

NAI Report Release

Calculation Number: NAI-1149-011

Revision Number: 0

Title: Primary Coolant Source Term Determination for Palisades Dose Calculations

Description:

The purpose of this calculation is to develop the PCS source term for use in AST dose calculations for Palisades. This source term will meet the 1.0 $\mu\text{Ci/gm}$ Dose Equivalent I-131 and 100/E-bar gross activity limits specified in the Palisades Technical Specifications. In addition, the secondary side source term equal to the Technical Specification limit of 0.1 $\mu\text{Ci/gm}$ Dose Equivalent I-131 will be determined.

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NAI Calculation Approval

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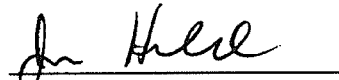
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Date

Scope of Review:

Review included:

- A general review of calculation methods was completed for consistency with plant-specific and generic regulatory requirements and guidance.
- ORIGEN computer qualification was verified as appropriate.
- Calc and code inputs and assumptions were verified against IAM document(s).
- References were verified as appropriate.
- Outputs from spreadsheets and utility programs were checked with hand calcs.
- Reported results were verified against computer outputs.
- Results and conclusions were reviewed for reasonableness.

Design Verification Rev. 0 – See Attachment 1



Reviewer
James R. Harrell

6/9/05
Date

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.

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1.0 Introduction

The purpose of this calculation is to develop the PCS source term for use in AST dose calculations for Palisades. This source term will meet the 1.0 $\mu\text{Ci/gm}$ Dose Equivalent I-131 and 100/E-bar gross activity limits specified in the Palisades Technical Specifications. In addition, the secondary side source term equal to the Technical Specification limit of 0.1 $\mu\text{Ci/gm}$ Dose Equivalent I-131 will be determined.

2.0 Summary of Results

The Palisades primary coolant source term is provided in Table 6-5 and the secondary side source term is provided in Table 6-6. The RADTRAD-NAI nuclide inventory file is provided in Attachment 2.

3.0 Design Input

The base Palisades primary coolant activities are provided in Table 2 of Reference 1.

4.0 Assumptions

The following assumptions were applied to the PCS and secondary side source term determinations:

1. When scaling the total iodine activity to 1.0 $\mu\text{Ci/gm}$ D.E. I-131, the relative concentrations of the iodine isotopes are assumed to remain the same.
2. When scaling the non-iodine isotope activities to 100/E-bar, the relative concentrations of the non-iodine isotopes are assumed to remain the same.
3. The relative concentrations of the iodine isotopes on the secondary side are assumed to be the same as the relative concentrations on the primary side.

5.0 Computer Codes

No computer codes were required for this calculation.

6.0 Calculations

6.1 Primary Coolant Source Term

The primary coolant source term was derived from Table 2 of Reference 1.

The iodine activities from Reference 1 (listed below in Table 6-1) were adjusted to achieve the Technical Specification limit of 1.0 $\mu\text{Ci/gm}$ dose equivalent I-131 (see Table 6-3). The non-iodine species were adjusted to achieve the Technical Specification limit of 100/E-bar for non-iodine activities (see Table 6-4). Table 6-5 presents the final adjusted primary coolant source term.

Table 6-1 Unadjusted Primary Coolant Source Term

Nuclide	$\mu\text{Ci/gm}$	Nuclide	$\mu\text{Ci/gm}$
Co-58	7.0E-03	Np-239	-
Co-60	8.0E-04	Pu-238	-
Cr-51	4.7E-03	Pu-239	-
Fe-55	1.8E-03	Pu-240	-
Fe-59	4.5E-04	Pu-241	-
Mn-54	2.4E-03	Am-241	-
Kr-85	5.3E-01	Cm-242	-
Kr-85m	1.2E+00	Cm-244	-
Kr-87	7.5E-01	I-130	1.1E-01
Kr-88	2.2E+00	Kr-83m	3.2E-01
Rb-86	1.5E-02	Xe-138	4.7E-01
Sr-89	5.4E-03	Xe-131m	4.5E-01
Sr-90	4.9E-04	Xe-133m	1.7E+00
Sr-91	1.5E-03	Xe-135m	4.8E-01
Sr-92	5.9E-04	Cs-138	7.0E-01
Y-90	6.4E-04	Cs-134m	4.6E-02
Y-91	1.8E-02	Rb-88	2.3E+00
Y-92	7.2E-04	Rb-89	5.8E-02
Y-93	4.4E-04	Sb-124	1.1E-03
Zr-95	1.2E-03	Sb-125	9.2E-03
Zr-97	4.9E-04	Sb-126	6.2E-04
Nb-95	1.2E-03	Te-131	1.5E-02
Mo-99	4.2E+00	Te-133	6.1E-03
Tc-99m	3.2E+00	Te-134	2.1E-02
Ru-103	1.2E-03	Te-125m	2.0E-03
Ru-105	1.4E-04	Te-133m	1.2E-02
Ru-106	5.3E-04	Ba-141	9.1E-05
Rh-105	5.5E-04	Ba-137m	2.5E+01
Sb-127	4.3E-02	Pd-109	-
Sb-129	2.4E-02	Rh-106	5.3E-04
Te-127	4.6E-02	Rh-103m	1.2E-03
Te-127m	7.2E-03	Tc-101	1.5E-02
Te-129	3.8E-02	Eu-154	-
Te-129m	2.2E-02	Eu-155	-
Te-131m	3.7E-02	Eu-156	-
Te-132	4.8E-01	La-143	1.1E-05

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Nuclide	μCi/gm	Nuclide	μCi/gm
I-131	5.2E+00	Nb-97	8.1E-05
I-132	1.2E+00	Nb-95m	8.5E-06
I-133	5.4E+00	Pm-147	1.2E-04
I-134	4.7E-01	Pm-148	1.7E-04
I-135	2.3E+00	Pm-149	3.0E-04
Xe-133	7.0E+01	Pm-151	8.3E-05
Xe-135	7.4E+00	Pm-148m	2.6E-05
Cs-134	4.9E+01	Pr-144	9.3E-04
Cs-136	4.3E+00	Pr-144m	1.6E-05
Cs-137	2.6E+01	Sm-153	-
Ba-139	4.3E-04	Y-94	1.4E-05
Ba-140	7.1E-03	Y-95	8.6E-06
La-140	3.4E-03	Y-91m	8.9E-04
La-141	2.4E-04	Br-82	2.5E-02
La-142	6.8E-05	Br-83	6.6E-02
Ce-141	1.1E-03	Br-84	2.7E-02
Ce-143	6.3E-04	Am-242	-
Ce-144	9.3E-04	Np-238	-
Pr-143	1.0E-03	Pu-243	-
Nd-147	4.3E-04		

Per the Palisades Technical Specifications, the primary coolant activity limit is 1.0 μ/gm Dose Equivalent I-131 and 100/E-bar μCi/gm gross radioactivity.

The definition for DOSE EQUIVALENT I-131 in the current Technical Specifications states that:

“DOSE EQUIVALENT I-131 shall be that concentration of I-131 (microcuries/gram) that alone would produce the same thyroid dose as the quantity and isotopic mixture of I-131, I-132, I-133, I-134, and I-135 actually present. The thyroid dose conversion factors used for this calculation shall be those listed in Table III of TID-14844, AEC, 1962, “Calculation of Distance Factors for Power and Test Reactor Sites.”

However, a revision is being proposed to this Technical Specification definition that will change the referenced thyroid dose conversion factors to the effective dose conversion factors provided in Table 2.1 of Federal Guidance Report No. 11.

The Tech. Spec. definition of Dose Equivalent I-131 (D.E. I-131) can be represented by the following equation:

$$D.E. I-131 (\mu Ci/gm) = \Sigma(a_i \times DCF_i) / DCF_{I-131}$$

- where: a_i = activity of individual isotope (μCi/gm)
- DCF_i = effective dose conversion factor for the individual isotope (Table 2.1 of FGR 11, Reference 3)
- DCF_{I-131} = effective dose conversion factor for I-131

Table 6-2 provides the determination of the D.E. I-131 for the Table 6-1 iodine activities:

Table 6-2 Primary System D.E. I-131 Determination

Isotope	Table 6-1 Activity ($\mu\text{Ci/gm}$)	DCF _i	Activity*DCF
I-131	5.20E+00	8.89E-09	4.6228E-08
I-132	1.20E+00	1.03E-10	1.2360E-10
I-133	5.40E+00	1.58E-09	8.5320E-09
I-134	4.70E-01	3.55E-11	1.6685E-11
I-135	2.30E+00	3.32E-10	7.6360E-10
		Total	5.5664E-08
D.E. I-131	Total / DCF _{I-131}	=	6.26140 $\mu\text{Ci/gm}^*$

*the numbers in the table are rounded, the actual computation of DE I-131 is performed in a spreadsheet.

Assuming that the relative iodine concentrations would remain the same, the Table 6-2 activities were adjusted by dividing the activities by 6.26140. This gives a D.E. I-131 of 1.0 $\mu\text{Ci/gm}$:

Table 6-3 Primary System Activities for D.E. I-131 = 1.0 $\mu\text{Ci/gm}$

Isotope	(Table 6-2 Activity / 6.26140) ($\mu\text{Ci/gm}$)	DCF _i	Activity*DCF
I-131	0.8305	8.89E-09	7.3830E-09
I-132	0.1917	1.03E-10	1.9740E-11
I-133	0.8624	1.58E-09	1.3626E-09
I-134	0.0751	3.55E-11	2.6647E-12
I-135	0.3673	3.32E-10	1.2195E-10
		Total	8.8900E-09
DE I-131	Total / DCF _{I-131}	=	1.00 $\mu\text{Ci/gm}$

The remaining isotopes in Table 6-1 were adjusted to achieve the Tech. Spec. limit of 100/E-bar microcuries per gram of gross activity. The Tech. Spec. definition of E-bar, Average Disintegration Energy, is:

“ \bar{E} shall be the average (weighted in proportion to the concentration of each radionuclide in the primary coolant at the time of sampling) of the sum of the average beta and gamma energies per disintegration (in MeV) for isotopes, other than iodines, with half lives > 15 minutes, making up at least 95% of the total noniodine activity in the coolant.”

The Tech. Spec. definition of E-bar can be represented by the following equation:

$$\bar{E} = [\sum(E_i^\beta + E_i^\gamma) \times a_i] / \sum a_i$$

where: a_i = activity of individual isotope ($\mu\text{Ci/gm}$)
 E_i^β = average beta emission energy (MeV/dis)
 E_i^γ = average gamma emission energy (MeV/dis)

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Table 6-4 presents the calculations performed to adjust the activities to equal 100/E-bar. In this table, the initial activities were multiplied by a common factor (0.734) so that the total activity equaled 100/E-bar. Values for E_i^{β} and E_i^{γ} were obtained from Table A.1 of Reference 4. Isotopes with half lives less than 15 minutes were deleted from the 100/E-bar calculation.

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Table 6-4 Primary System Activities = 100/E-bar

Nuclide	Activity uCi/gm	E-beta	E-gamma	$(E^{\beta}_i + E^{\gamma}_i) \times a_i$	Multiplier	Adjusted Activity	$(E^{\beta}_i + E^{\gamma}_i) \times a_i$
KR-83M	3.200E-01	0.039	0.003	1.344E-02	0.734	2.349E-01	9.865E-03
KR-85M	1.200E+00	0.255	0.158	4.956E-01	0.734	8.808E-01	3.638E-01
KR-85	5.300E-01	0.251	0.002	1.341E-01	0.734	3.890E-01	9.842E-02
KR-87	7.500E-01	1.324	0.793	1.588E+00	0.734	5.505E-01	1.165E+00
KR-88	2.200E+00	0.364	1.955	5.102E+00	0.734	1.615E+00	3.745E+00
XE-131M	4.500E-01	0.144	0.020	7.380E-02	0.734	3.303E-01	5.417E-02
XE-133M	1.700E+00	0.192	0.041	3.961E-01	0.734	1.248E+00	2.907E-01
XE-133	7.000E+01	0.136	0.046	1.274E+01	0.734	5.138E+01	9.351E+00
XE-135	7.400E+00	0.317	0.249	4.188E+00	0.734	5.432E+00	3.074E+00
BR-83	6.600E-02	0.321	0.008	2.171E-02	0.734	4.844E-02	1.594E-02
BR-84	2.700E-02	1.229	1.788	8.146E-02	0.734	1.982E-02	5.979E-02
RB-86	1.500E-02	0.668	0.095	1.145E-02	0.734	1.101E-02	8.401E-03
CS-134	4.900E+01	0.164	1.555	8.423E+01	0.734	3.597E+01	6.183E+01
CS-136	4.300E+00	0.139	2.166	9.912E+00	0.734	3.156E+00	7.275E+00
CS-137	2.600E+01	0.187	0.000	4.862E+00	0.734	1.908E+01	3.569E+00
CS-138	7.000E-01	1.207	2.361	2.498E+00	0.734	5.138E-01	1.833E+00
SR-89	5.400E-03	0.583	0.000	3.148E-03	0.734	3.964E-03	2.311E-03
SR-90	4.900E-04	0.196	0.000	9.604E-05	0.734	3.597E-04	7.049E-05
CR-51	4.700E-03	0.004	0.033	1.739E-04	0.734	3.450E-03	1.276E-04
FE-59	4.500E-04	0.118	1.189	5.882E-04	0.734	3.303E-04	4.317E-04
CO-60	8.000E-04	0.097	2.504	2.081E-03	0.734	5.872E-04	1.527E-03
SR-91	1.500E-03	0.656	0.697	2.030E-03	0.734	1.101E-03	1.490E-03
SR-92	5.900E-04	0.196	1.339	9.057E-04	0.734	4.331E-04	6.647E-04
Y-90	6.400E-04	0.935	0.000	5.984E-04	0.734	4.698E-04	4.392E-04
Y-91M	8.900E-04	0.027	0.530	4.957E-04	0.734	6.533E-04	3.639E-04
Y-91	1.800E-02	0.602	0.004	1.091E-02	0.734	1.321E-02	8.006E-03
Y-92	7.200E-04	1.446	0.252	1.223E-03	0.734	5.285E-04	8.974E-04
Y-93	4.400E-04	1.174	0.089	5.557E-04	0.734	3.230E-04	4.079E-04
ZR-95	1.200E-03	0.116	0.739	1.026E-03	0.734	8.808E-04	7.531E-04
NB-95	1.200E-03	0.044	0.766	9.720E-04	0.734	8.808E-04	7.134E-04

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Nuclide	Activity uCi/gm	E-beta	E-gamma	$(E_i^{\beta} + E_i^{\gamma}) \times a_i$	Multiplier	Adjusted Activity	$(E_i^{\beta} + E_i^{\gamma}) \times a_i$
MO-99	4.200E+00	0.392	0.150	2.276E+00	0.734	3.083E+00	1.671E+00
TC-99M	3.200E+00	0.016	0.126	4.544E-01	0.734	2.349E+00	3.335E-01
RU-103	1.200E-03	0.075	0.469	6.528E-04	0.734	8.808E-04	4.792E-04
RU-106	5.300E-04	0.010	0.000	5.300E-06	0.734	3.890E-04	3.890E-06
RH-103M	1.200E-03	0.038	0.002	4.800E-05	0.734	8.808E-04	3.523E-05
TE-125M	2.000E-03	0.109	0.036	2.900E-04	0.734	1.468E-03	2.129E-04
TE-127M	7.200E-03	0.082	0.011	6.696E-04	0.734	5.285E-03	4.915E-04
TE-127	4.600E-02	0.223	0.005	1.049E-02	0.734	3.376E-02	7.698E-03
TE-129M	2.200E-02	0.260	0.038	6.556E-03	0.734	1.615E-02	4.812E-03
TE-129	3.800E-02	0.544	0.059	2.291E-02	0.734	2.789E-02	1.682E-02
TE-131M	3.700E-02	0.202	1.425	6.020E-02	0.734	2.716E-02	4.419E-02
TE-132	4.800E-01	0.102	0.234	1.613E-01	0.734	3.523E-01	1.184E-01
TE-134	2.100E-02	0.300	0.886	2.491E-02	0.734	1.541E-02	1.828E-02
BA-140	7.100E-03	0.313	0.183	3.522E-03	0.734	5.211E-03	2.585E-03
LA-140	3.400E-03	0.537	2.315	9.697E-03	0.734	2.496E-03	7.117E-03
CE-141	1.100E-03	0.171	0.076	2.717E-04	0.734	8.074E-04	1.994E-04
CE-143	6.300E-04	0.433	0.282	4.505E-04	0.734	4.624E-04	3.306E-04
CE-144	9.300E-04	0.092	0.021	1.051E-04	0.734	6.826E-04	7.714E-05
PR-143	1.000E-03	0.314	0.000	3.140E-04	0.734	7.340E-04	2.305E-04
MN-54	2.400E-03	0.004	0.836	2.016E-03	0.734	1.762E-03	1.480E-03
FE-55	1.800E-03	0.004	0.002	1.080E-05	0.734	1.321E-03	7.927E-06
CO-58	7.000E-03	0.034	0.976	7.070E-03	0.734	5.138E-03	5.189E-03
ZR-97	4.900E-04	0.700	0.179	4.307E-04	0.734	3.597E-04	3.161E-04
RU-105	1.400E-04	0.400	0.784	1.658E-04	0.734	1.028E-04	1.217E-04
RH-105	5.500E-04	0.154	0.078	1.276E-04	0.734	4.037E-04	9.366E-05
SB-127	4.300E-02	0.316	0.688	4.317E-02	0.734	3.156E-02	3.169E-02
SB-129	2.400E-02	0.408	1.437	4.428E-02	0.734	1.762E-02	3.250E-02
XE-135M	4.800E-01	0.098	0.429	2.530E-01	0.734	3.523E-01	1.857E-01
CS-134M	4.600E-02	0.112	0.027	6.394E-03	0.734	3.376E-02	4.693E-03
RB-88	2.300E+00	2.066	0.629	6.199E+00	0.734	1.688E+00	4.550E+00
RB-89	5.800E-02	1.013	2.071	1.789E-01	0.734	4.257E-02	1.313E-01
SB-124	1.100E-03	0.387	1.817	2.424E-03	0.734	8.074E-04	1.780E-03

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SB-125	9.200E-03	0.100	0.431	4.885E-03	0.734	6.753E-03	3.586E-03
SB-126	6.200E-04	0.283	2.834	1.933E-03	0.734	4.551E-04	1.418E-03
TE-131	1.500E-02	0.719	0.420	1.709E-02	0.734	1.101E-02	1.254E-02
TE-133M	1.200E-02	0.705	2.313	3.622E-02	0.734	8.808E-03	2.658E-02
BA-141	9.100E-05	0.901	0.845	1.589E-04	0.734	6.679E-05	1.166E-04
BA-139	4.300E-04	0.898	0.043	4.046E-04	0.734	3.156E-04	2.970E-04
LA-141	2.400E-04	0.948	0.043	2.378E-04	0.734	1.762E-04	1.746E-04
LA-142	6.800E-05	0.846	2.753	2.447E-04	0.734	4.991E-05	1.796E-04
ND-147	4.300E-04	0.270	0.140	1.763E-04	0.734	3.156E-04	1.294E-04
NB-97	8.100E-05	0.468	0.655	9.096E-05	0.734	5.945E-05	6.677E-05
NB-95M	8.500E-06	0.166	0.068	1.989E-06	0.734	6.239E-06	1.460E-06
PM-147	1.200E-04	0.062	0.000	7.440E-06	0.734	8.808E-05	5.461E-06
PM-148	1.700E-04	0.724	0.575	2.208E-04	0.734	1.248E-04	1.621E-04
PM-149	3.000E-04	0.366	0.011	1.131E-04	0.734	2.202E-04	8.302E-05
PM-151	8.300E-05	0.306	0.321	5.204E-05	0.734	6.092E-05	3.820E-05
PM-148M	2.600E-05	0.170	2.000	5.642E-05	0.734	1.908E-05	4.141E-05
PR-144	9.300E-04	1.208	0.032	1.153E-03	0.734	6.826E-04	8.464E-04
Y-94	1.400E-05	1.675	1.110	3.899E-05	0.734	1.028E-05	2.862E-05
BR-82	2.500E-02	0.139	2.642	6.953E-02	0.734	1.835E-02	5.103E-02
Total	1.758E+02			1.363E+02		1.290E+02	1.000E+02
			E-bar =	7.752E-01			7.752E-01
			100/E-bar =	1.290E+02			1.290E+02

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

Table 6-5 Adjusted Primary Coolant Source Term

Nuclide	μCi/gm	Nuclide	μCi/gm
KR-83M	2.349E-01	BA-140	5.211E-03
KR-85M	8.808E-01	LA-140	2.496E-03
KR-85	3.890E-01	CE-141	8.074E-04
KR-87	5.505E-01	CE-143	4.624E-04
KR-88	1.615E+00	CE-144	6.826E-04
XE-131M	3.303E-01	PR-143	7.340E-04
XE-133M	1.248E+00	MN-54	1.762E-03
XE-133	5.138E+01	FE-55	1.321E-03
XE-135	5.432E+00	CO-58	5.138E-03
BR-83	4.844E-02	ZR-97	3.597E-04
BR-84	1.982E-02	RU-105	1.028E-04
RB-86	1.101E-02	RH-105	4.037E-04
CS-134	3.597E+01	SB-127	3.156E-02
CS-136	3.156E+00	SB-129	1.762E-02
CS-137	1.908E+01	XE-135M	3.523E-01
CS-138	5.138E-01	CS-134M	3.376E-02
SR-89	3.964E-03	RB-88	1.688E+00
SR-90	3.597E-04	RB-89	4.257E-02
CR-51	3.450E-03	SB-124	8.074E-04
FE-59	3.303E-04	SB-125	6.753E-03
CO-60	5.872E-04	SB-126	4.551E-04
SR-91	1.101E-03	TE-131	1.101E-02
SR-92	4.331E-04	TE-133M	8.808E-03
Y-90	4.698E-04	BA-141	6.679E-05
Y-91M	6.533E-04	BA-139	3.156E-04
Y-91	1.321E-02	LA-141	1.762E-04
Y-92	5.285E-04	LA-142	4.991E-05
Y-93	3.230E-04	ND-147	3.156E-04
ZR-95	8.808E-04	NB-97	5.945E-05
NB-95	8.808E-04	NB-95M	6.239E-06
MO-99	3.083E+00	PM-147	8.808E-05
TC-99M	2.349E+00	PM-148	1.248E-04
RU-103	8.808E-04	PM-149	2.202E-04
RU-106	3.890E-04	PM-151	6.092E-05
RH-103M	8.808E-04	PM-148M	1.908E-05
TE-125M	1.468E-03	PR-144	6.826E-04
TE-127M	5.285E-03	Y-94	1.028E-05
TE-127	3.376E-02	BR-82	1.835E-02
TE-129M	1.615E-02	I-131	0.8305
TE-129	2.789E-02	I-132	0.1917

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

Nuclide	$\mu\text{Ci/gm}$	Nuclide	$\mu\text{Ci/gm}$
TE-131M	2.716E-02	I-133	0.8624
TE-132	3.523E-01	I-134	0.0751
TE-134	1.541E-02	I-135	0.3673

6.2 Secondary Side Source Term

The secondary side source term is defined by Palisades Technical Specification LCO 3.7.17:

“The specific activity of the secondary coolant shall be $\leq 0.10 \mu\text{Ci/gm DOSE EQUIVALENT I-131}$.”

Thus, assuming that the relative concentrations of the iodine isotopes on the secondary side are the same as those on the primary side, the secondary side activity is 0.1 times the activity given in Table 6-3.

Table 6-6 Secondary Side Source Term

Isotope	$\mu\text{Ci/gm}$
I-131	0.0830
I-132	0.0192
I-133	0.0862
I-134	0.0075
I-135	0.0367

6.3 References

1. NAI Calculation Number NAI-1149-007 Rev. 0, "Primary Coolant Activity for Palisades".
2. Palisades Technical Specifications, through Amendment 213.
3. Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", September 1988.
4. Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil", September 1993.

Attachment 1 Comments on Revision 1

Comment 1

Please correct the title and calculation number in the header.

Response: Headers corrected.

Comment 2

Page 11, Second sentence – Should state that activities were “multiplied” by 0.734 versus “increased.”

Response: Fixed.

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

Attachment 2 Palisades PCS Activity Nuclide Inventory File (pal_pcs.nif)

```
Nuclide Inventory Name:
Palisades PCS Source 1.0 uCi/gm DE131 and 100/E-bar
Power Level:
  0.1000E+01
Nuclides:
107
Nuclide 001:
Co-58
  7
  0.6117120000E+07
  0.5800E+02
  0.5138E-02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 002:
Co-60
  7
  0.1663401096E+09
  0.6000E+02
  0.5872E-03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 003:
Kr-85
  1
  0.3382974720E+09
  0.8500E+02
  0.3890E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 004:
Kr-85m
  1
  0.1612800000E+05
  0.8500E+02
  0.8808E+00
Kr-85     0.2110E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 005:
Kr-87
  1
  0.4578000000E+04
  0.8700E+02
  0.5505E+00
Rb-87     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 006:
Kr-88
  1
  0.1022400000E+05
  0.8800E+02
  0.1615E+01
Rb-88     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 007:
Rb-86
  3
  0.1612224000E+07
  0.8600E+02
  0.1101E-01
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 008:
Sr-89
  5
  0.4363200000E+07
  0.8900E+02
  0.3964E-02
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 009:
Sr-90
  5
  0.9189573120E+09
  0.9000E+02
  0.3597E-03
Y-90     0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 010:
Sr-91
  5
  0.3420000000E+05
  0.9100E+02
  0.1101E-02
Y-91m   0.5780E+00
Y-91    0.4220E+00
none    0.0000E+00
Nuclide 011:
Sr-92
  5
  0.9756000000E+04
  0.9200E+02
  0.4331E-03
Y-92    0.1000E+01
none    0.0000E+00
none    0.0000E+00
Nuclide 012:
Y-90
  9
  0.2304000000E+06
  0.9000E+02
  0.4698E-03
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 013:
Y-91
  9
  0.5055264000E+07
  0.9100E+02
  0.1321E-01
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 014:
Y-92
  9
  0.1274400000E+05
  0.9200E+02
  0.5285E-03
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 015:
Y-93
  9
  0.3636000000E+05
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
0.9300E+02
0.3230E-03
Zr-93 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 016:
Zr-95
9
0.5527872000E+07
0.9500E+02
0.8808E-03
Nb-95m 0.7000E-02
Nb-95 0.9930E+00
none 0.0000E+00
Nuclide 017:
Zr-97
9
0.6084000000E+05
0.9700E+02
0.3597E-03
Nb-97m 0.9470E+00
Nb-97 0.5300E-01
none 0.0000E+00
Nuclide 018:
Nb-95
9
0.3036960000E+07
0.9500E+02
0.8808E-03
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 019:
Mo-99
7
0.2376000000E+06
0.9900E+02
0.3083E+01
Tc-99m 0.8760E+00
Tc-99 0.1240E+00
none 0.0000E+00
Nuclide 020:
Tc-99m
7
0.2167200000E+05
0.9900E+02
0.2349E+01
Tc-99 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 021:
Ru-103
7
0.3393792000E+07
0.1030E+03
0.8808E-03
Rh-103m 0.9970E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 022:
Ru-105
7
0.1598400000E+05
0.1050E+03
0.1028E-03
Rh-105 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 023:
Ru-106
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
7
0.3181248000E+08
0.1060E+03
0.3890E-03
Rh-106 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 024:
Rh-105
7
0.1272960000E+06
0.1050E+03
0.4037E-03
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 025:
Sb-127
4
0.3326400000E+06
0.1270E+03
0.3156E-01
Te-127m 0.1760E+00
Te-127 0.8240E+00
none 0.0000E+00
Nuclide 026:
Sb-129
4
0.1555200000E+05
0.1290E+03
0.1762E-01
Te-129m 0.2250E+00
Te-129 0.7750E+00
none 0.0000E+00
Nuclide 027:
Te-127
4
0.3366000000E+05
0.1270E+03
0.3376E-01
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 028:
Te-127m
4
0.9417600000E+07
0.1270E+03
0.5285E-02
Te-127 0.9760E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 029:
Te-129
4
0.4176000000E+04
0.1290E+03
0.2789E-01
I-129 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 030:
Te-129m
4
0.2903040000E+07
0.1290E+03
0.1615E-01
Te-129 0.6500E+00
I-129 0.3500E+00
none 0.0000E+00
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

Nuclide 031:
Te-131m
4
0.1080000000E+06
0.1310E+03
0.2716E-01
Te-131 0.2220E+00
I-131 0.7780E+00
none 0.0000E+00
Nuclide 032:
Te-132
4
0.2815200000E+06
0.1320E+03
0.3523E+00
I-132 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 033:
I-131
2
0.6946560000E+06
0.1310E+03
0.8305E+00
Xe-131m 0.1110E-01
none 0.0000E+00
none 0.0000E+00
Nuclide 034:
I-132
2
0.8280000000E+04
0.1320E+03
0.1917E+00
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 035:
I-133
2
0.7488000000E+05
0.1330E+03
0.8624E+00
Xe-133m 0.2900E-01
Xe-133 0.9710E+00
none 0.0000E+00
Nuclide 036:
I-134
2
0.3156000000E+04
0.1340E+03
0.7510E-01
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 037:
I-135
2
0.2379600000E+05
0.1350E+03
0.3673E+00
Xe-135m 0.1540E+00
Xe-135 0.8460E+00
none 0.0000E+00
Nuclide 038:
Xe-133
1
0.4531680000E+06
0.1330E+03
0.5138E+02
none 0.0000E+00

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
none      0.0000E+00
none      0.0000E+00
Nuclide 039:
Xe-135
  1
  0.3272400000E+05
  0.1350E+03
  0.5432E+01
Cs-135   0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 040:
Cs-134
  3
  0.6507177120E+08
  0.1340E+03
  0.3597E+02
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 041:
Cs-136
  3
  0.1131840000E+07
  0.1360E+03
  0.3156E+01
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 042:
Cs-137
  3
  0.9467280000E+09
  0.1370E+03
  0.1908E+02
Ba-137m  0.9460E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 043:
Ba-139
  6
  0.4962000000E+04
  0.1390E+03
  0.3156E-03
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 044:
Ba-140
  6
  0.1100736000E+07
  0.1400E+03
  0.5211E-02
La-140   0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 045:
La-140
  9
  0.1449792000E+06
  0.1400E+03
  0.2496E-02
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 046:
La-141
  9
  0.1414800000E+05
  0.1410E+03
```


Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
0.1762E-03
Ce-141  0.1000E+01
none    0.0000E+00
none    0.0000E+00
Nuclide 047:
La-142
  9
0.5550000000E+04
0.1420E+03
0.4991E-04
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 048:
Ce-141
  8
0.2808086400E+07
0.1410E+03
0.8074E-03
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 049:
Ce-143
  8
0.1188000000E+06
0.1430E+03
0.4624E-03
Pr-143  0.1000E+01
none    0.0000E+00
none    0.0000E+00
Nuclide 050:
Ce-144
  8
0.2456352000E+08
0.1440E+03
0.6826E-03
Pr-144m 0.1780E-01
Pr-144  0.9822E+00
none    0.0000E+00
Nuclide 051:
Pr-143
  9
0.1171584000E+07
0.1430E+03
0.7340E-03
none    0.0000E+00
none    0.0000E+00
none    0.0000E+00
Nuclide 052:
Nd-147
  9
0.9486720000E+06
0.1470E+03
0.3156E-03
Pm-147  0.1000E+01
none    0.0000E+00
none    0.0000E+00
Nuclide 053:
Np-239
  8
0.2034720000E+06
0.2390E+03
0.0000E+00
Pu-239  0.1000E+01
none    0.0000E+00
none    0.0000E+00
Nuclide 054:
Pu-238
  8
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
0.2768863824E+10
0.2380E+03
0.0000E+00
U-234 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 055:
Pu-239
8
0.7594336440E+12
0.2390E+03
0.0000E+00
U-235 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 056:
Pu-240
8
0.2062920312E+12
0.2400E+03
0.0000E+00
U-236 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 057:
Pu-241
8
0.4544294400E+09
0.2410E+03
0.0000E+00
U-237 0.2450E-04
Am-241 0.1000E+01
none 0.0000E+00
Nuclide 058:
Am-241
9
0.1363919472E+11
0.2410E+03
0.0000E+00
Np-237 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 059:
Cm-242
9
0.1406592000E+08
0.2420E+03
0.0000E+00
Pu-238 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 060:
Cm-244
9
0.5715081360E+09
0.2440E+03
0.0000E+00
Pu-240 0.1000E+01
none 0.0000E+00
none 0.0000E+00
Nuclide 061:
I-130
2
0.4449600000E+05
0.1300E+03
0.0000E+00
none 0.0000E+00
none 0.0000E+00
none 0.0000E+00
Nuclide 062:
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
Kr-83m
  1
  0.6588000000E+04
  0.8300E+02
  0.2349E+00
  none      0.0000E+00
  none      0.0000E+00
  none      0.0000E+00
  Nuclide 063:
  Xe-138
    1
    0.8502000000E+03
    0.1380E+03
    0.0000E+00
  Cs-138   0.1000E+01
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 064:
  Xe-131m
    1
    0.1028160000E+07
    0.1310E+03
    0.3303E+00
  none     0.0000E+00
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 065:
  Xe-133m
    1
    0.1890432000E+06
    0.1330E+03
    0.1248E+01
  Xe-133   0.1000E+01
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 066:
  Xe-135m
    1
    0.9174000000E+03
    0.1350E+03
    0.3523E+00
  Xe-135   0.1000E+01
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 067:
  Cs-138
    3
    0.1932000000E+04
    0.1380E+03
    0.5138E+00
  none     0.0000E+00
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 068:
  Cs-134m
    3
    0.1044000000E+05
    0.1340E+03
    0.3376E-01
  Cs-134   0.1000E+01
  none     0.0000E+00
  none     0.0000E+00
  Nuclide 069:
  Rb-88
    3
    0.1068000000E+04
    0.8800E+02
    0.1688E+01
  none     0.0000E+00
  none     0.0000E+00
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
none      0.0000E+00
Nuclide 070:
Rb-89
  3
  0.9120000000E+03
  0.8900E+02
  0.4257E-01
Sr-89     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 071:
Sb-124
  4
  0.5201280000E+07
  0.1240E+03
  0.8074E-03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 072:
Sb-125
  4
  0.8741455200E+08
  0.1250E+03
  0.6753E-02
Te-125m   0.2280E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 073:
Sb-126
  4
  0.1071360000E+07
  0.1260E+03
  0.4551E-03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 074:
Te-131
  4
  0.1500000000E+04
  0.1310E+03
  0.1101E-01
I-131     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 075:
Te-133
  4
  0.7470000000E+03
  0.1330E+03
  0.0000E+00
I-133     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 076:
Te-134
  4
  0.2508000000E+04
  0.1340E+03
  0.1541E-01
I-134     0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 077:
Te-125m
  4
  0.5011200000E+07
  0.1250E+03
  0.1468E-02
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

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```
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 078:
Te-133m
  4
  0.3324000000E+04
  0.1330E+03
  0.8808E-02
I-133     0.8700E+00
Te-133    0.1300E+00
none      0.0000E+00
Nuclide 079:
Ba-141
  6
  0.1096200000E+04
  0.1410E+03
  0.6679E-04
La-141    0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 080:
Ba-137m
  6
  0.1531200000E+03
  0.1370E+03
  0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 081:
Pd-109
  7
  0.4833720000E+05
  0.1090E+03
  0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 082:
Rh-106
  7
  0.2990000000E+02
  0.1060E+03
  0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 083:
Rh-103m
  7
  0.3367200000E+04
  0.1030E+03
  0.8808E-03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 084:
Tc-101
  7
  0.8520000000E+03
  0.1010E+03
  0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 085:
Eu-154
  9
  0.2777068800E+09
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
0.1540E+03
0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 086:
Eu-155
  9
0.1565256960E+09
0.1550E+03
0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 087:
Eu-156
  9
0.1312416000E+07
0.1560E+03
0.0000E+00
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 088:
La-143
  9
0.8538000000E+03
0.1430E+03
0.0000E+00
Ce-143   0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 089:
Nb-97
  9
0.4326000000E+04
0.9700E+02
0.5945E-04
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 090:
Nb-95m
  9
0.3117600000E+06
0.9500E+02
0.6239E-05
Nb-95    0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 091:
Pm-147
  9
0.8278820780E+08
0.1470E+03
0.8808E-04
Sm-147   0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 092:
Pm-148
  9
0.4639680000E+06
0.1480E+03
0.1248E-03
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 093:
Pm-149
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

Calculation Number: NAI-1149-011 Rev. 0

```
9
0.1910880000E+06
0.1490E+03
0.2202E-03
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 094:
Pm-151
9
0.1022400000E+06
0.1510E+03
0.6092E-04
Sm-151   0.1000E+01
none     0.0000E+00
none     0.0000E+00
Nuclide 095:
Pm-148m
9
0.3568320000E+07
0.1480E+03
0.1908E-04
Pm-148   0.4600E-01
none     0.0000E+00
none     0.0000E+00
Nuclide 096:
Pr-144
9
0.1036800000E+04
0.1440E+03
0.6826E-03
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 097:
Pr-144m
9
0.4320000000E+03
0.1440E+03
0.0000E+00
Pr-144   0.9990E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 098:
Sm-153
9
0.1681200000E+06
0.1530E+03
0.0000E+00
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 099:
Y-94
9
0.1146000000E+04
0.9400E+02
0.1028E-04
none     0.0000E+00
none     0.0000E+00
none     0.0000E+00
Nuclide 100:
Y-95
9
0.6420000000E+03
0.9500E+02
0.0000E+00
Zr-95    0.1000E+01
none     0.0000E+00
none     0.0000E+00
```

Primary Coolant Source Term Determination for Palisades Dose Calculations

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```
Nuclide 101:
Y-91m
  9
  0.2982600000E+04
  0.9100E+02
  0.6533E-03
Y-91      0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 102:
Br-82
  2
  0.1270800000E+06
  0.8200E+02
  0.1835E-01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 103:
Br-83
  2
  0.8604000000E+04
  0.8300E+02
  0.4844E-01
Kr-83m    0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 104:
Br-84
  2
  0.1908000000E+04
  0.8400E+02
  0.1982E-01
none      0.0000E+00
none      0.0000E+00
none      0.0000E+00
Nuclide 105:
Am-242
  9
  0.5767200000E+05
  0.2420E+03
  0.0000E+00
Cm-242    0.8270E+00
Pu-242    0.1730E+00
none      0.0000E+00
Nuclide 106:
Np-238
  8
  0.1829088000E+06
  0.2380E+03
  0.0000E+00
Pu-238    0.1000E+01
none      0.0000E+00
none      0.0000E+00
Nuclide 107:
Pu-243
  8
  0.1784160000E+05
  0.2430E+03
  0.0000E+00
Am-243    0.1000E+01
none      0.0000E+00
none      0.0000E+00
End of Nuclear Inventory File
```