AUDIT CALCULATIONS OF EX-VESSEL FISSION PRODUCT AND AEROSOL RELEASE TO CONTAINMENT FOR SELECTED ACCIDENT SEQUENCES

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ABSTRACT

Calculations of ex-vessel fission product and aerosol release to containment have been performed for selected accident sequences reported in the BMI-2104 report series. The codes which were chosen for these calcuations were CORCON/MOD1-C2 and VANESA. The specific accident sequences that were chosen are Peach Bottom AE, Surry TMLB', and Surry S2D. The purpose of the present BNL calculations is to provide an independent audit of the ex-vessel source term results which were reported in BMI-2104. The VANESA code was obtained from SNL and made operational on the BNL computer; CORCON/MOD1-C2 was already operational at BNL. No modifications were made to the codes other than to make them operational at BNL, link the codes for data transfer, and correct errors that were identified in the early version of VANESA. Code input parameters used in BMI-2104 were reviewed to ensure compatability of the audit calculations with BMI-2104. The Peach Bottom AE input was reviewed in great detail since significant changes were made to the input for this calculation by the ASTRP team in recognition of errors in the original reported results. A comparison of the BMI-2104 and BNL results indicates excellent agreement in ex-vessel source terms for the three base case audit calculations.

ACKNOWLEDGEMENTS

I would like to thank the staff at SNL, in particular D.A. Powers and D. Bradley, for their assistance in compiling the input for these calculations and getting CORCON/MOD2 and VANESA running at BNL. Conversations with the USNRC staff, in particular S.B. Burson, R. Curtis, M. Silberberg, R. Meyer, J. Rosenthal, J. Mitchell, and others, were extremely useful in ensuring the successful completion of this task in spite of the extremely severe time constraint imposed. I would like to express my continued appreciation to Y. Sanborn who was responsible for all the computer work that went into this task, including obtaining and getting the codes running, compiling the input, identifying uncertainties, and performing what seemed to be an endless series of calculations in such a short time. Finally, thanks are due to S. Monteleone and M. Marsch for preparing the document on such short notice.

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1. INTRODUCTION

1.1 Background

During the last several years the NRC has sponsored research related to severe accidents in Light Water Reactors (LWRs). In particular, the Accident Source Term Program Office (ASTPO), RES/NRC sponsored the development of a suite of severe accident phenomenology codes at BCL and SNL. These codes are intended to describe how a nuclear reactor core might degrade without adequate cooling and hence release radioactive fission products. The codes also follow the subsequent transport of the fission products from the damaged core to the environment if the containment fails or is bypassed. These codes therefore focus on the release and transport of fission products and were applied to model selected severe accidents for six representative reactor designs. The results of this code application effort are reported in BMI-2104.[1]

The methodology described in Ref. 1 has received extensive peer review over the last several months and is also under review by the American Physical Society (APS). As a result of questions raised during the APS review, a meeting was held at NRC to develop an appropriate response to the questions. Part of this response was to demonstrate that the ASTPO suite of severe accident codes, in particular the CORCON[2] and VANESA[3] codes, could be exported to an independent organization and that (by using similar input parameters and intercode data transfer) similar results to those reported for ex-vessel aerosol and fission product release to containment could be obtained. BNL was selected by the NRC to be the independent organization, and this informal report documents the results of this effort.

1.2 Objective and Scope of Audit Calculations

This effort was performed under a very severe time constraint. The meeting which initiated this effort was held on November 20, 1984. The Peach Bottom AE sequence was analyzed with CORCON/MOD1 and VANESA by December 5, 1984. Minor discrepancies in VANESA were subsequently identified and corrected, and this sequence reanalyzed. The SURRY TMLB' sequence was analyzed three ways reflecting the inconsistencies recognized in BMI-2104, Vol. V by BNL. One of these analyses was for the full Surry TMLB' audit calculation and is reported

in that letter report; the other two calculations were in the form of a sensitivity study. The case reported herein is a reproduction of the CORCON/VANESA results as reported in BMI-2104 and will not be identical to the CORCON/VANESA results used in the full Surry TMLB' audit calculation. Finally, the Surry S2D sequence was analyzed.

The primary objective of this effort is to demonstrate that the two codes used for the calculation of the ex-vessel source term, CORCON and VANESA, can be made operational at BNL and that the results in BMI-2104 can be reproduced.

1.3 Calculational Methods

The codes used to analyze the ex-vessel release of aerosols and fission products to the containment in these audit calculations are CORCON/MOD1-C2 and VANESA. It was specifically requested that no modifications be made either to the codes themselves or to their input. However, it was requested that effort be made to ensure that the same versions of the codes be used. With respect to CORCON, this meant determining that all official FORTRAN updates to the code be identified and attached for the calculation. One update was identified which had only been transmitted to BNL informally and this was used in the audit. With respect to VANESA, this meant getting the code running on the BNL computer, running a sample problem, and identifying errors in transcribing the FORTRAN version from the SNL H.P. version. Several errors and inconsistencies in the VANESA model sent to BNL were identified in this fashion and corrected. This ensured that the SNL and BNL versions of both CORCON/MOD1-C2 and VANESA were the same.

The BNL staff participating in this audit exercise are listed in Table 1.1.

Table 1.1. BNL Staff Participating in Audit Calculations

Code	Analyst	QA
CORCON	G. Greene	M. Khatib-Rahbar
VANESA	G. Greene	W. Yu
Code Integration	H. Ludewig	W.T. Pratt

2. COMPUTER MODELS AND AUDIT CALCULATIONS

The three accident sequences chosen for this audit of the ex-vessel aerosol and fission product release calculations from BMI-2104 are listed below:

Peach Bottom AE-γ

Surry TMLB'-ε

Surry S2D-ε

These will be briefly discussed below. A more complete description may be found in BMI-2104.

Peach Bottom AEγ

This sequence is a loss of coolant accident with a break in a recirculation line. The primary system is assumed to blow down to the drywell and vent into the suppression pool. The ECC systems are assumed not to operate also. Water remaining in the lower plenum reacts with the cladding generating considerable quantities of hydrogen which is predicted to fail the containment by overpressurization. If the containment failure, as predicted in BMI-2104, occurs in the drywell, much of the aerosols and fission products would bypass the suppression pool and little scrubbing of fission products could be expected. Following containment failure by hydrogen overpressure, the core melts through the lower head of the vessel and begins to attack the concrete. The ensuing core-concrete interaction augments the aerosol and fission products that were released in-vessel; this source term is calculated with the CORCON and VANESA codes.

Surry TMLB'-ε

This sequence is a station blackout accident with loss of primary system heat removal. The ε-basemat melt-through late failure mode is assumed. All active ECC systems and Containment Heat Removal Systems (CHRS) are assumed inoperable. First the secondary side heat sink (steam generators) boils dry. Once heat sink is lost, the primary system boils at the relief valve set point (high pressure) until the primary system water inventory is lost. Eventually

the reactor core will uncover, heat up, and degrade. The core will melt and slump into the lower head, attack the lower head, and fail the vessel into the reactor cavity. As the primary system depressurizes, the accumulators will inject water. Subsequently, there will be an ex-vessel core-concrete interaction in the reactor cavity with an overlying pool of water boiling over the molten core debris. The presence and amount of water in the reactor cavity after vessel failure is based upon modeling assumptions at BCL. The pool will contribute a DF to the ex-vessel source term until it boils dry. Eventually the containment will fail via basemat melt-through (by assumption), resulting in release of aerosols and fission products to the environment.

Surry S2D-ε

This sequence is a small pipe break accident with failure of ECC systems. However, the containment cooling and containment spray systems are operable in this sequence. As a result of containment spray and cooling systems, the pressure in containment remains relatively low during this sequence. As a result of the break in the primary system, the primary system pressure in this sequence is lower than for the TMLB' accident. After the core uncovers, the accumulators inject water which subsequently boils off. At this time the core begins to degrade, melt, and then slump. The lower head will fail, and the melt will stream into the reactor cavity, followed by the remaining residual water from the lower plenum. Similar to the TMLB' sequence, a core-concrete interaction will occur with a water pool boiling overhead, contributing a DF to the ex-vessel aerosol and fission product release to the containment. The concrete attack will continue, boiling off the water, eventually failing the containment by basemat penetration. However, continued operation of containment sprays throughout the accident will enhance the scrubbing of aerosols and fission products evolved in-vessel as well as mitigate the ex-vessel contribution calculated from CORCON and VANESA.

The codes described in Section 1.3 were applied to the above sequence in a manner similar to that assumed in BMI-2104. Input parameters and inter code data transfer have been carefully checked and an independent audit calculation performed. Each code used to model the above accident sequence is described in the following sections. During the audit calculation an inconsistency was

found for the TMLB'-ε sequence as reported in BMI-2104. The MARCH analysis assumed quenching of the core debris immediately after vessel failure and did not predict core/concrete interactions to begin until the cavity boiled dry (297 minutes after reactor scram). However, fission product release due to core/concrete interactions ws modeled separately from MARCH using the CORCON/VANESA codes, and this process was started at vessel failure (157 minutes after reactor scram). The airborne fission product masses in containment were modeled using NAUA, and the fission products generated by core/concrete interactions were input at 297 minutes, which is consistent with the MARCH calculation but inconsistent with the CORCON/VANESA calculation. This inconsistency was corrected in our Surry TMLB' audit calculation, and its impact on the predicted release of fission products is not great for the late containment failure mode. The CORCON-VANESA results which will be presented here will not be the same as used in the full SURRY audit calculation, but will be consistent with the assumptions employed in the SNL calculations as presented in BMI-2104, Vol. V.

A discussion of both CORCON and VANESA as utilized in these audit calculations follows.

2.1 CORCON

The CORCON code 2 was used to calculate the ex-vessel attack of molten core debris on the basemat, and this calculation drives the ex-vessel aerosol and fission product source term calculation. The CORCON code is the state-of-the-art model for the analysis of the interaction between molten fuel and structural materials with concrete. Typical output of CORCON calculations are the concrete erosion rate, generation rates of concrete decomposition gases, and the core melt/temperature history. These three quantities are necessary input to the VANESA code for the calculation of the ex-vessel release of fission products and aerosols into the containment during a core melt accident.

The version of the CORCON code used in the all BMI-2104 accident sequence source term calculations was CORCON/MOD1 with two official FORTRAN update packages documenting changes made to the original code by Sandia National Laboratory. This code is heretofore referred to as CORCON/MOD1-C2. A third up-

date which was not distributed was identified during this audit calculation and was used in the BNL calculations.

The input to the CORCON code consists primarily of concrete composition data (user input), core melt composition (MARCH output), cavity geometry (plant specifications/FSAR), surroundings temperature history (user input or MARCH), initial melt temperature and time after SCRAM at start of core/concrete interaction (MARCH), and melt/concrete/surroundings radiative emissivity vs. time (user input). Those input variables which are "user input" are left to the discretion and scientific judgement of the user. There are no internal parametric model variations possible through input. A more complete assessment of this computer code may be found in ORNL/TM-8842, Chapt. V.

The input for the Peach Bottom AE CORCON/MOD1-C2 audit calculation is shown in Table A.1 and is identical to that used in the Peach Bottom recalculation exercise ordered at the November 20, 1984 meeting. There are significant differences between this calculation and the original calculation which was reported in BMI-2104, Vol. II. Among these differences are the time after scram at which the core-concrete interaction starts, the mass of UO_2 in the core melt, the thermal radiative properties of the melt and surroundings, and the drywell surroundings temperature vs. time.

The input for the Surry TMLB' CORCON/MOD1-C2 audit calculation is shown in Table B.1. This input is identical to that used in BMI-2104, Vol. V, but differs from the input for the BNL full-audit Surry TMLB' calculation as follows. The SNL CORCON calculation was started at 157 minutes after SCRAM at an initial core debris temperature of 1807K and time-in-variant surroundings temperature of 500K. The BNL core/concrete interaction calculation was started at 287 minutes after SCRAM with time-invariant surrounding temperature of 1373K and initial melt temperature of 1777K. This was done to be consistent with the BNL MARCH calculation results of initial melt temperature, surroundings temperature, and start of core/concrete interactions at 287 minutes after SCRAM (corresponding to the time INTER allowed core/concrete interactions to occurs after adiabatic reheating from quenching). Both of the above core/concrete interaction calculations were performed at BNL and compared for

differences. It was found that only minor differences were calculated in erosion rate, gas generation rates, and melt temperature vs. time.

The input for the Surry S2D CORCON/MOD1-C2 audit calculation is shown in Table C.1 and is identical to that used in BMI-2104, Vol. V.

The results of the three sets of CORCON/MOD1-C2 calculations for the Peach Bottom AE, Surry TMLB', and Surry S2D sequences are shown in the figures in Appendices A-C as melt temperature history vs. time, integrated gas generation rates vs. time, and vertical and lateral erosion depths vs. time, respectively. These results, along with the integrated concrete erosion mass vs. time, were input to the VANESA model for calculation of the ex-vessel aerosol and fission product release rates.

2.2 VANESA

In order to account for the ex-vessel release of aerosols and fission products into the containment during the thermal interaction between molten core debris and structural concrete, the VANESA model was used. The VANESA model is a mechanistic description of the aerosol generation and fission product release during ex-vessel core-concrete interactions. A more complete description of the VANESA model may be found in ORNL/TM-8842, Chapter VI.[3] The VANESA model accepts as input the output of the CORSOR and CORCON computer codes.

From CORSOR, VANESA will get the mass of all species in the core melt inventory. At the present state of development, VANESA can accept explicitly 32 species; other species are surrogates of one of the 32 species. Examples of this are as follows:

Gd, Eu, Pm	→	La on molar basis
Np	→	Ce on molar basis
Cd	→	Cs on molar basis
In	→	Ag on mass basis

In addition, it is required to input the inventory of Nb as the equivalent mass of Nb_2O_5 directly into VANESA in Subroutine ASSEMB, line 41. These variations on melt species input reflect the ongoing development of the VANESA

model as new species were identified as important during the Accident Source Term Reassessment Study. The input species mass (kg) inventories for the Peach Bottom AE, Surry TMLB', and Surry S2D accident sequences are listed in Tables A-2, B-2, and C-2, lines 3-6, and are identified below:

CS	I	Xe	Kr	Te	Ba	Sn	Ru
UO_2	Zr	ZrO_2	Fe	FeO	Mo	Sr	Rb
Y	Tc	Rh	Pd	La	Ce	Pr	Nd
Sm	Pu	Cr	Mn	Ni	Ag	Sb	

From CORCON, VANESA receives the following information at each time step as calculated:

oxide melt temperature (K)
integrated gas release rates (kg)

H_2
H_2O
CO
CO_2

maximum radial erosion radius (m)
SiO_2 content of melt (kg)

The arrays of these seven input variables are not listed in the VANESA input since the two codes were linked and these variables were transferred automatically.

A detailed description of the output from VANESA has been documented elsewhere (Powers,[3] 1983) and will not be repeated here (see Table 2.1). The most important of the output quantities for subsequent use in the calculation of the ex-vessel source term are:

1. aerosol mass generation rate,
2. chemical composition of aerosolized mass,
3. aerosol mean particle size, and
4. aerosol density

Table 2.1. Output from the VANESA Model (ORNL/TM-8842)

Aerosol Properties

1. Density of aerosol material (g/cm^3)
2. Mean aerosol particle size (μm)
3. Mass flux of aerosols (g/s)
4. Aerosol concentration at STP (g/m^3)
5. Aerosol concentration in cavity (g/m^3)

Aerosol Composition

1. Fission Products (mass percent Cs, I, Te, Ru, Sb, Mo, Sr, Ba, U, Pu, Ce, La, Nb)
2. Concrete Constituents (mass percent Na, K, Al, Si, Ca, Fe)
3. Fuel and Structural Materials (mass percent Fe, Ni, Cr, Mn, Sn, Zr, U)

Kinetics Data

1. Source of Release (sparging, evaporation, mechanical)
2. Rate limitation (surface area, time, mass transport, or chemical kinetics)
3. Vapor phase speciation

Melt Composition

1. Change caused by aerosol formation
2. Change caused by metal oxidation
3. Change caused by concrete melting

Permanent Gas Characteristics

1. Composition (volume percent CO, CO_2, H_2, H_2O, OH, O, H)
2. Flux (moles/s)
3. Superficial velocity (m/s)

The version of VANESA used in these audit calculations was the first exportable FORTRAN version. This version was adapted from the original non-FORTRAN version written at SNL and used in the BMI-2104 study. The code was first received at BNL on November 15, 1984. It was successfully compiled and a sample problem executed on November 19, 1984. In the process of familiarization with the code, several minor transcription errors were identified in the FORTRAN version by the SNL and BNL staff and were corrected.

The Peach Bottom and Surry audit calculations were then run with the validated input from MARCH, CORSOR, and CORCON as previously specified. The results of these three sets of calculations were tabulated for each time step, listing the species in the aerosol, the source rate, oxide melt temperature,

aerosol density, and aerosol mean particle size and are shown in Tables A.3, B.3, and C.3. One exception that should be explicitly mentioned is the Cs_2O group. Recall that in the Surry calculations this species actually consists of both Cs_2O and Cd. A breakdown of this group for the first four time steps is given in Tables B.4 and C.4 on the basis of the actual Cd in this category on a mass basis. Also indicated in these tables are the source rates in gm/s for the times during which a water pool existed over the core melt. For these sequences, SNL calculated a decontamination factor (DF) by which the source rate was diminished. BMI-2104 Vol. V reports the source rates with the DF included; Tables B.4 and C.4 list the source rates both with and without the DFs for the BNL audit calculations. Comparison of the results in Tables A.3, B.3-4, and C.3-4 to Table 6.14 in BMI-2104, Vol. II (Peach Bottom AE) and Tables 6.14-6.15 in BMI-2104, Vol. V (Surry TMLB'-S2D) respectively demonstrates excellent agreement on a quantitative basis between the BMI-2104 results and the audit calculations.

3. SUMMARY

A summary of the ex-vessel release rates of aerosols and fission products from the BNL CORCON/VANESA calculations is presented in Tables A.3, B.3, and C.3, for the Peach Bottom AE, Surry TMLB', and Surry S2D sequences, respectively. The calculated source rates are generally in agreement with the BMI-2104 results within ± 5%, often closer to ± 1%. Calculated melt temperatures have been found to be in agreement generally within ±5-10 K. The fractional compostion of each species in the aerosol was calculated by BNL to be nearly identical to the results presented in BMI- 2104, disagreeing by no more than 2-3%. This level of agreement between the results of the BNL audit calculations and the results presented in BMI-2104 is generally found in all three of the cases examined. (The Peach Bottom AE ex-vessel source term was recalculated by SNL and the new results supercede those presented in BMI-2104, Volume II.)

The release fractions for five selected species were integrated over ten hours of core/concrete interactions and the BNL and SNL results are presented in Table 3.1. The SNL figures reflect the recent recalculation referred to above; the BNL figures reflect the results from the audit calculation. From the table, it is clear that the BNL and SNL (BMI-2104) results are in excellent agreement when integrated over ten hours. The results from the two sets of calculations differ, in fact, by no more than round off error.

Table 3.1 Comparison of Total Ex-Vessel Release Fractions(%) of Selected Species for Peach Bottom AE Sequence Calculation by SNL and BNL*

	La_2O_3	SrO	BaO	Te	CeO
SNL	1.8	67	48	69	2.9
BNL	1.9	68	49	68	3.0

*Integrated release from ex-vessel core/concrete interaction over ten hours.

This comparison demonstrates that the CORCON and VANESA codes can be successfully exported to an independent organization, and that the results in BMI-2104 can be reproduced if the same versions of the codes and identical input and modeling assumptions are used. The audit calculations have demonstrated that some inconsistencies exist in BMI-2104 regarding inter-code data transfer. However, for the particular sequences examined, these inconsistencies did not strongly influence the predicted ex-vessel aerosol and fission product release rates.

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APPENDIX A : PEACH BOTTOM AE INPUT AND RESULTS

Appendix A summarizes the input files for both the CORCON and VANESA calculations for the ex-vessel aerosol and fission product release to containment for the Peach Bottom AE sequence. Table A.1 is the CORCON input deck. Figures A.1-A.3 present the melt temperature, integrated gas generation rates, and erosion depths from the core-concrete interaction calculation. These quantities were input to VANESA for the aerosol and fission product release calculation. Table A.2 is the VANESA input deck. Table A.3 presents the VANESA results for each time step. Included is the aerosol source rate, melt temperature, aerosol density and size, as well as a fractional breakdown of the species in the aerosol for each time step.

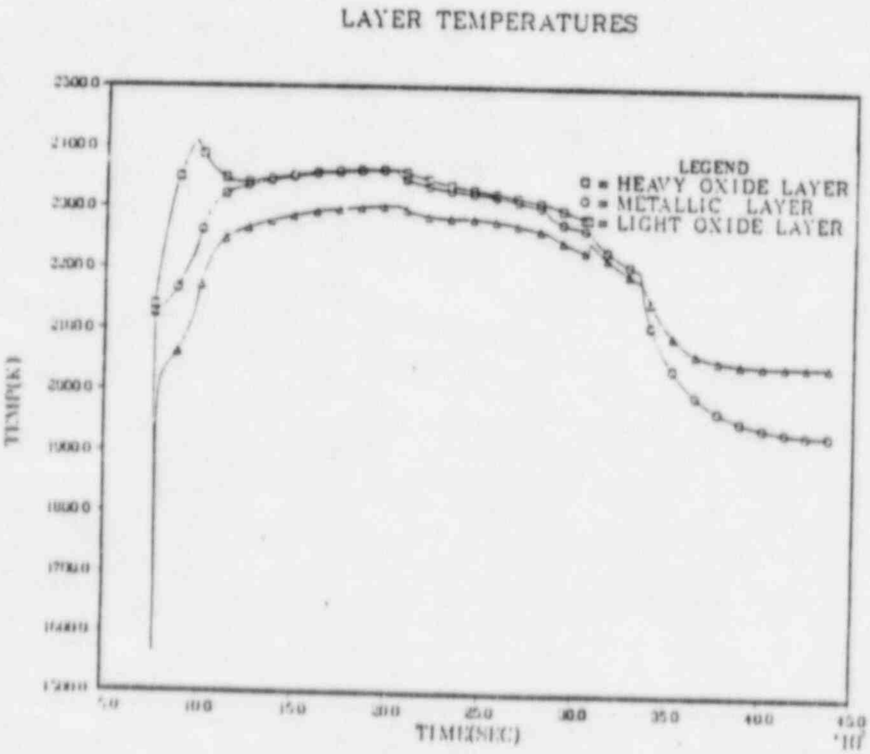

Figure A.1 Melt Temperature vs. Time: Peach Bottom AE

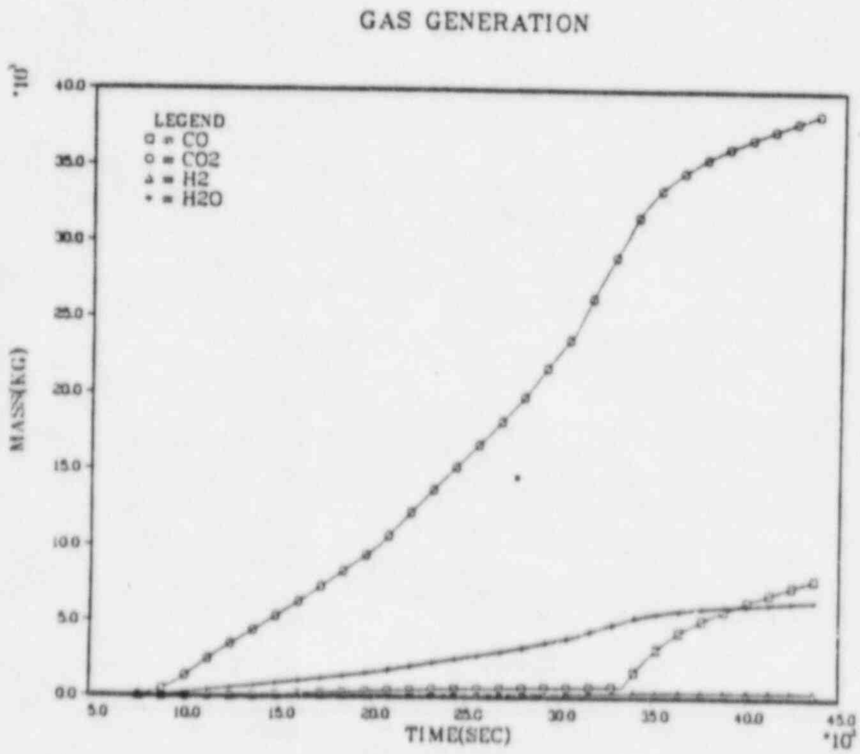

Figure A.2 Integrated Gas Release Rate vs. Time: Peach Bottom AE

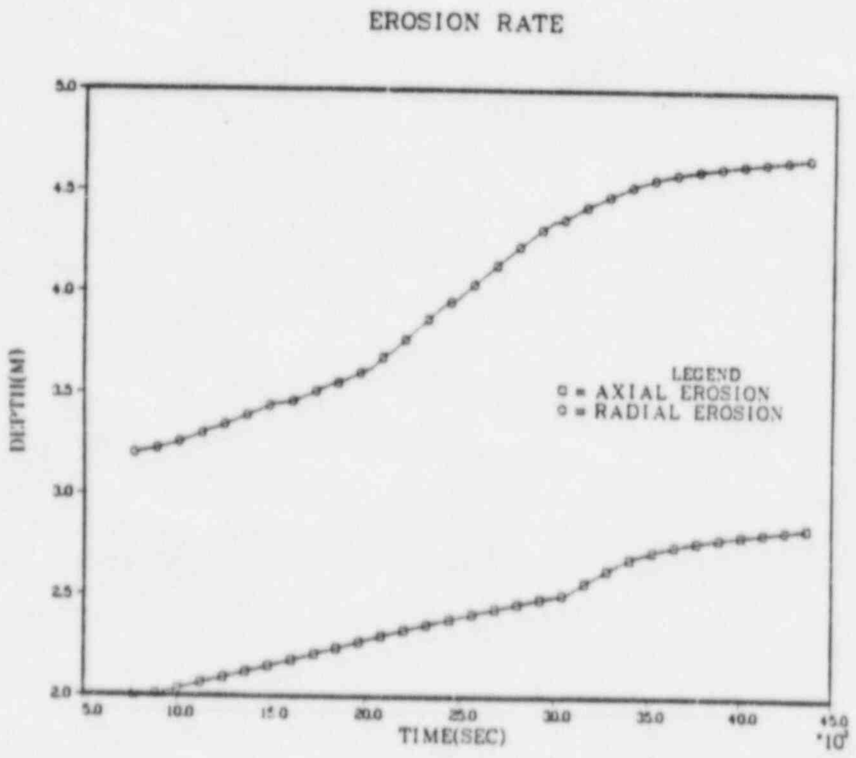

Figure A.3 Axial and Radial Concrete Erosion Depth vs. Time: Peach Bottom AE

```
   PEACH BOTTOM AE: CORCON  /VANESA SNL AUDIT CALCULATION
      0    0    2    3    0    0    1    0    0  20    0    0    0    1    0    0
         60.0      7575.     43575.        60.     43576.
     40         0.0        0.5
         0.0         3.2         2.5          0.1          4.5          3.0   10    6
       300.0       1875.          .6         .135
       3     4     2125.      2125.
   UO2         159400.
   ZRO2        32990.
   FEO         5000.
   FE          70160.
   ZR          41070.
   NI          6164.
   CR          11100.
         140.1       3293.     0
         4505.     2.14E5        525.    3
   N2                .70
   H2                .13
   CO2               .17
      7
   7575.      300.       11175.     900.       14775.     1000.      18376.     1175.
   20175.     1250.      23775.     1750.      60000.     1750.
   TIMETIMETIME
       2    4     2
         7575.         0.8    60000.        0.8
         7575.         0.1    20175.        0.1     20200.        0.8    60000.        0.1
         7575.         0.6    60000.        0.6
```

Table A.1 CORCON Input Deck for Peach Bottom AE Sequence

```
   PEACH BOTTOM AE: CORCON1/VANESA SNL AUDIT CALCULATION
0.0617     1.0
.3         .02        .56        .34        27.99      86.7       557.       171.
159400.    41337.     32990.     70160.     825.       209.1      58.4       .03
36.17      58.4       33.        82.7       375.5      232.1      80.34      277.8
53.76      742.4      11100.     1233.      6164.      0.         0.
 TWO TIME STEPS
1200.      1200.
 WT. FRACS FOR CAO,A1203,NA20,K20, SIO2,FEO
.8752      .0295      .0014      .0117      .0617      .0206
```

Table A.2 VANESA Input Deck for Peach Bottom AE Sequence

PEACH BOTTOM AE: CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES	TIME .0	1200.0	2400.0	3600.0	4800.0	6000.0	7200.0	8400.0
FEO	36.45	12.61	12.72	13.04	12.93	12.71	12.52	12.40
CR2O3	.1201E-16	.9109E-16	.2455E-15	.1766E-15	.1495E-15	.1559E-15	.1756E-15	.1973E-15
NI	.1509	.4070	.6162	.4438	.4131	.4276	.4444	.4597
MO	.1921E-07	.1934E-06	.3790E-06	.2175E-06	.1939E-06	.2074E-06	.2222E-06	.2359E-06
RU	.1640E-36	.1617E-05	.3153E-05	.1817E-05	.1621E-05	.1730E-05	.1856E-05	.1969E-05
SN	.4314	.4819	.6265	.5084	.4451	.4437	.4893	.4943
SB	0.	0.	0.	0.	0.	0.	0.	0.
TE	.7977	.5845	.5647	.5037	.4747	.4664	.4480	.4361
AG	0.	0.	0.	0.	0.	0.	0.	0.
MN	13.21	12.46	12.51	12.42	12.72	12.50	12.32	12.19
CAO	0.	25.36	25.67	26.37	26.23	25.89	25.54	25.35
AL2O3	0.	1.929	4.119	4.129	4.508	4.990	5.368	5.640
NA2O	0.	2.345	2.270	2.238	2.255	2.247	2.239	2.238
K2O	0.	10.96	11.23	11.68	11.71	11.58	11.48	11.41
SIO2	0.	14.94	18.64	19.79	21.24	22.47	23.47	24.25
UO2	.2819	.4815	.7008	.4690	.4173	.3968	.3966	.3819
ZRO2	.3347E-01	.2666E-01	.2736E-01	.2187E-01	.2178E-01	.2391E-01	.2139E-01	.2124E-01
CS2O	26.70	0.	0.	0.	0.	0.	0.	0.
BAO	7.987	3.483	3.394	2.847	2.428	2.096	1.846	1.632
SRO	6.610	4.258	4.346	3.237	2.592	2.280	1.895	1.637
LA2O3	.1476	.6305	1.018	.6427	.5997	.5604	.5644	.5649
CEO2	.4735	1.346	1.983	1.259	1.258	1.886	.9656	.9194
NB2O5	6.232	7.410	.1884	0.	0.	0.	0.	0.
CSI	.1157	.4492E-01	.3839E-12	.2599E-04	.8471E-12	.7954E-12	.7516E-12	.7135E-12
SOURCE RATE(GM/S)	21.57	91.22	140.6	151.6	139.0	136.7	143.0	149.7
OXIDE MELT TEMP(K)	2125.	2343.	2391.	2349.	2341.	2347.	2353.	2357.
AEROSOL DENSITY(GM/CM3)	5.089	3.304	3.251	3.187	3.151	3.127	3.109	3.894
AEROSOL SIZE(MICRON)	.6112	1.009	1.012	1.010	1.017	1.025	1.032	1.037

Table A.3 Ex-Vessel Aerosol Release Rate and Composition for Peach Bottom AE

PEACH BOTTOM AE1 CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES TIME	9600.0	10800.0	12000.0	13200.0	14400.0	15600.0	16800.0	18000.0
FEO	12.33	12.33	12.38	12.55	12.92	13.36	13.79	14.20
CR2O3	.2210E-15	.2446E-15	.2911E-15	.3596E-15	.3891E-15	.4153E-15	.4714E-15	.5787E-15
NI	.4720	.4808	.4878	.4811	.4503	.4307	.4198	.4138
MO	.2466E-06	.2534E-06	.2584E-06	.2498E-06	.2190E-06	.1988E-06	.1861E-06	.1777E-06
RU	.2057E-05	.2115E-05	.2156E-05	.2085E-05	.1831E-05	.1663E-05	.1558E-05	.1488E-05
SN	.4979	.4998	.5611	.4947	.4737	.4611	.4543	.4567
SB	0.	0.	0.	0.	0.	0.	0.	0.
TE	.4244	.4129	.4019	.3893	.3731	.3607	.3508	.3423
AG	0.	0.	0.	0.	0.	0.	0.	0.
MN	12.13	12.13	12.17	12.34	12.70	12.49	12.15	11.89
CAO	25.28	25.33	25.47	25.84	26.59	27.48	28.36	29.22
AL2O3	5.401	5.452	5.819	5.584	5.036	4.517	4.874	3.607
NA2O	2.172	2.147	2.145	2.125	2.098	2.130	2.189	2.240
K2O	11.40	11.42	11.49	11.68	12.33	12.42	12.86	13.15
SIO2	24.81	25.14	25.24	25.08	24.38	23.78	23.18	22.53
UO2	.3717	.3593	.3463	.3239	.2861	.2584	.2393	.2244
ZRO2	.2132E-01	.2131E-01	.2127E-01	.2096E-01	.2024E-01	.1989E-01	.1973E-01	.1967E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	1.448	1.289	1.150	1.023	.8980	.7876	.6913	.6832
SRO	1.417	1.228	1.067	.9173	.7679	.6462	.5484	.4654
LA2O3	.5587	.5469	.5298	.4931	.4243	.3731	.3347	.3031
CEO2	.8677	.8164	.7523	.6720	.5579	.4691	.4006	.3417
NB2O5	0.	0.	0.	0.	0.	0.	0.	0.
CSI	.6869E-12	.6531E-12	.6290E-12	.6100E-12	.5969E-12	.5462E-12	.5773E-12	.5691E-12
SOURCE RATE(GM/S)	155.2	158.6	173.0	198.1	204.2	194.3	186.4	182.6
OXIDE MELT TEMP(K)	2361.	2362.	2363.	2359.	2347.	2338.	2336.	2325.
AEROSOL DENSITY(GM/CM3)	3.083	3.075	3.070	3.068	3.071	3.065	3.058	3.054
AEROSOL SIZE(MICRON)	1.040	1.041	1.041	1.036	1.026	1.015	1.005	.9957

Table A.3 Ex-Vessel Aerosol Release Rate and Composition for Peach Bottom AE (Continued)

PEACH BOTTOM AE: CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES TIME	19200.0	20400.0	21600.0	22800.0	24000.0	25200.0	26400.0	27600.0
FEO	14.63	15.16	15.83	16.62	.4927	.5567	.5612	.3533
CR2O3	.7582E-15	.1172E-14	.2193E-14	.1016E-13	.2322	.2690	.1721	.6846E-01
NI	.4059	.3959	.3760	.3569	.6684	.5428	.3926	.2408
MO	.1683E-06	.1573E-06	.1412E-06	.1240E-06	.1431E-03	.1571E-03	.1831E-03	.2992E-03
RU	.1410E-05	.1319E-05	.1186E-05	.1042E-05	.1326E-05	.9276E-06	.5182E-06	.2213E-06
SN	.4457	.4402	.4296	.4172	2.926	2.844	2.736	2.696
SB	0.	0.	0.	0.	0.	0.	0.	0.
TE	.3334	.3254	.3163	.3076	.8193	.7546	.6783	.5846
AG	0.	0.	0.	0.	0.	0.	0.	0.
MN	11.40	11.49	11.67	10.62	24.30	21.53	17.90	13.62
CAO	30.10	31.16	32.49	34.11	57.87	61.00	66.10	72.74
AL2O3	3.673	2.467	1.710	.7985	.1687E-02	.1687E-02	.1671E-02	.1702E-02
NA2O	2.276	2.296	2.273	2.126	.3153	.4238	.4328	.3566
K2O	13.51	13.93	14.43	14.69	9.448	9.659	9.236	7.929
SIO2	21.74	20.90	19.95	19.00	1.318	.7248	.3972	.1502
UO2	.2099	.1957	.1788	.1622	1.833	1.615	1.376	1.198
ZRO2	.1957E-01	.1952E-01	.1945E-01	.1936E-01	.5753E-01	.5673E-01	.5728E-01	.5664E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.5183	.4337	.3356	.2047	.1806E-01	.1513E-01	.1150E-01	.9334E-02
SRO	.3494	.3173	.2388	.1398	.1078E-02	.8428E-03	.5772E-03	.4121E-03
LA2O3	.2702	.2349	.1986	.1334	.6144E-02	.4176E-02	.2392E-02	.1269E-02
CEO2	.2875	.2283	.1641	.9846E-01	.6099E-03	.5667E-03	.6339E-03	.5235E-03
NB2O5	0.	0.	0.	0.	0.	0.	0.	0.
CSI	.5618E-12	.5578E-12	.5566E-12	.5579E-12	.1729E-11	.1736E-11	.1723E-11	.1764E-11
SOURCE RATE(GM/S)	181.5	191.5	194.6	232.2	85.27	92.53	91.68	67.96
OXIDE MELT TEMP(K)	2318.	2311.	2300.	2287.	2222.	2195.	2153.	2097.
AEROSOL DENSITY(GM/CM3)	3.059	3.052	3.049	3.048	3.348	3.278	3.198	3.124
AEROSOL SIZE(MICRON)	.9856	.9745	.9610	.9454	.6123	.6043	.5914	.5761

Table A.3 Ex-Vessel Aerosol Release Rate and Composition for Peach Bottom AE (Continued)

PEACH BOTTOM AE: CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES	TIME 28800.0	30000.0	31200.0	32400.0	33600.0	34800.0	36000.0
FEO	.3321	.3841	.4306	.4740	.5161	.5566	.5943
CR2O3	.3774E-01	.3197E-01	.2965E-01	.2861E-01	.2818E-01	.2800E-01	.2782E-01
NI	.1766	.1541	.1425	.1363	.1328	.1305	.1284
MO	.4959E-03	.4981E-03	.4752E-03	.4593E-03	.4492E-03	.4417E-03	.4342E-03
RU	.1328E-06	.1075E-06	.9579E-07	.9016E-07	.8747E-07	.8596E-07	.8455E-07
SN	2.709	2.527	2.388	2.301	2.243	2.199	2.157
SB	0.	0.	0.	0.	0.	0.	0.
TE	.5142	.4740	.4478	.4293	.4151	.4031	.3920
AG	0.	0.	0.	0.	0.	0.	0.
MN	11.28	10.28	9.664	9.301	9.059	8.873	8.700
CAO	74.21	77.62	78.41	78.85	79.11	79.28	79.44
AL2O3	.1738E-02	.1754E-02	.1766E-02	.1777E-02	.1786E-02	.1794E-02	.1802E-02
NA2O	.3083	.3034	.3043	.3071	.3108	.3147	.3184
K2O	7.129	7.049	7.048	7.075	7.113	7.155	7.193
SIO2	.8193E-01	.6950E-01	.6482E-01	.6303E-01	.6262E-01	.6275E-01	.6288E-01
UO2	1.151	1.061	1.000	.9652	.9446	.9323	.9166
ZRO2	.5839E-01	.5763E-01	.5691E-01	.5623E-01	.5558E-01	.5497E-01	.5439E-01
CS2O	0.	0.	0.	0.	0.	0.	0.
BAO	.9019E-02	.8627E-02	.8280E-02	.8054E-02	.7907E-02	.7795E-02	.7689E-02
SRO	.3731E-03	.3513E-03	.3350E-03	.3256E-03	.3189E-03	.3081E-03	.2966E-03
LA2O3	.9691E-03	.8939E-03	.8574E-03	.8377E-03	.8263E-03	.8185E-03	.8112E-03
CEO2	.5212E-03	.5144E-03	.5086E-03	.5019E-03	.4961E-03	.4907E-03	.4855E-03
NB2O5	0.	0.	0.	0.	0.	0.	0.
CSI	.1756E-11	.1733E-11	.1712E-11	.1691E-11	.1672E-11	.1653E-11	.1636E-11
SOURCE RATE(GM/S)	46.85	34.42	28.47	25.63	23.84	22.61	21.67
OXIDE MELT TEMP(K)	2067.	2056.	2051.	2049.	2048.	2048.	2046.
AEROSOL DENSITY(GM/CM3)	3.489	3.266	3.152	3.143	3.137	3.133	3.129
AEROSOL SIZE(MICRON)	.5690	.5668	.5657	.5652	.5649	.5644	.5647

Table A.3 Ex-Vessel Aerosol Release Rate and Composition for Peach Bottom AE (Continued)

APPENDIX B: SURRY TMLB' INPUT AND RESULTS

Appendix B summarizes the input files for both the CORCON and VANESA calculations for the ex-vessel aerosol and fission product release to containment for the Surry TMLB' sequence. Table B.1 is the CORCON input deck. Figures B.1-B.3 present the melt temperature, integrated gas generation rates, and erosion depths from the core-concrete interaction calculation. These quantities were input to VANESA for the aerosol and fission product release calculation. Table B.2 is the VANESA input deck. Table B.3 presents the VANESA results for each time step. Included is the aerosol source rate, melt temperature, aerosol density and size, as well as a fractional breakdown of the species in the aerosol for each time step. Table B.4 presents a breakdown of the Cs_2O release group and the DF used while water was over the core melt.

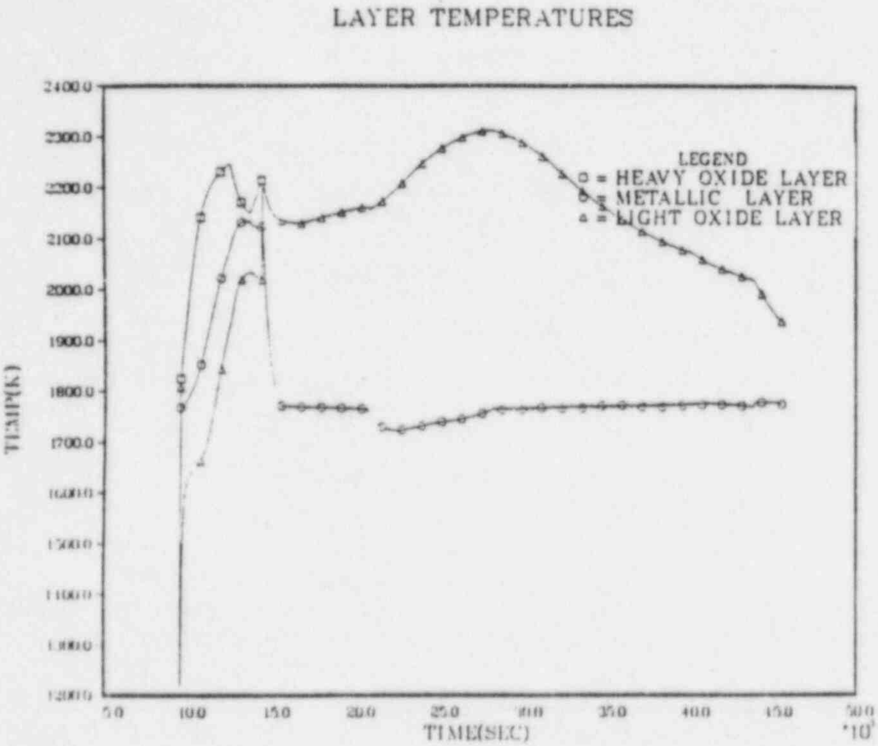

Figure B.1 Melt Temperature vs. Time: Surry TMLB'

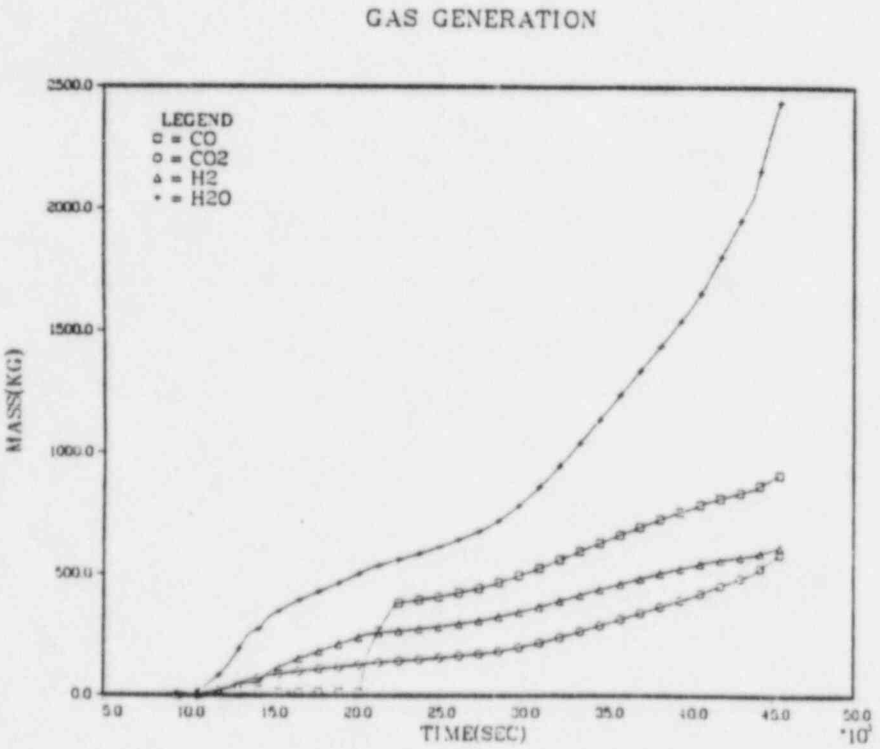

Figure B.2 Integrated Gas Release Rate vs. Time: Surry TMLB'

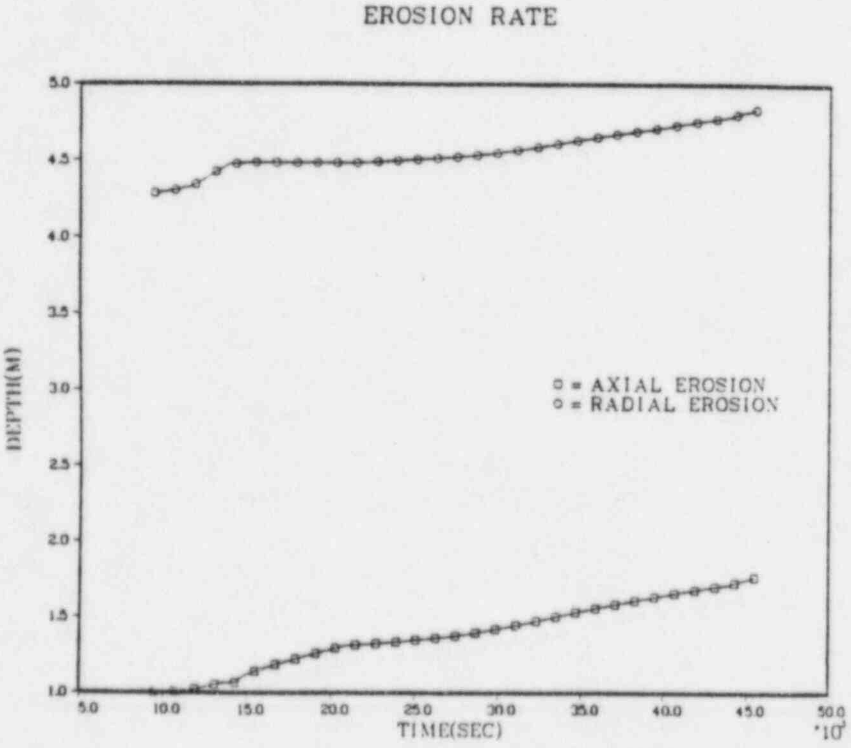

Figure B.3 Axial and Radial Concrete Erosion Depth vs. Time Surry TMLB'

```
SURRY TMLB' CORCON I/VANESA SNL AUDIT CALCULATION
    0     0     2     1     0     0     1     0     0    20     0     0     0     1     0     0
      60.0       9400.      45400.           60.     45401.
   40          0.0         0.5
      0.0        4.23        1.0          0.1          4.5          3.0   10    6
   300.0       1650.          .6       .135
    3     4    1307.       1807.
UO2       79630.
ZRO2      13210.
FEO       5000.
FE        34140.
ZR        6690.
NI        3006.
CR        5411.
       73.2        2441.      0
   4535.       2.30E5         644.     3
N2                .70
H2                .13
CO2               .17
   2
9400.       500.        45400.     500.
TIMETIMETIME
    2     2     2
     9400.          1.0    45400.         1.0
     9400.          1.0    45400.         1.0
     9400.          1.0    45400.         1.0
```

Table B.1 CORCON Input Deck for Surry TMLB' Sequence

```
    SURRY TMLB' CORCON-I/VANESA SNL AUDIT CALCULATION
0.5984     1.0
45.63      .1        1.5       .1        18.4      49.1      152.      103.
79630.     6690.     13210.    34140.    0.0       140.      43.7      .1
22.9       38.7      23.7      92.       62.3      131.      90.7      171.
34.        469.      5411.     157.      3306.     1693.     .31
 TWO TIME STEPS
1200.      1200.
 WT. FRACS FOR CAO,AL2O3,NA2O,K2O, SIO2,FEO
.164       .0338     .0197     .0588     .5934     .0663
```

Table B.2 VANESA Input Deck for Surry TMLB' Sequence

* Cd is 98.7 % of Cs_2O group mass

SURRY TMLB'T CORCON/VANESA SNL AUDIT CALCULATION

SPECIES	TIME .0	1200.0	2400.0	3600.0	4800.0	6000.0	7200.0	8400.0
FEO	.1502E-10	12.49	10.29	10.77	13.84	15.35	16.30	16.98
CR2O3	.1123E-18	.2392E-16	.2675E-01	.1314E-01	.1233E-01	.4667E-15	.4117E-14	.8022E-14
NI	.2913E-22	.6374E-01	.1258	.6373E-01	.1499	.7315E-01	.7615E-01	.8897E-01
MO	.1444E-18	.1197E-07	.4580E-07	.2030E-07	.4329E-07	.1474E-07	.1379E-07	.1586E-07
RU	0.	.9190E-17	.3564E-06	.1390E-06	.3377E-06	.1160E-06	.1086E-06	.1326E-06
SN	.4734E-01	.1138	.1379	.1219	.1801	.1318	.1226	.1368
SB	.1114E-04	.2654E-14	.2229E-04	.2596E-04	.3681E-04	.2839E-04	.2738E-04	.2855E-04
TE	.2523	.3942	.4283	.3693	.5067	.4333	.4287	.4457
AG	1.271	7.940	12.22	8.929	13.93	9.424	9.329	10.25
MN	.2871	1.414	2.023	1.529	2.321	1.643	1.626	1.764
CAO	0.	1.143	4.290	7.010	13.57	12.72	12.95	12.54
AL2O3	0.	.5311E-14	.1389E-03	.3038E-03	.5590E-03	.9394E-03	.1054E-02	.1211E-02
NA2O	0.	7.058	7.910	6.260	8.111	8.994	9.542	9.916
K2O	0.	11.26	9.748	10.71	14.07	15.29	16.25	17.33
SIO2	0.	15.44	21.03	23.17	29.78	33.03	31.14	29.28
UO2	.1032	.1329	.1518	.9398E-01	.1343	.7915E-01	.6854E-01	.6848E-01
ZRO2	.1842E-01	.3143E-02	.7591E-02	.7242E-02	.8549E-02	.8331E-02	.8800E-02	.8855E-02
* CS2O * (Cs2O + Cd)	96.07	37.35	29.25	27.94	0.	0.	0.	0.
BAO	.5914	1.937	1.083	1.295	1.412	1.023	.7201	.5522
SRO	1.257	2.235	2.229	1.542	1.775	1.117	.7729	.6028
LA2O3	.4224E-03	.2350E-03	.1882E-03	.1667E-03	.1959E-03	.1794E-03	.1610E-03	.1326E-03
CEO2	.8123E-01	.1339	.2688	.1334	.1960	.7705E-01	.5208E-01	.4423E-01
NB2O5	.4793E-09	.2633E-09	.2111E-09	.1868E-09	.2193E-09	.2326E-09	.1802E-09	.1708E-09
CSI	.1671	.3936	.2426	.2705E-01	.9697E-02	.9348E-03	.1778E-03	.7538E-04
SOURCE RATE(GM/S) {with % P}	[1.145 / 1.417]	[25.35 / 13.95]	[57.30 / 50.60]	[44.36 / 59.15]	[77.12 / 9?.1]	84.22	53.97	46.48
OXIDE MELT TEMP(K)	1967.	2132.	2229.	2179.	2288.	2136.	2230.	2141.
AEROSOL DENSITY(GM/CM3)	3.749	3.319	3.329	3.252	3.016	2.864	2.864	2.895
AEROSOL SIZE(MICRON)	.7974	1.012	1.080	1.081	1.009	.9914	.9718	.9550

Table B.3 Ex-Vessel Aerosol Release Rate and Composition for Surry TMLB'

SURRY TMLB' CORCON/VANESA SNL AUDIT CALCULATION

SPECIES	TIME 9600.0	10800.0	12000.0	13200.0	14400.0	15600.0	16800.0	18000.0
FEO	13.17	23.83	1.033	1.140	1.247	1.327	1.392	1.442
CR2O3	.1599E-13	.8447E-13	.1138	.1762	.2240	.2626	.2950	.3170
NI	.1022	.1270	.2616	.4256	.5010	.5614	.6365	.6333
MO	.2122E-07	.2336E-07	.9182E-04	.1528E-03	.2476E-03	.3336E-03	.4206E-03	.4958E-03
RU	.1866E-08	.2197E-08	.6703E-06	.9724E-06	.1494E-05	.1939E-05	.2372E-05	.2659E-05
SN	.1523	.1761	1.156	1.278	1.384	1.465	1.530	1.579
SB	.3273E-04	.3528E-04	.1022E-03	.1006E-03	.9836E-04	.9491E-04	.9182E-04	.8975E-04
TE	.4775	.5615	1.390	1.280	1.157	1.061	.9889	.9438
AG	11.13	13.90	37.90	39.69	41.04	41.78	42.08	42.12
MN	1.971	2.341	6.317	6.433	6.458	6.427	6.360	6.292
CAO	11.22	9.756	.4018	.4971	.6338	.6718	.7029	.7273
AL2O3	.1293E-02	.1684E-02	.4501E-02	.3935E-02	.3287E-02	.2880E-02	.2627E-02	.2520E-02
NA2O	13.78	11.96	4.043	3.790	3.417	3.173	3.000	2.909
K2O	18.22	19.37	36.42	32.42	25.26	23.20	23.15	22.10
SIO2	26.23	24.31	9.685	11.10	13.99	16.15	17.81	18.73
UO2	.7131E-01	.3132E-01	1.119	1.343	1.629	1.947	2.020	2.128
ZRO2	.9231E-02	.1035E-01	.2535E-01	.2105E-01	.1703E-01	.1443E-01	.1269E-01	.1168E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.4041	.1819	.3291E-01	.3794E-01	.4450E-01	.4336E-01	.4226E-01	.4144E-01
SRO	.4473	.2038	.3905E-02	.4544E-02	.5570E-02	.5565E-02	.5510E-02	.5435E-02
LA2O3	.1523E-03	.1616E-03	.3930E-03	.3263E-03	.2637E-03	.2234E-03	.1962E-03	.1806E-03
CEO2	.3583E-01	.1726E-01	.6226E-03	.5422E-03	.4736E-03	.4443E-03	.4231E-03	.4081E-03
NB2O5	.1634E-05	.1829E-05	.4399E-03	.3612E-03	.2952E-03	.7395E-03	.8722E-03	.9596E-03
CSI	.1763E-04	.2135E-04	.2599E-04	.2338E-04	.1968E-04	.1598E-04	.1364E-04	.1244E-04
SOURCE RATE(GM/S)	42.49	41.42	13.08	8.044	8.143	11.01	14.01	17.95
OXIDE MELT TEMP(K)	2131.	2150.	2172.	2208.	2245.	2275.	2297.	2310.
AEROSOL DENSITY(GM/CM3)	2.942	3.020	3.334	3.492	3.581	3.633	3.675	3.693
AEROSOL SIZE(MICRON)	.5228	.5797	.6217	.6498	.6895	.7216	.7470	.7612

Table B.3 Ex-Vessel Aerosol Release Rate and Composition for Surry TMLB' (Continued)

SURRY TMLB' CORCON2/VANESA SNL AUDIT CALCULATION

SPECIES TIME	19200.0	20400.0	21600.0	22800.0	24000.0	25200.0	26400.0	27600.0
FEO	1.463	1.467	1.436	1.361	1.261	1.158	1.051	.9549
CR2O3	.2261	.3025	.2714	.2273	.1848	.1576E-02	.1913E-02	.2243E-02
NI	.6253	.5950	.5447	.4775	.4127	.3609	.3150	.2792
MO	.5322E-03	.5292E-03	.5131E-03	.4822E-03	.4704E-03	.4925E-03	.5408E-03	.6339E-03
RU	.2553E-05	.2225E-05	.1756E-05	.1231E-05	.8793E-06	.6411E-06	.4711E-06	.3601E-06
SN	1.825	1.820	1.822	1.802	1.780	1.573	1.570	1.585
SB	.8932E-04	.9091E-04	.9298E-04	.9547E-04	.9745E-04	.9905E-04	.1003E-03	.1016E-03
TE	.9352	.9728	1.025	1.099	1.168	1.229	1.271	1.306
AG	41.99	41.56	41.04	39.67	38.32	36.79	35.12	33.59
MN	6.257	6.248	6.228	6.164	6.046	5.911	5.747	5.590
CAO	.7462	.7602	.7698	.7624	.7519	.7579	.7520	.7515
AL2O3	.2627E-02	.2979E-02	.3530E-02	.4361E-02	.5353E-02	.6381E-02	.7484E-02	.8566E-02
NA2O	2.547	3.112	3.345	3.640	3.906	4.107	4.250	4.332
K2O	22.53	24.39	27.24	31.29	35.46	39.24	42.72	45.62
SIO2	19.47	16.79	14.35	11.81	9.332	7.424	5.854	4.676
UO2	2.115	2.017	1.963	1.863	1.497	1.367	1.273	1.219
ZRO2	.1151E-01	.1242E-01	.1379E-01	.1590E-01	.1820E-01	.2034E-01	.2244E-01	.2428E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.4124E-01	.4168E-01	.4292E-01	.4380E-01	.4526E-01	.4696E-01	.4889E-01	.5115E-01
SRO	.5321E-02	.5269E-02	.5210E-02	.5115E-02	.5015E-02	.4950E-02	.4893E-02	.4895E-02
LA2O3	.1759E-03	.1922E-03	.2135E-03	.2463E-03	.2822E-03	.3153E-03	.3479E-03	.3764E-03
CEO2	.3999E-03	.3851E-03	.3899E-03	.4098E-03	.4421E-03	.4780E-03	.5010E-03	.5421E-03
NB2O5	.3525E-03	.8552E-03	.7237E-03	.2756E-05	.3157E-05	.3529E-05	.3893E-05	.4212E-05
CSI	.2151E-11	.2346E-11	.2606E-11	.3006E-11	.3443E-11	.3849E-11	.4246E-11	.4594E-11
SOURCE RATE(GM/S)	22.23	23.25	22.87	20.05	16.51	13.78	11.62	9.914
OXIDE MELT TEMP(K)	2307.	2289.	2263.	2229.	2194.	2155.	2138.	2115.
AEROSOL DENSITY(GM/CM3)	3.824	3.548	3.597	3.492	3.384	[illegible]	3.194	3.118
AEROSOL SIZE(MICRON)	.7549	.7289	.6946	.6542	.6181	.5894	.5648	.5447

Table B.3 Ex-Vessel Aerosol Release Rate and Composition for Surry TMLB' (Continued)

SURRY TMLB' CORCON2/VANESA SNL AUDIT CALCULATION

SPECIES TIME	28800.0	30000.0	31200.0	32400.0	33600.0	34800.0	36000.0
FEO	.8653	.8216	.7392	.6890	.6539	.5899	.4641
CR2O3	.2566E-02	.2861E-02	.3163E-02	.3463E-02	.3679E-02	.4123E-02	.4938E-02
NI	.2493	.2249	.2000	.1752	.1571	.1232	.7718E-01
MO	.7717E-03	.9672E-03	.1185E-02	.1396E-02	.1578E-02	.1809E-02	.1318E-02
RU	.2346E-06	.2255E-06	.1765E-06	.1330E-06	.1290E-06	0.	0.
SN	1.613	1.649	1.697	1.640	1.515	1.478	1.203
SB	.1129E-03	.1043E-03	.1051E-03	.1051E-03	.1042E-03	.1007E-03	.9266E-04
TE	1.334	1.352	1.367	1.376	1.373	1.377	1.364
AG	32.14	30.82	29.28	27.53	26.08	23.11	18.14
MN	5.429	5.292	5.117	4.909	4.727	4.347	3.682
CAO	.7526	.7599	.7605	.7547	.7509	.7082	.6190
AL2O3	.9884E-02	.1072E-01	.1191E-01	.1320E-01	.1429E-01	.1643E-01	.2049E-01
NA2O	4.376	4.387	4.394	4.397	4.395	4.391	4.287
K2O	48.15	53.37	52.75	55.32	57.37	61.59	68.57
SIO2	3.715	3.069	2.479	1.995	1.690	1.229	.7155
UO2	1.167	1.174	1.147	1.102	1.063	.9323	.7323
ZRO2	.2601E-01	.2748E-01	.2915E-01	.3093E-01	.3215E-01	.3546E-01	.4184E-01
CS2O	0.	0.	0.	0.	0.	0.	0.
BAO	.5773E-01	.5840E-01	.5904E-01	.6122E-01	.6272E-01	.6410E-01	.6532E-01
SRO	.4533E-02	.4933E-02	.5026E-02	.5321E-02	.4985E-02	.4303E-02	.4364E-02
LA2O3	.4031E-03	.4261E-03	.4519E-03	.4795E-03	.4984E-03	.5496E-03	.6486E-03
CEO2	.5216E-03	.6136E-03	.6508E-03	.6909E-03	.7178E-03	.7915E-03	.9340E-03
NB2O5	.4511E-09	.4767E-09	.5056E-09	.5365E-09	.5577E-09	.6150E-09	.7257E-09
CSI	.4922E-11	.5200E-11	.5515E-11	.5852E-11	.6083E-11	.6708E-11	.7915E-11
SOURCE RATE(GM/S)	8.668	7.754	7.003	6.024	6.005	7.225	5.820
OXIDE MELT TEMP(K)	2095.	2078.	2063.	2040.	2026.	1994.	1939.
AEROSOL DENSITY(GM/CM3)	3.032	2.996	2.933	2.883	2.811	2.703	2.539
AEROSOL SIZE(MICRON)	.5279	.5121	.4991	.4860	.4769	.4598	.4334

Table B.3 Ex-Vessel Aerosol Release Rate and Composition for Surry TMLB' (Continued)

Table B.4 Breakdown of Cs_2O grouping: Surry TMLB'

t (sec)	0	1200	2400	3600
Cs_2O (%)	1.26	.52	.41	.36
Cd (%)	95.56	39.34	30.92	27.21
Source rate (gm/s)				
w/DF	1.5	11.2	40.2	66.5
w/o DF	4.4	21.3	53.6	72.4
DF	2.947	1.903	1.334	1.088

APPENDIX C: SURRY S2D INPUT AND RESULTS

Appendix C summarizes the input files for both the CORCON and VANESA calculations for the ex-vessel aerosol and fission product release to containment for the Surry S2D sequence. Table C.1 is the CORCON input deck. Figures C.1-C.3 present the melt temperature, integrated gas generation rates, and erosion depths for the core-concrete interaction calculation. These quantities were input to VANESA for the aerosol and fission product release calculation. Table C.2 is the VANESA input deck. Table C.3 presents the VANESA results for each time step. Included is the aerosol source rate, melt temperature, aerosol density and size, as well as a fractional breakdown of the species in the aerosol for each time step. Table C.4 presents a breakdown of the Cs_2O release group and the DF used while water was over the core melt.

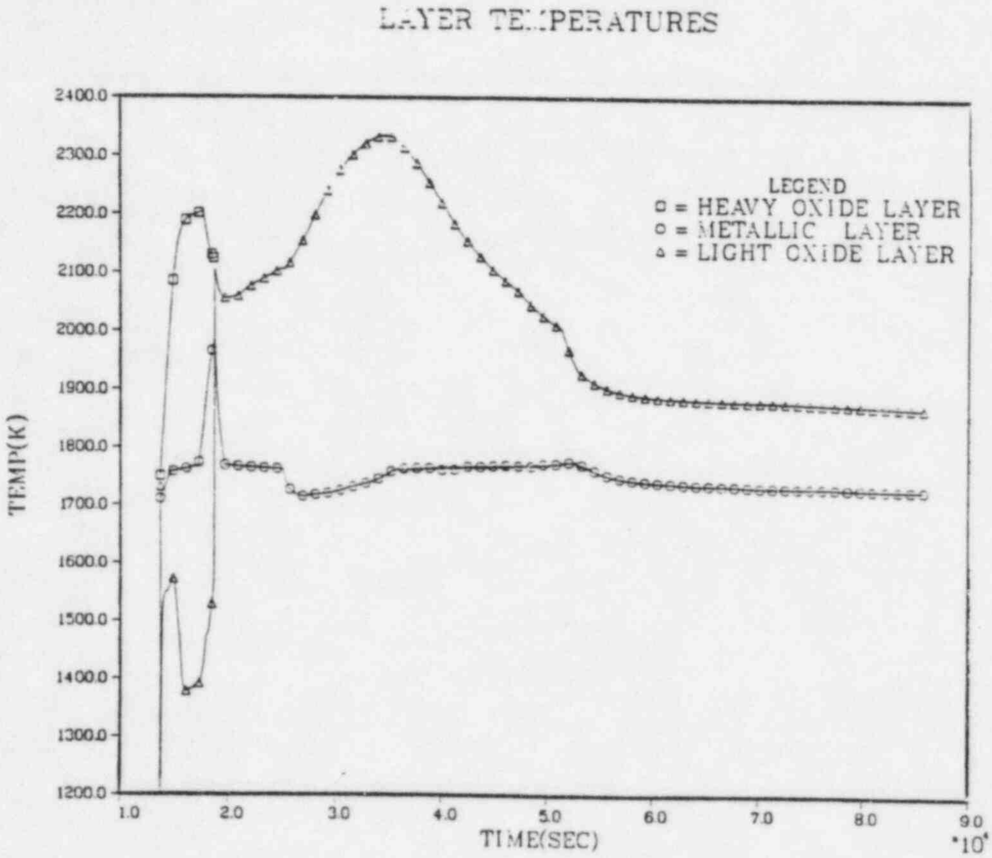

Figure C.1 Melt Temperature vs. Time: Surry S2D

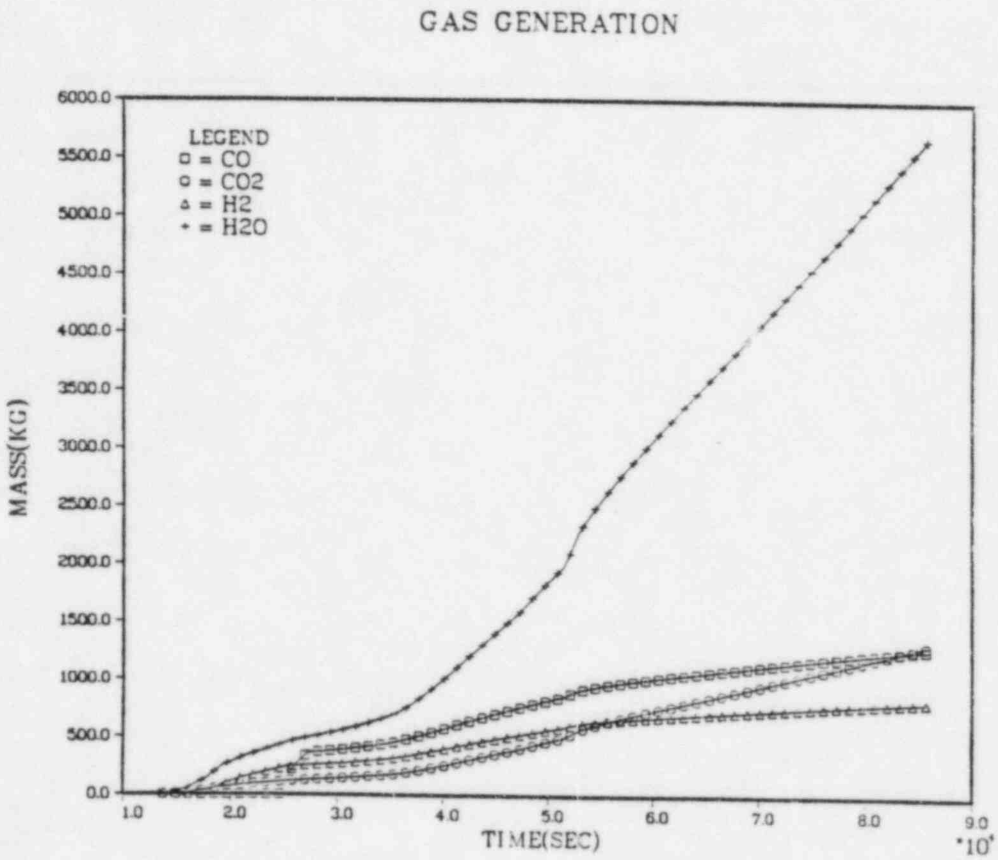

Figure C.2 Integrated Gas Release Rate vs. Time: Surry S2D

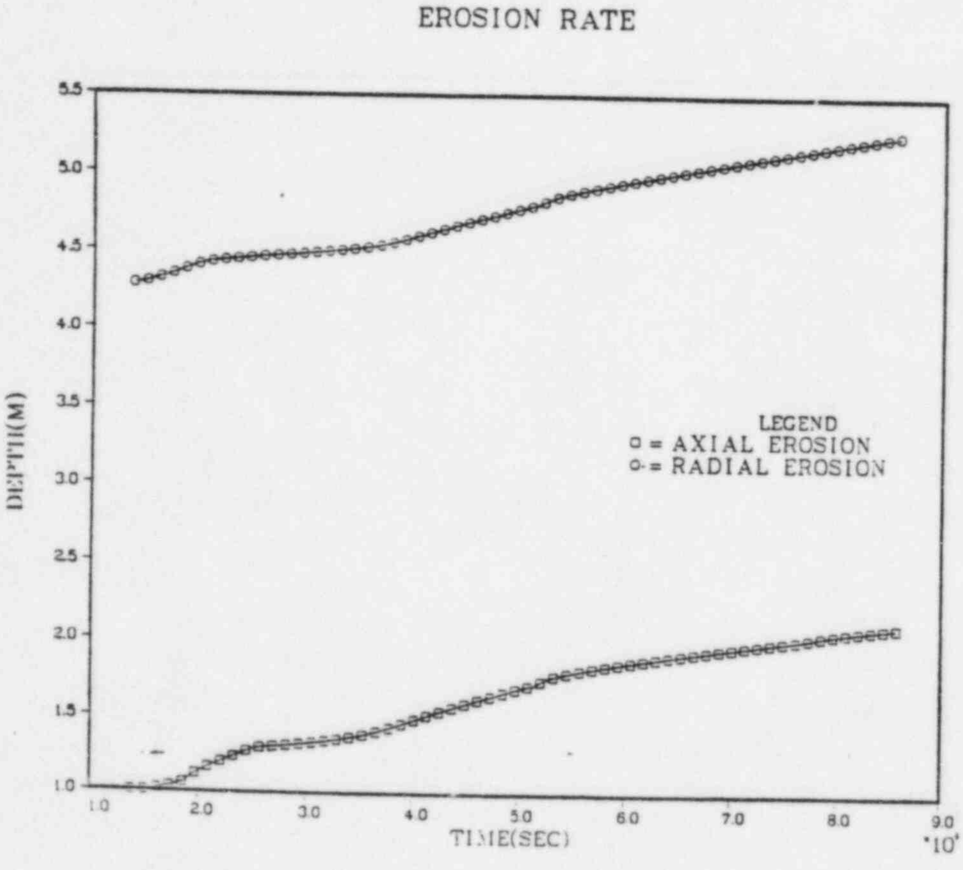

Figure C.3 Axial and Radial Concrete Erosion Depth vs. Time: Surry S2D

```
SURRY S2D: CORCON 1/VANESA SNL AUDIT CALCULATION
    0    0    2    1    0    0    1    0    0   20    0    0    0    1    0    0
      60.0     13650.    85650.       60.    90000.
   40       0.0        0.5
      0.0       4.28       1.0          0.1         4.5        3.0   10    6
     300.0     1650.        .6       .135
    3    4     1731.     1731.
UO2        79591.
ZRO2       13640.
FEO        5000.
FE         42110.
ZR         6367.
NI         3741.
CR         6734.
      70.2       2441.     0
     4505.    2.00E5       644.    3
N2                .70
H2                .13
CO2               .17
    2
13650.    500.       85650.    500.
TIMETIMETIME
    2    2    2
    13650.          1.0    85650.         1.0
    13650.          1.0    85650.         1.0
    13650.          1.0    85650.         1.0
```

Table C.1 CORCON Input Deck for Surry S2D Sequence

```
   SURRY S2D: CORCON1/VANESA SNL AUDIT CALCULATION
0.5984    1.0
42.57     0.        0.        0.        5.9       38.2      44.       102.
79591.    6367.     13640.    42110.    0.        125.      39.7      0.
22.9      36.4      20.5      51.5      62.3      131.      50.7      171.
34.       469.      6734.     153.      3741.     1841.     .11
 TWO TIME STEPS
1200.     1200.
 WT. FRACS FOR CAO,A12O3,NA2O,K2O, SIO2,FEO
.164      .0908     .0197     .0588     .5984     .0683
```

Table C.2 VANESA Input Deck for Surry S2D Sequence

* Cd is 100% of Cs₂O group

SURRY S2D: CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES	TIME .0	1200.0	2400.0	3600.0	4800.0	6000.0	7200.0	8400.0
FEO	.4409E-11	13.72	12.13	11.25	16.93	19.87	19.94	20.01
CR2O3	.2130E-19	.1173E-16	.1632E-01	.9884E-02	.3641E-15	.3730E-14	.4998E-14	.6761E-14
NI	.8328E-03	.3830E-01	.1118	.1172	.8876E-01	.4534E-01	.4629E-01	.5525E-01
MO	.7713E-18	.5692E-12	.2099E-07	.2388E-07	.1174E-07	.6824E-12	.8764E-12	.1624E-11
RU	0.	.3809E-07	.1821E-06	.2069E-06	.1025E-06	.3140E-07	.3275E-07	.4393E-07
SN	.2641E-02	.1240E-01	.2272E-01	.2266E-01	.2178E-01	.1512E-01	.1503E-01	.1652E-01
SB	.6546E-06	.2352E-05	.3636E-05	.3532E-05	.3719E-05	.2846E-05	.2779E-05	.2947E-05
TE	.5352E-01	.1865	.1332	.1263	.1518	.1350	.1323	.1368
AG	.4582	4.669	9.001	9.013	8.561	5.748	5.789	6.475
MN	.1194	.8726	1.540	1.524	1.817	1.878	1.880	1.189
CAO	0.	.4737	2.569	5.322	8.748	9.269	10.05	10.24
AL2O3	0.	.3192E-04	.1887E-03	.2244E-03	.5221E-03	.8840E-03	.1135E-02	.1294E-02
NA2O	0.	7.704	6.989	6.489	9.807	11.53	11.60	11.63
K2O	0.	12.12	11.19	10.82	16.78	20.25	20.45	20.36
SIO2	0.	15.36	17.76	21.87	30.35	30.15	29.53	28.78
UO2	.9483E-01	.8337E-01	.1360	.1260	.1891	.7574E-01	.6526E-01	.6278E-01
ZRO2	.1620E-01	.1009E-01	.9166E-02	.8149E-02	.1124E-01	.1174E-01	.1095E-01	.1058E-01
* CS2O = Cd	98.34	41.99	34.98	30.40	3.998	0.	0.	0.
BAO	.2259	1.165	1.355	1.402	1.239	.7393	.5290	.4315
SRO	.6928	1.602	1.947	1.515	1.590	1.835	.7327	.5763
LA2O3	.4094E-03	.2529E-03	.2243E-03	.1913E-03	.2583E-03	.2483E-03	.2855E-03	.1866E-03
CEO2	.5984E-03	.6884E-01	.1939	.1792	.1117	.4192E-01	.3889E-01	.2794E-01
NB2O5	.4583E-05	.2830E-05	.2511E-05	.2141E-05	.2801E-05	.2698E-05	.2388E-05	.2089E-05
CSI	0.	0.	0.	0.	0.	0.	0.	0.
SOURCE RATE(GM/S) {with D.F.}	[3.161 / .92]	[16.91 / 8.11]	[36.64 / 20.02]	[52.45 / 32.42]	[60.20 / 50.17]	[58.99 / 39.1]	44.71	39.67
OXIDE MELT TEMP(K)	1721.	2073.	2187.	2201.	2133.	2057.	2068.	2077.
AEROSOL DENSITY(GM/CM3)	3.760	3.220	3.270	3.183	2.896	2.784	2.782	2.801
AEROSOL SIZE(MICRON)	.7583	.9897	1.026	1.061	.9559	.9182	.9173	.9142

Table C.3 Ex-Vessel Aerosol Release Rate and Composition for Surry S2D

SURRY S2D: CORCON1/VANESA SNL AUDIT CALCULATION

SPECIES TIME	9600.0	10800.0	12000.0	13200.0	14400.0	15600.0	16800.0	18000.0
FEO	20.63	21.93	.9518	1.095	1.236	1.364	1.468	1.548
CR2O3	.1858E-13	.2609E-13	.1928E-03	.4450E-03	.2013	.2552	.3964	.3510
NI	.6459E-01	.7768E-01	.3872	.3808	.4699	.5631	.6455	.7092
MO	.2977E-11	.7412E-11	.3628E-04	.6159E-04	.1072E-03	.1662E-03	.2316E-03	.2981E-03
RU	.5558E-07	.7324E-07	.3156E-06	.4992E-06	.8069E-06	.1241E-05	.1756E-05	.2251E-05
SN	.1817E-01	.2063E-01	.2174	.2536	.2892	.3219	.3482	.3676
SB	.3152E-05	.3477E-05	.1572E-04	.1619E-04	.1695E-04	.1714E-04	.1693E-04	.1667E-04
TE	.1435	.1548	.5485	.5053	.4616	.4175	.3788	.3485
AG	7.214	8.274	31.10	33.73	35.91	37.54	38.44	38.78
MN	1.368	1.482	5.513	5.797	5.973	6.053	6.040	5.971
CAO	9.482	7.881	.3764	.4382	.5778	.6681	.7132	.7466
AL2O3	.1452E-02	.1651E-02	.6069E-02	.5275E-02	.4370E-02	.3628E-02	.3088E-02	.2730E-02
NA2O	11.95	12.66	4.666	4.590	4.213	3.845	3.525	3.283
K2O	28.64	21.49	47.69	42.57	37.06	32.08	27.96	25.11
SIO2	27.67	26.24	7.449	9.460	12.15	15.22	18.15	20.56
UO2	.6258E-01	.6513E-01	.9061	1.107	1.383	1.688	1.949	2.162
ZRO2	.1268E-01	.1100E-01	.3687E-01	.3045E-01	.2447E-01	.1976E-01	.1633E-01	.1398E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.3398	.2219	.2952E-01	.3832E-01	.3722E-01	.3908E-01	.3881E-01	.3684E-01
SRO	.4414	.2798	.3933E-02	.4202E-02	.5308E-02	.5797E-02	.5820E-02	.5764E-02
LA2O3	.1774E-03	.1753E-03	.5717E-03	.4721E-03	.3795E-03	.3062E-03	.2529E-03	.2163E-03
CEO2	.2373E-01	.1666E-01	.8618E-03	.7331E-03	.6244E-03	.5513E-03	.5889E-03	.4857E-03
NB2O5	.1985E-05	.1962E-05	.6399E-05	.5264E-05	.4248E-05	.3427E-05	.7822E-03	.9532E-03
CSI	0.	0.	0.	0.	0.	0.	0.	0.
SOURCE RATE(GM/S)	37.43	39.61	9.173	5.495	4.972	6.881	8.234	10.90
OXIDE MELT TEMP(K)	2898.	2182.	2115.	2153.	2196.	2238.	2274.	2301.
AEROSOL DENSITY(GM/CM3)	2.824	2.857	2.963	3.090	3.223	3.337	3.418	3.466
AEROSOL SIZE(MICRON)	.9024	.6609	.5752	.6002	.6366	.6762	.7142	.7467

Table C.3 Ex-Vessel Aerosol Release Rate and Composition for Surry S2D (Continued)

SURRY S2D: CORCON/VANESA SNL AUDIT CALCULATION

SPECIES TIME	19200.0	20400.0	21600.0	22800.0	24000.0	25200.0	26400.0	27600.0
FEO	1.414	1.669	1.789	1.718	1.702	1.648	1.557	1.434
CR2O3	.3875	.4144	.4250	.4065	.3715	.3251	.2742	.2231
NI	.7548	.7833	.7866	.7465	.6853	.6114	.5335	.4558
MO	.2608E-03	.4140E-03	.4433E-03	.4247E-03	.3981E-03	.3508E-03	.3150E-03	.2856E-03
RU	.2670E-05	.2958E-05	.2969E-05	.2577E-05	.2037E-05	.1512E-05	.1073E-05	.7409E-06
SN	.3821	.3933	.4006	.3995	.3959	.3874	.3756	.3606
SB	.1643E-04	.1630E-04	.1630E-04	.1658E-04	.1696E-04	.1734E-04	.1763E-04	.1781E-04
TE	.3261	.3118	.3072	.3192	.3394	.3639	.3893	.4140
AG	38.81	38.75	38.62	38.39	37.99	37.21	36.00	34.36
MN	5.804	5.780	5.656	5.774	5.705	5.762	5.684	5.545
CAO	.7728	.7956	.8139	.8256	.8336	.8330	.8226	.8023
AL2O3	.2508E-02	.2405E-02	.2444E-02	.2754E-02	.3272E-02	.3982E-02	.4870E-02	.5939E-02
NA2O	3.113	3.021	3.026	3.203	3.473	3.789	4.109	4.405
K2O	23.22	22.20	22.22	24.08	27.12	30.99	35.37	40.09
SIO2	22.36	23.50	23.57	21.80	19.19	16.19	13.21	10.44
UO2	2.216	2.411	2.417	2.274	2.069	1.838	1.611	1.400
ZRO2	.1248E-01	.1144E-01	.1113E-01	.1190E-01	.1327E-01	.1511E-01	.1727E-01	.1972E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.3576E-01	.3492E-01	.3443E-01	.3434E-01	.3495E-01	.3546E-01	.3600E-01	.3655E-01
SRO	.5669E-02	.5564E-02	.5469E-02	.5377E-02	.5271E-02	.5139E-02	.4981E-02	.4801E-02
LA2O3	.1917E-03	.1767E-03	.1720E-03	.1839E-03	.2053E-03	.2340E-03	.2677E-03	.3057E-03
CEO2	.4713E-03	.4597E-03	.4457E-03	.4287E-03	.4194E-03	.4243E-03	.4445E-03	.4787E-03
NB2O5	.1092E-02	.1106E-02	.1200E-02	.1075E-02	.9012E-03	.7214E-03	.2995E-05	.3421E-05
CSI	0.	0.	0.	0.	0.	0.	0.	0.
SOURCE RATE(GM/S)	13.60	16.63	21.13	23.71	22.87	20.33	17.55	14.59
OXIDE MELT TEMP(K)	2320.	2332.	2334.	2316.	2289.	2257.	2223.	2187.
AEROSOL DENSITY(GM/CM3)	3.491	3.498	3.494	3.467	3.416	3.344	3.253	3.150
AEROSOL SIZE(MICRON)	.7717	.7869	.7878	.7686	.7236	.6839	.6462	.6118

Table C.3 Ex-Vessel Aerosol Release Rate and Composition for Surry S2D (Continued)

SURRY S2D: CORCON2/VANESA SNL AUDIT CALCULATION

SPECIES	TIME 28800.0	30000.0	31200.0	32400.0	33600.0	34800.0	36000.0	37200.0
FEO	1.308	1.187	1.072	.9775	.8946	.7848	.7049	.6436
CR2O3	.1919E-02	.2295E-02	.2684E-02	.3041E-02	.3387E-02	.3872E-02	.4294E-02	.4669E-02
NI	.3924	.3416	.2984	.2683	.2431	.2070	.1829	.1639
MO	.2741E-03	.2784E-03	.2954E-03	.3341E-03	.3922E-03	.4525E-03	.5699E-03	.7211E-03
RU	.5261E-06	.3875E-06	.2960E-06	.2300E-06	.1865E-06	.1337E-06	.1035E-06	0.
SN	.3467	.3430	.3337	.3337	.3368	.3304	.3341	.3388
SB	.1796E-04	.1808E-04	.1824E-04	.1854E-04	.1893E-04	.1920E-04	.1976E-04	.2036E-04
TE	.4344	.4491	.4612	.4698	.4767	.4862	.4920	.4955
AG	32.70	31.08	29.50	28.25	27.13	25.29	23.94	22.73
MN	5.385	5.218	5.033	4.891	4.762	4.542	4.381	4.238
CAO	.7839	.7656	.7499	.7436	.7412	.7220	.7189	.7188
AL2O3	.7060E-02	.8152E-02	.9279E-02	.1038E-01	.1131E-01	.1280E-01	.1415E-01	.1542E-01
NA2O	4.634	4.780	4.875	4.915	4.923	4.923	4.877	4.816
K2O	44.41	48.01	51.24	53.69	55.79	58.93	61.18	63.08
SIO2	8.281	6.633	5.314	4.378	3.636	2.772	2.280	1.786
UO2	1.242	1.130	1.044	.9985	.9713	.9189	.8932	.8851
ZRO2	.2282E-01	.2481E-01	.2591E-01	.2739E-01	.2875E-01	.3111E-01	.3287E-01	.3441E-01
CS2O	0.	0.	0.	0.	0.	0.	0.	0.
BAO	.3718E-01	.3786E-01	.3873E-01	.3989E-01	.4122E-01	.4292E-01	.4504E-01	.4718E-01
SRO	.4631E-02	.4582E-02	.4484E-02	.4361E-02	.4354E-02	.4318E-02	.4339E-02	.4382E-02
LA2O3	.3415E-03	.3723E-03	.4017E-03	.4248E-03	.4458E-03	.4824E-03	.5097E-03	.5336E-03
CEO2	.5173E-03	.5369E-03	.5789E-03	.6121E-03	.6424E-03	.6951E-03	.7345E-03	.7689E-03
NB2O5	.3821E-05	.4165E-05	.4495E-05	.4752E-05	.4988E-05	.5397E-05	.5703E-05	.5970E-05
CSI	0.	0.	0.	0.	0.	0.	0.	0.
SOURCE RATE(GM/S)	12.84	10.26	8.647	7.539	7.363	6.598	5.602	6.114
OXIDE MELT TEMP(K)	2157.	2131.	2107.	2086.	2072.	2047.	2029.	2013.
AEROSOL DENSITY(GM/CM3)	3.052	2.971	2.900	2.847	2.802	2.733	2.686	2.646
AEROSOL SIZE(MICRON)	.5841	.5621	.5438	.5281	.5158	.4978	.4844	.4731

Table C.3 Ex-Vessel Aerosol Release Rate and Composition for Surry S2D (Continued)

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Table C.4 Breakdown of Cs_2O grouping: Surry S2D

t (sec)	0	1200	2400	3600	4800
Cs_2O (%)*	0	0	0	0	0
Cd (%)	98.34	41.99	34.98	30.40	4.00
Source rate (gm/s)					
w/DF	.82	8.1	20.0	32.4	50.2
w/o DF	3.2	16.9	36.6	52.5	60.2
DF	3.875	2.086	1.830	1.618	1.200

*There was no Cs in initial melt species inventory.