitter, 2001

EPRI TR-112579 Critical Characteristics for Acceptance of Seismically Sensitive Items (CCASSI), 2000

EPRI TR-1003105 Dedicating Commercial-Grade Items Procured From ISO 9000 Suppliers, 2001

NUPIC

NUPIC Commercial Dedication methodologies, as approved by the NRC, are encompassed in the US-APWR Equipment Qualification Program.

NUPIC, Document No. 10 Commercial Grade Survey Description, 1999

NAIC

Audit Procedures and Guidelines available to members only.

The US-APWR Equipment Qualification Program encompasses the above codes and standards.

3.8 Quality Assurance

US-APWR activities are conducted under the control of Quality Assurance Program (QAP) Description For Design Certification of the US-APWR (PQD-HD-19005) and in turn a project specific QAP is implemented. The project quality assurance requirements address the following:

10 CFR Part 50 Appendix B

"GDC 1 and 10 CFR Part 50, Appendix B, Criteria XVII establish the requirements for records concerning the qualification of equipment. To satisfy these requirements, complete and auditable records shall be available, and the applicant must maintain them, for the life of the plant, at a central location. These files shall describe the qualification method used for all equipment in sufficient detail to document the degree of compliance in accordance with the criteria set forth in the DCD, Sections 3.10 and 3.11. These records shall be updated and kept current as equipment is replaced, further tested, or otherwise further qualified by the licensee. The equipment qualification file contains Equipment Qualification Summary Data Sheets (EQSDS) for each piece of equipment (i.e., each mechanical and electrical component of each system), which summarize the component's qualification.

ASME NQA-1

Mechanical design and analysis activities controlled by various ASME codes require that quality assurance activities associated with this work comply with ASME NQA-1.

The US-APWR Equipment Qualification Program encompasses the above requirements.

4.0 EQUIPMENT QUALIFICATION EVALUATION PARAMETERS

Section 3.0 of this Technical Report identified the applicable statutory, regulatory, industry codes and standards that provide the guidance needed for the US-APWR equipment qualification process. In this section, the parameters that are applied to the qualification process are discussed. The US-APWR equipment qualification process is based on dividing plant environments into harsh or mild categories and then determining, by analysis, what the expected environmental parameters are for each location. For example, inside containment is considered a harsh environment because during a design basis accident, containment temperatures and pressures can exceed normal ambient conditions. The expected environmental parameters, determined by analysis, applicable to each SSC important to safety within the scope described in DCD Section 3.11, *Introduction*, are shown in the US-APWR DCD and applicable COLA. The evaluation process requires that the SSC location be determined, then the applicable equipment qualification conditions identified as the basis for qualification.

4.1 Definition of Plant Location by Type of Environment

4.1.1 Mild Environment

A mild environment is one that would, at no time, be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences. From IEEE 100, "*IEEE 100 The Authoritative Dictionary of IEEE Standard Terms Seventh Edition*", the definition is: An environment expected as a result of normal service conditions and extremes (abnormal) in service conditions where seismic is the only design basis accident (DBA) of consequence. IEEE 100 also provides definitions for qualified life and other terms applicable to the Equipment Qualification Program. Typically a mild environment conforms with the environmental parameter limits of Table 4-1.

Mild environments can have exposure to radiation levels during normal operation. Equipment important to safety within the scope described in DCD Section 3.11, *Introduction*, but not in the containment or other location where they could see the harsh environmental condition described below, would fall into the mild category. The equipment would be evaluated for accident conditions to assure the mild category still applies. Refer to RG 1.209, "Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants" for guidance for safety-related computer-based I&C system on this situation. Mild areas are further defined in the US-APWR DCD.

For electrical and mechanical equipment located in a mild environment, acceptable environmental design can be demonstrated by the "design/purchase" specification process for the equipment. The "design/purchase" specification contains a description of the functional requirements for a specific environmental zone during normal environmental conditions and anticipated operational occurrences. The maintenance/surveillance program, in conjunction with the preventive maintenance program, provides assurance that equipment meeting the design/purchase specifications is qualified for the designed life of the component. Compliance by the Licensee (owner) with 10 CFR 50.65, "Requirements for monitoring the effectiveness of maintenance at nuclear power plants," and associated guidance in RG 1.160 are considered sufficient to provide reasonable assurance that environmental considerations established during design are reviewed every refueling outage and maintained on a continuing basis to

ensure that the qualified design life has not been reduced by thermal, radiation, and/or cyclic degradation resulting from unanticipated operational occurrences or service conditions. The environmental design and qualification status of components in both mild and harsh environments are to be maintained by the Licensee Operational Equipment Qualification Program as described in Section 11.0. As stated in DCD Subsection 3.11.1.2, in mild environment, seismic and aging qualification may still require testing or additional analysis. Because seismic events are the only DBA taken into consideration in a mild environment, equipment located in mild environment is not precluded from being seismically qualified.

4.1.2 Harsh Environment

A harsh environment is expected as a result of the postulated service conditions appropriate for the design basis and post-design basis accidents of the station. A design basis accident is a postulated accident that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to ensure public health and safety. Harsh environments are the result of a loss-of-coolant accident (LOCA)/high-energy line break (HELB) inside containment and post-LOCA or HELB outside containment (this definition from IEEE 100, "*IEEE 100 The Authoritative Dictionary of IEEE Standard Terms Seventh Edition*").

These special conditions can cause the local environment for the equipment requiring environmental qualification to be harsh in one or more parameters. These special conditions can result from a DBA, main steam line break (MSLB), main feedwater line break (MFLB), or other HELB. High radiation areas outside of the containment are also in a harsh environment.

Equipment that must withstand the environmental conditions that would exist before, during, and following a DBA is qualified for use in harsh environments. A DBA, such as LOCA could subject this equipment to elevated pressures, temperatures, humidity, radiation, and chemical effects (including post accident pH control). This equipment must operate without a loss of its safety function, for the time required to perform its engineered safeguards function(s). These environmental conditions for which the equipment is qualified include applicable time dependent temperature and pressure profiles, humidity, chemical effects, radiation, aging, submergence, and those synergistic effects that have a significant effect on the equipment performance. Equipment identified as being qualified for harsh environment includes the following:

a. Equipment located within containment
b. Equipment subject to HELBs (e.g., MSLB) both inside and outside of containment
c. Other SSCs that connect, support, tie into, or that can influence the equipment listed in "a" and "b" above.

4.2 Equipment Qualification Evaluation Parameters

Equipment important to safety within the scope described in DCD Section 3.11, *Introduction*, is required to be qualified by verifying that the appropriate environmental parameters be identified and used in the evaluation process. The main parameters are identified in 10 CFR 50.49, IEEE 323 and IEEE 344. They include, in addition to location discussed in section 4.1, the following:

- Aging

- Operating Time
- Temperature
- Pressure
- Humidity
- Chemical Effects
- Vibration
- Radiation
- Submergence
- Synergistic Effects
- Seismic
- Margins
- Other Parameters
- EMI/RFI

4.2.1 Aging

The requirements for addressing aging are contained, in part, in 10 CFR 50.49 (e)(5), which reads: “Equipment qualified by test must be preconditioned by natural or artificial (accelerated) aging to its end-of-installed life condition.” This regulation describes the considerations for the aging testing including preconditioning a given SSC before any further aging tests. This testing is used to help determine the service life of a SSC requiring environmental qualification. Aging requirements are SSC specific and are implemented on a project specific basis. Aging analysis addresses concerns regarding the design life, shelf life, and qualified life of SSCs located in harsh environments. Qualified Life addresses issues relative to in service thermal, radiation, vibration and chemical effects. IEEE 323 as well as other technical references, provides guidance in addressing Aging and Qualified Life analysis requirements. Qualified life of a component is based on the components limiting operable time. In most cases this is caused by the effects of use and aging for both mechanical and electrical components. Qualified life is based on a specific set of service conditions. An alternate to qualified life is to establish an end condition (end of life condition). Age testing simulates the effects of aging on a component subject to aging degradation. Factors impacting aging include design, function, humidity, radiation levels, materials, storage, wear and tear, oxidation, loss of material strength, cycling, temperature, vibration and other items (see IEEE 1205, “IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Stations”). Margin is normally applied to aging simulations for the various parameters being evaluated. No margin is applied for the time component. Aging simulations are conducted in accordance with guidelines provided in IEEE 323, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations” and IEEE 1205. Mechanical components are also subject to degradation by the aging process. Methodologies for addressing aging during the qualification of mechanical components are delineated in ASME QME-1. There are various methods that have been established to extend the qualified life of a component. These are discussed in IEEE 323 and IEEE 1205 and generally involve additional surveillances and an analysis of the conservatism in the original qualification process.

4.2.2 Operability Time

Equipment operating times are determined by the individual piece of equipment’s function, location, and safety class. This information is the result of engineering analysis for each piece of equipment. This equipment is evaluated for a time dependent safety function after a DBA. The time dependent safety functions are for tripping the reactor after a LOCA or other accident

signal, engineered safeguards initiation, post-accident monitoring, or containment isolation. Post accident operating times are factored into equipment which must remain operational following a DBA such as post accident monitoring equipment. The results are tabulated in the US-APWR DCD.

4.2.2.1 Shorter Operability Times

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

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

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

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

4.2.3 Temperature and LOCA/MSLB Analysis

Normal Operating Temperature – This temperature is defined as that temperature seen by equipment requiring environmental qualification during normal operation. This would include the effects of transient operation that could normally be expected over the US-APWR plant lifetime. This temperature is a function of the equipment's location, system function, and effects of any engineered ventilation. These are tabulated in the US-APWR DCD.

Containment temperatures and main steam line area temperatures include both normal operating temperatures and accident condition temperatures. The accident temperatures may impact each piece of equipment differently.

Accident Temperature - This temperature is defined as that temperature seen by the equipment during its operation during an accident. This equipment is designed to function at the higher temperature for a period of time as described in the DCD The equipment temperature may be higher from the LOCA/MSLB accident depending on other factors such as location. Engineering evaluation of all such accidents listed in Chapter 6 of the DCD is considered when determining the maximum or accident temperature.

4.2.4 Pressure and Basis for Design

The plant will normally operate at or near atmospheric pressure. During accident conditions the containment and main steam line areas (HELB) will see higher pressures.
Containment Pressure is a maximum from the LOCA analysis results and impacts each piece of equipment differently. The containment pressure is bounded by the large break loss of coolant accident discussed in the US-APWR DCD. Similarly, containment temperature response is bounded by the containment vessel response to steam system piping failures as discussed in the DCD. The DCD lists specific design pressures of various compartments within the containment internal structure to be used for equipment qualification. Note that the

maximum containment DBA pressure listed in the DCD is 68 psig, which is the expected value that will be used for equipment qualification.

Pipe Whip and Jet Impingement are two subsets of the Containment Building accident analysis. These have impact loadings, jet impingement pressure loadings, and local temperature increases that are accounted for in the Equipment Qualification Program analysis.

4.2.5 Humidity

Humidity refers to moisture content in the atmosphere and for most mild locations, the amount of humidity will be controlled by the plant Heating, Ventilation and Air Conditioning (HVAC) systems. Loss of HVAC may result in elevated humidity levels for these locations and the maximum possible humidity level is used to qualify equipment in mild environments. For the mild environment outdoor locations may have rain, snow, ice or other humidity considerations that apply to the qualification of equipment in these locations.

Humidity levels inside containment factor in both the harsh environment category and the mild environment categories for accident normal conditions. Equipment which must function through a DBA is qualified for harsh humidity conditions.

4.2.5.1 Outdoor and Other Environmental Impacts from Outside, Chemicals, etc.

Outdoor environmental impacts include effects from nearby bodies of water (oceans or lakes), weather effects such as hot or cold ambient temperatures, dry conditions and other site-specific factors. These impacts would also include flooding for equipment that is located outdoors, as described in Subsection 4.2.9.1.

4.2.6 Indoor Chemical Environment – pH for Fluids

Indoor chemical environmental qualification requirements address exposure of SSCs to various chemicals that can be released into the equipment's environment during a DBA. Chemical exposure also includes the potential for exposure to hydrogen based in a 100% fuel-clad metalwater reaction. During a DBA, fluids can have an elevated pH that is damaging to SSCs. The concentration of chemicals used for qualification is equivalent to, or more severe than, that resulting from the most limiting mode of plant operation (e.g., containment spray, emergency core cooling system initiation, or recirculation phase). If the chemical composition of the chemical spray is affected by the equipment malfunctions, the most severe chemical environment results from a single failure and online maintenance of gas turbine generator.

4.2.7 Vibration

Systems, structures and components (SSC) requiring environmental qualification may be subject to fatigue, accelerated aging or other harmful effects associated with vibration occurring during normal operation. Additionally, the equipment qualification criteria contain provisions for qualification due to vibration caused by hydrodynamic loads. These considerations will be included in the procurement specifications for the equipment. Vibration is sometimes identified during synergistic evaluations conducted during pre-operational and power ascension testing.

4.2.8 Radiation Dose

The radiation environment for qualification of equipment, described in US-APWR DCD Section 3.11, is the total integrated dose (TID) resulting from the normally expected radiation environment over the installed life of the equipment, plus that associated with the most severe design basis accident for which the equipment must remain functional. Additionally, dose rates may be a design consideration. Current regulatory guidance for assumptions for evaluating radiation doses for equipment qualification is included in RG 1.89, Rev. 1, as modified by RG 1.183, Appendix I.

The normal operating dose rates and consequent 60-year design expected doses at various locations inside containment are derived from theoretical calculations assuming an expected 60 years of continuous operations with reactor power of 4,451 MW and steady state operating conditions (see DCD Chapter 1).

The equipment qualification radiation environment parameters of TID and maximum dose rates were determined for all compartments containing equipment requiring environmental qualification. Gamma, Beta, and Neutron sources will be addressed where applicable. This is primarily a post accident evaluated radiation dose for inside the Containment Building. Containment radiation dose is a maximum from the LOCA analysis results and impacts each piece of equipment differently. These impacts are determined by the individual piece of equipment's function, location, and safety class. This information is the result of engineering analysis for each piece of equipment within the scope of the program. Radiation sources can include both airborne activity in the containment and radioactivity containing equipment inside or outside of the containment. If necessary, particular equipment components may be subjected to more detailed evaluations based on their actual locations with respect to radiation sources. The results of these calculations are shown in the US-APWR Environmental Qualification Equipment List and databases as described in the DCD. The radiation environment parameters determined and documented in the Environmental Qualification Equipment List will be used as input to related equipment purchase specifications, along with other appropriate qualification requirements.

Radiation doses associated with postulated accidents are determined by analytical computer codes as described in the DCD, Chapter 15. The dose rate results (for each elevation inside the Containment Building and areas of the Reactor Building containing equipment requiring environmental qualification) are summarized in Dose Maps provided in DCD Chapter 12 at several times after the postulated accident (i.e., 1 hr, 1 day, 1 week, and 1 month). These show the gamma radiation levels in the areas from contained circulating post-accident fluids, and are intended to show that areas requiring post-accident accessibility are indeed accessible by operating personnel. Although they are not intended for equipment qualification purposes, the radiological basis accident scenario used to develop these maps forms the basis to develop the time-integrated equipment qualification gamma doses for up to 1 year of post-accident exposure, with sufficient time increments to allow consideration of particular equipment operational duration requirements, some of which are less than 1 year.

4.2.8.1 Nuclear Source Terms

The Nuclear source term for the LOCA accident analysis follows American National Standars Institute(ANSI)/ American Nuclear Society (ANS) and NRC guidelines. Specifically, the guidance of 10 CFR 50.67 and NRC RG 1.183 are incorporated into the dose analysis.

In NRC RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," guidance acceptable to the NRC staff for determining the radiation dose and dose rate for equipment during postulated accident conditions is provided. These criteria, as supplemented by those of RG 1.89, is used to evaluate the accident source term used in the environmental design and qualification of equipment requiring environmental qualification. The radiation environment is based on the integrated effects of the normally expected radiation environment over the equipment's installed life, plus the effects associated with the most severe design basis event, during or following the event, when the equipment is required to remain functional.

4.2.8.2 Beta Dose Considerations

Beta radiation exposure must also be considered for equipment qualification purposes where applicable. Specifically, beta radiation exposure from airborne radioactivity in containment must be considered. Beta shielding of cable insulation/jacketing (based on the relatively short range of beta radiation, some “sacrificial” layer may generally be considered without affecting the function) and sub-component shielding by enclosures will also be considered. Beta radiation must also be considered for components immersed in recirculating post-accident fluids, both inside and outside containment.

4.2.8.3 Neutron Dose Considerations

Neutron dose is only seen directly adjacent to the reactor vessel during normal operations. This is a shielded area with no safety significant SSC that is impacted by this exposure.

4.2.8.4 Special Mild and Harsh Radiation Environment Limits and Testing Considerations

A mild radiation environment for electronic components (with semiconductors or electronic components containing organic material) is a total integrated dose less than 10 Gy (1E3 rad), and a mild radiation environment for other equipment is less than 100 Gy (1E4 rad) [Refer to NUREG-1503, “Final SER ABWR, Chapter 3, Design of Structures, Components, Equipment, and Systems,” and NUREG-1793, “Final SER AP1000, Chapter 3, Design of Structures, Components, Equipment, and Systems”]. Environmental qualification for electrical equipment located in a “Radiation harsh” environment (i.e., locations where radiation is the only harsh environmental condition) may be accomplished in accordance with 10 CFR 50.49 (f) (4) using analysis of test data (from identical materials) combined with radiation test information (i.e., partial test data), and appropriate consideration of margin and aging effects for nonmetallic components/materials. (10 CFR 50.49 is entitled “Environmental qualification of electric equipment important to safety for nuclear power plants,” and section (f) (4) indicates, “Each item of electric equipment important to safety must be qualified by one of the following methods:
(4) Analysis in combination with partial type test data that supports the analytical assumptions and conclusions”).

4.2.9 Submergence - Containment Flooding Analysis

Containment Flooding is from the LOCA analysis results and impacts each piece of equipment differently. These impacts are determined by the individual piece of equipment’s function, location, and safety class. This information is the result of engineering analysis for each piece of equipment that is environmentally qualified by this program.

The flooding parameters, for purposes of qualification of equipment mounted within the standard plant, are defined as the potential flood levels inside the standard plant seismic category I buildings and structures as established by Section 3.4 of the US- APWR DCD Tier 2 Chapter 3.

4.2.9.1 Areas Outside Containment - Flooding Analysis

For purposes of qualification of site-specific equipment mounted within site-specific buildings and structures, interior flood levels are to be specified by the PEQO based on site-specific systems and flooding analysis. For qualification of equipment mounted in the plant yard, qualification shall be performed considering the exterior flood level parameters given in the associated COL for a specific project.

With respect to equipment qualification, it is the responsibility of the PEQO to determine whether a particular piece of equipment will be subject to submergence (partial or whole) based on the flood level present at its plant-specific elevation(s) and location(s).

4.2.9.2 Condensation

SSCs may be located in areas where condensation can impact the performance of the SSC. SSCs described in US-APWR DCD Section 3.11 located in areas subject to condensation will be rated for wet locations or otherwise protected. Condensation can be considered a synergistic effect and the US-APWR Equipment Qualification Program provides for synergistic inspections during pre-operational and power ascension testing to assist in identifying any areas in the plant which may be exposed to un-expected condensation.

4.2.10 Synergistic Effects

10 CFR 50.49 requires that equipment qualification programs include provisions to identify and mitigate synergistic effects to SSCs requiring environmental qualification. Synergistic effects can effect SSCs by accelerating aging, chemical effects, or other effects caused by differences in the as-installed environment over that of the as-design environment. Synergistic effects are identified by both analysis and physical inspection. A synergistic effects evaluation program will be implemented by the PEQO to evaluate SSCs requiring environmental qualification during initial construction and pre-operational testing (including hot functional) as well as during power ascension testing. Long term synergistic effects may be detected by the plant operator ongoing surveillance, testing and inspection programs.

4.2.11 Seismic Qualification of SSCs with Special Seismic Requirements

Appendix B of this Technical Report provides a detailed description of the US-APWR Equipment Seismic Qualification Program. The Seismic Qualification Program is a subset of the Equipment Qualification Program.

4.2.12 Margin

The term “margin” refers to the extent by which this equipment meets and exceeds the required equipment qualification parameter values defined in this Section. Margin is defined in 10 CFR 50.49(e)(8), which states:

8) *Margins*. Margins must be applied to account for unquantified uncertainty, such as the effects of production variations and inaccuracies in test instruments. These margins are in addition to any conservatisms applied during the derivation of local environmental conditions of the equipment unless these conservatisms can be quantified and shown to contain appropriate margins.

Thus selected equipment will have the qualified margins in equipment qualification parameters to assure that there is adequate conservatism in the equipment. It is not possible to quantify the amount of margin for a given environmental parameter with exact certainty, due to manufacturing tolerances, the selected equipment will be evaluated by the PEQO to verify that the margins are acceptable. This means that the procurement process will evaluate the margins and coordinate with the PEQO where appropriate. Table 4-2 lists margin requirements applied to the designated environmental parameters.

4.2.12.1 Normal and Accident Environmental Parameters

The margin requirements listed in Table 4-2 apply to both Normal and Accident Environmental Parameters where it is possible to exceed the analyzed value or where sufficient conservatism is required to account for the concerns identified in Section 4.3 and IEEE 323. Where exceptions are taken for some margin requirements, the reason for the exception is analyzed, reviewed, documented and approved by the PEQO.

4.2.12.2 Synergistic and Vibration Effects and Aging Margins

Margin is not applicable to synergistic effects. Margin is applied to aging in normal and post accident evaluations. Margin for vibration is not applied to normal and abnormal parameters, it is applied to accident parameters.

4.2.12.3 Radiation

A margin of 10 percent is applied to the calculated accident dose in abnormal and accident conditions.

4.2.12.4 High-Energy Line Break Conditions

High-energy line breaks are accidents resulting from various cases of loss-of-coolant accidents, main steam or feed water and other high-energy line breaks. Equipment qualification requirements are determined by combining pressure or temperature profiles versus time These profiles provide adequate margin applicable to any transient corresponding to a single break.

The US-APWR equipment qualification requires that the profiles should be additionally considered with a margin of 15°F of the temperature and 10% of the containment or building design pressure according to IEEE 323-1974.

4.2.12.5 Seismic Conditions

Required response spectra are discussed in Attachment B of this Technical Report. Amplitude margin is not added to these conditions. Peak broadening is also discussed in Attachment B of this Technical Report. Seismic qualification by analysis addresses margin requirements by other methods of conservatism while using the same sets of requirements - no amplitude

margin is included. Qualification by testing will increase the amplitude of seismic profiles by 10 percent to incorporate margin.

4.2.13 Other Parameters

Equipment defined in Section 2.0 is qualified to function within the parameters identified in this section. This equipment is first stored when it arrives on site during construction, before it is installed. After the plant begins operations, this equipment is also stored at the plant site in the form of spare parts, replacement parts, and equipment to support periodic maintenance activities, including refueling outages. This equipment may have an effective shelf life, therefore, the effects of aging and storage environment can impact the equipment's qualification for service. Aging and storage conditions impact non-metallic components such as O-rings and gaskets, as well as certain electronics and electrical equipment may shorten the Qualified Life. IEEE 323 defines design life as "the time period during which satisfactory performance can be expected for a specific set of service conditions". A components qualified life includes an element of shelf life (time in storage), if shelf life is shortened, then qualified life is shortened and the equipment may not enough qualified life to meet the design life of the component. Equipment Qualification Program implementation includes provisions to monitor storage conditions during construction and to maintain equipment addressed by the program in controlled environmental conditions prior to and after installation where appropriate.

4.2.14 EMI/RFI

The EMI/RFI qualification is specified to comply with the guidance provided in RG 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrument and Control Systems" and RG 1.209, "Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants". EMC qualification requirements are applicable to safety-related electrical equipment. EMC qualification requirements are not applicable to mechanical equipment".

4.3 Equipment Failures

Equipment qualification is a method of verifying and documenting that equipment defined in Section 2.0 will be capable of fulfilling their design safety function in all anticipated environmental and seismic conditions. The US-APWR incorporates four separate and redundant safety trains for all major safety functions. This effectively provides redundant and diversified coverage for random single failures. Periodic tests, inspections, calibrations and surveillance provide a proven mechanism to identify and correct, in a timely fashion, individual SSC failures. The plant OEQP provides assurances that individual failures are identified and corrected. The OEQP is described in Section 11 of this Technical Report.

4.4 Summary

The equipment qualification parameters used to qualify SSCs addressed by the Equipment Qualification Program were discussed in this section. The equipment qualification parameters that are used in the equipment qualification process are consistent with regulatory and industry standards. The selection and use of these parameters involves a number of considerations and these are factored into the overall Equipment Qualification Program as described in the following sections. The following sections start with the equipment qualification process and methods and continue into a description of the Equipment Qualification Program. The

Equipment Qualification Program description includes a more formal approach to equipment qualification of SSCs for the US-APWR.

Table 4-1 Typical Mild Environmental Parameter Limits

Parameter	Limit	Notes
Temperature	≤ 120 ºF ≤ 150 ºF ≤ 130 ºF	Inside Containment (Normal) Inside Containment (Abnormal) Outside Containment
Pressure	Atmospheric	Nominal
Humidity	Non-condensing	
Radiation	$\leq 10^3$ rads gamma $\leq 10^4$ rads gamma	Electronic devices and components Non-electronic devices and components
Chemistry	None	

Table 4-2 US-APWR Equipment Qualification Program Margin Values

Condition	Parameter	Required Margin	Notes
NORMAL:	Aging	+10%	+10% time margin, +10% radiation and/or selection of conservative test parameters.
ABNORMAL:	Temperature/ Humidity		Margin is in "time" at abnormal test extremes.
	Pressure	None	Nominally atmospheric.
	Radiation	+10%	Include in aging doses, if applicable.
	Chemical Effects	+10%	In alkalinity of adjusted sump pH. Not applicable outside containment.
	Voltage	+/- 10%	Simulated during temperature/humidity test.
	Frequency	+/- 5%	
	Submergence	Note 1	Generally, precluded by design.
ACCIDENT:	Transient Temperature and Pressure	Location Dependent	Temperature (+15°F) and pressure (+10 psig peak) margins added to transient profile.
	Chemical Effects	+10%	In alkalinity of adjusted sump pH. Not applicable outside containment.
	Radiation	+10%	Added to calculated total integrated dose.
	Submergence	Note 1	Generally, precluded by design.
	Seismic/ Vibration	+10%	Of acceleration at equipment mounting point for either SSE or line-mounted equipment vibration. (See subsection 4.5.4.)
	Post-accident Aging	+10%	In time demonstrated via Arrhenius time/temperature relationship calculation.

Note:
1. Margin in submergence conditions is achieved by increases in temperature (+15°F), pressure (+10%), and chemistry (+10% in alkalinity of adjusted sump pH). Also, accident conditions submergence testing envelops abnormal conditions submergence conditions.

5.0 NORMAL, ABNORMAL AND DESIGN BASIS ACCIDENT CONDITIONS

This section describes the equipment qualification categories and their associated conditions and parameters.
The categories of conditions and parameters are normal, abnormal, and design basis accident as considered in the equipment qualification of US-APWR equipment addressed in the Equipment Qualification Program.

- Normal conditions are the plant operating 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 conditions are the range of anticipated but occasional off normal plant conditions for which the equipment is designed to operate for its required period of time without any special maintenance or calibration.
- Design basis accident conditions are those post accident environmental parameters to which the equipment may be subjected while maintaining its specified operating characteristics under those conditions.

The following subsections define the basis for the normal, abnormal, design basis accident, and post-DBA environmental conditions specified for the qualification of equipment in the US-APWR Equipment Qualification Program.

5.1 Normal Operating Conditions

5.1.1 Pressure, Temperature and Humidity

The calculated values for temperature, pressure and humidity during normal operation are specified in Table 5-1 as a function of in-plant location.

5.1.2 Radiation Dose

The radiation environment for qualification of equipment requiring environmental qualification is the Total Integrated Dose resulting from the normally expected radiation environment over the installed life of the equipment, plus that associated with the most severe DBA for which the equipment must remain functional. Additionally, dose rates may be a design consideration.

The normal operating dose rates and consequent 60-year design expected doses at various locations inside containment are derived from radiation zones for normal operation (see DCD Chapter 12) assuming an expected 60 years of continuous operations with reactor power of 4,451 MW and steady state operating conditions (see DCD Chapter 1). The values for radiation during normal operation are specified in Table 5-4 as a function of in-plant location.

5.2 Abnormal Operating Conditions

The abnormal operating conditions are those environments caused by anticipated but occasional off normal plant conditions that lead to potential short-term changes in local equipment environment. Abnormal operating conditions are specified in Table 5-2 as a function of equipment location.

5.3 Seismic Events

See Attachment B of this Technical Report.

5.4 Containment Test Environment

RG 1.18 requires that containment integrated leak rate testing acceptance criteria is 1.15 times design pressure. The design pressure of the US-APWR containment is 68 psig. Consequently, the maximum pressure specified for the containment test is 68 x 1.15 = 78.2 psig. Environmental parameters, such as containment temperature and humidity associated with this test are enveloped by the parameters specified for normal or abnormal plant conditions.

5.5 Design Basis Accident Conditions

Equipment qualification requirements are specified where the design basis accident potentially changes the local environment due to increased temperature, pressure, humidity, radiation, or seismic effects. The environmental conditions for each applicable design basis accident are summarized in Table 5-3.

5.5.1 High-Energy Line Break Accidents Inside Containment

5.5.1.1 Radiation Environment – Loss-of-coolant Accident

The equipment qualification radiation environment parameters of Total Integrated Dose and maximum dose rates are determined for all compartments containing equipment requiring environmental qualification. Gamma and Beta sources are addressed where applicable. Analyses of radiation environments are performed in calculations. This is primarily a post accident evaluated radiation dose for inside the Containment. Radiation dose from containment is a maximum from the LOCA analysis results and impacts each piece of equipment differently. These impacts are determined by the individual piece of equipment's function, location, and safety class. This information is the result of engineering analysis for each piece of equipment requiring environmental qualification. Radiation sources can include both airborne activity in the containment and radioactivity containing equipment inside or outside of the containment. If necessary, particular equipment components may be subjected to more detailed evaluations based on their actual locations with respect to radiation sources.

Radiation doses associated with postulated accidents are determined by methods, models and assumptions described in Appendix E.

The Nuclear source term for the LOCA accident analysis follows ANSI/ANS and NRC guidelines. Specifically, the guidance of 10 CFR 50.34 and NRC RG 1.183 are incorporated into the dose analysis. Beta radiation is also considered for component inside Containment (Zone 1).

The dose rate results (for each elevation inside the Containment and areas of the Reactor Building containing equipment requiring environmental qualification) are summarized in Dose Maps provided in DCD Chapter 12 at several times after the postulated accident (i.e., 1 hr, 1 day, 1 week, and 1 month). These show the gamma radiation levels in the areas from contained circulating post-accident fluids, and are intended to show that areas requiring post-accident accessibility are indeed accessible by operating personnel. Although they are not

intended for equipment qualification purposes, the radiological basis accident scenario used to develop these maps forms the basis to develop the time-integrated equipment qualification gamma doses for up to 1 year of post-accident exposure, with sufficient time increments to allow consideration of particular equipment operational duration requirements, some of which are less than 1 year.

The values for radiation after the LOCA accident are specified in Table 5-5 as a function of in-plant location and time after accident. In Zone 6 (Penetration Area and Safeguard Component Area (Radiological Area)), it is conservatively assumed that the radiation doses are equal to the values of in Zone 1.

5.5.1.2 Radiation Environment – Steam Line Break Accident

Steam line break accident sources are based on the release of reactor coolant system radioactive, content with the design basis fuel defect level of 1.0 percent assumed during operation. Assuming that a "transient-initiated" iodine activity spike occurs, this increases the reactor coolant radioactivity during the Steam line break accident 500 times the normal radioactivity in the reactor coolant.

The activity inventory is instantaneously released into the containment (Zone 1) or the main steam piping area (Zone 10). It is conservatively assumed that the radiation doses in Zone 1 and Zone 10 resulting from a steam line break are equal to the values in Zone 1 for a loss-of-coolant accident.

The volume of the main steam/feedwater piping area is about 109,000 ft^3, while the free volume of the containment is about 2,800,000 ft^3, which is about 30 times that of the main steam/feedwater piping area. The amount of radioactivity released to the main steam/feedwater piping area at the time of a main steam line break (MSLB) is less than 1/30th of that released to the containment in the event of a loss of coolant accident (LOCA). Consequently, the concentration of radioactivity in the main steam/feedwater piping area at the time of MSLB is low compared to that inside the containment at the time of LOCA. Thus, it is concluded that the radiological environmental condition are less severe compared to that inside the containment at the time of LOCA.

Radioactivity in the primary coolant and that in the secondary coolant are taken into consideration as the source term, wherein the initial concentration of radioactivity in the secondary coolant is assumed to be 1/10th of that in the primary coolant.

Also the following iodine spikes are considered:
Pre-transient iodine spike: 60 μ Ci/g
Transient-initiated iodine spike: 500 × iodine reactor coolant concentration

The amount of radioactivity for pre-transient iodine spike is less than gap radioactivity (1% × 5% of the core inventory). The Regulatory Guide (RG) 1.183 notes that the transient initiated spikes need not be set larger than the available radioactivity for release from the fuel gap of all fuel pins. Thus, the amount of iodine to spike into the primary coolant is set at the amount of iodine in the gap.

Release due to primary-to-secondary leakage is assumed to continue for 14 hr for MSLB as in the case of radiological consequences (See DCD Chapter 15). The leak rate of 600 gpd results in a leakage of 350 gallons. As primary coolant is 646,000 lbm, about 0.5% of

radioactivity in the primary coolant will be released due to leakage from the primary system. It is also assumed that all primary-to-secondary leakage is discharged into the main steam/feedwater piping Reactor Building area.

The contribution due to release from the secondary coolant is taken into account. It is assumed that the total amount of initial radioactivity in the liquid phase of the steam generator (SG) will be released into the main steam/feedwater piping area. The SG water is assumed to be 968,000 lbm which corresponds to 4 SGs at the time of hot zero power. This means the released radioactivity from secondary coolant to the main steam/feedwater piping area is equivalent to about 15% of the radioactivity in the primary coolant. Thus, the total contribution including the primary-to-secondary leakage and secondary coolant is given as release of about 16% of radioactivity in primary coolant, except for noble gas. The noble gas is assumed not to exist in SG.

Since the amount of iodine in gap is 0.05% of core inventory, about 0.0003% of the core inventory is assumed to be released into the main steam/feedwater piping area due to the contribution of iodine spike.

Radioactivity released into the main steam/feedwater piping area during MSLB

	Contribution of radioactivity in primary coolant	Contribution of radioactivity in secondary coolant	Contribution of iodine spike
Noble gas	0.5% of primary coolant	-	-
Iodine	16% of primary coolant		0.0003% of core inventory
Others	16% of primary coolant		-

The radioactivity in primary coolant is sufficiently smaller than core inventory (See DCD Tables 15A-3 and 15A-10). The MSLB radioactivity released into the main steam/feedwater piping area as shown in the above table is less than 1/30th of that released to the containment in the LOCA. Thus, it is concluded that the radiological environmental condition in the main steam/feedwater piping area at the time of MSLB is less severe compared to that inside the containment at the time of LOCA.

5.5.1.3 Containment Pressure and Basis for Design

Maximum containment pressure transient is evaluated from the postulated LOCA analysis results and impacts each piece of equipment differently. The containment pressure is bounded by the large break LOCA discussed in the US-APWR DCD Chapter 6. Combined pressure curve considering various DBAs in the containment general region is presented in Figure 5-1. It doesn’t include margin from IEEE 323-1974.

5.5.1.4 Containment Temperature and LOCA/MSLB Analysis

Containment temperature calculated from the postulated LOCA or MSLB analysis impacts each piece of equipment differently.
This temperature is defined as that seen by the equipment during an accident. The equipment requiring environmental qualification is designed to function at the higher temperature for a time described in the DCD Chapter 6. The DCD contains tables and figures for specific temperature gradients to be used for equipment qualification. Equipment located within the

containment that is exposed to DBA would have its accident temperature determined by its location in the structure. Combined temperature curve considering various DBAs in the containment general region is presented in Figure 5-2. In this figure, margin required in IEEE 323-1974 is not included.

5.5.1.5 Indoor Chemical Environment – pH for Fluids

Indoor chemical environmental qualification requirements address exposure of SSCs to fluids inside the Containment Building post LOCA. These fluids can have an elevated pH that is damaging to SSCs. This requires the PEQO to perform engineering analysis and equipment qualification of SSCs to assure their performance maintains nuclear safety. The resulting equipment qualification requirements for chemical exposure are provided in the procurement documents and specifications.

The concentration of chemicals used for qualification is based on that resulting from the plant operation at DBA (e.g., containment spray, emergency core cooling system operation).
The PEQO is responsible for developing project level procedures to include these site-specific factors in the procurement effort.

5.5.1.6 Containment Flooding Analysis

Containment flooding is from the LOCA analysis results and impacts each piece of equipment differently. These impacts are determined by the individual piece of equipment's function, location, and safety class. This information is the result of engineering analysis for each piece of equipment that requires environmental qualification.

The flooding parameters, for purposes of qualification of equipment mounted within the standard plant, are defined as the potential flood levels inside the standard plant seismic category I buildings and structures as established by Section 3.4 of the US-APWR DCD Tier 2 Chapter 3.

5.5.2 High-Energy Line Break Accidents Outside Containment

Most of equipment outside containment is located in such regions that the normal operating environment is maintained even if a high-energy line break occurs. Some SSCs requiring environmental qualification are located in the main steam/feedwater (MS/MF) piping areas of the reactor building (R/B) where harsh environment are attained by postulated Steam Line Break (SLB) or Feedwater Line Break (FLB). The equipment that is qualified for the conditions resulting from such HELBs is required to operate and is presented in Table 3D-2 in the DCD.

Figures 5-3 and 5-4 show the combined design conditions for the equipment that is required to perform during and post SLB and FLB. Both of Figures 5-3 and 5-4 do not include margin from IEEE 323-1974. Margin for pressure and temperature for MS/MF Line B is not required as these maximum values are fixed to the maximum pressure/temperatures associated with full power operations. These values can not exceed full power operating values due to the thermodynamic nature of the process.

The maximum pressure for any accident in the R/B is 14.5 psig and maximum temperature is 327 $^{\circ}$F according to the results of GOTHIC calculation with multi-noding systems. Volumes of each compartment are underestimated by assuming loss volume is larger, compared to the actual design for conservatism. Parameters and options relevant to the junctions are set to

provide large flow resistance between compartments. Passive heat sinks, blowout panels with the openings to the outer atmosphere and drain flow paths to the turbine building (T/B) are considered as mitigation elements in the analysis. Condensation, natural convection and radiation heat transfer to the passive heat sinks are considered as mentioned in NUREG-0588 revision 1. 130 ^{o}F of initial compartment vapor temperature is assumed in the analysis as a maximum value during operative or non-operative plant status presented in Table 5-1.

The following are assumptions for released mass and energy which are considered as a boundary condition in the analysis:

Maximum 1 ft^2 of the broken area is assumed for the both SLB and FLB analyses, which is described in SRP Branch Technical Position 3-3.

Released mass and energy regarding SLB is calculated by MARVEL-M which was incorporated to the containment analysis regarding MSLB in DCD Chapter 6.

For FLB, initial critical flow discharge based on the semi-steady state and subsequently discharged flow by the main feedwater pump are considered by simple assumption in order to calculate the released mass and energy.

Table 5-1 Normal Operating Environments (Sheet 1 of 3)

Location/Parameter	Normal Range	Notes
Zone 1 Containment		
Temperature	50 - 120 ºF	
Pressure	-0.3 - +2.0 psig	
Humidity	Non-condensing	
Chemistry	None	
Zone 2 Main Control Room and Remote Shutdown Console Room		
Temperature	73 - 78 ºF	
Pressure	Atmospheric	
Humidity	25 - 60 %	
Chemistry	None	
Zone 3 Class 1E I&C Room		
Temperature	68 - 79 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 4 Class 1E Electrical Room, UPS Room, Battery Charger Room, and Reactor Trip Breaker Room		
Temperature	50 - 95 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 5 Class 1E Battery Room		
Temperature	65 - 77 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 6 Penetration Area and Safeguard Component Area (Radiological Area)		
Temperature	50 - 130 ºF	
Pressure	Slightly Negative	
Humidity	Non-condensing	
Chemistry	None	

Table 5-1 Normal Operating Environments (Sheet 2 of 3)

Location/Parameter	Normal Range	Notes
Zone 7 Safety-Related Component Area (Radiological Area)		
Temperature	50 - 130 ºF	
Pressure	Slightly Negative	
Humidity	Non-condensing	
Chemistry	None	
Zone 8 Safety-Related Component Area (Non-Radiological Area)		
Temperature	50 - 130 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 9 Essential Chiller Unit and Pump Room		
Temperature	50 - 105 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 10 Main Steam/Feedwater Piping Area		
Temperature	50 - 130 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 11 Gas Turbine Area		
Temperature	50 - 120 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	
Zone 12 Fuel Handling Area		
Temperature	50 - 105 ºF	
Pressure	Slightly Negative	
Humidity	Non-condensing	
Chemistry	None	

Table 5-1 Normal Operating Environments (Sheet 3 of 3)

Location/Parameter	Normal Range	Notes
Zone 13 Auxiliary Building General Mechanical Area (Radiological Area)		
Temperature	50 - 105 ºF	
Pressure	Slightly Negative	
Humidity	Non-condensing	
Chemistry	None	
Zone 14 Turbine Building General Mechanical Area (Non-Radiological Area)		
Temperature	50 - 105 ºF	
Pressure	Atmospheric	
Humidity	Non-condensing	
Chemistry	None	

Table 5-2 Abnormal Room Conditions

Zone[1]/Room	Maximum Temperature	Humidity
Zone 1 Containment	150 ºF	Non-Condensing
Zone 2, 3, 4 and 5 All Rooms	122 ºF	Non-Condensing
Zone 8 EFW (T/D) Pump Room	175 ºF	Non-Condensing

Notes:
1. See Table 5-1 for environmental zone.

Table 5-3 Accident Environments

Zone[1]/Rooms	Parameter	
Zone 1	Temperature, Pressure	See Figure 5-1, 2
Zone 2 Main Control Room	Pressure	Exceed + 0.125 inch w.g.[2]
	Humidity	Non-Condensing
Zone 6	Pressure	Below – 0.25 inch w.g.
Zone 10	Temperature, Pressure	See Figure 5-3, 4

Notes:
1. See Table 5-1 for environmental zone.
2. Relative to all adjacent spaces to the control room envelope.

Table 5-4 Radiation Environments (Normal Operation)

Location			radiation (rad/h)			
			γ	n	β	total
Zone 1 Containment	1-1	Reactor Vessel	1.3E+6	1.3E+6	-[1]	2.6E+6
	1-2	Nuclear Instrument System	3.1E+3	1.5E+5	-[1]	1.5E+5
	1-3	Inside Reactor Coolant System	1.7E+3	-[1]	-[1]	1.7E+3
	1-4	Inside Secondary Shield (including Regenerative HX Room)	5.0E+2	-[1]	-[2]	5.0E+2
	1-5	Under Operation Floor	1.0E+2	-[1]	-[1]	1.0E+2
	1-6	Above Operation Floor (including Refueling Water Storage Pit)	1.0E+0	-[1]	8.0E-2[3]	1.1E+0
Zone 2 MCR and Remote Shutdown Console Room			2.5E-4	-[1]	-[1]	2.5E-4
Zone 3 Class 1E I&C Room			2.5E-4	-[1]	-[1]	2.5E-4
Zone 4 Class 1E I&C Room, UPS Room, Battery Charger Room, and Reactor Trip Breaker Room			2.5E-4	-[1]	-[1]	2.5E-4
Zone 5 Class 1E Battery Room			2.5E-4	-[1]	-[1]	2.5E-4
Zone 6 Penetration Area and Safeguard Components Area(Radiological Area)			1.0E+2	-[1]	-[1]	1.0E+2
Zone 7 Safety Related Component Area(Radiological Area)			1.0E+2	-[1]	-[1]	1.0E+2
Zone 8 Safety Related Component Area (Non-Radiological Area)			2.5E-4	-[1]	-[1]	2.5E-4
Zone 9 Essential Chiller Unit and Pump Room			2.5E-4	-[1]	-[1]	2.5E-4
Zone 10 Main Steam/Feedwater Piping Area			2.5E-4	-[1]	-[1]	2.5E-4
Zone 11 Gas Turbine Area			2.5E-4	-[1]	-[1]	2.5E-4
Zone 12 Fuel Handling Area			1.5E-2	-[1]	4.6E-3[3]	2.0E-2
Zone 13 Reactor Building and Auxiliary Building General Mechanical Area (Radiological Area)	13-1	Auxiliary Building	5.0E+2	-[1]	-[1]	5.0E+2
	13-2	Reactor Building Sample HX Room	1.0E+2	-[1]	-[1]	1.0E+2
	13-3	Reactor Building Passage	2.5E-3	-[1]	-[1]	2.5E-3
Zone 14 Reactor Building and Turbine Building General Mechanical Area(Non-Radiological Area)			2.5E-4	-[1]	-[1]	2.5E-4

Notes to Table 5-4

1: This dose rate is negligible or zero when compared to the total dose rate.
2: Irradiation by beta radiation will be negligible as the thermocouple sensor in RCS hot/cold leg manifold is covered with a stainless steel sheath.
3: This dose rate is beta radiation from airborne.

Table 5-5 Total Integrated Dose for Zone (Sheet 1 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
1-1	5 min	6.9E+11	6.9E+11	-	1.4E+12	1.6E+3 (2.0E+3)[2]	4.8E+3	6.4E+3 (6.8E+3)[2]	1.4E+12 (1.4E+12)[2]	Harsh	Harsh
	2 wks [1]					4.0E+7 (5.8E+7)[2]	2.5E+8	2.9E+8 (3.1E+8)[2]	1.4E+12 (1.4E+12)[2]	Harsh	Harsh
	4 mos					5.3E+7 (1.1E+8)[2]	3.5E+8	4.0E+8 (4.6E+8)[2]	1.4E+12 (1.4E+12)[2]	Harsh	Harsh
	1 yr					5.3E+7 (1.7E+8)[2]	4.1E+8	4.6E+8 (5.8E+8)[2]	1.4E+12 (1.4E+12)[2]	Harsh	Harsh
1-2	5 min	1.7E+09	7.9E+10	-	8.1E+10	1.6E+3	4.8E+3	6.4E+3	8.1E+10	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	8.1E+10	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	8.1E+10	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	8.1E+10	Harsh	Harsh
1-3	5 min	9.0E+08	-	-	9.0E+08	1.6E+3	4.8E+3	6.4E+3	9.0E+8	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	1.2E+9	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	1.3E+9	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	1.4E+9	Harsh	Harsh

Table 5-5 Total Integrated Dose for Zone (Sheet 2 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
1-4	5 min	2.7E+08	-	-	2.7E+08	1.6E+3	4.8E+3	6.4E+3	2.7E+8	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	5.6E+8	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	6.7E+8	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	7.3E+8	Harsh	Harsh
1-5	5 min	5.3E+07	-	-	5.3E+07	1.6E+3	4.8E+3	6.4E+3	5.3E+7	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	3.5E+8	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	4.6E+8	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	5.2E+8	Harsh	Harsh
1-6	5 min	5.3E+05	-	4.3E+04	5.7E+05	1.6E+3 (2.0E+3)[2]	4.8E+3	6.4E+3 (6.8E+3)[2]	5.8E+5 (5.8E+5)[2]	Harsh	Harsh
	2 wks [1]					4.0E+7 (5.8E+7)[2]	2.5E+8	2.9E+8 (3.1E+8)[2]	2.9E+8 (3.1E+8)[2]	Harsh	Harsh
	4 mos					5.3E+7 (1.1E+8)[2]	3.5E+8	4.0E+8 (4.6E+8)[2]	4.1E+8 (4.6E+8)[2]	Harsh	Harsh
	1 yr					5.3E+7 (1.7E+8)[2]	4.1E+8	4.6E+8 (5.8E+8)[2]	4.7E+8 (5.9E+8)[2]	Harsh	Harsh

Table 5-5 Total Integrated Dose for Zone (Sheet 3 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
2	5 min	1.4E+02	-	-	1.4E+02	1.9E-01	-	1.9E-01	1.4E+02	Mild	Mild
	2 wks [1]					3.3E+01	-	3.3E+01	1.7E+02	Mild	Mild
	4 mos					4.2E+01	-	4.2E+01	1.8E+02	Mild	Mild
	1 yr					4.8E+01	-	4.8E+01	1.8E+02	Mild	Mild
3	5 min	1.4E+02	-	-	1.4E+02	1.9E-01	-	1.9E-01	1.4E+02	Mild	Mild
	2 wks [1]					3.3E+01	-	3.3E+01	1.7E+02	Mild	Mild
	4 mos					4.2E+01	-	4.2E+01	1.8E+02	Mild	Mild
	1 yr					4.8E+01	-	4.8E+01	1.8E+02	Mild	Mild
4	5 min	1.4E+02	-	-	1.4E+02	1.9E-01	-	1.9E-01	1.4E+02	Mild	Mild
	2 wks [1]					3.3E+01	-	3.3E+01	1.7E+02	Mild	Mild
	4 mos					4.2E+01	-	4.2E+01	1.8E+02	Mild	Mild
	1 yr					4.8E+01	-	4.8E+01	1.8E+02	Mild	Mild

Table 5-5 Total Integrated Dose for Zone (Sheet 4 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
5	5 min	1.4E+02	-	-	1.4E+02	1.9E-04	-	1.9E-04	1.4E+02	Mild	Mild
	2 wks [1]					3.8E-01	-	3.8E-01	1.4E+02	Mild	Mild
	4 mos					3.3E+00	-	3.3E+00	1.4E+02	Mild	Mild
	1 yr					9.7E+00	-	9.7E+00	1.5E+02	Mild	Mild
6	5 min	5.3E+07	-	-	5.3E+07	1.6E+3	4.8E+3	6.4E+3	5.3E+7	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	3.5E+8	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	4.6E+8	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	5.2E+8	Harsh	Harsh
7	5 min	5.3E+07	-	-	5.3E+07	9.2E+01	-	9.2E+01	5.3E+07	Harsh	Harsh
	2 wks [1]					1.9E+05	-	1.9E+05	5.3E+07	Harsh	Harsh
	4 mos					1.7E+06	-	1.7E+06	5.5E+07	Harsh	Harsh
	1 yr					4.9E+06	-	4.9E+06	5.8E+07	Harsh	Harsh

Table 5-5 Total Integrated Dose for Zone (Sheet 5 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
8	5 min	1.4E+02	-	-	1.4E+02	1.9E+01	-	1.9E+01	1.5E+02	Mild	Mild
	2 wks [1]					3.8E+04	-	3.8E+04	3.8E+04	Harsh	Harsh
	4 mos					3.3E+05	-	3.3E+05	3.3E+05	Harsh	Harsh
	1 yr					9.7E+05	-	9.7E+05	9.7E+05	Harsh	Harsh
9	5 min	1.4E+02	-	-	1.4E+02	1.9E-04	-	1.9E-04	1.4E+02	Mild	Mild
	2 wks [1]					3.8E-01	-	3.8E-01	1.4E+02	Mild	Mild
	4 mos					3.3E+00	-	3.3E+00	1.4E+02	Mild	Mild
	1 yr					9.7E+00	-	9.7E+00	1.5E+02	Mild	Mild
10	5 min	1.4E+02	-	-	1.4E+02	1.6E+3	4.8E+3	6.4E+3	6.5E+3	Harsh	Harsh
	2 wks [1]					4.0E+7	2.5E+8	2.9E+8	2.9E+8	Harsh	Harsh
	4 mos					5.3E+7	3.5E+8	4.0E+8	4.1E+8	Harsh	Harsh
	1 yr					5.3E+7	4.1E+8	4.6E+8	4.7E+8	Harsh	Harsh

Table 5-5 Total Integrated Dose for Zone (Sheet 6 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
11	5 min	1.4E+02	-	-	1.4E+02	1.9E-04	-	1.9E-04	1.4E+02	Mild	Mild
	2 wks [1]					3.8E-01	-	3.8E-01	1.4E+02	Mild	Mild
	4 mos					3.3E+00	-	3.3E+00	1.4E+02	Mild	Mild
	1 yr					9.7E+00	-	9.7E+00	1.5E+02	Mild	Mild
12	5 min	7.9E+03	-	2.5E+03	1.1E+04	1.9E-01	-	1.9E-01	1.1E+04	Harsh	Harsh
	2 wks [1]					3.3E+01	-	3.3E+01	1.1E+04	Harsh	Harsh
	4 mos					7.6E+01	-	7.6E+01	1.1E+04	Harsh	Harsh
	1 yr					1.8E+02	-	1.8E+02	1.1E+04	Harsh	Harsh
13-1	5 min	2.7E+08	-	-	2.7E+08	1.0E+04	-	1.0E+04	2.7E+08	Harsh	Harsh
	2 wks [1]					2.1E+07	-	2.1E+07	2.9E+08	Harsh	Harsh
	4 mos					1.8E+08	-	1.8E+08	4.4E+08	Harsh	Harsh
	1 yr					5.3E+08	-	5.3E+08	7.9E+08	Harsh	Harsh

Table 5-5 Total Integrated Dose for Zone (Sheet 7 of 7)

Zone	Operational Duration	Normal Operation Cumulative Dose (rad)				Accident Cumulative Dose (rad)			Total (rad)	Radiation Condition	
										Harsh or Mild	
		γ	n	β	Total	γ	β	Total		Electrical	Mechanical
13-2	5 min	5.3E+07	-	-	5.3E+07	9.2E+01	-	9.2E+01	5.3E+07	Harsh	Harsh
	2 wks [1]					1.9E+05	-	1.9E+05	5.3E+07	Harsh	Harsh
	4 mos					1.7E+06	-	1.7E+06	5.5E+07	Harsh	Harsh
	1 yr					4.9E+06	-	4.9E+06	5.8E+07	Harsh	Harsh
13-3	5 min	1.4E+03 (7.7E+02) [3]	-	-	1.4E+03 (7.7E+02) [3]	1.9E-01	-	1.9E-01	1.4E+03 (7.7E+02) [3]	Harsh (Mild) [3]	Mild
	2 wks [1]					3.3E+01	-	3.3E+01	1.4E+03 (8.0E+02) [3]	Harsh (Mild) [3]	Mild
	4 mos					7.6E+01	-	7.6E+01	1.4E+03 (8.5E+02) [3]	Harsh (Mild) [3]	Mild
	1 yr					1.8E+02	-	1.8E+02	1.4E+03 (9.4E+02) [3]	Harsh (Mild) [3]	Mild
14	5 min	1.4E+02	-	-	1.4E+02	1.9E-04	-	1.9E-04	1.4E+02	Mild	Mild
	2 wks [1]					3.8E-01	-	3.8E-01	1.4E+02	Mild	Mild
	4 mos					3.3E+00	-	3.3E+00	1.4E+02	Mild	Mild
	1 yr					9.7E+00	-	9.7E+00	1.5E+02	Mild	Mild

Notes
1. Including 30 min, 2 hr and 36 hr
2. Cumulative dose in parentheses include dose from recirculation water.
3. Normal operation cumulative dose for service life 35 years.

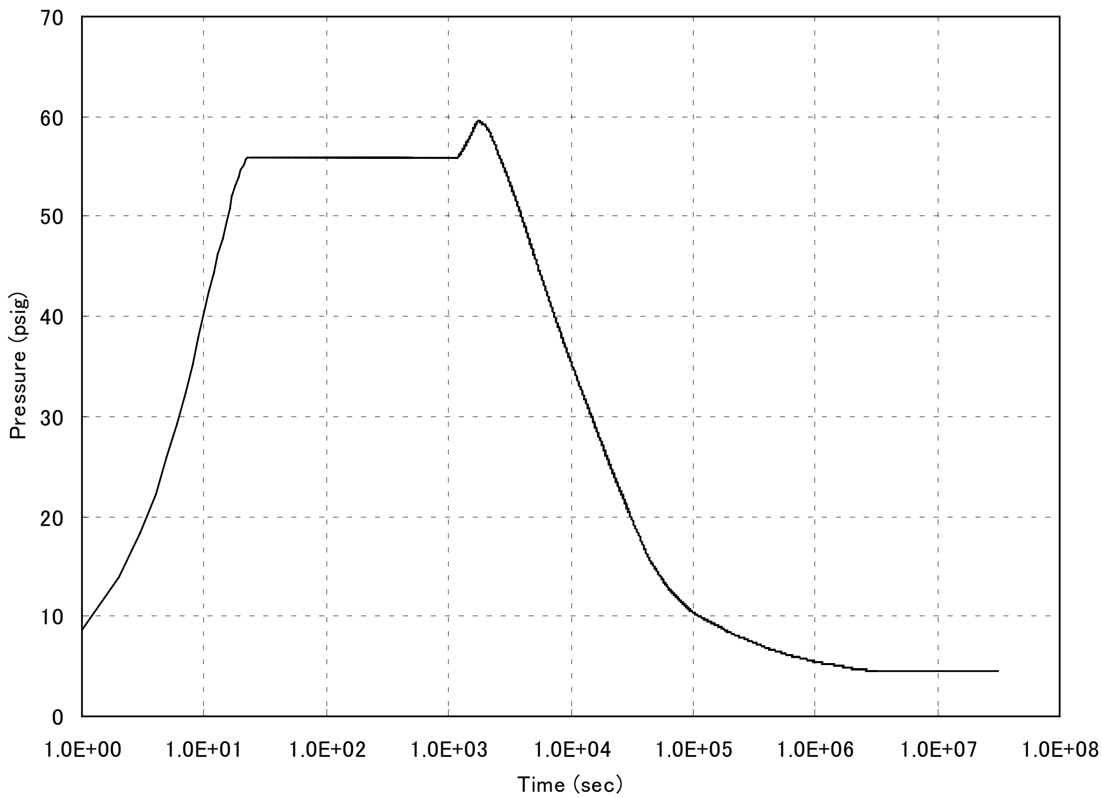


Figure 5-1 Environmental Curve for Containment Pressure Combining Various DBAs (Zone 1)

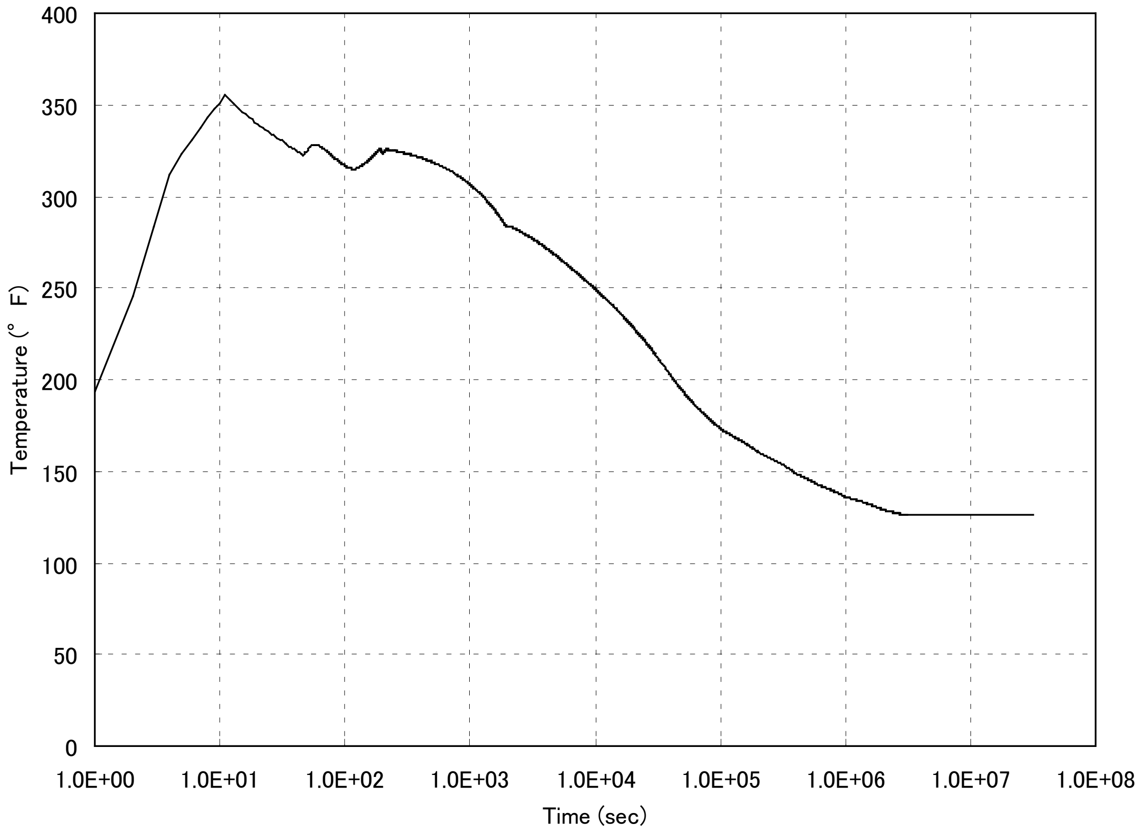


Figure 5-2 Environmental Curve for Containment Temperature Combining Various DBAs (Zone 1)

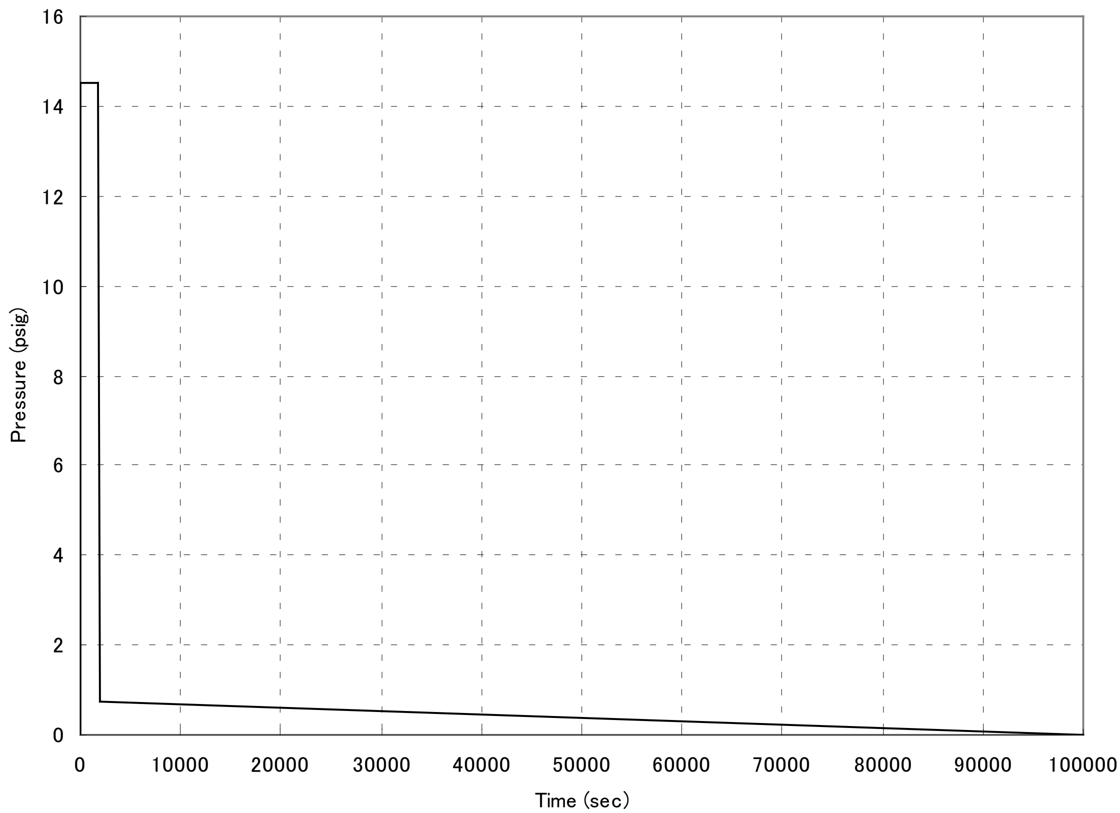


Figure 5-3 Environmental Curve for Pressure in MS/MF Piping Area

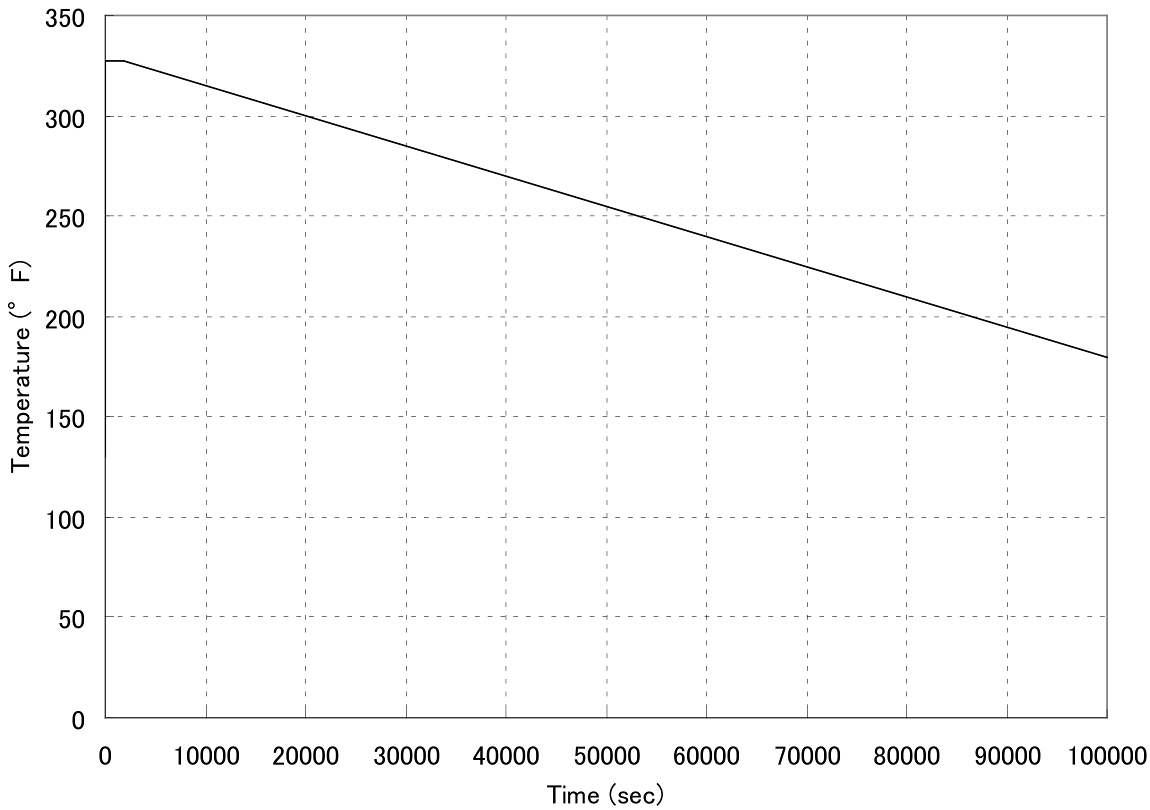


Figure 5-4 Environmental Curve for Temperature in MS/MF Piping Area

6.0 EQUIPMENT QUALIFICATION METHODS

The recognized methods available for qualifying electrical and mechanical equipment within scope of this Equipment Qualification Program are established in IEEE 323, IEEE 344-2004, ASME QME-1 and related standards (see Attachment A). These methods are also consistent with the requirements of 10 CFR 50.49. These are type testing, operating experience, analysis, on-going qualification, or a combination of these methods. The choice of qualification method for a particular item of equipment is based upon many factors. These factors include practicability, size and complexity of equipment, economics, and availability of previous qualification to earlier standards.

6.1 Type Test

The preferred method of environmental and seismic qualification of safety-related electrical and electromechanical equipment for the US-APWR Equipment Qualification Program is type testing according to the guidelines and requirements of IEEE 323-1974 and 344-2004.

Additionally, qualification based on type tests performed according to IEEE 323 and 344, but not specifically for the US-APWR, may be used as a qualification basis. Section 6.5 discusses the combination of qualification methods as they apply to the US-APWR Equipment Qualification Program (See subsection 6.5.1).

6.2 Analysis

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

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

The US-APWR Equipment Qualification Program provides specific direction on analytical techniques that are to be used in qualifying electrical and mechanical equipment. This guidance is briefly discussed in Section 7 and 8 of the Technical Report as well as in the proprietary Equipment Qualification program procedures (Restricted Equipment Qualification Program Procedures are not provided in their entirety as they are proprietary information, they are only briefly described in this Technical Report, see Section 8.).

6.2.1 Similarity

The US-APWR the equipment qualification program may use similarity evaluations and analysis to assist in the qualification of equipment. Similarity is often employed to facilitate the

qualification process for both environmental and seismic parameters. Similarity analysis may be performed to show that results of previous equipment tests (type or seismic) may be applied to the qualification of similar equipment. Similarity analysis is often performed when the variations between the "as-tested" and "to-be-qualified" equipment are minor and these differences can be evaluated by analysis. The use of similarity analysis is based on evaluations to demonstrate that the SSC to be qualified is an acceptable representative of the previously qualified SSC. Supporting analysis is used to demonstrate that the results of previous tests can be appropriately used to demonstrate the qualification of similar equipment. The various factors involved in similarity analysis are complex and depend, in part, on the type of SSC and the type of similar test. The guidance provided in following references, where applicable, is used to provide a basis for the US-APWR Equipment Qualification Program implementing procedures governing the qualification of SSCs when similarity analysis and evaluations are utilized:

IEEE 323, "Standard for the Qualifying of Class 1E Equipment for Nuclear Power Generating Stations"

IEEE 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"

ASME QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants"

The use of similarity analysis requires the documented evaluation of qualification parameters. These evaluation requirements include the following considerations:

<u>Mechanical Equipment:</u>

a. Are the service conditions and concurrent loads for the active mechanical equipment similar? Examples of such parameters are earthquakes, internal and external pressures/temperatures, relative humidity, radiation, vibration, corrosion effects, transients, etc.
b. Is the required margin in the qualification parameters similar?
c. Is the active mechanical component that is to be qualified subject to similarity of excitation, physical system, and function? Similarity of excitation constitutes likeness of the following parameters: spectral characteristics, duration, directions of excitation axes, and location of measurement for the motions relative to the equipment mounting.
d. Are mechanical components/part that are subject to aging, chemical exposure and radiation similar and were the qualifying tests similar to the conditions that the "to-be-qualified" component will be exposed to?
e. Are the qualified components environmental stressors similar to the "to-be-qualified component" environment?
f. Is the qualified life for the equipment similar?
g. Is the manufacturing process similar?
h. ASME QME-1 provides specific guidance in the use of similarity analysis for various active mechanical equipment.

<u>Electrical Equipment:</u>

a. Is the technology used to design and manufacture the equipment similar?
b. Is the type of the equipment similar (e.g., breaker-for-breaker)?
c. Is the mounting and installation arrangement similar?

d. Are the service conditions similar?
e. Are the safety functions similar?
f. Is the required margin in the qualification parameters similar?
g. Are aging parameters and characteristics similar?
h. Are aging mechanisms, synergistic effects and environmental stressors including thermal and radiation similar?
i. Was seismic testing similar?
j. Is similar equipment in service at other nuclear facilities and are the service conditions similar?
k. Are key material properties similar?
l. Is the qualified life for the equipment similar?
m. Are the effects from radiation type dose rate and configuration similar?
n. Are the exposure sequence effects similar?
o. The references listed in this report provide additional guidance in the use of similarity.

Certain SSCs may require additional attributes and parameters to be evaluated when qualification by similarity is employed in the equipment qualification process. Extrapolation or interpolation to other equipment by similarity can be used when the following conditions apply: same or equivalent materials, size differences are related by known scale factors, differences in shape shall not adversely impact performance, operating and environmental stresses are equal to or less than similarly qualified equipment, aging mechanism applicable to the tested equipment apply to the new equipment, and the equipment has the same safety function. Detailed similarity requirements are delineated in the project specific equipment qualification program procedures as described in Sections 8.0 and 9.0 of this Report.

6.2.2 Substitution

During the construction of a new US-APWR substitution or like-for-like replacement of qualified components may be required only if the original as-designed components are no longer available. In this case, the procurement and design documents would be suitably revised to reflect the use of a substitute component. In order for a substitute component to be used in the construction of a new US-APWR, this alternate component would be evaluated for form, fit and function, as well as other parameters to verify that its use would be acceptable. During the substitute equipment qualification process, parameters that would be analyzed include:

Materials: Are materials equivalent to the original? Are the materials acceptable for the installed environment? Is the source of the materials known and acceptable? Are there any changes to the materials used in the component which would compromise the component's operation during all anticipated environmental conditions? Will the component's materials allow it to perform its safety function?

Manufacturing Process: Is the manufacturing process similar to or better than the original process? Are there changes during the manufacturing process which could impact the components ability to function in all anticipated environmental conditions?

Manufacturer's Qualify Programs: Are quality programs equivalent or better than the original supplier's program?

Design: Is the design similar to or comparable to the original design? Are there changes in the design which could impact the component's ability to function?

Form, Fit and Function: Is the replacement or substitute component equivalent to the original component in relation to form, fit and function? Are components interchangeable or will other components need to be modified? Will the substitute component be capable of performing its intended safety function?

An evaluation including a review of the components critical characteristics, qualification of the vendor and product examination as well as other evaluations, including the required applicable equipment qualification parameter qualification will be performed and documented when and if need arises to use substitute components during the initial construction of a US-APWR. Especially, Qualification of substitute or replacement non-metallic parts of mechanical equipment shall be performed in accordance with ASME QME-1-2007 Appendix QR-B as endorsed by Regulatory Guide 1.100, Revision 3. These requirements are delineated in the project specific equipment qualification program procedures as described in Sections 8.0 and 9.0 of this Report.

6.3 Operating Experience

Qualification by experience is typically not employed in the US-APWR Equipment Qualification Program as a prime method of qualification. Operating experience provides supportive evidence to the prime method of qualification. For those instances where seismic experience data are to be used, the COL applicant will provide documentation of the methodology. Where such information is provided, it is demonstrated that the experience is applicable to the safety-related functional requirements of the equipment. This demonstration of applicability includes an evaluation of operating environments, mountings, performance requirements, and performance history.

6.4 On-Going Qualification

The US-APWR Equipment Qualification Program may employ on-going qualification through special maintenance and surveillance activities. However, this method of qualification is not suitable as a sole means for qualifying equipment for DBA conditions. On-going qualification, as a method, is used exclusively for safety-related equipment located in a mild environment area. Such use requires supplementary test, analysis, or experience data to address equipment operability and performance during and after a seismic design basis accident.

Documentation requirements for qualification that includes on-going qualification as a method are developed to conform with NRC guidance provided in RG 1.33, Revision 2.

6.5 Combinations of Methods

Qualification by a combination of the preceding methods is used whenever qualification by type test is not the sole basis of qualification under the US-APWR Equipment Qualification Program. If analysis is used, justification includes identifying a test or experience bases, and addressing concerns related to departure from the required type test sequence.

6.5.1 Use of Existing Qualification Reports

Pre-existing qualification programs and documents are used only if the seismic test program satisfies the guidelines of IEEE 344-2004 and the environmental qualification program satisfies the guidelines of IEEE 323-1974.

Qualification test and analysis reports conforming to those IEEE, but not specifically performed to the US-APWR Equipment Qualification Program parameters, may be acceptable as qualification bases. In such cases, supplementary qualification efforts described in subsections 6.2, 6.3, and 6.4 may be required to validate acceptability under the US-APWR Equipment Qualification Program. Justifications are documented as analyses.

6.5.1.1 Aging

Past qualification tests may provide sufficient basis to preclude new aging simulation testing as part of the US-APWR program. Also, simulation of both electrical and mechanical operational cycling may be waived where existing data demonstrates equipment durability greatly in the excess of the estimated number of operating cycles for Class 1E service. Application of past qualification and other tests is considered in the development of test plans and analysis procedures. The bases and justification is provided in qualification documentation for cases where applicable aging parameters are omitted from the test sequence. Aging analysis is used to determine qualified life, shelf life and design life. Identified aging mechanisms include in service thermal, chemical, vibration, radiation and cyclic conditions. The most limiting of these is used to set the qualified life of an SSC in a harsh environment.

6.5.1.2 Seismic

Seismic qualification generally relies on analyses and justification to verify the adequacy or applicability of generic testing to a particular installed configuration of similar equipment. Analytical methods and documentation guidelines of IEEE 344-2004, as supplemented by RG 1.100, Rev. 3, address these needs. Attachment B provides the US-APWR Equipment Qualification Program requirements regarding seismic qualification.

6.5.1.3 High-Energy Line Break Conditions

Typically, existing qualification tests address conditions of HELB environments occurring inside containment. These are used where it is demonstrated that the qualification envelops the applicable requirements.

6.6 Qualification of Mechanical Equipment

Environmental qualification of mechanical equipment defined in Section 2.0 of this report is required to show that this mechanical equipment can fulfill its intended safety function for the postulated design basis environmental conditions. Qualification is also intended to minimize the possibility of common mode failures impacting the fulfillment of safety functions. The qualification process applicable to qualification of mechanical equipment, both seismically and environmentally, is discussed in Section 7 and 8 of this Technical Report. Non-metallic components of mechanical equipment located in harsh environment are qualified in accordance with ASME QME-1-2007, Appendix QR-B as endorsed by RG 1.100 revision 3. Acceptance design of non-metallics located in mild environment is demonstrated by the design/purchase specifications which contains a description of the functional requirements for all anticipated service conditions. Environmental design and qualification status of non-metallic components in both harsh and mild environments is maintained during the operational life of the plant by maintenance and surveillance procedures as described in Section 11.0 of this report.

7.0 THE EQUIPMENT QUALIFICATION PROCESS

7.1 General

Section 3.0 of this Technical Report describes the statutory, regulatory and industry standards applicable to the equipment qualification process. Section 4.0 of this Technical Report describes the various equipment qualification parameters that are evaluated to verify that an SSC requiring equipment qualification is qualified for use in a US-APWR. Section 5 provides the calculated equipment qualification parameters for the US-APWR and Section 6 describes equipment qualification methods. This section describes the various evaluation methodologies and processes that are used to verify that SSCs are qualified. The general process is known as equipment qualification.

Equipment Qualification is defined as a systematic approach to verifying, demonstrating and documenting, by one or more defined methods, that SSCs addressed by the Equipment Qualification Program are qualified for use in all anticipated environmental conditions (including seismic) such that the SSC can fulfill its intended safety function during normal, testing, accident and post accident conditions including postulated design basis events. The process by which the qualification of this equipment is conducted and documented is referred to as an Equipment Qualification Program.

An Equipment Qualification Program provides for the generation and maintenance of evidence (records) to demonstrate that equipment requiring equipment qualification is qualified for use in all applicable plant environments. An Equipment Qualification Program generates and maintains equipment qualification records in accordance with established program procedures and quality assurance requirements. IEEE Standard 323 defines qualification to be "generation and maintenance of evidence to ensure that the equipment will operate on demand to meet system performance requirements." The US-APWR Equipment Qualification Program makes the distinction that equipment qualification is only the act of verifying or demonstrating that the equipment is qualified, and that the Equipment Qualification Program accounts for all of the necessary actions needed to qualify SSCs, including the generation and maintenance of the records associated with the equipment qualification process. Thus the definition of the "Program" defines the process that is used to meet the statutory requirements for equipment qualification consistent with the guidance identified in Section 1.0 of this Technical Report. The US-APWR Equipment Qualification Program is implemented on a project specific basis as described in Section 9.0 of this Technical Report. The Project Equipment Qualification Program (PEQP) provides a structured approach to identifying, cataloging, processing and documenting SSCs that are subject to the equipment qualification process.

To qualify an SSC, the first step in the equipment qualification process is to determine the applicable equipment qualification parameters in which the SSC must be able to function. Factors governing this include SSC location, safety function and safety classification.

7.2 SSC Location

The general location at which an SSC is installed in the plant will determine some of the applicable equipment qualification parameters (e.g., harsh or mild environment, seismic requirements). The location may change during the design process where it may be possible to relocate certain pieces of equipment to a location with less stringent equipment qualification requirements. Once the location of an SSC is finalized, the applicable equipment qualification

parameters can be designated based on the analysis performed for that area in the plant. Note that some equipment qualification parameters such as aging may not be directly location dependent. Each SSC must be analyzed in relation to its function or use (e.g., time of operation) and use relative to its location in the plant.

7.3 SSC Function and Classification

The function of an SSC factors into the classification of the SSC. An SSC may fall into four broad categories:

1. Equipment required to be environmentally qualified as described in US-APWR DCD Section 3.11
2. Active mechanical components required to be functionally qualified
3. Mechanical and electrical equipment with special seismic qualification requirements such as seismic categories I and II
4. Other safety-related and nonsafety-related SSCs not classified per 1 through 3 above, and therefore, not a candidate for inclusion in the Equipment Qualification Program.

The function of the SSC determines classification arrangement. The function arrangement depends on whether an SSC supports normal operations, emergency or accident condition mitigation or post accident restoration. This in turn defines the required operating time for the SSC. In this case, specific equipment qualification parameters may still apply to this equipment (e.g., seismic). In evaluating the function, the time element for the safety function to occur defines an element in the qualification process.

7.3.1 Time Element

In qualifying SSCs, the required operational time is one equipment qualification parameter which applies to the qualification process. For example, if a valve must operate for a few minutes in a harsh environment, and afterwards it then fails, as long as it fails in the correct (safe) position, then the equipment can be qualified for operation for only a few minutes in a harsh environment. The operating times for equipment associated with DBA are shown in the US-APWR DCD. It is necessary to apply a time element primarily to items located in potentially harsh environments because once an SSC has fulfilled its intended safety function; it does not need to remain operational. Applying a time element, as stated above, allows many standard commercial or industrial grade components to be effectively used in harsh environments. The qualification process thus may indicate the time element applicable to a specific SSC.

7.4 Deleted

7.5 Seismic II/I Criteria

Equipment Qualification Program Procedures include seismic analysis requirements as part of the implementation of a project-specific program. Including seismic analysis requirements, as stated above, follows the guidance for seismic analysis as listed in the US-APWR DCD. Displacements and support loads for the seismic II/I seismic loading are also considered as indicated in the DCD. Components or other equipment either included in seismic II/I piping such as valves and their operators are also evaluated for their structural integrity during an SSE. As needed, the results from this analysis may require seismic design for such non-

safety components and equipment qualification considerations for this seismic design in the procurement of these non-safety components. The implementation of the seismic II/I criteria is addressed in a project-specific equipment qualification program.

7.6 Critical Characteristics Applicable to the Design and Procurement Process

Critical SSC properties are those characteristics that are essential for the SSC's functional performance; the identifiable and/or measurable attributes of an SSC which provide assurance that the SSC will perform its design function (e.g., pump capacity, valve size, and material type).

Based on the design basis and performance of an SSC and its intended use, characteristics will be identified that are critical for acceptable performance. SSCs and their specification may inherently have one or more characteristics critical in assuring acceptability/equivalency of the SSC for an intended application. Purchase specifications provide (but are not limited to) guidance for this identification / selection process. Selection of equipment qualification parameters and component requirements is based on complexity, safety function, and performance of the SSC. Typical equipment qualification parameters to be considered are those listed in Section 4.0 of this Technical Report and include pressure, normal temperature, abnormal and/or peak temperature, humidity, radiation, submergence and qualified life (time). For seismic qualification, it should be determined if the SSC is seismically sensitive. If it is seismically sensitive, then the applicable documentation associated with the seismic qualification will be listed. This documentation may include additional equipment evaluation by screening and subsequent qualification testing, depending on screening results, which is required when in-structure response spectra (ISRS) used for equipment qualification exhibit high-frequency exceedances due to site-specific exceedances of the ground motion response spectra. As per the guidance of Section B.1 of US NRC RG 1.100 and US NRC interim staff guidance, such evaluations must be performed when exceedances occur in the 20 – 50 Hz range, and must demonstrate both structural integrity and functionality for seismic category I equipment.

This information is captured during the design phase of a project and the critical characteristics are documented on the Equipment Qualification Engineering Evaluation Form or other approved Quality Assurance (QA) document to contain the needed Equipment Qualification Program information.

7.7 Equipment Qualification Process

This section describes the combination of these guidance documents with the specific qualification of a given SSC. The nuclear safety determination for the individual component is determined by the system or structure in which it resides. Once that decision is made, the applicable environmental parameters are then established.

With any SSC, the engineering design for form, fit and function are the initial design steps. Components of a system will have design and operational requirements that are documented on the specifications and drawings for that component. Once the initial design is done for a specific project, then the equipment qualification process for the component can begin.

The nuclear safety determination is the first step in the determination of the equipment qualification process for that component. For example, a component inside containment may be subject to all of the environmental conditions discussed in the earlier parts of Section 4.0 of

this Technical Report. However, it must first be categorized as to its type. The type classification is mechanical, electrical or other (structural or fire protection containment penetrations seals are examples of the other category). The next step is to determine if harsh or mild environmental conditions apply. A typical equipment qualification method is to identify the most severe equipment qualification parameter for a specific SSC and then apply those equipment qualification requirements to all the components of a similar design used throughout the plant. This approach is appropriate for smaller, less expensive components where there is little savings to be achieved for custom design. This approach addresses one of the operational requirements for spare parts by keeping them the same for all components of the same design.

Section 4.0 of this Technical Report addresses the individual environmental parameters and their part in the qualification methodologies. Anticipated environmental conditions are the expected temperature, pressure, humidity (including submergence or impingement), chemical, radiation, seismic, aging and synergistic effects that an SSC may experience during normal, accident, testing and post accident conditions at the location within the facility at which the SSC requiring equipment qualification is installed. These environmental parameters must be considered when specifying the SSC. This is the engineering evaluation portion of the US-APWR Equipment Qualification Program which is performed for each project. The US-APWR engineering equipment qualification evaluations for a specific project provide:

- An auditable QA equipment qualification record
- SSC specifications with equipment qualification parameters as part of the procurement specifications
- Input to the Equipment Qualification Program database including the SSC design and environmental parameters
- Acquisition of engineering design parameters
- Input for SSC Operation and Maintenance Technical Manuals
- A partial spare parts database
- Construction data to support preoperational tests
- Input for the ITAAC process where applicable

Once the requirements are set, then working with a vendor for the SSC will determine if the vendor's tests are adequate for the equipment qualification or if separate performance tests are needed. These performance tests may be performed at a separate independent laboratory, or at the US-APWR nuclear plant site as part of startup qualification. Refer to Section 9.0 of this report for information regarding Laboratory Qualification and Vendor Testing. Refer to Section 10.0 of this report for additional information regarding the startup phase of a project.

7.7.1 Site Specific Equipment Qualification Process

The US-APWR DCD describes the generic plant and is part of the basis for MHI obtaining a manufacturing license from the NRC. A project or site specific COL application is part of the basis for a utility (licensee) to obtain authorization to construct and operate a US-APWR. The DCD identifies the standard plant equipment that is to be qualified in support of a specific project. The COL identifies site-specific equipment that must also be qualified for use on a specific US-APWR. The qualification processes used on site-specific equipment will use the

same methods defined for the generic plant, however, they will be site or project specific. This process is described in Sections 8, 9, 10 and 11 of this Technical Report.

7.8 Development of Aging Program, and Spare or Replacement Parts

Per 10 CFR 50.49(e)(5), "Equipment qualified by test must be preconditioned by natural or artificial (accelerated) aging to its end-of-installed life condition." The regulation describes the considerations for the aging testing including preconditioning a given SSC before any further aging tests. This testing is used to help determine the service life of an SSC. Aging requirements are SSC specific and are implemented on a project specific basis.

Spare parts lists are generated for each SSC requiring equipment qualification during the design and procurement phases of a project. On a specific US-APWR project, these spare parts are subject to the same equipment qualification requirements as the original SSC. Where existing spares with the same specifications as originally purchased are not available, a commercial grade dedication program for the equipment qualification process may be used subject to the limitations established for that project (see Section 8.0 of this Technical Report). Within the commercial grade dedication program, each critical characteristic for an SSC is identified, evaluated by engineering, and documented in accordance with project specific procedures. During the construction of a US-APWR, it may be necessary to maintain or otherwise support installed equipment. Replacement parts, as well as substitute SSCs, are qualified to the same equipment qualification parameters to which the original SSC was qualified in accordance with project specific procedures to insure the integrity of the equipment qualification process. Aging analysis requirements are defined in the referenced material and implemented in the Equipment Qualification Program procedures.

7.9 Turnover to Licensee

The equipment qualification process verifies that each SSC requiring equipment qualification is appropriately qualified for use in the US-APWR. The records generated by this program form the basis for the Licensee's Operational Equipment Qualification Program (OEQP). The turnover to the equipment qualification records to the utility (licensee) is described in Section 10.0 of this Technical Report.

Figure 7-1 Deleted

8.0 MHI US-APWR EQUIPMENT QUALIFICATION PROGRAM

8.1 Generic Program

The previous sections of this Technical Report have identified the regulatory and technical basis for the qualification of SSCs requiring equipment qualification used to construct the MHI US-APWR, and the parameters used in the equipment qualification process. Section 7.0 described the overall process of integrating the regulatory and technical basis into an Equipment Qualification Program. This section describes the US-APWR Equipment Qualification Program which implements the equipment qualification process on a project specific basis. The US-APWR is supplied by MHI (headquarter in Japan) and MNES which is the U.S. representative of MHI. MNES will be the primary contracting entity interfacing with a utility customer and other project participants. MHI/MNES are responsible for identifying the primary project participants. As such, MHI/MNES will define the Project Organization roles and responsibilities for a specific project. The Project Organization will consist of MHI, MNES, an A/E(s), a constructor(s), key suppliers, and the plant licensee (owner). An equipment qualification organization is formed from this project organization and is referred to as the PEQO. The proprietary generic Equipment Qualification Program is defined by equipment qualification Directives and Procedures that are briefly described in this section and Appendix C.

8.2 MHI US-APWR Equipment Qualification Program Directives

The MHI US-APWR Equipment Qualification Program is defined in the US-APWR DCD. The Equipment Qualification Program is a generic program that is implemented on a specific project basis. The Equipment Qualification Program directives are high level policy statements applicable to the US-APWR licensing process. The Equipment Qualification Program directives provide overall direction to the project organization on the implementation of the program. The Equipment Qualification Program directives are authorized by MHI and MNES management. The directives and a brief description of their purpose are listed below.

8.2.1 Dir-01, US-APWR Project Equipment Qualification Program Authorization

This directive recognizes the need for and authorizes the formation of a PEQO for a US-APWR Project.

8.2.2 Dir-02, US-APWR Project Equipment Qualification Program Definition and Organizational Responsibilities

This directive requires that the Project Organization responsible for the delivery of a US-APWR to a utility customer (licensee) establish a PEQO to oversee and implement PEQP for a US-APWR Project.

8.2.3 Dir-03, Application of Equipment Qualification Requirements to the US-APWR Design, Procurement, Fabrication, Construction and Startup

This directive recognizes the need to define the scope of the Equipment Qualification Program and requires that the Project Equipment Qualification Program applies to all phases of a US-APWR project.

8.2.4 Dir-04, US-APWR Equipment Qualification Program Documentation Requirements

This directive recognizes the need for and requires the PEQO to maintain appropriate equipment qualification documentation during the licensing, design, procurement, equipment fabrication, plant construction, plant startup and turnover phases of the project and to provide equipment qualification documentation to the licensee.

8.2.5 Dir-05, Quality Assurance Requirements for a US-APWR Equipment Qualification Program

This directive recognizes the need for and requires the PEQP to implement a PEQP consistent with the Project Quality Assurance requirements, the US APWR Equipment Qualification Program Directives and Procedures and associated references. The Project Quality Assurance Program shall be implemented under the auspices of the MNES QAP.

8.2.6 Dir-06, US-APWR Project Equipment Qualification Program Training Requirements

This directive recognizes the need for and requires the PEQO to provide training for personnel involved in equipment qualification activities and maintain training records.

8.3 MHI US-APWR Equipment Qualification Program Procedures

The MHI US-APWR Equipment Qualification Program is defined in the DCD. It is a generic program that is implemented on a project-specific basis and as such, project specific conditions govern its implementation. The Program procedures provide guidance to the PEQO for implementation of the PEQP to ensure compliance with basic statutory, regulatory and industry standards as committed to in the DCD. The PEQO is tasked with preparing project specific equipment qualification procedures following the guidance given in the Equipment Qualification Program procedures. The US-APWR Equipment Qualification Program implementing procedures are described below.

8.3.1 Pro-01, US-APWR Equipment Qualification Program Implementation for a Specific Project

This procedure provides guidance to the PEQO chartered to support delivery of a US-APWR to a utility (licensee) to develop a PEQP.

8.3.2 Pro-02, US-APWR Equipment Qualification Project Definitions and Equipment Qualification Program Implementation Boundaries

This procedure provides direction to the PEQO regarding definition of common terms applicable to the PEQP and the identification of the PEQP scope and boundary within the Project. The PEQO shall incorporate these definitions as well as project specific definitions into a specific PEQP procedure.

8.3.3 Pro-03, US-APWR Project Specific Equipment Qualification Program Organization Management Structure

This procedure requires the PEQO management structure, roles and responsibilities be defined by the Project Organization. This procedure requires the PEQO to prepare a specific

procedure that delineates the PEQO roles, responsibilities, authorities and project reporting structure. By doing this, the participants in the Project Organization have a clear understanding of the structure of the PEQO and PEQP.

8.3.4 Pro-04, US-APWR Equipment Qualification Program Selection and Identification of Structures Systems and Components

This procedure provides direction to the PEQO for preparation of project-specific procedures controlling the selection and identification of Equipment Qualification Program SSCs. In general, these will be SSCs identified in the DCD and the COL for the project. However, other SSCs may also be identified during the engineering, analysis, design and procurement phases that need to be included in the equipment qualification process. This procedure provides guidance to the project participants on the identification and selection of SSCs for the PEQP.

8.3.5 Pro-05, US-APWR Equipment Qualification Program Documentation and Records Retention

This procedure provides direction to the PEQO on the preparation of project-specific procedures controlling Equipment Qualification Program documentation and records retention. This procedure provides guidance to the project participants on dispositioning of equipment qualification records.

8.3.6 Pro-06, US-APWR Equipment Qualification Program Analysis Requirements

This procedure provides direction to the PEQO for the preparation of project-specific procedures controlling Equipment Qualification Program analysis requirements. The baseline analysis for SSCs is contained in the DCD. Analysis for site-specific SSCs is performed in conjunction with the implementation of a specific US-APWR project. This procedure identifies specific equipment qualification analysis required for SSCs identified in Pro-04.

8.3.7 Pro-07, US-APWR Equipment Qualification Program Quality Assurance Program

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the MHI/MNES QA requirements applied to equipment qualification of SSCs addressed by the Equipment Qualification Program.

8.3.8 Pro-08, US-APWR Equipment Qualification Program Application During the Design Phase of a Project

This procedure provides direction to the PEQO for preparation of project specific procedures to address equipment qualification during the design phase of the project.

8.3.9 Pro-09, US-APWR Equipment Qualification Program Application During Procurement

This procedure provides direction to the PEQO for application of the PEQP during the procurement phase of the project. This is a large procedure with several extensive attachments which provide guidance on the seismic and environmental qualification of mechanical and electrical equipment as it applies to testing, analysis, and procurement specifications.

8.3.10 Pro-10, US-APWR Equipment Qualification Program Application During the Construction Phase

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the PEQP requirements applied to SSCs addressed by the Equipment Qualification Program during the construction phase of the project.

8.3.11 Pro-11, US-APWR Equipment Qualification Program Application During Startup and Commissioning

This procedure provides direction to the PEQO for preparation of project-specific procedures to address application during startup and commissioning.

8.3.12 Pro-12, US-APWR Equipment Qualification Program Application During Initial Operations

This procedure provides direction to the PEQO for preparation of project-specific procedures controlling the PEQP requirements applied to SSCs addressed by the Equipment Qualification Program during initial operations.

8.3.13 Pro-13, US-APWR MHI/MNES Assignment of Equipment Qualification Program Execution to/from the Project Equipment Qualification Organization

This procedure provides guidance on the execution of an Equipment Qualification Program for a specific US-APWR Project and to allow the execution of such program by the PEQO. Since MHI/MNES is responsible for the Equipment Qualification Program, they may delegate the execution of the program to third parties. This delegation of execution is governed by this procedure.

8.3.14 Pro-14, US-APWR Equipment Qualification Program Transfer from MHI/MNES to Licensee (Owner)

This procedure provides direction on the formal transfer of the PEQP for a specific US-APWR PEQP to the plant licensee.

8.3.15 Pro-15, US-APWR Equipment Qualification Program Training Requirements

This procedure provides direction to the PEQO for institution of training requirements related to the US-APWR Equipment Qualification Program.

8.3.16 Pro-16, US-APWR Equipment Qualification Program Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSCs)

This procedure provides direction to the PEQO for preparation of equipment qualification packages for SSCs addressed by the Equipment Qualification Program following the project specific procedures of the PEQP.

8.3.17 Pro-17, US-APWR Equipment Qualification Program Qualification Methods

This procedure provides direction to the PEQO on which qualification methods can be used for equipment qualification.

8.3.18 Pro-18, US-APWR Equipment Qualification Program Qualification by Testing

This procedure provides direction to the PEQO for preparation of project-specific implementing procedures to address equipment qualification by testing.

8.3.19 Pro-19, US-APWR Equipment Qualification Program Qualification by Vendor Certification

This procedure provides direction to the PEQO for preparation of project-specific implementing procedures to address equipment qualification by vendor certification.

8.3.20 Pro-20, US-APWR Equipment Qualification Program Qualification by Analysis

This procedure provides direction to the PEQO for preparation of project-specific implementing procedures to address equipment qualification by analysis.

8.3.21 Pro-21, US-APWR Equipment Qualification Program Qualification by Using Experience Data Method

This procedure provides direction to the PEQO regarding environmental or seismic qualification of equipment through an experienced-based approach that relies on an experience database. This includes the use of commercial dedication methods where applicable.

8.3.22 Pro-22, US-APWR Equipment Qualification Program Project Records Management

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the Equipment Qualification Program records management requirements applied to SSCs addressed by the Equipment Qualification Program.

8.3.23 Pro-23, US-APWR Equipment Qualification Program Confidentiality and Proprietary Information

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the use of supplier equipment qualification documentation identified as confidential or proprietary associated with equipment qualification applicable to SSCs addressed by the Equipment Qualification Program.

8.3.24 Pro-24, US-APWR Equipment Qualification Program Exceptions and Open Items

This procedure provides direction to the PEQO for the preparation of project-specific procedures controlling the tracking and resolution of Equipment Qualification Program exceptions and open items associated with equipment qualification of SSCs addressed by the Equipment Qualification Program.

8.3.25 Pro-25, US-APWR Equipment Qualification Program Personnel Qualifications

This procedure provides direction to the PEQO for the preparation of project-specific procedures controlling Equipment Qualification Program personnel qualification.

8.4 MHI Equipment Qualification Program Project Implementation

The MHI US-APWR Equipment Qualification Program is implemented on a project-specific basis for actual design, procurement, construction, startup testing, power ascension testing and transfer to the plant owner (licensee) to occur. A generic program has been established to provide specific guidance to the Project Organization(s) on how to implement an Equipment Qualification Program that will comply with the equipment qualification commitments and requirements delineated in the US-APWR DCD. Under this arrangement, the Project Organization is tasked with preparing a formal Equipment Qualification Program for a specific project. Equipment qualification methodologies, approaches, technologies and practices continue to evolve based on industry experience and refinements in the requirements. The MHI Equipment Qualification Program has been designed to be flexible and allow the PEQO the ability to refine the equipment qualification approaches implemented, based on changes in equipment qualification methodologies, industry practices, records storage and retrieval technologies and licensee requirements. As formulated, the Equipment Qualification Program is implemented by a project specific organization that is likely to include personnel from MHI, MNES, A/E(s), Constructor(s), the Licensee and/or key Suppliers. The appropriate organizational structure for the PEQO is left to the Project Organization to define and implement. However, once it is established, then the PEQO must then prepare project-specific equipment qualification procedures and implement the program in support of the Project. The implementation is discussed in the next section.

8.5 Summary

This section has briefly described the generic Equipment Qualification Program directives and procedures. A more comprehensive description of these documents is provided in Attachment C of this Technical Report. The implementation of a project specific Equipment Qualification Program is discussed in the next Section.

9.0 EQUIPMENT QUALIFICATION IMPLEMENTATION

The US-APWR Equipment Qualification Program is a generic or baseline program that supports both the licensing process and the preparation of a project-specific Equipment Qualification Program. This Section of the Technical Report describes how the generic program would be implemented on a specific project. At the project level, the designated PEQO is responsible for implementation of the PEQP for US-APWR equipment.

The implementation framework for the PEQP is illustrated in Figure 2-1 of this Technical Report. Figure 2-1 depicts the scope of a project-specific Equipment Qualification Program for the recognized phases of a US-APWR project. A typical implementation milestone schedule for a PEQP is shown in Fig. 9.1 of this report. Projects can be divided into key phases or activities, with major phase completions representing milestones (e.g., licensing, purchasing, and design). The DCD process licenses the standardized US-APWR, including the generic Equipment Qualification Program.

The plant owner (licensee) is expected to obtain an OL for the plant by submitting a combined construction and operating license (COL) application. The COL is expected to be issued in such a way as to first authorize construction (Early Site Permit or Limited Work Authorization) and then to authorize an OL by issuing a lower power license (1%) to allow for fuel load and low power physics testing. The OL is then expected to be modified to allow for initial power ascension testing after which the COL transitions to a full or unlimited OL. The COL covers the scope associated with site-specific design, procurement, construction and startup phases of the project, and then subsequent long-term operation. The site design phase of the COL also includes the development of site-specific environmental data (including seismic). This site specific information is used to verify the standard design parameters are applicable to the DCD parameters (standard design) and for the identification and evaluation of the site-specific parameters of the plant, including input parameters for the equipment qualification process.

The PEQP covers the time period and project phases associated with the Project up to the point when an OL is authorized. The plant licensee is required to have an OEQP in place prior to the authorization of fuel load. The PEQP thus transitions to the owner's (plant licensee's) Equipment Qualification Program prior to fuel load. The licensee's Equipment Qualification Program is an operational program, primarily designed to assure the qualified status of equipment requiring equipment qualification is maintained properly and that only qualified replacement parts are used during the life of the plant. The US-APWR PEQP is a design, procure, construct and test, Equipment Qualification Program. Thus, for each US-APWR, there are three applicable and distinct Equipment Qualification Programs (Generic US-APWR Equipment Qualification Program (DCD), PEQP, and the Licensee's OEQP). The licensee's equipment qualification program is described in Ch. 13 of the COLA. The PEQP is expected to be implemented as described below with the understanding that 1) the Equipment Qualification Program directives form the policy basis for the program and 2) the Equipment Qualification Program procedures provide overall direction in implementing project specific equipment qualification procedures.

9.1 Project Licensing Phase

The plant licensee is responsible for submitting a COLA to the NRC. The licensee will describe the various Equipment Qualification Programs and how the OEQP will interface with the PEQP. In general, it is expected that the licensee will rely on the generic and project-specific Equipment Qualification Programs to describe how the licensee will qualify equipment

for a specific project. The licensee is also expected to describe the OEQP that will be used to support long-term operations for the plant. At the licensing phase, the Equipment Qualification Program process is primarily descriptive and commitment level document.

9.2 Project Authorization Phase

A project is generally not authorized by a utility (licensee) until after a COLA is submitted and accepted by the NRC for review. At this point, the licensee will decide if they wish to proceed with the project, and this is generally signified by the signing of an Engineering, Procurement and Construction (EPC) contract with MHI/MNES and other participant to the Project Organization including AE(s), constructor(s), and key suppliers. Following issuance of an EPC, MHI/MNES will define the Project participants (Project Organization) responsible for the overall delivery of a US-APWR to the licensee. Even though an EPC may have been issued, the actual site design and supporting work may not be authorized until some milestone is reached. When the project is ready to proceed, MHI/MNES will establish a Project Equipment Qualification Organization (PEQO) from or within the Project Organization. The PEQO is responsible for preparing project-specific equipment qualification procedures which form the basis for the PEQP. At this point, the Equipment Qualification Program directives form the basis for the authorization of the PEQO and PEQP. The PEQP is generated by the PEQO.

9.3 Project Equipment Qualification Organization (PEQO)

The US-APWR Equipment Qualification Program Directives and Procedures listed below provide the guidance for formation of the PEQO. This will occur as part of the Project Authorization for a new US-APWR order as described above.

<u>Directives</u>

Dir-01, *US-APWR Project Equipment Qualification Program Authorization*
Dir-02, *US-APWR Project Equipment Qualification Program Definitions and Organizational Responsibilities*
Dir-03, *Application of Equipment Qualification Requirements to the US-APWR Design, Procurement, Fabrication, Construction and Startup*
Dir-04, *US-APWR Equipment Qualification Program Documentation Requirements*
Dir-05, *Quality Assurance Requirements for a US-APWR Equipment Qualification Program*
Dir-06, *US-APWR Project Equipment Qualification Program Training Requirements*

9.4 Site Design and Project Engineering Phase

This phase of the Project includes site and detailed engineering design, analysis, the preparation of SSC specifications listing equipment qualification requirements where appropriate, equipment qualification record generation, and related documentation control activities. The Equipment Qualification Program related to design activities is addressed in part, by the following US-APWR Equipment Qualification Program procedures:

Pro-04, *US-APWR Equipment Qualification Program Selection and Identification of Structures, Systems and Components*
Pro-05, *US-APWR Equipment Qualification Program Documentation and Records Retention*
Pro-06, *US-APWR Equipment Qualification Program Analysis Requirements*

Pro-08, *US-APWR Equipment Qualification Program Application During the Design Phase of a Project*
Pro-13, *US-APWR MHI/MNES Assignment of Equipment Qualification Program Execution to/from the Project Equipment Qualification Organization*
Pro-16, *US-APWR Equipment Qualification Program Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSC)*
Pro-17, *US-APWR Equipment Qualification Program Qualification Methods*
Pro-20, *US-APWR Equipment Qualification Program Qualification by Analysis*
Pro-22, *US-APWR Equipment Qualification Program Project Records Management*

9.5 Personnel Training and Qualification for Personnel engaged in Equipment Qualification Activities including Vendor Personnel

All personnel, including vendor personnel, engaged in equipment qualification activities must be trained and qualified to perform their specific equipment qualification functions. The PEQO will develop the training and qualification procedures under the guidance of the following US-APWR Equipment Qualification Program procedures.

Pro-05, *US-APWR Equipment Qualification Program Documentation and Records Retention*
Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
Pro-15, *US-APWR Equipment Qualification Program Training Requirements*
Pro-25, *US-APWR Equipment Qualification Program Personnel Qualifications*

Note that personnel qualification records and training records are QA documents. The documents will be developed and retained in accordance with Procedures 5 and 7, above.

9.6 Procurement Phase

MHI/MNES, the A/E(s), Constructor(s), and equipment suppliers are responsible for completing certain PEQP activities during this phase of the project under the direction of the PEQO. This phase includes qualifications, documentation, preparation of equipment qualification Packages and vendor qualification activities. The equipment qualification related procurement activities are addressed, in part, by the following US-APWR Equipment Qualification Program procedures.

Pro-09, *US-APWR Equipment Qualification Program Application During Procurement*
Pro-19, *US-APWR Equipment Qualification Program Qualification by Vendor Certification*
Pro-21, *US-APWR Equipment Qualification Program Qualification by Using Experience Data Method*
Pro-23, *US-APWR Equipment Qualification Program Confidential and Proprietary Information*
Pro-24, *US-APWR Equipment Qualification Program Exceptions and Open Items*

9.7 International Procurement Phase

The components supplied for the US-APWR will include items manufactured from international suppliers, including MHI. MHI will supply the NSSS, digital control systems, main turbine and other components and systems primarily from Japanese and other international sources. As such, the project-specific PEQP Procedures will address the international aspects of the

design, engineering, procurement and construction phases for the US-APWR Project. The PEQP-related international procurement activities are addressed, in part, in the following US-APWR Equipment Qualification Program procedures.

Pro-03, *US-APWR Project Specific Equipment Qualification Program Organization Management Structure*
Pro-08, *US-APWR Equipment Qualification Program Application During the Design Phase of the Project*
Pro-17, *US-APWR Equipment Qualification Program Qualification Methods*
Pro-22, *US-APWR Equipment Qualification Program Project Records Management*
Pro-23, *US-APWR Equipment Qualification Program Confidential and Proprietary Information*

9.8 Vendor Qualification and Audit

The US-APWR PEQO is responsible for vendor qualification and audit for procurement of equipment addressed by the Equipment Qualification Program under the procurement authority provided by MHI/MNES. This is implemented by the following US-APWR Equipment Qualification Program procedures.

Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
Pro-09, *US-APWR Equipment Qualification Program Application During Procurement*

International vendor qualification and audit may be delegated by MNES to MHI and its subcontractors under MHI's qualified ASME Quality Assurance Plan. However, the ultimate responsibility remains with MHI/MNES for all procurement of equipment addressed by the Equipment Qualification Program.

9.8.1 Procurement Receipt Inspection

The US-APWR PEQO is responsible for, or will be involved in, procurement and receipt inspection of equipment addressed by the Equipment Qualification Program under the procurement authority provided by MHI/MNES. This is implemented by US-APWR Equipment Qualification Program procedure numbers:

Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
Pro-09*, US-APWR Equipment Qualification Program Application During Procurement*

Receipt inspection, in general, is part of the MHI/MNES QA Program which governs QA activities. The Equipment Qualification Program requirements the documentation associated with equipment qualification of SSCs are inputs to the QA Program primarily for vendor qualification, audit and documentation. As components are bought for a given US-APWR project, then document packages and equipment qualification packages should accompany the physical delivery of those components. As such, the details for receipt inspection on procurement can be prepared at commencement of detailed design of a US-APWR. These equipment qualification document packages are referred to as Equipment Qualification Data Summary Reports (EQDSR) or Equipment Environmental Qualification Report (EEQR) or Equipment Seismic Qualification Report (ESQR), or some other variation similar to this. That is similar names and phrases are used to signify the collection, presentation, cataloging and filing of the appropriate equipment qualification data for each SSC. It is expected that much of

this work will be highly computerized to minimize the need to handle large quantities of paper and to allow project participants ready access to this data.

9.8.2 Suppliers Problem Trending

The US-APWR PEQO is responsible for, or will be involved in, QA audit, quality control (QC) inspection and subsequent problem trending of equipment addressed by the Equipment Qualification Program under the procurement authority provided by MHI-MNES and MHI. This is covered by US-APWR Equipment Qualification Program procedure number Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program* and Procedure number Pro-09, *US-APWR Equipment Qualification Program Application During Procurement.* Also, Procedure number Pro-24, *US-APWR Equipment Qualification Program Exceptions and Open Items* is applicable.

9.9 Equipment Qualification Data Packages or Data Sheets

MNES will interface and coordinate the actions of the PEQO. Project equipment qualification procedures shall address interfaces between the Project Organization.

The US-APWR PEQO is responsible for equipment qualification data packages in accordance with industry standard practices. The Equipment Qualification Data Package template is presented in this Technical Report as Attachment D. This is implemented by Equipment Qualification Program procedure numbers:

Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
Pro-09, *US-APWR Equipment Qualification Program Application During Procurement*.
Pro-16, *US-APWR Equipment Qualification Program Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSC)*.

Equipment qualification data for each SSC will be compiled and organized for easy access by the licensee and other users of this information. The data is expected to be stored electronically with electronic copies of all test reports, specifications, analysis, etc. being retrievable electronically as discussed in a previous section.

9.10 Construction Phase

MHI/MNES, the A/E(s), Constructor(s) and licensee are responsible for this phase of project-specific Equipment Qualification Program. During construction, the Constructor will be responsible for ensuring that mounting, support and connection configurations established during equipment qualification is maintained in the installed condition. The work of performing the inspections may be delegated to the Project Quality Control Organization, but the responsibility remains with the PEQO. Deviations from the qualified configuration must be evaluated and documentation of the evaluations maintained in the equipment qualification record files as Quality Assurance records in auditable form for the life of the plant.

Once the plant construction is initiated, a comprehensive equipment qualification document control office is established on the plant site to receive, organize and control all equipment qualification document packages. Equipment Qualification Data Packages generated during the design and procurement phases will be transferred from other project organizations to this office for consolidation and archiving. Upon completion of construction and beginning with the first system startup activities, the construction document control is responsible for turnover of

the complete equipment qualification document package for a given system. Equipment qualification document packages are turned over to the utility (licensee) as systems are completed and accepted by the licensee.

Field changes will be reviewed by the PEQO to ensure that parameters established during equipment qualification are maintained. Deviations will be evaluated and documented in the equipment qualification record files. The following US-APWR Equipment Qualification Program Procedures provide guidance to the PEQO on equipment qualification activities during this phase of the Project.

Pro-05, *US-APWR Equipment Qualification Program Documentation and Record Retention*
Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
Pro-10, *US-APWR Equipment Qualification Program Application during the Construction Phase*
Pro-16, *US-APWR Equipment Qualification Program Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSC)*
Pro-22, *US-APWR Equipment Qualification Program Project Records Management*
Pro-24, *US-APWR Equipment Qualification Program Exceptions and Open Items*

9.11 Startup Phase

MHI/MNES, the A/E's, Constructor(s), and licensee are responsible for this phase of PEQP. This should include the pressure testing of mechanical systems and energizing testing of electrical equipment as part of the equipment qualification process. The major structural and component testing at this phase is the Integrated Leak Rate Testing (ILRT) of the Containment Building and all of its contents. The ILRT pressure tests the components inside containment against its containment pressure, thus performing an operational qualification and certification for power operation of the unit. This phase includes verification, testing and documentation. The US-APWR Equipment Qualification Program procedures listed below provides guidance to the PEQO on equipment qualification activities during this phase of the Project.

Pro-11, *US-APWR Equipment Qualification Program During Startup and Commissioning*
Pro-12, *US-APWR Equipment Qualification Program Application During Initial Operations*

More detailed startup testing procedures are outside of the scope of this Technical Report, but may have impact on the equipment qualification of individual components.

As the execution of the PEQP nears completion, prior to fuel load, the PEQO, acting as an agent for MHI/MNES, is to transfer the responsibility for the PEQP back to MNES/MHI. Refer to Procedure number Pro-13, *US-APWR MHI/MNES Assignment of Equipment Qualification Program Execution to/from the Project Equipment Qualification Organization*.

Upon receipt of the PEQP, MNES/MHI, following satisfactory review and acceptance of the PEQP, transfers the PEQP to the Licensee in accordance with Program procedure number Pro-14, *US-APWR Equipment Qualification Program Transfer from MHI/MNES to Licensee (Owner).*

9.12 Testing Laboratories Qualification and Audit

The US-APWR PEQO is responsible for, or will be involved with, the procurement of laboratory testing services for equipment addressed by the Equipment Qualification Program under the procurement authority provided by MHI/MNES. This is covered by US-APWR Equipment Qualification Program procedure number Pro-07*, US-APWR Equipment Qualification Program Quality Assurance Program* and procedure number Pro-18, *US-APWR Equipment Qualification Program Qualification by Testing.*

9.13 All Project Phases

Certain US-APWR Equipment Qualification Program procedures apply to all PEQP phases of a project and thus were not specifically listed in the descriptions provided for the various project phases. These procedures form the basis for implementing project-specific procedures governing common elements of the PEQP.

These procedures include the following:

- Pro-01, *US*-APWR *Equipment Qualification Program Implementation for a Specific Project*
- Pro-02*,* *US*-APWR *Equipment Qualification Project Definitions and Equipment Qualification Program Implementation Boundaries*
- Pro-03, *US-APWR Project Specific Equipment Qualification Program Organization Management Structure*
- Pro-05, *US-APWR* Equipment Qualification *Program Documentation and Records Retention*
- Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
- Pro-22, *US-APWR Equipment Qualification Program Project Records Management*
- Pro-25, *US-APWR Equipment Qualification Program Personnel Qualifications*

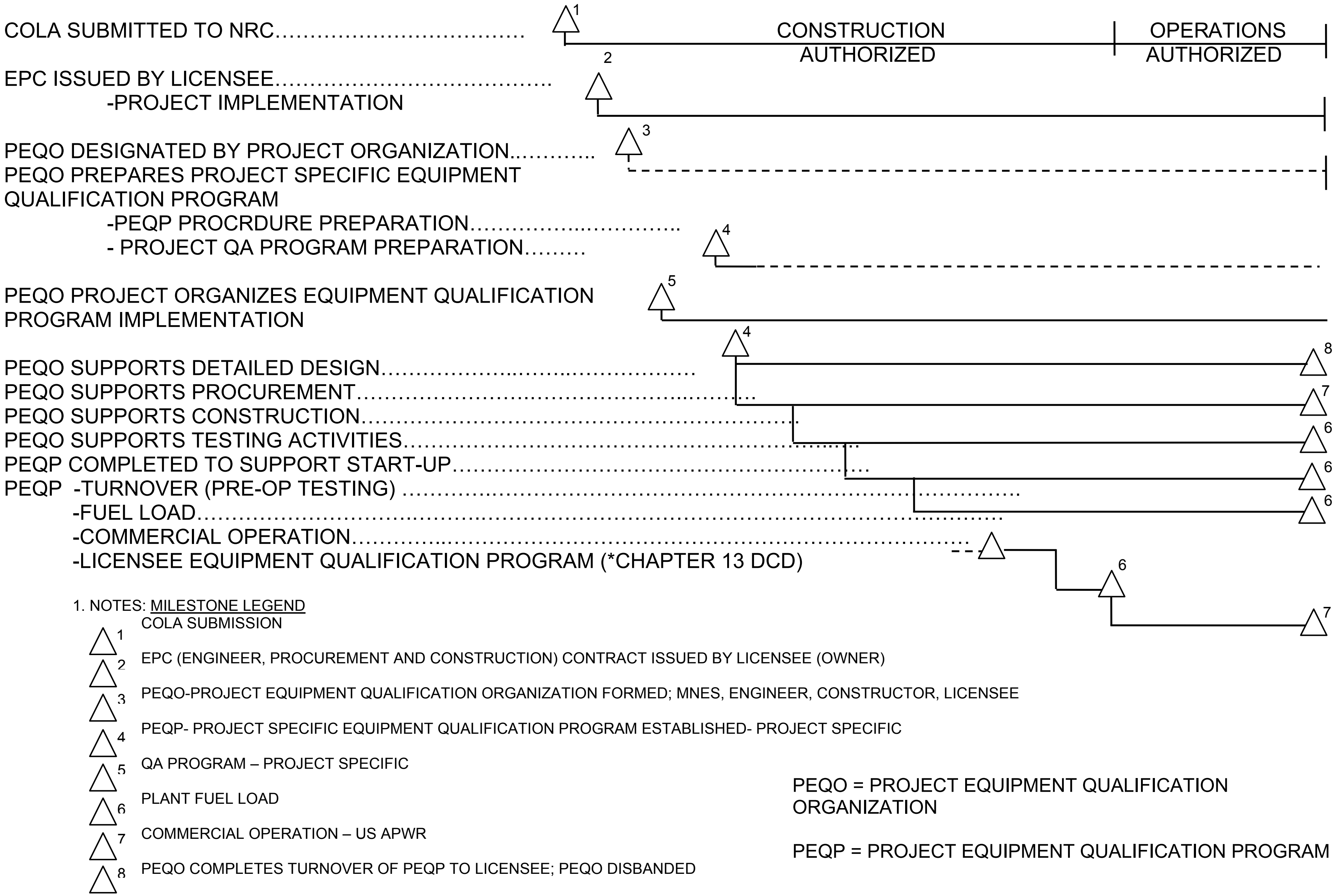
9.14 Operational Equipment Qualification Program (OEQP)

At the time the Licensee's fuel load is authorized by the NRC (OL licensure), the PEQP is transferred to the Licensee and becomes the OEQP. The OEQP will remain in place for the life of the plant.

9.15 Summary

This section has briefly described how the generic US-APWR Equipment Qualification Program would be implemented for a specific US-APWR project. The actual details of the implementation of a project-specific Equipment Qualification Program have been left to the PEQO. There are numerous options in providing the support to deliver a US-APWR to a licensee and thus the actual framework and organizational structure of a Project Organization cannot be fully defined at this time. The US-APWR Equipment Qualification Program has been designed to provide implementation flexibility, while at the same time providing the necessary guidance to a PEQO to allow the detailed formulization of a PEQP.

Figure 9-1 US-APWR Project Specific Equipment Qualification Program Milestone Schedule



10.0 EQUIPMENT QUALIFICATION PROGRAM TRANSFER TO U.S. UTILITY (LICENSEE) AND PEQP CLOSEOUT

MHI/MNES will turn over the PEQP to the U.S. utility (licensee) when the utility (licensee) accepts this responsibility prior to fuel load. At this time, the U.S. utility's (licensee) Quality Assurance and Document Control Program will provide oversight and audit responsibility for the OEQP program. This turnover process is described in US-APWR Equipment Qualification Program Directive No. Dir-03, *Application of Equipment Qualification Requirements to the US-APWR Design, Procurement, Fabrication, Construction, and Startup*, and US-APWR Equipment Qualification Program Procedure numbers Pro-12, Pro-13, and Pro-14. Program Procedure number Pro-14, *US-APWR Equipment Qualification Program Transfer from MHI/MNES to Licensee (Owner)* is the most applicable and descriptive of this transfer process.

10.1 U.S. Utility (Licensee) Assumption

The A/E(s), major suppliers and the Constructor(s) will have transmitted the equipment qualification documentation to the PEQO for their scope of supply. MHI will transfer the assembled equipment qualification, procurement, and other QA/QC construction documentation to the U.S. utility (licensee) as part of the project turnover process. The turnover documentation is usually assembled on a system or major component basis. Some of the major items this turnovers documentation consists of the following:

- Final procurement specifications and change orders for equipment addressed by the Equipment Qualification Program
- Procurement documentation packages to contain component drawings, certificates of compliance, nondestructive examination and other vendor test results
- Receipt inspection records, any non-conformance reports and the documents resolving deficiencies of any type such as vendor reports or engineering evaluations
- Maintenance manuals and spare parts lists
- Construction records including :
  - As built records
  - Field change requests and the documents resolving deficiencies of any type such as engineering evaluations
  - Test reports
  - Maintenance records where Construction had responsibility prior to turnover to the U.S. utility (licensee)
  - Inspection Reports
- Operational test results such as component and system hydrotests, start up testing, and checklists
- Final equipment qualification documentation packages to show compliance with regulatory requirements
- Open of missing information, if any, is normally tracked as part of the turnover process.

US-APWR Equipment Qualification Program Procedure number Pro-14, *US-APWR Equipment Qualification Program Transfer from MHI/MNES to Licensee (Owner)* is the applicable procedure for this turnover process. It should be recognized that there will be some open items when the transfer occurs and the closeout of these open items will take some time. The

open items will be evaluated to assure that they do not impact safe overall operation of the facility.

10.2 Construction during PEQP Turnover to Licensee

The PEQO is responsible for both Quality Assurance and Document Control of all equipment qualification documentation as it is received at the US-APWR plant site. As actual structures, systems and components (SSC) are either received as they are procured, or constructed as they are built, the construction organization is responsible for any maintenance or storage of components and systems until they are turned over to the U.S. utility (licensee). This also involves controlling the environments for these systems or warehouse storage of components as required by Regulatory Guide 1.38 and ANSI standard N45.2.2. [ANSI N45.2.2. is incorporated in ASME NQA-1].

The PEQO with the construction contract organization is responsible for ensuring that vendor recommended maintenance / surveillance is performed on stored and installed equipment during the construction period.

The PEQO is responsible for ensuring that mounting, support and connection configurations established during equipment qualification process are documented and maintained in the installed condition. The work of performing the initial and follow on inspections may be delegated to the Quality Control Organization, but the responsibility remains with the PEQO. Deviations from the as qualified configuration must be evaluated and documentation of the evaluations maintained in the equipment qualification record files for the life of the plant.

Field changes are reviewed by the PEQO to ensure that parameters established during equipment qualification are maintained. Deviations shall be evaluated and documented in the equipment qualification record files for the life of the plant. Final system walk downs assure installation of SSCs is completed and documented. Construction Phase activities will continue during and after the PEQP is turned over to the licensee, although with full licensee control and as punch list items are cleared. Thus there will be some PEQP activities that continue while these open construction items are closed out.

Refer to US-APWR Equipment Qualification Program procedure numbers Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program* and Pro-09, *US-APWR Equipment Qualification Program Application During Procurement*. Also refer to Program Procedure numbers Pro-10, *US-APWR Equipment Qualification Program Application during the Construction Phase* and Pro-16, *Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSC).*

10.2.1 Other Turnover Activities

At time of turnover, the equipment qualification documentation is only a portion of the total turnover package to the licensee, which may or may not be jointly compiled by the turnover organization. This will be determined on a project specific basis. Turnover records are subject to audit by the NRC in conjunction with establishing that the plant is ready for fuel load. The audited records include equipment qualification records as described above. The process of assembling and verifying that all turnover packages are complete is a tedious and detailed process and it may or will involve resolving discrepancies in the equipment qualifications of various SSCs. The PEQO is responsible for this process as well as the closeout of items carried in the plant ITACC as discussed in the next sections.

10.3 Inspections, Tests, Analysis, and Acceptance Criteria (ITAAC)

Completion of Inspections, Tests, Analyses and Acceptance Criteria (ITAAC), and the NRC approval of ITAAC closure are a constraint on fuel load for combined license holders. Therefore, the Equipment Qualification Program implementation must be integrated with the ITAAC closure process in order to assure effective identification and closure of program-related ITAAC activities.

10.3.1 Electrical Equipment

To ensure that the seismic design requirements of GDC 2 and the equipment qualification requirements of 10 CFR 50.49 are addressed, ITAAC are established for the applicable systems to verify the design aspects of Class 1E electrical equipment and other equipment requiring special seismic or environmental qualification. The design specifications and other descriptions for this equipment identify the seismic qualifications and environmental qualifications for equipment located in a harsh environment. ITAAC verify the qualification of systems and components for seismic and harsh environments.

Electrical and I&C equipment located in a mild environment are specified to meet the environmental and seismic conditions of their respective as-built locations.

10.3.2 Mechanical Equipment

Active Mechanical Equipment whose function is required to ensure the safe operation or safe shutdown of a nuclear power plant is qualified in accordance with ASME QME-1-2007, as endorsed by RG 1.100 Rev 3. ITAAC includes verification of component operation (e.g., pump and valve tests) seismic qualification and compliance with ASME Code, Section III requirements under design loading conditions where appropriate.

10.3.3 Pipe Break

To ensure that the applicable requirements of GDC 4 have been adequately addressed, ITAAC are established to verify that the safety-related SSCs have been designed to the dynamic effects of pipe breaks. In addition, ITAAC are established to verify by as-built inspections of as-built, high-energy pipe break mitigation features and of the pipe break analysis report that safety-related SSCs are protected against the dynamic and environmental effects associated with postulated high-energy pipe breaks.

10.3.4 As-built Reconciliation

To ensure that the final as-built plant structures are built in accordance with the certified design as required by 10 CFR Part 52, structural analyses are performed which reconcile the as-built configuration of the plant structures with the structural design bases of the certified design via ITAAC.

For the reactor vessel (RV), the key dimensions of the RV system are verified in conjunction with the basic configuration check of the system. The key dimensions of the RV system and the acceptable variations of the key dimensions are provided in the certified design description. Alternatively, acceptable variations and the bases for them are provided and a final analysis of the dimensions is performed.

For component qualification, tests, analyses, or a combination of tests and analyses are performed for seismic Category I mechanical and electrical equipment to demonstrate that the as-built equipment and associated anchorages are qualified to withstand design basis dynamic loads without loss of safety function. These test and analyses are performed as a part of ITAAC to verify the basic configuration of the system in which the equipment is located.

Detailed supporting information for dynamic qualification requirements, including seismic qualification records, are required for the Equipment Qualification Program prior to the turnover stage of construction.

10.3.5 Active Valves

The verification of the design qualification of valves with active safety functions is performed in conjunction with the ITAAC for mechanical equipment as discussed above.

10.3.6 Initial Test Program

Initial Test Program (ITP) for the Project shall interface to the PEQO and support the PEQP as necessary to qualify certain SSCs that are verified in the ITP as per RG 1.68 Initial Test Programs for Water-Cooled Nuclear Power Plants.

10.4 PEQP Closeout Process

The PEQO will establish a document control center for equipment qualification records. This record center may be part of a larger construction records center on the project or a specific equipment qualification only records center, depending on the project organizations direction. Assembled equipment qualification records are reviewed for completeness and cataloged in this record center. These records are available during the construction and testing phases of the project for QA and NRC review. As SSCs are constructed and tested and completed, the associated records documenting this are assembled as described in the previous section. The goal of the closeout process is to fully transfer all equipment qualification responsibilities to the licensee in an orderly and controlled manner. The records are reviewed by various project personnel including the licensee's personnel, QA-construction, QA-operations and vendor personnel in some cases. If these reviews are satisfactory, a recommendation is made to the licensee to accept the system as complete and in compliance with the requirements delineated in the DCD and other contract documents. The licensee may or may not accept the system. He may accept a portion of the system. He may accept on equipment qualification responsibilities and not the system in that the licensee may feel that there are too many open items to fully accept the system. The purpose of discussing this is to note that this turnover process is a dynamic process, will take some time, and will involve some "give and take" between the various parties to ensure that all items are fully and correctly addressed.

10.4.1 Closeout

For single unit plants this closeout process will require that portions of the PEQO remain mobilized to support the turnover and acceptance process following acceptance of the equipment qualification program responsibilities of by the licensee. In the case of dual units, for the first unit it is likely that the PEQO will also be tasked with the PEQP for the second unit and thus the turnover process of the first unit will allow the PEQO to support unit 1's open equipment qualification item closeout while supporting the PEQP for unit 2. In all likelihood,

open items closed on unit 1 will by default closeout potential open items for unit 2. At some point in this process the licensee will accept full responsibility for the equipment qualification records and the OEQP and the PEQO will be disbanded by the project organization. The disbanding of the PEQO will conclude the Equipment Qualification Program from the manufacturer's standpoint for a given project. This is consistent with the COL and NRC requirements that the licensee assumes responsibility for the Equipment Qualification Program when the plant becomes operational.

10.5 Summary

In summary, equipment described in Section 2.0 of this report is covered and followed by the PEQP from its design inception through the phases of procurement to its construction installation, testing and turnover. This involves active participation by both the PEQO and QA organizations to assure equipment qualification and other design criteria are met, maintained during construction and documented at the finish of US-APWR plant. The final goal of the PEQP is to provide a complete equipment qualification design basis for the new nuclear plant. This equipment qualification design basis would then be maintained for the operating life of the plant by the licensee. The licensee's OEQP is briefly described in the next section.

11.0 GENERAL DESCRIPTION OF UTILITY (LICENSEE) OPERATIONAL EQUIPMENT QUALIFICATION PROGRAM

This Technical Report provides a brief description of the Utility (Licensee) Operational Equipment Qualification Program (OEQP). The OEQP implementation represents the final step of the PEQO transferring all responsibility for equipment qualification to the Utility operating the US-APWR commercial nuclear power plant. This process is done over several steps, commencing prior to fuel load and prior to the commercial operation of the US-APWR. The OEQP is responsible for all aspects of the continuing equipment qualification program such as:

- Spare part inventory
- Procurement of replacement parts
- Addressing programmatic aspects of OEQP such as aging of non-metallic parts
- Evaluating engineering and design questions as they arise such as Synergistic effects during long term power operations while allowing for considerations like available operating life with a margin for fulfilling safety functions during a DBA or other analyzed accident
- Establishing or contributing to an establishment of a Inservice Inspection Program (ISI) and a Inservice Testing Program (IST) as described in Chapter 13 of the Licensee's COLA
- Implementing the ISI and IST programs described above to verify active mechanical components required to be functionally qualified such as the dynamic restraints (snubbers) remain capable of fulfilling their intended safety function
- Providing a commercial grade dedication program and engineering staff to implement the program
- Evaluating environmental qualification results for design life to establish activities to support continued environmental qualification
- Determining surveillance and preventive maintenance activities based on environmental qualification results
- Considering environmental qualification maintenance recommendations from equipment vendors
- Evaluating operating experience in developing surveillance and preventive maintenance activities for specific equipment
- Developing plant procedures that specify individual equipment identification, appropriate references, installation requirements, surveillance and maintenance requirements, post-maintenance testing requirements, condition monitoring requirements, replacement part identification, and applicable design changes and modifications
- Developing plant procedures for reviewing equipment performance and environmental qualification operational activities, and for trending the results to incorporate lessons learned through appropriate modifications to the environmental qualification operational program, and
- Developing plant procedures for the control and maintenance of environmental qualification records.

The above items are not a comprehensive listing but illustrate the activities the Utility shall have in place prior to fuel load. These programs are implemented, documented and controlled by appropriate plant operating and maintenance procedures. These programs are

administered by the plant staff. The plant operating and maintenance procedures are outside of the scope of the reactor vendor (MHI) and thus are not directly a part of this Equipment Qualification Program Technical Report. This section of the Technical Report is included to describe the continuity of the equipment qualification process after the plant is constructed and tested. . (See NRC direction in SECY 05-00197 regarding implementation and descriptions of licensee Operational Programs).

11.1 Summary Description of US-APWR Plant Procedures Relating to OEQP

As indicated in the appropriate COLA, all equipment qualification activities for a specific US-APWR project that affect SSCs addressed by the Equipment Qualification Program will be conducted by detailed, written, and approved procedures and instructions. These procedures and instructions include the OEQP in the Operation, Emergency Response, Maintenance, Test, Inspection, and Surveillance activities in the plant

The plant licensee develops and implements written administrative procedures that assign the responsibilities and authorities of the plant staff. These administrative procedures also provide the control measures for the preparation, review, approval, revision, and use of all station procedures and instructions that govern OEQP or quality related activities. Administrative procedures ensure that station procedures and instructions are reviewed by qualified personnel, approved by authorized personnel, and distributed to and used by the personnel performing the prescribed activity.

The administrative controls used during the operations phase are consistent with the provisions of RG 1.33. The QA program described in COLA Chapter 17 addresses document control, record retention, and adherence, assignment of responsibilities, approval, and change requirements for procedures. The station management position designated responsible for a given activity, as prescribed in the QA manual, is also responsible for the preparation of procedures and instructions for that activity.

The actual preparation of procedures and instructions may be performed by other plant personnel or by outside contractors. The final responsibility lies with the designated responsible position.

The purpose of this section of the Technical Report is to clarify and define the end point for the MHI Equipment Qualification Program as it applies to each US-APWR project. The MHI Equipment Qualification Program provides a structured approach to qualifying SSCs requiring equipment qualification and the subsequent turnover to the plant licensee.

12.0 SUMMARY

This Technical Report provides a description of the MHI US-APWR Equipment Qualification Program and its intended implementation for a specific US-APWR project. The General Design Criteria of 10 CFR 50, Appendix A provides the regulatory and technical basis for the MHI Equipment Qualification Program. Other regulatory requirements are derived from the GDCs and various Code of Federal Regulation (CFR) sections. The NRC has issued RGs addressing the equipment qualification requirements for SSCs. The RGs generally embrace industry codes and standards (e.g., IEEE and ASME) which provide direction for qualifying electrical and mechanical equipment. The US-APWR Equipment Qualification Program complies with the requirements outlined in these codes and standards. The process of qualifying SSCs involves a complex process during the analysis, design, procurement, construction, testing and turnover phases of a project. The equipment qualification process requires a dedicated programmatic approach to fulfilling the various equipment qualification requirements and this approach has been formulated, planned, documented and described in this Technical Report. The Equipment Qualification Program interfaces with the ITAAC and ITP programs and operating plant staff during project turnover to complete the licensing process.

At the completion of the construction and startup testing phase of a project, the NRC is expected to audit the Equipment Qualification Program and the associated equipment qualification records in support of granting a full term operating license to the plant owner. The PEQP records are transferred to the plant licensee at this time and the PEQP will become the OEQP.

Adherence to the MHI Equipment Qualification Program will insure that SSCs described in Section 2.0 of this report that are used to construct the US-APWR are qualified and capable of fulfilling their intended safety functions in all anticipated environmental conditions. The MHI Equipment Qualification Program provides a sound, documented basis for the plant licensee's OEQP. Equipment Qualification is a dynamic process involving many types of SSCs and as such, specific qualification processes, procedures and approaches vary with the SSC and the phase of a project. The actual formal formulization of the PEQP has been left to the Project Organization following the guidance provided in the US-APWR Equipment Qualification Program. This approach provides the flexibility and adaptability needed to address the various project contractual and licensing relationships that will evolve with each US-APWR project.

13.0 REFERENCES

13.1 U.S. Regulations

10 CFR 50.34, "Contents of Applications, Technical Information," Subsection (f) (2) (ix).

10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants."

10 CFR 50.67, "Accident Source Term."

10 CFR 50, Appendix A, General Design Criterion 1, "Quality Standards and Records;" General Design Criterion 2, "Design Basis for Protection against Natural Phenomena;" General Design Criterion 4, "Environmental and Dynamic Effects Design Basis;" General Design Criterion 14, "Reactor Coolant Pressure Boundary;" General Design Criterion 17, "Electric Power Systems;" General Design Criterion 19, "Control Room;" General Design Criterion 20, "Protection System Functions;" General Design Criterion 21, "Protection System Reliability and Testability;" General Desing Criterion 22, "Protection System Independence;" General Design Criterion 23, "Protection System Failure Modes;" General Design Criterion 24, "Separation of Protection and Control Systems;" General Design Criterion 29, "Protection Against Anticipated Operational Occurrences;" General Design Criterion 30, "Quality of Reactor Coolant Pressure Boundary;" and General Design Criterion 60, "Control of Releases of Radioactive Materials to the Environment."

10 CFR 50, Appendix B, Criterion III, "Design Control;" Criterion XI, "Test Control;" and Criterion XVII, "Quality Assurance Records."

10 CFR 52.47, "Contents for Applications."

10 CFR 52.97, "Issuance of Combined Licenses."

13.2 U.S. RGs

NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment."

NUREG/CR-6842, "Advanced Reactor Licensing: Experience with Digital I&C Technology in Evolutionary Plants."

NUREG/CR6901, "Guidelines for Electromagnetic Interference Testing in Power Plants."

NUREG-0737, "Clarification of TMI Action Plan Requirements."

NUREG-0800 SRP 3.10, "Seismic and Dynamic Qualification of Mechanical & Electrical Equipment."

NUREG-0800 SRP 3.11, "Environmental Qualification of Mechanical and Electrical Equipment."

NUREG-0800 SRP Branch Technical Position 3-3, "Protection against Postulated Piping Failures in Fluid Systems Outside Containment"

RG 1.22, “Periodic Testing of Protection System Actuation Functions.”

RG 1.29, “Seismic Design Classification.”

RG 1.30, (Safety Guide 30), “Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment.”

RG 1.33, “Quality Assurance Program Requirements (Operation).”

RG 1.40, “Qualification of Continuous Duty Safety-related Motors for Nuclear Power Plants.”

RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants.”

RG 1.63, “Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants.”

RG 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants.”

RG 1.73, “Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants.”

RG 1.89, “Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants.”

RG 1.92, “Combinning Modal Responses and Spatial Components in Seismic Response Analysis.”

RG 1.97, “Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants.”

RG 1.211, “Qualification of Safety-related Cables and Field Splices for Nuclear Power Plants.”

RG 1.122, “Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components.”

RG 1.151, “Instrument Sensing Lines.”

RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.”

RG 1.180, “Guidelines for Evaluation Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems.”

RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors.”

RG 1.139 “Guidance for Residual Heat Removal” (for Comment Rev. 0, May 1978) Note: Cold shutdown requirements as related to environmental qualification of equipment Conformance with exceptions. Criterion 7 applies to a site-specific operational program.

RG 1.156 “Environmental Qualification of Connection Assemblies for Nuclear Power Plants” (Rev. 0, November 1987) Conformance with no exceptions identified.

RG 1.158 “Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants” (Rev. 0, February 1989) Conformance with no exceptions identified.

RG 1.189, “Fire Protection for Nuclear Power Plants.”

RG 1.209, “Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants.”

RG 1.100, “Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants”.

13.3 Regulatory Review Precedent

Letter dated December 17, 1996, from L.E. Martin, Houston Lighting & Power, to the U.S. Nuclear Regulatory Commission, “South Texas Project, Units 1 and 2, Docket Nos. STN 50-498, STN 50-499, 10 CFR 50.59 Summary Report.”

Letter dated April 8, 1998, fro T. Alexion, NRC, to William Cottle, STP Nuclear Operating Company. “Request for Additional Information on Elimination of Environmental Qualification of Mechanical Components. South Texas Project, Units 1 and 2 (STP) (TAC Nos. M98912 and M98913).”

Letter dated May 6, 1998, from S.E. Thomas, STP Nuclear Operating Company, to U.S. Nuclear Regulatory Commission, “Response to Request for Additional Information on Elimination of Environmental Qualification of Mechanical Components,” Docket Nos. STN 50-498, STN 50-499, Units 1 and 2 (STP).

Letter dated September 24, 1998, from T. Alexion, NRC to PD IV-1 File, “Licensee’s 10 CFR 50.59 Evaluation of Elimination of Environmental Qualification of Mechanical Components, South Texas Project, Units 1 and 2 (STP) (TAC Nos. M98912 and M98913).”

SECY-05-0197, 10/28/2005, Review of Operational Programs in a Combined License Application and Generic Emergency Planning, Inspections, Tests, Analyses, and Acceptance Criteria.

13.4 NRC Inspection Procedures

NRC Inspection Procedure (IP) 38703, “Commercial Grade Dedication”.

NRC Inspection Procedure (IP) 43004, “Inspection of Commercial-Grade Dedication Programs”.

NRC Inspection Procedure (IP) 88108, “Quality Assurance: Control of Materials, Equipment, and Services (Pre-licensing and Construction)”.

13.5 U.S. Industry Codes and Standards

IEEE Std 100-2000, “IEEE 100 The Authoritative Dictionary of IEEE Standards terms Seventh Edition.”

IEEE Std C37.82-2004, ‘IEEE Standard for the Qualification of Switchgear Assemblies for Class 1E Applications in Nuclear Power Generating Stations.”

IEEE Std C37.105-1987, “IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations.”

IEEE Std 7.4.3.2-2003, “IEEE Standard Criteria for Digital Computers in Safety System of Nuclear Power Generating Stations.”

IEEE Std 317-1983 (reaffirmed 1992),” IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generation Stations.”

IEEE Std 323-1974,” IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.”

IEEE Std 323-2003, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.”

IEEE Std 334-2006, “IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations.”

IEEE Std 344-2004, “IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.”

IEEE Std 381-1977 (reaffirmed 1984), “IEEE Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations.”

IEEE Std 382-1972, “IEEE Trial-Use Guide for Type Test of Class 1 Electric Valve Operators for Nuclear Power Generating Stations.”

IEEE Std 383-2003, “IEEE Standard for Type Test of Class 1 Electric Cables and Field Splices for Nuclear Power Generating Stations.”

IEEE Std 387-1995, “IEEE Standard Criteria for Diesel Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.”

IEEE Std 497-2002, “IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations.”

IEEE Std 535-1986, “IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations.”

IEEE Std 572-1985, “IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations.”

IEEE Std 627-1980 (reaffirmed 1991), "IEEE Standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations."

IEEE Std 628-2001, "IEEE Standard Criteria for Design, Installation and Qualification of Raceway Systems."

IEEE Std 638-1992, "IEEE Standard for Qualification of Class 1E Transformation Nuclear Power Generating Stations."

IEEE Std 649-2006, "IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations."

IEEE Std 650-2006, "IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations."

IEEE Std 1202-1991, "IEEE Standard for Flame Propagation Testing of Wire and Cable."

IEEE Std 1205-2000, "Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment used in Nuclear Power Generating Stations."

IEEE Std 1290-1996, "IEEE Guide for Motor Operated Valve (MOV) Motor Application, Protection, Control, and Testing in Nuclear Power Generation Stations."

ASME NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications", 1994.

ASME NQA-1a, PART II, SUBPART 2.14, "Quality Assurance Requirements for Commercial Grade Items and Services", 2009

ASME QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants".

ASME Section III, "American Society of Mechanical Engineers Boiler and Pressure Vessel Code."

13.6 Industry Group References

EPRI, NP-5652, "*Guidelines for the Utilization of Commercial Grade Items in Nuclear Safety-Related Applications (NCIG-07)," 1988.*

EPRI, TR-102260, "*Supplemental Guidance for the Application of EPRI Report Np-5652 on the Utilization of Commercial Grade Items,*" 1994.

EPRI, TR-106439, "*Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications,*" 1996.

EPRI, TR-1001452, "Generic Qualification of Commercial Grade Digital Devices" Lessons Learned, 2001.

EPRI, TR 1001468, "Generic Qualification of the Rosemount 3051N Pressure Transmitter, Summary of Activities and Results," 2001.

EPRI, TR-112579, “Critical Characteristics for Acceptability of Seismic Sensitive Items (CCASSI), 2000.

EPRI, TR-1003105, “Dedicated Commercial-Grade Items Procured from ISO 9000 Suppliers,” 2001.

EPRI-TR-102323, Rev. 3, “Guidelines for Electromagnetic Interference Testing for Power Plants,” 2004 (1003697).

EPRI-TR-100516, “Nuclear Power Plant Equipment Qualification Reference Manual,” 1992

EPRI white paper, “Seismic Screening of Components Sensitive to High Frequency Vibratory Motions,” 2007.

EPRI, TR-1003585, “Generic Qualification/Dedication of Digital Components,” 2004.

EPRI, TR-017218, “Guideline for Sampling in the Commercial Grade Item Acceptance Process,” 1999.

INPO EPG-02, 2005 Engineering Program Guide, “Environmental Qualification of Electrical Equipment.” Note: This document primarily directed to operating utilities dealing with long term equipment qualification programs, however, it provides very good insight into formulization of the PEQO.

Nuclear Procurement Issues Committee (NUPIC) Joint Commercial Grade Survey Program Description, NUPIC Document No. 6 Joint Audit Program 2001 (see http://www.nupic.com/).

NUPIC, Document No. 10 Commercial Grade Survey Description, 1999.

Nuclear Industry Assessment Committee (NIAC)) Audit programs and assessments of nuclear suppliers using member programs, NIAC Checklists, govern assessments and audit (NIAC Audit Checklist, Rev. 6).

13.7 MHI Documents

MNES US-APWR QAPD SQ-QD-070001 “US-APWR Quality Assurance Program Description”.

US-APWR Topical Report, “Quality Assurance Program (QAP) Description For Design Certification of the US-APWR,” PQD-HD-19005, Rev. 5, May 2013.

US-APWR Technical Report, Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant,” MUAP-10006, Rev. 3, November 2012.

Attachment A Summary of Statutes, RGs, Industry Codes and Standards Applicable to the US-APWR Equipment Qualification Program

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
Federal Statutes	10 CFR 50 Energy	Defines Legal Requirements for Nuclear Plant Licensure	Invoked in sections for specific licenses
10 CFR 50, App A GDC 1	Quality Standards and Records	Basis for Nuclear Plant QA Program	Nuclear Plant QA is the basis for the Equipment Qualification Program
10 CFR 50, App A GDC 2	Design Basis for Protection Against Natural Phenomena	Design Basis for engineering safety analysis	Design Basis for engineering sets the environmental and performance requirements for the Equipment Qualification Program
10 CFR 50, App A GDC 4	Environmental and Dynamic Effects Design Basis	Expansion of requirements for GDC 2 Natural Phenomena	Sets seismic and other design basis requirements for Equipment Qualification Program
10 CFR 50, App A GDC 17	Electric Power Systems	Provides interface requirements for Nuclear Plant electric power systems	Sets engineering and performance design basis for electric power systems
10 CFR 50, App A GDC 19	Control Room	Define control room requirements including operating during DBA	Requires equipment be qualified to operate in DBA environments
10 CFR 50, App A GDC 20	Protection Systems Functions	Sets specific system functions for NSSS control systems	This is a major control system for the new nuclear plant with Equipment Qualification Program performance requirements
10 CFR 50, App A GDC 21	Protection System Reliability and Testability	Sets test requirements for NSSS control systems	This sets Equipment Qualification Program test and turnover requirements
10 CFR 50, App A GDC 22	Protection System Independence.	Prevents control and protection functions from interfering with protective function	Requires EMI/EMF evaluations to assure no interference

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
10 CFR 50, App A GDC 23	Protection System Failure Modes.	Sets criteria for control room including certain operation during accidents	Requires elements of control room to withstand some radiation exposure
10 CFR 50, App A GDC 24	Separation of Protection and Control Systems	Sets separation engineering and design requirements for protection and control systems	This GDC 24 has little input to Equipment Qualification Program; it is included only for reference to multiple train requirements for same equipment subject to Equipment Qualification Program
10 CFR 50, App A GDC 29	Protection Against Anticipated Operational Occurrences	Sets engineering and design requirements for protection and control system power operation	This GDC 29 has little input to Equipment Qualification Program; it is included only for reference to power operation
10 CFR 50, App A GDC 30	Quality of Reactor Coolant Pressure Boundary	High quality Reactor Coolant System (RCS) components and construction	Verify materials are qualified for environment used in reactor coolant pressure boundary
10 CFR 50.49	Qualification of Electrical Equipment Important to Safety	Assure equipment will function to mitigate a DBA	Mechanical equipment implied
RGs		Provide guidance in meeting regulatory requirements	Invoked in sections for specific licenses
RG 1.22	Periodic Testing of Protection System Actuation Function	Set specific system functions for NSSS control systems	This is a major control system for the Equipment Qualification Program performance requirements
RG 1.29	Seismic Design Classification	Provides guidelines for seismic design classification so that those SSCs which need to withstand an SSE can be identified	Seismic design is an Equipment Qualification Program critical characteristic of seismic category I and II SSCs
RG 1.33	Quality Assurance Program Requirements (Operations)	Used for reference and document adequacy evaluation to support turnover to licensee	Impacts records used for OEQP

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
RG 1.40	Qualification of Continuous Duty Safety-related Motors for Nuclear Power Plants	Sets testing criteria for equipment qualification and acceptance for safety-related motors inside Containment for LOCA analysis	Equipment Qualification Program critical characteristic of safety-related electrical component motors
RG 1.61	Damping Values for Seismic Design of Nuclear Power Plants	Identifies acceptable values for damping for elastic model seismic analysis	Used to support seismic qualification of SSCs
RG 1.63	Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants	IEEE Std 317-1983 endorsed by NRC	This standard prescribes requirements for the design, construction, testing, qualification, and installation of electric penetration assemblies in containment structures for stationary nuclear power generating stations
RG 1.68	Initial Test Programs for Water-Cooled Nuclear Power Plants	Initial Test Programs	SSCs to be tested to satisfy the requirements of GDC-1, “Quality Standards and Records”
RG 1.73	Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants	Sets acceptance values for electric valve operators installed inside the Containment	Equipment Qualification Program captures the critical requirements for electric valve operators installed inside the Containment
RG 1.89	Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants	Sets environmental qualification of electric equipment addressed by 10 CFR 50.49	Three categories of electric equipment are qualified for their application and specified performance and provide requirements for establishing environmental qualification methods and qualification parameters. These are (1) safety-related electric equipment (Class 1E), (2) non-safety-related electric equipment (non-Class 1E) whose failure under postulated environmental conditions could prevent satisfactory accomplishment of safety functions by safety-related equipment, and (3) certain post accident monitoring equipment

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
RG 1.92	Combining Model Response and Spatial Components in Seismic Response Analysis	Guidance for seismic analysis methodologies dealing with response spectrum modal dynamic analysis	Identify representative maximum for applicable response for three orthogonal spatial components
RG 1.97	Instrumentation for Light Water Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident		This endorses IEEE Std 497-2002
RG 1.100	Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants	Safety-related equipment covered under the Equipment Qualification Program added seismic requirements	RG 1.100 endorses, with exceptions and clarifications, IEEE Std 344-2004 and, for the first time, ASME QME-1.
RG 1.122	Development of Floor Design Response Spectra for Seismic Design of Floor Supported Equipment and Components	Guidance on specific methods to response spectra	Supporting seismic equipment qualification requirements.
RG 1.211	Qualification of Safety-related Cables and Field Splices for Nuclear Power Plants	Safety-related equipment covered under the Equipment Qualification Program	Refer to the DCD Section 8.1.5.3. This endorses IEEE 383-2003.
RG 1.156	Environmental Qualification of Connection Assemblies for Nuclear Power Plants	This RG provides additional guidance in meeting IEEE 323 requirements.	This endorses IEEE 572-1985.
RG 1.158	Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants	This RG provides additional guidance in meeting IEEE 323 requirements.	This endorses IEEE 535-1986.

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
RG 1.180	Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference for Safety-Related Instrument and Control Systems	This RG provides guidance in addressing EMI to Safety-Related I&C equipment	Discussed in DCD.
RG 1.209 & DG-1077	Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants	Safety-related electrical equipment, which consists of computer-based I&C systems, located in a mild environment is covered	This endorses IEEE Std 323-2003
RG 1.183 & DG 1081	Alternative Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors	This RG provides the basis for the radiation source term for evaluating design basis accidents	Equipment Qualification Program radiation doses input for analysis of equipment requiring environmental qualification
RG 1.210	Qualification of Safety-Related Battery Chargers and Inverters for Nuclear Power Plants	Qualification of battery chargers	IEEE Std 650-2006, “IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations,” endorsed by this RG with some exceptions
Industry Standards			
ASME Section III	American Society of Mechanical Engineers Boiler and Pressure Vessel Code	Addresses safety-related mechanical components and systems and the qualification needed to meet the mechanical requirements of that code	Seismic analysis criteria and methods for the mechanical and piping systems for the US-APWR. Note that active components are under ASME QME-1, very little Section III piping is within the Equipment Qualification Program scope, however, certain elements such as anchor bolts fall within the Equipment Qualification Program scope boundary

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
ASME NQA-1-1994	American Society of Mechanical Engineers Quality Assurance Requirements for Nuclear Facilities	Quality Assurance Program Requirements	Augments Equipment Qualification Program record keeping generation and maintenance and other QA functions.
ASME NQA-1a-2009, PART II, SUBPART 2.14	Amarican Society of Mechanical Engineers Qualification Assurance Requirements for Commercial Grade Items and Services	Defines commercial grade dedication process	Used to support commercial grade dedication process
ASME QME-1-2007	American Society of Mechanical Engineers Qualification of Active Mechanical Equipment Used in Nuclear Power Plants	Provides the requirements and guidelines for qualification of active mechanical equipment	Scope is for mechanical equipment whose function is required to ensure the safe operation of safe shutdown of a nuclear power plant
IEEE Std 344-2004	Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations	Industry standard	Endorsed by NRC in RG 1.100
IEEE Std 323-1974, 2003	IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations	Industry standard	Endorsed by NRC in RG 1.89
IEEE Std 535-1986	IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations	Industry standard	Endorsed by NRC in RG 1.158

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
IEEE Std 627-1980 & other IEEE standards	varies	Other IEEE standards apply to equipment qualification and all are not listed here but most are summarized under "Comments"	IEEE 627-1980, IEEE 308-2001, IEEE 317-1983, IEEE 381-1977, IEEE 382-1972, IEEE 383-2003, IEEE 420-1982, IEEE 494-1974, IEEE 535-1986, IEEE 572-1985, IEEE 603-1991, IEEE 649-2006, IEEE 650-2006, IEEE 741-1997, IEEE C37.98-1987
NUREG Series Publications			
NUREG 0800	Standard Review Plan 3.10, Seismic and Dynamic Qualification of Mechanical and Electrical Equipment	NUREG 0800 addresses the preparation of the US-APWR DCD and COLA FSAR and the licensing requirements therein	Sets forth details on Equipment Qualification Program requirements for licensing by U.S. NRC
NUREG 0800	Standard Review Plan 3.11, Environmental Qualification of Mechanical and Electrical Equipment	NUREG 0800 addresses the preparation of the US-APWR DCD and COLA FSAR and the licensing requirements therein	Sets forth details on Equipment Qualification Program requirements for licensing by U.S. NRC
Industry Practices			
EPRI reports	TR 102260	EPRI and NRC acceptance of commercial grade dedication pursuant to NRC guidelines	Filter to see if commercial grade items are acceptable
EPRI reports	TR-106439 Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Application	Prepared by operating utilities to address procurement of commercial grade items	Process accepted by NRC as delineated in TR-102260

DOCUMENT NUMBER	TITLE	PURPOSE	COMMENTS
EPRI white paper,	"Seismic Screening of Components Sensitive to High Frequency Vibratory Motions", Palo Alto, California, June 2007.	Detail requirements for evaluation and qualification of SSCs potentially sensitive to high frequency excitation.	
TR-1003585	Generic Qualification/Dedication of Digital Components	Basis for using commercial grade digital instrument and controls	IEEE supporting documents
TR-1003105	Dedicating Commercial-Grade Items Procured From ISO 9000 Suppliers	New process for using ISO 9000 suppliers	
TR-017218	Guideline for Sampling in the Commercial grade Item Acceptance Process	Example of commercial grade dedication procedures	
TR-112579	Critical Characteristics for Acceptance of Seismically Sensitive Items		
	NUPIC Audit Procedures	Provides audit of nuclear suppliers to show general compliance for 10 CFR 50, APP B QA requirements	See NAIC, utility initiative, NUPIC uses NUPIC audits and shares results. NUPIC methodologies acceptable to NRC.
	NAIC Audit Procedures	Provides audit of nuclear suppliers to show general compliance for 10 CFR 50, APP B QA requirements	See NUPIC, NAIC uses member audits and shares results. Process acceptable to NRC on a utility by utility basis.

Attachment B Description of the US-APWR Equipment Seismic Qualification Program

B.1 General Description

The program for seismic and dynamic qualification of equipment consists of procedures and criteria which are governed by and form a part of the overall MHI US-APWR Equipment Qualification Program.

The overall Equipment Qualification Program is comprised of the US-APWR Equipment Qualification Program Technical Report and Equipment Qualification Program directives and procedures that define the programmatic requirements for all environmental aspects of equipment qualification, including seismic / dynamic, radiation, pressure, temperature, humidity, aging, flooding, chemical, and synergistic effects. With respect to seismic/dynamic qualification, the program directives and procedures address topics such as:

- Program management structure
- Documentation and records retention and management
- Methods of qualification
- Quality assurance
- Personnel qualifications and training
- Implementation of the program during various phases (design, procurement, construction, startup/commissioning, initial operations, and turnover
- Preparation, maintenance, and control of equipment qualification files

The Equipment Qualification Program procedures also contain, or give direction on, sample document formats that can be used in implementing the equipment seismic qualification program. These include:

- Equipment Seismic Qualification Reports (ESQRs)
- Equipment Qualification Summary Data Sheets (EQSDS), which can be used for entry of seismic data into a project equipment qualification database
- Checklists for review of vendor/supplier seismic qualification reports

More detailed information on the ESQR is found in the example seismic analysis report format included at the end of this Attachment as a sample of the details included in a PEQP.

A complete listing and description of Equipment Qualification Program directives, procedures, and their attachments addressing the above topics is given in Section 8.0 of this Technical Report.

B.2 Scope of Equipment Seismic Qualification and Seismic Qualification Criteria

Seismic category I equipment is required to be seismically and dynamically qualified under the program by demonstrating that its structural integrity is maintained and that it is capable of performing its designated safety function during and after a postulated earthquake in conjunction with the full range of applicable normal and accident loads and conditions. Seismic category I equipment requiring qualification in accordance with the US-APWR Equipment Qualification Program is determined in accordance with the guidance in RG 1.29.

The equipment seismic qualification program criteria define specific technical requirements for seismic and dynamic qualification of seismic category I, safety-related mechanical equipment (excluding piping), and seismic category I (class 1E) electrical and instrumentation equipment, including associated supports and mountings. The program includes qualification of Category I tanks and reservoirs for hydrodynamic seismic loads, where applicable. All such equipment that is required to perform functionally or maintain its structural integrity, as described above, is subject to rigorous seismic/dynamic qualification. A detailed listing of MHI US-APWR standard plant seismic category I equipment, requiring seismic qualification, is given in Table 3.2-2 and Appendix 3D in Tier 2 of the MHI US-APWR DCD.

It should be noted that detailed criteria for functionality testing and inspection of mechanical and electrical equipment such as performance tests, hydrostatic tests, leakage tests, etc. are not within the scope of the equipment seismic qualification program. Also, qualification through dedication of commercial grade items (i.e., those items which are available commercially and not designed and manufactured under a quality assurance program complying with 10 CFR 50 Appendix B) is not within the scope of the equipment seismic qualification program or the overall generic Equipment Qualification Program. For commercial grade items that will be used in seismic category I applications, a commercial grade dedication plan and special technical evaluations are required which account for the critical design and acceptance characteristics of the items. MHI/MNES may utilize commercial grade dedication as appropriate for the project specific Equipment Qualification Program.

B.3 Seismic Category II Qualification Requirements

The equipment seismic qualification program criteria also define technical requirements for seismic and dynamic qualification of equipment whose failure could prevent satisfactory accomplishment of one or more of the safety-related functions of equipment described in Section B.2 above.

This includes seismic category II equipment, defined as that equipment which performs no safety-related function, and whose continued function is not required, but whose structural or functional failure or interaction could degrade the functioning or integrity of a seismic category I SSC to an unacceptable level, or could result in incapacitating injury to occupants of the control room.

Therefore, seismic category II equipment can be seismically qualified by demonstrating that it retains its position sufficiently in the event of an SSE to the extent that it will not cause unacceptable structural interaction with or failure of seismic category I SSCs. For fluid systems, this requires an appropriate level of pressure boundary integrity to prevent seismically-induced flooding that may cause adverse effects on safety-related SSCs.

Note that in cases where it is not possible or practical to isolate the seismic category I equipment, non-seismic equipment that is adjacent to seismic category I equipment is classified as seismic category II and analyzed and supported such that an SSE event does not cause an unacceptable interaction with the seismic category I equipment.

Based on the qualification objectives defined above for seismic category II equipment and supports, the degree of seismic qualification for seismic category II SSCs does not warrant the full extent of sophisticated dynamic analysis or seismic vibration testing that are typically applied for qualification of seismic category I equipment. Simplified analytical techniques such as the equivalent static method are acceptable for demonstrating structural integrity of seismic

category II equipment and supports. However, more sophisticated dynamic analyses can be applied in some cases where demonstration of pressure boundary integrity is required. Analysis of seismic category II equipment and supports under the scope of the US-APWR Equipment Qualification Program shall conform to the requirements for seismic analysis established in Chapter 3 Section 3.7 of the US-APWR DCD.

Criteria for qualification of seismic category I equipment are presented in MHI US-APWR criteria entitled "Seismic Qualification of Category I Electrical and Mechanical Equipment (including supports)." Equipment Qualification Program Procedure 9, "*US-APWR Equipment Qualification Program Application during Procurement Phase of Projects*" also includes seismic analysis requirements as a part of its detailed program.

B.4 Codes and Standards for Seismic / Dynamic Qualification

The program for seismic and dynamic qualification complements, and is consistent with, the technical requirements and parameters that are specific of Tier 2 of the MHI US-APWR Design Control Document, particularly those of Chapter 3 Sections 3.7, 3.10 and 3.11. The equipment seismic qualification program technical requirements are based largely on those contained within IEEE Std 344-2004 and ASME QME-1 (for functional qualification of active mechanical equipment). Requirements of IEEE Std 323 that are pertinent to seismic and dynamic qualification are incorporated into the program for equipment seismic qualification.

ASME QME-1-2007, Nonmandatory Appendices to Section QR along with the Appendix QR-A through QR-E, QDR (QDR-A through QDR-C), and QV and QV-1 provide guidance on qualifying active mechanical equipment such as pumps, valves and dynamic restraints particularly their nonmetallic parts. These Sections are intended as a guide in the absence of project specific procedures to direct the PEQO in developing related equipment qualification procedures for the qualification of active mechanical equipment such as pumps, valves and dynamic restraints. The following list from ASME QME-1-2007 Table of Contents indicates what items should be addressed by the PEQP:

Section QR
QR-A Seismic Qualification of Active Mechanical Equipment
    Appendix QR-A Figures
    Appendix QR-A Table
QR-B Guide for Qualification of Nonmetallic Parts
QDR Qualification of Dynamic Restraints
    QDR-A Functional Specification for Dynamic Restraints
    QDR-B Restraint Similarity
    QDR-C Typical Values of Restraint Functional Parameters
QP Qualification of Active Pump Assemblies
QP-A Pump Specification Checklist
QP-B Pump Shaft-Seal System Specification Checklist
QP-C Pump Turbine Driver Specification Checklist
QP-D Pump Similarity Checklist
QP-E Guidelines for Shaft-Seal System Material and Design Considerations
QV Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants
QV-1 Qualification Specification for Active Valves
QV-A Functional Specification for Active Valves for Nuclear Power Plants
QV-G Guide to Section QV

The project specific equipment qualification procedures for active mechanical equipment must be established to determine the suitability of materials, parts, and equipment needed for safety-related functions, and to verify that the design of such materials, parts, and equipment is adequate. The verification of design (i.e., qualification) for components located in harsh environments shall be demonstrated by appropriate testing and analysis. Testing at the actual conditions desired for qualification will normally be provided to assure that the non-metallic will perform acceptably. Analysis can be an alternate method of demonstrating the information for one non-metallic component to the qualification of another. Details of the material analysis such as description of analytical methods, assumptions, justifications, supporting test data, conclusions, and limitations shall be recorded in the qualification documentation for each component. The test/analysis shall establish a qualification life or replacement schedule for the nonmetallic component which shall be recorded in the qualification documentation.

Qualification for mechanical components is limited to non-metallic materials that are sensitive to environmental effects (e.g., seals, gaskets, lubricants, fluids for hydraulic systems, and diaphragms.) Qualification of non-metallic parts in mechanical equipment shall be performed in accordance with ASME QME-1-2007 Appendix QR-B as endorsed by RG 1.100 Rev 3. Section 6.6 of this Technical Report provides a general description of the US-APWR qualification process for mechanical equipment. The site specific PEQP fully describes the qualification process for mechanical components. The program description and its implementation should include attributes such as equipment identification, safety-related function, performance criteria, and identification of service conditions, material capabilities, and description of potential failures, qualification procedure, and equipment qualification maintenance records. The COL Applicant's site specific PEQP describes the qualification process for mechanical equipment and provides a COL information item for the COL applicant to address these issues.

The equipment seismic qualification program also incorporates supplemental seismic and dynamic qualification requirements from United States Nuclear Regulatory Commission (NRC) RG 1.100, NUREG-0800 Standard Review Plan 3.10, NUREG-0800 Standard Review Plan 3.11, NRC "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications."

The equipment seismic qualification program conforms to the requirements of Appendix S "Earthquake Engineering Criteria for Nuclear Power Plants" of Title 10, Part 50, of the Code of Federal Regulations (10 CFR Part 50) and applicable portions of the general requirements contained in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."

Sections of 10 CFR Part 50, Appendix A "General Design Criteria for Nuclear Power Plants" also provides general requirements for equipment seismic qualification including, but not limited to, the following GDC:

- GDC 1, "Quality Standards and Records"
- GDC 2, "Design Bases for Protection Against Natural Phenomena"
- GDC 4, "Environmental and Dynamic Effects Design Basis"
- GDC 14, "Reactor Coolant Pressure Boundary"
- GDC 22, "Protection System Independence"

- GDC 30, "Quality of Reactor Coolant Pressure Boundary"

Seismic category I SSCs must also meet the pertinent QA requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," related to all activities associated with design, procurement, fabrication, construction, inspection, and/or testing, including but not limited to:

- Criterion III, "Design Control"
- Criterion XI, "Test Control"
- Criterion XVII, "Quality Assurance Records"

Seismic category I SSCs meet the QA controls defined in Part I of the US-APWR QAPD and COL licensee's QAPD. Seismic category II SSCs meet the selected QA controls in Part III of the US-APWR standard design QAPD and COL licensee's QAPD.

The above-cited codes, standards, and regulatory documents are not intended to be an all-inclusive list. Refer to Attachment A of this Technical Report for a complete list of references applicable to the equipment seismic qualification program and the overall MHI US-APWR Equipment Qualification Program.

B.4.1 Computer Code Verification and Validation for Seismic Equipment Qualification

The computer codes and software used for seismic equipment qualification are listed in the DCD and project specific COLA. Each computer code is subject to Quality Assurance Verification and Validation (QV&V) for use on the US-APWR. This QV&V is not in the scope of the Equipment Qualification Technical Report but is found with the appropriate calculation and its associated documentation. Public domain software that has widespread industry usage is listed in the DCD and COLA for these analyses with the following examples:

- ANSYS
- NASTRAN
- SASSI

The MHI/MNES and COLA Applicant's Quality Assurance program addresses the QV&V requirements for qualifying the seismic analysis computer codes and software used as tools in the SEQ.

B.5 Required Response Spectra Used for Seismic Qualification

The required response spectra (RRS) in IEEE Std 344-2004 are defined as the spectra which represent the motion at the support of the seismic category I and II equipment shall serve as the basic seismic input/parameters for equipment to be qualified under the auspices of the US-APWR Equipment Qualification Program. The broadened SSE and Operating-basis Earthquake (OBE) in-structure response spectra (ISRS) corresponding to the location(s) and elevation(s) of a particular piece of equipment within a seismic category I building or structure define the seismic input motion to be used for qualification of that equipment. For equipment that is supported on foundations resting on the ground surface, the corresponding Foundation Input Response Spectra (FIRS) shall serve as RRS for their seismic qualification. Multiple sets of ISRS may be applicable to a single piece of equipment because it may be attached at several elevations, or because it may be part of a system that extends across multiple building/structure elevations and locations. In these cases, equipment seismic qualification

considers the effects of differential support motions. Multiple sets of ISRS may be applicable to a particular model or type of equipment because it may be used within multiple buildings or at multiple locations within a building or structure.

As per equipment qualification program procedural requirements, MHI/MNES must be contacted for resolution if at any time it becomes apparent that equipment to be qualified will be mounted at a location or elevation for which there are no corresponding ISRS. This condition can occur during detailed design or during the procurement phase as particular equipment mounting characteristics or positions/locations are determined. This can also occur during the construction phase of a project when field conditions require a certain SSC to be relocated. The PEQP procedures address these requirements.

The RRS may be subsequently converted to time histories for use as input for numerical time-history analyses or for setting shake table input motion. In so doing, the direction of US-APWR equipment seismic qualification program is that the time histories should be generated in accordance with the general guidance of NUREG 0800 SRP 3.7.1, with a Nyquist frequency of 100 Hz.

B.6 Standard Plant versus Site-Specific SSE RRS

The SSE used for seismic qualification of equipment is defined as that design earthquake which produces the maximum vibratory ground motion for which structures, systems and components, which perform a primary safety function, are designed to remain functional. The equipment seismic qualification for the US-APWR equipment qualification program uses two different types of SSE:

1) A site-independent SSE used for the qualification of US-APWR standard plant equipment where ground design motion is represented by the certified seismic design response spectra (CSDRS); and
2) A site-dependent (site-specific) SSE used for qualification of non-standard portions of the US-APWR where ground design motion is represented by site-dependent ground motion response spectra (GMRS) and Foundation Input Response Spectra (FIRS).

For standard plant seismic category I buildings and structures, the design does not vary and therefore the ISRS used as input for seismic qualification will be the same for each building and structure at every US-APWR site. US-APWR standard plant seismic category I buildings and structures include, but are not limited to, the R/B, prestressed concrete containment vessel (PCCV), containment internal structure, and east/west power source buildings (PS/BS). For these buildings and structures, the applicable SSE ISRS are the SSE ISRS presented in “Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant, MUAP-10006, Mitsubishi Heavy Industries, Ltd., November 2012.”

For equipment located in seismic category I buildings and structures that are not part of the US-APWR standard plant and are designed on a site-specific basis, SSE ISRS and FIRS are established on a site-specific basis. The ground motion response spectrum associated with the site-specific SSE must be enveloped by, but may have a different shape than, the standard plant CSDRS. As required by the US-APWR DCD Tier 2 Chapter 3, the site-specific SSE ISRS are to be developed based on the site-specific SSE response analysis using seismic analysis methods that are consistent with Section 3.7 of the DCD and with particular requirements for ISRS given in DCD. For purposes of equipment qualification, standard plant SSE ISRS may be used for qualification of equipment located in site-specific buildings and

structures, provided that it can be demonstrated that the applicable site-specific SSE ISRS are fully enveloped (both shape and magnitude) by the SSE ISRS used for the qualification, for all pertinent frequencies. In this case, the qualification documentation must identify this approach and clearly demonstrate how the applicable site-specific SSE ISRS are enveloped by the standard plant SSE ISRS. This approach may also be used for considering OBE ISRS – see Section B.7, below.

The COL Applicant is to investigate if site-specific in-structure response spectra generated for the COL application may exceed the standard US-APWR design's in-structure response spectra in the high-frequency range. Accordingly, the COL Applicant is to consider the functional performance of vibration-sensitive components, such as relays and other instrument and control devices whose output could be affected by high frequency excitation. Additional information to qualify or eliminate SSCs potentially sensitive to high-frequency is provided in Subsection B.14.

As per the US-APWR equipment seismic qualification equipment qualification programmatic requirements, it is the responsibility of the PEQO to ensure that appropriate ISRS are identified and included in the equipment vendors/suppliers procurement specifications for their use in seismic qualification of their equipment.

B.7 Consideration of OBE and Application of OBE ISRS for Equipment Seismic Qualification

The operational basis earthquake (OBE) specifies the magnitude of ground motion that requires plant shutdown. Consistent with Tier 2 Chapter 3, Section 3.7 of the MHI US-APWR DCD, the OBE is set on a site-specific basis by the COL Applicant for each individual US-APWR Project, but must be enveloped by 1/3 of the standard plant CSDRS.

Appendix S of 10 CFR 50 stipulates that the magnitude of an OBE can be adopted either as (A) 1/3 or less of the SSE; or (B) a value greater than 1/3 of the SSE. For Option A, explicit response or design analyses considering the OBE are not required to be performed for plant SSCs. If Option B is chosen, explicit analysis and design must be performed to demonstrate that all SSCs necessary for continued operation without undue risk to the health and safety of the public will remain functional within applicable stress, strain, and deformation limits.

Subsection 3.7.1 of the MHI US-APWR DCD has set OBE for design of the US-APWR standard plant at 1/3 of the SSE. Therefore, for purposes of standard plant equipment qualification, explicit analysis of standard plant equipment for OBE is not required.

However, it is recognized that during the life of the plant, equipment may be subjected to seismic excitations at lower levels than the SSE, which has the potential to reduce the "life expectancy" of those items sensitive to fatigue. Therefore, to account for fatigue effects, analysis and testing shall include the equivalent effects of five one-half SSE events followed by one full SSE event (10 full cycles of the maximum SSE stress range). Alternatively, a number of fractional peak cycles equivalent to the maximum peak cycle for five one-half SSE events may be used in accordance with Annex D, "Test Duration and Number of Cycles," to IEEE Std 344-2004, when followed by one full SSE. This is consistent with guidance given in NRC SECY-93-087 and RG 1.100.

For seismic qualification of equipment located in site-specific parts of US-APWR plant, the site-specific OBE RRS must be considered. Similar to the approach for the standard plant, if

OBE is set at 1/3 or less of the site-specific SSE, then for purposes of equipment qualification, explicit design and analysis of the site-specific equipment for OBE is not required (except for fatigue considerations). If, however, the site-specific OBE for a particular US-APWR Project site is set higher than 1/3 of the site-specific SSE, then explicit analysis of OBE is required for purposes of equipment qualification. As discussed in Section 7.6 of IEEE Std 344-2004, it may be acceptable to consider fewer than five site-specific OBE events, provided that technical justification is provided.

As per the US-APWR equipment seismic qualification equipment qualification programmatic requirements, it is the responsibility of MHI/MNES to ensure that appropriate OBE ISRS are identified and transmitted to equipment vendors/suppliers for their use in seismic qualification of their equipment.

B.8 Application of RRS and Equipment Qualification Criteria

The RRS, in conjunction with the following equipment qualification criteria established for the equipment seismic qualification program, serve as the basic inputs and technical requirements for analysis and testing of mechanical, electrical, and instrumentation equipment requiring seismic and dynamic qualification as per the MHI US-APWR Equipment Qualification Program:

- Seismic Qualification of Category I Mechanical Equipment and Inline Fluid System Components (including inline mounted equipment and supports)
- Seismic Qualification of Category I (Class 1E), Electrical and Instrumentation Equipment (including supports)
- Seismic Qualification of Category I Reservoirs and Tanks (including supports)
- Seismic Qualification of Category II Electrical and Mechanical Equipment (including supports)

The list of US-APWR Equipment Qualification Program Procedures provided in Attachment C lists requirements for seismic qualification of equipment and supports by analysis, testing, or a combination of analysis and testing, using the applicable ISRS. The requirements for qualification by analysis and qualification by testing are discussed in sections B10 and B.11 below respectively.

The US-APWR Equipment Qualification Program procedures previously discussed provide specific programmatic direction on how to apply and implement the ISRS and the criteria discussed above during the design and procurement phases of a US-APWR Project. The procedures direct that the criteria are to be referenced by or attached to procurement packages for mechanical, electrical, and instrumentation equipment that is required to be seismically qualified. As per the project procedures, vendors/suppliers of equipment for the US-APWR project are required to demonstrate conformance with the criteria. The qualification criteria may also be used by equipment manufacturers to establish and substantiate performance claims and verify equipment performance as part of their overall qualification effort. As per the US-APWR Equipment Qualification Program directives and procedures, any conflicts between the criteria and the equipment purchase specification, equipment design specification, or the codes and standards must be brought to the attention of the PEQO.

The following US-APWR seismic design criteria for equipment-related commodities and distribution systems complement the equipment qualification procedures of the equipment seismic qualification program:

- Heating, Ventilation and Air Conditioning (HVAC) Duct and Duct Supports Design Criteria
- Seismic Qualification of Cable Trays and Supports Design Criteria
- Conduit and Conduit Support Design Criteria

B.9 Vendor Certification Using Previous Qualification Data or Comparison by Similarity

The US-APWR Equipment Qualification Program allows for equipment to be seismically qualified by the vendor using the results of previous analysis, generic (type) testing, or previous testing for another nuclear plant project-specific application. In these cases, US-APWR Equipment Qualification Program procedures allow for seismic qualification by demonstrating that applicable US-APWR ISRS are enveloped by the RRS used for the previous qualification, and provided that all other US-APWR programmatic and technical requirements for qualification are met. See IEEE Std 323-2003 or the version referenced by the PEQO for each US-APWR project, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations” as endorsed in RG 1.89 for IEEE Std 323-1974.

B.10 Qualification by Analysis

Analysis under the scope of the US-APWR program for seismic qualification of equipment conforms to the requirements for seismic analysis established in Tier 2 Chapter 3, Section 3.7 of the US-APWR DCD. The requirements for analytical modeling and the methods of seismic analysis defined in Tier 2 Chapter 3, Sections 3.7, 3.9, and 3.12 of the US-APWR DCD are adopted for the US-APWR program for seismic qualification. Requirements for qualification by analysis are specified in the equipment qualification criteria previously listed.

The analysis method is not recommended for complex equipment that cannot be modeled to correctly predict its response. Qualification performed by the analysis method is expected to be extensive enough to consider all critical details of a component or assembly. Analysis without testing is acceptable only if structural integrity alone can assure the design-intended function.

In cases of complex equipment, it may be acceptable to perform qualification by analysis on a portion or portions of a component or equipment assembly that can be accurately and reliably modeled, and to perform qualification by testing on the remaining portion(s). In these cases, the limits and interfaces of each method must be clearly explained and in sufficient detail to provide adequate justification for the approach used. The choice of applied seismic analysis method depends on the desired level of precision and the level of complexity of the particular equipment or component being qualified. Detailed descriptions of seismic analysis methods are contained in the DCD and therefore are discussed only briefly here. The methods of analysis include:

- Modal response spectra analysis, which uses the broadened RRS as direct input for seismic qualification. For this method of analysis, the combination of multi-modal and multi-directional responses is in accordance with RG 1.92, “Combining Modal Responses and Spatial Components in Seismic Response Analysis.”
- Time history analysis, which uses seismic qualification input time histories generated from the broadened RRS. The generation of input time histories and the methodology of analysis should conform to the general requirements of NUREG 0800, SRP 3.7.1, unless justification is otherwise provided. The time history for each direction of the earthquake motion must be statistically independent of the others. The equipment /

component responses for each orthogonal direction are to be combined using either Square Root Sum of the Squares (SRSS) or the Newmark 100%-40%-40% method in accordance with RG 1.92.

- Equivalent static load analysis. The equivalent static load method of analysis is generally recommended for seismic qualification of rigid equipment or equipment support structures whose dynamic response can be represented by models with few degrees of freedom. The equivalent static load method is relatively simple and more conservative than the other more detailed methods. The US-APWR seismic qualification program adopts the same ISRS peak acceleration factors as documented in Subsection 3.7.3 of the US-APWR DCD. Maximum equipment/component responses for each orthogonal direction are to be combined using either SRSS or the Newmark 100%-40%-40% method in accordance with RG 1.92.

For the purpose of seismic and dynamic qualification of equipment by analysis, the rigid response range is defined as that having a natural frequency greater than 50 Hz. This matches the frequency at the beginning of the zero period acceleration (ZPA) for the CSDRS defined in Tier 2 Chapter 3, Subsection 3.7.1 of the US-APWR DCD, and the associated ISRS which serve to define the RRS for equipment locations. For equipment which is not sensitive to high-frequency excitation, setting the ZPA frequency of the time response spectrum (TRS) at 50 Hz will not yield significant new dynamic testing results with respect to qualification, and might unnecessarily invalidate the documentation of any technically acceptable equipment that was previously qualified using generic RRS with a ZPA of 33 Hz. Therefore for the purpose of testing equipment that is not sensitive to response levels caused by high frequency ground motions, rigid is defined as equipment with a natural frequency greater than 33 Hz. If the equipment to be tested is sensitive to response caused by high frequency ground motions, then rigid is defined as equipment having a natural frequency greater than 50 Hz. For equipment which may be sensitive to high frequency, the provisions of the MHI US-APWR Equipment Qualification Program procedures require additional screening and/or qualification testing for all high-frequency exceedances above 20 Hz. Such exceedances may occur at certain hard rock high-frequency sites as discussed in Subsection 3.7.1.1 of the DCD. In these cases, it is noted that the site-specific ZPA range may then actually be at frequencies greater than 50 Hz, and the ZPA for the TRS for any applicable qualification testing would then also need to be adjusted upward accordingly. See Section B.14 for further discussion of high-frequency exceedances of earthquake ground motion.

Load combinations and load factors for analysis are specified in the equipment seismic qualification program documents previously listed, and follow the load definitions and load combinations given in Chapter 3, Sections 3.8 and 3.9 of the US-APWR DCD.

Damping values used in qualification by analysis are specified in the qualification documents and are consistent with those given in RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” and Table 3.7.3-1 of the US-APWR DCD, unless otherwise justified in the form of documented test data. MHI Technical Reports ”Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant, MUAP-10006, Mitsubishi Heavy Industries, Ltd., November 2012” provide ISRS for various damping values. If the ISRS contained in these documents contain spectra at damping values that do not match the damping values of the equipment being analyzed, the analysis may be performed using a conservative value of damping which is lower than the value anticipated for the equipment and matches one of the damping values that is available. Alternatively, the US-APWR equipment seismic qualification procedures provide guidance for calculating ISRS at intermediate damping values. Otherwise,

US-APWR Equipment Qualification Program procedures require that MHI/MNES be contacted for resolution.

B.11 Qualification by Testing

The US-APWR program for seismic and dynamic qualification by testing conforms to the technical requirements of IEEE Std 344-2004 with pertinent seismic and dynamic requirements from IEEE Std 323 and ASME QME-1, and adopts additional limitations and restrictions imposed by NRC RG 1.100. Requirements for seismic and dynamic qualification by testing are specified in the equipment qualification procedures previously listed and include direction for appropriate equipment mounting and input waveform (frequency content, amplitude, and duration to generate a response at any point in the equipment sufficient to adequately replicate the anticipated design motion and fatigue effects).

Acceptable testing methods include proof, generic (type), and fragility testing. In accordance with IEEE Std 323, the following basic requirements are applied to all seismic qualification by testing for the US-APWR Equipment Qualification Program:

- Testing must exhibit a 10% margin above those acceleration requirements established at the mounting point of equipment unless otherwise justified in the seismic qualification report (Reference Section 6.3.1.6 of IEEE Std 323).
- Prior to seismic qualification testing, equipment or devices must be aged to the end of their service life, including applicable effects of all other relevant environmental aging mechanisms such as mechanical cycling (fatigue), radiation, temperature, pressure, humidity, chemical degradation, and synergistic effects.

Multi-frequency testing or single-frequency testing is used for seismic category I instrumentation and electrical equipment in accordance with the guidelines in IEEE Std 344-2004. Additional information on the use of multi- or single frequency testing is contained in Procedure No. 9 Attachments B and C and in the Equipment Qualification Specifications.

As per seismic qualification program procedures, when qualification by testing is used, the Test Response Spectra (TRS) must envelope the RRS derived from the ISRS over the entire frequency range of interest, except where high-frequency exceedances exist (greater than 20 Hz) and the equipment has been demonstrated to be insensitive to high-frequency disturbances. It is also preferred that the damping value of the RRS be the same as that of the TRS. In cases where the equipment damping is not established, it is recommended that the TRS be performed at 5% damping. When the damping for the TRS is greater than that for the RRS and the test method criteria are satisfied, then the damping is considered acceptable since it will produce conservative results. As per IEEE Std 344-2004, when the damping in the TRS is less than that in the RRS (for the frequency range of interest), a conclusive statement is not possible without further evaluation, including revised damping values for the TRS.

B.12 Qualification by Combined Testing and Analysis

The US-APWR program for seismic qualification permits individual equipment to be qualified using a combination of testing and analysis where it is not practical to perform qualification by testing or analysis alone. This is anticipated for large equipment such as motors, pumps, or multi-bay equipment racks and consoles that cannot fit on a shake table or has too large of a mass to be handled by a shake table. In these cases, modal testing may be employed to identify resonant frequencies and mode shapes for correlation with an analysis.

B.13 Qualification Using Experience Data

The US-APWR DCD Tier 2 Chapter 3, Subsection 3.10.1.1 “Qualification Standards” and Subsection 3.10.4.2 “Experience Based Qualification” state that “Experience-based qualification is not used for any equipment.” Therefore, the US-APWR Equipment Qualification Program does not permit use of an experience-based approach for equipment qualification.

Qualification of equipment using an experience-based approach involves qualification by comparison that justifies similarity with previously qualified equipment that has been exposed to more severe in-plant vibration or natural seismic disturbances. The experience-based approach is also commonly referred to as the seismic qualification utility group (SQUG) approach which was used for qualification of existing equipment in older nuclear power plants as part of the resolution for NRC USI-46. The experience-based approach typically relies on a previously established database of either earthquake experience data or test experience data and is greatly dependent on the technical basis provided for justification of similarities.

Qualification of equipment using an experience-based approach is permitted by IEEE Std 344-2004, subject to the limitations and restrictions imposed by NRC RG 1.100 and a case-by-case review of the NRC and with respect to:

1. The credibility and completeness of the compilation of the experience database
2. The rules for inclusion/exclusion of equipment in the experience database
3. The justification used to demonstrate similarity among the member items in a reference equipment class and the similarity between equipment in the experience database and those in the US-APWR project to be qualified
4. The justification used to demonstrate the reference equipment class functionality
5. The credibility of similarity among member items of a reference equipment class if a generic reference equipment class is proposed.

Further, in accordance with NRC RG 1.100, the experience-based approach (earthquake or test experience data) shall not be used for seismic qualification of electrical and active mechanical equipment that is exposed to harsh environments, aging, and earthquakes. Test experience data shall not be used for seismic qualification of high-frequency-sensitive equipment unless the tests were performed using IEEE Std 344-2004 type tests with intentional high-frequency contents. Use of experience data (earthquake or test experience data) shall be avoided for seismic qualification of equipment identified in NRC RG 1.100 as:

1. Certain active electrical components that may inadvertently change state during an earthquake such that they do not consistently perform their intended safety functions during and/or after an earthquake, such as certain types of relays, contactors, circuit breakers, switches, sensors, and potentiometers
2. Fragile electronic components, such as solid-state relays and microprocessors-based components
3. Electric equipment, such as battery chargers, inverters, relay and control panels, switchgear, and motor control centers (since the performance of this equipment is sensitive to its locations, orientations, and type of mounting within the plant).

In conclusion, an experience-based approach for equipment qualification shall not be implemented on any specific US-APWR project without an approved revision to or an approved departure from the DCD, and is subject to a case-by-case review by and the limitations imposed by the NRC.

B.14 High-Frequency Exceedances of Earthquake Ground Motion

Historically, there have been occurrences of ground motions which have caused an exceedance of a plant's design spectra in the high frequency range. Based on nuclear plant operating experience, the high frequency response motion exceedances were found to be non-damaging to passive structural components, which are typically qualified by analysis. However, nuclear industry experience has found that certain SSCs, in particular fragile components such as relays, contactors, circuit breakers, switches, sensors, potentiometers, microprocessors-based components and other electrical and instrumentation and control devices whose output signals could be affected by high frequency excitation, are potentially sensitive and can be damaged by high frequency exceedances of the design spectra.

The US-APWR seismic qualification program adopts the guidance of IEEE Std 344-2004, and NRC RG 1.100, NRC "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants" to establish a process to identify, evaluate, and qualify or eliminate such SSCs that are potentially sensitive to high frequency exceedances.

Rigid equipment if dynamically excited at its base follows the motion of its foundation, without attenuation. For the purpose of qualification of equipment by analysis, the rigid range is defined as having a natural frequency greater than 50 Hz if that level is consistent with the GMRS-based ISRS. If there are high-frequency exceedances above 50 Hz then high-frequency screening shall be performed on all safety-related equipment/devices and components that are potentially sensitive to high-frequency disturbances. Subsequent high-frequency qualification testing may be required depending on these screening results. For the purpose of testing equipment that is not sensitive to response levels caused by high frequency ground motions, rigid is defined as equipment with a natural frequency greater than 33 Hz. If it is established that the equipment, to be tested, is sensitive to response caused by high frequency ground motions, then rigid is defined as equipment having a natural frequency greater than 50 Hz. See above for high-frequency qualification requirements

Additional equipment evaluation by screening and subsequent qualification testing, depending on screening results, is required when ISRS used for equipment qualification exhibit high-frequency exceedances due to site-specific exceedances of the ground motion response spectra. As per the guidance of NRC RG 1.100 and NRC interim staff guidance, such evaluations must be performed when exceedances occur at 20 Hz and above, and must demonstrate both structural integrity and functionality for seismic category I equipment.

The components identified for high-frequency exceedance evaluation are consistent with those identified in NRC RG 1.100 and those historically identified in the U.S. nuclear industry. Those components are also consistent with EPRI white paper, "Seismic Screening of Components Sensitive to High Frequency Vibratory Motions", Palo Alto, California, June 2007. The detailed requirements for evaluation and qualification or elimination of SSCs that are potentially sensitive to high frequency exceedances are addressed in the equipment seismic qualification procedures previously listed.

B.15 Interfaces

US-APWR Equipment Qualification Program procedures and directives ensure proper interfaces for implementation of seismic qualification procedures and requirements. For example, US-APWR Equipment Qualification Program procedures ensure that:

- Equipment vendors/suppliers are suitably qualified to comply with US-APWR Equipment Qualification Program requirements.
- The appropriate seismic RRS (ISRS, GMRS, and FIRS, as applicable) are properly defined and transmitted to equipment vendors and suppliers for their use in equipment qualification.
- In cases where it becomes apparent that equipment will be mounted at a location or elevation for which there are no corresponding ISRS, that the PEQO is contacted for resolution.
- Equipment vendors/suppliers submit test procedures and methods, including proposed test table input motion, to the PEQO for review and approval prior to implementation.
- Equipment vendors/suppliers submit all requisite documentation and records, including but not limited to properly formatted seismic qualification reports, to provide a complete demonstration of qualification for each piece of equipment, assembly, or component/device, in accordance with the US-APWR qualification criteria and programmatic requirements.
- Overall equipment support reactions are included in the vendor/supplier seismic qualification report that is submitted to the PEQO such that the equipment supporting structure (floor slab or beam, wall, etc.) and the equipment anchorage can be evaluated and/or designed.
- Equipment assemblies and devices/components shall be mounted in the same configuration and orientation for which they were qualified, unless specific technical justification is otherwise included in the equipment qualification submittal.
- Any conflicts between the qualification criteria and the equipment purchase specification, equipment design specification, or the codes and standards are brought to the attention of MHI/MNES for resolution.
- Appropriate PEQO design and qualification reviews and approvals of vendor supplied equipment are performed.

Notes to Seismic Qualification Program Description

With any SSC, the engineering design for form, fit and function are the initial design steps. Components of a system will have design and operational requirements that are documented on the specifications and drawings for that component. Once the initial design is done for a specific project, then the Equipment Seismic Qualification Report (ESQR) process for the component can begin.

Equipment Qualification Program Procedures include seismic analysis requirements as part of the implementation of a project-specific program. Including seismic analysis requirements, as stated above, follows the guidance for seismic analysis as listed in the US-APWR DCD. As needed, the results from this analysis may require seismic design for components to be seismically qualified and equipment qualification considerations for this seismic design in the purchase of these components via a design/purchase specification process.

This design/purchase specification process shall include the following.

a. The vendor shall provide a certificate of conformance that the component meets all environmental parameters. The certificate shall include qualified life, replacement schedule, replacement instructions, and shelf life for each nonmetallic.

b. To ensure the nonmetallic meets the design/purchase specification and remains qualified for the design life determined by the vendor, the Utility must develop a maintenance/surveillance/preventive maintenance program to monitor the nonmetallic to ensure it remains qualified for the design life. This program should follow SRP (Section II, SRP Acceptance Criteria, item 15) for guidance for using the 10CFR 50.65 program and associated guidance in RG1.160 to provide reasonable assurance that nonmetallic remain qualified for the designed life.

The PEQP and its associated equipment qualification procedures further describe the process for demonstrating an acceptable design using design/purchase specifications.

Equipment Qualification Summary Data Sheet (EQSDS), Equipment Environmental Qualification Report (EEQR) and Equipment Seismic Qualification Report (ESQR) formats

For each piece of safety-related seismic category I equipment (i.e., each mechanical and electrical component of each system), the COL Applicant is to develop and maintain an equipment qualification file that contains a list of systems, equipment, and equipment support structures and summary data sheets referred to as an equipment qualification summary data sheet (EQSDS) of the seismic qualification summarizing the component's qualification.

ANALYSIS REPORT FORMAT – EXAMPLE ONLY
ACTUAL REPORT FORMAT TO BE DETERMINED LATER

ANALYSIS REPORT TITLE PAGE

The analysis report shall have a title page which includes the name of the report, the equipment vendor/supplier's name, the name of the company performing the analysis, the US-APWR plant name and unit identification, the name and description of the equipment being qualified, the US-APWR project number, and the analysis contract number.

ANALYSIS REPORT CERTIFICATION PAGE

The analysis report shall contain a certification page signed by the responsible engineer of the company performing the analysis, the vendor/supplier's responsible engineer, the contracts report writer, and a responsible officer of the contractor's company (the analysis report shall also be certified by a registered professional engineer).

MAIN BODY OF REPORT

1. Purpose and Scope

Identify and provide a brief description of the equipment being qualified including its intended elevation and location within the US-APWR. Such information should also include but not be limited to:

a. equipment name tag with unique identifier
b. identification of equipment's safety functions (Note: For seismic category II equipment, functional requirements may not be applicable.)
c. performance aspects of the equipment that were verified/included in the seismic/dynamic qualification testing
d. material properties, dimensions, configuration, and references to design drawings and calculations

If the report is based on previous qualification testing that was not performed explicitly for the US-APWR project, provide a synopsis of the previous testing.

2. References

a. ASME QME-1-2007, "Qualification of Active Mechanical Equipment used in Nuclear Power Plants".

b. IEEE Std 323-1974 and IEEE Std 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations”.
c. IEEE Std 336-2005, "IEEE Guide for Installation, Inspection, and Testing for Class1E Power, Instrumentation, and Control Equipment at Nuclear Facilities”.
d. IEEE Std 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations”.
e. NUREG-0800, "Standard Review Plan", Section 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment", Revision 3, March 2007.

References shown above are typical references, which may be used for seismic and dynamic qualification of mechanical, electrical, and instrumentation equipment. The list of typical references shown above shall be modified by the report author to add references that are applicable to and used for qualification of the particular piece of equipment or component being qualified, and, similarly, to delete references that are not applicable.

Include appropriate references to equipment-specific drawings (including mounting details), bills of material, instruction manuals, etc, needed to perform an adequate review of the equipment qualification. Provide copies of these references as attachments to the report or as separate submittals to MHI/MNES.

3. Approach and Methodology

a. Qualification Criteria/Specification

Identify qualification criteria/specification

Identify the ISRS (building, elevation/level, damping, etc.), which applies to a given equipment item.

a. identify the RRS for the horizontal axis and the vertical axis, with applicable damping values and indication of artificially broadened areas
b. when an RRS is not furnished, maximum accelerations of either floor or structure motion at all significant frequencies, or a time history
c. the required earthquake strong motion time duration
d. the required number and amplitude of the OBE and SSE

Identify and describe equipment.

a. identification of equipment, including vendor, model number, and location within each building
b. physical description, including dimensions, weight, and field mounting condition, and identification of whether the equipment is pipe-, floor-, or wall-supported
c. description of the equipment’s safety-related devices and circuitry and their safety functions within the system, during and after the SSE
d. environment in which the equipment is designed to perform its safety function
e. identification of all design (functional) specifications and qualification reports and their locations. Functional specifications for active valve assemblies should conform to RG 1.100.
f. equipment mounting details, including all interface connections
g. applicable loading and interface requirements
h. typical operating settings (or ranges) for adjustable devices

i. equipment limitations, list if appropriate

Include a description of equipment mounting and orientation for which it is being qualified, and explain how that compares to the intended mounting and orientation in the US-APWR project.

Include rationale of qualification determination obtained by analysis, test, experience, or combination.

a. test vs analysis decision factors
b. structural integrity and functionality verification qualification methods used
   - static and SSE event
   - postulated number of OBE occurrences
   - combinations
   - relevant dynamic loads
c. supports
d. experience database

b. Acceptance Criteria/Specification

Identify acceptance criteria for qualification of equipment, its installation, and mounting:

a. quality standards commensurate with its functions
b. requirements to withstand effects of natural phenomena
c. other dynamic effects such as missiles, jet impingement and whip
d. qualification of equipment at reactor coolant boundary
e. deflection requirements, if applicable
f. applicable margin requirements, if any IEEE Std 323-2003
g. qualification inspections, tests, analyses, and acceptance criteria for equipment meet the requirements of 10 CFR 52.47(b)(1) and 10 CFR 52.80(a)

Identify specific acceptance criteria and review procedures load combinations and methods for combining dynamic responses for mechanical and electrical equipment per SRP section 3.9.3

a. electrical equipment and supports
b. mechanical equipment and supports
c. equipment functionality acceptance criteria
d. seismic and dynamic qualification testing i.e. IEEE Std 344-2004 should follow sequence per Section 6 of IEEE Std 323-1974

c. Analysis Method and Procedure

Identify analysis method and procedures including monitoring for operability and acceptance criteria.

a. equipment functionality acceptance criteria
   - method of analysis; equivalent static force analysis method is acceptable when time history and response spectra analysis methods are impractical and when validity can be shown through analysis
   - operational condition test
   - multi-frequency vibration input

- vertical plus either one or both horizontal directional components
- consider dynamic coupling of equipment with other connected components
- load criteria and assumptions
- stress, deformation and stability criteria

b. analysis program based on representative number of components
c. analyze equipment supports to ensure structural capacity
d. special requirements for tests, analyses, or experience-based methods

4. Analysis Results

When analysis is performed, the method and data used and the failure modes considered should be presented in a format that is readily auditable by persons skilled in such analysis. Boundary conditions, including anchoring and other interferences, must be clearly defined. Input/output data required to support performance claims and any mathematical model verification testing performed should be included or referenced in the report. The reaction force(s) at the interface connection(s) to the support structure should also be included.

A statement should be made verifying that any computer programs used were validated on the computer hardware on which the program was executed. Computer programs, options, version numbers, dates, and systems utilized should be identified.

5. Results Summary and Conclusion

Include a detailed summary of the qualification analysis results. When a component or subassembly of equipment is qualified separately, the qualification should also be summarized.

a. provide a summary of the analysis input data, and the analysis results and conclusions
b. explain the analysis procedure, and explain or justify any deviations that may have occurred from the analysis procedure
c. compare the qualification specification requirements to the qualification results and conclusion, the results and conclusions must demonstrate the equipment qualification for its application

EQUIPMENT SEISMIC QUALIFICATION SUMMARY DATA SHEETS STANDARD FORMAT

1. Contents of Equipment Seismic Qualification Summary Data Sheets

a. identification and description of equipment

- identification of equipment, including vendor, model number, and location within each building. Valves that are part of the RCPB are identified.
- physical description, including dimensions, weight, and field mounting condition, and identification of whether the equipment is pipe-, floor-, or wall-supported
- a description of the equipment's function within the system
- identification of all design (functional) specifications and qualification reports and their locations. Functional specifications for active valve assemblies should conform to RG 1.100

b. description of analyses and methodology

- description of the required loads and their intensities for which the equipment must be qualified
- if qualification by test, identification of the test methods and procedures, important test parameters, and a summary of the test results, such as the Test Response Spectrum (TRS)
- if qualification by analysis, identification of the analysis methods and assumptions and comparisons between the calculated and allowable stresses and deflections for critical elements
- the natural frequency (or frequencies) of the equipment
- identification of whether the equipment may be affected by vibration fatigue cycle effects and a description of the methods and criteria used to qualify the equipment for such loading conditions
- documentation that the equipment has met the qualification requirements
- availability for inspection (i.e., statement of whether the equipment is already installed)
- a compilation of the required response spectra (or time history) and corresponding damping for each seismic and dynamic load specified for the equipment together with all other loads considered in the qualification and the method of combining all loads

c. quality assurance

- Signature of responsible engineer, checker, and approver
- theory and assumptions (analytical method)
- computer program documentation and verification, computer input and results files

Attachment C List of Implementing Directives and Procedures

MHI US-APWR Equipment Qualification Program

DIRECTIVES

1. Dir-01, *US-APWR Project Equipment Qualification Program Authorization*
2. Dir-02, *US-APWR Project Equipment Qualification Program Definitions and Organizational Responsibilities*
3. Dir-03, *Application of Equipment Qualification Requirements to the US-APWR Design, Procurement, Fabrication, Construction, and Startup*
4. Dir-04, *US-APWR Equipment Qualification Program Documentation Requirements*
5. Dir-05, *Quality Assurance Requirements for a US-APWR Equipment Qualification Program*
6. Dir-06, *US-APWR Project Equipment Qualification Program Training Requirements*

IMPLEMENTING PROCEDURES

1. Pro-01, *US-APWR Equipment Qualification Program Implementation for a Specific Project*
2. Pro-02 *US-APWR Equipment Qualification Project Definitions and Equipment Qualification Program Implementation Boundaries*
3. Pro-03, *US-APWR Project Specific Equipment Qualification Program Organization Management Structure*
4. Pro-04, *US-APWR Equipment Qualification Program Selection and Identification of Structures, Systems and Components*
5. Pro-05, *US-APWR Equipment Qualification Program Documentation and Records Retention*
6. Pro-06, *US-APWR Equipment Qualification Program Analysis Requirements*
7. Pro-07, *US-APWR Equipment Qualification Program Quality Assurance Program*
8. Pro-08, *US-APWR Equipment Qualification Program Application During the Design Phase of a Project*
9. Pro-09, *US-APWR Equipment Qualification Program Application During Procurement*
10. Pro-10, *US-APWR Equipment Qualification Program Application During the Construction Phase*
11. Pro-11, *US-APWR Equipment Qualification Program Application During Startup and Commissioning*
12. Pro-12, *US-APWR Equipment Qualification Program Application During Initial Operations*
13. Pro-13, *US-APWR MHI/MNES Assignment of Equipment Qualification Program Execution to/from the Project Equipment Qualification Organization*
14. Pro-14, *US-APWR Equipment Qualification Program Transfer from MHI/MNES to Licensee (Owner)*
15. Pro-15, *US-APWR Equipment Qualification Program Training Requirements*
16. Pro-16, *US-APWR Equipment Qualification Program Preparation of Equipment Qualification Packages for Structures, Systems and Components (SSC)*
17. Pro-17, *US-APWR Equipment Qualification Program Qualification Methods*

18. Pro-18, *US-APWR Equipment Qualification Program Qualification by Testing*
19. Pro-19, *US-APWR Equipment Qualification Program Qualification by Vendor Certification*
20. Pro-20, *US-APWR Equipment Qualification Program Qualification by Analysis*
21. Pro-21, *US-APWR Equipment Qualification Program Qualification by Using Experience Data Method*
22. Pro-22, *US-APWR Equipment Qualification Program Project Records Management*
23. Pro-23, *US-APWR Equipment Qualification Program Confidential and Proprietary Information*
24. Pro-24, *US-APWR Equipment Qualification Program Exceptions and Open Items*
25. Pro-25, *US-APWR Equipment Qualification Program Personnel Qualifications*

Note that the actual documents that comprise the MHI US-APWR Equipment Qualification are proprietary and not available to the public. This Appendix is only included to further define the general content of these procedures.

Equipment Qualification Program Procedures

Equipment Qualification Program Procedure Pro- 1, "US-APWR Equipment Qualification Program Implementation for Specific Project":

This procedure has been prepared under the general assumption that MNES will be contracted to deliver a US-APWR on a turnkey basis to a US utility as described in the latest revision of the Design Control Document (DCD). Under this arrangement, MNES will most likely contract with a qualified A/E and others (equipment suppliers) to deliver the plant to a US utility. This procedure requires MNES to designate the Project Equipment Qualification Organization (PEQO) that will be responsible for the implementation of the Project Equipment Qualification Program. This procedure shall be prepared, reviewed, and approved pursuant to the project Quality Assurance Program Requirements.

Equipment Qualification Program Procedure Pro- 2, "Project Definitions and Equipment Qualification Program Implementation Boundaries":

This procedure provides direction to the Project Equipment Qualification Organization (PEQO) regarding the definition of common terms applicable to the Project Equipment Qualification Program (PEQP) and the identification of the PEQP scope and boundary within the Project. The PEQO shall incorporate these definitions as well as project specific definitions into a specific PEQP procedure. This procedure shall also define and establish the scope and boundary for all SSCs that will be subject to inclusion in the PEQP. This procedure shall be prepared, reviewed, and approved pursuant to the project Quality Assurance Program Requirements.

Equipment Qualification Program Procedure Pro- 3, "Project Specific Equipment Qualification Program Organization Management Structure":

The purpose of this procedure is to provide guidance on the organizational and management structure of the Project Equipment Qualification Organization (PEQO) established to implement a project specific Equipment Qualification Program as described in these procedures and directives.

Equipment Qualification Program Procedure Pro- 4, "Systems and Components Selection and Identification"

This procedure provides direction to the PEQO for the preparation of project specific procedures controlling the identification and selection of SSCs for inclusion in the PEQP.

Equipment Qualification Program Procedure Pro- 5 "Equipment Qualification Program Documentation and Records Retention"

This procedure provides direction to the PEQO on the preparation of project specific procedures, controlling Equipment Qualification Program documentation and records retention. These requirements govern documents and quality assurance records generated by the PEQP and apply to all equipment qualified by the Equipment Qualification Program and apply to structures, systems and components (SSCs) during the licensing, design, procurement, construction, test, startup and turn over to the utility, phases of a US-APWR project.

Equipment Qualification Program Procedure Pro- 6 "Equipment Qualification Program Analysis Requirements"

This procedure provides direction to the PEQO for the preparation of project specific procedures controlling PEQP Analysis Requirements. These analyses requirements include all Class 1E and active mechanical equipment qualified by the PEQP, and apply to structures, systems and components (SSC's) during the licensing, design, procurement, construction, test, startup and turn over to the utility phases of a US-APWR project.

Equipment Qualification Program Procedure Pro- 7 "Equipment Qualification Program Quality Assurance Program"

This procedure provides direction to the PEQO for development of project specific procedures controlling the MNES Quality Assurance requirements applied to equipment qualification of structures, systems and components (SSCs) addressed by the Equipment Qualification Program.

These requirements provide the necessary direction to the PEQO for establishment of a Quality Assurance program and QA requirements that will control equipment qualification activities for structures, systems and components addressed by the Equipment Qualification Program during the licensing, design, procurement, construction, test, startup and turn over to the utility phases of a US-APWR project.

Equipment Qualification Program Procedure Pro- 8 "Equipment Qualification Program Application during Design Phase of Projects"

This procedure provides direction and guidance to the PEQO for preparation of project specific implementing procedure(s) to address Equipment Qualification during the design phase of US-APWR project.

Equipment Qualification Program Procedure Pro- 9 "Equipment Qualification Program Application during Procurement Phase of Projects"

This procedure establishes project specific Equipment Qualification Program requirements for application during the procurement of mechanical and electrical equipment. This procedure applies to all mechanical and electrical equipment that is required to be qualified by the Equipment Qualification Program during the procurement phase of a US-APWR project.

Equipment Qualification Program Procedure Pro- 10 "Equipment Qualification Program Application during Construction Phase of Projects"

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the Equipment Qualification Program requirements applied to structures, systems and components (SSCs) during the construction phase of the Project and to ensure that equipment qualification documentation integrity is maintained.

Equipment Qualification Program Procedure Pro- 11 "Equipment Qualification Program Application during Start up and Commissioning"

This procedure provides direction to PEQO relative to equipment qualification activities required during the startup and commissioning phases of a US-APWR project. The PEQO

shall develop project specific procedures that will ensure appropriate startup and construction tests are performed to demonstrate compliance with the equipment qualification requirements applicable to structures, systems and components (SCCs) addressed by the Equipment Qualification Program.

Equipment Qualification Program Procedure Pro- 12 "Equipment Qualification Program Application during Initial Operations"

This procedure provides direction to the PEQO for preparation of project specific procedures controlling the Equipment Qualification Program requirements applied to structures, systems and components (SSCs) addressed by the Equipment Qualification Program during initial operations. Procedures shall include directing the PEQO in conjunction with the power ascension organization to monitor environmental conditions in and around SSCs to validate the assumptions made in establishing equipment qualification endurance.

Equipment Qualification Program Procedure Pro- 13 "Equipment Qualification Program Turnover/Assignment from/to MHI/MNES to AE/Constructor"

The purpose of this procedure is to provide guidance on the execution of an Equipment Qualification Program for a specific US-APWR Project and to allow the execution of that program by the PEQO. Since MHI/MNES is responsible for the equipment qualification program, they may delegate the execution of the program to third parties. This delegation of execution is governed by this procedure.

Equipment Qualification Program Procedure Pro- 14 "Equipment Qualification Program Turnover from MHI/MNES to Licensee (Owner)"

The purpose of this procedure is to provide guidance on the formal transfer of a Project Equipment Qualification Program (PEQP) for a specific US-APWR Project to the plant Licensee. Following plant licensure (issuance of OL), the equipment qualification program responsibility is transferred to the licensee as the basis for the plant equipment qualification program. The plant equipment qualification program is maintained for the life of the facility by the Licensee.

Execution of this procedure provides the terminus of the PEQP, subject to closing out any remaining open items.

Equipment Qualification Program Procedure Pro- 15 "Equipment Qualification Program Training Requirements"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO), for institution of training requirements related to the US-APWR Equipment Qualification Program.

This procedure provides direction for establishing indoctrination and training requirements for all personnel performing activities affecting quality on a Project Equipment Qualification Program, including equipment vendor personnel.

Equipment Qualification Program Procedure Pro- 16 "Equipment Qualification Program Preparation of Equipment Qualification Packages for Components and Systems"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO) for the preparation of equipment qualification packages for structures, systems and components (SSCs) following project specific procedures of the Project Equipment Qualification Program (PEQP) during the licensing, design, procurement, construction, test, startup and turn over to the utility phases of a US-APWR project.

Equipment Qualification Program Procedure Pro- 17 "Equipment Qualification Program Qualification Processes"

This procedure provides direction to the PEQO, on qualification methods that can be used for equipment qualification.

This procedure establishes the equipment qualification methods to be used by the Project Equipment Qualification Program (PEQP) and provides direction on which methods to use. These methods apply to all mechanical and electrical equipment that is required to be qualified by the PEQP, and apply to structures, systems and components (SSCs) during the licensing, design, procurement, construction, test, startup and turnover to the utility phases of a US-APWR project.

Equipment Qualification Program Procedure Pro- 18 "Equipment Qualification Program Qualification by Testing"

This procedure provides direction and guidance to the PEQO, for preparation of project specific implementing procedures to address equipment qualification by testing.

The project specific PEQO procedures shall be developed to ensure that the applicable equipment qualification requirements as delineated in 10CFR50.49, RG 1.89, IEEE Std 323, IEEE Std 344-2004, ASME QME-1-2007 and other equipment specific IEEE qualification standards are met. Type testing as described in IEEE Std 323-1974, clause 5.1 is one of the acceptable methods for qualifying equipment for a US-APWR project. The selection of the method for qualification of particular equipment shall be agreed upon by the PEQO and the equipment vendor.

Equipment Qualification Program Procedure Pro- 19 "Equipment Qualification Program Qualification by Vendor Certification"

This procedure provides direction and guidance to the PEQO, for preparation of project specific implementing procedures to address equipment qualification by testing.

The project specific PEQO procedures shall be developed to ensure that the applicable equipment qualification requirements as delineated in 10CFR50.49, RG 1.89, IEEE Std 323, IEEE Std 344-2004, ASME QME-1-2007 and other equipment specific IEEE qualification standards are met. Type testing as described in IEEE Std 323-1974, clause 5.1 is one of the acceptable methods for qualifying equipment for a US-APWR project. The selection of the method for qualification of particular equipment shall be agreed upon by the PEQO and the equipment vendor.

Equipment Qualification Program Procedure Pro- 20 "Equipment Qualification Program Qualification by Analysis"

This procedure provides direction and guidelines to the Project Equipment Qualification Organization (PEQO) for preparation of project specific implementing procedure(s) to address equipment qualification by analysis.

The scope of this procedure covers qualification by analysis for structures, systems and components (SSCs) addressed by the Equipment Qualification Program and installed in a US-APWR nuclear power plant.

It should be noted that analysis alone cannot be used to demonstrate qualification. When an analysis method is used by a vendor for qualifying a piece of equipment, the analysis report should include a logical assessment, similarity evaluations, or a valid mathematical model to establish that the equipment to be qualified can perform its safety function(s) when subjected to the specified service conditions. Such analysis should account for all time-dependent environmental parameters originating from the qualification criteria.

Equipment Qualification Program Procedure Pro- 21 "Equipment Qualification Program Qualification by Use/History"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO), regarding environmental or seismic qualification of equipment through an experience-based approach which relies on an experience database or other approved sources. The US-APWR DCD Tier 2 Chapter 3 Subsection 3.10.1.1 "Qualification Standards" and Subsection 3.10.4.2 "Experience Based Qualification" state that "Experience-based qualification is not used for any equipment." Therefore, this procedure shall not be implemented without an approved revision to or an approved departure from the DCD.

Equipment Qualification Program Procedure Pro- 22 "Equipment Qualification Program Project Records Management"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO) for preparation of project specific procedures controlling the equipment qualification program Records Management requirements applied to structures, systems and components (SSCs) addressed in the Equipment Qualification Program.

This procedure provides the necessary direction to the PEQO for establishment of procedures to be utilized during the project life to ensure that equipment qualification documentation is complete and maintained.

Equipment Qualification Program Procedure Pro- 23 "Equipment Qualification Program Confidentiality and Security"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO) for preparation of project specific procedures controlling the use of supplier equipment qualification documentation identified as confidential or proprietary associated with equipment qualification of structures, systems and components (SSCs).

To comply with equipment qualification specification requirements equipment suppliers may provide documents/information considered to be company confidential or proprietary. It is the responsibility of the PEQO to protect this information. This procedure provides guidance on protection of confidential or proprietary supplier information.

Equipment Qualification Program Procedure Pro- 24 "Equipment Qualification Program Exceptions and Open Items"

This procedure provides guidance to the Project Equipment Qualification Organization (PEQO) for the preparation of project specific procedures controlling the tracking and resolution Equipment Qualification Program exceptions and open items associated with equipment qualification of structures, systems and components (SSCs).

This procedure provides direction the PEQO for preparation of procedures to be utilized during execution of US-APWR Equipment Qualification Program for a specific project(s). During implementation of the Equipment Qualification Program exceptions or open items will occur that require, tracking, resolution and close-out. This procedure provides direction to the PEQO to implement an equipment qualification exception and open item tracking program.

Equipment Qualification Program Procedure Pro- 25 "Equipment Qualification Program Personnel Qualifications"

This procedure provides direction to the Project Equipment Qualification Organization (PEQO) on the preparation of project specific procedures controlling Equipment Qualification Program personnel qualification.
This procedure includes requirements to govern qualification of personnel associated with the Project Equipment Qualification Program (PEQP) and applies to equipment qualification of structures, systems and components addressed by the Equipment Qualification Program during the licensing, design, procurement, construction, test, startup and turn over to the utility phases of a US-APWR project.

Attachment D Description of Equipment Qualification Data Package Template for MHI US-APWR Equipment Qualification Program

D.1 Introduction

As described in subsection 9.9 of this Technical Report, records and data documenting the qualification of electrical and mechanical equipment as a result of implementing the US-APWR Equipment Qualification Program are maintained in the Equipment Qualification Data Packages. The Equipment Qualification files contain copies of all pertinent equipment qualification documentation (e.g., specifications, test reports, vendor data sheets, and analysis reports). The combined file is referred to as the Equipment Qualification Data Package (EQDP). Implementation of the equipment qualification records retention process is governed by proprietary Equipment Qualification Program procedures as discussed in this Technical Report. The EQDP tracks and maintains records for a specific equipment of Structure, System and Component (SSC) starting at the completion of design when the equipment enters the procurement phase of a project. In general, most qualification activities take place during the procurement phase and could also occur during construction and startup. The documents generated during these phases of a project are maintained by the Project Equipment Qualification Organization (PEQO).

D.2 Purpose

The purpose of this attachment is to illustrate the content of the EQDP. The scope, qualification methods, verifications and requirements are described in this Technical Report, DCD Chapter 3.

D.3 Description of US-APWR Equipment Qualification Data Package

The equipment qualification records for a specific equipment is generated in accordance with the methods and guidance contained in this Technical Report and the associated references such as RG 1.89 Rev.1, RG 1.100 Rev.3, IEEE 323-1974, IEEE 323-2003, IEEE 344-2004 and ASME QME-1-2007.

The EQDP is formulated during the project phases and has parts which are arranged for key equipment qualification functions. The required data will be supplied by the PEQO, project design engineers or procurement personnel, and the information in the EQDP will be updated by the PEQO as the phase progresses. Designated reviewers review these records for accuracy and completeness.

As the project transitions from construction to operation, the EQDP and associated records (or copies thereof) will be transferred to the licensee's control to support the operational equipment qualification program (OEQP) as part of the plant turnover process.

EQDP consists of four parts, Part 1 to Part 4, as described below.

D.3.1 PART 1 EQUIPMENT QUALIFICATION SUMMARY

Part 1 identifies and summarizes the basic information and status of equipment to be qualified.

D.3.2 PART 2 PROCUREMENT, INSTALLATION AND MAINTENANCE INFORMATION

Part 2 contains information pertinent to procurement, installation and maintenance, including the storage information, and tracks the equipment from the procurement up to turnover. Part 2 also lists the maintenance requirements, if any, for the equipment while in storage (warehouse) or after installation, prior to turnover to the plant licensee, which require periodic maintenance, specific storage requirements, special storage requirements, steps to maintain the equipment in a qualified state (e.g., large motors require electrical heat to prevent moisture intrusion or periodic shaft rotations to prevent distortion) or a combination of such in order to maintain their qualification status.

D.3.3 PART 3 ENVIROMENTAL AND SEISMICQUALIFICATION REQUIREMENTS

Part 3 summarizes the pertinent environmental and seismic qualification parameters that apply to the equipment. These requirements are dependent on the type of equipment (electrical or mechanical) and the location (Harsh or Mild) as well as other factors such as high-energy line break, or flooding. The equipment qualification and seismic requirements (values) are project specific.

D.3.4 PART 4 QUALIFICATION METHODS AND RECORDS

Part 4 consists of qualification records such as qualification test reports, analysis reports and other documents that provide verification that the equipment is properly qualified. Equipment Seismic Qualification Report (ESQR) as discussed in Attachment B of this Technical Report is introduced here.

D.3.5 Equipment Qualification Data Package Template

Below is the example of the Equipment Qualification Data Package Template.

{EQDP No./Rev./Date Issued/Page No.}

EQUIPMENT QUALIFICATION DATA PACKAGE

Equipment ____________________

Manufacturer ____________________

Model ____________________

Application ____________________

Environment
(Circle one) Harsh Mild

Prepared by
(Print, Sign, and Date) ____________________

Reviewed by
(Print, Sign, and Date) ____________________

Approved by
(Print, Sign, and Date) ____________________

QA Approval
(Print, Sign, and Date) ____________________

This document provides or summarizes the seismic and environmental qualification of the equipment identified above in accordance with the US-APWR equipment qualification program methodology.

{EQDP No./Rev./Date Issued/Page No.}

<u>Program Objective</u>

The objective of this EQDP is to demonstrate, employing the recommended practices of Regulator Guides 1.89 and RG 1.100 and IEEE 323-1974, IEEE 323-2003, IEEE 344-1987, IEEE 344-2004 and ASME QME-1-2007, that equipment important to safety is capable of performing its designated safety function(s) described in this EQDP while exposed to the applicable conditions and events defined in PART 3 of this EQDP.

The end result of all qualification methods is to ensure that equipment important to safety is qualified, and that traceable and auditable documentation is developed, demonstrating the equipment's ability to perform its intended functions for its normal, abnormal, and accident environments.

{EQDP No./Rev./Date Issued/Page No.}

PART 1 EQUIPMENT QUALIFICATION SUMMARY

EQUIPMENT DESCRIPTION

Equipment Name ____________________
Description of Safety Function(s) for application ____________________
System/Plant Tag No. ____________________
Location ____________________
Environment Condition ____________________
Safety Classification ____________________
Seismic Classification ____________________
Quality Group ____________________
Manufacturer ____________________
Subcontractor ____________________
Model Number/Type/Style ____________________
Unit No./Lot No./Batch No. ____________________
Serial No. ____________________
Materials ____________________
10CFR50.59 Safety Evaluation ____________________
Vendor QA Information ____________________
Other Information

EQUIPMENT QUALIFICATION PROGRAM CONCLUSIONS

The equipment identified and described in this EQDP is qualified for its intended application by means of one or a combination of the methods listed in Part 3. Validity of the qualification, including the tests, is evaluated and confirmed by documentation referenced hereafter:

References: ____________________
Qualification Report (1) ____________________
Qualification Report (2) ____________________
____
____
____

Comments

Note: All documents pertinent to equipment qualification, including the document for identification of plant equipment, is identified in references and attached or retrievable. Document title (if any), document number, revision, issue date are clearly identified for all the documents, including references, codes and standards, design documents, specifications, reports, procedures, manuals, instructions and drawings, wherever referenced in EQDP.

{EQDP No./Rev./Date Issued/Page No.}

PART 2 PROCUREMENT, INSTALLATION AND MAINTENANCE INFORMATION

Equipment Name ______________________
System/Plant Tag No. ______________________

PROCUREMENT INFORMATION

Product Specifications ______________________
Purchase Order ______________________
Date Ordered ______________________
Storage and Maintenance Requirements ______________________
Storage and Maintenance Testing Requirements ______________________
Equipment Qualification Requirements Document ______________________
Seismic Requirements Document ______________________
Other Information ______________________
Comments ______________________

INSTALLATION INFORMATION

Installation Instructions ______________________
Special Installation Instructions ______________________
Installation Location ______________________
Date Installed ______________________
Other Information ______________________
Comments

ON SITE STORAGE/MAINTENANCE INFORMATION PRIOR TO TURNOVER

Receipt Inspection Report ______________________
Date Received ______________________
Vendor Manual ______________________
Vendor Drawings ______________________
Shelf life ______________________
Storage Location/Warehouse No. ______________________
Storage and Maintenance Instructions ______________________
Storage and Maintenance Testing Instructions ______________________
Date Required ______________________
Date Performed ______________________
Special Storage and Maintenance Instructions ______________________
Quantity on Hand ______________________
Qualified Quantity on Hand (as of date) ______________________
Date of Turnover ______________________
Comments ______________________

{EQDP No./Rev./Date Issued/Page No.}

PART 3 ENVIROMENTAL AND SEISMIC QUALIFICATION REQUIREMENTS

Equipment Name ____________________
System/Plant Tag No. ____________________

ENVIROMENTAL REQUIREMENTS
General

Applicable Codes and Standards		
Location/Zone		
Environment (circle one)	Harsh	Mild
Mounting (Methods and Orientations)		
Interfaces/Connections		
Configuration		
Monitoring*1		
Aging		
Margin*2		
HELB (circle)	MSLB inside containment	LOCA
	MSLB outside containment	Other
Loss of HVAC		
Outdoor		
Containment Test Condition*3		
Design Life		
Shelf Life		
Description of Operating Cycles (including periodic testing)		
Number of Operating Cycles		
Qualified Life		
Synergistic Effects		
Test Sequence*4		
Other		

Service Conditions to be simulated	Normal	Abnormal	DBE*5	Post DBE
Temperature*2				
Pressure*2				
Humidity*2				
Radiation*2				
Vibration*2				
Chemical or Water Spray (yes/no)				
Chemical Effects-pH				
Chemical Composition				
Operating Time*2				
Post-Accident Time*2				
Post-Accident Aging*2				
Submergence*6				

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Electrical Equipment

Applicable Codes and Standards	
Voltage*2	
Frequency*2	
Load	
EMI/RFI	
Accuracy	
Response Time	
Insulation	
Current	
Other	

Mechanical Equipment

Applicable Codes and Standards	
Material	
Grease/Oil	
Gasket	
Thrust	
Torque	
Time	
Load Profile	
Other	

SEISMIC REQUIREMENTS

Applicable Codes and Standards	
Seismic Category	
Acceleration*2 of Seismic Vibration	
SSE RRS	
OBE ISRS	
Other OBE ISRS	
FIRS (g)	
Other	

INFORMATION NOTICES (INs)

Applicable INs	

*1: Applicable monitoring variables are identified in accordance to Categories I to VII per IEEE323-1974.
*2: Margins indicated in Table 4-2 US-APWR Equipment Qualification Program Margin Values of this Technical Report are applied.
*3: See subsection 5.4 of MUAP-08015 for detail information.
*4: Test Sequence conforms to IEEE 323-1974, or justification for non-conformance is identified.
*5: DBE: Design Basis Event
*6: The margin described in Note 1 of Table 4-2 US-APWR Equipment Qualification Program Margin Values of this report is applied.

{EQDP No./Rev./Date Issued/Page No.}

PART 4 QUALIFICATION METHODS AND RECORDS

Equipment Name ____________________
System/Plant Tag No. ____________________
Applicable Qualification Method(s) ____________________

ENVIRONMENTAL QUALIFICATION BY TESTING

Applied Codes and Standards ____________________
Test Agency ____________________
Address ____________________
Test Procedure ____________________
Sample Size ____________________
Sample Similarity Analysis* ____________________
Preoperational Test(s) ____________________
Special Test(s) ____________________
Other ____________________
Summary of Tests ____________________
Calibration Report(s) ____________________
Environmental Test Report ____________________
Quality Assurance Review ____________________
Test Report Review ____________________
Test Anomalies Resolved (if any) ____________________
Comments ____________________

ENVIRONMENTAL QUALIFICATION BY ANALYSIS

Applied Codes and Standards ____________________
Analysis Procedure ____________________
Other ____________________
Analysis Report ____________________
Quality Assurance Review ____________________
Analysis Report Review ____________________
Comments ____________________

SEISMIC QUALIFICATION BY TESTING

Applied Codes and Standards ____________________
Test Agency ____________________
Address ____________________
Test Procedure ____________________
Sample Size ____________________
Sample Similarity Analysis* ____________________
Other ____________________
Summary of Tests ____________________
Seismic Test Report ____________________
Quality Assurance Review ____________________
Test Report Review ____________________
Test Anomalies Resolved (if any) ____________________
Comments ____________________

{EQDP No./Rev./Date Issued/Page No.}

SEISMIC QUALIFICATION BY ANALYSIS

Applied Codes and Standards __________
Analysis Procedure __________
Other __________
Analysis Report-(ESQR*) __________
Quality Assurance Review __________
Analysis Report Review __________
Comments __________

INFORMATION NOTICES (INs)

Applicable INs Resolved __________

*7: Qualification sample is identical to the installed devices and all type tests are performed on the same test specimen. If the sample is not identical, similarity analysis is provided.
*8: ESQR: Equipment Seismic Qualification Report

Attachment E Calculation Method for Radiation Dose after LOCA

E.1 Introduction

Table 5-5 "Total Integrated Dose for Zone" provides a summary of the cumulative normal and accident doses used to determine the total integrated dose (TID) for each environmental zone of the US-APWR. The cumulative accident doses listed in Table 5-5 for each environmental zone excluding the containment, annulus area, and main steam piping area outside containment (i.e., Zones 2-5, 7-9, and 11-14) are calculated using the upper limit dose rate of any location within the respective environmental zone shown in Figures 12.3-3 through 12.3-6 of US-APWR DCD Section 12.3. The cumulative accident doses of the containment, annulus area, and main steam piping area (Zones 1, 6, and 10) are calculated using the RADTRAD code (Reference 1) and the MicroShield code (Reference 2).

E.2 Cumulative Accident Dose inside Zones Excluding the Containment

For any zones not inside the containment, the annulus area, and the main steam piping area, the cumulative accident doses are calculated based on the dose rate for each zone (the highest dose rate of the upper limits of the areas within the same zone) shown in Figures 12.3-3 through 12.3-6 in the US-APWR DCD Section 12.3. The dose rates in Figures 12.3-3 through 12.3-6 in the US-APWR DCD Section 12.3 are set based on the dose rates (those for gamma rays) from radioactivity in the containment after LOCA. These are sorted out in Table E-1. The specific ways of the cumulative doses calculation are described below.

(1) 5 minutes later
For the cumulative dose following a time lapse of 5 minutes, the amount accumulated in 5 minutes was calculated on the assumption that the dose rate obtained by doubling the dose rate one hour after an accident is regarded as the dose rate measured immediately after the accident and this dose rate continues for one hour. An estimated margin of 10% is included. For example, in Zone 3 (Class 1E I&C Room), the upper limit dose rate after a lapse of 1 hour is 1 (rem/h) (refer to Table E-1) and the dose rate measured immediately after the accident is 2 (rem/h). Consequently, the following equation is derived:
[2 (rem/h) × 5 (min) / 60 (min)] × 1.1 ≈ 1.9E-01 (rem)
Here, when we assume 1 rem ≈ 1 rad, the cumulative dose becomes 1.9E-01 (rad). This approach is applied to all zones.

(2) 2 weeks later
At first, the cumulative dose for the first day was calculated on the assumption that the dose rate is obtained by doubling the dose rate one hour after an accident, which is regarded as the dose rate measured immediately after the accident, and the dose rate measured one hour after the accident continues for the following 23 hours. The accumulation was calculated on the assumption that the dose rate measured one day after the accident continues for six days following the second day and the dose rate measured one week after the accident continues for one week following the eighth day. In this case, an estimated margin of 10% is included. In the case of Zone 3 (Class 1E I&C Room), the following equations are provided or derived:
1st day: 2 (rem/h) ×1 (h) + 1 (rem/h) × 23 (h) = 25.0 (rem)
2nd day to 7th day: 15 (mrem/h) ×24 (h) ×6 (d) = 2.2 (rem)
8th day to 14th day: 15 (mrem/h) ×24 (h) ×7 (d) = 2.5 (rem)
Consequently, we derive that (25.0+2.2+2.5) (rem) × 1.1 ≈ 3.3E+01 (rem). Similarly, with 1 rem ≈ 1 rad assumed, we can derive 3.3E+01 (rad). This is the same for other zones.

(3) 4 months later (122 days later)
First, the value found in (2) is used for the two-week cumulative dose. The accumulation was calculated on the assumption that the dose rate measured one week after the accident continues from the 15th day to the first month and the dose rate measured one month after the accident continues for four months following the 31st day following the accident. In this case, a margin of 10% is included in the same manner as in the above cases. In the case of Zone 3 (Class 1E I&C Room), for example, we derive the following equations:
Through the 14th day: 29.7 (rem)
5th day to 30th day: 15 (mrem/h) × 24 (h) ×16 (d) = 5.8 (rem)
31st day to 122nd day:1 (mrem/h) × 24 (h) × 92 (d) = 2.2 (rem)
Accordingly, we derive that (29.7+5.8+2.2) (rem) × 1.1 ≈ 4.2E+01 (rem). Similarly, with 1 rem ≈ 1 rad assumed, we can derive 4.2E+01 (rad). This is the same for other zones.

(4) 1 year later (365 days later)
First, the value found in (3) is used for the four-month cumulative dose. The accumulation was calculated on the assumption that the dose rate measured one week after the accident continues from the 123rd day to the first one year and the dose rate measured one month after the accident continues for four months following the 30th day following the accident. In this case, a margin of 10% is also estimated in it in the same manner as in the case of 5 minutes later. In the case of Zone 3 (Class 1E I&C Room), for example, the following equations are derived:
Through the 122nd day: 37.7 (rem)
123rd day to 365th day: 1 (mrem/h) ×24 (h) ×243 (d) = 5.8 (rem)
Thus, (37.7+5.8) (rem) × 1.1 ≈ 4.8E+01 (rem) is derived. Similarly, with 1 rem ≈ 1 rad assumed, 4.8E+01 (rad) is derived. This is the same with other zones.

E.3 Cumulative Accident Dose inside the Containment

The following is the method we used to calculate the doses to equipment (inside and outside containment, immersed in sump fluids) after LOCA. Calculation flow of accident dose rate inside the containment shows Figure E-1.

(1) Airborne radioactive concentration in containment / radioactive concentration in recirculation water after LOCA

a) Radioactivity released into containment
As mentioned in 15A.1.1.3, for core inventory calculation, it is assumed that core has 2 regions and irradiation time for a cycle is 28 months, and average specific power is 32.1 MW/MTU, which correspond to burnup of about 55 GWD/MTU in 2 cycles. The core thermal power is 102 % of the design thermal power. Table 15A-10 lists the fission product inventories. The fractions of fission products released into containment are listed in Table 15A-13, which are based on Regulatory Guide 1.183. The radioactivity released into containment is calculated based on the above-mentioned core inventory and release fraction.

b) Airborne radioactive concentration in containment
The airborne radioactive concentration in containment is calculated based on the radioactivity released into containment and the following assumptions:

- Decreases due to deposit and attachment are not taken into consideration.
- The removal effect by spray is considered.

- It does not dissolve in recirculation water.

It is assumed that the period of using containment spray is for 30 days and 30 percent of the amount radioactivity which is transferred to recirculation water is floating by recirculation in the duration. Halfway water to refueling water storage pit is 30 percent of recirculation water volume. Halfway water means floating water in vapor phase and flowing water on floor and wall during recirculation. Thus, 30 percent of removed radioactivity by containment spray system is assumed to be contributed to the airborne source strength.

The airborne radioactive concentration is calculated by using the RADTRAD code that is used in DCD Chapter 15. The calculation conditions are same as that of DCD Chapter 15 Section 15.6.5.5 except for evaluation time after accident, no consideration of radioactivity leakage and no consideration of plate-out. Table E-2 summarizes the airborne radioactivity at typical times after a LOCA in the containment vessel.

c) Radioactive concentration in recirculation water
The radioactive concentration in the recirculation water is calculated based on the radioactivity released into containment and the following assumptions:

- All the radioactive material released into containment except for noble gas is dissolved in recirculation water.
- Decreases due to deposit and attachment are not taken into consideration.

Similar to the airborne calculation discussed above, the radioactive decay calculation has been made for various times after a LOCA by using the RADTRAD code. Table E-3 summarizes the recirculation water radioactivity at typical times after a LOCA in the containment vessel.

(2) Gamma ray source strength in containment and recirculation water after LOCA
The gamma ray source strengths can be calculated using the point-kernel shielding code MicroShield, and also using the airborne radioactive concentration in containment and the radioactive concentration in recirculation water.

(3) Beta ray source strength in containment and recirculation water after LOCA
The beta ray source strengths can be calculated by multiplying the airborne radioactive concentration in containment and the radioactivity in recirculation water by the effective energy of beta ray.

(4) Gamma dose in containment and recirculation water after LOCA
The gamma dose due to airborne radioactive materials in containment can be calculated using the point-kernel shielding code MicroShield. The gamma dose at the center of the source is calculated by using gamma ray source strength in containment and by modeling containment as cylinder with the containment free volume.

The gamma dose due to dissolved radioactive materials in recirculation water can be calculated using MicroShield code. The gamma dose at the surface of the source is calculated by using gamma ray source strength in recirculation water and by modeling recirculation water as cylinder with the volume of recirculation water.

In order to calculate gamma dose rates irradiated to the components due to airborne radioactive materials in the Containment Vessel (CV) after a LOCA, the CV is represented by

a cylinder with a free volume of 2.74E+6 ft^3 and an inner diameter of 1790 inches as shown in Figure E-2. The dose rate at the center of the cylinder is calculated by assuming a uniform distribution of the containment airborne radioactivity in the cylinder and using the point kernel method. The dose rate at the center is the maximum in the dose rate irradiated to the components located in the CV. The gamma source strengths of airborne radioactive materials in the CV are as shown in Table E-4.

However, MicroShield does not allow evaluation points to be set in the radioactive source. Therefore, a half-height cylinder is assumed, and the surface dose rate of the half-height cylinder is calculated. The air density is assumed for the density in the CV. The use of the same radioactivity for the half-height cylinder, which makes the radioactivity concentration twice that in the full-height cylinder, allows this dose rate to be equivalent to the dose rate at the center of the full-height cylinder.

In the calculation of gamma dose rates irradiated to the components from the recirculation water after a LOCA, as in the calculation for the airborne radioactive materials in the CV, the recirculation water is represented by a cylinder with the effective recirculation water volume of 5.80E+4 ft^3. The inner diameter (1790 inches) of the CV is used for the diameter of the cylinder. The dose rate at the surface of the cylinder is calculated by assuming a uniform distribution of the radioactivity of the recirculation water in the cylinder and using MicroShield. The gamma source strengths of the recirculation water are as shown in Table E-5.

Table E-6 shows the main MicroShield input parameters. As described in Table E-6, the MicroShield calculation assumes an input source term of 1.0E+0 (Photon/sec) for every energy group. The “actual” dose rates are calculated through a process of multiplying the MicroShield output dose rates for each group by the “actual” source term for each group as previously provided in Table E-4 and Table E-5. The cumulative gamma accident dose at various times after a LOCA is then calculated by multiplying the “actual” dose rate in water and air at various times after a LOCA by the appropriate time interval. Table E-7 summarizes the cumulative gamma accident dose at various times after a LOCA.

In order to determine the doses associated with the specific post-LOCA time intervals tabulated in Table 5-5, one must utilize the appropriate doses tabulated in Table E-7 and add a margin of 10%.

(5) Beta dose in containment and recirculation water after LOCA
It is possible to assume containment and recirculation water are an infinite space for beta ray, so that for beta dose calculation the submersion model is adopted. This model is commonly used in cases of uniform distribution of radioactive concentration. That is, the following equation is used.

$$H_\beta = \frac{K \cdot E_\beta}{\rho} \cdot \chi$$

where:

H_β: beta dose (Gy/s)
K: 1.6×10^{-10} ((Gy/s)(dis/MeV)(g/Bq)
E_β: effective energy of beta ray (MeV/dis)
ρ : density (g/cm^3)

χ : radioactive concentration (Bq/cm^3)

The effective energy of beta radiation is used to calculate beta dose rates irradiated to the components in the CV. The effective energy of beta radiation used is from Appendix A "Nuclear Decay Data" in Federal Guidance Report No.12 (Reference 3). The beta source strengths obtained from the effective energy are as shown in Table E-4. Table E-8 summarizes the cumulative beta accident dose at various times after a LOCA.

E.4 References

1. S.L Humphreys, RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation, U .S. Nuclear Regulatory Commission, NUREG/CR-6604, April 1998.
2. MicroShield User's Manual Version 7. Grove Software, Inc. 2006
3. External Exposure to Radionuclides in Air, Water, and Soil, EPA Federal Guidance Report No. 12, EPA 402-R-93-081, September 1993.

Table E-1 Upper Limit Dose Rate for Each Zone in DCD Figure 12.3-3 thru 12.3-6

<table>
<tr><th colspan="3" rowspan="2">Location</th><th colspan="4">Upper limit dose rate</th></tr>
<tr><th>1 hour</th><th>1 day</th><th>1 week</th><th>1 month</th></tr>
<tr><td colspan="3">Zone 1
Containment</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">Zone 2
Main Control Room and Remote Shutdown Console Room</td><td>1 rem/h</td><td>15 mrem/h</td><td>15 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 3
Class 1E I&C Room</td><td>1 rem/h</td><td>15 mrem/h</td><td>15 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 4
Class 1E Electrical Room, UPS Room, Battery Charger Room, and Reactor Trip Breaker Room</td><td>1 rem/h</td><td>15 mrem/h</td><td>15 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 5
Class 1E Battery Room</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 6
Penetration Area and Safeguard Component Area (Radiological Area)</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">Zone 7
Safety Related Component Area (Radiological Area)</td><td>500 Rad/h</td><td>500 Rad/h</td><td>500 Rad/h</td><td>500 Rad/h</td></tr>
<tr><td colspan="3">Zone 8
Safety Related Component Area (Non-Radiological Area)</td><td>100 rem/h</td><td>100 rem/h</td><td>100 rem/h</td><td>100 rem/h</td></tr>
<tr><td colspan="3">Zone 9
Essential Chiller Unit and Pump Room</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 10
Main Steam/Feedwater Piping Area</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">Zone 11
Gas Turbine Area</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td></tr>
<tr><td colspan="3">Zone 12
Fuel Handling Area</td><td>1 rem/h</td><td>15 mrem/h</td><td>15 mrem/h</td><td>15 mrem/h</td></tr>
<tr><td rowspan="3">Zone 13
Reactor Building and Auxiliary Building General Mechanical Area (Radiological Area)</td><td>13-1 [1)]</td><td>Auxiliary Building</td><td>5.45E+04 rem/h</td><td>5.45E+04 rem/h</td><td>5.45E+04 rem/h</td><td>5.45E+04 rem/h</td></tr>
<tr><td>13-2</td><td>Reactor Building Sample HX Room</td><td>500 Rad/h</td><td>500 Rad/h</td><td>500 Rad/h</td><td>500 Rad/h</td></tr>
<tr><td>13-3</td><td>Reactor Building Passage</td><td>1 rem/h</td><td>15 mrem/h</td><td>15 mrem/h</td><td>15 mrem/h</td></tr>
<tr><td colspan="3">Zone 14
Turbine Building General Mechanical Area</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td><td>1 mrem/h</td></tr>
</table>

Note

1. The maximum area of 13-1 is Zone X and there is no upper limit dose rate. The dose rate inside spent resin storage tank room in which dose rate is the highest is used.

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 1 of 11)

Nuclide	Time after LOCA (hr)										
	0.01	0.02	0.03	0.04	0.05	0.06	0.0667	0.08	0.0834	0.1	0.15
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	2.9E+02	2.0E+03	3.8E+03	5.5E+03	7.2E+03	9.0E+03	1.0E+04	1.2E+04	1.3E+04	1.6E+04	2.5E+04
Kr-85m	0.0E+00	0.0E+00	1.0E+05	1.5E+05	2.0E+05	2.5E+05	2.8E+05	3.4E+05	3.6E+05	4.4E+05	6.7E+05
Kr-87	0.0E+00	0.0E+00	1.2E+05	3.0E+05	3.9E+05	4.8E+05	5.4E+05	6.6E+05	6.9E+05	8.3E+05	1.3E+06
Kr-88	0.0E+00	9.4E+04	2.9E+05	4.2E+05	5.6E+05	6.9E+05	7.8E+05	9.5E+05	1.0E+06	1.2E+06	1.8E+06
Rb-86	0.0E+00	0.0E+00	7.4E+02	1.1E+03	1.4E+03	1.8E+03	2.0E+03	2.4E+03	2.6E+03	3.0E+03	4.2E+03
Sr-89	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Mo-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Tc-99m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-131m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	2.4E+04	1.7E+05	3.1E+05	4.6E+05	6.0E+05	7.4E+05	8.4E+05	1.0E+06	1.1E+06	1.3E+06	1.8E+06
I-132	0.0E+00	2.4E+05	4.5E+05	6.5E+05	8.6E+05	1.1E+06	1.2E+06	1.5E+06	1.5E+06	1.8E+06	2.5E+06
I-133	0.0E+00	3.5E+05	6.5E+05	9.5E+05	1.2E+06	1.5E+06	1.7E+06	2.1E+06	2.2E+06	2.6E+06	3.7E+06
I-134	0.0E+00	0.0E+00	7.1E+05	1.0E+06	1.3E+06	1.6E+06	1.9E+06	2.3E+06	2.4E+06	2.7E+06	3.7E+06
I-135	0.0E+00	3.3E+05	6.0E+05	8.8E+05	1.2E+06	1.4E+06	1.6E+06	2.0E+06	2.1E+06	2.4E+06	3.4E+06
Xe-133	5.0E+04	3.5E+05	6.5E+05	9.5E+05	1.2E+06	1.5E+06	1.7E+06	2.1E+06	2.2E+06	2.7E+06	4.2E+06
Xe-135	0.0E+00	1.1E+05	2.0E+05	2.9E+05	3.8E+05	4.8E+05	5.4E+05	6.6E+05	6.9E+05	8.5E+05	1.3E+06
Cs-134	5.7E+03	4.0E+04	7.3E+04	1.1E+05	1.4E+05	1.8E+05	2.0E+05	2.4E+05	2.5E+05	3.0E+05	4.2E+05
Cs-136	0.0E+00	1.1E+04	2.0E+04	2.9E+04	3.8E+04	4.8E+04	5.4E+04	6.6E+04	6.9E+04	8.1E+04	1.1E+05
Cs-137	3.2E+03	2.2E+04	4.2E+04	6.1E+04	8.0E+04	1.0E+05	1.1E+05	1.4E+05	1.4E+05	1.7E+05	2.4E+05
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pr-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nd-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Np-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 2 of 11)

Nuclide	Time after LOCA (hr)										
	0.2	0.3	0.4	0.5	0.5083	0.6	0.7	0.8	0.9	1	1.1
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.8E+01	1.3E+02	1.8E+02	2.3E+02	2.7E+02	3.1E+02
Kr-85	3.3E+04	5.1E+04	6.8E+04	8.5E+04	8.7E+04	2.0E+05	3.3E+05	4.6E+05	5.8E+05	7.1E+05	8.4E+05
Kr-85m	9.0E+05	1.3E+06	1.8E+06	2.2E+06	2.2E+06	5.2E+06	8.2E+06	1.1E+07	1.4E+07	1.7E+07	2.0E+07
Kr-87	1.6E+06	2.4E+06	3.0E+06	3.6E+06	3.6E+06	8.1E+06	1.2E+07	1.6E+07	2.0E+07	2.3E+07	2.5E+07
Kr-88	2.5E+06	3.7E+06	4.8E+06	5.9E+06	6.0E+06	1.4E+07	2.2E+07	2.9E+07	3.7E+07	4.3E+07	5.0E+07
Rb-86	5.3E+03	7.4E+03	9.3E+03	1.1E+04	1.1E+04	1.5E+04	1.9E+04	2.2E+04	2.6E+04	2.9E+04	3.1E+04
Sr-89	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+05	4.0E+05	5.6E+05	7.0E+05	8.4E+05	9.6E+05
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+04	3.3E+04	4.6E+04	5.8E+04	6.9E+04	8.0E+04
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E+05	5.0E+05	6.9E+05	8.7E+05	1.0E+06	1.2E+06
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.5E+05	4.6E+05	6.3E+05	7.7E+05	9.0E+05	1.0E+06
Y-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E+02	5.5E+02	7.2E+02	8.9E+02	1.1E+03
Y-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E+03	4.9E+03	7.0E+03	8.8E+03	1.0E+04	1.2E+04
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+04	2.4E+04	3.6E+04	5.0E+04	6.4E+04
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+03	5.8E+03	8.1E+03	1.0E+04	1.2E+04	1.4E+04
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+03	6.3E+03	8.9E+03	1.1E+04	1.3E+04	1.5E+04
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E+03	6.1E+03	8.6E+03	1.1E+04	1.3E+04	1.5E+04
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+03	6.3E+03	8.9E+03	1.1E+04	1.3E+04	1.5E+04
Mo-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E+04	8.0E+04	1.1E+05	1.4E+05	1.7E+05	1.9E+05
Tc-99m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+04	7.0E+04	9.9E+04	1.2E+05	1.5E+05	1.7E+05
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.4E+04	6.4E+04	9.0E+04	1.1E+05	1.3E+05	1.5E+05
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+04	3.7E+04	5.2E+04	6.4E+04	7.6E+04	8.5E+04
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+04	2.2E+04	3.1E+04	3.9E+04	4.7E+04	5.4E+04
Rh-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+04	3.9E+04	5.5E+04	6.9E+04	8.2E+04	9.4E+04
Sb-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E+04	8.8E+04	1.2E+05	1.6E+05	1.9E+05	2.1E+05
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+05	2.4E+05	3.3E+05	4.1E+05	4.8E+05	5.5E+05
Te-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.6E+04	8.7E+04	1.2E+05	1.5E+05	1.8E+05	2.1E+05
Te-127m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E+03	1.2E+04	1.6E+04	2.0E+04	2.4E+04	2.8E+04
Te-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+05	2.5E+05	3.5E+05	4.3E+05	5.1E+05	5.8E+05
Te-129m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+04	4.0E+04	5.6E+04	7.0E+04	8.4E+04	9.6E+04
Te-131m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.3E+04	1.2E+05	1.7E+05	2.1E+05	2.5E+05	2.9E+05
Te-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.4E+05	1.2E+06	1.7E+06	2.1E+06	2.5E+06	2.9E+06
I-131	2.3E+06	3.2E+06	4.0E+06	4.8E+06	4.9E+06	7.5E+06	1.0E+07	1.2E+07	1.4E+07	1.6E+07	1.8E+07
I-132	3.2E+06	4.4E+06	5.5E+06	6.5E+06	6.6E+06	1.0E+07	1.4E+07	1.6E+07	1.9E+07	2.1E+07	2.4E+07
I-133	4.7E+06	6.6E+06	8.3E+06	9.9E+06	1.0E+07	1.5E+07	2.0E+07	2.5E+07	2.9E+07	3.3E+07	3.6E+07
I-134	4.5E+06	5.9E+06	6.8E+06	7.5E+06	7.6E+06	1.1E+07	1.3E+07	1.5E+07	1.6E+07	1.7E+07	1.8E+07
I-135	4.4E+06	6.0E+06	7.5E+06	8.9E+06	9.0E+06	1.4E+07	1.8E+07	2.2E+07	2.5E+07	2.8E+07	3.1E+07
Xe-133	5.7E+06	8.7E+06	1.2E+07	1.5E+07	1.5E+07	3.5E+07	5.7E+07	7.9E+07	1.0E+08	1.2E+08	1.4E+08
Xe-135	1.8E+06	2.7E+06	3.7E+06	4.7E+06	4.8E+06	1.1E+07	1.8E+07	2.6E+07	3.3E+07	4.0E+07	4.7E+07
Cs-134	5.3E+05	7.4E+05	9.3E+05	1.1E+06	1.1E+06	1.5E+06	1.9E+06	2.2E+06	2.6E+06	2.9E+06	3.1E+06
Cs-136	1.4E+05	2.0E+05	2.5E+05	3.0E+05	3.0E+05	4.1E+05	5.2E+05	6.1E+05	7.0E+05	7.8E+05	8.5E+05
Cs-137	3.0E+05	4.2E+05	5.3E+05	6.3E+05	6.4E+05	8.7E+05	1.1E+06	1.3E+06	1.5E+06	1.6E+06	1.8E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E+05	4.6E+05	6.2E+05	7.4E+05	8.4E+05	9.2E+05
Ba-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+05	6.3E+05	8.8E+05	1.1E+06	1.3E+06	1.5E+06
La-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E+03	7.3E+03	1.1E+04	1.5E+04	1.8E+04	2.2E+04
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+03	7.3E+03	9.1E+03	1.1E+04	1.2E+04
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+03	3.0E+03	6.3E+03	8.7E+03
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E+03	1.5E+04	2.1E+04	2.6E+04	3.1E+04	3.6E+04
Ce-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.6E+03	1.4E+04	2.0E+04	2.5E+04	3.0E+04	3.4E+04
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.9E+03	1.1E+04	1.6E+04	2.0E+04	2.4E+04	2.7E+04
Pr-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+03	5.6E+03	7.9E+03	9.9E+03	1.2E+04	1.4E+04
Nd-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+03	2.3E+03	3.3E+03	4.2E+03	5.0E+03	5.7E+03
Np-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.4E+04	1.6E+05	2.2E+05	2.8E+05	3.3E+05	3.8E+05
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+01	4.4E+01	6.2E+01	7.8E+01	9.3E+01	1.1E+02
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E+00	3.3E+00	4.7E+00	5.9E+00	7.0E+00	8.1E+00
Pu-240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E+00	5.2E+00	7.4E+00	9.3E+00	1.1E+01	1.3E+01
Pu-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E+02	1.2E+03	1.6E+03	2.1E+03	2.4E+03	2.8E+03
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E-01	6.2E-01	8.8E-01	1.1E+00	1.3E+00	1.5E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.2E+01	1.5E+02	2.2E+02	2.7E+02	3.3E+02	3.8E+02
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.9E+00	1.9E+01	2.6E+01	3.3E+01	4.0E+01	4.6E+01

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 3 of 11)

Nuclide	Time after LOCA (hr)										
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8083	1.9	2	2.1
Co-60	3.5E+02	3.9E+02	4.2E+02	4.5E+02	4.9E+02	5.2E+02	5.5E+02	5.5E+02	5.1E+02	4.8E+02	4.5E+02
Kr-85	9.6E+05	1.1E+06	1.2E+06	1.3E+06	1.5E+06	1.6E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	2.2E+07	2.5E+07	2.7E+07	3.0E+07	3.2E+07	3.4E+07	3.6E+07	3.7E+07	3.6E+07	3.5E+07	3.5E+07
Kr-87	2.8E+07	3.0E+07	3.1E+07	3.3E+07	3.4E+07	3.5E+07	3.6E+07	3.6E+07	3.4E+07	3.2E+07	3.1E+07
Kr-88	5.6E+07	6.2E+07	6.7E+07	7.3E+07	7.8E+07	8.2E+07	8.7E+07	8.7E+07	8.5E+07	8.3E+07	8.1E+07
Rb-86	3.4E+04	3.7E+04	3.9E+04	4.2E+04	4.4E+04	4.6E+04	4.8E+04	4.9E+04	4.5E+04	4.3E+04	4.1E+04
Sr-89	1.1E+06	1.2E+06	1.3E+06	1.4E+06	1.5E+06	1.6E+06	1.7E+06	1.7E+06	1.6E+06	1.5E+06	1.4E+06
Sr-90	8.9E+04	9.9E+04	1.1E+05	1.2E+05	1.2E+05	1.3E+05	1.4E+05	1.4E+05	1.3E+05	1.2E+05	1.2E+05
Sr-91	1.3E+06	1.4E+06	1.5E+06	1.7E+06	1.8E+06	1.9E+06	1.9E+06	2.0E+06	1.8E+06	1.7E+06	1.6E+06
Sr-92	1.1E+06	1.2E+06	1.3E+06	1.3E+06	1.4E+06	1.4E+06	1.5E+06	1.5E+06	1.3E+06	1.2E+06	1.1E+06
Y-90	1.2E+03	1.4E+03	1.6E+03	1.7E+03	1.9E+03	2.1E+03	2.3E+03	2.3E+03	2.3E+03	2.3E+03	2.3E+03
Y-91	1.4E+04	1.5E+04	1.6E+04	1.8E+04	1.9E+04	2.0E+04	2.1E+04	2.1E+04	2.0E+04	1.9E+04	1.8E+04
Y-92	8.0E+04	9.6E+04	1.1E+05	1.3E+05	1.5E+05	1.6E+05	1.8E+05	1.8E+05	1.9E+05	2.1E+05	2.2E+05
Y-93	1.5E+04	1.7E+04	1.8E+04	1.9E+04	2.1E+04	2.2E+04	2.3E+04	2.3E+04	2.1E+04	2.0E+04	1.8E+04
Zr-95	1.7E+04	1.9E+04	2.1E+04	2.2E+04	2.4E+04	2.5E+04	2.7E+04	2.7E+04	2.5E+04	2.3E+04	2.2E+04
Zr-97	1.6E+04	1.8E+04	1.9E+04	2.1E+04	2.2E+04	2.4E+04	2.5E+04	2.5E+04	2.3E+04	2.1E+04	2.0E+04
Nb-95	1.7E+04	1.9E+04	2.1E+04	2.2E+04	2.4E+04	2.5E+04	2.7E+04	2.7E+04	2.5E+04	2.3E+04	2.2E+04
Mo-99	2.2E+05	2.4E+05	2.6E+05	2.8E+05	3.0E+05	3.2E+05	3.3E+05	3.4E+05	3.1E+05	2.9E+05	2.8E+05
Tc-99m	1.9E+05	2.1E+05	2.3E+05	2.5E+05	2.7E+05	2.8E+05	3.0E+05	3.0E+05	2.8E+05	2.6E+05	2.5E+05
Ru-103	1.7E+05	1.9E+05	2.1E+05	2.2E+05	2.4E+05	2.6E+05	2.7E+05	2.7E+05	2.5E+05	2.4E+05	2.2E+05
Ru-105	9.4E+04	1.0E+05	1.1E+05	1.2E+05	1.2E+05	1.3E+05	1.3E+05	1.3E+05	1.2E+05	1.1E+05	1.1E+05
Ru-106	6.1E+04	6.7E+04	7.3E+04	7.9E+04	8.4E+04	8.9E+04	9.5E+04	9.5E+04	8.8E+04	8.2E+04	7.8E+04
Rh-105	1.1E+05	1.2E+05	1.3E+05	1.4E+05	1.5E+05	1.6E+05	1.6E+05	1.7E+05	1.5E+05	1.4E+05	1.4E+05
Sb-127	2.4E+05	2.6E+05	2.9E+05	3.1E+05	3.3E+05	3.5E+05	3.7E+05	3.7E+05	3.4E+05	3.2E+05	3.1E+05
Sb-129	6.0E+05	6.5E+05	7.0E+05	7.4E+05	7.8E+05	8.2E+05	8.5E+05	8.6E+05	7.8E+05	7.2E+05	6.7E+05
Te-127	2.4E+05	2.6E+05	2.9E+05	3.1E+05	3.3E+05	3.5E+05	3.7E+05	3.7E+05	3.4E+05	3.2E+05	3.1E+05
Te-127m	3.1E+04	3.5E+04	3.8E+04	4.1E+04	4.4E+04	4.6E+04	4.9E+04	4.9E+04	4.6E+04	4.3E+04	4.1E+04
Te-129	6.5E+05	7.1E+05	7.6E+05	8.1E+05	8.6E+05	9.0E+05	9.5E+05	9.5E+05	8.7E+05	8.1E+05	7.6E+05
Te-129m	1.1E+05	1.2E+05	1.3E+05	1.4E+05	1.5E+05	1.6E+05	1.7E+05	1.7E+05	1.6E+05	1.5E+05	1.4E+05
Te-131m	3.2E+05	3.6E+05	3.9E+05	4.2E+05	4.4E+05	4.7E+05	5.0E+05	5.0E+05	4.6E+05	4.3E+05	4.1E+05
Te-132	3.3E+06	3.6E+06	3.9E+06	4.2E+06	4.5E+06	4.8E+06	5.1E+06	5.1E+06	4.7E+06	4.4E+06	4.2E+06
I-131	2.0E+07	2.1E+07	2.3E+07	2.5E+07	2.6E+07	2.8E+07	2.9E+07	2.9E+07	2.7E+07	2.6E+07	2.5E+07
I-132	2.6E+07	2.8E+07	2.9E+07	3.1E+07	3.3E+07	3.4E+07	3.6E+07	3.6E+07	3.3E+07	3.0E+07	2.8E+07
I-133	4.0E+07	4.3E+07	4.6E+07	4.9E+07	5.2E+07	5.5E+07	5.7E+07	5.8E+07	5.4E+07	5.1E+07	4.9E+07
I-134	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.7E+07	1.7E+07	1.6E+07	1.6E+07	1.4E+07	1.2E+07	1.1E+07
I-135	3.4E+07	3.7E+07	3.9E+07	4.1E+07	4.3E+07	4.5E+07	4.7E+07	4.7E+07	4.4E+07	4.1E+07	3.9E+07
Xe-133	1.7E+08	1.9E+08	2.1E+08	2.3E+08	2.5E+08	2.7E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08
Xe-135	5.5E+07	6.2E+07	6.9E+07	7.6E+07	8.4E+07	9.1E+07	9.8E+07	9.9E+07	9.8E+07	9.8E+07	9.7E+07
Cs-134	3.4E+06	3.7E+06	3.9E+06	4.1E+06	4.4E+06	4.6E+06	4.8E+06	4.8E+06	4.5E+06	4.3E+06	4.1E+06
Cs-136	9.2E+05	9.9E+05	1.1E+06	1.1E+06	1.2E+06	1.3E+06	1.3E+06	1.3E+06	1.2E+06	1.2E+06	1.1E+06
Cs-137	1.9E+06	2.1E+06	2.2E+06	2.4E+06	2.5E+06	2.6E+06	2.7E+06	2.8E+06	2.6E+06	2.4E+06	2.3E+06
Ba-139	9.8E+05	1.0E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.0E+06	8.9E+05	8.0E+05
Ba-140	1.7E+06	1.9E+06	2.1E+06	2.2E+06	2.4E+06	2.5E+06	2.7E+06	2.7E+06	2.5E+06	2.3E+06	2.2E+06
La-140	2.6E+04	3.0E+04	3.4E+04	3.9E+04	4.3E+04	4.7E+04	5.2E+04	5.2E+04	5.3E+04	5.4E+04	5.5E+04
La-141	1.3E+04	1.4E+04	1.5E+04	1.6E+04	1.7E+04	1.8E+04	1.9E+04	1.9E+04	1.7E+04	1.6E+04	1.5E+04
La-142	9.4E+03	9.9E+03	1.0E+04	1.1E+04	1.1E+04	1.1E+04	1.1E+04	1.1E+04	9.9E+03	8.9E+03	8.1E+03
Ce-141	4.0E+04	4.5E+04	4.9E+04	5.2E+04	5.6E+04	6.0E+04	6.3E+04	6.3E+04	5.9E+04	5.5E+04	5.2E+04
Ce-143	3.8E+04	4.2E+04	4.6E+04	5.0E+04	5.3E+04	5.6E+04	5.9E+04	6.0E+04	5.5E+04	5.1E+04	4.9E+04
Ce-144	3.1E+04	3.4E+04	3.7E+04	4.0E+04	4.2E+04	4.5E+04	4.8E+04	4.8E+04	4.4E+04	4.2E+04	3.9E+04
Pr-143	1.5E+04	1.7E+04	1.8E+04	2.0E+04	2.1E+04	2.3E+04	2.4E+04	2.4E+04	2.2E+04	2.1E+04	2.0E+04
Nd-147	6.4E+03	7.0E+03	7.7E+03	8.3E+03	8.8E+03	9.4E+03	9.9E+03	1.0E+04	9.2E+03	8.7E+03	8.2E+03
Np-239	4.3E+05	4.7E+05	5.1E+05	5.5E+05	5.9E+05	6.3E+05	6.7E+05	6.7E+05	6.2E+05	5.8E+05	5.5E+05
Pu-238	1.2E+02	1.3E+02	1.4E+02	1.6E+02	1.7E+02	1.8E+02	1.9E+02	1.9E+02	1.7E+02	1.6E+02	1.6E+02
Pu-239	9.1E+00	1.0E+01	1.1E+01	1.2E+01	1.3E+01	1.3E+01	1.4E+01	1.4E+01	1.3E+01	1.2E+01	1.2E+01
Pu-240	1.4E+01	1.6E+01	1.7E+01	1.8E+01	2.0E+01	2.1E+01	2.2E+01	2.2E+01	2.1E+01	1.9E+01	1.8E+01
Pu-241	3.2E+03	3.5E+03	3.8E+03	4.1E+03	4.4E+03	4.7E+03	4.9E+03	4.9E+03	4.6E+03	4.3E+03	4.1E+03
Am-241	1.7E+00	1.9E+00	2.0E+00	2.2E+00	2.4E+00	2.5E+00	2.7E+00	2.7E+00	2.5E+00	2.3E+00	2.2E+00
Cm-242	4.2E+02	4.7E+02	5.1E+02	5.5E+02	5.8E+02	6.2E+02	6.6E+02	6.6E+02	6.1E+02	5.7E+02	5.4E+02
Cm-244	5.1E+01	5.7E+01	6.2E+01	6.6E+01	7.1E+01	7.6E+01	8.0E+01	8.0E+01	7.4E+01	7.0E+01	6.6E+01

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 4 of 11)

Nuclide	Time after LOCA (hr)										
	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.2	3.23
Co-60	4.3E+02	4.2E+02	4.0E+02	3.9E+02	3.8E+02	3.7E+02	3.7E+02	3.6E+02	3.5E+02	3.5E+02	3.5E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	3.4E+07	3.4E+07	3.3E+07	3.3E+07	3.2E+07	3.2E+07	3.1E+07	3.1E+07	3.0E+07	2.9E+07	2.9E+07
Kr-87	2.9E+07	2.7E+07	2.6E+07	2.5E+07	2.3E+07	2.2E+07	2.1E+07	2.0E+07	1.9E+07	1.7E+07	1.6E+07
Kr-88	7.9E+07	7.7E+07	7.5E+07	7.4E+07	7.2E+07	7.0E+07	6.8E+07	6.7E+07	6.5E+07	6.2E+07	6.2E+07
Rb-86	3.9E+04	3.8E+04	3.7E+04	3.6E+04	3.5E+04	3.4E+04	3.4E+04	3.3E+04	3.3E+04	3.2E+04	3.2E+04
Sr-89	1.3E+06	1.3E+06	1.2E+06	1.2E+06	1.2E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06
Sr-90	1.1E+05	1.1E+05	1.0E+05	1.0E+05	9.7E+04	9.5E+04	9.3E+04	9.2E+04	9.1E+04	8.9E+04	8.8E+04
Sr-91	1.5E+06	1.4E+06	1.4E+06	1.3E+06	1.3E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.1E+06	1.1E+06
Sr-92	1.0E+06	9.8E+05	9.3E+05	8.8E+05	8.4E+05	8.0E+05	7.6E+05	7.3E+05	7.0E+05	6.5E+05	6.5E+05
Y-90	2.3E+03	2.4E+03	2.4E+03	2.4E+03	2.5E+03	2.5E+03	2.6E+03	2.6E+03	2.7E+03	2.8E+03	2.9E+03
Y-91	1.7E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.5E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04
Y-92	2.3E+05	2.3E+05	2.4E+05	2.5E+05	2.5E+05	2.6E+05	2.7E+05	2.7E+05	2.8E+05	2.9E+05	2.9E+05
Y-93	1.8E+04	1.7E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.4E+04	1.4E+04	1.4E+04	1.3E+04	1.3E+04
Zr-95	2.1E+04	2.0E+04	2.0E+04	1.9E+04	1.9E+04	1.8E+04	1.8E+04	1.8E+04	1.7E+04	1.7E+04	1.7E+04
Zr-97	1.9E+04	1.9E+04	1.8E+04	1.7E+04	1.7E+04	1.6E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.5E+04
Nb-95	2.1E+04	2.0E+04	2.0E+04	1.9E+04	1.9E+04	1.8E+04	1.8E+04	1.8E+04	1.7E+04	1.7E+04	1.7E+04
Mo-99	2.6E+05	2.5E+05	2.5E+05	2.4E+05	2.3E+05	2.3E+05	2.2E+05	2.2E+05	2.1E+05	2.1E+05	2.1E+05
Tc-99m	2.4E+05	2.3E+05	2.2E+05	2.1E+05	2.1E+05	2.0E+05	2.0E+05	2.0E+05	1.9E+05	1.9E+05	1.9E+05
Ru-103	2.1E+05	2.1E+05	2.0E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.7E+05	1.7E+05
Ru-105	1.0E+05	9.4E+04	9.0E+04	8.6E+04	8.3E+04	8.0E+04	7.7E+04	7.4E+04	7.2E+04	6.8E+04	6.8E+04
Ru-106	7.5E+04	7.2E+04	7.0E+04	6.8E+04	6.6E+04	6.5E+04	6.3E+04	6.2E+04	6.1E+04	6.0E+04	6.0E+04
Rh-105	1.3E+05	1.3E+05	1.2E+05	1.2E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.0E+05	1.0E+05
Sb-127	2.9E+05	2.8E+05	2.7E+05	2.6E+05	2.6E+05	2.5E+05	2.5E+05	2.4E+05	2.4E+05	2.3E+05	2.3E+05
Sb-129	6.3E+05	6.0E+05	5.7E+05	5.5E+05	5.2E+05	5.1E+05	4.9E+05	4.7E+05	4.6E+05	4.3E+05	4.3E+05
Te-127	2.9E+05	2.8E+05	2.7E+05	2.6E+05	2.6E+05	2.5E+05	2.5E+05	2.4E+05	2.4E+05	2.3E+05	2.3E+05
Te-127m	3.9E+04	3.7E+04	3.6E+04	3.5E+04	3.4E+04	3.3E+04	3.3E+04	3.2E+04	3.2E+04	3.1E+04	3.1E+04
Te-129	7.1E+05	6.8E+05	6.5E+05	6.2E+05	6.0E+05	5.8E+05	5.6E+05	5.5E+05	5.3E+05	5.1E+05	5.1E+05
Te-129m	1.3E+05	1.3E+05	1.2E+05	1.2E+05	1.2E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05
Te-131m	3.9E+05	3.7E+05	3.6E+05	3.5E+05	3.4E+05	3.3E+05	3.3E+05	3.2E+05	3.1E+05	3.1E+05	3.0E+05
Te-132	4.0E+06	3.8E+06	3.7E+06	3.6E+06	3.5E+06	3.4E+06	3.4E+06	3.3E+06	3.3E+06	3.2E+06	3.2E+06
I-131	2.4E+07	2.3E+07	2.3E+07	2.2E+07	2.2E+07	2.1E+07	2.1E+07	2.1E+07	2.0E+07	2.0E+07	2.0E+07
I-132	2.6E+07	2.5E+07	2.4E+07	2.2E+07	2.1E+07	2.0E+07	2.0E+07	1.9E+07	1.8E+07	1.7E+07	1.7E+07
I-133	4.7E+07	4.5E+07	4.4E+07	4.3E+07	4.2E+07	4.1E+07	4.0E+07	3.9E+07	3.9E+07	3.8E+07	3.8E+07
I-134	9.8E+06	8.8E+06	7.9E+06	7.2E+06	6.5E+06	5.9E+06	5.4E+06	4.9E+06	4.5E+06	3.7E+06	3.7E+06
I-135	3.7E+07	3.6E+07	3.4E+07	3.3E+07	3.2E+07	3.1E+07	3.1E+07	3.0E+07	2.9E+07	2.8E+07	2.8E+07
Xe-133	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08	3.0E+08
Xe-135	9.6E+07	9.6E+07	9.5E+07	9.4E+07	9.4E+07	9.3E+07	9.2E+07	9.2E+07	9.1E+07	9.0E+07	9.0E+07
Cs-134	3.9E+06	3.8E+06	3.7E+06	3.6E+06	3.5E+06	3.4E+06	3.4E+06	3.3E+06	3.3E+06	3.2E+06	3.2E+06
Cs-136	1.1E+06	1.0E+06	9.9E+05	9.7E+05	9.5E+05	9.3E+05	9.1E+05	9.0E+05	8.9E+05	8.7E+05	8.7E+05
Cs-137	2.2E+06	2.1E+06	2.1E+06	2.0E+06	2.0E+06	2.0E+06	1.9E+06	1.9E+06	1.9E+06	1.8E+06	1.8E+06
Ba-139	7.3E+05	6.7E+05	6.2E+05	5.7E+05	5.3E+05	4.9E+05	4.6E+05	4.3E+05	4.0E+05	3.6E+05	3.5E+05
Ba-140	2.1E+06	2.0E+06	2.0E+06	1.9E+06	1.9E+06	1.8E+06	1.8E+06	1.8E+06	1.7E+06	1.7E+06	1.7E+06
La-140	5.7E+04	5.8E+04	6.0E+04	6.1E+04	6.3E+04	6.5E+04	6.7E+04	6.9E+04	7.1E+04	7.5E+04	7.5E+04
La-141	1.4E+04	1.3E+04	1.2E+04	1.2E+04	1.1E+04	1.1E+04	1.0E+04	1.0E+04	9.8E+03	9.2E+03	9.1E+03
La-142	7.4E+03	6.8E+03	6.3E+03	5.8E+03	5.4E+03	5.1E+03	4.8E+03	4.5E+03	4.2E+03	3.8E+03	3.7E+03
Ce-141	5.0E+04	4.8E+04	4.6E+04	4.5E+04	4.4E+04	4.3E+04	4.2E+04	4.2E+04	4.1E+04	4.0E+04	4.0E+04
Ce-143	4.7E+04	4.5E+04	4.3E+04	4.2E+04	4.1E+04	4.0E+04	3.9E+04	3.8E+04	3.8E+04	3.7E+04	3.6E+04
Ce-144	3.8E+04	3.6E+04	3.5E+04	3.4E+04	3.3E+04	3.3E+04	3.2E+04	3.1E+04	3.1E+04	3.0E+04	3.0E+04
Pr-143	1.9E+04	1.8E+04	1.8E+04	1.7E+04	1.7E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04
Nd-147	7.9E+03	7.6E+03	7.3E+03	7.1E+03	6.9E+03	6.8E+03	6.6E+03	6.5E+03	6.4E+03	6.3E+03	6.3E+03
Np-239	5.2E+05	5.0E+05	4.9E+05	4.7E+05	4.6E+05	4.5E+05	4.4E+05	4.3E+05	4.3E+05	4.2E+05	4.1E+05
Pu-238	1.5E+02	1.4E+02	1.4E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02
Pu-239	1.1E+01	1.1E+01	1.0E+01	1.0E+01	9.9E+00	9.7E+00	9.5E+00	9.3E+00	9.2E+00	9.0E+00	9.0E+00
Pu-240	1.8E+01	1.7E+01	1.6E+01	1.6E+01	1.6E+01	1.5E+01	1.5E+01	1.5E+01	1.4E+01	1.4E+01	1.4E+01
Pu-241	3.9E+03	3.7E+03	3.6E+03	3.5E+03	3.4E+03	3.4E+03	3.3E+03	3.2E+03	3.2E+03	3.1E+03	3.1E+03
Am-241	2.1E+00	2.0E+00	2.0E+00	1.9E+00	1.9E+00	1.8E+00	1.8E+00	1.8E+00	1.7E+00	1.7E+00	1.7E+00
Cm-242	5.2E+02	5.0E+02	4.8E+02	4.7E+02	4.6E+02	4.5E+02	4.4E+02	4.3E+02	4.3E+02	4.2E+02	4.2E+02
Cm-244	6.3E+01	6.1E+01	5.9E+01	5.7E+01	5.6E+01	5.5E+01	5.4E+01	5.3E+01	5.2E+01	5.1E+01	5.1E+01

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 5 of 11)

Nuclide	Time after LOCA (hr)										
	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.5	6
Co-60	3.5E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.3E+02	3.3E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	2.9E+07	2.8E+07	2.7E+07	2.6E+07	2.5E+07	2.4E+07	2.4E+07	2.3E+07	2.2E+07	2.1E+07	1.9E+07
Kr-87	1.5E+07	1.3E+07	1.2E+07	1.1E+07	9.7E+06	8.7E+06	7.8E+06	7.0E+06	6.3E+06	4.8E+06	3.6E+06
Kr-88	5.9E+07	5.6E+07	5.4E+07	5.1E+07	4.9E+07	4.6E+07	4.4E+07	4.2E+07	4.0E+07	3.5E+07	3.1E+07
Rb-86	3.2E+04	3.2E+04	3.2E+04	3.2E+04	3.2E+04	3.1E+04	3.1E+04	3.1E+04	3.1E+04	3.1E+04	3.1E+04
Sr-89	1.1E+06	1.1E+06	1.1E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06
Sr-90	8.8E+04	8.8E+04	8.7E+04	8.7E+04	8.7E+04	8.7E+04	8.6E+04	8.6E+04	8.6E+04	8.5E+04	8.5E+04
Sr-91	1.1E+06	1.1E+06	1.1E+06	1.0E+06	1.0E+06	1.0E+06	9.8E+05	9.7E+05	9.5E+05	9.1E+05	8.7E+05
Sr-92	6.2E+05	5.8E+05	5.5E+05	5.2E+05	5.0E+05	4.7E+05	4.4E+05	4.2E+05	4.0E+05	3.5E+05	3.1E+05
Y-90	3.0E+03	3.2E+03	3.4E+03	3.5E+03	3.7E+03	3.9E+03	4.0E+03	4.2E+03	4.4E+03	4.8E+03	5.2E+03
Y-91	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04
Y-92	3.0E+05	3.1E+05	3.2E+05	3.3E+05	3.3E+05	3.4E+05	3.4E+05	3.4E+05	3.4E+05	3.5E+05	3.4E+05
Y-93	1.3E+04	1.3E+04	1.2E+04	1.2E+04	1.2E+04	1.2E+04	1.2E+04	1.1E+04	1.1E+04	1.1E+04	1.0E+04
Zr-95	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.6E+04	1.6E+04	1.6E+04
Zr-97	1.5E+04	1.5E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.3E+04	1.3E+04	1.3E+04
Nb-95	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.7E+04	1.6E+04	1.6E+04
Mo-99	2.1E+05	2.1E+05	2.1E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05
Tc-99m	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05
Ru-103	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.6E+05
Ru-105	6.6E+04	6.4E+04	6.2E+04	6.0E+04	5.7E+04	5.6E+04	5.4E+04	5.2E+04	5.0E+04	4.6E+04	4.2E+04
Ru-106	6.0E+04	6.0E+04	5.9E+04	5.9E+04	5.9E+04	5.9E+04	5.9E+04	5.8E+04	5.8E+04	5.8E+04	5.8E+04
Rh-105	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	9.9E+04	9.8E+04	9.7E+04
Sb-127	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.2E+05	2.2E+05	2.2E+05	2.2E+05
Sb-129	4.2E+05	4.0E+05	3.9E+05	3.8E+05	3.6E+05	3.5E+05	3.4E+05	3.3E+05	3.2E+05	2.9E+05	2.7E+05
Te-127	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.3E+05	2.2E+05	2.2E+05
Te-127m	3.1E+04	3.1E+04	3.1E+04	3.1E+04	3.1E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04
Te-129	4.9E+05	4.8E+05	4.7E+05	4.5E+05	4.4E+05	4.3E+05	4.2E+05	4.1E+05	3.9E+05	3.7E+05	3.4E+05
Te-129m	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Te-131m	3.0E+05	3.0E+05	3.0E+05	3.0E+05	2.9E+05	2.9E+05	2.9E+05	2.9E+05	2.8E+05	2.8E+05	2.7E+05
Te-132	3.2E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06
I-131	2.0E+07	2.0E+07	2.0E+07	2.0E+07	2.0E+07	2.0E+07	2.0E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07
I-132	1.6E+07	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.3E+07	1.2E+07	1.1E+07	1.1E+07	9.8E+06	8.8E+06
I-133	3.8E+07	3.7E+07	3.7E+07	3.6E+07	3.6E+07	3.6E+07	3.6E+07	3.5E+07	3.5E+07	3.4E+07	3.3E+07
I-134	3.2E+06	2.7E+06	2.3E+06	2.0E+06	1.7E+06	1.4E+06	1.2E+06	1.0E+06	8.8E+05	5.9E+05	4.0E+05
I-135	2.7E+07	2.7E+07	2.6E+07	2.6E+07	2.5E+07	2.4E+07	2.4E+07	2.3E+07	2.3E+07	2.2E+07	2.0E+07
Xe-133	3.0E+08	3.0E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08
Xe-135	8.9E+07	8.7E+07	8.6E+07	8.5E+07	8.4E+07	8.2E+07	8.1E+07	8.0E+07	7.9E+07	7.6E+07	7.3E+07
Cs-134	3.2E+06	3.2E+06	3.2E+06	3.2E+06	3.2E+06	3.2E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06
Cs-136	8.7E+05	8.6E+05	8.6E+05	8.6E+05	8.5E+05	8.5E+05	8.5E+05	8.5E+05	8.4E+05	8.4E+05	8.4E+05
Cs-137	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06	1.8E+06
Ba-139	3.2E+05	2.9E+05	2.6E+05	2.3E+05	2.1E+05	1.9E+05	1.7E+05	1.5E+05	1.4E+05	1.1E+05	8.3E+04
Ba-140	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06
La-140	8.0E+04	8.5E+04	9.0E+04	9.5E+04	1.0E+05	1.1E+05	1.1E+05	1.2E+05	1.2E+05	1.3E+05	1.4E+05
La-141	8.8E+03	8.5E+03	8.2E+03	7.9E+03	7.6E+03	7.3E+03	7.0E+03	6.8E+03	6.5E+03	5.9E+03	5.4E+03
La-142	3.4E+03	3.1E+03	2.9E+03	2.6E+03	2.4E+03	2.2E+03	2.0E+03	1.8E+03	1.6E+03	1.3E+03	1.0E+03
Ce-141	4.0E+04	4.0E+04	4.0E+04	3.9E+04	3.9E+04	3.9E+04	3.9E+04	3.9E+04	3.9E+04	3.9E+04	3.8E+04
Ce-143	3.6E+04	3.6E+04	3.6E+04	3.5E+04	3.5E+04	3.5E+04	3.5E+04	3.4E+04	3.4E+04	3.4E+04	3.3E+04
Ce-144	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04
Pr-143	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04
Nd-147	6.3E+03	6.2E+03	6.2E+03	6.2E+03	6.2E+03	6.1E+03	6.1E+03	6.1E+03	6.1E+03	6.0E+03	6.0E+03
Np-239	4.1E+05	4.1E+05	4.1E+05	4.0E+05	4.0E+05	4.0E+05	4.0E+05	4.0E+05	3.9E+05	3.9E+05	3.9E+05
Pu-238	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.2E+02	1.1E+02	1.1E+02
Pu-239	9.0E+00	8.9E+00	8.9E+00	8.9E+00	8.8E+00	8.8E+00	8.8E+00	8.8E+00	8.7E+00	8.7E+00	8.6E+00
Pu-240	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01	1.4E+01
Pu-241	3.1E+03	3.1E+03	3.1E+03	3.1E+03	3.1E+03	3.1E+03	3.0E+03	3.0E+03	3.0E+03	3.0E+03	3.0E+03
Am-241	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00
Cm-242	4.2E+02	4.1E+02	4.1E+02	4.1E+02	4.1E+02	4.1E+02	4.1E+02	4.1E+02	4.1E+02	4.0E+02	4.0E+02
Cm-244	5.1E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	4.9E+01	4.9E+01	4.9E+01	4.9E+01

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 6 of 11)

Nuclide	Time after LOCA (hr)										
	6.5	7	7.5	8	8.8	9	9.5	10	11	12	13
Co-60	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	1.8E+07	1.6E+07	1.5E+07	1.4E+07	1.2E+07	1.2E+07	1.1E+07	1.0E+07	8.8E+06	7.5E+06	6.5E+06
Kr-87	2.8E+06	2.1E+06	1.6E+06	1.2E+06	7.9E+05	7.1E+05	5.4E+05	4.1E+05	2.4E+05	1.4E+05	8.0E+04
Kr-88	2.8E+07	2.5E+07	2.2E+07	1.9E+07	1.6E+07	1.5E+07	1.3E+07	1.2E+07	9.2E+06	7.2E+06	5.7E+06
Rb-86	3.1E+04	3.1E+04	3.1E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04
Sr-89	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06
Sr-90	8.5E+04	8.4E+04	8.4E+04	8.4E+04	8.4E+04	8.4E+04	8.4E+04	8.4E+04	8.3E+04	8.3E+04	8.3E+04
Sr-91	8.4E+05	8.1E+05	7.8E+05	7.5E+05	7.0E+05	6.9E+05	6.7E+05	6.4E+05	6.0E+05	5.5E+05	5.1E+05
Sr-92	2.7E+05	2.4E+05	2.1E+05	1.8E+05	1.5E+05	1.4E+05	1.2E+05	1.1E+05	8.4E+04	6.5E+04	5.0E+04
Y-90	5.6E+03	6.0E+03	6.4E+03	6.8E+03	7.5E+03	7.6E+03	8.0E+03	8.4E+03	9.2E+03	1.0E+04	1.1E+04
Y-91	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04
Y-92	3.4E+05	3.3E+05	3.2E+05	3.0E+05	2.8E+05	2.8E+05	2.6E+05	2.5E+05	2.2E+05	2.0E+05	1.7E+05
Y-93	1.0E+04	9.7E+03	9.3E+03	9.0E+03	8.5E+03	8.4E+03	8.1E+03	7.8E+03	7.3E+03	6.8E+03	6.3E+03
Zr-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Zr-97	1.2E+04	1.2E+04	1.2E+04	1.2E+04	1.1E+04	1.1E+04	1.1E+04	1.1E+04	1.0E+04	9.8E+03	9.4E+03
Nb-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Mo-99	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05
Tc-99m	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05
Ru-103	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05
Ru-105	3.9E+04	3.6E+04	3.3E+04	3.1E+04	2.7E+04	2.6E+04	2.4E+04	2.2E+04	1.9E+04	1.6E+04	1.4E+04
Ru-106	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.7E+04	5.6E+04
Rh-105	9.6E+04	9.5E+04	9.5E+04	9.4E+04	9.3E+04	9.2E+04	9.2E+04	9.1E+04	8.9E+04	8.8E+04	8.6E+04
Sb-127	2.2E+05	2.2E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.0E+05
Sb-129	2.4E+05	2.2E+05	2.1E+05	1.9E+05	1.7E+05	1.6E+05	1.5E+05	1.4E+05	1.2E+05	9.9E+04	8.5E+04
Te-127	2.2E+05	2.2E+05	2.2E+05	2.2E+05	2.2E+05	2.2E+05	2.2E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05
Te-127m	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04
Te-129	3.2E+05	3.0E+05	2.8E+05	2.7E+05	2.4E+05	2.4E+05	2.2E+05	2.1E+05	1.9E+05	1.7E+05	1.5E+05
Te-129m	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Te-131m	2.7E+05	2.7E+05	2.6E+05	2.6E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.4E+05	2.3E+05	2.3E+05
Te-132	3.0E+06	2.9E+06	2.9E+06	2.9E+06	2.9E+06	2.9E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.7E+06
I-131	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.9E+07	1.8E+07	1.8E+07
I-132	8.0E+06	7.3E+06	6.7E+06	6.1E+06	5.4E+06	5.3E+06	4.9E+06	4.6E+06	4.2E+06	3.8E+06	3.5E+06
I-133	3.3E+07	3.2E+07	3.2E+07	3.1E+07	3.0E+07	3.0E+07	2.9E+07	2.9E+07	2.8E+07	2.7E+07	2.6E+07
I-134	2.7E+05	1.8E+05	1.2E+05	8.1E+04	4.3E+04	3.7E+04	2.5E+04	1.7E+04	7.5E+03	3.4E+03	1.5E+03
I-135	1.9E+07	1.8E+07	1.7E+07	1.6E+07	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.2E+07	1.1E+07	9.6E+06
Xe-133	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.9E+08	2.8E+08	2.8E+08	2.8E+08
Xe-135	7.1E+07	6.8E+07	6.6E+07	6.3E+07	6.0E+07	5.9E+07	5.7E+07	5.5E+07	5.1E+07	4.7E+07	4.4E+07
Cs-134	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06	3.1E+06
Cs-136	8.3E+05	8.3E+05	8.3E+05	8.2E+05	8.2E+05	8.2E+05	8.2E+05	8.2E+05	8.1E+05	8.1E+05	8.1E+05
Cs-137	1.8E+06	1.8E+06	1.8E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Ba-139	6.5E+04	5.0E+04	3.9E+04	3.0E+04	2.0E+04	1.8E+04	1.4E+04	1.1E+04	6.6E+03	4.0E+03	2.4E+03
Ba-140	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06	1.6E+06
La-140	1.6E+05	1.7E+05	1.8E+05	1.9E+05	2.1E+05	2.1E+05	2.3E+05	2.4E+05	2.6E+05	2.8E+05	3.0E+05
La-141	4.9E+03	4.5E+03	4.1E+03	3.8E+03	3.2E+03	3.1E+03	2.9E+03	2.6E+03	2.2E+03	1.8E+03	1.5E+03
La-142	8.2E+02	6.5E+02	5.2E+02	4.1E+02	2.9E+02	2.6E+02	2.1E+02	1.7E+02	1.1E+02	6.8E+01	4.3E+01
Ce-141	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.8E+04	3.7E+04	3.7E+04
Ce-143	3.3E+04	3.2E+04	3.2E+04	3.1E+04	3.1E+04	3.1E+04	3.0E+04	3.0E+04	2.9E+04	2.9E+04	2.8E+04
Ce-144	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.8E+04
Pr-143	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04
Nd-147	6.0E+03	5.9E+03	5.9E+03	5.9E+03	5.9E+03	5.9E+03	5.8E+03	5.8E+03	5.8E+03	5.8E+03	5.8E+03
Np-239	3.8E+05	3.8E+05	3.7E+05	3.7E+05	3.7E+05	3.7E+05	3.6E+05	3.6E+05	3.6E+05	3.5E+05	3.5E+05
Pu-238	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02
Pu-239	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00
Pu-240	1.4E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01
Pu-241	3.0E+03	3.0E+03	3.0E+03	3.0E+03	3.0E+03	3.0E+03	3.0E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03
Am-241	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00
Cm-242	4.0E+02	4.0E+02	4.0E+02	4.0E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02
Cm-244	4.9E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 7 of 11)

Nuclide	Time after LOCA (hr)										
	14	15	16	17	18	19	20	21	22	23	24
Co-60	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	5.5E+06	4.7E+06	4.1E+06	3.5E+06	3.0E+06	2.6E+06	2.2E+06	1.9E+06	1.6E+06	1.4E+06	1.2E+06
Kr-87	4.7E+04	2.7E+04	1.6E+04	9.1E+03	5.3E+03	3.0E+03	1.8E+03	1.0E+03	5.9E+02	3.4E+02	2.0E+02
Kr-88	4.4E+06	3.5E+06	2.7E+06	2.1E+06	1.7E+06	1.3E+06	1.0E+06	8.0E+05	6.3E+05	4.9E+05	3.9E+05
Rb-86	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	3.0E+04	2.9E+04
Sr-89	1.0E+06	1.0E+06	1.0E+06	9.9E+05	9.9E+05	9.9E+05	9.9E+05	9.9E+05	9.9E+05	9.9E+05	9.9E+05
Sr-90	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04
Sr-91	4.8E+05	4.4E+05	4.1E+05	3.8E+05	3.6E+05	3.3E+05	3.1E+05	2.9E+05	2.7E+05	2.5E+05	2.3E+05
Sr-92	3.9E+04	3.0E+04	2.3E+04	1.8E+04	1.4E+04	1.1E+04	8.3E+03	6.5E+03	5.0E+03	3.9E+03	3.0E+03
Y-90	1.2E+04	1.2E+04	1.3E+04	1.4E+04	1.5E+04	1.5E+04	1.6E+04	1.7E+04	1.8E+04	1.8E+04	1.9E+04
Y-91	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04
Y-92	1.5E+05	1.3E+05	1.1E+05	9.4E+04	8.0E+04	6.8E+04	5.8E+04	4.9E+04	4.1E+04	3.4E+04	2.9E+04
Y-93	5.9E+03	5.5E+03	5.1E+03	4.8E+03	4.5E+03	4.2E+03	3.9E+03	3.6E+03	3.4E+03	3.2E+03	3.0E+03
Zr-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Zr-97	9.0E+03	8.6E+03	8.3E+03	7.9E+03	7.6E+03	7.3E+03	7.0E+03	6.7E+03	6.5E+03	6.2E+03	6.0E+03
Nb-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Mo-99	1.8E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05
Tc-99m	1.7E+05	1.7E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.5E+05	1.5E+05
Ru-103	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05
Ru-105	1.2E+04	1.0E+04	8.7E+03	7.5E+03	6.4E+03	5.5E+03	4.7E+03	4.0E+03	3.4E+03	2.9E+03	2.5E+03
Ru-106	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04
Rh-105	8.5E+04	8.3E+04	8.2E+04	8.1E+04	7.9E+04	7.8E+04	7.6E+04	7.5E+04	7.3E+04	7.2E+04	7.1E+04
Sb-127	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Sb-129	7.2E+04	6.1E+04	5.2E+04	4.5E+04	3.8E+04	3.2E+04	2.8E+04	2.3E+04	2.0E+04	1.7E+04	1.4E+04
Te-127	2.1E+05	2.1E+05	2.1E+05	2.1E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05
Te-127m	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04
Te-129	1.4E+05	1.3E+05	1.2E+05	1.1E+05	1.1E+05	9.9E+04	9.4E+04	9.0E+04	8.6E+04	8.3E+04	8.0E+04
Te-129m	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	9.9E+04	9.9E+04	9.9E+04	9.9E+04	9.9E+04	9.9E+04
Te-131m	2.2E+05	2.2E+05	2.1E+05	2.1E+05	2.0E+05	2.0E+05	1.9E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05
Te-132	2.7E+06	2.7E+06	2.7E+06	2.6E+06	2.6E+06	2.6E+06	2.6E+06	2.6E+06	2.5E+06	2.5E+06	2.5E+06
I-131	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07	1.8E+07
I-132	3.3E+06	3.2E+06	3.0E+06	2.9E+06	2.9E+06	2.8E+06	2.7E+06	2.7E+06	2.7E+06	2.6E+06	2.6E+06
I-133	2.5E+07	2.4E+07	2.4E+07	2.3E+07	2.2E+07	2.1E+07	2.1E+07	2.0E+07	1.9E+07	1.9E+07	1.8E+07
I-134	7.0E+02	3.2E+02	1.4E+02	6.5E+01	3.0E+01	1.3E+01	6.1E+00	2.8E+00	1.3E+00	5.7E-01	2.6E-01
I-135	8.6E+06	7.8E+06	7.0E+06	6.3E+06	5.7E+06	5.1E+06	4.6E+06	4.1E+06	3.7E+06	3.4E+06	3.0E+06
Xe-133	2.8E+08	2.8E+08	2.8E+08	2.7E+08	2.7E+08	2.7E+08	2.7E+08	2.7E+08	2.7E+08	2.7E+08	2.6E+08
Xe-135	4.1E+07	3.8E+07	3.5E+07	3.3E+07	3.0E+07	2.8E+07	2.6E+07	2.4E+07	2.2E+07	2.1E+07	1.9E+07
Cs-134	3.1E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06
Cs-136	8.1E+05	8.0E+05	8.0E+05	8.0E+05	8.0E+05	8.0E+05	7.9E+05	7.9E+05	7.9E+05	7.9E+05	7.9E+05
Cs-137	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Ba-139	1.5E+03	8.8E+02	5.4E+02	3.2E+02	2.0E+02	1.2E+02	7.2E+01	4.3E+01	2.6E+01	1.6E+01	9.6E+00
Ba-140	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06
La-140	3.2E+05	3.4E+05	3.7E+05	3.9E+05	4.0E+05	4.2E+05	4.4E+05	4.6E+05	4.8E+05	5.0E+05	5.1E+05
La-141	1.3E+03	1.1E+03	9.1E+02	7.6E+02	6.4E+02	5.3E+02	4.5E+02	3.8E+02	3.1E+02	2.6E+02	2.2E+02
La-142	2.8E+01	1.8E+01	1.1E+01	7.2E+00	4.6E+00	2.9E+00	1.9E+00	1.2E+00	7.6E-01	4.8E-01	3.1E-01
Ce-141	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.7E+04
Ce-143	2.7E+04	2.7E+04	2.6E+04	2.6E+04	2.5E+04	2.5E+04	2.4E+04	2.4E+04	2.3E+04	2.3E+04	2.2E+04
Ce-144	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04
Pr-143	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04
Nd-147	5.8E+03	5.7E+03	5.7E+03	5.7E+03	5.7E+03	5.7E+03	5.7E+03	5.6E+03	5.6E+03	5.6E+03	5.6E+03
Np-239	3.4E+05	3.4E+05	3.3E+05	3.3E+05	3.3E+05	3.2E+05	3.2E+05	3.1E+05	3.1E+05	3.1E+05	3.0E+05
Pu-238	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02
Pu-239	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00
Pu-240	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01
Pu-241	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03
Am-241	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00
Cm-242	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02
Cm-244	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 8 of 11)

Nuclide	Time after LOCA (hr)										
	26	28	30	35	40	48	50	60	70	80	96
Co-60	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	8.6E+05	6.3E+05	4.7E+05	2.1E+05	9.9E+04	2.9E+04	2.1E+04	4.5E+03	9.6E+02	2.0E+02	1.7E+01
Kr-87	6.7E+01	2.3E+01	7.6E+00	5.0E-01	3.3E-02	4.2E-04	1.4E-04	6.0E-07	2.6E-09	0.0E+00	0.0E+00
Kr-88	2.4E+05	1.5E+05	8.9E+04	2.6E+04	7.8E+03	1.1E+03	6.8E+02	5.9E+01	5.1E+00	4.5E-01	9.0E-03
Rb-86	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.8E+04	2.8E+04	2.8E+04	2.7E+04	2.7E+04	2.6E+04
Sr-89	9.9E+05	9.9E+05	9.9E+05	9.8E+05	9.8E+05	9.8E+05	9.8E+05	9.7E+05	9.6E+05	9.6E+05	9.5E+05
Sr-90	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04
Sr-91	2.0E+05	1.7E+05	1.5E+05	1.0E+05	7.2E+04	4.0E+04	3.5E+04	1.7E+04	8.0E+03	3.9E+03	1.2E+03
Sr-92	1.8E+03	1.1E+03	6.5E+02	1.8E+02	5.0E+01	6.5E+00	3.9E+00	3.0E-01	2.3E-02	1.8E-03	3.0E-05
Y-90	2.0E+04	2.2E+04	2.3E+04	2.6E+04	2.9E+04	3.4E+04	3.5E+04	4.0E+04	4.4E+04	4.8E+04	5.4E+04
Y-91	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.5E+04
Y-92	2.0E+04	1.4E+04	9.9E+03	3.9E+03	1.5E+03	3.3E+02	2.3E+02	3.3E+01	4.7E+00	6.7E-01	2.9E-02
Y-93	2.6E+03	2.3E+03	2.0E+03	1.4E+03	9.9E+02	5.7E+02	5.0E+02	2.5E+02	1.3E+02	6.4E+01	2.1E+01
Zr-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.5E+04
Zr-97	5.5E+03	5.1E+03	4.7E+03	3.8E+03	3.1E+03	2.2E+03	2.1E+03	1.4E+03	9.0E+02	6.0E+02	3.1E+02
Nb-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Mo-99	1.5E+05	1.5E+05	1.5E+05	1.4E+05	1.3E+05	1.2E+05	1.2E+05	1.1E+05	9.8E+04	8.8E+04	7.4E+04
Tc-99m	1.5E+05	1.5E+05	1.4E+05	1.4E+05	1.3E+05	1.2E+05	1.2E+05	1.1E+05	9.5E+04	8.6E+04	7.2E+04
Ru-103	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.6E+05	1.5E+05	1.5E+05	1.5E+05	1.5E+05
Ru-105	1.8E+03	1.3E+03	9.8E+02	4.5E+02	2.1E+02	5.9E+01	4.3E+01	9.1E+00	1.9E+00	4.0E-01	3.3E-02
Ru-106	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04
Rh-105	6.8E+04	6.6E+04	6.3E+04	5.7E+04	5.2E+04	4.4E+04	4.3E+04	3.5E+04	2.9E+04	2.4E+04	1.7E+04
Sb-127	1.8E+05	1.8E+05	1.8E+05	1.7E+05	1.7E+05	1.6E+05	1.5E+05	1.4E+05	1.3E+05	1.2E+05	1.1E+05
Sb-129	1.1E+04	7.6E+03	5.5E+03	2.5E+03	1.1E+03	3.1E+02	2.2E+02	4.5E+01	9.0E+00	1.8E+00	1.4E-01
Te-127	2.0E+05	1.9E+05	1.9E+05	1.9E+05	1.8E+05	1.7E+05	1.7E+05	1.6E+05	1.5E+05	1.4E+05	1.3E+05
Te-127m	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04
Te-129	7.7E+04	7.4E+04	7.2E+04	6.8E+04	6.7E+04	6.5E+04	6.5E+04	6.4E+04	6.4E+04	6.3E+04	6.2E+04
Te-129m	9.9E+04	9.9E+04	9.9E+04	9.8E+04	9.8E+04	9.7E+04	9.7E+04	9.6E+04	9.5E+04	9.4E+04	9.3E+04
Te-131m	1.7E+05	1.6E+05	1.5E+05	1.4E+05	1.2E+05	1.0E+05	9.7E+04	7.7E+04	6.1E+04	4.9E+04	3.4E+04
Te-132	2.4E+06	2.4E+06	2.4E+06	2.3E+06	2.2E+06	2.0E+06	2.0E+06	1.8E+06	1.7E+06	1.5E+06	1.3E+06
I-131	1.8E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.6E+07	1.6E+07	1.6E+07	1.5E+07	1.4E+07	1.4E+07
I-132	2.5E+06	2.5E+06	2.5E+06	2.4E+06	2.3E+06	2.1E+06	2.1E+06	1.9E+06	1.7E+06	1.6E+06	1.4E+06
I-133	1.7E+07	1.6E+07	1.5E+07	1.3E+07	1.1E+07	8.1E+06	7.6E+06	5.4E+06	3.9E+06	2.8E+06	1.6E+06
I-134	5.3E-02	1.1E-02	2.2E-03	4.3E-05	8.2E-07	1.4E-09	2.7E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	2.5E+06	2.0E+06	1.6E+06	9.6E+05	5.7E+05	2.4E+05	2.0E+05	6.9E+04	2.4E+04	8.5E+03	1.6E+03
Xe-133	2.6E+08	2.6E+08	2.6E+08	2.5E+08	2.4E+08	2.3E+08	2.3E+08	2.2E+08	2.1E+08	1.9E+08	1.8E+08
Xe-135	1.7E+07	1.4E+07	1.2E+07	8.5E+06	5.8E+06	3.2E+06	2.7E+06	1.3E+06	6.0E+05	2.8E+05	8.3E+04
Cs-134	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06
Cs-136	7.8E+05	7.8E+05	7.8E+05	7.7E+05	7.6E+05	7.5E+05	7.4E+05	7.3E+05	7.1E+05	7.0E+05	6.7E+05
Cs-137	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Ba-139	3.5E+00	1.3E+00	4.7E-01	3.8E-02	3.1E-03	5.5E-05	2.0E-05	1.3E-07	8.6E-10	0.0E+00	0.0E+00
Ba-140	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.4E+06	1.4E+06	1.4E+06	1.4E+06	1.3E+06	1.3E+06
La-140	5.5E+05	5.8E+05	6.1E+05	6.8E+05	7.5E+05	8.4E+05	8.6E+05	9.4E+05	1.0E+06	1.1E+06	1.1E+06
La-141	1.6E+02	1.1E+02	7.7E+01	3.2E+01	1.3E+01	3.2E+00	2.3E+00	3.9E-01	6.6E-02	1.1E-02	6.7E-04
La-142	1.3E-01	5.1E-02	2.1E-02	2.2E-03	2.3E-04	6.4E-06	2.6E-06	2.9E-08	3.2E-10	0.0E+00	0.0E+00
Ce-141	3.7E+04	3.7E+04	3.7E+04	3.7E+04	3.6E+04	3.6E+04	3.6E+04	3.6E+04	3.6E+04	3.5E+04	3.5E+04
Ce-143	2.1E+04	2.0E+04	2.0E+04	1.8E+04	1.6E+04	1.3E+04	1.3E+04	1.0E+04	8.5E+03	6.9E+03	4.9E+03
Ce-144	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04
Pr-143	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.4E+04
Nd-147	5.6E+03	5.5E+03	5.5E+03	5.4E+03	5.4E+03	5.3E+03	5.2E+03	5.1E+03	5.0E+03	4.8E+03	4.6E+03
Np-239	3.0E+05	2.9E+05	2.8E+05	2.6E+05	2.5E+05	2.3E+05	2.2E+05	1.9E+05	1.7E+05	1.5E+05	1.3E+05
Pu-238	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02
Pu-239	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00	8.5E+00
Pu-240	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01
Pu-241	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03
Am-241	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00	1.6E+00
Cm-242	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02
Cm-244	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 9 of 11)

Nuclide	Time after LOCA (hr)										
	100	120	150	160	170	180	200	240	264	288	300
Co-60	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.3E+02	3.2E+02	3.2E+02	3.2E+02	3.2E+02
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	9.2E+00	4.2E-01	4.0E-03	8.6E-04	1.8E-04	3.9E-05	1.8E-06	3.6E-09	8.8E-11	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	3.4E-03	2.6E-05	1.7E-08	1.5E-09	1.3E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	2.6E+04	2.5E+04	2.4E+04	2.4E+04	2.4E+04	2.3E+04	2.2E+04	2.1E+04	2.0E+04	2.0E+04	1.9E+04
Sr-89	9.5E+05	9.4E+05	9.2E+05	9.2E+05	9.1E+05	9.1E+05	9.0E+05	8.8E+05	8.6E+05	8.5E+05	8.5E+05
Sr-90	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04
Sr-91	9.0E+02	2.1E+02	2.3E+01	1.1E+01	5.4E+00	2.6E+00	6.1E-01	3.3E-02	5.7E-03	9.9E-04	4.1E-04
Sr-92	1.1E-05	6.5E-08	3.0E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	5.5E+04	6.0E+04	6.7E+04	6.8E+04	7.0E+04	7.1E+04	7.4E+04	7.7E+04	7.8E+04	8.0E+04	8.0E+04
Y-91	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04
Y-92	1.3E-02	2.7E-04	7.5E-07	1.1E-07	1.5E-08	2.1E-09	4.2E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	1.6E+01	4.1E+00	5.2E-01	2.6E-01	1.3E-01	6.6E-02	1.7E-02	1.1E-03	2.1E-04	4.0E-05	1.8E-05
Zr-95	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	1.4E+04	1.4E+04	1.4E+04	1.4E+04
Zr-97	2.6E+02	1.2E+02	3.4E+01	2.3E+01	1.5E+01	9.9E+00	4.4E+00	8.5E-01	3.2E-01	1.2E-01	7.2E-02
Nb-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.6E+04
Mo-99	7.1E+04	5.8E+04	4.2E+04	3.8E+04	3.4E+04	3.1E+04	2.5E+04	1.6E+04	1.3E+04	9.9E+03	8.7E+03
Tc-99m	6.9E+04	5.6E+04	4.1E+04	3.7E+04	3.3E+04	3.0E+04	2.4E+04	1.6E+04	1.2E+04	9.6E+03	8.5E+03
Ru-103	1.5E+05	1.5E+05	1.4E+05	1.4E+05	1.4E+05	1.4E+05	1.4E+05	1.4E+05	1.3E+05	1.3E+05	1.3E+05
Ru-105	1.8E-02	7.8E-04	7.2E-06	1.5E-06	3.2E-07	6.6E-08	2.9E-09	5.7E-12	0.0E+00	0.0E+00	0.0E+00
Ru-106	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.6E+04	5.5E+04	5.5E+04	5.5E+04	5.5E+04
Rh-105	1.6E+04	1.1E+04	6.0E+03	4.9E+03	4.1E+03	3.3E+03	2.3E+03	1.0E+03	6.4E+02	4.0E+02	3.2E+02
Sb-127	1.1E+05	9.1E+04	7.3E+04	6.8E+04	6.3E+04	5.8E+04	5.0E+04	3.7E+04	3.1E+04	2.6E+04	2.4E+04
Sb-129	7.3E-02	3.0E-03	2.4E-05	4.8E-06	9.7E-07	2.0E-07	7.9E-09	1.3E-11	0.0E+00	0.0E+00	0.0E+00
Te-127	1.3E+05	1.1E+05	9.5E+04	9.1E+04	8.6E+04	8.2E+04	7.4E+04	6.2E+04	5.6E+04	5.2E+04	5.0E+04
Te-127m	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.9E+04	2.8E+04	2.8E+04	2.8E+04
Te-129	6.2E+04	6.1E+04	6.0E+04	5.9E+04	5.9E+04	5.8E+04	5.7E+04	5.5E+04	5.4E+04	5.3E+04	5.2E+04
Te-129m	9.3E+04	9.1E+04	8.9E+04	8.8E+04	8.7E+04	8.7E+04	8.5E+04	8.2E+04	8.1E+04	7.9E+04	7.8E+04
Te-131m	3.1E+04	1.9E+04	9.7E+03	7.7E+03	6.1E+03	4.8E+03	3.0E+03	1.2E+03	6.9E+02	4.0E+02	3.0E+02
Te-132	1.3E+06	1.1E+06	8.1E+05	7.4E+05	6.8E+05	6.2E+05	5.2E+05	3.7E+05	3.0E+05	2.4E+05	2.2E+05
I-131	1.3E+07	1.3E+07	1.1E+07	1.1E+07	1.0E+07	1.0E+07	9.4E+06	8.2E+06	7.5E+06	6.9E+06	6.6E+06
I-132	1.3E+06	1.1E+06	8.5E+05	7.8E+05	7.1E+05	6.5E+05	5.5E+05	3.8E+05	3.1E+05	2.5E+05	2.2E+05
I-133	1.4E+06	7.4E+05	2.7E+05	1.9E+05	1.4E+05	1.0E+05	5.1E+04	1.4E+04	6.1E+03	2.7E+03	1.8E+03
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	1.0E+03	1.3E+02	5.5E+00	1.9E+00	6.8E-01	2.4E-01	2.9E-02	4.4E-04	3.6E-05	2.9E-06	8.2E-07
Xe-133	1.7E+08	1.6E+08	1.3E+08	1.3E+08	1.2E+08	1.1E+08	1.0E+08	8.1E+07	7.1E+07	6.2E+07	5.8E+07
Xe-135	6.1E+04	1.3E+04	1.4E+03	6.4E+02	3.0E+02	1.4E+02	3.0E+01	1.4E+00	2.3E-01	3.7E-02	1.5E-02
Cs-134	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06
Cs-136	6.7E+05	6.4E+05	6.0E+05	5.8E+05	5.7E+05	5.6E+05	5.3E+05	4.9E+05	4.6E+05	4.4E+05	4.3E+05
Cs-137	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	1.3E+06	1.2E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.0E+06	9.3E+05	8.8E+05	8.3E+05	8.1E+05
La-140	1.1E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.1E+06	1.1E+06	1.0E+06	9.9E+05	9.4E+05	9.2E+05
La-141	3.3E-04	9.8E-06	4.9E-08	8.5E-09	1.4E-09	2.5E-10	7.3E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	3.5E+04	3.4E+04	3.3E+04	3.3E+04	3.3E+04	3.2E+04	3.2E+04	3.1E+04	3.0E+04	2.9E+04	2.9E+04
Ce-143	4.5E+03	3.0E+03	1.6E+03	1.3E+03	1.0E+03	8.4E+02	5.5E+02	2.4E+02	1.4E+02	8.7E+01	6.7E+01
Ce-144	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.8E+04
Pr-143	1.4E+04	1.4E+04	1.3E+04	1.3E+04	1.3E+04	1.2E+04	1.2E+04	1.1E+04	1.0E+04	9.9E+03	9.7E+03
Nd-147	4.6E+03	4.3E+03	4.0E+03	3.9E+03	3.8E+03	3.7E+03	3.5E+03	3.2E+03	3.0E+03	2.8E+03	2.7E+03
Np-239	1.2E+05	9.3E+04	6.4E+04	5.7E+04	5.0E+04	4.5E+04	3.5E+04	2.1E+04	1.6E+04	1.2E+04	1.0E+04
Pu-238	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02
Pu-239	8.5E+00	8.5E+00	8.5E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00
Pu-240	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01
Pu-241	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03
Am-241	1.6E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00	1.7E+00
Cm-242	3.9E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.7E+02	3.7E+02	3.7E+02
Cm-244	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 10 of 11)

Nuclide	Time after LOCA (hr)										
	312	336	360	400	480	500	600	700	720	960	1200
Co-60	3.2E+02	3.2E+02	3.2E+02	3.2E+02	3.2E+02	3.2E+02	3.2E+02	3.2E+02	0.0E+00	0.0E+00	0.0E+00
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.9E+04	1.8E+04	1.8E+04	1.6E+04	1.5E+04	1.4E+04	1.2E+04	1.0E+04	0.0E+00	0.0E+00	0.0E+00
Sr-89	8.4E+05	8.3E+05	8.2E+05	8.0E+05	7.6E+05	7.5E+05	7.1E+05	6.7E+05	0.0E+00	0.0E+00	0.0E+00
Sr-90	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	0.0E+00	0.0E+00	0.0E+00
Sr-91	1.7E-04	3.0E-05	5.2E-06	2.8E-07	8.2E-10	1.9E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	8.0E+04	8.1E+04	8.1E+04	8.2E+04	8.3E+04	8.3E+04	8.3E+04	8.3E+04	0.0E+00	0.0E+00	0.0E+00
Y-91	1.4E+04	1.4E+04	1.3E+04	1.3E+04	1.3E+04	1.3E+04	1.2E+04	1.1E+04	0.0E+00	0.0E+00	0.0E+00
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	7.7E-06	1.5E-06	2.9E-07	1.8E-08	7.6E-11	1.9E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	1.4E+04	1.4E+04	1.4E+04	1.3E+04	1.3E+04	1.3E+04	1.2E+04	1.2E+04	0.0E+00	0.0E+00	0.0E+00
Zr-97	4.4E-02	1.7E-02	6.2E-03	1.2E-03	4.5E-05	2.0E-05	3.3E-07	5.4E-09	0.0E+00	0.0E+00	0.0E+00
Nb-95	1.6E+04	1.6E+04	1.6E+04	1.6E+04	1.5E+04	1.5E+04	1.5E+04	1.5E+04	0.0E+00	0.0E+00	0.0E+00
Mo-99	7.7E+03	6.0E+03	4.6E+03	3.1E+03	1.3E+03	1.1E+03	3.7E+02	1.3E+02	0.0E+00	0.0E+00	0.0E+00
Tc-99m	7.5E+03	5.8E+03	4.5E+03	3.0E+03	1.3E+03	1.0E+03	3.6E+02	1.3E+02	0.0E+00	0.0E+00	0.0E+00
Ru-103	1.3E+05	1.3E+05	1.2E+05	1.2E+05	1.1E+05	1.1E+05	1.0E+05	9.7E+04	0.0E+00	0.0E+00	0.0E+00
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	5.5E+04	5.5E+04	5.5E+04	5.5E+04	5.4E+04	5.4E+04	5.4E+04	5.3E+04	0.0E+00	0.0E+00	0.0E+00
Rh-105	2.5E+02	1.6E+02	9.8E+01	4.5E+01	9.3E+00	6.3E+00	8.9E-01	1.2E-01	0.0E+00	0.0E+00	0.0E+00
Sb-127	2.2E+04	1.8E+04	1.5E+04	1.1E+04	6.1E+03	5.3E+03	2.5E+03	1.2E+03	0.0E+00	0.0E+00	0.0E+00
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	4.8E+04	4.4E+04	4.1E+04	3.7E+04	3.2E+04	3.1E+04	2.8E+04	2.6E+04	0.0E+00	0.0E+00	0.0E+00
Te-127m	2.8E+04	2.8E+04	2.8E+04	2.8E+04	2.7E+04	2.7E+04	2.6E+04	2.6E+04	0.0E+00	0.0E+00	0.0E+00
Te-129	5.2E+04	5.1E+04	5.0E+04	4.8E+04	4.5E+04	4.4E+04	4.0E+04	3.7E+04	0.0E+00	0.0E+00	0.0E+00
Te-129m	7.7E+04	7.6E+04	7.4E+04	7.2E+04	6.7E+04	6.6E+04	6.0E+04	5.5E+04	0.0E+00	0.0E+00	0.0E+00
Te-131m	2.3E+02	1.3E+02	7.5E+01	3.0E+01	4.7E+00	3.0E+00	2.9E-01	2.9E-02	0.0E+00	0.0E+00	0.0E+00
Te-132	1.9E+05	1.6E+05	1.3E+05	8.9E+04	4.4E+04	3.7E+04	1.5E+04	6.2E+03	0.0E+00	0.0E+00	0.0E+00
I-131	6.3E+06	5.8E+06	5.3E+06	4.6E+06	3.4E+06	3.2E+06	2.2E+06	1.6E+06	2.2E+05	9.1E+04	3.9E+04
I-132	2.0E+05	1.6E+05	1.3E+05	9.3E+04	4.6E+04	3.8E+04	1.6E+04	6.5E+03	0.0E+00	0.0E+00	0.0E+00
I-133	1.2E+03	5.5E+02	2.5E+02	6.5E+01	4.5E+00	2.3E+00	8.3E-02	3.0E-03	2.3E-04	7.7E-08	2.6E-11
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	2.3E-07	1.9E-08	1.5E-09	2.0E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-133	5.4E+07	4.7E+07	4.2E+07	3.3E+07	2.1E+07	1.9E+07	1.1E+07	6.4E+06	5.7E+06	1.5E+06	4.1E+05
Xe-135	5.9E-03	9.5E-04	1.5E-04	7.2E-06	1.6E-08	3.5E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	3.0E+06	0.0E+00	0.0E+00	0.0E+00
Cs-136	4.2E+05	4.0E+05	3.8E+05	3.4E+05	2.9E+05	2.8E+05	2.2E+05	1.8E+05	0.0E+00	0.0E+00	0.0E+00
Cs-137	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	0.0E+00	0.0E+00	0.0E+00
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	7.9E+05	7.4E+05	7.1E+05	6.4E+05	5.4E+05	5.1E+05	4.1E+05	3.3E+05	0.0E+00	0.0E+00	0.0E+00
La-140	9.0E+05	8.5E+05	8.1E+05	7.4E+05	6.2E+05	5.9E+05	4.7E+05	3.8E+05	0.0E+00	0.0E+00	0.0E+00
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	2.9E+04	2.8E+04	2.7E+04	2.7E+04	2.5E+04	2.4E+04	2.2E+04	2.0E+04	0.0E+00	0.0E+00	0.0E+00
Ce-143	5.2E+01	3.2E+01	1.9E+01	8.3E+00	1.5E+00	1.0E+00	1.2E-01	1.5E-02	0.0E+00	0.0E+00	0.0E+00
Ce-144	2.8E+04	2.8E+04	2.7E+04	2.7E+04	2.7E+04	2.7E+04	2.7E+04	2.7E+04	0.0E+00	0.0E+00	0.0E+00
Pr-143	9.4E+03	8.9E+03	8.5E+03	7.8E+03	6.6E+03	6.3E+03	5.1E+03	4.1E+03	0.0E+00	0.0E+00	0.0E+00
Nd-147	2.6E+03	2.5E+03	2.3E+03	2.1E+03	1.7E+03	1.6E+03	1.2E+03	9.5E+02	0.0E+00	0.0E+00	0.0E+00
Np-239	8.8E+03	6.6E+03	4.9E+03	3.0E+03	1.1E+03	8.8E+02	2.6E+02	7.6E+01	0.0E+00	0.0E+00	0.0E+00
Pu-238	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	1.1E+02	0.0E+00	0.0E+00	0.0E+00
Pu-239	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	8.6E+00	0.0E+00	0.0E+00	0.0E+00
Pu-240	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	1.3E+01	0.0E+00	0.0E+00	0.0E+00
Pu-241	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	0.0E+00	0.0E+00	0.0E+00
Am-241	1.8E+00	1.8E+00	1.8E+00	1.8E+00	1.8E+00	1.9E+00	1.9E+00	2.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.6E+02	3.6E+02	3.5E+02	3.5E+02	0.0E+00	0.0E+00	0.0E+00
Cm-244	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	4.8E+01	0.0E+00	0.0E+00	0.0E+00

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-2 Radioactivity at Typical Times after LOCA (for airborne) (Sheet 11 of 11)

Nuclide	Time after LOCA (hr)										
	1440	2160	2880	3600	4320	5040	5760	6480	7200	7920	8760
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.6E+06	1.6E+06	1.6E+06
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-89	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Mo-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Tc-99m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-131m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	1.6E+04	1.2E+03	9.2E+01	7.0E+00	5.2E-01	3.9E-02	3.0E-03	2.2E-04	1.7E-05	1.3E-06	6.2E-08
I-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-133	1.1E+05	2.1E+03	3.9E+01	7.4E-01	1.4E-02	2.7E-04	5.1E-06	9.6E-08	1.8E-09	3.5E-11	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-136	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pr-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nd-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Np-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Note

1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 1 of 11)

Nuclide	Time after LOCA (hr)										
	0.01	0.02	0.03	0.04	0.05	0.06	0.0667	0.08	0.0834	0.1	0.15
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	0.0E+00	0.0E+00	7.4E+02	1.1E+03	1.4E+03	1.8E+03	2.0E+03	2.4E+03	2.6E+03	3.1E+03	4.8E+03
Sr-89	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Mo-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Tc-99m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rh-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-129m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-131m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	2.4E+04	1.7E+05	3.1E+05	4.6E+05	6.0E+05	7.4E+05	8.4E+05	1.0E+06	1.1E+06	1.3E+06	2.0E+06
I-132	0.0E+00	2.4E+05	4.5E+05	6.5E+05	8.6E+05	1.1E+06	1.2E+06	1.5E+06	1.5E+06	1.9E+06	2.9E+06
I-133	0.0E+00	3.5E+05	6.5E+05	9.5E+05	1.2E+06	1.5E+06	1.7E+06	2.1E+06	2.2E+06	2.7E+06	4.2E+06
I-134	0.0E+00	3.8E+05	7.1E+05	1.0E+06	1.3E+06	1.6E+06	1.9E+06	2.3E+06	2.4E+06	2.8E+06	4.2E+06
I-135	0.0E+00	3.3E+05	6.0E+05	8.8E+05	1.2E+06	1.4E+06	1.6E+06	2.0E+06	2.1E+06	2.5E+06	3.9E+06
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	5.7E+03	4.0E+04	7.3E+04	1.1E+05	1.4E+05	1.8E+05	2.0E+05	2.4E+05	2.5E+05	3.1E+05	4.8E+05
Cs-136	0.0E+00	1.1E+04	2.0E+04	2.9E+04	3.8E+04	4.8E+04	5.4E+04	6.6E+04	6.9E+04	8.5E+04	1.3E+05
Cs-137	3.2E+03	2.2E+04	4.2E+04	6.1E+04	8.0E+04	1.0E+05	1.1E+05	1.4E+05	1.4E+05	1.8E+05	2.7E+05
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pr-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nd-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Np-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 2 of 11)

Nuclide	Time after LOCA (hr)										
	0.2	0.3	0.4	0.5	0.5083	0.6	0.7	0.8	0.9	1	1.1
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E+01	1.6E+02	2.4E+02	3.3E+02	4.1E+02	4.9E+02
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	6.5E+03	9.9E+03	1.3E+04	1.7E+04	1.7E+04	2.3E+04	3.0E+04	3.6E+04	4.3E+04	4.9E+04	5.6E+04
Sr-89	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+05	4.9E+05	7.5E+05	1.0E+06	1.3E+06	1.5E+06
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+04	4.1E+04	6.2E+04	8.4E+04	1.0E+05	1.3E+05
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+05	6.2E+05	9.4E+05	1.2E+06	1.6E+06	1.9E+06
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E+05	5.7E+05	8.5E+05	1.1E+06	1.4E+06	1.6E+06
Y-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E+02	7.5E+02	1.1E+03	1.4E+03	1.7E+03
Y-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+03	6.2E+03	9.4E+03	1.3E+04	1.6E+04	1.9E+04
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E+04	3.4E+04	5.6E+04	8.3E+04	1.1E+05
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.5E+03	7.2E+03	1.1E+04	1.5E+04	1.8E+04	2.2E+04
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+03	7.9E+03	1.2E+04	1.6E+04	2.0E+04	2.4E+04
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+03	7.6E+03	1.2E+04	1.5E+04	1.9E+04	2.3E+04
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+03	7.9E+03	1.2E+04	1.6E+04	2.0E+04	2.4E+04
Mo-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E+04	9.9E+04	1.5E+05	2.0E+05	2.5E+05	3.1E+05
Tc-99m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E+04	8.8E+04	1.3E+05	1.8E+05	2.2E+05	2.7E+05
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+04	7.9E+04	1.2E+05	1.6E+05	2.0E+05	2.4E+05
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+04	4.7E+04	7.0E+04	9.3E+04	1.1E+05	1.4E+05
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E+04	2.8E+04	4.2E+04	5.7E+04	7.1E+04	8.6E+04
Rh-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+04	4.8E+04	7.4E+04	9.9E+04	1.2E+05	1.5E+05
Sb-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E+04	1.1E+05	1.7E+05	2.2E+05	2.8E+05	3.4E+05
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E+05	3.0E+05	4.5E+05	5.9E+05	7.3E+05	8.7E+05
Te-127	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.2E+04	1.1E+05	1.7E+05	2.2E+05	2.8E+05	3.4E+05
Te-127m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.9E+03	1.4E+04	2.2E+04	2.9E+04	3.7E+04	4.4E+04
Te-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E+05	3.1E+05	4.7E+05	6.2E+05	7.7E+05	9.2E+05
Te-129m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+04	4.9E+04	7.5E+04	1.0E+05	1.3E+05	1.5E+05
Te-131m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.2E+04	1.5E+05	2.3E+05	3.0E+05	3.8E+05	4.6E+05
Te-132	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.2E+05	1.5E+06	2.3E+06	3.1E+06	3.8E+06	4.6E+06
I-131	2.8E+06	4.2E+06	5.6E+06	7.1E+06	7.2E+06	1.1E+07	1.5E+07	1.8E+07	2.2E+07	2.6E+07	3.0E+07
I-132	3.9E+06	5.8E+06	7.7E+06	9.5E+06	9.6E+06	1.4E+07	2.0E+07	2.4E+07	2.9E+07	3.4E+07	3.9E+07
I-133	5.7E+06	8.7E+06	1.2E+07	1.5E+07	1.5E+07	2.2E+07	3.0E+07	3.8E+07	4.5E+07	5.3E+07	6.1E+07
I-134	5.5E+06	7.7E+06	9.6E+06	1.1E+07	1.1E+07	1.6E+07	2.0E+07	2.3E+07	2.6E+07	2.8E+07	2.9E+07
I-135	5.3E+06	7.9E+06	1.1E+07	1.3E+07	1.3E+07	2.0E+07	2.6E+07	3.3E+07	4.0E+07	4.6E+07	5.2E+07
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	6.5E+05	9.9E+05	1.3E+06	1.7E+06	1.7E+06	2.3E+06	2.9E+06	3.6E+06	4.2E+06	4.9E+06	5.5E+06
Cs-136	1.8E+05	2.7E+05	3.6E+05	4.5E+05	4.6E+05	6.2E+05	8.0E+05	9.8E+05	1.2E+06	1.3E+06	1.5E+06
Cs-137	3.7E+05	5.6E+05	7.6E+05	9.5E+05	9.6E+05	1.3E+06	1.7E+06	2.0E+06	2.4E+06	2.8E+06	3.2E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E+05	5.8E+05	8.4E+05	1.1E+06	1.3E+06	1.5E+06
Ba-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+05	7.8E+05	1.2E+06	1.6E+06	2.0E+06	2.4E+06
La-140	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.1E+03	9.3E+03	1.5E+04	2.2E+04	2.9E+04	3.7E+04
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.6E+03	9.9E+03	1.3E+04	1.6E+04	1.9E+04
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E+03	1.0E+04	1.2E+04	1.4E+04
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.9E+03	1.9E+04	2.8E+04	3.8E+04	4.8E+04	5.7E+04
Ce-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.5E+03	1.8E+04	2.7E+04	3.6E+04	4.5E+04	5.5E+04
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.7E+03	1.4E+04	2.1E+04	2.9E+04	3.6E+04	4.3E+04
Pr-143	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+03	7.0E+03	1.1E+04	1.4E+04	1.8E+04	2.2E+04
Nd-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E+03	2.9E+03	4.5E+03	6.0E+03	7.5E+03	9.0E+03
Np-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.5E+04	2.0E+05	3.0E+05	4.0E+05	5.1E+05	6.1E+05
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E+01	5.5E+01	8.4E+01	1.1E+02	1.4E+02	1.7E+02
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+00	4.2E+00	6.3E+00	8.5E+00	1.1E+01	1.3E+01
Pu-240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E+00	6.5E+00	9.9E+00	1.3E+01	1.7E+01	2.0E+01
Pu-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.9E+02	1.4E+03	2.2E+03	2.9E+03	3.7E+03	4.5E+03
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E-01	7.8E-01	1.2E+00	1.6E+00	2.0E+00	2.4E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.2E+01	1.9E+02	2.9E+02	3.9E+02	5.0E+02	6.0E+02
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+01	2.3E+01	3.6E+01	4.8E+01	6.0E+01	7.2E+01

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 3 of 11)

Nuclide	Time after LOCA (hr)										
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8083	1.9	2	2.1
Co-60	5.8E+02	6.6E+02	7.5E+02	8.3E+02	9.1E+02	1.0E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	6.2E+04	6.9E+04	7.5E+04	8.2E+04	8.8E+04	9.5E+04	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Sr-89	1.8E+06	2.0E+06	2.3E+06	2.6E+06	2.8E+06	3.1E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06
Sr-90	1.5E+05	1.7E+05	1.9E+05	2.1E+05	2.3E+05	2.5E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	2.2E+06	2.4E+06	2.7E+06	3.0E+06	3.3E+06	3.6E+06	3.9E+06	3.9E+06	3.8E+06	3.8E+06	3.8E+06
Sr-92	1.8E+06	2.0E+06	2.2E+06	2.4E+06	2.6E+06	2.7E+06	2.9E+06	2.9E+06	2.9E+06	2.8E+06	2.7E+06
Y-90	2.1E+03	2.5E+03	2.9E+03	3.4E+03	3.8E+03	4.3E+03	4.8E+03	4.9E+03	5.1E+03	5.4E+03	5.7E+03
Y-91	2.2E+04	2.6E+04	2.9E+04	3.2E+04	3.5E+04	3.9E+04	4.2E+04	4.2E+04	4.2E+04	4.2E+04	4.3E+04
Y-92	1.5E+05	1.9E+05	2.3E+05	2.7E+05	3.2E+05	3.7E+05	4.2E+05	4.2E+05	4.7E+05	5.1E+05	5.5E+05
Y-93	2.5E+04	2.9E+04	3.2E+04	3.5E+04	3.9E+04	4.2E+04	4.5E+04	4.5E+04	4.5E+04	4.5E+04	4.4E+04
Zr-95	2.8E+04	3.2E+04	3.7E+04	4.1E+04	4.5E+04	4.9E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Zr-97	2.7E+04	3.1E+04	3.4E+04	3.8E+04	4.2E+04	4.5E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04
Nb-95	2.8E+04	3.3E+04	3.7E+04	4.1E+04	4.5E+04	4.9E+04	5.3E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04
Mo-99	3.6E+05	4.1E+05	4.6E+05	5.1E+05	5.6E+05	6.1E+05	6.6E+05	6.7E+05	6.7E+05	6.6E+05	6.6E+05
Tc-99m	3.2E+05	3.6E+05	4.1E+05	4.5E+05	5.0E+05	5.4E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05
Ru-103	2.9E+05	3.3E+05	3.7E+05	4.1E+05	4.5E+05	4.9E+05	5.3E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05
Ru-105	1.6E+05	1.8E+05	1.9E+05	2.1E+05	2.3E+05	2.5E+05	2.7E+05	2.7E+05	2.6E+05	2.6E+05	2.5E+05
Ru-106	1.0E+05	1.1E+05	1.3E+05	1.4E+05	1.6E+05	1.7E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	1.7E+05	2.0E+05	2.3E+05	2.5E+05	2.8E+05	3.0E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Sb-127	3.9E+05	4.5E+05	5.1E+05	5.6E+05	6.2E+05	6.8E+05	7.3E+05	7.4E+05	7.4E+05	7.4E+05	7.4E+05
Sb-129	1.0E+06	1.1E+06	1.2E+06	1.4E+06	1.5E+06	1.6E+06	1.7E+06	1.7E+06	1.7E+06	1.6E+06	1.6E+06
Te-127	3.9E+05	4.5E+05	5.1E+05	5.6E+05	6.2E+05	6.8E+05	7.3E+05	7.4E+05	7.4E+05	7.4E+05	7.4E+05
Te-127m	5.2E+04	5.9E+04	6.7E+04	7.4E+04	8.2E+04	8.9E+04	9.7E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	1.1E+06	1.2E+06	1.3E+06	1.5E+06	1.6E+06	1.7E+06	1.9E+06	1.9E+06	1.9E+06	1.8E+06	1.8E+06
Te-129m	1.8E+05	2.0E+05	2.3E+05	2.6E+05	2.8E+05	3.1E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Te-131m	5.3E+05	6.1E+05	6.8E+05	7.6E+05	8.3E+05	9.1E+05	9.8E+05	9.9E+05	9.9E+05	9.8E+05	9.8E+05
Te-132	5.4E+06	6.2E+06	6.9E+06	7.7E+06	8.5E+06	9.2E+06	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
I-131	3.4E+07	3.8E+07	4.2E+07	4.5E+07	4.9E+07	5.3E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07
I-132	4.3E+07	4.7E+07	5.2E+07	5.6E+07	6.0E+07	6.4E+07	6.8E+07	6.8E+07	6.6E+07	6.5E+07	6.3E+07
I-133	6.8E+07	7.6E+07	8.3E+07	9.1E+07	9.8E+07	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08
I-134	3.1E+07	3.2E+07	3.2E+07	3.2E+07	3.2E+07	3.2E+07	3.2E+07	3.2E+07	3.0E+07	2.8E+07	2.5E+07
I-135	5.8E+07	6.4E+07	7.0E+07	7.6E+07	8.1E+07	8.7E+07	9.2E+07	9.3E+07	9.2E+07	9.1E+07	9.0E+07
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	6.2E+06	6.9E+06	7.5E+06	8.2E+06	8.8E+06	9.5E+06	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	1.7E+06	1.9E+06	2.0E+06	2.2E+06	2.4E+06	2.6E+06	2.7E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06
Cs-137	3.5E+06	3.9E+06	4.3E+06	4.6E+06	5.0E+06	5.4E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	1.6E+06	1.8E+06	1.9E+06	2.0E+06	2.1E+06	2.2E+06	2.2E+06	2.2E+06	2.1E+06	2.0E+06	1.9E+06
Ba-140	2.8E+06	3.2E+06	3.6E+06	4.0E+06	4.5E+06	4.9E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06
La-140	4.5E+04	5.5E+04	6.5E+04	7.5E+04	8.7E+04	9.9E+04	1.1E+05	1.1E+05	1.2E+05	1.3E+05	1.4E+05
La-141	2.2E+04	2.5E+04	2.7E+04	3.0E+04	3.2E+04	3.4E+04	3.7E+04	3.7E+04	3.6E+04	3.6E+04	3.5E+04
La-142	1.5E+04	1.7E+04	1.8E+04	1.9E+04	2.0E+04	2.1E+04	2.2E+04	2.2E+04	2.1E+04	2.0E+04	1.9E+04
Ce-141	6.7E+04	7.7E+04	8.6E+04	9.6E+04	1.1E+05	1.2E+05	1.2E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05
Ce-143	6.4E+04	7.3E+04	8.2E+04	9.1E+04	1.0E+05	1.1E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05
Ce-144	5.1E+04	5.8E+04	6.5E+04	7.2E+04	8.0E+04	8.7E+04	9.4E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04
Pr-143	2.5E+04	2.9E+04	3.3E+04	3.6E+04	4.0E+04	4.4E+04	4.7E+04	4.7E+04	4.7E+04	4.7E+04	4.8E+04
Nd-147	1.1E+04	1.2E+04	1.4E+04	1.5E+04	1.7E+04	1.8E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04
Np-239	7.1E+05	8.1E+05	9.1E+05	1.0E+06	1.1E+06	1.2E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06
Pu-238	2.0E+02	2.3E+02	2.6E+02	2.8E+02	3.1E+02	3.4E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	1.5E+01	1.7E+01	1.9E+01	2.2E+01	2.4E+01	2.6E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	2.4E+01	2.7E+01	3.0E+01	3.4E+01	3.7E+01	4.1E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	5.2E+03	6.0E+03	6.7E+03	7.5E+03	8.2E+03	9.0E+03	9.7E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	2.8E+00	3.2E+00	3.6E+00	4.0E+00	4.4E+00	4.9E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00
Cm-242	7.0E+02	8.0E+02	9.0E+02	1.0E+03	1.1E+03	1.2E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	8.5E+01	9.7E+01	1.1E+02	1.2E+02	1.3E+02	1.5E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 4 of 11)

Nuclide	Time after LOCA (hr)										
	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.2	3.23
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Sr-89	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	3.8E+06	3.7E+06	3.7E+06	3.7E+06	3.7E+06	3.6E+06	3.6E+06	3.6E+06	3.6E+06	3.5E+06	3.5E+06
Sr-92	2.6E+06	2.6E+06	2.5E+06	2.4E+06	2.4E+06	2.3E+06	2.3E+06	2.2E+06	2.2E+06	2.0E+06	2.0E+06
Y-90	6.0E+03	6.3E+03	6.6E+03	6.9E+03	7.2E+03	7.5E+03	7.8E+03	8.1E+03	8.3E+03	8.9E+03	9.0E+03
Y-91	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04	4.3E+04
Y-92	6.0E+05	6.3E+05	6.7E+05	7.1E+05	7.4E+05	7.7E+05	8.0E+05	8.3E+05	8.5E+05	9.0E+05	9.1E+05
Y-93	4.4E+04	4.4E+04	4.4E+04	4.3E+04	4.3E+04	4.3E+04	4.2E+04	4.2E+04	4.2E+04	4.1E+04	4.1E+04
Zr-95	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Zr-97	4.9E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.7E+04	4.7E+04	4.7E+04	4.7E+04	4.7E+04
Nb-95	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04
Mo-99	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05	6.6E+05
Tc-99m	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05
Ru-103	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05
Ru-105	2.5E+05	2.5E+05	2.4E+05	2.4E+05	2.4E+05	2.3E+05	2.3E+05	2.2E+05	2.2E+05	2.1E+05	2.1E+05
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Sb-127	7.4E+05	7.4E+05	7.4E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05
Sb-129	1.6E+06	1.6E+06	1.5E+06	1.5E+06	1.5E+06	1.5E+06	1.4E+06	1.4E+06	1.4E+06	1.4E+06	1.4E+06
Te-127	7.4E+05	7.4E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05
Te-127m	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	1.8E+06	1.8E+06	1.8E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.7E+06	1.6E+06	1.6E+06	1.6E+06
Te-129m	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Te-131m	9.8E+05	9.8E+05	9.7E+05	9.7E+05	9.7E+05	9.7E+05	9.7E+05	9.6E+05	9.6E+05	9.6E+05	9.6E+05
Te-132	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
I-131	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07
I-132	6.2E+07	6.0E+07	5.9E+07	5.7E+07	5.6E+07	5.4E+07	5.3E+07	5.2E+07	5.1E+07	4.8E+07	4.8E+07
I-133	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.1E+08
I-134	2.4E+07	2.2E+07	2.0E+07	1.9E+07	1.7E+07	1.6E+07	1.5E+07	1.4E+07	1.2E+07	1.1E+07	1.0E+07
I-135	8.9E+07	8.8E+07	8.7E+07	8.6E+07	8.5E+07	8.4E+07	8.4E+07	8.3E+07	8.2E+07	8.0E+07	8.0E+07
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.8E+06	2.7E+06	2.7E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	1.8E+06	1.8E+06	1.7E+06	1.6E+06	1.5E+06	1.4E+06	1.4E+06	1.3E+06	1.2E+06	1.1E+06	1.1E+06
Ba-140	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06
La-140	1.5E+05	1.6E+05	1.6E+05	1.7E+05	1.8E+05	1.9E+05	2.0E+05	2.1E+05	2.2E+05	2.3E+05	2.4E+05
La-141	3.4E+04	3.4E+04	3.3E+04	3.3E+04	3.2E+04	3.2E+04	3.1E+04	3.0E+04	3.0E+04	2.9E+04	2.9E+04
La-142	1.9E+04	1.8E+04	1.7E+04	1.6E+04	1.6E+04	1.5E+04	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.2E+04
Ce-141	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05
Ce-143	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.1E+05	1.1E+05
Ce-144	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04
Pr-143	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04
Nd-147	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04
Np-239	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 5 of 11)

Nuclide	Time after LOCA (hr)										
	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.5	6
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Sr-89	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	3.5E+06	3.4E+06	3.4E+06	3.3E+06	3.3E+06	3.2E+06	3.2E+06	3.1E+06	3.1E+06	3.0E+06	2.9E+06
Sr-92	1.9E+06	1.8E+06	1.8E+06	1.7E+06	1.6E+06	1.5E+06	1.4E+06	1.4E+06	1.3E+06	1.1E+06	1.0E+06
Y-90	9.5E+03	1.0E+04	1.1E+04	1.1E+04	1.2E+04	1.2E+04	1.3E+04	1.4E+04	1.4E+04	1.6E+04	1.7E+04
Y-91	4.3E+04	4.4E+04	4.4E+04	4.4E+04	4.4E+04	4.4E+04	4.4E+04	4.4E+04	4.5E+04	4.5E+04	4.5E+04
Y-92	9.4E+05	9.8E+05	1.0E+06	1.0E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06
Y-93	4.1E+04	4.0E+04	4.0E+04	3.9E+04	3.8E+04	3.8E+04	3.7E+04	3.7E+04	3.6E+04	3.5E+04	3.4E+04
Zr-95	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Zr-97	4.6E+04	4.6E+04	4.6E+04	4.5E+04	4.5E+04	4.4E+04	4.4E+04	4.4E+04	4.3E+04	4.2E+04	4.2E+04
Nb-95	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04
Mo-99	6.6E+05	6.5E+05	6.5E+05	6.5E+05	6.5E+05	6.5E+05	6.5E+05	6.5E+05	6.4E+05	6.4E+05	6.4E+05
Tc-99m	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05	5.9E+05
Ru-103	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05
Ru-105	2.1E+05	2.0E+05	2.0E+05	1.9E+05	1.8E+05	1.8E+05	1.7E+05	1.7E+05	1.6E+05	1.5E+05	1.4E+05
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	3.3E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05
Sb-127	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.2E+05	7.2E+05	7.2E+05	7.2E+05	7.2E+05	7.2E+05
Sb-129	1.3E+06	1.3E+06	1.2E+06	1.2E+06	1.2E+06	1.1E+06	1.1E+06	1.1E+06	1.0E+06	9.4E+05	8.7E+05
Te-127	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.3E+05	7.2E+05
Te-127m	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	1.6E+06	1.5E+06	1.5E+06	1.4E+06	1.4E+06	1.4E+06	1.3E+06	1.3E+06	1.3E+06	1.2E+06	1.1E+06
Te-129m	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Te-131m	9.5E+05	9.5E+05	9.4E+05	9.4E+05	9.3E+05	9.3E+05	9.3E+05	9.2E+05	9.2E+05	9.1E+05	9.0E+05
Te-132	9.9E+06	9.9E+06	9.9E+06	9.9E+06	9.9E+06	9.8E+06	9.8E+06	9.8E+06	9.8E+06	9.8E+06	9.7E+06
I-131	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.7E+07	5.6E+07	5.6E+07
I-132	4.6E+07	4.4E+07	4.2E+07	4.0E+07	3.8E+07	3.7E+07	3.5E+07	3.4E+07	3.2E+07	2.9E+07	2.6E+07
I-133	1.1E+08	1.1E+08	1.1E+08	1.1E+08	1.0E+08	1.0E+08	1.0E+08	1.0E+08	1.0E+08	1.0E+08	9.8E+07
I-134	9.1E+06	7.8E+06	6.6E+06	5.7E+06	4.8E+06	4.1E+06	3.5E+06	3.0E+06	2.6E+06	1.7E+06	1.2E+06
I-135	7.8E+07	7.7E+07	7.5E+07	7.4E+07	7.2E+07	7.1E+07	6.9E+07	6.8E+07	6.6E+07	6.3E+07	6.0E+07
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	1.0E+06	9.1E+05	8.2E+05	7.4E+05	6.7E+05	6.1E+05	5.5E+05	5.0E+05	4.5E+05	3.5E+05	2.7E+05
Ba-140	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.3E+06	5.2E+06
La-140	2.5E+05	2.7E+05	2.9E+05	3.0E+05	3.2E+05	3.4E+05	3.5E+05	3.7E+05	3.9E+05	4.3E+05	4.7E+05
La-141	2.8E+04	2.7E+04	2.6E+04	2.5E+04	2.4E+04	2.3E+04	2.3E+04	2.2E+04	2.1E+04	1.9E+04	1.8E+04
La-142	1.1E+04	9.9E+03	9.0E+03	8.3E+03	7.6E+03	6.9E+03	6.3E+03	5.8E+03	5.3E+03	4.2E+03	3.4E+03
Ce-141	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05
Ce-143	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05
Ce-144	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04
Pr-143	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04
Nd-147	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04	2.0E+04
Np-239	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06	1.3E+06
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water)
(Sheet 6 of 11)

Nuclide	Time after LOCA (hr)										
	6.5	7	7.5	8	8.8	9	9.5	10	11	12	13
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05
Sr-89	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	2.8E+06	2.7E+06	2.6E+06	2.5E+06	2.3E+06	2.3E+06	2.2E+06	2.1E+06	2.0E+06	1.8E+06	1.7E+06
Sr-92	8.8E+05	7.7E+05	6.8E+05	6.0E+05	4.9E+05	4.6E+05	4.1E+05	3.6E+05	2.8E+05	2.2E+05	1.7E+05
Y-90	1.8E+04	2.0E+04	2.1E+04	2.3E+04	2.5E+04	2.5E+04	2.7E+04	2.8E+04	3.1E+04	3.3E+04	3.6E+04
Y-91	4.5E+04	4.6E+04	4.6E+04	4.6E+04	4.7E+04	4.7E+04	4.7E+04	4.7E+04	4.7E+04	4.8E+04	4.8E+04
Y-92	1.1E+06	1.1E+06	1.0E+06	1.0E+06	9.4E+05	9.2E+05	8.7E+05	8.3E+05	7.4E+05	6.5E+05	5.7E+05
Y-93	3.3E+04	3.2E+04	3.1E+04	3.0E+04	2.8E+04	2.8E+04	2.7E+04	2.6E+04	2.4E+04	2.3E+04	2.1E+04
Zr-95	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Zr-97	4.1E+04	4.0E+04	3.9E+04	3.8E+04	3.7E+04	3.7E+04	3.6E+04	3.5E+04	3.4E+04	3.3E+04	3.1E+04
Nb-95	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04
Mo-99	6.3E+05	6.3E+05	6.3E+05	6.2E+05	6.2E+05	6.2E+05	6.1E+05	6.1E+05	6.0E+05	6.0E+05	5.9E+05
Tc-99m	5.8E+05	5.8E+05	5.8E+05	5.8E+05	5.8E+05	5.8E+05	5.7E+05	5.7E+05	5.7E+05	5.6E+05	5.6E+05
Ru-103	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05
Ru-105	1.3E+05	1.2E+05	1.1E+05	1.0E+05	8.9E+04	8.7E+04	8.0E+04	7.4E+04	6.3E+04	5.4E+04	4.6E+04
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	3.2E+05	3.1E+05	3.1E+05	3.1E+05	3.1E+05	3.1E+05	3.0E+05	3.0E+05	3.0E+05	2.9E+05	2.9E+05
Sb-127	7.1E+05	7.1E+05	7.1E+05	7.1E+05	7.0E+05	7.0E+05	7.0E+05	6.9E+05	6.9E+05	6.8E+05	6.8E+05
Sb-129	8.0E+05	7.4E+05	6.8E+05	6.3E+05	5.5E+05	5.4E+05	4.9E+05	4.6E+05	3.9E+05	3.3E+05	2.8E+05
Te-127	7.2E+05	7.2E+05	7.2E+05	7.2E+05	7.2E+05	7.1E+05	7.1E+05	7.1E+05	7.1E+05	7.0E+05	7.0E+05
Te-127m	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	1.1E+06	9.9E+05	9.3E+05	8.8E+05	8.0E+05	7.8E+05	7.4E+05	7.0E+05	6.3E+05	5.7E+05	5.1E+05
Te-129m	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Te-131m	8.9E+05	8.8E+05	8.7E+05	8.6E+05	8.4E+05	8.4E+05	8.3E+05	8.2E+05	8.0E+05	7.8E+05	7.6E+05
Te-132	9.7E+06	9.6E+06	9.6E+06	9.5E+06	9.5E+06	9.5E+06	9.4E+06	9.4E+06	9.3E+06	9.2E+06	9.1E+06
I-131	5.6E+07	5.6E+07	5.6E+07	5.6E+07	5.6E+07	5.6E+07	5.6E+07	5.6E+07	5.5E+07	5.5E+07	5.5E+07
I-132	2.4E+07	2.2E+07	2.0E+07	1.9E+07	1.7E+07	1.6E+07	1.5E+07	1.5E+07	1.3E+07	1.2E+07	1.1E+07
I-133	9.7E+07	9.5E+07	9.4E+07	9.2E+07	9.0E+07	8.9E+07	8.8E+07	8.6E+07	8.3E+07	8.1E+07	7.8E+07
I-134	7.8E+05	5.3E+05	3.6E+05	2.4E+05	1.3E+05	1.1E+05	7.3E+04	4.9E+04	2.2E+04	1.0E+04	4.6E+03
I-135	5.7E+07	5.4E+07	5.1E+07	4.8E+07	4.5E+07	4.4E+07	4.1E+07	3.9E+07	3.5E+07	3.2E+07	2.9E+07
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	2.1E+05	1.6E+05	1.3E+05	1.0E+05	6.7E+04	6.0E+04	4.7E+04	3.6E+04	2.2E+04	1.3E+04	8.1E+03
Ba-140	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06	5.2E+06
La-140	5.1E+05	5.5E+05	5.9E+05	6.3E+05	7.0E+05	7.1E+05	7.5E+05	7.9E+05	8.6E+05	9.4E+05	1.0E+06
La-141	1.6E+04	1.5E+04	1.4E+04	1.2E+04	1.1E+04	1.0E+04	9.5E+03	8.7E+03	7.3E+03	6.1E+03	5.1E+03
La-142	2.7E+03	2.1E+03	1.7E+03	1.4E+03	9.6E+02	8.7E+02	7.0E+02	5.6E+02	3.6E+02	2.3E+02	1.4E+02
Ce-141	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05
Ce-143	1.1E+05	1.1E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	1.0E+05	9.9E+04	9.7E+04	9.5E+04	9.3E+04
Ce-144	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04
Pr-143	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.8E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04
Nd-147	2.0E+04	2.0E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04
Np-239	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06	1.2E+06
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water)
(Sheet 7 of 11)

Nuclide	Time after LOCA (hr)										
	14	15	16	17	18	19	20	21	22	23	24
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.0E+05	1.0E+05	1.0E+05	9.9E+04	9.9E+04	9.9E+04	9.9E+04	9.9E+04	9.9E+04	9.8E+04	9.8E+04
Sr-89	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	1.6E+06	1.5E+06	1.4E+06	1.3E+06	1.2E+06	1.1E+06	1.0E+06	9.6E+05	8.9E+05	8.3E+05	7.7E+05
Sr-92	1.3E+05	1.0E+05	7.7E+04	6.0E+04	4.6E+04	3.6E+04	2.8E+04	2.2E+04	1.7E+04	1.3E+04	1.0E+04
Y-90	3.9E+04	4.1E+04	4.4E+04	4.6E+04	4.9E+04	5.1E+04	5.4E+04	5.6E+04	5.8E+04	6.1E+04	6.3E+04
Y-91	4.9E+04	4.9E+04	4.9E+04	4.9E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.1E+04
Y-92	4.9E+05	4.3E+05	3.7E+05	3.1E+05	2.7E+05	2.3E+05	1.9E+05	1.6E+05	1.4E+05	1.1E+05	9.6E+04
Y-93	2.0E+04	1.8E+04	1.7E+04	1.6E+04	1.5E+04	1.4E+04	1.3E+04	1.2E+04	1.1E+04	1.1E+04	9.9E+03
Zr-95	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Zr-97	3.0E+04	2.9E+04	2.8E+04	2.6E+04	2.5E+04	2.4E+04	2.3E+04	2.2E+04	2.2E+04	2.1E+04	2.0E+04
Nb-95	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.4E+04
Mo-99	5.9E+05	5.8E+05	5.7E+05	5.7E+05	5.6E+05	5.6E+05	5.5E+05	5.4E+05	5.4E+05	5.3E+05	5.3E+05
Tc-99m	5.6E+05	5.5E+05	5.5E+05	5.4E+05	5.4E+05	5.3E+05	5.3E+05	5.2E+05	5.2E+05	5.1E+05	5.1E+05
Ru-103	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05	5.3E+05
Ru-105	4.0E+04	3.4E+04	2.9E+04	2.5E+04	2.1E+04	1.8E+04	1.6E+04	1.3E+04	1.1E+04	9.8E+03	8.3E+03
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	2.8E+05	2.8E+05	2.7E+05	2.7E+05	2.6E+05	2.6E+05	2.5E+05	2.5E+05	2.4E+05	2.4E+05	2.4E+05
Sb-127	6.7E+05	6.7E+05	6.6E+05	6.6E+05	6.5E+05	6.5E+05	6.4E+05	6.4E+05	6.3E+05	6.3E+05	6.3E+05
Sb-129	2.4E+05	2.0E+05	1.7E+05	1.5E+05	1.3E+05	1.1E+05	9.2E+04	7.8E+04	6.7E+04	5.7E+04	4.8E+04
Te-127	7.0E+05	6.9E+05	6.9E+05	6.9E+05	6.8E+05	6.8E+05	6.8E+05	6.7E+05	6.7E+05	6.6E+05	6.6E+05
Te-127m	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	4.7E+05	4.3E+05	4.0E+05	3.7E+05	3.5E+05	3.3E+05	3.1E+05	3.0E+05	2.9E+05	2.8E+05	2.7E+05
Te-129m	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05
Te-131m	7.5E+05	7.3E+05	7.1E+05	7.0E+05	6.8E+05	6.6E+05	6.5E+05	6.3E+05	6.2E+05	6.1E+05	5.9E+05
Te-132	9.0E+06	9.0E+06	8.9E+06	8.8E+06	8.7E+06	8.7E+06	8.6E+06	8.5E+06	8.4E+06	8.4E+06	8.3E+06
I-131	5.5E+07	5.5E+07	5.4E+07	5.4E+07	5.4E+07	5.4E+07	5.4E+07	5.3E+07	5.3E+07	5.3E+07	5.3E+07
I-132	1.1E+07	1.0E+07	1.0E+07	9.7E+06	9.4E+06	9.3E+06	9.1E+06	8.9E+06	8.8E+06	8.7E+06	8.6E+06
I-133	7.5E+07	7.3E+07	7.0E+07	6.8E+07	6.6E+07	6.4E+07	6.2E+07	6.0E+07	5.8E+07	5.6E+07	5.4E+07
I-134	2.1E+03	9.5E+02	4.3E+02	1.9E+02	8.8E+01	4.0E+01	1.8E+01	8.2E+00	3.7E+00	1.7E+00	7.7E-01
I-135	2.6E+07	2.3E+07	2.1E+07	1.9E+07	1.7E+07	1.5E+07	1.4E+07	1.2E+07	1.1E+07	1.0E+07	9.0E+06
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.7E+06	2.6E+06	2.6E+06	2.6E+06	2.6E+06	2.6E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	4.9E+03	2.9E+03	1.8E+03	1.1E+03	6.5E+02	3.9E+02	2.4E+02	1.4E+02	8.7E+01	5.3E+01	3.2E+01
Ba-140	5.2E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.1E+06	5.0E+06	5.0E+06
La-140	1.1E+06	1.1E+06	1.2E+06	1.3E+06	1.3E+06	1.4E+06	1.5E+06	1.5E+06	1.6E+06	1.7E+06	1.7E+06
La-141	4.3E+03	3.6E+03	3.0E+03	2.5E+03	2.1E+03	1.8E+03	1.5E+03	1.3E+03	1.0E+03	8.8E+02	7.4E+02
La-142	9.2E+01	5.9E+01	3.8E+01	2.4E+01	1.5E+01	9.7E+00	6.2E+00	4.0E+00	2.5E+00	1.6E+00	1.0E+00
Ce-141	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05
Ce-143	9.1E+04	8.9E+04	8.8E+04	8.6E+04	8.4E+04	8.2E+04	8.1E+04	7.9E+04	7.7E+04	7.6E+04	7.4E+04
Ce-144	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04
Pr-143	4.9E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04	4.9E+04	5.0E+04	5.0E+04	5.0E+04
Nd-147	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04	1.9E+04
Np-239	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.1E+06	1.0E+06	1.0E+06	1.0E+06	1.0E+06
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00	5.3E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 8 of 11)

Nuclide	Time after LOCA (hr)										
	26	28	30	35	40	48	50	60	70	80	96
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	9.8E+04	9.8E+04	9.7E+04	9.7E+04	9.6E+04	9.5E+04	9.4E+04	9.3E+04	9.2E+04	9.0E+04	8.8E+04
Sr-89	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.3E+06	3.2E+06	3.2E+06	3.2E+06	3.2E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	6.6E+05	5.7E+05	5.0E+05	3.4E+05	2.4E+05	1.3E+05	1.2E+05	5.6E+04	2.7E+04	1.3E+04	4.0E+03
Sr-92	6.0E+03	3.6E+03	2.2E+03	6.0E+02	1.7E+02	2.2E+01	1.3E+01	1.0E+00	7.8E-02	6.0E-03	1.0E-04
Y-90	6.8E+04	7.2E+04	7.7E+04	8.7E+04	9.7E+04	1.1E+05	1.2E+05	1.3E+05	1.5E+05	1.6E+05	1.8E+05
Y-91	5.1E+04	5.1E+04	5.1E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.1E+04	5.1E+04
Y-92	6.8E+04	4.7E+04	3.3E+04	1.3E+04	5.1E+03	1.1E+03	7.5E+02	1.1E+02	1.6E+01	2.2E+00	9.7E-02
Y-93	8.6E+03	7.5E+03	6.6E+03	4.6E+03	3.3E+03	1.9E+03	1.7E+03	8.4E+02	4.2E+02	2.1E+02	7.1E+01
Zr-95	5.3E+04	5.3E+04	5.3E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.2E+04	5.1E+04	5.1E+04
Zr-97	1.8E+04	1.7E+04	1.6E+04	1.3E+04	1.0E+04	7.4E+03	6.8E+03	4.5E+03	3.0E+03	2.0E+03	1.0E+03
Nb-95	5.4E+04	5.4E+04	5.4E+04	5.4E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Mo-99	5.2E+05	5.1E+05	5.0E+05	4.7E+05	4.5E+05	4.1E+05	4.0E+05	3.6E+05	3.3E+05	2.9E+05	2.5E+05
Tc-99m	5.0E+05	4.9E+05	4.8E+05	4.6E+05	4.3E+05	4.0E+05	3.9E+05	3.5E+05	3.2E+05	2.9E+05	2.4E+05
Ru-103	5.3E+05	5.3E+05	5.3E+05	5.2E+05	5.2E+05	5.2E+05	5.2E+05	5.2E+05	5.1E+05	5.1E+05	5.0E+05
Ru-105	6.1E+03	4.5E+03	3.3E+03	1.5E+03	6.9E+02	2.0E+02	1.4E+02	3.0E+01	6.3E+00	1.3E+00	1.1E-01
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05
Rh-105	2.3E+05	2.2E+05	2.1E+05	1.9E+05	1.7E+05	1.5E+05	1.4E+05	1.2E+05	9.6E+04	7.9E+04	5.8E+04
Sb-127	6.2E+05	6.1E+05	6.0E+05	5.8E+05	5.5E+05	5.2E+05	5.1E+05	4.8E+05	4.4E+05	4.1E+05	3.6E+05
Sb-129	3.5E+04	2.5E+04	1.8E+04	8.3E+03	3.7E+03	1.0E+03	7.4E+02	1.5E+02	3.0E+01	6.0E+00	4.6E-01
Te-127	6.5E+05	6.5E+05	6.4E+05	6.2E+05	6.0E+05	5.7E+05	5.7E+05	5.3E+05	5.0E+05	4.7E+05	4.3E+05
Te-127m	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04	9.8E+04
Te-129	2.6E+05	2.5E+05	2.4E+05	2.3E+05	2.2E+05	2.2E+05	2.2E+05	2.1E+05	2.1E+05	2.1E+05	2.1E+05
Te-129m	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.3E+05	3.2E+05	3.2E+05	3.2E+05	3.2E+05	3.1E+05	3.1E+05
Te-131m	5.6E+05	5.4E+05	5.1E+05	4.6E+05	4.1E+05	3.4E+05	3.2E+05	2.6E+05	2.0E+05	1.6E+05	1.1E+05
Te-132	8.1E+06	8.0E+06	7.8E+06	7.5E+06	7.2E+06	6.7E+06	6.6E+06	6.0E+06	5.5E+06	5.0E+06	4.4E+06
I-131	5.2E+07	5.2E+07	5.2E+07	5.1E+07	5.0E+07	4.8E+07	4.8E+07	4.6E+07	4.5E+07	4.3E+07	4.1E+07
I-132	8.5E+06	8.3E+06	8.2E+06	7.9E+06	7.5E+06	7.0E+06	6.9E+06	6.3E+06	5.8E+06	5.3E+06	4.6E+06
I-133	5.1E+07	4.7E+07	4.4E+07	3.7E+07	3.2E+07	2.4E+07	2.3E+07	1.6E+07	1.2E+07	8.4E+06	4.9E+06
I-134	1.6E-01	3.3E-02	6.7E-03	1.3E-04	2.5E-06	4.4E-09	9.1E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	7.3E+06	5.9E+06	4.8E+06	2.9E+06	1.7E+06	7.3E+05	5.9E+05	2.1E+05	7.3E+04	2.5E+04	4.8E+03
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.6E+06	2.6E+06	2.6E+06	2.6E+06	2.5E+06	2.5E+06	2.5E+06	2.4E+06	2.4E+06	2.3E+06	2.2E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	1.2E+01	4.3E+00	1.6E+00	1.3E-01	1.0E-02	1.8E-04	6.7E-05	4.4E-07	2.9E-09	0.0E+00	0.0E+00
Ba-140	5.0E+06	5.0E+06	5.0E+06	4.9E+06	4.9E+06	4.8E+06	4.7E+06	4.6E+06	4.5E+06	4.4E+06	4.3E+06
La-140	1.8E+06	1.9E+06	2.0E+06	2.3E+06	2.5E+06	2.8E+06	2.9E+06	3.1E+06	3.4E+06	3.6E+06	3.7E+06
La-141	5.2E+02	3.6E+02	2.6E+02	1.1E+02	4.4E+01	1.1E+01	7.5E+00	1.3E+00	2.2E-01	3.8E-02	2.2E-03
La-142	4.2E-01	1.7E-01	6.9E-02	7.3E-03	7.7E-04	2.1E-05	8.6E-06	9.6E-08	1.1E-09	0.0E+00	0.0E+00
Ce-141	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05	1.2E+05
Ce-143	7.1E+04	6.8E+04	6.5E+04	5.9E+04	5.3E+04	4.5E+04	4.3E+04	3.5E+04	2.8E+04	2.3E+04	1.6E+04
Ce-144	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.5E+04	9.4E+04	9.4E+04	9.4E+04	9.4E+04	9.4E+04	9.4E+04
Pr-143	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	5.0E+04	4.9E+04	4.9E+04	4.8E+04
Nd-147	1.9E+04	1.8E+04	1.8E+04	1.8E+04	1.8E+04	1.8E+04	1.7E+04	1.7E+04	1.7E+04	1.6E+04	1.5E+04
Np-239	9.8E+05	9.6E+05	9.4E+05	8.8E+05	8.3E+05	7.5E+05	7.3E+05	6.5E+05	5.7E+05	5.1E+05	4.2E+05
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01	2.8E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.3E+00	5.3E+00	5.3E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.5E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 9 of 11)

Nuclide	Time after LOCA (hr)										
	100	120	150	160	170	180	200	240	264	288	300
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	8.7E+04	8.5E+04	8.1E+04	8.0E+04	7.8E+04	7.7E+04	7.5E+04	7.0E+04	6.8E+04	6.5E+04	6.4E+04
Sr-89	3.2E+06	3.1E+06	3.1E+06	3.1E+06	3.0E+06	3.0E+06	3.0E+06	2.9E+06	2.9E+06	2.8E+06	2.8E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	3.0E+03	7.0E+02	7.8E+01	3.8E+01	1.8E+01	8.7E+00	2.0E+00	1.1E-01	1.9E-02	3.3E-03	1.4E-03
Sr-92	3.6E-05	2.2E-07	1.0E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	1.8E+05	2.0E+05	2.2E+05	2.3E+05	2.3E+05	2.4E+05	2.5E+05	2.6E+05	2.6E+05	2.7E+05	2.7E+05
Y-91	5.1E+04	5.0E+04	5.0E+04	4.9E+04	4.9E+04	4.9E+04	4.8E+04	4.7E+04	4.7E+04	4.6E+04	4.6E+04
Y-92	4.4E-02	8.9E-04	2.5E-06	3.5E-07	5.0E-08	7.0E-09	1.4E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	5.4E+01	1.4E+01	1.7E+00	8.7E-01	4.4E-01	2.2E-01	5.6E-02	3.6E-03	7.0E-04	1.3E-04	5.9E-05
Zr-95	5.1E+04	5.0E+04	5.0E+04	5.0E+04	4.9E+04	4.9E+04	4.9E+04	4.8E+04	4.7E+04	4.7E+04	4.7E+04
Zr-97	8.8E+02	3.9E+02	1.1E+02	7.5E+01	5.0E+01	3.3E+01	1.5E+01	2.8E+00	1.1E+00	3.9E-01	2.4E-01
Nb-95	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04	5.3E+04
Mo-99	2.4E+05	1.9E+05	1.4E+05	1.3E+05	1.1E+05	1.0E+05	8.3E+04	5.5E+04	4.2E+04	3.3E+04	2.9E+04
Tc-99m	2.3E+05	1.9E+05	1.4E+05	1.2E+05	1.1E+05	1.0E+05	8.1E+04	5.3E+04	4.1E+04	3.2E+04	2.8E+04
Ru-103	5.0E+05	4.9E+05	4.8E+05	4.8E+05	4.8E+05	4.7E+05	4.6E+05	4.5E+05	4.4E+05	4.4E+05	4.3E+05
Ru-105	5.9E-02	2.6E-03	2.4E-05	5.0E-06	1.1E-06	2.2E-07	9.7E-09	1.9E-11	0.0E+00	0.0E+00	0.0E+00
Ru-106	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05
Rh-105	5.3E+04	3.6E+04	2.0E+04	1.6E+04	1.4E+04	1.1E+04	7.5E+03	3.4E+03	2.1E+03	1.3E+03	1.1E+03
Sb-127	3.5E+05	3.0E+05	2.4E+05	2.3E+05	2.1E+05	1.9E+05	1.7E+05	1.2E+05	1.0E+05	8.6E+04	7.9E+04
Sb-129	2.4E-01	9.9E-03	8.0E-05	1.6E-05	3.2E-06	6.5E-07	2.6E-08	4.3E-11	0.0E+00	0.0E+00	0.0E+00
Te-127	4.2E+05	3.7E+05	3.2E+05	3.0E+05	2.9E+05	2.7E+05	2.5E+05	2.1E+05	1.9E+05	1.7E+05	1.7E+05
Te-127m	9.8E+04	9.7E+04	9.7E+04	9.7E+04	9.7E+04	9.6E+04	9.6E+04	9.5E+04	9.5E+04	9.4E+04	9.4E+04
Te-129	2.1E+05	2.0E+05	2.0E+05	2.0E+05	2.0E+05	1.9E+05	1.9E+05	1.8E+05	1.8E+05	1.8E+05	1.7E+05
Te-129m	3.1E+05	3.0E+05	3.0E+05	2.9E+05	2.9E+05	2.9E+05	2.8E+05	2.7E+05	2.7E+05	2.6E+05	2.6E+05
Te-131m	1.0E+05	6.4E+04	3.2E+04	2.6E+04	2.0E+04	1.6E+04	1.0E+04	4.0E+03	2.3E+03	1.3E+03	1.0E+03
Te-132	4.2E+06	3.5E+06	2.7E+06	2.5E+06	2.3E+06	2.1E+06	1.7E+06	1.2E+06	9.9E+05	8.0E+05	7.2E+05
I-131	4.0E+07	3.7E+07	3.4E+07	3.2E+07	3.1E+07	3.0E+07	2.8E+07	2.4E+07	2.2E+07	2.0E+07	2.0E+07
I-132	4.4E+06	3.7E+06	2.8E+06	2.6E+06	2.4E+06	2.2E+06	1.8E+06	1.3E+06	1.0E+06	8.3E+05	7.5E+05
I-133	4.3E+06	2.2E+06	8.1E+05	5.8E+05	4.2E+05	3.0E+05	1.5E+05	4.0E+04	1.8E+04	8.2E+03	5.5E+03
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	3.1E+03	3.8E+02	1.7E+01	5.8E+00	2.0E+00	7.1E-01	8.7E-02	1.3E-03	1.1E-04	8.6E-06	2.4E-06
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
Cs-136	2.2E+06	2.1E+06	2.0E+06	1.9E+06	1.9E+06	1.9E+06	1.8E+06	1.6E+06	1.5E+06	1.5E+06	1.4E+06
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	4.2E+06	4.1E+06	3.8E+06	3.7E+06	3.6E+06	3.5E+06	3.4E+06	3.1E+06	2.9E+06	2.8E+06	2.7E+06
La-140	3.8E+06	3.9E+06	3.9E+06	3.9E+06	3.8E+06	3.8E+06	3.7E+06	3.5E+06	3.3E+06	3.1E+06	3.1E+06
La-141	1.1E-03	3.3E-05	1.6E-07	2.8E-08	4.8E-09	8.3E-10	2.4E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	1.2E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.1E+05	1.0E+05	1.0E+05	9.8E+04	9.7E+04
Ce-143	1.5E+04	9.9E+03	5.2E+03	4.3E+03	3.4E+03	2.8E+03	1.8E+03	7.9E+02	4.8E+02	2.9E+02	2.2E+02
Ce-144	9.4E+04	9.4E+04	9.3E+04	9.3E+04	9.3E+04	9.3E+04	9.3E+04	9.3E+04	9.2E+04	9.2E+04	9.2E+04
Pr-143	4.8E+04	4.6E+04	4.4E+04	4.3E+04	4.2E+04	4.1E+04	4.0E+04	3.7E+04	3.5E+04	3.3E+04	3.2E+04
Nd-147	1.5E+04	1.4E+04	1.3E+04	1.3E+04	1.3E+04	1.2E+04	1.2E+04	1.1E+04	9.9E+03	9.3E+03	9.0E+03
Np-239	4.0E+05	3.1E+05	2.1E+05	1.9E+05	1.7E+05	1.5E+05	1.2E+05	7.1E+04	5.3E+04	4.0E+04	3.4E+04
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.8E+01	2.8E+01	2.8E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03
Am-241	5.5E+00	5.5E+00	5.6E+00	5.6E+00	5.6E+00	5.6E+00	5.6E+00	5.7E+00	5.8E+00	5.8E+00	5.8E+00
Cm-242	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.3E+03	1.2E+03	1.2E+03	1.2E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 10 of 11)

Nuclide	Time after LOCA (hr)										
	312	336	360	400	480	500	600	700	720	960	1200
Co-60	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03	1.1E+03
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	6.3E+04	6.1E+04	5.8E+04	5.5E+04	4.9E+04	4.7E+04	4.0E+04	3.5E+04	3.3E+04	2.3E+04	1.6E+04
Sr-89	2.8E+06	2.8E+06	2.7E+06	2.7E+06	2.5E+06	2.5E+06	2.4E+06	2.2E+06	2.2E+06	1.9E+06	1.7E+06
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Sr-91	5.7E-04	1.0E-04	1.7E-05	9.3E-07	2.7E-09	6.3E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05	2.8E+05
Y-91	4.6E+04	4.5E+04	4.5E+04	4.4E+04	4.2E+04	4.2E+04	4.0E+04	3.8E+04	3.7E+04	3.3E+04	3.0E+04
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	2.6E-05	5.0E-06	9.6E-07	6.1E-08	2.5E-10	6.4E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	4.6E+04	4.6E+04	4.5E+04	4.4E+04	4.3E+04	4.3E+04	4.1E+04	3.9E+04	3.8E+04	3.5E+04	3.1E+04
Zr-97	1.5E-01	5.5E-02	2.1E-02	4.0E-03	1.5E-04	6.6E-05	1.1E-06	1.8E-08	8.0E-09	0.0E+00	0.0E+00
Nb-95	5.3E+04	5.2E+04	5.2E+04	5.2E+04	5.1E+04	5.1E+04	5.0E+04	5.0E+04	4.9E+04	4.7E+04	4.4E+04
Mo-99	2.6E+04	2.0E+04	1.5E+04	1.0E+04	4.4E+03	3.6E+03	1.2E+03	4.4E+02	3.5E+02	2.8E+01	2.3E+00
Tc-99m	2.5E+04	1.9E+04	1.5E+04	9.9E+03	4.3E+03	3.5E+03	1.2E+03	4.2E+02	3.4E+02	2.8E+01	2.2E+00
Ru-103	4.3E+05	4.2E+05	4.1E+05	4.0E+05	3.8E+05	3.7E+05	3.5E+05	3.2E+05	3.2E+05	2.7E+05	2.2E+05
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.8E+05	1.7E+05	1.7E+05
Rh-105	8.4E+02	5.2E+02	3.3E+02	1.5E+02	3.1E+01	2.1E+01	3.0E+00	4.2E-01	2.8E-01	2.5E-03	2.3E-05
Sb-127	7.2E+04	6.0E+04	5.0E+04	3.7E+04	2.0E+04	1.8E+04	8.3E+03	3.9E+03	3.4E+03	5.6E+02	9.2E+01
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	1.6E+05	1.5E+05	1.4E+05	1.2E+05	1.1E+05	1.0E+05	9.4E+04	8.8E+04	8.7E+04	7.9E+04	7.4E+04
Te-127m	9.4E+04	9.3E+04	9.3E+04	9.2E+04	9.0E+04	9.0E+04	8.7E+04	8.5E+04	8.5E+04	7.9E+04	7.5E+04
Te-129	1.7E+05	1.7E+05	1.7E+05	1.6E+05	1.5E+05	1.5E+05	1.3E+05	1.2E+05	1.2E+05	9.9E+04	8.1E+04
Te-129m	2.6E+05	2.5E+05	2.5E+05	2.4E+05	2.2E+05	2.2E+05	2.0E+05	1.8E+05	1.8E+05	1.5E+05	1.2E+05
Te-131m	7.6E+02	4.4E+02	2.5E+02	1.0E+02	1.6E+01	9.9E+00	9.8E-01	9.7E-02	6.1E-02	2.4E-04	9.4E-07
Te-132	6.4E+05	5.2E+05	4.2E+05	3.0E+05	1.5E+05	1.2E+05	5.0E+04	2.1E+04	1.7E+04	2.1E+03	2.5E+02
I-131	1.9E+07	1.7E+07	1.6E+07	1.4E+07	1.0E+07	9.6E+06	6.7E+06	4.7E+06	4.3E+06	1.8E+06	7.7E+05
I-132	6.7E+05	5.4E+05	4.4E+05	3.1E+05	1.5E+05	1.3E+05	5.2E+04	2.2E+04	1.8E+04	2.2E+03	2.6E+02
I-133	3.7E+03	1.6E+03	7.4E+02	2.0E+02	1.4E+01	7.0E+00	2.5E-01	8.9E-03	4.6E-03	1.5E-06	5.2E-10
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	6.9E-07	5.6E-08	4.5E-09	6.8E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	9.9E+06	9.9E+06	9.9E+06	9.8E+06	9.7E+06
Cs-136	1.4E+06	1.3E+06	1.3E+06	1.1E+06	9.6E+05	9.2E+05	7.4E+05	5.9E+05	5.7E+05	3.3E+05	2.0E+05
Cs-137	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06	5.8E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	2.6E+06	2.5E+06	2.4E+06	2.1E+06	1.8E+06	1.7E+06	1.4E+06	1.1E+06	1.0E+06	6.0E+05	3.5E+05
La-140	3.0E+06	2.8E+06	2.7E+06	2.5E+06	2.1E+06	2.0E+06	1.6E+06	1.3E+06	1.2E+06	7.0E+05	4.0E+05
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	9.6E+04	9.4E+04	9.2E+04	8.8E+04	8.2E+04	8.1E+04	7.4E+04	6.8E+04	6.6E+04	5.4E+04	4.3E+04
Ce-143	1.7E+02	1.1E+02	6.4E+01	2.8E+01	5.1E+00	3.4E+00	4.1E-01	5.0E-02	3.3E-02	2.1E-04	1.4E-06
Ce-144	9.2E+04	9.2E+04	9.2E+04	9.1E+04	9.0E+04	9.0E+04	8.9E+04	8.8E+04	8.8E+04	8.6E+04	8.4E+04
Pr-143	3.1E+04	3.0E+04	2.8E+04	2.6E+04	2.2E+04	2.1E+04	1.7E+04	1.4E+04	1.3E+04	7.9E+03	4.7E+03
Nd-147	8.7E+03	8.2E+03	7.7E+03	6.9E+03	5.6E+03	5.3E+03	4.1E+03	3.2E+03	3.0E+03	1.6E+03	8.5E+02
Np-239	2.9E+04	2.2E+04	1.6E+04	1.0E+04	3.8E+03	2.9E+03	8.6E+02	2.5E+02	2.0E+02	1.0E+01	5.5E-01
Pu-238	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Pu-239	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.8E+03	9.7E+03	9.7E+03	9.7E+03	9.7E+03
Am-241	5.8E+00	5.9E+00	5.9E+00	6.0E+00	6.1E+00	6.2E+00	6.4E+00	6.5E+00	6.6E+00	7.0E+00	7.4E+00
Cm-242	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.1E+03	1.1E+03
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-3 Radioactivity at Typical Times after LOCA (for recirculation water) (Sheet 11 of 11)

Nuclide	Time after LOCA (hr)										
	1440	2160	2880	3600	4320	5040	5760	6480	7200	7920	8760
Co-60	1.1E+03	1.1E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+03	9.9E+02	9.8E+02	9.7E+02	9.5E+02
Kr-85	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-87	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-88	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-86	1.1E+04	3.6E+03	1.2E+03	3.9E+02	1.3E+02	4.2E+01	1.4E+01	4.5E+00	1.5E+00	4.8E-01	1.3E-01
Sr-89	1.5E+06	9.7E+05	6.4E+05	4.3E+05	2.8E+05	1.9E+05	1.2E+05	8.2E+04	5.5E+04	3.6E+04	2.2E+04
Sr-90	2.8E+05	2.8E+05	2.8E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05
Sr-91	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sr-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-90	2.8E+05	2.8E+05	2.8E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05	2.7E+05
Y-91	2.6E+04	1.8E+04	1.3E+04	9.0E+03	6.3E+03	4.4E+03	3.1E+03	2.2E+03	1.5E+03	1.1E+03	7.1E+02
Y-92	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Y-93	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	2.8E+04	2.0E+04	1.5E+04	1.0E+04	7.6E+03	5.5E+03	4.0E+03	2.9E+03	2.1E+03	1.5E+03	1.0E+03
Zr-97	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	4.2E+04	3.3E+04	2.6E+04	2.0E+04	1.5E+04	1.1E+04	8.1E+03	6.0E+03	4.4E+03	3.2E+03	2.2E+03
Mo-99	1.8E-01	9.5E-05	5.0E-08	2.6E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Tc-99m	1.8E-01	9.3E-05	4.8E-08	2.5E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	1.9E+05	1.1E+05	6.5E+04	3.8E+04	2.2E+04	1.3E+04	7.8E+03	4.6E+03	2.7E+03	1.6E+03	8.6E+02
Ru-105	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	1.7E+05	1.6E+05	1.5E+05	1.4E+05	1.3E+05	1.3E+05	1.2E+05	1.1E+05	1.1E+05	1.0E+05	9.5E+04
Rh-105	2.1E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-127	1.5E+01	6.9E-02	3.1E-04	1.4E-06	6.3E-09	2.8E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-127	6.9E+04	5.7E+04	4.7E+04	3.9E+04	3.2E+04	2.7E+04	2.2E+04	1.8E+04	1.5E+04	1.2E+04	9.9E+03
Te-127m	7.0E+04	5.8E+04	4.8E+04	3.9E+04	3.3E+04	2.7E+04	2.2E+04	1.8E+04	1.5E+04	1.3E+04	1.0E+04
Te-129	6.6E+04	3.5E+04	1.9E+04	1.0E+04	5.5E+03	3.0E+03	1.6E+03	8.6E+02	4.6E+02	2.5E+02	1.2E+02
Te-129m	9.8E+04	5.3E+04	2.8E+04	1.5E+04	8.2E+03	4.4E+03	2.4E+03	1.3E+03	6.9E+02	3.7E+02	1.8E+02
Te-131m	3.7E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-132	2.9E+01	5.0E-02	8.4E-05	1.4E-07	2.4E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	3.3E+05	2.5E+04	1.9E+03	1.4E+02	1.1E+01	7.9E-01	6.0E-02	4.5E-03	3.4E-04	2.5E-05	1.2E-06
I-132	3.1E+01	5.2E-02	8.8E-05	1.5E-07	2.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	9.6E+06	9.4E+06	9.1E+06	8.9E+06	8.6E+06	8.4E+06	8.2E+06	7.9E+06	7.7E+06	7.5E+06	7.3E+06
Cs-136	1.2E+05	2.4E+04	4.8E+03	9.9E+02	2.0E+02	4.1E+01	8.5E+00	1.7E+00	3.5E-01	7.2E-02	1.1E-02
Cs-137	5.8E+06	5.8E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06	5.7E+06
Ba-139	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ba-140	2.0E+05	4.0E+04	7.8E+03	1.5E+03	3.0E+02	5.8E+01	1.1E+01	2.2E+00	4.3E-01	8.5E-02	1.3E-02
La-140	2.3E+05	4.6E+04	9.0E+03	1.8E+03	3.4E+02	6.7E+01	1.3E+01	2.6E+00	5.0E-01	9.8E-02	1.5E-02
La-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
La-142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	3.5E+04	1.8E+04	9.8E+03	5.1E+03	2.7E+03	1.4E+03	7.5E+02	4.0E+02	2.1E+02	1.1E+02	5.2E+01
Ce-143	9.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	8.2E+04	7.6E+04	7.1E+04	6.6E+04	6.1E+04	5.7E+04	5.3E+04	4.9E+04	4.6E+04	4.2E+04	3.9E+04
Pr-143	2.8E+03	6.1E+02	1.3E+02	2.9E+01	6.2E+00	1.3E+00	2.9E-01	6.2E-02	1.3E-02	2.9E-03	4.8E-04
Nd-147	4.5E+02	6.8E+01	1.0E+01	1.5E+00	2.3E-01	3.5E-02	5.2E-03	7.9E-04	1.2E-04	1.8E-05	2.0E-06
Np-239	2.9E-02	4.2E-06	6.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	3.7E+02	3.7E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02	3.8E+02
Pu-239	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01	2.9E+01
Pu-240	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01	4.4E+01
Pu-241	9.7E+03	9.7E+03	9.6E+03	9.6E+03	9.6E+03	9.5E+03	9.5E+03	9.4E+03	9.4E+03	9.4E+03	9.3E+03
Am-241	7.9E+00	9.1E+00	1.0E+01	1.2E+01	1.3E+01	1.4E+01	1.5E+01	1.7E+01	1.8E+01	1.9E+01	2.1E+01
Cm-242	1.0E+03	8.9E+02	7.9E+02	6.9E+02	6.1E+02	5.4E+02	4.7E+02	4.1E+02	3.7E+02	3.2E+02	2.8E+02
Cm-244	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.6E+02	1.5E+02	1.5E+02	1.5E+02	1.5E+02

Note
1. The gamma ray source strengths are converted from the above amount of radioactivity using MicroShield

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 1 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	0.01	0.02	0.03	0.04	0.05	0.06	0.0667	0.08	0.0834	0.1	0.15
0.015	1.0E+14	1.1E+15	2.6E+15	3.8E+15	5.1E+15	6.3E+15	7.1E+15	8.7E+15	9.1E+15	1.1E+16	1.7E+16
0.02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.03	9.0E+14	6.9E+15	1.3E+16	2.0E+16	2.6E+16	3.2E+16	3.6E+16	4.4E+16	4.6E+16	5.6E+16	8.6E+16
0.04	3.3E+13	2.5E+14	4.7E+14	6.8E+14	8.9E+14	1.1E+15	1.3E+15	1.5E+15	1.6E+15	2.0E+15	3.0E+15
0.05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.06	0.0E+00	5.0E+13	9.2E+13	1.4E+14	1.8E+14	2.2E+14	2.5E+14	3.1E+14	3.2E+14	3.7E+14	5.3E+14
0.08	7.2E+14	5.0E+15	9.4E+15	1.4E+16	1.8E+16	2.2E+16	2.5E+16	3.1E+16	3.2E+16	4.0E+16	6.1E+16
0.1	0.0E+00	9.5E+12	2.6E+13	3.8E+13	5.0E+13	6.2E+13	7.0E+13	8.5E+13	8.9E+13	1.1E+14	1.6E+14
0.15	1.1E+12	2.2E+14	4.7E+15	6.9E+15	9.0E+15	1.1E+16	1.3E+16	1.5E+16	1.6E+16	1.9E+16	2.9E+16
0.2	2.4E+12	4.8E+15	1.1E+16	1.6E+16	2.1E+16	2.6E+16	2.9E+16	3.6E+16	3.8E+16	4.6E+16	7.0E+16
0.3	5.8E+13	1.5E+15	3.4E+15	5.0E+15	6.6E+15	8.1E+15	9.2E+15	1.1E+16	1.2E+16	1.4E+16	2.0E+16
0.4	7.2E+14	6.1E+15	1.7E+16	2.7E+16	3.5E+16	4.4E+16	4.9E+16	6.0E+16	6.3E+16	7.4E+16	1.1E+17
0.5	6.3E+12	1.5E+16	3.0E+16	4.4E+16	5.8E+16	7.2E+16	8.2E+16	1.0E+17	1.0E+17	1.2E+17	1.7E+17
0.6	3.2E+14	1.4E+16	3.5E+16	5.1E+16	6.7E+16	8.3E+16	9.4E+16	1.1E+17	1.2E+17	1.4E+17	2.0E+17
0.8	2.1E+14	1.3E+16	7.1E+16	1.0E+17	1.4E+17	1.7E+17	1.9E+17	2.3E+17	2.4E+17	2.8E+17	3.8E+17
1.0	5.9E+12	8.2E+15	2.6E+16	3.8E+16	4.9E+16	6.1E+16	6.9E+16	8.4E+16	8.8E+16	1.0E+17	1.4E+17
1.5	6.4E+12	9.0E+15	2.1E+16	3.1E+16	4.1E+16	5.0E+16	5.7E+16	7.0E+16	7.3E+16	8.5E+16	1.2E+17
2.0	0.0E+00	3.8E+15	1.2E+16	1.7E+16	2.3E+16	2.8E+16	3.2E+16	3.9E+16	4.0E+16	4.8E+16	7.1E+16
3.0	0.0E+00	3.2E+13	7.9E+14	1.8E+15	2.3E+15	2.9E+15	3.2E+15	3.9E+15	4.1E+15	5.0E+15	7.4E+15
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	0.0E+00	1.7E+16	7.4E+17	3.0E+18	6.5E+18	1.1E+19	1.5E+19	2.3E+19	2.6E+19	3.9E+19	8.7E+19

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 2 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	0.2	0.3	0.4	0.5	0.5083	0.6	0.7	0.8	0.9	1	1.1
0.015	2.3E+16	3.4E+16	4.5E+16	5.5E+16	5.6E+16	1.3E+17	2.1E+17	2.9E+17	3.7E+17	4.5E+17	5.2E+17
0.02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+15	1.9E+15	2.7E+15	3.4E+15	4.0E+15	4.6E+15
0.03	1.2E+17	1.7E+17	2.3E+17	2.9E+17	2.9E+17	6.9E+17	1.1E+18	1.5E+18	1.9E+18	2.4E+18	2.8E+18
0.04	4.1E+15	6.2E+15	8.2E+15	1.0E+16	1.0E+16	2.5E+16	4.0E+16	5.5E+16	7.0E+16	8.5E+16	1.0E+17
0.05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.4E+15	6.4E+15	9.0E+15	1.1E+16	1.4E+16	1.6E+16
0.06	6.7E+14	9.3E+14	1.2E+15	1.4E+15	1.4E+15	2.0E+15	2.6E+15	3.1E+15	3.5E+15	4.0E+15	4.4E+15
0.08	8.2E+16	1.2E+17	1.7E+17	2.1E+17	2.1E+17	5.0E+17	8.0E+17	1.1E+18	1.4E+18	1.7E+18	2.0E+18
0.1	2.2E+14	3.2E+14	4.1E+14	5.0E+14	5.1E+14	4.5E+15	8.1E+15	1.1E+16	1.4E+16	1.7E+16	1.9E+16
0.15	3.8E+16	5.5E+16	7.0E+16	8.5E+16	8.6E+16	1.9E+17	3.0E+17	4.0E+17	4.9E+17	5.9E+17	6.7E+17
0.2	9.3E+16	1.4E+17	1.9E+17	2.3E+17	2.3E+17	5.6E+17	9.0E+17	1.2E+18	1.6E+18	1.9E+18	2.2E+18
0.3	2.5E+16	3.6E+16	4.5E+16	5.4E+16	5.4E+16	9.4E+16	1.3E+17	1.7E+17	2.0E+17	2.3E+17	2.6E+17
0.4	1.4E+17	1.9E+17	2.4E+17	2.8E+17	2.8E+17	4.8E+17	6.7E+17	8.4E+17	9.9E+17	1.1E+18	1.3E+18
0.5	2.2E+17	3.0E+17	3.8E+17	4.4E+17	4.5E+17	7.0E+17	9.2E+17	1.1E+18	1.3E+18	1.5E+18	1.6E+18
0.6	2.5E+17	3.4E+17	4.1E+17	4.8E+17	4.9E+17	7.4E+17	9.8E+17	1.2E+18	1.3E+18	1.5E+18	1.7E+18
0.8	4.8E+17	6.4E+17	7.6E+17	8.7E+17	8.8E+17	1.3E+18	1.7E+18	2.0E+18	2.3E+18	2.5E+18	2.7E+18
1.0	1.8E+17	2.4E+17	3.0E+17	3.4E+17	3.5E+17	5.4E+17	7.1E+17	8.5E+17	9.8E+17	1.1E+18	1.2E+18
1.5	1.5E+17	2.1E+17	2.6E+17	3.1E+17	3.1E+17	5.2E+17	7.1E+17	8.8E+17	1.0E+18	1.2E+18	1.3E+18
2.0	9.2E+16	1.3E+17	1.7E+17	2.0E+17	2.1E+17	4.2E+17	6.3E+17	8.4E+17	1.0E+18	1.2E+18	1.4E+18
3.0	9.8E+15	1.4E+16	1.8E+16	2.1E+16	2.2E+16	4.8E+16	7.3E+16	9.6E+16	1.2E+17	1.3E+17	1.5E+17
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+12	3.1E+12	6.5E+12	9.0E+12
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	1.6E+20	3.3E+20	5.8E+20	8.9E+20	9.2E+20	1.3E+21	1.9E+21	2.9E+21	4.2E+21	5.7E+21	7.5E+21

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 3 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8083	1.9	2	2.1
0.015	5.9E+17	6.6E+17	7.3E+17	8.0E+17	8.7E+17	9.3E+17	1.0E+18	1.0E+18	9.9E+17	9.8E+17	9.7E+17
0.02	5.2E+15	5.7E+15	6.2E+15	6.7E+15	7.1E+15	7.6E+15	8.0E+15	8.1E+15	7.4E+15	7.0E+15	6.6E+15
0.03	3.2E+18	3.6E+18	4.0E+18	4.4E+18	4.8E+18	5.2E+18	5.6E+18	5.6E+18	5.6E+18	5.6E+18	5.6E+18
0.04	1.1E+17	1.3E+17	1.4E+17	1.6E+17	1.7E+17	1.9E+17	2.0E+17	2.1E+17	2.0E+17	2.0E+17	2.0E+17
0.05	1.7E+16	1.9E+16	2.1E+16	2.2E+16	2.4E+16	2.6E+16	2.7E+16	2.7E+16	2.5E+16	2.3E+16	2.2E+16
0.06	4.8E+15	5.2E+15	5.5E+15	5.9E+15	6.2E+15	6.5E+15	6.8E+15	6.9E+15	6.4E+15	6.0E+15	5.7E+15
0.08	2.3E+18	2.6E+18	2.9E+18	3.2E+18	3.5E+18	3.9E+18	4.2E+18	4.2E+18	4.2E+18	4.2E+18	4.2E+18
0.1	2.2E+16	2.4E+16	2.6E+16	2.8E+16	3.0E+16	3.2E+16	3.4E+16	3.4E+16	3.1E+16	3.0E+16	2.8E+16
0.15	7.6E+17	8.4E+17	9.2E+17	1.0E+18	1.1E+18	1.1E+18	1.2E+18	1.2E+18	1.2E+18	1.2E+18	1.1E+18
0.2	2.5E+18	2.8E+18	3.2E+18	3.5E+18	3.8E+18	4.1E+18	4.4E+18	4.4E+18	4.3E+18	4.3E+18	4.2E+18
0.3	2.9E+17	3.2E+17	3.4E+17	3.7E+17	3.9E+17	4.1E+17	4.4E+17	4.4E+17	4.2E+17	4.0E+17	3.9E+17
0.4	1.4E+18	1.5E+18	1.6E+18	1.7E+18	1.7E+18	1.8E+18	1.9E+18	1.9E+18	1.8E+18	1.7E+18	1.6E+18
0.5	1.8E+18	1.9E+18	2.0E+18	2.1E+18	2.3E+18	2.4E+18	2.5E+18	2.5E+18	2.3E+18	2.2E+18	2.1E+18
0.6	1.8E+18	1.9E+18	2.0E+18	2.1E+18	2.2E+18	2.3E+18	2.4E+18	2.4E+18	2.2E+18	2.0E+18	1.9E+18
0.8	2.9E+18	3.0E+18	3.1E+18	3.3E+18	3.3E+18	3.4E+18	3.5E+18	3.5E+18	3.2E+18	3.0E+18	2.7E+18
1.0	1.3E+18	1.4E+18	1.4E+18	1.5E+18	1.6E+18	1.6E+18	1.7E+18	1.7E+18	1.5E+18	1.4E+18	1.4E+18
1.5	1.4E+18	1.5E+18	1.6E+18	1.7E+18	1.8E+18	1.9E+18	2.0E+18	2.0E+18	1.9E+18	1.8E+18	1.7E+18
2.0	1.5E+18	1.7E+18	1.8E+18	1.9E+18	2.1E+18	2.2E+18	2.3E+18	2.3E+18	2.2E+18	2.2E+18	2.1E+18
3.0	1.6E+17	1.8E+17	1.9E+17	2.0E+17	2.0E+17	2.1E+17	2.2E+17	2.2E+17	2.1E+17	2.0E+17	1.9E+17
4.0	9.7E+12	1.0E+13	1.1E+13	1.1E+13	1.1E+13	1.1E+13	1.2E+13	1.2E+13	1.0E+13	9.2E+12	8.3E+12
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	9.5E+21	1.2E+22	1.4E+22	1.7E+22	1.9E+22	2.2E+22	2.5E+22	2.6E+22	2.9E+22	3.2E+22	3.5E+22

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 4 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.2	3.23
0.015	9.6E+17	9.5E+17	9.4E+17	9.3E+17	9.2E+17	9.2E+17	9.1E+17	9.0E+17	8.9E+17	8.8E+17	8.8E+17
0.02	6.3E+15	6.1E+15	5.9E+15	5.7E+15	5.5E+15	5.4E+15	5.3E+15	5.2E+15	5.1E+15	5.0E+15	5.0E+15
0.03	5.6E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18	5.5E+18
0.04	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17
0.05	2.1E+16	2.0E+16	2.0E+16	1.9E+16	1.9E+16	1.8E+16	1.8E+16	1.8E+16	1.7E+16	1.7E+16	1.7E+16
0.06	5.5E+15	5.3E+15	5.2E+15	5.0E+15	4.9E+15	4.8E+15	4.7E+15	4.7E+15	4.6E+15	4.5E+15	4.5E+15
0.08	4.2E+18	4.2E+18	4.2E+18	4.2E+18	4.2E+18	4.2E+18	4.2E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18
0.1	2.7E+16	2.6E+16	2.5E+16	2.5E+16	2.4E+16	2.3E+16	2.3E+16	2.3E+16	2.2E+16	2.1E+16	2.1E+16
0.15	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.0E+18	1.0E+18	1.0E+18	9.9E+17	9.7E+17	9.4E+17	9.4E+17
0.2	4.2E+18	4.1E+18	4.1E+18	4.0E+18	4.0E+18	3.9E+18	3.9E+18	3.9E+18	3.8E+18	3.7E+18	3.7E+18
0.3	3.8E+17	3.7E+17	3.6E+17	3.5E+17	3.4E+17	3.3E+17	3.3E+17	3.2E+17	3.2E+17	3.1E+17	3.0E+17
0.4	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18	1.2E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18
0.5	2.0E+18	1.9E+18	1.8E+18	1.8E+18	1.7E+18	1.7E+18	1.7E+18	1.6E+18	1.6E+18	1.5E+18	1.5E+18
0.6	1.8E+18	1.7E+18	1.6E+18	1.6E+18	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18	1.2E+18	1.2E+18
0.8	2.6E+18	2.4E+18	2.3E+18	2.2E+18	2.1E+18	2.0E+18	1.9E+18	1.8E+18	1.7E+18	1.6E+18	1.6E+18
1.0	1.3E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.0E+18	1.0E+18	9.7E+17	9.4E+17	8.9E+17	8.9E+17
1.5	1.6E+18	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18	1.2E+18	1.2E+18	1.2E+18
2.0	2.0E+18	2.0E+18	1.9E+18	1.9E+18	1.8E+18	1.8E+18	1.7E+18	1.7E+18	1.7E+18	1.6E+18	1.6E+18
3.0	1.8E+17	1.7E+17	1.6E+17	1.5E+17	1.4E+17	1.4E+17	1.3E+17	1.2E+17	1.2E+17	1.1E+17	1.1E+17
4.0	7.6E+12	7.0E+12	6.5E+12	6.0E+12	5.6E+12	5.2E+12	4.9E+12	4.6E+12	4.4E+12	3.9E+12	3.8E+12
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	3.8E+22	4.0E+22	4.3E+22	4.6E+22	4.8E+22	5.1E+22	5.3E+22	5.6E+22	5.8E+22	6.3E+22	6.3E+22

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 5 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.5	6
0.015	8.7E+17	8.6E+17	8.4E+17	8.3E+17	8.2E+17	8.1E+17	8.0E+17	7.9E+17	7.8E+17	7.6E+17	7.4E+17
0.02	5.0E+15	4.9E+15	4.9E+15	4.9E+15	4.9E+15	4.8E+15	4.8E+15	4.8E+15	4.8E+15	4.7E+15	4.7E+15
0.03	5.5E+18	5.4E+18	5.4E+18	5.4E+18	5.4E+18	5.4E+18	5.4E+18	5.4E+18	5.4E+18	5.3E+18	5.3E+18
0.04	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17	2.0E+17
0.05	1.7E+16	1.7E+16	1.7E+16	1.7E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16
0.06	4.5E+15	4.5E+15	4.5E+15	4.4E+15	4.4E+15	4.4E+15	4.4E+15	4.4E+15	4.4E+15	4.3E+15	4.3E+15
0.08	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18	4.1E+18
0.1	2.1E+16	2.1E+16	2.1E+16	2.0E+16	2.0E+16	2.0E+16	1.9E+16	1.9E+16	1.9E+16	1.8E+16	1.8E+16
0.15	9.1E+17	8.8E+17	8.5E+17	8.3E+17	8.0E+17	7.8E+17	7.5E+17	7.3E+17	7.1E+17	6.5E+17	6.0E+17
0.2	3.7E+18	3.6E+18	3.5E+18	3.5E+18	3.4E+18	3.3E+18	3.3E+18	3.2E+18	3.2E+18	3.0E+18	2.9E+18
0.3	3.0E+17	2.9E+17	2.8E+17	2.8E+17	2.7E+17	2.7E+17	2.6E+17	2.5E+17	2.5E+17	2.4E+17	2.2E+17
0.4	1.1E+18	1.0E+18	9.9E+17	9.6E+17	9.3E+17	9.0E+17	8.8E+17	8.5E+17	8.4E+17	7.9E+17	7.6E+17
0.5	1.5E+18	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.4E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18	1.3E+18
0.6	1.2E+18	1.1E+18	1.1E+18	1.0E+18	9.9E+17	9.5E+17	9.2E+17	8.9E+17	8.6E+17	7.9E+17	7.4E+17
0.8	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.0E+18	9.4E+17	8.6E+17
1.0	8.6E+17	8.3E+17	7.9E+17	7.7E+17	7.4E+17	7.1E+17	6.9E+17	6.7E+17	6.5E+17	6.0E+17	5.6E+17
1.5	1.1E+18	1.1E+18	1.1E+18	1.0E+18	9.9E+17	9.5E+17	9.2E+17	8.9E+17	8.6E+17	7.9E+17	7.3E+17
2.0	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.0E+18	9.1E+17	8.1E+17
3.0	9.7E+16	8.8E+16	8.0E+16	7.3E+16	6.6E+16	6.0E+16	5.5E+16	5.0E+16	4.5E+16	3.6E+16	2.9E+16
4.0	3.5E+12	3.2E+12	2.9E+12	2.7E+12	2.4E+12	2.2E+12	2.0E+12	1.8E+12	1.7E+12	1.3E+12	1.1E+12
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	6.7E+22	7.1E+22	7.6E+22	8.0E+22	8.4E+22	8.7E+22	9.1E+22	9.5E+22	9.8E+22	1.1E+23	1.2E+23

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 6 of 11)

Gamma Ray Energy （MeV）	Source Strength at Time after Release (MeV)										
	6.5	7	7.5	8	8.8	9	9.5	10	11	12	13
0.015	7.3E+17	7.1E+17	7.0E+17	6.9E+17	6.7E+17	6.6E+17	6.5E+17	6.4E+17	6.3E+17	6.2E+17	6.0E+17
0.02	4.6E+15	4.6E+15	4.5E+15	4.5E+15	4.4E+15	4.4E+15	4.4E+15	4.4E+15	4.3E+15	4.3E+15	4.2E+15
0.03	5.3E+18	5.3E+18	5.2E+18	5.2E+18	5.2E+18	5.2E+18	5.2E+18	5.1E+18	5.1E+18	5.1E+18	5.0E+18
0.04	2.0E+17	2.0E+17	2.0E+17	1.9E+17	1.9E+17	1.9E+17	1.9E+17	1.9E+17	1.9E+17	1.9E+17	1.9E+17
0.05	1.6E+16	1.6E+16	1.6E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16
0.06	4.3E+15	4.3E+15	4.3E+15	4.2E+15	4.2E+15	4.2E+15	4.2E+15	4.2E+15	4.2E+15	4.2E+15	4.1E+15
0.08	4.1E+18	4.1E+18	4.0E+18	4.0E+18	4.0E+18	4.0E+18	4.0E+18	4.0E+18	4.0E+18	3.9E+18	3.9E+18
0.1	1.8E+16	1.7E+16	1.7E+16	1.7E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.5E+16	1.5E+16	1.5E+16
0.15	5.6E+17	5.2E+17	4.8E+17	4.5E+17	3.9E+17	3.8E+17	3.6E+17	3.3E+17	2.9E+17	2.5E+17	2.1E+17
0.2	2.8E+18	2.6E+18	2.5E+18	2.4E+18	2.3E+18	2.2E+18	2.1E+18	2.1E+18	1.9E+18	1.8E+18	1.6E+18
0.3	2.1E+17	2.0E+17	1.9E+17	1.9E+17	1.7E+17	1.7E+17	1.6E+17	1.6E+17	1.5E+17	1.4E+17	1.3E+17
0.4	7.3E+17	7.1E+17	6.9E+17	6.8E+17	6.6E+17	6.5E+17	6.4E+17	6.4E+17	6.2E+17	6.1E+17	6.1E+17
0.5	1.2E+18	1.2E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.0E+18	9.8E+17	9.4E+17
0.6	6.9E+17	6.5E+17	6.2E+17	5.9E+17	5.4E+17	5.4E+17	5.2E+17	5.0E+17	4.7E+17	4.5E+17	4.3E+17
0.8	7.9E+17	7.4E+17	6.9E+17	6.5E+17	5.9E+17	5.8E+17	5.5E+17	5.3E+17	4.9E+17	4.6E+17	4.3E+17
1.0	5.2E+17	4.9E+17	4.6E+17	4.3E+17	3.9E+17	3.9E+17	3.7E+17	3.5E+17	3.1E+17	2.9E+17	2.6E+17
1.5	6.7E+17	6.3E+17	5.8E+17	5.4E+17	4.9E+17	4.7E+17	4.4E+17	4.2E+17	3.7E+17	3.3E+17	2.9E+17
2.0	7.2E+17	6.4E+17	5.7E+17	5.1E+17	4.3E+17	4.1E+17	3.7E+17	3.3E+17	2.6E+17	2.1E+17	1.7E+17
3.0	2.3E+16	1.9E+16	1.5E+16	1.3E+16	9.3E+15	8.6E+15	7.2E+15	6.1E+15	4.5E+15	3.3E+15	2.6E+15
4.0	8.4E+11	6.7E+11	5.4E+11	4.3E+11	3.0E+11	2.7E+11	2.2E+11	1.7E+11	1.1E+11	7.0E+10	4.5E+10
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	1.2E+23	1.3E+23	1.4E+23	1.4E+23	1.6E+23	1.6E+23	1.6E+23	1.7E+23	1.8E+23	1.9E+23	2.1E+23

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 7 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	14	15	16	17	18	19	20	21	22	23	24
0.015	6.0E+17	5.9E+17	5.8E+17	5.7E+17	5.7E+17	5.6E+17	5.6E+17	5.5E+17	5.5E+17	5.4E+17	5.4E+17
0.02	4.2E+15	4.1E+15	4.1E+15	4.0E+15	4.0E+15	3.9E+15	3.9E+15	3.8E+15	3.8E+15	3.7E+15	3.7E+15
0.03	5.0E+18	5.0E+18	4.9E+18	4.9E+18	4.9E+18	4.8E+18	4.8E+18	4.8E+18	4.8E+18	4.7E+18	4.7E+18
0.04	1.9E+17	1.9E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17
0.05	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.3E+16	1.3E+16	1.3E+16
0.06	4.1E+15	4.1E+15	4.1E+15	4.1E+15	4.1E+15	4.1E+15	4.0E+15	4.0E+15	4.0E+15	4.0E+15	4.0E+15
0.08	3.9E+18	3.9E+18	3.9E+18	3.8E+18	3.8E+18	3.8E+18	3.8E+18	3.8E+18	3.7E+18	3.7E+18	3.7E+18
0.1	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.2E+16
0.15	1.9E+17	1.6E+17	1.4E+17	1.2E+17	1.1E+17	9.7E+16	8.6E+16	7.7E+16	6.9E+16	6.2E+16	5.6E+16
0.2	1.5E+18	1.4E+18	1.3E+18	1.2E+18	1.1E+18	1.0E+18	9.8E+17	9.1E+17	8.5E+17	7.9E+17	7.4E+17
0.3	1.2E+17	1.2E+17	1.1E+17	1.1E+17	1.0E+17	1.0E+17	9.8E+16	9.5E+16	9.3E+16	9.1E+16	8.9E+16
0.4	6.0E+17	5.9E+17	5.9E+17	5.8E+17	5.8E+17	5.7E+17	5.7E+17	5.6E+17	5.6E+17	5.6E+17	5.5E+17
0.5	9.1E+17	8.8E+17	8.5E+17	8.2E+17	8.0E+17	7.7E+17	7.5E+17	7.2E+17	7.0E+17	6.8E+17	6.6E+17
0.6	4.1E+17	4.0E+17	3.9E+17	3.8E+17	3.7E+17	3.7E+17	3.6E+17	3.6E+17	3.5E+17	3.5E+17	3.4E+17
0.8	4.1E+17	3.9E+17	3.8E+17	3.7E+17	3.6E+17	3.5E+17	3.4E+17	3.4E+17	3.3E+17	3.2E+17	3.2E+17
1.0	2.4E+17	2.2E+17	2.1E+17	1.9E+17	1.8E+17	1.7E+17	1.6E+17	1.5E+17	1.4E+17	1.3E+17	1.3E+17
1.5	2.6E+17	2.4E+17	2.2E+17	2.0E+17	1.8E+17	1.7E+17	1.6E+17	1.4E+17	1.3E+17	1.3E+17	1.2E+17
2.0	1.4E+17	1.2E+17	9.5E+16	7.9E+16	6.6E+16	5.5E+16	4.7E+16	4.0E+16	3.4E+16	2.9E+16	2.5E+16
3.0	2.1E+15	1.7E+15	1.4E+15	1.3E+15	1.1E+15	1.0E+15	9.6E+14	9.1E+14	8.8E+14	8.6E+14	8.5E+14
4.0	2.9E+10	1.8E+10	1.2E+10	7.4E+09	4.7E+09	3.0E+09	1.9E+09	1.2E+09	7.8E+08	5.0E+08	3.2E+08
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	2.2E+23	2.3E+23	2.4E+23	2.5E+23	2.5E+23	2.6E+23	2.7E+23	2.8E+23	2.9E+23	3.0E+23	3.1E+23

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 8 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	26	28	30	35	40	48	50	60	70	80	96
0.015	5.3E+17	5.2E+17	5.2E+17	5.0E+17	4.9E+17	4.6E+17	4.6E+17	4.3E+17	4.1E+17	3.9E+17	3.6E+17
0.02	3.6E+15	3.5E+15	3.4E+15	3.2E+15	3.1E+15	2.8E+15	2.7E+15	2.4E+15	2.2E+15	1.9E+15	1.6E+15
0.03	4.6E+18	4.6E+18	4.5E+18	4.4E+18	4.3E+18	4.1E+18	4.0E+18	3.8E+18	3.6E+18	3.4E+18	3.1E+18
0.04	1.7E+17	1.7E+17	1.7E+17	1.6E+17	1.6E+17	1.5E+17	1.5E+17	1.4E+17	1.4E+17	1.3E+17	1.2E+17
0.05	1.3E+16	1.3E+16	1.3E+16	1.2E+16	1.1E+16	1.1E+16	1.1E+16	9.6E+15	8.8E+15	8.1E+15	7.0E+15
0.06	4.0E+15	4.0E+15	3.9E+15	3.9E+15	3.8E+15	3.7E+15	3.7E+15	3.6E+15	3.5E+15	3.4E+15	3.3E+15
0.08	3.7E+18	3.6E+18	3.6E+18	3.5E+18	3.4E+18	3.2E+18	3.2E+18	3.0E+18	2.9E+18	2.7E+18	2.5E+18
0.1	1.2E+16	1.2E+16	1.2E+16	1.1E+16	1.0E+16	9.4E+15	9.2E+15	8.2E+15	7.4E+15	6.6E+15	5.6E+15
0.15	4.7E+16	4.0E+16	3.4E+16	2.6E+16	2.2E+16	1.9E+16	1.9E+16	1.7E+16	1.6E+16	1.5E+16	1.4E+16
0.2	6.5E+17	5.7E+17	5.0E+17	3.7E+17	2.7E+17	1.8E+17	1.6E+17	1.1E+17	8.1E+16	6.6E+16	5.2E+16
0.3	8.6E+16	8.4E+16	8.2E+16	7.8E+16	7.6E+16	7.3E+16	7.2E+16	7.0E+16	6.8E+16	6.6E+16	6.3E+16
0.4	5.5E+17	5.4E+17	5.4E+17	5.3E+17	5.1E+17	5.0E+17	4.9E+17	4.8E+17	4.6E+17	4.4E+17	4.2E+17
0.5	6.2E+17	5.8E+17	5.5E+17	4.7E+17	4.1E+17	3.2E+17	3.1E+17	2.3E+17	1.8E+17	1.5E+17	1.1E+17
0.6	3.4E+17	3.3E+17	3.3E+17	3.2E+17	3.1E+17	2.9E+17	2.9E+17	2.8E+17	2.7E+17	2.6E+17	2.4E+17
0.8	3.1E+17	3.1E+17	3.0E+17	2.9E+17	2.7E+17	2.6E+17	2.6E+17	2.4E+17	2.3E+17	2.2E+17	2.1E+17
1.0	1.2E+17	1.1E+17	1.0E+17	8.7E+16	7.7E+16	6.8E+16	6.6E+16	6.0E+16	5.5E+16	5.2E+16	4.8E+16
1.5	1.1E+17	9.5E+16	8.7E+16	7.3E+16	6.5E+16	5.8E+16	5.7E+16	5.4E+16	5.4E+16	5.3E+16	5.3E+16
2.0	1.9E+16	1.5E+16	1.3E+16	8.2E+15	6.0E+15	4.3E+15	4.0E+15	3.3E+15	2.8E+15	2.6E+15	2.3E+15
3.0	8.5E+14	8.7E+14	8.9E+14	9.7E+14	1.0E+15	1.2E+15	1.2E+15	1.3E+15	1.4E+15	1.5E+15	1.5E+15
4.0	1.3E+08	5.3E+07	2.1E+07	2.3E+06	2.4E+05	6.5E+03	2.7E+03	3.0E+01	3.3E-01	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	3.2E+23	3.4E+23	3.5E+23	3.9E+23	4.2E+23	4.7E+23	4.8E+23	5.4E+23	5.9E+23	6.4E+23	7.1E+23

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 9 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	100	120	150	160	170	180	200	240	264	288	300
0.015	3.5E+17	3.1E+17	2.7E+17	2.5E+17	2.4E+17	2.3E+17	2.0E+17	1.6E+17	1.4E+17	1.3E+17	1.2E+17
0.02	1.5E+15	1.2E+15	8.6E+14	7.7E+14	6.9E+14	6.1E+14	4.9E+14	3.2E+14	2.5E+14	2.0E+14	1.8E+14
0.03	3.1E+18	2.7E+18	2.3E+18	2.2E+18	2.1E+18	2.0E+18	1.8E+18	1.4E+18	1.2E+18	1.1E+18	1.0E+18
0.04	1.2E+17	1.0E+17	8.8E+16	8.3E+16	7.9E+16	7.4E+16	6.7E+16	5.4E+16	4.7E+16	4.2E+16	3.9E+16
0.05	6.8E+15	5.7E+15	4.3E+15	4.0E+15	3.6E+15	3.3E+15	2.8E+15	2.0E+15	1.6E+15	1.3E+15	1.2E+15
0.06	3.2E+15	3.1E+15	2.9E+15	2.8E+15	2.7E+15	2.7E+15	2.6E+15	2.3E+15	2.2E+15	2.1E+15	2.0E+15
0.08	2.4E+18	2.2E+18	1.9E+18	1.8E+18	1.7E+18	1.6E+18	1.4E+18	1.1E+18	9.9E+17	8.7E+17	8.1E+17
0.1	5.3E+15	4.3E+15	3.1E+15	2.8E+15	2.6E+15	2.3E+15	1.9E+15	1.3E+15	1.0E+15	8.5E+14	7.6E+14
0.15	1.4E+16	1.3E+16	1.1E+16	1.1E+16	1.0E+16	9.8E+15	9.1E+15	7.8E+15	7.2E+15	6.7E+15	6.4E+15
0.2	5.0E+16	4.1E+16	3.2E+16	2.9E+16	2.7E+16	2.5E+16	2.1E+16	1.6E+16	1.3E+16	1.1E+16	1.0E+16
0.3	6.2E+16	5.8E+16	5.3E+16	5.2E+16	5.0E+16	4.9E+16	4.6E+16	4.1E+16	3.8E+16	3.6E+16	3.4E+16
0.4	4.1E+17	3.8E+17	3.4E+17	3.3E+17	3.2E+17	3.1E+17	2.9E+17	2.5E+17	2.3E+17	2.1E+17	2.0E+17
0.5	9.9E+16	7.4E+16	5.6E+16	5.2E+16	4.9E+16	4.7E+16	4.3E+16	3.8E+16	3.6E+16	3.3E+16	3.3E+16
0.6	2.4E+17	2.3E+17	2.1E+17	2.0E+17	2.0E+17	2.0E+17	1.9E+17	1.8E+17	1.7E+17	1.7E+17	1.7E+17
0.8	2.1E+17	2.0E+17	1.8E+17	1.8E+17	1.8E+17	1.7E+17	1.7E+17	1.6E+17	1.5E+17	1.5E+17	1.5E+17
1.0	4.7E+16	4.3E+16	3.9E+16	3.7E+16	3.6E+16	3.5E+16	3.3E+16	2.9E+16	2.7E+16	2.6E+16	2.5E+16
1.5	5.3E+16	5.2E+16	5.0E+16	4.9E+16	4.8E+16	4.8E+16	4.6E+16	4.2E+16	4.0E+16	3.8E+16	3.7E+16
2.0	2.2E+15	1.9E+15	1.5E+15	1.4E+15	1.3E+15	1.2E+15	1.1E+15	8.5E+14	7.3E+14	6.4E+14	6.0E+14
3.0	1.5E+15	1.6E+15	1.6E+15	1.6E+15	1.6E+15	1.5E+15	1.5E+15	1.4E+15	1.3E+15	1.3E+15	1.2E+15
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	7.3E+23	8.1E+23	9.2E+23	9.5E+23	9.8E+23	1.0E+24	1.1E+24	1.2E+24	1.2E+24	1.3E+24	1.3E+24

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 10 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	312	336	360	400	480	500	600	700	720	960	1200
0.015	1.1E+17	9.8E+16	8.6E+16	6.9E+16	4.6E+16	4.1E+16	2.5E+16	1.5E+16	1.1E+16	2.9E+15	7.9E+14
0.02	1.6E+14	1.3E+14	1.1E+14	8.2E+13	5.4E+13	5.0E+13	3.9E+13	3.4E+13	0.0E+00	0.0E+00	0.0E+00
0.03	9.6E+17	8.4E+17	7.4E+17	5.9E+17	3.8E+17	3.4E+17	2.0E+17	1.2E+17	9.9E+16	2.6E+16	7.1E+15
0.04	3.7E+16	3.2E+16	2.8E+16	2.3E+16	1.5E+16	1.3E+16	8.1E+15	4.9E+15	3.7E+15	9.9E+14	2.6E+14
0.05	1.0E+15	8.5E+14	6.9E+14	4.9E+14	2.5E+14	2.1E+14	9.5E+13	4.7E+13	0.0E+00	0.0E+00	0.0E+00
0.06	2.0E+15	1.9E+15	1.8E+15	1.6E+15	1.4E+15	1.3E+15	1.0E+15	8.4E+14	0.0E+00	0.0E+00	0.0E+00
0.08	7.6E+17	6.7E+17	5.9E+17	4.7E+17	3.0E+17	2.7E+17	1.6E+17	9.1E+16	8.0E+16	2.1E+16	5.7E+15
0.1	6.9E+14	5.7E+14	4.7E+14	3.5E+14	2.2E+14	2.0E+14	1.2E+14	8.9E+13	0.0E+00	0.0E+00	0.0E+00
0.15	6.2E+15	5.7E+15	5.4E+15	4.8E+15	3.9E+15	3.7E+15	2.9E+15	2.3E+15	1.3E+14	3.5E+13	9.4E+12
0.2	9.4E+15	8.0E+15	6.8E+15	5.4E+15	3.4E+15	3.1E+15	2.0E+15	1.4E+15	2.2E+13	9.1E+12	3.8E+12
0.3	3.3E+16	3.1E+16	2.9E+16	2.6E+16	2.1E+16	1.9E+16	1.5E+16	1.1E+16	5.3E+14	2.2E+14	9.3E+13
0.4	1.9E+17	1.8E+17	1.6E+17	1.4E+17	1.1E+17	9.8E+16	6.9E+16	4.8E+16	6.5E+15	2.8E+15	1.2E+15
0.5	3.2E+16	3.0E+16	2.8E+16	2.6E+16	2.2E+16	2.1E+16	1.8E+16	1.5E+16	3.0E+14	2.9E+14	2.8E+14
0.6	1.6E+17	1.6E+17	1.6E+17	1.5E+17	1.5E+17	1.5E+17	1.4E+17	1.4E+17	6.0E+14	2.5E+14	1.1E+14
0.8	1.4E+17	1.4E+17	1.4E+17	1.3E+17	1.3E+17	1.3E+17	1.2E+17	1.2E+17	1.4E+14	6.1E+13	2.6E+13
1.0	2.4E+16	2.3E+16	2.1E+16	2.0E+16	1.7E+16	1.6E+16	1.3E+16	1.1E+16	2.1E+05	7.0E+01	2.4E-02
1.5	3.6E+16	3.4E+16	3.3E+16	3.0E+16	2.6E+16	2.5E+16	2.0E+16	1.7E+16	2.1E+05	7.1E+01	2.4E-02
2.0	5.6E+14	4.9E+14	4.4E+14	3.6E+14	2.6E+14	2.4E+14	1.7E+14	1.3E+14	0.0E+00	0.0E+00	0.0E+00
3.0	1.2E+15	1.1E+15	1.1E+15	1.0E+15	8.3E+14	8.0E+14	6.3E+14	5.1E+14	0.0E+00	0.0E+00	0.0E+00
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	1.3E+24	1.3E+24	1.4E+24	1.4E+24	1.5E+24	1.5E+24	1.6E+24	1.7E+24	1.7E+24	1.8E+24	1.8E+24

Table E-4 Integrated gamma ray and beta source strengths in the CV after a LOCA (Sheet 11 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	1440	2160	2880	3600	4320	5040	5760	6480	7200	7920	8760
0.015	2.1E+14	5.4E+12	1.3E+12	1.2E+12	1.2E+12	1.2E+12	1.2E+12	1.1E+12	1.1E+12	1.1E+12	1.1E+12
0.02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.03	1.9E+15	3.8E+13	8.4E+11	2.5E+10	1.2E+09	7.6E+07	5.5E+06	4.1E+05	3.1E+04	2.3E+03	1.1E+02
0.04	7.1E+13	1.3E+12	2.5E+10	4.8E+08	9.2E+06	1.7E+05	3.3E+03	6.3E+01	1.2E+00	2.3E-02	0.0E+00
0.05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.08	1.5E+15	3.0E+13	6.3E+11	1.7E+10	7.0E+08	4.2E+07	2.9E+06	2.2E+05	1.6E+04	1.2E+03	6.0E+01
0.1	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.15	2.5E+12	4.7E+10	9.0E+08	1.7E+07	3.2E+05	6.1E+03	1.2E+02	2.2E+00	4.2E-02	8.0E-04	0.0E+00
0.2	1.6E+12	1.2E+11	9.1E+09	6.9E+08	5.2E+07	3.9E+06	2.9E+05	2.2E+04	1.7E+03	1.2E+02	6.1E+00
0.3	3.9E+13	2.9E+12	2.2E+11	1.7E+10	1.3E+09	9.4E+07	7.1E+06	5.4E+05	4.0E+04	3.0E+03	1.5E+02
0.4	4.9E+14	3.7E+13	2.8E+12	2.1E+11	1.6E+10	1.2E+09	8.9E+07	6.7E+06	5.1E+05	3.8E+04	1.9E+03
0.5	2.8E+14	2.7E+14	2.7E+14	2.7E+14	2.7E+14	2.7E+14	2.6E+14	2.6E+14	2.6E+14	2.6E+14	2.6E+14
0.6	4.5E+13	3.4E+12	2.6E+11	1.9E+10	1.5E+09	1.1E+08	8.2E+06	6.2E+05	4.7E+04	3.5E+03	1.7E+02
0.8	1.1E+13	8.2E+11	6.2E+10	4.6E+09	3.5E+08	2.6E+07	2.0E+06	1.5E+05	1.1E+04	8.5E+02	4.1E+01
1.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1.5	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
2.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
3.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beta	1.8E+24	1.8E+24	1.9E+24	1.9E+24	2.0E+24	2.0E+24	2.0E+24	2.1E+24	2.1E+24	2.2E+24	2.2E+24

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 1 of 11)

Gamma Ray Energy （MeV）	Source Strength at Time after Release (MeV)										
	0.01	0.02	0.03	0.04	0.05	0.06	0.0667	0.08	0.0834	0.1	0.15
0.015	4.8E+12	1.0E+14	1.9E+14	2.7E+14	3.5E+14	4.4E+14	4.9E+14	6.0E+14	6.3E+14	7.7E+14	1.2E+15
0.02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.03	4.5E+13	9.3E+14	1.7E+15	2.5E+15	3.3E+15	4.1E+15	4.6E+15	5.6E+15	5.9E+15	7.1E+15	1.1E+16
0.04	3.4E+11	1.6E+13	3.0E+13	4.4E+13	5.8E+13	7.2E+13	8.2E+13	1.0E+14	1.1E+14	1.3E+14	2.0E+14
0.05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
0.06	0.0E+00	5.0E+13	9.2E+13	1.4E+14	1.8E+14	2.2E+14	2.5E+14	3.1E+14	3.2E+14	3.9E+14	6.0E+14
0.08	2.3E+13	1.9E+14	3.5E+14	5.1E+14	6.7E+14	8.3E+14	9.4E+14	1.2E+15	1.2E+15	1.5E+15	2.3E+15
0.1	0.0E+00	2.6E+12	4.8E+12	7.0E+12	9.3E+12	1.1E+13	1.3E+13	1.6E+13	1.7E+13	2.0E+13	3.1E+13
0.15	0.0E+00	7.7E+14	1.4E+15	2.1E+15	2.7E+15	3.3E+15	3.7E+15	4.5E+15	4.7E+15	5.7E+15	8.5E+15
0.2	2.4E+12	7.6E+14	1.4E+15	2.1E+15	2.7E+15	3.3E+15	3.7E+15	4.6E+15	4.8E+15	5.8E+15	8.7E+15
0.3	5.8E+13	1.5E+15	2.8E+15	4.2E+15	5.5E+15	6.8E+15	7.6E+15	9.4E+15	9.8E+15	1.2E+16	1.8E+16
0.4	7.2E+14	7.8E+15	1.4E+16	2.1E+16	2.8E+16	3.4E+16	3.8E+16	4.7E+16	4.9E+16	6.0E+16	9.2E+16
0.5	6.3E+12	1.6E+16	3.0E+16	4.4E+16	5.8E+16	7.2E+16	8.1E+16	1.0E+17	1.0E+17	1.3E+17	2.0E+17
0.6	3.2E+14	1.9E+16	3.5E+16	5.1E+16	6.6E+16	8.2E+16	9.3E+16	1.1E+17	1.2E+17	1.4E+17	2.2E+17
0.8	2.1E+14	3.7E+16	6.9E+16	1.0E+17	1.3E+17	1.6E+17	1.8E+17	2.2E+17	2.3E+17	2.8E+17	4.2E+17
1.0	5.9E+12	1.4E+16	2.5E+16	3.7E+16	4.8E+16	5.9E+16	6.7E+16	8.1E+16	8.5E+16	1.0E+17	1.6E+17
1.5	6.4E+12	1.0E+16	1.9E+16	2.8E+16	3.7E+16	4.5E+16	5.1E+16	6.2E+16	6.5E+16	7.9E+16	1.2E+17
2.0	0.0E+00	2.7E+15	5.0E+15	7.3E+15	9.6E+15	1.2E+16	1.3E+16	1.6E+16	1.7E+16	2.1E+16	3.1E+16
3.0	0.0E+00	3.4E+13	6.2E+13	9.0E+13	1.2E+14	1.4E+14	1.6E+14	2.0E+14	2.1E+14	2.5E+14	3.7E+14
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 2 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	0.2	0.3	0.4	0.5	0.5083	0.6	0.7	0.8	0.9	1	1.1
0.015	1.6E+15	2.3E+15	3.1E+15	3.8E+15	3.8E+15	1.1E+16	1.9E+16	2.7E+16	3.4E+16	4.2E+16	4.9E+16
0.02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+15	2.4E+15	3.6E+15	4.9E+15	6.1E+15	7.3E+15
0.03	1.4E+16	2.1E+16	2.8E+16	3.5E+16	3.5E+16	7.4E+16	1.2E+17	1.6E+17	2.0E+17	2.4E+17	2.8E+17
0.04	2.7E+14	4.1E+14	5.5E+14	6.9E+14	7.0E+14	1.4E+15	2.2E+15	3.0E+15	3.7E+15	4.5E+15	5.2E+15
0.05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+15	8.0E+15	1.2E+16	1.6E+16	2.0E+16	2.5E+16
0.06	8.2E+14	1.2E+15	1.7E+15	2.1E+15	2.1E+15	3.0E+15	3.9E+15	4.9E+15	5.8E+15	6.7E+15	7.7E+15
0.08	3.1E+15	4.7E+15	6.3E+15	7.9E+15	8.0E+15	1.2E+16	1.6E+16	2.1E+16	2.5E+16	2.9E+16	3.3E+16
0.1	4.2E+13	6.4E+13	8.6E+13	1.1E+14	1.1E+14	4.0E+15	8.2E+15	1.2E+16	1.7E+16	2.1E+16	2.5E+16
0.15	1.1E+16	1.6E+16	2.0E+16	2.3E+16	2.4E+16	3.8E+16	5.2E+16	6.5E+16	7.6E+16	8.6E+16	9.5E+16
0.2	1.2E+16	1.7E+16	2.2E+16	2.6E+16	2.6E+16	6.3E+16	1.0E+17	1.4E+17	1.8E+17	2.1E+17	2.5E+17
0.3	2.5E+16	3.7E+16	5.0E+16	6.2E+16	6.3E+16	9.4E+16	1.3E+17	1.6E+17	1.9E+17	2.3E+17	2.6E+17
0.4	1.2E+17	1.8E+17	2.4E+17	3.0E+17	3.1E+17	4.5E+17	6.1E+17	7.6E+17	9.1E+17	1.1E+18	1.2E+18
0.5	2.6E+17	3.9E+17	5.2E+17	6.5E+17	6.6E+17	9.8E+17	1.3E+18	1.7E+18	2.0E+18	2.3E+18	2.7E+18
0.6	2.9E+17	4.3E+17	5.7E+17	6.9E+17	7.0E+17	1.0E+18	1.4E+18	1.7E+18	2.0E+18	2.3E+18	2.6E+18
0.8	5.5E+17	8.0E+17	1.0E+18	1.2E+18	1.2E+18	1.8E+18	2.3E+18	2.8E+18	3.2E+18	3.6E+18	3.9E+18
1.0	2.1E+17	3.1E+17	4.0E+17	4.8E+17	4.9E+17	7.1E+17	9.5E+17	1.2E+18	1.4E+18	1.6E+18	1.8E+18
1.5	1.6E+17	2.4E+17	3.2E+17	3.9E+17	4.0E+17	5.9E+17	8.0E+17	1.0E+18	1.2E+18	1.4E+18	1.6E+18
2.0	4.2E+16	6.1E+16	8.0E+16	9.7E+16	9.8E+16	1.4E+17	1.9E+17	2.3E+17	2.7E+17	3.1E+17	3.5E+17
3.0	4.8E+14	6.9E+14	8.6E+14	1.0E+15	1.0E+15	1.4E+15	1.8E+15	2.3E+15	2.6E+15	2.9E+15	3.1E+15
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.1E+12	1.0E+13	1.2E+13	1.4E+13
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 3 of 11)

Gamma Ray Energy （MeV）	Source Strength at Time after Release (MeV)										
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8083	1.9	2	2.1
0.015	5.7E+16	6.4E+16	7.2E+16	7.9E+16	8.6E+16	9.3E+16	1.0E+17	1.0E+17	1.0E+17	1.0E+17	1.0E+17
0.02	8.5E+15	9.8E+15	1.1E+16	1.2E+16	1.3E+16	1.5E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16
0.03	3.2E+17	3.5E+17	3.9E+17	4.3E+17	4.7E+17	5.0E+17	5.4E+17	5.4E+17	5.4E+17	5.4E+17	5.3E+17
0.04	5.9E+15	6.7E+15	7.4E+15	8.1E+15	8.8E+15	9.5E+15	1.0E+16	1.0E+16	1.0E+16	1.0E+16	1.0E+16
0.05	2.9E+16	3.3E+16	3.7E+16	4.1E+16	4.5E+16	4.9E+16	5.3E+16	5.4E+16	5.4E+16	5.4E+16	5.4E+16
0.06	8.6E+15	9.6E+15	1.0E+16	1.1E+16	1.2E+16	1.3E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16
0.08	3.8E+16	4.2E+16	4.6E+16	5.0E+16	5.5E+16	5.9E+16	6.3E+16	6.4E+16	6.4E+16	6.4E+16	6.4E+16
0.1	2.9E+16	3.3E+16	3.7E+16	4.1E+16	4.6E+16	5.0E+16	5.4E+16	5.4E+16	5.4E+16	5.4E+16	5.4E+16
0.15	1.0E+17	1.1E+17	1.2E+17	1.2E+17	1.3E+17	1.3E+17	1.4E+17	1.4E+17	1.3E+17	1.3E+17	1.2E+17
0.2	2.8E+17	3.2E+17	3.5E+17	3.8E+17	4.2E+17	4.5E+17	4.8E+17	4.8E+17	4.8E+17	4.8E+17	4.7E+17
0.3	2.9E+17	3.2E+17	3.5E+17	3.8E+17	4.1E+17	4.4E+17	4.7E+17	4.7E+17	4.7E+17	4.7E+17	4.6E+17
0.4	1.3E+18	1.5E+18	1.6E+18	1.7E+18	1.9E+18	2.0E+18	2.1E+18	2.2E+18	2.1E+18	2.1E+18	2.1E+18
0.5	3.0E+18	3.3E+18	3.6E+18	3.9E+18	4.2E+18	4.5E+18	4.8E+18	4.8E+18	4.8E+18	4.7E+18	4.7E+18
0.6	2.9E+18	3.1E+18	3.4E+18	3.6E+18	3.9E+18	4.1E+18	4.3E+18	4.4E+18	4.3E+18	4.2E+18	4.0E+18
0.8	4.2E+18	4.5E+18	4.8E+18	5.0E+18	5.3E+18	5.5E+18	5.7E+18	5.7E+18	5.5E+18	5.3E+18	5.1E+18
1.0	1.9E+18	2.1E+18	2.3E+18	2.4E+18	2.6E+18	2.7E+18	2.8E+18	2.8E+18	2.8E+18	2.7E+18	2.7E+18
1.5	1.7E+18	1.9E+18	2.1E+18	2.2E+18	2.4E+18	2.5E+18	2.7E+18	2.7E+18	2.6E+18	2.6E+18	2.5E+18
2.0	3.8E+17	4.2E+17	4.5E+17	4.8E+17	5.1E+17	5.4E+17	5.6E+17	5.7E+17	5.5E+17	5.4E+17	5.3E+17
3.0	3.3E+15	3.5E+15	3.6E+15	3.7E+15	3.8E+15	3.9E+15	4.0E+15	4.0E+15	3.8E+15	3.6E+15	3.4E+15
4.0	1.6E+13	1.7E+13	1.9E+13	2.0E+13	2.1E+13	2.2E+13	2.3E+13	2.3E+13	2.2E+13	2.1E+13	2.0E+13
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 4 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.2	3.23
0.015	1.0E+17	9.9E+16	9.9E+16	9.9E+16	9.8E+16	9.8E+16	9.8E+16	9.7E+16	9.7E+16	9.7E+16	9.7E+16
0.02	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16
0.03	5.3E+17	5.3E+17	5.3E+17	5.2E+17	5.2E+17	5.2E+17	5.2E+17	5.1E+17	5.1E+17	5.1E+17	5.1E+17
0.04	1.0E+16	1.0E+16	1.0E+16	1.0E+16	1.0E+16	9.9E+15	9.9E+15	9.9E+15	9.8E+15	9.8E+15	9.8E+15
0.05	5.4E+16	5.4E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16
0.06	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16
0.08	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16
0.1	5.4E+16	5.4E+16	5.4E+16	5.4E+16	5.4E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16
0.15	1.2E+17	1.1E+17	1.1E+17	1.1E+17	1.0E+17	1.0E+17	9.7E+16	9.5E+16	9.2E+16	8.7E+16	8.7E+16
0.2	4.7E+17	4.7E+17	4.6E+17	4.6E+17	4.6E+17	4.5E+17	4.5E+17	4.5E+17	4.5E+17	4.4E+17	4.4E+17
0.3	4.6E+17	4.6E+17	4.5E+17	4.5E+17	4.4E+17	4.4E+17	4.4E+17	4.4E+17	4.3E+17	4.3E+17	4.3E+17
0.4	2.1E+18	2.1E+18	2.1E+18	2.1E+18	2.1E+18	2.0E+18	2.0E+18	2.0E+18	2.0E+18	2.0E+18	2.0E+18
0.5	4.7E+18	4.6E+18	4.6E+18	4.5E+18	4.5E+18	4.5E+18	4.4E+18	4.4E+18	4.4E+18	4.3E+18	4.3E+18
0.6	3.9E+18	3.9E+18	3.8E+18	3.7E+18	3.6E+18	3.5E+18	3.4E+18	3.4E+18	3.3E+18	3.1E+18	3.1E+18
0.8	4.9E+18	4.7E+18	4.5E+18	4.4E+18	4.2E+18	4.1E+18	4.0E+18	3.9E+18	3.7E+18	3.5E+18	3.5E+18
1.0	2.6E+18	2.5E+18	2.5E+18	2.4E+18	2.4E+18	2.3E+18	2.3E+18	2.2E+18	2.2E+18	2.1E+18	2.1E+18
1.5	2.5E+18	2.5E+18	2.4E+18	2.4E+18	2.4E+18	2.3E+18	2.3E+18	2.3E+18	2.2E+18	2.2E+18	2.1E+18
2.0	5.2E+17	5.1E+17	5.0E+17	4.9E+17	4.8E+17	4.7E+17	4.6E+17	4.5E+17	4.5E+17	4.3E+17	4.3E+17
3.0	3.2E+15	3.1E+15	2.9E+15	2.8E+15	2.7E+15	2.5E+15	2.4E+15	2.3E+15	2.2E+15	2.1E+15	2.0E+15
4.0	1.9E+13	1.8E+13	1.7E+13	1.7E+13	1.6E+13	1.5E+13	1.5E+13	1.4E+13	1.3E+13	1.2E+13	1.2E+13
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 5 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.5	6
0.015	9.6E+16	9.6E+16	9.5E+16	9.5E+16	9.4E+16	9.4E+16	9.4E+16	9.3E+16	9.3E+16	9.2E+16	9.2E+16
0.02	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.6E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16
0.03	5.0E+17	5.0E+17	5.0E+17	4.9E+17	4.9E+17	4.9E+17	4.9E+17	4.8E+17	4.8E+17	4.8E+17	4.7E+17
0.04	9.7E+15	9.7E+15	9.7E+15	9.6E+15	9.6E+15	9.6E+15	9.5E+15	9.5E+15	9.5E+15	9.4E+15	9.4E+15
0.05	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.2E+16	5.2E+16	5.2E+16	5.2E+16	5.2E+16
0.06	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16
0.08	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16	6.3E+16
0.1	5.3E+16	5.3E+16	5.3E+16	5.3E+16	5.2E+16	5.2E+16	5.2E+16	5.2E+16	5.2E+16	5.2E+16	5.1E+16
0.15	8.3E+16	8.0E+16	7.7E+16	7.4E+16	7.2E+16	7.0E+16	6.8E+16	6.7E+16	6.5E+16	6.2E+16	6.0E+16
0.2	4.4E+17	4.4E+17	4.3E+17	4.3E+17	4.3E+17	4.2E+17	4.2E+17	4.2E+17	4.2E+17	4.1E+17	4.1E+17
0.3	4.2E+17	4.2E+17	4.1E+17	4.1E+17	4.0E+17	4.0E+17	3.9E+17	3.9E+17	3.8E+17	3.8E+17	3.7E+17
0.4	2.0E+18	2.0E+18	2.0E+18	2.0E+18	1.9E+18	1.9E+18	1.9E+18	1.9E+18	1.9E+18	1.9E+18	1.9E+18
0.5	4.3E+18	4.2E+18	4.2E+18	4.1E+18	4.1E+18	4.0E+18	4.0E+18	3.9E+18	3.9E+18	3.8E+18	3.7E+18
0.6	3.0E+18	2.9E+18	2.8E+18	2.7E+18	2.6E+18	2.5E+18	2.4E+18	2.3E+18	2.3E+18	2.1E+18	2.0E+18
0.8	3.3E+18	3.2E+18	3.0E+18	2.9E+18	2.8E+18	2.6E+18	2.5E+18	2.5E+18	2.4E+18	2.2E+18	2.0E+18
1.0	2.1E+18	2.0E+18	1.9E+18	1.9E+18	1.8E+18	1.8E+18	1.7E+18	1.7E+18	1.6E+18	1.5E+18	1.4E+18
1.5	2.1E+18	2.0E+18	2.0E+18	1.9E+18	1.9E+18	1.8E+18	1.8E+18	1.8E+18	1.7E+18	1.6E+18	1.5E+18
2.0	4.2E+17	4.0E+17	3.9E+17	3.8E+17	3.7E+17	3.6E+17	3.5E+17	3.4E+17	3.3E+17	3.1E+17	2.9E+17
3.0	1.9E+15	1.8E+15	1.7E+15	1.6E+15	1.5E+15	1.5E+15	1.4E+15	1.4E+15	1.3E+15	1.2E+15	1.2E+15
4.0	1.1E+13	1.0E+13	9.3E+12	8.5E+12	7.8E+12	7.1E+12	6.5E+12	5.9E+12	5.4E+12	4.3E+12	3.5E+12
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 6 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	6.5	7	7.5	8	8.8	9	9.5	10	11	12	13
0.015	9.1E+16	9.0E+16	9.0E+16	8.9E+16	8.8E+16	8.8E+16	8.8E+16	8.7E+16	8.6E+16	8.5E+16	8.5E+16
0.02	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.5E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16
0.03	4.7E+17	4.6E+17	4.6E+17	4.6E+17	4.5E+17	4.5E+17	4.5E+17	4.4E+17	4.4E+17	4.3E+17	4.3E+17
0.04	9.3E+15	9.3E+15	9.2E+15	9.2E+15	9.1E+15	9.1E+15	9.1E+15	9.1E+15	9.0E+15	9.0E+15	8.9E+15
0.05	5.2E+16	5.1E+16	5.1E+16	5.1E+16	5.1E+16	5.0E+16	5.0E+16	5.0E+16	5.0E+16	4.9E+16	4.9E+16
0.06	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16
0.08	6.2E+16	6.2E+16	6.2E+16	6.2E+16	6.2E+16	6.2E+16	6.2E+16	6.2E+16	6.1E+16	6.1E+16	6.1E+16
0.1	5.1E+16	5.1E+16	5.0E+16	5.0E+16	5.0E+16	4.9E+16	4.9E+16	4.9E+16	4.8E+16	4.8E+16	4.7E+16
0.15	5.9E+16	5.7E+16	5.6E+16	5.6E+16	5.5E+16	5.4E+16	5.4E+16	5.3E+16	5.3E+16	5.2E+16	5.2E+16
0.2	4.0E+17	4.0E+17	3.9E+17	3.9E+17	3.8E+17	3.8E+17	3.8E+17	3.7E+17	3.7E+17	3.6E+17	3.6E+17
0.3	3.6E+17	3.5E+17	3.5E+17	3.4E+17	3.3E+17	3.3E+17	3.2E+17	3.2E+17	3.1E+17	3.0E+17	3.0E+17
0.4	1.9E+18	1.9E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18	1.8E+18
0.5	3.6E+18	3.6E+18	3.5E+18	3.4E+18	3.3E+18	3.3E+18	3.2E+18	3.2E+18	3.0E+18	2.9E+18	2.8E+18
0.6	1.9E+18	1.8E+18	1.7E+18	1.6E+18	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18	1.2E+18
0.8	1.9E+18	1.8E+18	1.7E+18	1.7E+18	1.6E+18	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.3E+18
1.0	1.4E+18	1.3E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.0E+18	9.8E+17	9.0E+17	8.3E+17	7.7E+17
1.5	1.4E+18	1.4E+18	1.3E+18	1.2E+18	1.1E+18	1.1E+18	1.1E+18	1.0E+18	9.3E+17	8.5E+17	7.8E+17
2.0	2.7E+17	2.6E+17	2.4E+17	2.3E+17	2.1E+17	2.1E+17	2.0E+17	1.9E+17	1.7E+17	1.5E+17	1.4E+17
3.0	1.2E+15	1.2E+15	1.2E+15	1.2E+15	1.2E+15	1.3E+15	1.3E+15	1.3E+15	1.4E+15	1.5E+15	1.6E+15
4.0	2.8E+12	2.2E+12	1.8E+12	1.4E+12	9.8E+11	9.0E+11	7.2E+11	5.7E+11	3.7E+11	2.3E+11	1.5E+11
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 7 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	14	15	16	17	18	19	20	21	22	23	24
0.015	8.4E+16	8.3E+16	8.3E+16	8.2E+16	8.1E+16	8.1E+16	8.0E+16	7.9E+16	7.9E+16	7.8E+16	7.8E+16
0.02	1.4E+16	1.4E+16	1.4E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.2E+16	1.2E+16
0.03	4.3E+17	4.2E+17	4.2E+17	4.1E+17	4.1E+17	4.1E+17	4.0E+17	4.0E+17	4.0E+17	3.9E+17	3.9E+17
0.04	8.9E+15	8.8E+15	8.8E+15	8.7E+15	8.7E+15	8.6E+15	8.6E+15	8.6E+15	8.5E+15	8.5E+15	8.4E+15
0.05	4.8E+16	4.8E+16	4.7E+16	4.7E+16	4.7E+16	4.6E+16	4.6E+16	4.5E+16	4.5E+16	4.5E+16	4.4E+16
0.06	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.4E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16
0.08	6.1E+16	6.0E+16	6.0E+16	6.0E+16	6.0E+16	6.0E+16	5.9E+16	5.9E+16	5.9E+16	5.9E+16	5.8E+16
0.1	4.7E+16	4.6E+16	4.5E+16	4.5E+16	4.4E+16	4.4E+16	4.3E+16	4.3E+16	4.2E+16	4.2E+16	4.1E+16
0.15	5.1E+16	5.1E+16	5.1E+16	5.0E+16	5.0E+16	5.0E+16	4.9E+16	4.9E+16	4.9E+16	4.8E+16	4.8E+16
0.2	3.5E+17	3.5E+17	3.4E+17	3.4E+17	3.3E+17	3.3E+17	3.2E+17	3.2E+17	3.2E+17	3.1E+17	3.1E+17
0.3	2.9E+17	2.9E+17	2.8E+17	2.8E+17	2.7E+17	2.7E+17	2.7E+17	2.6E+17	2.6E+17	2.6E+17	2.6E+17
0.4	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.7E+18	1.6E+18
0.5	2.7E+18	2.6E+18	2.6E+18	2.5E+18	2.4E+18	2.3E+18	2.2E+18	2.2E+18	2.1E+18	2.0E+18	2.0E+18
0.6	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18
0.8	1.2E+18	1.2E+18	1.2E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.1E+18	1.0E+18	1.0E+18
1.0	7.1E+17	6.7E+17	6.2E+17	5.8E+17	5.5E+17	5.2E+17	4.9E+17	4.7E+17	4.4E+17	4.2E+17	4.0E+17
1.5	7.1E+17	6.6E+17	6.1E+17	5.6E+17	5.2E+17	4.9E+17	4.6E+17	4.3E+17	4.0E+17	3.8E+17	3.6E+17
2.0	1.2E+17	1.1E+17	1.0E+17	9.3E+16	8.5E+16	7.8E+16	7.1E+16	6.5E+16	6.0E+16	5.5E+16	5.1E+16
3.0	1.6E+15	1.7E+15	1.8E+15	1.9E+15	2.0E+15	2.1E+15	2.1E+15	2.2E+15	2.3E+15	2.4E+15	2.5E+15
4.0	9.5E+10	6.1E+10	3.9E+10	2.5E+10	1.6E+10	1.0E+10	6.4E+09	4.1E+09	2.6E+09	1.7E+09	1.1E+09
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 8 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	26	28	30	35	40	48	50	60	70	80	96
0.015	7.7E+16	7.6E+16	7.5E+16	7.2E+16	7.0E+16	6.7E+16	6.6E+16	6.3E+16	5.9E+16	5.6E+16	5.2E+16
0.02	1.2E+16	1.2E+16	1.1E+16	1.1E+16	1.0E+16	9.3E+15	9.1E+15	8.1E+15	7.2E+15	6.4E+15	5.3E+15
0.03	3.8E+17	3.8E+17	3.7E+17	3.6E+17	3.5E+17	3.3E+17	3.2E+17	3.0E+17	2.8E+17	2.6E+17	2.4E+17
0.04	8.3E+15	8.3E+15	8.2E+15	8.0E+15	7.8E+15	7.6E+15	7.5E+15	7.3E+15	7.0E+15	6.8E+15	6.5E+15
0.05	4.3E+16	4.3E+16	4.2E+16	4.0E+16	3.8E+16	3.6E+16	3.5E+16	3.2E+16	2.9E+16	2.7E+16	2.3E+16
0.06	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.3E+16	1.2E+16	1.2E+16	1.2E+16	1.2E+16	1.1E+16	1.1E+16
0.08	5.8E+16	5.8E+16	5.7E+16	5.6E+16	5.5E+16	5.3E+16	5.3E+16	5.1E+16	4.9E+16	4.8E+16	4.5E+16
0.1	4.0E+16	3.9E+16	3.9E+16	3.6E+16	3.4E+16	3.1E+16	3.1E+16	2.7E+16	2.5E+16	2.2E+16	1.9E+16
0.15	4.8E+16	4.7E+16	4.6E+16	4.5E+16	4.4E+16	4.2E+16	4.2E+16	3.9E+16	3.8E+16	3.6E+16	3.3E+16
0.2	3.0E+17	3.0E+17	2.9E+17	2.8E+17	2.6E+17	2.5E+17	2.4E+17	2.2E+17	2.0E+17	1.9E+17	1.6E+17
0.3	2.5E+17	2.5E+17	2.5E+17	2.4E+17	2.3E+17	2.3E+17	2.3E+17	2.2E+17	2.1E+17	2.1E+17	2.0E+17
0.4	1.6E+18	1.6E+18	1.6E+18	1.6E+18	1.5E+18	1.5E+18	1.5E+18	1.4E+18	1.4E+18	1.3E+18	1.2E+18
0.5	1.9E+18	1.7E+18	1.6E+18	1.4E+18	1.2E+18	9.8E+17	9.3E+17	7.2E+17	5.6E+17	4.5E+17	3.3E+17
0.6	1.0E+18	1.0E+18	1.0E+18	1.0E+18	9.8E+17	9.4E+17	9.4E+17	9.0E+17	8.7E+17	8.4E+17	7.9E+17
0.8	1.0E+18	9.9E+17	9.7E+17	9.3E+17	9.0E+17	8.5E+17	8.4E+17	8.0E+17	7.6E+17	7.3E+17	7.0E+17
1.0	3.7E+17	3.4E+17	3.2E+17	2.8E+17	2.5E+17	2.2E+17	2.2E+17	2.0E+17	1.8E+17	1.7E+17	1.6E+17
1.5	3.2E+17	2.9E+17	2.7E+17	2.3E+17	2.1E+17	1.9E+17	1.9E+17	1.8E+17	1.8E+17	1.8E+17	1.8E+17
2.0	4.4E+16	3.8E+16	3.3E+16	2.4E+16	1.9E+16	1.4E+16	1.3E+16	1.1E+16	9.5E+15	8.6E+15	7.5E+15
3.0	2.6E+15	2.7E+15	2.9E+15	3.2E+15	3.5E+15	3.9E+15	4.0E+15	4.3E+15	4.6E+15	4.9E+15	5.1E+15
4.0	4.3E+08	1.8E+08	7.1E+07	7.5E+06	8.0E+05	2.2E+04	8.9E+03	9.9E+01	1.1E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 9 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	100	120	150	160	170	180	200	240	264	288	300
0.015	5.1E+16	4.6E+16	4.1E+16	3.9E+16	3.8E+16	3.6E+16	3.4E+16	2.9E+16	2.7E+16	2.5E+16	2.4E+16
0.02	5.1E+15	4.0E+15	2.9E+15	2.6E+15	2.3E+15	2.0E+15	1.6E+15	1.1E+15	8.5E+14	6.7E+14	6.0E+14
0.03	2.3E+17	2.1E+17	1.8E+17	1.7E+17	1.6E+17	1.5E+17	1.4E+17	1.1E+17	1.0E+17	9.2E+16	8.7E+16
0.04	6.5E+15	6.2E+15	5.8E+15	5.7E+15	5.6E+15	5.5E+15	5.3E+15	4.9E+15	4.7E+15	4.5E+15	4.4E+15
0.05	2.3E+16	1.9E+16	1.4E+16	1.3E+16	1.2E+16	1.1E+16	9.3E+15	6.6E+15	5.3E+15	4.3E+15	3.9E+15
0.06	1.1E+16	1.0E+16	9.6E+15	9.3E+15	9.1E+15	8.9E+15	8.5E+15	7.8E+15	7.3E+15	7.0E+15	6.8E+15
0.08	4.4E+16	4.1E+16	3.7E+16	3.6E+16	3.5E+16	3.4E+16	3.2E+16	2.8E+16	2.5E+16	2.3E+16	2.2E+16
0.1	1.8E+16	1.4E+16	1.0E+16	9.5E+15	8.6E+15	7.7E+15	6.4E+15	4.3E+15	3.5E+15	2.8E+15	2.5E+15
0.15	3.3E+16	3.0E+16	2.7E+16	2.6E+16	2.5E+16	2.4E+16	2.3E+16	2.0E+16	1.9E+16	1.8E+16	1.7E+16
0.2	1.6E+17	1.3E+17	1.0E+17	9.7E+16	8.9E+16	8.3E+16	7.1E+16	5.2E+16	4.4E+16	3.7E+16	3.4E+16
0.3	1.9E+17	1.8E+17	1.7E+17	1.6E+17	1.6E+17	1.5E+17	1.5E+17	1.3E+17	1.2E+17	1.1E+17	1.1E+17
0.4	1.2E+18	1.1E+18	1.0E+18	9.9E+17	9.6E+17	9.2E+17	8.6E+17	7.4E+17	6.8E+17	6.3E+17	6.0E+17
0.5	3.1E+17	2.4E+17	1.8E+17	1.7E+17	1.6E+17	1.5E+17	1.4E+17	1.2E+17	1.2E+17	1.1E+17	1.1E+17
0.6	7.8E+17	7.4E+17	6.9E+17	6.7E+17	6.6E+17	6.4E+17	6.2E+17	5.8E+17	5.7E+17	5.5E+17	5.4E+17
0.8	6.9E+17	6.5E+17	6.1E+17	5.9E+17	5.8E+17	5.7E+17	5.5E+17	5.2E+17	5.0E+17	4.9E+17	4.8E+17
1.0	1.6E+17	1.4E+17	1.3E+17	1.2E+17	1.2E+17	1.2E+17	1.1E+17	9.7E+16	9.1E+16	8.5E+16	8.3E+16
1.5	1.8E+17	1.7E+17	1.7E+17	1.6E+17	1.6E+17	1.6E+17	1.5E+17	1.4E+17	1.3E+17	1.3E+17	1.2E+17
2.0	7.3E+15	6.3E+15	5.1E+15	4.8E+15	4.5E+15	4.2E+15	3.6E+15	2.8E+15	2.4E+15	2.1E+15	2.0E+15
3.0	5.2E+15	5.3E+15	5.3E+15	5.2E+15	5.2E+15	5.1E+15	5.0E+15	4.7E+15	4.5E+15	4.2E+15	4.1E+15
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 10 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	312	336	360	400	480	500	600	700	720	960	1200
0.015	2.3E+16	2.2E+16	2.0E+16	1.8E+16	1.5E+16	1.4E+16	1.1E+16	8.9E+15	8.5E+15	5.2E+15	3.3E+15
0.02	5.4E+14	4.4E+14	3.6E+14	2.7E+14	1.8E+14	1.7E+14	1.3E+14	1.1E+14	1.1E+14	9.0E+13	7.5E+13
0.03	8.3E+16	7.6E+16	6.9E+16	6.0E+16	4.6E+16	4.4E+16	3.3E+16	2.6E+16	2.4E+16	1.5E+16	1.0E+16
0.04	4.4E+15	4.2E+15	4.0E+15	3.8E+15	3.4E+15	3.3E+15	2.9E+15	2.5E+15	2.5E+15	1.9E+15	1.6E+15
0.05	3.5E+15	2.8E+15	2.3E+15	1.6E+15	8.3E+14	7.0E+14	3.2E+14	1.6E+14	1.4E+14	5.0E+13	3.5E+13
0.06	6.6E+15	6.2E+15	5.9E+15	5.4E+15	4.5E+15	4.3E+15	3.5E+15	2.8E+15	2.7E+15	1.6E+15	9.4E+14
0.08	2.2E+16	2.0E+16	1.8E+16	1.6E+16	1.2E+16	1.2E+16	8.3E+15	6.0E+15	5.6E+15	2.6E+15	1.3E+15
0.1	2.3E+15	1.9E+15	1.6E+15	1.2E+15	7.2E+14	6.5E+14	4.2E+14	3.0E+14	2.8E+14	1.5E+14	9.5E+13
0.15	1.6E+16	1.6E+16	1.5E+16	1.3E+16	1.1E+16	1.1E+16	8.8E+15	7.2E+15	7.0E+15	4.5E+15	3.0E+15
0.2	3.1E+16	2.6E+16	2.3E+16	1.8E+16	1.1E+16	1.0E+16	6.6E+15	4.6E+15	4.3E+15	2.2E+15	1.3E+15
0.3	1.1E+17	9.8E+16	9.2E+16	8.2E+16	6.5E+16	6.2E+16	4.7E+16	3.6E+16	3.4E+16	1.8E+16	1.0E+16
0.4	5.8E+17	5.3E+17	4.8E+17	4.2E+17	3.2E+17	2.9E+17	2.1E+17	1.4E+17	1.3E+17	5.7E+16	2.4E+16
0.5	1.0E+17	9.9E+16	9.3E+16	8.6E+16	7.3E+16	7.0E+16	5.8E+16	4.8E+16	4.7E+16	3.2E+16	2.3E+16
0.6	5.4E+17	5.3E+17	5.2E+17	5.0E+17	4.9E+17	4.8E+17	4.7E+17	4.6E+17	4.6E+17	4.5E+17	4.4E+17
0.8	4.8E+17	4.7E+17	4.6E+17	4.5E+17	4.2E+17	4.2E+17	4.0E+17	3.9E+17	3.9E+17	3.7E+17	3.5E+17
1.0	8.0E+16	7.6E+16	7.2E+16	6.5E+16	5.5E+16	5.3E+16	4.4E+16	3.7E+16	3.6E+16	2.5E+16	1.9E+16
1.5	1.2E+17	1.1E+17	1.1E+17	1.0E+17	8.5E+16	8.2E+16	6.7E+16	5.6E+16	5.4E+16	3.6E+16	2.5E+16
2.0	1.9E+15	1.6E+15	1.5E+15	1.2E+15	8.7E+14	8.0E+14	5.7E+14	4.3E+14	4.1E+14	2.3E+14	1.3E+14
3.0	4.0E+15	3.8E+15	3.6E+15	3.3E+15	2.8E+15	2.7E+15	2.1E+15	1.7E+15	1.6E+15	9.4E+14	5.4E+14
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-5 Integrated gamma ray and beta source strengths in the recirculation water after a LOCA (Sheet 11 of 11)

Gamma Ray Energy (MeV)	Source Strength at Time after Release (MeV)										
	1440	2160	2880	3600	4320	5040	5760	6480	7200	7920	8760
0.015	2.2E+15	9.5E+14	6.3E+14	5.1E+14	4.6E+14	4.2E+14	3.9E+14	3.7E+14	3.5E+14	3.3E+14	3.1E+14
0.02	6.4E+13	3.8E+13	2.4E+13	1.5E+13	9.4E+12	6.2E+12	4.3E+12	3.2E+12	2.5E+12	2.0E+12	1.7E+12
0.03	7.4E+15	4.4E+15	3.5E+15	3.0E+15	2.8E+15	2.6E+15	2.4E+15	2.3E+15	2.2E+15	2.1E+15	2.0E+15
0.04	1.4E+15	1.0E+15	9.0E+14	8.3E+14	7.8E+14	7.4E+14	7.1E+14	6.8E+14	6.5E+14	6.2E+14	6.0E+14
0.05	2.9E+13	1.8E+13	1.2E+13	8.0E+12	5.7E+12	4.3E+12	3.4E+12	2.8E+12	2.4E+12	2.1E+12	1.8E+12
0.06	5.6E+14	1.2E+14	3.4E+13	1.4E+13	9.0E+12	7.0E+12	5.9E+12	5.0E+12	4.3E+12	3.7E+12	3.1E+12
0.08	6.5E+14	1.4E+14	6.7E+13	5.2E+13	4.6E+13	4.3E+13	4.0E+13	3.7E+13	3.4E+13	3.2E+13	2.9E+13
0.1	6.1E+13	2.3E+13	1.4E+13	1.1E+13	9.3E+12	8.4E+12	7.7E+12	7.1E+12	6.6E+12	6.1E+12	5.6E+12
0.15	2.0E+15	8.5E+14	5.0E+14	3.6E+14	2.9E+14	2.5E+14	2.2E+14	2.0E+14	1.9E+14	1.7E+14	1.6E+14
0.2	7.7E+14	2.1E+14	1.0E+14	7.7E+13	7.0E+13	6.7E+13	6.4E+13	6.2E+13	6.1E+13	5.9E+13	5.7E+13
0.3	5.6E+15	1.1E+15	2.6E+14	9.3E+13	5.8E+13	4.9E+13	4.5E+13	4.3E+13	4.2E+13	4.0E+13	3.9E+13
0.4	1.1E+16	9.0E+14	1.1E+14	3.0E+13	1.7E+13	1.3E+13	1.0E+13	8.1E+12	6.6E+12	5.4E+12	4.2E+12
0.5	1.7E+16	9.8E+15	7.3E+15	6.1E+15	5.4E+15	5.0E+15	4.7E+15	4.4E+15	4.3E+15	4.1E+15	4.0E+15
0.6	4.3E+17	4.2E+17	4.1E+17	4.0E+17	3.9E+17	3.8E+17	3.7E+17	3.6E+17	3.5E+17	3.4E+17	3.3E+17
0.8	3.5E+17	3.3E+17	3.2E+17	3.1E+17	3.0E+17	2.9E+17	2.8E+17	2.8E+17	2.7E+17	2.6E+17	2.5E+17
1.0	1.5E+16	1.1E+16	9.7E+15	9.3E+15	9.0E+15	8.7E+15	8.5E+15	8.3E+15	8.0E+15	7.8E+15	7.6E+15
1.5	1.9E+16	1.2E+16	1.1E+16	1.0E+16	9.7E+15	9.5E+15	9.2E+15	9.0E+15	8.7E+15	8.5E+15	8.2E+15
2.0	7.5E+13	1.5E+13	2.9E+12	5.6E+11	1.1E+11	2.2E+10	4.6E+09	1.2E+09	5.6E+08	4.2E+08	3.9E+08
3.0	3.2E+14	6.2E+13	1.2E+13	2.4E+12	4.6E+11	9.0E+10	1.8E+10	3.4E+09	6.7E+08	1.3E+08	2.1E+07
4.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table E-6 Main MicroShield Input Parameters
(for airborne) (Sheet 1 of 2)

Geometry		Cylinder Volume – End Shields
Source Dimensions	Height	78 ft 6.1 in
	Radius	74 ft 7.0 in
Dose Points	X	0.0 in
	Y	78 ft 6.1 in
	Z	0.0 in
Source Density		Air (0.00122 g/cc)
Source Activity		1.0E+0 (Photon/sec) [1)]

Note
1. For all 25 energy groups, the actual dose rates are calculated by multiplying the respective MicroSheild group dose rate output by the respective group-related actual source term using Microsoft EXCEL.

Table E-6 Main MicroShield Input Parameters
(for recirculation water) (Sheet 2 of 2)

Geometry		Cylinder Volume – End Shields
Source Dimensions	Height	3 ft 3.8 in
	Radius	74 ft 7.0 in
Dose Points	X	0.0 in
	Y	3 ft 3.8 in
	Z	0.0 in
Source Density		Water (1 g/cc)
Source Activity		1.0E+0 (Photon/sec) [1)]

Note
1. For all 25 energy groups, the actual dose rates are calculated by multiplying the respective MicroSheild group dose rate output by the respective group-related actual source term using Microsoft EXCEL.

Table E-7 Accident Cumulative Dose (for gamma ray) at Various Times after LOCA (Sheet 1 of 3)

Time after LOCA (hr)	Airborne (rad)	Recirculation water (rad)
0.01	6.6E-01	1.4E-01
0.02	1.3E+00	2.9E-01
0.03	4.3E+01	1.8E+01
0.04	1.7E+02	5.2E+01
0.05	3.6E+02	1.0E+02
0.06	6.1E+02	1.6E+02
0.0667	8.2E+02	2.2E+02
0.08	1.3E+03	3.3E+02
0.0834	1.4E+03	3.7E+02
0.1	2.2E+03	5.6E+02
0.15	4.8E+03	1.2E+03
0.2	8.4E+03	2.3E+03
0.3	1.8E+04	5.0E+03
0.4	3.0E+04	9.1E+03
0.5	4.6E+04	1.4E+04
0.5083	4.8E+04	1.5E+04
0.6	6.5E+04	2.1E+04
0.7	9.6E+04	3.0E+04
0.8	1.4E+05	4.3E+04
0.9	1.9E+05	5.9E+04
1	2.6E+05	7.7E+04
1.1	3.3E+05	9.8E+04
1.2	4.1E+05	1.2E+05
1.3	5.0E+05	1.5E+05
1.4	5.9E+05	1.8E+05
1.5	6.9E+05	2.1E+05
1.6	8.0E+05	2.4E+05
1.7	9.1E+05	2.7E+05
1.8	1.0E+06	3.1E+05
1.8083	1.0E+06	3.1E+05
1.9	1.2E+06	3.5E+05
2	1.3E+06	3.8E+05
2.1	1.4E+06	4.2E+05
2.2	1.5E+06	4.6E+05
2.3	1.6E+06	4.9E+05
2.4	1.7E+06	5.3E+05
2.5	1.8E+06	5.6E+05
2.6	1.9E+06	5.9E+05
2.7	2.0E+06	6.3E+05
2.8	2.0E+06	6.6E+05
2.9	2.1E+06	6.9E+05
3	2.2E+06	7.2E+05
3.2	2.4E+06	7.8E+05
3.23	2.4E+06	7.9E+05
3.4	2.5E+06	8.4E+05
3.6	2.7E+06	8.9E+05
3.8	2.8E+06	9.5E+05
4	3.0E+06	1.0E+06
4.2	3.1E+06	1.1E+06
4.4	3.2E+06	1.1E+06
4.6	3.3E+06	1.2E+06
4.8	3.5E+06	1.2E+06

Table E-7 Accident Cumulative Dose (for gamma ray) at Various Times after LOCA (Sheet 2 of 3)

Time after LOCA (hr)	Airborne (rad)	Recirculation water (rad)
5	3.6E+06	1.2E+06
5.5	3.9E+06	1.4E+06
6	4.1E+06	1.5E+06
6.5	4.4E+06	1.6E+06
7	4.6E+06	1.7E+06
7.5	4.8E+06	1.8E+06
8	5.1E+06	1.9E+06
8.8	5.4E+06	2.0E+06
9	5.5E+06	2.0E+06
9.5	5.6E+06	2.1E+06
10	5.8E+06	2.2E+06
11	6.1E+06	2.3E+06
12	6.5E+06	2.5E+06
13	6.8E+06	2.6E+06
14	7.0E+06	2.7E+06
15	7.3E+06	2.9E+06
16	7.6E+06	3.0E+06
17	7.8E+06	3.1E+06
18	8.0E+06	3.2E+06
19	8.3E+06	3.3E+06
20	8.5E+06	3.4E+06
21	8.7E+06	3.5E+06
22	8.9E+06	3.6E+06
23	9.1E+06	3.7E+06
24	9.3E+06	3.8E+06
26	9.7E+06	4.0E+06
28	1.0E+07	4.1E+06
30	1.0E+07	4.3E+06
35	1.1E+07	4.7E+06
40	1.2E+07	5.1E+06
48	1.3E+07	5.6E+06
50	1.4E+07	5.7E+06
60	1.5E+07	6.3E+06
70	1.6E+07	6.9E+06
80	1.7E+07	7.4E+06
96	1.9E+07	8.2E+06
100	2.0E+07	8.4E+06
120	2.2E+07	9.3E+06
150	2.5E+07	1.1E+07
160	2.5E+07	1.1E+07
170	2.6E+07	1.1E+07
180	2.7E+07	1.2E+07
200	2.8E+07	1.2E+07
240	3.1E+07	1.4E+07
264	3.2E+07	1.5E+07
288	3.4E+07	1.5E+07
300	3.4E+07	1.6E+07
312	3.5E+07	1.6E+07
336	3.6E+07	1.7E+07
360	3.7E+07	1.7E+07
400	3.9E+07	1.8E+07
480	4.1E+07	2.0E+07

Table E-7 Accident Cumulative Dose (for gamma ray) at Various Times after LOCA (Sheet 3 of 3)

Time after LOCA (hr)	Airborne (rad)	Recirculation water (rad)
500	4.2E+07	2.1E+07
600	4.5E+07	2.3E+07
700	4.7E+07	2.4E+07
720	4.7E+07	2.5E+07
960	4.8E+07	2.9E+07
1200	4.8E+07	3.2E+07
1440	4.8E+07	3.5E+07
2160	4.8E+07	4.4E+07
2880	4.8E+07	5.2E+07
3600	4.8E+07	6.0E+07
4320	4.8E+07	6.8E+07
5040	4.8E+07	7.5E+07
5760	4.8E+07	8.2E+07
6480	4.8E+07	8.9E+07
7200	4.8E+07	9.6E+07
7920	4.8E+07	1.0E+08
8760	4.8E+07	1.1E+08

Table E-8 Accident Cumulative Dose (for beta ray) at Various Times after LOCA (Sheet 1 of 3)

Time after LOCA (hr)	Airborne (rad)
0.01	0.0E+00
0.02	2.9E+00
0.03	1.3E+02
0.04	5.0E+02
0.05	1.1E+03
0.06	1.9E+03
0.0667	2.5E+03
0.08	3.9E+03
0.0834	4.4E+03
0.1	6.6E+03
0.15	1.5E+04
0.2	2.6E+04
0.3	5.6E+04
0.4	9.8E+04
0.5	1.5E+05
0.5083	1.5E+05
0.6	2.1E+05
0.7	3.3E+05
0.8	5.0E+05
0.9	7.1E+05
1	9.7E+05
1.1	1.3E+06
1.2	1.6E+06
1.3	2.0E+06
1.4	2.4E+06
1.5	2.8E+06
1.6	3.3E+06
1.7	3.8E+06
1.8	4.3E+06
1.8083	4.3E+06
1.9	4.8E+06
2	5.4E+06
2.1	5.9E+06
2.2	6.4E+06
2.3	6.8E+06
2.4	7.3E+06
2.5	7.7E+06
2.6	8.2E+06
2.7	8.6E+06
2.8	9.0E+06
2.9	9.4E+06
3	9.8E+06
3.2	1.1E+07
3.23	1.1E+07
3.4	1.1E+07
3.6	1.2E+07
3.8	1.3E+07
4	1.3E+07
4.2	1.4E+07
4.4	1.5E+07
4.6	1.5E+07
4.8	1.6E+07

Table E-8 Accident Cumulative Dose (for beta ray) at Various Times after LOCA (Sheet 2 of 3)

Time after LOCA (hr)	Airborne (rad)
5	1.7E+07
5.5	1.8E+07
6	1.9E+07
6.5	2.1E+07
7	2.2E+07
7.5	2.3E+07
8	2.4E+07
8.8	2.6E+07
9	2.7E+07
9.5	2.8E+07
10	2.9E+07
11	3.1E+07
12	3.3E+07
13	3.5E+07
14	3.6E+07
15	3.8E+07
16	4.0E+07
17	4.1E+07
18	4.3E+07
19	4.5E+07
20	4.6E+07
21	4.7E+07
22	4.9E+07
23	5.0E+07
24	5.2E+07
26	5.4E+07
28	5.7E+07
30	5.9E+07
35	6.5E+07
40	7.1E+07
48	7.9E+07
50	8.1E+07
60	9.1E+07
70	1.0E+08
80	1.1E+08
96	1.2E+08
100	1.2E+08
120	1.4E+08
150	1.6E+08
160	1.6E+08
170	1.7E+08
180	1.7E+08
200	1.8E+08
240	2.0E+08
264	2.1E+08
288	2.1E+08
300	2.2E+08
312	2.2E+08
336	2.3E+08
360	2.3E+08
400	2.4E+08
480	2.5E+08

Table E-8 Accident Cumulative Dose (for beta ray) at Various Times after LOCA (Sheet 3 of 3)

Time after LOCA (hr)	Airborne (rad)
500	2.6E+08
600	2.7E+08
700	2.8E+08
720	2.8E+08
960	3.0E+08
1200	3.0E+08
1440	3.0E+08
2160	3.1E+08
2880	3.2E+08
3600	3.2E+08
4320	3.3E+08
5040	3.4E+08
5760	3.5E+08
6480	3.5E+08
7200	3.6E+08
7920	3.7E+08
8760	3.7E+08

Note
1. Beta dose from recirculation water is negligible compared with beta dose from airborne.

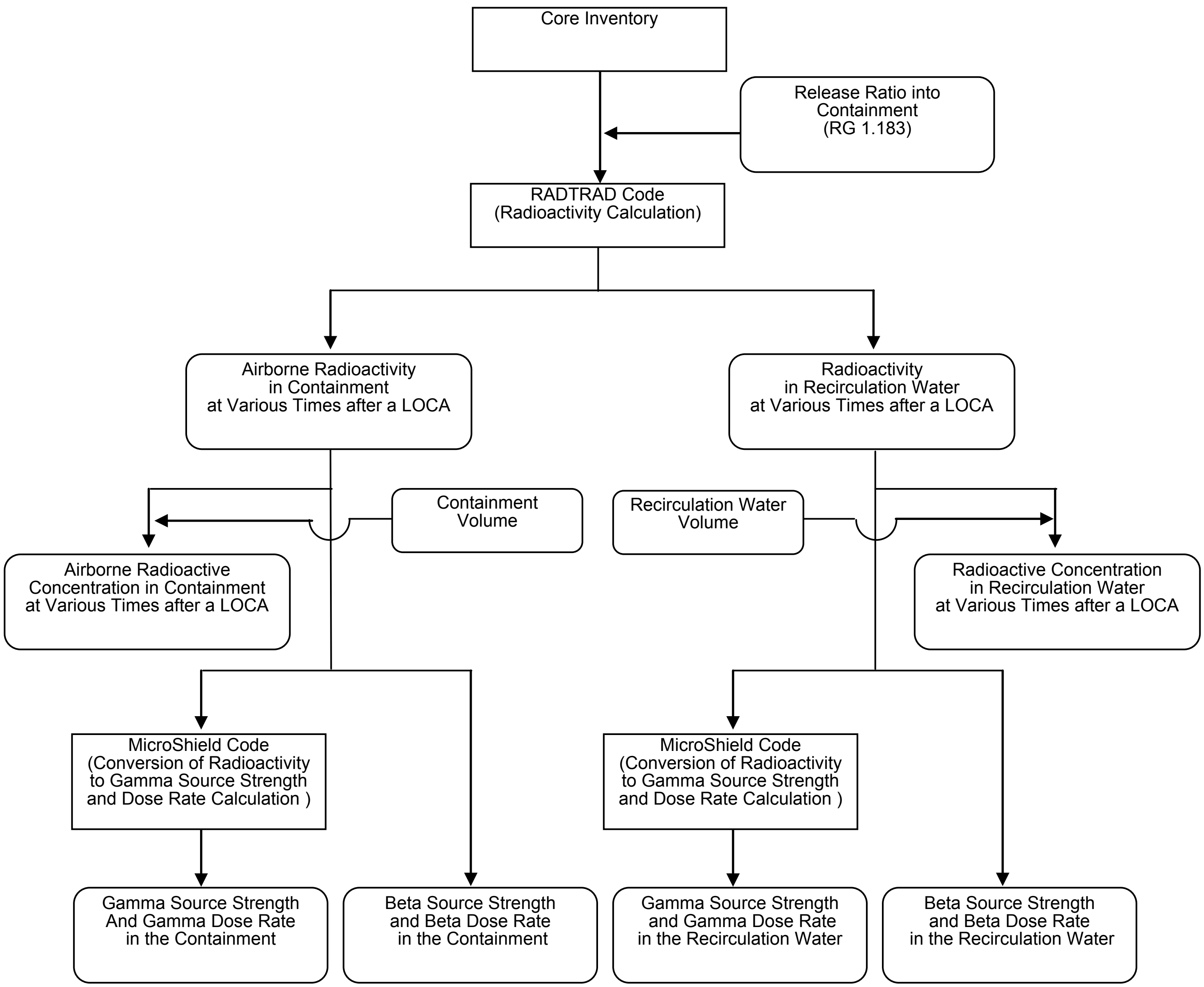

Figure E-1 Calculation Flow of Accident Dose Rate inside the Containment

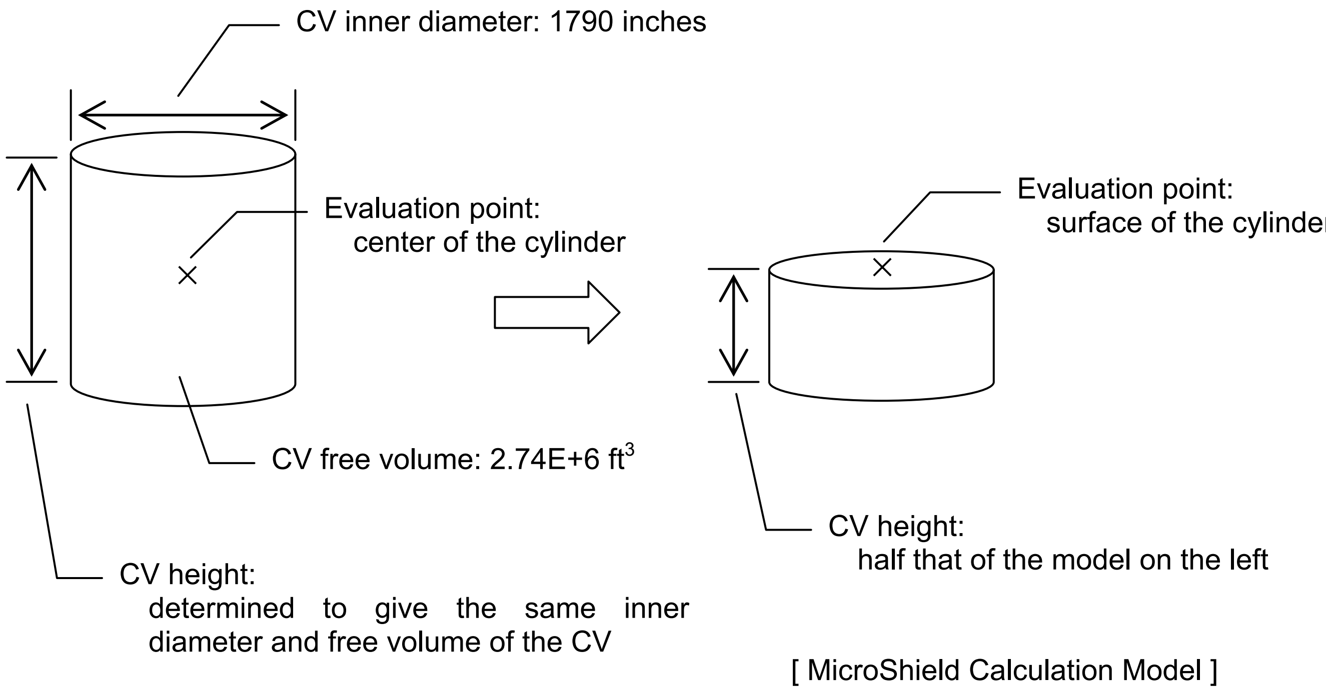

Figure E-2 Model for the Calculation of Gamma Dose rates in the CV after a LOCA

Attachment F Road Map for MHI US-APWR Equipment Qualification Program

F.1 Introduction

The US-APWR Equipment Qualification Program includes environmental qualification, seismic qualification, and functional qualification.

F.2 Purpose

The purpose of this attachment is to provide expanded roadmap to clarify the applicable portion of environmental qualification, functional qualification and seismic qualification in this Technical Report. The roadmap is shown in Table F-1.

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 1 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
1.0	PURPOSE	X	X	X	X	X
1.1	Applicable Codes and Standards	X	X	X	X	X
1.2	References to the US-APWR Design Control Document and Combined License Applications	X	X	X	X	X
1.3	Deleted	-	-	-	-	-
2.0	SCOPE	X	X	X	X	X
2.1	Equipment Qualification Program Technical Report Layout	X	X	X	X	X
3.0	REGULATORY STATUTES, REGULATORY GUIDES, INDUSTRY CODES AND STANDARDS APPLICABLE TO EQUIPMENT QUALIFICATION	-	-	-	-	-
3.1	Code of Federal Regulations and General Design Criteria	X	X	X	X	X
3.1.1	10 CFR 50.49 Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants	-	X	-	-	-
3.1.2	10 CFR 50 Appendix A: General Design Criteria for Nuclear Power Plants	X	X	X	X	X
3.2	NRC Staff Requirements Memoranda	X	X	X	X	-
3.3	NRC Regulatory Guides	X	X	X	X	X
3.4	ASME and Other Industry Standards Codes	-	-	-	-	-
	ASME Section III	X	-	X	-	-
	ASME NQA-1	X	X	X	X	X
	ASME QME-1-2007	X	-	-	X	-
	ASME QME-1-2007, Nonmandatory Appendices	X	-	-	X	-
	The AISC manual and material specifications	X	-	-	-	-
	AWS standards	X	-	-	-	-
3.5	NUREG-Series Publications (NRC Guidance Document for SRP for DCD)	X	X	X	X	X
3.6	IEEE and Other Standards	X	X	X	-	X
3.7	NSSS Industry Standards	X	X	X	X	X
3.8	Quality Assurance	X	X	X	X	X

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 2 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
4.0	EQUIPMENT QUALIFICATION EVALUATION PARAMETERS	X	X	X	-	-
4.1	Definition of Plant Location by Type of Environment	X	X	X	-	-
4.1.1	Mild Environment	X	X	X	-	-
4.1.2	Harsh Environment	X	X	-	-	-
4.2	Equipment Qualification Evaluation Parameters	X	X	X	-	X
4.2.1	Aging	X	X	-	-	-
4.2.2	Operability Time	X	X	-	-	-
4.2.2.1	Shorter Operability Times	X	X	-	-	-
4.2.3	Temperature and LOCA/MSLB Analysis	X	X	-	-	-
4.2.4	Pressure and Basis for Design	X	X	-	-	-
4.2.5	Humidity	X	X	-	-	-
4.2.5.1	Outdoor and Other Environmental Impacts from Outside, Chemicals, etc.	X	X	-	-	-
4.2.6	Indoor Chemical Environment – pH for Fluids	X	X	-	-	-
4.2.7	Vibration	X	X	-	-	X
4.2.8	Radiation Dose	X	X	-	-	-
4.2.8.1	Nuclear Source Terms	X	X	-	-	-
4.2.8.2	Beta Dose Considerations	X	X	-	-	-
4.2.8.3	Neutron Dose Considerations	X	X	-	-	-
4.2.8.4	Special Mild and Harsh Radiation Environment Limits and Testing Considerations	-	-	X	-	-
4.2.9	Submergence - Containment Flooding Analysis	X	X	-	-	-
4.2.9.1	Areas Outside Containment - Flooding Analysis	X	X	X	-	-
4.2.9.2	Condensation	X	X	-	-	-
4.2.10	Synergistic Effects	X	X	-	-	-
4.2.11	Seismic Qualification of SSCs with Special Seismic Requirements	-	-	-	-	X
4.2.12	Margin	X	X	X	-	X
4.2.12.1	Normal and Accident Environmental Parameters	X	X	X	-	-

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 3 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
4.2.12.2	Synergistic and Vibration Effects and Aging Margins	X	X	-	-	-
4.2.12.3	Radiation	X	X	X	-	-
4.2.12.4	High-Energy Line Break Conditions	X	X	-	-	-
4.2.12.5	Seismic Conditions	-	-	-	-	X
4.2.13	Other Parameters	X	X	X	X	X
4.2.14	EMI/RFI	-	X	X	-	-
4.3	Equipment Failures	X	X	X	X	X
4.4	Summary	-	-	-	-	-
5.0	NORMAL, ABNORMAL AND DESIGN BASIS ACCIDENT CONDITIONS	-	-	-	-	-
5.1	Normal Operating Conditions	-	-	-	-	-
5.1.1	Pressure, Temperature and Humidity	X	X	X	--	-
5.1.2	Radiation Dose	X	X	X	-	-
5.2	Abnormal Operating Conditions	X	X	X	-	-
5.3	Seismic Events	-	-	-	X	X
5.4	Containment Test Environment	X	X	-	-	-
5.5	Design Basis Accident Conditions	X	X	-	-	-
5.5.1	High-Energy Line Break Accidents Inside Containment	X	X	-	-	-
5.5.1.1	Radiation Environment – Loss-of-coolant Accident	X	X	-	-	-
5.5.1.2	Radiation Environment – Steam Line Break Accident	X	X	-	-	-
5.5.1.3	Containment Pressure and Basis for Design	X	X	-	-	-
5.5.1.4	Containment Temperature and LOCA/MSLB Analysis	X	X	-	-	-
5.5.1.5	Indoor Chemical Environment – pH for Fluids	X	X	-	-	-
5.5.1.6	Containment Flooding Analysis	X	X	-	-	-
5.5.2	High-Energy Line Break Accidents Outside Containment	X	X	-	-	-
6.0	EQUIPMENT QUALIFICATION METHODS	X	X	X	X	X
6.1	Type Test	X	X	X	X	X
6.2	Analysis	X	X	X	X	X
6.2.1	Similarity	X	X	X	X	X
6.2.2	Substitution	X	X	X	X	X

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 4 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
6.3	Operating Experience	X	X	X	X	X
6.4	On-Going Qualification	X	X	X	X	X
6.5	Combinations of Methods	X	X	X	X	X
6.5.1	Use of Existing Qualification Reports	X	X	X	X	X
6.5.1.1	Aging	X	X	-	-	-
6.5.1.2	Seismic	-	-	-	-	X
6.5.1.3	High-Energy Line Break Conditions	X	X			
6.6	Qualification of Mechanical Equipment	X	-	X	X	X
7.0	THE EQUIPMENT QUALIFICATION PROCESS	-	-	-	-	-
7.1	General	-	-	-	-	-
7.2	SSC Location	X	X	X	-	X
7.3	SSC Function and Classification	X	X	X	X	X
7.3.1	Time Element	X	X	-	X	X
7.4	Deleted.	-	-	-	-	-
7.5	Seismic II/I Criteria	-	-	-	-	X
7.6	Critical Characteristics Applicable to the Design and Procurement Process	X	X	X	X	X
7.7	Equipment Qualification Process	X	X	X	X	X
7.7.1	Site Specific Equipment Qualification Process	X	X	X	X	X
7.8	Development of Aging Program, and Spare or Replacement Parts	X	X	-	-	-
7.9	Turnover to Licensee	X	X	X	X	X
8.0	MHI US-APWR EQUIPMENT QUALIFICATION PROGRAM	-	-	-	-	-
8.1	Generic Program	-	-	-	-	-
8.2	MHI US-APWR Equipment Qualification Program Directives	X	X	X	X	X
8.3	MHI US-APWR Equipment Qualification Program Procedures	X	X	X	X	X
8.4	MHI Equipment Qualification Program Project Implementation	X	X	X	X	X
8.5	Summary	-	-	-	-	-
9.0	EQUIPMENT QUALIFICATION IMPLEMENTATION	X	X	X	X	X
9.1	Project Licensing Phase	X	X	X	X	X
9.2	Project Authorization Phase	X	X	X	X	X

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 5 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
9.3	Project Equipment Qualification Organization (PEQO)	X	X	X	X	X
9.4	Site Design and Project Engineering Phase	X	X	X	X	X
9.5	Personnel Training and Qualification for Personnel engaged in Equipment Qualification Activities including Vendor Personnel	X	X	X	X	X
9.6	Procurement Phase	X	X	X	X	X
9.7	International Procurement Phase	X	X	X	X	X
9.8	Vendor Qualification and Audit	X	X	X	X	X
9.8.1	Procurement Receipt Inspection	X	X	X	X	X
9.8.2	Suppliers Problem Trending	X	X	X	X	X
9.9	Equipment Qualification Data Packages or Data Sheets	X	X	X	X	X
9.10	Construction Phase	X	X	X	X	X
9.11	Startup Phase	X	X	X	X	X
9.12	Testing Laboratories Qualification and Audit	X	X	X	X	X
9.13	All Project Phases	X	X	X	X	X
9.14	Operational Equipment Qualification Program (OEQP)	X	X	X	X	X
9.15	Summary	-	-	-	-	-
10.0	EQUIPMENT QUALIFICATION PROGRAM TRANSFER TO U.S. UTILITY (LICENSEE) AND PEQP CLOSEOUT	X	X	X	X	X
10.1	U.S. Utility (Licensee) Assumption	X	X	X	X	X
10.2	Construction during PEQP Turnover to Licensee	X	X	X	X	X
10.2.1	Other Turnover Activities	X	X	X	X	X
10.3	Inspections, Tests, Analysis, and Acceptance Criteria (ITAAC)	X	X	-	X	X
10.3.1	Electrical Equipment	-	X	-	-	X
10.3.2	Mechanical Equipment	X	-	-	X	X
10.3.3	Pipe Break	X	X	-	-	-
10.3.4	As-built Reconciliation	-	-	-	-	X
10.3.5	Active Valves	-	-	-	X	X
10.3.6	Initial Test Program	-	X	-	X	-

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 6 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
10.4	PEQP Closeout Process	X	X	X	X	X
10.4.1	Closeout	X	X	X	X	X
10.5	Summary	-	-	-	-	-
11.0	GENERAL DESCRIPTION OF UTILITY (LICENSEE) OPERATIONAL EQUIPMENT QUALIFICATION PROGRAM	X	X	X	X	X
11.1	Summary Description of US-APWR Plant Procedures Relating to OEQP	-	-	-	-	-
12.0	SUMMARY	-	-	-	-	-
13.0	REFERENCES	-	-	-	-	-
13.1	U.S. Regulations	X	X	X	X	X
13.2	U.S. RGs	X	X	X	X	X
13.3	Regulatory Review Precedent	X	X	-	-	-
13.4	NRC Inspection Procedures	X	X	X	X	X
13.5	U.S. Industry Codes and Standards	X	X	X	X	X
13.6	Industry Group References	X	X	X	X	X
13.7	MHI Documents	-	-	-	-	-
	MNES US-APWR QAPD SQ-QD-070001 “US-APWR Quality Assurance Program Description”.	X	X	X	X	X
	US-APWR Topical Report, “Quality Assurance Program Description,” PQD-HD-19005, Rev. 5, May 2013.	X	X	X	X	X
Attach-ment A	Summary of Statutes, RGs, Industry Codes and Standards Applicable to the US-APWR Equipment Qualification Program	X	X	X	X	X
Attach-ment B	Description of the US-APWR Equipment Seismic Qualification Program	-	-	-	-	X
Attach-ment C	List of Implementing Directives and Procedures	X	X	X	X	X
Attach-ment D	Attachment D Description of Equipment Qualification Data Package Template for MHI US-APWR Equipment Qualification Program	X	X	X	X	X
Attach-ment E	Calculation Method for Radiation Dose after LOCA	X	X	X	-	-

Table F-1 Road Map for US-APWR Equipment Qualification Program (Sheet 7 of 7)

Section of MUAP-08015		Environmental Qualification			Functional Qualification	Seismic Qualification
		Harsh		Mild		
		M	E			
Attach-ment F	Road Map for MHI US-APWR Equipment Qualification Program	X	X	X	X	X
Table 4-1	Typical Mild Environmental Parameter Limits	X	X	X	-	-
Table 4-2	US-APWR Equipment Qualification Program Margin Values	X	X	X	-	X
Table 5-1	Normal Operating Environments	X	X	X	-	-
Table 5-2	Abnormal Room Conditions	X	X	X	-	-
Table 5-3	Accident Environments	X	X	-	-	-
Table 5-4	Radiation Environments (Normal Operation)	X	X	X	-	-
Table 5-5	Total Integrated Dose for Zone	X	X	X	-	-
Figure 2-1	Project Equipment Qualification Program (PEQP) Implementation Framework	X	X	X	X	X
Figure 5-1	Environmental Curve for Containment Pressure Combining Various DBAs (Zone 1)	X	X	-	-	-
Figure 5-2	Environmental Curve for Containment Temperature Combining Various DBAs (Zone 1)	X	X	-	-	-
Figure 5-3	Environmental Curve for Pressure in MS/MF Piping Area	X	X	-	-	-
Figure 5-4	Environmental Curve for Temperature in MS/MF Piping Area	X	X	-	-	-
Figure 7-1	Deleted	-	-	-	-	-
Figure 9-1	US-APWR Project Specific Equipment Qualification Program Milestone Schedule	X	X	X	X	X

M: Mechanical Equipment
E: Electrical Equipment
X: Applicable
-: Not Applicable