ATTACHMENT 7 to ENCLOSURE

FHA Analysis titled, "Fuel Handling Accident Dose Analysis - AST"

57 Pages Follow

Xcel Energy	Calculation Signature Sheet

Document Information

NSPM Calculation (Doc) No: GEN-PI-077	Revision: 0
Title: Fuel Handling Accident Dose Analysis - AST	
Facility: ☐ MT ☒ PI	Unit: ☒ 1 ☒ 2
Safety Class: ☒ SR ☐ Aug Q ☐ Non SR	
Special Codes: ☐ Safeguards ☐ Proprietary	
Type: **Calc** Sub-Type:	

NOTE:	Print **and** sign name in signature blocks, as required.

Major Revisions

EC Number: 13720	☐ Vendor Calc
Vendor Name or Code:	Vendor Doc No:
Description of Revision: Initial Issue	
Prepared by: Gopal J. Patel	Date: 10/07/2009
Reviewed by: Thomas J. Mscisz	Date: 10/08/2009
Type of Review: ☒ Design Verification ☐ Tech Review ☐ Vendor Acceptance	
Method Used (For DV Only): ☒ Review ☐ Alternate Calc ☐ Test	
Approved by: J. McClain	Date: 10/15/9

Minor Revisions

EC No:	☐ Vendor Calc:
Minor Rev. No:	
Description of Change:	
Pages Affected:	
Prepared by:	Date:
Reviewed by:	Date:
Type of Review: ☐ Design Verification ☐ Tech Review ☐ Vendor Acceptance	
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test	
Approved by:	Date:

(continued on next page)

Record Retention: Retain this form with the associated calculation for the life of the plant.

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Calculation Signature Sheet

EC No:	☐ Vendor Calc:
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Calculation Signature Sheet

NOTE:	This reference table is used for data entry into the PassPort Controlled Documents Module, reference tables (C012 Panel). It may also be used as the reference section of the calculation. The input documents, output documents and other references should all be listed here. Add additional lines as needed.

Reference Documents (PassPort C012 Panel from C020)

#	Controlled* Doc? + Type	Document Name	Document Number	Doc Rev	Ref Type** (if known)
1		Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors, July 2000	1.183	July 2000	☒Input ☐Output
2		A Simplified Model for Radionuclide Transport and Removal and Dose Estimation	NUREG/CR-6604	Dec 1997	☒Input ☐Output
3	☒ LTR	Westinghouse Letter, Subject: Core Activity Inventory and Coolant Activity Concentration	Letter NSP-07-59,	11/2/7	☒Input ☐Output
4	☒ TRNS	FHA Input Parameters	DIT # 13720-04	0	☒Input ☐Output
5	☒ TRNS	Control Room Input Parameters	DIT # 13720-07	1	☒Input ☐Output
6	☒ TRNS	Meteorological Input Parameters	DIT # 13720-03	0	☒Input ☐Output
7	☒ CALC	Prairie Island Atmospheric Dispersion Factors (χ/Q) – AST Additional Releases	GEN-PI-080	0	☒Input ☐Output
8	☒ Tech Spec	PINGP Units 1 & 2, Definition of Rated Thermal Power	1.1	U1/U2 Amendment 158/149	☒Input ☐Output
9	☒ Tech Spec	PINGP Units 1 & 2 LCO for Refueling Cavity Water Level	3.9.2	U1/U2 Amendment 158/149	☒Input ☐Output
10	☒ Tech Spec	PINGP Units 1 & 2 LCO for Spent Fuel Storage Pool Water Level	3.7.15	U1/U2 Amendment 158/149	☒Input ☐Output
11	☒ Tech Spec	Fuel Assemblies	4.2.1	U1/U2 Amendment 158/149	☒Input ☐Output

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Calculation Signature Sheet

12	☒ Tech Spec	PINGP Units 1 & 2 Ventilation Filter Testing Program (VFTP)	5.5.9	U1/U2 Amendment 186/176	☒Input ☐Output
13	☒ Tech Spec	PINGP Units 1 & 2 LCO for Shield Building Ventilation System (SBVS)	3.6.9	U1/U2 Amendment 186/176	☒Input ☐Output
14	☒ Tech Spec	PINGP Units 1 & 2 LCO for Control Room Special Ventilation System (CRSVS)	3.7.10	U1/U2 Amendment 158/149	☒Input ☐Output
15	☒ Tech Spec	PINGP Units 1 & 2 LCO for Spent Fuel Pool Special Ventilation System (SFPSVS)	3.7.13	U1/U2 Amendment 158/149	☒Input ☐Output
16	☒ Tech Spec	Control Room Special Ventilation System (CRSVS) Actuation Instrumentation Including Table 3.3.6-1	3.3.6	U1/U2 Amendment 158/149	☒Input ☐Output
17	☒ TS SR	Perform required SBVS filter testing in accordance with the Ventilation Filter Testing Program (VFTP)	SR 3.6.9.2	U1/U2 Amendment 158/149	☒Input ☐Output
18	☒ TS SR	Perform required SFSVS filter testing in accordance with the Ventilation Filter Testing Program (VFTP)	SR 3.7.13.2	U1/U2 Amendment 186/176	☒Input ☐Output
19	☒ CALC	Fission Product Inventories for AST Assessments	GEN-PI-046	0	☐Input ☒Output
20	☒ CALC	PI Control Room Atmospheric Dispersion Factors	GEN-PI-049	0, Add 2	☐Input ☒Output
21	☒ CALC	Fuel Handling Accident Dose Analysis	GEN-PI-051	1,	☐Input ☒Output
22	☒ CALC	Fuel Handling Accident Dose Analysis – Heavy Load Drop	GEN-PI-051	1, Add 1	☐Input ☒Output
23	☒ LA	PINGP Amendment Nos. 166 and 156 to Operating License Nos. DPR-42 and DPR-60, respectively, Selective Implementation Of Alternate Source Term For Fuel Handling Accidents	LA # 166 & 156		☒Input ☐Output
24		USNRC, "Laboratory Testing of Nuclear-Grade Activated Charcoal	99-02	5/3/99	☒Input ☐Output
25		Accident Source Term	10 CR 50.67		☒Input ☐Output

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26		Radiological Consequence Analyses Using Alternative Source Terms	15.0.1	0	☒Input ☐Output
27		Federal Guidance Report 11	EPA-520/1-88-020		☒Input ☐Output
28		Federal Guidance Report 12	EPA-402-R-93-081		☒Input ☐Output
29	☒ RPRT	Prairie Island Units 1 & 2 422V+ Reload Transition Safety Report	Westinghouse	0	☒Input ☐Output
30	☒ DRAW	PINGP HVAC Plan EL 755'-0" – Unit 1	NF-39609-1	T	☒Input ☐Output
31	☒ DRAW	PINGP HVAC Plan EL 755'-0" – Unit 1	NF-39609-2	Z	☒Input ☐Output
32	☒ DRAW	PINGP HVAC Spent Fuel Pool - Plan At EL 755'-0"	NF-39609-3	J	☒Input ☐Output
33	☒ DRAW	PINGP HVAC Spent Fuel Pool - Section At EL 755'-0"	NF-39609-25	D	☒Input ☐Output
34	☒ DRAW	PINGP Ventilation Flow Diagrams Reactor Building Unit 1	NF-39602-1	76	☒Input ☐Output
35	☒ DRAW	PINGP Ventilation Flow Diagram Reactor Building Unit 2	NF-39602-2	76	
36	☒ DRAW	PINGP Architectural Drawing Operating Floor Plan @ EL 735'-0"	NF-38502	76	☒Input ☐Output
37	☒ DRAW	PINGP Architectural Drawing Fuel Handling Floor @ EL 755'-0"	NF-38503,	K	☒Input ☐Output
38	☒ DRAW	PINGP Architectural Drawing East Elevation	NF-38510	J	☒Input ☐Output
39	☒ DRAW	PINGP Architectural Drawing West Elevation	NF-38511	G	☒Input ☐Output
40	☒ USAR	PINGP USAR Appendix D - Activity In Fuel Gap	Section D.2		☒Input ☐Output
41	☒ USAR	PINGP USAR Appendix D - Activity In One Fuel Assembly At 50 Hours After Shutdown	Table D.3-2		☐Input ☒Output
42	☒ USAR	PINGP USAR Appendix D - Thyroid Dose Conversion Factors for Iodine Inhalation	Table D.8-2		☐Input ☒Output
43	☒ USAR	PINGP USAR Appendix D - Standard Man Breathing Rates	Table D.8-3		☐Input ☒Output
44	☒ CALC	FHA Fission Product Inventories for AST Assessments	GEN-PI-047	0	☐Input ☒Output
45	☒ CALC	FHA Fission Product Inventories for AST Assessments	GEN-PI-047	0, Add 1	☐Input ☒Output
46	☒ USAR	Fuel Handling	Section 14.5.1		
47	☒ USAR	Assumptions Used for FHA in Containment Dose Analysis (AST)	Table 14.5-1		☐Input ☒Output
48	☒ USAR	Control Room Parameters for FHA Dose Analyses	Table 14.5-2		☐Input ☒Output

49	☒ USAR	Summary of 0-2 Hours χ/Q Results for Control Room Intake Fuel Handling Accident	Table 14.5-3	1	☐Input ☒Output
50	☒ CALC	Post-LOCA EAB, LPZ, and CR Doses – AST	GEN-PI-079	0	☒Input ☐Output
51		Design, Testing, and Maintenance Criteria for Post Accident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants	1.52	2	☒Input ☐Output
52	☒ DRAW	Admin Bldg, Screen House, & Control RM Flow Diagram	NF-39603-1, Rev 76, Including T-Mod EC 14090	76	☒Input ☐Output
53		Salem Nuclear Generating Station, Unit Nos. 1 and 2, Issuance of License Amendments 271 and 252 to Operating License Nos. DPR-70 and DPR-75, respectively, Alternate Source Term (TAC Nos. MC3094 and MC3095), NRC ADAMS Accession Number ML060040322	LA # 271 & 252	02/17/2006	☒Input ☐Output

*Controlled Doc checkmark means the reference can be entered on the C012 panel in black. Unchecked lines will be yellow. If checked, also list the Doc Type, e.g., CALC, DRAW, VTM, PROC, etc.)

**Corresponds to these PassPort "Ref Type" codes: Inputs/Both = ICALC, Outputs = OCALC, Other/Unknown = blank)

Other Pass Port Data

Associated System (PassPort C011, first three columns) **OR** **Equipment References** (PassPort C025, all five columns):

Facility	Unit	System	Equipment Type	Equipment Number
PI	0	ZF	SYS	SYS0ZF
PI	0	ZF	FILTER	069--221
PI	0	ZF	FILTER	069-222
PI	0	ZN	FILTER	069-241
PI	0	ZN	FILTER	069-242
PI	0	RD	RM	RM-23
PI	0	RD	RM	RM-24

Superseded Calculations (PassPort C019):

Facility	Calc Document Number	Title
PI	GEN-PI-051, Rev 1	Fuel Handling Accident Dose Analysis

Description Codes - Optional (PassPort C018):

Code	Description (optional)	Code	Description (optional)

Notes (Nts) - Optional (PassPort X293 from C020):

Topic Notes	Text
☐ Calc Introduction	☒ Copy directly from the calculation Intro Paragraph **or** ☐ See write-up below
The purpose of this analysis is to determine the Exclusion Area Boundary (EAB), Low Population Zone (LPZ) and Control Room (CR) doses due to a fuel handling accident (FHA) occurring with the reactor being shutdown for at least 50 hours. The post-FHA activity is postulated to release to the atmosphere through the common area of the auxiliary building, which has the most limiting atmospheric dispersion factor (χ/Qs) of all potential release paths, to maximize the radiological dose consequences.	
☐ (Specify)	

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Design Review Comment Form

Sheet ___ of ___

DOCUMENT NUMBER/ TITLE: GEN-PI-077/ Fuel Handling Accident Dose Analysis – AST

REVISION: 0 DATE: ________

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
1	Various editorial comments/suggestions made in the body of the calculation.	Incorporated.	Accepted 09/10/09
2	Section 2.2 indicates that the distance from the equipment hatch to the CR intake is much farther than the distance from the CA and therefore there is more atmospheric dispersion. Distance is only one part of the dispersion. We also need to say something about the direction (specifically with reference to the prevailing direction).	Distance is the dominant parameter for determining dispersion. Therefore, it is not necessary to address wind direction.	Accepted 09/10/09
3	Section 4.3 says; "It is assumed that the curie per Megawatt-thermal inventory of fission products in the reactor core and available for gap release from damaged fuel is based on the core thermal power level of 1,683 MWt including 2% power level measurement instrument uncertainty." Do you really mean 1852 as used in RADTRAD?	The isotope-specific curie per megawatt values are based on 1683 MWt (see Table 1). The curie release is based on scaling the Table 1 curie/MWt values by the assumed operating power level of 1852 MWt.	Accepted 09/10/09
4	Design Input 5.3.1.2 (Isotopic Core Inventory) is listed as "@ 1683 MW_t". Why is1683 specified and not 1852 as used in RADTRAD?	See response to Item #3. The curie/MWt data in DI 5.3.1.2 is based on 1683 MWt.	Accepted 09/10/09
5	Design Input 5.3.1.2 (Isotopic Core Inventory); why are there additional xenon isotopes included? (Also listed in Section 7.1)	There are no additional Xenon isotopes. Each of the Xenon isotopes listed in DI 5.3.1.2 and Section 7.1 is present at time of reactor shutdown (See Table 1). These isotopes are input into the RADTRAD runs (See Attachment A output file echo of input data). Some of these isotopes will have decayed away by time 50 hours, when the FHA is assumed to occur.	Accepted 09/10/09

Xcel Energy	Design Review Comment Form

Sheet ___ of ___

DOCUMENT NUMBER/ TITLE: GEN-PI-077/ Fuel Handling Accident Dose Analysis – AST

REVISION: 0 DATE: ________

ITEM #	REVIEWER'S COMMENTS	PREPARER'S RESOLUTION	REVIEWER'S DISPOSITION
6	Design Input 5.3.1.11 says that the Linear Heat Generation Rate of 6.3 kW/ft is exceeded. We should at least indicate the calculated amount and the number of bundles that exceed the limit.	As discussed in Section 2.4, the NRC reviewed the PINGP fuel management program and determined that exceeding an LHGR of 6.3 kW/ft is acceptable. Describing by how much the LHGR is exceeded is not needed to support this analysis. The details can be found in cited Reference 9.11 (PINGP License Amendments 166 and 156).	Accepted 09/10/09 TM
7	Section 7.3: Since additional isotopes are included in the .nif, the modified .inp file should be included to verify no errors exist in the file. Modifying this file can be tricky. The .nif and .rft files should also be included in the calc.	The data contained in the modified plant file (PI300FHA00.psf), nuclide inventory file (pifha_def.txt), and release fraction timing file (pifha_rft.txt) are echoed in the RADTRAD output file that is provided in Attachment A. The output file listing is a better choice for determining what is in these files, because it shows what the output file uses for input data.	Accepted 09/10/09 TM
8	Section 7.3: need to add RG 1.52 as well as GL 99-02.	RG 1.52 Revision 2 has been added as a reference. Revision 2 is listed because it is the Revision cited in VFTP Tech Spec Section 5.5.9.	Accepted 09/10/09 TM
	Reviewer: Thomas Mscisz Date: 09/08/2009	Preparer: Gopal J. Patel Date: 09/10/2009	

REVISION HISTORY

Revision	Description
0	Initial issue

SHEET REVISION INDEX

SHEET	REV	SHEET	REV
1	0	31	0
2	0	32	0
3	0	33	0
4	0	34	0
5	0	35	0
6	0	36	0
7	0	37	0
8	0	Attachment A	0
9	0		
10	0		
11	0		
12	0		
13	0		
14	0		
15	0		
16	0		
17	0		
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TABLE OF CONTENTS

1.0 PURPOSE and SUMMARY REPORT

Purpose:
The purpose of this analysis is to determine the Exclusion Area Boundary (EAB), Low Population Zone (LPZ) and Control Room (CR) doses due to a fuel handling accident (FHA) occurring with the reactor being shutdown for at least 50 hours. The post-FHA activity is postulated to release to the atmosphere through the common area of the auxiliary building, which has the most limiting atmospheric dispersion factor (χ/Qs) of all potential release paths, to maximize the radiological dose consequences.

The Alternative Source Term methodology is the current licensing basis for the PINGP FHA. The FHA re-analysis is performed using the guidance in Regulatory Guide 1.183, Appendix B, and TEDE dose criteria. The analysis supersedes FHA dose Calculation GEN-PI-051 (Refs. 9.9 and 9.10). This analysis differs from that of Calculation GEN-PI-051 in that various parameters are modeled with more conservative values, and this analysis uses revised common area of auxiliary building to Control Room χ/Qs.

Summary Report
The resulting post-FHA doses are shown in Section 8.0, which comply with the applicable regulatory allowable dose limits.

2.0 METHODOLOGY:

PINGP proposes to submit a License Amendment Request (LAR) to implement a full scope AST. The previous FHA analysis in Calculation GEN-PI-051 was performed to support License Amendment Request (LAR) L-PI-04-001 for selective scope implementation of AST to relax the containment integrity requirement during fuel handling. The NRC issued the facility operating license amendments 166 (PI Unit 1) and 156 (PI Unit 2) and thereby approved FHA analysis supporting the relaxation of the containment integrity and associated Technical Specification changes.

In the postulated FHA, a fuel assembly is assumed to be dropped and damaged during fuel handling. This accident may take place either in the containment or the spent fuel pool (SFP). The analysis design inputs and assumptions have been chosen such that the results of the single FHA analysis are bounding for the accident occurring in either the containment or the SFP. In order to do so, the most limiting 0 to 2 hour control room atmospheric dispersion factor (χ/Q) was selected from the various potential release paths. The SFP special ventilation system (SFPSVS) and shield building ventilation system (SBVS) are operable by Technical Specification LCO 3.7.13 (Ref. 9.6.9) and LCO 3.6.9 (Ref. 9.6.7), respectively. Although the analysis does not take credit for filtration by the SFPSVS and SBVS, the systems are not prevented from operating after an FHA. The post-FHA potential release paths are reviewed as follows:

2.1 FHA in SFP Enclosure

The SFP HVAC plan is shown in Reference 9.17.3. If the SFPSVS is credited, then the release is filtered before being exhausted through the Shield Building (SB) Vent Stack (Refs. 9.17.1, 9.17.2, & 9.17.3). Alternatively, the release may be exhausted through the SB Vent Stack with no credit taken for SFPSVS filtration. If normal ventilation is operating and credit is not taken for isolation by the high radiation signal, then the release is to the environment via the normal ventilation exhaust stack at Column M and

Row 11 (Refs. 9.17.3 & 9.17.4), which is farther from the CR intake, and therefore has greater atmospheric dispersion than the other potential release locations. Therefore, this release path is non-limiting for the analysis.

The SFP enclosure is located inside the auxiliary building (Ref. 9.17.3) but outside the Auxiliary Building Special Ventilation Zone (ABSVZ) (Refs. 9.17.3 & 9.19.2). This portion of the auxiliary building is a steel structure with sheet metal siding (Ref. 9.19.3, Sections @ COL Row J looking south). This area is referred to as "common area of auxiliary building" or "CA" in this calculation. This portion of the auxiliary building is not leak tight. In absence of a ventilation system operating, the radioactivity could exit the SFP enclosure by entering the CA, and then directly leak to the CR intake.

2.2 Equipment Hatch

When irradiated fuel (decayed more than 50 hours) is moved from the reactor, the containment integrity is not required to be maintained. For the FHA occurring inside containment, the source could exit containment directly to the atmosphere through the open Equipment Hatch. The distance from the equipment hatch to the CR intake is much farther than the distance from the CA (Refs. 9.19.1, 9.19.3 & 9.19.4).

2.3 FHA in Refueling Pool Inside Containment

The Reactor Building ventilation flow diagram is shown in Reference 9.18, which shows that if a FHA would occur in the containment building with its boundary intact during an outage, then there is no release path to the environment and no radiological consequences. However, if the containment is kept open through air locks, then the activity is released into the CA or Shield Building annulus. When the containment integrity is not maintained, the post-FHA leakage is released to the environment through various potential release paths and the 0 to 2 hour CR χ/Qs for these release paths are listed in the following table:

Summary of 0-2 Hour Control Room Intake χ/Qs for Various Post-FHA Release Paths

Release Source	Receptor Location	0-2 Hour CR χ/Q (sec/m^3)	Reference
Unit 1 Equipment Hatch	Unit 1 Control Room Intake	1.73E-03	9.8, Section 8.0
Unit 1 Equipment Hatch	Unit 2 Control Room Intake	4.79E-04	9.8, Section 8.0
Unit 2 Equipment Hatch	Unit 1 Control Room Intake	6.04E-04	9.8, Section 8.0
Unit 2 Equipment Hatch	Unit 2 Control Room Intake	3.11E-03	9.8, Section 8.0
Common Area of Aux Bldg	Unit 1 Control Room Intake	***6.71E-03***	9.5, Section 8.1.3
Common Area of Aux Bldg	Unit 2 Control Room Intake	***4.79E-03***	9.5, Section 8.1.3
Spent Fuel Pool Vent Normal Exhaust Stack	Unit 1 Control Room Intake	1.09E-03	9.8, Section 8.0
Spent Fuel Pool Vent Normal Exhaust Stack	Unit 2 Control Room Intake	2.82E-03	9.8, Section 8.0
Unit 1 Shield Bldg Vent Stack	Unit 1 Control Room Intake	3.76E-03	9.5, Section 8.1.1
Unit 1 Shield Bldg Vent Stack	Unit 2 Control Room Intake	8.33E-04	9.5, Section 8.1.1
Unit 2 Shield Bldg Vent Stack	Unit 1 Control Room Intake	1.23E-03	9.5, Section 8.1.1
Unit 2 Shield Bldg Vent Stack	Unit 2 Control Room Intake	4.53E-03	9.5, Section 8.1.1

A review of the above χ/Qs indicates that the CA represents the most limiting release path for the FHA occurring either in the SFP or in the containment. Therefore, the post-FHA doses are analyzed using CA to Unit 1 CR intake χ/Qs.

The Safety Evaluation approving the PINGP selective implementation of AST for the FHA (Ref. 9.11, Section 3.2, page 6) requires that the licensee should evaluate the effect on the FHA dose analysis of any change to the credited filtration efficiencies for the SFPSVS and SBVS filters or any change in assumed operation of these systems. Xcel Energy has proposed to remove both the SFPSVS and SBVS filtration systems from the PINGP Technical Specifications. Since the revised analysis in this calculation uses the most limiting χ/Q for the common area of auxiliary building without crediting any filtration, the resulting dose consequences will remain bounding for the post-FHA unfiltered releases from the SFP enclosure and containment.

2.4 Maximum Linear Heat Generation Rate

Note 11 to Table 3 of RG 1.183 (Ref. 9.1) requires that the maximum linear heat generation (LHGR) does not exceed 6.3 kw/ft peak rod average power for burnups exceeding 54 GWD/MTU. The Prairie Island fuel management program can result in some fuel assemblies being exposed to a maximum LHGR that exceeds 6.3 kw/hr at fuel burnups between 54 and 62 GWD/MTU (Ref. 9.20.1). To account for the higher LHGR a site-specific analysis was performed in Reference 9.21 and a computer code, "GAP" was developed and qualified using methodology presented in ANSI/ANS-5.4-1982 to perform the site-specific gap fraction analysis. The NRC reviewed the GAP code during approval of the PINGP license amendment for implementing selective implementation of AST for FHA (Ref. 9.11, Section 3.2) and determined that the analytical approach is consistent with the ANSI/ANS-5.4-1982 model, and that the GAP code is acceptable for analyzing the gap release fraction. The plant-specific gap fractions are compared with the RG 1.183 gap fractions in Table 2, which indicates that the gap fractions in Table 3 of RG 1.183 are bounding for the PINGP fuel assemblies exceeding the maximum LHGR of 6.3 kw/ft. The review of Table 2 indicates that the PINGP bounding fraction for the most limiting I-131 is a factor of 2 lower than that in the RG 1.183, Table 3. The PINGP bounding gap fraction in Table 2 has ample margin for the increased fuel burnup including the 10% EPU.

2.5 RADTRAD Model

The RADTRAD3.03 Code (Ref. 9.2) is used in this analysis. The same RADTRAD release model as depicted in Figure 1 is used to model the FHA occurring in either the spent fuel pool inside the SFP enclosure or in the refueling cavity inside Containment. The same model is applicable for each event because the source term and activity transport mechanisms are identical for each scenario.

The RADTRAD model considers a fictitious source volume of 1,000 cubic feet (Compartment #1), which initially contains all of the activity that is released to the Fuel Building or Containment air space. This source term, defined in Section 5.3.1, considers one damaged fuel assembly that has decayed for 50 hours, with a radial peaking factor of 1.90, fuel rod gap release fractions per Regulatory Guide 1.183 (Ref. 9.1), and pool water iodine, noble gas and particulate decontamination factors per RG 1.183.

Section 7.2 calculates a building release rate that will exhaust at least 99% of the radioactive material present in Compartment #1 to the environment (Compartment #2) over a 2-hour time period. The modeling of a 99% release rate has been accepted by the NRC Staff in various approved AST license amendment requests (e.g., Salem Units 1 and 2 [Ref. 9.25, Section 3.2.1]). No credit is taken for filtration of the activity released to the environment.

The two FHA events model the same sets of atmospheric dispersion factors that are modeled for releases to the Control Room, EAB, and LPZ (Sections 5.4.11, 5.5.1, and 5.5.5). The model for the control room (Compartment #3) is shown in Figure 2 and described in Section 5.4. The model for the EAB and LPZ dose receptors are described in Section 5.5.

2.6 CR Air Intake Radiation Monitor Response

Post-FHA Xe-133 activity in the CR @ 50.0036 hr (0.22 minute following a FHA)

= 1.6056 Ci (RADTRAD Run PI300FHA.o0)

Control room volume 61,315 ft^3 (Section 5.4.1) = 61,315 ft^3 / $(3.28\ ft/m)^3$ = 1,737.58 m^3

Xe-133 activity concentration in the CR @ 50.0036 hr (0.22 minute following a FHA)

= 1.6056 Ci / 1,737.58 m^3 = 9.24E-04 Ci/m^3 = 9.24E-04 μCi/cc, which exceeds CR monitor setpoint of 1E-05 μCi/cc for Xe-133 (Section 5.4.12).

Since the Xe-133 activity in the CR is circulated by the CR recirculation flow through the CR air supply duct (Ref. 9.28), the monitor setpoint is instantly exceeded. Therefore, the CR actuation delay of 5 minutes following a FHA is considered extremely conservative, and does not require any further justification.

3.0 ACCEPTANCE CRITERIA:

The following NRC regulatory requirement and guidance documents are applicable to this PINGP Alternative Source Term FHA Calculation:

- Regulatory Guide 1.183 (Ref. 9.1, Table 6)
- 10CFR50.67 (Ref. 9.13)
- Standard Review Plan section 15.0.1 (Ref. 9.24)

Dose Acceptance Criteria are:

Regulatory Dose Limits

Dose Type	Control Room (rem)	EAB and LPZ (rem)
TEDE Dose	5	6.3

4.0 ASSUMPTIONS:

Regulatory Guide 1.183 (Ref. 9.1) provides guidance on modeling assumptions that are acceptable to the NRC staff for the evaluation of the radiological consequences of a FHA. The following sections address the applicability of these modeling assumptions to this PINGP FHA analysis. These assumptions are considered validated assumptions and are incorporated as design inputs in Sections 5.3 through 5.5 and are incorporated in this analysis. There are no unvalidated assumptions used in this calculation.

Source Term Assumptions

4.1 It is assumed consistent with RG 1.183, Section 3.2 that the fractions of the core inventory assumed to be in the gap for the various radionuclides are as given in Table 3 of RG 1.183. The release fractions from Table 3 are incorporated in Design Input 5.3.1.3 in conjunction with the core fission product inventory in Design Input 5.3.1.2, with the maximum core radial peaking factor of 1.90 in Design Input 5.3.1.8, and with the proposed core thermal power level of 1,852 MWt in Design Input 5.3.1.1.

Per Section 2.4, the NRC has approved use of the isotopic release fractions specified in Table 3 of RG 1.183 for the PINGP fuel assemblies exceeding the maximum LHGR of 6.3 kw/ft at fuel burnups between 54 and 62 GWD/MTU. This approval was based on the RG 1.183 isotopic release fractions being conservatively greater than those calculated using the NRC-approved methodology of ANS-5.4-1982.

4.2 It is assumed consistent with Reference 9.1, Appendix B, Section 1.1 that the number of fuel rods damaged during the accident should be based on a conservative analysis that considers the most limiting case. All of the fuel rods in one spent fuel assembly are assumed to be damaged (see Design Input 5.3.1.5).

It is assumed consistent with Reference 9.1, Appendix B, Section 1.2, that the fission product release from the breached fuel is based on the fission product inventory in the fuel rod gap (Ref. 9.1, Table 3) and the estimate of the number of fuel rods breached (See Table 1).

4.3 Core Inventory

It is assumed that all the gap activity in the damaged rods is instantaneously released to the pool water. The radionuclides included are xenons, kryptons, and iodines. The fraction of fission product inventory in the gap is shown in Design Input 5.3.1.3. It is further assumed that irradiated fuel shall not be removed from the reactor without containment integrity until the unit has been shutdown for at least 50 hours (Design Input 5.3.1.7).

Non-iodine halogen isotopes (e.g., Bromine) are not modeled due to their short half lives that leave little activity in the source term at 50 hours (Ref. 9.3, Table 2-1). Alkali metal (i.e., particulate) isotopes are not modeled since they are not released from the water (Ref. 9.1, Appendix B, Section 3).

It is assumed that the curie per Megawatt-thermal inventory of fission products in the reactor core and available for gap release from damaged fuel is based on the core thermal power level of 1,683 MWt including 2% power level measurement instrument uncertainty. The fission product inventory is based on the current fuel enrichment of 5.0 w/o U-235, and a core average burnup of 25 GWD/MTU (Design Inputs 5.3.1.9 & 5.3.1.10).

4.4 Timing of Release Phase

It is assumed consistent with Reference 9.1, Section 3.3 that for non-LOCA DBAs in which fuel damage is projected, the release from the fuel gap is assumed to occur instantaneously with the onset of the projected damage.

4.5 Chemical Form

It is assumed consistent with Reference 9.1, Appendix B, Section 1.3, that the chemical form of radioiodine released from the fuel to the surrounding water should be assumed to be 95% cesium iodide (CsI), 4.85 percent elemental iodine, and 0.15 percent organic iodine (Design Input 5.3.1.12). The CsI released from the fuel is assumed to completely dissociate in the pool water. Because of the low pH of the pool water, the iodine re-evolves as elemental iodine. The release to the pool water is assumed to occur instantaneously.

4.6 Water Depth

It is assumed that if the depth of water above the damaged fuel is 23 feet or greater, the overall effective decontamination factor for iodine of 200 (i.e., 99.5% of the total iodine released from the damaged rods is retained by the water) (see Design Input 5.3.2.3; Ref. 9.1, Appendix B, Section 2). This iodine above the water is composed of 57% elemental and 43% organic species (Ref. 9.1, Appendix B, Section 2) (see Design Input 5.3.2.4).

4.7 Noble Gases and Particulates

It is assumed that the retention of noble gases in the water in the fuel pool or reactor cavity is negligible (i.e., decontamination factor of 1) (see Design Input 5.3.2.5). Particulate radionuclides are assumed to be retained by the water in the fuel pool or reactor cavity (i.e., infinite decontamination factor) (Ref. 9.1, Appendix B, Section 3) (see Design Input 5.3.2.9).

Fuel Handling Accidents Within Containment

For fuel handling accidents postulated to occur within the containment, the following assumption is acceptable to the NRC staff (Ref. 9.1, Appendix B, Section 5).

4.8a It is assumed that if the containment is open during fuel handling operations (e.g., personnel air lock or equipment hatch is open) the radioactive material that escapes from the reactor cavity pool to the containment is released to the environment over a 2-hour time period (Ref. 9.1, Section B.5.3) (Design Input 5.3.2.6). The activity release from the damaged fuel is postulated to release to the environment at a rate that will ensure that at least 99% of the post-FHA activity is removed from the source volume (Section 7.2). The modeling of a 99% release rate has been accepted by the NRC Staff in various approved AST license amendment requests (e.g., Salem Units 1 and 2 [Ref. 9.25, Section 3.2.1]).

Fuel Handling Accidents Within The SFP Enclosure

For fuel handling accidents postulated to occur within the SFP enclosure, the following assumptions are acceptable to the NRC staff (Ref. 9.1, Appendix B, Section 4).

4.8b It assumed that the radioactive material that escapes from the fuel pool to the SFP enclosure is assumed to be released to the environment over a 2-hour time period (Ref. 9.1, Section B.4.1) (Design Input 5.3.2.6). The activity released from the damaged fuel is postulated to release to the environment over a two-hour period at a rate that will ensure that at least 99% of the post-FHA activity is removed from the source volume (Section 7.2). The modeling of a 99% release rate has been accepted by the NRC Staff in various approved AST license amendment requests (e.g., Salem Units 1 and 2 [Ref. 9.25, Section 3.2.1]).

4.8c It is assumed that the radioactive material released from the fuel pool is not filtered by engineered safety feature (ESF) filter systems such as SFPSVS and SBVS in the radioactivity release analyses.

Control Room Dose Consequences

Regulatory Guide 1.183 (Ref. 9.1, Section 4.2) provides guidance to be used in determining the total effective dose equivalent (TEDE) for persons located in the control room (CR). The following sections address the applicability of this guidance to the PINGP FHA analysis. These assumptions are incorporated as design inputs in Sections 5.4.1 through 5.6.11.

4.9 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.2.1), that the CR TEDE analysis should consider the following sources of radiation that will cause exposure to control room personnel:

- Contamination of the control room atmosphere by the intake or infiltration of the radioactive material contained in the post-accident radioactive plume released from the facility (via CR air intake),
- Contamination of the control room atmosphere by the intake or infiltration of airborne radioactive material from areas and structures adjacent to the control room envelope (via CR unfiltered inleakage),
- Radiation shine from the external radioactive plume released from the facility (external airborne cloud),
- Radiation shine from radioactive material in the reactor containment (containment shine dose),
- Radiation shine from radioactive material in systems and components inside or external to the control room envelope, e.g., radioactive material buildup in recirculation filters (CR filter shine dose).

Note: Per Calculation GEN-PI-079 (Ref. 9.26, Section 8.1), the total post-LOCA external airborne cloud dose, containment shine dose, plus control room filter shine dose to the control room is less than 0.07 rem. This LOCA dose is based on both fuel rod gap and early in-vessel (i.e., core melt) activity releases associated with damage to all fuel assemblies in the core. The FHA activity releases are associated with only releases from only 1 of the 121 fuel assemblies in the core. Consequently, the external airborne cloud dose, containment shine dose, and CR filter shine dose due to a FHA are insignificant (i.e., 0.07 rem x [1 / 121] = 0.0006 rem) and are not evaluated for a FHA.

4.10 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.2.2), that the radioactive material releases and radiation levels used in the control room dose analysis are determined using the same source term, transport, and release assumptions used for determining the EAB and the LPZ TEDE values. These parameters do not result in non-conservative results for the control room.

4.11 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.2.6), that the CR dose receptor is the hypothetical maximum exposed individual who is present in the control room for 100% of the time during the first 24 hours after the event, 60% of the time between 1 and 4 days, and 40% of the time from 4 days to 30 days. For the duration of the event, the breathing rate of this individual should be assumed to be 3.5×10^{-4} cubic meters per second. These assumptions are incorporated as design inputs in Sections 5.4.8 and 5.4.10, respectively.

4.12 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.4), that the postulated CR doses should not exceed the 5 Rem TEDE criterion established in 10 CFR 50.67 (Ref. 9.13). This assumption is incorporated as a design input in Section 5.4.9.

CR Dose Acceptance Criteria: 5 Rem TEDE

4.13 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.2.4), that engineered safety features (ESF) that mitigate airborne radioactive material within the control room are credited. Such features include control room recirculation filtration. CR isolation is actuated by radiation monitors (RMs). Several aspects of CRSVS operation can delay the CR isolation. The CR air supply duct monitor response is calculated in Section 2.6 based on the post-accident CR Xe-133 activity, which is circulated by the CR recirculation flow through the CR air supply duct (Ref. 9.28). The CR XE-133 activity concentration instantly exceeds the monitor setpoint of 1E-05 μCi/cc for Xe-133. Therefore, a delay of 5 minutes for the CR isolation to be fully operational is considered to be conservative and no further sensitivity of delay time is required.

Offsite Dose Consequences

Regulatory Guide 1.183 (Ref. 9.1, Section 4.1) provides guidance to be used in determining the total effective dose equivalent (TEDE) for persons located at the exclusion area boundary (EAB) and at the outer boundary of the low population zone (LPZ). The following sections address the applicability of this guidance to the PINGP FHA analysis. These assumptions are incorporated as design inputs in Sections 5.5.1 through 5.5.7.

4.14 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.1.1) that the dose calculation determines the TEDE, which is the sum of the committed effective dose equivalent (CEDE) from inhalation and the deep dose equivalent (DDE) from external exposure; and these two components of the TEDE consider all radionuclides, including progeny from the decay of parent radionuclides that are significant with regard to dose consequences and the released radioactivity. These isotopes are listed in Section 5.3.1.2.

4.15 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.1.2), that the exposure-to-CEDE factors for inhalation of radioactive material are derived from the data provided in ICRP Publication 30, "Limits for Intakes of Radionuclides by Workers". This calculation models the CEDE dose conversion factors (DCFs) in the column headed "effective" yield doses in Table 2.1 of Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" (Ref. 9.14).

4.16 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.1.3), that for the first 8 hours, the breathing rate of persons offsite is assumed to be 3.5×10^{-4} cubic meters per second. From 8 to 24 hours following the accident, the breathing rate is assumed to be 1.8×10^{-4} cubic meters per second. After that and until the end of the accident, the rate is assumed to be 2.3×10^{-4} cubic meters per second. These offsite breathing rate assumptions are listed in Sections 5.5.2 and 5.5.4.

4.17 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.1.4), that the DDE is calculated assuming submergence in semi-infinite cloud assumptions with appropriate credit for attenuation by body tissue. The DDE is nominally equivalent to the effective dose equivalent (EDE) from external exposure if the whole body is irradiated uniformly. Since this is a reasonable assumption for submergence exposure situations, EDE is used in lieu of DDE in determining the contribution of external dose to the TEDE. This calculation models the EDE dose conversion factors in the column headed "effective" in Table III.1 of Federal Guidance Report 12, "External Exposure to Radionuclides in Air, Water, and Soil" (Ref. 9.15).

4.18 It is assumed consistent with RG 1.183 (Ref. 9.1, Sections 4.1.5 and 4.4), that the TEDE is determined for the most limiting person at the EAB. The maximum EAB TEDE for any two-hour period following the start of the radioactivity release is determined and used in determining compliance with the dose criteria in 10 CFR 50.67 (Ref. 9.13). For the FHA the postulated EAB doses should not exceed the criteria established in RG 1.183 Table 6. This assumption is incorporated as a design input in Section 5.5.6.

EAB Dose Acceptance Criterion: 6.3 Rem TEDE

The RADTRAD3.03 Code (Ref. 9.2) used in this analysis determines the maximum two-hour TEDE by calculating the postulated dose for a series of small time increments and performing a "sliding" sum over the increments for successive two-hour periods. The time increments appropriately reflect the progression of the accident to capture the peak dose interval between the start of the event and the end of radioactivity release.

4.19 It is assumed consistent with RG 1.183 (Ref. 9.1, Sections 4.1.6 and 4.4), that the TEDE is determined for the most limiting receptor at the outer boundary of the low population zone (LPZ) and is used in determining compliance with the dose criteria in 10 CFR 50.67 (Ref. 9.13). For the FHA the postulated LPZ doses should not exceed the criteria established in RG 1.183 Table 6. This assumption is incorporated as a design input in Section 5.5.7.

LPZ Dose Acceptance Criterion: 6.3 Rem TEDE

4.20 It is assumed consistent with RG 1.183 (Ref. 9.1, Section 4.1.7), that no correction is made for depletion of the effluent plume by deposition on the ground.

5.0 DESIGN INPUTS

5.1 General Considerations

5.1.1 Applicability of Prior Licensing Basis

The Alternative Source Term methodology is the current licensing basis for the PINGP FHA. The PINGP plant specific design inputs and assumptions used in the current facility's design basis FHA analysis were assessed for their validity to represent the as-built condition of the plant and evaluated for their compatibility to meet the AST and TEDE methodology. The analysis in this calculation ensures that analysis assumptions, design inputs, and methods are compatible with the AST and comply with RG 1.183, Appendix B requirements.

5.1.2 Credit for Engineered Safeguard Features

Credit is taken only for accident mitigation features that are classified as safety-related, are required to be operable by technical specifications, are powered by emergency power sources, and are either automatically actuated or, in limited cases, have actuation requirements explicitly addressed in emergency operating procedures. The Control Room special ventilation system (CRSVS) is operable by Technical Specification LCO 3.7.10 (Ref. 9.6.8). The CRSVS air intake monitors are required to be operable by TS 3.3.6 and Table 3.3.6-1 (Ref. 9.6.10) in Modes 1, 2, 3, & 4 and during movement of irradiated fuel assemblies. The CRSVS actuation during the FHA is credited in the analysis with a 5-minute system response delay.

The SFP special ventilation system (SFPSVS) and shield building ventilation system (SBVS) are operable by Technical Specification LCO 3.7.13 (Ref. 9.6.9) and LCO 3.6.9 (Ref. 9.6.7), respectively. The actuations of the SFPSVS and SBVS are conservatively not credited in the analysis. Although the analysis does not take credit for filtration by the SFPSVS and SBVS, the systems are not prevented from operating after an FHA.

5.1.3 Meteorology Considerations

The control room atmospheric dispersion factors (χ/Qs) for the several potential post-FHA release points including the Unit 1 & 2 Equipment Hatches, the Common Area of Auxiliary Building (AB), the Spent Fuel Pool Vent Normal Exhaust Stack, and the SB Vent Stacks release points - are developed (Refs. 9.5 & 9.8) using the NRC sponsored computer code ARCON96 and guidance provided for the use of ARCON96 in the Regulatory Guide 1.194. The EAB and LPZ χ/Qs were originally developed for the plant operating license and were accepted by the staff in the previous licensing amendments.

5.2 Accident-Specific Design Inputs/Assumptions

The design inputs and assumptions utilized in the post-FHA EAB, LPZ, and CR habitability analyses are listed in the following sections. The design inputs are compatible with the AST and TEDE dose criteria and assumptions are consistent with those identified in Section 3 and Appendix B of RG 1.183 (Ref. 9.1). The design inputs and assumptions in the following sections represent the as-built design of the plant.

5.3 Source Term and Transport Parameters

Design Input Parameter		Value Assigned		Reference	
5.3.1 Source Term					
5.3.1.1 Core Power Level		1,650 MW_t 1,683 MW_t (= 102% of 1,650 MW_t) 1,852 MW_t (= 110% of 1,683 MW_t)		9.6.1 10% EPU Power Level Used in the analysis	
5.3.1.2 Isotopic Core Inventory (Ci/MW_t) @ 1,683 MW_t				Table 1	
Isotope	**Activity**	**Isotope**	**Activity**	**Isotope**	**Activity**
KR-85 *	1.334E+01	I-133	4.259E+00	XE-135	1.931E+02
KR-85M	1.008E+02	I-134	4.758E+00	XE-135M	1.819E+02
KR-87	1.978E+02	I-135	4.068E+00	XE-138	7.203E+02
KR-88	2.631E+02	XE-131M	4.721E+00		
I-131 **	3.359E+00	XE-133	8.537E+02		
I-132	3.037E+00	XE-133M	2.668E+01		
* Kr-85 activity has been multiplied by a factor of 2 (0.10/0.05) to account for additional fractional release relative to other noble gas isotopes. ** I-131 activity has been multiplied by a factor of 1.6 (0.08/0.05) to account for additional fractional release relative to other iodine isotopes.					
5.3.1.3 Fraction of Fission Product Inventory in Gap					
Group		**Fraction**		9.1, Section 3.2, Table 3	
I-131		0.08			
Kr-85		0.10			
Other Noble Gases		0.05			
Other Halogens		0.05			
Alkali Metals		0.12			
5.3.1.4 Radionuclide Composition					
Group		**Elements**		9.1, Section 3.4, Table 5	
Noble Gases		Xe, Kr			
Halogens		I, Br			
Alkali Metals		Cs, Rb			
5.3.1.5 Number of Damaged Fuel Assembly		1		9.4.1, Item # 3	
5.3.1.6 Number of Fuel Assemblies In Core		121		9.6.4	
5.3.1.7 Irradiated Fuel Decay		50 Hrs		9.6.6 & 9.4.1, Item # 6	
5.3.1.8 Radial Peaking Factor		1.77 1.90		9.16, section 3.5 Used in the analysis	
5.3.1.9 Fuel Enrichment w/o U-235		5.0%		9.3, Table 6-1	
5.3.1.10 Fuel Cycle Burnup		25,000 MWD/MTU			
5.3.1.11 Linear Heat Generation Rate		6.3 kw/ft Exceeds this requirement		9.1, Table 3, Note # 11 See discussion in Section 2.4	

Design Input Parameter	Value Assigned	Reference
5.3.1.12 Iodine Chemical Form Released from Fuel to Water		
Iodine Chemical Form	**%**	9.1, Appendix B, Section 1.3
Aerosol (CsI)	95.0%	
Elemental	4.85%	
Organic	0.15%	
5.3.2 Activity Transportation		
5.3.2.1 Minimum Refueling Cavity and Pool Water Depths	23 feet	9.6.2 & 9.6.3
5.3.2.2 Deleted.		
5.3.2.3 Overall Effective Decontamination Factor (DF) for Iodine		
Total Iodine	200	9.1, Appendix B, Section 2
5.3.2.4 Chemical Form of Iodine Released From Pool Water		
Elemental	57%	9.1, Appendix B, Section 2
Organic	43%	
5.3.2.5 DF of Noble Gas	1	9.1, Appendix B, Section 3
5.3.2.6 Duration of Release (hr)	2	9.1, Appendix B, Section 5.3
5.3.2.7 Pool Node Volume	1,000 ft^3	Assumed
5.3.2.8 Activity release rate	39 cfm	See Section 7.2
5.3.2.9 DF of Particulates	Infinite	9.1, Appendix B, Section 3
5.4 Control Room (CR) Parameters		
5.4.1 CR Volume	61,315 ft^3	9.4.2, Item # 6
5.4.2 CRSVS Normal Flow Rate	1,818 cfm ± 10% 2,000 cfm < 5 minutes	9.4.2, Item # 10 Used in the analysis
5.4.3 CRSVS Makeup Rate	0.00 cfm > 5 minutes	CR operates in a recirculation mode
5.4.4 CRSVS Recirc Flow Rate	4,000 cfm ± 10% 3,600 cfm > 5 minutes	9.4.2, Item # 13 Used in the analysis
5.4.5 CRSVS Charcoal Filter Efficiencies	95% for elemental iodine 95% for organic iodide	Section 7.3.1
5.4.6 CRSVS HEPA Filter Efficiency	99%	Section 7.3.2
5.4.7 CR Unfiltered Inleakage Determined By Tracer Gas Testing	300 cfm (includes 10 cfm for ingress and egress) (nominal value measured, including uncertainty)	9.4.2, Item # 11
5.4.8 CR Breathing Rate	3.5E-04 m^3/sec	9.1, Section 4.2.6
5.4.9 CR Allowable Dose Limit	5 rem TEDE for the event duration	9.13
5.4.10 CR Occupancy Factors		
Time (Hr)	**%**	9.1, Section 4.2.6
0-24	100	
24-96	60	
96-720	40	

Design Input Parameter	Value Assigned	Reference
5.4.11 Unit 2 CR χ/Qs For FHA Release Through Common Area of Auxiliary Building (CA)		
Time (Hr)	**X/Q (sec/m^3)**	9.5, Section 8.1.3
0-2	6.71E-03	
2-8	2.89E-03	
8-24	1.22E-03	
24-96	9.21E-04	
96-720	7.44E-04	
5.4.12 CR Monitor Setpoint	1.0E-05 μCi/ml for Xe-133	9.4.2, Item # 9
5.5 Site Boundary Release Model Parameters		
5.5.1 EAB Atmospheric Dispersion Factor (χ/Q)	6.49E-04 sec/m^3	9.4.2, Item # 2
5.5.2 EAB Breathing Rate (m^3/sec)	3.5E-04	9.1, Section 4.1.3
5.5.3 LPZ Distance	2,414 m	9.4.3, Item # 3
5.5.4 LPZ Breathing Rate (m^3/sec)		
Time (Hr)	**(m^3/sec)**	9.1, Section 4.1.3
0-8	3.5E-04	
8-24	1.8E-04	
24-720	2.3E-04	
5.5.5 LPZ Atmospheric Dispersion Factors (χ/Qs)		
Time (Hr)	**χ/Q (sec/m^3)**	9.4.3, Item # 3
0-8	1.77E-04	
8-24	3.99E-05	
24-96	7.12E-06	
96-720	1.04E-06	
5.5.6 EAB allowable dose limit	6.3 rem TEDE for any 2-hour period	9.1, Section 4.1.5 and Table 6
5.5.7 LPZ allowable dose limit	6.3 rem TEDE for the event duration	9.1, Section 4.1.6 and Table 6

6.0 COMPUTER CODES & COMPLIANCE WITH REGULATORY REQUIREMENTS

6.1 COMPUTER CODES

RADTRAD 3.03 (Ref. 9.2): This is an NRC-sponsored code approved for use in determining control room and offsite doses from releases due to reactor accidents. This code was used by most of the AST license amendments that have been approved by the NRC. A rigorous high quality code qualification process was adopted to develop and procure the code by testing of the program elements, verification of input/output files, and examination of design specification. Therefore the RADTRAD3.03 computer code is considered to be qualified to comply with the quality assurance requirements of 10 CFR50, Appendix B and it can be safely used to perform the design basis accident analyses.

Calculation GEN-PI-079 (Ref. 9.26, Sections 2.6 & 8.2) documents a V&V of the RADTRAD3.03 code. Suitable acceptance test cases for the PWR radiological analysis were incrementally selected, initially defining simplified cases that could verified against analytical solutions, then adding complexity (typically a control room) and comparing the results against the RADTRAD3.03 and HABIT code analyses, adding more complexity (e.g., removal by decay chain) and comparing the results with the RADTRAD3.03 and HABIT codes again. The selected PWR code cases cover all essential characteristics of an FHA AST analysis, including transportation of activity within the compartment and in the atmosphere. All radiological features of the RADTRAD3.03 code were verified and validated by running the selected PWR code cases in the Microsoft Window XP environment. The results of V&V code cases were summarized in Calculation GEN-PI-079, Section 8.2, and compared with the RADTRAD3.03 and HABIT code results, which showed an excellent agreement.

Therefore, the code is considered validated for use in the PINGP AST analysis.

6.2 COMPLIANCE WITH REGULATORY REQUIREMENTS:

As discussed in Section 4.0, Assumptions, the analysis in this calculation complies with the line-by-line requirements in Regulatory Guide 1.183 including its Appendix B.

7.0 CALCULATIONS

7.1 PINGP Plant Specific Nuclide Inventory File (NIF) For RADTRAD3.03 Input

The parameter Ci/MW_t in the RADTRAD3.03 default nuclide inventory file Pwr_def.NIF is dependent on the plant-specific core thermal power level, reload design, fuel burnup, and fuel cycle, therefore, the NIF is modified based on the PINGP plant-specific isotopic Ci/MW_t information developed in Table 1. The newly developed RADTRAD nuclide inventory file PIFHA_def.txt is used in the analysis. Similarly, the Release Fraction Timing File (RFT) PIFHA_rft.txt, and Dose Conversion File (DCF) PIFHA_fg11&12.txt are generated to support the FHA analysis. The DCF input file includes additional noble gas isotopes (Xe-131M, Xe-133M, Xe-135M, and Xe-138) for completeness.

7.2 Activity Release Rates

The SFP is assigned a source node volume of 1,000 ft^3 and 99% of the post-FHA activity in this source node volume is postulated to release to the environment over two hours with the activity release rate calculated in the following section:

$A = A_0\, e^{-\lambda t}$
Where;
A_0 = Initial Activity in Source Node
A = Final Activity in Source Node
λ = Removal Rate (vol/hr)
t = Removal Time (hr) = 2.0 hr
Assuming that 99% of activity is released into the environment,

$A/A_0 = 0.01$
Therefore,
$A / A_0 = e^{-\lambda t}$
$0.01 = e^{-2\lambda}$
$\ln (0.01) = - 2\lambda \ln(e)$
$- 4.605 = - 2\, \lambda$
$\lambda = - 4.605/-2 = 2.303$ volume/hr
Containment Building Release Rate = 2.303 vol/hr x 1,000 ft^3 x 1 hr/60 min
Containment Building Release Rate = 38.38 ft^3/min $\cong$ 39.0 ft^3/min

7.3 CRSVS Filter Efficiency

The CRSVS charcoal and HEPA filter efficiencies are calculated based on RG 1.52 (Ref. 9.27) and Generic Letter (GL) 99-02 requirements (Ref. 9.12).

7.3.1 CRSVS Charcoal Filter Efficiency

Laboratory penetration testing acceptance criteria for the safety related Charcoal filters are as follows:

CRSVS Charcoal Filter – in-laboratory testing methyl iodide penetration < 2.5% (Ref. 9.6.5, Section 5.5.9.c)
Generic Letter 99-02 (Ref. 9.12) requires a safety factor of at least 2 to be used to determine the filter efficiencies to be credited in the design basis accident.
Testing methyl iodide penetration (%) = $(100\% - \eta)$/safety factor = $(100\% - \eta)/2$
Where η = charcoal filter efficiency to be credited in the analysis

CRSVS Charcoal Filter
$2.5\% = (100\% - \eta)/2$
$5\% = (100\% - \eta)$
$\eta = 100\% - 5\% = 95\%$

7.3.2 CRSVS HEPA Filter Efficiency

CRSVS HEPA Filter – in-place DOP penetration and bypass < 0.05% (Ref. 9.6.5, Section 5.5.9.a)
Generic Letter 99-02 (Ref. 9.12) requires a safety factor of at least 2 to be used to determine the filter efficiencies to be credited in the design basis accident.
Testing DOP penetration (%) = $(100\% - \eta)$/safety factor = $(100\% - \eta)/2$
Where η = HEPA filter efficiency to be credited in the analysis

CRSVS HEPA Filter
$0.05\% = (100\% - \eta)/2$
$0.10\% = (100\% - \eta)$
$\eta = 100\% - 0.10\% = 99.9\%$

Regulatory Guide 1.52 (Ref. 9.27, Regulatory Position C.5.c) states that if the in-place penetration and bypass testing results are <0.05%, the condition can be considered to warrant a 99% removal efficiency for particulates in accident dose evaluations. Therefore, a HEPA filter efficiency of 99% is used in the analysis.

Safety Grade Filter	Filter Efficiency Credited (%)		
	Aerosol	Elemental	Organic
CRSVS	99	95	95

8.0 RESULTS SUMMARY/CONCLUSIONS:

8.1 Result Summary:

The post-FHA EAB, LPZ, and CR doses are summarized in the following table:

Post-FHA Activity Release Path	Post-FHA TEDE Dose (Rem)		
	Receptor Location		
	Control Room	EAB	LPZ
Common Area of Auxiliary Building	3.64E+00	2.28E+00 (50.0 hr after shutdown; 0.0 hr following FHA)	6.21E-01
Total	**3.64E+00**	**2.28E+00**	**6.21E-01**
Allowable TEDE Limit	**5.0E+00**	**6.3E+00**	**6.3E+00**
	RADTRAD Computer Run No.		
	PI300FHA00.o0	PI300FHA00.o0	PI300FHA00.o0

8.2 Conclusions:

The results of analysis in Section 8.1 indicate that the EAB, LPZ, and CR doses are within allowable limits for a FHA occurring either in the containment or the SFP enclosure without containment integrity. The results demonstrate that the following PINGP Technical Specification requirements can be relaxed:

The irradiated fuel can be moved in the reactor pressure vessel, reactor water cavity, and SFP enclosure after the reactor has been shutdown for at least 50 hours without crediting the SBVS and SFPSVS filtrations. The SBVS vent and recirculation charcoal filter could be physically deleted or abandoned in-place with the deletion of the Surveillance Requirement SR 3.6.9.2 (Ref. 9.6.11) for LCO 3.6.9. Similarly, the SFPSVS filter could be physically deleted or abandoned in-place with the deletion of the Surveillance Requirement SR 3.7.13.2 (Ref. 9.6.12) for LCO 3.7.13.

9.0 REFERENCES

1. U.S. NRC Regulatory Guide 1.183, Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors, July 2000
2. S.L. Humphreys et al., "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation," NUREG/CR-6604, USNRC, April 1998
3. Westinghouse Letter NSP-07-59, Dated 11/02/2007, Subject: Core Activity Inventory and Coolant Activity Concentration
4. Design Input Transmittal Nos
   - 4.1 DIT No. 13720-04, Rev 0, FHA Dose Analysis Input Parameters
   - 4.2 DIT No. 13720-07, Rev 1, Control Room Input Parameters
   - 4.3 DIT No. 13720-03, Rev 0, Meteorological Input Parameters
5. PINGP Calculation No. GEN-PI-080, Rev 0, Prairie Island Atmospheric Dispersion Factors (χ/Qs) – AST Additional Releases
6. PINGP Technical Specifications:
   - 6.1 Specification 1.1, PINGP Units 1 & 2, Rated Thermal Power
   - 6.2 Specification LCO 3.9.2, Refueling Cavity Water Level
   - 6.3 Specification LCO 3.7.15, Spent Fuel Storage Pool Water Level
   - 6.4 Specification 4.2.1, Fuel Assemblies
   - 6.5 Specification 5.5.9, Ventilation Filter Testing Program (VFTP)
   - 6.6 Basis B 3.9, Refueling Operation
   - 6.7 Specification LCO 3.6.9, Shield Building Ventilation System (SBVS)
   - 6.8 Specification LCO 3.7.10, Control Room Special Ventilation System (CRSVS)
   - 6.9 Specification LCO 3.7.13, Spent Fuel Pool Special Ventilation System (SFPSVS)
   - 6.10 Specification 3.3.6, Control Room Special Ventilation System (CRSVS) Actuation Instrumentation Including Table 3.3.6-1
   - 6.11 Surveillance Requirement SR 3.6.9.2, Perform required SBVS filter testing in accordance with the Ventilation Filter Testing Program (VFTP)
   - 6.12 Surveillance Requirement SR 3.7.13.2, Perform required SFSVS filter testing in accordance with the Ventilation Filter Testing Program (VFTP)
7. PINGP Calculation No. GEN-PI-046, Rev 0, Fission Product Inventories for AST Assessments
8. PINGP Calculation No. GEN-PI-049, Rev 0, Addenda 2, PI Control Room Atmospheric Dispersion Factors
9. PINGP Calculation No. GEN-PI-051, Rev 1, Fuel Handling Accident Dose Analysis
10. PINGP Calculation No. GEN-PI-051, Rev 1, Addendum 1, Fuel Handling Accident Dose Analysis – Heavy Load Drop

11. Prairie Island Nuclear Generating Plant Amendment Nos. 166 and 156 to Operating License Nos. DPR-42 and DPR-60, respectively, Selective Implementation Of Alternate Source Term For Fuel Handling Accidents (TAC Nos. MC1843 and MC1844), September 10, 2004, NRC ADAMS Accession Number ML042430504.

12. USNRC, "Laboratory Testing of Nuclear-Grade Activated Charcoal", NRC Generic Letter 99-02, June 3, 1999

13. 10 CFR 50.67, "Accident Source Term"

14. Federal Guidance Report 11, EPA-5201/1-88-020, Environmental Protection Agency

15. Federal Guidance Report 12, EPA-402- R-93-081, Environmental Protection Agency

16. Prairie Island Units 1 & 2 422V+ Reload Transition Safety Report, Rev 0, by Westinghouse, May 2008

17. PINGP Auxiliary Building HVAC Drawings:
    - 17.1 NF-39609-1, Rev T, Plan EL 755'-0" – Unit 1
    - 17.2 NF-39609-2, Rev Z, Plan EL 755'-0" – Unit 2
    - 17.3 NF-39609-3, Rev J, Spent Fuel Pool - Plan At EL 755'-0"
    - 17.4 NF-39609-25, Rev D, Spent Fuel Pool - Section At EL 755'-0"

18. PINGP Ventilation Flow Diagrams:
    - 18.1 NF-39602-1, Rev 76, Reactor Building Unit 1
    - 18.2 NF-39602-2, Rev 76, Reactor Building Unit 2

19. PINGP Architectural Drawings:
    - 19.1 NF-38502, Rev 76, Operating Floor Plan @ EL 735'-0"
    - 19.2 NF-38503, Rev K, Fuel Handling Floor @ EL 755'-0"
    - 19.3 NF-38510, Rev J, East Elevation
    - 19.4 NF-38511, Rev G, West Elevation

20. PINGP USAR Appendix D Sections & Tables:
    - 20.1 Section D.2, Activity In Fuel Gap
    - 20.2 Table D.3-2, Activity In One Fuel Assembly At 50 Hours After Shutdown
    - 20.3 Table D.8-2, Thyroid Dose Conversion Factors for Iodine Inhalation
    - 20.4 Table D.8-3, Standard Man Breathing Rates

21. PINGP Calculation No. GEN-PI-047, Rev 0, Addendum 1, FHA Fission Product Inventories for AST Assessments

22. Not Used.

23. PINGP USAR Section 14.5.1 & Tables:
    - 23.1 Section 14.5.1, Fuel Handling
    - 23.2 Table 14.5-1, Assumptions Used for FHA in Containment Dose Analysis (AST)

23.3 Table 14.5-2, Control Room Parameters for FHA Dose Analyses

23.4 Table 14.5-3, Summary of 0-2 Hours χ/Q Results for Control Room Intake Fuel Handling Accident

24. NUREG-0800, Standard Review Plan, "Radiological Consequence Analyses Using Alternative Source Terms," SRP 15.0.1, Rev. 0, July 2000

25. Salem, Unit Nos. 1 and 2, Issuance of License Amendments 251 and 232 Re: Refueling Operations - Fuel Decay Time Prior to Commencing Core Alterations or Movement of Irradiated Fuel, October 10, 2002 (ADAMS Accession Number ML022770181)

26. PINGP Calculation No. GEN-PI-079, Rev 0, Post-LOCA EAB, LPZ, and CR Doses – AST

27. U.S. NRC Regulatory Guide 1.52, Revision 2, "Design, Testing, and Maintenance Criteria for Post Accident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants", March 1978

28. PINGP Flow Diagram No. NF-39603-1, Rev 76, Including T-Mod EC 14090, Admin Bldg, Screen House, & Control RM Flow Diagram

10.0 TABLES

Table 1
Un-decayed Post-FHA Activity Released From Damaged Fuel Assembly Used In RADTRAD Nuclide Inventory File

Isotope	Core Inventory At Shutdown (Ci) A	Radial Peaking Factor B	Total Number of Fuel Assembly In Core C	Number of Fuel Assembly Damaged D	Activity In Damaged Fuel Assembly (Ci) E=A*B*D/C	DF F	RADTRAD Nuclide Inventory File (NIF) (Ci) G=E/F	RADTRAD Nuclide Inventory File (NIF) (Ci/MW_t) H = G/1683
KR-85*	1.43E+06	1.90	121	1	2.245E+04	1.0	2.245E+04	1.334E+01
KR-85M	1.08E+07	1.90	121	1	1.696E+05	1.0	1.696E+05	1.008E+02
KR-87	2.12E+07	1.90	121	1	3.329E+05	1.0	3.329E+05	1.978E+02
KR-88	2.82E+07	1.90	121	1	4.428E+05	1.0	4.428E+05	2.631E+02
I-131**	7.20E+07	1.90	121	1	1.131E+06	200.0	5.653E+03	3.359E+00
I-132	6.51E+07	1.90	121	1	1.022E+06	200.0	5.111E+03	3.037E+00
I-133	9.13E+07	1.90	121	1	1.434E+06	200.0	7.168E+03	4.259E+00
I-134	1.02E+08	1.90	121	1	1.602E+06	200.0	8.008E+03	4.758E+00
I-135	8.72E+07	1.90	121	1	1.369E+06	200.0	6.846E+03	4.068E+00
XE-131M	5.06E+05	1.90	121	1	7.945E+03	1.0	7.945E+03	4.721E+00
XE-133	9.15E+07	1.90	121	1	1.437E+06	1.0	1.437E+06	8.537E+02
XE-133M	2.86E+06	1.90	121	1	4.491E+04	1.0	4.491E+04	2.668E+01
XE-135	2.07E+07	1.90	121	1	3.250E+05	1.0	3.250E+05	1.931E+02
XE-135M	1.95E+07	1.90	121	1	3.062E+05	1.0	3.062E+05	1.819E+02
XE-138	7.72E+07	1.90	121	1	1.212E+06	1.0	1.212E+06	7.203E+02

A from Reference 9.3, Table 2-1 except noted as follows

* KR-85 activity has been multiplied by a factor of 2 (0.10/0.05) to account for additional fractional release relative to other noble gas isotopes.

** I-131 activity has been multiplied by a factor of 1.6 (0.08/0.05) to account for additional fractional release relative to other iodine isotopes

B From Section 5.3.1.8

C From Reference 9.6.4

D From Section 5.3.1.5

F From RG 1.183, Appendix B, Sections 2 and 3

Table 2
Comparison of Gap Fractional Releases for Prairie Island Fuel Rod
To RG 1.183, Table 3

Radionuclide Or Radionuclide Group	Fractional Release	
	Bounding Prairie Island Result A	RG 1.183 Table 3 B
I-131	0.036	0.08
Kr-85	0.056	0.10
Other Noble Gases	0.024	0.05
Other Halogens	0.013	0.05
Alkali Metals	0.072	0.12

A From Reference 9.21

11.0 FIGURES:

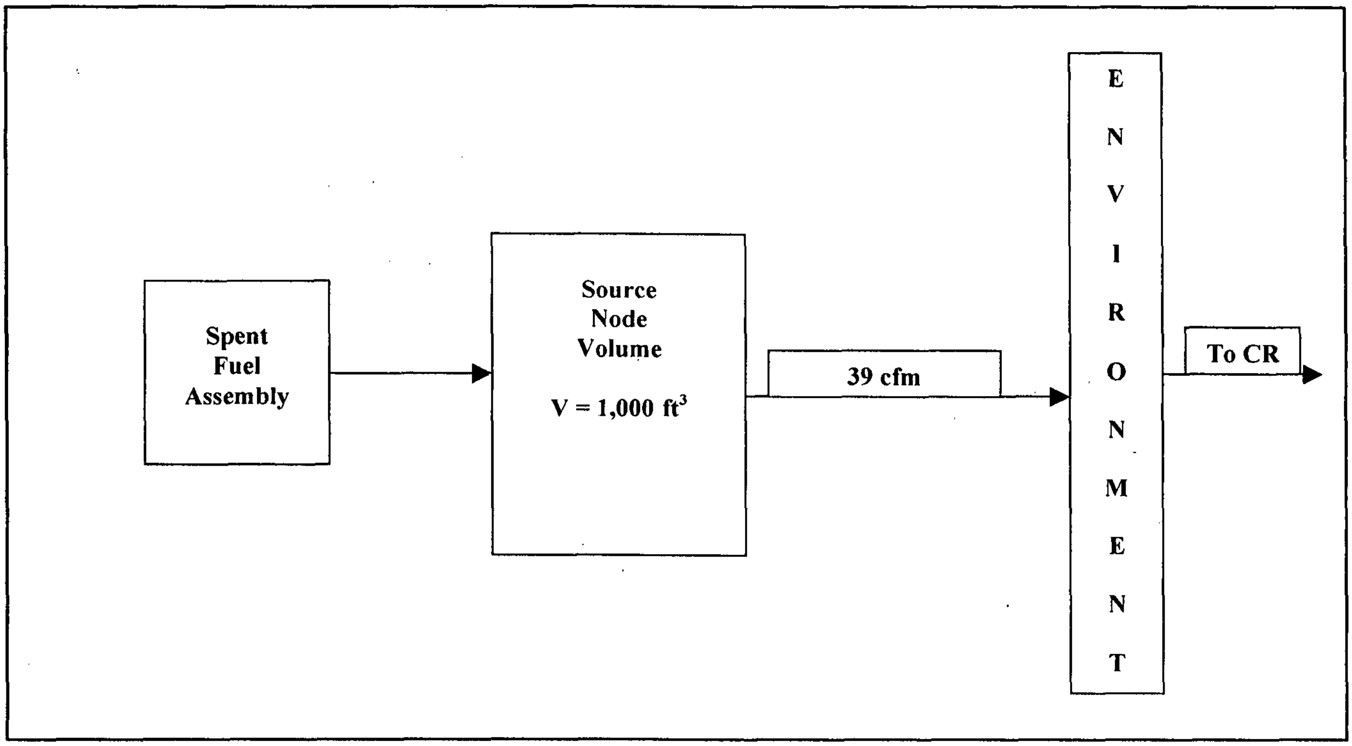

Figure 1: FHA Occurring Either In SFP Enclosure or Containment Building, RADTRAD Nodalization

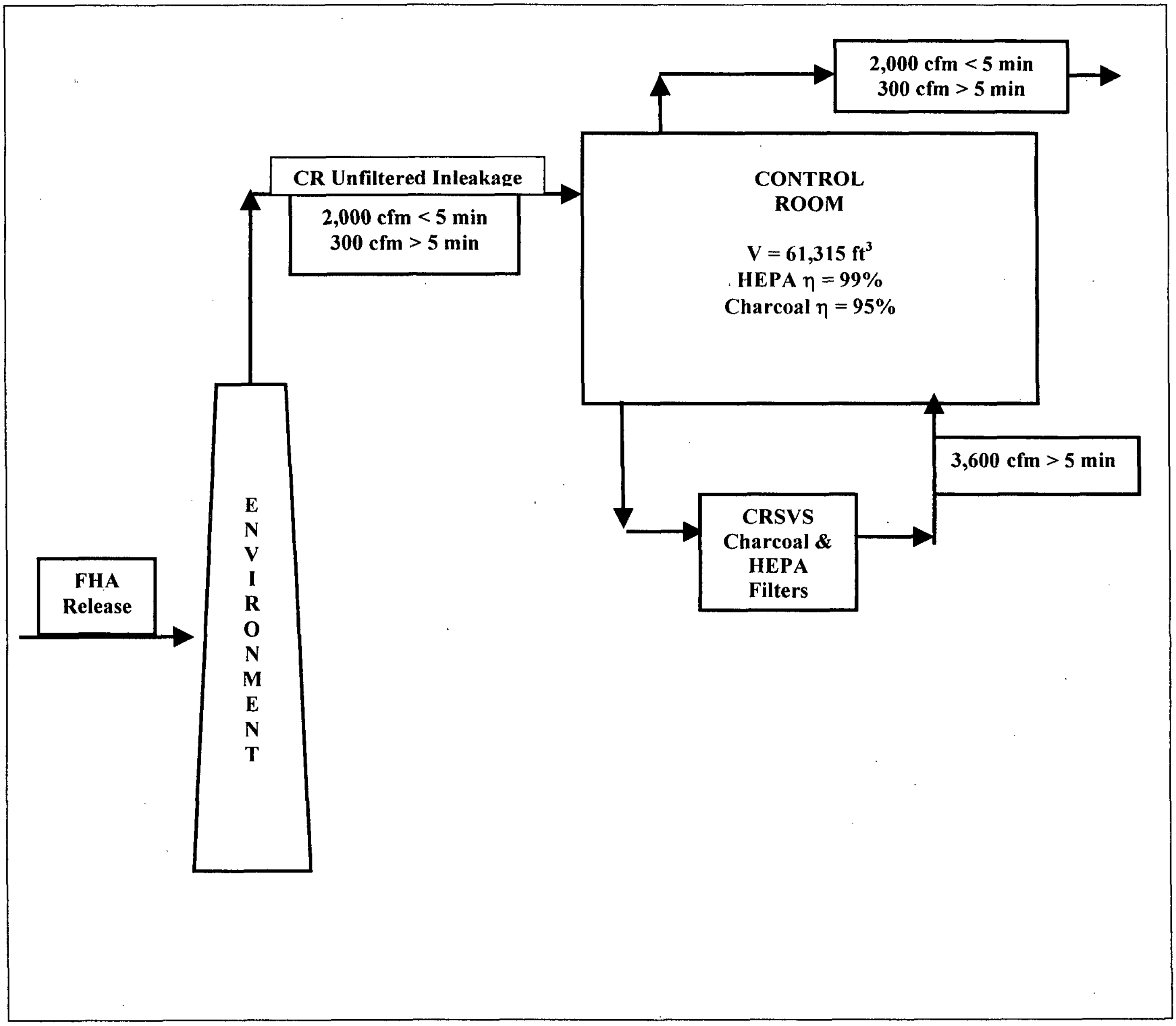

Figure 2 – PINGP Post-FHA Control Room Response AST RADTRAD Nodalization

12.0 AFFECTED DOCUMENTS:

Upon approval of the AST Licensing Change Request, the following documents will be revised or superseded:

12.1 PINGP Calculation No. GEN-PI-046, Rev 0, Fission Product Inventories for AST Assessments
12.2 PINGP Calculation No. GEN-PI-051, Rev 1, Fuel Handling Accident Dose Analysis
12.3 PINGP Calculation No. GEN-PI-047, Rev 0, FHA Fission Product Inventories for AST Assessments
12.4 PINGP Calculation No. GEN-PI-047, Rev 0, Addendum 1, FHA Fission Product Inventories for AST Assessments
12.5 PINGP USAR Appendix D Section D.2 & Tables:
- 12.6.1 Section D.2, Activity In Fuel Gap
- 12.6.2 Table D.3-2, Activity In One Fuel Assembly At 50 Hours After Shutdown
- 12.6.3 Table D.8-2, Thyroid Dose Conversion Factors for Iodine Inhalation
- 12.6.4 Table D.8-3, Standard Man Breathing Rates

12.6. PINGP USAR Section 14.5.1 & Tables:
- 12.7.1 Section 14.5.1, Fuel Handling
- 12.7.2 Table 14.5-1, Assumptions Used for FHA in Containment Dose Analysis (AST)
- 12.7.3 Table 14.5-2, Control Room Parameters for FHA Dose Analyses
- 12.7.4 Table 14.5-3, Summary of 0-2 Hours χ/Q Results for Control Room Intake Fuel Handling Accident

13.0 ATTACHMENTS:

Attachment A – RADTRAD Output File PI300FHA00.o0

Attachment A
RADTRAD Output File PI300FHA00.o0

```
########################################################################
   RADTRAD Version 3.03 (Spring 2001) run on   4/06/2009  at 23:25:11
########################################################################

########################################################################
                    File information
########################################################################

Plant file           = G:\Radtrad 3.03\Input\PI\PI-GEN-077\PI300FHA00.psf
Inventory file       = g:\radtrad 3.03\defaults\pifha_def.txt
Release file         = g:\radtrad 3.03\defaults\pifha_rft.txt
Dose Conversion file = g:\radtrad 3.03\defaults\pifha_fg11&12.txt




    #####    ####   #####    #  #     #  #####   #    #  #####
    #    #  #       #        #  ##    #  #    #  #    #    #
    #    #  #       #        #  # #   #  #    #  #    #    #
    #####    ####   ####     #  #  #  #  #####   #    #    #
    #            #  #        #  #   # #  #       #    #    #
    #            #  #        #  #    ##  #       #    #    #
    #        ####   #        #  #     #  #        ####     #


Radtrad 3.03 4/15/2001
Prairie Island FHA  AST Analysis - CR Charcoal Filtration Starts @ 5 minutes, and CR
Unfiltered Inleakage = 300 cfm
Nuclide Inventory File:
g:\radtrad 3.03\defaults\pifha_def.txt
Plant Power Level:
 1.8520E+03
Compartments:
  3
Compartment 1:
Fuel Pool
  3
 1.0000E+03
  0
  0
  0
  0
  0
Compartment 2:
Environment
  2
 0.0000E+00
  0
  0
  0
  0
```

```
  0
Compartment 3:
Control Room
  1
 6.1315E+04
  0
  0
  1
  0
  0
Pathways:
  3
Pathway 1:
FHA Release to Environment
  1
  2
  2
Pathway 2:
Environment to Control Room
  2
  3
  2
Pathway 3:
Control Room to Environment
  3
  2
  2
End of Plant Model File
Scenario Description Name:

Plant Model Filename:

Source Term:
  1
  1   1.0000E+00
g:\radtrad 3.03\defaults\pifha_fg11&12.txt
g:\radtrad 3.03\defaults\pifha_rft.txt
  5.0000E+01
  1
  0.0000E+00   5.7000E-01   4.3000E-01   1.0000E+00
Overlying Pool:
  0
  0.0000E+00
  0
  0
  0
  0
Compartments:
  3
Compartment 1:
  0
  1
  0
  0
  0
  0
  0
```

```
  0
  0
Compartment 2:
  0
  1
  0
  0
  0
  0
  0
  0
  0
Compartment 3:
  1
  1
  0
  0
  0
  0
  1
  3.6000E+03
  3
  5.0000E+01   0.0000E+00   0.0000E+00   0.0000E+00
  5.0083E+01   9.9000E+01   9.5000E+01   9.5000E+01
  7.7000E+02   0.0000E+00   0.0000E+00   0.0000E+00
  0
  0
Pathways:
  3
Pathway 1:
  0
  0
  0
  0
  0
  1
  2
  5.0000E+01   3.9000E+01   0.0000E+00   0.0000E+00   0.0000E+00
  5.2000E+01   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
  0
  0
  0
  0
  0
  0
Pathway 2:
  0
  0
  0
  0
  0
  1
  3
  5.0000E+01   2.0000E+03   0.0000E+00   0.0000E+00   0.0000E+00
  5.0083E+01   3.0000E+02   0.0000E+00   0.0000E+00   0.0000E+00
  7.7000E+02   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
  0
```

```
  0
  0
  0
  0
  0
Pathway 3:
  0
  0
  0
  0
  0
  1
  3
  5.0000E+01   2.0000E+03   0.0000E+00   0.0000E+00   0.0000E+00
  5.0083E+01   3.0000E+02   0.0000E+00   0.0000E+00   0.0000E+00
  7.7000E+02   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
  0
  0
  0
  0
  0
  0
Dose Locations:
  3
Location 1:
Exclusion Area Boundary
  2
  1
  2
  5.0000E+01   6.4900E-04
  7.7000E+02   0.0000E+00
  1
  2
  5.0000E+01   3.5000E-04
  7.7000E+02   0.0000E+00
  0
Location 2:
Low Population Zone
  2
  1
  5
  5.0000E+01   1.7700E-04
  5.8000E+01   3.9900E-05
  7.4000E+01   7.1200E-06
  1.4600E+02   1.0400E-06
  7.7000E+02   0.0000E+00
  1
  4
  5.0000E+01   3.5000E-04
  5.8000E+01   1.8000E-04
  7.4000E+01   2.3000E-04
  7.7000E+02   0.0000E+00
  0
Location 3:
Control Room
  3
  0
```

```
  1
  2
  5.0000E+01   3.5000E-04
  7.7000E+02   0.0000E+00
  1
  4
  5.0000E+01   1.0000E+00
  7.4000E+01   6.0000E-01
  1.4600E+02   4.0000E-01
  7.7000E+02   0.0000E+00
Effective Volume Location:
  1
  6
  5.0000E+01   6.7100E-03
  5.2000E+01   2.8900E-03
  5.8000E+01   1.2200E-03
  7.4000E+01   9.2100E-04
  1.4600E+02   7.4400E-04
  7.7000E+02   0.0000E+00
Simulation Parameters:
  6
  5.0000E+01   1.0000E-01
  5.2000E+01   5.0000E-01
  5.8000E+01   1.0000E+00
  7.4000E+01   2.0000E+00
  1.4600E+02   5.0000E+00
  7.7000E+02   0.0000E+00
Output Filename:
G:\Radtrad 3.o24
  1
  1
  1
  0
  0
End of Scenario File
```

```
########################################################################
   RADTRAD Version 3.03 (Spring 2001) run on  4/06/2009  at 23:25:11
########################################################################

########################################################################
                    Plant Description
########################################################################

Number of Nuclides =  60

Inventory Power =   1.0000E+00 MWth
Plant Power Level =   1.8520E+03 MWth

Number of compartments    =   3

Compartment information

Compartment number  1  (Source term fraction =   1.0000E+00
)
Name: Fuel Pool
Compartment volume =   1.0000E+03 (Cubic feet)
Compartment type is Normal
Pathways into and out of compartment  1
   Exit Pathway Number    1: FHA Release to Environment

Compartment number  2
Name: Environment
Compartment type is Environment
Pathways into and out of compartment  2
   Inlet Pathway Number   1: FHA Release to Environment
   Inlet Pathway Number   3: Control Room to Environment
   Exit Pathway Number    2: Environment to Control Room

Compartment number  3
Name: Control Room
Compartment volume =   6.1315E+04 (Cubic feet)
Compartment type is Control Room
Removal devices within compartment:
     Filter(s)
Pathways into and out of compartment  3
   Inlet Pathway Number   2: Environment to Control Room
   Exit Pathway Number    3: Control Room to Environment

Total number of pathways =   3
```

```
##########################################################################
   RADTRAD Version 3.03 (Spring 2001) run on  4/06/2009  at 23:25:11
##########################################################################

##########################################################################
                    Scenario Description
##########################################################################


Time between shutdown and first release =    5.0000E+01 (Hours)

Radioactive Decay is enabled
Calculation of Daughters is enabled

Release Fractions and Timings
                GAP        EARLY IN-VESSEL  LATE RELEASE    RELEASE MASS
             0.003600 hr    0.0000 hrs      0.0000 hrs         (gm)
NOBLES       5.0000E-02     0.0000E+00      0.0000E+00       3.593E+00
IODINE       5.0000E-02     0.0000E+00      0.0000E+00       3.008E-03
CESIUM       1.2000E-01     0.0000E+00      0.0000E+00       0.000E+00
TELLURIUM    0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00
STRONTIUM    0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00
BARIUM       0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00
RUTHENIUM    0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00
CERIUM       0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00
LANTHANUM    0.0000E+00     0.0000E+00      0.0000E+00       0.000E+00

Inventory Power =      1852. MWt

Nuclide  Group  Specific     half      Whole Body   Inhaled     Inhaled
 Name          Inventory     life        DCF        Thyroid    Effective
               (Ci/MWt)      (s)     (Sv-m3/Bq-s)   (Sv/Bq)     (Sv/Bq)
 Kr-85     1   1.334E+01  3.383E+08   1.190E-16   0.000E+00   0.000E+00
 Kr-85m    1   1.008E+02  1.613E+04   7.480E-15   0.000E+00   0.000E+00
 Kr-87     1   1.978E+02  4.578E+03   4.120E-14   0.000E+00   0.000E+00
 Kr-88     1   2.631E+02  1.022E+04   1.020E-13   0.000E+00   0.000E+00
 I-131     2   3.359E+00  6.947E+05   1.820E-14   2.920E-07   8.890E-09
 I-132     2   3.037E+00  8.280E+03   1.120E-13   1.740E-09   1.030E-10
 I-133     2   4.259E+00  7.488E+04   2.940E-14   4.860E-08   1.580E-09
 I-134     2   4.758E+00  3.156E+03   1.300E-13   2.880E-10   3.550E-11
 I-135     2   4.068E+00  2.380E+04   8.294E-14   8.460E-09   3.320E-10
 Xe-131m   1   4.721E+00  1.028E+06   3.890E-16   0.000E+00   0.000E+00
 Xe-133    1   8.537E+02  4.532E+05   1.560E-15   0.000E+00   0.000E+00
 Xe-133m   1   2.668E+01  1.890E+05   1.370E-15   0.000E+00   0.000E+00
 Xe-135    1   1.931E+02  3.272E+04   1.190E-14   0.000E+00   0.000E+00
 Xe-135m   1   1.819E+02  9.174E+02   2.040E-14   0.000E+00   0.000E+00
 Xe-138    1   7.203E+02  8.502E+02   5.770E-14   0.000E+00   0.000E+00

Nuclide     Daughter  Fraction    Daughter  Fraction    Daughter  Fraction
 Kr-85m     Kr-85      0.21        none      0.00        none       0.00
 Kr-87      Rb-87      1.00        none      0.00        none       0.00
 Kr-88      Rb-88      1.00        none      0.00        none       0.00
 I-131      Xe-131m    0.01        none      0.00        none       0.00
 I-133      Xe-133m    0.03        Xe-133    0.97        none       0.00
 I-135      Xe-135m    0.15        Xe-135    0.85        none       0.00
 Xe-133m    Xe-133     1.00        none      0.00        none       0.00
 Xe-135     Cs-135     1.00        none      0.00        none       0.00
```

Xe-135m	Xe-135	1.00	none	0.00	none	0.00
Xe-138	Cs-138	1.00	none	0.00	none	0.00

Iodine fractions
Aerosol = 0.0000E+00
Elemental = 5.7000E-01
Organic = 4.3000E-01

COMPARTMENT DATA

Compartment number 1: Fuel Pool

Compartment number 2: Environment

Compartment number 3: Control Room

Compartment Filter Data

Time (hr)	Flow Rate (cfm)	Filter Efficiencies (%) Aerosol	Elemental	Organic
5.0000E+01	3.6000E+03	0.0000E+00	0.0000E+00	0.0000E+00
5.0083E+01	3.6000E+03	9.9000E+01	9.5000E+01	9.5000E+01
7.7000E+02	3.6000E+03	0.0000E+00	0.0000E+00	0.0000E+00

PATHWAY DATA

Pathway number 1: FHA Release to Environment

Pathway Filter: Removal Data

Time (hr)	Flow Rate (cfm)	Filter Efficiencies (%) Aerosol	Elemental	Organic
5.0000E+01	3.9000E+01	0.0000E+00	0.0000E+00	0.0000E+00
5.2000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Pathway number 2: Environment to Control Room

Pathway Filter: Removal Data

Time (hr)	Flow Rate (cfm)	Filter Efficiencies (%) Aerosol	Elemental	Organic
5.0000E+01	2.0000E+03	0.0000E+00	0.0000E+00	0.0000E+00
5.0083E+01	3.0000E+02	0.0000E+00	0.0000E+00	0.0000E+00
7.7000E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

Pathway number 3: Control Room to Environment

Pathway Filter: Removal Data

Time (hr)	Flow Rate (cfm)	Filter Efficiencies (%) Aerosol	Elemental	Organic
5.0000E+01	2.0000E+03	0.0000E+00	0.0000E+00	0.0000E+00
5.0083E+01	3.0000E+02	0.0000E+00	0.0000E+00	0.0000E+00
7.7000E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

LOCATION DATA
Location Exclusion Area Boundary is in compartment 2

```
     Location X/Q Data
      Time (hr)         X/Q (s * m^-3)
       5.0000E+01          6.4900E-04
       7.7000E+02          0.0000E+00

     Location Breathing Rate Data
      Time (hr)         Breathing Rate (m^3 * sec^-1)
       5.0000E+01                  3.5000E-04
       7.7000E+02                  0.0000E+00
     Location Low Population Zone     is in compartment   2

     Location X/Q Data
      Time (hr)         X/Q (s * m^-3)
       5.0000E+01          1.7700E-04
       5.8000E+01          3.9900E-05
       7.4000E+01          7.1200E-06
       1.4600E+02          1.0400E-06
       7.7000E+02          0.0000E+00

     Location Breathing Rate Data
      Time (hr)         Breathing Rate (m^3 * sec^-1)
       5.0000E+01                  3.5000E-04
       5.8000E+01                  1.8000E-04
       7.4000E+01                  2.3000E-04
       7.7000E+02                  0.0000E+00
     Location Control Room     is in compartment   3

     Location X/Q Data
      Time (hr)         X/Q (s * m^-3)
       5.0000E+01          6.7100E-03
       5.2000E+01          2.8900E-03
       5.8000E+01          1.2200E-03
       7.4000E+01          9.2100E-04
       1.4600E+02          7.4400E-04
       7.7000E+02          0.0000E+00

     Location Breathing Rate Data
      Time (hr)         Breathing Rate (m^3 * sec^-1)
       5.0000E+01                  3.5000E-04
       7.7000E+02                  0.0000E+00

     Location Occupancy Factor Data
      Time (hr)         Occupancy Factor
       5.0000E+01            1.0000E+00
       7.4000E+01            6.0000E-01
       1.4600E+02            4.0000E-01
       7.7000E+02            0.0000E+00

USER SPECIFIED TIME STEP DATA - SUPPLEMENTAL TIME STEPS
     Time               Time step
      0.0000E+00          1.0000E-01
      2.0000E+00          5.0000E-01
      8.0000E+00          1.0000E+00
      2.4000E+01          2.0000E+00
      9.6000E+01          5.0000E+00
      7.2000E+02          0.0000E+00
```

```
#######################################################################
   RADTRAD Version 3.03 (Spring 2001) run on  4/06/2009  at 23:25:11
#######################################################################



     ####   #    #  #####  #####   #    #  #####
    #    #  #    #    #    #    #  #    #    #
    #    #  #    #    #    #    #  #    #    #
    #    #  #    #    #    #####   #    #    #
    #    #  #    #    #    #       #    #    #
    #    #  #    #    #    #       #    #    #
     ####    ####     #    #        ####     #


####################################################################
          Dose, Detailed model and Detailed Inventory Output
####################################################################

Exclusion Area Boundary Doses:

Time (h) =  50.0036    Whole Body  Thyroid       TEDE
Delta dose (rem)        1.0953E-03  2.8075E-01  9.6697E-03
Accumulated dose (rem)  1.0953E-03  2.8075E-01  9.6697E-03

Low Population Zone Doses:

Time (h) =  50.0036    Whole Body  Thyroid       TEDE
Delta dose (rem)        2.9871E-04  7.6568E-02  2.6372E-03
Accumulated dose (rem)  2.9871E-04  7.6568E-02  2.6372E-03

Control Room Doses:

Time (h) =  50.0036    Whole Body  Thyroid       TEDE
Delta dose (rem)        1.0980E-06  7.9530E-03  2.4399E-04
Accumulated dose (rem)  1.0980E-06  7.9530E-03  2.4399E-04

Control Room Compartment Nuclide Inventory:

Time (h) =  50.0036        Ci          kg          Atoms       Decay
Kr-85                   3.2774E-02  8.3537E-08  5.9185E+17  1.1155E+10
Kr-85m                  1.0815E-04  1.3141E-14  9.3105E+10  3.6817E+07
Kr-88                   3.2391E-06  2.5832E-16  1.7677E+09  1.1028E+06
I-131                   6.8978E-03  5.5638E-11  2.5577E+14  2.3478E+09
I-132                   2.1299E-09  2.0634E-19  9.4136E+05  7.2521E+02
I-133                   1.9776E-03  1.7457E-12  7.9045E+12  6.7312E+08
I-135                   5.2801E-05  1.5035E-14  6.7069E+10  1.7974E+07
Xe-131m                 1.0286E-02  1.2280E-10  5.6451E+14  3.5009E+09
Xe-133                  1.6056E+00  8.5778E-09  3.8840E+16  5.4649E+11
Xe-133m                 3.3953E-02  7.5669E-11  3.4262E+14  1.1557E+10
Xe-135                  1.1216E-02  4.3921E-12  1.9592E+13  3.8180E+09
Xe-135m                 9.1992E-06  1.0099E-16  4.5049E+08  3.1236E+06

Control Room Transport Group Inventory:
```

```
Time (h) =  50.0036     Atmosphere     Sump
Noble gases (atoms)     6.3161E+17  0.0000E+00
Elemental I (atoms)     1.5033E+14  0.0000E+00
Organic I (atoms)       1.1341E+14  0.0000E+00
Aerosols (kg)           0.0000E+00  0.0000E+00
Dose Effective (Ci/cc)  I-131 (Thyroid)          4.1632E-12
Dose Effective (Ci/cc)  I-131 (ICRP2 Thyroid)    4.2798E-12
Total I (Ci)                                     8.9281E-03

                        Deposition Recirculating
Time (h) =  50.0036      Surfaces     Filter
Noble gases (atoms)     0.0000E+00  0.0000E+00
Elemental I (atoms)     0.0000E+00  0.0000E+00
Organic I (atoms)       0.0000E+00  0.0000E+00
Aerosols (kg)           0.0000E+00  0.0000E+00

Environment to Control Room Transport Group Inventory:

                          Pathway
Time (h) =  50.0036      Filtered   Transported
Noble gases (atoms)     0.0000E+00  6.3310E+17
Elemental I (atoms)     0.0000E+00  1.5069E+14
Organic I (atoms)       0.0000E+00  1.1368E+14
Aerosols (kg)           0.0000E+00  0.0000E+00

Control Room to Environment Transport Group Inventory:

                          Pathway
Time (h) =  50.0036      Filtered   Transported
Noble gases (atoms)     1.4848E+15  0.0000E+00
Elemental I (atoms)     3.5342E+11  0.0000E+00
Organic I (atoms)       2.6661E+11  0.0000E+00
Aerosols (kg)           0.0000E+00  0.0000E+00

Exclusion Area Boundary Doses:

Time (h) =  50.0830     Whole Body   Thyroid       TEDE
Delta dose (rem)         4.4029E-02  1.1286E+01  3.8871E-01
Accumulated dose (rem)   4.5124E-02  1.1567E+01  3.9838E-01

Low Population Zone Doses:

Time (h) =  50.0830     Whole Body   Thyroid       TEDE
Delta dose (rem)         1.2008E-02  3.0780E+00  1.0601E-01
Accumulated dose (rem)   1.2307E-02  3.1545E+00  1.0865E-01

Control Room Doses:

Time (h) =  50.0830     Whole Body   Thyroid       TEDE
Delta dose (rem)         1.2142E-03  8.7942E+00  2.6980E-01
Accumulated dose (rem)   1.2153E-03  8.8021E+00  2.7004E-01

Control Room Compartment Nuclide Inventory:

Time (h) =  50.0830        Ci            kg          Atoms        Decay
Kr-85                   1.2482E+00  3.1815E-06  2.2541E+19  1.3213E+13
Kr-85m                  4.0686E-03  4.9439E-13  3.5027E+12  4.3332E+10
```

Kr-88	1.2099E-04	9.6493E-15	6.6033E+10	1.2932E+09
I-131	2.6263E-01	2.1184E-09	9.7385E+15	2.7803E+12
I-132	7.9199E-08	7.6727E-18	3.5005E+07	8.4844E+05
I-133	7.5118E-02	6.6311E-11	3.0025E+14	7.9618E+11
I-135	1.9943E-03	5.6787E-13	2.5332E+12	2.1198E+10
Xe-131m	3.9166E-01	4.6760E-09	2.1496E+16	4.1462E+12
Xe-133	6.1124E+01	3.2655E-07	1.4786E+18	6.4714E+14
Xe-133m	1.2918E+00	2.8789E-09	1.3035E+16	1.3681E+13
Xe-135	4.2461E-01	1.6627E-10	7.4170E+14	4.5080E+12
Xe-135m	3.4718E-04	3.8113E-15	1.7002E+10	3.3357E+09

Control Room Transport Group Inventory:

Time (h) = 50.0830	Atmosphere	Sump	
Noble gases (atoms)	2.4055E+19	0.0000E+00	
Elemental I (atoms)	5.7235E+15	0.0000E+00	
Organic I (atoms)	4.3177E+15	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		1.5850E-10
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		1.6292E-10
Total I (Ci)			3.3974E-01

Time (h) = 50.0830	Deposition Surfaces	Recirculating Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	0.0000E+00
Organic I (atoms)	0.0000E+00	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

Time (h) = 50.0830	Pathway Filtered	Transported
Noble gases (atoms)	0.0000E+00	2.6083E+19
Elemental I (atoms)	0.0000E+00	6.2082E+15
Organic I (atoms)	0.0000E+00	4.6834E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

Time (h) = 50.0830	Pathway Filtered	Transported
Noble gases (atoms)	2.0327E+18	0.0000E+00
Elemental I (atoms)	4.8381E+14	0.0000E+00
Organic I (atoms)	3.6498E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Exclusion Area Boundary Doses:

Time (h) = 52.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	2.1234E-01	5.4534E+01	1.8778E+00
Accumulated dose (rem)	2.5746E-01	6.6100E+01	2.2762E+00

Low Population Zone Doses:

Time (h) = 52.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	5.7910E-02	1.4873E+01	5.1212E-01
Accumulated dose (rem)	7.0216E-02	1.8027E+01	6.2077E-01

Control Room Doses:

Time (h) = 52.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	6.6985E-02	1.0402E+02	3.2438E+00
Accumulated dose (rem)	6.8201E-02	1.1283E+02	3.5139E+00

Control Room Compartment Nuclide Inventory:

Time (h) = 52.0000	Ci	kg	Atoms	Decay
Kr-85	1.3304E+00	3.3911E-06	2.4025E+19	4.1128E+14
Kr-85m	3.2236E-03	3.9171E-13	2.7752E+12	1.1701E+12
Kr-88	8.0775E-05	6.4418E-15	4.4083E+10	3.2279E+10
I-131	4.0142E-03	3.2380E-11	1.4885E+14	1.7977E+13
I-132	6.8402E-10	6.6267E-20	3.0232E+05	4.9022E+06
I-133	1.0846E-03	9.5740E-13	4.3350E+12	5.0874E+12
I-135	2.5104E-05	7.1482E-15	3.1887E+10	1.3173E+11
Xe-131m	4.1553E-01	4.9609E-09	2.2806E+16	1.2877E+14
Xe-133	6.4481E+01	3.4449E-07	1.5598E+18	2.0042E+16
Xe-133m	1.3425E+00	2.9919E-09	1.3547E+16	4.2060E+14
Xe-135	3.9110E-01	1.5315E-10	6.8318E+14	1.3073E+14
Xe-135m	1.8821E-05	2.0661E-16	9.2166E+08	4.3815E+10

Control Room Transport Group Inventory:

Time (h) = 52.0000	Atmosphere	Sump	
Noble gases (atoms)	2.5622E+19	0.0000E+00	
Elemental I (atoms)	8.7334E+13	0.0000E+00	
Organic I (atoms)	6.5883E+13	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		2.4164E-12
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		2.4802E-12
Total I (Ci)			5.1239E-03

Time (h) = 52.0000	Deposition Surfaces	Recirculating Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	9.2080E+15
Organic I (atoms)	0.0000E+00	6.9464E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

Time (h) = 52.0000	Pathway Filtered	Transported
Noble gases (atoms)	0.0000E+00	4.4567E+19
Elemental I (atoms)	0.0000E+00	1.0600E+16
Organic I (atoms)	0.0000E+00	7.9962E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

Time (h) = 52.0000	Pathway Filtered	Transported
Noble gases (atoms)	1.8929E+19	0.0000E+00
Elemental I (atoms)	1.2915E+15	0.0000E+00
Organic I (atoms)	9.7431E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Exclusion Area Boundary Doses:

Time (h) = 58.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	2.5746E-01	6.6100E+01	2.2762E+00

Low Population Zone Doses:

Time (h) = 58.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	7.0216E-02	1.8027E+01	6.2077E-01

Control Room Doses:

Time (h) = 58.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	8.0881E-02	9.1259E-01	1.0875E-01
Accumulated dose (rem)	1.4908E-01	1.1374E+02	3.6226E+00

Control Room Compartment Nuclide Inventory:

Time (h) = 58.0000	Ci	kg	Atoms	Decay
Kr-85	2.2857E-01	5.8258E-07	4.1275E+18	9.0392E+14
Kr-85m	2.1888E-04	2.6597E-14	1.8844E+11	2.0498E+12
Kr-88	3.2087E-06	2.5590E-16	1.7512E+09	5.1214E+10
I-131	1.2843E-12	1.0360E-20	4.7624E+04	1.8099E+13
Xe-131m	7.0358E-02	8.3999E-10	3.8615E+15	2.8183E+14
Xe-133	1.0725E+01	5.7299E-08	2.5945E+17	4.3643E+16
Xe-133m	2.1308E-01	4.7488E-10	2.1502E+15	9.0383E+14
Xe-135	4.2523E-02	1.6652E-11	7.4280E+13	2.5445E+14

Control Room Transport Group Inventory:

Time (h) = 58.0000	Atmosphere	Sump	
Noble gases (atoms)	4.3930E+18	0.0000E+00	
Elemental I (atoms)	2.7810E+04	0.0000E+00	
Organic I (atoms)	2.0980E+04	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		7.6763E-22
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		7.8463E-22
Total I (Ci)			1.5790E-12

Time (h) = 58.0000	Deposition Surfaces	Recirculating Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	9.2882E+15
Organic I (atoms)	0.0000E+00	7.0069E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

Time (h) = 58.0000	Pathway Filtered	Transported
Noble gases (atoms)	0.0000E+00	4.4567E+19
Elemental I (atoms)	0.0000E+00	1.0600E+16
Organic I (atoms)	0.0000E+00	7.9962E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

	Pathway	
Time (h) = 58.0000	Filtered	Transported
Noble gases (atoms)	4.0134E+19	0.0000E+00
Elemental I (atoms)	1.2986E+15	0.0000E+00
Organic I (atoms)	9.7961E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Exclusion Area Boundary Doses:

Time (h) = 74.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	2.5746E-01	6.6100E+01	2.2762E+00

Low Population Zone Doses:

Time (h) = 74.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	7.0216E-02	1.8027E+01	6.2077E-01

Control Room Doses:

Time (h) = 74.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	1.5787E-02	2.8992E-10	1.5787E-02
Accumulated dose (rem)	1.6487E-01	1.1374E+02	3.6384E+00

Control Room Compartment Nuclide Inventory:

Time (h) = 74.0000	Ci	kg	Atoms	Decay
Kr-85	2.0848E-03	5.3137E-09	3.7647E+16	1.0022E+15
Kr-85m	1.6796E-07	2.0409E-17	1.4459E+08	2.1129E+12
Kr-88	5.8950E-10	4.7013E-20	3.2172E+05	5.1990E+10
Xe-131m	6.1737E-04	7.3706E-12	3.3883E+13	3.1185E+14
Xe-133	8.9735E-02	4.7940E-10	2.1707E+15	4.8177E+16
Xe-133m	1.5737E-03	3.5072E-12	1.5880E+13	9.9180E+14
Xe-135	1.1451E-04	4.4842E-14	2.0003E+11	2.6918E+14

Control Room Transport Group Inventory:

Time (h) = 74.0000	Atmosphere	Sump	
Noble gases (atoms)	3.9868E+16	0.0000E+00	
Elemental I (atoms)	1.3181E-21	0.0000E+00	
Organic I (atoms)	9.9435E-22	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		3.6209E-47
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		3.6712E-47
Total I (Ci)			7.0101E-38

	Deposition	Recirculating
Time (h) = 74.0000	Surfaces	Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	9.2882E+15
Organic I (atoms)	0.0000E+00	7.0069E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

Time (h) = 74.0000	Pathway Filtered	Transported
Noble gases (atoms)	0.0000E+00	4.4567E+19
Elemental I (atoms)	0.0000E+00	1.0600E+16
Organic I (atoms)	0.0000E+00	7.9962E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

Time (h) = 74.0000	Pathway Filtered	Transported
Noble gases (atoms)	4.4482E+19	0.0000E+00
Elemental I (atoms)	1.2986E+15	0.0000E+00
Organic I (atoms)	9.7961E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Exclusion Area Boundary Doses:

Time (h) = 146.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	2.5746E-01	6.6100E+01	2.2762E+00

Low Population Zone Doses:

Time (h) = 146.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	7.0216E-02	1.8027E+01	6.2077E-01

Control Room Doses:

Time (h) = 146.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	7.9077E-05	1.5583E-35	7.9077E-05
Accumulated dose (rem)	1.6495E-01	1.1374E+02	3.6385E+00

Control Room Compartment Nuclide Inventory:

Time (h) = 146.0000	Ci	kg	Atoms	Decay
Kr-85	1.3780E-12	3.5123E-18	2.4884E+07	1.0030E+15
Xe-131m	3.4283E-13	4.0930E-21	1.8816E+04	3.1209E+14
Xe-133	4.0135E-11	2.1442E-19	9.7087E+05	4.8212E+16

Control Room Transport Group Inventory:

Time (h) = 146.0000	Atmosphere	Sump	
Noble gases (atoms)	2.5878E+07	0.0000E+00	
Elemental I (atoms)	1.4854-135	0.0000E+00	
Organic I (atoms)	1.1205-135	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		4.0515-161
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		4.0583-161
Total I (Ci)			7.1311-152

Time (h) = 146.0000	Deposition Surfaces	Recirculating Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	9.2882E+15
Organic I (atoms)	0.0000E+00	7.0069E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

	Pathway Filtered	Transported
Time (h) = 146.0000		
Noble gases (atoms)	0.0000E+00	4.4567E+19
Elemental I (atoms)	0.0000E+00	1.0600E+16
Organic I (atoms)	0.0000E+00	7.9962E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

	Pathway Filtered	Transported
Time (h) = 146.0000		
Noble gases (atoms)	4.4522E+19	0.0000E+00
Elemental I (atoms)	1.2986E+15	0.0000E+00
Organic I (atoms)	9.7961E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

Exclusion Area Boundary Doses:

Time (h) = 770.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	2.5746E-01	6.6100E+01	2.2762E+00

Low Population Zone Doses:

Time (h) = 770.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	0.0000E+00	0.0000E+00	0.0000E+00
Accumulated dose (rem)	7.0216E-02	1.8027E+01	6.2077E-01

Control Room Doses:

Time (h) = 770.0000	Whole Body	Thyroid	TEDE
Delta dose (rem)	2.3271E-14	1.1624-149	2.3271E-14
Accumulated dose (rem)	1.6495E-01	1.1374E+02	3.6385E+00

Control Room Compartment Nuclide Inventory:

Time (h) = 770.0000	Ci	kg	Atoms	Decay

Control Room Transport Group Inventory:

Time (h) = 770.0000	Atmosphere	Sump	
Noble gases (atoms)	6.8902E-73	0.0000E+00	
Elemental I (atoms)	0.0000E+00	0.0000E+00	
Organic I (atoms)	0.0000E+00	0.0000E+00	
Aerosols (kg)	0.0000E+00	0.0000E+00	
Dose Effective (Ci/cc)	I-131 (Thyroid)		0.0000E+00
Dose Effective (Ci/cc)	I-131 (ICRP2 Thyroid)		0.0000E+00
Total I (Ci)			0.0000E+00

Time (h) = 770.0000	Deposition Surfaces	Recirculating Filter
Noble gases (atoms)	0.0000E+00	0.0000E+00
Elemental I (atoms)	0.0000E+00	9.2882E+15
Organic I (atoms)	0.0000E+00	7.0069E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Environment to Control Room Transport Group Inventory:

Time (h) = 770.0000	Pathway Filtered	Transported
Noble gases (atoms)	0.0000E+00	4.4567E+19
Elemental I (atoms)	0.0000E+00	1.0600E+16
Organic I (atoms)	0.0000E+00	7.9962E+15
Aerosols (kg)	0.0000E+00	0.0000E+00

Control Room to Environment Transport Group Inventory:

Time (h) = 770.0000	Pathway Filtered	Transported
Noble gases (atoms)	4.4522E+19	0.0000E+00
Elemental I (atoms)	1.2986E+15	0.0000E+00
Organic I (atoms)	9.7961E+14	0.0000E+00
Aerosols (kg)	0.0000E+00	0.0000E+00

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##
I-131 Summary
##

Time (hr)	Fuel Pool I-131 (Curies)	Environment I-131 (Curies)	Control Room I-131 (Curies)
50.000	4.0083E+01	2.6060E-02	1.6499E-04
50.004	2.5881E+02	1.0916E+00	6.8978E-03
50.083	2.1487E+02	4.4963E+01	2.6263E-01
50.400	1.0222E+02	1.5742E+02	1.4177E-01
50.700	5.0604E+01	2.0894E+02	7.5461E-02
51.000	2.5052E+01	2.3445E+02	3.9126E-02
51.300	1.2402E+01	2.4708E+02	1.9962E-02
51.600	6.1398E+00	2.5333E+02	1.0081E-02
51.900	3.0396E+00	2.5643E+02	5.0574E-03
52.000	2.4045E+00	2.5706E+02	4.0142E-03
52.300	2.4019E+00	2.5706E+02	1.3454E-03
52.600	2.3994E+00	2.5706E+02	4.5093E-04
52.900	2.3968E+00	2.5706E+02	1.5114E-04
53.200	2.3942E+00	2.5706E+02	5.0655E-05
53.500	2.3916E+00	2.5706E+02	1.6977E-05
53.800	2.3890E+00	2.5706E+02	5.6902E-06
54.100	2.3865E+00	2.5706E+02	1.9071E-06
54.400	2.3839E+00	2.5706E+02	6.3920E-07
54.700	2.3813E+00	2.5706E+02	2.1423E-07
55.000	2.3788E+00	2.5706E+02	7.1803E-08
55.300	2.3762E+00	2.5706E+02	2.4066E-08
55.600	2.3736E+00	2.5706E+02	8.0659E-09
55.900	2.3711E+00	2.5706E+02	2.7034E-09
56.200	2.3685E+00	2.5706E+02	9.0606E-10
56.500	2.3660E+00	2.5706E+02	3.0368E-10
56.800	2.3634E+00	2.5706E+02	1.0178E-10
57.100	2.3609E+00	2.5706E+02	3.4113E-11
57.400	2.3583E+00	2.5706E+02	1.1433E-11
57.700	2.3558E+00	2.5706E+02	3.8320E-12
58.000	2.3533E+00	2.5706E+02	1.2843E-12

58.300	2.3507E+00	2.5706E+02	4.3046E-13
58.600	2.3482E+00	2.5706E+02	1.4427E-13
58.900	2.3457E+00	2.5706E+02	4.8355E-14
59.200	2.3431E+00	2.5706E+02	1.6207E-14
59.500	2.3406E+00	2.5706E+02	5.4319E-15
59.800	2.3381E+00	2.5706E+02	1.8206E-15
60.100	2.3356E+00	2.5706E+02	6.1018E-16
60.400	2.3331E+00	2.5706E+02	2.0451E-16
74.000	2.2218E+00	2.5706E+02	6.1431E-38
146.000	1.7155E+00	2.5706E+02	7.0152-152
770.000	1.8235E-01	2.5706E+02	0.0000E+00

###
Cumulative Dose Summary
###

	Exclusion Area Bounda		Low Population Zone		Control Room	
Time (hr)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)
50.000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
50.004	2.8075E-01	9.6697E-03	7.6568E-02	2.6372E-03	7.9530E-03	2.4399E-04
50.083	1.1567E+01	3.9838E-01	3.1545E+00	1.0865E-01	8.8021E+00	2.7004E-01
50.400	4.0491E+01	1.3945E+00	1.1043E+01	3.8032E-01	6.0268E+01	1.8526E+00
50.700	5.3738E+01	1.8506E+00	1.4656E+01	5.0472E-01	8.6334E+01	2.6601E+00
51.000	6.0294E+01	2.0763E+00	1.6444E+01	5.6627E-01	1.0003E+02	3.0898E+00
51.300	6.3538E+01	2.1880E+00	1.7328E+01	5.9672E-01	1.0708E+02	3.3158E+00
51.600	6.5143E+01	2.2432E+00	1.7766E+01	6.1179E-01	1.1065E+02	3.4352E+00
51.900	6.5937E+01	2.2706E+00	1.7983E+01	6.1925E-01	1.1245E+02	3.4996E+00
52.000	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1283E+02	3.5139E+00
52.300	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1343E+02	3.5408E+00
52.600	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1364E+02	3.5547E+00
52.900	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1370E+02	3.5637E+00
53.200	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1373E+02	3.5708E+00
53.500	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1373E+02	3.5768E+00
53.800	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.5822E+00
54.100	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.5871E+00
54.400	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.5916E+00
54.700	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.5956E+00
55.000	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.5993E+00
55.300	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6027E+00
55.600	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6058E+00
55.900	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6086E+00
56.200	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6112E+00
56.500	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6136E+00
56.800	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6157E+00
57.100	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6177E+00
57.400	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6195E+00
57.700	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6211E+00
58.000	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6226E+00
58.300	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6240E+00
58.600	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6253E+00
58.900	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6264E+00
59.200	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6274E+00
59.500	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6284E+00
59.800	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6293E+00
60.100	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6301E+00
60.400	6.6100E+01	2.2762E+00	1.8027E+01	6.2077E-01	1.1374E+02	3.6308E+00

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 74.000 6.6100E+01 2.2762E+00 1.8027E+01 6.2077E-01 1.1374E+02 3.6384E+00
146.000 6.6100E+01 2.2762E+00 1.8027E+01 6.2077E-01 1.1374E+02 3.6385E+00
770.000 6.6100E+01 2.2762E+00 1.8027E+01 6.2077E-01 1.1374E+02 3.6385E+00

####################################################################
                        Worst Two-Hour Doses
####################################################################

Exclusion Area Boundary
   Time   Whole Body     Thyroid         TEDE
   (hr)     (rem)         (rem)          (rem)
   50.0   2.5746E-01   6.6100E+01   2.2762E+00
```