NAI Report Release

Report Number: NAI-1149-007

Revision Number: 0

Title: Primary Coolant Activity for Palisades

Description:

The purpose of this calculation is to determine the activity in the primary coolant system assuming 1% fuel failure. The end-of-cycle core inventory was provided by a separate ORIGEN calculation. This analysis balances the addition of nuclides from the fuel and daughter products with the loss of nuclides due to decay and filtering within the purification loop. A GOTHIC calculation was used to model the fuel nuclide source term in the primary coolant system along with the flow through the purification loop which extracts nuclides in the mixed bed demineralizer, cation demineralizer, degassing volume control tank and radwaste demineralizer/evaporator system. Corrosion products were assessed using the approach of ANSI/ANS-18.1-1999.

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NAI Calculation Approval

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Scope of Review:

Computer codes were checked for appropriate qualification. Calculation and code inputs and assumptions were verified against input documents and/or checked for reasonableness and conservatism. Computations were checked for correctness. References were verified as appropriate. Reported results were verified against computer outputs. Results and conclusions were reviewed for reasonableness. The document was checked for grammatical and typographical errors.

Jim Harrell 10/20/04

Reviewer Date
Jim Harrell

Check items in the following lists to verify that project documentation and engineering calculations are complete. Mark any items that are not applicable with N/A notation.

Project Documentation Checklist:

N/A

- ☐ Project QA Plan.
- ☐ Project Organization.
- ☐ Project Work Scope and Design Plan.
- ☐ Project Calculation and Document Index.
- ☐ Project QA Requirements.
- ☐ Project Engineer Training and Qualification Forms.
- ☐ Project QA Training Certification Forms.
- ☐ Project Correspondence.

Engineering Calculations Checklist:

- ☑ Identification by subject, originator, reviewer, date and Project so that the calculation is retrievable.
- ☑ Table of contents.
- ☑ Statement of the objective of the analysis.
- ☑ Analysis inputs and their sources.
- ☑ Assumptions and how they were developed or determined.
- ☑ Hand calculations.
- ☑ Identification of computer calculations, including computer type, computer program name and version, code input and output.
- ☑ Conclusions.
- ☑ Review summary.
- ☑ Responses to review comments.
- ☑ References.
- ☑ Each page of the calculation shall be numbered and the first page shall indicate the total number of pages. The calculation pages may be numbered by sections with the first page of the section indicating the total number of pages in the section.
- ☑ The Calculation Approval Sheet shall be signed and dated by the originator.

NUMERICAL APPLICATIONS INC.

NAI-1149-007
(CALCULATION #)

Revision 0

Primary Coolant Activity for Palisades

for

Nuclear Management Company

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1.0 Purpose

The purpose of this calculation is to determine the activity in the primary coolant system assuming 1% fuel failure. The end-of-cycle core inventory was provided by a separate ORIGEN calculation. This analysis balances the addition of nuclides from the fuel and daughter products with the loss of nuclides due to decay and filtering within the purification loop. A GOTHIC calculation was used to model the fuel nuclide source term in the primary coolant system along with the flow through the purification loop which extracts nuclides in the mixed bed demineralizer, cation demineralizer, degassing volume control tank and radwaste demin/evaporator. Corrosion products were assessed utilizing the approach of ANSI/ANS-18.1-1999 from Reference 1.

2.0 Results

The results of this calculation are the primary coolant activity levels as given in the rightmost column of Table 2 on page 13. Note that the results for six corrosion product isotopes (Co-58, Co-60, Cr-51, Fe-55, Fe-59 and Mn-54) are determined via the methods described in Reference 1.

3.0 Assumptions and Inputs

This analysis assumes 1% of the fuel is failed (with the exception of the corrosion product activities which are based on Reference 1).

The Waste Gas Processing System is assumed to be active due to the duration required to achieve steady-state isotopic concentrations.

The inputs for this calculation are summarized in Reference 2, with supporting information in Reference 3. The initial core nuclide inventory calculated by ORIGEN in Reference 4 is used to determine the GOTHIC source term.

4.0 Methodology

GOTHIC version 7.1pcs is used for this analysis. This version of GOTHIC was developed as a branch of version 7.1 to allow input for multiple nuclides per GOTHIC source and add a filter model that removes nuclides from the flow stream according to an input efficiency. GOTHIC version 7.1 is documented in References 5 to 7. The changes for version 7.1pcs are qualified in Reference 8. The calculation was executed on an HP J5600 workstation.

Corrosion product activities are determined in accordance with ANSI/ANS-18.1-1999 in Reference 1.

5.0 Computations

The GOTHIC model is described in Section 5.1. The ORIGEN core inventory at end-of-cycle is converted to a nuclide source term for GOTHIC in Subsection 5.1.5. Dose significant nuclides are selected for the analysis by using the same set of nuclides as the Palisades RADTRAD model from Reference 4. Results from the GOTHIC calculation are presented in Section 5.2.

5.1 GOTHIC Model

GOTHIC was used to model the primary coolant system and purification (letdown) loop which includes the mixed bed demineralizer, cation demineralizer, radwaste demineralizer/evaporator and degassing system as shown in Figure 1. Three control volumes are used to represent the primary coolant system, the outlet of the mixed bed demineralizer and the outlet of the cation demineralizer. An isotope source is placed in primary coolant system volume to represent the release from the failed fuel in the core.

Flow rates are set by three volumetric fans – one for the total purification flow (1Q), another for cation demineralizer flow (2Q) and the last for the radwaste demin/evaporator flow (3Q). A portion of the purification flow bypasses the cation demineralizer through flow path 2.

Four filters are used, one each for the mixed bed demineralizer (1S), cation demineralizer (2S), degassing system (3S) and radwaste demin/evaporator (4S). Filters remove nuclides from the flow stream according to a filter efficiency that is specified for each isotope.

Attachment A lists the GOTHIC input tables used in this analysis. The principal input for these tables are developed in the rest of this section.

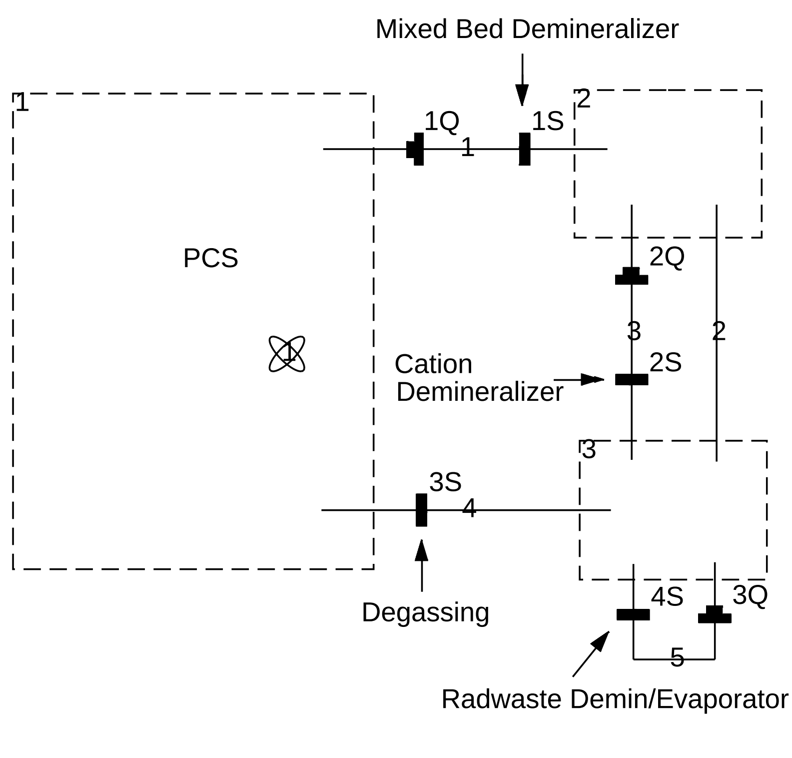

Figure 1 – GOTHIC Model

5.1.1 Control Volumes

Three control volumes are used to represent the primary coolant system, the outlet of the mixed bed demineralizer and the outlet of the cation demineralizer. The volume of the primary coolant system is used. References 2 and 3 give the total primary coolant system mass as 459,445 lbs based on a volume of 10,105.4 ft^3. This was arbitrarily divided as 9,905.4 ft^3 in the PCS and 100 ft^3 in each of the demineralizer outlet volumes. The volume only impacts the transient response of the concentration. The equilibrium nuclide concentrations will be independent of the volume. Arbitrary and default values were used for the other control volume data since they have no impact on the calculated equilibrium activity results. Air is used for the working fluid since GOTHIC isotopes can only exist in the vapor phase.

5.1.2 Flow Paths

Five flow paths are used to connect the volumes as shown in Figure 1. The elevation and heights were uniformly set to the same values in all the flow paths to prevent gravity induced flow. Once again, the geometry values are arbitrary and do not impact the equilibrium activity results.

5.1.3 Volumetric Fans

Three volumetric fans are used. Fan 1Q models the total purification flow of 40 gpm (Reference 2, Attachment A, Sheet 2) in Flow Path 1. This was converted to 5.348 cfm. The minimum cation demineralizer flow is set by Fan 2Q as 58,400 gal/year (Reference 2, Attachment A, Sheet 4) or 0.01486 cfm in Flow Path 3. Fan 2Q specifies the radwaste demin/evaporator flow rate of 586,600 gal/year (Reference 2, Attachment A, Sheet 4) or 0.1492 cfm in Flow Path 5. This flow was confirmed in Table 11-2 and Section 11.2.3.1of the Palisades FSAR (Reference 10). It represents the flow stream through the Clean Waste Section of the Liquid Radioactive Waste System. In the case of the letdown flow and cation demineralizer flow, the minimum flow values were selected to minimize isotope removal rates and conservatively maximize the PCS activities. In the case of the Liquid Radioactive Waste System flow associated with CVCS, the direct value from the Palisades FSAR was used as it produced reasonable equilibrium isotopic concentrations when compared with other PWRs. Default values are appropriate for the other volumetric fan parameters.

5.1.4 Isotopes

The 107 isotopes, half-lives and decay daughter fractions were obtained from the Palisades RADTRAD "nif" file in Reference 4, Attachment 14.

5.1.5 Source Term

A spreadsheet was used to calculate the GOTHIC source term from the ORIGEN nuclide inventory. Rounded results from the spreadsheet are shown below in Table 1. The number, nuclide and half-life in the first three columns are from the Palisades RADTRAD "nif" file in Reference 4, Attachment 14. The ORIGEN data from Reference 4, Attachment 22 is shown in the fourth column. The core inventory in the fifth column was calculated from:

$$n(\text{atoms}) = \frac{A}{\lambda} = \frac{A(\text{Ci}) \bullet 3.7\times10^{10}\,(\text{atoms/s/Ci})}{\dfrac{0.693}{t_{1/2}}}$$

where, A is the activity in curies and $t_{1/2}$ is the half-life in seconds. The sixth column is the escape rate coefficient for each nuclide as taken from Sheet 3 of Attachment A of Reference 2. Finally, the GOTHIC source term in the seventh column is calculated as the product of the core inventory, the escape rate coefficient and a 0.01 factor for the assumed 1% failed fuel. This data was electronically imported into GOTHIC.

Table 1 – GOTHIC Source Term Calculation

GOTHIC Nuclide No.	Nuclide	Half-life (sec)	ORIGEN Activity (Ci)	Core Inventory (Atoms)	Escape Coeff. (1/s)	GOTHIC 1% Source (Atoms/s)
1	Co-58	6.117E+06	0.000E+00	0.000E+00		0.000E+00
2	Co-60	1.663E+08	0.000E+00	0.000E+00		0.000E+00
3	Kr-85	3.383E+08	1.010E+06	1.824E+25	6.50E-08	1.186E+16
4	Kr-85m	1.613E+04	1.961E+07	1.689E+22	6.50E-08	1.098E+13
5	Kr-87	4.578E+03	3.781E+07	9.242E+21	6.50E-08	6.007E+12
6	Kr-88	1.022E+04	5.324E+07	2.906E+22	6.50E-08	1.889E+13
7	Rb-86	1.612E+06	2.026E+05	1.744E+22	1.30E-08	2.267E+12
8	Sr-89	4.363E+06	7.231E+07	1.685E+25	1.00E-11	1.685E+12
9	Sr-90	9.190E+08	8.148E+06	3.998E+26	1.00E-11	3.998E+13
10	Sr-91	3.420E+04	8.935E+07	1.632E+23	1.00E-11	1.632E+10
11	Sr-92	9.756E+03	9.615E+07	5.008E+22	1.00E-11	5.008E+09
12	Y-90	2.304E+05	8.448E+06	1.039E+23	1.60E-12	1.663E+09
13	Y-91	5.055E+06	9.281E+07	2.505E+25	1.60E-12	4.008E+11
14	Y-92	1.274E+04	9.655E+07	6.569E+22	1.60E-12	1.051E+09
15	Y-93	3.636E+04	1.107E+08	2.149E+23	1.60E-12	3.438E+09
16	Zr-95	5.528E+06	1.236E+08	3.648E+25	1.60E-12	5.837E+11
17	Zr-97	6.084E+04	1.210E+08	3.930E+23	1.60E-12	6.289E+09
18	Nb-95	3.037E+06	1.248E+08	2.024E+25	1.60E-12	3.238E+11
19	Mo-99	2.376E+05	1.377E+08	1.747E+24	2.00E-09	3.494E+13
20	Tc-99m	2.167E+04	1.206E+08	1.395E+23	2.00E-09	2.791E+12
21	Ru-103	3.394E+06	1.241E+08	2.249E+25	1.60E-12	3.598E+11
22	Ru-105	1.598E+04	9.186E+07	7.839E+22	1.60E-12	1.254E+09
23	Ru-106	3.181E+07	5.492E+07	9.328E+25	1.60E-12	1.493E+12
24	Rh-105	1.273E+05	8.485E+07	5.767E+23	1.60E-12	9.227E+09
25	Sb-127	3.326E+05	9.001E+06	1.599E+23	1.00E-09	1.599E+12
26	Sb-129	1.555E+04	2.552E+07	2.119E+22	1.00E-09	2.119E+11
27	Te-127	3.366E+04	8.929E+06	1.605E+22	1.00E-09	1.605E+11
28	Te-127m	9.418E+06	1.198E+06	6.024E+23	1.00E-09	6.024E+12
29	Te-129	4.176E+03	2.513E+07	5.603E+21	1.00E-09	5.603E+10
30	Te-129m	2.903E+06	3.742E+06	5.800E+23	1.00E-09	5.800E+12
31	Te-131m	1.080E+05	1.110E+07	6.401E+22	1.00E-09	6.401E+11
32	Te-132	2.815E+05	1.049E+08	1.577E+24	1.00E-09	1.577E+13
33	I-131	6.947E+05	7.475E+07	2.772E+24	1.30E-08	3.604E+14
34	I-132	8.280E+03	1.069E+08	4.726E+22	1.30E-08	6.144E+12
35	I-133	7.488E+04	1.471E+08	5.881E+23	1.30E-08	7.645E+13
36	I-134	3.156E+03	1.611E+08	2.715E+22	1.30E-08	3.529E+12
37	I-135	2.380E+04	1.377E+08	1.749E+23	1.30E-08	2.274E+13
38	Xe-133	4.532E+05	1.475E+08	3.569E+24	6.50E-08	2.320E+15
39	Xe-135	3.272E+04	4.725E+07	8.255E+22	6.50E-08	5.366E+13
40	Cs-134	6.507E+07	2.153E+07	7.480E+25	1.30E-08	9.724E+15
41	Cs-136	1.132E+06	6.055E+06	3.659E+23	1.30E-08	4.757E+13
42	Cs-137	9.467E+08	1.092E+07	5.520E+26	1.30E-08	7.176E+16
43	Ba-139	4.962E+03	1.311E+08	3.473E+22	1.00E-11	3.473E+09
44	Ba-140	1.101E+06	1.264E+08	7.428E+24	1.00E-11	7.428E+11
45	La-140	1.450E+05	1.312E+08	1.016E+24	1.60E-12	1.625E+10
46	La-141	1.415E+04	1.197E+08	9.042E+22	1.60E-12	1.447E+09
47	La-142	5.550E+03	1.160E+08	3.437E+22	1.60E-12	5.500E+08

GOTHIC Nuclide No.	Nuclide	Half-life (sec)	ORIGEN Activity (Ci)	Core Inventory (Atoms)	Escape Coeff. (1/s)	GOTHIC 1% Source (Atoms/s)
48	Ce-141	2.808E+06	1.212E+08	1.817E+25	1.60E-12	2.907E+11
49	Ce-143	1.188E+05	1.120E+08	7.104E+23	1.60E-12	1.137E+10
50	Ce-144	2.456E+07	9.667E+07	1.268E+26	1.60E-12	2.028E+12
51	Pr-143	1.172E+06	1.107E+08	6.925E+24	1.60E-12	1.108E+11
52	Nd-147	9.487E+05	4.811E+07	2.437E+24	1.60E-12	3.899E+10
53	Np-239	2.035E+05	1.818E+09	1.975E+25		0.000E+00
54	Pu-238	2.769E+09	4.586E+05	6.780E+25		0.000E+00
55	Pu-239	7.594E+11	3.520E+04	1.427E+27		0.000E+00
56	Pu-240	2.063E+11	5.628E+04	6.199E+26		0.000E+00
57	Pu-241	4.544E+08	1.349E+07	3.273E+26		0.000E+00
58	Am-241	1.364E+10	1.622E+04	1.181E+25		0.000E+00
59	Cm-242	1.407E+07	5.115E+06	3.841E+24		0.000E+00
60	Cm-244	5.715E+08	1.117E+06	3.408E+25		0.000E+00
61	I-130	4.450E+04	3.926E+06	9.327E+21	1.30E-08	1.213E+12
62	Kr-83m	6.588E+03	9.182E+06	3.230E+21	6.50E-08	2.099E+12
63	Xe-138	8.502E+02	1.214E+08	5.511E+21	6.50E-08	3.582E+12
64	Xe-131m	1.028E+06	8.357E+05	4.588E+22	6.50E-08	2.982E+13
65	Xe-133m	1.890E+05	4.675E+06	4.719E+22	6.50E-08	3.067E+13
66	Xe-135m	9.174E+02	2.997E+07	1.468E+21	6.50E-08	9.542E+11
67	Cs-138	1.932E+03	1.344E+08	1.386E+22	1.30E-08	1.802E+12
68	Cs-134m	1.044E+04	4.892E+06	2.727E+21	1.30E-08	3.545E+11
69	Rb-88	1.068E+03	5.409E+07	3.084E+21	1.30E-08	4.010E+11
70	Rb-89	9.120E+02	6.946E+07	3.382E+21	1.30E-08	4.397E+11
71	Sb-124	5.201E+06	1.834E+05	5.093E+22	1.00E-09	5.093E+11
72	Sb-125	8.741E+07	1.524E+06	7.113E+24	1.00E-09	7.113E+13
73	Sb-126	1.071E+06	1.105E+05	6.321E+21	1.00E-09	6.321E+10
74	Te-131	1.500E+03	6.601E+07	5.287E+21	1.00E-09	5.287E+10
75	Te-133	7.470E+02	8.658E+07	3.453E+21	1.00E-09	3.453E+10
76	Te-134	2.508E+03	1.223E+08	1.638E+22	1.00E-09	1.638E+11
77	Te-125m	5.011E+06	3.311E+05	8.859E+22	1.00E-09	8.859E+11
78	Te-133m	3.324E+03	5.423E+07	9.624E+21	1.00E-09	9.624E+10
79	Ba-141	1.096E+03	1.191E+08	6.971E+21	1.00E-11	6.971E+08
80	Ba-137m	1.531E+02	1.035E+07	8.461E+19	1.00E-11	8.461E+06
81	Pd-109	4.834E+04	3.303E+07	8.524E+22		0.000E+00
82	Rh-106	2.990E+01	5.977E+07	9.542E+19	1.60E-12	1.527E+06
83	Rh-103m	3.367E+03	1.117E+08	2.008E+22	1.60E-12	3.213E+08
84	Tc-101	8.520E+02	1.261E+08	5.736E+21	2.00E-09	1.147E+11
85	Eu-154	2.777E+08	1.282E+06	1.901E+25		0.000E+00
86	Eu-155	1.565E+08	8.899E+05	7.437E+24		0.000E+00
87	Eu-156	1.312E+06	2.314E+07	1.621E+24		0.000E+00
88	La-143	8.538E+02	1.112E+08	5.069E+21	1.60E-12	8.111E+07
89	Nb-97	4.326E+03	1.220E+08	2.818E+22	1.60E-12	4.509E+08
90	Nb-95m	3.118E+05	8.864E+05	1.475E+22	1.60E-12	2.361E+08
91	Pm-147	8.279E+07	1.193E+07	5.273E+25	1.60E-12	8.437E+11
92	Pm-148	4.640E+05	2.045E+07	5.066E+23	1.60E-12	8.105E+09
93	Pm-149	1.911E+05	4.442E+07	4.532E+23	1.60E-12	7.251E+09
94	Pm-151	1.022E+05	1.588E+07	8.668E+22	1.60E-12	1.387E+09
95	Pm-148m	3.568E+06	2.711E+06	5.165E+23	1.60E-12	8.264E+09
96	Pr-144	1.037E+03	9.721E+07	5.381E+21	1.60E-12	8.610E+07

GOTHIC Nuclide No.	Nuclide	Half-life (sec)	ORIGEN Activity (Ci)	Core Inventory (Atoms)	Escape Coeff. (1/s)	GOTHIC 1% Source (Atoms/s)
97	Pr-144m	4.320E+02	1.161E+06	2.678E+19	1.60E-12	4.285E+05
98	Sm-153	1.681E+05	4.325E+07	3.882E+23		0.000E+00
99	Y-94	1.146E+03	1.110E+08	6.792E+21	1.60E-12	1.087E+08
100	Y-95	6.420E+02	1.188E+08	4.072E+21	1.60E-12	6.515E+07
101	Y-91m	2.983E+03	5.186E+07	8.258E+21	1.60E-12	1.321E+08
102	Br-82	1.271E+05	5.357E+05	3.635E+21	1.30E-08	4.725E+11
103	Br-83	8.604E+03	9.158E+06	4.207E+21	1.30E-08	5.469E+11
104	Br-84	1.908E+03	1.601E+07	1.631E+21	1.30E-08	2.120E+11
105	Am-242	5.767E+04	7.812E+06	2.405E+22		0.000E+00
106	Np-238	1.829E+05	4.576E+07	4.469E+23		0.000E+00
107	Pu-243	1.784E+04	4.739E+07	4.514E+22		0.000E+00

5.1.6 Filters

Four filters are used to remove nuclides from the primary coolant system. Since every nuclide is removed by at least one filter, all nuclides will come to equilibrium when the removal rate through the filter in the purification loop and by decay matches the nuclide source term production rate. Filter efficiency is input for each nuclide for every filter. Since Reference 2 only provides decontamination factors (DF), they were converted to efficiency (η) by the following equation:

$$\eta = 1 - \frac{1}{DF}$$

5.1.6.1 Mixed Bed Demineralizer Filter

Filter 1S models the mixed bed demineralizer in Flow Path 1. Reference 2, Attachment A, Sheet 4 gives a mixed bed DF of 10 (η=0.9) for all isotopes except Cs, Y and Mo which are not removed and have a DF of 1 (η=0) according to Reference 9, Table 3, page 22. Noble gas isotopes are not removed either.

5.1.6.2 Cation Demineralizer Filter

Filter 2S models the cation demineralizer in Flow Path 3. Consistent with Reference 2, Attachment A, Sheet 4, Reference 9, Table 3, page 22 gives a cation decontamination factor of 10 (η=0.9) only for Cs, Y and Mo isotopes.

5.1.6.3 Degassing Filter

Filter 3S models the degassing in the Volume Control Tank assuming the Waste Gas Processing System is active in Flow Path 4. Reference 2, Attachment A, Sheets 2 and 3 give the gas stripping fractions as 0.85 for Kr-83m, 0.66 for Kr-85, 0.78 for Kr-85m, 0.88 for Kr-87, 0.81 for Kr-88, 0.58 for Xe-131m and Xe-133, 0.59 for Xe-133m, 0.65 for Xe-135, 0.95 for Xe-135m and 0.96 for Xe-138. These values are used directly as the filter efficiencies in Filter 3S. These values were confirmed via comparison with values previously determined for plants with similar design.

The gas stripping fractions for Kr-89 and Xe-137 from Reference 2 are not used because their half lives of 3.16 and 3.84 minutes are less than 15 minutes. The definition of E-bar (average disintegration energy) in Palisades Technical Specification Section 1.1 only addresses radionuclides with half-lives greater than 15 minutes. Additionally, Table III.1 (Dose Coefficients for Air Submersion) and Table A.1 (Summary Information on the Nuclear Transformation of the Radionuclides) of Federal Guidance Report 12 do not include these isotopes. That means there are no dose conversion factors specified for these two isotopes in the NRC-recommended source for air submersion dose conversion factors

5.1.6.4 Radwaste Demineralizer/Evaporator Filter

Filter 4S models the Clean Waste Section of the Liquid Radioactive Waste System in Flow Path 5. This waste is processed through demineralizers which have a DF of 10 for all isotopes except noble gases per Reference 2, Attachment A, Sheet 5. It then passes through the radwaste evaporators which have a DF of 1000 for iodine isotopes and 10,000 for all other isotopes. Noble gases are totally removed by vacuum degassing, diffusion in the clean waste receiver tanks and by the evaporators. Since the DF for components in series is the product of the individual DFs, the DFs for Filter 4S become 10,000 (η=0.9999) for iodine, infinite (η=1) for noble gases and 100,000 (η=0.99999) for all other isotopes.

5.2 GOTHIC Results

The GOTHIC calculation is executed for 50 million seconds which is well past the time when equilibrium activities are achieved. Columns three and four in Table 2 show the GOTHIC calculated activities at 4.9×10^7 and 5×10^7 seconds. The fifth column shows the percent change in activity between those two times. The maximum change is 0.00% so equilibrium is reached for all isotopes. This is also confirmed by the plotted activities in Attachment B.

The sixth column gives the final result of this analysis. The activity at 50 million seconds is converted from Ci/ft^3 to μCi/g by dividing by the average PCS density of 45.47 lbm/ft^3 (calculated from the ratio of the PCS mass to volume, 459,445/10,105.4 per References 2 and 3) and converting units.

The first six isotopes are corrosion products whose activity was determined via the methods of Reference 1 as discussed in Section 5.3 below.

Table 2 – Activity Results

GOTHIC Nuclide No.	Nuclide	Activity at 4.9e7 sec (Ci/ft3)	Activity at 5e7 sec (Ci/ft3)	Activity Change	Activity (μCi/g)
1	Co-58	0.000E+00	0.000E+00		7.0E-03*
2	Co-60	0.000E+00	0.000E+00		8.0E-04*
	Cr-51				4.7E-03*
	Fe-55				1.8E-03*
	Fe-59				4.5E-04*
	Mn-54				2.4E-03*
3	Kr-85	1.102E-02	1.102E-02	0.00%	5.3E-01
4	Kr-85m	2.564E-02	2.564E-02	0.00%	1.2E+00
5	Kr-87	1.554E-02	1.554E-02	0.00%	7.5E-01
6	Kr-88	4.638E-02	4.638E-02	0.00%	2.2E+00
7	Rb-86	3.112E-04	3.112E-04	0.00%	1.5E-02
8	Sr-89	1.110E-04	1.110E-04	0.00%	5.4E-03
9	Sr-90	1.013E-05	1.013E-05	0.00%	4.9E-04
10	Sr-91	3.174E-05	3.174E-05	0.00%	1.5E-03
11	Sr-92	1.224E-05	1.224E-05	0.00%	5.9E-04
12	Y-90	1.326E-05	1.326E-05	0.00%	6.4E-04
13	Y-91	3.800E-04	3.800E-04	0.00%	1.8E-02
14	Y-92	1.480E-05	1.480E-05	0.00%	7.2E-04
15	Y-93	9.083E-06	9.083E-06	0.00%	4.4E-04
16	Zr-95	2.420E-05	2.420E-05	0.00%	1.2E-03
17	Zr-97	1.001E-05	1.001E-05	0.00%	4.9E-04
18	Nb-95	2.478E-05	2.478E-05	0.00%	1.2E-03
19	Mo-99	8.584E-02	8.584E-02	0.00%	4.2E+00

GOTHIC Nuclide No.	Nuclide	Activity at 4.9e7 sec (Ci/ft3)	Activity at 5e7 sec (Ci/ft3)	Activity Change	Activity (μCi/g)
20	Tc-99m	6.702E-02	6.702E-02	0.00%	3.2E+00
21	Ru-103	2.410E-05	2.410E-05	0.00%	1.2E-03
22	Ru-105	2.877E-06	2.877E-06	0.00%	1.4E-04
23	Ru-106	1.090E-05	1.090E-05	0.00%	5.3E-04
24	Rh-105	1.127E-05	1.127E-05	0.00%	5.5E-04
25	Sb-127	8.894E-04	8.894E-04	0.00%	4.3E-02
26	Sb-129	4.880E-04	4.880E-04	0.00%	2.4E-02
27	Te-127	9.434E-04	9.434E-04	0.00%	4.6E-02
28	Te-127m	1.489E-04	1.489E-04	0.00%	7.2E-03
29	Te-129	7.883E-04	7.883E-04	0.00%	3.8E-02
30	Te-129m	4.554E-04	4.554E-04	0.00%	2.2E-02
31	Te-131m	7.701E-04	7.701E-04	0.00%	3.7E-02
32	Te-132	9.989E-03	9.989E-03	0.00%	4.8E-01
33	I-131	1.076E-01	1.076E-01	0.00%	5.2E+00
34	I-132	2.436E-02	2.436E-02	0.00%	1.2E+00
35	I-133	1.111E-01	1.111E-01	0.00%	5.4E+00
36	I-134	9.690E-03	9.690E-03	0.00%	4.7E-01
37	I-135	4.844E-02	4.844E-02	0.00%	2.3E+00
38	Xe-133	1.443E+00	1.443E+00	0.00%	7.0E+01
39	Xe-135	1.534E-01	1.534E-01	0.00%	7.4E+00
40	Cs-134	1.020E+00	1.020E+00	0.00%	4.9E+01
41	Cs-136	8.931E-02	8.931E-02	0.00%	4.3E+00
42	Cs-137	5.369E-01	5.369E-01	0.00%	2.6E+01
43	Ba-139	8.942E-06	8.942E-06	0.00%	4.3E-04
44	Ba-140	1.459E-04	1.459E-04	0.00%	7.1E-03
45	La-140	7.051E-05	7.051E-05	0.00%	3.4E-03
46	La-141	4.992E-06	4.992E-06	0.00%	2.4E-04
47	La-142	1.407E-06	1.407E-06	0.00%	6.8E-05
48	Ce-141	2.352E-05	2.352E-05	0.00%	1.1E-03
49	Ce-143	1.304E-05	1.304E-05	0.00%	6.3E-04
50	Ce-144	1.912E-05	1.912E-05	0.00%	9.3E-04
51	Pr-143	2.143E-05	2.143E-05	0.00%	1.0E-03
52	Nd-147	8.774E-06	8.774E-06	0.00%	4.3E-04
53	Np-239	0.000E+00	0.000E+00		-
54	Pu-238	0.000E+00	0.000E+00		-
55	Pu-239	0.000E+00	0.000E+00		-
56	Pu-240	0.000E+00	0.000E+00		-
57	Pu-241	0.000E+00	0.000E+00		-
58	Am-241	0.000E+00	0.000E+00		-
59	Cm-242	0.000E+00	0.000E+00		-
60	Cm-244	0.000E+00	0.000E+00		-
61	I-130	2.172E-03	2.172E-03	0.00%	1.1E-01
62	Kr-83m	6.584E-03	6.584E-03	0.00%	3.2E-01
63	Xe-138	9.668E-03	9.668E-03	0.00%	4.7E-01
64	Xe-131m	9.258E-03	9.258E-03	0.00%	4.5E-01
65	Xe-133m	3.500E-02	3.500E-02	0.00%	1.7E+00
66	Xe-135m	9.947E-03	9.947E-03	0.00%	4.8E-01
67	Cs-138	1.445E-02	1.445E-02	0.00%	7.0E-01
68	Cs-134m	9.470E-04	9.470E-04	0.00%	4.6E-02

GOTHIC Nuclide No.	Nuclide	Activity at 4.9e7 sec (Ci/ft3)	Activity at 5e7 sec (Ci/ft3)	Activity Change	Activity (μCi/g)
69	Rb-88	4.721E-02	4.721E-02	0.00%	2.3E+00
70	Rb-89	1.186E-03	1.186E-03	0.00%	5.8E-02
71	Sb-124	2.243E-05	2.243E-05	0.00%	1.1E-03
72	Sb-125	1.893E-04	1.893E-04	0.00%	9.2E-03
73	Sb-126	1.273E-05	1.273E-05	0.00%	6.2E-04
74	Te-131	3.096E-04	3.096E-04	0.00%	1.5E-02
75	Te-133	1.259E-04	1.259E-04	0.00%	6.1E-03
76	Te-134	4.336E-04	4.336E-04	0.00%	2.1E-02
77	Te-125m	4.119E-05	4.119E-05	0.00%	2.0E-03
78	Te-133m	2.524E-04	2.524E-04	0.00%	1.2E-02
79	Ba-141	1.876E-06	1.876E-06	0.00%	9.1E-05
80	Ba-137m	5.079E-01	5.079E-01	0.00%	2.5E+01
81	Pd-109	0.000E+00	0.000E+00		-
82	Rh-106	1.090E-05	1.090E-05	0.00%	5.3E-04
83	Rh-103m	2.396E-05	2.396E-05	0.00%	1.2E-03
84	Tc-101	3.096E-04	3.096E-04	0.00%	1.5E-02
85	Eu-154	0.000E+00	0.000E+00		-
86	Eu-155	0.000E+00	0.000E+00		-
87	Eu-156	0.000E+00	0.000E+00		-
88	La-143	2.189E-07	2.189E-07	0.00%	1.1E-05
89	Nb-97	1.674E-06	1.674E-06	0.00%	8.1E-05
90	Nb-95m	1.747E-07	1.747E-07	0.00%	8.5E-06
91	Pm-147	2.379E-06	2.379E-06	0.00%	1.2E-04
92	Pm-148	3.437E-06	3.437E-06	0.00%	1.7E-04
93	Pm-149	6.105E-06	6.105E-06	0.00%	3.0E-04
94	Pm-151	1.722E-06	1.722E-06	0.00%	8.3E-05
95	Pm-148m	5.262E-07	5.262E-07	0.00%	2.6E-05
96	Pr-144	1.912E-05	1.912E-05	0.00%	9.3E-04
97	Pr-144m	3.398E-07	3.398E-07	0.00%	1.6E-05
98	Sm-153	0.000E+00	0.000E+00		-
99	Y-94	2.937E-07	2.937E-07	0.00%	1.4E-05
100	Y-95	1.766E-07	1.766E-07	0.00%	8.6E-06
101	Y-91m	1.846E-05	1.846E-05	0.00%	8.9E-04
102	Br-82	5.176E-04	5.176E-04	0.00%	2.5E-02
103	Br-83	1.353E-03	1.353E-03	0.00%	6.6E-02
104	Br-84	5.651E-04	5.651E-04	0.00%	2.7E-02
105	Am-242	0.000E+00	0.000E+00		-
106	Np-238	0.000E+00	0.000E+00		-
107	Pu-243	0.000E+00	0.000E+00		-

* These isotope activities were determined in accordance with Reference 1 and not using the GOTHIC system model.

5.3 Corrosion Product Activities

The corrosion product activities from Table 2 above are taken from the ANSI_Primary_Activity.xls Excel spreadsheet that implements the methodology of Reference 1 combined with the inputs specified in Reference 2. The columns of the spreadsheet are defined as follows:

Column B – Base activity in μCi/gm from the Reactor Coolant column of Table 6 of Reference 1

Column C – Half-life in seconds

Column D – Decay constant = ln(2)/half-life

Column E – Removal rate, R_n, from Table 9 of Reference 1 in sec^{-1}

Column F – Palisades Boron recovery flow (FB) in lbs/sec

Column G – Palisades letdown flow (FD) in lbs/sec

Column H – Weight of water in reactor coolant system (WP) from Table 2 of Reference 1 in lbs

Column I – Palisades reactor coolant weight in lbs

Column J – VCT stripping fraction (Y)

Column K – Palisades cation demineralizer flow (FA) in lbs/sec

Column L – Palisades cation removal fraction (NA)

Column M – Palisades mixed bed demineralizer removal fraction (NB)

Column N – New R value calculated as follows based on Palisades values and depending on the nuclide class:

$$R_1 = \frac{FB + (FD - FB) \times Y}{WP}$$

$$R_{2,3,6} = \frac{(FD \times NB) + (1 - NB)(FB + (FA \times NA))}{WP}$$

Column O – Thermal power from Table 2 of Reference 1 in MW_t

Column P – Palisades thermal power in MW_t

Column Q – New activity in μCi/gm

6.0 Computer Files

The computer files used and created in this analysis are archived in CentralStor as:

```
$ cstor -d projects/nmc/1149_CRHab/pcs ls -lCcv
23329 -rwxdc      tim   29696 ------ Jul 22 2004 09:08:58 ANSI_Primary_Activity.xls:1
  "Activity spreadsheet for corrosion product isotopes"
37956 -rw-dc      tim 1245980 ------ Jul 28 2004 14:23:29 pal_activity.GTH:1
  "GOTHIC model"
28928 -rw-dc      tim 1278415 ------ Jul 28 2004 14:16:11 pal_activity.SGR:1
  "GOTHIC solver graphics"
19709 -rw-dc      tim   15455 ------ Jul 26 2004 14:25:37 pal_activity.SIN:1
  "GOTHIC solver input"
46487 -rw-dc      tim 1831948 ------ Jul 28 2004 14:16:11 pal_activity.SOT:1
  "GOTHIC solver output"
10580 -rwxdc      tim   46080 ------ Jul 29 2004 14:45:08 pal_activity.xls:1
  "Activity spreadsheet for non-corrosion isotopes"
```

7.0 References

1. ANSI/ANS-18.1-1999, "Radioactive Source Term for Normal Operation of Light Water Reactors," approved September 21, 1999.
2. NAI-E03-211 Project Memo - 2004-08, Primary Coolant System Activity Inputs, from Jeffrey L. Voskuil, NMC, to Jim Harrell, NAI, dated 8/18/04.
3. NAI-E03-211 Project Memo – 2004-09, Additional Inputs, from Jeffrey L. Voskuil, NMC, to Jim Harrell, NAI, dated 10/20/04.
4. Calculation NAI-1149-001, Revision 1, "Source Terms for Palisades Dose Calculations," 10/6/04.
5. NAI 8907-02, Revision 14, GOTHIC Containment Analysis Package User Manual, Version 7.1, January 2003.
6. NAI 8907-06, Revision 13, GOTHIC Containment Analysis Package Technical Manual, Version 7.1, January 2003.
7. NAI 8907-09, Revision 7, GOTHIC Containment Analysis Package Qualification Report, Version 7.1, January 2003.
8. GOTHIC Action Item 7.1-60, "GOTHIC Primary System Activity Validation," October 28, 2003.
9. Report ORNL-4792, "Use of Ion Exchange for the Treatment of Liquids in Nuclear Power Plants," K. H. Lin, Oak Ridge National Laboratory, December 1973.
10. Palisades Final Safety Analysis Report (FSAR), Revision 24.

ATTACHMENT A

GOTHIC Input Listing

Filename: pal_activity

pal_activity 1
Jul/28/2004 15:20:32
GOTHIC Version 7.1pcs(QA) - August 2003
File: /home/gothic/projects/nmc/palisades/pcs/pal_activity

Control Volumes

Vol #	Description	Vol (ft3)	Elev (ft)	Ht (ft)	Hyd. D. (ft)	L/V IA (ft2)	Burn Opt
1	PCS	9905.4	0.	30.	1.	DEFAULT	NONE
2	MB Demin Outlet	100.	0.	30.	1.	DEFAULT	NONE
3	Cation Outlet	100.	0.	30.	1.	DEFAULT	NONE

Laminar Leakage

Vol #	Lk Rate Factor (%/hr)	Ref Press (psia)	Ref Temp (F)	Ref Humid (%)	Sink /Src BC	Model Option	Rep Wall	Subvol Option	Leak Area (ft2)
1	0.					CNST T		UNIFORM	DEFAULT
2	0.					CNST T		UNIFORM	DEFAULT
3	0.					CNST T		UNIFORM	DEFAULT

Turbulent Leakage

Vol #	Lk Rate Factor (%/hr)	Ref Press (psia)	Ref Temp (F)	Ref Humid (%)	Sink /Src BC	Model Option	Rep Wall	Subvol Option	Leak Area (ft2)	fL/D
1	0.					CNST T		UNIFORM	DEFAULT	
2	0.					CNST T		UNIFORM	DEFAULT	
3	0.					CNST T		UNIFORM	DEFAULT	

Flow Paths - Table 1

F.P. #	Description	Vol A	Elev (ft)	Ht (ft)	Vol B	Elev (ft)	Ht (ft)
1	Mixed Bed Demin	1	5.	0.1	2	5.	0.1
2	Bypass	2	5.	0.1	3	5.	0.1
3	Cation Demin	2	5.	0.1	3	5.	0.1
4	Degassing	3	5.	0.1	1	5.	0.1
5	Boron Bled/Feed	3	5.	0.1	3	5.	0.1

pal_activity 2
Jul/28/2004 15:20:32
GOTHIC Version 7.1pcs(QA) - August 2003
File: /home/gothic/projects/nmc/palisades/pcs/pal_activity

Flow Paths - Table 2

Flow Path #	Flow Area (ft2)	Hyd. Diam. (ft)	Inertia Length (ft)	Friction Length (ft)	Relative Rough- ness	Dep Bend (deg)	Mom Trn Opt	Strat Flow Opt
1	10.	1.	10.	10.			-	NONE
2	10.	1.	10.	10.			-	NONE
3	10.	1.	10.	10.			-	NONE
4	10.	1.	10.	10.			-	NONE
5	10.	1.	10.	10.			-	NONE

Flow Paths - Table 3

Flow Path #	Fwd. Loss Coeff.	Rev. Loss Coeff.	Comp. Opt.	Critical Flow Model	Exit Loss Coeff.	Drop Breakup Model
1			OFF	OFF	0.	OFF
2			OFF	OFF	0.	OFF
3			OFF	OFF	0.	OFF
4			OFF	OFF	0.	OFF
5			OFF	OFF	0.	OFF

Volumetric Fan - Table 1

Vol Fan #	Description	Flow Path #	On Trip #	Off Trip #	Min DP (psi)	Max DP (psi)
1Q	Total flow	1			DEFAULT	DEFAULT
2Q	Cation flow	3			DEFAULT	DEFAULT
3Q	Boron flow	5			DEFAULT	DEFAULT

Volumetric Fan - Table 2

Vol Fan #	Flow Option	Flow Rate (CFM)	Flow Rate FF	Heat Option	Heat Rate (Btu/s)	Heat Rate FF	Disch Vol
1Q	Time	5.348		Time			2
2Q	Time	0.01486		Time			3
3Q	Time	0.1492		Time			3

Isotopes

Iso #	Description	Half Life (s)	Dtr #1	Dtr #1 Frac	Dtr #2	Dtr #2 Frac	Dtr #3	Dtr #3 Frac
1	Co-58	6120000.		0.		0.		0.
2	Co-60	1.66e+08		0.		0.		0.
3	Kr-85	3.38e+08		0.		0.		0.
4	Kr-85m	16100.	3	0.211		0.		0.
5	Kr-87	4580.		1.		0.		0.
6	Kr-88	10200.	69	1.		0.		0.
7	Rb-86	1610000.		0.		0.		0.
8	Sr-89	4360000.		0.		0.		0.
9	Sr-90	9.19e+08	12	1.		0.		0.
10	Sr-91	34200.	101	0.578	13	0.422		0.
11	Sr-92	9760.	14	1.		0.		0.
12	Y-90	230000.		0.		0.		0.
13	Y-91	5060000.		0.		0.		0.
14	Y-92	12700.		0.		0.		0.
15	Y-93	36400.		1.		0.		0.
16	Zr-95	5530000.	90	0.007	18	0.993		0.
17	Zr-97	60800.		0.947	89	0.053		0.
18	Nb-95	3040000.		0.		0.		0.
19	Mo-99	238000.	20	0.876		0.124		0.
20	Tc-99m	21700.		1.		0.		0.
21	Ru-103	3390000.	83	0.997		0.		0.
22	Ru-105	16000.	24	1.		0.		0.
23	Ru-106	3.18e+07	82	1.		0.		0.
24	Rh-105	127000.		0.		0.		0.
25	Sb-127	333000.	28	0.176	27	0.824		0.
26	Sb-129	15600.	30	0.225	29	0.775		0.
27	Te-127	33700.		0.		0.		0.
28	Te-127m	9420000.	27	0.976		0.		0.
29	Te-129	4180.		1.		0.		0.
30	Te-129m	2900000.	29	0.65		0.35		0.
31	Te-131m	108000.	74	0.222	33	0.778		0.
32	Te-132	282000.	34	1.		0.		0.
33	I-131	695000.	64	0.0111		0.		0.
34	I-132	8280.		0.		0.		0.
35	I-133	74900.	65	0.029	38	0.971		0.
36	I-134	3160.		0.		0.		0.
37	I-135	23800.	66	0.154	39	0.846		0.
38	Xe-133	453000.		0.		0.		0.
39	Xe-135	32700.		1.		0.		0.
40	Cs-134	6.51e+07		0.		0.		0.
41	Cs-136	1130000.		0.		0.		0.
42	Cs-137	9.47e+08	80	0.946		0.		0.
43	Ba-139	4960.		0.		0.		0.
44	Ba-140	1100000.	45	1.		0.		0.

Isotopes (cont.)

Iso #	Description	Half Life (s)	Dtr #1	Dtr #1 Frac	Dtr #2	Dtr #2 Frac	Dtr #3	Dtr #3 Frac
45	La-140	145000.		0.		0.		0.
46	La-141	14100.	48	1.		0.		0.
47	La-142	5550.		0.		0.		0.
48	Ce-141	2810000.		0.		0.		0.
49	Ce-143	119000.	51	1.		0.		0.
50	Ce-144	2.46e+07	97	0.0178	96	0.9822		0.
51	Pr-143	1170000.		0.		0.		0.
52	Nd-147	949000.	91	1.		0.		0.
53	Np-239	203000.	55	1.		0.		0.
54	Pu-238	2.77e+09		1.		0.		0.
55	Pu-239	7.59e+11		1.		0.		0.
56	Pu-240	2.06e+11		1.		0.		0.
57	Pu-241	4.54e+08	58	1.		0.		0.
58	Am-241	1.36e+10		1.		0.		0.
59	Cm-242	1.41e+07	54	1.		0.		0.
60	Cm-244	5.72e+08	56	1.		0.		0.
61	I-130	44500.		0.		0.		0.
62	Kr-83m	6590.		0.		0.		0.
63	Xe-138	850.	67	1.		0.		0.
64	Xe-131m	1030000.		0.		0.		0.
65	Xe-133m	189000.	38	1.		0.		0.
66	Xe-135m	917.	39	1.		0.		0.
67	Cs-138	1930.		0.		0.		0.
68	Cs-134m	10400.	40	1.		0.		0.
69	Rb-88	1070.		0.		0.		0.
70	Rb-89	912.	8	1.		0.		0.
71	Sb-124	5200000.		0.		0.		0.
72	Sb-125	8.74e+07	77	0.228		0.		0.
73	Sb-126	1070000.		0.		0.		0.
74	Te-131	1500.	33	1.		0.		0.
75	Te-133	747.	35	1.		0.		0.
76	Te-134	2510.	36	1.		0.		0.
77	Te-125m	5010000.		0.		0.		0.
78	Te-133m	3320.	35	0.87	75	0.13		0.
79	Ba-141	1100.	46	1.		0.		0.
80	Ba-137m	153.		0.		0.		0.
81	Pd-109	48300.		0.		0.		0.
82	Rh-106	29.9		0.		0.		0.
83	Rh-103m	3370.		0.		0.		0.
84	Tc-101	852.		0.		0.		0.
85	Eu-154	2.78e+08		0.		0.		0.
86	Eu-155	1.57e+08		0.		0.		0.
87	Eu-156	1310000.		0.		0.		0.
88	La-143	854.	49	1.		0.		0.

Isotopes (cont.)

Iso #	Description	Half Life (s)	Dtr #1	Dtr #1 Frac	Dtr #2	Dtr #2 Frac	Dtr #3	Dtr #3 Frac
89	Nb-97	4330.		0.		0.		0.
90	Nb-95m	312000.	18	1.		0.		0.
91	Pm-147	8.28e+07		1.		0.		0.
92	Pm-148	464000.		0.		0.		0.
93	Pm-149	191000.		0.		0.		0.
94	Pm-151	102000.		1.		0.		0.
95	Pm-148m	3570000.	92	0.046		0.		0.
96	Pr-144	1040.		0.		0.		0.
97	Pr-144m	432.	96	0.999		0.		0.
98	Sm-153	168000.		0.		0.		0.
99	Y-94	1150.		0.		0.		0.
100	Y-95	642.	16	1.		0.		0.
101	Y-91m	2980.	13	1.		0.		0.
102	Br-82	127000.		0.		0.		0.
103	Br-83	8600.	62	1.		0.		0.
104	Br-84	1910.		0.		0.		0.
105	Am-242	57700.	59	0.827		0.173		0.
106	Np-238	183000.	54	1.		0.		0.
107	Pu-243	17800.		1.		0.		0.

Isotope Source
1

Isotope #	Isotope Name	Rate (p/sec)	Rate FF
1	Co-58	0.	
2	Co-60	0.	
3	Kr-85	1.186e+16	
4	Kr-85m	1.098e+13	
5	Kr-87	6.007e+12	
6	Kr-88	1.889e+13	
7	Rb-86	2.267e+12	
8	Sr-89	1.685e+12	
9	Sr-90	3.998e+13	
10	Sr-91	1.632e+10	
11	Sr-92	5.008e+09	
12	Y-90	1.663e+09	
13	Y-91	4.008e+11	
14	Y-92	1.051e+09	
15	Y-93	3.438e+09	

Isotope Source (cont.)
1

Isotope #	Isotope Name	Rate (p/sec)	Rate FF
16	Zr-95	5.837e+11	
17	Zr-97	6.289e+09	
18	Nb-95	3.238e+11	
19	Mo-99	3.494e+13	
20	Tc-99m	2.791e+12	
21	Ru-103	3.598e+11	
22	Ru-105	1.254e+09	
23	Ru-106	1.493e+12	
24	Rh-105	9.227e+09	
25	Sb-127	1.599e+12	
26	Sb-129	2.119e+11	
27	Te-127	1.605e+11	
28	Te-127m	6.024e+12	
29	Te-129	5.603e+10	
30	Te-129m	5.8e+12	
31	Te-131m	6.401e+11	
32	Te-132	1.577e+13	
33	I-131	3.604e+14	
34	I-132	6.144e+12	
35	I-133	7.645e+13	
36	I-134	3.529e+12	
37	I-135	2.274e+13	
38	Xe-133	2.32e+15	
39	Xe-135	5.366e+13	
40	Cs-134	9.724e+15	
41	Cs-136	4.757e+13	
42	Cs-137	7.176e+16	
43	Ba-139	3.473e+09	
44	Ba-140	7.428e+11	
45	La-140	1.625e+10	
46	La-141	1.447e+09	
47	La-142	550000000.	
48	Ce-141	2.907e+11	
49	Ce-143	1.137e+10	
50	Ce-144	2.028e+12	
51	Pr-143	1.108e+11	
52	Nd-147	3.899e+10	
53	Np-239	0.	
54	Pu-238	0.	
55	Pu-239	0.	
56	Pu-240	0.	
57	Pu-241	0.	
58	Am-241	0.	

Isotope Source (cont.)
1

Isotope #	Isotope Name	Rate (p/sec)	Rate FF
59	Cm-242	0.	
60	Cm-244	0.	
61	I-130	1.213e+12	
62	Kr-83m	2.099e+12	
63	Xe-138	3.582e+12	
64	Xe-131m	2.982e+13	
65	Xe-133m	3.067e+13	
66	Xe-135m	9.542e+11	
67	Cs-138	1.802e+12	
68	Cs-134m	3.545e+11	
69	Rb-88	4.01e+11	
70	Rb-89	4.397e+11	
71	Sb-124	5.093e+11	
72	Sb-125	7.113e+13	
73	Sb-126	6.321e+10	
74	Te-131	5.287e+10	
75	Te-133	3.453e+10	
76	Te-134	1.638e+11	
77	Te-125m	8.859e+11	
78	Te-133m	9.624e+10	
79	Ba-141	697100000.	
80	Ba-137m	8461000.	
81	Pd-109	0.	
82	Rh-106	1527000.	
83	Rh-103m	321300000.	
84	Tc-101	1.147e+11	
85	Eu-154	0.	
86	Eu-155	0.	
87	Eu-156	0.	
88	La-143	81110000.	
89	Nb-97	450900000.	
90	Nb-95m	236100000.	
91	Pm-147	8.437e+11	
92	Pm-148	8.105e+09	
93	Pm-149	7.251e+09	
94	Pm-151	1.387e+09	
95	Pm-148m	8.264e+09	
96	Pr-144	86100000.	
97	Pr-144m	428500.	
98	Sm-153	0.	
99	Y-94	108700000.	
100	Y-95	65150000.	
101	Y-91m	132100000.	

Isotope Source (cont.)
1

Isotope #	Isotope Name	Rate (p/sec)	Rate FF
102	Br-82	4.725e+11	
103	Br-83	5.469e+11	
104	Br-84	2.12e+11	
105	Am-242	0.	
106	Np-238	0.	
107	Pu-243	0.	

Isotope Filter
1S

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
1	Co-58	0.9	
2	Co-60	0.9	
3	Kr-85	0.	
4	Kr-85m	0.	
5	Kr-87	0.	
6	Kr-88	0.	
7	Rb-86	0.9	
8	Sr-89	0.9	
9	Sr-90	0.9	
10	Sr-91	0.9	
11	Sr-92	0.9	
12	Y-90	0.	
13	Y-91	0.	
14	Y-92	0.	
15	Y-93	0.	
16	Zr-95	0.9	
17	Zr-97	0.9	
18	Nb-95	0.9	
19	Mo-99	0.	
20	Tc-99m	0.9	
21	Ru-103	0.9	
22	Ru-105	0.9	
23	Ru-106	0.9	
24	Rh-105	0.9	
25	Sb-127	0.9	
26	Sb-129	0.9	
27	Te-127	0.9	

Isotope Filter (cont.)
1S

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
28	Te-127m	0.9	
29	Te-129	0.9	
30	Te-129m	0.9	
31	Te-131m	0.9	
32	Te-132	0.9	
33	I-131	0.9	
34	I-132	0.9	
35	I-133	0.9	
36	I-134	0.9	
37	I-135	0.9	
38	Xe-133	0.	
39	Xe-135	0.	
40	Cs-134	0.	
41	Cs-136	0.	
42	Cs-137	0.	
43	Ba-139	0.9	
44	Ba-140	0.9	
45	La-140	0.9	
46	La-141	0.9	
47	La-142	0.9	
48	Ce-141	0.9	
49	Ce-143	0.9	
50	Ce-144	0.9	
51	Pr-143	0.9	
52	Nd-147	0.9	
53	Np-239	0.9	
54	Pu-238	0.9	
55	Pu-239	0.9	
56	Pu-240	0.9	
57	Pu-241	0.9	
58	Am-241	0.9	
59	Cm-242	0.9	
60	Cm-244	0.9	
61	I-130	0.9	
62	Kr-83m	0.	
63	Xe-138	0.	
64	Xe-131m	0.	
65	Xe-133m	0.	
66	Xe-135m	0.	
67	Cs-138	0.	
68	Cs-134m	0.	
69	Rb-88	0.9	
70	Rb-89	0.9	

Isotope Filter (cont.)
1S

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
71	Sb-124	0.9	
72	Sb-125	0.9	
73	Sb-126	0.9	
74	Te-131	0.9	
75	Te-133	0.9	
76	Te-134	0.9	
77	Te-125m	0.9	
78	Te-133m	0.9	
79	Ba-141	0.9	
80	Ba-137m	0.9	
81	Pd-109	0.9	
82	Rh-106	0.9	
83	Rh-103m	0.9	
84	Tc-101	0.9	
85	Eu-154	0.9	
86	Eu-155	0.9	
87	Eu-156	0.9	
88	La-143	0.9	
89	Nb-97	0.9	
90	Nb-95m	0.9	
91	Pm-147	0.9	
92	Pm-148	0.9	
93	Pm-149	0.9	
94	Pm-151	0.9	
95	Pm-148m	0.9	
96	Pr-144	0.9	
97	Pr-144m	0.9	
98	Sm-153	0.9	
99	Y-94	0.	
100	Y-95	0.	
101	Y-91m	0.	
102	Br-82	0.9	
103	Br-83	0.9	
104	Br-84	0.9	
105	Am-242	0.9	
106	Np-238	0.9	
107	Pu-243	0.9	

Isotope Filter
2S
Cation Demin

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
1	Co-58	0.	
2	Co-60	0.	
3	Kr-85	0.	
4	Kr-85m	0.	
5	Kr-87	0.	
6	Kr-88	0.	
7	Rb-86	0.	
8	Sr-89	0.	
9	Sr-90	0.	
10	Sr-91	0.	
11	Sr-92	0.	
12	Y-90	0.9	
13	Y-91	0.9	
14	Y-92	0.9	
15	Y-93	0.9	
16	Zr-95	0.	
17	Zr-97	0.	
18	Nb-95	0.	
19	Mo-99	0.9	
20	Tc-99m	0.	
21	Ru-103	0.	
22	Ru-105	0.	
23	Ru-106	0.	
24	Rh-105	0.	
25	Sb-127	0.	
26	Sb-129	0.	
27	Te-127	0.	
28	Te-127m	0.	
29	Te-129	0.	
30	Te-129m	0.	
31	Te-131m	0.	
32	Te-132	0.	
33	I-131	0.	
34	I-132	0.	
35	I-133	0.	
36	I-134	0.	
37	I-135	0.	
38	Xe-133	0.	
39	Xe-135	0.	
40	Cs-134	0.9	
41	Cs-136	0.9	
42	Cs-137	0.9	
43	Ba-139	0.	

Isotope Filter (cont.)
2S
Cation Demin

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
44	Ba-140	0.	
45	La-140	0.	
46	La-141	0.	
47	La-142	0.	
48	Ce-141	0.	
49	Ce-143	0.	
50	Ce-144	0.	
51	Pr-143	0.	
52	Nd-147	0.	
53	Np-239	0.	
54	Pu-238	0.	
55	Pu-239	0.	
56	Pu-240	0.	
57	Pu-241	0.	
58	Am-241	0.	
59	Cm-242	0.	
60	Cm-244	0.	
61	I-130	0.	
62	Kr-83m	0.	
63	Xe-138	0.	
64	Xe-131m	0.	
65	Xe-133m	0.	
66	Xe-135m	0.	
67	Cs-138	0.9	
68	Cs-134m	0.9	
69	Rb-88	0.	
70	Rb-89	0.	
71	Sb-124	0.	
72	Sb-125	0.	
73	Sb-126	0.	
74	Te-131	0.	
75	Te-133	0.	
76	Te-134	0.	
77	Te-125m	0.	
78	Te-133m	0.	
79	Ba-141	0.	
80	Ba-137m	0.	
81	Pd-109	0.	
82	Rh-106	0.	
83	Rh-103m	0.	
84	Tc-101	0.	
85	Eu-154	0.	
86	Eu-155	0.	

Isotope Filter (cont.)
2S
Cation Demin

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
87	Eu-156	0.	
88	La-143	0.	
89	Nb-97	0.	
90	Nb-95m	0.	
91	Pm-147	0.	
92	Pm-148	0.	
93	Pm-149	0.	
94	Pm-151	0.	
95	Pm-148m	0.	
96	Pr-144	0.	
97	Pr-144m	0.	
98	Sm-153	0.	
99	Y-94	0.9	
100	Y-95	0.9	
101	Y-91m	0.9	
102	Br-82	0.	
103	Br-83	0.	
104	Br-84	0.	
105	Am-242	0.	
106	Np-238	0.	
107	Pu-243	0.	

Isotope Filter
3S
Degassing

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
1	Co-58	0.	
2	Co-60	0.	
3	Kr-85	0.66	
4	Kr-85m	0.78	
5	Kr-87	0.88	
6	Kr-88	0.81	
7	Rb-86	0.	
8	Sr-89	0.	
9	Sr-90	0.	
10	Sr-91	0.	
11	Sr-92	0.	
12	Y-90	0.	

Isotope Filter (cont.)
3S
Degassing

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
13	Y-91	0.	
14	Y-92	0.	
15	Y-93	0.	
16	Zr-95	0.	
17	Zr-97	0.	
18	Nb-95	0.	
19	Mo-99	0.	
20	Tc-99m	0.	
21	Ru-103	0.	
22	Ru-105	0.	
23	Ru-106	0.	
24	Rh-105	0.	
25	Sb-127	0.	
26	Sb-129	0.	
27	Te-127	0.	
28	Te-127m	0.	
29	Te-129	0.	
30	Te-129m	0.	
31	Te-131m	0.	
32	Te-132	0.	
33	I-131	0.	
34	I-132	0.	
35	I-133	0.	
36	I-134	0.	
37	I-135	0.	
38	Xe-133	0.58	
39	Xe-135	0.65	
40	Cs-134	0.	
41	Cs-136	0.	
42	Cs-137	0.	
43	Ba-139	0.	
44	Ba-140	0.	
45	La-140	0.	
46	La-141	0.	
47	La-142	0.	
48	Ce-141	0.	
49	Ce-143	0.	
50	Ce-144	0.	
51	Pr-143	0.	
52	Nd-147	0.	
53	Np-239	0.	
54	Pu-238	0.	
55	Pu-239	0.	

Isotope Filter (cont.)
3S
Degassing

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
56	Pu-240	0.	
57	Pu-241	0.	
58	Am-241	0.	
59	Cm-242	0.	
60	Cm-244	0.	
61	I-130	0.	
62	Kr-83m	0.85	
63	Xe-138	0.96	
64	Xe-131m	0.58	
65	Xe-133m	0.59	
66	Xe-135m	0.95	
67	Cs-138	0.	
68	Cs-134m	0.	
69	Rb-88	0.	
70	Rb-89	0.	
71	Sb-124	0.	
72	Sb-125	0.	
73	Sb-126	0.	
74	Te-131	0.	
75	Te-133	0.	
76	Te-134	0.	
77	Te-125m	0.	
78	Te-133m	0.	
79	Ba-141	0.	
80	Ba-137m	0.	
81	Pd-109	0.	
82	Rh-106	0.	
83	Rh-103m	0.	
84	Tc-101	0.	
85	Eu-154	0.	
86	Eu-155	0.	
87	Eu-156	0.	
88	La-143	0.	
89	Nb-97	0.	
90	Nb-95m	0.	
91	Pm-147	0.	
92	Pm-148	0.	
93	Pm-149	0.	
94	Pm-151	0.	
95	Pm-148m	0.	
96	Pr-144	0.	
97	Pr-144m	0.	
98	Sm-153	0.	

Isotope Filter (cont.)
3S
Degassing

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
99	Y-94	0.	
100	Y-95	0.	
101	Y-91m	0.	
102	Br-82	0.	
103	Br-83	0.	
104	Br-84	0.	
105	Am-242	0.	
106	Np-238	0.	
107	Pu-243	0.	

Isotope Filter
4S
Boron Bled/Feed

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
1	Co-58	0.99999	
2	Co-60	0.99999	
3	Kr-85	1.	
4	Kr-85m	1.	
5	Kr-87	1.	
6	Kr-88	1.	
7	Rb-86	0.99999	
8	Sr-89	0.99999	
9	Sr-90	0.99999	
10	Sr-91	0.99999	
11	Sr-92	0.99999	
12	Y-90	0.99999	
13	Y-91	0.99999	
14	Y-92	0.99999	
15	Y-93	0.99999	
16	Zr-95	0.99999	
17	Zr-97	0.99999	
18	Nb-95	0.99999	
19	Mo-99	0.99999	
20	Tc-99m	0.99999	
21	Ru-103	0.99999	
22	Ru-105	0.99999	
23	Ru-106	0.99999	
24	Rh-105	0.99999	

Isotope Filter (cont.)
4S
Boron Bled/Feed

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
25	Sb-127	0.99999	
26	Sb-129	0.99999	
27	Te-127	0.99999	
28	Te-127m	0.99999	
29	Te-129	0.99999	
30	Te-129m	0.99999	
31	Te-131m	0.99999	
32	Te-132	0.99999	
33	I-131	0.9999	
34	I-132	0.9999	
35	I-133	0.9999	
36	I-134	0.9999	
37	I-135	0.9999	
38	Xe-133	1.	
39	Xe-135	1.	
40	Cs-134	0.99999	
41	Cs-136	0.99999	
42	Cs-137	0.99999	
43	Ba-139	0.99999	
44	Ba-140	0.99999	
45	La-140	0.99999	
46	La-141	0.99999	
47	La-142	0.99999	
48	Ce-141	0.99999	
49	Ce-143	0.99999	
50	Ce-144	0.99999	
51	Pr-143	0.99999	
52	Nd-147	0.99999	
53	Np-239	0.99999	
54	Pu-238	0.99999	
55	Pu-239	0.99999	
56	Pu-240	0.99999	
57	Pu-241	0.99999	
58	Am-241	0.99999	
59	Cm-242	0.99999	
60	Cm-244	0.99999	
61	I-130	0.9999	
62	Kr-83m	1.	
63	Xe-138	1.	
64	Xe-131m	1.	
65	Xe-133m	1.	
66	Xe-135m	1.	
67	Cs-138	0.99999	

Isotope Filter (cont.)
4S
Boron Bled/Feed

Isotope #	Isotope Name	Efficiency (frac)	Efficiency FF
68	Cs-134m	0.99999	
69	Rb-88	0.99999	
70	Rb-89	0.99999	
71	Sb-124	0.99999	
72	Sb-125	0.99999	
73	Sb-126	0.99999	
74	Te-131	0.99999	
75	Te-133	0.99999	
76	Te-134	0.99999	
77	Te-125m	0.99999	
78	Te-133m	0.99999	
79	Ba-141	0.99999	
80	Ba-137m	0.99999	
81	Pd-109	0.99999	
82	Rh-106	0.99999	
83	Rh-103m	0.99999	
84	Tc-101	0.99999	
85	Eu-154	0.99999	
86	Eu-155	0.99999	
87	Eu-156	0.99999	
88	La-143	0.99999	
89	Nb-97	0.99999	
90	Nb-95m	0.99999	
91	Pm-147	0.99999	
92	Pm-148	0.99999	
93	Pm-149	0.99999	
94	Pm-151	0.99999	
95	Pm-148m	0.99999	
96	Pr-144	0.99999	
97	Pr-144m	0.99999	
98	Sm-153	0.99999	
99	Y-94	0.99999	
100	Y-95	0.99999	
101	Y-91m	0.99999	
102	Br-82	0.99999	
103	Br-83	0.99999	
104	Br-84	0.99999	
105	Am-242	0.99999	
106	Np-238	0.99999	
107	Pu-243	0.99999	

Volume Initial Conditions

Vol #	Total Pressure (psia)	Vapor Temp. (F)	Liquid Temp. F	Relative Humidity (%)	Liquid Volume Fract.	Ice Volume Fract.	Ice Surf.A. (ft2)
def	14.7	80.	80.	60.	0.	0.	0.

Initial Gas Pressure Ratios

Vol #	Air Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6	Gas 7	Gas 8
def	1.	0.	0.	0.	0.	0.	0.	0.

Noncondensing Gases

Gas No.	Description	Symbol	Type	Mol. Weight	Lennard-Jones Diameter (Ang)	Parameters e/K (K)
1	Air	Air	POLY	28.97	3.617	97.

Noncondensing Gases - Cp/Visc. Equations

Gas No.	Cp Tmin (R)	Equation Tmax (R)	(Required) Cp (Btu/lbm-R)	Visc. Tmin (R)	Equation Tmax (R)	(Optional) Viscosity (lbm/ft-hr)
1	360.	2880.	0.238534-6.2006			

Ice Condenser Parameters

Initial Temp. (F)	Bulk Density (lbm/ft3)	Surface Area Multiplier Function	Heat Transfer Option
15.	33.43		UCHIDA

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Run Control Parameters (Seconds)

Time Dom	DT Min	DT Max	DT Ratio	End Time	Print Int	Graph Int	Max CPU	Dump Int	Phs Chng Time Scale
1	0.001	50.	1.	1e+06	1e+05	10000.	7200.	1e+06	DEFAULT
2	0.001	100.	1.	2e+06	1e+05	10000.	10800.	1e+06	DEFAULT
3	0.001	200.	1.	4e+06	5e+05	20000.	14400.	1e+06	DEFAULT
4	0.001	200.	1.	5e+07	1e+06	2e+05	2e+05	2e+06	DEFAULT

Solution Options

Time Dom	Solution Method	Imp Conv Limit	Imp Iter Limit	Pres Sol Method	Pres Conv Limit	Pres Iter Limit	Differ Scheme	Burn Sharp
1	SEMI-IMP	0.	1	DIRECT	0.	1	FOUP	0.
2	SEMI-IMP	0.	1	DIRECT	0.	1	FOUP	0.
3	SEMI-IMP	0.	1	DIRECT	0.	1	FOUP	0.
4	SEMI-IMP	0.	1	DIRECT	0.	1	FOUP	0.

Run Options

Option	Setting
Restart Time (sec)	0.0
Restart Time Step #	0
Restart Time Control	NEW
Revaporization Fraction	DEFAULT
Fog Model	OFF
Maximum Mist Density (lbm/ft3)	DEFAULT
Drop Diam. From Mist (in)	DEFAULT
Minimum HT Coeff. (B/h-ft2-F)	0.0
Reference Pressure (psia)	IGNORE
Forced Ent. Drop Diam. (in)	DEFAULT
Vapor Phase Head Correction	INCLUDE
Kinetic Energy	IGNORE
Vapor Phase	INCLUDE
Liquid Phase	INCLUDE
Drop Phase	INCLUDE
Force Equilibrium	IGNORE
Drop-Liq. Conversion	INCLUDE
QA Logging	OFF
Debug Output Level	0
Restart Dump on CPU Interval (sec)	3600.

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GOTHIC Version 7.1pcs(QA) - August 2003
File: /home/gothic/projects/nmc/palisades/pcs/pal_activity

Water Properties	
Option	Setting
Water Type	LIGHT

Graphs							
Graph #	Title	Mon	Curve Number 1	2	3	4	5
0	M&E Imbalance		EM	EE			
1	Br-82 Br-83 Br-		102i1	103i1	104i1		
2	Kr-85 Kr-85m Kr		3i1	4i1	5i1	6i1	62i1
3	Sr-89 Sr-90 Sr-		8i1	9i1	10i1	11i1	7i1
4	Y-90 Y-91 Y-92		12i1	13i1	14i1	15i1	
5	Zr-95 Zr-97 Nb-		16i1	17i1	18i1		
6	Mo-99 Tc-99m		19i1	20i1			
7	Ru-103 Ru-105 R		21i1	22i1	23i1	24i1	
8	Rh-106 Rh-103m		82i1	83i1	84i1		
9	Sb-124 Sb-125 S		71i1	72i1	73i1	25i1	26i1
10	Te-127 Te-127m		27i1	28i1	29i1		
11	Te-129m Te-131m		30i1	31i1	32i1	61i1	
12	I-131 I-132 I-1		33i1	34i1	35i1	36i1	37i1
13	Xe-133 Xe-135		38i1	39i1			
14	Cs-134 Cs-136 C		40i1	41i1	42i1	80i1	
15	Ba-139 Ba-140 L		43i1	44i1	45i1	46i1	47i1
16	Ce-141 Ce-143 C		48i1	49i1	50i1	51i1	52i1
17	Xe-138 Xe131m X		63i1	64i1	65i1	66i1	
18	Cs-138 Cs-134m		67i1	68i1	69i1	70i1	
19	Te-131 Te-133 T		74i1	75i1	76i1	77i1	78i1
20	La-143 Nb-97 Nb		88i1	89i1	90i1	79i1	
21	Pr-144 Pr-144m		96i1	97i1	99i1	100i1	101i1
22	Pm-147 Pm-148 P		91i1	92i1	93i1	94i1	95i1

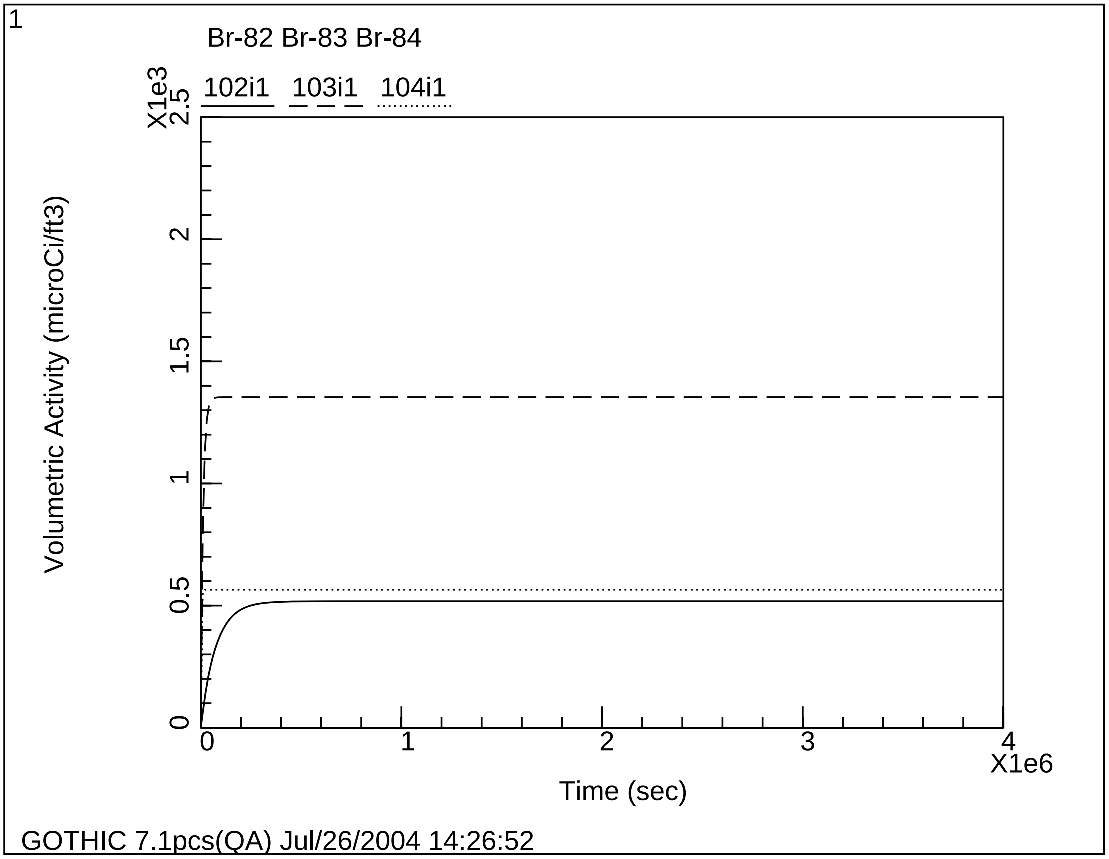
Envelope Sets			
Set No.	Description	Set Type	No. Items

ATTACHMENT B

GOTHIC Graphical Results

Filename: pal_activity

pal_activity 23
Jul/28/2004 14:23:15
GOTHIC Version 7.1pcs(QA) - August 2003
File: /home/gothic/projects/nmc/palisades/pcs/pal_activity



pal_activity
Jul/28/2004 14:23:15
GOTHIC Version 7.1pcs(QA) - August 2003
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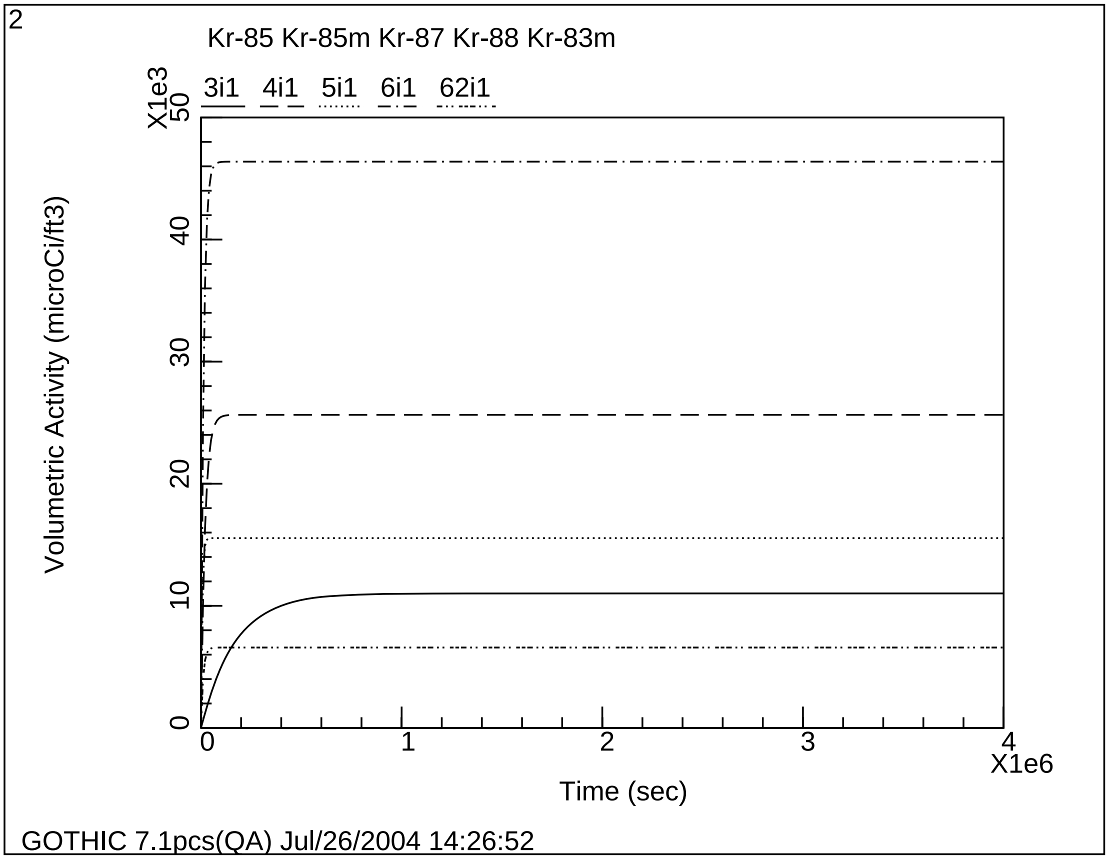
24



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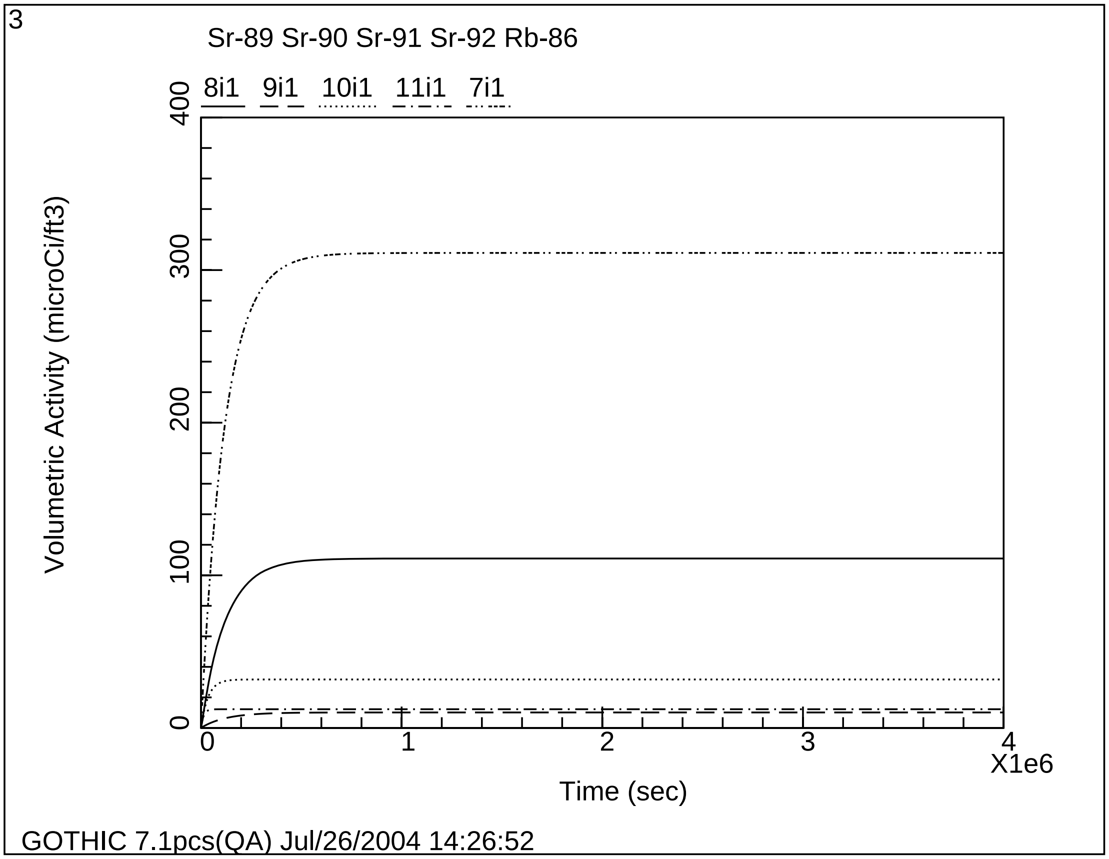

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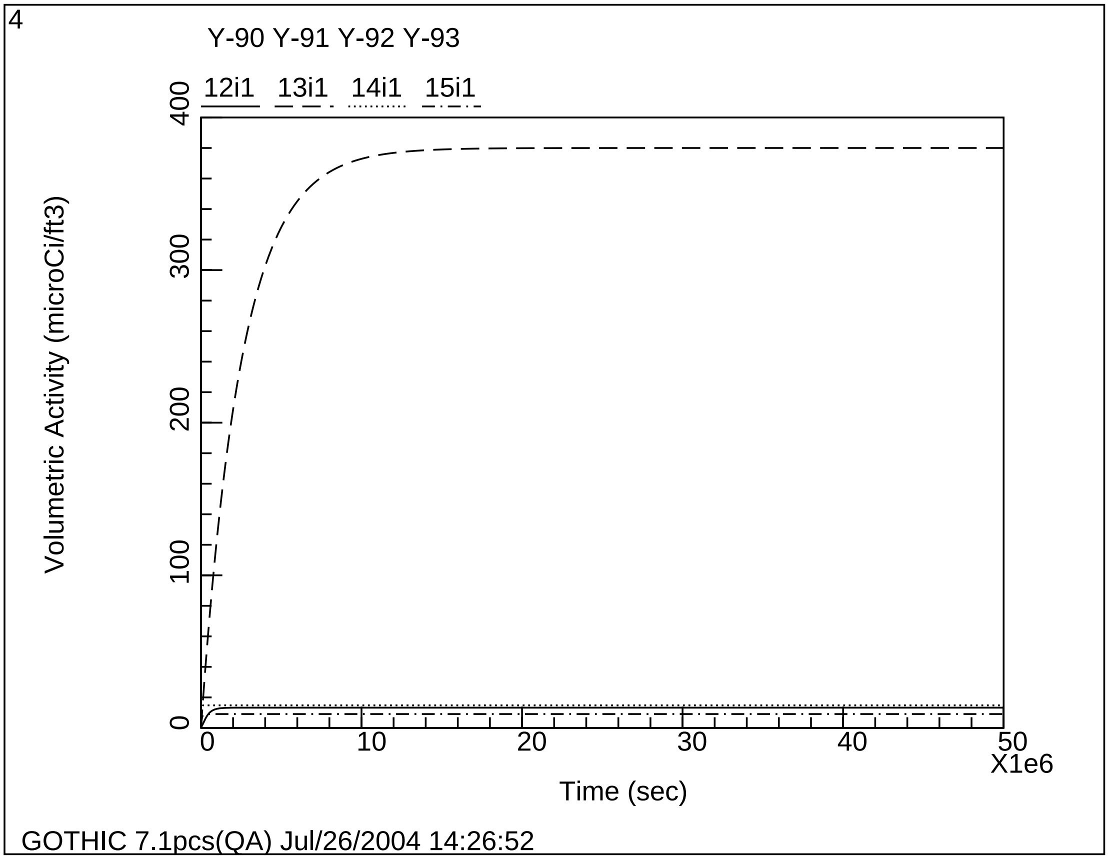

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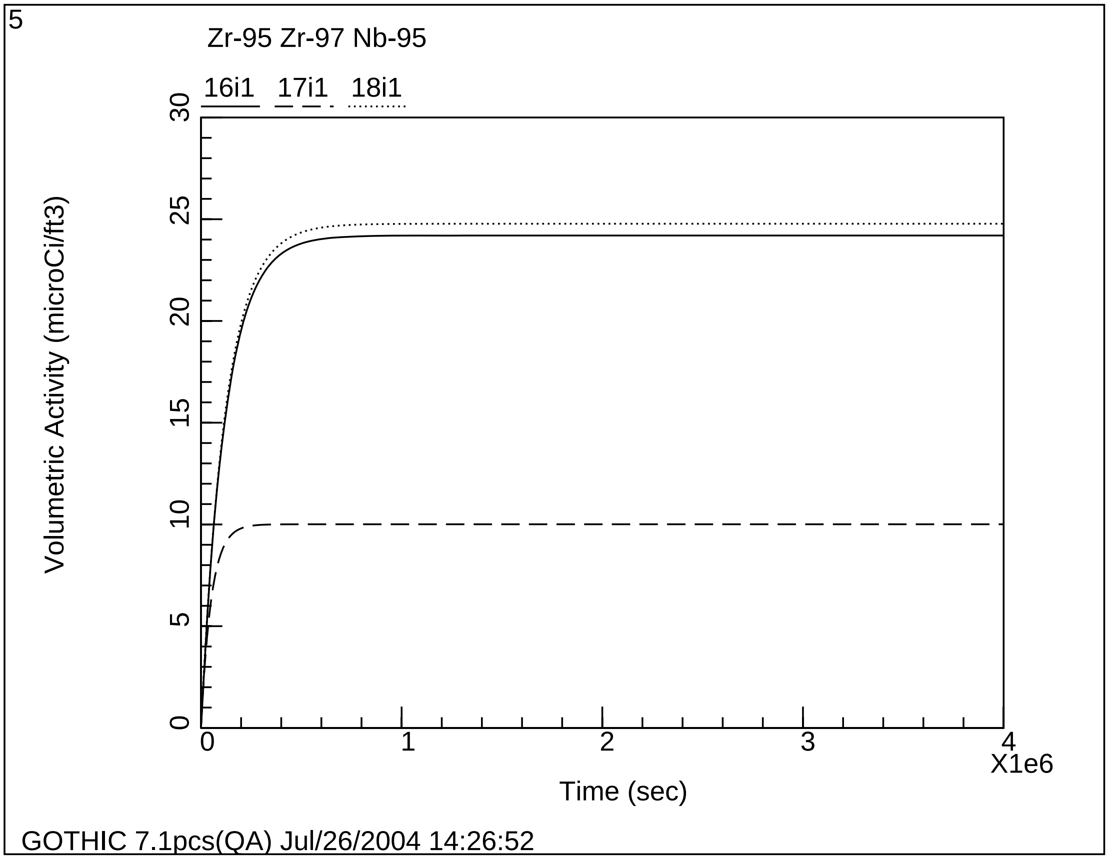

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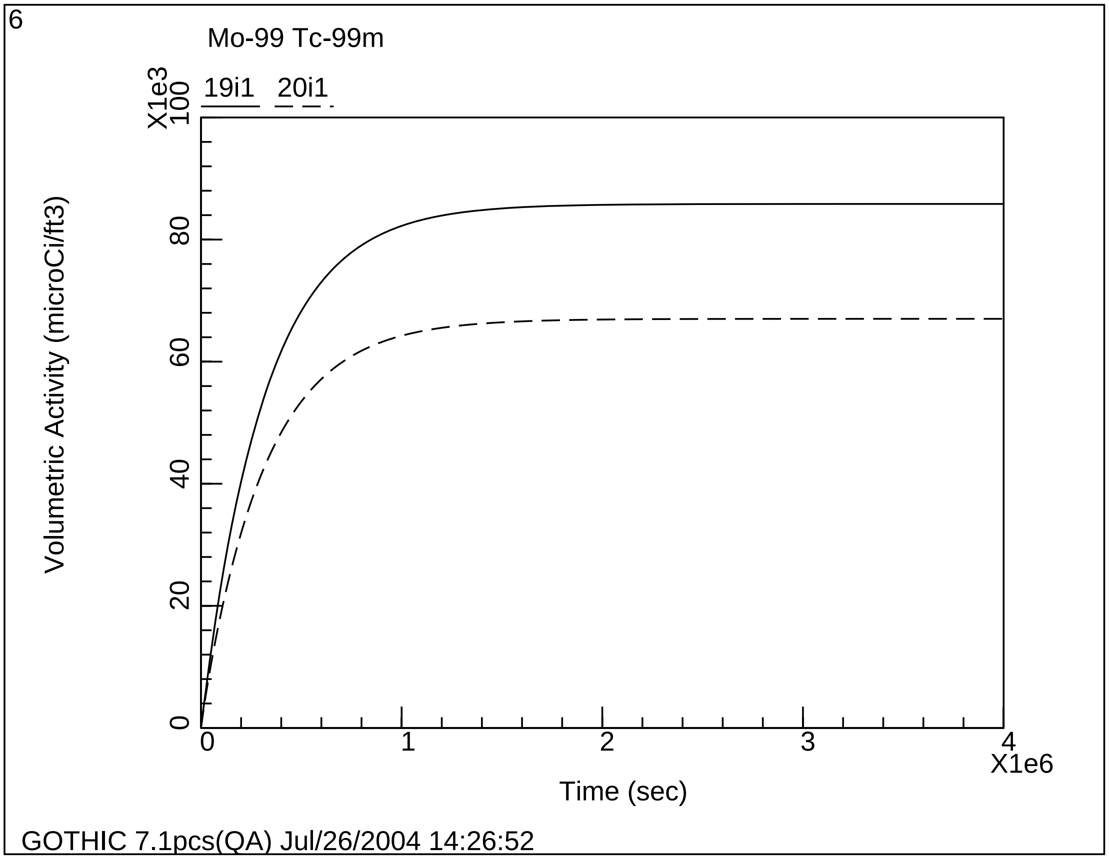

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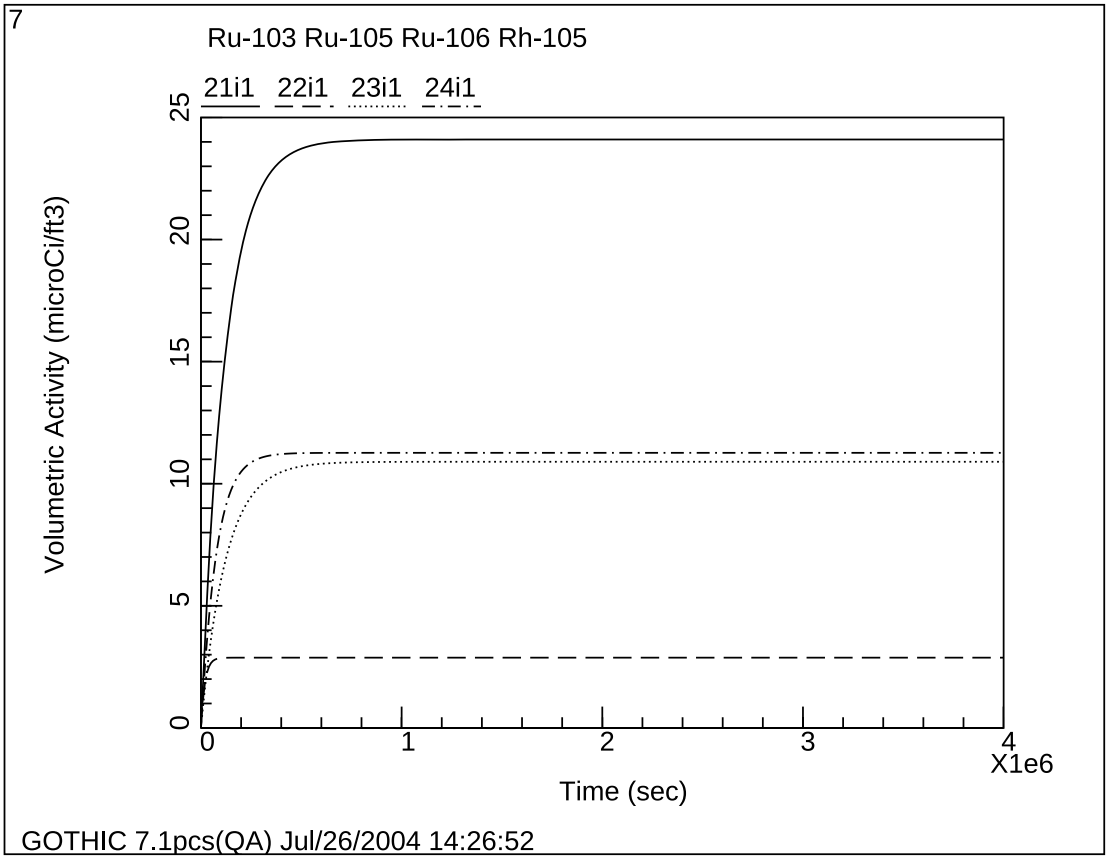

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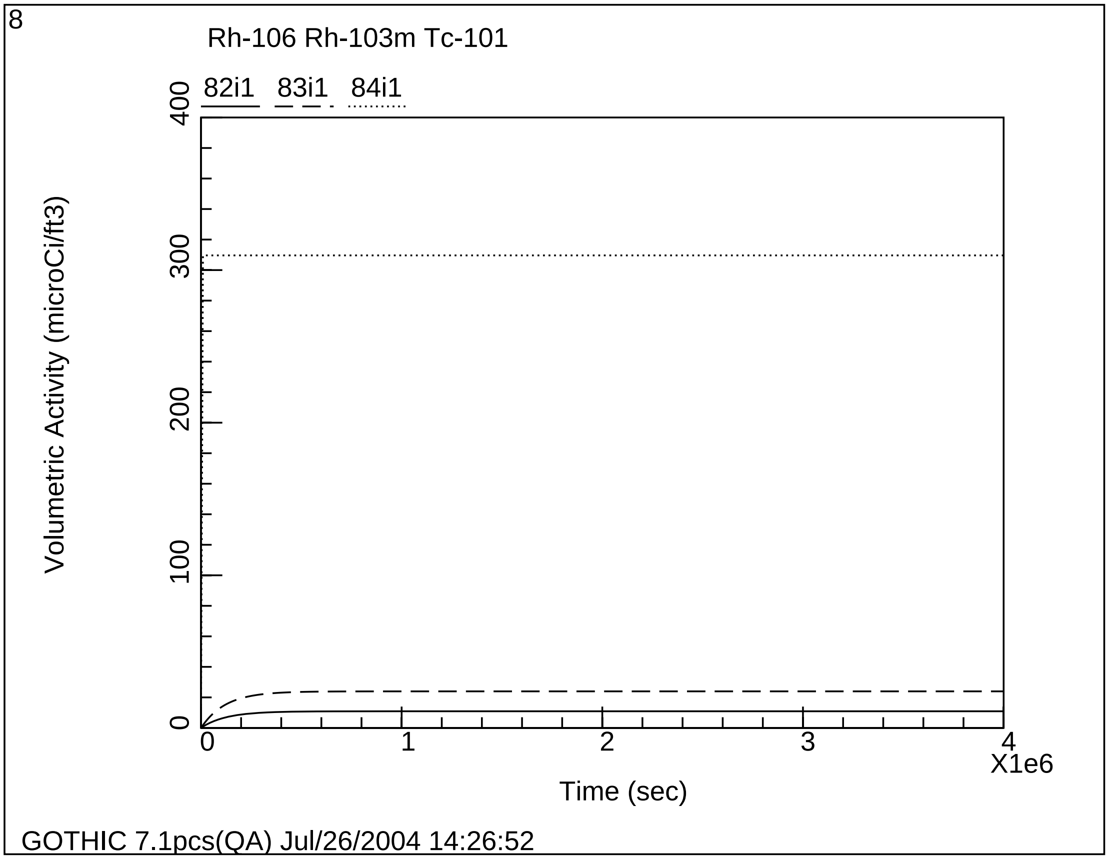
30



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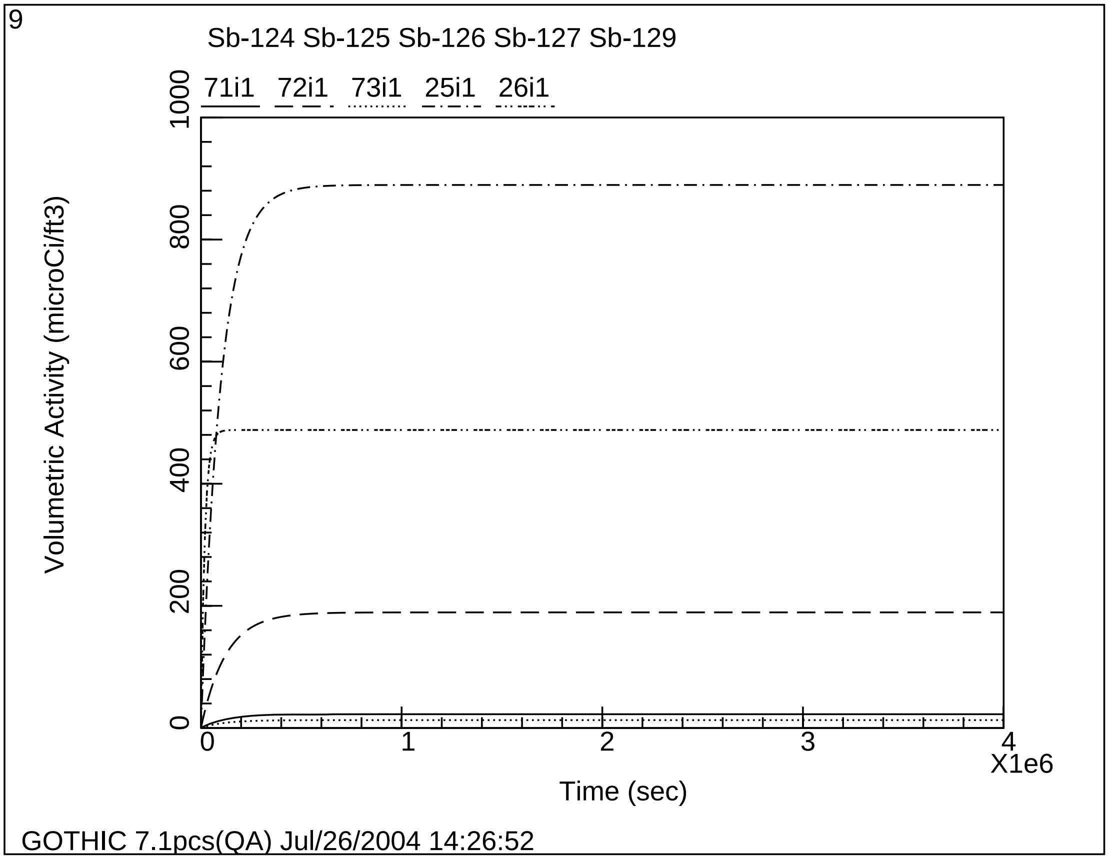

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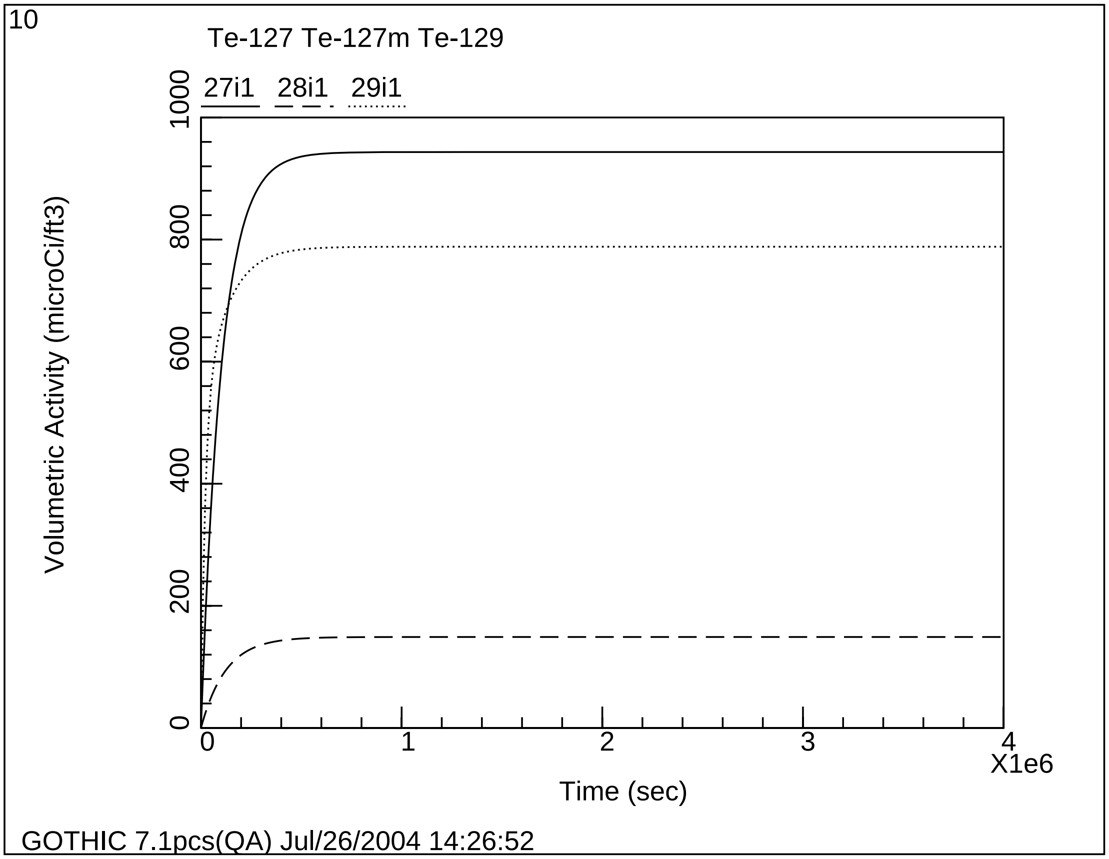

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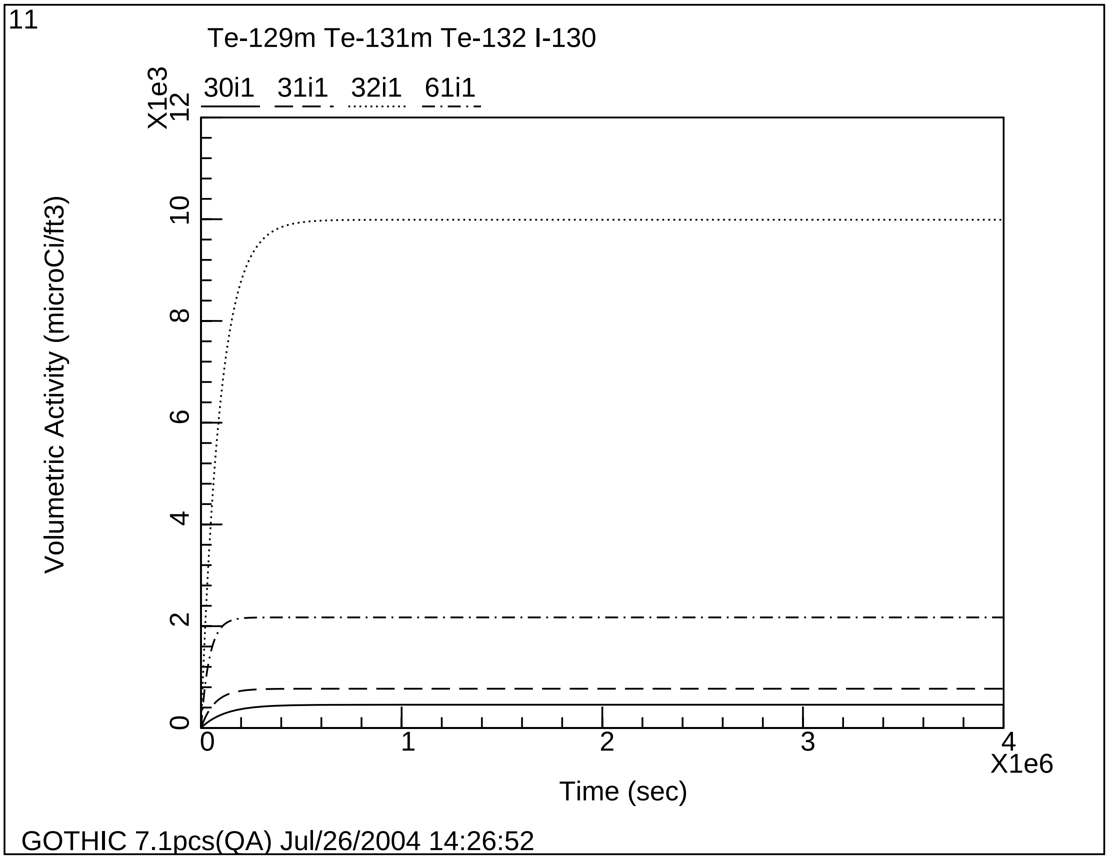

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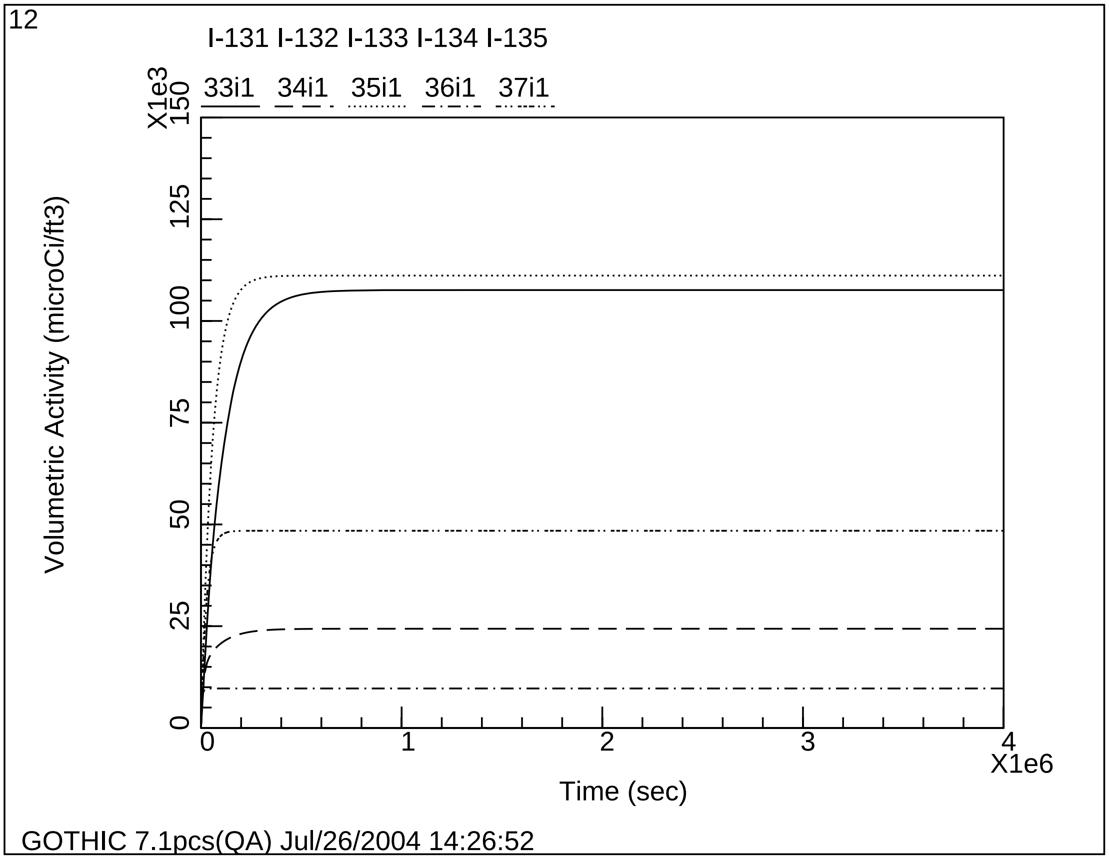

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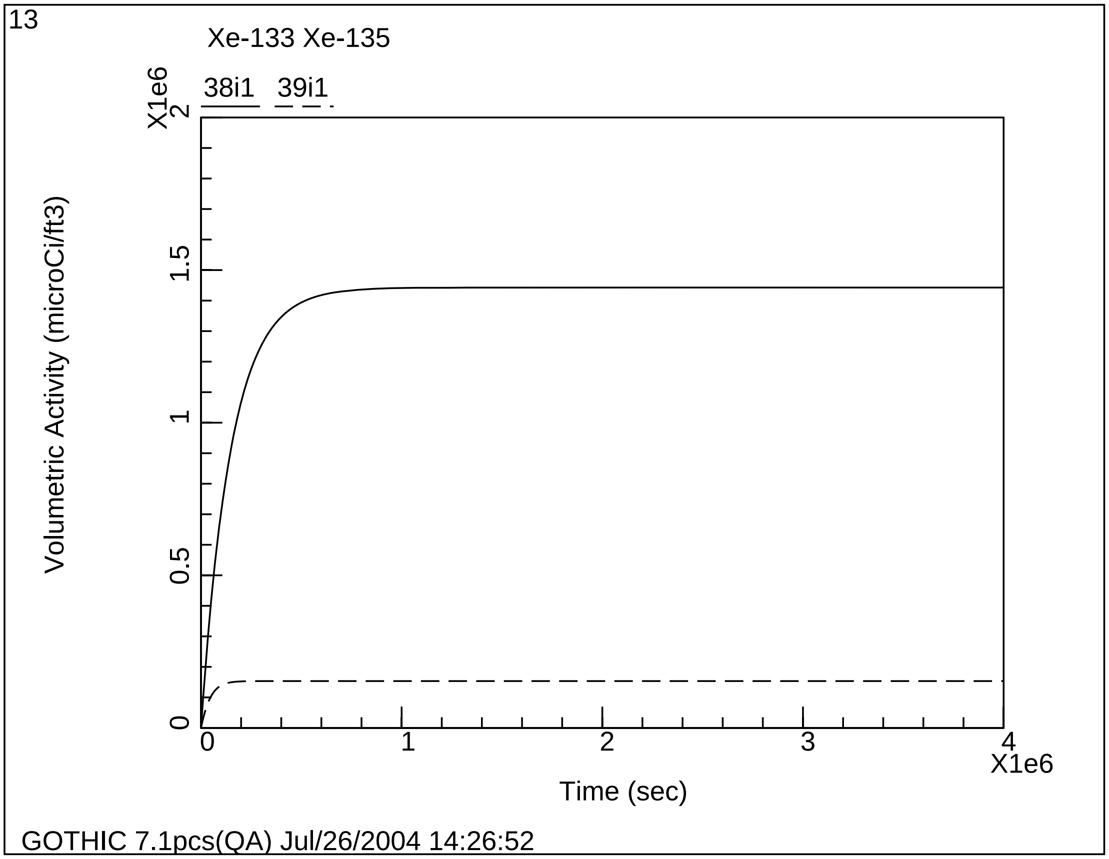

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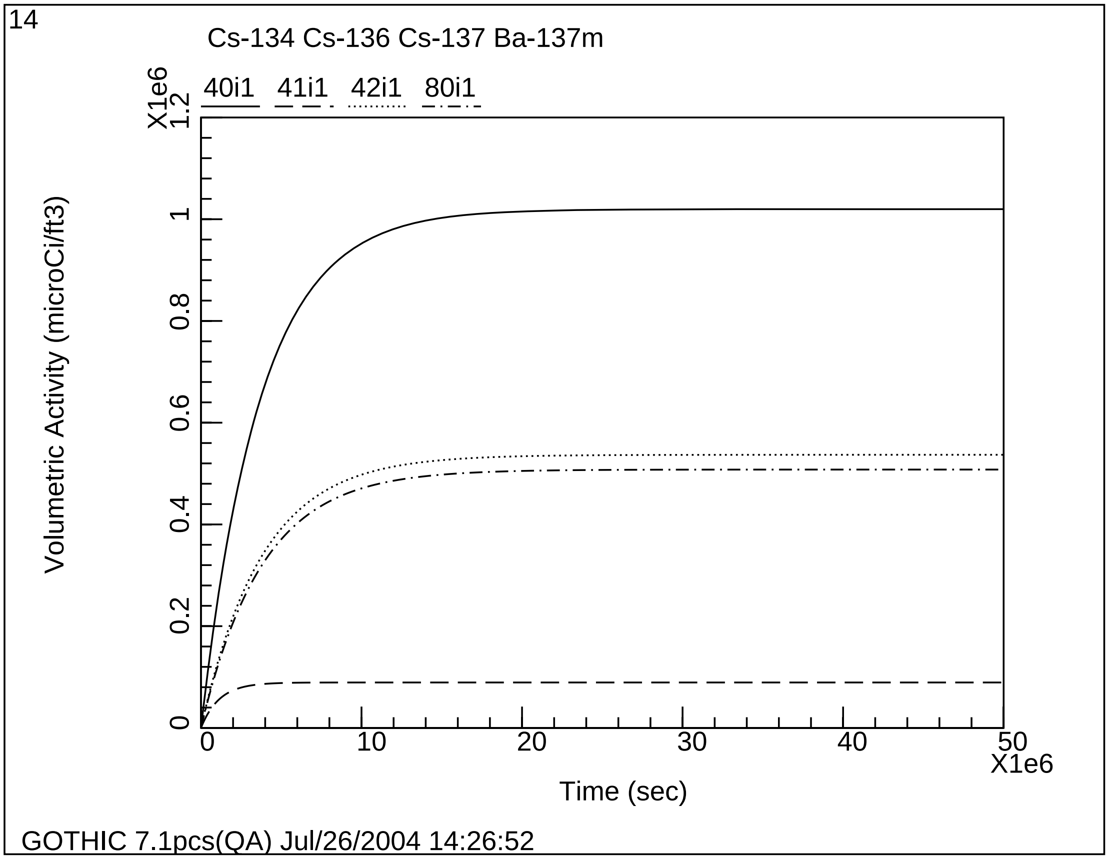

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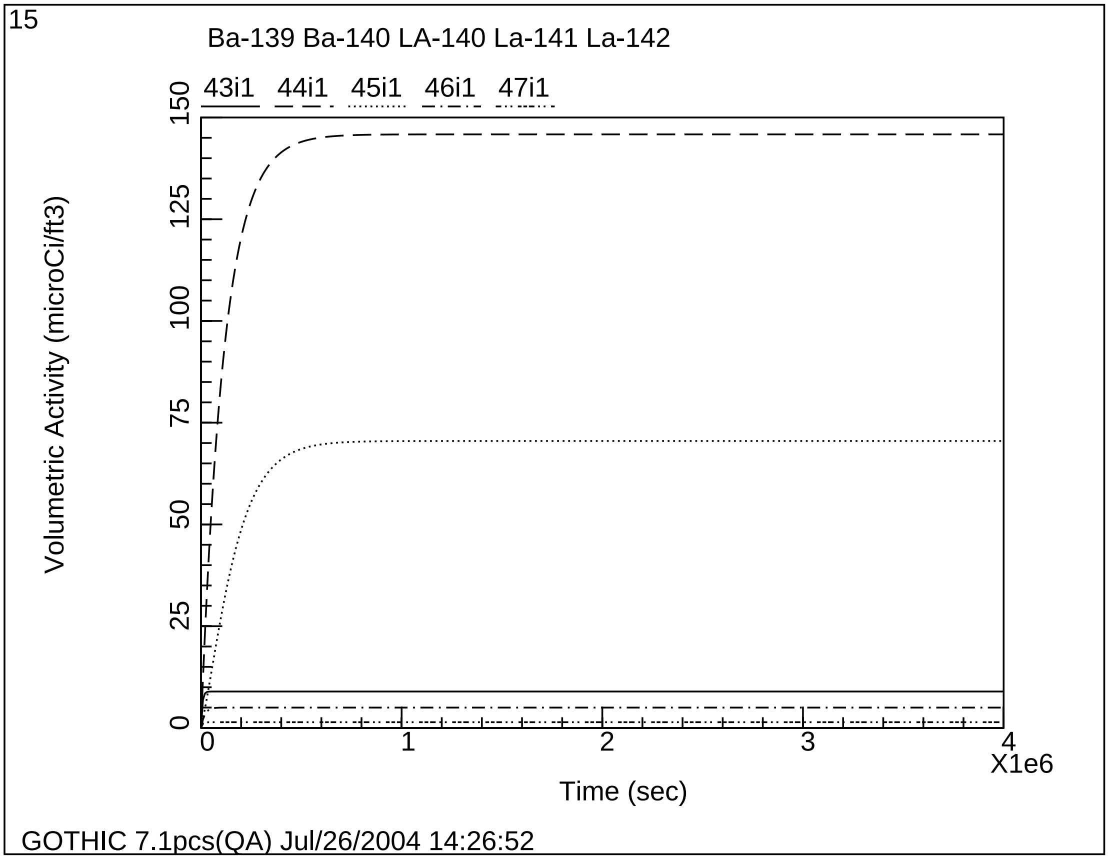

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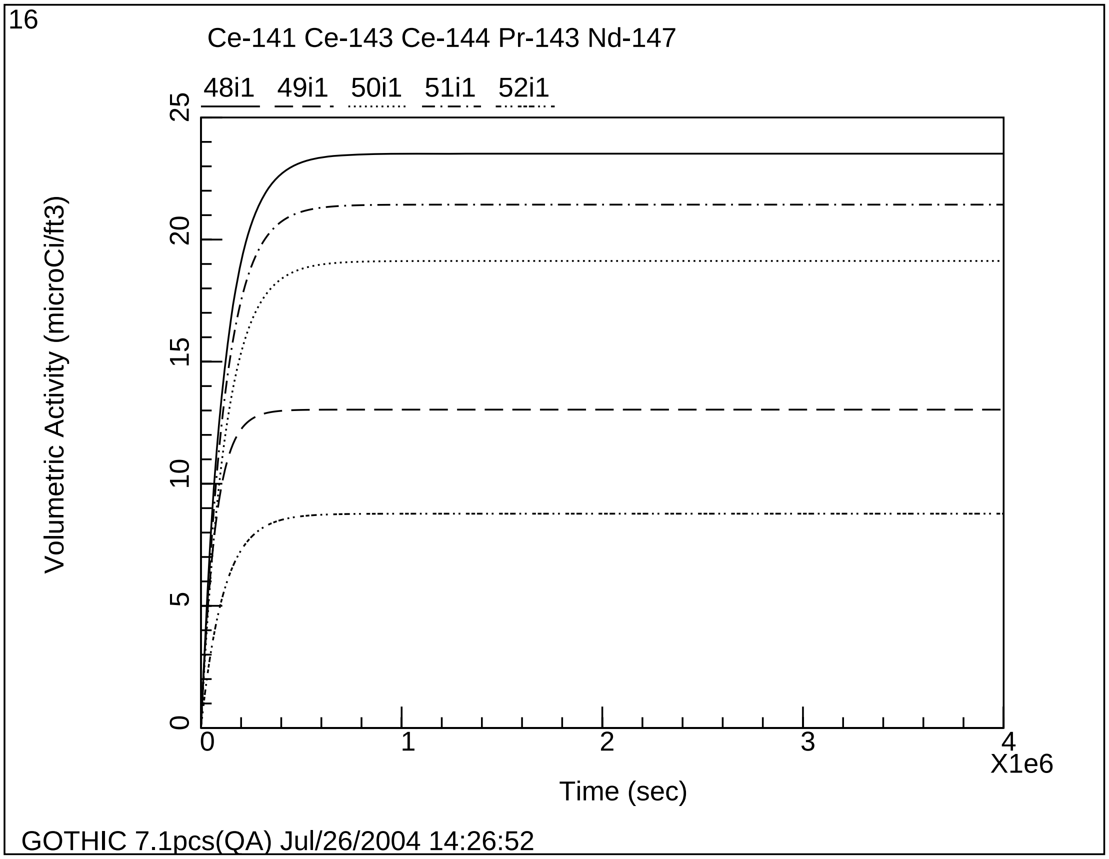

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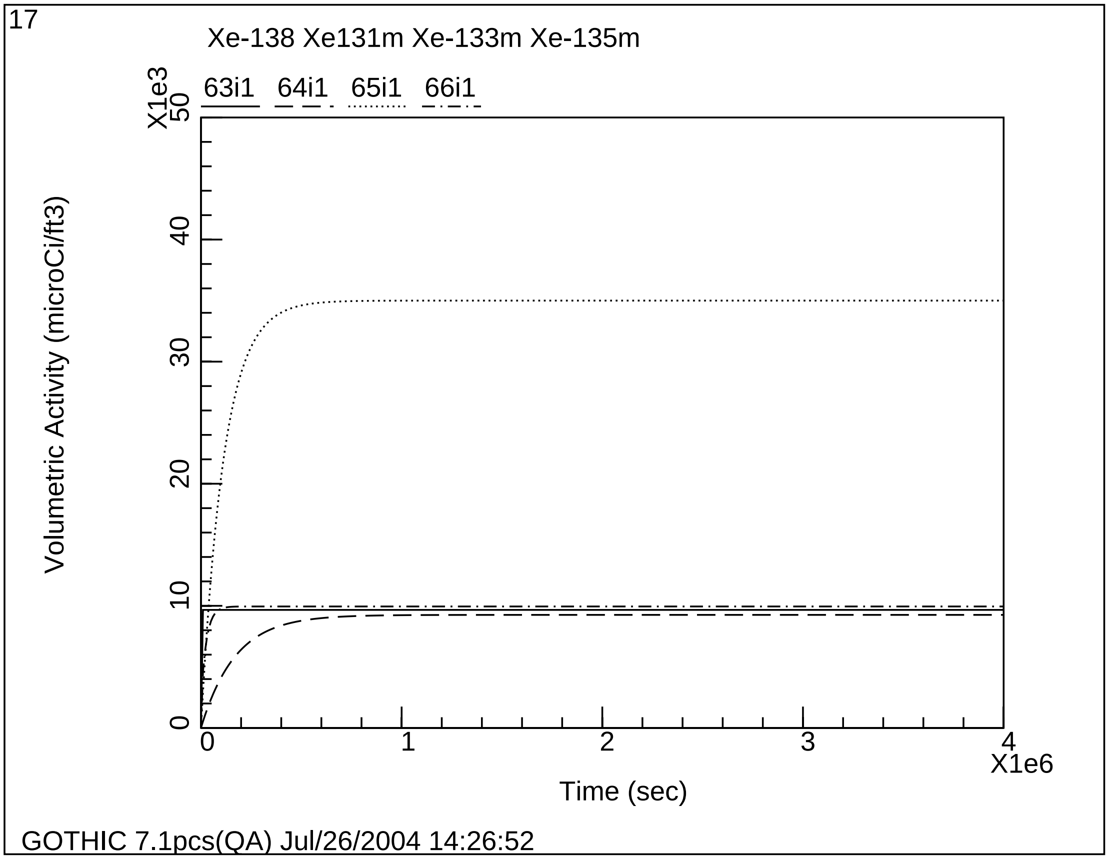

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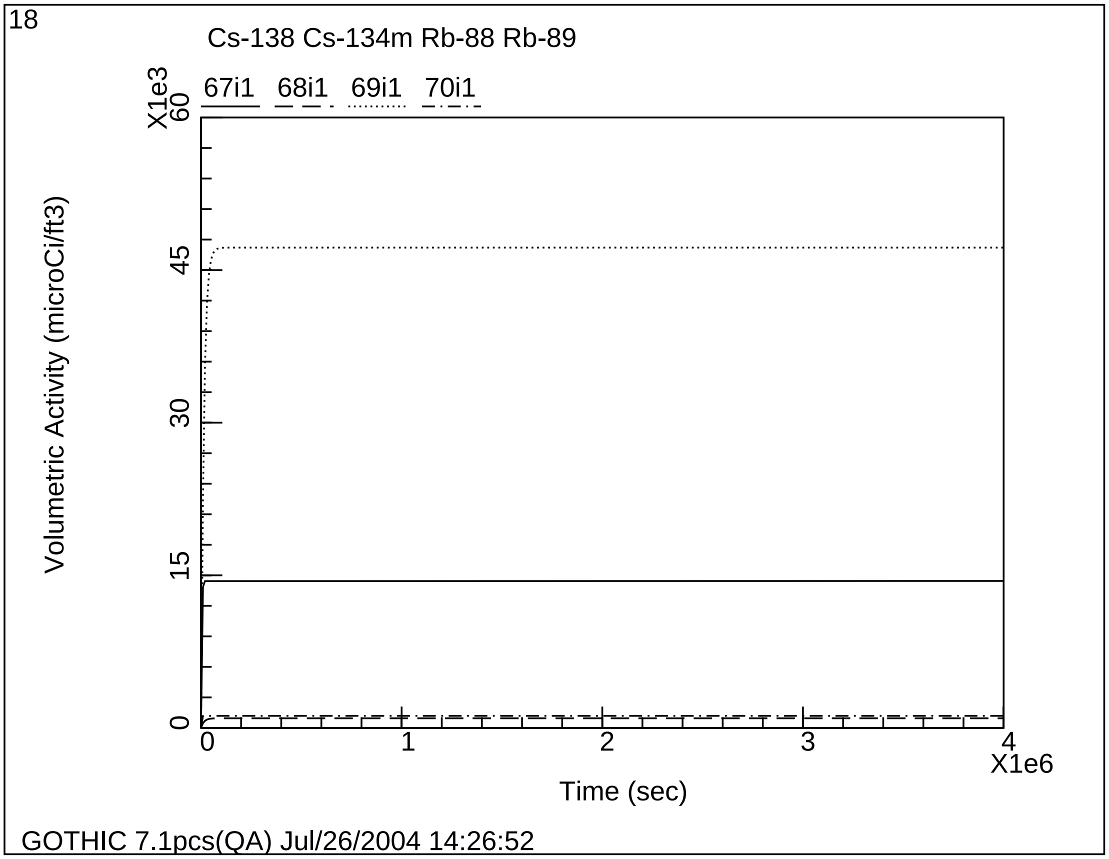

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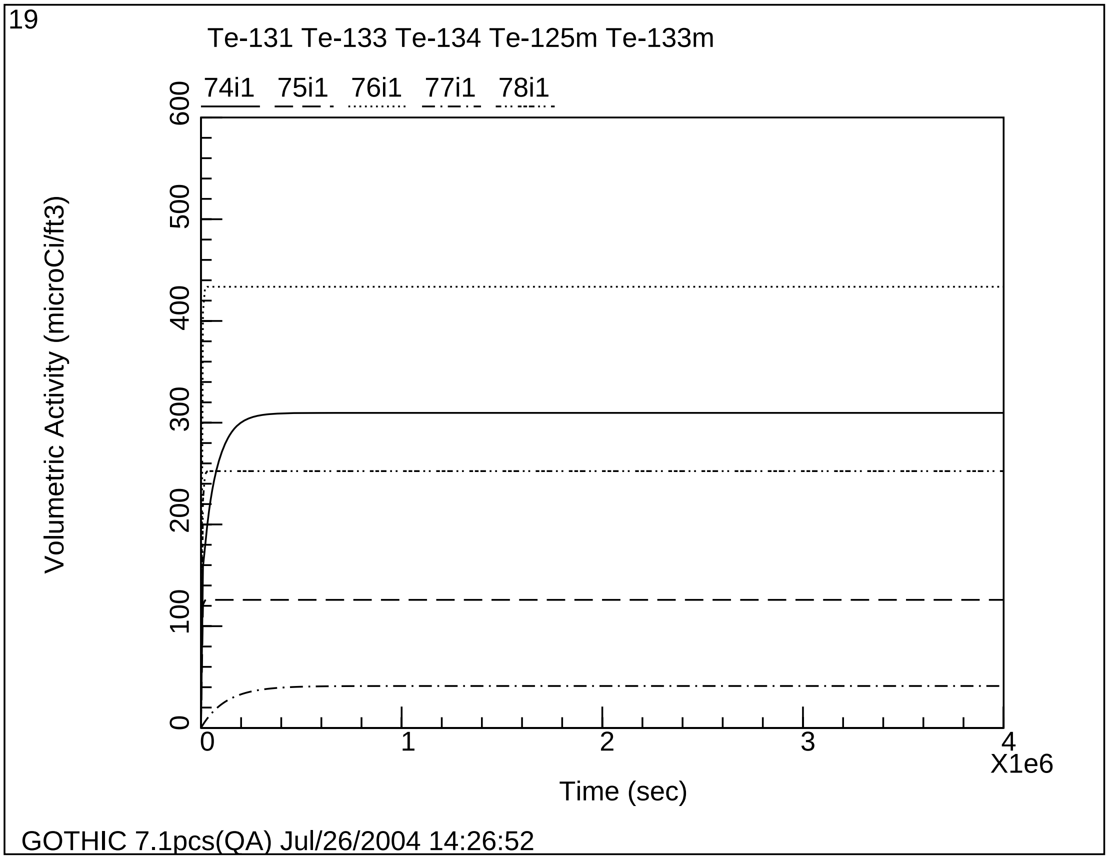

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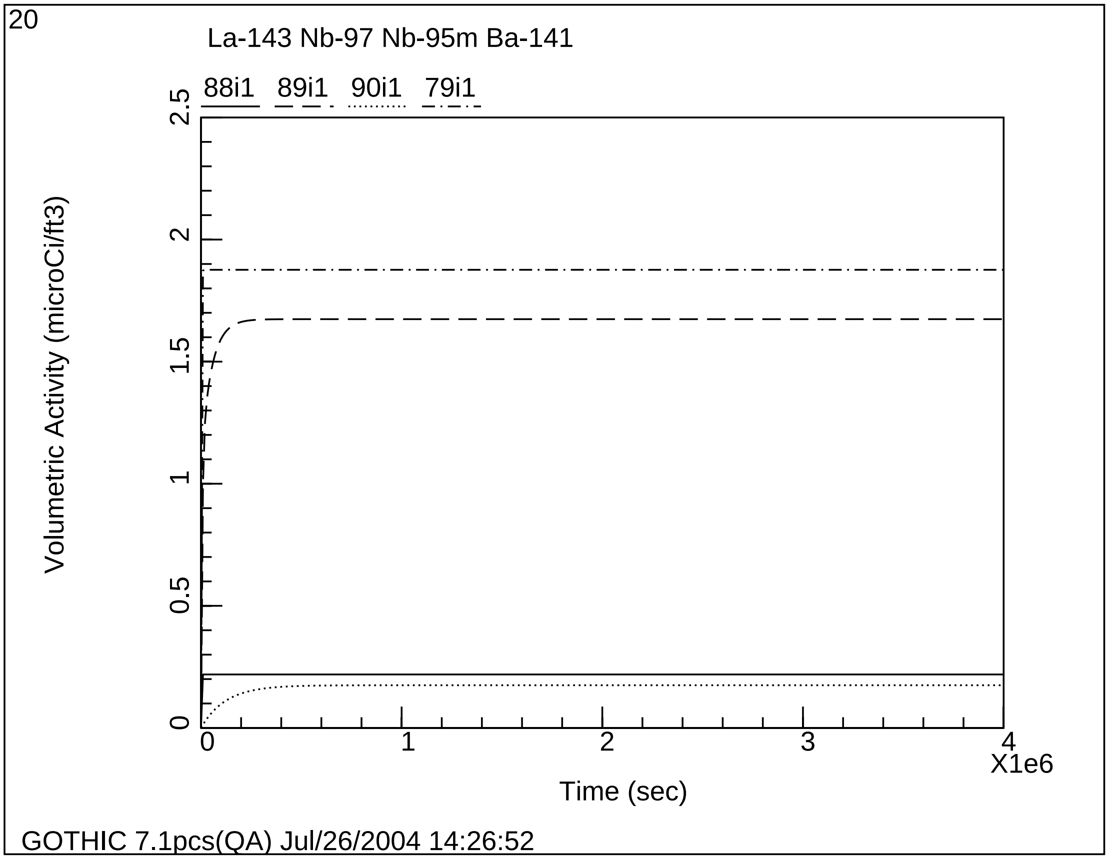

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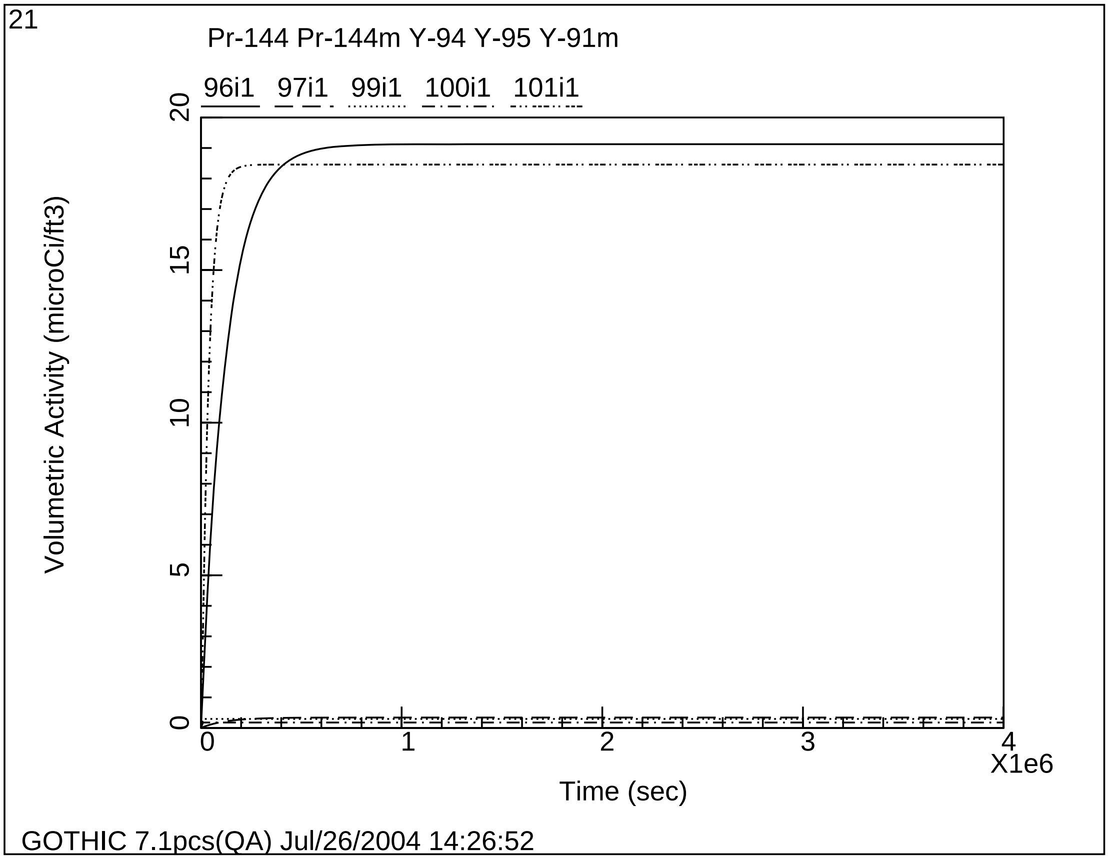

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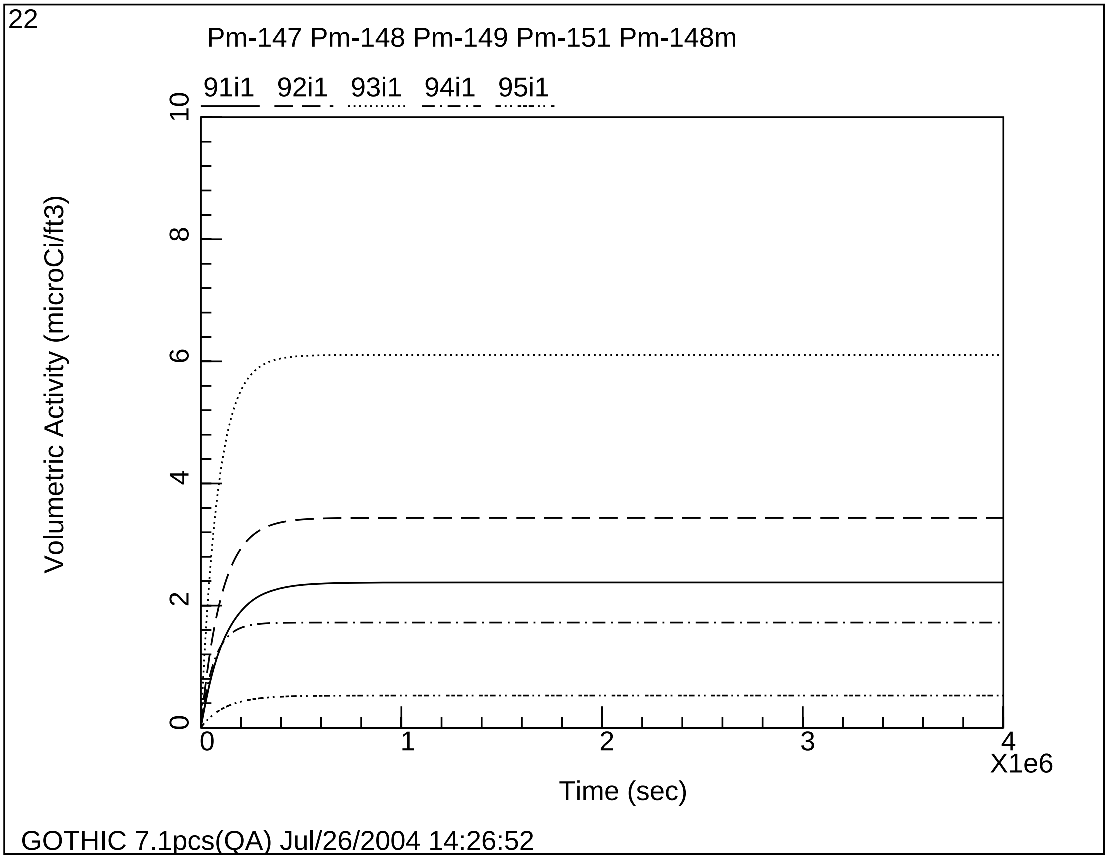

Review Comments

Tim Guidotti was the author and Jim Harrell was the reviewer of this notebook except for the corrosion product activity determination per ANSI/ANS-18.1-1999. Joe Sinodis and Jim Harrell were the author and reviewer of the corrosion product activity spreadsheet.

1. Correct typographical errors based on mark-up.
2. The description of Flow Path 5 includes a typographical error (“Bled” instead of “Bleed”), which does not impact the results and may be left as-is to eliminate modifying computer runs.

Review Response

1. Added based on mark-up.