ENCLOSURE 2

CALCULATION WBNTSR-009, CONTROL ROOM OPERATOR AND OFFSITE DOSES FROM A FUEL HANDLING ACCIDENT, REVISION 14

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO. B26 890302 008	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV 0) T71 110920 801

Calc Title: **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	WBN	NTB	WBNTSR-009	R13	R14	Entire calc ☒
NEW	CN	NUC						Selected pages ☐

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
1/2	N/A	N/A

DCN.EDC.N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
NA	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☒ No ☒ DGF 9/19/11	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	DESIGN VERIFICATION METHOD	NEW METHOD OF ANALYSIS
Marc Berg	423-785-5483	WorleyParsons	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Marc C Berg *Marc C. Berg*	9-19-11	George C Dyer *[signature]*	9/19/11
DESIGN VERIFIER SIGNATURE	DATE	APPROVAL SIGNATURE ~~DGF 9/19/11~~ FAP BY TELECON/DGF 9/19/11	DATE
George C Dyer *[signature]*	9/19/11	*[signature]*	9/20/11

STATEMENT OF PROBLEM/ABSTRACT

This calculation was performed to determine the dose to control room operators following a design basis fuel handling accident (FHA). In addition, the offsite doses resulting from a design basis FHA were also calculated. Base assumptions utilize either Regulatory Guide 1.25 (Safety Guide 25) or Regulatory Guide 1.183 (Alternate Source Term). A TPBAR only accident is also analyzed.

The calculation considers a FHA occurring in containment with activity passing directly to the environment (no Purge Filters) until isolation in 12.7 seconds, a FHA in containment exhausting to the environment via Purge Filters, a FHA in containment with contamination migrating due to open penetrations to the AB with release through the Auxiliary Building vent (no filters). Finally, a FHA in the spent fuel pit (Auxiliary Building) with releases through the Auxiliary Building vent (no ABI and no filters). The FHA is assumed to occur at 100 hours after shutdown. All of the other assumptions used to calculate the activity released are in accordance with Safety Guide 25 and NUREG/CR-5009 or Regulatory Guide 1.183 (Alternate Source Term/AST). All of the activity is assumed to be released over a two hour time period per Safety Guide 25 or RG 1.183.

The computer code STP was used to calculate the activity released after a FHA. The activity released to the environment as determined by STP was input into the computer code COROD The control room model used is identical to that described in TI-RPS-198 except that the containment shine is not included. This calculation also considers the effect of a 40 second unfiltered bypass flow due to the finite closure time of the control room isolation dampers (14 sec) and instrument actuation time (26 sec). The activity released to the environment as determined by STP was also used as input to computer code FENCDOSE to calculate the doses at the Site Boundary (SB)/Exclusion Area Boundary after 2 hours and at the Low Population Zone (LPZ) boundary after 30 days. The FENCDOSE model came from TI-RPS-197.

The control room operator doses are below the 10CFR50 Appendix A, GDC 19 limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 10CFR50.67 limit of 5 rem TEDE. The offsite doses are less than 25% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, 300 rem thyroid, and 10CFR50.67 limit of 25 rem TEDE (= 6.25 rem gamma, 75 rem beta/thyroid, and 6.25 rem TEDE).

If the design basis of the plant is Regulatory Guide 1.183, then there are no Special Requirements/Limiting Conditions. See Page 10 for Special Requirements for a Regulatory Guide 1.25 accident.

This calculation directly impacts FSAR Table 15.5-23

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S) ~~TVA-F-W002566~~ TVA-F-W002566/DGF 9/19/11

☐ LOAD INTO EDMS AND DESTROY2
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY ADDRESS EQB 1N-WBN
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Scott Helm 9/19/11
SIGNATURE R14 DATE

NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	WBNTSR-009	014

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☐
NA	NA	NA	NA	~~WorleyParsons~~ POLESTAR	
CATEGORIES: NA					

SDH 9/19/11

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	PE	GEN	NTB	~~PER~~ 429145	

SDH 9/19/11

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-009**

Title **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	This revision was performed because the key references changed, resulting in COROD and FENCDOSE models needing revision. Also, the case of a FHA occurring in the Auxiliary Building was added Pages added: 2.1-2.4, 4.1 Pages changed: 1-12
2	This revision was performed because the previous analysis oversimplified the dilution process. The error has been corrected analytically without running the STP code. Ref. 12, FSAR chapter 15 was deleted as it was sufficient to refer to ref. 4. Safety Guide 25. Ref. 11 MR 482000 was no longer valid and replaced by WB-DC-36.1 R4. The control room operator doses are slightly reduced. There is no impact on the conclusions of the calculation. Pages added: 1a, 2.1, 2.5 Pages deleted: 2.1 Pages changed: 1, 2, 2.2, 4, 7, 8, 9, 10 Total pages: 35 CCRIS and DCCM were checked on 01.04.93 and no changes which impact this calculation were found. This calculation does not require impact review as no other discipline uses it as design input.
3	Revision 3 was performed to take into account a single failure of the Auxiliary Building General Ventilation Exhaust Fan in the "on" position concurrent with a single isolation damper failing to close resulting in ABGTS filter bypass. All pages were rewritten for legibility and renumbered. Only areas with changed text are identified with revision bars. Pages added: all Pages deleted: all Pages changed: all
4	Revision 4 was performed because the ABGTS bypass was fixed by DCN M-29141-A. R4 reinstated the R2 models and results. Pages added: 1(new cover) Pages changed: 1.1(old cover), 2-6, 8, 9, 11, 13-15, 17 Pages deleted: none
5	Revision 5 was performed because the X/Q values changed Pages added: 1.2 Pages deleted: none Pages changed: 1-8, 10-14, 16, 17
6	Revision 6 was performed because the control room makeup flow was changed. Pages changed: 1, 1.2, 2-6, 8, 12-14, 16, 17 Pages added: none Pages deleted: none

TVAN CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER **WBNTSR-009**	
Title	**Control Room Operator and Offsite Doses From a Fuel Handling Accident**
Revision No.	DESCRIPTION OF REVISION
7	Revision 7 was performed to upgrade the calculation to the cycle 2 1000 EFPD, extended burnup (18 month) fuel. pages added: 1, 2.1 pages changed: 1a (old cover), 1.2, 3-17 pages deleted: none
8	Revision 8 was performed to change the FHA source terms from 1000 EFPD to 1500 EFPD as part of the corrective action of WBPER960798. pages added: none pages changed: 1, 2.1, 3-7, 9, 10, 12, 14-17 pages deleted: 1a, 1.1, 1.2
9	Revision 9 is performed to discuss the impact of D-50378-A which allow containment penetrations to be open during fuel movement. There was no impact on the final answers. Pages changed: 1, 2.1, 3, 17 Pages added: 9.1 Pages deleted: none R9: 36 total pages
10	Revision 10 is performed to incorporate NUREG/CR-5009 gap inventories, increased isolation time (WBNPER 01-000080-000), incorporate X/Q values as determined by ARCON96, and incorporate the Tritium Production Core (TPC). The latest versions of COROD (R5) and FENCDOSE (R4) were used, which determine thyroid doses based on both ICRP-2 and ICRP-30 dose conversion factors, as well as determine the TEDE. Also, independent third party review comments by Westdyne (Westinghouse) and NYSIS were incorporated where appropriate. Due to the extent of the changes, all pages were renumbered. Actual text changes are marked with revision bars. Changes in this revision will be screened for 50.59 applicability via the EDC referenced on the coversheet. Pages added: all Pages deleted all Pages changed: all R10: 47 total pages
11	Revision 11 is performed in support of PERs 61493 (control room recirculation rate modeling), 94426 (control room time increment modeling), 95217 (potential for 15 minute unfiltered releases and migration of contamination to other un-isolated areas), and 96939 (failure to evaluate FHA in the transfer canal or cask loading area) and EDC 51930 (downgrade Purge Filters) and also to add Alternate Source Term (AST) cases. EDC 51930 downgrades the Reactor Building Purge filters to non-safety related and thus credit cannot be taken for them to mitigate the FHA. The design basis for a FHA in containment is to take credit for containment isolation, which occurs in 12.7 seconds once EDC 51930 is implemented. PER 61493 documents that the wrong control room recirculation flow rate is used. The recirculation flow rate is 3600 cfm- makeup flow (711) = 2889 cfm. 2 trains of CREVS in operation for the first 2 hours is addressed in an assumption. Another case was added to analyze a FHA in containment with migration to the AB after isolation through open penetrations. The discussion about penetrations on page 11 of R10 was deleted and a Special Requirement was added to require a CVI with an ABI and vice versa. It was also required that the ABSCE be established within 4 minutes even if there are other penetrations to outside the ABSCE. AST cases were performed with and without Purge/ABGTS filters. This calculation directly impacts FSAR Table 15.5-23. EDC 51930 contains a Technical Specification change for the Reactor Building Purge filters Pages Revised/Replaced:1, 2, 4-29, renamed Attachment 4 as Attachment 1, renamed Attachment 5 as Attachment 2, renamed Attachment 6 as Attachment 3 Pages Added: 15, 23 Pages Deleted: old cover (2.1), Design Verification form, 11,13, old attachments 1-3 Total Pages = 29

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER WBNTSR-009

Title **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

Revision No.	DESCRIPTION OF REVISION
12	Revision 12 is performed to address replacement of the analog ratemeters with digital RM1000 ratemeters by DCN 52012. The longer response time of the RM1000 ratemeter is incorporated by increasing the control room isolation time from 20.6 seconds to 40 seconds (14 sec damper closure + 26 sec instrument response) The primary change is to increase the control room HVAC time to isolation from 20.6 seconds to 40 seconds. A secondary change is to bring the total tritium release in the RG 1.25 cases into agreement with the RG 1.183 (AST) cases. In revision 11, 100% of the spent fuel pool (SFP) tritium inventory was released in the RG 1.25 cases and 25% was released in the RG 1.183 (AST) cases. The 100% value is unduly conservative, and as shown in Assumption 13, the 25% release is also very conservative. Therefore, using 25% of the SFP tritium inventory for all cases is both consistent and conservative. The STP, COROD, and FENCDOSE inputs are affected. However, because not all calculations are affected, only the STP/COROD/FENCDOSE runs that are affected are rerun. The results from those that are not rerun are retained from revision 11. See calculation WBNTSR028, Rev. 7, (ref. 13) for the revised time delay of 40 seconds. FSAR sections 15.5.6 and Technical Specifications were reviewed by _Lynn Cowan_ and Table 15.5-23 is impacted by the change in isolation time from 20.6 seconds to 40 seconds. Pages Added: 5, 6, 22-25 Pages Deleted: none Pages Revised/Replaced: 1, 2, 7-10, 12-14, 16-21, 23, 24, 26, 27 R12: 34 total pages.
13	Revision 13 is performed to upgrade the X/Qs to the 1991-2010 meteorological data set. Cases were performed for a 7 second unfiltered release or a 17 second unfiltered release from the Auxiliary Building as documented in PER 252012, with the control room isolating in 40 seconds. Other cases were performed with this 7 second or 17 second unfiltered release, but with the control room already isolated. A TPBAR only accident is also analyzed. All cases with unfiltered release from the Auxiliary Building now use the normal ventilation flow for the 7 or 17 seconds. FSAR sections 15.5.6 and Technical Specifications were reviewed by _Marc Berg_ and Table 15.5-20 and -23 are impacted by the change. The following calculations are impacted by this revision: WBNSPA3-050, -085, WBNTSR-020, -023. The revision of these successors will be tracked by WITEL item PL-11-3861. Pages Added: none Pages Deleted: none Pages Revised/Replaced: 1, 2, 5, 6, 8-28 R13: 34 total pages.
14	Revision 14 is performed to delete RG 1.25 cases (except for containment FHA with purge or containment FHA with 12.7 sec release, no filters). Added a RG 1.183 case for containment FHA with 12.7 sec release through the Shield Building (no filters), with remainder release through the Auxiliary Building vent (no AB and no filters). Appendix B is added to address PER 429145 issue of nonconforming TEDE formulas in COROD/FENCDOSE with RG 1.183. Corrected input for STP run case series 4 and 11 for initial H3 inventory (25% factor incorrectly included in initial inventory and also in "S" card). FSAR sections 15.5.6 and Technical Specifications were reviewed by _Marc Berg_ and Table 15.5-20 and -23 are impacted by the change. The following calculations are impacted by this revision: WBNSPA3-050, -085, WBNTSR-020, -023. Pages Added: Appendix A (page 23), Appendix B (pages 24-29) Pages Deleted: none Pages Revised/Replaced: 1, 2, 5-22 R14: 36 total pages.

NPG CALCULATION VERIFICATION FORM

Calculation Identifier	WBNTSR-009	Revision 14

Method of verification used		
1 Design Review	☒	Verifier [signature] Date 9/19/11
2. Alternate Calculation	☐	
3. Qualification Test	☐	

Comments.
This calculation was reviewed and verified for technical adequacy, methodology, and accuracy in accordance with the requirements of NEDP-2. All comments have been resolved with the preparer. The changes described in the Record of Revision have been found to be technically adequate in format and content.

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: **WBNTSR-009**	Revision: 14	

TABLE OF CONTENTS

NPG COMPUTER INPUT FILE STORAGE INFORMATION SHEET

Document **WBNTSR-009**	Rev. 14	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses From a Fuel Handling Accident

☐ Electronic storage of the input files for this calculation is not required. Comments:

■ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

R6: The computer input is permanently stored in FILEKEEPER file # 263662

R7: The computer input is permanently stored in FILEKEEPER file # 292579

R8: The computer input is permanently stored in FILEKEEPER file # 300126

R10: The computer input is permanently stored in FILEKEEPER file # 303621

R11: The computer input is permanently stored in FILEKEEPER file # 308333,308360

R12: The computer input is permanently stored in FILEKEEPER file # 314526

The WORD file for R12 is stored in FILEKEEPER file# 314525

R13: The computer input is permanently stored in eFiche file # TVA-F-W002485 and TVA-F-W002502

R14: The computer input is permanently stored in eFiche file # TVA-F-~~W002509~~ W002566 JDG 7 9/19/11

☒ Microfiche/eFiche

See next page

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document **WBNTSR-009**	Rev. 14	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses From a Fuel Handling Accident

Microfiche Number	Description
R3:TVA-F-G104672 R5:TVA-F-C000074 R6:TVA-F-C000108 R7:TVA-F-C000138 R8:TVA-F-C000219 R10: TVA-F-W000221	R10: Name Code Description TS9S10$ STP source term TS9C10#$ COROD control room operator dose TS9F10#$ FENCODSE Offsite dose where $= A = standard core, instant control room isolation B = standard core, 20.6 sec control room isolation C = Tritium Production Core, once burned assembly, instant control room isolation D = Tritium Production Core, once burned assembly, 20.6 sec control room isolation E = Tritium Production Core, twice burned assembly, instant control room isolation F = Tritium Production Core, twice burned assembly, 20.6 sec control room isolation G = Tritium Production Core, 3X burned assembly, instant control room isolation H = Tritium Production Core, 3X burned assembly, 20.6 sec control room isolation X = standard core, 20.6 sec isolation time, revision 9 (old Halitsky) X/Q values #= A= Spent Fuel Pit/Auxiliary Building/ABGTS FHA P = Containment/PAE FHA
R11: TVA-F-W000575 TVA-F-W000622 TVA-F-W000624	R11: Name Code Description TS9S11$# STP release models TS9C11$# COROD control room dose with 1 train of CREVS, 20.6 sec control room isol TS9F11$# FENCDOSE offsite dose where $= A = standard core B = Tritium Production Core, once burned assembly C = Tritium Production Core, twice burned assembly D = Tritium Production Core, thrice burned assembly #= 1= RG 1.25 Contain FHA w/ 12.7 sec contain isolation, containment closed to AB, no Purge Filters 2= RG 1.25Spent Fuel Pit/Auxiliary Building FHA, AB open or closed to containment 3 = RG 1.25 Containment FHA with Purge Filters (no containment isolation) 4=RG 1.183 AST Auxiliary Building FHA with no ABI 5=RG 1.183 AST Auxiliary Building FHA with ABI (ABGTS)
R12: TVA-F-W001564	R12: Name Code Description TS9S12$# STP Release models TS9C12$# COROD Control room dose with 1 train of CREVS, 40.0 second control room isolation TS9F12$# FENCDOSE Offsite dose Where: $ = A = standard core B = Tritium Production Core, once burned assembly C = Tritium Production Core, twice burned assembly D = Tritium Production Core, thrice burned assembly E = TPBAR only # = 1= RG 1.25 Contain FHA w/ 12.7 sec contain isolation, containment closed to AB, no Purge Filters 2 = RG 1.25Spent Fuel Pit/Auxiliary Building FHA, AB open or closed to containment 3 = RG 1.25 Containment FHA with Purge Filters (no containment isolation) 4 = RG 1.183 AST Auxiliary Building FHA with no ABI 5 = RG 1.183 AST Auxiliary Building FHA with ABI (ABGTS)
R13: TVA-F-W002485 And TVA-F-W002502	R13: Name Code Description TS9C13$# COROD Control room dose with 1 train of CREVS, 40.0 second control room isolation TS9F13$# FENCDOSE Offsite dose Where:$ =see R12 above; # = see R12 above and 6=7 sec unfiltered release from AB, 7=7 sec unfiltered AB release & CR already isolated, 8=TPBAR onlyR14:
R14: TVA-F-~~W02509~~ W002566 /DGP 9/19/11	R14: TS9S14$# STP source terms TS9C14$# COROD Control room dose with 1 train of CREVS, 40.0 second control room isolation Where:$ =see R12 above; # =11 = case 11 for RG 1.183 containment FHA, 12.7 sec SB unfiltered release, remainder unfiltered release through AB vent

Purpose

The purpose of this calculation is to determine the dose to the control room operators following a design basis Fuel Handling Accident (FHA). In addition, the offsite doses resulting from a FHA is also to be determined. This calculation is to address concerns raised during the vertical slice review program as to whether the Loss of Coolant Accident (LOCA) actually produces the bounding control room operator doses (ref.1). Revision 12 is performed to address replacement of the analog ratemeters with digital RM1000 ratemeters by DCN 52012. The longer response time of the RM1000 ratemeter is incorporated by increasing the control room isolation time from 20.6 seconds to 40 seconds (14 sec damper closure + 26 sec instrument response. Revision 12 also brings the total tritium release in the RG 1.25 cases into agreement with the RG 1.183 (AST) cases. In revision 11, 100% of the spent fuel pool (SFP) tritium inventory was released in the RG 1.25 cases and 25% was released in the RG 1.183 (AST) cases. The 100% value is unduly conservative, and as shown in Assumption 13, the 25% release is also very conservative. Revision 13 is performed to upgrade the X/Qs to the 1991-2010 data set. Revision 14 deletes all RG 1.25 Auxiliary Building FHA cases, and added a RG 1.183 Alternate Source Term (AST) case 11 for a containment FHA with 12.7 seconds unfiltered release through the Shield Building vent, with the remainder released through the Auxiliary Building vent (no ABI and no filters).

Special Requirements/Limiting Conditions

If the design basis for WBN is RG 1.25, then if the equipment hatch or any penetration between the Auxiliary Building and Containment is open, the containment purge system shall be operational during fuel movement and an Auxiliary Building Isolation (ABI) due to a high radiation signal shall initiate a Containment Ventilation Isolation (CVI) and a CVI due to a high radiation signal must initiate an ABI. If other penetrations are open to the outside of the ABSCE, the ABGTS system must be able to draw down within 4 minutes of the initiating event.

Also, for RG 1.25, the HVAC intake vent in the transfer canal must be blocked, and the -103 monitor must be raised so that it has a line of sight across the 757' floor. The HVAC intake vents for the cask loading area shall be blocked when handling irradiated fuel in this area. The -102 monitor is far enough away so that it will see very close to the floor at the canal/cask loading area, therefore it will not have to be raised (see assumption 17 for further discussion). This requirement is to prevent radioisotopes from entering the HVAC ductwork in the transfer canal (and ultimately released via the Auxiliary Building Vent without filtration) and therefore bypassing the isolation function of the -102 and -103 radiation monitors.

If the design basis for WBN is RG 1.183 (AST), then there are no special requirements or limiting conditions. Based on the results of this analysis, no isolation of either containment or the auxiliary building is required following a Fuel Handling Accident for AST.

Introduction

The computer code STP is used to determine the releases. Using the STP output, the computer code FENCDOSE determines the offsite doses, and the computer code COROD determines the control room doses. The FHA accident is analyzed for both the Auxiliary Building and the Containment. Also, 4 types of assemblies are analyzed: the 1500 EFPD end of life assembly for a standard core, a once burned TPC assembly with 24 TPBAR rods (which contain the tritium), a twice burned TPC assembly with 24 TPBAR rods, and a three times burned TPC assembly (no TPBARs).

Assumptions

1. The FHA occurs at 100 hours after shutdown, consistent with the FSAR and the Technical Specifications (ref.4 and 18).

2. All of the rods in the worst fuel assembly are assumed to be damaged.
Technical Justification: Safety Guide 25, ref.4, implies that the activity from the worst peak assembly is released. It is conservative to assume that all rods will break, thereby maximizing the release. Regulatory Guide 1.183 (AST), ref.36, section 3.6 requires that the case with the highest radioactivity release should be analyzed.

3. For all cases except the 12.7 containment isolation case, it is assumed that everything is released to the environment within 2 hours (ref.4, 36). To assure this, at 2 hours all remaining isotopes above the spent fuel pool (or in containment) are stepped into the environment (using the appropriate filter efficiency as a multiplication factor).

4. deleted in R14

5. For the RG.1.25 containment FHA cases (case series 1, found in Appendix A), all of the gap activity in the damaged rods is released which consists of 10% of the inventory in the rods at the time of the accident (ref.4), except for the following (per NUREG/CR-5009 for 60 GWd/t, note for lesser burnups the releases are less, therefore use of these 60 GWd/t values for all burnups is conservative):
Kr-85 = 14%
Kr-87 = 10% Note: The NUREG/CR-5009 value is actually 0.7%. Since STP is limited to 9 classes, and the halflife of Kr-87 is 76 min (ref.33), after 100 hours of decay there will be exp(-100*ln(2)/(76/60)) = 1.7E-24 or 1.7E-22% left. Therefore the increase in the gap percentage does not affect the results.
Kr-88 = 10% Note: The NUREG/CR-5009 value is actually 1%. Since STP is limited to 9 classes, and the halflife of Kr-88 is 2.84 hr (ref.33), after 100 hours of decay there will be exp(-100*ln(2)/2.84) = 2.5E-11 or 2.5E-9% left. Therefore the increase in the gap percentage does not affect the results.
Kr-89 = 10%
Xe-133 = 5%
Xe-135 = 2%
I-131 = 12%
For the RG 1.183 AST cases, all of the gap activity in the damaged rods is released which consists of 8% I-131, 10% Kr-85, 5% other noble gasses and other halogens. Note that RG 1.183 also specifies 12% of Alkali metals (Cs, Rb), however since particulates have essentially an infinite partition factor, no alkali metals will be released and therefore are not included in this analysis.

6. The values assumed for individual fission product inventories are calculated assuming full power operation at the end of core life immediately preceding shutdown with a radial peaking factor of 1.65 (ref.4, 36) for the standard core assembly. For the TPC assemblies, the inventories are taken at the end of cycle, with the factor of 1.65 applied to all isotopes except tritium. Also, the factor of 1.65 is the maximum peaking factor allowed by the COLR. The factor of 1.65 is not applied to the tritium isotope because the maximum inventory of tritium is used already at a maximum (see assumptions #13, and ref.29) at 1.2g tritium/rod with 24 rods/assembly. It would be too conservative to apply the 1.65 to a value which is already the maximum inventory which can occur.

7. From RG 1.25 (ref.4), the iodine gap inventory is composed of inorganic species (99.75%) and organic species (0.25%). From RG 1.183, the inorganic species is 99.85% and the organic species is 0.15%. An overall decontamination factor is utilized in the RG 1.183 cases(see assumption 8), therefore the makeup of the species is not utilized in AST.
8. From RG 1.25, the pool decontamination factors for the inorganic iodine is assumed to be 133, and organic iodine is assumed to be 1 (ref.4). From RG 1.183 (AST) the decontamination factors are specified to be 500 for elemental (inorganic) iodine, and 1 for organic iodine. Doing the math, this leads to an overall decontamination factor of 286 =1/(0.9985/500+0.0015/1). However, RG 1.183 also specifies an overall decontamination factor of 200. The use of the 200 factor is more conservative (also, BFN was asked by the NRC to use the overall factor instead of the species specific factors), and therefore the overall factor of 200 for AST will be used in this analysis.

9. The retention of noble gasses in the pool is negligible (ref.4, 36).

10. For FHA in containment, with isolation (case series 1 and 11), it is assumed that the Purge Air Exhaust (PAE) System isolates in 12.7 seconds (ref. 2). This includes instrument loop response time (6.7 sec) and containment purge valve closure time (6 sec). This should be noted to be a very conservative value. The instrument loop response time contains very conservative assumptions and rounding. In the event that containment needs to be purged (for instance if entry is required into containment), then it is possible to defeat the isolation.

11. For RG 1.25 cases, the filter efficiencies for the PAE filter are 90% for inorganic iodines and 30% for organic iodines (ref.3). EDC 51930 downgrades the filters to non-safety related. R.G. 1.140 R3 will be the standard to which these filters conform to. The guide specifies the filter efficiency as 95%. Therefore using the original 90%/30% is conservative.
12. The filter efficiency for the ABGTS is 99% for all iodines (ref.3).

13. It is assumed that all 24 TPBARs break (in a TPC once or twice burned assembly) or a TPBAR only accident. It is also assumed that <u>**25% of**</u> the tritium in the spent fuel pool is released following the FHA through evaporation of the pool.
Technical Justification:

All TPBARs breaking is conservative.

There will not be 100% release of tritium from a TPBAR failure in a FHA because there are no high temperatures involved with the accident. Reference 26, Section 2.3, states that the release from the TPBARs will not cause the water tritium concentration to exceed 60μCi/gm. At this concentration, the total spent fuel pool inventory would be 84,490 Ci.

$$60\mu Ci/gm * 372{,}000\ gal * 3{,}785.4\ cc/gal * 1\ gm/cc * 1E\text{-}6\ Ci/\mu Ci = 84490\ Ci$$

A large fraction of the spent fuel pool will not evaporate in 8 hours if the spent fuel pool cooling system maintains the temperature below the boiling point. Furthermore, from page 23 of reference 38, even if the normal spent fuel pool cooling system is not in service, the pool will not reach 212 °F for at least 9 hours. Finally, from page 22 of reference 38, in the unlikely event that the spent fuel pool does boil, the boil off rate is 24,496.7 lb/hr, which is approximately 3000 gal/hr. Over a period of 8 hours, 3000 gal/hr is 24,000 gal, which is less than 6.5% of the pool volume. Therefore, assuming that 25% of the water evaporates in 2 hours or less is conservative.

14. For the RG 1.25 case, the effective volume of upper containment is taken as 1/2 the upper containment free volume.
Technical Justification: This takes into account incomplete mixing and dead end spaces and is typical for the representation of air mixing volumes.

15. deleted in R14

16. NUREG/CR-5009 implies that Cs-134 and Cs-137 are also in the gap. This calculation assumes these isotopes do not get released to the environs.
Technical Justification: Cs-134 decays to either Xe-134 or Ba-134, both of which are stable. Cs-137 decays to Ba-137m which in turn decays to Ba-137, which is stable. Per Regulatory Guide 1.183, particulates (Cs, Ba) have an infinite decontamination factor in the spent fuel pool/reactor vessel water. Therefore, Cs-134 and Cs-137, and their daughters, may be neglected from the calculation.

17. deleted in R14

18. The RG 1.25 cases utilize exponential releases. That is, the releases are governed by the mixing volume and the exhaust flow rate. This results in conservative releases compared to linear releases as more gets released in the beginning of the accident when there is less control room filtration (it takes 40 sec to isolate the control room) and also allows more to be released prior to isolation.

The RG 1.183 cases utilize linear releases. That is, all releases are constant over the 2 hour time period. This is implied in RG 1.183 by requiring all releases to be within 2 hours. (RG 1.183 section 3.3 and RG 1.183 Appendix B section 4.3). Also, this methodology is utilized by Westinghouse for SQN and other utilities.

19. Only one train of CREVS is in operation. Normally, each CREVS train takes suction from separate intakes with no cross communication between trains. This leads to one contaminated train, and one uncontaminated train. The only way a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For this to happen, one intake path would require a failed closed intake path **AND** a fail open of normally closed passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

Calculations

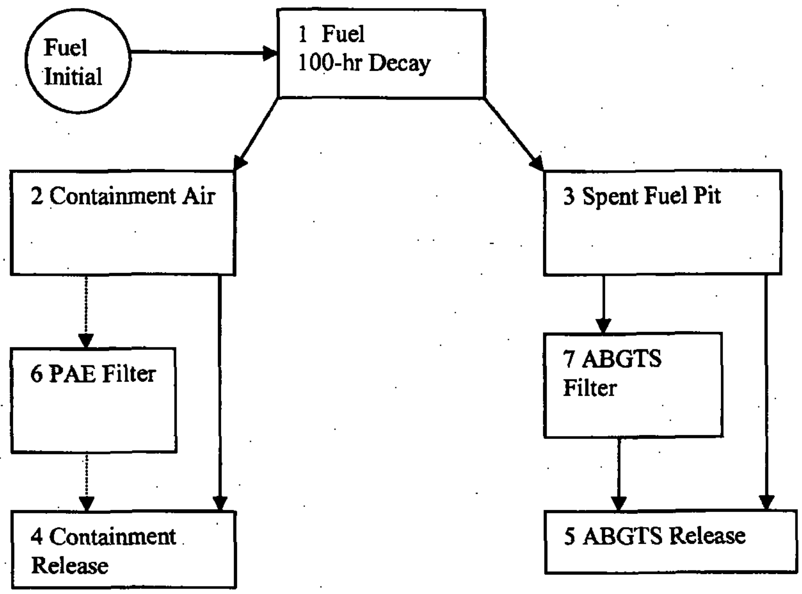
This calculation considers several cases broken down into Regulatory Guide 1.25 and Regulatory Guide 1.183 (AST) groupings.

I. Regulatory Guide 1.25 Cases:

One case is for a FHA in containment with the activity released directly to the environment until containment isolation (12.7 seconds), there are no penetrations open to the AB, and the PAE filters are not credited (case series 1, found in Appendix A). Another case utilizes a containment release without isolation but with Purge Filters Credited (case series 3). Computer code STP (ref.6) is used to calculate the activity released after a FHA. Figure 1 shows the model. To insure a conservative dose, the radioisotopes are allowed only 100 hours of decay after shutdown, and are released from the containment based on PAE flow. The step source fractions of the core inventory are based on NUREG/CR-5009 and Reg.Guide 1.25. The source terms are the 1500 EFPD maximum burnup for 18 month fuel cycle from WBNAPS3-084 (ref.14) for the standard core. These source terms are used instead of the core average 1000 EFPD source terms because the accident involves a single fuel assembly, not the entire core (as in a LOCA). For the TPC, the source terms for the once burned, twice burned, and 3 times burned assemblies are taken from WBNAPS3-098 (ref.29). The 24 TPBAR release apply only to the once and twice burned assemblies (the 3 times burned assembly will not have any TPBARs).

The following flow chart of the STP model includes the ABGTS filters. This is an historical artifact. No Auxiliary Building releases with filtration cases are used in R14. These flows are left in the model, but the results for this flow path are not used and do not impact the results.

Figure 1
STP Model



Note: the arrow from component 2 to 4 (for crediting purge filters) and 3 to 5 does not imply a filter bypass. It indicates how STP models a filter with the "U" card, where F 2-6 = F*(efficiency), F2-4 = F*(1-efficiency)

Component 1: Fuel volume=1.0 (arbitrary)
Component 2: Containment Air volume = 647,000 cuft (ref.30) /2 = 3.235E5 cuft (see assumption #15)
Component 3: Spent Fuel Pit volume = 10,017 cuft = 39.5'x31.7'x8' (ref.31). Note: the dimensions come from ref.31b. The 8' dimension (air above the pool) is an arbitrary value to account for the rise of the gasses above the pool. This is reasonable and consistent with references 31a and 31c.
Component 4: Containment Release volume =1.0 (arbitrary)
Component 5: ABGTS Release volume=1.0 (arbitrary)
Component 6: PAE Filter volume =1.0 (arbitrary)
Component 7: ABGTS Filter volume =1.0 (arbitrary)

Flow from containment through PAE to release (U 2 6 4)= purge rate = 14954 cfm (ref.30, note the actual value should be 14958 cfm, but this will not change the results so is not corrected) = 8.9724E5 cfh with Purge Air Exhaust filter efficiencies: 90% inorganic iodine, 30% organic (ref.3), 0% for tritium

Flow from spent fuel pit through ABGTS to release (U 3 7 5) = ABGTS flow = 9900 cfm = 5.94E5 cfh (see assumption #16) with filter efficiencies of 99% for iodines. NOTE: This is not used in R14, but left in for historical context, and possible future revisions.

Fuel activities are as given in WBNAPS3-084 (ref.14) and WBNAPS3-098 (ref.29), with the inorganic iodines equal to 99.75% of total, and organic iodines equal to 0.25% of total iodines.
Peaking Factor for the highest activity fuel assembly = 1.65 (ref.4) except for tritium isotope, which is 1.0 (see assumption #6).

ABGTS filter efficiencies: 99% (ref.3), for iodines, 0% for tritium NOTE: This is not used in R14, but left in for historical context, and possible future revisions.

The gap activity in the damaged rods is released which consists of 10% of the inventory in the rods at the time of the accident, except for the following: Kr-85=14%, Xe-133=5%, Xe-135=2%, I-131=12%
Partition Factors: 133 for inorganic iodine.

The step fractions from the fuel to the containment (or spent fuel pit) are:
S = 0.1 for Kr-83m, Kr-85m, Kr-87, Kr-88, Kr-89, Xe-131m, Xe-133m, Xe-135m, Xe-138, organic iodine (except I-131)
S= 0.14 for Kr-85
S=0.05 for Xe-133
S=0.02 for Xe-135
S=0.000752 for I-132, I-133, I-134, I-134 (=0.1/133)
S=0.000902 for I-131 (=0.12/133)
S=0.12 for I-131 (organic iodine)

All of the activity is to be released after 2 hours. To simulate this all activity remaining in the Reactor Building at the end of 2 hours is put into a new "source" which is stepped to the environment. The stepping fraction is equal to what would have gotten through the filters (i.e. 1-efficiency) had the isotopes been released through the filters. For the Containment case with isolation, the purge flow (F 2 4 0) is set to 0 cfm after 12.7 seconds.

The activity released to the environment as calculated by STP is used as input to computer code COROD (ref.7) to determine the control room operator doses. The control room model is identical to that described in TI-RPS-198 (ref.5) except for the shine from containment which is neglected (all activity inside the containment from FHA is released).

During the vertical slice review of the control room, a concern was raised that when the control room is isolated by a signal from the main control room intake radiation monitors, some amount of unfiltered activity could enter the control room before the isolation dampers close (ref.9). This could be the case for a fuel handling accident because there will be no safety injection signal to isolate the control room. The isolation dampers downstream from the radiation monitors are 0-FCV-31-3 and 0-FCV-31-4 (ref.10). It is required by reference 11 that the closure time of the dampers is 14 seconds, with a signal response time of 26 seconds (ref.13), which gives a total closure time of 40 seconds. Therefore all cases will analyze the first 40 seconds without CREVS filtration. The ARCON96 X/Q values used (which supersede the Halitsky X/Q values) for the Shield Building Vent were: from ref.34: 1.09E-03 sec/m^3 for 0-2 hr (since all releases are < 2 hours, X/Q values after 2 hours are unimportant. The Auxiliary Building Vent X/Q is 2.56E-3 sec/m^3.

Prior to isolation the intake flow is 3000 cfm (ref.10). (3200 cfm has been used in previous revisions and was previously shown on the drawing 1-47W866-4. The 3200 cfm will be retained in this calculation revision since this value produces conservative results.) It is assumed that the unfiltered inleakage is the same as for the isolated case (51 cfm, due to open doors, leaky valves, etc.) After isolation, the total flow rate into the control room is 711 cfm filtered plus 51 cfm unfiltered (ref.5). The circulation flow rate in the control room is the total flow – the makeup flow = 3600 – 711 = 2889 cfm (ref.5). Note: the recirculation nominal flow is 4000 cfm. The 4000 cfm – 10% is chosen as this will result in longer residence time in the Control Room. If 4000 cfm + 10% were to be used, the radioisotopes would recirculate through the filters faster, and therefore be filtered out of the Control Room faster.

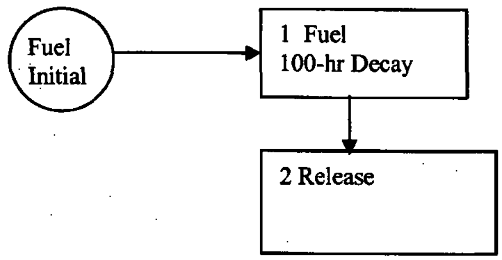
Cases were performed for the standard core using ARCON96 X/Q values and ICRP-30 dose conversion factors (see note on methodologies in Conclusion section).

The activity released to the environment as calculated by STP is used as input to computer code FENCDOSE (ref.8) to determine the site boundary dose. The FENCDOSE model is the same as that found in reference 19.

II. Regulatory Guide 1.183 (Alternate Source Term) Cases:

There are two AST FHA cases. One is in the spent fuel pit/Auxiliary Building with no ABI and with unfiltered releases through the Auxiliary Building vent. A second case is an accident in the containment with unfiltered release for 12.7 seconds through the Shield Building vent, with the remainder released unfiltered through the Auxiliary Building vent (no ABI and no filtration). The AB Vent has less favorable X/Q values than the Shield Building Vent. Computer code STP (ref.6) is used to calculate the activity released after a FHA. Figure 2 shows the model. To insure a conservative dose, the radioisotopes are allowed only 100 hours of decay after shutdown, and are released to the environment linearly. The step source fractions of the core inventory are based on Reg.Guide 1.183. The source terms are the 1500 EFPD maximum burnup for 18 month fuel cycle from WBNAPS3-084 (ref.14) for the standard core. These source terms are used instead of the core average 1000 EFPD source terms because the accident involves a single fuel assembly, not the entire core (as in a LOCA). For the TPC, the source terms for the once burned, twice burned, and 3 times burned assemblies are taken from WBNAPS3-098 (ref.29). The 24 TPBAR release apply only to the once and twice burned assemblies (the 3 times burned assembly will not have any TPBARs).

Figure 2
AST STP Model



The STP model consists of the assembly inventory stepped into the Fuel component with a 1.65 peaking factor and allowed to decay for 100 hours. The remaining decayed isotopes are then stepped into the Release component based on filtration efficiency (=99% for iodines for ABI case, =0% filtered for no ABI case).
Component 1: Fuel volume=1.0 (arbitrary)
Component 2: Release volume = 1.0 (arbitrary)ABGTS filter efficiencies: 99% (ref.3), for iodines, 0% for tritium

The gap activity in the damaged rods is released which consists of 5% of the inventory in the rods at the time of the accident, except for the following: Kr-85=10%, I-131=8% NOTE: Filtration is not used in R14, but left in for historical context, and possible future revisions.
Partition Factors: 200 for all iodines (see assumption 8).
The 40 second delay in Control Room isolation is taken into account through the appropriate Step fractions
****

The Auxiliary Building FHA step fractions from the fuel to the outside "Release" component are:
0-40 sec:
S= 2.778E-4 (=0.05*(40sec/7200sec)) for all except Kr-85, iodines, and H-3
S= 5.556E-4 (=0.1*(40sec/7200sec)) for Kr-85
S= 1.389E-6 (=0.05*(40sec/7200sec/200)) with no ABI for iodines except I-131
S= 2.222E-6 (=0.08*(40sec/7200sec/200)) with no ABI for I-131
S= 1.389E-3 (=1.00*(40sec/7200sec*25%)) for H-3

40 sec-2 hr:
S= 4.972E-2 (=0.05*(7200 sec-40sec)/7200sec) for all except Kr-85, iodines, and H-3
S=9.944E-2 (=0.1*(7200 sec-40sec)/7200sec) for Kr-85
S= 2.486E-4 (=0.05*(7200 sec-40sec)/7200sec/200) with no ABI for iodines except I-131
S= 3.978E-4 (=0.08*(7200 sec-40sec)/7200sec/200) with no ABI for I-131
S= 2.486E-1 (=1.00*(7200 sec-40sec)/7200sec*25%) for H-3
****

The containment FHA step fractions from the fuel to the outside "Release" component are:
0-12.7 sec
S= 8.819E-5 (=0.05*(12.7sec/7200sec)) for all except Kr-85, iodines, and H-3
S= 1.764E-4 (=0.1*(12.7sec/7200sec)) for Kr-85
S= 4.410E-7 (=0.05*(12.7sec/7200sec/200)) with no ABI for iodines except I-131
S= 7.056E-7 (=0.08*(12.7sec/7200sec/200)) with no ABI for I-131
S= 4.410E-4 (=1.00*(12.7sec/7200sec*25%)) for H-3

12.7-40 sec (=27.3 sec):
S= 1.896E-4 (=0.05*(27.3sec/7200sec)) for all except Kr-85, iodines, and H-3
S= 3.792E-4 (=0.1*(27.3 sec sec/7200sec)) for Kr-85
S= 9.479E-7 (=0.05*(27.3 sec sec/7200sec/200)) with no ABI for iodines except I-131
S= 1.517E-6 (=0.08*(27.3 sec sec/7200sec/200)) with no ABI for I-131
S= 9.479E-4 (=1.00*(27.3 sec sec/7200sec*25%)) for H-3

40 sec-2 hr:
S= 4.972E-2 (=0.05*(7200 sec-40sec)/7200sec) for all except Kr-85, iodines, and H-3
S=9.944E-2 (=0.1*(7200 sec-40sec)/7200sec) for Kr-85
S= 2.486E-4 (=0.05*(7200 sec-40sec)/7200sec/200) with no ABI for iodines except I-131
S= 3.978E-4 (=0.08*(7200 sec-40sec)/7200sec/200) with no ABI for I-131
S= 2.486E-1 (=1.00*(7200 sec-40sec)/7200sec*25%) for H-3

The activity released to the environment as calculated by STP is used as input to computer code COROD (ref.7) to determine the control room operator doses. The control room model is identical to that described in TI-RPS-198 (ref.5) except for the shine from containment which is neglected (all activity inside the containment from FHA is released). For AST, all breathing rates for all times are the same 3.47E-4 m^3/sec (note: this should be 3.5E-4. Also, the TEDE as determined by COROD or FENCDOSE does not use this value. See Appendix B for conservatism and acceptability of use of FENCDOSE/COROD TEDE calculation methodology).

The ARCON96 X/Q values used for Shield Building Vent releases (which supersede the Halitsky X/Q values) are: from ref.34: 1.09E-03 sec/m^3 for 0-2 hr. For Auxiliary Building Vent releases (when there is no ABI), the X/Q value is: 2.56E-3 sec/m^3 for 0-2 hr.

Prior to isolation the intake flow is 3000 cfm (ref.10). (3200 cfm has been used in previous revisions and was previously shown on the drawing 1-47W866-4. The 3200 cfm will be retained in this calculation revision since this value produces conservative results.) It is assumed that the unfiltered inleakage is the same as for the isolated case (51 cfm, due to open doors, leaky valves, etc.) After isolation, the total flow rate into the control room is 711 cfm filtered plus 51 cfm unfiltered (ref.5). The circulation flow rate in the control room is the total flow – the makeup flow = 3600 – 711 = 2889 cfm (ref.5).

The activity released to the environment as calculated by STP is used as input to computer code FENCDOSE (ref.8) to determine the site boundary dose. The FENCDOSE model is the same as that found in reference 19.

III. TPBAR Only Accident

The TPBAR only accident will result in 25% of the tritium inventory being released over 2 hours. Since tritium is low energy beta decay only, the Spent Fuel Pit Monitors and the Control Room Intake monitors will not respond to the tritium. Therefore, the Auxiliary Building will not be isolated (all Auxiliary Building releases will be out the Auxiliary Building

Results

The control room doses with 1 train of CREVS and 40 sec control room isolation are as follows (rem):

TPBAR Only Control Room Doses [rem]

Run: TS9C13%# %=E; #=8	TPBAR only	limit
Gamma	0.000E+00	5
Beta	7.080E-02	30
Thyroid (ICRP-30)	0.000E+00	30
TEDE	1.157E+00	5

Regulatory Guide 1.25 Control Room Doses [rem]

Containment FHA with Purge Filters (closed to Auxiliary Building)

Run: TS9C13%# %=A,B,CorD; #=3	Conventional Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned
Gamma	2.723E-01	3.111E-01	2.345E-01	3.060E-01
Beta	2.245E+00	2.518E+00	1.954E+00	2.502E+00
Thyroid (ICRP-30)	6.814E+00	7.232E+00	5.645E+00	7.572E+00
TEDE	5.097E-01	1.102E+00	9.693E-01	5.699E-01

Regulatory Guide 1.183 Alternate Source Term (AST) Control Room Doses [rem]

Auxiliary Building FHA with no ABI (Auxiliary Building Vent Release)

Run: TS9C14%#	Conventional	TPC Once	TPC Twice	TPC Thrice
%=A,B,CorD; #=4	Core	Burned	Burned	Burned
Gamma	5.864E-01	6.706E-01	5.052E-01	6.591E-01
Beta	4.678E+00	5.337E+00	4.120E+00	5.227E+00
Thyroid (ICRP-30)	1.321E+01	1.402E+01	1.094E+01	1.468E+01
TEDE	1.015E+00	2.869E+00	2.602E+00	1.136E+00

Containment FHA with 12.7 sec release, no Purge filters, remaining release through AB vent (no ABI, no filters) [rem]

Run: TS9C14%#	Conventional	TPC Once	TPC Twice	TPC Thrice
%=A, B, C or D; #=11	Core	Burned	Burned	Burned
Gamma	5.839E-01	6.678E-01	5.031E-01	6.563E-01
Beta	4.658E+00	5.279E+00	4.067E+00	5.205E+00
Thyroid (ICRP-30)	1.279E+01	1.358E+01	1.059E+01	1.421E+01
TEDE	1.000E+00	2.277E+00	2.014E+00	1.119E+00

The offsite doses were determined to be (rem):

TPBAR Only Offsite Doses [rem]

Run: TS9F13%#	TPBAR only		
%=E; #=8	2-hr EAB	30-Day LPZ	limit
Gamma	0.000E+00	0.000E+00	6.25
Beta	1.761E-02	4.922E-03	75
Thyroid (ICRP-30)	0.000E+00	0.000E+00	75
TEDE	2.883E-01	8.059E-02	6.25

Regulatory Guide 1.25 Offsite Doses [rem]:

Containment FHA with Purge Filters (closed to Auxiliary Building

Run: TS9F13%#	Conventional	Core	TPC Once	Burned	TPC Twice	Burned	TPC Thrice	Burned	
%=A,B,CorD; #=3	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	limit
Gamma	4.313E-01	1.206E-01	4.909E-01	1.372E-01	3.706E-01	1.036E-01	4.839E-01	1.353E-01	6.25
Beta	1.243E+00	3.475E-01	1.395E+00	3.899E-01	1.081E+00	3.022E-01	1.385E+00	3.873E-01	75
Thyroid (ICRP-30)	4.146E+01	1.159E+01	4.399E+01	1.230E+01	3.434E+01	9.599E+00	4.605E+01	1.287E+01	75
TEDE	1.849E+00	5.170E-01	2.268E+00	6.339E-01	1.827E+00	5.106E-01	2.056E+00	5.748E-01	6.25

Regulatory Guide 1.183 Alternate Source Term (AST) Offsite Doses [rem]

Auxiliary Building FHA with no ABI (Auxiliary Building Vent Release)

Run: TS9F13%#	Conventional	Core	TPC Once	Burned	TPC Twice	Burned	TPC Thrice	Burned	
%=A,B,CorD; #=4	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	limit
Gamma	4.291E-01	1.199E-01	4.887E-01	1.366E-01	3.688E-01	1.031E-01	4.815E-01	1.346E-01	6.25
Beta	1.193E+00	3.334E-01	1.352E+00	3.778E-01	1.041E+00	2.909E-01	1.333E+00	3.726E-01	75
Thyroid (ICRP-30)	5.508E+01	1.540E+01	5.847E+01	1.634E+01	4.560E+01	1.275E+01	6.121E+01	1.711E+01	75
TEDE	2.383E+00	6.660E-01	2.834E+00	7.923E-01	2.268E+00	6.339E-01	2.650E+00	7.407E-01	6.25

Containment FHA with 12.7 sec release, no Purge filters, remaining release through AB vent (no ABI, no filters)
Same offsite doses as Auxiliary Building FHA with no ABI

The control room dose margins with 1 train of CREVS and 40 sec control room isolation are as follows. The following Unit 1 margins were calculated from the doses in the Tables above. Where: margin = limit – dose, and percent = (limit-dose)/limit

TPBAR Only Control Room Dose Margins

	TPBAR Margin	Only Percent
Gamma	5.00	100.00
Beta	29.93	99.76
Thyroid (ICRP-30)	30.00	100.00
TEDE	3.84	76.86

Regulatory Guide 1.25 Control Room Dose Margins

Containment FHA with Purge Filters

	Conv. Margin	Core Percent	TPC Once Margin	Burned Percent	TPC Twice Margin	Burned Percent	TPC Thrice Margin	Burned Percent
Gamma	4.73	94.55	4.69	93.78	4.77	95.31	4.69	93.88
Beta	27.76	92.52	27.48	91.61	28.05	93.49	27.50	91.66
Thyroid (ICRP-30)	23.19	77.29	22.77	75.89	24.36	81.18	22.43	74.76
TEDE	4.49	89.81	3.90	77.96	4.03	80.61	4.43	88.60

Regulatory Guide 1.183 Alternate Source Term (AST) Control Room Dose Margins

Auxiliary Building FHA with no ABI (Auxiliary Building Vent Release)

	Conv. Margin	Core Percent	TPC Once Margin	Burned Percent	TPC Twice Margin	Burned Percent	TPC Thrice Margin	Burned Percent
Gamma	4.41	88.27	4.33	86.59	4.49	89.90	4.34	86.82
Beta	25.32	84.41	24.75	82.51	25.97	86.56	24.77	82.58
Thyroid (ICRP-30)	16.79	55.97	15.98	53.27	19.06	63.53	15.32	51.07
TEDE	3.99	79.70	3.58	71.58	3.85	76.92	3.86	77.28

Containment FHA with 12.7 sec release, no Purge filters, remaining release through AB vent (no ABI, no filters)

	Conv. Margin	Core Percent	TPC Once Margin	Burned Percent	TPC Twice Margin	Burned Percent	TPC Thrice Margin	Burned Percent
Gamma	4.42	88.32	4.33	86.64	4.50	89.94	4.34	86.87
Beta	25.34	84.47	25.95	86.49	25.93	86.44	24.80	82.65
Thyroid (ICRP-30)	17.21	57.37	16.42	54.73	19.41	64.70	15.79	52.63
TEDE	4.00	80.00	2.48	49.52	2.99	59.72	3.88	77.62

TPBAR Only Offsite Dose Margins

	TPBAR only 2-hr EAB Margin	Percent	30-Day LPZ Margin	Percent
Gamma	6.25	100.00	6.25	100.00
Beta	74.98	99.98	75.00	99.99
Thyroid (ICRP-30)	75.00	100.00	75.00	100.00
TEDE	5.96	95.39	6.17	98.71

Regulatory Guide 1.25 Offsite Dose Margins:

Containment FHA with Purge Filters

	Conv. Core 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Once Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Twice Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Thrice Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%
Gamma	5.82	93.10	6.13	98.07	5.76	92.15	6.11	97.80	5.88	94.07	6.15	98.34	5.77	92.26	6.11	97.84
Beta	73.76	98.34	74.65	99.54	73.61	98.14	74.61	99.48	73.92	98.56	74.70	99.60	73.62	98.15	74.61	99.48
Thyroid (ICRP-30)	33.54	44.72	63.41	84.55	31.01	41.35	62.70	83.60	40.66	54.21	65.40	87.20	28.95	38.60	62.13	82.84
TEDE	4.40	70.42	5.73	91.73	3.98	63.71	5.62	89.86	4.42	70.77	5.74	91.83	4.19	67.10	5.68	90.80

Regulatory Guide 1.183 Alternate Source Term (AST) Offsite Dose Margins

Auxiliary Building FHA with no ABI (Auxiliary Building Vent Release)

	Conv. Core 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Once Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Twice Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%	TPC Thrice Burned 2-hr EAB Margin	%	30-Day LPZ Margin	%
Gamma	5.82	93.13	6.13	98.08	5.76	92.18	6.11	97.81	5.88	94.10	6.15	98.35	5.77	92.30	6.12	97.85
Beta	73.81	98.41	74.67	99.56	73.65	98.20	74.62	99.50	73.96	98.61	74.71	99.61	73.67	98.22	74.63	99.50
Thyroid (ICRP-30)	19.92	26.56	59.60	79.47	16.53	22.04	58.66	78.21	29.40	39.20	62.25	83.00	13.79	18.39	57.89	77.19
TEDE	3.87	61.87	5.58	89.34	3.42	54.66	5.46	87.32	3.98	63.71	5.62	89.86	3.60	57.60	5.51	88.15

Containment FHA with 12.7 sec release, no Purge filters, remaining release through AB vent (no ABI, no filters)
Same as Auxiliary Building FHA with no ABI

Conclusions

The control room operator doses resulting from a Fuel Handling Accident are less than the 10CFR50, Appendix A, GDC 19 limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and less than the 10CFR50.67 limit of 5 rem TEDE.

The 2 hour Site Boundary (SB)/Exclusion Area Boundary and 30 day Low Population Zone (LPZ) doses from a FHA are less than 25% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid (=6.25 rem gamma, 75 rem beta, 75 rem thyroid, 6.25 rem TEDE). 10CFR50.67 provides the TEDE equivalence to the gamma limits.

The Auxiliary Building/Spent Fuel Pit releases with no ABI or filtration are through the Auxiliary Building vent which have worse X/Q values than the containment FHA with Shield Building releases. Therefore the Auxiliary Building AST FHA will bound a containment AST FHA.

TPBAR only accident doses are all less than the 10CFR100/10CFR50.67 offsite control room limits and 10CFR50 App.A GDC 19 limits.

Note on methodologies used:

This calculation determined the doses using different methodologies. The gamma, beta and Thyroid (ICRP-30) doses are all based on TID-14844 methodologies utilizing the ICRP-30 iodine dose conversion factors. The other methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is required for AST, however is not required for RG 1.25 methodology. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium.

The effect of the increased time delay had been evaluated in this calculation, and it has been shown that adequate margin remains between the calculated doses and regulatory limits to accommodate instrument errors and uncertainties.

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5. TI-RPS-198 R24 "Dose to Control Room Personnel Due to a Regulatory Guide 1.4 Loss of Coolant Accident,"
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27. N3-78-4001 R8 "Spent Fuel Pool Cooling and Cleaning System"
28a. Memorandum from James S. Chardos to Cheryl K. Thornhill, TVATP-00-068, October 23, 2000 "Verification of Design Inputs for Calculations of Breached TPBAR Leaching in the Spent Fuel Pool" Att. 5
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30. TI-535 R2 "Max. Expected Airborne Concentration in Primary Containment, Turbine Building, Auxiliary Building, and Instrument Room During Normal Operation"
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31b. DCN W-23167-A
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Appendix A: RG 1.25 Containment FHA with 12.7 sec unfiltered release, containment closed to Auxiliary Building

This appendix supplies an additional case performed in previous revisions, with the following criteria: RG 1.25 Containment FHA with 12.7 seconds unfiltered release (no purge filters) and the containment is closed to the Auxiliary Building.

Control Room Doses [rem]:

Containment FHA with 12.7 sec containment isolation, containment closed to AB, no Purge Filters					
Run: TS9C13%#	Conventional	TPC Once	TPC Twice	TPC Thrice	limit
%=A,B,CorD; #=1	Core	Burned	Burned	Burned	
Gamma	1.037E-02	1.184E-02	8.930E-03	1.165E-02	5
Beta	8.553E-02	9.591E-02	7.441E-02	9.532E-02	30
Thyroid (ICRP-30)	4.762E+00	5.054E+00	3.943E+00	5.291E+00	30
TEDE	1.603E-01	1.913E-01	1.534E-01	1.782E-01	5

Offsite Doses [rem]

Run: TS9F13%#	Conventional	Core	TPC Once	Burned	TPC Twice	Burned	TPC Thrice	Burned	
%=A,B,CorD; #=1	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	2-Hr EAB	30-Day LPZ	limit
Gamma	4.545E-03	1.271E-03	5.148E-03	1.439E-03	3.894E-03	1.089E-03	5.095E-03	1.424E-03	6.25
Beta	1.227E-02	3.430E-03	1.376E-02	3.846E-03	1.067E-02	2.981E-03	1.368E-02	3.823E-03	75
Thyroid (ICRP-30)	1.615E+00	4.513E-01	1.713E+00	4.790E-01	1.337E+00	3.737E-01	1.794E+00	5.014E-01	75
TEDE	6.605E-02	1.846E-02	7.309E-02	2.043E-02	5.756E-02	1.609E-02	7.339E-02	2.052E-02	6.25

Control Room Margins:

	Conv.	Core	TPC Once	Burned	TPC Twice	Burned	TPC Thrice	Burned
	Margin	**Percent**	**Margin**	**Percent**	**Margin**	**Percent**	**Margin**	**Percent**
Gamma	4.99	99.79	4.99	99.76	4.99	99.82	4.99	99.77
Beta	29.91	99.71	29.90	99.68	29.93	99.75	29.90	99.68
Thyroid (ICRP-30)	25.24	84.13	24.95	83.15	26.06	86.86	24.71	82.36
TEDE	4.84	96.79	4.81	96.17	4.85	96.93	4.82	96.44

Offsite Dose Margins:

	Conv.	Core			TPC Once	Burned			TPC Twice	Burned			TPC Thrice	Burned		
	2-hr EAB		30-Day LPZ		2-hr EAB		30-Day LPZ		2-hr EAB		30-Day LPZ		2-hr EAB		30-Day LPZ	
	Margin	**%**	**Margin**	**%**	**Margin**	**%**	**Margin**	**%**	**Margin**	**%**	**Margin**	**%**	**Margin**	**%**	**Margin**	**%**
Gamma	6.25	99.93	6.25	99.98	6.24	99.92	6.25	99.98	6.25	99.94	6.25	99.98	6.24	99.92	6.25	99.98
Beta	74.99	99.98	75.00	100.00	74.99	99.98	75.00	99.99	74.99	99.99	75.00	100.00	74.99	99.98	75.00	99.99
Thyroid (ICRP-30)	73.39	97.85	74.55	99.40	73.29	97.72	74.52	99.36	73.66	98.22	74.63	99.50	73.21	97.61	74.50	99.33
TEDE	6.18	98.94	6.23	99.70	6.18	98.83	6.23	99.67	6.19	99.08	6.23	99.74	6.18	98.83	6.23	99.67

Discussion and Conclusion:

This RG 1.25 case with the containment FHA and an unfiltered 12.7 sec release, has all limits less than the 10CFR100 offsite dose limits and 10CFR50 App.A GDC 19 dose limits.

Appendix B
TEDE Calculation per Regulatory Guide 1.183

Purpose
The purpose of this Appendix is to calculate the TEDE value as outlined in Regulatory Guide 1.183. COROD and FENCDOSE calculate TEDE differently and so a comparison is needed (PER 429145). Based on the results in the body of the calculation, the TPC once burned case is bounding for the control room dose and the thrice burned TPC case is bounding for the offsite dose. Therefore these cases will be utilized to compare to the RG 1.183 methodology.

Introduction
R.G. 1.183 specifies calculating the TEDE by summing the Committed Effective Dose Equivalent (CEDE) with the Deep Dose Equivalent (DDE). Position 4.1.2 states that exposure to CEDE factors in Table 2.1 of Federal Guidance Report (FGR) 11 are acceptable to calculate the CEDE. When calculating the CEDE value, a breathing rate of 3.5E-4 m^3/sec should be used for the first 8 hours, 1.8E-4 m^3/sec from 8-24 hrs, and 2.3E-4 m^3/sec for times greater than 24 hrs (position 4.1.3). Position 4.1.4 states that DDE DCFs from Table III.1 of Federal Guidance report 12 are acceptable to use when calculating the DDE. The following table provides the DCFs from these two tables.

Table 1 - RG 1.183 acceptable DCFs.

	DDE		CEDE	
	Sv/(Bq s m^{-3})	rem/(Ci hr m^{-3})	Sv/Bq	rem/Ci
KRM 83	1.50E-18	2.00E-02	0.00E+00	0.00E+00
KRM 85	7.48E-15	9.96E+01	0.00E+00	0.00E+00
KR 85	1.19E-16	1.59E+00	0.00E+00	0.00E+00
KR 87	4.12E-14	5.49E+02	0.00E+00	0.00E+00
KR 88	1.02E-13	1.36E+03	0.00E+00	0.00E+00
KR 89	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 131	3.89E-16	5.18E+00	0.00E+00	0.00E+00
XEM 133	1.37E-15	1.82E+01	0.00E+00	0.00E+00
XE 133	1.56E-15	2.08E+01	0.00E+00	0.00E+00
XEM 135	2.04E-14	2.72E+02	0.00E+00	0.00E+00
XE 135	1.19E-14	1.59E+02	0.00E+00	0.00E+00
XE 138	5.77E-14	7.69E+02	0.00E+00	0.00E+00
I 131	1.82E-14	2.42E+02	8.89E-09	3.29E+04
I 132	1.12E-13	1.49E+03	1.03E-10	3.81E+02
I 133	2.94E-14	3.92E+02	1.58E-09	5.85E+03
I 134	1.30E-13	1.73E+03	3.55E-11	1.31E+02
I 135	7.98E-14	1.06E+03	3.32E-10	1.23E+03
H 3	3.31E-19	4.41E-03	1.73E-11	6.40E+01

The DDE is converted to rem/(Ci hr m^{-3}) by multiplying the values from Table III.1 by 3.7E12 (rem/Ci)/(Sv/Bq) * 3600 sec/hr. The CEDE values are converted by multiplying the values from Table 2.1 by 3.7E12 (rem/Ci)/(Sv/Bq)

Calculation

The following describes how the DDE and CEDE were calculated using methods as recommended in RG 1.183 for offsite and control room dose.

Deep Dose Equivalent
The DDE is calculated as follows:

$$\text{Concentration (Ci*hr/m}^3\text{) x DCF}_{DDE}\text{ (rem/Ci*hr*m}^{-3}\text{)}$$

Committed Effective Dose Equivalent
The CEDE is calculated as follows:

$$\text{Concentration (Ci*hr/m}^3\text{) x breathing rate (m}^3\text{/hr) x DCF}_{CEDE}\text{(rem/Ci)}$$

Since the FHA lasts only 2 hours the breathing rate will be 3.5E-4 m^3/sec = 1.26 m^3/hr

Concentration
COROD calculates and prints out the concentration in Ci hr/m^3 for each time period. Therefore this can be easily obtained from the output. The following is the concentration as output in COROD for the once burned case (B4):

Table 2 - Concentrations (Ci*hr/m^3) from COROD Case B4

	0-40 sec	40 sec-2 HRS	2-8 HRS	8-24 HRS	1-4 DAYS	4-30 DAYS
KRM 83	6.82E-24	3.83E-20	5.57E-20	2.13E-21	3.19E-25	0.00E+00
KRM 85	4.41E-14	2.81E-10	6.46E-10	1.01E-10	4.98E-13	2.00E-23
KR 85	9.75E-09	6.84E-05	2.34E-04	1.16E-04	7.14E-06	1.97E-11
KR 87	9.62E-31	4.92E-27	5.34E-27	7.08E-29	6.72E-34	0.00E+00
KR 88	1.14E-17	6.86E-14	1.28E-13	1.08E-14	1.20E-17	5.92E-31
KR 89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 131	7.40E-09	5.18E-05	1.76E-04	8.53E-05	5.06E-06	1.17E-11
XEM 133	1.80E-08	1.25E-04	4.13E-04	1.84E-04	9.16E-06	1.01E-11
XE 133	1.06E-06	7.36E-03	2.48E-02	1.17E-02	6.60E-04	1.23E-09
XEM 135	6.76E-12	1.54E-08	3.22E-09	1.32E-16	0.00E+00	0.00E+00
XE 135	2.02E-09	1.35E-05	3.76E-05	1.03E-05	1.82E-07	2.15E-15
XE 138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 131	4.00E-09	3.22E-06	5.18E-06	1.80E-06	1.04E-07	2.22E-13
I 132	3.26E-22	2.20E-19	1.90E-19	7.10E-21	3.16E-24	0.00E+00
I 133	2.71E-10	2.14E-07	3.20E-07	8.65E-08	3.04E-09	7.63E-16
I 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 135	1.98E-13	1.50E-10	1.90E-10	2.93E-11	3.19E-13	4.64E-22
I* 131	1.00E-11	8.07E-09	1.30E-08	4.50E-09	2.61E-10	5.57E-16
I* 132	8.18E-25	5.53E-22	4.75E-22	1.78E-23	7.92E-27	0.00E+00
I* 133	6.78E-13	5.36E-10	8.01E-10	2.17E-10	7.62E-12	1.91E-18
I* 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I* 135	4.97E-16	3.76E-13	4.77E-13	7.34E-14	8.01E-16	1.16E-24
H 3	8.76E-08	6.15E-04	2.10E-03	1.04E-03	6.42E-05	1.77E-10

FENCDOSE does not explicitly print out concentration in terms of Ci*hr/m^3. Therefore it must be back calculated. FENCDOSE calculates the TEDE by multiplying the DCFS found in Table 5-1 of EPA-400-R-92-001 by the concentration. The TEDE values for each isotope in each time period are printed out. Therefore to obtain the concentration for offsite dose, the TEDE values must be divided by the DCF values. The following are the TEDE values from FENCDOSE TPC thrice burned case (D4), the DCFs used in FENCDOSE, and the back calculated concentration.

	TEDE [rem]		DCF (Table 5.1)	Concentration*Ci*hr/m^3	
	0-2 HRS	2-HR EAB	rem/(μCi cm^{-3} hr)	0-2 HRS	2-HR EAB
KRM 83	0.00E+00	0.00E+00	1.00E+20	0.00E+00	0.00E+00
KRM 85	9.07E-09	3.24E-08	9.30E+01	9.75E-11	3.49E-10
KR 85	7.27E-05	2.60E-04	1.30E+00	5.59E-05	2.00E-04
KR 87	1.05E-24	3.74E-24	5.10E+02	2.05E-27	7.34E-27
KR 88	3.12E-11	1.12E-10	1.30E+03	2.40E-14	8.58E-14
KR 89	0.00E+00	0.00E+00	1.20E+03	0.00E+00	0.00E+00
XEM 131	1.23E-04	4.40E-04	4.90E+00	2.51E-05	8.98E-05
XEM 133	9.16E-04	3.28E-03	1.70E+01	5.39E-05	1.93E-04
XE 133	6.17E-02	2.21E-01	2.00E+01	3.08E-03	1.10E-02
XEM 135	5.00E-06	1.79E-05	2.50E+02	2.00E-08	7.15E-08
XE 135	8.07E-04	2.89E-03	1.40E+02	5.77E-06	2.06E-05
XE 138	0.00E+00	0.00E+00	7.20E+02	0.00E+00	0.00E+00
I 131	6.63E-01	2.37E+00	5.30E+04	1.25E-05	4.48E-05
I 132	4.93E-15	1.76E-14	4.90E+03	1.01E-18	3.60E-18
I 133	1.19E-02	4.26E-02	1.50E+04	7.93E-07	2.84E-06
I 134	0.00E+00	0.00E+00	3.10E+03	0.00E+00	0.00E+00
I 135	4.70E-06	1.68E-05	8.10E+03	5.80E-10	2.08E-09
I* 131	1.66E-03	5.95E-03	5.30E+04	3.14E-08	1.12E-07
I* 132	1.24E-17	4.42E-17	4.90E+03	2.52E-21	9.01E-21
I* 133	2.98E-05	1.07E-04	1.50E+04	1.99E-09	7.11E-09
I* 134	0.00E+00	0.00E+00	3.10E+03	0.00E+00	0.00E+00
I* 135	1.18E-08	4.22E-08	8.10E+03	1.46E-12	5.20E-12
H 3	0.00E+00	0.00E+00	7.70E+01	0.00E+00	0.00E+00

* Note that conversion from μci to Ci and cm^3 to m^3, cancel each other out. Therefore the correct units are obtained without multiplying by any conversion factors.

Results

Offsite - TPC Thrice Burned - Case D4

DDE-rem	0-2 HRS	2-HR EAB
KRM 83	0.00E+00	0.00E+00
KRM 85	9.72E-09	3.48E-08
KR 85	8.86E-05	3.17E-04
KR 87	1.13E-24	4.03E-24
KR 88	3.26E-11	1.17E-10
KR 89	0.00E+00	0.00E+00
XEM 131	1.30E-04	4.65E-04
XEM 133	9.83E-04	3.52E-03
XE 133	6.41E-02	2.29E-01
XEM 135	5.43E-06	1.94E-05
XE 135	9.14E-04	3.27E-03
XE 138	0.00E+00	0.00E+00
I 131	3.03E-03	1.09E-02
I 132	1.50E-15	5.36E-15
I 133	3.11E-04	1.11E-03
I 134	0.00E+00	0.00E+00
I 135	6.17E-07	2.21E-06
I* 131	7.61E-06	2.72E-05
I* 132	3.76E-18	1.34E-17
I* 133	7.79E-07	2.79E-06
I* 134	0.00E+00	0.00E+00
I* 135	1.55E-09	5.53E-09
H 3	0.00E+00	0.00E+00
Totals	6.96E-02	2.49E-01

CEDE-rem	0-2 HRS	2-HR EAB
KRM 83	0.00E+00	0.00E+00
KRM 85	0.00E+00	0.00E+00
KR 85	0.00E+00	0.00E+00
KR 87	0.00E+00	0.00E+00
KR 88	0.00E+00	0.00E+00
KR 89	0.00E+00	0.00E+00
XEM 131	0.00E+00	0.00E+00
XEM 133	0.00E+00	0.00E+00
XE 133	0.00E+00	0.00E+00
XEM 135	0.00E+00	0.00E+00
XE 135	0.00E+00	0.00E+00
XE 138	0.00E+00	0.00E+00
I 131	5.19E-01	1.86E+00
I 132	4.83E-16	1.73E-15
I 133	5.84E-03	2.09E-02
I 134	0.00E+00	0.00E+00
I 135	8.98E-07	3.21E-06
I* 131	1.30E-03	4.65E-03
I* 132	1.21E-18	4.33E-18
I* 133	1.46E-05	5.24E-05
I* 134	0.00E+00	0.00E+00
I* 135	2.25E-09	8.06E-09
H 3	0.00E+00	0.00E+00
Totals	5.26E-01	1.88E+00

2 hr EAB TEDE = 2.49E-01 + 1.88E00 = 2.13E00 rem
30 day LPZ TEDE = 6.96E-2 + 5.26E-1 = 5.95E-01 rem

Control Room - TPC Once Burned - Case B4

Based on position 4.2.6 of RG 1.183, the occupancy factor for personnel in the control is 100% for the first 24 hrs, 60% between 1 and 4 days and 40% between 4 days and 30 days. This is taken into account by multiplying the sum of all isotopes of each time step by the appropriate occupancy factors. Position 4.2.7 allows correcting the DDE DCFs for the difference between a finite cloud geometry and a semi-infinite cloud geometry. The correction factor is given as $V^{0.338}/1173$, where V is the control room volume in ft^3. The control room volume found in the COROD runs is 257198 ft^3. Therefore the correction factor is 5.75E-2. This is multiplied to the DDE totaled over all time periods with occupancy factors included.

DDE-rem	0-40 sec	40 sec-2 HRS	2-8 HRS	8-24 HRS	1-4 DAYS	4-30 DAYS
KRM 83	1.36E-25	7.65E-22	1.11E-21	4.25E-23	6.36E-27	0.00E+00
KRM 85	4.40E-12	2.80E-08	6.44E-08	1.01E-08	4.96E-11	1.99E-21
KR 85	1.55E-08	1.08E-04	3.71E-04	1.83E-04	1.13E-05	3.13E-11
KR 87	5.28E-28	2.70E-24	2.93E-24	3.88E-26	3.69E-31	0.00E+00
KR 88	1.54E-14	9.31E-11	1.74E-10	1.47E-11	1.63E-14	8.05E-28
KR 89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 131	3.83E-08	2.68E-04	9.12E-04	4.42E-04	2.62E-05	6.08E-11
XEM 133	3.28E-07	2.28E-03	7.54E-03	3.36E-03	1.67E-04	1.83E-10
XE 133	2.19E-05	1.53E-01	5.15E-01	2.44E-01	1.37E-02	2.56E-08
XEM 135	1.84E-09	4.19E-06	8.76E-07	3.59E-14	0.00E+00	0.00E+00
XE 135	3.20E-07	2.13E-03	5.95E-03	1.64E-03	2.88E-05	3.41E-13
XE 138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 131	9.70E-07	7.81E-04	1.26E-03	4.36E-04	2.52E-05	5.38E-11
I 132	4.87E-19	3.29E-16	2.83E-16	1.06E-17	4.71E-21	0.00E+00
I 133	1.06E-07	8.37E-05	1.25E-04	3.39E-05	1.19E-06	2.99E-13
I 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 135	2.11E-10	1.59E-07	2.02E-07	3.11E-08	3.39E-10	4.93E-19
I* 131	2.43E-09	1.96E-06	3.15E-06	1.09E-06	6.32E-08	1.35E-13
I* 132	1.22E-21	8.24E-19	7.09E-19	2.65E-20	1.18E-23	0.00E+00
I* 133	2.66E-10	2.10E-07	3.14E-07	8.49E-08	2.98E-09	7.49E-16
I* 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I* 135	5.28E-13	4.00E-10	5.07E-10	7.80E-11	8.51E-13	1.24E-21
H 3	3.86E-10	2.71E-06	9.27E-06	4.58E-06	2.83E-07	7.82E-13
Total	2.37E-05	1.59E-01	5.31E-01	2.50E-01	1.40E-02	2.59E-08
w/Occupancy	2.37E-05	1.59E-01	5.31E-01	2.50E-01	8.38E-03	1.04E-08
DDE Total	9.48E-01					
Corrected	5.45E-02					

CEDE - rem	0-40 sec	40 sec-2 HRS	2-8 HRS	8-24 HRS	1-4 DAYS	4-30 DAYS
KRM 83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KRM 85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KR 85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KR 87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KR 88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KR 89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XE 133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XEM 135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XE 135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XE 138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 131	1.66E-04	1.33E-01	2.15E-01	7.45E-02	4.31E-03	9.20E-09
I 132	1.57E-19	1.06E-16	9.11E-17	3.41E-18	1.52E-21	0.00E+00
I 133	1.99E-06	1.57E-03	2.35E-03	6.37E-04	2.24E-05	5.62E-12
I 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 135	3.07E-10	2.32E-07	2.94E-07	4.53E-08	4.94E-10	7.18E-19
I* 131	4.16E-07	3.34E-04	5.38E-04	1.87E-04	1.08E-05	2.31E-11
I* 132	3.93E-22	2.65E-19	2.28E-19	8.54E-21	3.80E-24	0.00E+00
I* 133	4.99E-09	3.95E-06	5.90E-06	1.60E-06	5.61E-08	1.41E-14
I* 134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I* 135	7.69E-13	5.82E-10	7.38E-10	1.14E-10	1.24E-12	1.80E-21
H 3	7.06E-06	4.96E-02	1.70E-01	8.38E-02	5.18E-03	1.43E-08
Total	1.75E-04	1.85E-01	3.87E-01	1.59E-01	9.52E-03	2.35E-08
w/Occupancy	1.75E-04	1.85E-01	3.87E-01	1.59E-01	5.71E-03	9.41E-09
CEDE Total	7.37E-01					

TEDE = 5.45E-02 + 7.37E-01 = 7.91E-01 rem.

Conclusions

Based on the results of this appendix it can be seen that the method COROD and FENCDOSE utilizes to calculate TEDE is conservative as it produces higher results.

TEDE	RG 1.183	FENCDOSE/COROD	Difference
2 hr EAB	2.13E+00	2.65E+00	24%
30 day LPZ	5.95E-01	7.41E-01	24%
Control Room	7.91E-01	1.42E+00	80%

TRITIUM TECHNOLOGY PROGRAM

UNCLASSIFIED TPBAR RELEASES, INCLUDING TRITIUM

TTQP-1-091

Revision 10

Effective Date: ____

TTQP-1-091

TRITIUM TECHNOLOGY PROGRAM

UNCLASSIFIED TPBAR RELEASES, INCLUDING TRITIUM

Revision 10

Prepared By:	D.D. Lanning, Author	3/16/06 Date
Reviewed By:	E.R. Gilbert, Independent Reviewer	3/16/06 Date
Concurrence:	E.P. Love, Authorized Derivative Classifier	3/24/06 Date
	T.M. Brewer, Quality Engineer	3/17/06 Date
	B.D. Reid, Design Task Manager	3/23/06 Date
Approval:	C.K. Thornhill, TTP Project Manager	3/24/06 Date

1.0 INTRODUCTION

This document provides a complete listing of all unclassified tritium release values that should be assumed for unclassified analysis. Much of the information is brought forth from the related documents listed in Section 4.0 to provide a single-source listing of unclassified release values. Some information, however, is new or updated based on current design analysis and available experimental data.

This document provides unclassified information for a larger number of release scenarios than previously analyzed. This information is summarized in Tables 1, 2, and 3. In addition, a section is included to address lithium and aluminum release in the event of a 24-TPBAR breach in the spent fuel pool.

2.0 SUMMARY OF UNCLASSIFIED RELEASES, INCLUDING TRITIUM

All tritium-producing burnable absorber rod (TPBAR) analysis assumes a maximum of 1.2 grams of tritium per TPBAR will be generated during an 18-month operating cycle.

2.1 Intact TPBAR In-reactor Tritium Permeation

The in-reactor tritium permeation rate deduced from RCS tritium activity for the group of 240 TPBARs in Watts Bar Nuclear Cycle, 6 averaged over a year extending to end-of-cycle, was 2.4 ± 1.8 Ci/TPBAR/year (95% confidence interval) (Lanning and Pagh, 2005). The 95% upper bound of 2.4 +1.8 = 4.2 Ci/TPBAR/year is recommended as the basis for assessing the tritium release from intact TPBARs.

2.2 In-reactor Tritium Release from a Failed TPBAR

The first scenario involves a TPBAR that may have a fabrication defect or may be damaged prior to insertion into the reactor for irradiation. In this case, 100 percent of the tritium generated in the TPBAR is assumed to be released to the reactor coolant as it is generated.

2.3 TPBAR Releases from Spent Fuel Pool Accidents

2.3.1 Spent Fuel Pool Tritium Concentration Limit

It has been determined that following the simultaneous breach of 24 TPBARs, the Tennessee Valley Authority take-action limit for tritium concentration in the spent fuel pool water will not be exceeded. The concentration limit is 60 microcuries per milliliter. The best estimate of total tritium release in this event is less than 25% of the TPBAR inventory. ~~r. The best estimate tritium release is less than 25% of the TPBAR inventory.~~ The release will not be instantaneous, but will occur at a steady rate over a time period substantially greater than 8 hours. The rate will thus be less than 3% (of initial inventory) per hour.

2.3.2 Instantaneous Tritium Release per TPBAR

In particular, the instantaneous release of tritium from breached TPBARs in the spent fuel pool (as gas within the released gas from the TPBARs) will not exceed 0.001 Ci/TPBAR.

2.3.3 Lithium and Aluminum Release

In the event of a 24-TPBAR breach in the spent fuel, the following concentration limits for lithium and aluminum will not be exceeded:

- 400 ppb lithium
- 50 ppb aluminum.

2.4 Tritium Releases from TPBARs within Storage Canisters (<200°F)

The upper-bounding tritium partial pressure within storage canisters containing lead test assembly (LTA) TPBARs and sections is not expected to exceed 20 torr under nominal storage conditions (~86°F). The quoted bounding pressure for maximum temperatures (<200°F) is estimated by increasing this figure by the ratio of Kelvin temperatures, to 25 torr.

Tritium release from extracted TPBARs in storage will not exceed 1% of the declared post-extraction residual tritium (Clemmer et al. 1984; and Johnson et al. 1976).

In both cases, the form of the released tritium will be tritiated water vapor or condensate (HTO).

2.5 TPBAR Transportation Cask Event Releases

2.5.1 Intact TPBARs

2.5.1.1 For TPBAR temperatures ranging from ambient to less than 200°F, and for casks containing 1,200 or less TPBARs, the tritium release from the entire cask loading would be less than 0.19 mCi per hour, based on extrapolation from an in-reactor upper bound observed permeation rate of 4.2 Ci/TPBAR/year. The tritium would be released from the TPBARs in the form of molecular tritium gas (i.e., T_2 or HT).

2.5.1.2 For TPBAR temperatures ranging from 200°F to 650°F, the average tritium release would be less than 0.48 mCi per TPBAR per hour based on the upper-bound in-reactor release rate of 4.2 Ci/TPBAR/year. The tritium would be released from the TPBARs in the form of tritium gas.

2.5.1.3 For TPBAR temperatures ranging from 650°F up to 1050°F (565°C), the tritium release should be considered to be an instantaneous release of less than 0.5 Ci per TPBAR per hour. Again, the tritium would be released from the TPBARs in the form of tritium gas.

The potential for TPBAR rupture was assessed at 1050°F because this is one of the temperature break-points in the Modal Study matrix cited earlier (Laity 1998). It was determined that the TPBARs are unlikely to rupture at temperatures less than 1050°F, but may rupture at higher temperatures.

2.5.1.4 Helium release from intact TPBARs is negligible.

2.5.2 Event-failed TPBARs

2.5.2.1 For TPBAR temperatures ranging from ambient to 200°F, the tritium release from a TPBAR whose cladding fails mechanically (e.g., due to impact forces) after cask loading should be considered to be less than 0.1 Ci per TPBAR per hour, not to exceed 1% of the tritium inventory in the lithium aluminate pellets. The release should be considered to be in the form of tritiated water and a very small fraction of methane.

2.5.2.2 For TPBAR temperatures ranging from 200°F to 650°F, the tritium release from a TPBAR whose cladding fails mechanically (e.g., due to impact forces) after cask loading should be considered to be less than 55 curies total due to desorption release. The release should be considered to be in the form of tritiated water and a very small fraction of methane.

2.5.2.3 For TPBAR temperatures ranging from 650°F to 1050°F, the tritium release should be considered to be up to 100% of the TPBAR tritium inventory, in the form of tritiated water and methane.

Attachment 2

T35 001023 938

October 23, 2000 TVATP-00-068

Ms. Cheryl K. Thornhill
TTQP Project Manager
Pacific Northwest National Laboratory
P. O. Box 999
Richland, WA 99352

SUBJECT: VERIFICATION OF DESIGN INPUTS FOR CALCULATIONS OF BREACHED TPBAR LEACHING IN THE SPENT FUEL POOL

REF: C. K. Thornhill to J. S. Chardos letter dated September 19, 2000, same subject

Dear Cheryl:

TVA has reviewed the design assumptions in the referenced letter and finds them to be correct except for assumption number 2. The value for tritium should be 60 uc/ml not 60 mc/ml. If you have any questions, please call.

Sincerely,

James S. Chardos
Tritium Program Manager

JSC/LDR
cc: F. A. Koontz, EQB 1A-WBN
D. M. LaFever, OPS 2B-SQN
J. A. Flanigan, BR 3F-C
EDMS WT 3B-K

Attachment 3

Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

September 19, 2000

TTQP-00-175

Mr. James S. Chardos, Project Manager
ADM-1V-WBN
Tennessee Valley Authority
Watts Bar Nuclear Plant
Spring City, TN 37381

bcc: DD Lanning
BD Reid
GC Sorensen
Records T1.16.1/File/LB.00-175

Dear Mr. Chardos:

VERIFICATION OF DESIGN INPUTS FOR CALCULATIONS OF BREACHED TPBAR LEACHING IN THE SPENT FUEL POOL

This letter serves to document the plant specific design assumptions proposed for use in calculating the tritium leaching from breached TPBARs in the spent fuel pool. The purpose of the leaching calculations is to define how quickly remedial actions, if any, are required to address the consequences of breached TPBARs. Tennessee Valley Authority (TVA) is requested to confirm the acceptability of the following design assumptions for application at both Watts Bar and Sequoyah Nuclear Plants.

The proposed design assumptions include:

1. The simultaneous breaching of 24 TPBARs.
2. The action limit for tritium concentration in the spent fuel pool water is 60 µCi/ml.
3. The spent fuel pool water volume is 372,000 gallons.
4. The spent fuel pool water depth is 39 feet.

The above-proposed design assumption for the spent fuel water volume was selected to be conservative. A defendable larger pool volume would benefit the analysis.

If you have any questions, please contact Bruce Reid on 509-372-4135.

Sincerely,

for Cheryl K. Thornhill, Manager
Tritium Target Qualification Project

/bjk

cc: O. W. Taylor, DOE-HQ, DP-251
J. K. Turner, DOE-RL

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