CALCULATION PACKAGE FOR

APPLICATION OF THE REVISED DBA SOURCE TERM

TO THE BROWNS FERRY NUCLEAR POWER PLANT

prepared by:

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for the

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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	Revison 1 of Attachment 3	James Metcalf 2/2/96	Dave Leaver 2/5/96

ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3
TECHNICAL SPECIFICATION (TS) 356, INCREASE IN ALLOWABLE MAIN STEAM ISOLATION VALVE (MSIV) LEAKAGE RATE

CONTROL ROOM OPERATOR AND OFFSITE DOSE CALCULATIONS
(NON-PROPRIETERY VERSIONS)

(SEE ATTACHED)

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Attachments	Revision	Title and Date
1	0	ABB-CE Calculation 1066-S&T95-C-002, "Calculation of Containment Leakage Doses for Browns Ferry", September 29, 1995 which includes a letter dated September 20, 1995 from James Metcalf (Project Manager, PSAT) to Raymond Schneider (ABB-CE Technical Contact) modifying the original contract workscope
2	1	PSAT Project Data Base 04000U.03, September 22, 1995
3	1	PSAT Calculation 04011H.01, "Volumetric Flowrate as a Function of Time from Drywell to Torus (and Return)", December 6, 1995
4	0	PSAT Calculation 04001H.02, "Aerosol Decay Rates (Lambda) in Drywell", September 1, 1995
5	0	PSAT Calculation 04011H.03, "Maximum Elemental Iodine Decontamination Factors", September 1, 1995
6	0	PSAT Calculation 04011H.04, "Suppression Pool Scrubbing Efficiency (Including Pool Bypass)", September 1, 1995
7	0	PSAT Calculation 04011H.05, "Additional Radionuclide Data", September 19, 1995

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	0	PSAT Calculation 04002H.08, "Aerosol Decontamination Factor in Main Steam Lines", September 19, 1995
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
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
Leak from stack room	Equal to 300 cfh (assumed to be same as inleakage, see "SGTS operation", above) - leak is to the environment
Leak from main condenser	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)

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
- Deposition in the main steamlines up to the drain line connection
- 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 considered via the high pressure turbine. Discussion: From Reference 6 it is observed that the flow split between the drainline/main condenser flowpath and the high pressure turbine flowpath is about 200:1. Since deposition in the steamlines applies to either flowpath and since deposition in the steamlines is the only deposition considered for MSIV leakage (see Attachments 1, 10, and 11), the only mechanism that could create a difference in the calculated relative dose between the two pathways is delay in the main condenser. This effect is estimated to be of the order of a factor of two to three in dose reduction; therefore, the importance of including the high pressure turbine release would be to increase the dose by one percent to one-and-a-half percent. This is considered negligible.

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: The steamline flowrate used to assess aerosol deposition in the steamline is based on 100 scfh per line. However, the overall dose assessment is based on the assumption that the total flowrate for four steamlines is 250 scfh. Therefore, overall deposition has been understated. 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.

- Conservatism 11: Deposition in the drain lines and in the main condenser is neglected. See Attachments 10 and 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 (Item 4.7 of Attachment 2).

- PSAT 04002H.09 (Attachment 11):

  This calculation provides the removal efficency 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	Dose Magnitude - rem 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.