Attachment 2 **LR-N10-0306**

Calculation H-1-ZZ-MDC-1880, Revision 4, "Post-LOCA EAB, LPZ, and CR Doses"

Design Analysis Major Revision Cover Sheet

Design Analysis (Major Revision)		Last Page No. [6] 117	
Analysis No.: [1]	H-1-ZZ-MDC-1880	Revision: [2]	4
Title: [3]	Post-LOCA EAB, LPZ, and CR Doses		
DCP No(s)./ Revision: [4]	DCP 80102144 Revision 0	AD No(s)./ Revision: [5]	M01 Revision 0

		Component(s): [14]	
Station(s): [7]	Hope Creek		
Unit No.: [8]	1	N/A	
Discipline: [9]	Mechanical Design		
Safety/QA Class: [11]	SR		
System Code: [12]	N/A		
Structure: [13]	N/A		

CONTROLLED DESIGN INPUTS AND OUTPUTS [15]

Document No.:	From/To	Document No.:	From/To
H-1-ZZ-MDC-1879, Rev 1	From	H-1-ZZ-MDC-1923	To
GE-NE-T2300759-00-02	From	H-1-ZZ-MDC-1927	To
H-1-ZZ-MDC-0364, Rev 1	From	VHC-MD-ST.GK-0002	To
For remaining References see Section 10	From		

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, Order#:

This Design Analysis SUPERCEDES: [18] H-1-ZZ-MDC-1880, Rev 3 in its entirety.

Description of Revision (list affected pages for partials): [19]

Revision 4 deletes the evaluation of the radiological impact of keeping the PCIVs open for 120 seconds following a design basis LOCA, revises the MSIV model to include elements of the Revision 2 model that was reviewed by the NRC staff as part of the EPU License Amendment 174 (ADAMS.ML081230640), and reduces the control room envelope unfiltered in-leakage rate to 300 cfm.

	Print Name	Sign Name	Date
Preparer: [20]	Gopal J. Patel (NUCORE)	[signature]	08/10/2010

Method of Review: [21] Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐

	Print Name	Sign Name	Date
Reviewer: [22]	Mark Drucker (NUCORE)	[signature]	08/10/2010

Review Notes: [23] Independent review ☒ Peer review ☐

Print Name	Sign Name	Date
Mark Drucker (NUCORE)	[signature]	08/10/2010

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [24]	N/A		
PSEG Reviewer: [25]	John Duffy / Vijay Chandra	J.S. Boyer (For V. Chandra) / J. Duffy	8/10/2010

Independent 3rd Party Review Reqd? [26] Yes ☐ No ☒

	Print Name	Sign Name	Date
PSEG Approver: [27]	James Boyer	[signature]	8/10/2010

ATTACHMENT 2
Owners Acceptance Review Checklist for External Design Analysis

DESIGN ANALYSIS NO. H-1-ZZ-MDC-1880 ________ **REV:** 4

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☒	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
3.	Do the design inputs have sufficient rationale?	☒	☐	☐
4.	Are design inputs correct and reasonable?	☒	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☒	☐	☐
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☒	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☒	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☐	☐	☒
12.	Are there any unverified assumptions?	☐	☒	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☒
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☒	☐	☐
15.	Do the sources of inputs **and** analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	☒	☐	☐
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	☒	☐	☐
17.	Has the Vendor supplied the native electronic file(s)?	☒	☐	☐

PSEG REVIEWER: John. Duffy*/ J. Duffy **DATE:** 8/10/2010
Print / Sign

M. Drucker of NUCORE performed a detailed review. Additionally, A. Klazura of S&L provided an external subject matter review.

REVISION HISTORY

Revision	Revision Description
0	Original issue.
1	Removed the credit of FRVS recirculation charcoal filter efficiencies, reduced the FRVS vent charcoal filter efficiencies, control room unfiltered inleakage, and ESF leakage from 10 gpm to 1 gpm, and increased the core thermal power level by 11.9% to be consistent with a proposed power uprate.
2	Revised to assess radiological impact of increased core thermal power level of 3,917 MW_t. As of 12/07/2005, the EPU project decided to adopt the AST analysis performed for the increased core thermal power level for the current design and licensing bases because it conservatively bounds the EPU project design. Section 8.2 indicates that the proposed increases in the EAB, LPZ, and CR doses and the total doses are less than the corresponding minimal dose increases and applicable regulatory allowable limits as defined in the 10 CFR 50.59 rule. The implementation or cancellation of the proposed core thermal power related DCP would not have any adverse impact on this analysis. Some of the design inputs are taken from documents that support higher core thermal power operation. If the HCGS license is not amended for the proposed increased power level, these design inputs would become conservative assumptions without having any adverse impact on the validity of this analysis.
3	Analysis is revised to evaluate the radiological impact of increases in the primary containment isolation valves (PCIVs) closure time to 120 seconds and ESF leak rate to 2.85 gpm. The MSIV leakage aerosol deposition model is revised in a conservative manner consistent with the regulatory guidance to create the dose margin for these changes. The revised aerosol deposition model is consistent with the NRC approved models documented in recent BWR AST license amendments. This is a General Revision (no revision change bars) to reformat for compliance with EXELON calculation procedure, resulting in some Revision 2 text rolling from one page to the next page.
4	Analysis is revised to delete the evaluation of the increased PCIV closure time and to include other modeling changes listed in Table 1E.

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1.0 PURPOSE:

The purpose of this calculation is to evaluate the post-LOCA Exclusion Area Boundary (EAB), Low Population Zone (LPZ), and Control Room (CR) doses for Hope Creek Generating Station (HCGS) using conservative as-built design inputs and assumptions with an assumed core thermal power level of 3,917 MWt. The doses are calculated using the Alternate Source Term (AST), Regulatory Guide (RG) 1.183 requirements, NRC sponsored RADTRAD3.02 computer code, and Total Effective Dose Equivalent (TEDE) dose methodology.

The following design basis post-LOCA release paths are analyzed:

1. Containment Leakage.
2. Engineered Safety Feature (ESF) Leakage.
3. Main Steam Isolation Valve (MSIV) Bypass Leakage.

This calculation is revised in response to Notification 20470663 which requires that the evaluation of the increased Primary Containment Isolation Valve (PCIV) closure time of 120 seconds be removed from the analysis. The calculation is also being revised to

- eliminate the 50% reduction in containment leakage and MSIV leakage after 24 hours,
- to change the number of main steam pipe segment volumes in the MSIV leakage analysis RADTRAD model from two volumes in each of the intact and failed main steam line pathways to one volume in each of the intact and failed main steam line pathways,
- to change the percentile aerosol deposition settling velocities from 50^{th} %/30^{th} % that was used in the two volume RADTRAD model to 40^{th} %,
- to change the approach for calculating elemental iodine removal in the main steam lines, and
- to reduce the control room envelope unfiltered inleakage rate to 300 cfm.

The resulting revision incorporates elements of the MSIV leakage model that were used in Revision 2.

A sensitivity study was performed to address the addition of 12 Co-60 ITAs to the HCGS core – See Attachment 14.2.

2.0 METHODOLOGY

The design basis LOCA is analyzed using a conservative set of assumptions and as-built design inputs to demonstrate the performance of one or more aspects of the facility design to protect the control room operator and the health and safety of the general public. The guidance in Regulatory Guide 1.183 (Ref. 10.1) is followed along with the plant-specific design input parameters to demonstrate compliance with the AST and TEDE dose criteria. The numeric values of the post-accident performance of ESF components are conservatively selected to assure an appropriate and prudent safety margin against unpredicted events in the course of an accident and compensate for large uncertainties in facility parameters, accident progression, radioactive material transport, and atmospheric dispersion.

Changes in input parameters and methodologies between Revisions 2, 3, and 4 of this calculation are identified in Table 1E.

2.1 Radiation Source Terms:

The reactor core radionuclide inventory is based on a maximum power level of 3917 MWt, which includes 2% instrument uncertainty (Assumption 4.2). Radiation source term radionuclides used in this evaluation are those used in Alternative Source Term analyses and are identified in Tables 1A through 1D. Radionuclide inventories (Ci/MWt) presented in Tables 1A and 1B are bounding inventories for a discharged bundle and the radionuclide inventories provided in Tables 1C and 1D are average inventories over the reactor core. Since this is a LOCA evaluation which involves the release of radionuclides from the entire core, the average radionuclide inventories from Tables 1C and 1D are used in this evaluation. As recommended in RADTRAD Table 1.4.3.3-2, the inventories listed for some of the parent isotopes include their significant daughter products. The composite average core inventory is shown in Table 1D. The RADTRAD Nuclide Inventory File (NIF) HEPULOCA1_def.txt is developed based on the uprated core inventory in Table 1D and used for the containment, ESF, and MSIV leakage paths. The source term design inputs are shown in Sections 5.3.1.1 through 5.3.1.8.

HCGS intends to include 12 Isotope Test Assemblies (ITAs) in the reactor core. The ITAs will contain Co-59 targets which will be irradiated in the reactor core in order to produce Co-60. GE-Hitachi Report NEDC-33529P and RAI#17 of PSEG Letter LR-N10-0163 provide an analysis of the impact of the introduction of the 12 ITAs on LOCA dose evaluations. The impact on doses was determined to be negligible for the control room, EAB, and LPZ doses. The same analysis was re-performed using the design inputs and assumptions in Sections 4.0 & 5.0 of this Revision 4 of the calculation (see Attachment 14.2). The same result of negligible impact was obtained.

2.1.1 <u>Activity Transport In Primary Containment (Table 1E, Item I-1):</u>

The average core inventory (Ci/MWt) listed in Tables 1C and 1D is released into the containment at the release timing and fractions shown in RG 1.183 Tables 3 and 4 (Ref. 10.1, RGPs 3.2 and 3.3). The RADTRAD default Release Fraction and Timing (RFT) file BWR_DBA starts the gap release phase at time t= 0 sec after onset of a LOCA without 2 minutes delay (Ref. 10.1, Table 4). The same BWR_DBA RFT file was used in the previous revisions of this analysis. Since the post-LOCA minimum suppression chamber water pH is greater than 7.0 (Ref. 10.43), the chemical form of radioiodine released into the containment is assumed to be 95% cesium iodide (CsI), 4.85 percent elemental iodine, and 0.15 percent organic iodide as shown in RG 1.183 RGP 3.5 (Assumption 4.5). With the exception of elemental and organic iodine and noble gases, the remaining fission products are assumed to be in particulate form (Ref 10.1, RGP 3.5). In accordance with Assumption 3.1 of Appendix A to R.G. 1.183, the radioactivity released from the fuel is assumed to mix instantaneously and homogeneously throughout the free air volume of the primary containment (drywell) as discussed below. The radioactivity release into the containment is assumed to terminate at the end of the early in-vessel phase, which occurs at the end of 2 hrs after the onset of a LOCA (Ref. 10.1, Table 4). The design inputs for the transport in the primary containment are shown in Sections 5.3.2.1 through 5.3.2.10.

Radioactivity is released from the core and diluted into the drywell air volume. Following the initial blowdown of the reactor pressure vessel, the steaming in the RPV carries fission products to the containment. When core cooling is restored, the fuel damage is terminated. The steam and the ESF flows carry any remaining fission products from the vessel, through the break, to the primary containment and provide new steam flow for rapid drywell- suppression air space mixing. After 2 hours the containment drywell and suppression chamber air volumes are expected to become well mixed due to a very high flow established between drywell and wetwell as a result of steaming and condensing phenomenon (Ref. 10.22, Table 2) and thus after 2 hours, airborne activity dilution is credited in the combined air volumes of the drywell and suppression chamber (Table 1E, Item I-1). Taking credit for dilution of containment airborne activity within the drywell and suppression chamber combined air volumes over the remaining course of the accident (after 2 hours) is in accordance with guidance provided in Section 3.1 of Appendix A to R.G. 1.183. In Revision 2 of this calculation, radionuclide activity released into containment was assumed to mix instantaneously within the drywell and suppression chamber air volumes. Confining the airborne activity to the drywell air volume during the first 2 hours is conservative because it increases the amount of airborne activity released from containment during the first 2 hours and increased activity releases result in larger doses.

2.1.2 Reduction In Airborne Activity Inside Containment

Aerosol Deposition
The gravitational deposition of aerosols from the containment atmosphere is credited by using the RADTRAD "POWERS MODEL" with 10 percentile uncertainty distribution resulting in the lowest removal rate of the aerosols from the containment. Crediting the reduction in aerosol airborne activity from the containment atmosphere by using the RADTRAD "Powers Model" with 10 percentile uncertainty is in accordance with the methodology described in Section 3.2 of Appendix A to R.G. 1.183 and in AEB-98-03.

Suppression Pool Scrubbing
Iodine removal by suppression pool scrubbing is not credited because the timed release of activity associated with the Alternative Source Term methodology results in the bulk of core activity being released to containment well after the initial mass and energy release.

Natural Deposition on Containment Surfaces (Table 1E, Item I-2)
In accordance with Section 3.2 of Appendix A to R. G. 1.183, reduction in containment airborne radioactivity by natural deposition within containment may be credited using the models described in SRP 6.5.2, even if no credit is taken for containment sprays (Table 1E, Item I-2). The Decontamination Factor (DF) of elemental iodine is based on the Standard Review Plan (SRP) 6.5.2 guidance and is limited to a DF of 200 (see Section 7.11) (Ref. 10.41, page 6.5.2-12). The SRP 6.5.2 calculation of the elemental iodine removal rate is based on a minimized wetted surface area that conservatively results in a smaller elemental removal coefficient and a longer time to reach an elemental iodine decontamination factor (DF) of 200 (see Section 7.10). This longer time to reach the DF allows the elemental iodine to remain airborne in the drywell atmosphere for a longer time prior to release to the environment via containment and MSIV leakage. This results in a larger release and a higher dose. The drywell wetted surface area is conservatively minimized by crediting 25% of the drywell lining surface, and 50% of the major equipment and structure surfaces, and then by applying a 25% reduction to the estimated surface area. The resultant modeled surface area of 33,200 ft^2 is less than half of the available 69,126 ft^2 drywell wetted surface area. The removal of elemental iodine by the wetted surface area is consistent with the guideline provided in Standard Review Plan (SRP) 6.5.2 (Ref. 10.41) and RG 1.183 (Ref. 10.1). The suppression pool water pH is greater than 7 (Design Input 5.4.4). A pH greater than 7 inhibits the iodine that deposits on containment surfaces from re-evolving back into containment atmosphere during containment spray recirculation.

The RADTRAD code calculates the elemental and organic iodine atoms in the drywell atmosphere. The following procedure is established to calculate the cutoff time of the elemental iodine removal by wall deposition inside the drywell:

1. The isotopic elemental iodine atoms are calculated using the atoms/curie relationship established in Table 8.
2. The initial isotopic elemental iodine activity in the drywell is determined based on the RG 1.183 (Section 3.2, Table 1, and Section 3.5), which is 4.85% of the total 30% iodine released in the drywell (Ref. 10.1, Table 1) (see Table 9).

3. The initial isotopic elemental iodine atoms in the drywell are totaled and then divided by the Decontamination Factor of 200 to determine the elemental iodine atoms expected to be in the drywell when the DF of 200 is reached, which is 3.752E+20 atoms (Table 9).
4. The containment leakage case is analyzed in RADTRAD Run CUTOFF.o0 using an elemental iodine removal rate of 3.16 hr^{-1} for the first 2.0 hours of the accident, and then an elemental iodine removal rate of 1.74 hr^{-1} for the remainder of the accident as calculated in Section 7.11. This RADTRAD run provides the elemental iodine atoms in the containment at different time intervals. RADTRAD output CUTOFF.o0 indicates the drywell elemental iodine atoms reach a value of 3.8056E+20 at 4.02 hrs and 3.7400E+20 at 4.03 hrs.

This means that an elemental iodine DF of 200 is reached in the drywell at 4.03 hrs. Therefore, elemental iodine wall removal is not credited in the analysis beyond 4.0 hrs.

2.2 POST-LOCA CONTAINMENT LEAKAGE PATHWAY (TABLE 1E, ITEMS III-1 AND VI-1)

The post LOCA containment leakage model is shown in Figure 1. The time dependent radionuclide source term airborne in containment and available for leakage is that described in Section 2.1 of this evaluation with credit taken for dilution (Section 2.1.1) and reduction of airborne activity (Section 2.1.2). The containment is assumed to leak at the technical specification leak rate of 0.5 volume percent per day over the course of the accident, i.e., 720 hours (Design Input 5.3.2.5). No credit is taken for a reduction in containment leak rate (e.g., at 24 hours post LOCA or subsequently during the LOCA duration) due to a reduction in containment pressure with time (Table 1E, Item III-1). Keeping the containment leakage rate at the technical specification limit for the duration of the accident is conservative since it maximizes the amount of radioactivity released which maximizes doses.

Primary containment leakage is into the reactor building, however, for the first 375 seconds primary containment leakage is released directly to the environment with no credit for holdup or filtration. The time of 375 seconds is the draw down time (Design Input 5.3.2.6), i.e., the time it takes to bring the reactor pressure down to 0.25-inch water gauge negative pressure relative to adjacent areas as defined in technical specifications (Ref. 10.1 RGP A.4.2). After 375 seconds, primary containment leakage is via the reactor building through the FRVS filter system. The FRVS recirculation system circulates reactor building air at a recirculation flow rate of 108000 cfm (Design Input 5.3.2.16). The volume of the reactor building is 4.00E+06 cubic feet (Design Input 5.3.2.9) and thus the FRVS recirculation system recirculates reactor building air at a rate of 1.62 reactor building volumes/hr (i.e., 108000 cfm x 60 min/hr x $(4.00E+06\ cu\ ft)^{-1}$). Although the FRVS provides good mixing of airborne activity within the reactor building, for conservatism, credit is taken for mixing and dilution of activity in only 50% of the reactor building volume (Ref. 10.1, RGP A.4.4). To account for 50% mixing in the reactor building, the FRVS vent system exhaust rate to the environment is doubled (Design Input 5.3.2.15). The FRVS ventilation system exhaust rate varies with time as shown by the equation in Design Input 5.3.2.12. Design Input 5.3.2.15 provides the FRVS exhaust flow rates at 100% and 50% mixing. Airborne activity in the reactor building is reduced by both the FRVS recirculation and FRVS vent filtration systems before it is released to the environment. FRVS exhaust filter and FRVS recirculation filter efficiencies are presented in Design Inputs 5.3.2.13 and 5.3.2.14, respectively.

Containment Purge During Normal Operation

The Bases for HCGS Technical Specification Section 3.6.1.8 (Ref. 10.6.18) states that the use of the drywell and suppression chamber purge exhaust lines for pressure control during plant operational conditions 1, 2, and 3 is unrestricted provided 1) only the inboard purge exhaust isolation valves on these lines and the vent valves on the 2-inch vent paths are used and 2) the outboard purge exhaust isolation valves remain closed. It is also required that the design of the purge supply and exhaust isolation valves and the 6" nitrogen supply valves meet the requirements of Branch Technical Position

CSB 6-4, "Containment Purging During Normal Plant Operations". Item B.1.F of Branch Technical Position 6-4 of NUREG-0800 (Ref. 10.56) states that the purge system isolation valve closure times, including instrumentation delays, should not exceed 5 seconds to facilitate compliance with 10 CFR 100 for offsite radiological consequences. The drywell and suppression chamber purge supply and exhaust valves and the 6" nitrogen supply valves are shown on HCGS Containment Atmosphere Control P&ID M-57-1 (Ref. 10.53). The relevant valves are drywell purge exhaust isolation valves HV-4950 and HV-4952, drywell purge supply isolation valves HV-4956 and HV-4979, suppression chamber purge supply isolation valves HV-4980 and HV-4958, suppression chamber purge exhaust isolation valves HV-4962 and HV-4964, and nitrogen purge isolation valve HV-4978. Table 3.6.3-1 of the HCGS Technical Requirements Manual (Ref. 10.54) indicates that the maximum isolation time for each of these valves is 5 seconds. HCGS Technical Specification Section 3.6.1.8 (Ref. 10.6.18) states that the drywell and suppression chamber purge system, including the 6 inch nitrogen supply line, may be in operation for up to 500 hours each 365 days with the supply and exhaust isolation valves in one supply line and one exhaust line open. The Bases to Technical Specification 3.6.1.8 states that the 500 hour/365 day limit for operation of the purge valves and the 6" nitrogen supply valve during plant operational conditions 1, 2, and 3 is intended to reduce the probability of a LOCA occurrence when the applicable combination of the above valves are open. A dose analysis was performed that concludes that the dose associated with a containment purge while operating, concurrent with LOCA is negligible (UFSAR 1.14.1.7) compared to the dose due to the release of design basis LOCA sources. The negligible purge dose is based on limiting the purge isolation valve closure time to 5 seconds and so the radiation source term released via the purge system is reactor coolant. In light of the previous discussion, calculation of radiological consequences is not required due to a normal containment purge coincident with a LOCA (Table 1E, Item VI-1).

Containment Purge During LOCA

Section 7 of Appendix A to R.G. 1.183 states that if post LOCA primary containment purging is performed as a combustible gas or pressure control measure or if primary containment purging is required within 30 days following a LOCA, then radiological consequences should be analyzed. It further states that if the containment purging capabilities are maintained for purposes of severe accident management and are not credited in any design basis analysis, then radiological consequences need not be evaluated. The HCGS containment is not purged for combustible gas or pressure control measure within 30 days following a LOCA (Assumption 4.6.3). Therefore, in accordance with guidance provided in Section 7 of Appendix A to R.G. 1.183, radiological consequences associated with a purge release during LOCA conditions need not be evaluated (Table 1E, Item VI-1).

2.3 Post-LOCA ESF Leakage Pathway (Table 1E, Item IV-1):

The post-LOCA ESF leakage release model is shown in Figure 2. The ESF systems that recirculate suppression pool water outside of the primary containment are assumed to leak during their intended operation. This release source includes leakage through valve packing glands, pump shaft seals, flanged connections, and other similar components. The radiological consequences from the postulated leakage is analyzed and combined with the consequences from other fission product release paths to determine the total calculated radiological consequences from the LOCA (see Section 8.0 of this calc). The ESF components are located in the Reactor Building.

The ESF leakage rate is 2.85 gpm (Design Input 5.4.2). The ESF leakage rate was increased from 1 gpm (in Revision 2 of this calculation) to 2.85 gpm in Revision 3 of this calculation to facilitate operational flexibility by providing additional operating margin for ESF leakage (Table 1E, Item IV-1). This ESF leak rate is doubled (Ref 10.1, Section A.5.2) and assumed to start at time t=0.0 minute after onset of a LOCA. Ten percent of the iodine in the suppression pool water that leaks becomes airborne

(Design Input 5.4.6). All remaining fission products in the recirculating liquid are assumed to be retained in the liquid phase. The design inputs for the ESF leakage are shown in Section 5.4.

ESF leakage is into the reactor building. As indicated in Section 2.2 of this calculation, for containment leakage, airborne radioactivity released due to ESF leakage is released directly to the environment for the first 375 seconds, i.e., during draw down. After 375 seconds, credit is taken for mixing in the reactor building volume and for airborne activity removal by the FRVS recirculation and exhaust filter systems.

The EAB, LPZ, and CR TEDE doses that result from ESF leakage are shown in the Section 8.0 of this calculation.

2.3.1 Suppression Pool Water Source Term:

With the exception of noble gases, all the fission products released from the fuel to the containment (as defined in Sections 5.3.1.3 and 5.3.1.5) are assumed to instantaneously and homogeneously mix in the suppression pool water at the time of release from the core. The radioiodine that is postulated to be available for release to the environment is assumed to be 97% elemental and 3% organic (Ref. 10.1, RGP A.5.6).

2.4 Post-LOCA MSIV Leakage Pathway (Table 1E, Items V-1, V-2):

The post-LOCA MSIV Leakage model is shown in Figures 3 and 4. The four main steam lines, which penetrate the primary containment, are automatically isolated by the MSIVs in the event of a LOCA. There are two MSIVs on each steam line, one inside containment and one outside containment. The MSIVs are functionally part of the primary containment boundary and design leakage through these valves provides a leakage path for fission products that bypass the secondary containment and enter the environment as a ground-level release. MSIV leakage is postulated to be release to the environment through the MSIV failed steam line and one of the three remaining intact steam lines.

The main steam isolation valves (MSIVs) are postulated to leak at a total design leak rate of 250 scfh at 50.6 psig . This is the maximum allowable technical specification value (250 scfh combined through all 4 main steam lines per Design Input 5.5.1). Measured leakage through any one steam line cannot exceed 150 scfh. In order to maximize dose results, the leak rate of 150 scfh is applied to the main steam line with the failed MSIV (Design Input 5.5.2) and the leak rate of 100 scfh is applied to the intact main steam line (Table 1E, Item V-2). Use of the maximum technical specification leak rate is in accordance with Assumption 6.2 of Appendix A to R.G. 1.183.

The time dependent radionuclide source term airborne in containment and available for leakage via the main steam lines is that described in Section 2.1 of this evaluation with credit taken for dilution (Section 2.1.1) and reduction of airborne activity (Section 2.1.2). As indicated in Section 2.2, no credit is taken for a reduction in containment leak rate due to a reduction in containment pressure. This is also true for the MSIV leak rate, i.e., no credit is taken for a reduction in the MSIV leak rate due to a reduction in containment pressure at 24 hours post LOCA or subsequently during the LOCA duration (Table 1E, Item V-1).

MSIV leakage is modeled in this revision using a single main steam pipe volume on the failed main steam line and a single main steam pipe volume on the intact main steam line. Revision 2 of this evaluation also used a single main steam pipe volume for the failed main steam line and for each intact main steam line, whereas Revision 3 used two main steam pipe volumes on both the failed main steam line and on one intact main steam line (Table 1E, Item V-5). Use of a single main steam line pipe volume in lieu of two pipe volumes is conservative in that dose consequences of the release are larger for a single main steam pipe volume than they are when multiple pipe volumes are used. Dose consequences are smaller when multiple main steam pipe volumes are considered in series because there is a compounding of the radioactivity removal efficiencies for the mechanisms that remove airborne radioactivity from the pipe volume, such as aerosol deposition.

2.4.1 MSIV Leak Rates (Table 1E, Items V-2 and V-8)

A total of 250 scfh MSIV leakage is assumed to occur as follows:

(1) 150 scfh through the shortest steam line. This line is modeled as having the failed inboard MSIV. The deposition of aerosol and removal of elemental iodine activities are not credited in the steam line between the RPV nozzle and the inboard MSIV because this section of pipe is assumed to be broken and exposed directly to the drywell atmosphere. The deposition of aerosols and removal of elemental iodine are conservatively credited only in the horizontal pipe between the inboard MSIV and turbine stop valve (TSV) for 0-96 hrs only. A removal time between 0 and 96 hours was also used in Revision 3 of this calculation whereas a removal time of 0 to 30 days was used in Revision 2 of this calculation. The shorter removal time means less of the aerosols and elemental iodine will be removed which results in greater dose consequences which is conservative.

(2) 100 scfh through shortest of the three intact steam lines. The deposition of aerosol and removal of elemental iodine activities are conservatively credited only in the horizontal pipe segments between the RPV nozzle and TSV for 0-96 hrs only. Revision 2 modeled 50 scfh in each of two intact steam lines.

(3) 0 scfh through second shortest intact steam line.

(4) 0 scfh through third shortest intact steam line.

Since the shortest steam line is allotted the maximum allowed leakage, it is assured that leakage through any other line is bounded. Use of the shortest main steam line as the failed steam line and use of the shortest of the three intact steam lines as the intact steam line minimizes pipe surface areas for aerosol deposition and elemental iodine removal which minimizes the amount of aerosols and elemental iodine removed which is conservative.

No credit is taken for a reduction in the MSIV leakage due to a reduction in containment pressure with time. Keeping the MSIV leakage rate at the technical specification limit for the duration of the accident is conservative since it maximizes the amount of radioactivity released which maximizes doses.

2.4.2 Main Steam Line Flow Model (Table 1E, Item V-4)

A well mixed flow model is used to model the transport of radioactivity within the main steam pipe volumes. Revision 3 to this calculation also used a well mixed flow model, however, a plug flow model that took credit for holdup of radioactivity within the main steam pipe volume, was used in revision 2 (Table 1E, Item V-4). Credit for holdup in the main steam pipe volume is not applicable when the well mixed flow model is used.

The basis for using a well mixed flow model instead of the plug flow model is provided in R.G. 1.183 (Ref. 10.1) and AEB-98-03 (Ref. 10.22). Assumption 6.3 of Appendix A to R.G. 1.183 discusses reduction in radioactivity in steam system piping by deposition and plateout. It states that the model used to address reduction in the amount of released radioactivity by deposition and plateout should generally be based on the assumption of well mixed volumes, but other models such as slug flow may be used if justified. A discussion in AEB-98-03 states that for the same leak rate into the main steam line, plug flow is expected to result in less offsite release than the well-mixed flow, because the concentration of the material released to the environment is at the concentration of the material in the plug at the end of the pipe. The text in AEB-98-03 goes on to state that the NRC staff believes that, at this time, a well mixed model is more appropriate than the plug flow model for settling along the main steam lines.

Since the well mixed flow model results in greater radioactivity releases from the main steam pipe volumes for the same leak rate, use of the well mixed flow model will result in larger doses and is therefore conservative.

2.4.3 Determination of MSIV Volumetric Leak Rates (Table 1, Item V-3)

The total MSIV leakage from all main steam lines is assumed to be 250 scfh measured at 50.6 psig, with a maximum of 150 scfh from any one of the 4 main steam lines. The total MSIV leak rate of 250 scfh is converted using the ideal gas law to determine the actual leakage rate (cfh) based on the post-LOCA peak temperature and pressure in Section 7.2 (Table 1E, Item V-3). The actual MSIV leak rate from the drywell atmosphere into the main steam pipe volumes is smaller than the measured leak rates due to the combined effects of accident condition compression (due to the high pressure) and expansion (due to the high temperature). Use of the actual MSIV leak rate based on drywell LOCA conditions is supported by RIS-2001-19 (Ref. 10.57). Section 3.f of Reference 10.57 states that with regard to volumetric flow rates specified as Limiting Conditions of Operation (LCOs), the density used should be consistent with the density that is assumed in the surveillance procedure that demonstrates compliance with the LCO. Since the peak drywell pressure is incorporated into the MSIV leakage surveillance requirement (Technical Specification LCO 3.6.1.2.c, Ref. 10.6.17), adjusting for actual drywell conditions is appropriate.

MSIV leak rates from the main steam line pipe volumes to the environment through the TSVs are conservatively calculated in Section 7.2 and listed in Table 7, using the Ideal Gas Law and drywell post-LOCA peak pressure and temperature conditions in the pipe volume and standard atmospheric conditions for the environment. To account for the assumed mixing between the wetwell and drywell after 2 hours and the resulting activity dilution, the flow rate through the MSIVs is reduced by the ratio of the drywell volume to the total volume at two hours (Section 7.2).

MSIV leakage flow rates from the drywell that are calculated in Revision 3 of this evaluation are also calculated using post LOCA drywell temperature and pressure. Revision 2 of this calculation directly used the measured MSIV leakage values that represent standard atmospheric pressure and temperature conditions. Adjusting the measured MSIV leak rates for LOCA drywell pressure and temperature conditions to quantify MSIV leak rates for Revisions 3 and 4 of this evaluation represents an adjustment of input parameters to reflect actual plant conditions.

A comparison of the MSIV leak rate reductions between Revision 2 to Revision 4 for both the MSIV failed and intact steam lines is shown in the following table:

Post-LOCA Time Interval (hr)	MSIV Leakage from Drywell			
	Revision 2		Revision 4	
	MSIV Failed Line A (scfh & cfm)	2 Intact Lines B (scfh & cfm)	MSIV Failed Line C (scfh/cfh & cfm)	1 Intact Line D (scfh/cfh & cfm)
0-2	150	50	150 / 48.47	100 / 32.31
	2.5	0.833	0.808	0.539
2-24	150	50	150 / 26.77	100 / 17.84
	2.5	0.833	0.446	0.297
24-720	75	25	150 / 26.77	100 / 17.84
	1.25	0.417	0.446	0.297

A From H-1-ZZ-MDC-1880, Rev 2, Section 5.5.2
A From H-1-ZZ-MDC-1880, Rev 2, Sections 5.5.3 and 5.5.4
C and D from Table 7

A review of the MSIV leak rate information in the above table indicates that there is a substantial reduction in the post-LOCA MSIV cfm leakage rates in both the MSIV failed and intact lines, which reduces the dose contribution resulting from the MSIV leakage release path without accounting for the aerosol deposition.

2.4.4 Aerosol Deposition in Main Steam Piping (Table 1E, Item V-8)

The aerosols in the MSIV leakage settle down in the main steam line due to gravitational deposition. The aerosol removal from the MSIV leakage is calculated in Section 7.4 using the NRC approved method in AEB-98-03 (Ref. 10.22), which uses the Monte Carlo distribution of aerosol settling velocity in well mixed flow. Assumption 6.5 of Appendix A to R.G. 1.183 allows for a reduction in MSIV releases that is due to holdup and deposition in main steam piping downstream of the MSIVs if the piping is capable of performing its safety function during and following a safe shutdown earthquake. The analysis in Section 7.4 of this evaluation takes credit for the aerosol deposition and elemental iodine removal in piping upstream and downstream of the outboard MSIVs because the steam lines from the RPV nozzles to the TSVs are seismically designed and supported for the safe shutdown earthquake (Ref. 10.26 and 10.37). The analysis in Section 7.4.1 determines that a large amount of airborne aerosol in MSIV leakage will be deposited on the steam pipe surface.

The aerosol deposition removal efficiencies for the main steam lines are determined based on the methodology in Appendix A of AEB-98-03 (Ref. 10.22) as shown in Tables 2 through 6 using the information in Sections 7.3 and 7.4.

Credit is taken for aerosol removal from main steam piping via deposition for times between 0 and 96 hours post LOCA (Table 1E, Item V-8).

Main Steam Pipe Segment Lengths for Aerosol Deposition (Table 1E, Items V-5 and V-6)
The failed main steam line consists of a single well mixed volume between the inboard MSIV and the TSV. The intact main steam line consists of a single well mixed volume between the RPV and the TSV.

In Revision 3 of this calculation, the failed main steam line consisted of 2 well mixed pipe volumes. One volume was between the inboard and outboard MSIV and the second volume was between the outboard MSIV and the TSV. The intact main steam line in Revision 3 of this calculation also consisted of 2 main steam pipe volumes. One volume was between the RPV nozzle and the outboard MSIV and the second volume was between the outboard MSIV and the TSV. The failed main steam line pipe volume in Revision 2 of this calculation consisted of one plug flow volume that extended from the RPV nozzle to the TSV, while conservatively neglecting the main steam line length between the inboard and outboard MSIVs. The intact main steam pipe volumes in Revision 2 of this calculation for the 2 intact main steam lines extended from the RPV nozzle to the TSV.

The main steam piping layouts in the drywell through main steam tunnel to the TSV are shown in the piping isometric drawings in References 10.12 and 10.21 with the piping parameters. The review of these isometric drawings indicates that the steam header A and the steam header D share the shortest horizontal pipe length between the RPV nozzle and inboard MSIVs, which provides the minimum horizontal pipe surface area and consequently results in the least aerosol deposition. The main steam piping volumes and horizontal pipe surface are calculated in Section 7.3 and listed in Tables 2 through 4.

Main Steam Pipe Surface Areas for Aerosol Deposition (Table 1E, Item V-6)
Main steam pipe aerosol deposition surface areas for the failed and intact main steam lines are calculated in Sections 7.3.2 and 7.3.3 of this calculation, respectively. For conservatism, deposition of aerosols is only credited in horizontal pipe segments. Gravitational force naturally removes the airborne aerosol particles in the main steam piping during their migration through the pipe to the atmosphere. The horizontal main steam piping projected surface area (Diameter x Length) provides a favorable condition for aerosol deposition (Table 1E, Item V-6). Only considering aerosol deposition in horizontal pipe segments and calculating a settling area as D x L, is in accordance with Section 2 of Reference 10.55.

Aerosol deposition surface areas in Revision 3 of this calculation were also calculated for a projected surface area by applying the formula of D x L to horizontal pipe surface areas. In the Revision 2 analysis, the total pipe surface area (π x D x L) was used for aerosol deposition. Use of the total pipe surface area instead of the projected surface area overestimates the deposition surface since aerosol deposition is a result of gravitational force. Use of the projected surface area in lieu of the total pipe surface area is conservative since it results in a smaller surface area for aerosol deposition and thus removal of a smaller fraction of the aerosol activity.

Percentile Settling Velocity for Aerosol Deposition (Table 1E, Item V-7)
AEB-98-03 (Ref. 10.22) states that given the conservatisms associated with using a well mixed model for the entire length of the pipe and a number of additional conservatisms inherent in the piping deposition analysis, use of a 10th percentile settling velocity with a well mixed model is not appropriate. It goes on to state that given the conservatism of the well mixed assumption, it is acceptable to use median values for percentile settling velocity as opposed to more conservative values.

The rate constants (λ_s) for different piping segments in the MSIV leakage release paths are calculated in Table 5 using a 40th percentile aerosol settling velocity in piping segments upstream and downstream of the outboard MSIV in both the failed and intact main steam lines (Ref. 10.22, Appendix A, Table A-1) and applicable horizontal settling areas and volumes from Table 4 (Table 1E, Item V-7). The aerosol removal efficiencies due to gravitational depositions on the horizontal pipe surfaces are calculated using the mass balance equation for the well mixed volumes in Section 7.4 and listed in Table 6. The 40th percentile settling velocity is smaller than the mean (i.e., 50th) percentile settling velocity recommended in AEB-98-03. Use of the smaller settling velocity means there is more aerosol activity available for release which results in larger dose consequences and is therefore conservative.

A 40th percentile settling velocity was also used in Revision 2 of this calculation to determine aerosol deposition removal rate constants for the failed and intact main steam lines. The main steam pipe model used in Revision 3 of the calculation consisted of 2 pipe segment volumes in series in both the failed and intact main steam lines. Percentile settling velocities of 50^{th} percentile and 30^{th} percentile were used for the 2 pipe volumes in both the failed and intact main steam lines. The 30^{th} percentile settling velocity was applied to the 2^{nd}, downstream pipe volume and is smaller to account for the reduction in the size of the aerosol particles in the downstream volume. The overall effect of changing from a two compartment model with a 50^{th} percentile settling velocity in the first compartment and a 30^{th} percentile settling velocity in the second compartment to a single compartment model with a 40^{th} percentile settling velocity is a larger release which results in larger doses.

2.4.5 Elemental Iodine Removal (Table 1E, Items V-8 and V-9)

The reduction in elemental iodine activity in the MSIV leakage is calculated in Section 7.4.2 using the staff recommended guidance for an acceptable method as documented in Reference 10.52 (Reference A-9 of RG 1.183). The natural removal efficiencies for elemental iodine in each steam line volume are calculated in Tables 1F through 1M using the J.E. Cline model (Table 1E, Item V-9). The elemental iodine removal efficiencies calculated in Tables 1F through 1M are as previously approved by the NRC in the Hope Creek AST license amendment (Ref. 10.49). The information in these tables are revised due to minor changes in the surface areas and volumes.

The J. E. Cline method for calculation of elemental iodine removal from the main steam pipe volumes was also used in Revision 2 of this calculation. Revision 3 of this calculation applied a factor of 2 reduction for elemental iodine in each main steam line volume. The factor of 2 reduction is in accordance with the methodology prescribed in Appendix B of AEB-98-03 (Ref. 10.22). Credit is taken for removal of elemental iodine activity from the main steam piping for times between 0 and 96 hours post LOCA (Table 1E, Item V-8).

2.4.6 Parametric Study to Validate Aerosol Deposition Model

Parametric studies are not needed to validate the aerosol deposition model used in the MSIV leakage analysis.

(1) The elemental iodine removal efficiencies used in Revision 4 (Tables 1F through 1M) have been previously reviewed by the NRC staff and approved in the Hope Creek AST license amendment (Ref. 10.49). The post-LOCA temperature profile used for these elemental iodine removal efficiencies remains bounding for EPU (Section 5.3.1.9).

(2) Revision 4 uses one well mixed volume node for the MSIV failed line and for the intact line. This model was previously reviewed by the NRC staff and approved in the Hope Creek AST license amendment (Ref. 10.49).

(3) In Revision 4, the 40^{th} percentile aerosol settling velocity is used for the one well mixed volume in the MSIV failed line and in the intact line, which is conservative with respect to AEB 98-03, which states that the use of the 50^{th} percentile aerosol settling velocity is appropriate. The use of the 40^{th} percentile aerosol settling was previously reviewed by the NRC staff and approved in the Hope Creek AST license amendment (Ref. 10.49).

2.5 Control Room Model

The post-LOCA control room RADTRAD nodalization is shown in Figure 5 with the design input parameters. The post-LOCA radioactive releases that contribute the CR TEDE dose are as follows:

- Post-LOCA Containment Leakage
- Post-LOCA ESF Leakage
- Post-LOCA MSIV Leakage

The radioactivity from the above sources are assumed to be released into the atmosphere and transported to the CR air intake, where it may leak into the CR envelope or be filtered by the CR intake and recirculation filtration system and distributed in the CR envelope. There are four major radioactive sources, which contribute to the CR TEDE dose are:

- Post-LOCA airborne activity inside the CR
- Post-LOCA airborne cloud external to CR
- Post-LOCA containment shine to CR
- Post-LOCA CREF filter shine

2.5.1 Post-LOCA Airborne Activity Inside CR

The post-LOCA radioactive releases from various sources are discussed in Sections 2.2 through 2.4 above and shown in Figure 5. The activity releases from the various sources are diluted by the atmospheric dispersions and carried to the CR air intake. The atmospheric dispersion factors are shown in Sections 5.6.9 and 5.6.11 for the containment/ESF and MSIV leakages. The containment and ESF leakages have the same release point (FRVS vent) and X/Qs. The RADTRAD release models are developed for each release path using appropriate design inputs from Sections 5.3, 5.4, and 5.5. The CR dose model is developed using the design input parameters in Section 5.6. The CR airborne TEDE dose contributions from the above post-LOCA sources are calculated and tabulated in Section 8.0.

2.5.2 Control Room Unfiltered Inleakage (Table 1E, Item II-1)

The maximum CR inleakage is measured to be 155 ± 10 cfm in the recently performed (year 2009) Tracer Gas Test (Ref. 10.46, Table 19). In the last two Tracer Gas Tests, all CR inleakage was consistently measured to be filtered. Although all CR inleakage is filtered, the analyses in Revision 2 and Revision 3 assumed 350 cfm unfiltered inleakage, which is conservative. This Revision 4 analysis assumes the CR unfiltered inleakage is 300 cfm, including 10 cfm for ingress/egress. Use of 300 cfm in Revision 4 reduces the control room dose. This assumption remains conservative with respect to the fact that all CR inleakage is filtered.

2.5.3 Post-LOCA Airborne Cloud External to CR

The radioactive plumes released from various post-LOCA sources are carried over the CR building, submerging the CR in the radioactive cloud. The CR operator is exposed to direct radiation from the radioactive cloud external to the CR structure. The review of control building concrete structure drawings (Ref. 10.27 through 10.31) indicate that the CR is surrounded by at least 2'-10-1/2" (1' ceiling at EL 155'-3" and 1'-10-1/2" roof at EL 172'0") concrete shielding with a minimum distance of 29 feet from the least shielding (172'-0" – (137'-0" + 6'-0" tall person)). This minimum-shielding configuration provides an adequate protection to the CR operator to reduce the CR operator external cloud dose to a negligible amount.

2.5.4 Post-LOCA Containment Shine to CR

The post-LOCA airborne activity in the containment is released into the reactor building (RB) via containment leakage through the penetrations and openings and gets uniformly distributed inside the RB. The airborne activity confined in the dome space of the RB contributes direct shine dose to the CR operator. The review of the containment building concrete structure drawing (Ref. 10.35) indicates that the minimum dome concrete thickness is 1'-6". The CR minimum roof/ceiling concrete shielding is 2'-10-1/2". The combined concrete shielding of 4'-4-1/2" (1'-6" + 2'-10-1/2" = 4'-4-1/2") provides ample shielding to reduce the CR operator containment shine dose to an insignificant amount.

2.5.5 Post-LOCA CREF Filter Shine

The two trains of CREF charcoal and HEPA filters are located above the CR operating floor at elevation 155'-3" (Refs. 10.28, 10.29, and 10.39). The CR operating floor is located at elevation 137'-0" (Ref. 10.28c). The concrete floor at EL 155'-3" is 1 foot thick (Ref. 10.29). The filter assembly is placed on a 6" concrete pad (Ref. 10.39c, Section DD), which provides the total concrete shielding of 1'-6" between the CR operator and the charcoal/HEPA filter. The review of the CREF unit locations (Ref. 10.39) and CR area normally occupied by the CR operator (Ref. 10.30) indicates that the CR area below the CREF units are not occupied during routine operation. The CREF unit 1AVH400 is relatively closer to the normally occupied CR area compared to CREF unit 1BVH400 (Refs. 10.29, 10.30, and 10.39). Using full size drawings (Refs. 10.30 and 10.39), Section 7.6.4 determines that the slant distance and slant angle between the center line of CREF unit 1AVH400 and the horseshoe control panel and console are 30.99 feet and 27.38°, respectively. Based on this slant angle, Section 7.6.4 determines that the slant concrete shielding provided by the 1'-6" concrete ceiling and used in the MicroShield model is 3.26 feet. The iodine and aerosol activities are conservatively collected on the charcoal bed. The dimensions of charcoal filter housing are obtained from Reference 10.38 and are conservatively approximated to 3' (L) × 3' (H) × 4' (W) by summing all of the charcoal filter trays within a filter housing as shown in Figure 6, which also shows the dose point location. The post-LOCA aerosol buildup on the HEPA filter and the iodine buildup on the charcoal filter are calculated as follows.

2.5.5.1 Post-LOCA Iodine and Aerosol Activity On CREF Charcoal/HEPA Filter - Containment Leakage

The RADTRAD3.02 code calculates the cumulative elemental and organic iodine atoms and the aerosol mass deposited on the CR recirculation charcoal/HEPA filters. The CREF intake filter iodine and aerosol activities are calculated in Section 7.6.1 for the containment leakage. The relationship between the aerosol mass and activity is established in Table 11 based on the information obtained from RADTRAD run HEPU300CL00.o0. The aerosol mass deposited on the CREF HEPA recirc filter is calculated by the RADTRAD code for the duration of the accident. Knowing the CR intake and recirc filtration flow rates, the relationship can be established to calculate the aerosol mass deposited on the intake HEPA filter as shown in Section 7.6.1. The total aerosol mass deposited on the CREF HEPA filter due to the containment leakage is calculated, which is used with the aerosol mass/activity relation established in Table 11 to calculate the aerosol isotopic activities deposited on the CREF HEPA filter. This aerosol mass is added with the aerosol mass from the MSIV leakage in Section 7.6.3A and then converted into the isotopic aerosol activities in Table 12 using the atom/activity relation in Table 11. The total (elemental + organic) iodine atoms deposited on the CREF charcoal filter due to the containment leakage are calculated in Section 7.6.1. The iodine atoms are added with the atoms from other release paths in Section 7.6.3A and then converted into the isotopic iodine activities in Table 10 using the atom/activity relation in Table 8. The iodine isotopic activities deposited on the CREF charcoal filter due to the containment, ESF, and MSIV leakages are shown in Table 13.

2.5.5.2 Post-LOCA Iodine and Aerosol Activity On CREF Charcoal/HEPA Filter – ESF Leakage

Similarly, the iodine deposited on the CREF charcoal filter is calculated in Section 7.6.2 for the post-LOCA ESF leakage. The post-LOCA ESF leakage consists of a non-aerosol iodine release (97% of elemental iodine + 3% of organic iodine) (Ref. 10.1, Section 5.6) only, therefore, there is no aerosol mass deposited on the CR HEPA filter (HEPU300ES00.o0, CR Compartment Nuclide Inventory @ 720 hrs). The total (elemental + organic) iodine atoms deposited on the CREF charcoal filter due to the ESF leakage is calculated in Section 7.6.2. The iodine atoms are added with the atoms from other release paths in Section 7.6.3A and then converted into the isotopic iodine activities in Table 10 using the atom/activity relation established in Table 8. The iodine isotopic activities deposited on the CREF charcoal filter due to the containment, ESF, and MSIV leakages are shown in Table 13.

2.5.5.3 Post-LOCA Iodine and Aerosol Activity On CR Charcoal/HEPA Filter – MSIV Leakage

The CREF intake filter iodine and aerosol activities are calculated in Section 7.6.3 for the MSIV leakage. The total aerosol mass deposited on the CREF HEPA filter due to the MSIV leakage is calculated, which is used with the aerosol mass/activity relation established in Table 11 to calculate the aerosol isotopic activities deposited on the CREF HEPA filter. This aerosol mass is added with the aerosol mass from the containment leakage in Section 7.6.3A and then converted into the isotopic aerosol activities in Table 12 using the atom/activity relation in Table 11. The total (elemental + organic) iodine atoms deposited on the CREF charcoal filter due to the MSIV leakage is calculated in Section 7.6.3. The iodine atoms are added with the atoms from other release paths in Section 7.6.3A and then converted into the isotopic iodine activities in Table 10 using the atom/activity relation established in Table 8. The iodine and aerosol isotopic activities deposited on the CREF charcoal/HEPA filter due to the containment, ESF, and MSIV leakages are shown in Table 13.

2.5.5.4 MicroShield Analysis of CR Charcoal/HEPA Filter Shine

The total CREF charcoal/HEPA filter iodine and aerosol isotopic activities in Table 13 are input into the MicroShield (Ref. 10.9) Computer Run HCCRFLT2.MS5 with the source geometry, dimension, and detector location as shown in Figures 6 and 7 to compute the direct dose rate from the CREF filter. Due to the limitations of the MicroShield code, which calculates the dose rate at the dose point location within the projected area (width and height dimension), the dose point location at the center of the charcoal filter projected area is conservatively modeled at a distance of 20.0' from the ceiling because the actual dose point involves the slant distance of 30.99 feet (Section 7.6.4). The concrete thickness of 3.0' is conservatively modeled because the slant distance in the concrete shielding is 3.26' (Section 7.6.4). The 720-hrs direct dose from the CR filter shine is calculated in Section 7.6.5 using the CR occupancy factors and added to doses from other post-LOCA sources in Section 8.0.

2.6 CR and FRVS Vent Charcoal/HEPA Filter Efficiencies

The CR and FRVS vent charcoal filters are tested to comply with Generic Letter 99-02 requirements (Refs. 10.3 and 10.6). However, since there is no specific criteria to establish the HEPA filter efficiency, the GL 99-02 criterion is used to determine the HEPA filter efficiency. The in-place penetration testing acceptance requirements are given in Hope Creek Technical Specifications (Ref. 10.6). The filter efficiencies credited in this analysis are calculated in Section 7.7 based on the testing criteria in Reference 10.6 and GL 99-02 (Ref. 10.3).

2.7 Determine Compliance of Increased Dose Consequences With 10CFR50.59 Guidance

Consistent with the RG 1.183, Section 1.1.1, once the initial AST implementation has been approved by the staff and has become part of the facility design basis, the licensee may use 10 CFR 50.59 and its supporting guidance in assessing safety margins related to subsequent facility modifications and changes to procedures. The NRC Safety Evaluation Report for Amendments 134 and 146 (Refs. 10.49 and 10.50) approved the AST for the HCGS licensing basis analyses.

An increase in control room, EAB or LPZ dose consequence is considered acceptable under the 10 CFR 50.59 rule if the magnitude of the increase is minimal (as defined by the guidance in Refs. 10.36 and 10.44), and if the total calculated dose is less than the allowable Regulatory Guide 1.183 dose limit. The current licensing basis analysis is documented in the calculation H-1-ZZ-MDC-1880, Rev 3. The increases in the expected EAB, LPZ, and CR doses are compared with the 10 CFR 50.59 allowable minimal dose increases in Section 8.2. Similarly, the proposed calculated total doses are compared with the allowable regulatory guide limits. The comparisons in Section 8.2 confirm that the expected increases in the EAB, LPZ, and CR doses and the total calculated doses are less than the corresponding minimal dose increases and allowable regulatory guide limits. Therefore, pursuant to 10 CFR 50.59 guidance as defined in References 10.36 and 10.44, the proposed increase in the core thermal power level and resulting post-LOCA doses can be adopted as current design and licensing bases for the HCGS.

3.0 <u>ACCEPTANCE CRITERIA</u>

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

- Regulatory Guide 1.183 (Ref. 10.1)
- 10CFR50.67 (Ref. 10.4)
- Standard Review Plan section 15.0.1 (Ref. 10.18)

Dose Acceptance Criteria are:

Regulatory Dose Limits

Dose Type	Control Room (rem)	EAB and LPZ (rem)
TEDE Dose	5	25

4.0 ASSUMPTIONS:

The following assumptions used in evaluating the offsite and control room doses resulting from a Loss of Coolant Accident (LOCA) are based on the requirements in the Regulatory Guide 1.183 (Ref. 10.1). These assumptions become the design inputs in Sections 5.3 through 5.7 and are incorporated in the analyses.

4.1 Source Term Assumptions

Acceptable assumptions regarding core inventory and the release of radionuclides from the fuel are provided in Regulatory Positions (RGP) 3.1 through 3.4 of Reference 10.1 as follows:

4.2 Core Inventory

The assumed inventory of fission products in the reactor core and available for release to the containment is based on the maximum power level of 3,917 MWt corresponding to current fuel enrichment and fuel burnup, which is 1.173 times the HCGS current licensed thermal power of 3,339 MW_t (Ref. 10.6.9) including the 2% instrumentation uncertainty. Per Section 3.1 of RG 1.183, for DBA LOCA, all fuel assemblies in the core are assumed to be affected, therefore, the core average inventory is used in the analysis (Table 1D).

4.3 Release Fractions and Timing

The core inventory release fractions, by radionuclide groups, for the gap release and early in-vessel damage for a Design Basis Accident (DBA) LOCA are listed in Design Input 5.3.1.5. These fractions are applied to the equilibrium core inventory described in Design Input 5.3.1.3 (Ref. 10.1, Tables 1 and 4).

4.4 Radionuclide Composition

The elements in each radionuclide group to be considered in design basis analyses are shown in Design Input 5.3.1.4 (Ref. 10.1, RGP 3.4).

4.5 Chemical Form

The suppression pool water pH is greater than 7 during and following a LOCA (10.43, page 11). Consequently, the chemical forms of radioiodine released to the containment can be assumed to be 95% cesium iodide (CsI), 4.85 percent elemental iodine, and 0.15 percent organic iodide (Ref. 10.1, RGP 3.5 and A.2). These are shown in Design Inputs 5.3.1.7. With the exception of elemental and organic iodine and noble gases, fission products are assumed to be in particulate form (Ref. 10.1, RGP 3.5 and A.2).

4.6 Assumptions on Activity Transport in Primary Containment

4.6.1 The radioactivity released from the fuel is assumed to mix instantaneously and homogeneously throughout the free air volume of the primary containment.

4.6.2 Reduction in airborne radioactivity in the containment by natural deposition within the containment is credited using the RADTRAD3.02 Powers model for aerosol removal coefficient with a 10-percentile probability (Ref. 10.1 RGP A.3.2 and Ref. 10.2 Section 2.2.2.1.2).

4.6.3 The HCGS drywell and suppression chamber may be purged for up to 500 hrs per year (Ref. 10.6.18). Normally, per RG 1.183, RGP A.7, the radiological consequences from post-LOCA primary containment purging as a combustible gas or pressure control measure should be analyzed. If the primary containment purging is required within 30 days of the LOCA, the results of this analysis should be combined with consequences postulated for other fission product release paths to determine the total calculated radiological consequences from the LOCA. Per

Reference 10.42, Safety Evaluation Section 3.1, the revised 10 CFR 50.44 no longer defines a design-basis LOCA hydrogen release, and eliminates requirements for hydrogen control systems to mitigate such a release. The installation of hydrogen recombiners and/or vent and purge systems required by 10 CFR 50.44(b)(3) was intended to address the limited quantity and rate of hydrogen generation that was postulated from a design-basis LOCA. The Commission has found that this hydrogen release is not risk-significant because the design-basis LOCA hydrogen release does not contribute to the conditional probability of a large release up to approximately 24 hours after the onset of core damage. In addition, these systems were ineffective at mitigating hydrogen releases from risk-significant beyond design-basis accidents (BDBA). Therefore, the Commission eliminated the hydrogen release associated with a design-basis LOCA from 10 CFR 50.44 and the associated requirements that necessitated the need for ***the hydrogen recombiners and the backup hydrogen vent and purge systems.*** As a result, the HCGS deleted hydrogen recombiners from the its licensing basis (Ref. 10.6.2). The post-LOCA containment pressure is reduced to less than 31 psia within a few days (Ref. 10.15). Containment purging is not required for the combustible gas or pressure control measure within 30 days of the LOCA. Therefore, the release from containment purging is not analyzed.

4.7 Offsite Dose Consequences

The following assumptions are used in determining the TEDE for a maximum exposed individual at EAB and LPZ locations:

4.7.1 The offsite dose is determined in the TEDE, which is the sum of the committed effective dose equivalent (CEDE) from inhalation and the deep dose equivalent (DDE) from external exposure. The calculation of these two components of the TEDE should consider all radionuclides, including progeny from the decay of parent radionuclides, that are significant with regard to dose consequences and the released radioactivity (Ref. 10.1, RGP 4.1.1, Ref 10.7). The RADTRAD3.02 computer code (Ref. 10.2) performs this summation to calculate the TEDE.

4.7.2 The offsite dose analysis is performed using the RADTRAD3.02 code (Ref. 10.2), which uses the Committed Effective Dose (CED) Conversion Factors for inhalation. (Ref. 10.1, RGP 4.1.2, Refs. 10.7 and 10.8).

4.7.3 Since RADTRAD3.02 calculates Deep Dose Equivalent (DDE) using whole body submergence in semi-infinite cloud with appropriate credit for attenuation by body tissue, the DDE can be assumed nominally equivalent to the effective dose equivalent (EDE) from external exposure. Therefore, the offsite dose analysis uses DDE in lieu of EDE Dose Conversion Factors in determining external exposure (Ref. 10.1, RGP 4.1.4; and Ref 10.8).

4.7.4 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 acceptance criteria in 10 CFR 50.67 (Ref. 10.1, RGP 4.1.5 and RGP 4.4, and Ref. 10.4).

EAB Dose Acceptance Criteria: 25 Rem TEDE (50.67(b)(2)(i))

4.7.5 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 (Refs. 10.1, RGP 4.1.6 and RGP 4.4 and Ref. 10.4).

LPZ Dose Acceptance Criteria: 25 Rem TEDE (50.67(b)(2)(ii))

4.7.6 No correction is made for depletion of the effluent plume by deposition on the ground (Ref. 10.1, RGP 4.1.7).

4.7.7 The breathing rates used for persons at offsite locations is given in Reference 10.1, RGPs 4.1.3 and 4.4. These rates are incorporated in design inputs 5.7.2 and 5.7.4.

4.8 Control Room Dose Consequences

The following guidance is used in determining the TEDE for maximum exposed individuals located in the control room:

4.8.1 The CR TEDE analysis considers the following sources of radiation that will cause exposure to control room personnel (Ref. 10.1, RGP 4.2.1). See applicable Design Inputs 5.6.1 through 5.6.13.

- 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), and
- 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).

4.8.2 The radioactivity releases and radiation levels used for the control room dose are determined using the same source term, transport, and release assumptions used for determining the exclusion area boundary (EAB) and the low population zone (LPZ) TEDE values (Ref. 10.1, RGP 4.2.2).

4.8.3 The occupancy and breathing rate of the maximum exposed individual present in the control room are incorporated in design inputs 5.6.12 and 5.6.13 (Ref. 10.1, RGP 4.2.6).

4.8.4 10 CFR 50.67 (Ref. 10.4) establishes the following radiological criterion for the control room. This criterion is stated for evaluating reactor accidents of exceedingly low probability of occurrence and low risk of public exposure to radiation, e.g., a large-break LOCA (Ref. 10.1, RGP 4.4).

CR Dose Acceptance Criteria: 5 Rem TEDE (50.67(b)(2)(iii))

4.8.5 Credit for engineered safety features that mitigate airborne activity within the control room is taken for control room isolation/pressurization and intake and recirculation filtration (Ref. 10.1, RGP 4.2.4). The control room design is often optimized for the DBA LOCA and the protection afforded for other accident sequences may not be as advantageous. In most designs, control room isolation is actuated by engineered safety feature (ESF) signals or radiation monitors (RMs). In some cases, the ESF signal is effective only for selected accidents, placing reliance on the RMs. Several aspects of RMs can delay the isolation, including the delay for activity to build up to concentrations equivalent to the alarm setpoint and the effects of different radionuclide accident isotopic mixes on monitor response. The CR emergency filtration system is conservatively assumed to be initiated at 30 minutes (Design Input 5.6.5) after a LOCA, after the CR normal supply fan has been tripped.

4.8.6 The CR unfiltered inleakage is conservatively assumed to be 500 cfm (Design Input 5.6.7) during the CREF transition period of 30 minutes after a LOCA. This unfiltered inleakage includes 10 cfm for CR ingress and egress (Design Input 5.6.7). A conservative model would consider the normal ventilation mode for the transition period, which is of short duration (less than two minutes) until the control room envelop is fully pressurized following CREF initiation. Such a model would result in total unfiltered inleakage of 6,600 ft^3 (3000 ft^3/min × 2 min × 1.1 [for 10% variation in flow] = 6,600 ft^3). The conservative assumption of 500 cfm unfiltered inleakage during the transition period would result in 15,000 ft^3 (500 ft^3/min × 30 min = 15,000 ft^3) unfiltered air, which is 2 times higher.

4.8.7 No credits for KI pills or respirators are taken (Ref. 10.1, RGP 4.2.5).

5.0 DESIGN INPUTS:

5.1 General Considerations

5.1.1 Applicability of Prior Licensing Basis

The implementation of an AST is a significant change to the design basis of the facility and assumptions and design inputs used in the analyses. The characteristics of the AST and the revised TEDE dose calculation methodology may be incompatible with many of the analysis assumptions and methods currently used in the facility's design basis analyses. The HCGS plant specific design inputs and assumptions used in the TID-14844 analyses 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 requirements of the AST and the TEDE criteria.

5.1.2 Credit for Engineered Safety Features

Credit is taken only for those 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 single active component failure modeled in this calculation is an 'A' or 'B' EDG failure concurrent with a loss of offsite power (LOP) resulting in the MSIV release at the ground level instead of released through the south plant vent (SPV). The consequences of an EDG failure is translated throughout the calculation by assuming that only four out of six FRVS recirculation filtration trains are available and one out of four inboard MSIV fails open. Assumptions regarding the occurrence and timing of a LOP are selected for the CREF system with the objective of maximizing the postulated radiological consequences.

5.1.3 Assignment of Numeric Input Values

The numeric values that are chosen as inputs to analyses required by 10 CFR 50.67 are compatible to AST and TEDE dose criteria and selected with the objective of maximizing the postulated dose. As a conservative alternative, the limiting value applicable to each portion of the analysis is used in the evaluation of that portion. The use of containment, ESF, and MSIV leakage values higher than actually measured, use of 10% lower flow rates for the FRVS and CREFS recirculation systems, use of 10% higher flow rate for FRVS vent, 30 minutes delay in the CREF initiation time, and use of ground release χ/Qs demonstrate the inherent conservatisms in the plant design and post-accident response. Most of the design input parameter values used in the analysis are those specified in the Technical Specifications (Ref. 10.6).

5.1.4 Meteorology Considerations

Atmospheric dispersion factors (χ/Qs) for the onsite release points such as the FRVS vent for containment and ESF leakage release path and turbine building louvers for MSIV leakage release path are re-developed (Ref. 10.5) using the NRC sponsored computer code ARCON96. The EAB and LPZ χ/Qs are reconstituted using the HCGS plant specific meteorology and appropriate regulatory guidance (Ref. 10.32). The site boundary χ/Qs reconstituted in Reference 10.32 were accepted by the staff in the previous licensing proceedings.

5.2 Accident-Specific Design Inputs/Assumptions

The design inputs/assumptions utilized in the EAB, LPZ, and CR habitability analyses are listed in the following sections. The design inputs are compatible with the requirements of the AST and TEDE dose criteria and the assumptions are consistent with those identified in Regulatory Position 3 and Appendix A of RG 1.183 (Ref. 10.1). The design inputs and assumptions in the following sections represent the as-built design of the plant.

Design Input Parameter	Value Assigned	Reference
5.3 CONTAINMENT LEAKAGE MODEL PARAMETERS		
5.3.1 Source Term		
5.3.1.1 Thermal Power Level	3,917 MWt	Section 7.9
5.3.1.2 Not Used		

5.3.1.3 Isotopic Average Core Inventory (Ci/MWt) (Table 1D) (Ref. 10.45, Appendix A) See Note Below

Isotope	Ci/MW$_t$	Isotope	Ci/MW$_t$	Isotope	Ci/MW$_t$
CO-58*	1.529E+02	RU103	7.700E+04	CS136	1.860E+03
CO-60*	1.830E+02	RU105	2.700E+04	CS137	6.760E+03
KR 85	3.330E+02	RU106	2.940E+04	BA139	4.950E+04
KR 85M	7.350E+03	RH105	2.530E+04	BA140	4.780E+04
RB 86	1.420E+04	SB127	2.800E+03	LA140	5.080E+04
KR 87	2.000E+04	SB129	8.490E+03	LA141	4.510E+04
KR 88	6.350E+01	TE127	2.780E+03	LA142	4.370E+04
SR 89	2.690E+04	TE127M	3.710E+02	CE141	4.540E+04
SR 90	2.640E+03	TE129	8.350E+03	CE143	4.220E+04
SR 91	5.300E+04	TE129M	1.240E+03	CE144	7.424E+04
SR 92	3.610E+04	TE131M	2.764E+04	PR143	4.080E+04
Y 90	2.810E+03	TE132	3.810E+04	ND147	1.810E+04
Y 91	3.440E+04	I131	2.670E+04	NP239	5.220E+05
Y 92	3.620E+04	I132	3.870E+04	PU238	9.040E+01
Y 93	4.160E+04	I133	5.510E+04	PU239	1.090E+01
ZR 95	4.850E+04	I134	6.060E+04	PU240	1.410E+01
ZR 97	1.468E+05	I135	6.220E+04	PU241	4.090E+03
NB 95	4.870E+04	XE133	5.300E+04	AM241	4.600E+00
MO 99	5.100E+04	XE135	1.820E+04	CM242	1.090E+03
TC 99M	4.460E+04	CS134	5.350E+03	CM244	5.240E+01

* CO-58 & CO-60 activities are obtained from RADTRAD User's Manual, Table 1.4.3.2-3 (Ref. 10.2)

Note: Additional daughter isotopes added to parent isotopes are shown in Table 1C

5.3.1.4 Radionuclide Composition

Group	Elements	
Noble Gases	Xe, Kr	10.1, RGP 3.4, Table 5
Halogens	I, Br	
Alkali Metals	Cs, Rb	
Tellurium Group	Te, Sb, Se, Ba, Sr	
Noble Metals	Ru, Rh, Pd, Mo, Tc, Co	
Lanthanides	La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am	
Cerium	Ce, Pu, Np	

5.3.1.5 Timing of Release Phase (Ref. 10.1, Table 4)

Phase	Onset	Duration	
Gap Release	2 min	0.5 hr	Gap release starts at 0.0 sec
Early In-Vessel Release	0.5 hr	1.5 hr	

5.3.1.6 Iodine Chemical Form

Iodine Chemical Form	%	
Aerosol (CsI)	95.0%	10.1, RGP 3.5
Elemental	4.85%	
Organic	0.15%	

Design Input Parameter	Value Assigned	Reference
5.3.1.7 Release Fraction (Ref 10.1, Table 1)		
BWR Core Inventory Fraction Released Into Containment		
Group	**Gap Release Phase**	**Early In-Vessel Release Phase**
Noble Gases	0.05	0.95
Halogens	0.05	0.25
Alkali Metals	0.05	0.20
Tellurium Metals	0.00	0.05
Ba, Sr	0.00	0.02
Noble Metals	0.00	0.0025
Cerium Group	0.00	0.0005
Lanthanides	0.00	0.0002
5.3.1.8 Fuel Burnup	58 GWD/MTU < 62 GWD/MTU	10.45 and 10.1
5.3.1.9 Post-LOCA Drywell Temperature		
Post-LOCA Time (Hr)	Temperature (^{0}F)	Temperature values are bounding based on information in Reference 10.25, pages 35 through 45.
0	340	
3	320	
6	250	
24	208	
96	180	
240	170	
480	150	
720		
5.3.2 Activity Transport in Primary Containment		
5.3.2.1 Primary Containment Parameters		
5.3.2.2 Drywell Air Volume	169,000 ft^3	10.6.6 and 10.16
5.3.2.3 Suppression Chamber Air Volume	137,000 ft^3	10.6.6 and 10.16
5.3.2.4 Containment Air Volume	306,000 ft^3	DI 5.3.2.2 + DI 5.3.2.3
5.3.2.5 Containment Leak Rate		
0-720 hrs	0.5 v%/day	10.6.4 and 10.15
5.3.2.6 Draw Down Time	375 sec	10.6.8
5.3.2.7 Cont. Leakage Before Draw Down Time (< 375 sec)	Directly Released to Environment	10.1, RGP A.4.2
5.3.2.8 Cont. Leakage After Draw Down Time (>375 sec)	Directly Released to Reactor Building	10.1, RGP A.4.2
5.3.2.9 Reactor Building Volume	4,000,000 ft^3	10.6.7
5.3.2.10 Reactor Building Mixing	50%	10.1, RGP A.4.4
5.3.2.11 FRVS Vent Exhaust Rate Before Draw Down	9000 cfm ± 10%	10.6.3, and 10.6.16
5.3.2.12 FRVS Vent Exhaust Flow Rate After Draw Down	$3324 + 5676e^{-1.18t}$ Flow Rates calculated in Design Input 5.3.2.15	Actual Eqn in Ref. 10.19, page 24 is $3324 + 5637e^{-1.18t}$

Design Input Parameter	Value Assigned	Reference
5.3.2.13 FRVS Vent Exhaust Filter Efficiency		
Iodine Species	**Efficiency (%)**	
Elemental	90%	10.47
Aerosol	99%	Section 7.7
Organic	90%	10.47
5.3.2.14 FRVS Recirc Filter Efficiency		
Iodine Species	**Efficiency (%)**	
Elemental	0%	Assumed
Aerosol	99%	Section 7.7
Organic	0%	Assumed
5.3.2.15 Post Draw Down FRVS Exhaust Rates For 50% Mixing (using Design Input 5.3.2.12)		
Post-LOCA Time (hr)	**Normal Flow Rate (cfm)** **$A = 3324 + 5676e^{-1.18t}$**	**50% Mixing Flow Rate (cfm)** **A x 1.1 x 2**
0	9000	19800
0.104 (375 sec)	9000	19800
0.437	7154	15739
2.104	3860	8492
4.104	3375	7425
8.104	3324	7313
24	3324	7313
96	3324	7313
5.3.2.16 FRVS Recirc Flow Rate	120,000 cfm - 10% (or, 108,000 cfm)	10.6.12
5.4 ESF Leakage Model Parameters		
5.4.1 Sump Water Volume	118,000 ft^3	10.6.5 and 10.16
5.4.2 ESF Leakage	2.85 gpm	Assumption
5.4.3 ESF Leakage Initiation Time	0 minute	Assumption
5.4.4 Suppression Pool Water pH	>7	10.1, RGP A.2, 10.43, page 11
5.4.5 Sump Water Activity (Ref. 10.1, RGP A.5.1, A.5.3 and Tables 1 and 4)		
Group	Gap Release Phase	Early In-Vessel Release Phase
Timing Duration (Hrs)	2 min – 0.50 Hr	0.50 – 2.0 Hr
Halogen	0.05	0.25
5.4.6 Iodine Flashing Factor	10%	10.1, RGP A.5.5, and 10.25, pages 35 through 45
5.4.7 Chemical Form Iodine In ESF Leakage		
Elemental	97%	10.1, RGP A.5.6
Organic	3%	
5.4.8 Pool Peak Temperature	212.3^0F	10.17, Attachment 1, PUSAR Table 4-1

Design Input Parameter	Value Assigned	Reference
5.5 MSIV Leakage Model Parameters		
5.5.1 Total MSIV Leak Rate Through All Four Lines	≤ 250 scfh	10.6.17
5.5.2 MSIV Leak Rate Through Line With MSIV Failed	150 scfh	10.6.17
5.5.3 MSIV Leak Rate Through First Intact Line	100 scfh	Assumed
5.5.4 Not Used		
5.5.5 Number of Steam Lines	4	10.11 and 10.12e
5.5.6 Diameter and Wall Thickness of Pipe Between RPV Nozzle and Inboard Isolation Valves HV F022A/B/C/D	Diameter = 26" Wall Thickness = 1.117"	10.13b 10.14c
5.5.7 Diameter and Wall Thickness of Pipe Between Inboard and Outboard Isolation Valves HV F028A/B/C/D	Diameter = 26" Wall Thickness = 1.117"	10.12e 10.14c
5.5.8 Diameter and Wall Thickness of Pipe Between Outboard and 3rd Isolation Valves HV 3631A/B/C/D	Diameter = 26" Wall Thickness = 1.023	10.12e 10.14a
5.5.9 Diameter of Pipe Between 3rd Isolation and Turbine Stop Valves MSV1/2/3/4	Diameter = 28" Wall Thickness = 0.934"	10.12a 10.14b
5.5.10 Corrosion Allowance For Steam	0.12"	10.14
5.5.11 Drywell Peak Pressure	50.6 psig	10.17, Section 3.3.1
5.5.12 Drywell Peak Temperature	298^0F	10.17, Section 3.3.1
5.6 Control Room Model Parameters		
5.6.1 CR Volume	85,000 ft^3	10.33, Page 10
5.6.2 CREF System Flow Rate	1,000 cfm 1,050 cfm	10.6.16 Assumed
5.6.3 CR Minimum Recirculation Flow Rate	2,600 cfm	10.6.15
5.6.4 CR Unfiltered Inleakage After CREV System Initiation	155 ± 10 cfm actually measured + 10 cfm for ingress and egress Total = 300 cfm	10.46, Table 19 10.23, Section 2.5 Assumed
5.6.5 CREV System Initiation Time After a LOCA	30 minutes	Assumption 4.8.5
5.6.6 CR Charcoal and HEPA Filter Efficiencies	99%	Sections 7.7 and 7.9
5.6.7 CR Unfiltered Inleakage Prior to CREV System Initiation	10 cfm for ingress and egress 500 cfm (including 10 cfm for ingress and egress)	10.23, Section 2.5 10.40, page 6.4-8 and Assumption 4.8.6

Design Input Parameter	Value Assigned	Reference
5.6.8 CR Concrete Wall, Floor, and Ceiling Thickness		
Walls	>3 feet	10.27 through 10.31
Floor	>3 feet	
Total Roof Thickness	2'-10-1/2"	
Ceiling Above CR	1'-0"	10.29a and 10.29b
5.6.9 CR χ/Qs For Containment and ESF Leakage Release Via FRVS Vent Ground Level Release		
Time	**X/Q (sec/m^3)**	
0-2	1.25E-03	10.5, page 34
2-8	8.09E-04	
8-24	3.04E-04	
24-96	2.10E-04	
96-720	1.59E-04	
5.6.10 CR Occupancy Factors		
Time (Hr)	**%**	
0-24	100	10.1, RGP 4.2.6
24-96	60	
96-720	40	
5.6.11 CR X/Qs For MSIV Leakage Release Via Turbine Building Louvers Ground Level Release		
Time	**X/Q (sec/m^3)**	
0-2	6.17E-04	10.5, page 35
2-8	4.00E-04	
8-24	1.44E-04	
24-96	1.00E-04	
96-720	7.49E-05	
5.6.12 CR Breathing Rate	3.5E-04 (m^3/sec)	10.1, RGP 4.2.6
5.6.13 Minimum Reactor Bldg Wall Thickness	1'-6"	10.35
5.7 Site Boundary Release Model Parameters		
5.7.1 EAB X/Q (0-2 Hrs)	1.9E-04 sec/m^3	10.32, pages 5 and 9
5.7.2 EAB Breathing Rate	3.5E-04 m^3/sec	10.1
5.7.3 LPZ X/Qs (0-720 Hrs)		
Time	**X/Q (sec/m^3)**	
0-2	1.9E-05	10.32, pages 5 and 9
2-4	1.2E-05	
4-8	8.0E-06	
8-24	4.0E-06	
24-96	1.7E-06	
96-720	4.7E-07	

Design Input Parameter	Value Assigned	Reference
5.7.4 Offsite Breathing Rates		
Time	**BR (m^3/sec)**	
0-8	3.5E-04	10.1, RGPs 4.1.3 and 4.4
8-24	1.8E-04	
24-720	2.3E-04	
5.7.5 CR Charcoal Filter Dimensions Approximated Conservatively		
Length	3 feet	10.38
Height	3 feet	
Width	4 feet	
5.7.6 Charcoal Density	0.70 g/cc	Assumed
5.7.7 Concrete Density	2.3 g/cc	Assumed
5.7.8 Dose Point Location	143'-0"	6' above EL 137'-0"

6.0 COMPUTER CODES AND COMPLIANCE WITH REGULATORY REQUIREMENTS

6.1 Computer Codes

All computer codes used in this calculation have been approved for use with appropriate Verification and Validation (V & V) documentation. Computer codes used in this analysis include:

RADTRAD 3.02 (Ref. 10.48): 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 PSEG Nuclear in various AST license amendments, which are approved by the NRC. PSEG Nuclear performed in-house V&V of the code (Ref. 10.48). Therefore, the code is considered acceptable to be used for the HCGS AST analysis.

RADTRAD 3.02 is used rather than the current RADTRAD 3.03 to maintain consistency with previous revisions of Calculation H-1-ZZ-MDC-1880. Per the RADTRAD 3.03 V&V report, the following technical modifications, which have minimal impact on the RADTRAD 3.02 dose results, have been incorporated into RADTRAD 3.03:

- Modifications to correct logic errors that existed in the previous version
  - Multiple release paths from a compartment to the environment caused a significant conservative error in the control room dose, it became proportional to the number of paths
  - Control room filter deposition used incorrect array (< 0.1% effect on calculated dose)
  - Invalid filter loading values for all cases (no effect on calculated dose)
  - Suppression pool decontamination used incorrect volume (NAI-11) (< 0.1% effect on calculated dose)
  - A coefficient for the Gormley & Kennedy turbulent deposition model was in error (no effect on calculated dose)
  - Natural deposition model for APWR had a coefficient error (NAI-12) (no effect on calculated dose)
  - Powers natural deposition model used a derived removal coefficient instead of the current value (< 0.1% effect on calculated dose)
  - Dose conversion filename length could cause the code to terminate (no effect on calculated dose)
  - RADTRAD control of time steps to improve dose accuracy (RADTRAD v3.02) (< 1% effect on calculated dose)
  - Suppression pool decontamination that removed noble gases was corrected to allow their passage through the pool. (RADTRAD v3.02) (potential significant non-conservative effect on calculated dose)

- Modification to the definition of a control room
  - This modification was essentially a change to the definition of a control room. The control room was defined to be a compartment not included in the mass balance. This allows the offsite dose to be independent of the existence of a control room. Previously, the offsite dose would change (<1%) when a control room with a significant through flow was added. (NAI-7)
  - NRC Acceptance Test Case 16 (Table 8-1) originally called the auxiliary building a control room. As the mass balance excludes the control room, the input for this case was modified to allow a correct offsite and control room dose calculation. Doses can still be calculated in the auxiliary room by using an effective inlet χ/Q and an iodine protection factor formulation as was done in the rebaselining (Callan 1998) or by executing the model twice, first with the control room modeled as the control room and second with the auxiliary building modeled as the control

room. This is the same procedure one would use to evaluate dose on the Technical Support Center.

MicroShield 5.05 (Ref. 10.9): A commercially available and accepted code used to determine dose rates at various source-receptor combinations. Several runs were made at various times during the LOCA since the source strength varies over time. This code was used by PSEG Nuclear in various AST license amendments, which are approved by the NRC. PSEG Nuclear performed in-house V&V of the code (Ref. 10.9). Therefore, the code is considered acceptable to be used for the HCGS AST analysis.

7.0 CALCULATIONS

7.1 HCGS Plant Specific Nuclide Inventory File (NIF) For RADTRAD3.02 Input

The RADTRAD nuclide inventory file HEPULOCA1_DEF.txt establishes the power dependent radionuclide activity in Ci/MW_t for the reactor core source term. Since these core radionuclide activities are dependent on the core thermal power level, reload design, and burnup, the NIF is modified based on the plant-specific core inventory information obtained from Reference 10.45. The RADTRAD NIF HEPULOCA1_DEF.txt is modified based on the higher power core inventory in Table 1D and used in the analyses.

7.2 Determination of MSIV Leak Rates

7.2.1 Analyzed Case

The total leakage from all main steam lines is 250 scfh measured at 50.6 psig, allowing a maximum of 150 scfh from any one of the 4 main steam lines.

The total containment leakage is 0.5 w%/day. No leakage reduction is credited after 24 hours. The total containment leakage does not include the leakage through the MSIVs.

7.2.2 MSIV Leakage During 0-2 hrs

Note: The RADTRAD runs model MSIV leakage beginning at 0 minutes, which is prior to the 2 minute start of the gap release per Section 5.3.1.5.

Total Drywell volume = 169,000 ft^3 (Ref. 10.16)

Total MSIV leakage measured @ 50.6 psig = 250 scfh

Per the ideal gas law, PV= nRT or PV/T = nR. Given that nR is a constant for the air leakage, PV/T at post-LOCA conditions is equal to PV/T at STP conditions.
P @LOCA = Drywell peak pressure = 50.6 psig (Ref. 10.17, Section 3.3.1)
T @LOCA = Drywell peak temperature = 298°F (Ref. 10.17, Section 3.3.1) = 298^0F + 460 = 758^0R
P @STP = Standard pressure = 14.7 psia
T @STP = Standard temperature = 68^0F = 68^0F + 460 = 528^0R
V @STP = MSIV leakage based @ 50.6 psig = 250 scfh

V @LOCA = (PV/T @STP) x (T/P @LOCA)
0-2 hrs MSIV leakage @ drywell peak pressure of 50.6 psig and temperature of 298^0F
= 250 scfh x [14.7 psia / (50.6 psig + 14.7 psia)] x [758^0R / 528^0R]
= 250 scfh x 0.225 x 1.436 = 80.78 cfh
= (80.78 ft^3/hr x 24 hr/day) x 100% / 1.69E+05 ft^3 = **1.147 %/day**
= (80.78 ft^3/hr) / (60 min/hr) = 1.346 cfm

The 0-2 hrs 250 scfh MSIV leakage is released via two of the four Main Steam (MS) lines. A maximum allowable leak rate of 150 scfh is postulated from the shortest MS line with its inboard MSIV failed. The remaining leak rate of 100 scfh is postulated from the shortest of the three intact MS lines (i.e., the second shortest of the four MS lines). No leakage is postulated from the remaining two intact MS Lines.

0-2 hrs allowable leakage from the MS line with a failed MSIV (at maximum 150 scfh leak rate)
= (150 scfh / 250 scfh total) x 80.78 cfh = 48.47 cfh = 0.808 cfm
0-2 hrs allowable leakage from the shortest intact MS line (at maximum 100 scfh leak rate)
= (100 scfh / 250 scfh total) x 80.78 cfh = 32.31 cfh = 0.539 cfm

7.2.3 MSIV Leakage During 2-720 hrs

Two hours after a LOCA the drywell and suppression chamber volumes are expected to reach an equilibrium condition and the post-LOCA activity is expected to be homogeneously distributed between these volumes. The homogeneous mixing in the primary containment will decrease the activity concentration and therefore decrease the activity release rate through the MSIVs. To model the effect of this mixing, the MSIV flow rate used in the RADTRAD model is decreased by calculating a new leak rate based on the combined volumes of the drywell and suppression chamber.

Drywell + Suppression Chamber free air volume = 306,000 ft^3 (Design Input 5.3.2.4)

2-720 hrs MSIV leakage @ drywell peak pressure of 50.6 psig = 80.78 cfh (Section 7.2.2)

= (80.78 cfh x 24 hr/day) x 100% / 3.06E+05 ft^3 = **0.634 %/day**

Corresponding MSIV leak rate = 80.78 cfh x (1.69E+05 ft^3 / 3.06E+05 ft^3) = 44.61 cfh
2-720 hrs allowable leakage from the MS Line with a failed MSIV (at maximum 150 scfh leak rate)
= (150 scfh / 250 scfh total) x 44.61 cfh = 26.77 cfh = 0.446 cfm
2-720 hrs allowable leakage from the shortest intact MS Line (at maximum 100 scfh leak rate)
= (100 scfh / 250 scfh total) x 44.61 cfh = 17.84 cfh = 0.297 cfm

7.2.4 Deleted.

7.2.5 MSIV Leakage To Environment:

7.2.5.1 MSIV Leakage into the pipe spool between outboard MSIV and TSV and environment from MSIV failed line (MSIV Failed MS Line 1)

0-720 hrs

It is conservatively assumed that the MSIV leakage past the TSV expands to the atmospheric condition as follows:

Upstream of inboard MSIV in MSIV failed line (Section 7.2.2):
V1 = 48.47 cfh   P1 = 50.6 psig + 14.7 = 65.3 psia   T1 = (298^0F + 460) = 758^0R

Downstream of outboard MSIV in MSIV failed line (Atmospheric Condition):
V2 = TBD   P2 = 14.7 psia   T2 = (68^0F + 460) = 528^0R

MSIV Leakage into the pipe spool between outboard MSIV and TSV and environment from MSIV failed line (MS Line 1):
V2 = (PV/T @1) x (T/P @2)
= (65.3 psia x 48.47 cfh / 758^0R) x (528^0R / 14.7 psia)
≈ 150 cfh = 2.5 cfm

This is as expected, given that the 48.47 cfh leakage rate is equivalent to 150 scfh upstream of the outboard MSIV, and therefore it is equivalent to 150 cfh downstream of the outboard MSIV in the presence of standard pressure and temperature atmospheric conditions.

7.2.5.2 MSIV Leakage into the pipe spool between outboard MSIV and TSV and environment from MSIV shortest intact line (Intact MS Line 2)

<u>0-720 hrs</u>

Upstream of inboard MSIV in the shortest intact MS Line (Section 7.2.2):
V1 = 32.31 cfh P1 = 50.6 psig + 14.7 = 65.3 psia T1 = (298^0F + 460) = 758^0R

Downstream of inboard MSIV in intact line (assumed Atmospheric Condition):
V2 = TBD P2 = 14.7 psia T2 = (68^0F + 460) = 528^0R

MSIV Leakage into the intact pipe spools between the inboard and outboard MSIVs and between the outboard MSIV and TSV (and environment) from the intact line:
V2 = (PV/T @1) x (T/P @2)
= (65.3 psia x 32.31 cfh / 758^0R) x (528^0R / 14.7 psia)
$\approx$ 100 cfh = 1.667 cfm

This is as expected, given that the pressure and temperature conditions in the intact pipe spools between the inboard and outboard MSIVs and between the outboard MSIV and TSV are assumed to be the same as the standard pressure and temperature atmospheric conditions present in the environment.

7.3 Main Steam Line Volumes and Surface Area for Plateout of Activity

The two shortest main stream lines are selected for the aerosol deposition, namely the steam lines "A" and "D" connected to the reactor pressure vessel (RPV) nozzle N3A and N3D (Ref. 10.21). The steam line A is postulated to ruptured. The inboard MSIV connected to line A is postulated to fail to close and remains open during the accident to meet the single active failure requirement. The horizontal length of piping between the outboard MSIV and TSV becomes very critical in determining the aerosol deposition in the MSIV failed line, which contributes a major dose. The dimensions associated with the HCGS main steam piping in References 10.12, 10.13, and 10.21 are documented in the following section.

7.3.1 <u>Piping Parameters:</u>

The piping parameters for the various piping segments between the RPV nozzle and TSV are listed in the following sections based on the pipe classes. The piping parameters are typical for all steam similar segments inside and outside drywell.

7.3.1.1 <u>MSIV Line Between RPV Nozzle and Outboard Isolation Valve:</u>

Piping Class = DLA (Ref. 10.13b)
Pipe Diameter = 26" (Ref. 10.13b)
Minimum Wall Thickness = 1.117" (Ref. 10.14.c)
Corrosion Allowance For Steam = 0.12" (Ref. 10.14c)

Total Minimum Thickness = 1.117" + 0.12" = 1.237"
26" Pipe ID = OD – (2 x Min Wall Thickness) = 26" – 2 x 1.237" = 23.526" = 1.961'
Pipe Flow Area = $(\pi/4)$ x (Pipe I.D.)^2 = (3.14 / 4) x (1.961 ft)^2 = 3.019 ft^2

Length of short radius (SR) elbow = $R\theta$
Where R = radius of SR elbow = 26" and
θ = Angle subtended by elbow in radian = 90 degree/57.29 degree/radian
Length of SR elbow = 26" x 90/57.29 = 40.84" = 3.4' (typical SR elbow length)
SR Elbow Volume = 3.019 ft^2 x 3.4 ft = 10.27 ft^3 (typical 26" SR elbow volume)

Length of long radius (LR) elbow = $R\theta$
Where R = radius of LR elbow = 1. 5 x 26" = 39" = 3.25' and
θ = Angle subtended by elbow in radian = 90 degree/57.29 degree/radian
Length of LR elbow = 39" x 90/57.29 = 61.27" = 5.11' (typical LR elbow length)
LR Elbow Volume = 3.019 ft^2 x 5.11 ft = 15.43 ft^3 (typical 26" LR elbow volume)

7.3.1.2 MSIV Line Between Outboard and Third Isolation Valve

Piping Class = DBB (Ref. 10.11 and 10.12e)
Pipe Diameter = 26" (Ref. 10.12e)
Minimum Wall Thickness = 1.023" (Ref. 10.14a)
Corrosion Allowance For Steam = 0.12" (Ref. 10.14a)
Total Minimum Thickness = 1.023" + 0.12" = 1.143"
26" Pipe ID = OD – (2 x Min Wall Thickness) = 26" – 2 x 1.143" = 23.714" = 1.976'
Pipe Flow Area = $(\pi/4)$ x (Pipe I.D.)^2 = (3.14 / 4) x (1.976 ft)^2 = 3.065 ft^2

7.3.1.3 MSIV Line Between Third Isolation Valve and Turbine Stop Valve

Piping Class = DBC (Ref. 10.11 and 10.12a)
Pipe Diameter = 28" (Ref. 10.12a)
Minimum Wall Thickness = 0.934" (Ref. 10.14b)
Corrosion Allowance For Steam = 0.12" (Ref. 10.14b)
Total Minimum Thickness =0.934" + 0.12" = 1.054"
28" Pipe ID = OD – (2 x Min Wall Thickness) = 28" – 2 x 1.054" = 25.892" = 2.158'
Pipe Flow Area = $(\pi/4)$ x (Pipe I.D.)^2 = (3.14 / 4) x (2.158 ft)^2 = 3.656 ft^2
Length of short radius (SR) elbow = $R\theta$
Where R = radius of elbow = 28" and
θ = Angle subtended by elbow in radian = 90 degree/57.29 degree/radian
Length of SR elbow = 28" x 90/57.29 = 43.99" = 3.666' (typical SR elbow length)
SR Elbow Volume = 3.656 ft^2 x 3.666 ft = 13.40 ft^3 (typical 28" SR elbow volume)

7.3.2. Piping Volume and Surface Area for Aerosol Deposition – MSIV Failed Line

7.3.2.1 Piping from Inboard MSIV V028 to Outboard MSIV V032 (Ref. 10.12.e and 10.21.a):

Length of Pipe Between Inboard and Outboard Isolation Valves
Distance between the RPV centerline and inner edge of inboard MSIV
= 21'-8-5/8" + 2'-9-7/8" = 24'-6-1/2" = 24.542' (Ref. 10.21.a)
Distance between outer edge of drywell main steam penetration and centerline of RPV
= 49'-2-1/2" (Ref. 10.12.e)

Distance between inner edge of inboard MSIV and outer edge of drywell main steam penetration
= 49'-2-1/2' – 24'-6-1/2" = 24'-8" = 24.667'
Distance between outer edges of drywell main steam penetration and outboard MSIV
= 3'-10" + 5'-3" = 9'-1"
Distance between inner edge of inboard MSIV and outer edge of outboard MSIV
= 24'-8" + 9'-1" = 33.75'
Total Pipe Volume = Flow Area x Total Length V_1 = 3.019 ft^2 x 33.75 ft = 101.89 ft^3 = 2.89 m^3
Total projected horizontal pipe surface area = D x L (Horizontal Length)
= 1.961 ft x 33.75 ft = 66.18 ft^2
Total horizontal pipe surface area = π D x L
= 3.14 x 1.961 ft x 33.75 ft = 207.82 ft^2 = 19.32 m^2
Total horizontal pipe volume = 101.89 ft^3

7.3.2.2 Piping from Outboard MSIV V032 to Third MSIV V003 (Ref. 10.12.e):

Horizontal pipe = 7'-11" – 26" = 5.75'
Horizontal volume = Flow area x Length = 3.065 ft^2 x 5.75 ft = 17.62 ft^3
SR elbow volume = 10.27 ft^3 (Section 7.3.1.1)
Vertical pipe = 19'-6-1/2" – 26" = 17.375'
Vertical volume V = Flow area x Length = 3.065 ft^2 x 17.375 ft = 53.25 ft^3
SR elbow volume = 10.27 ft^3 (Section 7.3.1.1)
Horizontal pipe = 6'-0" + 5'-3" = 11.25'
Horizontal volume V = Flow area x Length = 3.065 ft^2 x 11.25 ft = 34.48 ft^3

Total Pipe Volume = 17.62 ft^3 + 10.27 ft^3 + 53.25 ft^3 + 10.27 ft^3 + 34.48 ft^3 = 125.89 ft^3
Total projected horizontal pipe surface area = D x L (Horizontal Length)
= 1.976 ft x (5.75' + 11.25') = 33.59 ft^2
Total horizontal pipe surface area = π D x L
= 3.14 x 1.976 ft x (5.75' + 11.25') = 105.48 ft^2 = 9.80 m^2

Total horizontal pipe volume = 17.62 ft^3 + 34.48 ft^3 = 52.10 ft^3

7.3.2.3 Piping from Third MSIV V003 to Turbine Stop Valve MSV 3 (Ref. 10.12.c):

Horizontal pipe = 38'-0" + 39'-0" + 41'-6-1/2" + 21'-6-1/2" – 28" = 137'-9" = 137.75'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 137.75 ft = 503.61 ft^3
Horizontal SR elbow length = 3.666 ft (Section 7.3.1.3)
Horizontal SR elbow volume = 13.40 ft^3 (Section 7.3.1.3)
Horizontal pipe = 14'-11" + 38'-0" + 38'-0" - 28" = 88'-7" = 88.583'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 88.583 ft = 323.86 ft^3
Horizontal SR elbow length = 3.666 ft (Section 7.3.1.3)
Horizontal SR elbow volume = 13.40 ft^3 (Section 7.3.1.3)
Horizontal pipe = 11'-1-1/2" + 32'-4" = 43'-5-1/2" = 43.458'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 43.458 ft = 158.88 ft^3

Total pipe volume = 503.61 ft^3 + 13.40 ft^3 + 323.86 ft^3 + 13.40 ft^3 + 158.88 ft^3 = 1,013.15 ft^3
Total projected horizontal pipe surface area = D x L (Horizontal Length)
= 2.158 ft x (137.75 ft + 3.666 ft + 88.583 ft + 3.666 ft + 43.458 ft)
= 2.158 ft x 277.123 ft = 598.03 ft^2
Total horizontal pipe surface area = π D x L

= 3.14 x 2.158' x 277.123 ft = 1,877.81 ft^2 = 174.54 m^2
Total horizontal pipe volume = 1,013.15 ft^3

7.3.2.4 Volume and Surface Area for Aerosol Deposition – Outboard MSIV to TSV MSV 3

Combined total pipe volume V_2 = Outboard MSIV to Third MSIV + Third MSIV to TSV MSV 3
= 125.89 ft^3 (Section 7.3.2.2) + 1,013.15 ft^3 (Section 7.3.2.3) = 1,139.04 ft^3 = 32.28 m^3
Combined total projected horizontal pipe surface area
= 33.59 ft^2 (Section 7.3.2.2) + 598.03 ft^2 (Section 7.3.2.3) = 631.62 ft^2
Combined total horizontal pipe surface area
= 9.8 m^2 (Section 7.3.2.2) + 174.54 m^2 (Section 7.3.2.3) = 184.34 m^2
Total horizontal pipe volume
= 52.10 ft^3 (Section 7.3.2.2) + 1,013.15 ft^3 (Section 7.3.2.3) = 1,065.25 ft^3

7.3.2.5 Volume and Surface Area for Aerosol Deposition – Inboard MSIV to TSV MSV 3

Combined total pipe volume V_{11}
= 101.89 ft^3 (section 7.3.2.1) + 1,139.04 ft^3 (section 7.3.2.4) = 1,240.93 ft^3 = 35.17 m^3
Combined total projected horizontal pipe surface area
= 66.18 ft^2 (section 7.3.2.1) + 631.62 ft^2 (section 7.3.2.4) = 697.8 ft^2
Combined total horizontal pipe surface area
= 207.82 ft^2 (section 7.3.2.1) + 105.48 ft^2 (Section 7.3.2.2) + 1,877.81 ft^2 (Section 7.3.2.3)
= 2,191.11 ft^2 = 203.66 m^2
Total horizontal pipe volume
= 101.89 ft^3 (section 7.3.2.1) + 1,065.25 ft^3 (section 7.3.2.4) = 1,167.14 ft^3

7.3.3. Piping Volume and Surface Area for Aerosol Deposition – Intact Steam Line (RPV Nozzle N3D)

7.3.3.1 Piping from RPV Nozzle N3D to Inboard MSIV V031 (Ref. 10.21.b):

Nozzle elevation (Center Line) = 170'-1-1/2"
Straight pipe = 17'-0-1/2" – 13'-0" = 4'-0-1/2" = 4.04'
Subtraction for short radius elbow = 26" = 2'-2" = 2.17'
Length of straight pipe = 4.04 – 2.17' = 1.87'
Volume = 3.019 ft^2 x 1.87 ft = 5.66 ft^3
LR Elbow Volume = 15.43 ft^3 (Section 7.3.1.1)
SR elbow volume = 10.27 ft^3 (Section 7.3.1.1)
Height of 10'-10" Bend = 11'-7/14" / Sin 75^0 ≅ 12'-0"
Elevation of bend = 123'-6" + 12'-0" = 135'-3"
Vertical Pipe = 170'-1-1/2" – 135'- 3" – 2'2" = 32'- 8-1/2" = 32.708'
Vertical Volume, V = 3.019 ft^2 x 32.708 ft = 98.75 ft^3
SR elbow V = 10.27 ft^3
Length of bend = 11'-7-1/4" – 5.11 = 6.494'
Vertical Volume, V = 3.019 ft^2 x 6.494' = 19.61 ft^3
LR elbow V = 15.43 ft^3
Horizontal bend pipe = 4'-4-15/16 + 9'-2-3/8" = 13.609'
Volume = 3.019 ft^2 x 13.609 ft = 41.09 ft^3
LR elbow V = 15.43 ft^3
Vertical pipe = 123'-5-1/2" – 107'-0-3/8" – 39" = 13.18'
Vertical volume = 3.019 ft^2 x 13.18 ft = 39.79 ft^3

LR elbow V = $\underline{15.43\ ft^3}$
Horizontal length = 4'-7" – 39" = 1.33'
Horizontal volume = 3.019 ft^2 x 1.33 ft = $\underline{4.02\ ft^3}$
Horizontal LR elbow = 3.019 ft^2 x 5.11 ft = $\underline{15.43\ ft^3}$
Horizontal length = 3'-6-1/4" = 3.521'
Horizontal volume = 3.019 ft^2 x 3.521 ft = $\underline{10.63\ ft^3}$

Total Volume of Steam Header From RPV Nozzle A To Inboard MSIV AO-80A 2VA_{T1}
= 5.66 ft^3 + 10.27 ft^3 + 98.75 ft^3 + 10.27 ft^3 + 19.61 ft^3 + 15.43 ft^3 + 41.09 ft^3 + 15.43 ft^3 + 39.79 ft^3 + 15.43 ft^3 + 4.02 ft^3 + 15.43 ft^3 + 10.63 ft^3 = $\underline{301.81\ ft^3}$ = $\underline{8.55\ m^3}$

Total horizontal pipe length = 1.87' + 13.609' + 1.33' + 5.11' + 3.521' = 25.44'
Total projected horizontal pipe surface area = D x L = 1.961 ft x 25.44 ft = $\underline{49.89\ ft^2}$
Total horizontal pipe surface area = π D x L = 3.14 x 1.961 ft x 25.44 ft = $\underline{156.65\ ft^2}$
Total horizontal pipe volume = 5.66 ft^3 + 41.09 ft^3 + 4.02 ft^3 + 15.43 ft^3 + 10.63 ft^3 = $\underline{76.83\ ft^3}$

7.3.3.2 <u>Piping from Inboard MSIV V031 to Outboard MSIV V035 (Ref. 10.12.e and 10.21.b):</u>

Same as in Section 7.3.2.1

Total Pipe Volume = Flow Area x Total Length = $\underline{101.89\ ft^3}$ = 2.89 m^3
Total projected horizontal pipe surface area = D x L (Horizontal Length) = $\underline{66.18\ ft^2}$
Total horizontal pipe surface area = π D x L = 3.14 x 66.18 ft^2 = 207.81 ft^2 = 19.32 m^2
Total horizontal pipe volume = $\underline{101.89\ ft^3}$

7.3.3.3 Piping from Outboard MSIV 035 to Third MSIV V006 (Ref. 10.12.e):

Same as in Section 7.3.2.2

Total Pipe Volume = $\underline{125.89\ ft^3}$
Total projected horizontal pipe surface area = D x L (Horizontal Length) = $\underline{33.59\ ft^2}$
Total projected horizontal pipe surface area = π D x L = 3.14 x 33.59 ft^2 = 105.47 ft^2 = 9.80 m^2
Total horizontal pipe volume = $\underline{52.10\ ft^3}$

7.3.3.4 Piping from Third MSIV V006 to Turbine Stop Valve MSV 2 (Ref. 10.12.b):

Horizontal pipe = 38'-0" + 39'-0" + 41'-6-1/2" + 15-7-1/2" – 28" = 131'-10" = 131.833'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 131.833 ft = $\underline{481.98\ ft^3}$
Horizontal SR elbow length = 3.666 ft (Section 7.3.1.3)
Horizontal SR elbow volume = 13.40 ft^3 (Section 7.3.1.3)
Horizontal pipe = 6'7" + 40'-0" + 43'6" - 28" = 87'-9" = 87.75'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 87.75 ft = $\underline{320.81\ ft^3}$
Horizontal SR elbow = 13.40 ft^3
Horizontal pipe = 26'-4-1/2" + 23'-0" = 49'-4-1/2" = 49.375'
Horizontal volume = Flow area x Length = 3.656 ft^2 x 49.375 ft = $\underline{180.52\ ft^3}$

Total pipe volume = 481.98 ft^3 + 13.40 ft^3 + 320.81 ft^3 + 13.40 ft^3 + 180.52 ft^3 = $\underline{1,010.11\ ft^3}$
Total projected horizontal pipe surface area = D x L (Horizontal Length)
= 2.158 ft x (131.833 ft + 3.666 ft + 87.75 ft + 3.666 ft + 49.375 ft)
= 2.158 ft x 276.29 ft = $\underline{596.23\ ft^2}$

Total horizontal pipe surface area = π D x L
= 3.14 x 596.23 ft^2 = 1,872.16 ft^2 = 174.02 m^2
Total horizontal pipe volume = 1,010.11 ft^3

7.3.3.5 Volume and Surface Area for Aerosol Deposition – RPV to Outboard MSIV 035:

Combined total pipe volume V_3 = RPV Nozzle to Inboard MSIV + Inboard MSIV to Outboard MSIV
= 301.81 ft^3 (Section 7.3.3.1) + 101.89 ft^3 (Section 7.3.3.2) = 403.70 ft^3 = 11.44 m^3
Combined projected total horizontal pipe surface area
= 49.89 ft^2 (Section 7.3.3.1) + 66.18 ft^2 (Section 7.3.3.2) = 116.07 ft^2
Combined total horizontal pipe surface area
= 156.65 ft^2 (Section 7.3.3.1) + 207.81 ft^2 (section 7.3.3.2) = 364.46 ft^2
Combined total horizontal pipe volume
= 76.83 ft^3 (Section 7.3.3.1) + 101.89 ft^3 (Section 7.3.3.2) = 178.72 ft^3

7.3.3.6 Volume and Surface Area for Aerosol Deposition – Outboard MSIV 035 to TSV MSV 3

Combined total pipe volume V_4 = Outboard MSIV to Third MSIV + Third MSIV to TSV MSV 3
= 125.89 ft^3 (Section 7.3.3.3) + 1,010.11 ft^3 (Section 7.3.3.4) = 1,136.00 ft^3 = 32.19 m^3
Combined projected total horizontal pipe surface area
= 33.59 ft^2 (Section 7.3.3.3) + 596.23 ft^2 (Section 7.3.3.4) = 629.82 ft^2
Combined total horizontal pipe surface area
= 105.47 ft^2 (Section 7.3.3.3) + 1,872.16 ft^2 (Section 7.3.3.4) =1,977.63 ft^2
Combined total horizontal pipe volume
= 52.10 ft^3 (Section 7.3.3.3) + 1,010.11 ft^3 (Section 7.3.3.4) = 1,062.21 ft^3

7.3.3.7 Volume and Surface Area for Aerosol Deposition – RPV to TSV MSV 3

Combined total pipe volume V_{33}
= 403.70 ft^3 (section 7.3.3.5) + 1,136.00 ft^3 (section 7.3.3.6) = 1,539.70 ft^3 = 43.63 m^3
Combined total projected horizontal pipe surface area
= 116.07 ft^2 (section 7.3.3.5) + 629.82 ft^2 (section 7.3.3.6) = 745.89 ft^2
Combined total horizontal pipe surface area
= 364.46 ft^2 (section 7.3.3.5) + 1,977.63 ft^2 (section 7.3.3.6) = 2,342.09 ft^2= 217.69 m^2
Combined total horizontal pipe volume
= 178.72 ft^3 (section 7.3.3.5) + 1,062.21 ft^3 (section 7.3.3.6) = 1,240.93 ft^3

7.4 Plateout of Activity in Main Steam Lines

7.4.1 Aerosol Deposition

Reference 10.37 indicates that the HCGS main steam piping from the reactor pressure vessel (RPV) nozzle to the turbine stop valve is seismically analyzed to assure the piping wall integrity during and after a seismic (safe shutdown earthquake [SSE]) event. The Hope Creek turbine building is classified as Non-seismic, however, codes and criteria similar to those for Seismic Category I structure, were used for the structure design of the entire building (Ref. 10.26, Section 1.2). The turbine building was dynamically analyzed and design to accommodate an SSE event (Ref. 10.37, page 1-2) so that it does not collapse on, or interact with, adjacent seismic Cat I structures for SSE. RG 1.183, Appendix A, Section 6.5 requires that the components and piping systems used in the release path are capable of performing their safety function during and following a SSE. The main steam lines credited in the MSIV leakage path are qualified to withstand the SSE, therefore, these lines are credited for the aerosol deposition in the following section:

The Brockmann model for aerosol deposition (Ref. 10.2, Section 2.2.6.1) is based on the plug flow model. The staff concluded that the plug flow model for aerosol deposition in the main steam piping under-predicts the dose (Ref 10.22, Appendix A). The aerosol settling velocity in the well-mixed flow model depends on the variables having a large range of uncertainty (see Equation 5 of Appendix A of Ref. 10.22). The following aerosol deposition model is used, which is accepted by the Staff in Reference 10.22, Appendix A). The Staff performed a Monte Carlo analysis to determine the distribution of aerosol settling velocities for the main steam line during the in-vessel release phase. The accepted 40th percentile settling velocity is reasonably conservative for aerosol deposition in the MSIV leakage. The results of the Monte Carlo analysis for settling velocity in the main steam line are given in the following Table:

Percentile	Settling Velocity (m/sec)	Removal Rate Constant (hr^{-1})
60th (average)	0.00148	11.43
50th (median)	0.00117	9.04
40th	0.00081	6.26
10th	0.00021	1.62

The Staff concluded that use of a 10th percentile settling velocity with a well-mixed model is overly conservative and not appropriate (Ref. 10.22, page 11). Instead, the Staff believes it is acceptable to utilize median values (i.e., 50th percentile settling velocity) (Ref. 10.22, page 11). This analysis is conservative relative to the Staff's recommendation, in that it models a 40th percentile settling velocity for aerosol deposition in the MSIV leakage paths beyond the inboard MSIVs.

The derivation of the staff's well-mixed model begins with a mass balance as follows (Ref. 10.22, Page A-2):

$$V * \frac{dC}{dt} = Q * C_{in} - Q * C - \lambda_s * V * C \quad (1)$$

Where V = volume of well-mixed region

C = concentration of nuclides in volume

Q = volumetric flow rate into volume

λ_s = rate constant for settling

And

$$\lambda_s = \frac{u_s * A}{V}$$

Where u_s = settling velocity

A = settling area

The aerosol settling velocities in the different control volumes are calculated in Table 5 using the above equation based on the horizontal pipe projected areas and well mixed horizontal volumes obtained from Tables 2 through 4 and Sections 7.3.

Under steady-state condition, the derivative in the above equation (1) becomes zero. Equation (1) can be simplified as follows:

$$C \equiv C_{in} * \frac{1}{1 + \frac{\lambda_s * V}{Q}}$$

RADTRAD allows input of filter efficiency for each flow path. Noting that C is also the concentration of nuclides leaving the volume, the above equation can be used to determine an equivalent filter efficiency as follows:

$$\eta_{filt} = 1 - \frac{C}{C_{in}} = 1 - \frac{1}{1 + \frac{\lambda_s * V}{Q}} \qquad (2)$$

The aerosol removal efficiencies are calculated in Table 6 using Equation (2). The rate constant for settling velocity λ_s is calculated in Table 5 using the horizontal settling surface area and volume from Table 4. The aerosol removal efficiencies are calculated in Table 6 using the well-mixed pipe volumes from Table 3 and the volumetric full flow rates of 150 and 100 scfh in the MSIV failed and intact steam lines, respectively.

7.4.2 Elemental Iodine

Gaseous iodine tends to deposit on the piping surface by chemical adsorption. The elemental iodine being the most reactive has the highest deposition rate. The iodine deposited on the surface undergoes both physical and chemical changes and can be re-emitted as an airborne gas (re-suspension) or permanently fixed to the surface (fixation). The RGP A.6.5 (Ref. 10.1) indicates that Reference A-9 provides acceptable models for deposition of iodine on the pipe surface. Reference 10.52, which is Reference A-9 of Regulatory Guide 1.183 is used to determine the deposition and resuspension rates of elemental iodine as follows:

d_i = elemental iodine vapor deposition velocity (cm/s)
= $\mathbf{e}^{(2809/T - 12.80 (\pm 0.33))}$ = $\mathbf{e}^{(2809/T - 12.5)}$ (Ref. 10.52, pages 4 and 12).

Where T = gas temperature (^{0}K)

This equation is same as equation 30 in Bixler Model in the RADTRAD3.02 code (Ref. 10.2, page 212).

The elemental iodine deposition velocities are calculated in Table 1F based the post-LOCA drywell temperature shown in Design Input 5.3.1.9.

The elemental iodine deposition rate λ_{ed} (hr^{-1}) = $\mathbf{\frac{d_i * S * 3600}{V}}$ (Ref. 10.52, page 4)

Where d_i = deposition velocity (m/sec)
S = surface area of deposition (m^2)
V = volume (m^3)

The deposition velocity in cm/sec (which is converted into m/sec) and elemental iodine deposition rates at various drywell temperatures are calculated in Tables 1G and 1H for the MSIV failed line Volume V11 and Intact line Volume V33, respectively.

The portion of elemental iodine deposited on the pipe surface will be resuspended as an airborne gas (organic iodine). Since the CR filtration efficiencies are same for all iodine spices, the resuspension of elemental iodine will produce the same thyroid organ dose irrespective of the form of iodine.

Resuspension rate of elemental iodine (sec^{-1})

$$= \mathbf{2.32\ (\pm 2.00)\ x\ 10^{-5}\ e^{-600/T} = 4.32\ x\ 10^{-5}\ e^{-600/T}}$$

Resuspension rate of elemental iodine λ_{er} (hr^{-1})

$$= \mathbf{4.32\ x\ 3600\ x\ 10^{-5}\ e^{-600/T}}$$

The resuspension rates of elemental iodine at various drywell temperatures are calculated in Table 1I.

The net deposition of elemental iodine on the pipe surface is the difference of deposition rate and resuspension rate. The net elemental iodine deposition rates at various drywell temperatures are calculated in Tables 1J and 1K for the MSIV failed line Volume V11 and intact line Volume V33, respectively.

Net Deposition Rate of Elemental Iodine $\lambda_e = \lambda_{ed} - \lambda_{er}$

$1/DF = 1 - \eta = exp^{(-\lambda e * t)}$ (Ref 10.2, Equations 4 and 5, page 196)

Where DF = decontamination factor

η = filter efficiency for elemental iodine

λe = elemental iodine removal rate (hr^{-1})

t = time (hr)

Therefore, Elemental Iodine Filter Efficiency = $\mathbf{1 - e^{-(\lambda e * t)}}$

The net elemental iodine deposition rates (λe) are obtained from Tables 1J and 1K and the corresponding filter efficiencies at various drywell temperatures are calculated in Tables 1L and 1M for the MSIV failed line Volume V11 and intact line Volume V33, respectively. The conservative values are used for each time step in RADTRAD model rather than using average values for each time step.

The elemental iodine removal efficiencies at various drywell temperatures are used along with aerosol removal efficiency (Section 7.4.1) in the RADTRAD3.02 MSIV release model.

7.5 ESF Leak Rates

The design basis ESF leakage is 2.85 gpm, which is doubled and converted into cfm as follows:
2.85 gallon/min × 2 × 1/7.481 ft^3/gallon = 0.762 cfm
10% of ESF leakage becomes airborne = 0.1 × 0.762 cfm = 7.62E-02 cfm

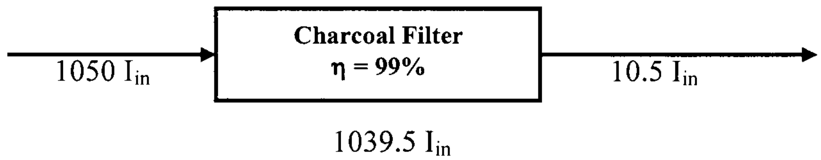
7.6 Post-LOCA CREF Filter Shine Dose

The post-LOCA CREF filter shine doses due to the containment, ESF, and MSIV leakages are calculated in the following sections

7.6.1 Iodine/Aerosol Deposition on CREF Charcoal/HEPA Filter – Containment Leakage:

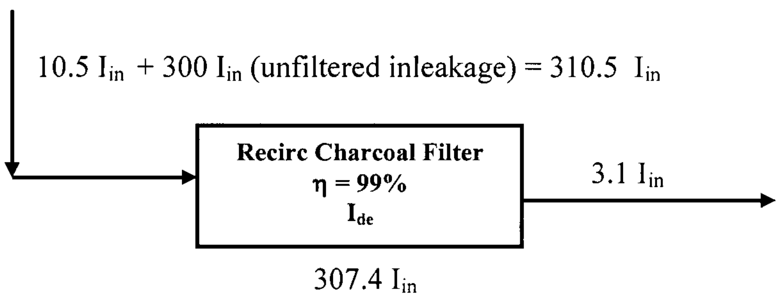
Iodine Activity Deposited On CREF Charcoal Filter:

As shown in Figure 5, the CR intake and recirculation charcoal filter elemental and iodine removal efficiency is 99% with the intake and recirculation flow rates of 1,050 cfm and 2,600 cfm, respectively.



Suppose Air Intake Iodine Activity (atoms) = I_{in} and Iodine Activity Deposited on Recirc Filter = I_{de}

Activity deposited on the intake charcoal filter = I_{in} x 0.99 x 1,050 cfm = 1039.5 I_{in}
Filtered inflow activity introduced into the CR = I_{in} x (1 – 0.99) x 1,050 cfm = 10.5 I_{in}



Activity deposited on recirc charcoal filter (conservatively assuming only one pass through the recirc charcoal filter) = I_{de} = 0.99 x (310.5 I_{in} cfm) = 307.4 I_{in} ; Rearranging: $I_{in} = I_{de}$ / 307.4

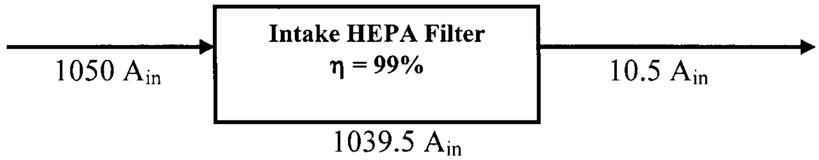
Therefore, the activity deposited on the intake charcoal filter = 1039.5 I_{in} = (1039.5/307.4) I_{de}

Total elemental and organic iodine activity deposited on intake + recirc charcoal filter
= (1039.5/307.4 I_{de}) + I_{de} = 4.38 I_{de}

I_{de} = 1.1742E+14 Atoms (Elemental Iodine) + 4.6921E+14 Atoms (Organic Iodine) (HEPU300CL00.o0, CR Recirculating Filter Nuclide Inventory @ 720 hrs)
= 5.8663E+14 Atoms
Total iodine activity deposited on the CR intake + recirc charcoal filter due to containment leakage
= 4.38 x 5.8663E+14 Atoms = 2.5694E+15 Atoms

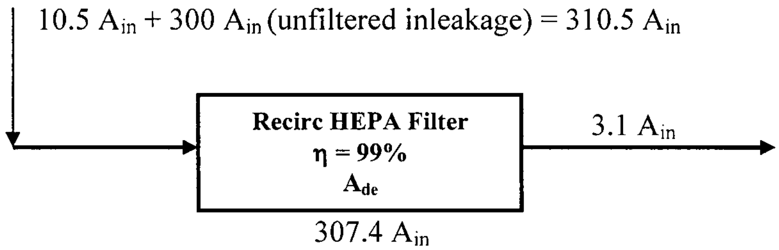
Aerosol Mass Deposited On CREF HEPA Filter:

As shown in Figure 5, the CR intake and recirculation HEPA filter aerosol removal efficiency is 99% for the intake and recirculation flow rates of 1,050 cfm and 2,600 cfm respectively.



Suppose aerosol mass in intake air = A_{in} and aerosol mass deposited on recirc filter = A_{de}

Aerosol mass deposited on HEPA filter = A_{in} x 0.99 x 1,050 cfm = 1039.5 A_{in}
Filtered inflow aerosol mass introduced into the CR = A_{in} x (1 – 0.99) x 1,050 cfm = 10.5 A_{in}



Aerosol mass deposited on recirc HEPA filter (conservatively assuming only one pass through the recirc HEPA filter) = A_{de} = 0.99 x (310.5 A_{in} cfm) = 307.4 A_{in} ;   Rearranging: $A_{in} = A_{de} / 307.4$

Therefore, the aerosol mass deposited on intake HEPA filter = 1039.5 A_{in}= (1039.5/307.4) A_{de}
Total aerosol mass deposited on intake + recirc HEPA filter
= (1039.5/307.4 A_{de}) + A_{de} = 4.38 A_{de}

A_{de} = 8.4925E-09 kg (HEPU300CL00.o0, CR Recirculating Filter Nuclide Inventory @ 720 hrs)
Total aerosol mass deposited on CR intake + recirc HEPA filter due to containment leakage
= 4.38 x 8.4925E-09 kg = 3.7197E-08 kg

7.6.2 Iodine/Aerosol Deposition on CREF Charcoal/HEPA Filter – ESF Leakage:

Iodine Activity Deposited On CREF Charcoal Filter:

As discussed in Section 7.6.1 above:

Total elemental and organic iodine activity (atoms) deposited on intake + recirc charcoal filter = 4.38 I_{de}

I_{de} = 6.4972E+16 Atoms (Elemental Iodine) + 2.0094E+15 Atoms (Organic Iodine) (HEPU300ES00.o0, CR Recirculating Filter Nuclide Inventory @ 720 hrs)
= 6.6981E+16 Atoms.
Total iodine atoms deposited on the CREF intake + recirc charcoal filter due to the ESF leakage
= 4.38 x 6.6981E+16Atoms = 2.9338E+17 Atoms

Aerosol Mass Deposited On CREF HEPA Filter:

Since post-LOCA ESF leakage consists of only a non-aerosol iodine release (97% of elemental iodine + 3% of organic iodine) (Ref. 10.1, Section 5.6), there is no aerosol deposited on the CREF intake + recirc HEPA filter (HEPU300ES00.o0, CR Compartment Nuclide Inventory @ 720 hrs).

7.6.3 Iodine/Aerosol Deposition on CREF Charcoal/HEPA Filter – MSIV Leakage:

Iodine Activity Deposited On CREF Charcoal Filter:

As discussed in Section 7.6.1 above:
Total elemental and organic iodine activity (atoms) deposited on intake + recirc charcoal filter = 4.38 I_{de}

I_{de} = 5.7277E+14 Atoms (Elemental Iodine) + 2.8004E+15 Atoms (Organic Iodine) (H1N300MS00.o0, CR Recirculating Filter Nuclide Inventory @ 720 hrs)
= 3.3732E+15 Atoms.
Total iodine atoms deposited on the CREF intake + recirc charcoal filter due to the MSIV leakage
= 4.38 x 3.3732E+15 Atoms = 1.4775E+16 Atoms

Aerosol Mass Deposited On CREF HEPA Filter:

As discussed in Section 7.6.1 above:
Total aerosol mass deposited on intake + recirc HEPA filter = 4.38 A_{de}

A_{de} = 2.2329E-08 kg (H1N300MS00.o0, CR Recirculating Filter Nuclide Inventory @ 720 hrs)
Total aerosol mass deposited on CREF intake + recirc HEPA filter due to the MSIV leakage
= 4.38 x 2.2329E-08 kg = 9.7801E-08 kg

7.6.3A Total Iodine/Aerosol Deposition on CREF Charcoal/HEPA Filter

Total iodine atoms deposited on the CREF charcoal
= Iodine atoms from containment leakage + Iodine atoms from ESF leakage + Iodine atoms from MSIV leakage

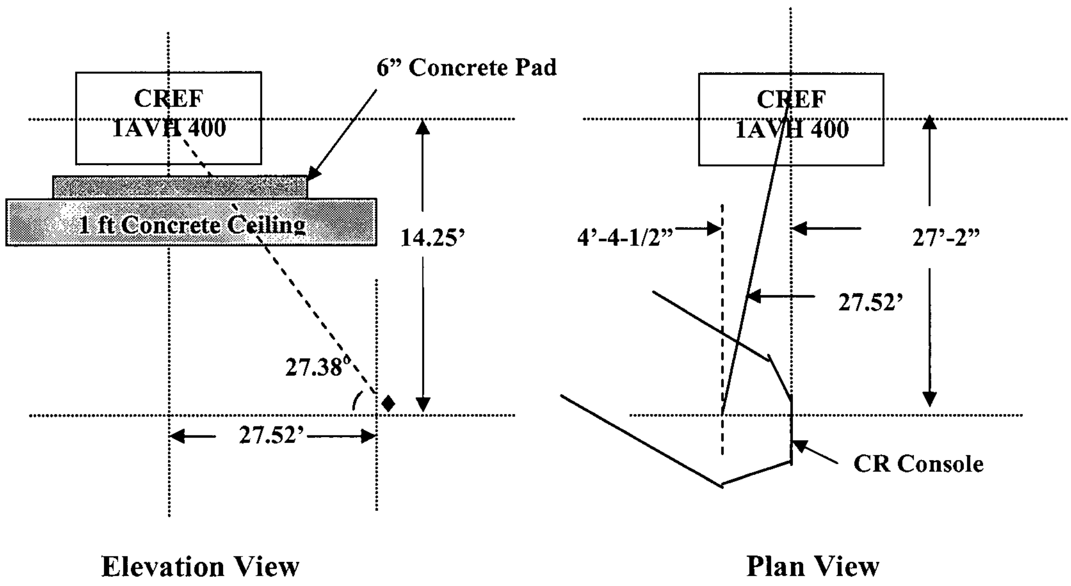
= 2.5694E+15 Atoms + 2.9338E+17 Atoms + 1.4775E+16 Atoms = 3.1072E+17 Atoms, which is used in Table 10 to obtain the total iodine isotopic activities on the CREF charcoal.

Total aerosol mass deposited on the CREF HEPA Filter
= Aerosol mass from containment leakage + Aerosol mass from ESF leakage + Aerosol mass from MSIV leakage

= 3.7197E-08 kg + 0.00 kg + 9.7801E-08 kg = 1.3500E-07 kg, which is used in Table 12 to obtain the total aerosol isotopic activities on the CREF HEPA Filter.

7.6.4 CREF Shielding Model

The CREF unit location with respect to the center line of CR console is measured from the full scale drawings and used to determine the slant distance and angle through the concrete ceiling as follows:



Horizontal distance = $[(27\text{'-}2\text{"})^2 + (4\text{'-}4\text{-}1/2\text{"})^2]^{1/2}$ = 27.52'
CREF center line elevation
= CR ceiling elevation + Thickness of concrete base + ½ CREF height [see Figure 6]
= 155'-3" (Ref. 10.39.c) + 6" (Ref. 10.39.c) + ½ (3'-0") =157'-3"
Vertical distance between CR operator and CREF unit
= 157'-3" – (137'-0" + 6'-0") = 157'-3" – 143'-0" = 14'-3" Assuming a 6 foot tall CR operator standing on the CR floor @ 137'-0".
Slant Distance = $[(14.25')^2 + (27.52')^2]^{1/2}$ = 30.99'
Slant Angle Through Concrete Ceiling = $\theta = \tan^{-1} (14.25/27.52) = 27.38^0$
Slant shielding thickness for 1'-6" concrete ceiling over the CR
= $1.5'/\sin 27.38^0 = 1.5'/0.46 = 3.26'$
The CR operator dose from the CREF shine dose is conservatively calculated using the concrete shielding of 3.0' and distance of 20' without taking the credit of shadow shielding of structure steel and equipment and CREF housing steel.

7.6.5 <u>CR Direct Dose From Filter Shine</u>

CR Filter Shine Dose Rate = 4.065E-02 mRem/hr (MicroShield Run HCCRFLT2.MS5)

CR Operator Exposure Time = 1 × (24 hr) + 0.60 (96 hr – 24 hr) + 0.40 (720 hr – 96 hr)
= 24 hr + 0.60 (72 hr) + 0.40 (624 hr) = 316.8 hr
Total CR Dose From Filter Shine
= 4.065E-02 mRem/hr × 1/1000 Rem/mRem × 316.8 hr = 1.29E-02 Rem

7.7 <u>FRVS Vent and Recirc. and CR Charcoal/HEPA Filters Efficiencies</u>

<u>HEPA Filter:</u>

In-place penetration testing acceptance criteria for the safety related HEPA filters are as follows:
FRVS Vent HEPA Filter – in-laboratory testing penetration < 0.05% (Ref. 10.6.1)
FRVS Recirc HEPA Filter – in-laboratory testing penetration < 0.05% (Ref. 10.6.10)

CREF HEPA Filter – in-laboratory testing penetration < 0.05% (Ref. 10.6.13)
GL 99-02 (Ref 10.3) requires a safety factor of at least 2 should be used to determine the filter efficiencies to be credited in the design basis accident.
Testing penetration (%) = (100% - η)/safety factor = (100% - η)/2
Where η = HEPA filter efficiency to be credited in the analysis
0.05% = (100% - η)/2
0.1% = (100% - η)
η = 100% - 0.1% = 99.9%
Conservatively, the HEPA filter efficiency of 99% is credited in the analysis

Charcoal Filter:

In-place penetration testing acceptance criteria for the safety related Charcoal filters are as follows:
CREF Recirculation Charcoal Filter – in- laboratory testing methyl iodide penetration < 0.5% (Ref. 10.6.14)
Testing methyl iodide penetration (%) = (100% - η)/safety factor = (100% - η)/2
Where η = CREF charcoal filter efficiency to be credited in the analysis
CFREF Charcoal Filter
0.5% = (100% - η)/2
1% = (100% - η)
η = 100% - 1% = 99%
FRVS Vent Charcoal Filter
Elemental Iodine η = 90% (Ref. 10.47)
Organic Iodine η = 90% (Ref. 10.47)

Safety Grade Filter	Filter Efficiency Credited (%)		
	Aerosol	Elemental	Organic
FRVS Vent	99	90	90
FRVS Recirc	99	0	0
Control Room	99	99	99

7.8 Isotopic Activities Released To Environment
The isotopic activities released to the environment at various post-LOCA time intervals are listed in Tables 14 through 18. These isotopic activities are obtained from the RADTRAD computer Runs HEPU300CL00.o0, HEPU300ES00.o0, and H1N300MS00.o0. This information is used in the MIDAS computer code to assess dose profile during a design basis accident for Emergency Planning.

7.9 Expected Higher Core Power Level
Current Licensed Power Level = 3,339 MW_t (Ref. 10.34)
Proposed Power Level Increase = 15%
Instrument Uncertainty = 2% (Ref. 10.10)
Expected Higher Core Power Level = 3,339 $MW_t \times 1.15 \times 1.02 \approx 3{,}917\ MW_t$

7.10 Drywell Wetted Surface Area

The drywell surface area is calculated in Reference 10.24. The use of a smaller wetted surface is conservative because it results in a smaller elemental removal coefficient and it takes a longer time to reach an elemental iodine decontamination factor (DF) of 200, which allows the elemental iodine to remain airborne in the drywell atmosphere for release to the atmosphere via containment and MSIV leakage.

Total drywell surface area = 152,261 ft^2 excluding the RPV surface area (Ref. 10.24, page 15)

The surface areas below the drywell spray ring are subject to be wetted in the spray solution, which are listed as follows based on areas presented in Ref. 10.24, page 15. The drywell wetted surface area is conservatively minimized as discussed in Section 2.1.3:

Estimated 25% of drywell lining surface	= 4,463 ft^2 (17,850 ft^2 /4 = 4,463 ft^2)
Downcomer (to water level)	= 3,168 ft^2
Vent header and line	= 9,727 ft^2
Suppression chamber (to water level)	= 15,408 ft^2
Estimated 50% of major equipment	= 5,306 ft^2 (10,612 ft^2 /2 = 5,306 ft^2)
Estimated 50% of structures	= 6,181 ft^2 (12,361 ft^2 /2 = 6,181 ft^2)
Total estimated wetted drywell surface area	= 44,253 ft^2 (69,126 ft^2 without reductions)
75% of total estimated wetted drywell surface area	≈ 33,200 ft^2 (0.75 x 44,253 ft^2)

7.11 Containment Elemental Iodine Removal Coefficient

Natural deposition on containment surfaces (plateout) of the elemental iodine released to containment is calculated using the methodology outlined in NUREG-0800, Standard Review Plan 6.5.2 (Ref. 10.41, page 6.5.2-10) as follows:

The equation for the elemental iodine removal by adsorption on wetted surface area is:

$\lambda_W = K_W \times A/V$

Where:

λ_W = first order removal coefficient by wall deposition
K_W = mass transfer coefficient = 4.9 m/hr (Ref. 10.41, page 6.5.2-10)
A = wetted surface area = 33,200 ft^2 (Section 7.7)
V = drywell net free air volume = 1.69E+05 ft^3 for < 2.0 hrs and 3.06E+05 ft^3 for > 2.0 hrs

Elemental iodine removal coefficient for < 2.0 hrs
$\lambda_W = K_W \times A/V$ = 4.9 m/hr x (3.2808 ft/m) (33,200 ft^2) / (1.69E+05 ft^3) = 3.16 hr^{-1}

Elemental iodine removal coefficient for > 2.0 hrs
$\lambda_W = K_W \times A/V$ = 4.9 m/hr x (3.2808 ft/m) (33,200 ft^2) / (3.06E+05 ft^3) = 1.74 hr^{-1}

Maximum DF of elemental iodine = 200

The containment leakage case is analyzed in RADTRAD Run CUTOFF.o0 using the above calculated elemental iodine removal coefficients along with the information in Table 9 to determine the cutoff time for terminating elemental iodine removal from the containment atmosphere, which is 4.03 hrs (CUTOFF.o0). The cutoff time of 4.0 hrs is used in the containment and MSIV leakage path releases to the atmosphere.

8.0 RESULTS SUMMARY

The results of AST analyses are summarized in the following sections:

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

Post-LOCA Activity Release Path	**Post-LOCA TEDE Dose (Rem)**		
	Receptor Location		
	Control Room	**EAB**	**LPZ**
Containment Leakage	5.37E-01	3.87E-01 (3.1 hr)	1.47E-01
ESF Leakage	2.88E+00	5.22E-01 (14.2 hr)	2.64E-01
MSIV Leakage	6.13E-01	8.68E-01 (3.0 hr)	2.63E-01
Containment Purge	0.00E+00	0.00E+00	0.00E+00
Containment Shine	0.00E+00	0.00E+00	0.00E+00
External Cloud	0.00E+00	0.00E+00	0.00E+00
CR Filter Shine	1.29E-02	0.00E+00	0.00E+00
Total	**4.04E+00**	**1.78E+00**	**6.74E-01**
Allowable TEDE Limit	**5.0 E+00**	**2.50E+01**	**2.50E+01**
	RADTRAD Computer Run No.		
Containment Leakage	HEPU300CL00.o0	HEPU300CL00.o0	HEPU300CL00.o0
ESF Leakage	HEPU300ES00.o0	HEPU300ES00.o0	HEPU300ES00.o0
MSIV Leakage	H1N300MS00.o0	H1N300MS00.o0	H1N300MS00.o0

8.2 COMPLIANCE OF REVISED DOSES WITH THE 10 CFR 50.59 RULE IS SHOWN IN THE FOLLOWING TABLE:

Design Basis Accident	Current Total Dose (rem) TEDE A	Proposed Total Dose (rem) TEDE B	Regulatory Dose Limit (rem) TEDE C	Proposed Dose Increase (rem) TEDE D=B-A	Minimal Dose Increase Per 10CFR50.59 (rem) TEDE E=0.1(C-A)	SRP Dose Limit (rem) TEDE F
Loss of Coolant Accident (LOCA)	H-1-ZZ-MDC-1880, Rev 3	H-1-ZZ-MDC-1880, Rev 4				
Control Room	4.17	4.04	5	-0.13	0.083	5
Exclusion Area Boundary	1.43	1.78	25	0.35	2.35	25
Low Population Zone	0.548	0.674	25	0.13	2.44	25

C From 10 CFR 50.67 (Ref. 10.4)
F From Standard Review Plan 15.0.1, Section II (Ref. 10.18)

8.3 Dose Impact Due to Changes in Input Parameters and Methodology in Revisions 2, 3, and 4

This calculation determines control room, EAB, and LPZ doses due to post LOCA radioactivity releases from containment via three release pathways, i.e., containment leakage, ESF leakage, and MSIV leakage. Changes in input parameters and methodology that affect the quantity of radioactivity released via a pathway or that affect the quantity of radioactivity that reaches a dose location have an impact on calculated doses. Changes incorporated into Revisions 3 and 4 of this calculation that are expected to have significant dose impacts are:

1) the increase in ESF leakage from 1 gpm to 2.85 gpm (Table 1E, Item IV-1),
2) the change in MSIV leakage volumetric flow rate after converting the volumetric flow rate from measured values at standard temperature and pressure conditions to drywell post LOCA atmospheric conditions (Table 1E, Item V-3),
3) changing the MSIV release pathway along the failed and intact main steam lines from two well mixed volumes from both the failed and intact main steam lines to one well mixed volume for both the failed and intact main steam lines (Table 1E, Items V-4 and V-5),
4) crediting removal of elemental iodine via wall deposition on wetted containment surfaces (Table 1E, Item I-2),
5) changes to containment air dilution volume, i.e., changing from instantaneous mixing of containment airborne activity in the drywell and suppression chamber air volume to drywell mixing only for the first 2 hours and then mixing in the drywell and suppression chamber air volumes instantaneously at 2 hours (Table 1E, Item I-1),
6) not crediting a reduction in containment atmosphere pressure for a reduction in containment and MSIV leakage after 24 hours (Table 1E, Items III-1 and V-1), and
7) reduction in the control room unfiltered inleakage from 350 cfm to 300 cfm (Table 1E, Item II-1).

Revisions 2 and 4 of this calculation used the J. E. Cline model for calculating natural removal of elemental iodine from the main steam line compartment volumes. Revision 3 of this calculation applies a decontamination factor of 2 to account for natural removal of elemental iodine from each main steam line compartment volume. The factor of 2 decontamination factor is from Appendix B of AEB-98-03.

Application of the J. E. Cline model results in larger elemental iodine releases for the first 6 hours post LOCA than would be attained by applying a decontamination factor of 2 (Refer to Tables 1L and 1M). Application of a decontamination factor of 2 for post LOCA times greater than 6 hours would result in larger elemental iodine releases from the main steam line compartment volumes than would be attained using the J. E. Cline model. Credit for elemental iodine removal from main steam line pipe compartment volumes is terminated for post LOCA times greater than 96 hours in Revisions 3 and 4. Use of the J. E. Cline model for calculating EAB doses due to MSIV leakage, as opposed to using the decontamination factor of 2 approach, will result in larger EAB doses since the EAB dose is limited to the first few hours post LOCA. Application of the J. E. Cline model is therefore conservative with respect to calculation of EAB doses due to MSIV leakage. Use of the J. E. Cline model for calculating the 30 day post LOCA control room and LPZ doses due to MSIV leakage, as opposed to using the decontamination factor of 2 approach, is expected to be slightly nonconservative with respect to the dose contribution attributed to MSIV leakage, but the differences in doses obtained using the 2 different models are expected to be small. The following is a comparison of the dose contributions in Revisions 2, 3, and 4 to the control room, the EAB, and the LPZ doses from the three release pathways and an assessment of the impact that changes in input parameters and changes in methodology have on control room, EAB, and LPZ doses for the three release pathways.

Comparison of Revision 2, 3, and 4 Doses					
		Post LOCA TEDE Dose (Rem)			
		Containment Leakage	ESF Leakage	MSIV Leakage	Total Dose (1)
Control Room	Revision 2	1.01E+00	1.17E+00	1.97E+00	4.16E+00
	Revision 3	4.79E-01	3.33E+00	3.31E-01	4.17E+00
	Revision 4	5.37E-01	2.88E+00	6.13E-01	4.04E+00
EAB	Revision 2	4.25E-01	1.80E-01	2.49E+00	3.10E+00
	Revision 3	3.87E-01	5.22E-01	5.01E-01	1.43E+00
	Revision 4	3.87E-01	5.22E-01	8.68E-01	1.78E+00
LPZ	Revision 2	1.69E-01	9.19E-02	4.35E-01	6.96E-01
	Revision 3	1.31E-01	2.64E-01	1.51E-01	5.48E-01
	Revision 4	1.47E-01	2.64E-01	2.63E-01	6.74E-01

(1) In addition to the dose contributions from the three release pathways (i.e., containment leakage, ESF leakage, and MSIV leakage) the control room dose includes a dose contribution due to shine from the control room filter. The contribution from the control room filter to the control room dose is 1.03E-02 rem, 1.26E-02 rem, and 1.29E-02 rem for Revisions 2, 3, and 4, respectively.

<u>ESF Leakage Release Pathway</u>

Revision 2 to Revision 3

The only input parameter that changed between Revision 2 and Revision 3 and that impacts the doses due to releases from this release pathway is the ESF leak rate that was changed from 1 gpm to 2.85 gpm. Doses at the EAB, the LPZ, and in the control room are expected to increase in direct proportion to the increase in ESF leak rate (i.e., to increase by the ratio of 2.85/1). The doses calculated in Revision 2 from the ESF leakage pathway are 1.17, 0.180, and 0.0919 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 3 are 3.33, 0.522, and 0.264 rem. A comparison of the dose results from Revision 3 to dose results of Revision 2 indicates that the doses do increase in direct proportion to the ESF leak rate.

Revision 3 to Revision 4
The input parameter that changed between Revision 3 and Revision 4 which impacts the doses due to releases from this release pathway is the control room unfiltered inleakage rate which was reduced from 350 cfm to 300 cfm. The ESF leakage rate remains at 2.85 gpm. A reduction in the control room unfiltered inleakage rate results in a smaller dose to the control room, but does not affect the EAB or LPZ doses due to releases via the ESF leakage pathway. Section 7.6.1 of this calculation shows that the unfiltered inleakage accounts for over 95% of the radioactivity that gets into the control room. As such, the control room dose is nearly directly proportional to the unfiltered inleakage rate and the control room dose impact associated with reducing the control room unfiltered inleakage rate from 350 cfm to 300 cfm is expected to result in a control room dose reduction of approximately 14% (i.e., 50 cfm/350 cfm). The doses calculated in Revision 3 from the ESF leakage pathway are 3.33, 0.522, and 0.264 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 4 are 2.88, 0.522, and 0.264 rem. A comparison of the dose results from Revision 4 to dose results of Revision 3 indicates that the EAB and LPZ doses remain unchanged from the doses calculated in Revision 3 and the control room dose is reduced by 0.45 rem (i.e., 3.33 – 2.88) which is approximately 14% (i.e., 100 x 0.45/3.33).

Revision 2 to Revision 4
The input parameters that changed between Revision 2 and Revision 4 which impact the doses due to releases from this release pathway are the ESF leak rate which changed from 1 gpm in Revision 2 to 2.85 gpm in Revision 4 and the control room unfiltered inleakage rate which was reduced from 350 cfm in Revision 2 to 300 cfm in Revision 4. EAB and LPZ doses are expected to increase in direct proportion to the increase in ESF leak rate. The reduction in the control room unfiltered inleakage rate reduces the effect of the increase in ESF leak rate on the control room dose. As previously indicated, unfiltered inleakage accounts for the majority of the dose to the control room. The combined impact of an increase in the ESF leak rate and a reduction in the control room unfiltered inleakage rate on the control room doses is proportional to the product of the ratio of the ESF leak rates (i.e., 2.85/1) and the ratio of the control room unfiltered rate (i.e., 300/350). The doses calculated in Revision 2 from the ESF leakage pathway are 1.17, 0.18, and 0.0919 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 4 are 2.88, 0.522, and 0.264 rem. A comparison of the dose results from Revision 4 to dose results of Revision 3 indicates that the EAB and LPZ doses increase in direct proportion to the ESF leak rate and the control room dose increases in proportion to the product of (2.85/1) x (300/350).

<u>Containment Leakage Release Pathway</u>

Revision 2 to Revision 3
The input parameters that changed between Revision 2 and Revision 3 which impact the doses due to releases from this release pathway are changes in the containment air dilution volume and credit for plateout of elemental iodine on wetted containment surfaces. In Revision 2, activity released into containment is immediately mixed within the drywell and suppression chamber air volumes (306000 ft^3). In Revision 3, activity released into containment during the first 2 hours of the LOCA is mixed within the drywell air volume (169000 ft^3). After 2 hours airborne activity is mixed within the drywell and suppression chamber air volumes. Limiting the dilution volume for containment airborne sources to the drywell air volume for the first 2 hours, increases the concentration of airborne radioactivity within the drywell air which increases the amount of activity released into the environment. Therefore, changes in the containment air dilution volume result in increased dose contributions for the first 2 hours

following the LOCA. Credit for plateout of elemental iodine on wetted containment surfaces reduces the amount of airborne activity in containment atmosphere that is available for release which reduces the amount of activity released to the environment. Elemental iodine is removed from containment atmosphere onto containment wetted surfaces until a decontamination factor of 200 is reached which occurs at approximately 4 hours into the LOCA. The reduction in EAB, LPZ and control room doses associated with the reduction in containment airborne activity due to elemental iodine removal via plateout on containment wetted surfaces is larger than the increase in doses associated with increased radioactivity releases during the first 2 hours due to limiting airborne activity to the drywell volume. The overall effect is a reduction in control room, EAB, and LPZ doses. The doses calculated in Revision 2 from the containment leakage pathway are 1.01, 0.425, and 0.169 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 3 are 0.479, 0.387, and 0.131 rem. A comparison of the dose results from Revision 3 to dose results of Revision 2 indicates that the control room, EAB, and LPZ doses all decrease.

Revision 3 to Revision 4
The input parameters that changed between Revision 3 and Revision 4 which impact the doses due to releases from this release pathway are the control room unfiltered inleakage rate which was reduced from 350 cfm to 300 cfm, and in Revision 4 the containment leak rate was held constant during the course of the accident whereas in Revision 3, the containment leak rate was reduced by a factor of 2 at 24 hours. Since the containment leak rate is not reduced by a factor of 2 at 24 hours more activity is leaked from the containment building after 24 hours and so the dose contributions from containment leakage after 24 hours would increase for Revision 4. Since the EAB dose is acquired within the first few hours following the LOCA, there is not expected to be a significant change to the EAB dose in Revisions 4 from the dose in Revision 3. This is observed by comparing the dose results between Revision 3 and Revision 4. Specifically, the EAB dose (0.387 Rem) which is acquired within 24 hours is the same for Revisions 3 and 4. The control room and LPZ doses calculated in Revision 3 from the containment leakage pathway are 0.479 and 0.131 rem, respectively. The corresponding doses in Revision 4 are 0.537 and 0.147 rem. The control room and LPZ doses in Revision 4 are larger than the doses in Revision 3 by approximately 12%. This increase is attributed to the additional release of activity from containment atmosphere after 24 hours since a containment leak rate reduction factor of 2 was not applied to Revision 4. The increase in the control room dose is slightly smaller than the increase in the LPZ dose which is attributed to a reduction in the control room unfiltered inleakage.

Revision 2 to Revision 4
The input parameters that changed between Revision 2 and Revision 4 which impact the doses due to releases from this release pathway are changes in the containment air dilution volume, credit for plateout of elemental iodine on wetted containment surfaces, changes in the control room unfiltered inleakage rate which was reduced from 350 cfm to 300 cfm and changes in the containment leak rate. In Revision 4 the containment leak rate was held constant during the course of the accident whereas in Revision 2 the containment leak rate was reduced by a factor of 2 at 24 hours. In Revision 2, activity released into containment is immediately mixed within the drywell and suppression chamber air volumes whereas in Revision 4 radioactivity released in the containment is confined to the drywell air volume for the first 2 hours and after 2 hours airborne activity is mixed within the drywell and suppression chamber air volumes. Changes in the containment air dilution volume and the containment leak rate increase radioactivity releases via the containment leakage pathway in Revision 4 while crediting for elemental iodine plateout on wetted containment surfaces reduce radioactivity releases via this leakage pathway. The reduction in the control room unfiltered inleakage rate in Revision 4 reduces the amount of radioactivity that enters the control room. The doses calculated in Revision 2 from the containment leakage pathway are 1.01, 0.425, and 0.169 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 4 are 0.537, 0.387, and 0.147 rem. The effect of the

changes made in Revision 4 on the doses at the EAB, LPZ and control room are dominated by the reduction in radioactivity releases due to plateout of elemental iodine on containment wetted surfaces. The combined effect of the changes is a reduction in the EAB, the LPZ, and the control room doses. The control room dose is reduced the most in Revision 4 because the reduction in unfiltered inleakage reduces the amount of radioactivity that enters the control room compared to Revision 2.

MSIV Leakage Release Pathway

Revision 2 to Revision 3

Changes between Revision 2 and Revision 3 which are expected to have significant impact on doses due to releases from this pathway include changes in the MSIV leakage volumetric flow rates, changes in the number of main steam line compartment volumes considered in both the failed and intact main steam lines, use of plug flow model with credit for holdup in Revision 2 versus a well mixed flow model with no credit for holdup in Revision 3, differences in determination of pipe surface area for aerosol deposition, and taking credit for elemental iodine plateout on containment wetted surfaces. The MSIV leakage volumetric flow rate in Revision 2 is the measured flow rate at standard temperature and pressure conditions whereas the MSIV leakage volumetric flow in Revision 3 is the standard measured volumetric flow rate adjusted for containment post LOCA temperature and pressure conditions. It is indicated in Section 7.2 of this calculation that the volumetric flow rate at post LOCA temperature and pressure conditions is approximately a third of the measured volumetric flow rate at standard temperature and pressure conditions for the first 2 hours post LOCA and a fifth of measured volumetric flow rates thereafter. The amount of radioactivity released through the MSIV pathway is directly proportional to the volumetric flow rate and therefore the change in determination of volumetric flow rate in Revision 3 is expected to result in the greatest change in doses and result in dose reductions by approximately a factor of 3. The failed and intact main steam lines in Revision 2 are each treated as a single pipe volume for determining aerosol deposition and elemental iodine removal. In Revision 3 the failed and intact main steam lines are both modeled as two separate compartment volumes in series for calculating aerosol deposition and elemental iodine removal. The use of two pipe volumes in series compounds the removal efficiency for aerosols and elemental iodine. Use of two pipe volumes in series as opposed to one, is expected to result in the second greatest reduction in Revision 3 doses via the MSIV release pathway. All of the identified changes between Revision 2 and Revision 3 cause a reduction in radioactivity releases via the MSIV leakage release pathway and thus a reduction in doses. Changes in volumetric flow rate and number of pipe volumes dominate dose impacts and the other changes made between Revision 2 and Revision 3 have secondary effects on doses. The doses calculated in Revision 2 from the MSIV leakage pathway are 1.97, 2.49, and 0.435 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 3 are 0.331, 0.501, and 0.151 rem. A comparison of the dose results from Revision 2 to Revision 3 indicates that the control room dose was reduced by approximately a factor of 6, the EAB dose was reduced by approximately a factor of 5 and the LPZ dose was reduced by approximately a factor of 3.

Revision 3 to Revision 4

Changes between Revision 3 and Revision 4 which impact the doses due to releases from this release pathway are changes in the control room unfiltered inleakage rate which was reduced from 350 cfm to 300 cfm, changes in the containment leak rate, and changes in the number of main steam line compartment volumes considered in both the failed and intact main steam lines. The failed and intact main steam lines were each modeled as a single compartment volume in Revision 4 whereas they were modeled as two compartment volumes in series for each the failed and intact main steam line for Revision 3. In Revision 4 the MSIV leak rate was held constant during the course of the accident whereas in Revision 3 the MSIV leak rate was reduced by a factor of 2 at 24 hours. The reduction in control room unfiltered inleakage in Revision 4 reduces the amount of activity that enters the control room and thus it reduces the control room dose. The unfiltered inleakage accounts for over 95% of the radioactivity that gets into the control room. As such, the control room dose is nearly directly proportional to the unfiltered inleakage rate and the control room dose impact associated with reducing the control room unfiltered inleakage rate from 350 cfm to 300 cfm is expected to result in a control room dose reduction of approximately 14% (i.e., 50 cfm/350 cfm). The remaining changes that were made in Revision 4 result in greater radioactivity releases via the MSIV leakage pathway and therefore larger doses to the control room, to the EAB, and to the LPZ, than the doses of Revision 3. The doses calculated in Revision 3 for the MSIV leakage pathway are 0.331, 0.501, and 0.151 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 4 are 0.613, 0.868, and 0.263 rem. A comparison of the dose results from Revision 3 to Revision 4 indicate that the overall increase in the control room dose is approximately 80% (from 0.331 Rem to 0.613 Rem). The EAB and LPZ doses increased by approximately 73% and 74%, respectively.

Revision 2 to Revision 4

Changes between Revision 2 and Revision 4 which are expected to result in significant reductions in doses due to releases from this pathway include changes in the MSIV leakage volumetric flow rates, credit for removal of elemental iodine from containment atmosphere onto wetted containment surfaces, and changes in the control room unfiltered inleakage rate which was reduced from 350 cfm to 300 cfm. The MSIV leakage volumetric flow rate in Revision 2 is the measured flow rate at standard temperature and pressure conditions whereas the MSIV leakage volumetric flow in Revision 3 is the standard measured volumetric flow rate adjusted for containment post LOCA temperature and pressure conditions. As indicated in the discussion for differences between Revision 2 and 3 for this release pathway, the change in determination of volumetric flow rate in Revision 4 is expected to result in dose reductions by approximately a factor of 3. The reduction in control room unfiltered inleakage in Revision 4 reduces the amount of activity that enters the control room and thus it reduces the control room dose by approximately 14% as indicated in the discussion of differences between Revision 3 and Revision 4 for this release pathway. Changes between Revision 2 and Revision 4 which are expected to result in significant increases in control room, EAB, and LPZ doses due to releases from this pathway include changes in MSIV leak rate. In Revision 4 the MSIV leak rate is held constant during the course of the accident whereas in Revision 2 the MSIV leak rate was reduced by a factor of 2 at 24 hours. The change in the MSIV leak rate results in larger doses in Revision 4 for the LPZ (which receives dose contributions during the entire accident) but it will not affect the EAB dose which is limited to a few hours after the accident. The doses calculated in Revision 2 from the MSIV leakage pathway are 1.97, 2.49, and 0.435 rem for the control room, the EAB, and the LPZ, respectively. The corresponding doses in Revision 4 are 0.613, 0.868, and 0.263 rem. A comparison of the dose results from Revision 2 to Revision 4 indicates that the control room dose was reduced by slightly more than a factor of 3, the EAB dose was reduced by slightly less than a factor of 3, and the LPZ dose was reduced by less than a factor of 2. The dose reduction in Revision 4 is dominated by the change in determination of volumetric flow rate. The larger reduction in the control room dose compared to the LPZ dose is attributed primarily to reduced unfiltered inleakage into the control room.

Impact of Changes on Combined Doses from All Release Pathways

Revision 2 to Revision 3

A comparison of the Revision 3 control room, EAB, and LPZ doses for the ESF leakage pathway to the Revision 2 doses indicates that the doses increase significantly in Revision 3. The increase in doses is approximately a factor of 2.85 and is directly proportional to the increase in ESF leakage which is increased from 1 gpm to 2.85 gpm. The increase in control room doses due to ESF leakage (i.e., an increase of 2.16 rem (3.33 – 1.17) to the control room) is offset by the reduction in doses from the containment leakage pathway (i.e., 0.531 rem (1.01 – 0.479)) and MSIV leakage pathway (i.e., 1.639

rem (1.97 – 0.331)). The reduction in the control room, EAB, and LPZ doses in the containment leakage pathway is primarily attributed to crediting for reduction in airborne elemental iodine from the containment atmosphere due to plateout on wetted containment surfaces. The reduction in the control room, EAB, and LPZ doses due to releases via the MSIV leakage pathway is primarily attributed to using post LOCA drywell temperature and pressure to determine MSIV volumetric flow rate instead of using the volumetric flow rate associated with standard temperature and pressure conditions. Determining MSIV releases using volumetric flow rates based on post LOCA drywell temperature and pressure conditions reduces the doses by approximately a factor of 3. Other contributors to the reduction in doses via the MSIV leakage pathway are the reduction in airborne elemental iodine from the containment atmosphere due to plateout on wetted containment surfaces and the use of two compartment volumes in series on both the failed and intact main steam lines for Revision 3. In Revision 2, only one compartment volume was used for each of the failed and intact main steam lines.

Revision 2 to Revision 4
A comparison of the Revision 4 control room, EAB, and LPZ doses for the ESF leakage pathway to the Revision 2 doses indicates that the doses increase significantly in Revision 4. The increase in EAB and LPZ doses is approximately a factor of 2.85 and is directly proportional to the increase in ESF leakage which is increased from 1 gpm to 2.85 gpm. The increase in the control room dose is less than a factor of 2.85 (i.e., an increase by a factor of 2.46 (2.88/1.17)) and is attributed to a reduction in the control room unfiltered inleakage rate from 350 cfm to 300 cfm in Revision 4. The increase in doses due to ESF leakage (i.e., an increase of 1.71 rem (2.88 – 1.17) to the control room) is offset by the reduction in doses from the containment leakage pathway (i.e., 0.473 rem (1.01 – 0.537)) and MSIV leakage pathway (i.e., 1.357 rem (1.97 – 0.613)). The reduction in the control room, EAB, and LPZ doses in the containment leakage pathway is primarily attributed to crediting for reduction in airborne elemental iodine from the containment atmosphere due to plateout on wetted containment surfaces. The reduction in Revision 4 containment leakage pathway doses compared to Revision 2 doses is not as great as the reduction attained in Revision 3 containment leakage pathway doses compared to Revision 2 doses because Revision 4 doesn't credit a 50% reduction in containment leakage (at 24 hours or any other time post LOCA) due to reduced containment pressure. The reduction in the control room, EAB, and LPZ doses due to releases via the MSIV leakage pathway is primarily attributed to using post LOCA drywell temperature and pressure to determine MSIV volumetric flow rate instead of using the volumetric flow rate associated with standard temperature and pressure conditions. Determining MSIV releases using volumetric flow rates based on drywell post LOCA temperature and pressure conditions reduces the doses by approximately a factor of 3. Another contributor to the reduction in doses via the MSIV leakage pathway is the reduction in airborne elemental iodine from the containment atmosphere due to plateout on wetted containment surfaces. Note, Revision 4 modeled a single compartment volume for both the failed and intact main steam lines. Revision 2 also used single compartment volumes and so there was no dose reduction due to use of two compartment volumes in series as there was for Revision 3. The compounding effect that two main steam line volume compartments in series have on aerosol deposition and elemental iodine removal account for the much smaller control room, EAB, and LPZ doses seen in Revision 3 for the MSIV pathway releases.

9.0 CONCLUSIONS

The Section 8.1 results, indicate that the EAB, LPZ, and CR doses are within their allowable TEDE limits for the increased ESF leakage rate up to 2.85 gpm and the updated MSIV leakage model.

The comparisons in Section 8.2 show that the CR, EAB and LPZ total calculated doses are less than previously calculated values.

10.0 REFERENCES

10.1 U.S. NRC Regulatory Guide 1.183, Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors, July 2000.

10.2 S.L. Humphreys et al., "RADTRAD V3.02: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation," NUREG/CR-6604, USNRC, April 1998.

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

10.4 10 CFR 50.67, "Accident Source Term."

10.5 Calculation No. H-1-ZZ-MDC-1879, Rev 1, Control Room & Technical Support Center χ/Qs Using ARCON96 Code.

10.6 HCGS Technical Specifications:

10.6.1 Specification 4.6.5.3.1.c.1, FRVS Vent HEPA Filter Testing Criterion

10.6.2 Specification 3/4.6.6 Primary Containment Atmosphere Control

10.6.3 Specification 4.6.5.3.1.c.3, FRVS Vent HEPA/Charcoal Filter Flow Rate Testing Criterion

10.6.4 Specification 6.8.4.f, Primary Containment Leak Rate Testing Program

10.6.5 Bases 3/4.6.2, Depressurization Systems

10.6.6 Specification 5.2.1, Containment Configuration

10.6.7 Specification 5.2.3, Secondary Containment

10.6.8 Specification 4.6.5.1, Secondary Containment Integrity

10.6.9 Specification 1.35, Rated Thermal Power.

10.6.10 Specification 4.6.5.3.2.c.1, FRVS Recirc HEPA Filter Testing Criterion

10.6.11 Not Used.

10.6.12 Specification 4.6.5.3.2.c.3, FRVS Recirc HEPA/Charcoal Filter Flow Rate Testing Criterion

10.6.13 Specification 4.7.2.1.c.1, Control Room Emergency Filtration System Surveillance Requirements

10.6.14 Specification 4.7.2.1.c.2, Control Room Emergency Filtration System Surveillance Requirements

10.6.15 Specification 4.7.2.1.c.3, Control Room Emergency Filtration System Surveillance Requirements

10.6.16 Specification 4.7.2.1.e.3, Control Room Emergency Filtration System Surveillance Requirements

10.6.17 Specification 3.6.1.2.c, Primary Containment Leakage Limiting Condition For Operation

10.6.18 Specification 3.6.1.8, Drywell and Suppression Chamber Purge System

10.7 Federal Guidance Report 11, EPA-520/1-88-020, Environmental Protection Agency.

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

10.9 MicroShield Computer Code, V&V Version 5.05, Grove Engineering and A-0-ZZ-MCS-0209, Sheet 1, Rev 0, MicroShield 5.05.

10.10 U.S. NRC Regulatory Guide 1.49, Rev 1, Power Levels of Nuclear Power Plants.

10.11 Drawing No. 1-P-AB-01, Rev 18, System Isometric / Turbine Building Main Steam Lead.

10.12 Fabrication Isometric Main Steam Lead – Turbine Building Unit #1 Drawings:

10.12.a 1-P-AB-001, Rev 11

10.12.b 1-P-AB-002, Rev 9

10.12.c 1-P-AB-003, Rev 9

10.12.d 1-P-AB-004, Rev 9

10.12.e 1-P-AB-011, Rev 11

10.12.f 1-P-AB-01, Rev 18

10.13 Piping Area Drawings:

10.13.a P-1703-1, Rev 3, Reactor Building Area 17, Plan EL 100'-2"

10.13.b P-1704-1, Rev 2, Reactor Building Area 17, Plan EL 112'-0"

10.13.c P-1705-1, Rev 2, Reactor Building Area 17, Plan EL 121'-7-1/2"

10.13.d P-1712-1, Rev 2, Reactor Building Area 17, Section B17 – B17

10.13.e P-1713-1, Rev 4, Reactor Building Area 17, Section C17 – C17

10.13.f P-1403-1, Rev 2, Reactor Building Area 14, Plan At EL 102'-0"

10.13.g P-1414-1, Rev 1, Reactor Building Area 14, Section D14 – D14

10.13.h P-1304-1, Rev 4, Piping Area Drawing, Reactor Building Area 13, Plan at El. 132'-0" & El. 145'

10.13.i P-1711-1, Rev 2, Reactor Building Area 17, Section A17 – A17

10.14 Piping Class Sheet Drawing No. 10855-P-0500:

10.14.a Sheet 16, Rev 9, Class DBB

10.14.b Sheet 17, Rev 7, Class DBC

10.14.c Sheet 24, Rev 7, Class DLA

10.15 GE-NE-T2300759-00-02, HCGS Containment Analysis With 100 ^{0}F SACS Temperature, September 1998 (VTD 323835, Sheet 2, Rev 1).

10.16 Calculation No. 12-0025, Rev 3, "Drywell Volume & Torus Air & Water Volumes."

10.17 Vendor Technical Document (VTD) No. 430024, Volume 002, EPU TR T0400 – Containment System Response.

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

10.19 Calculation No. GU-0013, Rev. 4, Filtration Recirculation and Ventilation System Exhaust Rate

10.20 GE-Hitachi Report NEDC-33529P, "Safety Analysis Report to Support Introduction of GE 14i Isotope Test Assemblies (ITAs) in Hope Creek Generating Station," Revision 0, December 2009.

10.21 Main Steam Isometric Drawings:

10.21.a. FSK-P-214, Rev 14, Main Steam A & B Inside Drywell

10.21.b. FSK-P-215, Rev 15, Main Steam C & D Inside Drywell

10.22 NRC Report AEB-98-03, " Assessment of Radiological Consequences For the Perry Pilot Plant Application Using the Revised (NUREG-1465) Source Term.

10.23 U.S. NRC Regulatory Guide 1.197, Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors, May 2003.

10.24 Hope Creek Calculation No. 12-102(Q), Rev 0, Surface Area Inside Drywell

10.25 Calculation No. No. H-1-ZZ-MDC-0364, Rev 1, Drywell Temperature After Recirculation Line Break.

10.26 EQE International, Inc., Report No. 200235-R-01, November 12, 1998, Hope Creek Nuclear Plant Main Steam Isolation System Alternate Leakage Treatment Pathway Seismic Evaluation.

10.27 General Arrangement Drawings:

10.27.a P-0006-0, Rev 7, Plan EL 153'-0" & 162'-0"

10.27.b P-0011-0, Rev 5, Sections C-C & D-D

10.28 Equipment Location Drawings:

10.28.a P-0035-0, Rev 10, Service & Radwaste Area Plan EL 137'-0"

10.28.b P-0036-0, Rev 16, Service & Radwaste Area Plan EL 153'-0" & 155'-3"

10.28.c P-0055-0, Rev 15, Control & D/G Area, Plan EL 137'-0" & EL 146'-0" & EL 150'-0"

10.28.d P-0056-0, Rev 16, Control & D/G Area, Plan EL 155'-3" & EL 163'-6"

10.29 Auxiliary Bldg – Control Area Drawings:

10.29.a C-1317-0, Rev 22, Floor Plan EL 155'-3" Area 25

10.29.b C-1319-0, Rev 12, Floor Plan EL 155'-3" Area 26

10.29.c C-1321-0, Rev 5, Roof Plan EL 172-0" Area 25

10.29.d C-1323-0, Rev 4, Roof Plan EL 172-0" Area 26

10.30 Auxiliary Bldg – Control Area Drawings:

10.30.a C-1313-0, Rev 11, Floor Plan EL 137'-0" Area 25

10.30.b C-1315-0, SH 2, Rev 3, Floor Plan EL 137'-0" Area 26

10.31 Auxiliary Bldg – Diesel Generator Area Drawings:

10.31.a C-1413-0, Rev 20, Floor Plan EL 146'-0", EL 150'-0", EL 155'-3" Area 27

10.31.b C-1415-0, Rev 22, Floor Plan EL 146'-0", EL 150'-0", EL 155'-3" Area 28

10.32 Calculation No. H-1-ZZ-MDC-1820, Rev 0, Offsite Atmospheric Dispersion Factors.

10.33 Calculation No. H-1-ZZ-MDC-1882, Rev 0, Control Room Envelope Volume.

10.34 NRC Safety Evaluation Report NUREG-1048, October 1984, Operation of Hope Creek Generating Station.

10.35 Drawing No. C-0738-0, Rev 6, Reactor Building Dome Reinforcement Plan Section & Details.

10.36 PSEG Procedure No. LS-AA-104-1000, Revision 3, 50.59 Resource Manual.

10.37 Specification No 10855-P-0501, Rev 34, Line Index For The Hope Creek Generating Station.

10.38 American Air Filter Drawing No. M786(Q)-5(1), Rev 10, Housing Assy Filter (Control Room Emergency Filter).

10.39 HVAC Area Drawings:

10.39.a P-9266-1, Rev 25, Aux Bldg Area 26, Plan At EL 155'-3"& 163'-6"

10.39.b P-9256-1, Rev 24, Aux Bldg Area 25, Plan At EL 155'-3"& 175'-0"

10.39.c P-9267-1, Sheet 1 of 4, Rev 17, Aux Building Area 25 & 26 Sections

10.40 U.S. NRC Standard Review Plan 6.4, Control Room Habitability System.

10.41 NUREG-0800, Standard Review Plan, "Containment Spray as a Fission Product Cleanup System," SRP 6.5.2, Revision 2, 1988.

10.42 Hope Creek License Amendment 160, RE: Elimination of Requirements for Hydrogen Recombiners and Hydrogen/Oxygen Monitors Using Consolidated Line Item Improvement Process (TAC No. MC4792)

10.43 Calculation No. H-1-ZZ-MDC-1886, Rev 0, Hope Creek Post-Accident pH.

10.44 Nuclear Energy Institute Report No. NEI 96-07, Rev 1, Guidelines for 10 CFR 50.59 Implementation.

10.45 Vendor Technical Document (VTD) No. 430058, Volume 002, Rev 1, EPU TR T0802, Radioactive Source Term – Core Inventory.

10.46 NCS Corporation, "Control Room Envelope Inleakage Testing At Hope Creek Generating Station", December 28, 2009.

10.47 E-mail From John P. Cichello To Gopal Patel, Dated 03/15/02, Subject: FRVS Vent Charcoal Filter Efficiencies (Attachment A)

10.48 Critical Software Package Identification No. A-0-ZZ-MCS-0225, Rev 2, RADTRAD Computer Code.

10.49 NRC Safety Evaluation Report, Hope Creek Generating Station – Issuance of Amendment No. 134 for Increase in Allowable MSIV Leakage Rate and Elimination of MSIV Sealing System.

10.50 NRC letter to PSEG Nuclear dated April 15, 2003, "Hope Creek Generating Station – Issuance of Amendment 146 Re: Containment Requirements During Fuel Handling and Removal of Charcoal Filters (TAC No. MB5548)."

10.51 Not Used.

10.52 MSIV Leakage Iodine Transport Analysis By J.E. Cline & Associates, March 26, 1991, Contract NRC-03-87-029, Task Order 75

10.53 HCGS Containment Atmosphere Control P & ID M-57-1, Revision 41 (Sheet 1 of 2).

10.54 HCGS Technical Requirements Manual, Revision 2

10.55 "NRC Regulatory Issue Summary 2006-04 Experience with Implementation of Alternative Source Terms," RIS 2006-04, US NRC, March 7, 2006 (ADAMS Accession No. ML053460347).

10.56 NUREG-0800, Standard Review Plan, Branch Technical Position 6-4 "Containment Purging During Normal Plant Operations," BTP 6-4, Revision 3, March 2007.

10.57 "NRC Regulatory Issue Summary 2001-19 Deficiencies in the Documentation of Design Basis Radiological Analyses Submitted in Conjunction with License Amendment Requests," RIS 2001-19, US NRC, October 18, 2001 (ADAMS Accession No. ML011860407).

11.0 TABLES

Table 1A
Discharge Bundle Inventory Including Parent/Daughter Isotopes Per Reference 10.45, Appendix C
End of Cycle Discharge Bundle Inventory at Shutdown

Isotope	Discharge Bundle Inventory (Ci/MWt)	Discharge Bundle Inventory (Ci/MWt)	Isotope	Discharge Bundle Inventory (Ci/MWt)	Discharge Bundle Inventory (Ci/MWt)
CO-58*	1.529E+02	1.529E+02	TE-131	2.461E+04	
CO-60*	1.830E+02	1.830E+02	TE-131M	4.153E+03	2.876E+04
KR-85	4.711E+02	4.711E+02	TE-132	3.917E+04	3.917E+04
KR-85M	5.908E+03	5.908E+03	I-131	2.779E+04	2.779E+04
KR-87	1.097E+04	1.097E+04	I-132	3.991E+04	3.991E+04
KR-88	1.539E+04	1.539E+04	I-133	5.454E+04	5.454E+04
RB-86	1.300E+02	1.300E+02	I-134	5.937E+04	5.937E+04
SR-89	2.056E+04	2.056E+04	I-135	5.117E+04	6.235E+04
SR-90	3.790E+03	3.790E+03	XE-135M	1.118E+04	
SR-91	2.677E+04	4.231E+04	XE-133	5.306E+04	5.306E+04
Y-91M	1.554E+04		XE-135	1.482E+04	1.482E+04
SR-92	2.990E+04	2.990E+04	CS-134	1.319E+04	1.319E+04
Y-90	3.981E+03	3.981E+03	CS-136	3.704E+03	3.704E+03
Y-91	2.750E+04	2.750E+04	CS-137	5.626E+03	1.096E+04
Y-92	3.005E+04	3.005E+04	BA-137M	5.329E+03	
Y-93	3.607E+04	3.607E+04	BA-139	4.760E+04	4.760E+04
ZR-95	4.217E+04	4.217E+04	BA-140	4.590E+04	4.590E+04
ZR-97	4.419E+04	1.307E+05	LA-140	4.981E+04	4.981E+04
NB-97M	4.191E+04		LA-141	4.325E+04	4.325E+04
NB-97	4.464E+04		LA-142	4.134E+04	4.134E+04
NB-95	4.237E+04	4.237E+04	CE-141	4.350E+04	4.350E+04
MO-99	5.278E+04	5.278E+04	CE-143	3.910E+04	3.910E+04
TC-99M	4.621E+04	4.621E+04	CE-144	3.581E+04	7.234E+04
RU-103	4.703E+04	8.941E+04	PR-144	3.610E+04	
RH-103M	4.238E+04		PR-144M	4.303E+02	
RU-105	3.529E+04	3.529E+04	PR-143	3.783E+04	3.783E+04
RU-106	2.259E+04	4.722E+04	ND-147	1.783E+04	1.783E+04
RH-106	2.463E+04		NP-239	6.917E+05	6.917E+05
RH-105	3.237E+04	3.237E+04	PU-238	3.442E+02	3.442E+02
SB-127	3.379E+03	3.379E+03	PU-239	1.333E+01	1.333E+01
SB-129	9.569E+03	9.569E+03	PU-240	2.675E+01	2.675E+01
TE-127	3.355E+03	3.355E+03	PU-241	5.419E+03	5.419E+03
TE-127M	4.508E+02	4.508E+02	AM-241	7.266E+00	7.266E+00
TE-129	9.430E+03	9.430E+03	CM-242	2.567E+03	2.567E+03
TE-129M	1.401E+03	1.401E+03	CM-244	5.188E+02	5.188E+02

* CO-58 and CO-60 activities are obtained from RADTRAD User's Manual, Table 1.4.3.2-3 (Ref. 10.2)

Table 1B
Core Inventory - Discharge Bundle Inventory

Isotope	Discharge Bundle Inventory (Ci/MWt)	Isotope	Discharge Bundle Inventory (Ci/MWt)
CO-58*	1.529E+02	TE-131M	2.876E+04
CO-60*	1.830E+02	TE-132	3.917E+04
KR-85	4.711E+02	I-131	2.779E+04
KR-85M	5.908E+03	I-132	3.991E+04
KR-87	1.097E+04	I-133	5.454E+04
KR-88	1.539E+04	I-134	5.937E+04
RB-86	1.300E+02	I-135	6.235E+04
SR-89	2.056E+04	XE-133	5.306E+04
SR-90	3.790E+03	XE-135	1.482E+04
SR-91	4.231E+04	CS-134	1.319E+04
SR-92	2.990E+04	CS-136	3.704E+03
Y-90	3.981E+03	CS-137	1.096E+04
Y-91	2.750E+04	BA-139	4.760E+04
Y-92	3.005E+04	BA-140	4.590E+04
Y-93	3.607E+04	LA-140	4.981E+04
ZR-95	4.217E+04	LA-141	4.325E+04
ZR-97	1.307E+05	LA-142	4.134E+04
NB-95	4.237E+04	CE-141	4.350E+04
MO-99	5.278E+04	CE-143	3.910E+04
TC-99M	4.621E+04	CE-144	7.234E+04
RU-103	8.941E+04	PR-143	3.783E+04
RU-105	3.529E+04	ND-147	1.783E+04
RU-106	4.722E+04	NP-239	6.917E+05
RH-105	3.237E+04	PU-238	3.442E+02
SB-127	3.379E+03	PU-239	1.333E+01
SB-129	9.569E+03	PU-240	2.675E+01
TE-127M	4.508E+02	PU-241	5.419E+03
TE-127	3.355E+03	AM-241	7.266E+00
TE-129M	1.401E+03	CM-242	2.576E+03
TE-129	9.430E+03	CM-244	5.188E+02

Total Core Inventory From Table 1A

Table 1C
Higher Core Inventory Including Parent/Daughter Isotopes Per Reference 10.46, Appendix A
End of Cycle Core Average Inventory at Shutdown

Isotope	Core Inventory (Ci/MWt)	Core Inventory (Ci/MWt)	Isotope	Core Inventory (Ci/MWt)	Core Inventory (Ci/MWt)
CO-58*	1.529E+02	1.529E+02	TE-131	2.380E+04	
CO-60*	1.830E+02	1.830E+02	TE-131M	3.840E+03	2.764E+04
KR-85	3.330E+02	3.300E+02	TE-132	3.810E+04	3.810E+04
KR-85M	7.350E+03	7.350E+03	I-131	2.670E+04	2.670E+04
KR-87	1.420E+04	1.420E+04	I-132	3.870E+04	3.870E+04
KR-88	2.000E+04	2.000E+04	I-133	5.510E+04	5.510E+04
RB-86	6.350E+01	6.350E+01	I-134	6.060E+04	6.060E+04
SR-89	2.690E+04	2.690E+04	I-135	5.150E+04	6.220E+04
SR-90	2.640E+03	2.640E+03	XE-135M	1.070E+04	
SR-91	3.350E+04	5.300E+04	XE-133	5.300E+04	5.300E+04
Y-91M	1.950E+04		XE-135	1.820E+04	1.820E+04
SR-92	3.610E+04	3.610E+04	CS-134	5.350E+03	5.350E+03
Y-90	2.810E+03	2.810E+03	CS-136	1.860E+03	1.860E+03
Y-91	3.440E+04	3.440E+04	CS-137	3.470E+03	6.760E+03
Y-92	3.620E+04	3.620E+04	BA-137M	3.290E+03	
Y-93	4.160E+04	4.160E+04	BA-139	4.950E+04	4.950E+04
ZR-95	4.850E+04	4.850E+04	BA-140	4.780E+04	4.780E+04
ZR-97	4.970E+04	1.468E+05	LA-140	5.080E+04	5.080E+04
NB-97M	4.710E+04		LA-141	4.510E+04	4.510E+04
NB-97	5.000E+04		LA-142	4.370E+04	4.370E+04
NB-95	4.870E+04	4.870E+04	CE-141	4.540E+04	4.540E+04
MO-99	5.100E+04	5.100E+04	CE-143	4.220E+04	4.220E+04
TC-99M	4.460E+04	4.460E+04	CE-144	3.680E+04	7.424E+04
RU-103	4.050E+04	7.700E+04	PR-144	3.700E+04	
RH-103M	3.650E+04		PR-144M	4.420E+02	
RU-105	2.700E+04	2.700E+04	PR-143	4.080E+04	4.080E+04
RU-106	1.410E+04	2.940E+04	ND-147	1.810E+04	1.810E+04
RH-106	1.530E+04		NP-239	5.220E+05	5.220E+05
RH-105	2.530E+04	2.530E+04	PU-238	9.040E+01	9.040E+01
SB-127	2.800E+03	2.800E+03	• PU-239	1.090E+01	1.090E+01
SB-129	8.490E+03	8.490E+03	PU-240	1.410E+01	1.410E+01
TE-127	2.780E+03	2.780E+03	PU-241	4.090E+03	4.090E+03
TE-127M	3.710E+02	3.710E+02	AM-241	4.600E+00	4.600E+00
TE-129	8.350E+03	8.350E+03	CM-242	1.090E+03	1.090E+03
TE-129M	1.240E+03	1.240E+03	CM-244	5.240E+01	5.240E+01

* CO-58 and CO-60 activities are obtained from RADTRAD User's Manual, Table 1.4.3.2-3 (Ref. 10.2)

Table 1D
Core Inventory - Core Average Exposure

Isotope	Total Core Inventory (Ci/MWt)	Isotope	Total Core Inventory (Ci/MWt)
CO-58*	1.529E+02	TE-131M	2.764E+04
CO-60*	1.830E+02	TE-132	3.810E+04
KR-85	3.330E+02	I-131	2.670E+04
KR-85M	7.350E+03	I-132	3.870E+04
KR-87	1.420E+04	I-133	5.510E+04
KR-88	2.000E+04	I-134	6.060E+04
RB-86	6.350E+01	I-135	6.220E+04
SR-89	2.690E+04	XE-133	5.300E+04
SR-90	2.640E+03	XE-135	1.820E+04
SR-91	5.300E+04	CS-134	5.350E+03
SR-92	3.610E+04	CS-136	1.860E+03
Y-90	2.810E+03	CS-137	6.760E+03
Y-91	3.440E+04	BA-139	4.950E+04
Y-92	3.620E+04	BA-140	4.780E+04
Y-93	4.160E+04	LA-140	5.080E+04
ZR-95	4.850E+04	LA-141	4.510E+04
ZR-97	1.468E+05	LA-142	4.370E+04
NB-95	4.870E+04	CE-141	4.540E+04
MO-99	5.100E+04	CE-143	4.220E+04
TC-99M	4.460E+04	CE-144	7.424E+04
RU-103	7.700E+04	PR-143	4.080E+04
RU-105	2.700E+04	ND-147	1.810E+04
RU-106	2.940E+04	NP-239	5.220E+05
RH-105	2.530E+04	PU-238	9.040E+01
SB-127	2.800E+03	PU-239	1.090E+01
SB-129	8.490E+03	PU-240	1.410E+01
TE-127	2.780E+03	PU-241	4.090E+03
TE-127M	3.710E+02	AM-241	4.600E+00
TE-129	8.350E+03	CM-242	1.090E+03
TE-129M	1.240E+03	CM-244	5.240E+01

Total Core Inventory From Table 1C

Table 1E
Comparison of Modeling Differences between Revision 2, Revision 3, and Revision 4 of Calculation H-1-ZZ-MDC-1880

Item #	Changed Parameter	Calc H-1-ZZ-MDC-1880, Revision 2	Calc H-1-ZZ-MDC-1880, Revision 3	Calc H-1-ZZ-MDC-1880, Revision 4	Type of Change Input or Methodology
I. Airborne Radioactivity in Containment Atmosphere					
I-1	Airborne Activity Dilution in Containment	Radioactivity released from the fuel mixes instantaneously and homogeneously in containment free air volume which consists of drywell and suppression chamber air volumes.	Radioactivity released from core is diluted in drywell air volume for first 2 hours of the LOCA and then in combined drywell plus suppression chamber air volumes.	Same as Revision 3.	Methodology (See Section 2.1.1)
I-2	Elemental Iodine Removal from Containment Atmosphere	No credit taken for elemental iodine removal via deposition on wetted surfaces.	Removal of elemental iodine by wall deposition on wetted surfaces inside containment is credited in accordance with SRP 6.5.2.	Same as Revision 3.	Methodology (See Section 2.1.2)
II. Control Room Inleakage					
II-1	Control Room Inleakage Following CREV System Initiation.	350 cfm unfiltered.	Same as Revision 2	300 cfm unfiltered.	Input (See Section 2.5.2)
III. Containment Leakage Pathway					
III-1	Containment Leakage Rate Reduction	Containment leak rate is reduced by 50% after 24 hours.	Same as Revision 2	The leakage rate is not reduced at 24 hours (or subsequently during the LOCA duration) in response to a reduction in containment pressure.	Input (See Section 2.2)
IV. ESF Leakage Pathway					
IV-1	ESF Leakage Rate	1 gpm	2.85 gpm	Same as Revision 3.	Input (See Section 2.3)

Table 1E
Comparison of Modeling Differences between Revision 2, Revision 3, and Revision 4 of Calculation H-1-ZZ-MDC-1880

Item #	Changed Parameter	Calc H-1-ZZ-MDC-1880, Revision 2	Calc H-1-ZZ-MDC-1880, Revision 3	Calc H-1-ZZ-MDC-1880, Revision 4	Type of Change Input or Methodology
V. MSIV Leakage Pathway					
V-1	MSIV Leakage Rate Reduction	MSIV leak rate is reduced by 50% after 24 hours.	Same as Revision 2.	The leakage rate is not reduced at 24 hours (or subsequently during the LOCA duration) in response to a reduction in containment pressure.	Input (See Section 2.4)
V-2	MSIV Leakage Configuration	One failed main steam line with maximum TS allowed leakage of 150 scfh and 2 intact main steam lines with 50 scfh MSIV leakage from each line.	One failed main steam line with 150 scfh leakage and 1 intact main steam line with 100 scfh leakage.	Same as Revision 3.	Methodology (See Section 2.4)
V-3	MSIV Leakage Volumetric Flow Rates	MSIV volumetric leakage flow rates are from the technical specification limits specified at standard temperature and pressure conditions.	MSIV leakage flow rates are the technical specification volumetric flow rate limits (scfm), adjusted to containment post LOCA temperature and pressure conditions, using the Ideal Gas Law.	Same as Revision 3.	Input (See Section 2.4.3)
V-4	Main Steam Line Flow Model	Plug flow model, credit is taken for holdup and radiodecay in the failed and intact main steam lines.	Well mixed flow model. No credit for holdup.	Same as Revision 3.	Methodology (See Section 2.4.2)
V-5	Number of Main Steam Pipe Volume Nodes for Aerosol Deposition and Elemental Iodine Removal	<u>Failed Main Steam Line</u> 1 pipe volume. <u>Intact Main Steam Line</u> 1 pipe volume.	<u>Failed Main Steam Line</u> 2 pipe volumes (between inboard and outboard MSIV and between outboard MSIV and TSV). <u>Intact Main Steam Line</u> 2 pipe volumes (between RPV and outboard MSIV and between outboard MSIV and TSV).	Same as Revision 2	Methodology (See Sections 2.4.1 and 2.4.4)

Table 1E
Comparison of Modeling Differences between Revision 2, Revision 3, and Revision 4 of Calculation H-1-ZZ-MDC-1880

Item #	Changed Parameter	Calc H-1-ZZ-MDC-1880, Revision 2	Calc H-1-ZZ-MDC-1880, Revision 3	Calc H-1-ZZ-MDC-1880, Revision 4	Type of Change Input or Methodology
V-6	Pipe Surface Area for Aerosol Deposition	Based on horizontal pipe surface area (π x D x L). Aerosol deposition is credited in failed main steam line from RPV to inboard MSIV and from outboard MSIV to TSV. Aerosol deposition is credited in intact main steam line from RPV to TSV.	Based on pipe horizontal projected area (D x L). Aerosol deposition in failed main steam line is credited between inboard MSIV and TSV. Aerosol deposition is credited in intact main steam line from RPV to TSV.	Same as Revision 3.	Methodology (See Section 2.4.4)
V-7	Percentile Settling Velocity for Aerosol Deposition	40^{th} % for both failed and intact main steam lines.	50^{th} % upstream of outboard MSIV for both failed and intact main steam lines. 30^{th} % downstream of outboard MSIV for both failed and intact main steam lines.	Same as revision 2.	Input (See Section 2.4.4)
V-8	Time Credited for Aerosol Deposition and Elemental Iodine Removal in Main Steam Piping.	0 to 30 days	0 to 96 hours	Same as Revision 3.	Methodology (See Sections 2.4.1 and 2.4.4)
V-9	Elemental Iodine Removal Within Main Steam Lines	Calculated using the J. E. Cline methodology.	50% (i.e., decontamination factor of 2) due to natural removal of elemental iodine in each main steam line volume per Appendix B of AEB-98-03.	Same as Revision 2.	Methodology (See Section 2.4.5)

Table 1E
Comparison of Modeling Differences between Revision 2, Revision 3, and Revision 4 of Calculation H-1-ZZ-MDC-1880

Item #	Changed Parameter	Calc H-1-ZZ-MDC-1880, Revision 2	Calc H-1-ZZ-MDC-1880, Revision 3	Calc H-1-ZZ-MDC-1880, Revision 4	Type of Change Input or Methodology
VI. Primary Containment Isolation Valve Release Pathway					
VI-1	Release of Containment (i.e., Drywell) Airborne Activity via Primary Containment Isolation Valves.	This pathway not considered.	Reactor coolant activity released with drywell atmosphere from 0 to 120 seconds post LOCA via open primary containment isolation valves (i.e., drywell and suppression chamber purge exhaust isolation valves). Direct release to the environment.	Same as Revision 2.	Methodology (See Section 2.2)

Table 1F

Elemental Iodine Deposition Velocity - MSIV Leakage

Time	Temp Degree* F	Temp Degree K	(2809/T -12.5)	Deposition Velocity cm/sec	Deposition Velocity m/sec
0	340	444.26	-6.18	0.002076	2.076E-05
3	320	433.15	-6.01	0.002442	2.442E-05
6	250	394.26	-5.38	0.004630	4.630E-05
24	208	370.93	-4.93	0.007248	7.248E-05
96	180	355.37	-4.60	0.010096	1.010E-04
240	170	349.82	-4.47	0.011446	1.145E-04
480	150	338.71	-4.21	0.014896	1.490E-04
720					

* From Design Input 5.3.1.9

Table 1G

Elemental Iodine Deposition Rate - MSIV Failed Line Volume V11

Time	Deposition Velocity	Main Steam Line		Elemental Iodine Removal Rate
		Total Surface Area	Total Volume	
Hr	m/sec	(m^2)	(m^3)	(hr^{-1})
	A	B	C	(AxB)x3600/C
0	2.076E-05	203.66	35.17	0.4328
3	2.442E-05	203.66	35.17	0.5091
6	4.630E-05	203.66	35.17	0.9651
24	7.248E-05	203.66	35.17	1.5109
96	1.010E-04	203.66	35.17	2.1047
240	1.145E-04	203.66	35.17	2.3862
480	1.490E-04	203.66	35.17	3.1053
720				

A From Table 1F
B and C From Section 7.3.2.5

Table 1H

Elemental Iodine Deposition Rate - MSIV Intact Line Volume V33

Time	Deposition Velocity	Main Steam Line		Elemental Iodine Removal Rate
		Total Surface Area	Total Volume	
Hr	m/sec	(m^2)	(m^3)	(hr^{-1})
	A*	B	C	(AxB)x3600/C
0	2.076E-05	217.69	43.63	0.3730
3	2.442E-05	217.69	43.63	0.4386
6	4.630E-05	217.69	43.63	0.8316
24	7.248E-05	217.69	43.63	1.3018
96	1.010E-04	217.69	43.63	1.8135
240	1.145E-04	217.69	43.63	2.0560
480	1.490E-04	217.69	43.63	2.6756
720				

A From Table 1F
B and C From Section 7.3.3.7

Table 1I

Elemental Iodine Resuspension Rate - MSIV Leakage

Post-LOCA Time (hr)	Temp Degree F	Temp Degree K	-600/T	Resuspension Rate (hr^{-1})
0	340	444.26	-1.35	0.0403
3	320	433.15	-1.39	0.0389
6	250	394.26	-1.52	0.0340
24	208	370.93	-1.62	0.0309
96	180	355.37	-1.69	0.0287
240	170	349.82	-1.72	0.0280
480	150	338.71	-1.77	0.0265
720				

Resuspension Rate $(sec)^{-1}$ = 2.32 (2.00) x 10^{-5} $e^{-600/T}$ = 4.32 x 10-5 $e^{-600/T}$

Resuspension Rate $(hr)^{-1}$ = 4.32 x 3600 x 10^{-5} $e^{-600/T}$

Table 1J

Net Elemental Iodine Removal Rate - MSIV Failed Line Volume V11

Post-LOCA Time (hr)	Temp Degree F	Iodine Removal Rate A (hr-1)	Iodine Resuspension Rate B (hr-1)	Net Iodine Removal Rate C = A - B (hr-1)
0	340	0.4328	0.0403	0.3926
3	320	0.5091	0.0389	0.4701
6	250	0.9651	0.0340	0.9312
24	208	1.5109	0.0309	1.4800
96	180	2.1047	0.0287	2.0759
240	170	2.3862	0.0280	2.3582
480	150	3.1053	0.0265	3.0789
720				

A From Table 1G
B From Table 1I

Table 1K

Net Elemental Iodine Removal Rate - Intact Line Volume V33

Post-LOCA Time (hr)	Temp Degree F	Iodine Removal Rate A (hr-1)	Iodine Resuspension Rate B (hr-1)	Net Iodine Removal Rate C = A - B (hr-1)
0	340	0.3730	0.0403	0.3327
3	320	0.4386	0.0389	0.3997
6	250	0.8316	0.0340	0.7976
24	208	1.3018	0.0309	1.2709
96	180	1.8135	0.0287	1.7847
240	170	2.0560	0.0280	2.0280
480	150	2.6756	0.0265	2.6492
720				

A From Table 1H
B From Table 1I

Table 1L

Elemental Iodine Removal Efficiency - MSIV Failed Line
Volume V11

Post-LOCA Time (hr)	Temp Degree F	Net Iodine Removal Rate A (hr-1)	Elemental Iodine Removal Efficiency B (%)
0	340	0.3926	32.47
3	320	0.4701	37.51
6	250	0.9312	60.59
24	208	1.4800	77.24
96	180	2.0759	87.46
240	170	2.3582	90.54
480	150	3.0789	95.40
720			

A From Table 1J
B = 1-e^-A

Table 1M

Elemental Iodine Removal Efficiency - Intact Line
Volume V33

Post-LOCA Time (hr)	Temp Degree F	Net Iodine Removal Rate A (hr-1)	Elemental Iodine Removal Efficiency B (%)
0	340	0.3327	28.30
3	320	0.3997	32.95
6	250	0.7976	54.96
24	208	1.2709	71.94
96	180	1.7847	83.22
240	170	2.0280	86.84
480	150	2.6492	92.93
720			

A From Table 1K
B = 1-e^-A

Table 2
Hope Creek Main Steam Horizontal Piping Volume and Projected Horizontal Pipe Inside Surface Area

Main Steam Piping Horizontal Pipe Inside Volume (ft^3)		Main Steam Piping Projected Horizontal Pipe Inside Surface Area (ft^2)	
Header A	Header D	Header A	Header D
Piping Between RPV Nozzle and Inboard MSIV			
N/A	76.83	N/A	49.89
Piping Between Inboard and Outboard MSIVs			
101.89	101.89	66.18	66.18
Piping Between Outboard MSIV and Turbine Stop valve			
1065.25	1062.21	631.62	629.82
Total			
1167.14	1240.93	697.8	745.89

Table 3
Hope Creek Main Steam Piping Volume

Main Steam Piping Inside Volume (ft^3)	
Header A MSIV Failed Line	Header D Intact Line
Piping Between RPV Nozzle and Inboard MSIV	
N/A	301.81
Piping Between Inboard and Outboard MSIVs	
101.89	101.89
Piping Between Outboard MSIV and Turbine Stop valve	
1139.04	1136.00
Total Inside Volume	
1,240.93	1,539.70

Table 4
Main Steam Piping Parameters Used
In MSIV Leakage Release Path Model

Main Steam Header ID	**Main Steam Piping Between RPV Nozzle and Outboard MSIV – Horizontal: Inside Volume (ft^3)**	**Main Steam Piping Between RPV Nozzle and Outboard MSIV – Horizontal: Surface Area (ft^2)**
MSIV Failed Line Steam Header A* (First Shortest Line)	1167.14	697.8
MSIV Intact Line Steam Header D (Second Shortest Line)	1240.93	745.89

Main Steam Header Volume and Surface Area Information From Table 2
*Pipe Segment Between RPV and Inboard MSIV Excluded

Table 5
Rate Constant for MSIV Leakage Release Path with 40th%/40th% Settling Velocities

Steam Header	**Settling Velocity μ_s (ft/hr) A**	**Horizontal Settling Area (ft^2) B**	**Horizontal Pipe Volume (ft^3) C**	**Rate Constant for Settling λ_s (hr^{-1}) D**
MSIV Failed Line - Header A Inboard MSIV To Turbine Stop Valve SV-3	9.56	697.8	1167.14	5.72
MSIV Intact Line - Header B RPV Nozzle To Turbine Stop Valve	9.56	745.89	1240.93	5.75

A = 40th Percentile Settling Velocity = 0.00081 m/sec x 3.28 ft/m x 3600 sec/hr = 9.56 ft/hr for main steam lines upstream of outboard MSIVs
B and C From Table 4 and D = λs = (Ax B)/C

Table 6
Gravitational Deposition Aerosol Removal Efficiency On Horizontal Pipe Surface With 40th%/40th% Settling Velocity (250 scfh)

Post-LOCA Time Interval (hr)	Settling Rate Constant λ_s A (hr^{-1})	Well Mixed Volume V_2 B (ft^3)	Volumetric Flow Rate (ft^3/hr)	Aerosol Removal Efficiency MSIV Failed Line (%)	Post-LOCA Time Interval (hr)	Settling Rate Constant λ_s A (hr^{-1})	Well Mixed Volume V_4 B (ft^3)	Volumetric Flow Rate (ft^3/hr)	Aerosol Removal Efficiency Intact Line (%)
MSIV Failed Main Steam Line Between Inboard MSIV and TSV					**Intact Main Steam Line Between RPV and TSV**				
0-24	5.72	1240.93	150.00	97.93	0-24	5.75	1539.70	100.00	98.88
24-96	5.72	1240.93	150.00	97.93	24-96	5.75	1539.70	100.00	98.88
96-720	5.72	1240.93	150.00	0.00	96-720	5.75	1539.70	100.00	0.00

A From Table 5
B From Table 3

Table 7
MSIV Leak Rate In Different Control Volume (Total = 250 scfh and Max = 150 scfh)

Post-LOCA Time Interval (hr)	MSIV Leak Rate In Various Control Volumes (cfh)/(cfm)			
	Drywell To MSIV Failed Volume V_{11}	Volume V_{11} To Atmosphere	Drywell To Intact Line Volume V_{33}	Volume V_{33} To Atmosphere
0-2	48.47	150.00	32.31	100.00
	0.808	2.500	0.539	1.667
2-720	26.77	150.00	17.84	100.00
	0.446	2.500	0.297	1.667

MSIV Leak Rate Information From Section 7.2

Table 8
Conversion of Iodine Activity Into Iodine Atom

Isotope	Drywell Region @ 0.5 hr Activity (Curie) A	Drywell Region @ 0.5 hr Atoms B	Iodine (Atoms Per Curie) Ci = Bi/Ai	Isotopic Iodine Fraction Di = Bi/ΣB
I-131	4.247E+06	1.575E+23	3.708E+16	7.589E-01
I-132	5.673E+06	2.507E+21	4.420E+14	1.208E-02
I-133	8.630E+06	3.449E+22	3.997E+15	1.662E-01
I-134	6.499E+06	1.095E+21	1.685E+14	5.276E-03
I-135	9.400E+06	1.194E+22	1.270E+15	5.753E-02
Total		2.075E+23		1.000E+00

A and B From RADTRAD Run CUTOFF.o0 output file @ 0.5 hr from Containment Compartment Nuclide Inventory

Table 9
Elemental Iodine Activity @ DF of 200

Isotope	Iodine Core Inventory (Ci/MWt) A	Core Thermal Power Level MWt B	Iodine Core Activity (Ci) C=AxB	Elemental Iodine Activity Released In Drywell (Ci) D=Cx0.3x0.0485	Iodine (Atoms Per Curie) E	Iodine Atoms F=DxE
I-131	2.670E+04	3917	1.046E+08	1.522E+06	3.708E+16	5.643E+22
I-132	3.870E+04	3917	1.516E+08	2.206E+06	4.420E+14	9.749E+20
I-133	5.510E+04	3917	2.158E+08	3.140E+06	3.997E+15	1.255E+22
I-134	6.060E+04	3917	2.374E+08	3.454E+06	1.685E+14	5.818E+20
I-135	6.220E+04	3917	2.436E+08	3.545E+06	1.270E+15	4.503E+21
Total Elemental Iodine Atoms						7.504E+22
Total Iodine Elemental Atoms @ DF of 200						3.752E+20

A from Table 1D
B From Section 7.9
D Reference 10.1, Appendix A, Section 3.3
E From table 8

Table 10
Post-LOCA Cont. Leakage Iodine Activity Deposited on CR Charcoal Filter

Isotope	Iodine Atoms Per Curie A	Fraction Of Iodine B	Elemental and Organic Iodine Atoms On CR Charcoal 720 Hrs C	Iodine Atoms on CR Charcoal Filter At 720 Hrs Di =Bi * C	Iodine Activity CR Charcoal Filter At 720 Hrs Ci Ei = Di / Ai
I-131	3.708E+16	7.589E-01	3.107E+17	2.358E+17	6.359E+00
I-132	4.420E+14	1.208E-02		3.754E+15	8.494E+00
I-133	3.997E+15	1.662E-01		5.165E+16	1.292E+01
I-134	1.685E+14	5.276E-03		1.639E+15	9.731E+00
I-135	1.270E+15	5.753E-02		1.788E+16	1.407E+01
Total Iodine Atoms/Activity				3.107E+17	5.158E+01

A and B From Table 8
C From Section 7.6.3A

Table 11
Relationship of Aerosol Mass and Activity

Isotope	CR Region @ 2.0 hr		Aerosol	Isotopic
	Activity (Curie) A	Mass (kg) Bi	Mass Per Ci (kg/Ci) Ci = Bi /Ai	Aerosol Fraction Di = Bi/ΣB
Co-58	1.120E-08	3.523E-16	3.145E-08	4.245E-07
Co-60	1.342E-08	1.187E-14	8.846E-07	1.430E-05
Rb-86	6.277E-07	7.714E-15	1.229E-08	9.295E-06
Sr-89	1.576E-05	5.425E-13	3.442E-08	6.537E-04
Sr-90	1.549E-06	1.135E-11	7.331E-06	1.368E-02
Sr-91	2.687E-05	7.411E-15	2.759E-10	8.930E-06
Sr-92	1.270E-05	1.010E-15	7.956E-11	1.217E-06
Y-90	3.381E-08	6.214E-17	1.838E-09	7.488E-08
Y-91	2.077E-07	8.471E-15	4.078E-08	1.021E-05
Y-92	2.901E-06	3.015E-16	1.039E-10	3.633E-07
Y-93	2.127E-07	6.376E-17	2.997E-10	7.682E-08
Zr-95	2.842E-07	1.323E-14	4.655E-08	1.594E-05
Zr-97	7.932E-07	4.149E-16	5.231E-10	5.000E-07
Nb-95	2.856E-07	7.305E-15	2.557E-08	8.802E-06
Mo-99	3.662E-06	7.634E-15	2.085E-09	9.199E-06
Tc-99m	3.271E-06	6.220E-16	1.902E-10	7.495E-07
Ru-103	5.637E-06	1.747E-13	3.099E-08	2.105E-04
Ru-105	1.449E-06	2.155E-16	1.488E-10	2.597E-07
Ru-106	2.155E-06	6.442E-13	2.989E-07	7.762E-04
Rh-105	1.849E-06	2.191E-15	1.185E-09	2.640E-06
Sb-127	4.045E-06	1.515E-14	3.745E-09	1.825E-05
Sb-129	9.032E-06	1.606E-15	1.778E-10	1.935E-06
Te-127	4.051E-06	1.535E-15	3.789E-10	1.849E-06
Te-127m	5.441E-07	5.769E-14	1.060E-07	6.951E-05
Te-129	1.026E-05	4.899E-16	4.775E-11	5.903E-07
Te-129m	1.819E-06	6.039E-14	3.319E-08	7.276E-05

Table 11 (Cont'd)
Relationship of Aerosol Mass and Activity

Isotope	CR Region @ 2.0 hr		Aerosol Mass Per Ci (kg/Ci) Ci = Bi /Ai	Isotopic Aerosol Fraction Di = Bi/ΣB
	Activity (Curie) A	Mass (kg) Bi		
Te-131m	3.870E-05	4.853E-14	1.254E-09	5.848E-05
Te-132	5.489E-05	1.808E-13	3.294E-09	2.178E-04
Cs-134	5.304E-05	4.100E-11	7.729E-07	4.940E-02
Cs-136	1.836E-05	2.505E-13	1.364E-08	3.019E-04
Cs-137	6.703E-05	7.706E-10	1.150E-05	9.285E-01
Ba-139	1.062E-05	6.492E-16	6.114E-11	7.823E-07
Ba-140	2.791E-05	3.812E-13	1.366E-08	4.594E-04
La-140	7.932E-07	1.427E-15	1.799E-09	1.720E-06
La-141	1.859E-07	3.287E-17	1.768E-10	3.961E-08
La-142	1.043E-07	7.286E-18	6.986E-11	8.779E-09
Ce-141	6.652E-07	2.335E-14	3.510E-08	2.813E-05
Ce-143	5.933E-07	8.935E-16	1.506E-09	1.077E-06
Ce-144	1.088E-06	3.411E-13	3.135E-07	4.110E-04
Pr-143	2.401E-07	3.566E-15	1.485E-08	4.297E-06
Nd-147	1.056E-07	1.305E-15	1.236E-08	1.573E-06
Np-239	7.469E-06	3.220E-14	4.311E-09	3.879E-05
Pu-238	1.326E-09	7.743E-14	5.841E-05	9.330E-05
Pu-239	1.599E-10	2.572E-12	1.609E-02	3.099E-03
Pu-240	2.068E-10	9.074E-13	4.388E-03	1.093E-03
Pu-241	5.997E-08	5.822E-13	9.708E-06	7.015E-04
Am-241	2.700E-11	7.866E-15	2.914E-04	9.478E-06
Cm-242	6.391E-09	1.928E-15	3.017E-07	2.324E-06
Cm-244	3.073E-10	3.799E-15	1.236E-05	4.578E-06
Total		8.299E-10		1.00E+00

A and B From RADTRAD Run HEPU300CL00 output file @ 2.0 hr from Control Room Compartment Nuclide Inventory

Table 12
Post-LOCA Total Aerosol Isotopic Activity On CR HEPA Filter @ 720 Hrs

Isotope	Aerosol Mass Per Ci (kg/Ci) A	Fraction of Aerosol Bi	Total CR Filter Aerosol Mass At 720 Hr (kg) C	Aerosol Isotopic	
				Aerosol Mass On CR Filter At 720 Hr (kg) Di =Bi * C	Aerosol Activity On CR Filter At 720 Hr (Ci) Ei = Di / Ai
Co-58	3.145E-08	4.245E-07	1.350E-07	5.730E-14	1.822E-06
Co-60	8.846E-07	1.430E-05	1.350E-07	1.931E-12	2.183E-06
Rb-86	1.229E-08	9.295E-06	1.350E-07	1.255E-12	1.021E-04
Sr-89	3.442E-08	6.537E-04	1.350E-07	8.824E-11	2.564E-03
Sr-90	7.331E-06	1.368E-02	1.350E-07	1.847E-09	2.519E-04
Sr-91	2.759E-10	8.930E-06	1.350E-07	1.206E-12	4.370E-03
Sr-92	7.956E-11	1.217E-06	1.350E-07	1.643E-13	2.065E-03
Y-90	1.838E-09	7.488E-08	1.350E-07	1.011E-14	5.500E-06
Y-91	4.078E-08	1.021E-05	1.350E-07	1.378E-12	3.379E-05
Y-92	1.039E-10	3.633E-07	1.350E-07	4.905E-14	4.720E-04
Y-93	2.997E-10	7.682E-08	1.350E-07	1.037E-14	3.460E-05
Zr-95	4.655E-08	1.594E-05	1.350E-07	2.152E-12	4.623E-05
Zr-97	5.231E-10	5.000E-07	1.350E-07	6.750E-14	1.290E-04
Nb-95	2.557E-08	8.802E-06	1.350E-07	1.188E-12	4.647E-05
Mo-99	2.085E-09	9.199E-06	1.350E-07	1.242E-12	5.956E-04
Tc-99m	1.902E-10	7.495E-07	1.350E-07	1.012E-13	5.320E-04
Ru-103	3.099E-08	2.105E-04	1.350E-07	2.841E-11	9.170E-04
Ru-105	1.488E-10	2.597E-07	1.350E-07	3.506E-14	2.357E-04
Ru-106	2.989E-07	7.762E-04	1.350E-07	1.048E-10	3.506E-04
Rh-105	1.185E-09	2.640E-06	1.350E-07	3.563E-13	3.008E-04
Sb-127	3.745E-09	1.825E-05	1.350E-07	2.464E-12	6.579E-04
Sb-129	1.778E-10	1.935E-06	1.350E-07	2.613E-13	1.469E-03
Te-127	3.789E-10	1.849E-06	1.350E-07	2.497E-13	6.589E-04
Te-127m	1.060E-07	6.951E-05	1.350E-07	9.384E-12	8.851E-05
Te-129	4.775E-11	5.903E-07	1.350E-07	7.969E-14	1.669E-03
Te-129m	3.319E-08	7.276E-05	1.350E-07	9.823E-12	2.959E-04

Table 12 (Cont'd)
Post-LOCA Total Aerosol Isotopic Activity On CR HEPA Filter @ 720 Hrs

Isotope	Aerosol Mass Per Ci (kg/Ci) A	Fraction of Aerosol Bi	Total CR Filter Aerosol Mass At 720 Hr (kg) C	Aerosol Isotopic Aerosol Mass On CR Filter At 720 Hr (kg) Di =Bi * C	Aerosol Isotopic Aerosol Activity On CR Filter At 720 Hr (Ci) Ei = Di / Ai
Te-131m	1.254E-09	5.848E-05	1.350E-07	7.895E-12	6.295E-03
Te-132	3.294E-09	2.178E-04	1.350E-07	2.941E-11	8.928E-03
Cs-134	7.729E-07	4.940E-02	1.350E-07	6.669E-09	8.628E-03
Cs-136	1.364E-08	3.019E-04	1.350E-07	4.075E-11	2.987E-03
Cs-137	1.150E-05	9.285E-01	1.350E-07	1.253E-07	1.090E-02
Ba-139	6.114E-11	7.823E-07	1.350E-07	1.056E-13	1.727E-03
Ba-140	1.366E-08	4.594E-04	1.350E-07	6.202E-11	4.540E-03
La-140	1.799E-09	1.720E-06	1.350E-07	2.321E-13	1.290E-04
La-141	1.768E-10	3.961E-08	1.350E-07	5.347E-15	3.024E-05
La-142	6.986E-11	8.779E-09	1.350E-07	1.185E-15	1.697E-05
Ce-141	3.510E-08	2.813E-05	1.350E-07	3.798E-12	1.082E-04
Ce-143	1.506E-09	1.077E-06	1.350E-07	1.453E-13	9.652E-05
Ce-144	3.135E-07	4.110E-04	1.350E-07	5.548E-11	1.770E-04
Pr-143	1.485E-08	4.297E-06	1.350E-07	5.801E-13	3.906E-05
Nd-147	1.236E-08	1.573E-06	1.350E-07	2.124E-13	1.718E-05
Np-239	4.311E-09	3.879E-05	1.350E-07	5.237E-12	1.215E-03
Pu-238	5.841E-05	9.330E-05	1.350E-07	1.260E-11	2.156E-07
Pu-239	1.609E-02	3.099E-03	1.350E-07	4.184E-10	2.601E-08
Pu-240	4.388E-03	1.093E-03	1.350E-07	1.476E-10	3.363E-08
Pu-241	9.708E-06	7.015E-04	1.350E-07	9.471E-11	9.756E-06
Am-241	2.914E-04	9.478E-06	1.350E-07	1.280E-12	4.392E-09
Cm-242	3.017E-07	2.324E-06	1.350E-07	3.137E-13	1.040E-06
Cm-244	1.236E-05	4.578E-06	1.350E-07	6.180E-13	5.000E-08
Total CR Aerosol Mass/Activity @ 720 hrs				1.350E-07	6.375E-02

A and B From Table 11
C From Section 7.6.3A

Table 13
720-hrs Post-LOCA Total Iodine and Aerosol Activity
On CREF Charcoal/HEPA Filters (Ci)

Isotope	Total Activity Ci A	Isotope	Total Activity Ci A
Co-58	1.822E-06	Te-131m	6.295E-03
Co-60	2.183E-06	Te-132	8.928E-03
Rb-86	1.021E-04	Cs-134	8.628E-03
Sr-89	2.564E-03	Cs-136	2.987E-03
Sr-90	2.519E-04	Cs-137	1.090E-02
Sr-91	4.370E-03	Ba-139	1.727E-03
Sr-92	2.065E-03	Ba-140	4.540E-03
Y-90	5.500E-06	La-140	1.290E-04
Y-91	3.379E-05	La-141	3.024E-05
Y-92	4.720E-04	La-142	1.697E-05
Y-93	3.460E-05	Ce-141	1.082E-04
Zr-95	4.623E-05	Ce-143	9.652E-05
Zr-97	1.290E-04	Ce-144	1.770E-04
Nb-95	4.647E-05	Pr-143	3.906E-05
Mo-99	5.956E-04	Nd-147	1.718E-05
Tc-99m	5.320E-04	Np-239	1.215E-03
Ru-103	9.170E-04	Pu-238	2.156E-07
Ru-105	2.357E-04	Pu-239	2.601E-08
Ru-106	3.506E-04	Pu-240	3.363E-08
Rh-105	3.008E-04	Pu-241	9.756E-06
Sb-127	6.579E-04	Am-241	4.392E-09
Sb-129	1.469E-03	Cm-242	1.040E-06
Te-127	6.589E-04	Cm-244	5.000E-08
Te-127m	8.851E-05	I-131	6.359E+00
Te-129	1.669E-03	I-132	8.494E+00
Te-129m	2.959E-04	I-133	1.292E+01
		I-134	9.731E+00
		I-135	1.407E+01

A - Aerosol From Table 12
A - Iodine From Table 10

Table 14
0-1 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-1 Hr) (Ci)			Total Integrated Activity (Ci) A+B+C
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	
Co-58	8.161E-06	0.000E+00	1.727E-05	2.543E-05
Co-60	9.771E-06	0.000E+00	2.068E-05	3.045E-05
Kr-85	1.836E+00	0.000E+00	1.671E+00	3.507E+00
Kr-85m	3.592E+01	0.000E+00	3.237E+01	6.828E+01
Kr-87	5.160E+01	0.000E+00	4.514E+01	9.673E+01
Kr-88	9.123E+01	0.000E+00	8.171E+01	1.729E+02
Rb-86	2.919E-02	0.000E+00	3.132E-03	3.232E-02
Sr-89	1.148E-02	0.000E+00	2.431E-02	3.579E-02
Sr-90	1.128E-03	0.000E+00	2.387E-03	3.514E-03
Sr-91	2.118E-02	0.000E+00	4.481E-02	6.598E-02
Sr-92	1.221E-02	0.000E+00	2.580E-02	3.801E-02
Y-90	1.597E-05	0.000E+00	3.403E-05	5.001E-05
Y-91	1.484E-04	0.000E+00	3.141E-04	4.625E-04
Y-92	9.437E-04	0.000E+00	2.041E-03	2.985E-03
Y-93	1.669E-04	0.000E+00	3.531E-04	5.200E-04
Zr-95	2.071E-04	0.000E+00	4.383E-04	6.454E-04
Zr-97	6.039E-04	0.000E+00	1.278E-03	1.882E-03
Nb-95	2.080E-04	0.000E+00	4.403E-04	6.483E-04
Mo-99	2.697E-03	0.000E+00	5.708E-03	8.405E-03
Tc-99m	2.383E-03	0.000E+00	5.044E-03	7.427E-03
Ru-103	4.108E-03	0.000E+00	8.696E-03	1.280E-02
Ru-105	1.250E-03	0.000E+00	2.643E-03	3.893E-03
Ru-106	1.570E-03	0.000E+00	3.322E-03	4.892E-03
Rh-105	1.351E-03	0.000E+00	2.859E-03	4.209E-03
Sb-127	2.970E-03	0.000E+00	6.285E-03	9.254E-03
Sb-129	7.829E-03	0.000E+00	1.656E-02	2.439E-02
Te-127	2.960E-03	0.000E+00	6.265E-03	9.226E-03
Te-127m	3.962E-04	0.000E+00	8.386E-04	1.235E-03
Te-129	8.327E-03	0.000E+00	1.763E-02	2.595E-02
Te-129m	1.325E-03	0.000E+00	2.803E-03	4.128E-03

Table 14 (Cont'd)
0-1 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-1 Hr) (Ci)			Total Integrated Activity (Ci) A+B+C
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	
Te-131m	2.890E-02	0.000E+00	6.116E-02	9.005E-02
Te-132	4.036E-02	0.000E+00	8.541E-02	1.258E-01
I-131	1.245E+01	3.802E+00	3.000E+00	1.926E+01
I-132	1.741E+01	5.064E+00	3.715E+00	2.619E+01
I-133	2.559E+01	7.752E+00	6.043E+00	3.938E+01
I-134	2.547E+01	6.562E+00	3.698E+00	3.573E+01
I-135	2.860E+01	8.511E+00	6.447E+00	4.356E+01
Xe-133	2.918E+02	8.516E-02	2.656E+02	5.575E+02
Xe-135	1.061E+02	1.104E+00	9.739E+01	2.045E+02
Cs-134	2.460E+00	0.000E+00	2.642E-01	2.724E+00
Cs-136	8.550E-01	0.000E+00	9.169E-02	9.467E-01
Cs-137	3.108E+00	0.000E+00	3.338E-01	3.442E+00
Ba-139	1.336E-02	0.000E+00	2.821E-02	4.157E-02
Ba-140	2.038E-02	0.000E+00	4.312E-02	6.350E-02
La-140	3.309E-04	0.000E+00	7.069E-04	1.038E-03
La-141	1.640E-04	0.000E+00	3.467E-04	5.107E-04
La-142	1.238E-04	0.000E+00	2.615E-04	3.853E-04
Ce-141	4.847E-04	0.000E+00	1.026E-03	1.511E-03
Ce-143	4.421E-04	0.000E+00	9.355E-04	1.378E-03
Ce-144	7.923E-04	0.000E+00	1.677E-03	2.469E-03
Pr-143	1.745E-04	0.000E+00	3.693E-04	5.437E-04
Nd-147	7.713E-05	0.000E+00	1.632E-04	2.404E-04
Np-239	5.512E-03	0.000E+00	1.167E-02	1.718E-02
Pu-238	9.653E-07	0.000E+00	2.043E-06	3.008E-06
Pu-239	1.164E-07	0.000E+00	2.464E-07	3.628E-07
Pu-240	1.506E-07	0.000E+00	3.187E-07	4.692E-07
Pu-241	4.367E-05	0.000E+00	9.244E-05	1.361E-04
Am-241	1.965E-08	0.000E+00	4.160E-08	6.125E-08
Cm-242	4.655E-06	0.000E+00	9.852E-06	1.451E-05
Cm-244	2.238E-07	0.000E+00	4.737E-07	6.975E-07

A From HEPU300CL00.o0
B From HEPU300ES00.o0
C From H1N300MS00.o0

Table 15
0-2 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-2 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Co-58	1.475E-04	0.000E+00	4.377E-04	5.851E-04
Co-60	1.766E-04	0.000E+00	5.242E-04	7.008E-04
Kr-85	2.540E+01	0.000E+00	2.549E+01	5.089E+01
Kr-85m	4.369E+02	0.000E+00	4.377E+02	8.747E+02
Kr-87	4.569E+02	0.000E+00	4.544E+02	9.113E+02
Kr-88	1.031E+03	0.000E+00	1.032E+03	2.063E+03
Rb-86	3.603E-02	0.000E+00	2.661E-02	6.264E-02
Sr-89	2.075E-01	0.000E+00	6.159E-01	8.234E-01
Sr-90	2.038E-02	0.000E+00	6.050E-02	8.088E-02
Sr-91	3.635E-01	0.000E+00	1.076E+00	1.439E+00
Sr-92	1.846E-01	0.000E+00	5.420E-01	7.266E-01
Y-90	3.812E-04	0.000E+00	1.182E-03	1.563E-03
Y-91	2.713E-03	0.000E+00	8.071E-03	1.078E-02
Y-92	3.015E-02	0.000E+00	9.727E-02	1.274E-01
Y-93	2.874E-03	0.000E+00	8.506E-03	1.138E-02
Zr-95	3.742E-03	0.000E+00	1.111E-02	1.485E-02
Zr-97	1.060E-02	0.000E+00	3.142E-02	4.203E-02
Nb-95	3.760E-03	0.000E+00	1.116E-02	1.492E-02
Mo-99	4.838E-02	0.000E+00	1.436E-01	1.919E-01
Tc-99m	4.306E-02	0.000E+00	1.278E-01	1.709E-01
Ru-103	7.422E-02	0.000E+00	2.203E-01	2.945E-01
Ru-105	2.024E-02	0.000E+00	5.971E-02	7.995E-02
Ru-106	2.837E-02	0.000E+00	8.421E-02	1.126E-01
Rh-105	2.437E-02	0.000E+00	7.233E-02	9.669E-02
Sb-127	5.339E-02	0.000E+00	1.584E-01	2.118E-01
Sb-129	1.264E-01	0.000E+00	3.728E-01	4.993E-01
Te-127	5.338E-02	0.000E+00	1.584E-01	2.118E-01
Te-127m	7.162E-03	0.000E+00	2.126E-02	2.842E-02
Te-129	1.405E-01	0.000E+00	4.156E-01	5.561E-01
Te-129m	2.394E-02	0.000E+00	7.107E-02	9.502E-02

Table 15 (Cont'd)
0-2 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-2 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Te-131m	5.138E-01	0.000E+00	1.524E+00	2.038E+00
Te-132	7.248E-01	0.000E+00	2.151E+00	2.876E+00
I-131	1.687E+01	1.674E+01	2.287E+01	5.648E+01
I-132	2.248E+01	1.879E+01	2.578E+01	6.705E+01
I-133	3.426E+01	3.313E+01	4.501E+01	1.124E+02
I-134	2.830E+01	1.467E+01	1.629E+01	5.926E+01
I-135	3.731E+01	3.396E+01	4.555E+01	1.168E+02
Xe-133	4.027E+03	1.443E+00	4.044E+03	8.073E+03
Xe-135	1.487E+03	1.763E+01	1.507E+03	3.011E+03
Cs-134	3.037E+00	0.000E+00	2.247E+00	5.285E+00
Cs-136	1.055E+00	0.000E+00	7.787E-01	1.834E+00
Cs-137	3.838E+00	0.000E+00	2.840E+00	6.678E+00
Ba-139	1.710E-01	0.000E+00	4.968E-01	6.678E-01
Ba-140	3.677E-01	0.000E+00	1.091E+00	1.459E+00
La-140	8.622E-03	0.000E+00	2.702E-02	3.564E-02
La-141	2.619E-03	0.000E+00	7.717E-03	1.034E-02
La-142	1.642E-03	0.000E+00	4.782E-03	6.423E-03
Ce-141	8.758E-03	0.000E+00	2.600E-02	3.475E-02
Ce-143	7.872E-03	0.000E+00	2.335E-02	3.122E-02
Ce-144	1.432E-02	0.000E+00	4.250E-02	5.682E-02
Pr-143	3.158E-03	0.000E+00	9.376E-03	1.253E-02
Nd-147	1.391E-03	0.000E+00	4.130E-03	5.521E-03
Np-239	9.876E-02	0.000E+00	2.930E-01	3.918E-01
Pu-238	1.745E-05	0.000E+00	5.179E-05	6.924E-05
Pu-239	2.104E-06	0.000E+00	6.246E-06	8.351E-06
Pu-240	2.721E-06	0.000E+00	8.078E-06	1.080E-05
Pu-241	7.894E-04	0.000E+00	2.343E-03	3.133E-03
Am-241	3.553E-07	0.000E+00	1.055E-06	1.410E-06
Cm-242	8.413E-05	0.000E+00	2.497E-04	3.338E-04
Cm-244	4.045E-06	0.000E+00	1.201E-05	1.605E-05

A From HEPU300CL00.o0
B From HEPU300ES00.o0
C From H1N300MS00.o0

Table 16
0-4 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-4 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Co-58	3.773E-04	0.000E+00	2.599E-03	2.976E-03
Co-60	4.520E-04	0.000E+00	3.114E-03	3.566E-03
Kr-85	1.341E+02	0.000E+00	1.725E+02	3.065E+02
Kr-85m	1.904E+03	0.000E+00	2.432E+03	4.336E+03
Kr-87	1.307E+03	0.000E+00	1.624E+03	2.931E+03
Kr-88	4.049E+03	0.000E+00	5.144E+03	9.193E+03
Rb-86	4.531E-02	0.000E+00	1.244E-01	1.698E-01
Sr-89	5.309E-01	0.000E+00	3.656E+00	4.187E+00
Sr-90	5.217E-02	0.000E+00	3.594E-01	4.116E-01
Sr-91	8.823E-01	0.000E+00	5.870E+00	6.752E+00
Sr-92	3.962E-01	0.000E+00	2.416E+00	2.812E+00
Y-90	1.287E-03	0.000E+00	1.084E-02	1.212E-02
Y-91	7.043E-03	0.000E+00	4.916E-02	5.620E-02
Y-92	1.047E-01	0.000E+00	9.033E-01	1.008E+00
Y-93	6.996E-03	0.000E+00	4.664E-02	5.363E-02
Zr-95	9.574E-03	0.000E+00	6.595E-02	7.552E-02
Zr-97	2.633E-02	0.000E+00	1.779E-01	2.042E-01
Nb-95	9.624E-03	0.000E+00	6.630E-02	7.592E-02
Mo-99	1.229E-01	0.000E+00	8.424E-01	9.653E-01
Tc-99m	1.101E-01	0.000E+00	7.580E-01	8.681E-01
Ru-103	1.899E-01	0.000E+00	1.308E+00	1.498E+00
Ru-105	4.638E-02	0.000E+00	2.965E-01	3.429E-01
Ru-106	7.261E-02	0.000E+00	5.002E-01	5.728E-01
Rh-105	6.215E-02	0.000E+00	4.271E-01	4.892E-01
Sb-127	1.359E-01	0.000E+00	9.329E-01	1.069E+00
Sb-129	2.888E-01	0.000E+00	1.843E+00	2.131E+00
Te-127	1.363E-01	0.000E+00	9.374E-01	1.074E+00
Te-127m	1.833E-02	0.000E+00	1.263E-01	1.446E-01
Te-129	3.318E-01	0.000E+00	2.165E+00	2.497E+00
Te-129m	6.129E-02	0.000E+00	4.223E-01	4.835E-01

Table 16 (Cont'd)
0-4 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-4 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Te-131m	1.293E+00	0.000E+00	8.809E+00	1.010E+01
Te-132	1.843E+00	0.000E+00	1.265E+01	1.449E+01
I-131	2.386E+01	6.742E+01	9.854E+01	1.898E+02
I-132	2.907E+01	5.688E+01	9.145E+01	1.774E+02
I-133	4.743E+01	1.280E+02	1.871E+02	3.625E+02
I-134	3.005E+01	2.503E+01	3.317E+01	8.825E+01
I-135	4.940E+01	1.194E+02	1.745E+02	3.433E+02
Xe-133	2.115E+04	1.294E+01	2.722E+04	4.838E+04
Xe-135	7.566E+03	1.425E+02	9.918E+03	1.763E+04
Cs-134	3.823E+00	0.000E+00	1.053E+01	1.435E+01
Cs-136	1.326E+00	0.000E+00	3.639E+00	4.965E+00
Cs-137	4.830E+00	0.000E+00	1.330E+01	1.813E+01
Ba-139	3.184E-01	0.000E+00	1.730E+00	2.049E+00
Ba-140	9.396E-01	0.000E+00	6.466E+00	7.405E+00
La-140	3.089E-02	0.000E+00	2.686E-01	2.995E-01
La-141	5.918E-03	0.000E+00	3.747E-02	4.339E-02
La-142	3.146E-03	0.000E+00	1.752E-02	2.066E-02
Ce-141	2.241E-02	0.000E+00	1.543E-01	1.767E-01
Ce-143	1.984E-02	0.000E+00	1.353E-01	1.551E-01
Ce-144	3.665E-02	0.000E+00	2.525E-01	2.891E-01
Pr-143	8.097E-03	0.000E+00	5.587E-02	6.397E-02
Nd-147	3.555E-03	0.000E+00	2.446E-02	2.801E-02
Np-239	2.505E-01	0.000E+00	1.716E+00	1.966E+00
Pu-238	4.466E-05	0.000E+00	3.077E-04	3.524E-04
Pu-239	5.387E-06	0.000E+00	3.712E-05	4.250E-05
Pu-240	6.966E-06	0.000E+00	4.799E-05	5.496E-05
Pu-241	2.021E-03	0.000E+00	1.392E-02	1.594E-02
Am-241	9.097E-07	0.000E+00	6.268E-06	7.178E-06
Cm-242	2.153E-04	0.000E+00	1.483E-03	1.699E-03
Cm-244	1.036E-05	0.000E+00	7.134E-05	8.170E-05

A From HEPU300CL00.o0
B From HEPU300ES00.o0
C From H1N300MS00.o0

Table 17
0-8 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-8 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Co-58	4.278E-04	0.000E+00	6.484E-03	6.912E-03
Co-60	5.126E-04	0.000E+00	7.775E-03	8.288E-03
Kr-85	5.695E+02	0.000E+00	7.315E+02	1.301E+03
Kr-85m	5.606E+03	0.000E+00	7.210E+03	1.282E+04
Kr-87	2.046E+03	0.000E+00	2.590E+03	4.636E+03
Kr-88	9.938E+03	0.000E+00	1.277E+04	2.271E+04
Rb-86	4.729E-02	0.000E+00	2.950E-01	3.423E-01
Sr-89	6.019E-01	0.000E+00	9.119E+00	9.721E+00
Sr-90	5.916E-02	0.000E+00	8.974E-01	9.565E-01
Sr-91	9.794E-01	0.000E+00	1.290E+01	1.388E+01
Sr-92	4.230E-01	0.000E+00	4.101E+00	4.524E+00
Y-90	1.643E-03	0.000E+00	4.374E-02	4.538E-02
Y-91	8.040E-03	0.000E+00	1.275E-01	1.355E-01
Y-92	1.269E-01	0.000E+00	2.680E+00	2.807E+00
Y-93	7.774E-03	0.000E+00	1.033E-01	1.110E-01
Zr-95	1.086E-02	0.000E+00	1.645E-01	1.754E-01
Zr-97	2.949E-02	0.000E+00	4.127E-01	4.422E-01
Nb-95	1.091E-02	0.000E+00	1.655E-01	1.764E-01
Mo-99	1.389E-01	0.000E+00	2.063E+00	2.202E+00
Tc-99m	1.248E-01	0.000E+00	1.881E+00	2.006E+00
Ru-103	2.153E-01	0.000E+00	3.261E+00	3.476E+00
Ru-105	5.047E-02	0.000E+00	5.735E-01	6.239E-01
Ru-106	8.233E-02	0.000E+00	1.249E+00	1.331E+00
Rh-105	7.030E-02	0.000E+00	1.049E+00	1.120E+00
Sb-127	1.537E-01	0.000E+00	2.297E+00	2.451E+00
Sb-129	3.140E-01	0.000E+00	3.542E+00	3.856E+00
Te-127	1.544E-01	0.000E+00	2.324E+00	2.478E+00
Te-127m	2.079E-02	0.000E+00	3.154E-01	3.362E-01
Te-129	3.640E-01	0.000E+00	4.400E+00	4.764E+00
Te-129m	6.950E-02	0.000E+00	1.054E+00	1.123E+00

Table 17 (Cont'd)
0-8 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-8 Hr) (Ci)			Total Integrated Activity (Ci)
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	A+B+C
Te-131m	1.456E+00	0.000E+00	2.109E+01	2.255E+01
Te-132	2.084E+00	0.000E+00	3.106E+01	3.315E+01
I-131	2.929E+01	2.615E+02	2.299E+02	5.207E+02
I-132	3.197E+01	1.197E+02	1.598E+02	3.115E+02
I-133	5.679E+01	4.598E+02	4.135E+02	9.300E+02
I-134	3.023E+01	2.976E+01	3.722E+01	9.721E+01
I-135	5.639E+01	3.602E+02	3.429E+02	7.594E+02
Xe-133	8.866E+04	1.115E+02	1.140E+05	2.028E+05
Xe-135	2.738E+04	9.991E+02	3.652E+04	6.490E+04
Cs-134	3.991E+00	0.000E+00	2.503E+01	2.902E+01
Cs-136	1.384E+00	0.000E+00	8.615E+00	9.999E+00
Cs-137	5.043E+00	0.000E+00	3.163E+01	3.667E+01
Ba-139	3.296E-01	0.000E+00	2.330E+00	2.659E+00
Ba-140	1.065E+00	0.000E+00	1.608E+01	1.714E+01
La-140	4.018E-02	0.000E+00	1.135E+00	1.175E+00
La-141	6.412E-03	0.000E+00	7.044E-02	7.685E-02
La-142	3.273E-03	0.000E+00	2.455E-02	2.783E-02
Ce-141	2.540E-02	0.000E+00	3.848E-01	4.102E-01
Ce-143	2.235E-02	0.000E+00	3.252E-01	3.475E-01
Ce-144	4.156E-02	0.000E+00	6.303E-01	6.718E-01
Pr-143	9.189E-03	0.000E+00	1.402E-01	1.494E-01
Nd-147	4.027E-03	0.000E+00	6.077E-02	6.480E-02
Np-239	2.830E-01	0.000E+00	4.189E+00	4.472E+00
Pu-238	5.064E-05	0.000E+00	7.682E-04	8.189E-04
Pu-239	6.109E-06	0.000E+00	9.269E-05	9.880E-05
Pu-240	7.899E-06	0.000E+00	1.198E-04	1.277E-04
Pu-241	2.291E-03	0.000E+00	3.476E-02	3.705E-02
Am-241	1.032E-06	0.000E+00	1.566E-05	1.669E-05
Cm-242	2.441E-04	0.000E+00	3.702E-03	3.946E-03
Cm-244	1.174E-05	0.000E+00	1.781E-04	1.899E-04

A From HEPU300CL00.o0
B From HEPU300ES00.o0
C From H1N300MS00.o0

Table 18
0-720 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-720 Hr) (Ci)			Total Integrated Activity (Ci) A+B+C
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	
Co-58	4.310E-04	0.000E+00	1.525E-02	1.568E-02
Co-60	5.164E-04	0.000E+00	1.843E-02	1.894E-02
Kr-85	1.635E+05	0.000E+00	2.067E+05	3.702E+05
Kr-85m	1.327E+04	0.000E+00	1.656E+04	2.983E+04
Kr-87	2.201E+03	0.000E+00	2.780E+03	4.980E+03
Kr-88	1.592E+04	0.000E+00	2.009E+04	3.601E+04
Rb-86	4.741E-02	0.000E+00	6.660E-01	7.134E-01
Sr-89	6.063E-01	0.000E+00	2.139E+01	2.199E+01
Sr-90	5.960E-02	0.000E+00	2.127E+00	2.187E+00
Sr-91	9.835E-01	0.000E+00	1.973E+01	2.071E+01
Sr-92	4.235E-01	0.000E+00	4.621E+00	5.045E+00
Y-90	1.705E-03	0.000E+00	3.499E-01	3.516E-01
Y-91	8.108E-03	0.000E+00	3.294E-01	3.375E-01
Y-92	1.280E-01	0.000E+00	4.108E+00	4.236E+00
Y-93	7.808E-03	0.000E+00	1.602E-01	1.680E-01
Zr-95	1.094E-02	0.000E+00	3.867E-01	3.976E-01
Zr-97	2.965E-02	0.000E+00	7.148E-01	7.445E-01
Nb-95	1.099E-02	0.000E+00	3.921E-01	4.031E-01
Mo-99	1.398E-01	0.000E+00	4.309E+00	4.449E+00
Tc-99m	1.256E-01	0.000E+00	4.060E+00	4.186E+00
Ru-103	2.168E-01	0.000E+00	7.624E+00	7.841E+00
Ru-105	5.058E-02	0.000E+00	7.237E-01	7.742E-01
Ru-106	8.295E-02	0.000E+00	2.956E+00	3.039E+00
Rh-105	7.076E-02	0.000E+00	2.102E+00	2.172E+00
Sb-127	1.548E-01	0.000E+00	4.934E+00	5.089E+00
Sb-129	3.147E-01	0.000E+00	4.439E+00	4.753E+00
Te-127	1.554E-01	0.000E+00	5.144E+00	5.299E+00
Te-127m	2.094E-02	0.000E+00	7.471E-01	7.680E-01
Te-129	3.651E-01	0.000E+00	6.531E+00	6.896E+00
Te-129m	7.001E-02	0.000E+00	2.464E+00	2.534E+00

Table 18 (Cont'd)
0-720 Hr Isotopic Activity Released To Environment

Isotope	Isotopic Cumulative Integrated Activity Released To Environment (0-720 Hr) (Ci)			Total Integrated Activity (Ci) A+B+C
	Containment Leakage A	ESF Leakage B	MSIV Leakage C	
Te-131m	1.464E+00	0.000E+00	4.019E+01	4.166E+01
Te-132	2.098E+00	0.000E+00	6.585E+01	6.795E+01
I-131	2.907E+02	2.988E+04	3.574E+03	3.374E+04
I-132	3.351E+01	1.641E+02	2.924E+02	4.900E+02
I-133	1.096E+02	5.499E+03	1.182E+03	6.791E+03
I-134	3.023E+01	3.010E+01	3.735E+01	9.769E+01
I-135	6.693E+01	1.221E+03	5.329E+02	1.821E+03
Xe-133	6.786E+06	6.750E+04	8.538E+06	1.539E+07
Xe-135	1.377E+05	1.599E+04	1.748E+05	3.285E+05
Cs-134	4.001E+00	0.000E+00	5.794E+01	6.194E+01
Cs-136	1.388E+00	0.000E+00	1.927E+01	2.065E+01
Cs-137	5.056E+00	0.000E+00	7.327E+01	7.833E+01
Ba-139	3.297E-01	0.000E+00	2.388E+00	2.718E+00
Ba-140	1.072E+00	0.000E+00	3.670E+01	3.777E+01
La-140	4.149E-02	0.000E+00	7.852E+00	7.893E+00
La-141	6.425E-03	0.000E+00	8.625E-02	9.267E-02
La-142	3.274E-03	0.000E+00	2.542E-02	2.869E-02
Ce-141	2.559E-02	0.000E+00	8.979E-01	9.235E-01
Ce-143	2.248E-02	0.000E+00	6.280E-01	6.505E-01
Ce-144	4.187E-02	0.000E+00	1.491E+00	1.533E+00
Pr-143	9.258E-03	0.000E+00	3.338E-01	3.430E-01
Nd-147	4.056E-03	0.000E+00	1.380E-01	1.421E-01
Np-239	2.848E-01	0.000E+00	8.620E+00	8.905E+00
Pu-238	5.102E-05	0.000E+00	1.821E-03	1.872E-03
Pu-239	6.154E-06	0.000E+00	2.201E-04	2.262E-04
Pu-240	7.958E-06	0.000E+00	2.841E-04	2.920E-04
Pu-241	2.308E-03	0.000E+00	8.238E-02	8.469E-02
Am-241	1.039E-06	0.000E+00	3.743E-05	3.847E-05
Cm-242	2.459E-04	0.000E+00	8.746E-03	8.992E-03
Cm-244	1.183E-05	0.000E+00	4.222E-04	4.340E-04

A From HEPU300CL00.o0
B From HEPU300ES00.o0
C From H1N300MS00.o0

12.0 FIGURES

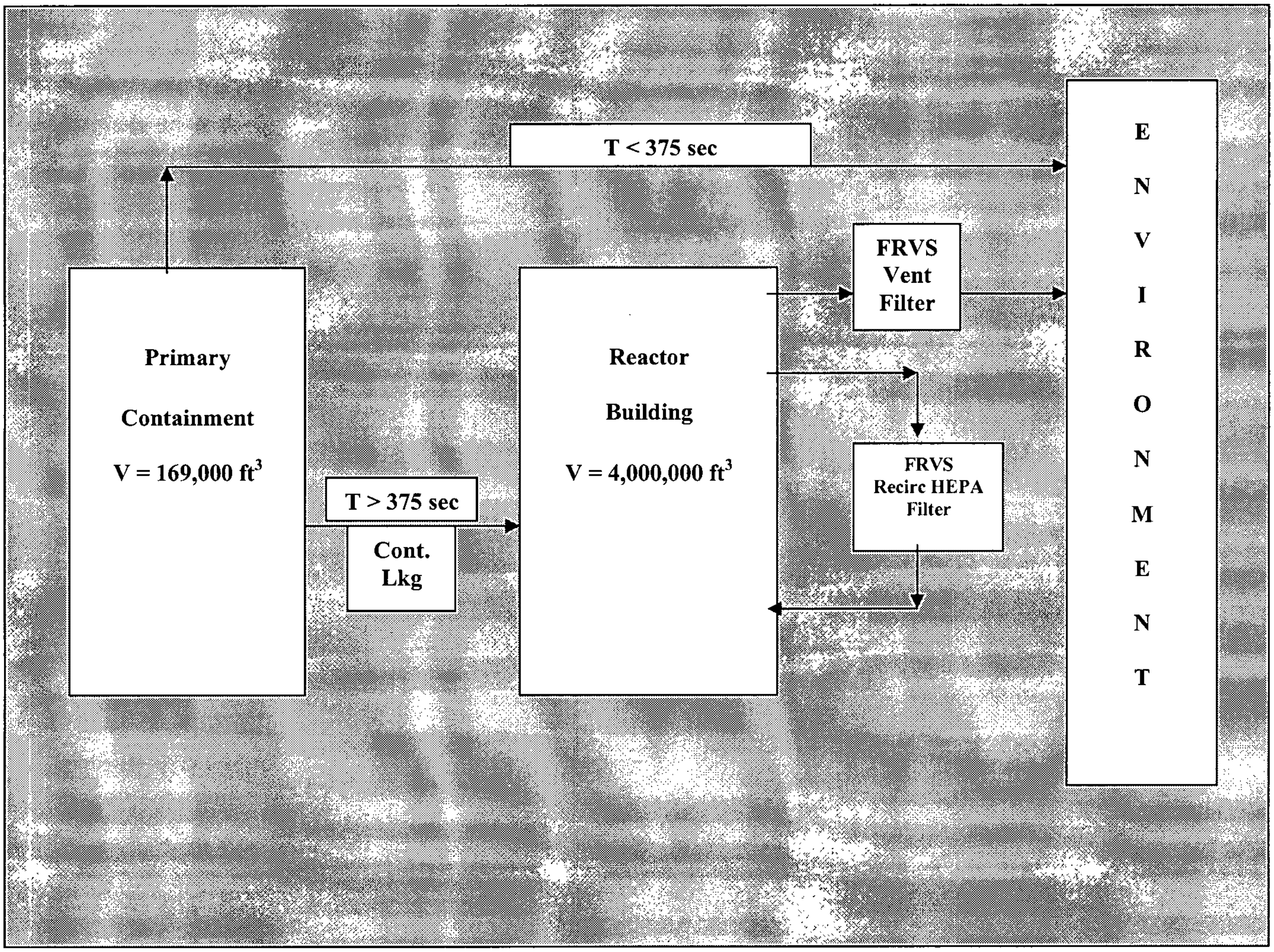


Figure 1: Containment Leakage RADTRAD Nodalization

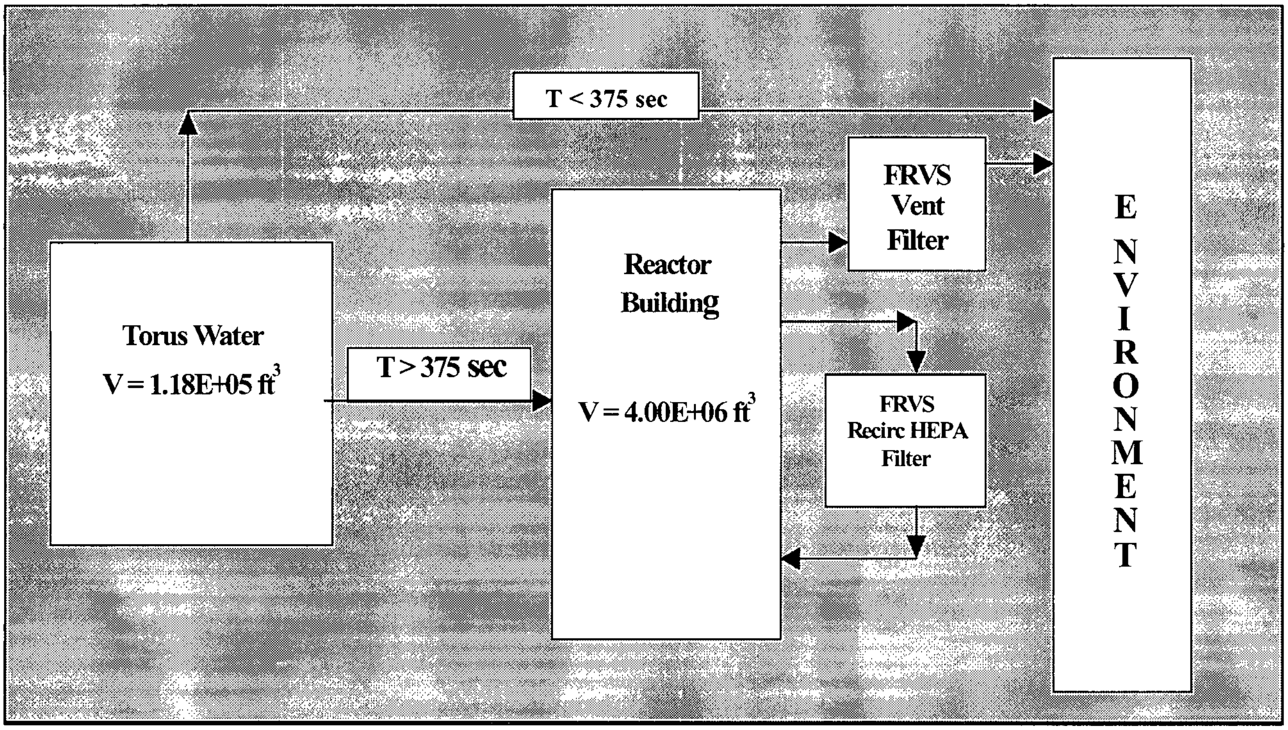


Figure 2: HCGS ESF Leakage RADTRAD Nodalization

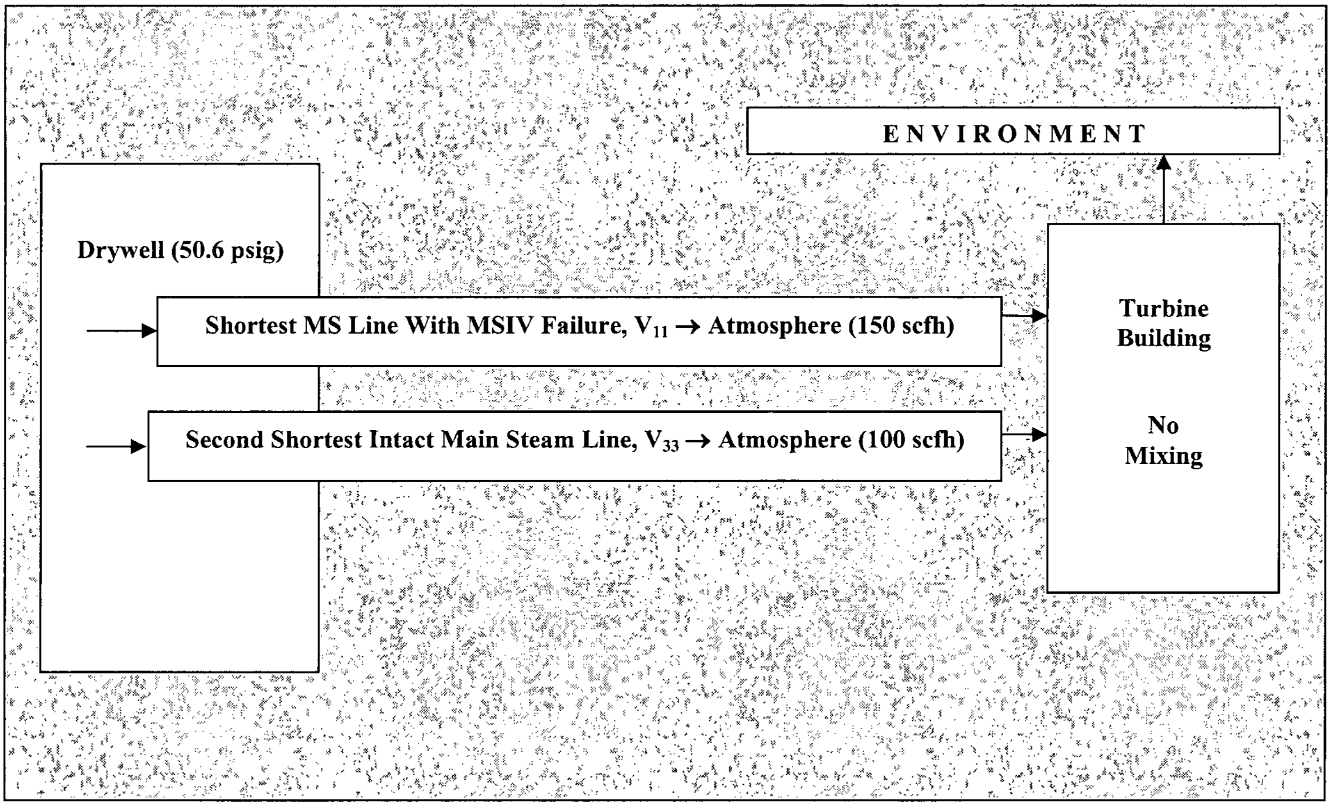


Figure 3: HCGS MSIV Leakage Path Volumetric Distribution

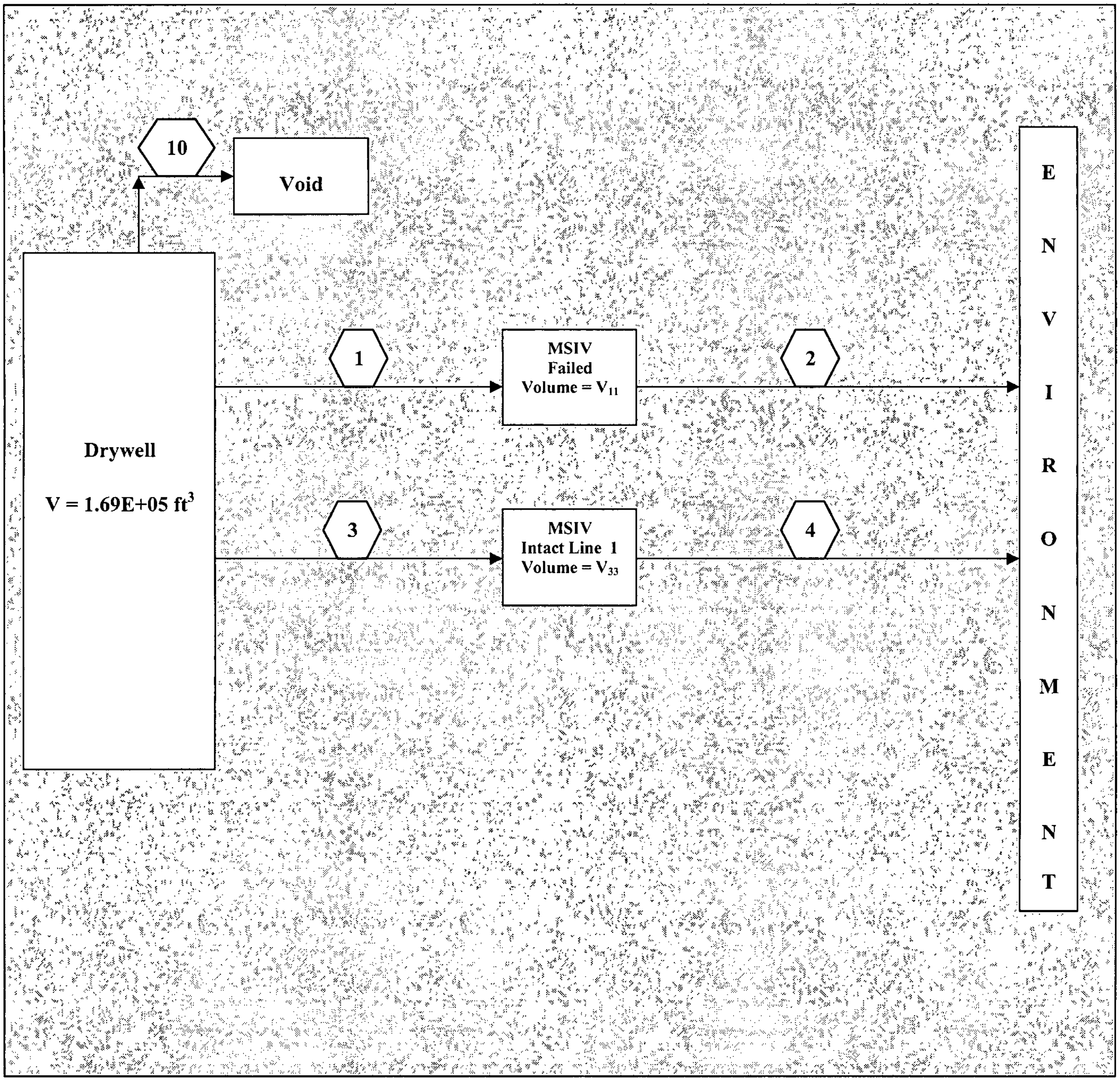


Figure 4: HCGS MSIV Leakage RADTRAD Nodalization

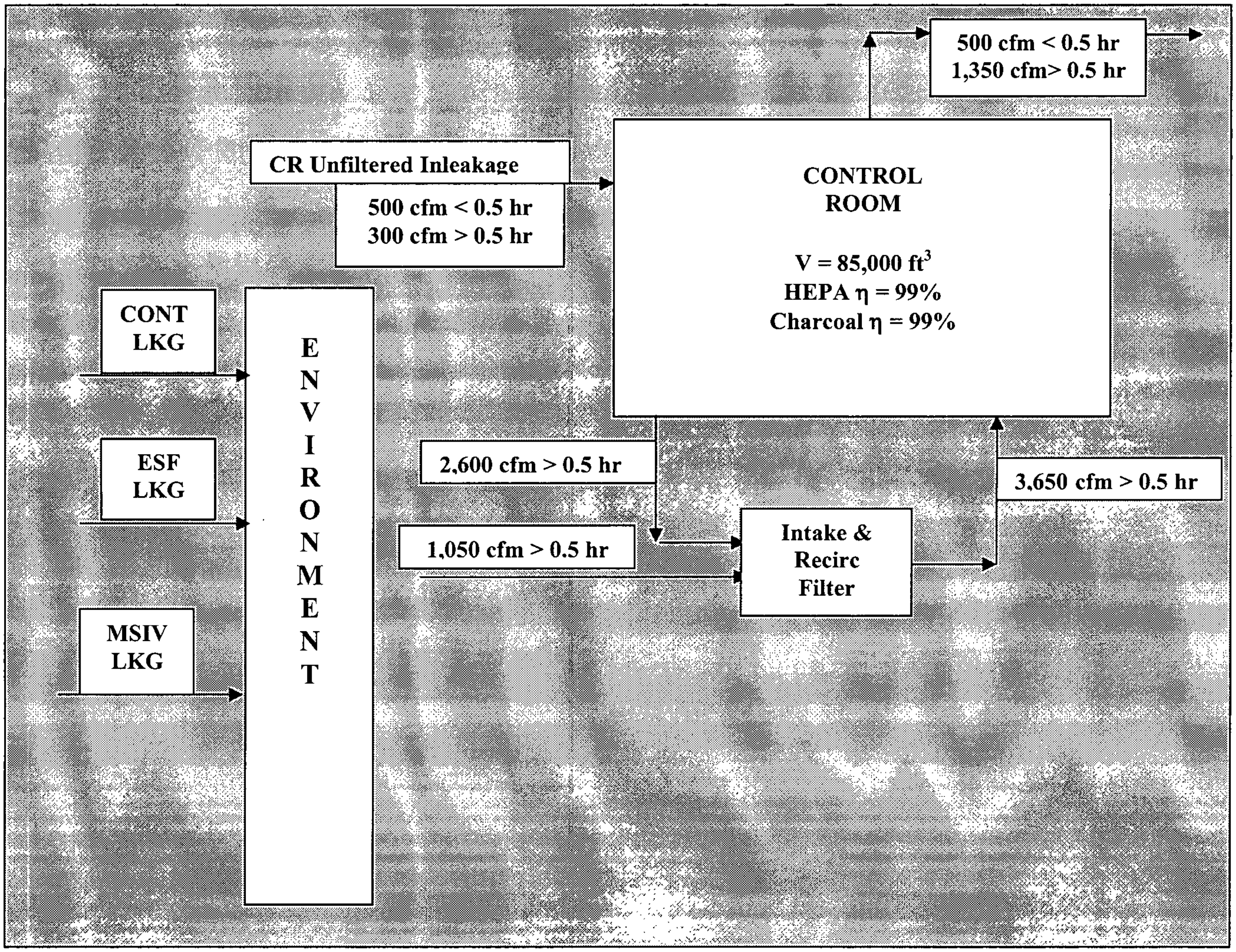


Figure 5 – HCGS Control Room RADTRAD Nodalization

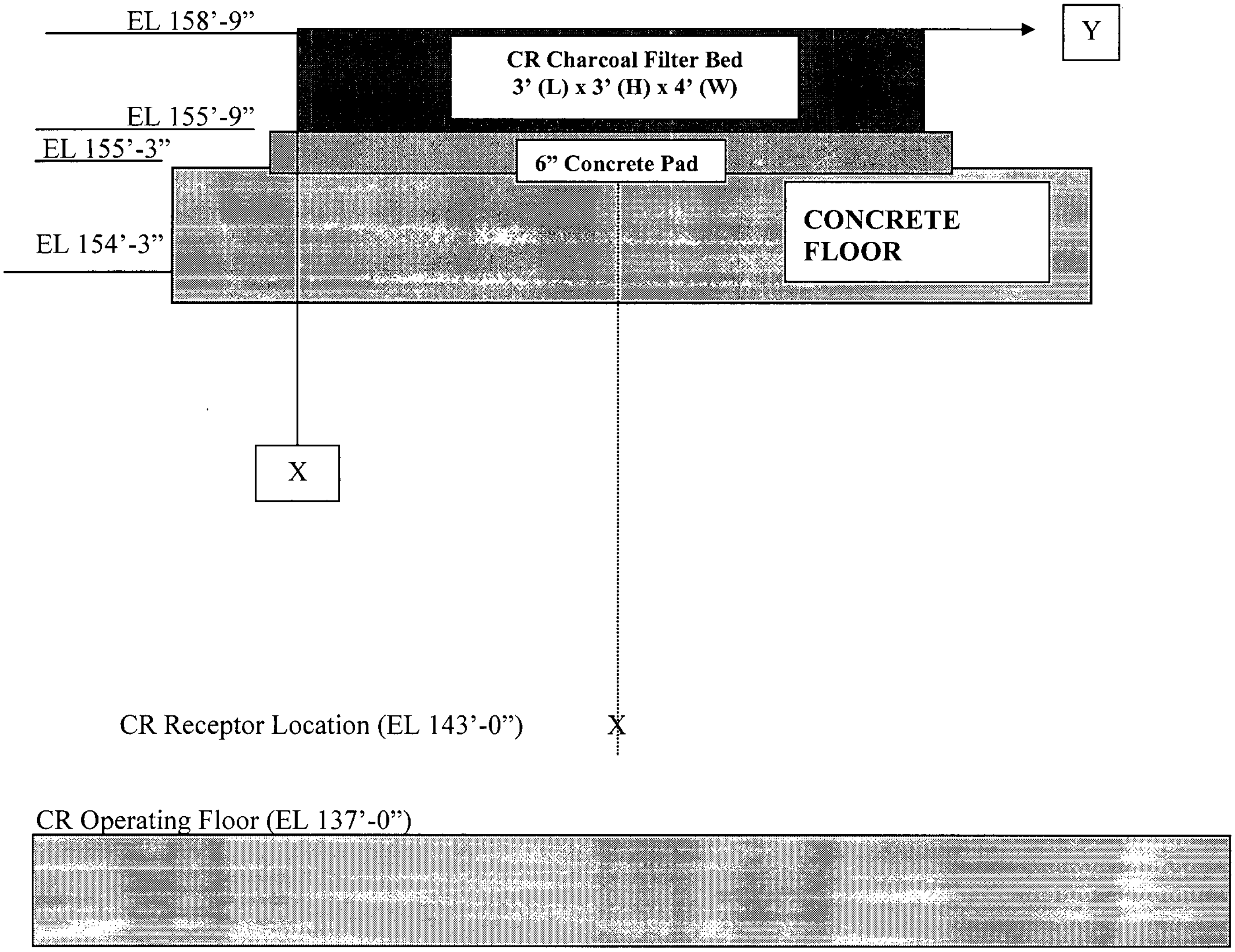
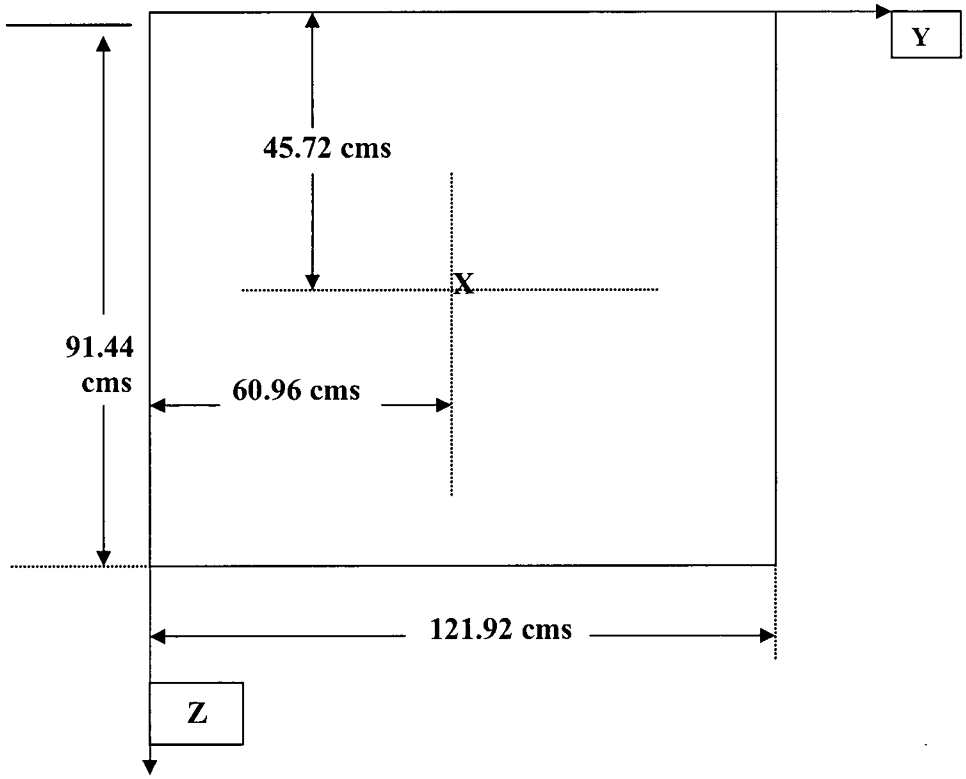


Figure 6 – CR Filter Shine Dose
(Elevation View)



X Indicates Dose Point Location

Figure 7 – CR Filter Shine Dose
(Plan View)

13.0 AFFECTED DOCUMENTS:

HC Calculation H-1-ZZ-MDC-1880, Rev 3 will be superseded upon approval of this calculation.

The following documents will be revised:

1. HCGS UFSAR Section 6.4
2. HCGS UFSAR Section 15.6.5.5.1
3. HCGS UFSAR Section 15.6.5.5.2
4. HCGS UFSAR Table 6.4-2
6. HCGS UFSAR Table 6.4-4
7. UFSAR Table 15.6-12
8. UFSAR Table 15.6-16
9. UFSAR Figure 15.6-3
10. Calculation H-1-ZZ-MDC-1923
11. Calculation H-1-ZZ-MDC-1927
12. Procedure VHC.MD-ST.GK-0002

14.0 ATTACHMENTS

14.1 E-mail Subject: FRVS Vent Charcoal Filter Efficiencies
14.2 Evaluation for Co-60 Isotope Test Assembly
14.3 1 CD with the following electronic files:
Calculation No: H-1-ZZ-MDC-1880, Rev 4.
RADTRAD computer runs

Attachment 14.1

From: Cichello, John P.
Sent: Friday, March 15, 2002 10:40 AM
To: Patel, Gopal J.
Cc: Barkley, Barry L.; Duffy, John F.
Subject: RE: FRVS Vent Charcoal Filter Efficiencies

Gopal,

The CAV Units at Salem are tested for efficiency per ASTM 3803-89 at 30 degs C/95% RH (40 FPM with a 2" bed). These parameters are the same conditions that the FRVS Vent Units will be revised to. Both systems will not have heaters and live in similar environments. The following is the CAV historical data.

CAV 1 Penetration results	
1/8/99	0.508%
9/28/00	0.542%

CAV 2 Penetration results	
1/5/99	0.448%
10/4/00	0.678%
1/28/02	0.805%

Cichello

-----Original Message-----
From: Patel, Gopal J.
Sent: Monday, March 11, 2002 3:13 PM
To: Cichello, John P.
Cc: Barkley, Barry L.; Duffy, John F.
Subject: FRVS Vent Charcoal Filter Efficiencies

John:

Please provide me a reference for the FRVS vent elemental and organic charcoal filter efficiencies of 90% without humidity control. As you told me that currently the Salem 1 & 2 charcoal is tested with 100% humidity with the in-laboratory methyl iodide penetration < 2.5%, which provides equivalent iodine removal efficiency of 95% or greater. Please provide me an E-mail response, which will attached as a reference for the same.

I thank you very much for your cooperation and appreciate your quick response.

Gopal J. Patel
1282

Attachment 14.2 (pages 106 - 116) contains GEH Proprietary Information –
It has been extracted from this document

Attachment 14.3

1 CD With Various Electronic Files