AREVA

February 20, 2008
NRC:08:013

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

U.S. EPR Final Safety Analysis Report, Supplement 2

Ref. 1: Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Application for Standard Design Certification of the U.S. EPR (Project No. 733)," NRC:07:070, December 11, 2007.

On December 11, 2007, AREVA NP Inc. (AREVA NP) tendered an application for a standard design certification for the U.S. EPR (Reference 1). The application included a Final Safety Analysis Report (FSAR). Since the application was tendered, AREVA NP has identified several areas where information in the FSAR needs to be supplemented to support the NRC's review of the design certification application as well as future combined license applications.

Attachment A provides a summary description of the changes provided in this supplemental information.

Attachment B provides the revised sections in a redline/strikeout format and supplements the FSAR submitted by Reference 1. These pages provide the NRC staff with information to support the U.S. EPR design certification review. Editorial changes may appear on some of the pages. Please note the page numbering may vary from the complete FSAR.

This supplemental information will be included in Revision 1 to the U.S. EPR FSAR.

If you have any questions related to this submittal, please contact Ms. Sandra M. Sloan, Regulatory Affairs Manager for New Plants Deployment. She may be reached by telephone at 434-832-2369 or by e-mail at sandra.sloan@areva.com.

Sincerely,

Ronnie L. Gardner

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ATTACHMENT A

DESCRIPTION OF CHANGES

Item	Tier	Section	Changed Pages	Description of Changes
1	1	5.0	5.0-4	In Table 5.0-1, revised wording in minimum shear wave velocity statement.
2	2	Table 1.8-2	1.8-16	Corrected Section reference for COL item 3.4-3.
3	2	2.4	2.4-1	Revised yard grade definition from "zero" to "1 foot below ground floor top of concrete."
4	2	2.5.4.10.2	2.5-7	Removed two sentences discussing 3" settlement.
5	2	3.6.2.2	3.6-31	Deleted text of COL item that is not in Table 1.8-2 (guard pipe).
6	2	1.8 3.7.2.8	1.8-1, 1.8-4, 1.8-5 3.7-98 – 3.7-99	1) Added text for COL item identified in Table 1.8-2 (Item 3.7-6) for fire protection storage tanks. 2) Delineated fire protection storage tanks and buildings as conceptual information. 3) Added fire water distribution system as an interface item in Table 1.8-1. 4) Revised Reference from 3.7 to 3.7.2 for location of conceptual information.
7	2	3.7.2.8	3.7-95	Added text for COL item identified in Table 1.8-2 (Item 3.7-2) for access building and turbine building separation.
8	2	1.8 6.4	1.8-2, 1.8-4 6.4-1 – 6.4-7	1) Delineated parts of MCR habitability system related to toxic gas as conceptual. 2) Added toxic gas detectors for MCR as an interface item for Table 1.8-1.
9	2	9.4.1	9.4-2, 9.4-3, 9.4-7, 9.4-9, 9.4-13	Delineated parts of MCR HVAC description related to toxic gas as conceptual.
10	2	Ch 16 TS 3.7.10 TS 5.5.17 B 3.7.10 B 3.7.12	 3.7.10-1 5.5-14 – 5.5-15 B3.7.10-1 – B3.7.10-8 B3.7.12-4	Delineated information related to toxic gas in technical specifications and bases as conceptual
11	2	Table 1.8-2	1.8-33	1) Added COL item identified in text of Chapter 10 to provide a list of material specifications for the alternate turbine-generator components if an alternate turbine is selected. 2) Section reference for COL item 10.2-2 and editorial text change of "data from" to "properties of."

Item	Tier	Section	Changed Pages	Description of Changes
12	2	Tables 6.2.1-18, 6.2.1-19, and 6.2.1-20	6.2-68 – 6.2-99	Revised mass and energy release tables to extend the time duration.
13	2	6.2.1; Tables 6.2.1-23, 6.2.1-24, and 6.2.1-25	6.2-19, 6.2-107 – 6.2-115	1) Added energy inventory tables 2) Revised Section numbering.
14	2	Figures 6.2.1-16, 6.2.1-17, 6.2.1-30, 6.2.1-31	6.2-117, 6.2-118, 6.2-131, and 6.2-132	Replaced figures to reflect results of revised calculations which corrected modeling error of safety injection.

ATTACHMENT B

SUPPLEMENTAL INFORMATION CONTENTS

Section	Pages
Tier 1, 5.0	5.0-1 – 5.0-6
Tier 2, 1.8	1.8-1 – 1.8-5 1.8-16, 1.8-33
Tier 2, 2.4	2.4-1
Tier 2, 2.5.4.10.2	2.5-7
Tier 2, 3.6.2.2	3.6-30 – 3.6-31
Tier 2, 3.7.2.8	3.7-95 – 3.7-99
Tier 2, 6.2.1	6.2-19
Tier 2, Tables 6.2.1-18, 6.2.1-19, 6.2.1-20, 6.2.1-23, 6.2.1-24, and 6.2.1-25	6.2-68 – 6.2-99 6.2-107 – 6.2-115
Tier 2, Figures 6.2.1-16, 6.2.1-17, 6.2.1-30, 6.2.1-31	6.2-117, 6.2-118, 6.2-131, 6.2-132
Tier 2, 6.4	6.4-1 – 6.4-7
Tier 2, 9.4.1	9.4-1 – 9.4-14
<u>Tier 2, Ch 16</u> TS 3.7.10 TS 5.5.17 B 3.7.10 B 3.7.12	 3.7.10-1 5.5-14 – 5.5-15 B3.7.10-1 – B3.7.10-9 B3.7.12-4

5.0 SITE PARAMETERS

Assuming the certified design will be referenced for a wide range of sites, it is necessary to specify a set of site parameters enveloping the conditions that could be present at most potential power plant sites in the United States. These parameters are provided in Table 5.0-1. It is intended that any facility that references the certified design will utilize a site where the actual site-specific conditions are within the defined envelope.

In the case of seismic design parameters, deviations from the defined conditions may be justified by site-specific soil-structure interaction analyses. The results may be used to confirm the seismic design adequacy of the certified design using approved methods and acceptance criteria.

Table 5.0-1—Site Parameters for the U.S. EPR Design (5 Sheets)

Parameter	Value(s)
Precipitation	
Parameter	**Value(s)**
Rainfall rate (for roof design)	Maximum site rainfall rate of 19.4 inches per hour.
Snow & Ice Load (for roof design)	Maximum snow and ice load of 100 psf extreme live load.
Seismology	
Parameter	**Value(s)**
Seismology (SSE response spectra using figures)	Horizontal design ground motion shall be the certified seismic design response spectra shapes anchored to a peak ground acceleration of 0.3 g. Vertical spectra shall be the same as the horizontal spectra.
Flood Level	
Parameter	**Value(s)**
Maximum flood or tsunami	Maximum flood or tsunami level is no more than 1 ft below grade.
Temperature	
Parameter	**Value(s)**
Design ambient temperature	The 0% exceedance maximum ambient temperature is 115°F Dry Bulb and 80°F Wet Bulb coincident. The 0% exceedance minimum ambient temperature is -40°F. The 1% exceedance maximum ambient temperature is 100°F Dry Bulb and 77°F Wet Bulb, coincident. The 1% exceedance minimum ambient temperature is -10°F.
Wind	
Parameter	**Value(s)**
Maximum sustained speed	The normal maximum wind speed is 145 mph.
Tornado	
Parameter	**Value(s)**

Table 5.0-1—Site Parameters for the U.S. EPR Design (5 Sheets)

Tornado (maximum speed, pressure drop, radius of maximum rotational speed, rate of pressure drop, missile spectra)	Maximum tornado wind speed of 230 mph. Maximum rotational speed of 184 mph. Maximum tornado pressure drop of 1.2 pounds per square inch at 0.5 psi per second. Radius of maximum rotational speed is 150 ft

Table 5.0-1—Site Parameters for the U.S. EPR Design (5 Sheets)

Soil	
Parameter	**Value(s)**
Soil properties (minimum shear wave velocity, minimum bearing capacity (static), liquefaction potential)	Minimum shear wave velocity (low strain best estimate average value at bottom of basemat) of 1000 feet per second. ~~Minimum bearing capacity (static)~~ ~~(Low strain best estimate average value at bottom of basemat)~~ Minimum bearing capacity (static) of 22ksf in localized areas at the bottom of the Nuclear Island basemat and 15ksf on average across the total area of the bottom of the Nuclear Island basemat. No potential for liquefaction.
Maximum ground water level	Maximum ground water level is 3.3 ft below grade.
Maximum Differential Settlement (across the basemat)	1/2 inch in 50 ft in any direction
Slope Failure Potential	No slope failure potential is considered in the design of safety-related SSC for U.S. EPR design certification.

Table 5.0-1—Site Parameters for the U.S. EPR Design (5 Sheets)

Inventory of Radionuclides which Could Potentially Seep Into the Groundwater							
Nuclide	Activity (µCi/g)	Nuclide	Activity (µCi/g)	Nuclide	Activity (µCi/g)	Nuclide	Activity (µCi/g)
Br-83	3.2E-02	Mn-54	1.0E-03	Y-91M	5.2E-04	TE-129	2.4E-03
Br-84	1.7E-02	Fe-55	7.6E-04	Y-91	8.1E-05	TE-131M	3.7E-03
Br-85	2.0E-03	Fe-59	1.9E-04	Y-92	1.4E-04	TE-131	2.6E-03
I-129	4.6E-08	Co-58	2.9E-03	Y-93	6.5E-05	TE-132	4.1E-02
I-130	5.0E-02	Co-60	3.4E-04	ZR-95	9.3E-05	TE-134	6.7E-03
I-131	7.4E-01	Na-24	3.7E-02	NB-95	9.3E-05	BA-137M	1.0E-01
I-132	3.7E-01	Zn-65	3.2E-04	M0-99	1.1E-01	BA-140	6.2E-04
I-133	1.3E+00	W-187	1.8E-03	TC-99M	4.6E-02	LA-140	1.6E-04
I-134	2.4E-01	Rb-88	1.0E+00	RU-103	7.7E-05	CE-141	8.9E-05
I-135	7.9E-01	Rb-89	4.7E-02	RU-106	2.7E-05	CE-143	7.6E-05
Cs-134	1.7E-01	Sr-89	6.3E-04	RH-103M	6.8E-05	CE-144	6.9E-05
Cs-136	5.3E-02	Sr-90	3.3E-05	RH-106	2.7E-05	PR-143	8.8E-05
Cs-137	1.1E-01	Sr-91	1.0E-03	AG-110M	2.0E-07	PR-144	6.9E-05
Cs-138	2.2E-01	Sr-92	1.7E-04	TE-127M	4.4E-04	NP-239	8.7E-04
Cr-51	2.0E-03	Y-90	7.7E-06	TE-129M	1.5E-03		

Table 5.0-1—Site Parameters for the U.S. EPR Design (5 Sheets)

Atmospheric Dispersion Factors (χ/Q)	
Parameter	**Value(s)**
Meteorological Dispersion (values at EAB, and LPZ at appropriate time intervals for short and long term)	Atmospheric dispersion factors – χ/Q (sec/m^3) - Exclusion Area Boundary (0.5 mi) χ/Q 0 - 2 hours $\leq$ 1.00E-03 - Low Population Zone (1.5 mi) χ/Q 0 – 2 hours $\leq$ 1.75E-04 2 – 8 hours $\leq$ 1.35E-04 8 – 24 hours $\leq$ 1.00E-04 1 – 4 days $\leq$ 5.40E-05 4 – 30 days $\leq$ 2.20E-05

1.8 Interfaces with Standard Designs and Early Site Permits

This section addresses the requirements of 10 CFR 52.47(a)(25) and describes the standard plant scope interfaces for the U.S. EPR as they relate to design certification between the standard U.S. EPR plant and the COL applicant. The site-specific items that must be included by a COL applicant that references the U.S. EPR design certification are also provided in this section.

Interface requirements for systems, structures, and components (SSCs) that relate to specific mechanical, electrical, nuclear, or structural systems are covered in the appropriate chapter and identified by a specific COL information item to be addressed by the applicant. A COL applicant that references the U.S. EPR design certification will describe where the interface requirements are satisfied in the COL Final Safety Analysis Report (FSAR) to demonstrate compatibility with the U.S. EPR design. Interface requirements in Tier 1 of the U.S. EPR FSAR will demonstrate that conformance with the interface requirements can be verified with inspections, tests, or analyses and that the method for verification is included in the proposed inspections, tests, analyses, and acceptance criteria (ITAAC), per 10 CFR 52.47(a)(26).

The U.S. EPR design plant consists of the following structures and the SSCs therein:

- Reactor Building.
- Safeguard Buildings.
- Fuel Building.
- Nuclear Auxiliary Building.
- Radioactive Waste Processing Building.
- Emergency Power Generating Buildings.
- Ultimate Heat Sink (UHS) Structures.

Site-specific assumptions on which the U.S. EPR standard design is based are presented in Section 1.2.1 and Chapter 2. The physical boundary of the U.S. EPR is provided in the site plan in Section 1.2. A more detailed listing of the systems included in the U.S. EPR standard design is included in Section 3.2.

The representative conceptual designs for the portions of the plant that are not submitted for certification are described in the FSAR to satisfy the requirement of 10 CFR 52.47(a)(24). These conceptual designs are outside the scope of the U.S. EPR standard design, but conceptual design information is provided as discussed below.

- The Access Building, Turbine Building, and the Fire Protection Storage Tanks and Pump Building. Conceptual design information for these structures is included, delineated by double brackets ([[ ]]), in Section 1.2 and Section 3.7.2.

- The Switchgear Building. Conceptual design information for this structure is included, delineated by double brackets ([[ ]]), in Section 1.2, Section 8.3, and Section 8.4.

- The auxiliary power and generator transformer areas. Conceptual design information for these components is included, delineated by double brackets ([[ ]]), in Section 8.2.

- Buried conduit duct banks, pipe ducts, and piping. Conceptual design information for these components is included, delineated by double brackets ([[ ]]), in Section 3.8.

- Toxic gas detectors for main control room. Conceptual design information that includes protection from hazardous chemicals and toxic gases is included, delineated by double brackets ([[ ]]), in Section 6.4, Section 9.4.1, and Section 16.0 – Technical Specifications 3.7.10, 5.5.17, and corresponding bases for 3.7.10 and 3.7.12.

- The portions of the circulating water supply system outside the Turbine Building. Conceptual design information for this system is presented, delineated by double brackets ([[ ]]), in Section 10.4.5, based upon a cooling tower approach.

- Security structures, systems, and components outside the U.S. EPR buildings listed above. Conceptual design information for these structures, systems, and components is included, delineated by double brackets ([[ ]]), in Section 13.6.

- The offsite power transmission system including the main switchyard area. Conceptual design information for this system is included, delineated by double brackets ([[ ]]), in Section 8.2.

- The lightning protection and grounding system grid. Conceptual design information for this system is included, delineated by double brackets ([[ ]]), in Section 8.3.1.

Table 1.8-1—Summary of U.S. EPR Plant Interfaces with Remainder of Plant, identifies the interfaces between the U.S. EPR standard design and the remainder of the plant. The safety-related interface requirements in Table 1.8-1 have been selected based on a review of interfaces between the U.S. EPR standard design and other COL applicant or site-specific items. The interface types are classified as follows:

- U.S. EPR interface: Assumptions made for the U.S. EPR design that must be verified during the coordination effort between the designer of the U.S. EPR and the COL applicant.

- Site Parameters: Site-related parameters upon which the U.S. EPR design is based.

The classification of SSCs is further described in Section 3.2. The representative conceptual designs for the portions of the plant that are not submitted for certification are described in the FSAR to satisfy the requirement of 10 CFR 52.47(a)(24).

1.8.1 COL Information Items

Table 1.8-2—U.S. EPR Combined License Information Items, lists the COL information items and the section where the information is discussed. A COL applicant that references the U. S. EPR design certification will identify the FSAR section, or provide a list, that demonstrates how the COL information items have been addressed. The applicable FSAR sections and Table 1.8-2 also identify when an activity required by a COL information item requires as-built information or other conditions that are not available when the COL application is submitted. These activities are completed prior to fuel load.

1.8.2 Departures

A COL applicant that references the U. S. EPR design certification will provide a list of any departures from the FSAR in the COL FSAR.

Table 1.8-1—Summary of U.S. EPR Plant Interfaces with Remainder of Plant
Sheet 1 of 2

Item No.	Interface	Interface Type	Section
1-1	Switchgear Building	U.S. EPR Interface	1.2, 8.3, 8.4
1-2	Access Building	U.S. EPR Interface	1.2, 3.7.2
1-3	Turbine Building	U.S. EPR Interface	1.2, 3.7.2
1-4	Fire Protection Storage Tanks and Building	U.S. EPR Interface	1.2, 3.7.2
2-1	Envelope of U.S. EPR site related design	Site Parameter	2.0, Table 2.1-1
2-2	Consequences of potential hazards from nearby industrial, transportation and military facilities	Site Parameter	2.2
2-3	Site-specific χ/Q values based on site-specific meteorological data at the exclusion area boundary (EAB), low population zone (LPZ), and control room	Site Parameter	2.3
2-4	Site-specific seismic parameters	Site Parameter	2.5, 3.7
2-5	Soil conditions and profiles	Site Parameter	2.5, 3.7
2-6	Bearing pressure of soil beneath the nuclear island basemat	Site Parameter	2.5
2-7	Foundation settlements	Site Parameter	2.5
3-1	Missiles generated from nearby facilities	Site Parameter	3.5
3-2	Missiles generated by tornadoes or extreme winds	Site Parameter	3.5
3-3	Aircraft hazards	Site Parameter	3.5
3-4	Site-specific loads that lie within the standard plant design envelope for Seismic Category I structures	Site Parameter	3.8
3-5	Buried conduit duct banks, pipe ducts, and piping	U.S. EPR Interface	3.8
6-1	Toxic gas detectors for the main control room	U.S. EPR Interface	6.4, 9.4.1, 16 - TS&B - 3.7.10, TS - 5.5.17, B-3.7.12
8-1	Off-site ac power transmission system connections to the switchyard and the connection to the plant power distribution system	U.S. EPR Interface	8.2
8-2	On-site ac power transmission system connections to the switchyard and the connection to the plant power distribution system	U.S. EPR Interface	8.3
8-3	Auxiliary power and generator transformer areas	U.S. EPR Interface	8.2
8-4	Lightning protection and grounding system grid	U.S. EPR Interface	8.3.1
9-1	New fuel and spent fuel storage racks	U.S. EPR Interface	9.1.1, 9.1.2

Table 1.8-1—Summary of U.S. EPR Plant Interfaces with Remainder of Plant
Sheet 2 of 2

Item No.	Interface	Interface Type	Section
9-2	Provide support systems such as makeup water, blowdown and chemical treatment (to control biofouling) for the UHS	U.S. EPR Interface	9.2.5
9-3	Raw water system	U.S. EPR Interface	9.2.9
9-4	Fire water distribution system	U.S. EPR Interface	9.5.1
10-1	Design details for circulating water system including makeup water, and water treatment	U.S. EPR Interface	10.4.5
11-1	Process Control program and program aspects of process and effluent monitoring and sampling	U.S. EPR Interface	11.5
13-1	Site-specific information for administrative, operating, emergency, maintenance, and other operating procedures.	U.S. EPR Interface	13.5
13-2	Site-specific emergency plan	U.S. EPR Interface	13.3
13-3	Site-specific security assessment and Physical Security Plan	U.S. EPR Interface	13.6
14-1	Site-specific information for development of the initial test program	U.S. EPR Interface	14

Table 1.8-2—U.S. EPR Combined License Information Items
Sheet 11 of 40

Item No.	Description	Section	Action Required by COL Applicant	Action Required by COL Holder
3.3-2	A COL applicant that references the U.S. EPR design certification will demonstrate that failure of site-specific structures or components not included in the U.S. EPR standard plant design, and not designed for wind loads, will not affect the ability of other structures to perform their intended safety functions.	3.3.1	Y	
3.3-3	A COL applicant that references the U.S. EPR design certification will demonstrate that failure of site-specific structures or components not included in the U.S. EPR standard plant design, and not designed for tornado loads, will not affect the ability of other structures to perform their intended safety functions.	3.3.2	Y	
3.4-1	A COL applicant that references the U.S. EPR design certification will confirm the potential site specific external flooding events are bounded by the U.S. EPR design basis flood values or otherwise demonstrate that the design is acceptable.	3.4.3.2	Y	
3.4-2	A COL applicant that references the U.S. EPR design certification will perform a flooding analysis for the ultimate heat sink makeup water intake structure based on the site-specific design of the structures and the flood protection concepts provided herein.	3.4.3.10	Y	
3.4-3	A COL applicant that references the U.S. EPR design certification will define the need for a site-specific permanent dewatering system.	3.4.43.11	Y	
3.5-1	A COL applicant that references the U.S. EPR design certification will describe controls to confirm that unsecured maintenance equipment, including that required for maintenance and that are undergoing maintenance, will be removed from containment prior to operation, moved to a location where it is not a potential hazard to SSCs important to safety, or seismically restrained to prevent it from becoming a missile.	3.5.1.2.3	Y	

Table 1.8-2—U.S. EPR Combined License Information Items
Sheet 28 of 40

Item No.	Description	Section	Action Required by COL Applicant	Action Required by COL Holder
9.5-14	A COL applicant that references the U.S. EPR design certification will submit site specific information to address the Regulatory Guide 1.189, Regulatory Position C.6.2.6, Cooling Towers.	Table 9.5.1-1, Section C.6.2.6	Y	
9.5-15	A COL applicant that references the U.S. EPR design certification will submit site specific information to address Regulatory Guide 1.189, Regulatory Position C.7.6, Nearby Facilities.	Table 9.5.1-1, Section C.7.6	Y	
10.0-1	A COL applicant that references the U.S. EPR design certification will select Sections 10.1, 10.2 and 10.4.7 or 10.1A, 10.2A and 10.4.7A for inclusion in the COL FSAR as applicable to the chosen turbine-generator design option.	10.0	Y	
10.2-1	A COL applicant that references the U.S. EPR design certification will provide the site-specific turbine rotor inservice inspection program consistent with the recommendations of the manufacturer.	10.2A.3.6	Y	
10.2-2	A COL applicant that references the U.S. EPR design certification will provide applicable material ~~data from~~ properties of the turbine rotor after the site-specific turbine has been procured.	10.2.3.~~3~~1 10.2A.3.~~3~~1		Y
10.2-3	A COL applicant that references the U.S. EPR design certification will provide applicable turbine disk rotor specimen test data, load-displacement data from the compact tension specimens and the fracture toughness properties after the site-specific turbine has been procured.	10.2.3.2 10.2A.3.2		Y
10.2-4	A COL applicant that references the U.S. EPR design certification, and selects the alternate turbine, will provide a list of material specifications for the alternate turbine-generator components.	10.2A.2.1.1	Y	
10.3-1	A COL applicant that references the U.S. EPR design certification will identify the authority responsible for implementation and management of the secondary side water chemistry program.	10.3.5	Y	

2.4 Hydrologic Engineering

The U.S. EPR is designed for a groundwater elevation up to 3.3 feet below the finished grade elevation and an exterior flood level of one foot below the finished grade elevation. For factored load combinations, the lateral soil load is based on saturated soil associated with flooding and groundwater. The finished yard grade is nominally one foot below ground floor top of concrete~~zero feet elevation~~, with slopes provided for drainage to preclude water from entering the buildings. No safety-related dewatering systems are provided in the U.S. EPR. Flood protection features are described in Section 3.4.

The U.S. EPR is designed for a maximum rainfall rate of 19.4 inches per hour. A rain, snow, and ice load of 100 pounds per square foot has been used, which includes the weight of the 100-year return period snow pack and the weight of the 48-hour probable maximum winter precipitation.

The hydrologic information in Section 2.4 is site specific and will be provided by the Combined License (COL) applicant that references the U.S. EPR design certification.

Sites are acceptable that are within the envelope of the groundwater and flood water maximum elevations described for the U.S. EPR standard plant design.

2.4.1 Hydrologic Description

A COL applicant that references the U.S. EPR design certification will provide a site-specific description of the hydrologic characteristics of the plant site.

2.4.2 Floods

A COL applicant that references the U.S. EPR design certification will identify site-specific information related to flood history, flood design considerations, and effects of local intense precipitation.

2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers

A COL applicant that references the U.S. EPR design certification will provide site-specific information to describe the probable maximum flood of streams and rivers and the effect of flooding on the design.

2.4.4 Potential Dam Failures, Seismically Induced

A COL applicant that references the U.S. EPR design certification will verify that the site-specific potential hazards to safety-related facilities due to the seismically-induced failure of upstream and downstream water control structures are within the hydro-geologic design basis.

2.5.4.10 Static Stability

Static stability pertaining to bearing capacity and settlement for the U.S. EPR is described in the following section. Additional information is provided in Section 3.8.5 for the foundations of Seismic Category I structures.

2.5.4.10.1 Bearing Capacity

The maximum bearing pressure under static loading conditions for the foundation basemat beneath the NI Common Basemat Structures is 22,000 lb/ft^2, which includes the dead weight of the structure and components and 25 percent of the live load. The maximum bearing pressure under safe shutdown earthquake loads combined with other loads, as described in Section 3.8.5, is 25,000lb/ft^2. Refer to Appendix 3E for details of these bearing pressures under the basemat (GDC 2).

A COL applicant that references the U.S. EPR design certification will verify that site-specific foundation soils beneath the foundation basemats of Seismic Category I structures have the capacity to support the bearing pressure with a factor of safety of 3.0 under static conditions.

2.5.4.10.2 Settlement

Safety-related structures, systems and components are housed primarily in structures supported by the foundation basemat for the NI Common Basemat Structures and independent foundation basemats for the EPGBs and the ESWBs. The design of the Seismic Category I foundations for the U.S. EPR is based on a maximum differential settlement of ½ inch per 50 ft in any direction across the basemat. Settlements within this limit will not adversely affect the function of safety-related structures, systems, or components based on the design basis for relative displacements between SSCs (GDC 2).

Total settlement is dependent on site specific conditions, construction sequence, loading conditions, and excavation and dewatering plans. ~~Up to three inches of settlement might occur following first placement of concrete. At settlement values on the order of three inches, no shear failure of the foundations, general or local, is expected.~~ It is expected that all elastic settlement and most of the consolidation settlement will occur by the time of completion of construction. There are limited interfaces between systems located on different basemats. The effects of settlement and differential settlement are considered where these interfaces occur. As described in Section 3.8.4.1.8 and Section 3.8.4.1.9, the design of safety-related buried conduits and piping is site-specific. These features will be designed for site-specific values of settlement and differential settlement expected at the interface with the foundation basemat after connections are made. Alternatively, site-specific structural features such as tunnels may be used to limit the imposition of differential settlement.

A COL applicant that references the U.S. EPR design certification will verify that the differential settlement value of ½ inch per 50 ft in any direction across the foundation basemat of a Seismic Category I structure is not exceeded. Settlement values larger than this may be demonstrated acceptable by performing additional site-specific evaluations.

- The pipe movement is assumed to occur in the direction of the jet reaction, unless it is physically limited by means of whip restraint, structural members, or pipe stiffness as established by inelastic limit analysis.

3.6.2.1.3.3 Leakage Cracks

Leakage cracks are postulated at axial locations specified in Section 3.6.2.1.1.3 for high-energy piping and in those moderate-energy piping systems that are not exempted in Item 1 of Section 3.6.2.1.2.2.

- Leakage cracks are not postulated in piping one inch NPS or smaller.
- For high-energy piping, leakage cracks are postulated in the circumferential locations that yield the most severe environmental consequences, and for moderate-energy piping leakage cracks are postulated at circumferential and axial locations that yield the most severe environmental consequences.
- Leakage cracks are postulated to be circular openings with an area equal to a rectangle with dimensions ½ d_p x ½ t_n, where d_p is the inside pipe diameter and t_n is the nominal wall thickness.
- The flow from a leakage crack is assumed to result in an environment that wets unprotected components within the compartment, with consequent flooding in the compartment and communicating compartments. Flooding effects are determined on the basis of a conservatively estimated time period required to take corrective actions. Section 3.4 provides additional information on flooding effects.

3.6.2.2 Guard Pipe Assembly Design Criteria

Guard pipes in containment penetration areas meet the requirements of Class MC, Subsection NE of Section III of the ASME Code where the guard pipe is part of the containment boundary. In addition, the guard pipe assemblies are designed to also meet the following requirements:

- Guard pipe assemblies are tested to a pressure not less than their design pressure.
- Design pressure and temperature are not less than the maximum operating pressure and temperature of the enclosed pipe during normal plant conditions.
- Containment design pressure and temperature, combined with safe shutdown earthquake loading, does not cause stress in the guard pipe assemblies to exceed Level C service limits from Subarticle NE-3220 in Section III of the ASME Code.
- Guard pipes do not prevent access for performing inservice inspections of piping welds, as required by Item 3 in Section 3.6.2.1.1.1. Additional information on inservice inspection and testing of the reactor coolant pressure boundary is provided in Sections 5.2.4 and 6.6.8.

- ~~A COL applicant that references the U.S EPR design certification will provide information regarding the implementation of the design criteria relating to protective assemblies or guard pipes, including their final design and arrangement of the access openings used to examine the process pipe welds within such protective assemblies to meet the requirements of the inservice inspection program for the plant.~~

3.6.2.3 Analytical Methods to Define Forcing Functions and Response Models

Movement of pipe, due to pipe breaks and cracks, is analyzed to show that the motion does not result in overstress of any structure, system, or component important to safety. This section will address the criteria for dynamic or pseudo-dynamic analysis of piping systems, targets, and protection devices. Criteria for the dynamic analysis that will be followed are:

- For each postulated pipe break an analysis of the dynamic response of the broken pipe is performed.
- In the case of circumferential pipe breaks, the need for a pipe whip dynamic analysis is determined based on the driving energy of the fluid.
- Mass inertia and stiffness properties of the systems, elastic and inelastic deformation of piping systems, impact and rebound, and support boundary conditions are adequately accounted for when calculating the dynamic response of piping and restraints.
- Loading condition (pressure, temperature, and inertial effects) prior to rupture is used in the evaluation of postulated breaks. For piping pressurized during normal power operation, the initial conditions are the greater of system energy at hot standby or at 102 percent of rated power.
- Crushable material used to dissipate the energy of a moving pipe is limited to 80 percent of its rated energy dissipating capacity. A 10 percent increase of the design yield strength (S_Y) is used to account for strain rate effects.
- Unrestrained whipping pipe is considered to be capable of causing circumferential and longitudinal breaks, individually, in smaller NPS piping and leakage cracks in piping that is of equal or larger NPS with thinner wall thickness, except where analytical or experimental justification is provided that demonstrates that the impact does not cause rupture.

A representative mathematical model of a piping system and its restraints is shown in Figure 3.6.2-1—Representative Mathematical Model of a Piping System and its Restraints. The analytical methods used to predict the response of the piping and restraint system are presented in the sections below.

3.7.2.7 Combination of Modal Responses

When the response spectrum method of analysis is used, the maximum modal responses are combined using one of the methods specified in RG 1.92, Section C, Revision 2. Such combination methods include the grouping method, ten percent method and double sum methods, and they consider the effects of closely spaced modes having frequencies differing from each other by 10 percent or less of the lower frequency.

The effect of missing mass for modes not included in the analysis is accounted for by calculating the residual seismic load equal to the ZPA on the input response spectrum times the missing mass. The residual seismic load is added to the combined modal response determined from the response spectrum method of analysis.

3.7.2.8 Interaction of Non-Seismic Category I Structures with Seismic Category I Structures

Figure 1.2-1 and Figure 3B-1 show the layout of structures for a typical U.S. EPR standard plant. The Access Building and Turbine Building are site-specific structures. A COL applicant that references the U.S. EPR design certification will provide the site-specific separation distances for the Access Building and Turbine Building. The potential for seismic-induced interaction between Seismic Category I structures and non-seismic Category I structures is assessed to verify the ability of Seismic Category I SSCs to perform their safety functions. The basis for the seismic interaction assessment guidelines given below is the prevention of structure-to-structure impact.

- The collapse of the non-Category I structure does not cause the non-Category I structure to strike a Category I SSC.
- The collapse of the non-Category I structure does not impair the integrity of seismic Category I SSCs, nor result in incapacitating injury to control room occupants.
- Conventional Seismic structures that have the potential to interact with Seismic Category I structures are assessed for collapse potential under SSE and tornado loading (acting independently). Seismic demand for the SSE is computed in accordance with ASCE 4-98, Reference 1 and the methodologies in Section 3.7.2. Seismic load combinations are developed in accordance with ASCE 43-05 (Reference 5), using a limiting acceptable condition for the structure characterized as short of collapse, but structurally stable (i.e., Seismic Design Category 5 - Limit State A) as specified in the Standard.
- For Conventional Seismic structures that have the potential to interact with Seismic Category I structures, the combined seismic deflection is less than the separation distance (i.e., gap) between the structures.

- In the case where damage to Category I SSCs cannot be precluded by the criteria above, the structure is classified as Seismic Category II and designed to the same criteria as Seismic Category I structures.

The seismic interaction criteria and assessment guidelines are summarized in Table 3.7.2-29 —Seismic Structural Interaction Criteria for Building Structures. The Vent Stack, NAB, Access Building (AB), and the Turbine Building (TB) are Conventional Seismic structures that have potential to interact with the NI Common Basemat Structures. Results of the seismic interaction assessment for those structures are presented below, with associated discussions of the Radioactive Waste Processing Building (RWPB) and Fire Protection Storage Tanks and Building.

Vent Stack

The vent stack is described in Section 3.7.2.4.2 as a steel structure approximately 100 ft high located on top of the stair towercase structure between the FB and SB 4 (see Figure 3B-1). The vent stack is classified as Seismic Category II and designed to the same requirements as Seismic Category I structures. The stack is also designed for design basis tornado loading. Therefore, the vent stack has no potential for adverse interaction with the NI Common Basemat Structures.

Nuclear Auxiliary Building

Figure 3B-1 shows that the separation gap between the Nuclear Auxiliary Building and the NI Common Basemat Structures is a minimum of 18 in. An evaluation of the potential for seismic interaction between the NAB and the NI Common Basemat Structures indicates that the maximum relative displacement, based on absolute values, between the two structures is slightly less than 9 in, or approximately one-half of the separation distance. The seismic induced displacements of NI Common Basemat Structures and NAB are calculated from a series of nonlinear analyses on finite element models of each structure with reduced degrees of freedom. The NI Common Basemat Structures and the NAB are modeled with five degrees of freedom each, consisting of three translations and two rotations (about the horizontal X-X and Y-Y axes). The reduced degree of freedom models capture the predominant structural and soil deformation modes, namely lateral displacements and rocking. The values of the masses, springs and dampers, as well as the geometry, are derived from the detailed finite element models of the respective structures.

To provide sufficient design margin to prevent collapse or unacceptable performance under SSE loading, the design forces and moments for critical structural elements of the NAB are modified in accordance with the guidance of Reference 5. A reduction in the forces and moments due to seismic effects is taken using an inelastic energy absorption factor (F_μ) from Table 5-1 of ASCE 43-05 (Reference 5) for reinforced concrete shear walls. The inelastic energy absorption factor is based on the Limit State A criterion of ASCE 43-05 where permanent distortion, short of collapse, is permitted.

The factor is for seismic design criteria and, hence, no reduction in force and moments is taken for other load cases including tornado effects. The F_{μ} factor is applied to tension, in-plane shear, and out-of-plane bending moment. A value of $F_{\mu} = 2$ is adopted for in-plane bending moments and shear in conjunction with axial tension. Per Section C5.1.2.3 of ASCE 43-05, a value of $F_{\mu} = 1$ is used for out-of-plane shear in conjunction with axial tension. For elements subjected to combined axial force and bending, a value of $F_{\mu} = 2$ is only applied to moment. Applicable provisions and design criteria for RS structures are also applied in finalizing the design.

Access Building

[[The separation gaps between the AB and SBs 3 and 4 is 0.98 ft and 1.31 ft, respectively (see Figure 3B-1).]] The walls of the AB are not physically connected to the SBs except through crossovers (passageways) providing access to the SBs. SB 3 is protected by the aircraft hazard (ACH) shield wall which not only protects the structure but also isolates control room personnel from adverse impact effects. SB 4 is not protected by the ACH shield wall. The seismic interaction assessment of the AB confirms that the separation gaps between SBs 3 and 4 are sufficient to preclude interaction. The crossover passageways are designed to accommodate the differential displacements without imparting unacceptable loads to the supporting structures.

Turbine Building

[[The separation between the TB and NI Common Basemat Structures is approximately 30 ft (see Figure 3B-1).]] Seismic interaction between the TB and NI Common Basemat Structures is prevented through application of the following design approach, which is also summarized in Table 3.7.2-29.

- Design of the TB to the requirements of the International Building code, which invokes ACI 318 (Reference 6) for concrete structures.
- Use of AISC specification, "Seismic Provisions for Structural Steel Buildings (ANSI/AISC 341)," (Reference 7) for lateral load-carrying steel bracing. (This follows the guidance in ANSI/AISC 360, "Specifications for Structural Steel Buildings," (Reference 7) for use of AISC 341 in a 'High Seismic Application' (Reference 9).
- Use of Appendix 11A, "Quality Assurance Provisions," of ASCE Standard 7-05 for QA requirements for the lateral bracing system (Reference 9).

Structural collapse under SSE loading is prevented by using the limiting acceptance criteria of ASCE 43-05, Seismic Design Category 5 - Limit State A.

In addition, crossovers from the TB to the NI Common Basemat Structures are supported primarily by the walls or roof of the ACH shield structure. Seismic interaction through the crossover is between the TB and the ACH shield structure rather than with SBs 2 and 3. Design measures limit the interaction forces between the NI Common Basemat Structures and TB transmitted through the crossover structures. The ACH shield structure and design measures isolate control room personnel from adverse effects of the interaction forces generated through the crossover structures.

Radioactive Waste Processing Building

The RWPB has no significant potential to seismically interact with either the NI Common Basemat Structures or with the nearest Seismic Category I structure not on the common basemat (i.e., the EPGB) therefore, the RWPB is not evaluated for SSE. The NAB is located between the RWPB and the NI Common Basemat Structures and shields the NI Common Basemat Structures from potential interaction. Both the NAB and RWPB are classified as RS structures and are designed for the standard plant 1/2 SSE using criteria in RG 1.143 for RW-IIa structures. The resulting designs are ductile designs with inherent margin against catastrophic collapse under SSE. In addition, this same robust design provides inherent margin against progressive collapse of the NAB caused by seismic interaction with the RWPB. In addition, the evaluation of the NAB itself for seismic interaction with the NI Common Basemat Structures under SSE loading is described above. Therefore, the NAB shields the NI Common Basemat Structures from any adverse effect of collapse of the RWPB.

Potential interaction between the RWPB and EPGB is precluded by separation and by design and site selection and foundation design criteria for the RWPB. The RWPB is embedded over 31.5 ft below grade and has a clear height above grade of +52.5 ft, while the clearance between the RWPB and EPGB is 52.06 ft (see Figure 3B-1). Therefore, the separation between the two is only 5.28 in. less than the height above grade of the RWPB. Failure of the RWPB in such a manner as to strike the EPGB is not considered credible due to the separation distance and because of the seismic design for 1/2 SSE loading described above. In addition, site selection and foundation design criteria for the U.S. EPR standard plant ensure that the RWPB is founded on competent soils, while the embedded section 31.5 ft below grade provides additional stabilization against rotation.

[[Fire Protection Storage Tanks and Buildings]]

[[The Fire Protection Storage Tanks and Buildings are classified as Conventional Seismic Structures.]] RG 1.189 requires that a water supply be provided for manual firefighting in areas containing equipment for safe plant shutdown in the event of a SSE. ~~Therefore, t~~[[The fire protection storage tanks and building are designed to provide system pressure integrity under SSE loading conditions. Seismic load combinations are developed in accordance with the requirements of ASCE 43-05 using a limiting acceptance condition for the structure characterized as essentially elastic behavior with no damage (i.e., Limit State D) as specified in the Standard.]]

The Fire Protection Storage Tanks and Buildings are site-specific structures. A COL applicant that references the U.S. EPR design certification will provide the seismic design basis for the sources of fire protection water supply for safe plant shutdown in the event of a SSE.

3.7.2.9 Effects of Parameter Variations on Floor Response Spectra

Uncertainties in seismic modeling, due to such items as uncertainties in material properties, mass properties, concrete cracking under normal loading, and structural and soil modeling techniques can affect the accuracy of floor response spectra calculated using any of the approaches for seismic analysis presented in Section 3.7.2.1. To compensate for the effect of these uncertainties, the ISRS for U.S. EPR Seismic Category I structures are broadened by ±15 percent. These broadened ISRS are used in the subsequent design of structural elements of those structures, including flexible floors and walls.

3.7.2.10 Use of Constant Vertical Static Factors

Vertical seismic loads are generated from the SSI analysis for use in the seismic design of U.S. EPR Seismic Category I structures and Seismic Category II structures. Therefore, there is no need for the use of constant vertical static factors in the design of those structures.

3.7.2.11 Method Used to Account for Torsional Effects

Torsional effects due to the eccentricity built into the stick models or 3D FEM of the structures are accounted for during the seismic SSI analysis. Additional seismic loads due to accidental torsion are accounted for as required by Standard Review Plan, Section 3.7.2, Seismic System Analysis, paragraph II.11 (Reference 2) and in ASCE 4-98, Reference 1. This is to account for uncertainties in material densities, member sizes, architectural variations, equipment loads, etc., from design assumptions. Due to these potential uncertainties, an additional torsional moment is introduced into the design and evaluation of structural members.

For the NI Common Basemat Structures, the additional torsional moment at a particular elevation is calculated as the story inertia force in each horizontal direction of interest times a moment arm equal to five percent of the building plan dimension in the perpendicular direction. Results due to the story inertia forces in both horizontal directions are summed to produce the total additional torsional moment at the particular elevation. For design purposes, this torsional moment is taken to be resisted by only selected major shear walls, and a simplified 3D FEM is developed for each of the NI Common Basemat Structures which includes only the selected shear walls. The additional torsional moment at each given elevation is applied to all wall nodes at the same elevation, constrained like a rigid diaphragm, of the simplified FEM to determine the additional design shear forces in the selected shear walls.

- The RCS primary side fluid mass and internal energy, including the pressurizer.
- The secondary side fluid mass and internal energy, from feedwater inlet to the exit of the steam from the SG.
- The SIS injection flow and enthalpy.
- The RCS pressure, the average temperature for the vapor and liquid, and the final liquid-to-volume fraction.
- The mass flow of the SIS.

6.2.1.3.5 Single Failure Analysis

The effect of single failures of various SIS/RHR system components on the M&E releases is included in these analyses. No single failure is assumed in determining the M&E releases for the maximum safeguards case. For the minimum safeguards case, the single failure assumed is the loss of one emergency diesel generator that results the loss of one complete train of ESF equipment, including the loss of one safety injection train. The analysis of both maximum and minimum safeguards cases bounds the effects of credible single failures.

6.2.1.3.6 Metal-Water Reaction

The exothermic metal-water reaction is calculated using the Baker-Just correlation, as specified in 10 CFR 50, Appendix K.

6.2.1.3.7 Energy Inventories

Inventories of the energy transferred from the primary and secondary systems to the containment, as well as the energy remaining in the primary and secondary systems, are provided in Table 6.2.1-23, Table 6.2.1-24, and Table 6.2.1-25 for the three break locations analyzed.

6.2.1.3.8 Additional Information Required for Confirmatory Analysis

System parameters and hydraulic characteristics needed to perform confirmatory analysis are provided in Table 6.2.1-21 and Figure 6.2.1-22 through Figure 6.2.1-33.

6.2.1.4 Mass and Energy Release Analysis for Postulated Secondary Pipe Ruptures inside Containment

Steam line ruptures inside a reactor containment structure may result in significant releases of high energy fluid to the containment environment, producing high containment temperatures and pressures. The M&E release following a main steam line break (MSLB) depends upon the configuration of the plant's main steam system, the containment design, the plant operating conditions, and the size of the pipe

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 1 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
0	2298.5	0	1212.4	0	410	2298.2	0	1197	0	600
0.0001	2339.8	0	1212.4	1000	510	2231.8	0	1197	1000	600
0.1001	1611.5	2307	1171.3	45552	626.6	1212	4870	1193.7	32209	571.8
0.2001	1443.2	3334	1178.1	42748	610.2	990.3	5041	1196.1	31580	560.3
0.3001	1426.5	3420	1179.3	42303	606.4	852	4478	1199.3	27477	555.9
0.4001	1387.8	3740	1181.6	41043	601.2	767.7	4730	1204.7	23684	530
0.5	1358.4	3977	1183.6	40025	596.9	730.8	4478.5	1206.5	23083.1	519.2
0.6	1333.9	4187	1185	39138	593.5	701.7	4210	1207.5	22918	512.6
0.7	1310.4	4409	1186.4	38258	590.5	684.5	4008	1207.9	22884	505.9
0.8	1286.7	4685	1187.7	37254	587.4	670.6	3813	1208.8	23488	500
0.9	1259.5	5171	1189.5	35760	584.3	650.9	3773	1209	22980	496.5
1	1219.7	5891	1190.4	33477	580.7	632.3	3760	1209.5	22343	492.6
1.1	1202	5799	1189.5	31884	587.6	601	4026	1213.9	21742	480.2
1.2	1181.2	5690	1189.2	30521	595.1	585.7	4065	1215.5	21053	473.2
1.3	1156.7	5742	1189.3	29158	598.9	573.3	4037	1216	20668	470.3
1.4	1132.2	5992	1190.3	27780	597.9	562.9	4009	1216.1	20360	467.9
1.5	1106.5	6240	1191.8	26575	594.9	554.4	3976	1216.7	20122	465.9
1.6	1082.9	6427	1193.5	25569	591.2	547.5	3938	1216.4	19972	464.2

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
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	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
1.7	1063.3	6562	1194.7	24794	587.4	542.2	3889	1216.7	19910	462.8
1.8	1019.7	6321	1196.9	25056	573.1	538.6	3833	1216.7	19932	461.8
1.9	1006.9	5978	1197.7	26377	564.5	536.3	3773	1216.4	20028	461.1
2	990.7	5970	1198.1	26078	561.6	534.9	3714	1216.2	20158	460.7
2.1	974.5	5998	1199.4	25630	558.5	533.7	3662	1216.1	20278	460.3
2.2	958.4	6094	1200.1	24987	555.8	532.2	3623	1215.7	20354	460
2.3	944.3	6214	1201.2	24267	553.5	529.8	3596	1216.1	20360	459.5
2.4	931.6	6306	1201.9	23659	551.4	526.3	3585	1215.8	20278	458.9
2.5	903.8	6726	1206.9	23009	540.4	521.7	3585	1216.1	20109	458
2.6	894.9	6980	1210.8	22339	530.4	515.9	3595	1216	19866	456.9
2.7	884.9	6969	1211.4	22048	528.7	510.4	3603	1216.5	19600	455.5
2.8	876.2	6941	1211.7	21841	527.2	503.3	3620	1216.7	19284	454.2
2.9	868.2	6895	1212.1	21717	525.8	496.1	3641	1217.3	18911	452.6
3	860.8	6835	1212.2	21658	524.5	489	3661	1217.4	18543	451
3.1	853.8	6762	1212.5	21650	523.3	481.9	3676	1217.9	18181	449.4
3.2	846.9	6686	1212.5	21664	522.1	475.5	3688	1218	17847	447.8
3.3	840.2	6606	1212.7	21692	521	469.3	3695	1218.4	17535	446.3
3.4	833.7	6528	1212.9	21726	519.9	463.3	3698	1218.7	17254	444.9
3.5	827.5	6452	1212.9	21763	518.8	457.7	3699	1219	16990	443.5

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
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	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
3.6	821.4	6380	1213	21792	517.7	452.5	3701	1219.1	16728	442.2
3.7	816.1	6315	1213.1	21806	516.7	446.9	3701	1219.5	16474	440.9
3.8	810.7	6261	1213.1	21798	515.7	442.5	3699	1219.7	16244	439.7
3.9	808.9	6220	1213.4	21796	515.1	437.4	3696	1219.8	16033	438.5
4	802.2	6202	1213.3	21708	514.3	433.1	3696	1219.9	15795	437.3
4.1	796.9	6150	1213.6	21678	513.3	428.9	3689	1220.3	15623	436.4
4.2	793.3	6101	1213.6	21658	512.4	424.2	3694	1220.2	15378	435.2
4.3	788.8	6074	1213.8	21611.9	511.8	419.4	3697	1220.7	15128.9	434
4.4	784.2	6044	1213.7	21545	511	414.6	3703	1221	14860	432.8
4.5	780.5	5998	1214	21541	510.2	410.2	3707	1221.2	14609	431.7
4.6	777.6	5949	1214.1	21568	509.6	405.6	3708	1221.3	14376	430.5
4.7	775.9	5902	1214	21637	509.2	401.4	3708	1221.5	14137	429.4
4.8	773.6	5854	1213.8	21712.9	508.8	398	3701	1221.7	13964.9	428.4
4.9	770.7	5792	1213.7	21803	508.3	395	3688	1221.9	13852	427.5
5	768.6	5717	1213.8	21934	507.8	391.5	3678	1222.1	13718	426.7
5.1	767	5645	1213.5	22081	507.4	388.2	3671	1222.2	13563	425.8
5.2	765.9	5580	1213.4	22217	507.2	385.4	3662	1221.9	13438	424.9
5.3	764.6	5526	1213.2	22327.9	506.9	382.6	3649	1222.4	13337.9	424.2
5.4	762.4	5478	1213.2	22405	506.6	379.8	3643	1222.2	13213	423.4

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
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	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
5.5	759.9	5436	1213.2	22452	506.2	377	3637	1222.8	13076	422.7
5.6	757.5	5403	1213.1	22488	505.7	374.3	3631	1222.5	12955	421.9
5.7	754.8	5375	1213.1	22499	505.2	371.7	3625	1222.7	12831	421.2
5.8	752.1	5352	1213.2	22488.9	504.8	369	3621	1222.7	12698	420.5
5.9	748.9	5333	1213.3	22459	504.2	366.5	3614	1223.2	12578	419.7
6	747.3	5323	1213.4	22430	503.9	364	3609	1223	12460	419.1
6.1	743.6	5324	1213.6	22321	503.3	361.5	3605	1223	12335	418.4
6.2	740.4	5320	1213.6	22229	502.7	359.1	3598	1223.4	12216	417.7
6.3	736.9	5321	1213.9	22117.9	502.1	356.7	3592	1223.4	12104	417
6.4	733.3	5328	1214	21982	501.4	354.3	3588	1223.5	11980	416.3
6.5	729.5	5336	1214.4	21833	500.8	352	3585	1223.3	11856	415.7
6.6	725.6	5347	1214.4	21673	500.1	349.6	3578	1223.7	11742	415
6.7	721.8	5356	1214.6	21514	499.4	347.2	3571	1224.1	11624	414.4
6.8	718	5362	1214.9	21366.9	498.7	344.7	3566	1223.8	11498	413.6
6.9	714.7	5362	1215.1	21249	498.1	342.3	3559	1223.9	11379	412.9
7	711.4	5353	1215.2	21170	497.5	340.1	3548	1224	11287	412.3
7.1	708	5336	1215.4	21112	496.9	338.3	3534	1224.1	11227	411.7
7.2	704.3	5322	1215.1	21041	496.2	336.6	3521	1224.2	11176	411.2
7.3	700.4	5316	1215.7	20923.9	495.5	335.4	3514	1223.9	11120	410.7

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 5 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
7.4	696.3	5325	1215.8	20756	494.8	334	3508	1224	11069	410.3
7.5	691.8	5342	1215.9	20552	494	332.7	3498	1224.4	11024	409.9
7.6	687.2	5361	1216.1	20328	493.2	330.5	3489	1223.9	10971	409.4
7.7	682.8	5371	1216.4	20134	492.3	327.6	3475	1224.1	10861	408.6
7.8	678.6	5369	1216.9	19985.9	491.5	324.6	3471	1224.4	10680	407.7
7.9	674.7	5361	1216.8	19872	490.8	321.6	3475	1224.8	10453	406.9
8	670.9	5347	1216.9	19781	490	318.5	3482	1225	10203	406
8.1	667	5330	1217	19699.9	489.3	315.4	3487	1225.4	9943	405.1
8.2	663.1	5312	1217.3	19619.1	488.5	312.3	3490	1225.5	9686.1	404.2
8.3	659.1	5297	1217.4	19528.9	487.8	309	3491	1225.6	9424	403.2
8.4	654.3	5297	1217.5	19364.1	486.9	305.4	3492	1226.2	9152.1	402.2
8.5	649.5	5306	1217.7	19151.9	486	301.7	3495	1226.7	8864	401.1
8.6	644.8	5312	1218.3	18947.9	485.1	298.1	3499	1226.7	8561	400
8.7	640.5	5313	1218.3	18777.1	484.3	294.4	3500	1227.3	8257	398.8
8.8	636.5	5305	1218.4	18649.9	483.4	290.9	3499	1227.7	7956	397.8
8.9	632.4	5289	1218.6	18549.1	482.7	287.3	3495	1227.9	7668	396.7
9	628.5	5270	1218.7	18459.9	481.9	284	3488	1228.1	7392	395.5
9.1	624.4	5251	1218.7	18371.9	481	280.9	3480	1228.5	7125	394.5
9.2	620.3	5234	1219	18267.1	480.2	277.9	3470	1228.8	6871	393.5

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 6 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
9.3	616	5223	1218.9	18140.9	479.4	275	3459	1228.7	6624	392.6
9.4	611.7	5214	1219.3	17999.1	478.5	272.3	3445	1229.2	6387	391.6
9.5	607.5	5208	1219.5	17847.9	477.7	269.7	3432	1228.9	6159	390.7
9.6	603	5203	1219.7	17691.9	476.8	267.3	3415	1229.4	5946	389.9
9.7	598.4	5198	1219.7	17525.1	475.9	265	3399	1229	5757	389
9.8	593.9	5191	1220.1	17351.9	475	262.7	3379	1229.4	5594	388.2
9.9	589.3	5187	1220.2	17171.1	474.1	260.6	3360	1229.1	5460	387.4
10	584.3	5183	1220.6	16973.9	473.1	258.5	3339	1229.2	5353	386.7
10.1	578.8	5179	1220.7	16755.9	472	256.5	3319	1229.2	5266	385.9
10.2	573.1	5171	1221	16530.1	470.9	254.7	3301	1228.8	5189	385.2
10.3	567.2	5156	1221.4	16318.9	469.6	253.1	3283	1229.1	5108	384.6
10.4	561.2	5137	1221.4	16121.1	468.4	251.6	3267	1229.3	5013	384
10.5	555.1	5115	1221.6	15923.9	467.1	249.9	3256	1228.7	4900	383.4
10.6	548.8	5093	1221.9	15717.9	465.8	248.4	3245	1229.2	4765	382.9
10.7	542.4	5072	1222	15501.1	464.4	247	3237	1229.2	4612	382.3
10.8	536.8	5049	1222.4	15295.9	463.1	246	3230	1229.2	4441	381.9
10.9	530.4	5008	1222.4	15198.1	461.8	245.1	3223	1229	4260	381.6
11	526	4877	1222.2	15448.9	460.4	244.1	3214	1229.2	4077	381.1
11.1	524	4683	1221.2	16066.9	459.5	242.3	3208	1229	3896	380.6

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 7 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
11.2	519.5	4557	1220.6	16372.1	458.7	240.6	3199	1229.4	3719	380.1
11.3	512.7	4538	1221	16169.9	457.4	239.1	3189	1229.3	3547	379.4
11.4	505.5	4569	1221.4	15737.1	455.8	237.8	3177	1229.4	3375	378.9
11.5	498.4	4615	1222	15227.9	454.3	236.8	3164	1229.3	3205	378.4
11.6	491.6	4666	1222.7	14691.9	452.9	235.9	3149	1229	3038	378
11.7	485.2	4708	1223.1	14190.1	451.4	234.3	3131	1229	2880	377.6
11.8	478.9	4732	1223.8	13748.9	450	232.7	3110	1228.8	2743	376.8
11.9	472.7	4744	1224.4	13351.1	448.6	230.8	3085	1228.5	2634	376.2
12	466.5	4748	1224.5	12984	447.2	228.6	3056	1228.5	2562	375.3
12.5	437.5	4716.6	1225.6	12045.8	443	218.7	2973.6	1228.1	2483	372.5
13	410.5	4600.8	1226.6	10793.6	436.1	214.2	2880.8	1227.4	2183.6	369.9
13.5	382.7	4446.8	1227.4	9660	429.1	211.6	2806.8	1226.8	1810.6	367.7
14	356.1	4276.4	1228.2	8555.2	421.5	216.3	2767.2	1225.5	1327.8	368.2
14.5	332	4113.2	1228.8	7457.2	414.4	220.6	2703.4	1223.4	764.4	369.5
15	307.9	3962.2	1229.6	6353	407.1	216.4	2584.6	1221	386.4	369.5
16	265.9	3689.2	1230.2	4972.4	396.7	195	2334.1	1218.3	177.9	364
17	229.4	3278.6	1229.6	3534.3	382.6	162.4	1980.4	1217.7	70.3	351.3
18	200.5	2848.5	1227.4	2286.9	369.1	133.7	1634.2	1223.3	42.5	336.9
19	143	2372.6	1223.5	1193.2	354.6	69.7	1211.8	1228.6	22.9	311.3

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 8 of 10

Time sec	Reactor Vessel Side of the Break: Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	SG Side of the Break: Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
20	120.6	1669.8	1217.1	707.2	323.4	52	557.2	1219.8	41.2	254
22	92.8	1253.5	1210.6	454.6	300.7	59.8	681.1	1205.6	86.4	263.6
24	82.3	1252.9	1209.6	378.1	299.4	73	795.5	1204	140.4	274.6
26	80.5	1111.9	1209.8	1509.3	291	72.1	916.4	1207.1	265.2	279.4
28	72.7	815.3	1198.3	3306	285.1	64.8	731.2	1215.1	56.4	270.4
30	65.3	681.2	1194.1	3655.7	275.9	56.7	699.8	1221.9	40.6	272.1
34	49.3	515	1188.3	3377.8	261.4	36.4	518.8	1225.6	21.7	252.4
38	44.5	280	1178.7	4514	248.8	23.1	342.8	1198.5	54.9	215.8
42	37.5	159.6	1172.6	5691.7	238.4	22.9	330.2	1183.7	133.3	211.3
46	31.1	100.7	1168.3	5865.5	224.6	19.9	306.5	1181.3	135.2	208.8
50	25.2	47.8	1163.2	6909.2	202.8	19.1	243.2	1173.8	132.4	201.3
54	23.3	33	1163.2	6614.1	192.7	17.8	201.3	1168.6	146	196.4
58	18.7	111.3	1183.5	1797.9	196.9	15.3	135.6	1162.7	125.2	189.4
62	18	78.8	1186.1	1857.1	190	14.8	42	1156.9	63.6	181.4
66	16	86.8	1189.5	808.5	187.5	14.7	22.4	1158.9	22.5	180.4
69.9	16.9	78.8	1182.9	678.1	184.9	14.7	3.9	1146.7	5.6	179.1
90.1	21.3	167.5	1164.8	1000.8	200	14.7	0.9	1186.7	0	180
120.1	21.9	164.9	1165.1	1163.9	201.9	14.7	76.3	1162.3	68.1	187
150.1	22.1	186.8	1166.7	999	202.4	15.2	82.8	1155.5	208.9	183.9

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 9 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
180.1	20.1	205.5	1169.2	568.7	199.5	14.9	50.3	1153.2	186.7	181.6
210.1	19.7	192.9	1167.7	517.9	197.5	14.8	31.1	1154.6	48.9	181
240.1	19.3	167.9	1164.9	658.2	196.4	14.7	12.9	1182.3	1.8	177.2
270.1	19.2	154.9	1163.3	622.1	194.6	14.7	0.3	1180	0	240
300.1	19.8	136.1	1161.6	834.6	194.8	14.7	0.3	1073.3	0	240
330.1	19.3	133.4	1161.1	739.5	193.5	14.7	0.1	1030	0	240
360.1	19.3	124.7	1160	888.7	194.3	14.7	0.5	1124	0	240
400	18.5	109.6	1158.8	914.5	192.6	14.7	0	1430	0	240
Begin Long-Term Release (Total Break Flow)[1]										
430	14.7	126	1160	870	193	—	—	—	—	—
500	14.7	116	1159	870	192	—	—	—	—	—
700	14.7	93	1157	870	190	—	—	—	—	—
910	14.7	79	1156	870	188	—	—	—	—	—
1120	14.7	74	1156	870	187	—	—	—	—	—
1508	14.7	61	1154	870	184	—	—	—	—	—
2016	14.7	53	1152	870	183	—	—	—	—	—
3997	14.7	35	1152	870	182	—	—	—	—	—
4903	14.7	20	1150	870	181	—	—	—	—	—
5038	14.7	29	1151	870	181	—	—	—	—	—

Table 6.2.1-18—Mass and Energy Results for Case 7A Blowdown HL
Sheet 10 of 10

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
5098	14.7	24	1151	870	181	—	—	—	—	—
5158	14.7	13	1151	870	181	—	—	—	—	—
5188	14.7	9	1146	870	181	—	—	—	—	—
5308	14.7	7.5	1143	870	181	—	—	—	—	—
5529[2]	Note 3	4.5	1318	870	200	—	—	—	—	—
6244	Note 3	4.1	1391	870	200	—	—	—	—	—
7009	Note 3	4.0	1407	870	210	—	—	—	—	—
8005	Note 3	4.0	1410	870	212	—	—	—	—	—
13409	Note 3	4.0	1412	870	213	—	—	—	—	—
13509	Note 3	0	—	870	213	—	—	—	—	—
86400	Note 3	0	—	870	149	—	—	—	—	—

Notes:

1. Tabulated values are produced by averaging the instantaneous mass and energy releases at discrete times.
2. The code transition from RELAP5/MOD2-B&W to GOTHIC results in a discontinuity in the mass and energy releases due to distinct modeling approaches.
3. RCS upstream pressure equal to containment pressure over this interval.

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 1 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
0	2246.8	0	1212.4	0	410	2247.9	0	1197	0	460
0.0001	2237.2	0	1212.4	1000	440	2237.1	0	1197	1000	460
0.1001	938.8	1945	1203.7	32873	522	599	2695	1206	28447	516.7
0.2001	948.7	1690	1196.5	40287	532.7	595.5	2696	1205.7	24065	503.7
0.3001	923.7	1332	1196.2	41197	540	634.3	2412	1205.1	24370	511.5
0.4001	1007.2	1010	1196.5	39172	539.7	642.1	2365	1205	22869	511.7
0.5	1002.1	944.9	1196.9	39293.3	543.2	638.2	2307.3	1204.4	23655.7	516.1
0.6	1006.5	979	1195.9	39238	543.8	639.5	2311	1204.5	23405	518.2
0.7	1012.6	1019	1196.1	39275	544.4	639.9	2349	1204.6	23203	519.8
0.8	1018.1	1070	1195.6	39316	545	639.7	2396	1204.4	22946	521.5
0.9	1025.6	1133	1194.9	39362	545.5	639.2	2453	1205	22644	523.1
1	1027.7	1212	1196	39352	545.9	634.7	2533	1204.5	22214	524.4
1.1	1025.5	1300	1195.6	39142	546.1	628.7	2626	1205	21638	525.3
1.2	1022.9	1376	1196.1	38869	546.5	625.6	2702	1205.1	21120	526.7
1.3	1018.3	1473	1195.8	38529	546.8	624.2	2781	1205.5	20673	528.3
1.4	1008.2	1649	1196.5	38016	545.6	617.2	2881	1205.6	20168	529.1
1.5	993.7	1834	1196.9	37404	543.8	609.3	3002	1205.8	19490	528.8
1.6	977.4	2035	1198.3	36649	541.5	603.1	3094	1206.8	18888	529.4

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 2 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
1.7	911.7	2168	1200	35183	533.4	567.3	4807	1217	18570	486.7
1.8	906.5	2343	1200.7	34810	527.4	531.2	4984	1221.9	15516	463.1
1.9	899.4	2755	1202.1	34177	520.4	515.1	4993	1223	14661	459.4
2	892.6	2920	1202.7	33844	518.2	505.8	5003	1223.7	13990	456.7
2.1	881.9	3010	1202.9	33370	517.5	495.7	5024	1224.5	13367	454.7
2.2	845.6	3053	1204.5	32270	517.4	456.9	4974	1225.5	11947	449.1
2.3	829.4	3061	1210.7	30953	517.7	429.4	4819	1226.9	10276	440.3
2.4	824.7	3008	1230.2	30804	516.8	421.3	4704	1227	9921	436.6
2.5	816.2	2967	1240.6	30315	517.9	414.2	4717	1227.7	9246	434.5
2.6	808	2936	1247.1	29911	519.1	409.5	4736	1228.3	8820	433.4
2.7	795.4	2916	1254.1	29428	519.2	403.3	4737	1228.7	8426	432
2.8	781.5	2913	1264	28820	518.6	395.8	4722	1229.4	7991	430.3
2.9	768	2938	1271.1	28185	517.4	388	4694	1229.6	7565	428.2
3	755.6	2979	1274.2	27571	516.3	380.7	4660	1230	7156	426.2
3.1	744.5	3018	1274.1	27003	515.4	374.5	4626	1230.4	6780	424.4
3.2	734.8	3042	1272.4	26520	514.7	369.6	4593	1230.7	6480	422.9
3.3	726.1	3046	1271.2	26136	514.1	365.7	4561	1230.7	6284	421.6
3.4	718.4	3041	1268.2	25844	513.4	362.4	4529	1230.8	6182	420.6
3.5	711.5	3026	1266.6	25619	512.6	359.6	4497	1230.8	6149	419.8

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 3 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
3.6	705.5	3011	1264.1	25443	511.7	357.1	4465	1230.8	6161	419
3.7	700.2	2994	1262.3	25305	510.9	355.1	4436	1230.4	6202	418.3
3.8	695.6	2979	1260.3	25196	510.1	353.3	4406	1230.6	6261	417.8
3.9	691.5	2965	1258.8	25102	509.3	351.8	4378	1230.6	6332	417.2
4	687.8	2954	1257.3	25021	508.6	350.5	4352	1230.2	6406	416.8
4.1	684.4	2946	1255.8	24946	507.8	349.2	4325	1230.4	6483	416.3
4.2	681.2	2940	1254.6	24873	507.1	348	4301	1230.3	6558	416
4.3	678.2	2936	1253.6	24801.9	506.4	346.9	4279	1229.9	6631	415.6
4.4	675.4	2936	1252	24731	505.8	345.9	4257	1229.9	6700	415.3
4.5	672.7	2937	1250.9	24663	505.1	345	4236	1229.9	6762	415
4.6	670.2	2941	1249.7	24597	504.5	344.1	4217	1229.7	6821	414.6
4.7	667.7	2946	1248.9	24527	504	343.2	4198	1229.7	6870	414.5
4.8	665.4	2953	1247.9	24455.9	503.4	342.5	4181	1229.5	6917	414.1
4.9	663.2	2961	1246.9	24384	502.9	341.7	4165	1229.4	6959	413.9
5	660.9	2971	1245.7	24305	502.4	341	4149	1229.5	6996	413.7
5.1	658.8	2982	1244.6	24224	501.9	340.4	4135	1229.3	7029	413.4
5.2	656.7	2993	1243.8	24140	501.5	339.7	4121	1229.3	7059	413.2
5.3	654.6	3005	1242.9	24052.9	501.1	339.1	4109	1229	7087	413
5.4	655.1	3021	1241.9	23967	500.7	338.7	4096	1229.1	7114	412.8

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 4 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
5.5	641.6	3540	1228.5	23786	489	334.8	4097	1229	7198	413.2
5.6	640.1	3816	1213.2	23527	483.1	333	4043	1229.2	7055	411.3
5.7	634.9	3837	1213.5	23275	482	329.1	4012	1228.9	7003	410.4
5.8	629.6	3864	1213.5	23025.9	480.9	324.8	3972	1228.9	6916	409.1
5.9	624.5	3891	1213.5	22776	479.9	320.8	3933	1228.9	6828	407.9
6	619.7	3915	1214	22541	478.9	317.2	3897	1229.1	6753	406.6
6.1	615.1	3938	1214.4	22313	478	313.7	3865	1229.3	6688	405.6
6.2	610.8	3962	1214.4	22093	477.2	310.5	3837	1228.9	6632	404.5
6.3	606.9	3985	1214.7	21880.9	476.4	307.6	3809	1229.1	6577	403.6
6.4	602.6	4009	1214.9	21666	475.6	304.7	3783	1229.3	6524	402.6
6.5	598.2	4035	1215.1	21430	474.7	301.6	3756	1229.3	6458	401.7
6.6	594	4061	1215.4	21191	473.8	298.5	3728	1229.1	6391	400.6
6.7	590.1	4086	1215.8	20956	473	295.6	3700	1229.3	6330	399.6
6.8	586.3	4113	1215.8	20722.9	472.2	292.8	3674	1229.2	6272	398.6
6.9	582.5	4139	1216.5	20488	471.5	290.1	3648	1229.4	6211	397.8
7	578.8	4169	1216.4	20247	470.7	287.5	3624	1229.2	6147	396.9
7.1	575.2	4200	1216.6	19998	470	284.9	3599	1229.2	6078	396
7.2	571.9	4231	1217.3	19748	469.3	282.5	3575	1229.4	6007	395.1
7.3	568.7	4271	1217.1	19479.9	468.7	280.3	3554	1229.2	5939	394.4

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 5 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
7.4	563.6	4324	1217.8	19112	467.9	277.7	3531	1229.5	5869	393.5
7.5	557.2	4397	1218.1	18587	466.8	273.7	3500	1229.2	5764	392.4
7.6	552.2	4476	1218.8	18031	465.6	269.6	3460	1229.1	5626	391
7.7	548.2	4551	1219.3	17577	464.7	266.7	3425	1229.4	5501	389.7
7.8	545.1	4612	1219.8	17233.9	464.1	264.5	3402	1229	5392	388.9
7.9	542.4	4658	1220.2	16953	463.5	262.5	3381	1229.1	5294	388
8	539.4	4694	1220.4	16709	462.9	260.5	3363	1229.1	5205	387.4
8.1	536.1	4723	1220.9	16466.9	462.3	258.4	3345	1229.3	5120	386.7
8.2	532.8	4751	1221	16220.1	461.6	256.3	3326	1229.3	5034	385.9
8.3	529.5	4776	1221.5	15975.9	460.9	254.3	3308	1229.1	4948	385.1
8.4	525.9	4798	1221.7	15736.1	460.3	252.2	3289	1229.3	4862	384.3
8.5	522.4	4813	1222	15513.9	459.5	250	3269	1229.2	4775	383.6
8.6	518.9	4824	1222.2	15305.9	458.8	248	3249	1228.9	4697	382.8
8.7	515.9	4828	1222.3	15135.1	458	246.1	3228	1229.1	4630	382.1
8.8	512.5	4823	1222.7	14999.9	457.4	244.3	3209	1229.2	4578	381.4
8.9	510.2	4815	1222.5	14902.1	456.7	242.8	3191	1228.6	4531	380.7
9	508.7	4805	1222.7	14850.9	456.2	242	3177	1229.1	4507	380.3
9.1	506.2	4790	1222.9	14812.9	455.8	241	3169	1228.9	4497	380
9.2	503.8	4775	1222.8	14743.1	455.2	239.5	3153	1229	4471	379.4

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction Sheet 6 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
9.3	501.9	4762	1222.9	14694.9	454.7	238.3	3138	1228.8	4444	379
9.4	500	4749	1222.8	14659.1	454.3	237.1	3125	1228.7	4423	378.5
9.5	498.4	4736	1222.9	14623.9	453.9	236	3111	1229.1	4401	377.9
9.6	496.9	4726	1223	14593.9	453.5	235	3100	1228.8	4376	377.6
9.7	495.3	4719	1223	14546.1	453.2	233.9	3089	1228.7	4345	377.3
9.8	493.6	4718	1222.9	14470.9	452.8	232.8	3077	1228.7	4302	376.7
9.9	491.8	4722	1223.2	14363.1	452.4	231.6	3066	1228.4	4240	376.3
10	489.8	4735	1223.3	14207.9	452	230.4	3053	1228.7	4159	375.8
10.1	487.2	4755	1223.5	13998.9	451.5	229.1	3040	1228.6	4058	375.4
10.2	484.4	4780	1223.9	13738.1	450.9	227.7	3024	1228.5	3943	374.7
10.3	481.4	4806	1224.2	13452.9	450.3	226.3	3005	1228.6	3822	374.2
10.4	478.3	4828	1224.4	13173.1	449.7	224.9	2987	1228.1	3708	373.7
10.5	475.1	4842	1224.8	12917	449	223.5	2968	1228.3	3612	373
10.6	471.8	4847	1225.2	12685	448.2	221.9	2953	1228.3	3535	372.4
10.7	468.6	4848	1225.1	12485.1	447.5	220.4	2938	1228	3473	371.8
10.8	465.6	4843	1225.5	12309	446.8	219	2922	1228	3424	371.2
10.9	462.8	4837	1225.5	12158.1	446	217.7	2906	1228.1	3384	370.5
11	460.1	4828	1225.6	12035	445.4	216.5	2892	1227.9	3350	370.1
11.1	457.7	4817	1226	11930	444.8	215.5	2878	1228	3323	369.6

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 7 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
11.2	454.8	4806	1225.9	11801.1	444.1	214	2864	1227.5	3296	369.1
11.3	452.1	4793	1225.9	11690	443.5	212.5	2844	1227.8	3263	368.5
11.4	449.6	4780	1226	11598.1	442.8	211.3	2827	1227.7	3237	367.8
11.5	447.2	4770	1226.1	11486	442.2	210.1	2812	1227.7	3213	367.4
11.6	444.8	4762	1226.3	11358	441.7	209	2798	1227.4	3189	367
11.7	442.4	4755	1226.3	11224.1	441.1	207.8	2784	1227.1	3167	366.4
11.8	440.1	4748	1226.4	11087	440.5	206.8	2769	1227.4	3146	365.9
11.9	437.6	4741	1226.6	10938.1	439.9	205.7	2756	1227	3126	365.4
12	435	4735	1226.6	10770	439.3	204.6	2741	1227.5	3104	364.9
12.5	422.7	4711.4	1227	10252.4	437.5	199.8	2704.8	1226.9	3045.2	363.7
13	409.4	4630.4	1227.3	9692.8	434.2	193.7	2638.4	1226.6	2962.2	361.3
13.5	398.4	4533.2	1227.4	9350	430.9	189.1	2571.8	1226.3	2894	358.8
14	387.2	4465	1227.7	8866.8	428	184.8	2517.4	1226	2864.6	356.7
14.5	375	4407	1228.2	8379.8	424.9	179.5	2463	1225.7	2761.2	354.5
15	360.6	4329.6	1228.7	7889.4	421.2	173	2394.4	1225.5	2628.8	351.6
16	333.3	4187.9	1229.3	7172	415.3	161.6	2294.4	1225	2440.3	347.3
17	315	3972.5	1229.2	6755.2	408.6	151.9	2165.8	1224.5	2471.9	341.5
18	286.1	3857.8	1230.5	5031.3	401.4	147.9	2066.1	1223.1	1693.2	338
19	256.3	3552	1230.3	3890.1	390.8	133.4	1924.4	1221.2	1259.8	332.7

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 8 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
20	235.5	3239.8	1229.4	3730.7	381.3	123.8	1736	1219.3	1076.3	324.2
22	213.5	2918.2	1226.3	1702.9	374.9	152.3	1712.4	1216.1	497	326.3
24	170	2218.4	1221.3	690.2	350.4	126.5	1408.3	1210.1	124.3	316.1
26	107.9	1600	1212.3	110.5	330.1	80	1183.5	1206.7	27.7	310.3
28	105.4	1303.8	1214.2	1344.8	313.2	65.3	801.7	1199	112.8	273.5
30	99.5	1264.7	1213	1775.5	319.3	64.1	826.3	1198.6	23.3	278
34	83.5	922.6	1202.7	1676.8	301	55.9	704.3	1197.9	37	265.8
38	73.3	620.1	1193	2209.4	286	49.4	627.5	1194	88.7	256.6
42	57.1	286.8	1197.1	5482.7	265.6	38.1	502.8	1190	53.9	241.8
46	31.7	67.9	1200.1	9950.5	236.5	30.8	454.3	1187.5	78	234.4
50	29	56.3	1197	8307.7	207.7	30.2	433.1	1186.8	60.2	233.4
54	40.9	50	1194.2	7899.6	209	37.5	369.8	1194.8	8.8	232.3
58	45.3	29.4	1205.6	7474.4	202.2	25	291.3	1202.5	5.8	221.6
62	32.5	32	1198	6726.4	184.4	23	277.7	1189.6	27.3	208
66	32	19.9	1176.9	6382.5	186.2	20.3	251.1	1176.4	30.5	201.4
70	20.9	31.2	1178.6	5177.5	188.6	16.2	229.8	1179	34.2	197.1
74	21.2	45.9	1168.9	3207.7	187.7	15.1	167.7	1164.8	76.3	191.2
78	21.1	90.7	1168.7	1291.3	201.2	15.3	177.7	1172.2	36.5	192.2
82	21.1	118.7	1169.5	630.1	200.9	16.1	171.7	1177.5	21.5	191.6

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 9 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
86	20.3	114.4	1166.3	629.4	200	15.6	163.9	1167.4	33.3	191.3
90	20.8	108.9	1165	632.4	199.2	15.8	157.2	1164.8	39.8	190.1
120	20	96.2	1161.9	663.9	197.1	15.5	137.5	1160.3	67.4	188.1
150	19.7	93.8	1160.9	667.6	196.5	15.6	134.8	1160.1	69.9	188.1
180	19.7	92.4	1160.5	703.5	196.6	15.3	134.7	1160	75.2	188
210	20.1	91.8	1159.9	682	196.1	15.8	132.3	1159.3	72.2	187.8
240	19.8	90.5	1161	685.5	195.9	15	125.9	1158.4	87	187
270	18.9	82.6	1159.9	719	194.5	15.2	126	1158.5	62.5	186.9
300	18.5	75.8	1158.7	683.8	192.5	15	113.5	1157.5	63.6	185.8
330	17.2	69.3	1160	670.6	190	14.5	102.6	1155.9	51.1	184.7
360	16.9	63.4	1160	638.2	188	14.5	94.6	1156.5	35.5	183.7
400	16.7	56.6	1160.8	620.5	186.1	14.5	86.8	1158.1	31	183

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 10 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
Begin Long-Term Release (Total Break Flow)[1]										
480	14.7	130	1160	636	183	—	—	—	—	—
580	14.7	117	1155	711	183	—	—	—	—	—
600	14.7	126	1158	675	184	—	—	—	—	—
700	14.7	120	1156	727	184	—	—	—	—	—
1400	14.7	91	1153	762	181	—	—	—	—	—
1800	14.7	84	1154	761	179	—	—	—	—	—
2200	14.7	70	1152	752	178	—	—	—	—	—
2800	14.7	62	1153	800	175	—	—	—	—	—
4200	14.7	38	1150	829	170	—	—	—	—	—
5400	14.7	35	1153	850	158	—	—	—	—	—
6600	14.7	26	1148	871	152	—	—	—	—	—
8800	14.7	24	1151	900	148	—	—	—	—	—
10000	14.7	18.6	1147	893	146	—	—	—	—	—
10811[2]	Note 3	11.1	1271	871	177	—	—	—	—	—
11811	Note 3	12.2	1242	868	177	—	—	—	—	—
12811	Note 3	12.2	1237	867	177	—	—	—	—	—
15611	Note 3	11.6	1234	867	177	—	—	—	—	—
17211	Note 3	10.8	1234	867	177	—	—	—	—	—

Table 6.2.1-19—Mass and Energy Results for Case 14E Cold Leg Pump Suction
Sheet 11 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Press psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
18811	Note 3	9.8	1233	868	177	—	—	—	—	—
20211	Note 3	9.1	1232	869	177	—	—	—	—	—
25011	Note 3	7.6	1230	870	176	—	—	—	—	—
30011	Note 3	5.8	1227	872	174	—	—	—	—	—
35011	Note 3	4.7	1225	873	173	—	—	—	—	—
40012	Note 3	1.2	1221	876	171	—	—	—	—	—
45012	Note 3	0.68	1217	877	170	—	—	—	—	—
49412	Note 3	0	—	878	168	—	—	—	—	—
86400	Note 3	0	—	879	158	—	—	—	—	—

Notes:

1. Tabulated values are produced by averaging the instantaneous mass and energy releases at discrete times.
2. The code transition from RELAP5/MOD2-B&W to GOTHIC results in a discontinuity in the mass and energy releases due to distinct modeling approaches.
3. RCS upstream pressure equal to containment pressure over this interval.

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 1 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
0	2356.7	0.0	1212.4	0.0	410.0	2357.1	0.0	1197.0	0.0	480.0
1E-04	2286.4	0.0	1212.4	1000.0	350.0	2428.9	0.0	1197.0	1000.0	480.0
0.1001	998.9	889.0	1194.0	38745.0	551.9	1289.4	1160.0	1194.0	45578.0	548.4
0.2001	1089.4	1181.0	1197.3	39244.0	546.6	1476.9	3265.0	1176.8	55632.0	558.1
0.3001	1080.9	362.0	1191.3	41977.0	557.5	1076.8	4061.0	1175.9	49473.0	564.6
0.4001	1030.5	1605.0	1197.2	37513.0	542.0	1464.7	2386.0	1177.9	58683.0	557.2
0.5	994.2	1669.7	1198.7	37128.1	540.4	1432.7	2525.5	1181.2	56345.3	555.1
0.6	980.0	1788.0	1198.7	36662.0	538.3	1424.8	2633.0	1181.3	55836.0	554.0
0.7	985.7	1882.0	1199.8	36283.0	536.6	1276.7	2675.0	1181.7	55029.0	553.1
0.8	981.9	1959.0	1199.3	35906.0	535.2	1004.7	2627.0	1184.6	52955.0	551.8
0.9	950.8	2119.0	1200.7	35143.0	532.5	1026.4	2276.0	1184.5	53552.0	551.5
1	880.6	2257.0	1201.0	34426.0	530.1	1449.7	2122.0	1185.4	52719.0	550.8
1.1	858.6	2380.0	1201.3	33917.0	527.6	1362.5	2044.0	1185.3	53786.0	550.7
1.2	851.4	2473.0	1202.3	33469.0	525.7	1272.6	2111.0	1186.2	51991.0	549.5
1.3	864.7	2502.0	1202.6	33337.0	524.9	1309.5	2210.0	1186.1	50762.0	548.8
1.4	886.9	2585.0	1202.7	32935.0	523.2	1367.8	2525.0	1186.3	49886.0	547.4
1.5	879.5	2705.0	1204.0	32215.0	520.5	1224.5	1902.0	1188.4	48374.0	548.9
1.6	867.2	2682.0	1203.2	32281.0	520.6	979.3	2104.0	1191.6	45592.0	546.9

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 2 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
1.7	787.1	2937.0	1205.1	30841.0	515.5	1314.0	1533.0	1191.5	49046.0	547.2
1.8	820.6	2987.0	1204.8	30632.0	513.8	950.5	1992.0	1191.5	46321.0	545.1
1.9	827.9	3007.0	1205.1	30098.0	513.0	999.6	1742.0	1190.6	46547.0	547.7
2	771.4	3035.0	1205.0	30169.0	512.6	1161.5	1182.0	1192.4	45365.0	549.7
2.1	811.6	3065.0	1205.0	29750.0	511.2	1112.6	1535.0	1190.8	48642.0	547.5
2.2	782.1	3022.0	1205.1	29709.0	511.8	1019.4	1648.0	1194.7	42938.9	545.5
2.3	761.2	3083.0	1205.4	29225.0	510.2	1276.7	1273.0	1193.1	46668.0	548.9
2.4	818.5	3016.0	1205.0	29713.0	511.6	958.1	1636.0	1193.2	43486.9	546.6
2.5	774.8	3030.0	1205.4	29223.0	510.8	1007.0	1427.0	1195.2	41955.0	546.6
2.6	736.2	3029.0	1204.8	28669.0	510.2	1051.7	1226.0	1194.4	41959.0	548.6
2.7	711.3	2959.0	1205.0	28026.0	510.4	1150.5	1266.0	1194.4	41491.9	547.7
2.8	709.0	2828.0	1205.0	27333.0	511.8	1174.0	1315.0	1195.0	41511.0	547.0
2.9	751.3	2708.0	1204.3	26793.0	513.7	1115.1	1390.0	1193.8	41173.9	546.7
3	747.8	2656.0	1204.9	26225.0	514.2	973.9	1567.0	1195.9	39921.0	545.1
3.1	713.2	2539.0	1204.2	25506.0	515.6	960.2	1593.0	1195.5	39856.0	544.6
3.2	695.8	2462.0	1204.7	24876.0	516.4	957.4	1623.0	1195.4	39880.9	544.1
3.3	694.2	2404.0	1204.2	24391.0	517.2	946.9	1700.0	1196.0	39893.0	543.6
3.4	674.5	2364.0	1204.6	23779.0	517.3	945.7	1794.0	1195.4	39651.9	542.6
3.5	676.9	2268.0	1204.1	23232.0	518.9	955.5	1794.0	1195.9	39657.0	542.7

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B) Sheet 3 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
3.6	666.4	2263.0	1204.3	22793.0	518.7	950.9	1871.0	1195.8	39342.0	541.4
3.7	639.9	2270.0	1204.5	22400.0	518.4	1220.0	1944.0	1196.9	38782.9	540.3
3.8	601.8	2286.0	1204.5	22123.0	518.1	1067.1	2092.0	1198.4	37226.0	539.1
3.9	602.0	2303.0	1204.5	22020.0	518.3	1002.5	2230.0	1197.2	38189.9	534.3
4	595.6	2297.0	1204.8	21490.0	518.1	995.4	2483.0	1198.1	37682.0	530.1
4.1	588.2	2295.0	1205.3	21181.0	518.2	983.5	2589.0	1198.9	37148.0	529.2
4.2	580.6	2289.0	1204.8	20806.0	518.4	973.5	2705.0	1199.2	36563.0	528.2
4.3	573.6	2279.0	1205.6	20445.9	518.7	962.7	2817.0	1199.9	35992.9	527.5
4.4	569.7	2270.0	1205.1	20154.0	519.2	949.5	2920.0	1200.5	35361.0	526.9
4.5	565.0	2258.0	1205.8	19939.0	519.8	935.2	3026.0	1200.7	34636.0	525.9
4.6	560.2	2250.0	1205.7	19680.0	520.4	922.3	3087.0	1201.8	34013.0	525.3
4.7	556.4	2246.0	1205.9	19430.0	520.9	910.1	3125.0	1202.0	33435.0	525.0
4.8	554.2	2271.0	1205.9	19165.9	521.6	898.2	3160.0	1202.9	32851.9	524.9
4.9	552.5	2316.0	1206.5	18896.0	522.6	889.5	3211.0	1203.0	32266.0	525.2
5	549.4	2334.0	1206.2	18693.0	523.0	881.7	3228.0	1203.7	31888.0	525.1
5.1	547.0	2350.0	1206.6	18514.0	522.9	873.4	3238.0	1203.8	31563.0	524.7
5.2	543.7	2375.0	1206.5	18345.0	522.6	863.3	3281.0	1204.7	31222.0	523.3
5.3	539.0	2436.0	1206.7	18050.9	521.8	853.1	3314.0	1205.9	30869.9	522.0
5.4	534.3	2502.0	1206.8	17714.0	520.9	843.5	3329.0	1206.8	30530.0	521.0

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 4 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
5.5	544.7	3972.0	1216.2	18189.0	485.3	766.6	3814.0	1216.6	29331.0	505.8
5.6	504.0	4598.0	1220.8	16142.0	458.8	763.3	4820.0	1237.3	28079.0	476.4
5.7	479.5	4587.0	1222.7	14753.0	451.8	761.3	5201.0	1246.3	27917.0	467.4
5.8	466.6	4580.0	1223.4	13921.9	447.6	759.6	5387.0	1249.4	27511.9	466.0
5.9	455.0	4551.0	1224.0	13443.0	444.9	750.1	5299.0	1249.1	26973.0	469.3
6	441.7	4575.0	1224.8	12610.0	441.9	751.0	5220.0	1248.5	26174.0	475.0
6.1	384.3	4347.0	1225.5	11553.0	432.8	753.9	5164.0	1253.3	25977.0	477.3
6.2	363.8	4125.0	1227.0	10279.0	422.2	748.0	5156.0	1259.4	25842.0	477.4
6.3	351.2	4084.0	1227.4	9372.0	417.9	741.3	5126.0	1253.1	24772.9	485.3
6.4	341.8	4045.0	1228.3	8686.0	414.8	733.7	5133.0	1238.6	23533.0	492.8
6.5	335.0	4012.0	1228.5	8163.0	412.5	728.3	5229.0	1221.4	22408.0	498.0
6.6	328.8	3977.0	1228.8	7773.0	410.6	721.4	5361.0	1215.2	21553.0	499.4
6.7	322.7	3935.0	1228.9	7469.0	408.8	714.9	5476.0	1215.5	20904.0	498.5
6.8	317.0	3891.0	1229.0	7207.0	406.9	707.7	5562.0	1216.0	20382.9	497.4
6.9	311.4	3844.0	1229.0	6962.0	405.1	699.1	5634.0	1216.5	19857.0	495.9
7	307.6	3808.0	1229.1	6791.0	403.7	696.3	5674.0	1216.9	19549.0	494.9
7.1	304.0	3776.0	1229.1	6668.0	402.4	690.8	5690.0	1217.3	19351.0	494.2
7.2	300.5	3745.0	1229.3	6539.0	401.4	684.9	5705.0	1217.5	19082.0	493.2
7.3	296.8	3716.0	1229.0	6355.0	400.2	678.6	5748.0	1217.9	18709.9	492.1

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 5 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
7.4	292.2	3679.0	1229.2	6125.0	398.8	670.9	5813.0	1218.6	18216.0	490.9
7.5	287.8	3648.0	1229.3	5881.0	397.3	664.2	5888.0	1219.3	17640.0	489.5
7.6	283.3	3623.0	1229.9	5612.0	395.9	658.6	5984.0	1219.9	17040.0	488.5
7.7	278.7	3598.0	1229.5	5310.0	394.3	652.2	6096.0	1220.7	16320.0	487.5
7.8	275.1	3567.0	1230.1	4994.0	393.0	647.0	6211.0	1221.4	15517.9	486.4
7.9	272.2	3546.0	1229.7	4690.0	391.9	643.5	6323.0	1222.2	14749.0	485.7
8	269.4	3534.0	1230.2	4391.0	390.9	638.2	6429.0	1222.8	13895.0	485.1
8.1	267.0	3522.0	1230.2	4092.0	390.0	632.9	6546.0	1223.6	13046.0	484.1
8.2	264.7	3502.0	1230.1	3756.0	389.2	628.7	6692.0	1224.4	12207.1	483.4
8.3	263.8	3477.0	1229.9	3433.0	388.5	625.1	6821.0	1225.2	11349.0	482.7
8.4	263.4	3473.0	1229.6	3142.0	388.4	622.6	6942.0	1226.0	10546.1	482.3
8.5	263.7	3464.0	1229.6	2878.0	388.1	619.6	7033.0	1226.5	9765.0	481.8
8.6	264.4	3469.0	1229.8	2664.0	388.3	616.7	7085.0	1226.9	9084.0	481.4
8.7	265.3	3472.0	1229.3	2480.0	388.7	611.5	7088.0	1227.1	8460.0	480.5
8.8	265.2	3467.0	1229.0	2308.0	388.7	607.5	7117.0	1227.4	7956.0	479.8
8.9	265.3	3451.0	1229.0	2166.0	388.7	604.6	7131.0	1227.7	7564.0	478.9
9	265.7	3443.0	1228.6	2021.0	388.6	601.1	7159.0	1228.0	7177.0	478.4
9.1	266.4	3429.0	1228.5	1895.0	388.9	597.9	7156.0	1228.4	6810.0	477.6
9.2	266.9	3422.0	1228.2	1788.0	389.0	594.8	7157.0	1228.4	6501.0	477.1

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 6 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
9.3	267.8	3416.0	1227.6	1691.0	389.1	591.3	7136.0	1228.5	6199.0	476.4
9.4	268.2	3409.0	1227.6	1615.0	389.3	588.8	7119.0	1228.7	5965.0	475.8
9.5	268.9	3401.0	1227.4	1540.0	389.4	585.8	7096.0	1228.7	5736.0	475.3
9.6	270.0	3402.0	1227.1	1464.0	389.7	582.7	7056.0	1228.6	5468.0	474.4
9.7	270.3	3405.0	1227.0	1395.0	390.0	578.9	7022.0	1228.7	5212.0	474.0
9.8	269.3	3390.0	1227.3	1339.0	389.7	573.0	6979.0	1228.7	5014.0	472.8
9.9	267.1	3367.0	1226.7	1291.0	389.2	566.3	6921.0	1228.9	4831.0	471.4
10	264.5	3333.0	1226.7	1262.0	388.6	558.3	6845.0	1229.1	4715.0	469.9
10.1	262.7	3300.0	1226.5	1218.0	387.2	551.0	6765.0	1229.2	4547.0	468.2
10.2	259.2	3266.0	1226.1	1186.0	386.7	543.9	6691.0	1229.5	4407.0	466.7
10.3	255.2	3222.0	1226.3	1182.0	384.9	536.4	6609.0	1229.4	4359.0	465.1
10.4	250.6	3178.0	1226.1	1185.0	383.5	529.0	6523.0	1229.6	4331.0	463.3
10.5	245.7	3133.0	1226.1	1221.0	381.8	523.9	6453.0	1229.6	4406.0	462.0
10.6	240.6	3084.0	1225.9	1267.0	379.9	516.1	6369.0	1229.7	4509.0	460.5
10.7	235.4	3029.0	1226.1	1304.0	378.0	508.7	6290.0	1229.9	4598.0	458.8
10.8	231.0	2983.0	1226.0	1335.0	376.0	503.4	6219.0	1230.1	4646.0	457.2
10.9	226.7	2939.0	1226.3	1364.0	374.4	496.8	6160.0	1230.3	4691.0	456.0
11	223.4	2899.0	1225.7	1386.0	372.8	491.6	6087.0	1230.3	4695.0	454.5
11.1	221.0	2866.0	1226.1	1382.0	371.5	485.5	6032.0	1230.3	4615.0	453.3

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B) Sheet 7 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
11.2	218.5	2838.0	1225.7	1368.0	370.6	478.9	5959.0	1230.4	4470.0	451.7
11.3	215.4	2805.0	1225.6	1359.0	369.6	471.3	5879.0	1230.5	4331.0	450.0
11.4	210.8	2759.0	1225.5	1375.0	367.8	462.8	5789.0	1230.6	4270.0	448.2
11.5	204.9	2707.0	1225.0	1420.0	365.5	454.0	5685.0	1230.7	4300.0	445.7
11.6	198.3	2649.0	1225.7	1486.0	363.1	444.9	5587.0	1230.5	4412.0	443.8
11.7	191.7	2586.0	1225.2	1554.0	360.3	436.1	5486.0	1231.0	4550.0	441.4
11.8	185.9	2518.0	1225.2	1618.0	357.2	427.9	5392.0	1231.2	4697.0	439.2
11.9	181.0	2455.0	1225.1	1675.0	354.9	421.8	5311.0	1231.0	4856.0	437.5
12	175.4	2396.0	1224.3	1737.0	352.4	414.0	5218.0	1231.0	5021.0	435.5
12.5	157.3	2244.4	1224.5	1884.2	345.2	375.8	4895.0	1230.6	5415.0	429.8
13	157.2	2199.6	1224.5	2242.6	343.1	372.3	4054.4	1226.1	5346.8	426.8
13.5	143.7	2097.2	1224.1	2475.2	338.2	344.7	3534.4	1224.3	5403.4	419.7
14	134.5	1947.0	1223.2	2435.6	331.6	317.0	3222.0	1224.6	5203.2	411.8
14.5	127.6	1853.2	1222.3	2548.0	327.2	301.5	2866.8	1223.4	5031.6	406.4
15	121.1	1773.8	1221.7	2657.4	323.4	281.8	2589.4	1218.5	4892.4	402.0
16	106.2	1621.5	1220.3	2660.1	315.8	247.6	2285.7	1223.0	4710.4	390.0
17	98.0	1462.5	1217.6	2935.2	308.5	217.7	1951.1	1246.0	4926.7	366.0
18	89.6	1353.6	1216.1	3217.5	302.5	201.5	1723.6	1254.7	4808.6	345.7
19	109.4	1012.2	1205.6	3584.2	309.8	203.3	1629.6	1263.9	4443.4	323.9

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 8 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
20	100.7	873.8	1201.3	3079.6	303.4	185.6	1446.7	1264.9	3800.6	309.9
22	68.8	734.8	1195.6	2839.8	298.3	121.0	1153.4	1256.7	3625.5	299.5
24	69.7	550.4	1189.6	2630.4	283.5	113.7	705.3	1242.5	3817.5	284.8
26	59.0	478.6	1188.7	1683.6	275.8	70.7	605.9	1218.9	2563.4	276.2
28	60.7	231.6	1189.5	615.7	261.6	60.6	268.8	1228.2	908.7	264.1
30	60.0	245.0	1202.7	239.8	263.2	62.6	256.8	1209.0	376.6	264.6
34	60.0	208.5	1180.8	284.6	263.1	61.9	227.1	1201.4	529.6	264.1
38	60.2	133.9	1212.7	242.0	260.4	67.9	133.1	1262.5	537.3	261.9
42	62.7	143.4	1192.4	2280.5	256.2	61.4	195.4	1250.8	1689.6	262.0
46	62.4	95.5	1212.6	3491.6	236.4	60.9	173.3	1253.1	1090.7	249.6
50	66.0	107.0	1220.0	2005.3	228.2	60.4	139.3	1260.0	661.1	254.2
54	60.2	113.7	1215.0	1166.5	238.3	61.9	136.0	1248.2	516.8	247.4
58	60.2	139.6	1232.6	225.0	257.3	61.7	153.7	1228.8	472.8	258.9
62	60.2	149.2	1230.0	145.2	261.1	61.5	161.5	1210.5	333.0	262.4
66	60.2	155.5	1205.7	220.4	261.4	61.7	176.5	1196.9	456.2	262.7
90	60.1	79.2	1203.3	27.4	257.4	60.2	68.9	1263.9	66.2	259.2
120	60.2	149.4	1193.6	57.7	262.0	61.3	143.5	1206.8	133.7	262.9
150	60.3	154.2	1188.2	77.1	262.1	61.0	152.7	1194.0	214.0	263.0
180	60.2	97.7	1208.5	87.3	256.6	60.6	87.2	1220.8	225.4	258.8

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B) Sheet 9 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
210	60.1	146.0	1183.6	236.0	261.7	61.5	173.7	1184.0	572.9	262.6
240	60.3	129.8	1185.3	73.3	260.2	60.8	122.5	1196.9	183.4	261.6
270	60.2	127.0	1184.0	70.2	261.4	60.8	122.3	1184.4	201.4	262.5
300	60.1	127.3	1191.1	147.0	258.5	61.2	131.8	1185.4	424.5	259.9
350	60.2	110.6	1192.7	127.0	251.8	60.8	103.0	1191.0	308.0	254.2
400	60.0	110.8	1186.6	44.2	260.7	60.6	108.3	1184.5	113.9	262.1
450	60.1	108.1	1188.0	39.7	260.8	60.5	106.1	1184.7	98.2	262.0
500	60.1	108.7	1180.9	41.9	260.6	60.5	106.6	1181.0	119.5	262.1
550	60.0	102.9	1181.4	38.7	259.6	60.5	101.2	1181.5	107.3	261.7
600	60.1	93.7	1182.0	58.9	257.9	60.3	89.9	1181.2	165.3	260.2
650	60.1	87.7	1181.8	68.0	256.1	60.4	82.1	1182.5	167.3	258.2
700	60.1	90.3	1180.3	62.0	257.2	60.4	86.3	1181.5	149.7	259.5
750	60.1	86.8	1181.8	52.5	256.8	60.3	83.6	1181.3	136.0	259.3
800	60.0	87.7	1179.2	51.7	256.6	60.4	85.2	1179.5	145.2	259.2
850	60.1	87.9	1179.5	57.7	258.1	60.4	85.1	1179.9	161.6	260.0
900	60.0	85.5	1178.8	62.5	257.6	60.4	82.4	1179.9	174.2	259.8
950	60.0	82.7	1179.4	55.3	256.8	60.3	80.5	1179.3	151.1	259.5
1000	60.0	81.1	1179.1	62.3	257.1	60.3	78.2	1179.0	162.8	259.2

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B) Sheet 10 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
Begin Long-Term Release (Total Break Flow)[1]										
1125	60	152	1180	225	258	=	=	=	=	=
1375	60	134	1180	252	254	=	=	=	=	=
1625	60	116	1179	265	250	=	=	=	=	=
1875	60	104	1179	283	240	=	=	=	=	=
2500	60	88	1179	303	229	=	=	=	=	=
3500	60	69	1179	335	212	=	=	=	=	=
4500	60	54	1177	378	218	=	=	=	=	=
5500	60	48	1178	391	230	=	=	=	=	=
6500	60	46	1179	391	236	=	=	=	=	=
7500	60	37	1180	391	240	=	=	=	=	=
9000	60	32	1179	391	222	=	=	=	=	=
9252[2]	Note 3	18.6	1221	391	252	=	=	=	=	=
10000	Note 3	16.0	1263	391	250	=	=	=	=	=
15000	Note 3	15.8	1263	391	243	=	=	=	=	=
18000	Note 3	14.4	1255	391	241	=	=	=	=	=
35000	Note 3	6.2	1214	391	231	=	=	=	=	=
40000	Note 3	5.2	1210	397	228	=	=	=	=	=
50000	Note 3	2.8	1202	397	222	=	=	=	=	=

Table 6.2.1-20—Mass and Energy Results for Case 31 CLPD (Long-Term Case B)
Sheet 11 of 11

	Reactor Vessel Side of the Break					SG Side of the Break				
Time sec	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm	Upstream Pressure psia	Average Steam Mass Flow lbm/sec	Average Steam Enthalpy BTU/lbm	Average Liquid Mass Flow lbm/sec	Average Liquid Enthalpy BTU/lbm
60000	Note 3	1.8	1197	397	219	—	—	—	—	—
70000	Note 3	1.1	1194	397	216	—	—	—	—	—
86400	Note 3	0.075	1189	397	213	—	—	—	—	—

Notes:

1. Tabulated values are produced by averaging the instantaneous mass and energy releases at discrete times.
2. The code transition from RELAP5/MOD2-B&W to GOTHIC results in a discontinuity in the mass and energy releases due to distinct modeling approaches.
3. RCS upstream pressure equal to containment pressure over this interval.

Table 6.2.1-23—Containment Energy Distribution for Hot Leg Break
Sheet 1 of 2

Energy (BTU)

	Prior to LOCA t = 0 seconds	End of Blowdown t = 20 seconds	Peak Pressure t = 26 seconds	End of Reflood t =3957 seconds	1 day into recirculation
Reactor Coolant Internal Energy	4.004E+08	3.886E+07	4.135E+07	3.402E+07	5.398E+07
Accumulator Coolant Internal Energy	3.5577E+07	2.9167E+07	2.2555E+07	1.3066E+05	1.3066E+05
Energy Stored in RV Internals	N/A (included in Pressurizer, Primary Piping, Valves and Pumps)				
Energy Stored in Core	3.545E+07	1.369E+07	1.104E+07	5.207E+06	(Included in Energy stored in Pressurizer, Primary Piping, Valves, and Pumps)
Energy Generated During Shutdown from Decay Heat	0.000E+00	1.140E+07	1.290E+07	4.129E+08	5.213E+08 [1]
Energy Stored in Pressurizer, Primary Piping, Valves, and Pumps	2.140E+08	2.034E+08	2.014E+08	1.308E+08	4.135E+07
Energy Stored in SG Metals	2.075E+08	2.077E+08	2.076E+08	1.814E+08	1.234E+08
Secondary Coolant Internal Energy in SG	4.801E+08	5.113E+08	5.152E+08	4.189E+08	(Included in SG Metals)
Energy Content in RCB Atmosphere	2.996E+07	4.495E+08	4.536E+08	2.183E+08	7.426E+07
Energy Content in RCB and Internals	3.863E+09	3.882E+09	3.890E+09	4.235E+09	4.764E+09
Energy Content of Recirculation Intake Water (IRWST)	2.831E+08	2.908E+08	2.944E+08	6.494E+08	5.753E+08
Energy Content of BWST Water	N/A (See Energy Content of Recirculation Intake Water (IRWST))				
Energy Removed by LHSI Heat Exchangers	N/A (For prior to long term transition see ΔQ of ECCS source)				3.382E+09 [2]

Table 6.2.1-23—Containment Energy Distribution for Hot Leg Break
Sheet 2 of 2

Energy (BTU)

	Prior to LOCA t = 0 seconds	End of Blowdown t = 20 seconds	Peak Pressure t = 26 seconds	End of Reflood t =3957 seconds	1 day into recirculation
Energy Removed by Reactor Containment Building Fan Coolers	N/A to U.S. EPR				
SIS Pump Energy	0.000E+00	0.000E+00	0.000E+00	5.592E+06	1.237E+08
RCP Energy	N/A (LOOP)				
Decay Heat (after transition)	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.996E+09 [3]
ΔQ of ECCS Source	0.000E+00	0.000E+00	0.000E+00	1.969E+08	3.036E+08 [4]
Accumulator Nitrogen	0.000E+00	1.914E+06	1.919E+06	1.919E+06	9.186E+05
Main Feedwater	0.000E+00	3.696E+07	4.324E+07	4.927E+07	4.927E+07
Energy Balance					
Initial Energy	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09
Sum of Energy Added	0.0000E+00	5.0270E+07	5.8053E+07	4.6970E+08	3.6907E+09
Total 1	5.5488E+09	5.5990E+09	5.6068E+09	6.0185E+09	9.2394E+09
Final Energy	5.5488E+09	5.6260E+09	5.6368E+09	5.8733E+09	5.6328E+09
Sum of Energy Removed	0.0000E+00	0.0000E+00	0.0000E+00	1.9690E+08	3.6853E+09
Total 2	5.5488E+09	5.6260E+09	5.6368E+09	6.0702E+09	9.3181E+09
Difference	0.0%	-0.5%	-0.5%	-0.9%	-0.9%

Notes:

1. This is decay heat prior to long term transition. It should be added to decay heat after transition (see Note 3) for total decay heat in 24 hours.
2. RHR heat removal after long term transition.

3. Decay heat after long term transition.
4. This is heat removed by RHR system prior to long term transition. It should be added to heat removed after transition (see Note 2) for total RHR heat removal in 24 hours.

Table 6.2.1-24—Containment Energy Distribution for Cold Leg Pump Suction Break
Sheet 1 of 2
Energy (BTU)

	Prior to LOCA t = 0 seconds	Peak Pressure t = 40 seconds	End of Blowdown t=50.5 seconds	End of Reflood t =4000 seconds	1 day into recirculation
Reactor Coolant Accumulator Internal Energy	4.004E+08	4.132E+07	3.510E+07	2.935E+07	3.660E+07
Accumulator Coolant Internal Energy	3.5577E+07	1.6547E+07	8.5671E+06	1.3155E+05	1.3155E+05
Energy Stored in RV Internals	N/A (included in Pressurizer, Primary Piping, Valves and Pumps)				
Energy Stored in Core	3.545E+07	8.626E+06	8.601E+06	5.782E+06	(Included in Energy stored in Pressurizer, Primary Piping, Valves, and Pumps)
Energy Generated During Shutdown from Decay Heat	0.000E+00	1.774E+07	2.000E+07	4.170E+08	7.997E+08 [1]
Energy Stored in Pressurizer, Primary Piping, Valves, and Pumps	2.140E+08	1.974E+08	1.945E+08	1.328E+08	3.659E+07
Energy Stored in SG Metals	2.075E+08	2.076E+08	2.072E+08	1.614E+08	2.777E+08
Secondary Coolant Internal Energy in SG	4.801E+08	5.698E+08	5.898E+08	5.717E+08	(Included in SG Metals)
Energy Content in RCB Atmosphere	2.996E+07	4.609E+08	4.710E+08	2.588E+08	7.611E+07
Energy Content in RCB and Internals	3.863E+09	3.898E+09	3.908E+09	4.262E+09	4.874E+09
Energy Content of Recirculation Intake Water (IRWST)	2.831E+08	2.986E+08	3.036E+08	6.359E+08	6.225E+08
Energy Content of BWST Water	N/A (See Energy Content of Recirculation Intake Water (IRWST))				

Table 6.2.1-24—Containment Energy Distribution for Cold Leg Pump Suction Break
Sheet 2 of 2
Energy (BTU)

	Prior to LOCA t = 0 seconds	Peak Pressure t = 40 seconds	End of Blowdown t=50.5 seconds	End of Reflood t =4000 seconds	1 day into recirculation
Energy Removed by LHSI Heat Exchangers	N/A (For prior to long term transition see ΔQ of ECCS source)				2.988E+09 [2]
Energy Removed by Reactor Containment Building Fan Coolers	N/A to U.S. EPR				
SIS Pump Energy	0.000E+00	1.718E+04	3.222E+04	5.688E+06	1.237E+08
RCP Energy	0.000E+00	7.479E+04	7.479E+04	7.479E+04	7.479E+04
Decay Heat (after transition)	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.737E+09 [3]
ΔQ of ECCS Source	0.000E+00	1.783E+04	4.674E+04	1.987E+08	6.008E+08 [4]
Accumulator Nitrogen	0.000E+00	1.919E+06	1.919E+06	1.919E+06	1.919E+06
Main Feedwater	0.000E+00	9.855E+07	1.244E+08	2.489E+08	2.489E+08
Energy Balance					
Initial Energy	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09
Sum of Energy Added	0.0000E+00	1.1830E+08	1.4644E+08	6.7363E+08	3.9117E+09
Total 1	5.5488E+09	5.6671E+09	5.6952E+09	6.2224E+09	9.4605E+09
Final Energy	5.5488E+09	5.6987E+09	5.7264E+09	6.0579E+09	5.9232E+09
Sum of Energy Removed	0.0000E+00	1.7834E+04	4.6739E+04	1.9871E+08	3.6971E+09
Total 2	5.5488E+09	5.6987E+09	5.7265E+09	6.2566E+09	9.5121E+09
Difference	0.0%	-0.6%	-0.5%	-0.5%	-0.5%

Notes:

1. This is decay heat prior to long term transition. It should be added to decay heat after transition (see Note 3) for total decay heat in 24 hours.
2. RHR heat removal after long term transition.
3. Decay heat after long term transition.
4. This is heat removed by RHR system prior to long term transition. It should be added to heat removed after transition (see Note 2) for total RHR heat removal in 24 hours.

Table 6.2.1-25—Containment Energy Distribution for Cold Leg Pump Discharge Break
Sheet 1 of 2

Energy (BTU)

	Prior to LOCA t = 0 seconds	Peak Pressure t = 24 seconds	End of Blowdown t=30.5 seconds	Peak P after End of Blowdown t=1300 s	End of Reflood t=4000 s	1 day into recirculation
Reactor Coolant Internal Energy	4.004E+08	2.725E+07	2.442E+07	4.019E+07	4.302E+07	4.702E+07
Accumulator Coolant Internal Energy	3.5577E+07	1.9557E+07	1.3053E+07	1.3096E+05	1.3096E+05	1.3096E+05
Energy Stored in RV Internals	N/A (included in Reactor Coolant Internal Energy)					
Energy Stored in Core	3.545E+07	1.248E+07	1.185E+07	7.864E+06	7.650E+06	(Included in Energy stored in Pressurizer, Primary Piping, Valves, and Pumps)
Energy Generated During Shutdown from Decay Heat	0.000E+00	8.136E+06	9.667E+06	1.760E+08	4.110E+08	7.356E+08 [1]
Energy Stored in Pressurizer, Primary Piping, Valves, and Pumps	2.140E+08	2.031E+08	2.017E+08	1.829E+08	1.384E+08	4.168E+07
Energy Stored in SG Metals	2.075E+08	2.077E+08	2.075E+08	1.866E+08	1.654E+08	1.822E+08
Secondary Coolant Internal Energy in SG	4.801E+08	5.348E+08	5.492E+08	6.499E+08	6.045E+08	(Included in SG Metals)
Energy Content in RCB Atmosphere	2.996E+07	4.648E+08	4.606E+08	3.289E+08	2.887E+08	9.634E+07
Energy Content in RCB and Internals	3.863E+09	3.888E+09	3.897E+09	4.114E+09	4.278E+09	5.086E+09
Energy Content of Recirculation Intake Water (IRWST)	2.831E+08	3.010E+08	3.078E+08	5.083E+08	5.853E+08	6.754E+08
Energy Content of BWST Water	N/A (See Energy Content of Recirculation Intake Water (IRWST))					

Table 6.2.1-25—Containment Energy Distribution for Cold Leg Pump Discharge Break

Sheet 2 of 2

Energy (BTU)

	Prior to LOCA t = 0 seconds	Peak Pressure t = 24 seconds	End of Blowdown t=30.5 seconds	Peak P after End of Blowdown t=1300 s	End of Reflood t=4000 s	1 day into recirculation
Energy Removed by LHSI Heat Exchangers	N/A (For prior to long term transition see ΔQ of ECCS source)					3.008E+09 [2]
Energy Removed by Reactor Containment Building Fan Coolers	N/A to U.S. EPR					
SIS Pump Energy	0.000E+00	0.000E+00	5.112E+03	1.823E+06	5.689E+06	1.237E+08
RCP Energy	0.000E+00	6.908E+04	6.908E+04	6.908E+04	6.908E+04	6.908E+04
Decay Heat (after transition)	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.791E+09 [3]
ΔQ of ECCS Source	0.000E+00	0.000E+00	7.314E+03	3.147E+07	1.522E+08	4.366E+08 [4]
Accumulator Nitrogen	0.000E+00	1.923E+06	1.923E+06	1.923E+06	1.923E+06	1.923E+06
Main Feedwater	0.000E+00	5.913E+07	7.514E+07	2.517E+08	2.517E+08	2.517E+08
Energy Balance						
Initial Energy	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09	5.5488E+09
Sum of Energy Added	0.0000E+00	6.9257E+07	8.6808E+07	4.3149E+08	6.7036E+08	3.9042E+09
Total 1	5.5488E+09	5.6180E+09	5.6356E+09	5.9803E+09	6.2191E+09	9.4529E+09
Final Energy	5.5488E+09	5.6591E+09	5.6725E+09	6.0190E+09	6.1113E+09	6.1288E+09
Sum of Energy Removed	0.0000E+00	0.0000E+00	7.3135E+03	3.1467E+07	1.5221E+08	3.4447E+09
Total 2	5.5488E+09	5.6591E+09	5.6725E+09	6.0505E+09	6.2635E+09	9.5736E+09
Difference	0.0%	-0.7%	-0.7%	-1.2%	-0.7%	-1.3%

Notes:

1. This is decay heat prior to long term transition. It should be added to decay heat after transition (see Note 3) for total decay heat in 24 hours.
2. RHR heat removal after long term transition.
3. Decay heat after long term transition.
4. This is heat removed by RHR system prior to long term transition. It should be added to heat removed after transition (see Note 2) for total RHR heat removal in 24 hours.

Figure 6.2.1-16—LOCA Containment Pressure vs. Time (CLPS Break Long-term)

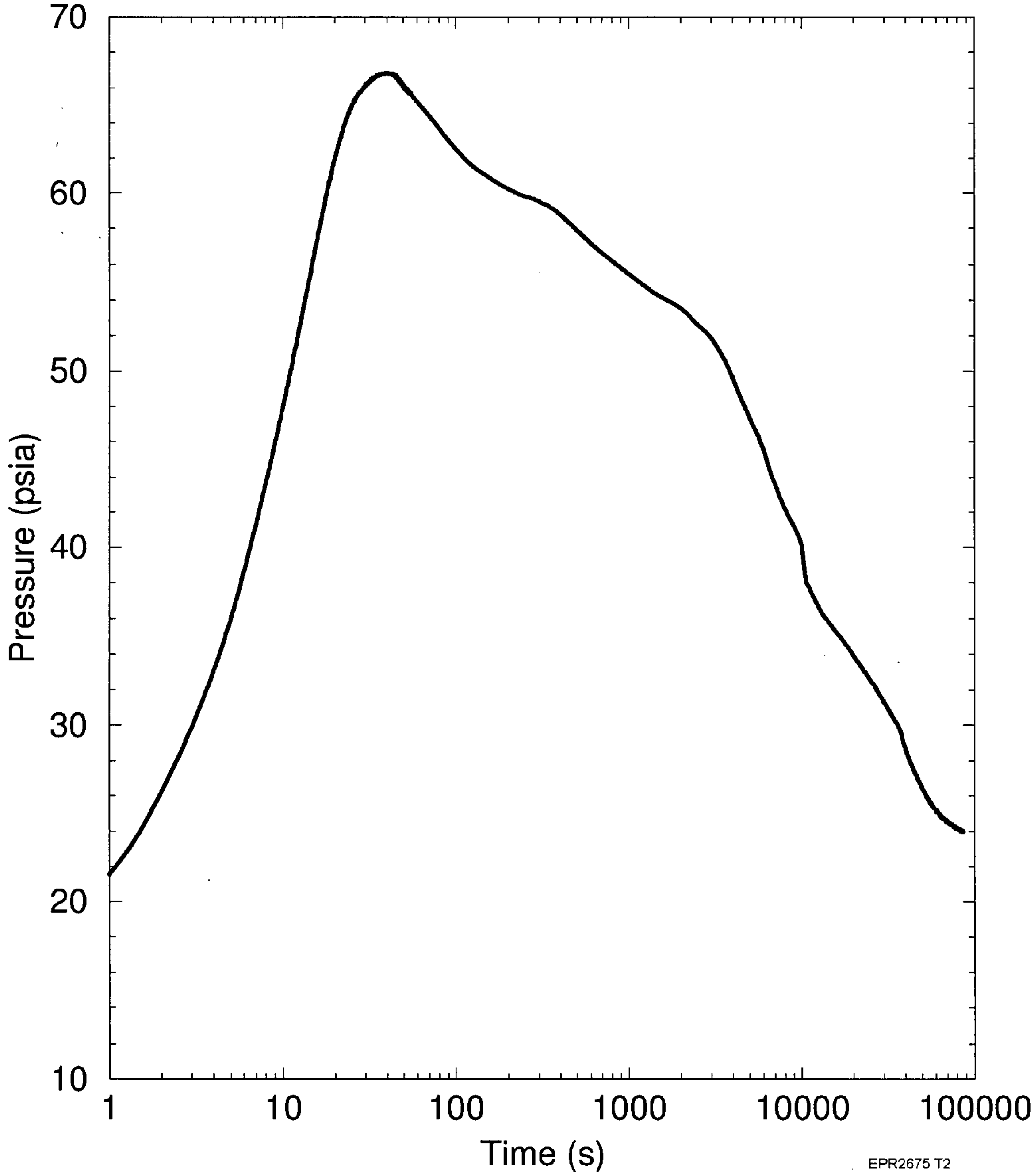


Figure 6.2.1-17—LOCA Containment Temperature vs. Time (CLPS Break Long-term)

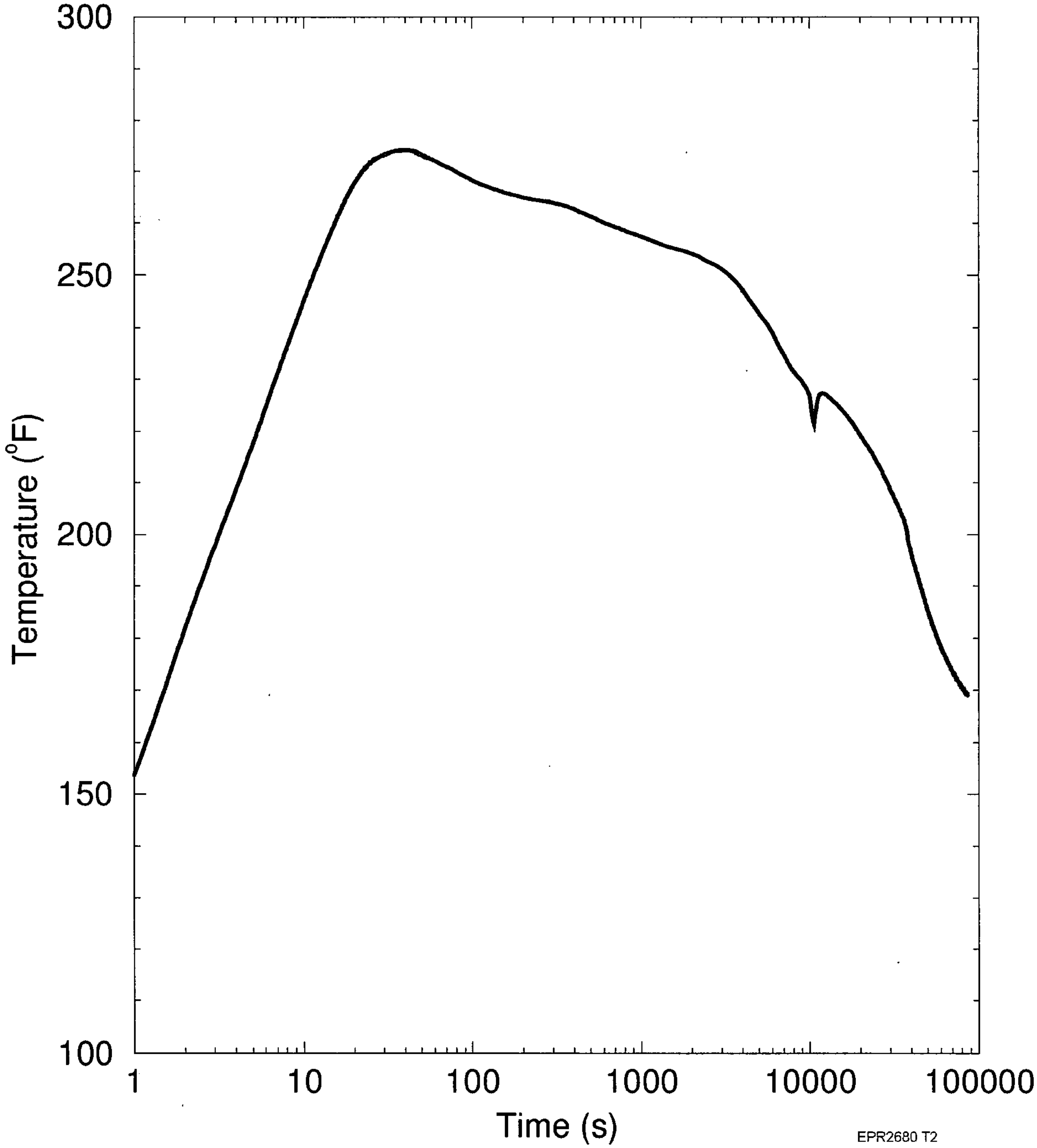


Figure 6.2.1-30—LOCA Integrated Break Mass Flow vs. Time (CLPS Break, Long-Term)

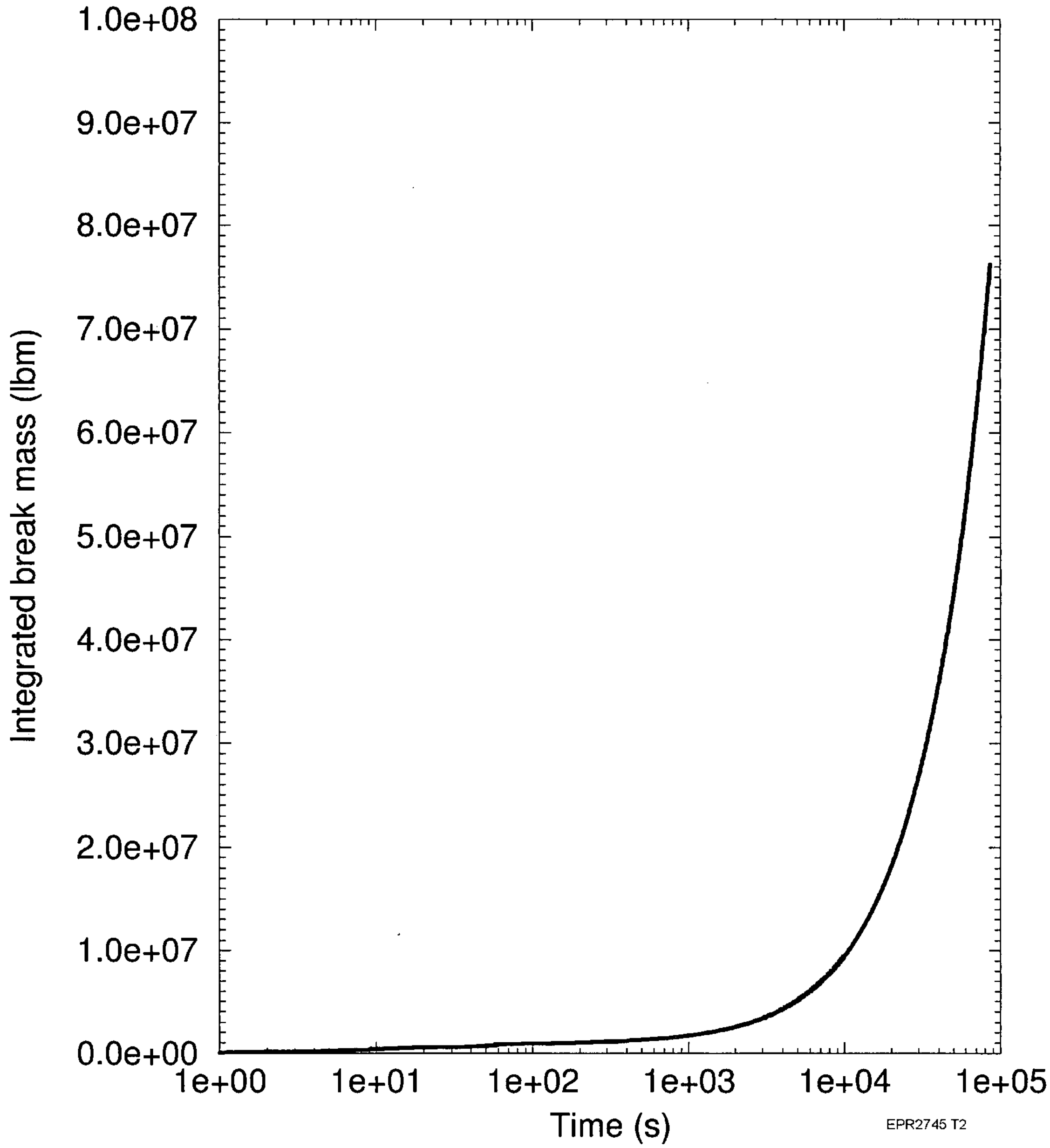
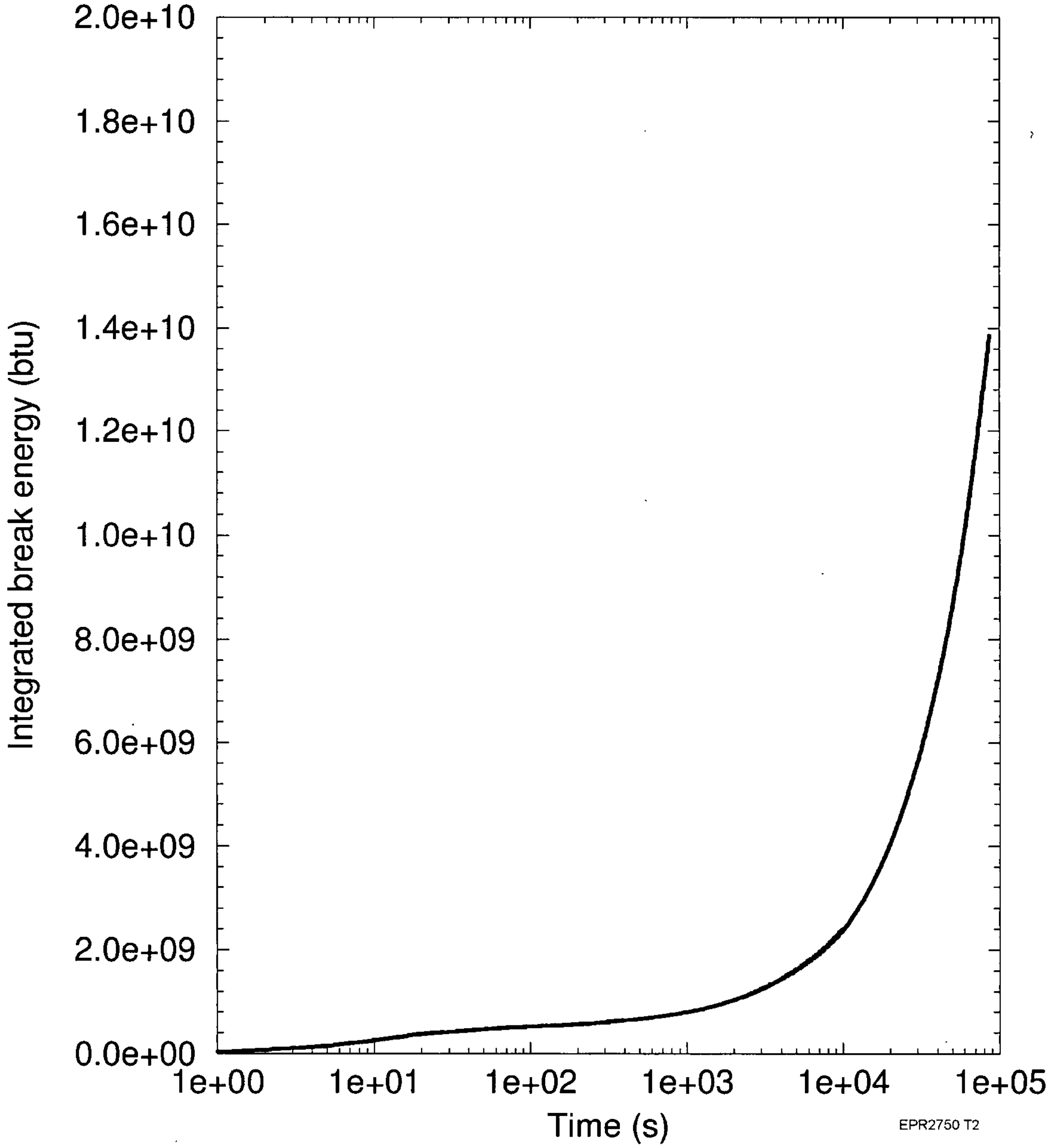


Figure 6.2.1-31—LOCA Integrated Break Energy Flow vs. Time (CLPS Break, Long-Term)



6.4 Habitability Systems

The main control room (MCR) habitability systems are designed to allow control room operators to remain in the MCR to operate the plant safely under normal conditions and to maintain the plant in a safe state under accident conditions.

The habitability systems protect the plant operators from the effects of accidental releases of [[toxic and]] radioactive gases. The systems also provide the necessary support for the technical support center (TSC) personnel in case of an accident or abnormal event. The TSC is contained within the control room envelope (CRE).

The term "habitability systems" refers to equipment, supplies, and procedures. The habitability equipment is defined in Section 6.4.2.1.

Control room habitability system objectives include:

- Missile protection and radiation shielding (Section 3.8).
- Air filtration (Section 6.5.1, Section 9.4.1).
- Pressurization and air conditioning (Section 9.4.1).
- Fire protection (Section 9.5.1).
- Radiation monitoring (Section 12.3.4).
- [[Detection of and protection from toxic gases and hazardous chemicals.]]
- Lighting (Section 9.5.3).
- Personnel support.

6.4.1 Design Basis

Control room habitability is provided, so that the plant can be operated safely under normal conditions, and maintained safely under accident conditions or abnormal events. These design bases relate to MCR habitability:

- Habitability systems are designed to accommodate the effects of environmental conditions associated with normal operation, maintenance, testing, and postulated accidents and are protected against dynamic effects that may result from equipment failures and from events and conditions outside the nuclear power unit (GDC 4).
- The MCR habitability systems are not shared among multiple nuclear power units (GDC 5).
- The CRE is protected from radiological releases to permit access and occupancy of the main control room under accident conditions (GDC 19).

- [[The CRE is protected from hazardous chemical releases to permit access and occupancy of the main control room.]]
- The main control room air conditioning system (CRACS) provides the capability to isolate the CRE from the surrounding areas, pressurize the CRE to prevent in-leakage, and filter supply air to remove radioactive halogens (10 CFR 50.34(f)(2)(xxviii)).
- The air intake structures are physically separated and located away from potential radiological sources, (10 CFR 50.34(f) (2) (xxviii)).
- The CRE design permits periodic testing and in-service inspection to confirm integrity.

The CRACS design bases are presented in Section 9.4.1.

6.4.2 System Design

6.4.2.1 Definition of Control Room Envelope

The MCR contains the equipment necessary to monitor and control the plant during all operating conditions and to bring the plant to a safe shutdown state.

The CRE comprises these areas:

- Main control room.
- Shift supervisor's office.
- Integrated operations area including:
  - Technical support center.
  - NRC office area.
  - Break area.
- Sanitary facilities.
- Instrumentation and controls (I&C) service center.
- Service corridors.
- Computer rooms.
- Equipment rooms that contain MCR ventilation supply, filtration, and air conditioning systems.

The CRE is housed within Safeguard Buildings 2 and 3. The CRE is shown in Figure 6.4–1—Control Room Envelope Plan View 1, Figure 6.4–2—Control Room Envelope

Plan View 2, and Figure 6.4–3—Control Room Envelope Elevation View. The total free-air volume of the CRE is approximately 200,000 ft^3.

These personnel support items are maintained within the confines of CRE in sufficient quantities for required operational personnel:

- Non-perishable food supply and drinking water.
- Emergency medical supply kits.
- SCBA units, air supply equipment and protective clothing for protection from smoke [[, and toxic or noxious gases]].
  - SCBA units contain a minimum of six hours of air supply capacity~~,~~ [[as specified by RG 1.78]].

Food, water, and medical needs of the control room personnel are met using the site emergency preparedness process for providing these services to emergency centers, following the guidance of NUREG-0654 (Reference 1). Emergency planning is addressed in Section 13.3.

6.4.2.2 Ventilation System Design

The CRACS design is described in Section 9.4.1, which identifies and describes major components, design parameters and classifications, instrumentation and controls, and provides a system schematic. Figure 15.0-4 presents airflows through the system for post-accident filtration. Section 6.5.1 describes the engineered safety features (ESF) filter systems and fission product removal capability for the CRACS.

Section 3.8.4 contains elevation and plan views of the Safeguard Buildings. Figure 2.3–1 provides the relative locations of potential radiological release points and the CRACS air intakes. The evaluation of potential toxic chemical accidents is addressed in Section 2.2.3. Figure 6.4–1 through Figure 6.4–3 illustrate the CRE layout, including surrounding corridors, doors, stairwells and shielded walls.

The CRACS intakes are located on the roof of Safeguard Buildings 2 and 3, to prevent [[intrusion of toxic gases or]] radiological contamination. The two intakes are physically separated and are removed from potential radiological release points, including the main steam relief exhaust, the Safeguard Building depressurization shafts, and the stack, in both lateral and vertical directions. Section 15.0.3 identifies the bounding atmospheric release point used in the radiological analyses.

Radiation monitors in the CRACS supply air duct continuously measure the concentration of radioactive materials in the supply air. The control room airborne radioactivity monitoring system is addressed in Section 12.3.4.

The main features related to control room habitability of the CRACS design are:

- Under normal operating conditions:

  - The ventilation system operates in the recycling mode with fresh air makeup.
  - The air makeup rate corresponds to the exhausts from the kitchen and sanitary rooms and leakage out of the area due to the controlled overpressure.
- The ventilation system maintains an ambient condition for comfort and safety of control room occupants and to support operability of the MCR components during normal operation, anticipated operational occurrences (AOO), and design based accidents (DBA).
- The ventilation system maintains a positive pressure of 0.125 inches water gauge as a minimum within the CRE areas with respect to adjacent environmental zones to prevent uncontrolled, unfiltered in-leakage during normal and accident conditions. The filtered outside air supply rate during accident conditions corresponds to 0.3 volume changes per hour.
- During a site radiological contamination event, the air intake is redirected through the ESF filter system trains.
- [[Control room operators are protected from chlorine releases and other toxic gases in accordance with RG 1.52, RG 1.78, and ASME AG-1 (Reference 2).]]
- The ventilation system can be operated in full recirculation mode without outside air makeup during DBAs [[or events involving toxic gas releases]]. The recirculated airflow rate is 17,000 cfm.
- The ventilation system provides adequate capacity for proper temperature and humidity within the CRE.
  - Redundancy for air cooling, filtration, and toxic gas protection is provided by having two independent trains for critical functions.
  - Redundancy is provided for proper operation of the system when one active component is out of service.
  - Power supplies of the active components are backed up with emergency power so that they function in case of a loss of offsite power.

6.4.2.3 Leaktightness

The CRACS is maintained in a manner that minimizes the unfiltered in-leakage across the CRE boundary. Adequate leak tightness for air sealing components supports operator habitability within the CRE boundary during normal operation, AOOs and DBAs.

Leak tightness provisions for pressure boundary components are:

- Pipe penetrations are sealed and tested for air leakage after initial construction.
- Cable penetrations are sealed and tested for air leakage after initial construction.

- Doors used for personnel or equipment access are sealed and remain substantially air-tight to maintain pressurization of the CRE area. Doors are arranged to allow access by necessary operational personnel and maintain pressurization of the CRE area. Two access doors are arranged in series to form a configuration similar to an air lock, minimizing in-leakage from surrounding areas.

- Open ended drain lines are provided with water seals.

- All building joints within the CRE boundary are sealed.

The CRACS maintains a positive pressure of 0.125 inches water gauge as a minimum within the CRE boundary, which limits unfiltered in-leakage through walls, ceiling, doors, pipes and cable penetrations.

The CRE boundary limits leakage from adjacent environmental zones to a maximum of 50 cfm unfiltered in-leakage. The system design requirements are provided in Section 9.4.1 and testing requirements are specified in the control room envelope habitability program in the technical specifications Section 5.5.17.

6.4.2.4 Interaction with Other Zones and Pressure-Containing Equipment

The CRACS does not supply air to areas other than the CRE. The air supply filtration and air conditioning systems are within the pressure boundary, thus minimizing the potential in-leakage of contaminated air into the MCR through fan shafts or ductwork connections.

The CRE area is isolated and pressurized in the event of an outside fire, [[external toxic gas release,]] smoke, and excessive concentrations of carbon monoxide or carbon dioxide. During these events, outside air is automatically isolated and CRACS operates in full recirculation mode. Upon detection of [[toxic gas or]] smoke, audible or visual alarms are actuated in the MCR. The CRACS and filter systems can be manually aligned from the MCR.

Fire barriers with a three hour fire rating enclose the MCR. Openings penetrating the fire barrier are furnished with both fire doors and fire dampers or approved fire rate seals meeting the associated barrier fire duration rating. In case of a fire within the CRE area, the room supply and exhaust are isolated by fire dampers and monitoring and control of the plant can be performed from the remote shutdown station (RSS). The RSS is located in a different fire zone and is on a different elevation than the MCR, and is not contained within the CRE boundary. The RSS is described in Section 7.4.

The CRACS does not interact with air conditioning equipment serving adjacent zones, minimizing the possibility of transferring [[toxic or]] radioactive gases into the CRE. Piping not connected or related to the equipment within the CRE boundary is routed outside the pressurized boundary of the CRE.

The MCR is not located near pressure-containing tanks, equipment, or piping, such as CO_2 tanks or steam lines, which upon failure could transfer dangerous or hazardous material to the CRE. However, portable self-contained breathing apparatus (SCBA) are available for use by the control room operators.

6.4.2.5 Shielding Design

Massive concrete structures separate the MCR from the reactor containment atmosphere and the external environment, as described in Section 3.8. The thick concrete walls prevent any significant direct radiation shine from outside the Safeguard Buildings. The MCR is protected against direct shine from the MCR charcoal filtration system by a 19 inch concrete floor. Radiation sources and shielding requirements are identified in Section 12.2 and Section 15.0.3. The MCR dose calculations that are presented in these sections identify the contribution from direct radiation shine and demonstrate that the total MCR dose under accident conditions is within regulatory limits.

6.4.3 System Operational Procedures

During normal plant operation, the CRACS maintains acceptable environmental conditions within the CRE boundary. Upon receipt of a high radiation signal in the air intakes or a primary containment isolation signal, the system is automatically switched so that the intake is routed through the emergency filtration system. The operating modes of the CRACS are described in Section 9.4.1.

[[Upon detection of any hazardous chemicals in the environment which have a potential for infiltration within the CRE boundary, the control room operator will take protective measures within a short period of time from the initiation of the toxic gas sensors and alarms. The operators are not subjected to prolonged exposures during this time.]] Storage provisions for SCBAs and procedures for their use allow operators to begin using the SCBAs within a short period of time after detection of a radiological event [[or a hazardous release]].

A COL applicant that references the U.S. EPR design certification will provide written emergency planning and procedures in the event of a radiological or a hazardous chemical release within or near the plant, and will provide training of control room personnel.

6.4.4 Design Evaluations

Section 9.4.1 contains the design evaluation of the CRACS. Fire protection inside and outside the CRE boundary is addressed in Section 9.5.1.

The total effective dose equivalent (TEDE) for the MCR occupants throughout the duration of any postulated DBA does not exceed the limits of GDC 19. The evaluation of radiological exposure to control room operators and the dose calculation model for the MCR is described in Section 15.0.3.

The CRE is designed, maintained and tested in accordance with RG 1.196 and RG 1.197. Habitability systems provide the capability to detect and protect personnel within the CRE boundaries from external fires, smoke, [[toxic gases]] and airborne radioactivity.

A COL applicant that references the U.S. EPR design certification will confirm that the radiation exposure of MCR occupants resulting from a DBA at a nearby unit on a multi-unit site is bounded by the radiation exposure from the postulated design basis accidents analyzed for the U.S. EPR; or confirm that the limits of GDC 19 are met.

The evaluation of potential toxic chemical accidents is addressed by the applicant in Section 2.2.3 and includes the identification of toxic chemicals. A COL applicant that references the U.S. EPR design certification will evaluate the results of the toxic chemical accidents from Section 2.2.3 and address their impact on control room habitability in accordance with RG 1.78.

6.4.5 Testing and Inspection

Testing and inspection of the CRACS are described in Section 9.4.1.Refer to Section 14.2 (test abstract #082) for initial plant testing.

Periodic testing to confirm CRE integrity is performed using testing methods and at testing frequencies consistent with RG 1.197. The air in-leakage test (tracer gas test) of the CRE boundary is performed in accordance with ASTM E741 (Reference 3). Air quality testing is performed in accordance with ASHRAE 62 (Reference 4).

The control room envelope habitability program in the technical specifications Section 5.5.17 defines testing requirements.

6.4.6 Instrumentation Requirements

The instrumentation and control features of the CRACS are described in Section 9.4.1. Radiation monitoring equipment for the CRE is described in Section 12.3.4.

[[Toxic chemicals whose release has the potential to affect control room operators are monitored by toxic gas sensors. A list of chemicals and their locations is provided in Section 2.2.]] A COL applicant that references the U.S. EPR design certification will identify any Seismic Category I Class IE toxic gas sensors necessary for control room operator protection.

6.4.7 References

1. NUREG-0654/FEMA-REP-1 Revision 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," November 1980.
2. ASME AG-1–2003, "Nuclear Air and Gas Treatment," American society of Mechanical Engineers, 2003.
3. ASTM E741–2000, "Standard Test Methods for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution," American Society for Testing and Materials, 2000.
4. ASHRAE 62–1989, "Ventilation for Acceptable Indoor Air Quality," American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1989.

9.4 Air Conditioning, Heating, Cooling and Ventilation Systems

The heating, ventilation, and air-conditioning (HVAC) system for each major building or area is provided in the following subsections.

9.4.1 Main Control Room Air Conditioning System

The main control room air conditioning system (CRACS) is designed to maintain a controlled environment in the control room envelope (CRE) area for the comfort and safety of control room personnel and to support operability of the control room components during normal operation, anticipated operational occurrences and design basis accidents. CRACS is also relied upon to cope with and recover from a station blackout (SBO) event.

The air conditioning system for the CRE area operates in the recirculation mode with fresh air makeup. The fresh outside air intake and recirculated air are filtered and conditioned through the filtration trains. The conditioned air is then supplied to the CRE area. During a site radiological contamination event, the fresh air intake is redirected through the iodine filtration trains.

The main control room (MCR) habitability system, including the definition of the CRE area, is addressed in Section 6.4.

Under emergency conditions, when the iodine filtration train subsystem of CRACS is utilized, the subsystem function is designated as control room emergency filtration (CREF). See Technical Specification 3.7.10 in Chapter 16.

9.4.1.1 Design Bases

All components of the CRACS are safety related and designed to Seismic Category I requirements.

- The CRACS components are located inside the Safeguard Building (SB) divisions two and three. These buildings are designed to withstand the effect of natural phenomena, such as earthquake, tornados, hurricanes, floods and external missiles (GDC 2).
- The quality group classification (Section 3.2) meets the requirements of RG 1.26. The seismic design of the system meets the guidance of RG 1.29 (Position C.1 for the safety-related portion and Position C.2 for the non-safety-related portion).
- The CRACS components are appropriately protected against dynamic effects and designed to accommodate the effects of, and be compatible with the environmental conditions of normal operation, maintenance, testing, and postulated accidents (GDC 4).

- The safety-related components and systems of the CRACS are not shared among nuclear power units (GDC 5).
- The CRACS provides adequate protection against radiation [[and hazardous chemical releases]] to permit access to and occupancy of the control room under accident conditions (GDC 19). [[The control room occupancy protection requirements meet the guidance of RG 1.78.]]
- The release of radioactive materials to the environment is controlled by meeting the guidance of RG 1.52 and 1.140 (GDC 60). In case of an alarm from the area radiation monitors, the CRACS directs the air intake automatically through activated carbon filtration beds. The air from CRE areas can also be recirculated through the same activated carbon filtration beds.
- Capability for withstanding or coping with a SBO event is provided to comply with the requirements of 10CFR 50.63. Acceptance is based on meeting the applicable guidance of RG 1.155, including position C.3.2.4. Refer to Section 8.4 for a description of the design features to cope with the SBO event.
- The CRACS maintains habitability of the CRE areas during a site radiological contamination event [[or toxic contamination of the environment]] (Refer to Section 6.4).
- Control and maintain a positive pressure of 0.125 inches water gauge as a minimum within the CRE areas with respect to the surrounding area to prevent uncontrolled incoming leakage.
- The CRACS maintains system performance in the event of failure of a single active safety-related component.
- The CRACS outside air intake is capable of detecting radiation~~,~~ and smoke [[~~,~~and toxic chemicals]] (see Section 6.4.2.~~4 for discussion of toxic gas sensors and COL applicant's responsibility to identify those sensors~~). Associated monitors actuate alarms in the MCR.
- Upon receipt of a containment isolation signal, or high radiation alarm signal in the air intake duct, the iodine filtration train starts automatically and the outside air and CRE recirculation air are automatically diverted through the iodine filtration train. The outside makeup air along with the CRE recirculation air maintains a positive pressure inside the CRE area relative to the adjacent areas. The CRE air inlet and recirculation dampers operate automatically.
- [[Upon actuation of the plant toxic gas alarm signal, the outside air intake dampers close automatically and the CRE air is automatically diverted in the recirculation mode without outside air.]]

The CRACS is capable of isolating all non-safety-related system penetrations of the CRE boundary so that occupation and habitability of the control room is not compromised.

- The CRACS maintains the following temperature and humidity ranges for the areas serviced:
  - Main Control Room: 65°F to 76°F (40 to 60 percent humidity).
  - Other areas of CRE: 68°F to 79°F (30 to 60 percent humidity).

9.4.1.2 System Description

9.4.1.2.1 General Description

The CRACS is designed to maintain acceptable ambient conditions inside the CRE areas to provide for proper operation of equipment and for personnel access to conduct inspection, testing and maintenance. The CRE area is shown in Figures 6.4-1 through 6.4-3.

The CRACS consists of following subsystems:

- Air intake.
- Iodine filtration train.
- Recirculation air handling.
- Air supply and recirculation.
- Kitchen and sanitary rooms exhaust.

Air Intake Subsystem

The air intake subsystem is illustrated in Figure 9.4.1-1—Control Room Air Intake and Iodine Filtration Train Subsystems.

Fresh air is supplied by an outside air intake through a wire mesh grille, one intake for SB division two and another for SB division three. Sensors on the outside air inlet protect against [[toxic gas (refer to Section 6.4.2.4) and]] radiological intrusion. Each outside air intake is equipped with an electrically heated, weather protected grille to prevent ice formation. Outside air is diverted into two fresh air intake trains for each division (total of four trains).

Two identical fresh air intake trains for each division are physically separated. In each train, air is directed through motorized dampers, an electric heater, and a prefilter. Fresh air is then mixed with the recirculated air from the CRE area prior to conditioning by the air handling units.

Iodine Filtration Train Subsystem

The iodine filtration train subsystem is illustrated in Figure 9.4.1-1.

There are two iodine filtration trains located separately in the SB divisions two and three (one train in each division) in parallel with the associated intake trains. These trains provide an alternate path for fresh air intake and CRE recirculated air when site contamination is detected. Each train consists of an inlet motorized isolation damper, an electric heater, a prefilter, an upstream high efficiency particulate air (HEPA) filter, an iodine filter with activated carbon, a downstream HEPA filter, an outlet motorized isolation damper, a supply air fan, and a backdraft damper. The motorized dampers operate automatically to isolate or align the iodine filtration trains.

Recirculation Air Handling Subsystem

The recirculation air handling subsystem is illustrated in Figure 9.4.1-2—Control Room Recirculation Air Handling Subsystem.

There are four recirculation air handling units located in the SB divisions two and three (two trains in each division). Recirculated and fresh air is processed through these air handling units and supplied to a common supply air plenum in divisions two and three. Each train includes an isolation damper, a volume control manual damper, a cooling coil, a moisture separator, fan suction and discharge silencers, a supply air fan, a HEPA filter, a steam humidifier, a non-return damper, and a volume control electric damper. The cooling coil is supplied with chilled water from the safety chilled water system (SCWS). The humidifier is supplied with water from the potable and sanitary water system (PSWS). The relative humidity in the rooms is controlled by modulation of the humidifiers.

The air conditioning system for the CRE area operates in the recirculation mode with fresh air makeup. The fresh air flow rate corresponds to the exhaust of kitchens and sanitary rooms and the leakage rate in the CRE area due to controlled overpressure. The exhaust from the kitchen and sanitary rooms is directed to the electrical division of the SB ventilation system (SBVSE) air outlet duct (refer to Section 9.4.6).

Air Supply and Recirculation Subsystem

The air supply and recirculation subsystem is illustrated in Figure 9.4.1-3— CRE Air Supply and Recirculation Subsystem.

The common supply air plenum (one in the SB division two and one in the SB division three) provides conditioned air to the CRE areas through the ductwork distribution network. Electric air heaters are installed in the supply air ducts to maintain individual room temperatures. The exhaust air from the CRE area, except the exhaust from kitchen and sanitary rooms, is recirculated through the recirculation air handling units. The exhaust from kitchen and sanitary rooms is separated from the recirculated return air and is processed separately through the SBVSE.

9.4.1.2.2 Component Description

The major components of the CRACS are listed below, along with the applicable codes and standards. Refer to Section 3.2 for the seismic and system quality group classification of these components.

Ductwork and Accessories

The main supply and exhaust air shafts are constructed of concrete with painted surfaces. The air supply and exhaust duct branches for each area are fed from the main supply and exhaust air shafts. These ducts are constructed of galvanized sheet steel and are structurally designed for fan shutoff pressures. The ductwork meets the design, testing and construction requirements per ASME AG-1-2003 (Reference 1).

Electric Heaters

The electric heaters are installed in the supply duct to maintain room ambient conditions. These are controlled by local room temperature sensors and control circuits. The heaters meet the requirements of Reference 1.

Filter Air Heaters

Filter air heaters are located upstream of iodine filtration units to prevent excessive moisture accumulation in the carbon filter beds. The heaters meet the requirements of Reference 1.

Prefilters

The prefilters are located upstream of the HEPA filters and collect large particles to increase the useful life of the high efficiency filters. The prefilters meet the requirements of ANSI/ASHRAE Standard 52.2-1999 (Reference 2).

HEPA Filters

HEPA filters are constructed, qualified and tested in accordance with Reference 1. The periodic inplace testing of HEPA filters to determine the leak tightness is performed per ASME N510-1989 (Reference 3).

Adsorbers

Carbon filters are used to remove radioactive iodine from the supply of fresh and recirculated air. The efficiency of removal of methyl iodine is based on the decontamination efficiency assigned during the laboratory tests. The periodic inplace testing of adsorbers to determine the leak tightness is performed per Reference 3.

Fans

The supply and exhaust fans are centrifugal or axial type with electric motor drivers. Fan performance is rated in accordance with ANSI/AMCA-210-99 (Reference 4), ANSI/AMCA-211-1987 (Reference 5) and ANSI/AMCA-300-1985 (Reference 6).

Isolation dampers

Manual dampers are adjusted during initial plant startup testing to establish accurate air flow balance between the rooms. The motor-operated dampers will fail to "close" or "open" position in case of power loss, depending on the safety function of the damper. The performance and testing requirements of the dampers are per Reference 1.

Fire Dampers

Fire dampers are installed where ductwork penetrates a fire barrier. Fire damper design meets the requirements of UL 555 (Reference 7) and the damper fire rating is commensurate with the fire rating of the barrier penetrated.

Cooling Coils and Moisture Separator

The cooling coils are of the finned tube, coil type and are connected to the safety chilled water system (SCWS). The cooling coils are designed in accordance with Reference 1. The moisture separator collects condensate which is directed to the drain system.

Humidifier

Humidifiers are installed to restore ambient humidity conditions as required for each area. Humidity levels are maintained in all areas within the acceptable range defined in the design basis. The humidifier is supplied with water from the PSWS. The relative humidity in the rooms is controlled by modulation of the humidifiers.

9.4.1.2.3 System Operation

Normal Plant Operation

During normal plant operation, fresh air is admitted via two of four air intake trains. The fresh air passes through two auto-opened isolation dampers and is heated by electric heaters depending on the fresh air temperature. The fresh air passes through a prefilter, and then mixes with the recirculated air from the CRE area.

The fresh and recirculated air is admitted through two of four air handling units which provide heating, cooling and humidity control of the supply air. The conditioned air is then distributed through a ductwork distribution network to the CRE area. The room air conditioning is provided by the supply and exhaust air flows based on minimum air renewal rate, equipment and personnel heat loads and heat balance between the rooms.

Heating of air streams is provided by electric heaters located in the supply air ducts. The operation of heaters is automatically controlled by the temperature sensors located in the corresponding rooms.

The CRE area is maintained at a pressure above atmospheric pressure to provide habitability in the event of radioactive or toxic contamination of the environment.

Both iodine filtration trains are secured and fully bypassed with the motorized inlet dampers in the auto-closed position during normal plant operation.

The air conditioning system for the CRE area operates in the recirculation mode with fresh air makeup. During the recirculation mode, the fresh air supply rate is equal to the rate of exhaust air from the kitchens and sanitary rooms plus accounting for the leakage rate in the area due to controlled overpressure. The four fresh air intake trains are not cross-connected; therefore, the air intake in operation corresponds to the recirculation train in operation.

Exhaust air from the kitchen and sanitary rooms is not recirculated. The exhaust air is directed by a separate exhaust duct and exhaust fans to the SBVSE air outlet duct.

Abnormal Operating Conditions

Redundancy of air supply and air conditioning trains is provided. A loss of function or power to any single train or component does not affect overall system operation. The train separation and independent power source limit common mode failure of active multiple trains and abnormal operating conditions.

Loss of a single cooling train will not result in a loss of system functional capability because four cooling trains are provided. The iodine filtration trains do not operate during normal plant operation, but loss of a single iodine filtration train during any design basis accident will not result in a loss of iodine filtration capability because two iodine filtration trains are provided.

[[During a toxic gas accident event, the CRACS is placed in full recirculation mode without any outside air makeup (refer to Section 6.4.2.2).]]

Loss of Offsite Power

During loss of offsite power (LOOP), the air intake and recirculation air handling electrical components located inside SB division two receive power for one train from the emergency diesel generators (EDG) of division two, and for the other train from the EDGs of division one. The electrical components located inside the SB division three receive power on one train from the EDGs of division three, and for the other train from the EDGs of division four. The humidity is not controlled during this event.

During LOOP, the iodine filtration train electrical components located inside the SB division two receive power from the EDGs of division one. The electrical components located inside the SB division three receive power from the EDGs of division four.

Station Blackout

- In the event of station blackout (SBO), the electrical components which receive power from the EDG of division one are backed-up by alternate AC (AAC) power from the SBO diesel generators (SBODG) of division one. The electrical components which receive power from the EDG of division four are backed up by the AAC power from the SBODGs of division four.
- In the event of a simultaneous SBO and site radiological event, the CRE area is isolated and CRACS is maintained in a full recirculation mode through the iodine filtration train until site power is restored or EDGs are started. Power restoration is assumed to occur within eight hours following the occurrence of a SBO event.

Loss of Ultimate Heat Sink

The conditioned air supply is cooled by chilled water provided by the SCWS. Two water-cooled chillers are located in SB divisions two and three, and two air-cooled chillers are located in SB divisions one and four. In case of loss of ultimate heat sink (LUHS), the water-cooled chillers are not available. The safety chilled water is then supplied by air-cooled chillers which provide the cooling function for the filtration trains located in divisions one and four, which also include both iodine filtration trains. The cooling function for the filtration trains in divisions two and three is not available.

Operation During Radiological Site Contamination

During a site radiological contamination event, the fresh air supply is automatically redirected through the iodine filtration trains, instead of the normal intake air supply, by closing and opening the associated dampers. When one iodine filtration train operates, the outside fresh airflow rate of 1000 cfm and CRE recirculation airflow rate of 3000 cfm (a total flow rate of 4000 cfm) provides an unlimited stay by the CRE personnel.

Exhaust from the kitchen and sanitary rooms is stopped and all other exhaust air is recirculated.

The operation of CRACS creates an overpressure of 0.125 inches water gauge as a minimum inside the CRE area with respect to the surrounding area, which limits unfiltered incoming air leakage into these areas.

[[Operation During a Toxic Gas Event

Outside air is continuously monitored for toxic gas by the toxic gas sensors located at the air intakes. Upon detection of a toxic gas condition, audible and visual alarms are actuated in the MCR.]]

Operation during External Fire, Smoke [[or Toxic Gas Release]]

In the event of an external fire, [[external toxic gas release,]] smoke, or excessive concentration of CO and CO_2, outside air to the CRACS is isolated manually or automatically and the system operates in full recirculation mode without fresh air.

9.4.1.3 Safety Evaluation

The CRACS is designed to maintain ambient conditions inside the CRE area for personnel comfort and to allow safe operation of the equipment during normal plant operation, outages, and under all anticipated occurrences including postulated accidental events (refer to Section 15.0.3 for a discussion of radiological consequences).

The CRACS keeps the CRE area at a positive pressure of 0.125 inches water gauge at a minimum with respect to the surrounding area to provide habitability in the event of radioactive contamination of the environment, and to prevent uncontrolled incoming air leakage.

During a site radiological contamination event, the fresh air intake is redirected through the iodine filtration trains. The CRACS also can be operated in full recirculation mode without fresh air during abnormal operation or postulated accident events.

Redundancy for air cooling and iodine filtration is provided by multiple independent trains for critical functions. Sufficient redundancy is provided for proper operation of the system when one active component is out of service.

In case of fire in any room within the CRE area, the room air supply and exhaust are isolated by fire dampers and, if necessary, the plant is controlled by the remote shutdown station (RSS). The four air conditioning trains are installed in four different fire zones. Two of these zones contain the two iodine filtration trains.

Capability for withstanding or coping with an SBO event is met by the design of the AAC power source satisfying the ten minutes criteria; that is, the AAC power source can be started from the MCR within ten minutes after the onset of an SBO event. The AAC diesel generators are designed to operate for a minimum of twenty-four hours with available onsite fuel supplies.

9.4.1.4 Inspection and Testing Requirements

Refer to Section 14.2 (test abstracts #082 and #203) for initial plant testing. Initial inplace acceptance testing of the CRACS components is performed in accordance with Reference 1 and Reference 3.

Periodic testing will be performed to verify the unfiltered in-leakage into the CRE area per RG 1.197.

Refer to Section 16 (SR 3.7.10 and SR 3.7.11) for surveillance requirements.

9.4.1.5 Instrumentation Requirements

Indication of the operational status of the equipment, position of dampers, and instrument indications and alarms are provided in the MCR. Fans, motor-operated dampers, heaters and cooling units are operable from the MCR. Local instruments are provided to monitor flow, temperature and pressure. The fire detection and sensor information are delivered to the fire detection system (refer to Section 9.5.1).

The minimum instrumentation, indication and alarms for ESF filter systems are provided in Table 9.4.1-1—Minimum Instrumentation, Indication, and Alarm Features for ESF Filter Systems.

9.4.1.6 References

1. ASME AG-1-2003, “Code on Nuclear Air and Gas Treatment,” The American Society of Mechanical Engineers, 2003 [including the AG-1a, 2004 Addenda].

2. ANSI/ASHRAE Standard 52.2-1999, “Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size,” American Society of Heating, Refrigerating and Air Conditioning Engineers, 1999.

3. ASME N510-1989 (R1995), “Testing of Nuclear Air-Treatment Systems,” The American Society of Mechanical Engineers, 1989.

4. ANSI/AMCA-210-99, “Laboratory Methods of Testing Fans for Aerodynamic Performance Rating,” American National Standards Institute/AMCA, December 1999.

5. ANSI/AMCA 211-1987, “Certified Ratings Program–Air Performance,” American National Standards Institute/AMCA, 1987.

6. ANSI/AMCA-300-1985, “Reverberant Room Method of Testing Fans for Rating Purposes,” American National Standards Institute/AMCA, 1985.

7. UL 555, “Standard for Fire Dampers,” Underwriter’s Laboratories, Sixth Edition, June 1999.

Table 9.4.1-1—Minimum Instrumentation, Indication, and Alarm Features for ESF Filter Systems

Sensing Location	Local Indication/Alarm	MCR Indication/Alarm
Unit inlet or outlet	Flow rate (indication)	Flow rate (recorded indication, high and low alarm signals)
Unit inlet	Radiation indication	Radiation indication / alarm
Unit inlet	Temperature indication	Temperature indication
Electric heater	On/Off indication	On/Off indication
Electric heater inlet	Temperature indication	Temperature indication /alarm
Electric heater outlet	Temperature indication	Temperature indication / alarm
Prefilter	Pressure drop (indication / high alarm signal)	
Upstream-HEPA	Pressure drop (indication / high alarm signal)	
Adsorber	Pressure drop (indication / high alarm signal)	
Downstream-HEPA	Pressure drop (indication / high alarm signal	
System Filters inlet to outlet		Summation of pressure drop across entire filtration train (indication / high alarm signal
Fan		Hand switch, status indication
Damper/Operator		Status indication
Unit outlet	Temperature indication	Temperature indication

Figure 9.4.1-1—Control Room Air Intake and Iodine Filtration Train Subsystems

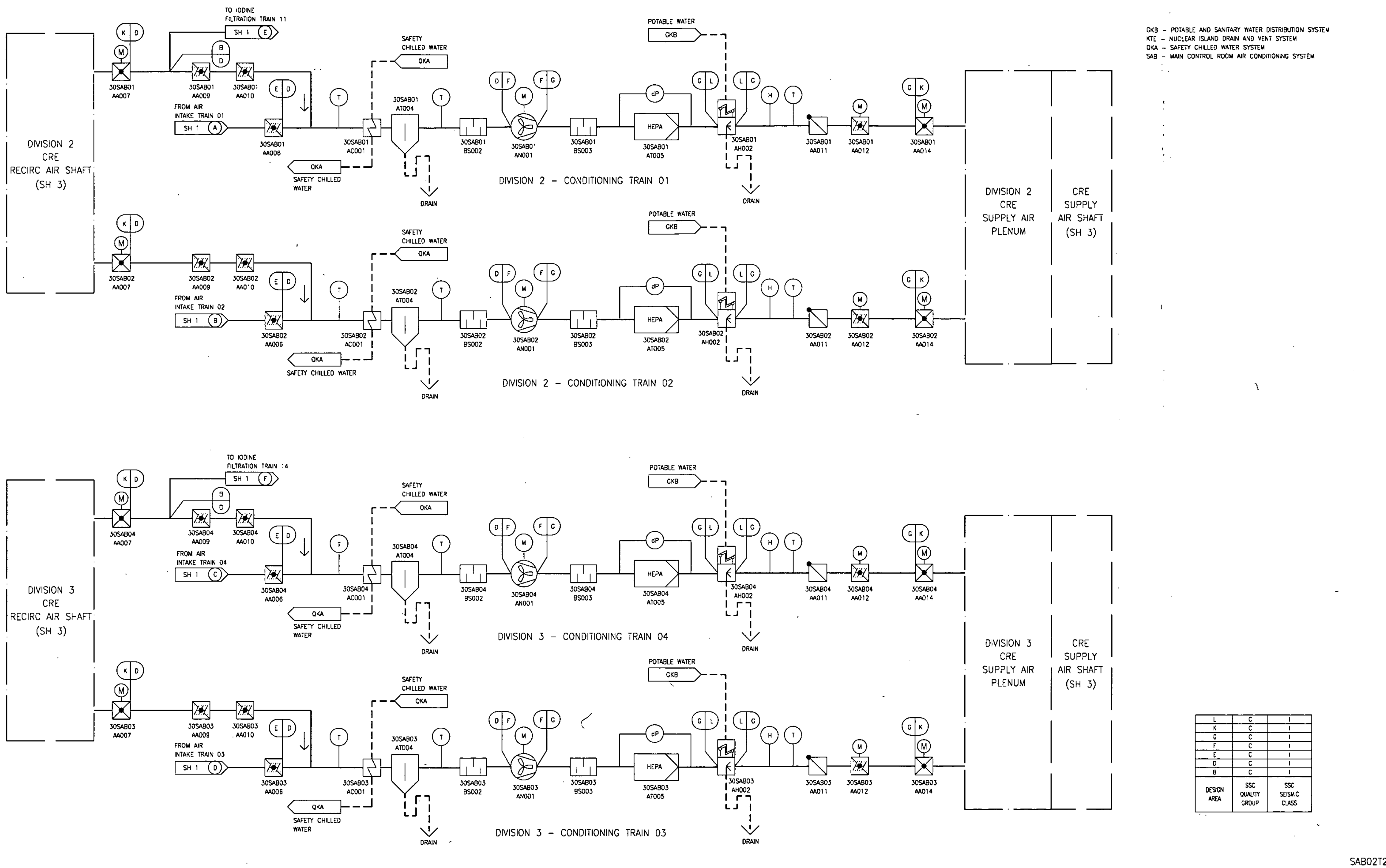
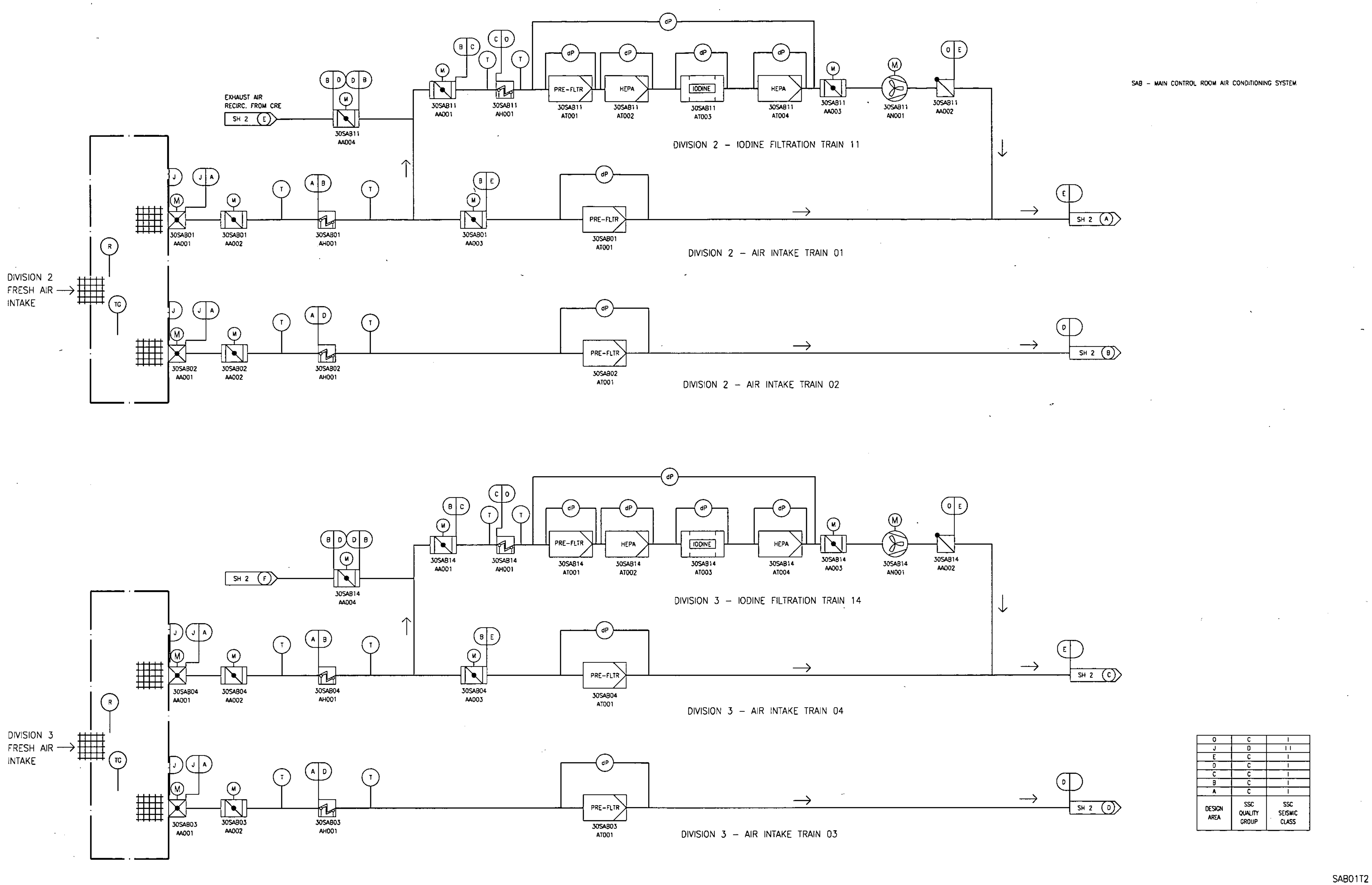
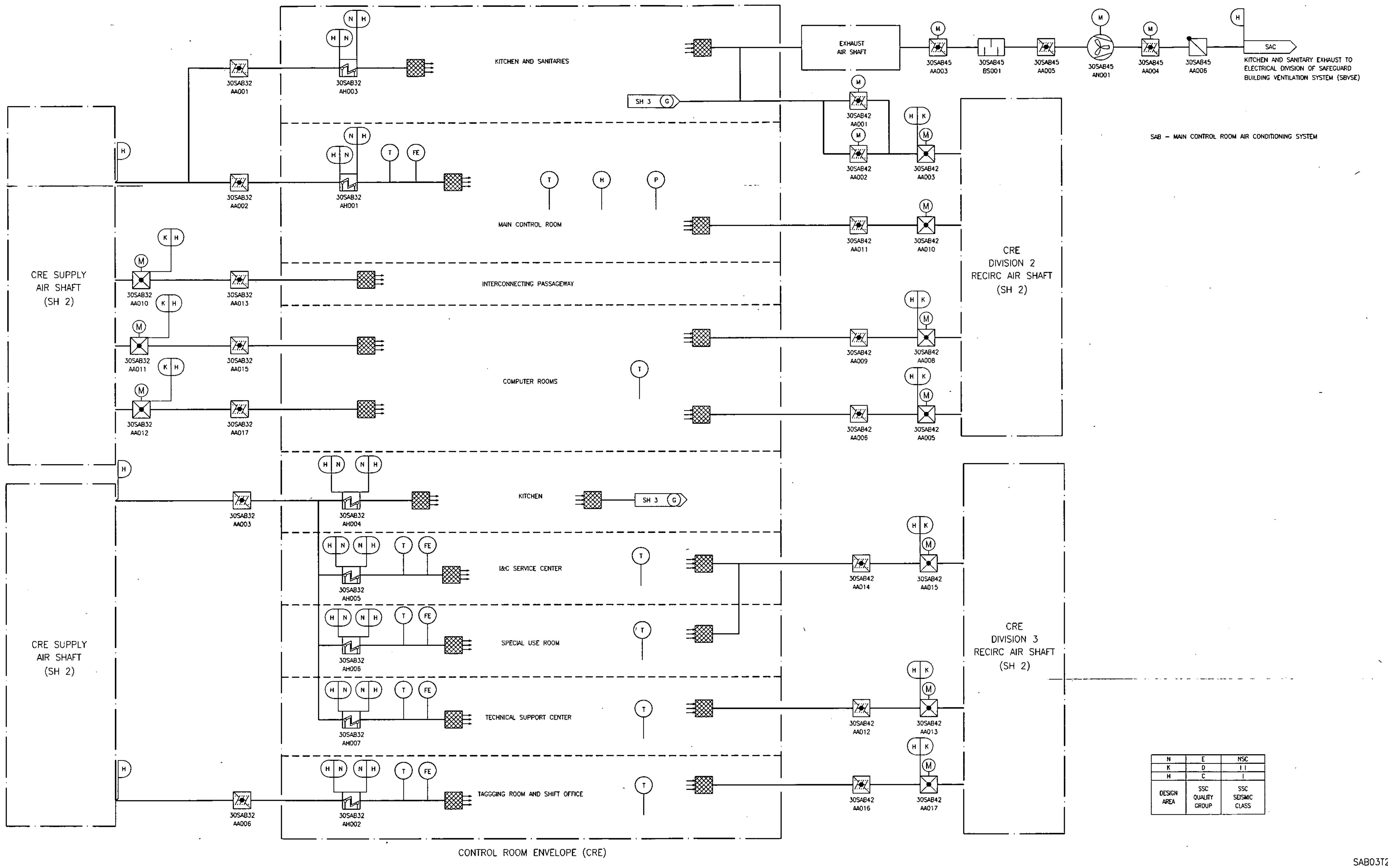


Figure 9.4.1-2—Control Room Recirculation Air Handling Subsystem



[[TG-Toxic Gas Sensors]]

Figure 9.4.1-3—Control Room Envelope Air Supply and Recirculation Subsystem



3.7 PLANT SYSTEMS

3.7.10 Control Room Emergency Filtration (CREF)

LCO 3.7.10 Two CREF trains shall be OPERABLE.

---NOTE---
The control room envelope (CRE) may be opened intermittently under administrative control.

APPLICABILITY: MODES 1, 2, 3, 4, 5, and 6,
During movement of irradiated fuel assemblies.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One CREF train inoperable.	A.1 Restore CREF train to OPERABLE status.	7 days
B. Two CREF trains inoperable due to inoperable CRE boundary in MODE 1, 2, 3, or 4	B.1 Initiate action to implement mitigating actions.	Immediately
	<u>AND</u>	
	B.2 Verify mitigating actions ensure CRE occupant exposures to radiological, [[chemical,]] and smoke hazards will not exceed limits.	24 hours
	<u>AND</u>	
	B.3 Restore CRE boundary to OPERABLE status.	90 days

5.5 Programs and Manuals

5.5.15 Containment Leakage Rate Testing Program (continued)

e. The provisions of SR 3.0.3 are applicable to the Containment Leakage Rate Testing Program.

--------------------------------------REVIEWER'S NOTE--------------------------------------
As discussed in FSAR Section 6.2.6, the U.S. EPR has no penetrations that are classified as bypass leakage paths.

5.5.16 Battery Monitoring and Maintenance Program

This Program provides for battery restoration and maintenance, based on the recommendations of IEEE Standard 450-2002, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications," or of the battery manufacturer including the following:

a. Actions to restore battery cells with float voltage < 2.13 V, and

b. Actions to equalize and test battery cells that had been discovered with electrolyte level below the top of the plate.

5.5.17 Control Room Envelope Habitability Program

A Control Room Envelope (CRE) Habitability Program shall be established and implemented to ensure that CRE habitability is maintained such that, with an OPERABLE Control Room Emergency Filtration System (CREFS), CRE occupants can control the reactor safely under normal conditions and maintain it in a safe condition following a radiological event, [[hazardous chemical release,]] or a smoke challenge. The program shall ensure that adequate radiation protection is provided to permit access and occupancy of the CRE under design basis accident (DBA) conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent (TEDE) for the duration of the accident. The program shall include the following elements:

a. The definition of the CRE and the CRE boundary;

b. Requirements for maintaining CRE boundary in its design condition including configuration control and preventive maintenance;

5.5 Programs and Manuals

5.5.17 Control Room Envelope Habitability Program (continued)

c. Requirements for (i) determining the unfiltered air inleakage past the CRE boundary into the CRE in accordance with the testing methods and at the Frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors," Revision 0, May 2003, and (ii) assessing CRE habitability at the Frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, Revision 0;

d. Measurement, at designated locations, of the CRE pressure relative to all external areas adjacent to the CRE boundary during the pressurization MODE of operation by one train of the CREFS, operating at the flow rate required by the VFTP, at a Frequency of 24 months on a STAGGERED TEST BASIS. The results shall be trended and used as part of the 24 month assessment of the CRE boundary;

e. The quantitative limits on unfiltered air inleakage into the CRE. These limits shall be stated in a manner to allow direct comparison to the unfiltered air inleakage measured by the testing described in Specification 5.5.17.c. The unfiltered air inleakage limit for radiological challenges is the inleakage flow rate assumed in the licensing basis analyses of DBA consequences. Unfiltered air inleakage limits for [[hazardous chemicals or]] smoke must ensure that exposure of CRE occupants to these hazards will be within the assumptions in the licensing basis; and

f. The provisions of SR 3.0.2 are applicable to the Frequencies for assessing CRE habitability, determining CRE unfiltered inleakage, and measuring CRE pressure and assessing the CRE boundary as required by Specifications 5.5.17.c and 5.5.17.d, respectively.

B 3.7 PLANT SYSTEMS

B 3.7.10 Control Room Emergency Filtration (CREF)

BASES

BACKGROUND

The CREF provides a protected environment from which occupants can control the unit following an uncontrolled release of radioactivity, [[hazardous chemicals,]] or smoke.

The CREF consists of two 100% capacity iodine filtration trains which operate when radioactive contamination is detected at the site or inside the control room envelope (CRE) area. The iodine filtration train is a bypass path of the fresh air intake train for the Control Room Air Conditioning System (CRACS) normal air supply. The air from CRE can also be recirculated through the CREF Iodine Filtration trains. The iodine filtration trains are provided as bypass lines on two of the four normal CRACS air intake trains; other two CRACS intake trains do not have the bypass iodine filtration trains. During an emergency, the fresh outside air and recirculated air are directed through air intake motorized damper and electric heater through the CREF Iodine Filtration train. Each iodine filtration train consists of motorized damper, electric heater, prefilter, upstream HEPA filter, an activated carbon iodine filter, downstream HEPA filter, booster fan, and manual isolation damper. The filtered and clean air is then directed through one or both CRACS normal 75% capacity air conditioning train. Each air conditioning train consists of volume control manual damper, cooling coil, moisture separator, fan suction and discharge silencers, supply air fan, HEPA filter, steam humidifier, non-return damper, volume control electric damper, and fire dampers. The conditioned and clean air is then supplied to the CRE areas. Electric heaters are installed in the CRE supply air ducts to maintain individual room temperatures and relative humidity. The exhaust air from the CRE areas is directed through the recirculation air shaft and then recycled either through the iodine filtration trains or CRACS air conditioning trains. The exhaust from kitchen and sanitary areas is separated from the recycle return air and processed separately.

The prefilters remove any large particles in the air, and any entrained water droplets present, to prevent excessive loading of the HEPA filters and carbon adsorbers. The HEPA filter bank downstream of the carbon iodine filter collects carbon fines and provides backup in case of failure of the upstream HEPA filter bank. Continuous operation of each train for at least 10 hours per month, with the heaters on, reduces moisture buildup on the HEPA filters and carbon adsorbers.

BASES

BACKGROUND (continued)

The CRE is the area within the confines of the CRE boundary that contains the spaces that control room occupants inhabit to control the unit during normal and accident conditions. This area encompasses the control room, and may encompass other non-critical areas to which frequent personnel access or continuous occupancy is not necessary in the event of an accident. The CRE is protected during normal operation, natural events, and accident conditions. The CRE boundary is the combination of walls, floor, roof, ducting, doors, penetrations and equipment that physically form the CRE. The OPERABILITY of the CRE boundary must be maintained to ensure that the inleakage of unfiltered air into the CRE will not exceed the inleakage assumed in the licensing basis analysis of design basis accident (DBA) consequences to CRE occupants. The CRE and its boundary are defined in the Control Room Envelope Habitability Program.

The CREF train is an emergency system, which may also operate during normal unit operations in the standby mode of operation. Upon receipt of the actuating signal(s), the outside fresh air supply to the CRE is isolated, and the outside air is directed through the CREF train. The CRE ventilation air is recycled through the air conditioning filter trains and/or CREF train.

Actuation of the CREF places the system in either of two separate states (emergency radiation state or toxic gas isolation state) of the emergency mode of operation, depending on the initiation signal. Actuation of the system to the emergency radiation state of the emergency mode of operation, closes the unfiltered outside air intake and unfiltered exhaust dampers, and aligns the system for recirculation of the air within the CRE through the CREF trains. The emergency radiation state also maintains control room pressurization and filtered ventilation of the air supply to the CRE.

Outside makeup air is supplied through the iodine filtration train and added to the air being recirculated from the CRE. Pressurization of the CRE minimizes infiltration of unfiltered air through the CRE boundary from all the surrounding areas adjacent to the CRE boundary. The actions taken in the toxic gas isolation state are the same, except that the signal switches the CREF to an isolation alignment to minimize any outside air from entering the CRE through the CRE boundary.

The outside air entering the CRE is continuously monitored by radiation [[and toxic gas]] detectors. One detector output above the setpoint will cause actuation of the emergency radiation state or toxic gas isolation state, as required. The actions of the toxic gas isolation state are more restrictive, and will override the actions of the emergency radiation state.

BASES

BACKGROUND (continued)

One CREF operating at a flow rate of < 4000 cfm will pressurize the CRE to ≥ 0.125 inches water gauge relative to all external areas adjacent to the CRE boundary. The CREF operation in maintaining the CRE habitability is discussed in FSAR Section 9.4.1 (Ref. 1).

Redundant supply and recirculation trains provide the required filtration should an excessive pressure drop develop across one of the other filter trains. Normally open isolation dampers are arranged in series so the failure of one damper to shut will not result in a breach of isolation. The CREF train components are designed in accordance with Seismic Category I requirements.

The CREF is designed to maintain a habitable environment in the CRE for 30 days of continuous occupancy after a postulated accident without exceeding a 5 rem whole body dose or its equivalent to any part of the body 5 rem total effective ~~does~~ dose equivalent (TEDE).

APPLICABLE SAFETY ANALYSES

The CREF components are arranged in redundant, safety related ventilation trains. The location of components and ducting within the CRE ensures an adequate supply of filtered air to all areas requiring access. The CREF provides airborne radiological protection for the CRE occupants, as demonstrated by the CRE occupant dose analyses for the most limiting design basis loss of coolant accident, fission product release presented in Chapter 15 (Ref. 2).

The CREF consists of two 100% capacity iodine filtration trains. Each iodine filtration train can be aligned with one of the two 75% capacity air conditioning trains. There are only two iodine filtration trains since only slow failure modes are assumed and filtration efficiency is checked periodically. Both CREF trains with the associated air conditioning trains are required to be OPERABLE. One CREF train is assumed to be lost to a single failure. The other train provides 100% of the ventilation to the CRE.

The CREF provides protection from smoke [[and hazardous chemicals to the CRE occupants. Reference 3 discusses protection of CRE occupants following a hazardous chemical release]]. Reference 4 discusses protection of the CRE occupants and their ability to control the reactor from the control room or from the remote shutdown panels in the event of a smoke challenge.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The worst case single active failure of a component of the CREF, assuming a loss of offsite power, does not impair the ability of the system to perform its design function.

The CREF satisfies Criterion 3 of 10 CFR 50.36(d)(2)(ii).

LCO

In the event of a postulated accident, one iodine filtration train is required to provide an adequate supply of filtered air to the CRE. To ensure that this requirement is met, both CREF trains must be OPERABLE. The basis for this approach is that two trains are required to satisfy all design requirements (i.e., one train is needed to mitigate the event and other train is assumed to have a single active failure). The failure of both iodine filtration trains could result in exceeding a dose of 5 rem whole body or its equivalent to any part of the body 5 rem TEDE in the event of a large radioactive release.

Each CREF train is considered OPERABLE when the individual components necessary to limit CRE occupant exposure are OPERABLE. A CREF train is OPERABLE when the associated:

a. Fan is OPERABLE;

b. Prefilters, HEPA filters, and carbon adsorbers are not excessively restricting flow, and are capable of performing their filtration functions; and

c. Heater, ductwork, and dampers are OPERABLE, and air circulation can be maintained.

In order for the CREF trains to be considered OPERABLE, the CRE boundary must be maintained such that the CRE occupant dose from a large radioactive release does not exceed the calculated dose in the licensing basis consequence analyses for postulated accidents, and that CRE occupants are protected from [[hazardous chemicals and]] smoke.

The LCO is modified by a Note allowing the CRE boundary to be opened intermittently under administrative controls. This Note only applies to openings in the CRE boundary that can be rapidly restored to the design conditions, such as doors, hatches, floor plugs, and access panels. For entry and exit through doors, the administrative control of the opening is performed by the person(s) entering or exiting the area. For other openings, these controls should be procedurelized, and consist of

BASES

LCO (continued)

stationing a dedicated individual at the opening who is in continuous communication with the operators in the CRE. This individual will have a method to rapidly close the opening and to restore the CRE boundary to a condition equivalent to the design condition when a need for CRE isolation is indicated.

APPLICABILITY

In MODES 1, 2, 3, and 4, and during movement of irradiated fuel assemblies, the CREF trains must be OPERABLE to ensure that the CRE will remain habitable during and following a postulated accident (i.e., LOCA, main steam line break, rod ejection, and fuel handling accident).

In MODE 5 or 6, the CREF is also required to cope with a failure of the Gaseous Waste Processing System.

ACTIONS

A.1

With one CREF train inoperable, for reasons other than an inoperable CRE boundary, action must be taken to restore OPERABLE status within 7 days. In this Condition, the OPERABLE CREF train is adequate to perform the CRE occupant protection function. However, the overall system reliability is reduced. The 7 day Completion Time is based on the low probability of a postulated accident occurring during this time period, and ability of the remaining trains to provide the required capability.

B.1, B.2, and B.3

If the unfiltered inleakage of potentially contaminated air past the CRE boundary and into the CRE can result in CRE occupant radiological dose greater than the calculated dose of the licensing basis analyses of postulated accident consequences (allowed to be up to 5 rem whole body or its equivalent to any part of the body 5 rem TEDE), or inadequate protection of CRE occupants from [[hazardous chemicals or]] smoke, the CRE boundary is inoperable. Actions must be taken to restore an OPERABLE CRE boundary within 90 days

During the period that the CRE boundary is considered inoperable, action must be initiated to implement mitigating actions to lessen the effect on CRE occupants from the potential hazards of a radiological [[or chemical]] event or a challenge from smoke. Actions must be taken within 24 hours to verify that in the event of a postulated accident, the mitigating actions will ensure that CRE occupant radiological exposures will not exceed the calculated dose of the licensing basis analyses of postulated accident

ACTIONS (continued)

consequences, and that CRE occupants are protected from [[hazardous chemicals and]]smoke. These mitigating actions (i.e., actions that are taken to offset the consequences of the inoperable CRE boundary) should be preplanned for implementation upon entry into the condition, regardless of whether entry is intentional or unintentional. The 24 hour Completion Time is reasonable based on the low probability of a postulated accident occurring during this time period, and the use of mitigating actions. The 90 day Completion Time is reasonable based on the determination that the mitigating actions will ensure protection of CRE occupants within analyzed limits while limiting the probability that CRE occupants will have to implement protective measures that may adversely affect their ability to control the reactor and maintain it in a safe shutdown condition in the event of a postulated accident. In addition, the 90 day Completion Time is a reasonable time to diagnose, plan and possibly repair, and test most problems with the CRE boundary.

C.1 and C.2

In MODE 1, 2, 3, or 4, if any Required Action and Completion Time of Condition A or B cannot be met, the unit must be placed in a MODE that minimizes accident risk. To achieve this status, the unit must be placed in at least MODE 3 within 6 hours, and in MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required unit conditions from full power conditions in an orderly manner.

D.1 and D.2

In MODE 5 or 6, or during movement of irradiated fuel assemblies, if the inoperable CREF train cannot be restored to OPERABLE status within the required Completion Time, action must be taken to immediately place the OPERABLE CREF train in the emergency mode. This action ensures that the other train is OPERABLE, that no failures preventing automatic actuation will occur, and that any active failure would be readily detected.

An alternative to Required Action D.1 is to immediately suspend activities that could result in a release of radioactivity that might require isolation of the CRE. This places the unit in a condition that minimizes risk. This does not preclude the movement of fuel to a safe position.

Required Action D.1 is modified by a Note indicating to place the system in the toxic gas isolation state with outside air isolated.

BASES

ACTIONS (continued)

E.1

In MODE 5 or 6, or during movement of irradiated fuel assemblies, with two CREF trains inoperable, action must be taken immediately to suspend activities that could result in a release of radioactivity that might enter the CRE. This places the unit in a condition that minimizes accident risk. This does not preclude the movement of fuel to a safe position.

F.1

With both Iodine Filtration trains and associated Air Conditioning trains inoperable in MODE 1, 2, 3, or 4 for reasons other than an inoperable CRE boundary (i.e., Condition B), the CREF may not be capable of performing the intended function and the unit is in a condition outside the accident analyses. Therefore, LCO 3.0.3 must be entered immediately.

SURVEILLANCE REQUIREMENTS

SR 3.7.10.1

Standby systems should be checked periodically to ensure that they function properly. As the environment and normal operating conditions on this system are not too severe, testing each train once every month provides an adequate check of this system. Monthly heater operations which dry out any moisture accumulated in the carbon from humidity in the ambient air should be performed. Each Iodine filtration train must be operated for ≥ 15 minutes with the heaters energized. The 31 day Frequency is based on the reliability of the equipment and the two train redundancy.

SR 3.7.10.2

This SR verifies that the required CREF train testing is performed in accordance with the Ventilation Filter Testing Program (VFTP). The VFTP includes testing the performance of the HEPA filter, carbon adsorber efficiency, minimum flow rate, and the physical properties of the activated carbon. Specific test Frequencies and additional information are discussed in detail in the VFTP.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.7.10.3

This SR verifies that each CREF train starts and operates on an actual or simulated actuation signal. The Frequency of 24 months is based on industry operating experience and is consistent with the typical refueling cycle.

SR 3.7.10.4

This SR verifies the OPERABILITY of the CRE boundary by testing for unfiltered air inleakage past the CRE boundary and into the CRE. The details of the testing are specified in the Control Room Envelope Habitability Program.

The CRE is considered habitable when the radiological dose to CRE occupants calculated in the licensing basis analyses of postulated accident consequences is no more than 5 rem whole body or its equivalent to any part of the body 5 rem TEDE and the CRE occupants are protected from [[hazardous chemicals and]]smoke. This SR verifies that the unfiltered air inleakage into the CRE is no greater than the flow rate assumed in the licensing basis analyses of postulated accident consequences. When unfiltered air inleakage is greater than the assumed flow rate, Condition B must be entered. Required Action B.3 allows time to restore the CRE boundary to OPERABLE status provided mitigating actions can ensure that the CRE remains within the licensing basis habitability limits for the occupants following an accident. Mitigating actions, or compensatory measures, are discussed in Regulatory Guide 1.196, Section 2.7.3, (Ref. 5) which endorses, with exceptions, NEI 99-03, Section 8.4 and Appendix F (Ref. 6). These compensatory measures may also be used as mitigating measures as required by Required Action B.2. Temporary analytical methods may also be used as compensatory measures (Ref. 7). Options for restoring the CRE boundary to OPERABLE status include changing the licensing basis postulated accident consequence analysis, repairing the CRE boundary, or a combination of these actions. Depending upon the nature of the problem and the corrective action, a full scope inleakage test may not be necessary to establish that the CRE boundary has been restored to OPERABLE status.

BASES

REFERENCES

1. FSAR Section 9.4.

2. Chapter 15.

3. FSAR Section 6.4.

4. FSAR Section 9.5.

5. Regulatory Guide 1.196.

6. NEI 99-03, "Control Room Habitability Assessment," March 2003.

7. Letter from Eric J. Leeds (NRC) to James W. Davis (NEI) dated January 30, 2005, "NEI Draft White Paper, Use of Generic Letter 91-18 Process and Alternative Source Terms in the Context of Control Room Habitability" (ADAMS Accession No. ML040300694).

BASES

ACTIONS (continued)

B.1

-------------------------------------REVIEWER'S NOTE------------------------------
Adoption of Condition B is dependent on a commitment from the licensee to have guidance available describing compensatory measures to be taken in the event of an intentional and unintentional entry into Condition B.

If the safeguard buildings or fuel building boundary is inoperable in MODE 1, 2, 3, or 4, the SBVS trains may not be able to perform their intended functions. Actions must be taken to restore an OPERABLE safeguard buildings and fuel building boundaries within 24 hours. During the period that the safeguard buildings or fuel building boundary is inoperable, appropriate compensatory measures consistent with the intent, as applicable, of GDC 19 and 10 CFR Part 100 should be utilized to protect plant personnel from potential hazards such as radioactive contamination, [[toxic chemicals,]]smoke, temperature and relative humidity, and physical security. Preplanned measures should be available to address these concerns for intentional and unintentional entry into the condition. The 24 hour Completion Time is reasonable based on the low probability of a postulated accident occurring during this time period, and the use of compensatory measures. The 24 hour Completion Time is a typically reasonable time to diagnose, plan and possibly repair, and test most problems with the safeguard buildings or fuel building boundary.

C.1 and C.2

In MODE 1, 2, 3, or 4, when Required Action A.1 or B.1 cannot be completed within the associated Completion Time, or when both SBVS Accident Exhaust Filtration trains are inoperable for reasons other than an inoperable safeguard building or fuel building boundary (i.e., Condition B), the unit must be placed in a MODE in which the LCO does not apply. To achieve this status, the unit must be placed in MODE 3 within 6 hours and in MODE 5 within 36 hours. The Completion Times are reasonable, based on operating experience, to reach the required unit conditions from full power conditions in an orderly manner and without challenging unit systems.