Enclosure (2)

CA06450 FHA

Radiological Consequences

Design Basis Calculation

Using AST

Calvert Cliffs Nuclear Power, Inc.
November 3, 2005

ESP No.:	ES200100401	Supp No.	000	Rev. No.	000	Page 1 of 1

FORM 19, CALCULATION COVER SHEET

A. INITIATION (Control Doc Type - DCALC) Page 1 of 71

DCALC No.: CA06450 Revision No.: 000

Vendor Calculation (Check one): ☐ Yes ☒ No

Responsible Group: FOSU

Responsible Engineer: Gerard E. Gryczkowski

B. CALCULATION

ENGINEERING DISCIPLINE:

☐ Civil ☐ Instr & Controls ☒ Nuc Engrg
☐ Electrical ☐ Mechanical ☐ Nuc Fuel Mngmt
☐ Other: ☐ Reliability Engrg

Title: FUEL HANDLING ACCIDENT USING ALTERNATE SOURCE TERMS

Unit ☐ 1 ☐ 2 ☒ COMMON

Proprietary or Safeguards Calculation ☐ YES ☒ NO

Comments: NA

Vendor Calc No.: NA REVISION NO.: NA

Vendor Name: NA

Safety Class (Check one): ☒ SR ☐ AQ ☐ NSR

There are assumptions that require Verification during walkdown: AIT #: NA

This calculation **SUPERSEDES**: NA

C. REVIEW AND APPROVAL:

	Printed Name and Signature	Date
Responsible Engineer:	Gerard E. Gryczkowski [signature]	3/18/2005
Independent Reviewer:	Ian Sommerville [signature]	6-23-05
Approval:	Phillip I. Wawrzonek [signature]	7/1/05

IF the results or conclusions of this calculation or revision might affect a procedure or the basis of a procedure, a Change Notification Form (Form 14) shall be forwarded to the Procedure Development Unit with a summary of the calculation's purpose and results.

2. LIST OF EFFECTIVE PAGES

Page	Latest Rev	Page	Latest Rev	Page	Latest Rev	Page	Latest Rev	Page	Latest Rev
001	0	002	0	003	0	004	0	005	0
006	0	007	0	008	0	009	0	010	0
011	0	012	0	013	0	014	0	015	0
016	0	017	0	018	0	019	0	020	0
021	0	022	0	023	0	024	0	025	0
026	0	027	0	028	0	029	0	030	0
031	0	032	0	033	0	034	0	035	0
036	0	037	0	038	0	039	0	040	0
041	0	042	0	043	0	044	0	045	0
046	0	047	0	048	0	049	0	050	0
051	0	052	0	053	0	054	0	055	0
056	0	057	0	058	0	059	0	060	0
061	0	062	0	063	0	064	0	065	0
066	0	067	0	068	0	069	0	070	0
071	0								

3. REVIEWER COMMENTS

(1) p.9 Reference 5 - Be more specific about location of info in Ref 5
Response: OK. Added reference to Case CRCB.

(2) p.11 One column in the ADC does not appear correct compared with the Ref - ctmt1-wr
Response: The The dispersion coefficients in question (Ctmt1-wr taut string) are listed on page 22 of CA06012.

(3) p.11 ACU 12 or 13 ?
Response: ACU 11 and 12 denote the Air Conditioning Units (ACU) 11 and 12 in the control room. These are not to be confused with Access Controls (AC) 11 and 13, which are on the roof of the Auxiliary Building.

(4) p.18 Should state where (file name) the values are calculated.
Response: OK FHA.XLS(FHAINP3)

(5) p.24 What are the large values of DF for. They don't seem to be calculated or used in a calcualation
Response: They are Westinghouse's measured values of DF, which are used by the NRC to generate their values. They are described in Section 9.2 and calculated in DF.XLS(WCAP-7518-L) (Attachment A). They are less conservative than those calculated using the Burley methodology. The Burley methodology was employed in this work; however, the Westinghouse data was presented to demonstrate the conservative nature of the methodology used.

(6) Compartment 3 - 9,000 cfm ??
Response: Control room recirculation flow is 9000 cfm (the minimum value of Input 17a.

(7) p. 42 I-135 #'s don't seem to match FGR 11
Response: Per the description in FGR14.INP, the I-135 DCFs include the contribution frim the daughetr Xe-135m. The branching fraction for I-135 to Xe-135m is 0.15 per the LOCADOSE User's Manual. Thus, the DCF value in FGR14.INP of inhalation gonads should be I-135 value in FGR-11 plus 15% of the Xe-135m value in FGR-11. ==> I-135 (Inhalation-gonads) = (1.70E-11+0.15*0.00e+00) = 1.70E-11 Sv/Bq.

(8) p.42 I-135 #'s don't seem to match FGR 12
Response: Per the description in FGR14.INP, the I-135 DCFs include the contribution frim the daughetr Xe-135m. The branching fraction for I-135 to Xe-135m is 0.15 per the LOCADOSE User's Manual. Thus, the DCF value in FGR14.INP of cloudshine gonads should be I-135 value in FGR-12 plus 15% of the Xe-135m value in FGR-12. ==> I-135 (clodshine-gonads) = (7.77E-14+0.15*2.00e-14) = 8.07E-14 Sv-sec/Bq-m^3.

(9) p.42 Xe -133 - = 0.0 not per Ref
Response: There are no inhalation doses for the xenon isotopes in FGR-11.

4. TABLE OF CONTENTS

5. INTRODUCTION

UFSAR 14.18 presents the licensing basis evaluation of the Fuel Handling Accident (FHA), which is assumed to occur in the spent fuel pool (SFP) handling area or in the containment by dropping a fuel assembly during fuel movement operations. The analyses for a FHA in the refueling pool and the SFP both assume that gas gap activity from 176 fuel rods of the highest power assembly is released. In the SFP the fuel assemblies are stored within the racks at the bottom of the SFP. The top of the rack extends above the tops of the stored fuel assemblies. A dropped fuel assembly could not strike more than one fuel assembly in the storage rack. Impact could occur only between the ends of the involved fuel assemblies, the bottom end fitting of the dropped fuel assembly impacting against the top end fitting of the stored fuel assembly. The results of an analysis of the end on energy absorption capability of a fuel assembly indicate that a fuel assembly is capable of absorbing the kinetic energy of the drop with no fuel rod failures. The worst FHA that could occur in the SFP is the dropping of a fuel assembly to the fuel pool floor. Because of the high energy absorption required to rupture a fuel rod, 176 represents the maximum number of damaged pins expected from any credible fuel handling incident scenario.

The likelihood of a FHA is minimized by administrative controls and physical limitations imposed on fuel handling operations. All refueling operations are conducted in accordance with prescribed procedures under direct surveillance of a qualified supervisor. The possibility of damage to a fuel assembly as a consequence of mishandling is minimized by thorough training, detailed procedures, and equipment design. The single-failure-proof design of the Spent Fuel Cask Handling Crane prevents the drop of heavy objects such as shipping/transfer casks on the spent fuel storage racks. Inadvertent disengagement of a fuel assembly from the fuel handling machine is prevented by mechanical interlocks; consequently, the possibility of dropping and damaging of a fuel assembly is remote.

Should a fuel assembly be dropped or otherwise damaged during handling, radioactive release could occur in either the containment or the Auxiliary Building. The air in both of these areas is monitored. The radiation monitors immediately indicate the increased activity level and alarm. The affected area would then be evacuated. The SFP ventilation system draws air across the SFP area; this air is discharged to the atmosphere through the plant vent. If the cask loading hatch and all exterior hatches to the 69' level of the Auxiliary Building are closed, this is the only route for the release of activity from the SFP area to the environment. After a FHA in containment, the activity may be released through the personnel air lock (PAL), the containment outage door (COD), the containment walls themselves, or via the hydrogen or 48" purge lines into the plant vent. The release through the plant vent is most limiting, and thus a FHA in the containment and the SFP will both be assumed to be released to the environment through the plant vent stack.

The original design-basis FHA offsite doses were calculated in calculation NC-94-030 (Ref.20) for a FHA in the SFP with credit for the SFP HEPA and charcoal filters. This bounded the FHA offsite doses in containment, where no activity release was postulated due to the containment closure requirement for fuel movement. Calculation 000-DA-9302 (Ref.19) recalculated the offsite doses to allow the personnel air locks to be open during fuel movement. The containment offsite doses then became bounding due to a lack of filtration credit. This was approved by the NRC in License Amendments 194/171 (Ref.21). The reasoning was extended to the containment outage door. The NRC allowed the COD to be open during fuel movement in License Amendments 242/216 (Ref.22).

Note that this work also supports Technical Specification Task Force (TSTF)-312 (Ref.42), which allows penetration flow paths that have direct access from the containment atmosphere to the outside atmosphere to be unisolated under administrative control. Since this current analysis assumes that the radioactive release is unfiltered, completely released over a two hour time period, and released with the most limiting dispersion coefficients, the analysis will also apply to the containment penetration flow paths that are opened under administrative control.

The NRC requested additional information regarding the control room doses that would result from a FHA in containment with the PAL doors open. Ref.23 documented the FHA control room analysis, which calculated a 30-day control room thyroid dose of 47.94 Rem without protective measures, which exceeds the regulatory limit of 30 Rem thyroid per 10 CFR 50 Appendix A GDC 19. However, Ref.23 also determined that the operators would have approximately 3.89 hours to initiate protective measures (SCBAs) to remain within the regulatory dose limit of 30 rem thyroid. This was reported to the NRC in Ref.24. Subsequently, the NRC issued approval of CCNPP's control room habitability analysis in Ref.25. These analyses were revised to incorporate increased control room inleakage values of 4600 and 3500 cfm in Refs.26-27. Ref.27 determined that the operators would have approximately 82 minutes to initiate protective measures to remain within the regulatory dose limit of 30 rem thyroid.

Failed fuel rods that have released their active gas gap inventory can be stored in encapsulated fuel tubes. These encapsulated fuel tubes can be stored in the peripheral guide tubes of host assemblies or empty grid cages in the SFP. A single encapsulation tube containing a damaged fuel rod can be stored in an incore instrumentation (ICI) trash can, can be laid temporarily atop the SFP storage racks with administrative restrictions on fuel movement in the laydown area, or can be placed at the bottom of an upender trench with the associated upender tagged out. The addition of up to four encapsulated fuel rods in a host assembly will not cause the radiological consequences of a FHA to increase since administrative controls are employed to ensure that only fuel rods with sufficient clad damage to ensure no residual gas gap activity are stored in the encapsulation tubes in fuel assemblies. The failed rods cannot contribute to gas gap release, since their gas inventory has already been released. Undamaged fuel rods can only be stored in the encapsulation tubes in empty grid cages. This will guarantee that the consequences of a FHA will not be increased. Only damaged fuel rods with no gas gap activity can be stored in encapsulation tubes stored in ICI trash cans, temporarily atop the SFP storage racks, or at the bottom of an upender trench, thus precluding any fission gas release.

Reconstitution or inspection of a fuel assembly can take place in individual SFP storage racks with spent fuel assemblies placed on rack spacers and with their upper end fittings removed. In such a configuration, the structural integrity of the fuel assemblies is reduced, and the fuel rods may protrude above the SFP racks. Since fuel damage could occur if a heavy object is dropped on top of an assembly seated on a rack spacer with its upper end filling removed, administrative controls will restrict movement of loads over the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies. Heavy loads may only be moved in this area via the single-failure-proof crane, if assemblies are seated on rack spacers with their upper end fittings removed. Only the single-failure-proof crane or single-failure-proof rigging will be used over the reconstitution area in the SFP for loads other than tools. A knowledgeable and briefed person will be present for the entire time that the upper end fitting or template is removed from an assembly to restrict movement of loads other than tools in this area of the SFP. In addition, after the upper end fillings have been removed, the spent fuel handling machine will be administratively prohibited from nearing the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies.

The FHA analysis assumes a total iodine decontamination factor (DF) of 200 based on a minimum water depth of 23' per Ref.08. In the refueling pool this assumption is preserved by the Technical Specification requirement of 23' of water above fuel assemblies seated in the reactor core. In the SFP, the Technical Specification only requires 21.5' of water above fuel assemblies seated in the SFP storage racks. This Technical Specification was deemed sufficient to preserve the required 23' of water because a FHA was assumed to occur as a fuel assembly strikes the bottom of the SFP. When assemblies are placed on rack spacers and their upper end fillings are removed, a FHA from a dropped heavy object would require a lower DF based on reduced water coverage. A revised DF of 120 for a FHA during reconstitution/inspection with 20.4' of water between the top of the pin and the surface of the water was computed for a 20.5" rack spacer. Note that this is very conservative, since normal level control will result in at least 21.5' of water above exposed fuel pins.

Previously, power reactor licensees have typically used the U.S.A.E.C Technical Information Document TID-14844, "Calculation of Distance Factors for Power and Test Reactor Sites," (Ref.18) as the basis for DBA analysis source terms. TID-14844 is referenced in 10 CFR 100.11, the power reactor siting regulation, which contains offsite dose limits in terms of whole body and thyroid doses. In December 1999, the NRC issued a new regulation, 10 CFR 50.67, "Accident Source Term," which provided a mechanism for licensed power reactors to replace the traditional accident source term used in their DBA analyses with an alternate source term. Regulatory guidance for the implementation of these ASTs is provided in Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors" (Ref.08). Section 50.67 of 10 CFR requires a licensee seeking to use AST to apply for a license amendment and requires that the application contain an evaluation of the consequences of affected DBAs. As part of the implementation of the AST, the total effective dose equivalent (TEDE) acceptance criterion of 10 CFR 50.67 replaces the previous whole body and thyroid dose guidelines of 10 CFR 100.11 and 10

CFR 50, Appendix A, GDC-19 for the loss-of-coolant accident (LOCA), the main steam line break (MSLB), the steam generator tube rupture (SGTR), the seized rotor event (SRE), the fuel handling accident (FHA), and the control rod ejection accident (CREA).

The current work utilizes the alternate source term (AST) methodology of 10 CFR 50.67 and Regulatory Guide 1.183 to calculate offsite and control room doses for a FHA. A bounding control room inleakage value of 3500 cfm was assumed. Modification of the control room emergency ventilation system to a nominal 10000 cfm flow with a 90% filtration efficiency was credited. SFP filtration was not credited. Also credited was installation of automatic isolation dampers and radiation monitors at Access Controls 11 and 13 on the Auxiliary Building Roof. This modification limits activity egress into the control room from either the West Road Inlet or the Turbine Building, thus limiting the atmospheric dispersion coefficient value.

The site boundary, low population zone, and control room doses for the design-basis FHA in containment and the SFP calculated in Attachments I, J, and K, are detailed in the following table.

Fuel Handling Accident Doses in REM TEDE				
	Containment/SFP	Containment/SFP	Spent Fuel Pool	Regulatory Limit
DF	200	200	120	
Decay Time (hr)	100	72	72	
EAB	0.6167	0.6958	1.1136	6.3 (RG 1.183)
LPZ	0.1452	0.1638	0.2622	6.3 (RG 1.183)
Control Room	2.0765	2.3314	3.8538	5.0 (10CFR50.67)

Note that all values are below the regulatory limits. Since the reconstitution SFP case is the most limiting, it will be considered as the design-basis fuel handling accident for alternate source terms.

6. INPUT DATA

The input data to determine the site boundary, low population zone, and control room doses from a Fuel Handling Accident in the containment and in the SFP are the following:

(01) Initial thermal power is 2754 MWt (UFSAR 3.2.1/Ref.1).

(02) The pin power peaking factor is 1.70. Per the Core Operating Limits Reports for Units 1 and 2, (Refs.2-3), the total integrated radial peaking factors (F_r^T) are less than or equal to 1.65. For conservatism,a pin power peaking factor of 1.70 will be used in this work.

(03) Fuel movement does not occur until 72 hours after reactor shutdown. Per TRM 15.9.1, fuel movement can occur 100 hours after reactor shutdown; however, this value was decreased to 72 hours for conservatism.

(04) Containment volume:

(a) Net free volume:	2.035E+06 cf	(UFSAR Tab.14.20-3, Ref.04)
(b) Containment sprayed volume:	1.48E+06 cf	(Ref.04)
Volume fraction:	0.7273	(Ref.04)
(c) Containment unsprayed volume:	0.555E+06 cf	(Ref.04)
Volume fraction:	0.2727	(Ref.04)

(05) The isotopic source terms (CI/MWT) were extracted from Ref.05 Case CRCB and generated via SAS2H calculations. The isotopic decay constants (1/sec) were also extracted from Ref.06.

Isotope	Source (CI/MWT)	Decay Constant (1/SEC)
I-131	2.7562E+04	9.9783E-07
I-132	3.9464E+04	8.3713E-05
I-133	5.5715E+04	9.2568E-06
I-134	6.2858E+04	2.1963E-04
I-135	5.2694E+04	2.9129E-05
XE-133M	1.7354E+03	3.6632E-06
XE-133	5.5707E+04	1.5296E-06
XE-135M	1.1635E+04	7.5506E-04
XE-135	1.7708E+04	2.1182E-05
XE-138	4.9330E+04	8.1932E-04
KR-85M	7.9679E+03	4.2978E-05
KR-85	3.7180E+02	2.0489E-09
KR-87	1.6208E+04	1.5141E-04
KR-88	2.2658E+04	6.7796E-05

(06) Per Ref.07, damaged fuel rods are assumed to release their gas gap activities consisting of the following isotopes:

16% I-131
10% other iodines
20% Kr-85
10% other noble gases

(07) For assemblies on the storage rack spacers in the SFP for reconstitution/inspection, the height of water above the exposed fuel rods can be calculated to be 20.4'.

21.5'	Technical Specification 3.7.13, height of water above assembly seated in storage racks in SFP
-1.7083'	20.5" rack spacer height per Ref.29
+0.6055'	7.266" Upper end fitting (UEF) height per Ref.28
=20.4'	Height of water above assembly seated on rack spacers with their UEF removed

(08) Per Section 9.2, a decontamination factor of 200 is appropriate for assemblies seated in the storage racks or in the core with internal pin pressures up to 1400 psig, while a decontamination factor of 120 is appropriate for assemblies seated on rack spacers with internal pin pressures up to 1400 psig. The decontamination factor of noble gases in the pool is unity per Ref.08.

(09) The control room volume of 289194 ft^3 is extracted from Ref.30.

(10) The breathing rates are extracted from Ref.08:

Time (hours)	Breathing Rate (m3/sec)
0-8	3.5E-04
8-24	1.8E-04
24-720	2.3E-04

(11) The control room occupancy factors are extracted from Ref.08:

Time (hours)	Occupancy Factor
0-24	1.0
24-96	0.6
96-720	0.4

(12) The ventilation stack-to-site boundary, two-hour, atmospheric dispersion coefficient of 1.44E-4 sec/m^3 was calculated via the Gifford wake model extracted from UFSAR 2.3.6, as follows

$\chi/Q = 1/[\mu * (\pi\sigma_y\sigma_z + cA)] = 1.44E\text{-}4$ sec/m^3

where for 1150 m exclusion area boundary distance and 5% frequency

μ = average wind speed = 1 m/sec

σ_y= standard deviation of the distribution in the lateral direction = 92 m (UFSAR Table 2-14)

σ_z= standard deviation of the distribution in the vertical direction = 24 m (UFSAR Table 2-14)

c= wake factor

A= cross-sectional area of structure from which material is released = 0 m

(13) Atmospheric dispersion coefficients from containment to low population zone (2 miles) (UFSAR Fig.2.3-3/UFSAR 14.24.3)

Time (hours)	χ/Q (sec/m^3)
0-2	3.39E-05
2-24	2.20E-06
24-720	5.40E-07

Note that the 0-2 hour value was adjusted via the Gifford wake model for a vent stack release rather than a containment release.

(14) The dose conversion factors (DCFs) were extracted from Refs.31-32. This data is included in the Conversion Factor File FGR14.INP in Attachment H for use by RADTRAD. Note that the cloudshine data in FGR14.INP corresponds to the FGR-12 data, while the inhaled chronic data in FGR14.INP corresponds to the worst-case effective data in FGR-11. The remaining data in FGR14.INP is extraneous and not used by RADTRAD.

(15) Atmospheric dispersion coefficients from the ventilation stack to the Control Room: (Ref.30)
The spent fuel pool ventilation system draws air across the spent fuel pool area; this air is discharged to the atmosphere through the plant vent. If the cask loading hatch and all exterior hatches to the 69' level of the Auxiliary Building are closed, this is the only route for the release of activity from the spent fuel pool area to the environment. After a FHA in containment, the activity may be released through the personnel air lock (PAL), the containment outage door (COD), the containment walls themselves, or via the hydrogen or 48" purge lines into the plant vent. The release through the plant vent is most limiting, and thus a FHA in the containment and the SFP will both be assumed to be released to the environment through the plant vent stack. The main control room inleakage points include the west road inlets, the turbine building, and Access Controls 11 and 13 on the Auxiliary Building roof. Installation of automatic isolation dampers and radiation monitors at Access Controls 11 and 13 on the Auxiliary Building Roof are credited in this work.

Atmospheric Dispersion Coefficients						
	cod2-tb	cod1-wr	ctmt2-tb	ctmt1-wr	vs1-wr	vs2-tb
0-2 hr	1.02E-03	1.16E-03	1.02E-03	1.11E-03	9.54E-04	1.68E-03
2-8 hr	8.48E-04	9.49E-04	7.98E-04	7.29E-04	6.86E-04	1.34E-03
8-24hr	3.34E-04	3.90E-04	3.19E-04	3.19E-04	2.95E-04	5.14E-04
1-4 days	2.31E-04	2.70E-04	2.56E-04	2.36E-04	2.13E-04	3.84E-04
4-30 days	1.90E-04	2.36E-04	2.14E-04	1.98E-04	1.56E-04	3.12E-04

The atmospheric dispersion coefficients corresponding to the Unit 2 vent stack to the turbine building will be conservatively utilized in this work.

(16) Control room inleakage: The control room inleakages for the two trains Air Conditioning Units (ACU) 11 and 12 were measured by NUCON International Inc. via sulfur hexaflouride (SF_6) tracer gas tests as documented in Refs.34-37 (Attachment L). An additional inleakage test was performed by Brookhaven National Laboratory (BNL) via a perfluorocarbon tracer gas (PFT) test as documented in Ref.38 (Attachment M).

	ACU 11	ACU 12
SF_6 Test 11/11/97	4300±300 cfm	3000±300 cfm
SF_6 Test 11/11/97	3600±600 cfm	2550±450 cfm
SF_6 Test 11/11/97	2900±250 cfm	2750±380 cfm
SF_6 Test 1/18/00	2600±200 cfm	3000±250 cfm
PFT Test 5/1/02	2930±185 cfm	2930±185 cfm

The latest SF_6 and PFT tests show fairly good agreement, as indicated above. A conservative value of 3500 cfm will be utilized in this work.

The control room inleakage points were deduced from the PFT testing carried out by Brookhaven National Laboratory and include the Auxiliary Building West Road inlet (WR), the Turbine Building inlet (TB), Access Control 11 (AC11), Access Control 13 (AC13), the Switchgear Rooms (SWGRs), and the Main Steam Isolation Valve Rooms (MSIVs). AC11 and AC13 will be equipped with dampers and radiation monitors, which will isolate this leakage path in case of an accident. The SWGRs are in continual recirculation mode and thus are also isolated from the environment. The MSIV rooms are also isolated from the environment, except for the Main Steam Line Break Accident which occurs in these rooms, due to the thermal buoyancy of the air in these rooms and due to the Jneck exhaust. For conservatism, all of the measured inleakage will be assumed to enter the control room from the most conservative pathway of either the West Road or Turbine Building inlets.

(17) Control room recirculation flow:
(a) Flowrate: 10000.± 1000 cfm
(Note that this value will be the result of a new modification.)
(b) Initiation delay time: 20 minutes
(Ref.40 conservatively assumes a 20 minute time delay for a manual start of the Control Room Emergency Ventilation System.)
(c) Filter efficiencies: 90% for all iodine species
(Ref.39 and Technical Specification 5.5.11 allow a 95% filter efficiency for a 2" activated carbon bed depth; however, NRC Generic Letter 99-02 (Ref.41) requires plants that test their activated charcoal to the ASTM D3803-1989 standards to use a safety factor of two. This results in a maximum credited efficiency of 90% for accident analyses.)

(18) The SFP filters are not credited in this work.

(19) The activity discharged from the 176 broken fuel pins is released from the SFP or containment over a 2 hour time period. This is reflected in the release fraction and timing file FHA.RFT displayed in Attachment G.

(20) Additional RADTRAD Inputs;

- Compartments
  - Containment: 1 ft^3
  - Environment
  - Control Room: 289194 ft^3, 9000 cfm recirculation filters @ 90/90/90 efficiency for 0.3333-720 hrs
- Transfer Pathways
  - Containment to environment: 100 cfm filter @ 0/0/0 efficiency for 0-720 hrs
  - Environment to control room: 3500 cfm filter @ 0/0/0 efficiency for 0-720 hrs
  - Control room to environment: 3500 cfm filter @ 0/0/0 efficiency for 0-72- hrs
- Dose Locations
  - EAB
  - LPZ
  - Control Room
- Source Term and DCF
  - Nuclear Inventory File: FHA14072.NIF, FHA14100.NIF, FHA14072R.NIF
  - Release Fraction and Timing File: FHA.RFT
  - DCF File: FGR14.INP
  - Decay and Daughter Products Option

7. TECHNICAL ASSUMPTIONS

The following technical assumptions were utilized in this work:

(01) All 176 rods from the highest power fuel assembly will be damaged in the FHA.

(02) No credit is taken for atmospheric cleanup systems in containment or the SFP (spray, filter, plateout).

(03) No credit is taken for deposition of the plume on the ground or decay of isotopes in transit to the site boundary.

(04) Buildup of daughter nuclides is taken into account as source term nuclides decay.

8. REFERENCES

(01) "Power Levels of Nuclear Power Plants", Regulatory Guide 1.49 Rev.1, 12/73.

(02) CCNPP Core Operating Limits Report for Unit 1 Cycle 17 Rev.1

(03) CCNPP Core Operating Limits Report for Unit 2 Cycle 16 Rev.0

(04) "Offsite and Control Room Doses Following a LOCA", Bechtel Calculation M-89-33 Rev.3, 7/9/91.

(05) "Control Room Habitability Source Term Calculations", CA06358.

(06) "Chart of the Nuclides - Nuclides and Isotopes", GE Nuclear Energy, Fifteenth Edition.

(07) "Gas Gap Isotopic Fraction Calculations", CA06321.

(08) "Alternate Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", Regulatory Guide 1.183

(09) "Topical Report Radiological Consequences of a Fuel Handling Accident", WCAP-7518-L

(10) "Topical Report Radiological Consequences of a Fuel Handling Accident Supplemental Information", WCAP-7518-L, Addendum I.

(11) "Validation of CCNPP FHA for Increased Fuel Rod Pressure of 1400 Psi", CA06067

(12) "Evaluation of Fission Product Release and Transport for a Fuel Handling Accident", G. Burley, 10/5/71

(13) "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation", NUREG/CR-6604, SAND98-0272

(14) "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation", NUREG/CR-6604, SAND98-0272/1, Supplement 1.

(15) "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation", NUREG/CR-6604, Supplement 2

(16) "RADTRAD 3.03 Installation and Verification on PCB386", CA06210

(17) "RADTRAD 3.03 Validation", CA06207

(18) "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844, 3/23/62.

(19) "Revaluation of Fuel Handling Accident Supporting Both Personnel Air Lock Doors Open During Fuel Movement - Open Door Policy", 000-DA-9302 Rev.1, 10/13/93.

(20) "Offsite Doses at the Exclusion Area Boundary Associated with a Fuel Handling Accident in the Spent Fuel Pool Area", NC-94-030 Rev.0, 12/22/94.

(21) SER Amendment Numbers 194/171 8/31/94: "Allow Containment Personnel Air Locks to Be Open During Fuel Movement and Core Alterations"

(22) SER Amendment Numbers 242/216 3/12/01: "Allow Containment Outage Door to Be Open During Fuel Movement and Core Alterations"

(23) "Control Room Doses from a Fuel Handling Accident", NS-94-009, 3/2/94.

(24) "Supplement to License Amendment Request: Personnel Air Lock Open During Core Alterations", NRC-94-018, 3/94.

(25) Correspondence NRC to BGE 6/22/95: Control Room Interim Analysis for Thyroid Dose

(26) CA04807: SCBA Utilization Post FHA with Enhanced Control Room Inleakage

(27) CA04986: SCBA Utilization Post FHA with 3500 CFM Control Room Inleakage

(28) "Fuel Bundle Assembly", BGE Drawing 12131-0250 Rev.0

(29) Storage Rack Spacer", BGE Drawing 12309-0068SH0001 Rev.1

(30) CA06012: CRHVAC Atmospheric Dispersion Coefficient Calculations

(31) Federal Guidance Report (FGR) 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors," 1989

(32) Federal Guidance Report (FGR) 12, "External Exposure to Radionuclides in Air, Water, and Soil," 1993,

(33) "Fuel Performance Analysis", Westinghouse Calculation CN-WFE-02-45, Rev.0

(34) "Control Room HVAC Inleakage Test", ETP-97-064R Rev.0, 11/11/1997 (First Run)

(35) "Control Room HVAC Inleakage Test", ETP-97-064R Rev.0, 11/11/1997 (Third Run)

(36) "Control Room HVAC Inleakage Test", ETP-97-064R Rev.0, 11/11/1997 (Fourth Run)

(37) "Control Room HVAC Inleakage Test", ETP-97-064R Rev.0, 1/18/2000.

(38) "Perfluorocarbon Tracer Gas Testing", ETP-01-035R Rev.0, 5/1/2002

(39) "Power Levels of Nuclear Power Plants", Regulatory Guide 1.49 Rev.1, 12/73.

(40) "Control Room Recirculation Filter Initiation Time Delay", NEU-95-026

(41) NRC Generic Letter 99-02: Laboratory Testing of Nuclear-Grade Activated Charcoal

(42) Industry/TSTF Standard Technical Specification Change Traveler TSTF-312, Administratively Control Containment Penetrations, Revision 1

9. METHODS OF ANALYSIS

(9.1) RADTRAD Computations

The current work re-analyzes control room habitability for the containment FHA and SFP FHA with and without reconstitution based on the alternate source term methodology of Ref.08 and control room inleakage of 3500 cfm This was accomplished by utilizing the RADTRAD computer code (Refs.13-15).

The RADTRAD computer code calculates TEDE and thyroid doses to personnel at the site boundary, low population zone, and control room per 10 CFR 50.67 resulting from any postulated accident which releases radioactivity within the containment, spent fuel pool, or within any primary system. RADTRAD models the transport of radioactivity (elemental, particulate, and organic iodine isotopes and krypton and xenon isotopes for the FHA) from the sprayed and unsprayed regions of a primary containment or a SFP area, through the secondary containment if any, and then to the environment and to the control room. The code includes the capability to model time-dependent activity release; containment spray, filtration, and leakage; control room filtration and inleakage; primary and secondary containment purge filters; control room intake filters; atmospheric dispersion; and natural decay. Doses are calculated for individuals residing at the site boundary or low population zone and in the control room. RADTRAD is documented and benchmarked in Refs.13-17.

The FHA in containment model is constructed assuming that an FHA occurs at time t=0 and assuming that the isotopes A_{i0} calculated in an EXCEL spreadsheet are released at time t=0 to the primary containment. No cleanup mechanisms (spray, filtration, plateout) are assumed in containment, thus the sprayed/unsprayed classification has no effect on the results. This activity escapes to the environment assuming complete release in two hours and is transported to the site boundary and to the control room via appropriate atmospheric dispersion coefficients. While time-dependent control room inleakage can be modeled by RADTRAD, it is a constant in this work. The control room and site boundary doses are calculated based on appropriate breathing rates and occupancy factors and on ICRP 30 dose conversion factors.

The FHA in the SFP model is constructed assuming that an FHA occurs at time t=0 and assuming that the isotopes A_{i0} calculated in the EXCEL spreadsheet are released immediately and uniformly into the SFP area. No secondary containment is modeled. No spray or plateout cleanup mechanisms are assumed in the SFP. The SFP ventilation system processes 32000±10% cfm of the SFP volume into the environment with no credit for the HEPA/charcoal filters for the duration of the accident. The SFP activity is also completely released over a two hour time interval. This activity is transported to the site boundary and to the control room via appropriate atmospheric dispersion coefficients. While time-dependent control room inleakage can be modeled by RADTRAD, it is a constant in this work. The control room and site boundary doses are calculated based on appropriate breathing rates and occupancy factors and on ICRP 30 dose conversion factors.

(9.2) Decontamination Factors

When an assembly is damaged in the SFP or RP, the fission product gases and helium are released from the broken rods, carrying the iodine isotopes into the pool. As the gas bubbles rise to the surface, most of the iodine will be transferred from the bubble, dissolve, and hydrolyze in the boric acid solution. The ratio of the initial iodine activity as released from the broken rod to the final iodine activity as released from the pool is designated as the decontamination factor, DF. Note that organic iodine (e.g. CH_3I) is not readily absorbed in the pool and thus has a DF of unity (DFO=1). Likewise, noble gases are not absorbed in the pool and also have a DF of unity.

In an effort to determine a decontamination factor (DFI) for inorganic iodine isotopes (e.g. elemental iodine I_2, I, HI and particulate iodine CsI), Westinghouse performed a series of experiments (Refs.9-11) which measured DFI as a function of release depth (h), rise time (t), bubble diameter (d), and initial pressure. These simulations assumed that damage to the fuel assembly resulted in complete and instantaneous shearing of all the vertically-oriented fuel rods, which released the contained gases in a burst. The results of these experiments are displayed in Attachment A and can be summarized by the following algorithm:

$$DFI = 73 * \exp(0.313 * t / d * h / 23)$$

DF = 1 / (IFO/DFO + IFI/DFI)

Thus at a depth of 23 feet and 1200 psig internal rod pressure, a DFI of 579.65 was determined. Assuming an inorganic iodine fraction (IFI) of 0.9985 and an organic iodine fraction of 0.0015 (IFO) per Ref.08, an overall DF of 310 can be calculated.

Refs. 11 and 33 indicate that the internal pin pressure can exceed 1200 psig for zirlo-clad value-added-pellet (VAP) fuel. In addition, reconstitution or inspection operations in the SFP require assemblies to be put on 20.5" spacers, which reduce the minimum water level to 20.4' (Section 6-07). Thus, at a depth of 20 feet and 1400 psig internal rod pressure, a DFI of 392.58 can be determined by assuming a linear decrease in bubble rise time with decreasing depth, resulting in an overall DF of 247. Both values (310 and 247) are well above the value of 200 allowed in RG 1.183 (Ref.08).

An alternate methodology for calculating DF, which is endorsed by the NRC, is the methodology of Burley (Ref.12). The results of this methodology are displayed in Attachment B and can be summarized by the following algorithms:

$$DFI = \exp(6 * Keff * h / d / v)$$

$$v = 29.86 * V^{(1/6)} = \text{bubble velocity}$$

$$V = 4 * \pi / 3 * (d / 2)^3 = \text{bubble volume}$$

$$Keff = 1/[1 / (1.646*0.278/d + 0.00375*v) + 1 / (11.3*(0.0000127*v/d)^{0.5}]$$

Based on a depth of 23 feet and 1200 psig internal rod pressure, DFI is defined as 500 per Ref.08 resulting in a bubble diameter of 2.0685 cm. Thus at a depth of 20.4 feet, and 1400 psig internal rod pressure, a DFI of 152 can be determined by assuming a linear increase in bubble volume with increasing pressure, resulting in an overall DF of 124.

Thus a DF of 120 will be conservatively utilized in this work for a depth of 20.4 feet and an internal rod pressure of 1400 psig.

Per Ref.08, the iodine gap activity is composed of 99.85% inorganic species and 0.15% organic species of iodine. If the pool decontamination factors are 285.29 for the inorganic iodine and 1 for the organic iodine, this yields an overall effective decontamination factor of 200. This difference in decontamination factor for inorganic and organic iodine species results in the iodine above the fuel pool being composed of 70% inorganic and 30% organic species. If the pool decontamination factors are 146.12 for the inorganic iodine and 1 for the organic iodine, this yields an overall effective decontamination factor of 120. This difference in decontamination factor for inorganic and organic iodine species results in the iodine above the fuel pool being composed of 82% inorganic and 18% organic species.

(9.3) Gas Gap Release Activities

EXCEL spreadsheets FHA.XLS(FHAINP3) were developed to calculate the activity released to the containment or SFP atmosphere post-FHA. Four sets of isotopic activities were generated:

- DF of 200 with 100 hours of decay prior to fuel movement
- DF of 200 with 72 hours of decay prior to fuel movement
- DF of 120 with 100 hours of decay prior to fuel movement (Reconstitution mode)
- DF of 120 with 72 hours of decay prior to fuel movement (Reconstitution mode)

Note that the SFP HEPA and charcoal filters are not credited in this work, thus the isotopic activities released to the atmosphere are the same in containment and in the SFP area.

The initial isotopic activity in Curies released to the containment or SFP for isotope 'i' is based on the following algorithm:

$$A_{i0} = AST_i * P * PPF * RF_i / NASSM / DF_i * \exp(-\lambda_{Di} * t_0 * 3600.)$$

where AST_i = Isotopic activity per unit power (Ci/MWT)
P = Core power (MWT)
PPF = Power peaking factor
RF_i = Isotopic gas gap release fraction
DF_i = Isotopic decontamination factor
λ_{Di} = Isotopic decay constant (1/sec)
t_0 = Time from power shutdown to FHA (hr)
NASSM = Number of assemblies in core = 217

The isotopic activities were inserted into nuclear inventory files for use by RADTRAD. These RADTRAD files are listed in Attachments D through F and consist of the 14 gas-gap noble gas and iodine isotopes. The activities are the total gas gap activities that are released from the pool water at the appropriate decay time and are not per unit power. Thus a power of one should be designated when employing these files.

10. CALCULATIONS

The following computational calculations were performed in this calculational package:

	Cases		
	FHACTMT100	FHACTMT72	FHACTMT72R
Location	Containment or SFP	Containment or SFP	Containment or SFP
Decontamination Factor	200	200	120
Water depth above fuel	23 feet	23 feet	20.4 feet
Decay Period	100 houre	72 hours	72 hours
Nuclear Inventory File	FHA14100.NIF	FHA14072.NIF	FHA14072R.NIF
Release Fraction File	FHA.RFT	FHA.RFT	FHA.RFT
DCF File	FGR14.INP	FGR14.INP	FGR14.INP
Case File	FHACTMT100.PSF	FHACTMT72.PSF	FHACTMT72R.PSF
Output File	FHACTMT100.o0	FHACTMT72.o0	FHACTMT72R.o0
Control Room Inleakage	3500 cfm	3500 cfm	3500 cfm
Control Room Filtration	9000 cfm	9000 cfm	9000 cfm
Control Room Efficiency	90% after 20 min	90% after 20 min	90% after 20 min
SFP Filtration	0 cfm	0 cfm	0 cfm
Release Point to Environment	Unit 2 Ventillation Stack	Unit 2 Ventillation Stack	Unit 2 Ventillation Stack
Entrance Point to Control Room	Turbine Building	Turbine Building	Turbine Building

11. DOCUMENTATION OF COMPUTER CODES

This work employed the RADTRAD computer code, which was verified, benchmarked, and documented in Refs.13-17 and which models the transport of halogen and noble gas isotopes from a primary containment to a secondary containment and thence to the environment and control room. The installation of RADTRAD is detailed in Ref.16 and the validation in Ref.17.

The RADTRAD computer code can calculates TEDE and thyroid doses to personnel at the site boundary, low population zone, and control room per the alternate source term methodology 10 CFR 50.67 and Regulatory Guide 1.183 or can calculates whole body and thyroid doses to personnel at the site boundary, low population zone, and control room per the standard source term methodology of TID-14844 (Ref.18) resulting from any postulated accident which releases radioactivity within the containment, spent fuel pool, or within any primary system. RADTRAD models the transport of radioactivity from up to 63 radioisotopes from the sprayed and unsprayed regions of a primary containment or a SFP area, through the secondary containment if any, and then to the environment and to the control room. The code includes the capability to model time-dependent activity release; containment spray, filtration, and leakage; control room filtration and inleakage; primary and secondary containment purge filters; control room intake filters; atmospheric dispersion; and natural decay. Doses are calculated for individuals residing at the site boundary or low population zone and in the control room.

Some inputs for the RADTRAD computer program were generated via an EXCEL spreadsheet.

12. RESULTS

UFSAR 14.18 presents the licensing basis evaluation of the Fuel Handling Accident (FHA), which is assumed to occur in the spent fuel pool (SFP) handling area or in the containment by dropping a fuel assembly during fuel movement operations. The analyses for a FHA in the refueling pool and the SFP both assume that gas gap activity from 176 fuel rods of the highest power assembly is released. In the SFP the fuel assemblies are stored within the racks at the bottom of the SFP. The top of the rack extends above the tops of the stored fuel assemblies. A dropped fuel assembly could not strike more than one fuel assembly in the storage rack. Impact could occur only between the ends of the involved fuel assemblies, the bottom end fitting of the dropped fuel assembly impacting against the top end fitting of the stored fuel assembly. The results of an analysis of the end on energy absorption capability of a fuel assembly indicate that a fuel assembly is capable of absorbing the kinetic energy of the drop with no fuel rod failures. The worst FHA that could occur in the SFP is the dropping of a fuel assembly to the fuel pool floor. Because of the high energy absorption required to rupture a fuel rod, 176 represents the maximum number of damaged pins expected from any credible fuel handling incident scenario.

The likelihood of a FHA is minimized by administrative controls and physical limitations imposed on fuel handling operations. All refueling operations are conducted in accordance with prescribed procedures under direct surveillance of a qualified supervisor. The possibility of damage to a fuel assembly as a consequence of mishandling is minimized by thorough training, detailed procedures, and equipment design. The single-failure-proof design of the Spent Fuel Cask Handling Crane prevents the drop of heavy objects such as shipping/transfer casks on the spent fuel storage racks. Inadvertent disengagement of a fuel assembly from the fuel handling machine is prevented by mechanical interlocks; consequently, the possibility of dropping and damaging of a fuel assembly is remote.

Should a fuel assembly be dropped or otherwise damaged during handling, radioactive release could occur in either the containment or the Auxiliary Building. The air in both of these areas is monitored. The radiation monitors immediately indicate the increased activity level and alarm. The affected area would then be evacuated. The SFP ventilation system draws air across the SFP area; this air is discharged to the atmosphere through the plant vent. If the cask loading hatch and all exterior hatches to the 69' level of the Auxiliary Building are closed, this is the only route for the release of activity from the SFP area to the environment. After a FHA in containment, the activity may be released through the personnel air lock (PAL), the containment outage door (COD), the containment walls themselves, or via the hydrogen or 48" purge lines into the plant vent. The release through the plant vent is most limiting, and thus a FHA in the containment and the SFP will both be assumed to be released to the environment through the plant vent stack.

Failed fuel rods that have released their active gas gap inventory can be stored in encapsulated fuel tubes. These encapsulated fuel tubes can be stored in the peripheral guide tubes of host assemblies or empty grid cages in the SFP. A single encapsulation tube containing a damaged fuel rod can be stored in an incore instrumentation (ICI) trash can, can be laid temporarily atop the SFP storage racks with administrative restrictions on fuel movement in the laydown area, or can be placed at the bottom of an upender trench with the associated upender tagged out. The addition of up to four encapsulated fuel rods in a host assembly will not cause the radiological consequences of a FHA to increase since administrative controls are employed to ensure that only fuel rods with sufficient clad damage to ensure no residual gas gap activity are stored in the encapsulation tubes in fuel assemblies. The failed rods cannot contribute to gas gap release, since their gas inventory has already been released. Undamaged fuel rods can only be stored in the encapsulation tubes in empty grid cages. This will guarantee that the consequences of a FHA will not be increased. Only damaged fuel rods with no gas gap activity can be stored in encapsulation tubes stored in ICI trash cans, temporarily atop the SFP storage racks, or at the bottom of an upender trench, thus precluding any fission gas release.

Reconstitution or inspection of a fuel assembly can take place in individual SFP storage racks with spent fuel assemblies placed on rack spacers and with their upper end fittings removed. In such a configuration, the structural integrity of the fuel assemblies is reduced, and the fuel rods may protrude above the SFP racks. Since fuel damage could occur if a heavy object is dropped on top of an assembly seated on a rack spacer with its upper end filling removed, administrative controls will restrict movement of loads over the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies. Heavy loads may only be moved in this area via the single-failure-proof crane, if assemblies are seated on rack spacers with their upper end fittings removed. Only the single-failure-proof crane or single-failure-proof rigging will be used over the reconstitution area in the SFP for loads other than tools. A knowledgeable and briefed person will be present for the entire time that the upper end fitting or template is removed from an assembly to restrict movement of loads other than tools in this area of the SFP. In addition, after the upper end fillings have been removed, the spent fuel handling machine will be administratively prohibited from nearing the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies.

The current work utilizes the alternate source term (AST) methodology of 10 CFR 50.67 and Regulatory Guide 1.183 to calculate offsite and control room doses for a FHA. A bounding control room inleakage value of 3500 cfm was assumed. Modification of the control room emergency ventilation system to a nominal 10000 cfm flow with a 90% filtration efficiency was credited. SFP filtration was not credited. Also credited was installation of automatic isolation dampers and radiation monitors at Access Controls 11 and 13 on the Auxiliary Building Roof. This modification limits activity egress into the control room from either the West Road Inlet or the Turbine Building, thus limiting the atmospheric dispersion coefficient value.

The site boundary, low population zone, and control room doses for the design-basis FHA in containment and the SFP calculated in Attachments I, J, and K, are detailed in the following table.

Fuel Handling Accident Doses in REM TEDE				
	Containment/SFP	Containment/SFP	Spent Fuel Pool	Regulatory
DF	200	200	120	Limit
Decay Time (hr)	100	72	72	
EAB	0.6167	0.6958	1.1136	6.3 (RG 1.183)
LPZ	0.1452	0.1638	0.2622	6.3 (RG 1.183)
Control Room	2.0765	2.3314	3.8538	5.0 (10CFR50.67)

13. CONCLUSIONS

All offsite and control room doses are below the regulatory limits. Since the reconstitution SFP case is the most limiting, it will be considered as the design-basis fuel handling accident for alternate source terms. For a VAP assembly at 72 hours post-shutdown and at 1400 psig internal rod pressure, the EAB, LPZ, and control room doses are 1.2, 0.3, and 3.9 Rem TEDE, respectively.

This work supports the following changes in plant operation:

- This analysis supports a pin power peaking factor of 1.70.
- This analysis supports fuel movement 72 hours after reactor shutdown for assemblies with internal pin pressures up to 1400 psig.
- This analysis allows assemblies to be seated on rack spacers in the SFP with internal pin pressures up to 1400 psig 72 hours after reactor shutdown.
- This analysis credits the SFP ventilation system, but not the SFP filtration system.
- The Personnel Air Lock and Containment Outage Door are allowed to be open during fuel movement. This work also supports Technical Specification Task Force (TSTF)-312 (Ref.42), which allows penetration flow paths that have direct access from the containment atmosphere to the outside atmosphere to be unisolated under administrative control. Since this current analysis assumes that the radioactive release is unfiltered, completely released over a two hour time period, and released with the most limiting dispersion coefficients, the analysis will also apply to the containment penetration flow paths that are opened under administrative control.

This work relies on the following modifications and new methodologies:

- Modification of the control room emergency ventilation system to a nominal 10000 cfm flow with a 90% filtration efficiency was credited.
- Installation of automatic isolation dampers and radiation monitors at Access Controls 11 and 13 on the Auxiliary Building Roof was credited.
- Alternate Source Term Methodology was employed.

14. ATTACHMENTS

ATTACHMENT A
DECONTAMINATION FACTORS PER WCAP-7518-L

WCAP-7518-L Large-Scale Test													
alpha=	1												
beta=	0.313												
DF = alpha * 73 *exp(beta*t/d*h2/h1) Algorithm generated in WCAP-7518-L.													
				23			26				40		
t	d	v		t/d	DF		t/d	DF	DF		t/d	DF	DF
sec	cm	cm/sec		sec/cm			sec/cm		WCAP		sec/cm		WCAP
8.8	1.01	79.8		8.7129	1116.0915		9.8493	1592.8826	1750		15.1528	8377.3925	9200
7.8	0.935	89.9		8.3422	993.84617		9.4304	1397.1136	1550		14.5083	6846.8427	7600
6.6	0.857	106.2		7.7013	813.18708		8.7058	1113.6236	1210		13.3935	4830.1674	5600
5.6	0.780	125.4		7.1795	690.65397		8.1159	925.88431	1000		12.4861	3635.8481	4200
4.7	0.710	149.4		6.6197	579.65394		7.4832	759.52138	810		11.5126	2680.8487	3000
t	d	v		p	h		t/d	DFI	DF				
sec	cm	cm/sec		psig	ft		sec/cm		AST				
8.8	1.01	79.8		100	23		8.7129	1116.09	417.60				
7.8	0.935	89.9		200	23		8.3422	993.85	399.25				
6.6	0.857	106.2		600	23		7.7013	813.19	366.58				
5.6	0.780	125.4		900	23		7.1795	690.65	339.47				
4.7	0.710	149.4		1200	23		6.6197	579.65	310.31				
4.1	0.663	165.4		1400	23		6.1809	505.26	287.67				
3.8	0.64	173.4		1500	23		5.9375	468.20	275.28				
3.565	0.663	165.4		1400	20		5.3747	392.58	247.31				
t = bubble rise time in sec													
d = bubble diameter in cm													
v = bubble velocity in cm/sec													
p = internal rod pressure in psig													
h = initial bubble depth in feet													

ATTACHMENT B
DECONTAMINATION FACTORS PER BURLEY

Iodine decontamination Factor Calculation at 23 ft depth and 1200 psig							
The decontamination factor (DF) is defined as the ratio of the initial iodine concentration to the final							
iodine concentration. Gas transfer from a bubble into the surrounding liquid occurs by successive							
processes of gas phase diffusion, transfer across the bubble interface, and solution in the liquid phase.							
The most important parameters in the evaluation of mass transfer characteristics include the bubble							
dimensions, contact time, and the partition factor. The following calculations are conservative in that							
the reaction of iodine with zircaloy and the vapor pressure limitation on the gas phase concentration are							
neglected.							
IFO	0.0015		Organic iodine fraction			RG 1.183	
IFI	0.9985		Inorganic iodine fraction			RG 1.183	
DFO	1.0000		Organic DF			RG 1.183	
d-clad	0.97536	cm	Clad ID			UFSAR Tab 3.3-1	
P	10		Instantaneous partition factor			Burley	
DG	0.278	cm2/sec	I2 diffusivity in He			Burley	
DL	1.27E-05	cm2/sec	I2 diffusivity in water			Burley	
V-bub	4.6341	cm3	Bubble volume			Assumed	
d-bub	2.0685	cm	Bubble diameter			Assumed	
v-bub=29.86*V-bub^(1/6)			Bubble velocity				
v-bub	38.5553	cm/sec				Burley	
Ko=1.646*DG/d-bub						Burley	
Ko	0.2212	cm/sec					
Kc=3.75E-3*v-bub			For turbulent flow			Burley	
Kc	0.1446	cm/sec					
Kl=1.13*(DL*v-bub/d-bub)^(1/2)						Burley	
Kl	0.0174	cm/sec					
Keff=1./(1./(Ko+Kc)+1./(Kl*P))						Burley	
Keff	0.1178						
H	23.0000	ft	701.0400	cm			
DFI=exp(6*Keff*H/d-bub/v-bub)						Burley	
DFI	5.00E+02						
DF=1/(IFO/DFO+IFI/DFI)						Burley	
DF	286						

Iodine decontamination Factor Calculation at 23 feet depth and 1400 psig							
The decontamination factor (DF) is defined as the ratio of the initial iodine concentration to the final iodine concentration. Gas transfer from a bubble into the surrounding liquid occurs by successive processes of gas phase diffusion, transfer across the bubble interface, and solution in the liquid phase. The most important parameters in the evaluation of mass transfer characteristics include the bubble dimensions, contact time, and the partition factor. The following calculations are conservative in that the reaction of iodine with zircaloy and the vapor pressure limitation on the gas phase concentration are neglected.							
IFO	0.0015		Organic iodine fraction			RG 1.183	
IFI	0.9985		Inorganic iodine fraction			RG 1.183	
DFO	1.0000		Organic DF			RG 1.183	
d-clad	0.97536	cm	Clad ID			UFSAR Tab 3.3-1	
P	10		Instantaneous partition factor			Burley	
DG	0.278	cm2/sec	I2 diffusivity in He			Burley	
DL	1.27E-05	cm2/sec	I2 diffusivity in water			Burley	
V-bub	5.4064	cm3	Bubble volume			Assumed	
d-bub	2.1776	cm	Bubble diameter			Assumed	
v-bub=29.86*V-bub^(1/6)			Bubble velocity				
v-bub	39.5587	cm/sec				Burley	
Ko=1.646*DG/d-bub						Burley	
Ko	0.2101	cm/sec					
Kc=3.75E-3*v-bub			For turbulent flow			Burley	
Kc	0.1483	cm/sec					
Kl=1.13*(DL*v-bub/d-bub)^(1/2)						Burley	
Kl	0.0172	cm/sec					
Keff=1./(1./(Ko+Kc)+1./(Kl*P))						Burley	
Keff	0.1161						
H	23.0000	ft	701.0400	cm			
DFI=exp(6*Keff*H/d-bub/v-bub)						Burley	
DFI	2.89E+02						
DF=1/(IFO/DFO+IFI/DFI)						Burley	
DF	202						

Iodine decontamination Factor Calculation at 20.4 feet depth and 1200 psig						
The decontamination factor (DF) is defined as the ratio of the initial iodine concentration to the final iodine concentration. Gas transfer from a bubble into the surrounding liquid occurs by successive processes of gas phase diffusion, transfer across the bubble interface, and solution in the liquid phase. The most important parameters in the evaluation of mass transfer characteristics include the bubble dimensions, contact time, and the partition factor. The following calculations are conservative in that the reaction of iodine with zircaloy and the vapor pressure limitation on the gas phase concentration are neglected.						
IFO	0.0015		Organic iodine fraction			RG 1.183
IFI	0.9985		Inorganic iodine fraction			RG 1.183
DFO	1.0000		Organic DF			RG 1.183
d-clad	0.97536	cm	Clad ID			UFSAR Tab 3.3-1
P	10		Instantaneous partition factor			Burley
DG	0.278	cm2/sec	I2 diffusivity in He			Burley
DL	1.27E-05	cm2/sec	I2 diffusivity in water			Burley
V-bub	4.6341	cm3	Bubble volume			Assumed
d-bub	2.0685	cm	Bubble diameter			Assumed
v-bub=29.86*V-bub^(1/6)			Bubble velocity			
v-bub	38.5553	cm/sec				Burley
Ko=1.646*DG/d-bub						Burley
Ko	0.2212	cm/sec				
Kc=3.75E-3*v-bub			For turbulent flow			Burley
Kc	0.1446	cm/sec				
Kl=1.13*(DL*v-bub/d-bub)^(1/2)						Burley
Kl	0.0174	cm/sec				
Keff=1./(1./(Ko+Kc)+1./(Kl*P))						Burley
Keff	0.1178					
H	20.4000	ft	621.7920	cm		
DFI=exp(6*Keff*H/d-bub/v-bub)						Burley
DFI	2.48E+02					
DF=1/(IFO/DFO+IFI/DFI)						Burley
DF	181					

Iodine decontamination Factor Calculation at 20.4 feet depth and 1400 psig

The decontamination factor (DF) is defined as the ratio of the initial iodine concentration to the final iodine concentration. Gas transfer from a bubble into the surrounding liquid occurs by successive processes of gas phase diffusion, transfer across the bubble interface, and solution in the liquid phase. The most important parameters in the evaluation of mass transfer characteristics include the bubble dimensions, contact time, and the partition factor. The following calculations are conservative in that the reaction of iodine with zircaloy and the vapor pressure limitation on the gas phase concentration are neglected.

IFO	0.0015		Organic iodine fraction			RG 1.183	
IFI	0.9985		Inorganic iodine fraction			RG 1.183	
DFO	1.0000		Organic DF			RG 1.183	
d-clad	0.97536	cm	Clad ID			UFSAR Tab 3.3-1	
P	10		Instantaneous partition factor			Burley	
DG	0.278	cm2/sec	I2 diffusivity in He			Burley	
DL	1.27E-05	cm2/sec	I2 diffusivity in water			Burley	
V-bub	5.4064	cm3	Bubble volume			Assumed	
d-bub	2.1776	cm	Bubble diameter			Assumed	
v-bub=29.86*V-bub^(1/6)			Bubble velocity				
v-bub	39.5587	cm/sec				Burley	
Ko=1.646*DG/d-bub						Burley	
Ko	0.2101	cm/sec					
Kc=3.75E-3*v-bub			For turbulent flow			Burley	
Kc	0.1483	cm/sec					
Kl=1.13*(DL*v-bub/d-bub)^(1/2)						Burley	
Kl	0.0172	cm/sec					
Keff=1./(1./(Ko+Kc)+1./(Kl*P))						Burley	
Keff	0.1161						
H	20.4000	ft	621.7920	cm			
DFI=exp(6*Keff*H/d-bub/v-bub)						Burley	
DFI	1.52E+02						
DF=1/(IFO/DFO+IFI/DFI)						Burley	
DF	124						

ATTACHMENT C
GAS GAP RELEASE ACTIVITIES FROM POOL

Calculation of Fuel Handling Accident Release Activities								
	Halflife	lambda	Core	DF	Gas Gap	Release Src	Release Src	Release Src
			Source		Fractions	Zero Decay	72 hr decay	100 hr decay
	sec	1/sec	CI/MWT			Ci	Ci	Ci
	A	B	C	D	E	F	G	H
Kr-85	3.3830E+08	2.0489E-09	3.7180E+02	1	0.20	1.6043E+03	1.6035E+03	1.6031E+03
Kr-85m	1.6128E+04	4.2978E-05	7.9679E+03	1	0.10	1.7191E+04	2.4964E-01	3.2800E-03
Kr-87	4.5780E+03	1.5141E-04	1.6208E+04	1	0.10	3.4969E+04	3.1607E-13	7.4406E-20
Kr-88	1.0224E+04	6.7796E-05	2.2658E+04	1	0.10	4.8885E+04	1.1414E-03	1.2289E-06
I-131	6.9466E+05	9.9783E-07	2.7562E+04	200	0.16	4.7572E+02	3.6731E+02	3.3216E+02
I-132	8.2800E+03	8.3713E-05	3.9464E+04	200	0.10	4.2572E+02	1.6054E-07	3.4743E-11
I-133	7.4880E+04	9.2568E-06	5.5715E+04	200	0.10	6.0103E+02	5.4559E+01	2.1460E+01
I-134	3.1560E+03	2.1963E-04	6.2858E+04	200	0.10	6.7808E+02	1.2821E-22	3.1137E-32
I-135	2.3796E+04	2.9129E-05	5.2964E+04	200	0.10	5.7135E+02	3.0054E-01	1.5949E-02
Xe-133	4.5317E+05	1.5296E-06	5.5707E+04	1	0.10	1.2019E+05	8.0850E+04	6.9298E+04
Xe-135	3.2724E+04	2.1182E-05	1.7708E+04	1	0.10	3.8205E+04	1.5766E+02	1.8641E+01
Xe-133m	1.8922E+05	3.6632E-06	1.7354E+03	1	0.10	3.7441E+03	1.4487E+03	1.0014E+03
Xe-135m	9.1800E+02	7.5506E-04	1.1635E+04	1	0.10	2.5103E+04	2.5295E-81	2.2324E-114
Xe138	8.4600E+02	8.1932E-04	4.9330E+04	1	0.10	1.0643E+05	6.2607E-88	8.4962E-124
Kr-85	3.3830E+08	2.0489E-09	3.7180E+02	1	0.20	1.6043E+03	1.6035E+03	1.6031E+03
Kr-85m	1.6128E+04	4.2978E-05	7.9679E+03	1	0.10	1.7191E+04	2.4964E-01	3.2800E-03
Kr-87	4.5780E+03	1.5141E-04	1.6208E+04	1	0.10	3.4969E+04	3.1607E-13	7.4406E-20
Kr-88	1.0224E+04	6.7796E-05	2.2658E+04	1	0.10	4.8885E+04	1.1414E-03	1.2289E-06
I-131	6.9466E+05	9.9783E-07	2.7562E+04	120	0.16	7.9287E+02	6.1218E+02	5.5360E+02
I-132	8.2800E+03	8.3713E-05	3.9464E+04	120	0.10	7.0953E+02	2.6756E-07	5.7905E-11
I-133	7.4880E+04	9.2568E-06	5.5715E+04	120	0.10	1.0017E+03	9.0932E+01	3.5767E+01
I-134	3.1560E+03	2.1963E-04	6.2858E+04	120	0.10	1.1301E+03	2.1368E-22	5.1894E-32
I-135	2.3796E+04	2.9129E-05	5.2964E+04	120	0.10	9.5225E+02	5.0091E-01	2.6582E-02
Xe-133	4.5317E+05	1.5296E-06	5.5707E+04	1	0.10	1.2019E+05	8.0850E+04	6.9298E+04
Xe-135	3.2724E+04	2.1182E-05	1.7708E+04	1	0.10	3.8205E+04	1.5766E+02	1.8641E+01
Xe-133m	1.8922E+05	3.6632E-06	1.7354E+03	1	0.10	3.7441E+03	1.4487E+03	1.0014E+03
Xe-135m	9.1800E+02	7.5506E-04	1.1635E+04	1	0.10	2.5103E+04	2.5295E-81	2.2324E-114
Xe138	8.4600E+02	8.1932E-04	4.9330E+04	1	0.10	1.0643E+05	6.2607E-88	8.4962E-124

ATTACHMENT D
Nuclear Inventory File FHA14072.NIF

Nuclide Inventory Name:
Normalized MACCS Sample 3412 MWth PWR Core Inventory
Power Level:
0.1000E+01
Nuclides:
14
Nuclide 001:
Kr-85
1
0.3382974720E+09
0.8500E+02
1.6035E+03
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 002:
Kr-85m
1
0.1612800000E+05
0.8500E+02
2.4964E-01
Kr-85 0.2100E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 003:
Kr-87
1
0.4578000000E+04
0.8700E+02
3.1607E-13
Rb-87 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 004:
Kr-88
1
0.1022400000E+05
0.8800E+02
1.1414E-03
Rb-88 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 005:
I-131
2
0.6946560000E+06
0.1310E+03
3.6731E+02
Xe-131m 0.1100E-01
none 0.0000E+00

none 0.0000E+00
Nuclide 006:
I-132
2
0.8280000000E+04
0.1320E+03
1.6054E-07
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 007:
I-133
2
0.7488000000E+05
0.1330E+03
5.4559E+01
Xe-133m 0.2900E-01
Xe-133 0.9700E+00
none 0.0000E+00
Nuclide 008:
I-134
2
0.3156000000E+04
0.1340E+03
1.2821E-22
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 009:
I-135
2
0.2379600000E+05
0.1350E+03
3.0054E-01
Xe-135m 0.1500E+00
Xe-135 0.8500E+00
none 0.0000E+00
Nuclide 010:
Xe-133
1
0.4531680000E+06
0.1330E+03
8.0850E+04
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 011:
Xe-135
1
0.3272400000E+05
0.1350E+03
1.5766E+02
Cs-135 0.1000E+01
none 0.0000E+00

none 0.0000E+00
Nuclide 012:
Xe-133m
1
0.1892200000E+06
0.1330E+03
1.4487E+03
Xe-133 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 013:
Xe-135m
1
0.9180000000E+03
0.1350E+03
1.0000E-12
Xe-135 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 014:
Xe-138
1
0.8460000000E+03
0.1380E+03
1.0000E-12
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
End of Nuclear Inventory File

ATTACHMENT E
Nuclear Inventory File FHA14100.NIF

Nuclide Inventory Name:
Normalized MACCS Sample 3412 MWth PWR Core Inventory
Power Level:
0.1000E+01
Nuclides:
14
Nuclide 001:
Kr-85
1
0.3382974720E+09
0.8500E+02
1.6031E+03
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 002:
Kr-85m
1
0.1612800000E+05
0.8500E+02
3.2800E-03
Kr-85 0.2100E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 003:
Kr-87
1
0.4578000000E+04
0.8700E+02
1.0000E-12
Rb-87 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 004:
Kr-88
1
0.1022400000E+05
0.8800E+02
1.2289E-06
Rb-88 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 005:
I-131
2
0.6946560000E+06
0.1310E+03
3.3216E+02
Xe-131m 0.1100E-01
none 0.0000E+00

none 0.0000E+00
Nuclide 006:
I-132
2
0.8280000000E+04
0.1320E+03
3.4743E-11
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 007:
I-133
2
0.7488000000E+05
0.1330E+03
2.1460E+01
Xe-133m 0.2900E-01
Xe-133 0.9700E+00
none 0.0000E+00
Nuclide 008:
I-134
2
0.3156000000E+04
0.1340E+03
1.0000E-12
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 009:
I-135
2
0.2379600000E+05
0.1350E+03
1.5949E-02
Xe-135m 0.1500E+00
Xe-135 0.8500E+00
none 0.0000E+00
Nuclide 010:
Xe-133
1
0.4531680000E+06
0.1330E+03
6.9298E+04
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 011:
Xe-135
1
0.3272400000E+05
0.1350E+03
1.8641E+01
Cs-135 0.1000E+01
none 0.0000E+00

none 0.0000E+00
Nuclide 012:
Xe-133m
1
0.1892200000E+06
0.1330E+03
1.0014E+03
Xe-133 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 013:
Xe-135m
1
0.9180000000E+03
0.1350E+03
1.0000E-12
Xe-135 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 014:
Xe-138
1
0.8460000000E+03
0.1380E+03
1.0000E-12
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
End of Nuclear Inventory File

ATTACHMENT F
Nuclear Inventory File FHA14072R.NIF

Nuclide Inventory Name:
Normalized MACCS Sample 3412 MWth PWR Core Inventory
Power Level:
0.1000E+01
Nuclides:
14
Nuclide 001:
Kr-85
1
0.3382974720E+09
0.8500E+02
1.6035E+03
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 002:
Kr-85m
1
0.1612800000E+05
0.8500E+02
2.4964E-01
Kr-85 0.2100E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 003:
Kr-87
1
0.4578000000E+04
0.8700E+02
3.1607E-13
Rb-87 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 004:
Kr-88
1
0.1022400000E+05
0.8800E+02
1.1414E-03
Rb-88 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 005:
I-131
2
0.6946560000E+06
0.1310E+03
6.1218E+02
Xe-131m 0.1100E-01
none 0.0000E+00

none 0.0000E+00
Nuclide 006:
I-132
2
0.8280000000E+04
0.1320E+03
2.6756E-07
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 007:
I-133
2
0.7488000000E+05
0.1330E+03
9.0932E+01
Xe-133m 0.2900E-01
Xe-133 0.9700E+00
none 0.0000E+00
Nuclide 008:
I-134
2
0.3156000000E+04
0.1340E+03
2.1368E-22
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 009:
I-135
2
0.2379600000E+05
0.1350E+03
5.0091E-01
Xe-135m 0.1500E+00
Xe-135 0.8500E+00
none 0.0000E+00
Nuclide 010:
Xe-133
1
0.4531680000E+06
0.1330E+03
8.0850E+04
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 011:
Xe-135
1
0.3272400000E+05
0.1350E+03
1.5766E+02
Cs-135 0.1000E+01
none 0.0000E+00

none 0.0000E+00
Nuclide 012:
Xe-133m
1
0.1892200000E+06
0.1330E+03
1.4487E+03
Xe-133 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 013:
Xe-135m
1
0.9180000000E+03
0.1350E+03
1.0000E-12
Xe-135 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 014:
Xe-138
1
0.8460000000E+03
0.1380E+03
1.0000E-12
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
End of Nuclear Inventory File

ATTACHMENT G
RELEASE FRACTION AND TIMING FILE FHA.RFT

Release Fraction and Timing Name:
PWR, RG 1.183, Table 2 Section 3.2
Duration (h): Design Basis Accident
2.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Noble Gases:
1.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Iodine:
1.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Cesium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Tellurium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Strontium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Barium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Ruthenium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Cerium:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Lanthanum:
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
Non-Radioactive Aerosols (kg):
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
End of Release File

ATTACHMENT H
CONVERSION FACTORS FILE FGR14.INP

```
FGRDCF 10/24/95   03:24:50   beta-test version 1.10, minor FORTRAN fixes 5/4/95
Implicit daughter halflives (m) less than  90 and less than 0.100 of parent
         9 ORGANS DEFINED IN THIS FILE:
GONADS
BREAST
LUNGS
RED MARR
BONE SUR
THYROID
REMAINDER
EFFECTIVE
SKIN(FGR)
        14 NUCLIDES DEFINED IN THIS FILE:
Kr-85
Kr-85m
Kr-87
Kr-88
I-131     D
I-132     D
I-133     D
I-134     D
I-135     D      Including:Xe-135m
Xe-133
Xe-135
Xe-133m
Xe-135m
Xe-138
          CLOUDSHINE  GROUND     GROUND     GROUND      INHALED    INHALED   INGESTION
                     SHINE 8HR SHINE 7DAY SHINE RATE ACUTE      CHRONIC
Kr-85
GONADS      1.170E-16 8.121E-14 1.704E-12 2.820E-18-1.000E+00 0.000E+00 0.000E+00
BREAST      1.340E-16 7.891E-14 1.656E-12 2.740E-18-1.000E+00 0.000E+00 0.000E+00
LUNGS       1.140E-16 7.056E-14 1.481E-12 2.450E-18-1.000E+00 0.000E+00 0.000E+00
RED MARR    1.090E-16 6.998E-14 1.469E-12 2.430E-18-1.000E+00 0.000E+00 0.000E+00
BONE SUR    2.200E-16 1.287E-13 2.702E-12 4.470E-18-1.000E+00 0.000E+00 0.000E+00
THYROID     1.180E-16 7.459E-14 1.565E-12 2.590E-18-1.000E+00 0.000E+00 0.000E+00
REMAINDER   1.090E-16 6.941E-14 1.457E-12 2.410E-18-1.000E+00 0.000E+00 0.000E+00
EFFECTIVE   1.190E-16 7.603E-14 1.596E-12 2.640E-18-1.000E+00 0.000E+00 0.000E+00
SKIN(FGR)   1.320E-14 2.304E-11 4.835E-10 8.000E-16-1.000E+00 0.000E+00 0.000E+00
Kr-85m
GONADS      7.310E-15 2.594E-12 3.653E-12 1.570E-16-1.000E+00 0.000E+00 0.000E+00
BREAST      8.410E-15 2.527E-12 3.560E-12 1.530E-16-1.000E+00 0.000E+00 0.000E+00
LUNGS       7.040E-15 2.379E-12 3.351E-12 1.440E-16-1.000E+00 0.000E+00 0.000E+00
RED MARR    6.430E-15 2.346E-12 3.304E-12 1.420E-16-1.000E+00 0.000E+00 0.000E+00
BONE SUR    1.880E-14 5.286E-12 7.446E-12 3.200E-16-1.000E+00 0.000E+00 0.000E+00
THYROID     7.330E-15 2.395E-12 3.374E-12 1.450E-16-1.000E+00 0.000E+00 0.000E+00
REMAINDER   6.640E-15 2.313E-12 3.257E-12 1.400E-16-1.000E+00 0.000E+00 0.000E+00
EFFECTIVE   7.480E-15 2.511E-12 3.537E-12 1.520E-16-1.000E+00 0.000E+00 0.000E+00
SKIN(FGR)   2.240E-14 2.247E-11 3.164E-11 1.360E-15-1.000E+00 0.000E+00 0.000E+00
Kr-87
```

GONADS	4.000E-14	4.962E-12	5.026E-12	7.610E-16	-1.000E+00	0.000E+00	0.000E+00
BREAST	4.500E-14	4.740E-12	4.802E-12	7.270E-16	-1.000E+00	0.000E+00	0.000E+00
LUNGS	4.040E-14	4.603E-12	4.663E-12	7.060E-16	-1.000E+00	0.000E+00	0.000E+00
RED MARR	4.000E-14	4.708E-12	4.769E-12	7.220E-16	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	6.020E-14	6.514E-12	6.598E-12	9.990E-16	-1.000E+00	0.000E+00	0.000E+00
THYROID	4.130E-14	4.473E-12	4.531E-12	6.860E-16	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	3.910E-14	4.590E-12	4.650E-12	7.040E-16	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	4.120E-14	4.773E-12	4.835E-12	7.320E-16	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.370E-13	8.802E-11	8.916E-11	1.350E-14	-1.000E+00	0.000E+00	0.000E+00
Kr-88							
GONADS	9.900E-14	2.278E-11	2.655E-11	1.800E-15	-1.000E+00	0.000E+00	0.000E+00
BREAST	1.110E-13	2.177E-11	2.537E-11	1.720E-15	-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.010E-13	2.139E-11	2.493E-11	1.690E-15	-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.000E-13	2.190E-11	2.552E-11	1.730E-15	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	1.390E-13	2.886E-11	3.363E-11	2.280E-15	-1.000E+00	0.000E+00	0.000E+00
THYROID	1.030E-13	2.012E-11	2.345E-11	1.590E-15	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	9.790E-14	2.139E-11	2.493E-11	1.690E-15	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.020E-13	2.202E-11	2.567E-11	1.740E-15	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.350E-13	5.607E-11	6.534E-11	4.430E-15	-1.000E+00	0.000E+00	0.000E+00
I-131							
GONADS	1.780E-14	1.119E-11	1.789E-10	3.940E-16	-1.000E+00	2.530E-11	4.070E-11
BREAST	2.040E-14	1.082E-11	1.730E-10	3.810E-16	-1.000E+00	7.880E-11	1.210E-10
LUNGS	1.760E-14	1.016E-11	1.626E-10	3.580E-16	-1.000E+00	6.570E-10	1.020E-10
RED MARR	1.680E-14	1.022E-11	1.635E-10	3.600E-16	-1.000E+00	6.260E-11	9.440E-11
BONE SUR	3.450E-14	1.675E-11	2.679E-10	5.900E-16	-1.000E+00	5.730E-11	8.720E-11
THYROID	1.810E-14	1.053E-11	1.685E-10	3.710E-16	-1.000E+00	2.920E-07	4.760E-07
REMAINDER	1.670E-14	9.908E-12	1.585E-10	3.490E-16	-1.000E+00	8.030E-11	1.570E-10
EFFECTIVE	1.820E-14	1.067E-11	1.707E-10	3.760E-16	-1.000E+00	8.890E-09	1.440E-08
SKIN(FGR)	2.980E-14	1.825E-11	2.920E-10	6.430E-16	-1.000E+00	0.000E+00	0.000E+00
I-132							
GONADS	1.090E-13	2.523E-11	2.771E-11	2.320E-15	-1.000E+00	9.950E-12	2.330E-11
BREAST	1.240E-13	2.414E-11	2.652E-11	2.220E-15	-1.000E+00	1.410E-11	2.520E-11
LUNGS	1.090E-13	2.305E-11	2.532E-11	2.120E-15	-1.000E+00	2.710E-10	2.640E-11
RED MARR	1.070E-13	2.360E-11	2.592E-11	2.170E-15	-1.000E+00	1.400E-11	2.460E-11
BONE SUR	1.730E-13	3.327E-11	3.655E-11	3.060E-15	-1.000E+00	1.240E-11	2.190E-11
THYROID	1.120E-13	2.381E-11	2.616E-11	2.190E-15	-1.000E+00	1.740E-09	3.870E-09
REMAINDER	1.050E-13	2.283E-11	2.509E-11	2.100E-15	-1.000E+00	3.780E-11	1.650E-10
EFFECTIVE	1.120E-13	2.403E-11	2.640E-11	2.210E-15	-1.000E+00	1.030E-10	1.820E-10
SKIN(FGR)	1.580E-13	8.199E-11	9.007E-11	7.540E-15	-1.000E+00	0.000E+00	0.000E+00
I-133							
GONADS	2.870E-14	1.585E-11	6.748E-11	6.270E-16	-1.000E+00	1.950E-11	3.630E-11
BREAST	3.280E-14	1.519E-11	6.468E-11	6.010E-16	-1.000E+00	2.940E-11	4.680E-11
LUNGS	2.860E-14	1.446E-11	6.156E-11	5.720E-16	-1.000E+00	8.200E-10	4.530E-11
RED MARR	2.770E-14	1.466E-11	6.242E-11	5.800E-16	-1.000E+00	2.720E-11	4.300E-11
BONE SUR	4.870E-14	2.161E-11	9.202E-11	8.550E-16	-1.000E+00	2.520E-11	4.070E-11
THYROID	2.930E-14	1.502E-11	6.393E-11	5.940E-16	-1.000E+00	4.860E-08	9.100E-08
REMAINDER	2.730E-14	1.418E-11	6.038E-11	5.610E-16	-1.000E+00	5.000E-11	1.550E-10
EFFECTIVE	2.940E-14	1.509E-11	6.425E-11	5.970E-16	-1.000E+00	1.580E-09	2.800E-09
SKIN(FGR)	5.830E-14	1.150E-10	4.897E-10	4.550E-15	-1.000E+00	0.000E+00	0.000E+00
I-134							
GONADS	1.270E-13	1.200E-11	1.202E-11	2.640E-15	-1.000E+00	4.250E-12	1.100E-11
BREAST	1.440E-13	1.145E-11	1.147E-11	2.520E-15	-1.000E+00	6.170E-12	1.170E-11
LUNGS	1.270E-13	1.100E-11	1.102E-11	2.420E-15	-1.000E+00	1.430E-10	1.260E-11
RED MARR	1.250E-13	1.127E-11	1.129E-11	2.480E-15	-1.000E+00	6.080E-12	1.090E-11

BONE SUR	1.960E-13	1.568E-11	1.571E-11	3.450E-15	-1.000E+00	5.310E-12	9.320E-12
THYROID	1.300E-13	1.127E-11	1.129E-11	2.480E-15	-1.000E+00	2.880E-10	6.210E-10
REMAINDER	1.220E-13	1.091E-11	1.093E-11	2.400E-15	-1.000E+00	2.270E-11	1.340E-10
EFFECTIVE	1.300E-13	1.150E-11	1.152E-11	2.530E-15	-1.000E+00	3.550E-11	6.660E-11
SKIN(FGR)	1.870E-13	4.477E-11	4.485E-11	9.850E-15	-1.000E+00	0.000E+00	0.000E+00
I-135							
GONADS	8.078E-14	3.113E-11	5.489E-11	1.599E-15	-1.000E+00	1.700E-11	3.610E-11
BREAST	9.143E-14	2.971E-11	5.240E-11	1.526E-15	-1.000E+00	2.340E-11	3.850E-11
LUNGS	8.145E-14	2.886E-11	5.089E-11	1.482E-15	-1.000E+00	4.410E-10	3.750E-11
RED MARR	8.054E-14	2.965E-11	5.228E-11	1.523E-15	-1.000E+00	2.240E-11	3.650E-11
BONE SUR	1.184E-13	3.983E-11	7.024E-11	2.046E-15	-1.000E+00	2.010E-11	3.360E-11
THYROID	8.324E-14	2.852E-11	5.030E-11	1.465E-15	-1.000E+00	8.460E-09	1.790E-08
REMAINDER	7.861E-14	2.883E-11	5.084E-11	1.481E-15	-1.000E+00	4.700E-11	1.540E-10
EFFECTIVE	8.294E-14	2.989E-11	5.271E-11	1.535E-15	-1.000E+00	3.320E-10	6.080E-10
SKIN(FGR)	1.156E-13	9.826E-11	1.733E-10	5.047E-15	-1.000E+00	0.000E+00	0.000E+00
Xe-133							
GONADS	1.610E-15	1.465E-12	2.052E-11	5.200E-17	-1.000E+00	0.000E+00	0.000E+00
BREAST	1.960E-15	1.505E-12	2.107E-11	5.340E-17	-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.320E-15	1.045E-12	1.464E-11	3.710E-17	-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.070E-15	8.791E-13	1.231E-11	3.120E-17	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	5.130E-15	4.254E-12	5.958E-11	1.510E-16	-1.000E+00	0.000E+00	0.000E+00
THYROID	1.510E-15	1.181E-12	1.653E-11	4.190E-17	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.240E-15	1.042E-12	1.460E-11	3.700E-17	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.560E-15	1.299E-12	1.819E-11	4.610E-17	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	4.970E-15	1.953E-12	2.734E-11	6.930E-17	-1.000E+00	0.000E+00	0.000E+00
Xe-135							
GONADS	1.170E-14	5.455E-12	1.194E-11	2.530E-16	-1.000E+00	0.000E+00	0.000E+00
BREAST	1.330E-14	5.325E-12	1.166E-11	2.470E-16	-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.130E-14	4.959E-12	1.086E-11	2.300E-16	-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.070E-14	4.959E-12	1.086E-11	2.300E-16	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	2.570E-14	9.120E-12	1.997E-11	4.230E-16	-1.000E+00	0.000E+00	0.000E+00
THYROID	1.180E-14	5.023E-12	1.100E-11	2.330E-16	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.080E-14	4.829E-12	1.058E-11	2.240E-16	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.190E-14	5.217E-12	1.142E-11	2.420E-16	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	3.120E-14	4.506E-11	9.867E-11	2.090E-15	-1.000E+00	0.000E+00	0.000E+00
Xe-133m							
GONADS	1.420E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BREAST	1.700E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.190E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.100E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	3.230E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
THYROID	1.360E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.150E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	1.370E-15	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.040E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
Xe-135m							
GONADS	2.000E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BREAST	2.290E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
LUNGS	1.980E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
RED MARR	1.910E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	3.500E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
THYROID	2.040E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	1.890E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	2.040E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00

SKIN(FGR)	2.970E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
Xe-138							
GONADS	5.590E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BREAST	6.320E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
LUNGS	5.660E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
RED MARR	5.600E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
BONE SUR	8.460E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
THYROID	5.770E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
REMAINDER	5.490E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
EFFECTIVE	5.770E-14	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00
SKIN(FGR)	1.070E-13	0.000E+00	0.000E+00	0.000E+00	-1.000E+00	0.000E+00	0.000E+00

ATTACHMENT I
FHACTMT72 OUTPUT FILE

##
Cumulative Dose Summary
##

	eab		lpz		cr	
Time (hr)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)
0.000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.333	3.4121E+00	1.1633E-01	8.0328E-01	2.7387E-02	4.4337E+00	1.3616E-01
0.733	7.5028E+00	2.5579E-01	1.7663E+00	6.0216E-02	1.6158E+01	4.9692E-01
1.033	1.0566E+01	3.6021E-01	2.4874E+00	8.4799E-02	2.6093E+01	8.0341E-01
1.333	1.3626E+01	4.6449E-01	3.2077E+00	1.0935E-01	3.6451E+01	1.1235E+00
1.633	1.6681E+01	5.6862E-01	3.9270E+00	1.3386E-01	4.7007E+01	1.4503E+00
1.933	1.9733E+01	6.7261E-01	4.6454E+00	1.5834E-01	5.7652E+01	1.7802E+00
2.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	6.0025E+01	1.8538E+00
2.300	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	6.7663E+01	2.0917E+00
2.600	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.1369E+01	2.2087E+00
2.900	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.3167E+01	2.2668E+00
3.200	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4039E+01	2.2959E+00
3.500	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4462E+01	2.3109E+00
3.800	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4667E+01	2.3188E+00
4.100	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4767E+01	2.3231E+00
4.400	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4815E+01	2.3257E+00
4.700	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4839E+01	2.3272E+00
5.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4850E+01	2.3283E+00
5.300	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4856E+01	2.3290E+00
5.600	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4858E+01	2.3295E+00
5.900	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4860E+01	2.3299E+00
6.200	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4860E+01	2.3302E+00
6.500	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3304E+00
6.800	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3306E+00
7.100	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3308E+00
7.400	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3309E+00
7.700	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3310E+00
8.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3311E+00
8.300	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3311E+00
8.600	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3312E+00
8.900	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3312E+00
9.200	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3312E+00
9.500	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3313E+00
9.800	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3313E+00
10.100	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3313E+00
10.400	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3313E+00
24.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3314E+00
96.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3314E+00
720.000	2.0410E+01	6.9571E-01	4.8050E+00	1.6378E-01	7.4861E+01	2.3314E+00

##
Worst Two-Hour Doses
##

eab

Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
0.0	7.3317E-02	2.0410E+01	6.9571E-01

ATTACHMENT J
FHACTMT100 OUTPUT FILE

##
Cumulative Dose Summary
##

	eab		lpz		cr	
Time (hr)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)
0.000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.333	3.0436E+00	1.0307E-01	7.1652E-01	2.4264E-02	3.9550E+00	1.2130E-01
0.733	6.6930E+00	2.2664E-01	1.5756E+00	5.3355E-02	1.4415E+01	4.4270E-01
1.033	9.4263E+00	3.1919E-01	2.2191E+00	7.5142E-02	2.3279E+01	7.1575E-01
1.333	1.2156E+01	4.1162E-01	2.8618E+00	9.6902E-02	3.2522E+01	1.0010E+00
1.633	1.4883E+01	5.0394E-01	3.5038E+00	1.1864E-01	4.1943E+01	1.2921E+00
1.933	1.7607E+01	5.9614E-01	4.1450E+00	1.4034E-01	5.1445E+01	1.5861E+00
2.000	1.8212E+01	6.1663E-01	4.2874E+00	1.4516E-01	5.3563E+01	1.6516E+00
2.300	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.0381E+01	1.8636E+00
2.600	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.3689E+01	1.9678E+00
2.900	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.5295E+01	2.0194E+00
3.200	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6074E+01	2.0453E+00
3.500	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6451E+01	2.0586E+00
3.800	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6635E+01	2.0655E+00
4.100	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6724E+01	2.0694E+00
4.400	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6767E+01	2.0716E+00
4.700	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6788E+01	2.0729E+00
5.000	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6798E+01	2.0738E+00
5.300	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6803E+01	2.0744E+00
5.600	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6805E+01	2.0749E+00
5.900	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6807E+01	2.0752E+00
6.200	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6807E+01	2.0755E+00
6.500	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6807E+01	2.0757E+00
6.800	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0758E+00
7.100	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0760E+00
7.400	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0761E+00
7.700	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0761E+00
8.000	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0762E+00
8.300	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0763E+00
8.600	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0763E+00
8.900	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0763E+00
9.200	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0764E+00
9.500	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0764E+00
9.800	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0764E+00
10.100	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0764E+00
10.400	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0764E+00
24.000	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0765E+00
96.000	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0765E+00
720.000	1.8212E+01	6.1663E-01	4.2875E+00	1.4517E-01	6.6808E+01	2.0765E+00

##
Worst Two-Hour Doses
##

eab

Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
0.0	6.1767E-02	1.8212E+01	6.1663E-01

ATTACHMENT K
FHACTMT72R OUTPUT FILE

##
Cumulative Dose Summary
##

	eab		lpz		cr	
Time (hr)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)	Thyroid (rem)	TEDE (rem)
0.000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.333	5.6869E+00	1.8619E-01	1.3388E+00	4.3833E-02	7.3895E+00	2.2634E-01
0.733	1.2505E+01	4.0939E-01	2.9438E+00	9.6378E-02	2.6931E+01	8.2555E-01
1.033	1.7610E+01	5.7653E-01	4.1457E+00	1.3572E-01	4.3489E+01	1.3341E+00
1.333	2.2709E+01	7.4344E-01	5.3461E+00	1.7502E-01	6.0752E+01	1.8649E+00
1.633	2.7802E+01	9.1013E-01	6.5450E+00	2.1426E-01	7.8345E+01	2.4063E+00
1.933	3.2888E+01	1.0766E+00	7.7423E+00	2.5345E-01	9.6087E+01	2.9527E+00
2.000	3.4017E+01	1.1136E+00	8.0082E+00	2.6215E-01	1.0004E+02	3.0746E+00
2.300	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.1277E+02	3.4678E+00
2.600	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.1895E+02	3.6602E+00
2.900	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2194E+02	3.7548E+00
3.200	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2340E+02	3.8017E+00
3.500	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2410E+02	3.8252E+00
3.800	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2444E+02	3.8373E+00
4.100	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2461E+02	3.8437E+00
4.400	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2469E+02	3.8472E+00
4.700	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2473E+02	3.8493E+00
5.000	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2475E+02	3.8505E+00
5.300	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2476E+02	3.8513E+00
5.600	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2476E+02	3.8519E+00
5.900	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8523E+00
6.200	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8527E+00
6.500	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8529E+00
6.800	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8531E+00
7.100	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8532E+00
7.400	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8534E+00
7.700	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8534E+00
8.000	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8535E+00
8.300	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8536E+00
8.600	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8536E+00
8.900	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8537E+00
9.200	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8537E+00
9.500	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8537E+00
9.800	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00
10.100	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00
10.400	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00
24.000	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00
96.000	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00
720.000	3.4017E+01	1.1136E+00	8.0083E+00	2.6215E-01	1.2477E+02	3.8538E+00

##
Worst Two-Hour Doses
##

eab

Time (hr)	Whole Body (rem)	Thyroid (rem)	TEDE (rem)
0.0	7.6244E-02	3.4017E+01	1.1136E+00

ATTACHMENT L
ETP-97-064R CONTROL ROOM INLEAKAGE RESULTS

CONTROLLED COPY

CA06450 Rev. 0
Page 51

4730
MUUU

CALVERT CLIFFS NUCLEAR POWER PLANT

TECHNICAL PROCEDURE

ENGINEERING TEST PROCEDURE

UNIT 0

ETP 97-064R

CONTROL ROOM HVAC SYSTEM INLEAKAGE TEST

REVISION 0

Effective Date 11/11/1997

Safety Related X
Non-Safety Related ______

Writer: D. T. McElheny

Sponsor: V. P. Spunar

Approved ________________ 11/11/97
Date

CONTROLLED COPY

FT-86 (Rev. 1 10/97) ACU #11

NUCON International, Inc.

Decay Test Data

Estimated duration of test: 2 hours
Beginning concentration (*CI*): 19.0 ppb
Ending concentration (*C(O)*): 2.7 ppb
Time at start of test: Time "zero" for decay test was at 01:15 hours on 18 Nov 97.
Time at end of test: 03:12 hours on 19 Nov 97
Sample time intervals: 15 minute, except for last sample

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
01:15 / 19.0	/	/	/
01:30 / 14.8	/	/	/
01:45 / 12.1	/	/	/
02:00 / 8.3	/	/	/
02:15 / 6.7	/	/	/
02:30 / 5.1	/	/	/
03:12 / 2.7	/	/	/

(*A*) Air Change Rate (1/min)

0.0170

(*Q*) Inleakage Flow Rate (CFM)

4300

95% Confidence Limit

(*A*) = 0.0170 ± 0.0012

95% Confidence Interval

4000 < *Q* < 4600

Comments: Decay samples taken at a sample port on the discharge of #11 return fan. All sample concentrations in the ppb range.

Walt O. Wiboff W. Peter Freeman

Test personnel signature(s) and date: NUCON International Inc.

FT-86 (Rev. 1 10/97) *ACU #12*

NUCON International, Inc.

Decay Test Data

Estimated duration of test: 1.4 hours
Beginning concentration (Ci): 40.5 ppb
Ending concentration ($C(O)$): 14.2 ppb
Time at start of test: Time "zero" for decay test was at 23:16 hours on 19 Nov 97.
Time at end of test: 00:46 hours on 20 Nov 97
Sample time intervals: 15 minute

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
23:16 / 40.5	/	/	/
23:31 / 35.2	/	/	/
23:46 / 21.2	/	/	/
00:01 / 26.7	/	/	/
00:16 / 20.3	/	/	/
00:31 / 16.7	/	/	/
00:46 / 14.2	/	/	/

(A) Air Change Rate (1/min)

0.0118

(Q) Inleakage Flow Rate (CFM)

3000

95% Confidence Limit

(A) = 0.0118 ± 0.0012

95% Confidence Interval

2900 $< Q <$ 3300

Comments: Decay samples taken at a sample port on the discharge of #12 return fan. These samples were taken in conjunction with samples taken in CAS and on both CSR return ducts. The decay sample taken at 23:46 hours was disregarded due to a faulty gas sample bag.

Walt O. Wikoff W. Peter Freeman

Test personnel signature(s) and date: NUCON International Inc.

CA0 6450 Rev. 0
Page 54

CALVERT CLIFFS NUCLEAR POWER PLANT

TECHNICAL PROCEDURE

ENGINEERING TEST PROCEDURE

UNIT 0

ETP 97-064R

CONTROL ROOM HVAC SYSTEM INLEAKAGE TEST

REVISION 0

3rd Run of ETP

Effective Date 11/11/1997

Safety Related X
Non-Safety Related ________

CONTROLLED COPY

Writer: D. T. McElheny

Sponsor: V. P. Spunar

Approved ____________________ 11/11/97
Date

Att. 1 Chron Log
Page 3 of 7

CA06450 Rev. 0
Page 55

NUCON International, Inc.
P.O. BOX 29151 7000 HUNTLEY ROAD
COLUMBUS, OHIO 43229 U.S.A.

TELEPHONE: (614) 846-5710
OUTSIDE OHIO: 1-800-992-5192
FAX: (614) 431-0858

Control Room Inleakage Test Report

performed for:

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Station
1850 Calvert Cliffs Pkwy.
Lusby, Maryland
20657

P.O. No. 16582

20 April 1998

Distribution:

BG&E:
Dale McElheny (1)

NUCON:

12BG847 MF	(1)
Field Test	(1)
QA	(1)
Marketing	(1)

NUCON 12BG847 /02

Decay Test Data

Estimated duration of test: 120 minutes
Beginning concentration (*Ct*): 25.0 ppb
Ending concentration (*C(O)*): 4.1 ppb
Time at start of test: Time "zero" for decay test was at 22:03 hrs. on 10 Feb 98
Time at end of test: 00:03 hrs. on 11 Feb 98
Sample time intervals: 20 minutes apart

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
22:03 / 25.0	/	/	/
22:23 / 17.9	/	/	/
22:43 / 11.9	/	/	/
23:03 / 9.7	/	/	/
23:23 / 9.0	/	/	/
23:43 / 5.7	/	/	/
00:03 / 4.1	/	/	/

(*A*) Air Change Rate (1/min)

0.0143

(*Q*) Inleakage Flow Rate (CFM)

3,600

95% Confidence Limit

(*A*) = 0.0143 ± 0.0025

95% Confidence Interval

3000 < *Q* < ~~4300~~ 4200 * DJM

Comments: Decay samples taken at a sample port on the discharge of #11 return fan. All sample concentrations in the ppb range.

* Per conversation w/ Pete Freeman 5/27/98. DJM

Test personnel signature(s) and date: NUCON International Inc.

Decay Test Data

Estimated duration of test: 120 minutes
Beginning concentration (*Ct*): 47 ppb
Ending concentration (*C(O)*): 12.6 ppb
Time at start of test: Time "zero" for decay test was at 02:05 hrs. on 11 Feb 98
Time at end of test: 04:05 hrs. on 11 Feb 98
Sample time intervals: 20 minutes apart

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
02:05 / 47.0	/	/	/
02:25 / 33.2	/	/	/
02:45 / 27.4	/	/	/
03:05 / 24.8	/	/	/
03:25 / 21.4	/	/	/
03:45 / 16.1	/	/	/
04:05 / 12.6	/	/	/

(*A*) Air Change Rate (1/min)

0.0101

(*Q*) Inleakage Flow Rate (CFM)

2550

95% Confidence Limit

(*A*) = 0.0101 ± 0.0018

95% Confidence Interval

2100 < *Q* < 3000

Comments: Decay samples taken at a sample port on the discharge of #12 return fan. All sample concentrations in the ppb range.

Test personnel signature(s) and date: NUCON International Inc.

CA06450 Rev. 0
Page 58

CALVERT CLIFFS NUCLEAR POWER PLANT

TECHNICAL PROCEDURE

ENGINEERING TEST PROCEDURE

UNIT 0

ETP 97-064R

CONTROL ROOM HVAC SYSTEM INLEAKAGE TEST

REVISION 0

4th Run of ETP

Effective Date 11/11/1997

Safety Related X
Non-Safety Related ________

CONTROLLED COPY

Writer: D. T. McElheny

Sponsor: V. P. Spunar

Approved ________________ 11/11/97
Date

Att. 1. Chron. Log

Page 3 of 11

CA06450 Rev. 0
Page 59

NUCON International, Inc.

P.O. BOX 29151 7000 HUNTLEY ROAD
COLUMBUS, OHIO 43229 U.S.A.

TELEPHONE: (614) 846-5710
OUTSIDE OHIO: 1-800-992-5192
FAX: (614) 431-0858

Control Room Inleakage Test Report

performed for:

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Station
1850 Calvert Cliffs Pkwy.
Lusby, Maryland
20657

P.O. No. 16582

20 April 1998

Distribution:

BG&E:
Dale McElheny (1)

NUCON:

12BG847 MF	(1)
Field Test	(1)
QA	(1)
Marketing	(1)

NUCON 12BG847 /02

Decay Test Data

Estimated duration of test: 120 minutes
Beginning concentration (*Ct*): 37.5 ppb
Ending concentration (*C(O)*): 9.2 ppb
Time at start of test: Time "zero" for decay test was at 01:15 hrs on 12 Feb 98
Time at end of test: 03:15 hrs on 12 Feb 98
Sample time intervals: 20 minutes apart

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
1:15 / 37.5	/	/	/
1:35 / 28.1	/	/	/
1:55 / 24.7	/	/	/
2:15 / 19.3	/	/	/
2:35 / 15.7	/	/	/
2:55 / 11.7	/	/	/
3:15 / 9.2	/	/	/

(*A*) Air Change Rate (min^{-1})

0.0115

(*Q*) Inleakage Flow Rate (CFM)

2,900

95% Confidence Limit

$(A) =$ 0.0115 ± .0010

95% Confidence Interval

2650 < Q < 3150

Comments: Decay samples taken at a sample port on the discharge of #11 return fan. All sample concentrations in the ppb range.

Test personnel signature(s) and date: NUCON International Inc.

Decay Test Data

Estimated duration of test: 120 minutes
Beginning concentration (*Ct*): 37.5 ppb
Ending concentration (*C(O)*): 9.2 ppb
Time at start of test: Time "zero" for decay test was at 21:25 hrs. on 11 Feb 98
Time at end of test: 23:25 hrs. on 11 Feb 98
Sample time intervals: 20 minutes apart

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
21:25 / 37.6	/	/	/
21:45 / 30.2	/	/	/
22:05 / 25.2	/	/	/
22:25 / 22.7	/	/	/
22:45 / 15.5	/	/	/
23:05 / 13.4	/	/	/
23:25 / 10.5	/	/	/

(*A*) Air Change Rate (1/min)

0.0109

95% Confidence Limit

(*A*) = 0.0109 ± .0015

(*Q*) Inleakage Flow Rate (CFM)

2,750

95% Confidence Interval

2370 < *Q* < 3130

Comments: Decay samples taken at a sample port on the discharge of #12 return fan. All sample concentrations in the ppb range.

Test personnel signature(s) and date: NUCON International Inc.

CA06450 Rev.0
Page 62

x4688-185

Kevin Spr 1744

CALVERT CLIFFS NUCLEAR POWER PLANT

TECHNICAL PROCEDURE

ENGINEERING TEST PROCEDURE

UNIT 0

ETP 97-064R

CONTROL ROOM HVAC SYSTEM INLEAKAGE TEST

x5901 - Al.

REVISION 1

Effective Date 1/18/00

Safety Related X
Non-Safety Related ____

CONTROLLED COPY

Writer: D. T. McElheny

Sponsor: T. R. Lupold

Approved ____________________ 1/18/00
Date

CA06450 Rev. 0 Page 63
ETP 97-064R
Rev 1

Attachment 1
Page 2 of 14

NUCON International, Inc.

P.O. BOX 29151 7000 HUNTLEY ROAD
COLUMBUS, OHIO 43229 U.S.A.

TELEPHONE: (614) 846-5710
TOLL FREE: 1-800-992-5192
FAX: (614) 431-0858
WEB SITE: www.nucon-int.com

Control Room Inleakage Test Report

performed for:

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Station
1850 Calvert Cliffs Pkwy.
Lusby, Maryland
20657

P.O. No. 16582

3 March 2000

Distribution:

BG&E:
Dale McElheny (1)

NUCON:

12BG658 MF	(1)
Field Test	(1)
QA	(1)
Marketing	(1)

NUCON 12BG658 /01

Decay Test Data

Estimated duration of test: 180 minutes
Beginning concentration (Ct): 51.4 ppb
Ending concentration ($C(O)$): 13.2 ppb
Time at start of test: Time "zero" for decay test was at 01:05 hrs. on 26 Jan 00
Time at end of test: 04:05 hrs. on 26 Jan 00
Sample time intervals: 15 minutes apart

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
/	120/23.8	/	/
30/ 51.4	135/21.0	/	/
45/ 47.6	150/17.8	/	/
60/ 41.9	165/16.4	/	/
75/ 33.0	180/13.2	/	/
90/ 30.7	/	/	/
105/ 29.3	/	/	/

(A) Air Change Rate (1/min)

0.00896

(Q) Inleakage Flow Rate (CFM)

2600

95% Confidence Limit

(A) = 0.00896 ± 0.00065

95 % Confidence Interval

2400 < Q < 2800

Comments: Decay samples taken at a sample port on the discharge of #12 return fan. All sample concentrations in the ppb range.

W. Peter Freeman Eric M Banks 3 March 00

Test personnel signature(s) and date: NUCON International Inc.

Decay Test Data

Estimated duration of test: 180 minutes
Beginning concentration (Ct): 59.2 ppb @ 15 minutes into test
Ending concentration ($C(O)$): 8.8 ppb @ 195 minutes into test
Time at start of test: Time "zero" for decay test was at 23:35 hrs. on 26 Jan 00
Time at end of test: 03:00 hrs. on 27 Jan 00
Sample time intervals: 15 minutes apart to 105 minutes then @ 140, 165, and 195 minutes

Time / Sample Concentration

Time/Conc.	Time/Conc.	Time/Conc.	Time/Conc.
15/59.2	165/13.8	/	/
30/52.5	195/8.8	/	/
45/42.8	/	/	/
60/40.2	/	/	/
75/36.1	/	/	/
105 /26.2	/	/	/
140/ 17.4	/	/	/

(A) Air Change Rate (1/min)

0.0103

(Q) Inleakage Flow Rate (CFM)

3000

95% Confidence Limit

(A) = 0.0103 ± 0.00085

95 % Confidence Interval

2750 < Q < 3250

Comments: Decay samples taken at a sample port on the discharge of #11 return fan. All sample concentrations in the ppb range.

W. Peter Freeman Eric M Banks 3 March 00
Test personnel signature(s) and date: NUCON International Inc.

ATTACHMENT M
ETP 01-035R PERFLUOROCARBON TRACER GAS TESTING

CAO6450 Rev.0
Page 67

CALVERT CLIFFS NUCLEAR POWER PLANT

TECHNICAL PROCEDURE

ENGINEERING TEST PROCEDURE

UNIT 0

ETP 01-035R

PERFLUOROCARBON TRACER GAS TESTING

REVISION 0

CONTROLLED COPY

Effective Date 5/1/02

Safety Related X
Non-Safety Related ______

Writer: D. T. McElheny

Sponsor: M. A. Junge

Approved Richard L. Spoels 5-1-02
Date

Step 7.0.C Vendor Analysis Data

Page 1 of 9

CA06450 Rev.0
Page 68

TRACER TECHNOLOGY CENTER
BROOKHAVEN NATIONAL LABORATORY

FACSIMILE

DATE: July 29, 2002

TO: John E. Wynn Jr.
Aux Systems Engr Unit
Calvert Cliffs Nuclear Power Plant
Lusby, MD 20657

FAX NO: (410) 495 - 4727

MESSAGE:

John,

I'm on vacation this week but wanted to send you the final results but without my final assessment. Remarkably, total inleakage was 2930 ± 185 cfm. Other flows, in cfm, were:

Zone	From/To	CR Inleakage	% of total	CR Outleakage	% of total
0	Outside	275 ± 185	9	1866 ± 470	64
2	AB	436 ± 157	15	366 ± 248	13
3	TB	466 ± 172	16	599 ± 415	20
4	MSIVs	272 ± 134	9	44 ± 33	2
5	AC11	274 ± 33	9	19 ± 3	1
6	AC13	387 ± 38	13	11 ± 8	0
7	SWGRs	818 ± 114	28	21 ± 10	1

More next week. I'll put a copy in the mail also.

Russ

Total no. of pages including this cover page: 4

From: Russell N. Dietz – Head
Tracer Technology Center
Atmospheric Sciences Division
Brookhaven National Laboratory
Bldg 815E
Upton, NY 11973-5000

Telephone: (631) 344-3059
Fax: (631) 344-2887
Confirmation: (631) 344-3275
Email: dietz@bnl.gov
Secretary: Barbara J. Roland
Secretary's email: roland@bnl.gov

BNL—AIMS

12:36:28 07-26-2002

PROJECT: CALVERT CLIFFS START: 09:00 (06-06-1902) BNL CODE: CAL1A0
HOUSE: CALVERT CLIFFS STOP: 10:00 (06-18-1902) ANALYZED: 06-27-1902

************************************* RATES *************************************

OVERALL INFILTRATION RATE = %515878.1 q 85992.1(m^3/h)
OVERALL AIR EXCHANGE RATE = 1.461 q 0.251(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	CR	%663.0	1	41812	3170.4	787.9	464.8	379.6	0.055	0.045
2	AB	%3858.0	4	973219	30896.3	11048.8	32707.5	11645.0	0.680	0.244
3	TB	%3870.0	12	%3399361	411130.1	88819.1	419373.8	90345.6	1.482	0.328
4	MSIVs	%458.0	4	189594	22087.4	10568.3	5694.9	8281.4	4.658	6.778
5	No.11 AC	%2150.0	1	132691	30819.8	3244.6	32226.2	3348.5	19.042	2.196
6	No.13 AC	6.4	30	12620	14492.4	1194.7	8912.2	1907.4	2.460	0.541
7	SWGRs	9.2	10	6435	3381.7	10458.4	16598.8	1527.7	2.348	0.246

ZONE-ZONE	RATE	q SD (m^3/h)	ZONE-ZONE	RATE	q SD (m^3/h)
1 - 2	622.2	421.7	2 - 1	741.3	267.9
1 - 3	1018.1	704.6	3 - 1	792.5	292.2
1 - 4	74.5	56.7	4 - 1	462.9	227.2
1 - 5	32.3	5.2	5 - 1	464.8	56.1
1 - 6	19.4	13.7	6 - 1	657.3	64.0
1 - 7	36.5	16.9	7 - 1	1389.7	193.2
2 - 3	2870.3	1460.4	3 - 2	145.4	465.7
2 - 4	31.1	69.4	4 - 2	378.6	448.3
2 - 5	12.0	6.0	5 - 2	334.8	258.1
2 - 6	11.2	21.7	6 - 2	314.4	243.9
2 - 7	552.1	220.7	7 - 2	611.4	556.4
3 - 4	17034.4	%11524.3	4 - 3	154.4	133.2
3 - 5	163.4	115.6	5 - 3	807.0	235.2
3 - 6	8416.2	1965.2	6 - 3	1002.9	424.6
3 - 7	215.4	133.1	7 - 3	12671.2	%11138.9
4 - 5	60.1	35.6	5 - 4	138.1	86.7
- 6	12.7	6.5	6 - 4	755.3	506.8
- 7	30.9	19.1	7 - 4	-541.5	547.4
5 - 6	60.8	11.3	6 - 5	125.9	120.7
5 - 7	22.3	7.0	7 - 5	27.6	62.7
6 - 7	91.1	20.9	7 - 6	7.0	214.7

TOTAL FLOW IN OR OUT

ZONE	RATE q SD (m^3/h)	ACH q SD(/h)	ZONE	RATE q SD (m^3/h)	ACH q SD(/h)
1	4873.4 ± 310.5	0.586 0.047	2	35114.3 %12483.9	0.730 0.262
3	%437897.5 %93722.6	1.547 0.340	4	23186.9 %11083.4	18.966 9.115
5	32647.6 3389.9	19.291 2.223	6	17439.5 1095.1	4.814 0.386
7	17547.1 1595.5	2.480 0.257			

************************************* ANALYSIS *************************************

→ Total Infiltration(m^3/h) = 2930 ± 185 cfm

AVG. TRACER CONC. (pL/L) q SD

VOL m^3	SOURCE TYPE	ptPDCH	PMCP	PDCB	I-PTCH	PMCH	ocPDCH	iPPCH
8480	ptPDCH	3.447 q 0.403	4.466 q 0.173	2.352 q 0.111	0.786 q 0.076	0.386 q 0.014	0.101 q 0.005	0.106 q 0.009
48110	PMCP	0.151 q 0.086	27.815 q 9.791	0.174 q 0.065	0.103 q 0.090	0.046 q 0.026	0.009 q 0.004	0.008 q 0.005
263000	PDCB	0.021 q 0.013	0.219 q 0.049	7.784 q 1.632	0.006 q 0.001	0.009 q 0.001	0.002 q 0.001	0.011 q 0.009
1223	I-PTCH	0.043 q 0.011	0.196 q 0.026	5.846 q 2.452	8.184 q 3.895	0.033 q 0.009	0.025 q 0.011	0.000 q 0.000
1692	PMCH	0.009 q 0.001	0.017 q 0.003	0.067 q 0.021	0.016 q 0.005	4.065 q 0.389	0.003 q 0.003	0.000 q 0.001
3622	ocPDCH	0.020 q 0.001	0.129 q 0.010	3.764 q 0.299	0.010 q 0.001	0.019 q 0.002	0.725 q 0.035	0.006 q 0.0[illegible]
75	iPPCH	0.023 q 0.007	0.888 q 0.143	0.136 q 0.054	0.019 q 0.005	0.008 q 0.001	0.004 q 0.001	0.367 q 0.0[illegible]

	CATS#	ptPDCH	PMCP	PDCB	I-PTCH	PMCH	ocPDCH	IPPCH	otPDCH	mtPDCH	mPDCH	2-PTCH	
1	4277	7.147	3.899	2.686	0.637	0.375	0.096	0.083	0.000	8.279	7.315	0.191	DELETED
1	580	7.742	4.630	2.584	1.290	0.335	0.090	0.115	0.000	9.085	6.045	0.400	DELETED
1	8149	8.107	4.402	2.249	0.733	0.399	0.097	0.096	0.000	9.463	8.384	0.223	
1	12400	9.277	4.810	2.428	0.808	0.415	0.109	0.107	0.000	10.964	9.738	0.244	
1	12921	8.890	4.691	2.325	0.794	0.391	0.106	0.109	0.000	10.546	9.361	0.238	
1	12055	8.689	4.280	2.432	0.804	0.393	0.104	0.122	0.000	10.329	9.165	0.241	
1	12631	8.324	4.340	2.500	0.777	0.379	0.101	0.123	0.000	9.886	8.765	0.232	
1	10181	8.262	4.382	2.327	0.758	0.425	0.107	0.103	0.000	9.774	8.664	0.232	
1	12057	8.446	4.598	2.370	0.978	0.389	0.101	0.105	0.000	10.017	8.883	0.304	
1	11079	7.998	4.410	2.484	0.712	0.394	0.096	0.096	0.000	9.357	8.289	0.218	
1	1329	8.082	4.327	2.169	0.721	0.383	0.093	0.100	0.000	9.420	8.346	0.221	
1	938	8.415	4.409	2.298	0.777	0.392	0.100	0.105	0.000	9.924	8.800	0.237	
1	520	7.126	3.865	2.295	0.657	0.804	0.101	0.089	0.000	8.413	7.441	0.198	DELETED
1	2268	6.923	4.160	2.469	0.644	0.526	0.110	0.087	0.000	8.174	7.227	0.194	DELETED
1	2198	7.555	4.335	2.589	0.698	0.559	0.118	0.096	0.000	8.920	7.896	0.211	DELETED
1	3644	9.586	2.498	3.554	0.326	0.184	0.145	0.052	0.000	4.003	3.510	0.094	DELETED
1	12390	0.204	0.418	15.834	0.020	0.015	0.002	0.007	0.000	0.187	0.164	0.006	DELETED
1	12036	5.449	3.128	7.235	0.502	0.276	0.067	0.065	0.000	6.274	5.527	0.149	DELETED
1	12302	5.119	2.808	5.224	0.475	0.475	0.140	0.062	0.000	5.907	5.200	0.139	DELETED
2	12083	1.035	0.619	3.481	0.090	0.876	0.310	0.018	0.000	1.259	1.098	0.025	DELETED
2	4779	0.031	0.098	2.728	0.014	1.359	0.490	0.005	0.000	0.459	0.400	0.005	DELETED
2	4627	3.552	2.287	1.977	0.323	1.448	0.122	0.043	0.000	3.944	3.458	0.082	DELETED
2	13497	2.791	1.837	1.829	0.249	1.879	0.106	0.034	0.000	3.014	2.637	0.070	DELETED
2	12183	0.030	11.417	0.020	0.002	0.009	0.001	0.003	0.000	0.000	0.000	0.000	DELETED
2	12063	0.028	10.242	0.141	0.001	0.014	0.002	0.007	0.000	0.000	0.000	0.000	DELETED
2	12393	0.028	1.611	1.886	0.088	1.488	0.338	0.005	0.000	0.330	0.289	0.028	DELETED
2	12009	0.072	16.480	0.089	0.076	0.035	0.011	0.014	0.000	0.000	0.000	0.021	
2	12264	0.143	35.832	0.214	0.202	0.057	0.013	0.008	0.000	0.000	0.000	0.056	
2	12376	0.167	43.634	0.244	0.257	0.030	0.006	0.008	0.000	0.000	0.000	0.072	
2	12297	0.522	14.879	1.321	0.682	0.536	0.119	0.009	0.000	0.641	0.560	0.201	DELETED
2	12191	0.169	16.484	1.166	0.638	0.538	0.118	0.008	0.000	0.308	0.269	0.188	DELETED
2	12379	0.335	30.172	0.222	0.061	0.088	0.012	0.005	0.000	0.408	0.357	0.017	
2	12012	1.489	20.586	0.519	0.175	0.295	0.030	0.018	0.000	1.561	1.362	0.049	DELETED
2	12244	0.112	25.193	0.138	0.061	0.069	0.003	0.003	0.000	0.182	0.160	0.017	
2	12155	0.107	26.430	0.094	0.044	0.031	0.003	0.003	0.000	0.181	0.159	0.012	
2	12384	0.507	0.312	4.404	0.044	0.923	0.253	0.011	0.000	0.688	0.600	0.012	DELETED
2	11218	4.134	2.583	1.088	0.367	0.203	0.049	0.067	0.000	4.586	4.026	0.107	DELETED
2	561	0.055	3.165	0.464	0.092	0.219	0.070	0.008	0.000	0.124	0.109	0.025	DELETED
2	2018	0.122	16.860	0.214	0.018	0.014	0.012	0.016	0.000	0.177	0.155	0.006	
3	11151	0.013	0.204	5.908	0.005	0.010	0.002	0.026	0.000	0.020	0.018	0.002	
3	9590	0.019	0.397	7.035	0.005	0.009	0.002	0.006	0.000	0.025	0.022	0.002	
3	12402	0.020	0.176	7.297	0.006	0.010	0.002	0.009	0.000	0.026	0.023	0.002	
3	12337	0.014	0.156	6.492	0.004	0.009	0.002	0.004	0.000	0.020	0.018	0.002	
3	12417	0.017	0.235	9.217	0.007	0.009	0.003	0.008	0.000	0.024	0.022	0.002	
3	12425	0.030	0.205	8.388	0.008	0.010	0.003	0.005	0.000	0.038	0.034	0.003	
3	12468	0.062	0.381	15.438	0.009	0.009	0.004	0.008	0.000	0.064	0.057	0.003	DELETED
3	12383	0.015	0.195	6.342	0.005	0.007	0.001	0.011	0.000	0.021	0.019	0.002	
3	12203	0.055	0.320	10.741	0.008	0.009	0.003	0.004	0.000	0.056	0.050	0.003	
3	12178	0.013	0.279	9.691	0.006	0.009	0.001	0.005	0.000	0.019	0.017	0.002	
3	12288	0.031	0.382	12.712	0.013	0.008	0.002	0.011	0.000	0.035	0.031	0.004	DELETED
3	12269	0.018	0.221	6.731	0.006	0.007	0.002	0.029	0.000	0.025	0.022	0.002	
4	12022	0.051	0.215	7.580	5.430	0.026	0.018	0.000	0.000	0.000	0.000	1.799	
4	12156	0.036	0.177	4.112	10.938	0.039	0.033	0.000	0.000	0.000	0.000	3.610	
5	1818	0.009	0.019	0.081	0.020	4.340	0.005	0.001	0.000	0.019	0.017	0.006	
5	8706	0.008	0.015	0.052	0.012	9.780	0.001	0.000	0.000	0.014	0.012	0.004	
6	1319	0.020	0.139	3.849	0.011	0.019	0.751	0.006	0.000	0.677	0.591	0.004	
6	707	0.020	0.128	4.011	0.009	0.021	0.685	0.006	0.000	0.612	0.534	0.004	
6	1281	0.019	0.120	3.432	0.009	0.017	0.739	0.005	0.000	0.687	0.582	0.004	
7	12340	0.013	0.970	0.178	0.022	0.010	0.004	0.325	0.000	0.027	0.025	0.006	
7	12502	0.016	1.129	0.208	0.027	0.009	0.005	0.378	0.000	0.034	0.031	0.008	
7	12307	0.024	0.751	0.080	0.015	0.007	0.004	0.399	0.000	0.040	0.035	0.005	
7	12300	0.031	0.890	0.095	0.019	0.008	0.004	0.385	0.000	0.046	0.041	0.006	
7	2158	0.019	0.963	0.182	0.022	0.007	0.005	0.392	0.000	0.038	0.034	0.007	
7	6706	0.017	0.942	0.173	0.022	0.008	0.005	0.389	0.000	0.037	0.033	0.007	
7	7750	0.029	0.728	0.084	0.013	0.007	0.003	0.332	0.000	0.044	0.039	0.004	
7	10831	0.031	0.732	0.085	0.015	0.006	0.003	0.339	0.000	0.043	0.038	0.005	

C.F.:	PDCB	PMCP	PMCH	ocPDCH	ptPDCH	mPDCH	PTCH	COEFFICIENTS FILE
	0.74	0.74	0.82	0.62	0.65	0.88	0.71	6C177

********************************** NOTES **********************************

All gas volumes are reported at 21.5 C. and 1 atm.
The standard deviation in the source strength has been set at 4 %.
The standard deviation in the volume measurement has been set at 5 %.
The overall normalized condition number (K(C)/N^1.5)= 0.429
K(DC)/N = 1.136
Zonal condition numbers are:

ZONE	1	2	3	4	5	6	7
Condition Number	1.083	1.017	1.379	1.248	1.005	1.134	1.044

FLOW_RATIOS STD DEV

CA06450 Rev. 0
Page 71

	FLOW-RATIOS	STD.DEV.
FILTRN/EXFILTRN		
NE 1	0.147	0.1142
NE 2	1.059	0.0455
NE 3	1.020	0.0363
NE 4	0.258	0.3540
NE 5	1.046	0.0108
NE 6	0.615	0.1209
NE 7	4.908	15.1200
TERZONAL		
2/ 2- 1	0.839	0.4851
3/ 3- 1	1.285	0.9277
4/ 4- 1	0.161	0.0969
5/ 5- 1	0.069	0.0093
6/ 6- 1	0.029	0.0209
7/ 7- 1	0.026	0.0122
3/ 3- 2	-19.743	62.9947
4/ 4- 2	0.082	0.1957
5/ 5- 2	0.036	0.0273
6/ 6- 2	0.036	0.0723
7/ 7- 2	0.903	0.7688
4/ 4- 3	110.353	89.6471
5/ 5- 3	0.203	0.1401
6/ 6- 3	8.392	3.1448
7/ 7- 3	0.017	0.0174
- 4	0.435	0.2269
6/ 6- 4	0.017	0.0085
7/ 7- 4	-0.057	0.0552
6/ 6- 5	0.483	0.4655
7/ 7- 5	0.809	1.8474
7/ 7- 6	12.975	396.7011

ANDARD DEVIATION OF ptPDCH IN ZONE 2 IS GREATER THAN 25 %
ANDARD DEVIATION OF ptPDCH IN ZONE 3 IS GREATER THAN 25 %
ANDARD DEVIATION OF ptPDCH IN ZONE 4 IS GREATER THAN 25 %
ANDARD DEVIATION OF ptPDCH IN ZONE 7 IS GREATER THAN 25 %
ANDARD DEVIATION OF PMCP IN ZONE 2 IS GREATER THAN 25 %
ANDARD DEVIATION OF PDCB IN ZONE 2 IS GREATER THAN 25 %
ANDARD DEVIATION OF PDCB IN ZONE 4 IS GREATER THAN 25 %
TANDARD DEVIATION OF PDCB IN ZONE 5 IS GREATER THAN 25 %
TANDARD DEVIATION OF PDCB IN ZONE 7 IS GREATER THAN 25 %
TANDARD DEVIATION OF T-PTCH IN ZONE 2 IS GREATER THAN 25 %
TANDARD DEVIATION OF T-PTCH IN ZONE 4 IS GREATER THAN 25 %
TANDARD DEVIATION OF T-PTCH IN ZONE 5 IS GREATER THAN 25 %
TANDARD DEVIATION OF PMCH IN ZONE 2 IS GREATER THAN 25 %
TANDARD DEVIATION OF PMCH IN ZONE 4 IS GREATER THAN 25 %
TANDARD DEVIATION OF ocPDCH IN ZONE 2 IS GREATER THAN 25 %
TANDARD DEVIATION OF ocPDCH IN ZONE 3 IS GREATER THAN 25 %
TANDARD DEVIATION OF ocPDCH IN ZONE 4 IS GREATER THAN 25 %
TANDARD DEVIATION OF ocPDCH IN ZONE 5 IS GREATER THAN 25 %
TANDARD DEVIATION OF iPPCH IN ZONE 2 IS GREATER THAN 25 %
T' [illegible]D DEVIATION OF iPPCH IN ZONE 3 IS GREATER THAN 25 %
TA[illegible]RD DEVIATION OF iPPCH IN ZONE 5 IS GREATER THAN 25 %