PSAT 04000U.04

CALCULATION PACKAGE FOR

APPLICATION OF THE REVISED DBA SOURCE TERM

TO THE BROWNS FERRY NUCLEAR POWER PLANT

prepared by:

POLESTAR APPLIED TECHNOLOGY, INC.

for the

ELECTRIC POWER RESEARCH INSTITUTE

Revision Number	Reason for Revision	Project Manager (print/sign/date)	Reviewer (print/sign/date)
0	Initial Issue	James Metcalf 9/28/95	Dave Leaver 9/29/95
1	Revision 1 of Attachment 3	James Metcalf 2/2/96	Dave Leaver 2/5/96
2	Modified discussion of two leak paths: - MSIV leak - Main condenser leak Clarified main steamline/condenser deposition in list of TVADOSE features Revised "Key Assumption 3" to reflect deposition in main condenser Changed Conservatism 9 Removed Conservatism 11 Revised title and summary of Calc 04002H.08 to include main condenser Revision 2 of Attachment 2 Revision 2 of Attachment 3 Revision 1 of Attachment 5 Revision 1 of Attachment 6 Revision 1 of Attachment 7 Revision 1 of Attachment 10	James Metcalf 6/27/96	Dave Leaver 6/28/96

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8	0	PSAT Calculation 04011H.06, "Source Term for Use on Browns Ferry Application of NUREG-1465", September 28, 1995
9	0	PSAT Calculation 04011H.07, "Drywell Leakage Rate Direct to Environment Mimicking Case 2 Early Bypass of SGTS", September 28, 1995
10	1	PSAT Calculation 04002H.08, "Aerosol Removal Efficiency in Main Steam Lines and Main Condenser", May 31, 1996
11	0	PSAT Calculation 04002H.09, "Elemental Iodine Filter Efficiency in Main Steam Lines", September 28, 1995
12	N/A	Fax dated September 1, 1995 from Don McCamy (TVA Technical Contact) to James Metcalf (PSAT Project Manager) providing a reference for Item 3.28 of the Project Data Base
13	N/A	Notes of Telecon dated September 13, 1995 between James Metcalf (PSAT Project Manager) and Don McCamy (TVA Technical Contact) providing concurrence for time-shift of fumigation X/Qs (Item 5.1 of Project Data Base)

Purpose

The purpose of this calculation package is to compile a set of Safety-Related calculations which, together, constitute the application of the revised DBA source term from Reference 1 to the Browns Ferry Nuclear Power Station for the purpose of demonstrating compliance with 10CFR100 and with 10CFR50, Appendix A, GDC-19. Two cases are calculated: Case 1 which includes three trains of SGTS operating and Case 2 which includes two trains of SGTS operating.

Methodology

The approach makes use of two computer models and manual calculations documented in Attachments 1 through 11. Attachment 2 is not a calculation, itself, but rather a plant-specific data base which has been used to control and coordinate the preparation of the calculations in three locations (the two Polestar Applied Technology offices in Los Altos, CA and Portsmouth, NH and the ABB-Combustion Engineering office, a subcontractor to Polestar, in Windsor, CT) as well as to facilitate TVA-Browns Ferry review of plant-specific input.

The two computer models include STARNAUA (Reference 2), an aerosol physics code

proprietary to Polestar, and TVADOSE (Reference 3), a slightly modified version of the proprietary LDOSE dose calculation code belonging to ABB-CE.

The overall approach has been to treat the containment as a two-control volume model (drywell and torus airspace) up until the time that the core debris from the recovered core damage accident (see Key Assumption 1 and Attachment 3) has been quenched. Beyond that time, a high mixing rate is used between the two control volumes to effectively create a single-control volume containment similar to current practice. Prior to the debris quench, vent flow and suppression pool bypass from the drywell to the torus is considered. The source term (the activity release from the reactor to the drywell) is based on Reference 1 (see Attachment 8).

Release paths that are included are as follows (see Attachment 1):

Path	Comment
Drywell leak	Equal to two percent of the drywell volume per day - leak is to the reactor building
Torus airspace leak	Equal to two percent of the torus airspace volume per day - leak is to the reactor building
MSIV leak	Equal to 250 scfh from the drywell (total for four steamlines) - leak is to the main condenser via the drain line pathway and to the high pressure (HP) turbine via the stop valve leakage pathway (only the former pathway is included in the dose model - see "Leak from main condenser" below)
CAD operation	Equal to 8340 cfh from the torus airspace intermittently over 30 days (containment is well-mixed by the time of CAD operation so a drywell source would be equivalent) - all of the flow is through the SGTS filters, 99.97% of the flow is to the stack, 0.03% to the stack room (i.e., stack bypass)
Torus vent leak	Equal to 10 cfh from the torus airspace - leak is to the stack
SGTS operation	Equal to 1.32E6 cfh for Case 1 and 0.9E6 cfh for Case 2 - flow is from the reactor building to the stack (except for 300 cfh which goes to the stack room as bypass) through the SGTS filters
SGTS bypass	Equal to 3.1E-3 cfh directly from drywell for Case 2 only (leakrate is two percent per day with reduction factor of approximately 40000 to account for reactor building hold-up) - leak is to the

environment

Stack room leak	Equal to 300 cfh (assumed to be same as inleakage, see "SGTS operation", above) - leak is to the environment
Main condenser leak	Equal to 250 cfh (assumed to be same as leakage out of drywell as scfh, see "MSIV leak", above) - leak is to the environment (leak is actually to turbine building but turbine building hold-up is neglected - leak also includes 0.5% which goes to HP turbine, but since HP turbine hold-up is equivalent to main condenser hold-up, only the main condenser pathway is modeled for dose assessment)

The TVADOSE code integrates the release through the various pathways; and, using Reference 4-based dose conversion factors, calculates doses at the EAB (integrated over the first two hours of the accident) and at the LPZ and in the control room (integrated over 30 days). TVADOSE also includes the following:

- Deposition in the drywell and, after core debris quench, in the torus airspace
- Suppression pool scrubbing
- Filtration in the main steamlines representing main steamline/condenser deposition
- Active filtration by the SGTS and CREVS, but without credit for charcoal adsorbers

These effects are included in TVADOSE via filtration efficiencies and removal "lambdas" provided by Polestar. These matters are discussed further under Summary of Calculations.

Key Assumptions/Conservatisms

Key Assumption 1: The core damage which leads to the DBA source term of Reference 1 is arrested by the restoration of core cooling at about two hours after the start of the accident. Discussion: This is an extension to operating plants of a position presented in Reference 5 for advanced LWRs and is discussed fully in Attachment 3.

Key Assumption 2: The source terms of Reference 1 can be applied to Browns Ferry without regard for fuel burn-up limitations. Discussion: This issue derives from a caveat in Section 3.6 of Reference 1 and is being pursued separately by NEI with NRC. Since the Reference 1 source term is specified in terms of fractions of core inventory and since core inventories are calculated for this

application to Browns Ferry using an appropriate burn-up, the caveat is not related to core inventory. As noted in Reference 1, the focus of the caveat is the gap activity release; and because of the nature of this application to Browns Ferry, the results would not be greatly sensitive to the exact gap release timing or magnitude in any case.

Key Assumption 3: The MSIV leakage release is entirely through the drainline and main condenser; there is no release included via the high pressure (HP) turbine. Discussion: From Reference 6 it is observed that the flow split between the drainline/main condenser flowpath and the HP turbine flowpath is about 200:1. Since deposition in the steamlines applies to either flowpath, the only potential difference between the two flowpaths is differential hold-up and retention in the main condenser vs. the HP turbine. HP turbine retention is assumed to be zero in the calculation of the main steamline/main condenser overall aerosol and elemental radioiodine removal efficiencies (see Attachments 10 and 11); and, therefore, the only other mechanism that could create a difference in the calculated relative dose between the two pathways is unequal delay due to hold-up. The hold-up effect is estimated to be of the order of a factor of two to three in dose reduction based on the main condenser (non-negligible); but since Reference 6 gives a hold-up volume about a factor of 200 less for the HP turbine (which is the same as the flow split), similar hold-up would be expected for the HP turbine. Therefore, the HP turbine flowpath can be modeled as a simple bypass of the main condenser in the calculation of the overall main steamline/main condenser "filter" efficiency (which is what is done in Attachment 10), and the HP turbine volume, itself, can be neglected in the dose model; i.e., all of the flow can be assumed to go through the main condenser (which is what is done in Attachment 1).

Key Assumption 4: A pH value of at least 6.0 will be maintained in the containment water (in particular, the suppression pool) for at least 30 days (3.7 half-lives of I-131) after the start of the accident. Discussion: A non-Safety Related scoping study was conducted as part of this project to support this assumption. This non-Safety Related study is being followed-up with a Safety-Related calculation being performed under a separate contract.

Key Assumption 5: The results of these analysis are sufficiently conservative to constitute a basis for demonstrating compliance with the requirements of 10CFR100 and with 10CFR50, Appendix A, GDC-19. Discussion: The source terms of Reference 1 are comparable in conservatism to the DBA source terms previously used on Browns Ferry as based on 10CFR100 (and Reference 7) and subsequent regulatory guidance. The noble gas and iodine release

fractions (which are the main determinants of the whole body and thyroid dose evaluations specified in 10CFR100) are about the same. The Reference 1 timing and chemical form, while different from the previous source terms, are nonetheless conservative compared to what is expected under actual accident conditions (e.g., the 1979 accident at Three Mile Island) and provide a more physically correct representation of activity release to the containment. Moreover, in terms of activity transport within and through the containment system and release to the environment, there are many other conservatisms included in the calculations of Attachments 3 through 11. These are as follows:

- Conservatism 1: Only gamma energy is considered in calculating the core power used to determine vent flow from the drywell to the torus during core degradation and the associated debris quench. Core debris sensible heat during the core degradation (and the formation of a debris bed that would enhance heat transfer to the overlaying water), metal-water reactions, and beta heating are neglected. See Attachment 3.

- Conservatism 2: A conservatively small sedimentation area has been specified for the drywell. Moreover, the sedimentation removal lambdas calculated for the drywell are applied to the torus airspace after the debris quench. (No sedimentation is credited in the torus airspace prior to the debris quench). Due to the effects of pool bypass (see Conservatism 5) the mass airborne in the torus airspace at the end of the quench is greater than that airborne in the drywell, and the torus airspace has a smaller volume and a greater sedimentation area. Therefore, to apply drywell lambdas in the torus after debris quench is a significant conservatism. See Attachment 4.

- Conservatism 3: Hygroscopicity is neglected in the determination of sedimentation lambdas. See Attachment 4.

- Conservatism 4: The maximum iodine DF is based on the maximum pool temperature and does not consider the long-term iodate reaction which will tend to suppress iodine re-evolution. Both of these effects will tend to limit the long-term potential for iodine re-evolution even if the containment pH falls below the value of 6.0 assumed in the analysis. See Attachment 5.

- Conservatism 5: The pool bypass flow area used to assess the impact of pool bypass on pool scrubbing efficiency is ten times the value used as the basis

for the surveillance test acceptance limit. Moreover, a review of surveillance test data indicates that the actual measured value is, on average, substantially below the test acceptance value. See Attachment 6.

- Conservatism 6: Te-132 is treated as elemental I-132 except for half-life which corresponds to Te-132. This is to account for the fact that Te-132 (which may have been removed as particulate and subsequently held up on filters and/or in main steam piping) may re-evolve as elemental I-132. By treating the Te-132 as elemental I-132 from the beginning (with the Te-132 half-life), the same amount of I-132 activity is released as would be the case in a mechanistic model of the process described, but the release occurs much more rapidly. This means that more adverse X/Q values, breathing rates, and control room occupancy factors are used in calculating the thyroid dose contribution of Te-132 than would be the case with a mechanistic model. See Attachment 7.

- Conservatism 7: In general, the PWR gap release is expected to occur much more rapidly than the BWR gap release (refer to discussion in Reference 1). However, this application has used a gap release start time of 30 seconds (appropriate for a PWR) to represent the Browns Ferry BWR. See Attachment 8.

- Conservatism 8: The impact of non-noble gas and non-radioiodine components of the release on the 10CFR100 and GDC-19 dose calculations has been assessed in two ways: (1) the important isotopes of radiocesium and Te-132 have been included explicitly, and (2) the "other" radionuclides have been approximated using a one percent release to the containment atmosphere as described in Reference 7 (with the exception that these radionuclides are subsequently treated as aerosol and released to the environment accordingly). By doing so, the impact of the "Other" has been overstated by about a factor of ten as compared to rigorous application of Reference 1. See Attachments 7 and 8.

- Conservatism 9: Aerosol retention in the steamline portions inboard of the outboard MSIVs has been neglected. See Attachment 10.

- Conservatism 10: The conversion of deposited elemental iodine to re-evolved organic iodine is assumed to be instantaneous as opposed to requiring several days. See Attachment 11.

References

Reference 1: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 2: "STARNAUA, A Code for Evaluating Severe Accident Aerosol Behavior in Nuclear Power Plant Containments: Code Description and Validation and Verification Report", PSAT C101.02, Revision 0, May 1995

Reference 3: ABB-Combustion Engineering Calculation "TVADOSE: A Computer Program for the Calculation of Browns Ferry Advanced Source Term (ABB-Combustion Engineering Proprietary)", 1066-S&T95-C-001, September 1995

Reference 4: International Commission on Radiological Protection, "Limits for Intake of Radionuclides by Workers", ICRP Publication 30, 1979

Reference 5: Taylor, J., "Proposed Issuance of Final NUREG-1465, 'Accident Source Terms for Light-Water Nuclear Power Plants'", SECY-94-300, December 15, 1994

Reference 6: General Electric Nuclear Energy, "Browns Ferry Nuclear Plant, Calculation of LOCA Doses to the Control Room from MSIV Leakage", DRF A00-04146, Section C, Attached to Letter ALJ92049 from A.L. Jenkins (GE Nuclear Energy) to J.L. Kamphouse (TVA) dated August 28, 1992

Reference 7: DiNunno, J. J., et al., "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844, March 1962

Summary of Calculations

Polestar calculations provide the following:

- PSAT 04011H.01 (Attachment 3):

  This calculation establishes the overall thermal-hydraulic behavior of the containment and calculates the exchange rate between the drywell and the torus airspace (Items 3.10 and 3.11 of Attachment 2).

- PSAT 04001H.02 (Attachment 4):

  This calculation establishes the removal rate of aerosol and elemental iodine from the containment atmosphere (Items 4.3 and 4.4 of Attachment 2) and the volumetric leakrate

for MSIV leakage (Item 3.23 of Attachment 2).

- PSAT 04011H.03 (Attachment 5):

  This calculation establishes the maximum iodine decontamination factor (ratio of total iodine in containment to that airborne)(Items 4.5 and 4.6 of Attachment 2).

- PSAT 04011H.04 (Attachment 6):

  This calculation establishes the scrubbing efficiency of the suppression pool (Item 4.2 of Attachment 2).

- PSAT 04011H.05 (Attachment 7):

  This calculation provides radionuclide data not available in the TACT5 User's Manual (NUREG/CR-5106) for Item 1 of Attachment 2.

- PSAT 04011H.06 (Attachment 8):

  This calculation defines the source term for Browns Ferry based on Reference 1 (Items 2.1 through 2.3 of Attachment 2).

- PSAT 04011H.07 (Attachment 9):

  This calculation provides the leakrate directly from the drywell to the environment for the early part of the Case 2 dose assessment (when the reactor building internal pressure is not sub-atmospheric)(Item 3.20 of Attachment 2).

- PSAT 04002H.08 (Attachment 10):

  This calculation provides the removal efficiency for aerosol in the main steamline/main condenser (Item 4.7 of Attachment 2).

- PSAT 04002H.09 (Attachment 11):

  This calculation provides the removal efficiency for elemental iodine and tellurium in the main steamline (Item 4.7 of Attachment 2).

In addition to the above Polestar calculations, the ABB-CE dose calculation 1066-S&T95-C-002 provides the EAB, LPZ, and control room thyroid, whole body, and (for the control room) skin doses. This calculation is Attachment 1.

Results

The results are presented in the following table. Case 1 (three trains of SGTS operating) produces the highest doses and is, therefore, the limiting case.

Location and Duration	Dose Type	Dose Magnitude - rem Case 1	Case 2
Control Room - 30 day	Thyroid	17.9	17.4
	Whole Body	0.046	0.045
	Skin	1.79	1.78
EAB - 2 hour	Thyroid	3.16	2.74
	Whole Body	0.075	0.059
LPZ - 30 day	Thyroid	5.79	5.55
	Whole Body	0.282	0.269

Limiting case contributions are as follows:

- I-131 to control room thyroid dose = 16.64 rem
  I-133 to control room thyroid dose = 1.13 rem
  Te-132 to control room thyroid dose = 0.06 rem
  Other contributors = 0.07 rem
- Of the 16.64 rem I-131 thyroid dose in control room:
  12.51 rem organic
  3.21 rem elemental
  0.92 rem particulate
- Non-noble gas, radioiodine, radiocesium, Te-132 (i.e., the "Other") whole body dose is 0.7% of the 2-hour EAB total and 0.12% of the 30-day LPZ total and is, therefore, confirmed to be negligible.

Conclusions

These doses, which have been conservatively calculated, are well within the limits of 10CFR100 and 10CFR50, Appendix A, GDC-19.

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Attachment 1

ABB-CE Calculation 1066-S&T95-C-002

"Calculation of Containment Leakage Doses for Browns Ferry"

9604180255 48pp

Document Title: CALCULATION OF CONTAINMENT LEAKAGE DOSES FOR BROWNS FERRY

RECORD OF REVISIONS

Rev. No.	Explanation of Revision	Revised Page No.	Author	Reviewer	Approver	Date
0	Initial Document	n/a	R. E. Schneider	M. Michonski	R. E. Jaquith	9/29/95

CHECKLIST NO. 2
REVIEW OF DESIGN ANALYSIS

1. Is the material presented sufficiently detailed as to purpose, method, assumptions, design input, references, and units? ☑ Yes ☐ N/A

2. Were the inputs correctly selected and incorporated into the analysis? ☑ Yes ☐ N/A

3. Have the assumptions necessary to perform the analysis been adequately documented and justified? ☑ Yes ☐ N/A

4. Are applicable codes, standards, and regulatory requirements, including issue and addenda, employed in the analysis properly identified, and were their requirements met? ☑ Yes ☐ N/A

5. Have interface requirements been satisfied? ☑ Yes ☐ N/A

6. Have the adjustment factors, uncertainties, and empirical correlations used in the analysis been correctly applied? ☑ Yes ☐ N/A

7. Was an appropriate analysis or calculation method used? ☑ Yes ☐ N/A

8. Have the versions of the computer codes employed in the analysis been certified for application? If not, has sufficient information been provided to enable verification of the program and results? ☑ Yes ☐ N/A

9. Is the purpose sufficiently clear, and are the results and conclusions reasonable when compared to inputs? ☑ Yes ☐ N/A

10. Has an appropriate title page similar to Exhibit 3.4-1 been used? ☑ Yes ☐ N/A

11. Are all pages sequentially numbered and marked with the analysis number? ☑ Yes ☐ N/A

12. Where necessary, are the assumptions identified for subsequent reverifications when the detailed design activities are completed? ☑ Yes ☐ N/A

13. Is the presentation legible and reproducible? ☑ Yes ☐ N/A

14. Have all cross-outs or overstrikes in the documentation been initialed and dated by the Author? ☑ Yes ☐ N/A

Michael D. Michorski 9/29/95

Reviewer Signature Date

REVIEWER'S COMMENTS

No significant errors were discovered. The results of the cases are reasonable considering the inputs which were used.

TABLE OF CONTENTS

I. INTRODUCTION/PURPOSE

The purpose of this calculation is to provide containment leakage dose assessments for the TVA Browns Ferry Nuclear Unit for a design basis maximum hypothetical accident using source term input based on the revised source term as defined in NUREG-1465 (Reference 7). This information will be combined with other calculations to be performed by Polestar Applied Technology, Inc.(PSAT) to establish the total radiological dose following the 10CFR100 maximum hypothetical accident.

Specifically, this report provides two calculations for the 2 hour and 30 day doses in the control room and at the exclusion area boundary (EAB) and low population zone (LPZ):

Case 1: Three SGTS Fans
no SGTS/CREVS charcoal filters
SGTS flow of 22,000 CFM

Case 2: Two SGTS Fans
no SGTS/CREVS charcoal filters
SGTS flow of 15,000 CFM

Main steam line leakage is assumed to be initially 120 CFH and increase after 7230 seconds to 177.5 CFH and remain at that value for the remainder of the 30 day calculation.

Calculations will be performed using TVADOSE (See Reference 2) (version TVD92395). The equations governing TVADOSE are presented herein. The validation of TVADOSE for application to Browns Ferry is contained in Reference 2.

Results of this calculation show that the leakage contribution to the 30 day control room dose is under 18 Rem. Case 1 was predicted to be the more limiting case due to the higher outflow from the Reactor Building. Additional details, including the EAB and LPZ thyroid, and whole body are presented in Section VII.

II. DISCUSSION and METHOD OF ANALYSIS

II.1 Introduction

The methodology used for this calculation is defined below. The equations defined in this section are implemented for the Browns Ferry Nuclear Unit. The resultant program (TVADOSE) has evolved from an Combustion Engineering's "in house" LDOSE computer code (Reference 1). The modified code version is fully described and specifically qualified for use in the Browns Ferry calculation in Reference 2 . Modifications made to LDOSE to create TVADOSE are based on the workscope outlined in Reference

The model and equations implemented in TVADOSE are based on standard engineering methodology for the calculation of activity transport; doses calculations are based on a Dose Conversion Factors (DCFs) Methodology with DCFs provided to ABB via Polestar Applied Technology , Inc. in Reference 3. All relevant equations are presented in this document.

II.2 Overview of Model

II.2.1 Calculation of Area Activity

The computer model to be used for TVADOSE consists of 7 nodes, with eight identified regions (See Figure II-1). These regions are:

1. Atmosphere
2. Drywell
3. Wetwell
4. Control Room
5. Reactor Building
6. Stack Base
7. Main Steam Line Piping
8. Condenser

The model follows the guidelines of Reference 2. The regions are defined as follows:

FIGURE II.1. NODAL ARRANGEMENT FOR TVADOSE

PROPRIETARY

FIGURE II.2. SOURCES OF ACTIVITY TO THE CONTROL ROOM

PROPRIETARY

FIGURE II.3 SOURCES OF ACTIVITY TO THE EXCLUSION AREA BOUNDARY

PROPRIETARY

FIGURE II.4 SOURCES OF ACTIVITY TO THE LOW POPULATION ZONE

PROPRIETARY

Region 1: Atmosphere

Region 1 is not used in the activity calculations. Their impact on dose is evaluated based on the methodology defined in section II.2.2.

Region 2: Drywell

Region 2 is the drywell. All source releases from the RCS fuel are directed into region 2. Radionuclide removal in this region is allowed via natural and active removal mechanisms. This is accomplished by providing a radionuclide removal time constant. This time constant is user specified.

Region 3: Wetwell

Region 3 is the BWR wetwell (torus). All flow from the drywell that passes into the wetwell must pass through vent pipes. When the vacuum breakers on the vent pipes are closed, the gas mixture driven from the drywell into the wetwell will exit at a submerged elevation within the suppression pool. Fission products traversing this pass will be scrubbed (decontaminated) prior to entering the wetwell air space.

When the vent pipe vacuum breakers are open, the gas space of the wetwell and drywell communicate directly, without further scrubbing.

Fission product removal in the wetwell air space is considered via a user input table of radionuclide removal time constant.

Region 4: Control Room

Region 4 is the Control Room. The control room receives air intake from the environment. Both filtered and unfiltered air enters the control room.

The activity entering the control room originates from:

- reactor building and wetwell releases through the stack
- stack room releases
- drywell releases
- main condenser releases due to leakages through the main steam isolation valve

Region 5: Reactor Building

Region 5 is the reactor building. In this model the reactor building accepts containment leakage from the drywell and wetwell air space. ESF leakage is not modeled in the TVADOSE model. This is consistent with the guidelines of Reference 4.

Region 6: Stack Room

Region 6 is room at the base of the stack. Leakage may enter this room via filtered leakage originating in the wetwell and the reactor building. Leakage from the stack room is not filtered.

Region 7 and 8:Main Steam Line and Main Condenser

Node 7 and 8 are only weakly coupled to the remainder of the model. Flow leaving the Drywell (Region 2) through the MSIVs enters the main steam line volume (Region 7). The activity of this flow is decremented by the decontamination factor associated with pipe settling, plateout and natural deposition processes.

Region 8 is the Main Condenser. Fission products enter the main condenser at a low rate and are diluted by the large air volume of the condenser. Settling of the fission products within the condenser is modeled with a user input radionuclide removal time constant.

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Introduction of the source into the containment drywell is based on the Revised Source Term and is provided as input into this calculation via Reference 3. This information is summarized below.

Source Term (S(I,i,k)) (fraction of initial inventory released to the drywell) (Ref. 3)					
	TIME(SEC)				
	0 TO 1830	1830-7230			
Noble Gases	.05	0.95			
Iodine	.05	0.25			
Cesium	.05	0.20			
Te-132	0.0	0.05			
other	0.0	0.01			

III. ASSUMPTIONS / INPUT

A list of assumptions follows:

1. ESF leakage is not considered

   Per scope of project as defined by Polestar Technology , Inc. and TVA (Reference 4).

2. Source term composition and release characteristics are based on NUREG-1465 Revised Source Term. This information is provided in Reference 4.

   This is consistent with the intent of the calculations. Releases into containment are assumed linear over the appropriate time interval.
   All releases are delayed until 30 seconds.

3. Dose Conversion Factors based on specifications supplied in the Polestar data base. (Reference 4)

4.. Tellurium is considered to behave as elemental iodine for purposes of scrubbing. Tellurium doses are based on I-132 DCFs (See workscope, Reference 4))

5. Atmospheric dispersion from regions 3 and 6 are assumed equal. No impact on results since region 3 releases do not contribute to dose calculations

6. Kr-90 contribution is neglected due to its short half life (see References 3 and 6). This is accomplished by setting DCFs for Kr-90 equal to zero.

7. All filters neglect removal due to charcoal filters. Elemental and organic Iodine removal in HEPA filters assumed to have a zero efficiency (References 3 and 4)

8. No fission product removal due to settling or plateout is assumed in the Main condenser.

   This is a conservative assumption in that increased airborne activities implies increased leakage.

9. Fission product removal in the main steam line allowed for elemental iodine and particulates (See References 3 and 4)

10. radionuclides are assumed to instantaneously mix with volume atmosphere. This assumption is consistent with standard review plan methodology and the current workscope (Reference 4)

11. Fumigation time interval is selected at the worst one half hour period over the first two hours. This occurs in the 1.5 to 2 hour time frame. Including this effect later in the event acknowledges the impact of the later release of radionuclides. Doses will be maximized with this assumption since the later interval has the higher atmospheric releases.

IV. CALCULATION

IV.1 Radionuclide and Dose Data

Data for Radionuclide Activity, decay constants and Dose Conversion Factors are obtained from Reference 3, Section 1.

	ISOTOPE	L D O S E NAME	ACTIVITY	D E C A Y LAMBDA	WB DCF	BETA DCF (skin)	THYROID DCF
			CI	DIS /SEC	Rem-m³/(Ci-S)	Rem-m³/(Ci-S)	10⁴/ci*
IS		ISNAM(IS)	AOREF(IS)	YD(IS)	DCFWB2(IS)	DCFSK2(IS)	DCFTH2(IS)
10	Kr-83m	KRYPTO	1.127E+07	1.04E-04	1.27E-05	0	0
11	Kr-85m	KRYPTO	2.351E+07	4.39E-05	2.30E-02	4.97E-02	0
12	Kr-85	KRYPTO	1.360E+06	2.04E-09	3.31E-04	4.84E-02	0
13	Kr-87	KRYPTO	4.481E+07	1.52E-04	1.33E-01	3.36E-01	0
14	Kr-88	KRYPTO	6.303E+07	6.89E-05	3.38E-01	7.76E-02	0
15	Kr-89	KRYPTO	7.653E+07	3.63E-03	3.03E-01	3.47E-01	0
16	Kr-90**	KRYPTO	7.554E+07	.215E-1	0.0	0.0	0
17	Xe-131m	XENON	1.050E+06	6.68E-07	1.25E-03	1.33E-02	0
18	Xe-133m	XENON	5.960E+06	3.49E-06	4.29E-03	2.96E-02	0
19	xe-133	XENON	1.847E+08	1.52E-06	4.96E-03	9.67E-03	0
20	Xe-135m	XENON	3.761E+07	7.40E-04	6.37E-02	2.14E-02	0
21	Xe-135	XENON	6.610E+07	2.09E-05	3.59E-02	6.32E-02	0
22	Xe-137	XENON	1.655E+08	2.96E-03	2.83E-02	4.59E-01	0
23	Xe-138	XENON	1.552E+08	6.80E-04	1.87E-01	1.47E-01	0
1	I-131	IODINE	9.378E+07	9.96E-07	5.59E-02	3.07E-02	110
2	I-132	IODINE	1.355E+08	8.27E-05	3.55E-01	1.10E-01	0.63
3	I-133	IODINE	1.898E+08	9.22E-06	9.11E-02	8.90E-02	18
4	I-134	IODINE	2.081E+08	2.23E-04	4.11E-01	1.42E-01	0.11
5	I-135	IODINE	1.778E+08	2.86E-05	2.49E-01	7.86E-02	3.1
6	Cs-134	CESIUM	2.508E+07	9.55E-09	2.58E-01	1.15E-01	0
7	Cs-137	CESIUM	1.503E+07	7.29E-10	9.30E-02	1.27E-01	0
8	Te-132	TELLUR	1.333E+08	2.51E-06	3.55E-01	1.10E-01	0.63
9	Other	OTHER	4.967E+9	7.05E-5	.168	0	0

* INHALED
** DCF set = 0.00 per ref. 6
The following factors are not used in the TVADOSE calculation: DCFTH1, DCFSK1, DCFWB1, EB and EG these parameters appear in the database but are not used in TVADOSE.

```
LOCATOR CONSTANTS:

I131- "IS" SUBCRIPT FOR ENTRY FOR I-131  :  1
NID - TOTAL NUMBER OF IODINE ISOTOPES: 5
KRN -TOTAL NUMBER OF KRYPTON ISOTOPES: 7
IST -TOTAL NUMBER OF ISOTOPES: 23
NOI-TOTAL NUMBER OF OTHER ISOTOPES: 1
NCS-TOTAL NUMBER OF CESIUM ISOTOPES:2
NXE-TOTLA NUMBER OF XENON ISOTOPES :7
```

IV.2 Revised Source Term Release Profile

Data obtained from Reference 3 items 2.1, 2.2, 2.3.

a) Fractional Releases (REVISED SOURCE TERM)

Fractional Releases into Containment in time Interval					
Time Interval (sec)	Noble Gases	Iodine	Cesium	Tellurium	Other
0 to 30	0	0	0	0	0
30 to 1830	0.05	0.05	0.05	0	
1830-7230	0.95	0.25	0.20	0.05	0.01
7230 to End	0.0	0.0	0.0	0.0	0.0

Note that the Iodine contribution includes aerosols (CsI) + elemental + organic iodine

From Reference 5 item 2.2 and 2.3

total iodine between 30 to 1830 sec = .0024 + .000075 + .0475 =.049975 (round up to .05)

Ratio of CSI/Total = .0475/.05= 0.95
Ratio of I2(elemental) / Total = 0.048
Ratio of Organic I/Total = .000075/.05 =.0015
Note the ratios do not add to 1. Therefore,

Fraction CsI = 0.95
Fraction I2(gas)=.0485
Fraction Organic=.0015

This composition applies to both early and late releases

b) Iodine Composition

From (a) above

FRCTK:

Particulate Iodine: 0.95
Elemental Iodine : 0.0485
Organic Iodine : 0.0015

The code assumes the following:

All aerosols are particulate in nature and can be filtered via particulate filters

All noble gases cannot be filtered

Tellurium is an aerosol that is assumed to not be filtered via filter flowpaths (treated like elemental iodine)

IV.3 Browns Ferry Model System Description

a) Volumes (Data taken from Reference 3)

NODE NO	TVADOSE var.	ITEM NO Ref. 3	DESCRIPTION	VOLUME CUBIC FT	COMMENT
1			ENVIRONMENT	1.00E+08	ARBITRARY VV(1) NOT USED
2	VV(2)	3.1	DRYWELL	159000	ITEM 3.1
3	VV(3)	3.2	WETWELL	124000	ITEM 3.2
4	VV(4)	3.6	CONTROL ROOM	210000	ITEM 3.6
5	VV(5)	3.4	REACTOR BLDG	1.93E+06	ITEM 3.4
6	VV(6)	3.5	STACK ROOM	34560	ITEM 3.5
7	VV(7)	3.7	MS PIPE	692	ITEM 3.7
8	VV(8)	3.8	MAIN CONDENSER	122400	ITEM 3.8

IV.4 REGION FLOWRATES

TVADOSE ALLOWS FIXED AND VARIABLE FLOWRATES. THE FLOWRATES THAT ARE FIXED ARE:

L25, L35 L31U, L81,L51, L61, L56, L78, L14U, L14F --

FLOWRATES THAT VARY WITH TIME INCLUDE:

L21, L23, L31F, L32, L27

ALL LEAKAGES ARE INPUT TO THE CODE AS A PARAMETER WITH GG REPLACING L.

SUMMARY OF FIXED FLOWRATES			
VARIABLE NAME	DESCRIPTION	VALUE (CFH)	REF 3, ITEM
GG14U	CR UNFILTERED INFLOW	2.23E+5	3.22
GG14F	CR FILTERED INFLOW	1.8E+5	3.21
GG25	DW TO RB LEAKAGE	132.5	3.12
GG31U	WW TO STACK THROUGH HARDENED VENT	10	3.16
GG61	STACK ROOM TO ENVIRONMENT	300	3.19
GG35	WETWELL LEAKAGE TO RB	103.3	3.13
GG51 CASE 1	RB FLOW TO SGTS FILTER TO STACK	1.32E+6	3.14
GG51 CASE 2	RB FLOW TO SGTS FILTER TO STACK	0.9E+6	3.14
GG56	FLOW FROM SGTS FILTER TO STACK ROOM	300	3.15
GG78	MAIN STEAM LINE TO CONDENSER	475	3.24
GG81	LEAKAGE FROM MAIN CONDENSER	250	3.25

IV.4 (CONT'D)

TIME VARYING FLOWS:

FLOW GG21: FLOW FROM DRYWELL TO ENVIRONMENT: UNFILTERED (ITEM 3.20 OF Ref 3)

GG21 = 0 for all time for case 1.

TIME(sec)	FLOWRATE (CFH)
0.0	3.1E-3 (case 2)
105	0.0
3.E+6	0.0

FLOW GG23 AND GG32 MIXING AND TRANSPORT FLOWS WITHIN THE CONTAINMENT (ITEMS 3.10 AND 3.11)

TIME (SEC)	GG23:DW-WW	GG32:WW-DW
	CFH	CFH
0.0	0.0	0.0
1830.	1.6E+5	0.0
7230	1.2E+6	0.0
7890	1.2E+6	1.2E+6
3.E+6	1.2E+6	1.2E+6

NOTE 30 DAYS = 2.592E+6 SECONDS (CASE RUNS TO 30 DAYS)

GG27: LEAKAGE FROM DRYWELL TO MAIN STEAM LINE (3.23)

TIME(SEC)	GG27 (CFH)
0.0	120
7230	177.5
3.E+6	177.5

GG31F: FILTERED FLOE FROM WW THROUGH CAD (ITEM3.17)

TIME (DAYS)	GG31F (CFH)
0	0.0
10	8340
11	0.0
20	8340.
21	0.0
29	8340
30	0.0

SET FLOW BEYOND 30 DAYS =0. (NOT USED IN CALC)

PROPRIETARY

B) REMOVAL COEFFICIENTS:

Removal coefficients are provided for the drywell, wetwell gas space and the main condenser gas space. See items 4.3 and 4.4 of Reference 3.

TIME (SEC)	LAMBDA DW		TIME (SEC)	LAMBDA WW	
	(PER HOUR)	REF. ITEM 4.3		(PER HOUR)	REF ITEM 4.4
0	0		0	0	
30	.35		7890	.95	
2400	.45		8570	.85	
3200	.55		9840	.75	
4000	.65		11760	.65	
4885	.75		14530	.55	
6300	.85		18650	.45	
7360	.95		24980	.35	
8570	.85		35570	.25	
9840	.75		57220	.162	
11760	.65		100000	0	
14530	.55		3.E+6	0	
18650	.45				
24980	.35				
35570	.25				
57220	.162				
10000	0.0				
3. E + 6	0.0				

IV.6 Atmospheric Dispersion

CHI/Q Values for Various Regions (SEC/M3)					
node 5			STACK RELEASE		
XQ5..	ITEM 5.1	T I M E INT(XQ5T) (hrs)	EAB XQ5EB	LPZ XQ5LP	CR XQ5CR
	1	0 TO 1.5	9.70E-07	8.00E-07	5.91E-15
	2	1.5 TO 2	2.40E-05	1.300E-05	3.31E- 5
	3	2 TO 8		8.00E-07	3.80E-15
	4	8 TO 24		4.00E-07	3.00E-15
	5	24 TO 96		2.00E-07	1.90E-15
	6	96 TO 720		6.50E-08	9.60E-16
node 6				STACK ROOM RELEASE	
XQ6..	ITEM 5.2	XQ6T(hrs)	EAB- XQ6EB	LPZ XQ6LP	CR XQ6CR
	1	0 TO 2	1.22E-04	5.65E-05	8.89E-04
	2	2 TO 8		5.65E-05	7.30E-04
	3	8 TO 24		2.24E-05	6.60E-04
	4	24 TO 96		7.94E-06	5.40E-04
	5	96 TO 720		1.71E-06	4.00E-04
node 8				MAIN CONDENSER RELEASE	
XQ8..	ITEM	end time interval			
	ITEM 5.3	XQ8T(hrs)	EAB XQ8EB	LPZ XQ8LP	CR XQ8CR
	1	O TO 2	2.70E-04	1.32E-04	1.74E-04
	2	2 TO 8		6.02E-05	1.47E-04
	3	8 TO 24		4.07E-05	1.27E-04
	4	24 TO 96		1.73E-05	1.01E-04
	5	96 TO 720		5.10E-06	7.20E-05
node 2				DRYWELL RELEASE	
XQ2..	5.4				
	1	2	0	0	1.12E-03

XQ2 ONLY IMPACTS RELEASE FOR DURATION OF GG21 RELEASE

IV.7 Breathing Rates and Occupancy Factors

(Data From Ref. 3)

a. breathing rates		ITEM 5.5
	end time	rate
	(hr)	m3/sec
	8	3.47E-04
	24	1.75E-04
	720	2.32E-04

b. occupancy factors			ITEM 5.6
	end time		factor
	(hrs)		
	24		1
	96		0.6
	720		0.4

V. CODE USED / UPDATES

The calculation employs the TVADOSE computer code (See Reference 2) version TVD92395.

VI. COMPUTER RUN SUMMARY

Case 1 refers to the base analysis as defined in Section IV. Case 2 is similar to case 1 except that per Reference 3:

GG21 = 3.1E-3 CFH for 105 seconds

and

GG51 = 0.9E+6 CFH

COMPUTER OUTPUT LIST

Case # or Name	JOB ID	Run Date/Time Cd Rom Date	Description
1 or BFCASE1	see below	Run date 9/23/95 Run time 11:22:57 Cd Rom date 9/25/95	HIGH RB FLOW; OUTPUT: BFCASE1.OUT
2 or BFCASE2	see below	Run date 9/23/95 Run time 11:25:40 Cd Rom date 9/25/95	LOW RB FLOW OUTPUT; BFCASE2.OUT

Filename:	Job Id:	Description:
bfcase1.inp	0u5ha26c.cdf	Input file
bfcase1.out	0u5hab88.cdf	Standard output file
* bfcase1.act	0u5h980o.cdf	Regional activity file
bfcase1.dpr	0u5h9s4g.cdf	Detailed debug edits
bfcase2.inp	0u5hcdho.cdf	Input file
bfcase2.out	0u5hcsjk.cdf	Standard output file
* bfcase2.act	0u5hb8c0.cdf	Regional activity file
bfcase2.dpr	0u5hc1fs.cdf	Detailed debug edits

Computer output stored in directory /misc/6602r00/out on the CD-ROM volume identified on the cover sheet. Output files are also included in Appendices.

* Note, in the file which contains the activity information, the following heading is used:

ACTIVITIES (CI) -- REGION NUMBERS IN ( )

DW (2) WW (3) RR (4) RB (5) SR (6) MSL (7) MC (4)

In this heading "RR (4)" should be interpreted to mean the Control Room (Region 4) and "MC (4)" should actually be indicating Main Condenser (Region 8). This code anomaly should not cause any significant problems.

VII. RESULTS AND CONCLUSIONS

The criteria for control room habitability given in NUREG-0800, Standard Review Plan 6.4, Rev. 2, 1981 is as follows:

limit for 30 day dose accumulation:

5 Rem whole body
30 Rem Thyroid (iodine inhalation)
30 Rem skin

The NRC allowable offsite doses are given in 10CFR100.11 to be:

25 Rem total whole body
300 Rem total to the thyroid due to iodine exposure.

These limits apply to EAB 2 hour and LPZ thirty day doses.

The results of the two cases are summarized in the table below: The maximum thyroid dose in the CR is under 18 rem. Dose summaries can be found on pages A-56 thru A-58 and B-56 thru B-58 of Appendices.

LOCATION	DOSE TYPE	CASE 1		CASE 2	
		2 HR DOSE (REM)	30 DAY DOSE (REM)	2 HR DOSE (REM)	30 DAY DOSE (REM)
CR	THYROID		17.9		17.41
CR	SKIN		1.794		1.782
CR	WHOLE BODY		0.046		0.045
EAB	THYROID	3.159		2.738	
EAB	SKIN	0.05658		0.0441	
EAB	WHOLE BODY	0.0750		0.059	
LPZ	THYROID		5.786		5.552
LPZ	SKIN		0.4928		0.4826
LPZ	WHOLE BODY		0.2823		0.269

The contribution of "other" isotopes to the whole body LPZ and EAB doses are as follows:

Case 1: EAB 2 hour : other contribution = .000527 Rem
Case 1: LPZ 30 day: other contribution = .00034 Rem
Case 2: EAB 2 hour : other contribution = .00050 Rem
Case 2: LPZ 30 day: other contribution = .00033 Rem

For case 1 Iodine -131 contributes 16.64 rem to the control room thyroid dose (30 day), distributed among the three iodine forms as follows:

elemental : 3.21 Rem
organic: 12.51 Rem
Particulate:0.9232 Rem

Additional details associated with the radionuclide contributions to the dose can be found in the computer output files (See Appendices A and B). Also included in the appendices are the predicted plant activities for various times into the event.

VIII. REFERENCES

1. TML-90-120, "Analytical Models for LOCA Radiological Dose Consequences (Basis for LDOSE Program)", S. Rosen, November, 1, 1990.(Combustion Engineering Proprietary)

2. 1066-S&T95-C-001 TVADOSE:COMPUTER PROGRAM FOR THE CALCULATION OF BROWNS FERRY ADVANCED SOURCE TERM LEAKAGE DOSES, M. Michonski, September 29, 1995, (Combustion Engineering Proprietary)

3. PSAT-04000U.03,Rev. 1, "Design Data Base for Application of the Revised DBA Source Term to the TVA Browns Ferry Nuclear Power Plant", J. Metcalf, September 22, 1995

4. Attachment A "Workscope" to Letter L. Brown-Herzl (Polstar Applied Technology, Inc) to Raymond Schneider (Combustion Engineering, Inc.) August 31, 1995.

5. PVNGS UPDATED FSAR (APPENDIX 15B)

6. Letter from J. Metcalf (PSAT) to Ray Schneider (ABB), dated September 20, 1995

7. NUREG-1465, Accident Source Terms for Light Water Power Plants, January 1995, USNRC

IX. APPENDICES

NOTICE

This Non-Proprietary Version of Calculation Number 1066-S&T95-C-002 Rev. 0 (Attachment 1 to Non-Proprietary PSAT 04000U.04) does not include anyof the four appendices identified in the Table of Contents. Appendices A, B, and D are proprietary, and Appendix C contains information identical to that of Attachment 2 of PSAT 04000U.04.