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December 5, 1984

Ralph Meyer
Fuel Behavior Research Branch
Nuclear Regulatory Commission
Washington, DC 20555

Dear Ralph:

This letter is our report for Task 1 as defined in Mel Silberberg's memo of November 16 on "Plan to Address Concerns Related to Lanthanum Releases in BMI-2104". The efforts under this task are defined as:

1. Examination of Peach Bottom AE Results

BCL will verify that SNL has the correct input for CORCON/VANESA. SNL will reanalyze the Peach Bottom sequences using CORCON-Mod1/VANESA, and supply the results to BCL. BCL will run NAUA and other codes as necessary to revise tables 6.14 and 7.16 of Vol. II. SNL will review all CORCON calculations used in BMI-2104 and identify any sequences in which an excessive temperature excursion occurs. The results of this review will be transmitted by letter to BCL and the NRC. BCL will prepare a letter report that (a) discusses any discrepancies discovered, (b) presents the revised tables 6.14 and 7.16, and (c) recommends reanalysis necessary to correct other tables in BMI-2104 (e.g., tables 6.15 and 6.16 of Vol. II).

This letter is divided into sections covering items a, b and c as defined above.

(a) Discrepancies Discovered

Based on results of a sensitivity analysis reported by Dana Powers at our meeting in Silver Spring on November 20, it can be estimated that the CORCON, Mod1 version should be adequate for this analysis and should not give results substantially different than the Mod1V or Mod2 versions. Therefore, the efforts under this task have been based on use of the Mod1 version. The Mod1 version was used in performing calculations for the BMI-2104 report.

In reviewing the input for the AE sequence as reported for the WASH-1400 fission product group in BMI-2104, several inconsistencies were noted between parameters used and parameters that should have been used.

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One area of slight difference between the previous analyses and this reanalysis is the fission product composition of the melt at the initiation of the core-concrete interaction. The original analysis assumed a homogeneous core composition while the current case uses a typical power distribution to specify the spatial fission product concentration. The result is a slight difference in composition of the melt but not nearly enough difference to affect predicted core-concrete interaction behavior. The small differences do translate into slightly different amounts of fission products being released ex-vessel compared with in-vessel. Again the effects are minimal. The melt composition used in this reanalysis is shown in Table 1.

Other items subject to revision have concerned the radius of the reactor cavity, the amounts of structural steel and fuel contained initially in the melt, and the time from scram to the core-concrete interaction initiation. These revisions are noted in more detail in Table 2.

A final discrepancy was found in the identification of elements predicted to be released by the VANESA code. The apparent elemental composition of the release as given by Table 6.14 of Vol. II contains, in fact, several groupings which were not identified to the Battelle staff earlier. The groupings are as follows:

Ru = Ru, Tc, Rh and Pd

La_2O_3 = La_2O_3, Eu_2O_3, Pr_2O_3, Nd_2O_3, Pm_2O_3, Sm_2O_3 and Gd_2O_3

CeO_2 = CeO_2, NpO_2 and PuO_2

Since it is now known that these groupings were already included in the VANESA output, the release rates and inventories can be interpreted properly. Estimates of the effect of the grouping indicate that the source term reported previously for Peach Bottom, AE sequence, would be reduced by a factor of about 6 for the lanthanum group, and 1.5 for the ruthenium group. This grouping effect alone has a considerable impact.

(b) Revised Results for Peach Bottom, AE

Using corrected values for the various parameters and using a correct interpretation of VANESA output, the source term by WASH-1400 fission product group was recalculated for Peach Bottom, AE sequence. Revised versions of Tables 6.14 and 7.16 from BMI-2104, Vol. II have been prepared and are attached. The results are seen to be essentially identical to the previous BMI-2104 values for cesium, iodine and tellurium releases. The strontium group release is now predicted to be somewhat lower than previously predicted and the lanthanum group is much lower than previous predictions. These latest source term predictions are believed to be much more realistic than the previous estimates because of the corrections made for previous discrepancies and misinterpretations.

(c) Recommended Reanalyses

Reanalyses of various sequences throughout the current BMI-2104 volumes can be recommended for several reasons. Review of the Peach Bottom analyses (Vol. II) suggest that the sequences (TC and TW) other than the AE sequence considered here should be repeated at least to correct the fission product releases during core-concrete interaction and Tables 6.15 and 6.16 replaced with updated versions. This would require use of codes CORCON, VANESA, NAUA and SPARC.

The problem identified with the grouping of elements within the VANESA output suggests that all source terms for the WASH-1400 groups in all volumes are in error and should be corrected. This would require analyses using primarily the NAUA and SPARC codes.

Finally, it has been identified that the CORCON Modl code may give unrealistically high melt temperatures for some cores, especially these having basaltic concrete. A review of this possibility is being performed by Sandia and the previous CORCON calculations are being checked for possible erroneous results. Based on discussions with Dana Powers, the results of this review will be transmitted directly from Sandia to the NRC.

If you have any questions, let me know.

Sincerely,

Jim

James A. Gieseke
Physico-Chemcial Systems Section

JAG:cjh

Attachments

cc: M. Silberberg

TABLE 1. MELT COMPOSITION AT START OF CORE CONCRETE INTERACTION

Element/Compound	Mass, kg	Element/Compound	Mass, kg
Xe	0.55	Pm	11.5
Kr	0.04	Sm	53.8
I	0.02	Np	41.2
Cs	0.30	Pu	742.4
Rb	0.03	Nb	4.3
Te	28.0	Zr (fp)	266.8
Sr	58.4	U	140500.
Ba	86.7	Zr (clad)	41070.
Ru	171.0	ZrO_2 (clad)	32990.
Tc	58.4	Fe	70160.
Rh	33.0	FeO	825.
Pd	82.7	Cr	11100.
Mo	209.1	Ni	6164.
La	98.2	Sn	557.
Nd	270.8	Gd	287.
Eu	14.1	Mn	1233.
Y	36.2	Ag	0
Ce	207.8	In	0
Pr	80.3	Cd	0

TABLE 2. INPUT FOR CORE CONCRETE INTERACTION CALCULATIONS

Input	BMI-2104 Value	Revised Value
Time from scram to start of concrete attack (minutes)	81.8	126.26
Reactor cavity radius (m)	2.4384	3.2
Reactor operating power (MW thermal)	3400	3293
UO_2 mass in core (kg)	137977	159400
Debris temperature at the start of core debris/concrete interaction (K)	2161	2125
Concrete composition	CORCON default (a)	CORCON default (a)

(a) High limestone, low silica

TABLE 6.14

AEROSOL COMPOSITION AND TOTAL RELEASE RATE FOR PEACH BOTTOM; AE(NOVEMBER 30, 1984)

(UNIT:PERCENT)

SPECIES	0	1200	2400	3600	4800	6000	7200	8400	9600
FeO	37.1	12.7	12.8	13.1	13.0	12.8	12.6	12.5	12.4
Cr_2O_3	-	-	-	-	-	-	-	-	-
Ni	0.15	0.40	0.60	0.43	0.40	0.41	0.43	0.44	0.46
Mo	-	2e-07	4e-07	2e-07	2e-07	2e-07	2e-07	2e-07	2e-07
Ru (1)	2e-07	2e-06	3e-06	2e-06	2e-06	2e-06	2e-06	2e-06	2e-06
Sn	0.44	0.48	0.62	0.50	0.47	0.48	0.48	0.49	0.49
Sb	-	-	-	-	-	-	-	-	-
Te	0.80	0.50	0.56	0.50	0.47	0.46	0.45	0.44	0.42
Ag	-	-	-	-	-	-	-	-	-
Mn	13.3	12.4	12.5	12.9	12.8	12.6	12.4	12.3	12.2
CaO	-	25.5	25.7	26.5	26.4	26.0	25.7	25.5	25.5
Al_2O_3	-	1.91	4.07	4.05	4.39	4.85	5.21	5.47	5.62
Na_2O	-	2.37	2.28	2.25	2.27	2.26	2.25	2.23	2.19
K_2O	-	11.0	11.3	11.7	11.8	11.7	11.6	11.5	11.5
SiO_2	-	15.0	18.1	19.8	21.2	22.4	23.3	24.1	24.6
UO_2	0.28	0.47	0.68	0.45	0.39	0.38	0.37	0.37	0.36
ZrO_2	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Ce_2O (2)	25.0	-	-	-	-	-	-	-	-
BaO	7.99	3.47	3.37	2.83	2.39	2.08	1.83	1.62	1.44
SrO	6.64	4.21	4.29	3.19	2.55	2.17	1.87	1.62	1.40
La_2O_3 (3)	0.15	0.61	0.98	0.62	0.53	0.53	0.54	0.53	0.53
CeO_2 (4)	0.48	1.31	1.89	1.21	1.01	0.96	0.92	0.88	0.83
Nb_2O_5	6.25	7.64	0.25	-	-	-	-	-	-
CeI (2)	0.12	0.04	4e-03	3e-05	-	-	-	-	-
Cd	-	-	-	-	-	-	-	-	-
SOURCE RATE, G/SEC.	21.96	92.48	141.81	153.03	140.06	136.79	142.51	148.81	154.00

TABLE 6.14 (Continued)

SPECIES	10800	12000	13200	14400	15600	16800	18000	19200	20400
FeO	12.4	12.5	12.7	13.0	13.5	13.9	14.3	14.7	15.2
Cr_2O_3	–	–	–	–	–	–	–	–	–
Ni	0.46	0.47	0.47	0.44	0.42	0.41	0.40	0.40	0.39
Mo	2e-07	2e-07	2e-07	2e-07	2e-07	2e-07	2e-07	2e-07	2e-07
Ru(1)	2e-06	2e-06	2e-06	2e-06	2e-06	1e-06	1e-06	1e-06	1e-06
Sn	0.49	0.49	0.49	0.47	0.46	0.45	0.45	0.44	0.44
Sb	–	–	–	–	–	–	–	–	–
Te	0.41	0.40	0.39	0.37	0.36	0.35	0.34	0.34	0.33
Ag	–	–	–	–	–	–	–	–	–
Mn	12.2	12.3	12.4	12.8	12.4	12.1	12.0	11.7	11.5
CaO	25.5	25.7	26.0	26.8	27.7	28.6	29.3	30.3	31.3
Al_2O_3	5.66	5.62	5.39	4.86	4.39	3.93	3.47	2.95	2.35
Na_2O	2.17	2.17	2.15	2.12	2.15	2.21	2.26	2.29	2.31
K_2O	11.5	11.6	11.8	12.1	12.5	12.9	13.2	13.6	14.0
SiO_2	24.9	25.0	24.8	24.2	23.6	23.0	22.3	21.6	20.8
UO_2	0.34	0.33	0.31	0.27	0.25	0.23	0.22	0.20	0.19
ZrO_2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cs_2O(2)	–	–	–	–	–	–	–	–	–
BaO	1.28	1.14	1.02	0.89	0.78	0.69	0.60	0.51	0.43
SrO	1.22	1.06	0.91	0.76	0.64	0.55	0.46	0.39	0.32
La_2O_3(3)	0.52	0.50	0.47	0.40	0.35	0.32	0.29	0.26	0.22
CeO_2(4)	0.77	0.71	0.64	0.53	0.45	0.38	0.33	0.27	0.22
Nb_2O_5	–	–	–	–	–	–	–	–	–
CsI(2)	–	–	–	–	–	–	–	–	–
Cd	–	–	–	–	–	–	–	–	–
SOURCE RATE, G/SEC.	157.12	171.21	195.83	201.64	191.58	184.15	180.87	179.67	190.33

TABLE 6.14 (Continued)

SPECIES	21600	22800	24000	25200	26400	27600	28800	30000	31200
FeO	15.9	16.7	5.50	0.56	0.47	0.32	0.31	0.36	0.40
Cr_2O_3	–	–	0.24	0.27	0.16	0.06	0.03	0.03	0.03
Ni	0.37	0.35	0.65	0.54	0.38	0.25	0.20	0.19	0.19
Mo	1e-07	1e-07	1e-04	2e-04	2e-04	4e-04	6e-04	7e-04	7e-04
Ru(1)	1e-06	1e-06	1e-06	9e-07	5e-07	2e-07	2e-07	1e-07	1e-07
Sn	0.43	0.42	2.90	2.89	2.77	3.01	3.27	3.25	3.25
Sb	–	–	–	–	–	–	–	–	–
Te	0.32	0.31	0.83	0.78	0.71	0.64	0.60	0.58	0.58
Ag	–	–	–	–	–	–	–	–	–
Mn	11.0	10.6	24.3	21.9	18.2	14.7	13.1	12.8	12.6
CaO	32.6	34.3	58.0	60.6	66.1	71.7	74.1	74.7	74.9
Al_2O_3	1.60	0.68	2e-03	2e-03	2e-03	2e-03	2e-03	2e-03	2e-03
Na_2O	2.28	2.09	0.33	0.43	0.42	0.34	0.29	0.29	0.29
K_2O	14.5	14.9	9.49	9.63	9.10	7.63	6.82	6.70	6.65
SiO_2	19.8	18.9	0.97	0.70	0.36	0.13	0.07	0.06	0.06
UO_2	0.17	0.16	1.74	1.54	1.26	1.16	1.12	1.03	0.97
ZrO_2	0.02	0.02	0.06	0.06	0.06	0.06	0.06	0.06	0.05
Ce_2O(2)	–	–	–	–	–	–	–	–	–
BaO	0.33	0.19	0.02	0.01	0.01	9e-03	9e-03	8e-03	8e-03
SrO	0.23	0.13	1e-03	8e-04	5e-04	4e-04	4e-04	3e-04	3e-04
La_2O_3(3)	0.18	0.12	6e-03	4e-03	2e-03	1e-03	9e-04	9e-04	8e-04
CeO_2(4)	0.15	0.08	6e-04	6e-04	5e-04	5e-04	5e-04	5e-04	5e-04
Nb_2O_5	–	–	–	–	–	–	–	–	–
CeI(2)	–	–	–	–	–	–	–	–	–
Cd	–	–	–	–	–	–	–	–	–
SOURCE RATE, G/SEC.	193.33	235.15	85.41	94.20	91.28	65.53	45.35	34.88	29.38

TABLE 6.14 (Continued)

SPECIES	32400	33600	34800	36000	37200	38400	39600	40800	42000
FeO	0.43	0.47	0.50	0.53					
Cr_2O_3	0.03	0.03	0.03	0.02					
Ni	0.19	0.19	0.19	0.19					
Mo	7e-04	7e-04	7e-04	7e-04					
Ru[1]	1e-07	1e-07	1e-07	1e-07					
Sn	3.28	3.34	3.40	3.45					
Sb	-	-	-	-					
Te	0.57	0.57	0.57	0.57					
Ag	-	-	-	-					
Mn	12.7	12.8	13.0	13.1					
CaO	74.8	74.7	74.4	74.2					
Al_2O_3	2e-03	2e-03	2e-03	2e-03					
Na_2O	0.29	0.29	0.29	0.29					
K_2O	6.63	6.62	6.62	6.61					
SiO_2	0.06	0.06	0.06	0.06					
UO_2	0.93	0.91	0.89	0.87					
ZrO_2	0.05	0.05	0.05	0.05					
Cs_2O[2]	-	-	-	-					
BaO	8e-03	8e-03	7e-03	7e-03					
SrO	3e-04	3e-04	3e-04	3e-04					
La_2O_3[3]	8e-04	8e-04	8e-04	7e-04					
CeO_2[4]	5e-04	5e-04	5e-04	5e-04					
Nb_2O_5	-	-	-	-					
CsI[2]	-	-	-	-					
Cd	-	-	-	-					
SOURCE RATE, G/SEC.	26.15	24.34	23.46	23.24					

TABLE 6.14 (Continued)

1) Percent for Ru includes Ru, Tc, Pd and Rh.
2) Percent for Cs includes Cs and Rb.
3) Percent for La_2O_3 includes La_2O_3, Eu_2O_3 Y_2O_3, Pr_2O_3, Nd_2O_3, Pm_2O_3, Sm_2O_3, and Gd_2O_3.
4) Percent for CeO_2 includes CeO_2 NpO_2 and PuO_2.

TABLE 7.16. FRACTION OF CORE INVENTORY RELEASED TO THE ATMOSPHERE FOR GROUPS OF REACTOR SAFETY STUDY (AE)[(1)]

Time (hr)	I Group 2	Cs Group 3	Te Group 4	Sr Group 5	Ru Group 6	La Group 7
0.5	0	0	0	0	0	0
1	0.11	0.18	2.0×10^{-2}	6.5×10^{-3}	1.5×10^{-3}	5.1×10^{-5}
2	0.21	0.20	7.2×10^{-2}	1.1×10^{-2}	3.1×10^{-3}	9.1×10^{-5}
4	0.32	0.31	0.23	0.24	4.6×10^{-3}	9.7×10^{-3}
7	0.32	0.31	0.43	0.46	4.6×10^{-3}	1.9×10^{-2}
10	0.32	0.31	0.62	0.50	4.8×10^{-3}	2.1×10^{-2}
15	0.32	0.31	0.67	0.50	5.0×10^{-3}	2.1×10^{-2}

(1) Species considered are
Group 2 I
Group 3 Cs Rb
Group 4 Te
Group 5 Sr, Ba
Group 6 Ru, Rh, Pd, Tc, Mo
Group 7 La, Y, Eu, Nd, Np, Sm, Pm, Pu, Zr, Ce, Nb, Pr,

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On the attached figure (from J. K. Dickens, et al "Fission Product Energy Release for Times Following Thermal-Neutron Fission of U235 Between 2 and 1400 S", NSE 74 p 106 (1980)) we have superimposed decay heat calculated results using the 1979 ANSI standard. The lower dot is the fission product decay power and the upper dot includes the contribution from the actinides and from neutron capture. As expected the ANSI standard results without actinide and neutron capture heat are very close to the experimental values which involved short irradiation times (the ANSI standard was largely based on this work). The heavy element contribution accounts for U239 and Np239 decay. Note that for a 2-year irradiation the capture and heavy element decay account for 8 to 38 percent of the total, depending on decay time.

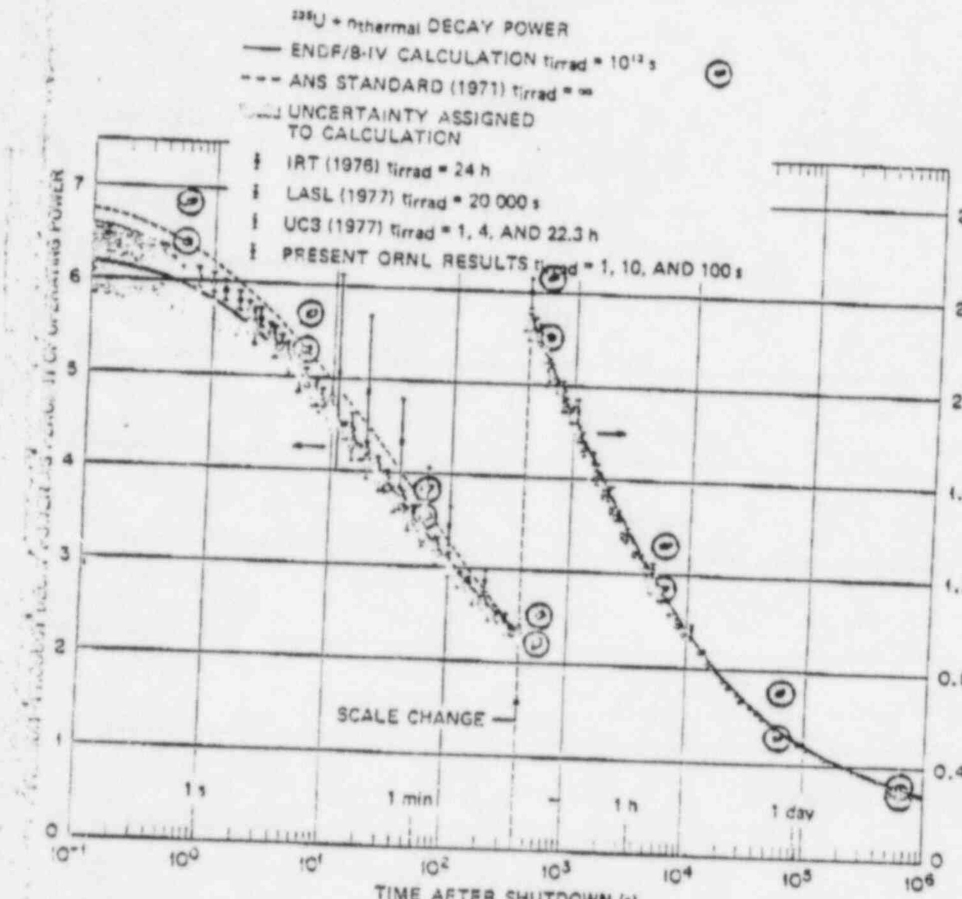

Fig. 8. Fission-product energy release following a long period of thermal-neutron fission of ^{235}U. The summation calculation ...s obtained using ORIGEN (Ref. 11) and the ENDF/B-IV data file (Ref. 19). The 1973 ANS Standard was obtained from ...f. 1. The data sets are from IRT (Ref. 5), LASL (Ref. 4), UCB (Ref. 6), and the present results; all data sets adjusted to agree ...th summation calculation for data obtained at the longest time after shutdown for the particular experiment.

...ta contribute to the result, since all three experi-...ents report measurements for cooling times $>10^5$ s. ...or example, for the time interval t_{irrad} = 100 s, ... = 600 s, 99.5% of the determination of $F(t,T)$ ...omes from the first term in square brackets in ... (9). Interpolations, when needed, were obtained ... linear interpolation of the logarithms of t and ...(t,T).

There are several puzzling differences among the values given in Table IV. For the third and fourth time intervals, i.e., for $20 \leq t \leq 600$ s, the ORNL beta-ray data are smaller than calculation by up to 15%, but the ORNL gamma-ray data agree very well with calculation. However, for the time interval $1200 \leq t \leq 6000$ s, the ORNL gamma-ray data are smaller than calculation but the beta-ray data are slightly larger. We were interested to see if other data sets behaved in a similar or in a different