

CALCULATION RA-0050, REVISION 0

**KEWAUNEE RESIN CASK DROP DOSE CONSEQUENCE
ANALYSIS**



Calculation Worksheet

Instructions: To update the Table of Contents page numbers, click within the Table of Contents to select the table, then select **"Print Preview,"** (Click the **Office Button** at the upper left of the computer screen; then select **"Print,"** and then **"Print Preview"**) close **"Print Preview."** The page numbers should update.

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1. Record of Revision and Addenda

Original Issue

2. Cumulative Effects Review (Required for Revisions and Addenda)

N/A

3. References

- 1) NRC Regulatory Guide 1.183 Rev. 0, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000.
- 2) Waste Manifest and Supporting Documentation for Kewaunee Resin Shipment SPF-0513-01 (Selected pages included as Attachment 2 of this calculation).
- 3) EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," May 1992.
- 4) Calculation CN-CRA-00-2, Revision 3, "Kewaunee – LOCA Doses with Increased Control Room Unfiltered Inleakage," 5/10/07.
- 5) EPA 402-R-93-081 (Federal Guidance Report No. 12), "External Exposure to Radionuclides In Air, Water, and Soil," September 1993.
- 6) EPA 520/1-88-020 (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. Computer Codes Used

None

5. Identification of Computer Inputs and Outputs

None

6. Purpose

The purpose of this calculation is to determine the dose consequences at the Kewaunee site boundary resulting from a resin cask drop accident.



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7. Background (OPTIONAL)

N/A

8. Design Inputs

Inhalation rate = $3.5\text{E-}4 \text{ m}^3/\text{sec}$ (Reference 1)

X/Q = $2.23\text{E-}4 \text{ sec/m}^3$ (95th Percentile Worst Case X/Q, Reference 4)

Bounding Resin Cask Nuclide Content (Reference 2):

Nuclide	mCi
H-3	1.77E+01
C-14	4.26E+01
Mn-54	7.80E+02
Fe-55	5.28E+03
Co-57	4.05E+02
Co-58	5.64E+03
Co-60	6.88E+03
Ni-59	5.64E+02
Ni-63	6.85E+04
Zn-65	7.08E+01
Sr-89	5.44E-01
Sr-90	3.24E+00
Sb-125	3.61E+02
Cs-137	1.85E+02
Pu-238	1.63E-02
Pu-239	1.10E-02
Pu-241	4.18E+00
Am-241	5.35E-03
Cm-243	5.38E-03
Ce-144	5.58E+01

0.946 is the fraction of the Cs-137 nuclear transformations forming Ba-137m. (Reference 5 pg. 203)



Effective Dose Coefficients for Air Submersion (Reference 5, Table III.1):

Nuclide	Dose Coefficient Sv m ³ /Bq s
H-3	3.13E-19
C-14	2.24E-19
Mn-54	4.09E-14
Fe-55	0.00E+00
Co-57	5.61E-15
Co-58	4.76E-14
Co-60	1.26E-13
Ni-59	0.00E+00
Ni-63	0.00E+00
Zn-65	2.90E-14
Sr-89	7.73E-17
Sr-90	7.53E-18
Sb-125	2.02E-14
Cs-137	7.74E-18
Pu-238	4.88E-18
Pu-239	4.24E-18
Pu-241	7.25E-20
Am-241	8.18E-16
Cm-243	5.88E-15
Ce-144	8.53E-16
Ba-137m	2.88E-14



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Effective Committed Dose Equivalent per Unit Intake (Reference 6, Table 2.1):

Nuclide	Inhalation Sv / Bq
H-3	1.73E-11
C-14	5.64E-10
Mn-54	1.81E-09
Fe-55	7.26E-10
Co-57	2.45E-09
Co-58	2.94E-09
Co-60	5.91E-08
Ni-59	3.58E-10
Ni-63	8.39E-10
Zn-65	5.51E-09
Sr-89	1.12E-08
Sr-90	3.51E-07
Sb-125	3.30E-09
Cs-137	8.63E-09
Pu-238	1.06E-04
Pu-239	1.16E-04
Pu-241	2.23E-06
Am-241	1.20E-04
Cm-243	8.30E-05
Ce-144	1.01E-07
Ba-137m	0.00E+00

9. Assumptions

1. Assume the resin release fraction to be either 10% or 100%. 10% should be conservative, while 100% produces a limiting case.
2. Accident time interval = 1 hour (Assumption. Given that atmospheric dispersion is modeled as instantaneous and no decay over the release time is modeled, the cumulative dose is independent of the release interval provided that the dose is integrated over the entire release interval.)
3. No decay from the date of plant shutdown is modeled. This is a conservative assumption

**10. Methodology**

The integrated dose over a given time period is equal to the sum of the external dose (EDE) and the internal dose (CEDE). The EDE for a given nuclide is calculated as the product of the curies released, the X/Q, and the effective dose coefficient for air submersion. The CEDE for a given nuclide is calculated as the product of the curies released, the X/Q, the inhalation rate, and the committed dose equivalent per Unit Intake coefficient.

Two cases will be evaluated, corresponding to the 10% and 100% release fractions.

11. Calculations

An example calculation of the EDE dose from H-3 is as follows.

$$\text{EDE} = (1.77\text{E-}2 \text{ Ci})(2.23\text{E-}4 \text{ sec/m}^3)(3.13\text{E-}19 \text{ Sv m}^3/\text{Bq sec})(3.7\text{E}10 \text{ Bq/Ci})(100 \text{ Rem/Sv}) = 4.58\text{E-}12 \text{ Rem}$$

An example calculation of the CEDE dose from H-3 is as follows.

$$\text{CEDE} = (1.77\text{E-}2 \text{ Ci})(2.23\text{E-}4 \text{ sec/m}^3)(3.5\text{E-}4 \text{ m}^3/\text{sec})(1.73\text{E-}11 \text{ Sv/Bq})(3.7\text{E}10 \text{ Bq/Ci})(100 \text{ Rem/Sv}) = 8.84\text{E-}8 \text{ Rem}$$



Calculation Worksheet

The 100% release fraction case is as follows, for a total dose of 0.148 Rem:

Table 1: Dose Consequences from a Resin Cask Drop Accident with a 100% Release Fraction

Nuclide	Curies Released	EDE External Dose (Rem)	CEDE 1 Hr Inhalation Dose (Rem)	Total Dose (Rem)
H-3	1.77E-02	4.57E-12	8.84E-08	8.84E-08
C-14	4.26E-02	7.87E-12	6.94E-06	6.94E-06
Mn-54	7.80E-01	2.63E-05	4.08E-04	4.34E-04
Fe-55	5.28E+00	0.00E+00	1.11E-03	1.11E-03
Co-57	4.05E-01	1.87E-06	2.87E-04	2.88E-04
Co58	5.64E+00	2.22E-04	4.79E-03	5.01E-03
Co-60	6.88E+00	7.15E-04	1.17E-01	1.18E-01
Ni-59	5.64E-01	0.00E+00	5.83E-05	5.83E-05
Ni-63	6.85E+01	0.00E+00	1.66E-02	1.66E-02
Zn-65	7.08E-02	1.69E-06	1.13E-04	1.14E-04
Sr-89	5.44E-04	3.47E-11	1.76E-06	1.76E-06
Sr-90	3.24E-03	2.01E-11	3.28E-04	3.28E-04
Sb-125	3.61E-01	6.02E-06	3.44E-04	3.50E-04
Cs-137	1.85E-01	1.18E-09	4.61E-04	4.61E-04
Pu-238	1.63E-05	6.56E-14	4.99E-04	4.99E-04
Pu-239	1.10E-05	3.85E-14	3.68E-04	3.68E-04
Pu-241	4.18E-03	2.50E-13	2.69E-03	2.69E-03
Am-241	5.35E-06	3.61E-12	1.85E-04	1.85E-04
Cm-243	5.38E-06	2.61E-11	1.29E-04	1.29E-04
Ce-144	5.58E-02	3.93E-08	1.63E-03	1.63E-03
Ba-137m	1.75E-01	4.16E-06	0.00E+00	4.16E-06
Total		9.77E-04	1.47E-01	1.48E-01



Calculation Worksheet

The 10% release fraction case is as follows, for a total dose of 0.015 Rem:

Table 2: Dose Consequences from a Resin Cask Drop Accident with a 10% Release Fraction

Nuclide	Curies Released	EDE External Dose (Rem)	CEDE 1 Hr Inhalation Dose (Rem)	Total Dose (Rem)
H-3	1.77E-03	4.57E-13	8.84E-09	8.84E-09
C-14	4.26E-03	7.87E-13	6.94E-07	6.94E-07
Mn-54	7.80E-02	2.63E-06	4.08E-05	4.34E-05
Fe-55	5.28E-01	0.00E+00	1.11E-04	1.11E-04
Co-57	4.05E-02	1.87E-07	2.87E-05	2.88E-05
Co58	5.64E-01	2.22E-05	4.79E-04	5.01E-04
Co-60	6.88E-01	7.15E-05	1.17E-02	1.18E-02
Ni-59	5.64E-02	0.00E+00	5.83E-06	5.83E-06
Ni-63	6.85E+00	0.00E+00	1.66E-03	1.66E-03
Zn-65	7.08E-03	1.69E-07	1.13E-05	1.14E-05
Sr-89	5.44E-05	3.47E-12	1.76E-07	1.76E-07
Sr-90	3.24E-04	2.01E-12	3.28E-05	3.28E-05
Sb-125	3.61E-02	6.02E-07	3.44E-05	3.50E-05
Cs-137	1.85E-02	1.18E-10	4.61E-05	4.61E-05
Pu-238	1.63E-06	6.56E-15	4.99E-05	4.99E-05
Pu-239	1.10E-06	3.85E-15	3.68E-05	3.68E-05
Pu-241	4.18E-04	2.50E-14	2.69E-04	2.69E-04
Am-241	5.35E-07	3.61E-13	1.85E-05	1.85E-05
Cm-243	5.38E-07	2.61E-12	1.29E-05	1.29E-05
Ce-144	5.58E-03	3.93E-09	1.63E-04	1.63E-04
Ba-137m	1.75E-02	4.16E-07	0.00E+00	4.16E-07
Total		9.77E-05	1.47E-02	1.48E-02

12. Acceptance Criteria (OPTIONAL)

The dose to an individual at the EAB should be less than 1 Rem integrated over the period of the radiological release. This limit is consistent with the Protective Action Guide (PAG) for the Early Release phase of an atmospheric release of 1 Rem defined in Section 2.3.1 of Reference 3.



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13. Results and/or Conclusions

Both the 10% release and 100% release cases produce dose consequences at the site boundary that are less than the 1 Rem acceptance criteria (0.015 Rem and 0.148 Rem, respectively). These results are bounding values because each value is based on a bounding resin curie content and no decay of the resin following plant shutdown.

14. Precautions and Limitations

This calculation was prepared, reviewed, and approved in accordance with Dominion fleet procedure CM-AA-CLC-301 and GaRD CM-AA-CLC-301-1001. A Kewaunee Owner's Review of this calculation is required prior to use in accordance with Kewaunee Procedure CM-KW-REV-101.

15. Recommendations (OPTIONAL)

None

16. Calculation Review Checklist

See Attachment 1

17. List of Attachments

Attachment 1 – Calculation Review Checklist

Attachment 2 – Selected Pages from the Kewaunee Resin Shipment Manifest and Supporting Documentation



Calculation RA-0050 Rev. 0 Attachment 1

NOTE: If "Yes" is not answered, an explanation may be provided below. Reference may be made to explanations contained in the calculation or addendum.

Questions:	Yes	N/A
1. Have the sources of design inputs been correctly selected and referenced in the calculation?	[X]	[]
2. Are the sources of design inputs up-to-date and retrievable/attached to the calculation?	[X]	[]
3. Where appropriate, have the other disciplines reviewed or provided the design inputs for which they are responsible?	[X]	[]
4. Have design inputs been confirmed by analysis, test, measurement, field walkdown, or other pertinent means as appropriate for the configuration analyzed?	[X]	[]
5. Have the bases for assumptions been adequately and clearly presented and are they bounded by the Station Design Basis?	[X]	[]
6. Were appropriate calculation/analytic methods used and are outputs reasonable when compared to inputs?	[X]	[]
7. Are computations technically accurate?	[X]	[]
8. Has the calculation made appropriate allowances for instrument errors and calibration equipment errors?	[X]	[]
9. Have those computer codes used in the analysis been referenced in the calculation?	[X]	[]
10. Have all exceptions to station design basis criteria and regulatory requirements been identified and justified in accordance with NQA-1-1994?	[X]	[]
11. Has the design authority/original preparer for this calculation been informed of its revision or addendum, if required?	[X]	[]

Comments: (Attach additional pages if needed)

This calculation was prepared, reviewed, and approved in accordance with Dominion fleet procedure CM-AA-CLC-301 and GaRD CM-AA-CLC-301-1001. A Kewaunee Owner's Review of this calculation is required prior to use in accordance with Kewaunee Procedure CM-KW-REV-101.

Reviewer's Comment

During the review process, decay chains for the isotopes present in the resin were evaluated for daughter isotope contributions. It was determined that most isotopes decayed either to stable isotopes or to isotopes with half-lives >> 10,000 years. Exceptions were identified for the following daughter isotopes: Y-90, Te-125m and Pr-144. Adding dose consequences for Y-90, Te-125m, and Pr-144 to the results presented in Tables 1 and 2 has no effect on the total dose calculated (assuming secular equilibrium and decay fractions of 1, 0.23 and 1, respectively, from their parent isotopes).

Signature: CA Ford Date: 9-23-13
 (Preparer)

Signature: EM Johnson Date: 9-23-13
 (Reviewer)

Note: Physical or electronic signatures are acceptable.

FORM 540 (6-2004)	U.S. NUCLEAR REGULATORY COMMISSION		5. SHIPPER - NAME AND FACILITY		SHIPPER I.D. NUMBER	7. NRC FORM 540 AND 540A PAGE 1 OF	8. MANIFEST NUMBER (Use this number on all continuation pages)
	UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST		DOMINION ENERGY KEWAUNEE, INC. KEWAUNEE POWER STATION M490 HIGHWAY 42 KEWAUNEE, WI 54216-9511		042913-1	1 PAGE(S) 2 PAGE(S) PAGE(S)	
SHIPPING PAPER		USER PERMIT NUMBER	SHIPMENT NUMBER	X	GENERATOR TYPE (Specify) NP	9. CONSIGNEE - Name and Facility Address	

1. EMERGENCY TELEPHONE NUMBER (Include Area Code) (920)388-8311		CONTACT Don Allison		TELEPHONE NUMBER (Include Area Code) (920)388-8224		CONTACT SPFE Shift Supervisor TELEPHONE NUMBER (Include Area Code) (423)722-5160	
2. IS THIS AN "EXCLUSIVE USE" SHIPMENT?		3. TOTAL NUMBER OF PACKAGES IDENTIFIED ON THIS MANIFEST		3. CARRIER - Name and Address		SIGNATURE - Authorized carrier acknowledging waste receipt	
<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		1		Hittman Transport Services 1560 Bear Creek Road Oak Ridge, TN 37830		DATE 6.1.13	

4. DOES EPA REGULATED WASTE REQUIRING A MANIFEST ACCOMPANY THIS SHIPMENT?		EPA MANIFEST NUMBER	CONTACT	EPA I.D. NUMBER	10. CERTIFICATION	DATE
<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		N/A	Jeff Packet	N/A	This is to certify that the herein-named materials are properly classified, described, packaged, marked, and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation. This also certifies that the materials are classified, packaged, marked, and labeled and are in proper condition for transportation and disposal as described in accordance with the applicable requirements of 10 CFR Parts 20 and 61, or equivalent state regulations.	4-29-13
If "Yes," provide Manifest Number			SIGNATURE - Authorized carrier acknowledging waste receipt <i>Mary D. Patten</i>	DATE	AUTHORIZED SIGNATURE	TITLE <i>RUE SUPERVISOR</i>

11. U.S. DEPARTMENT OF TRANSPORTATION DESCRIPTION (Including proper shipping name, hazard class, UN ID number, and any additional information)	12. DOT LABEL "RADIOACTIVE"	13. TRANSPORT INDEX	14. PHYSICAL AND CHEMICAL FORM	15. INDIVIDUAL RADIONUCLIDES			16. TOTAL PACKAGE ACTIVITY IN SI UNITS	17. LSA/SCO CLASS	18. TOTAL WEIGHT OR VOLUME (Use appropriate units)	19. IDENTIFICATION NUMBER OF PACKAGE
UN3321, Radioactive material, low specific activity (LSA-II), ? Fissile Excepted, RQ - Radionuclides 18-120A Cask Decontaminated Resin	YELLOW II	0.6	Solids Metal Oxides	H-3 Fe-55	C-14 Co-57	Mn-54 Co-58	3.29E+08 MBq (8.88E+04 mCi)	LSA II	26717.0 Kg 58900.0 Lbs	DOT 7A Type A 8-120A-4
				Co-60 Zn-65	Ni-63 Sr-89	Ni-63 Sr-90				
				Sr-90 Pu-238	Cs-137 Pu-239	Co-144 Pu-241				
				Am-241 (I-129-LLO)	Cm-243	(Ic-89-LLO)				

FOR ONLY
 Calculation RA-0050, Rev. 0, Attachment 2,
 Total Pages = 2

DOT Classification Summary

Package ID Number : 13-002
 Material Weight (gms) : 1.99E+06

Shipment Date : 04/29/2013
 Shipment Number : SPF-0513-01

Nuclide	Activity (mCi)	A2		RQ		LSA II Fraction
		Curies	Fraction	Curies	Fraction	
Co-60	6.88E+03	1.08E+01	6.37E-01 *	1.00E+01	6.88E-01	3.20E-07
Co-58	5.64E+03	2.70E+01	2.09E-01 *	1.00E+01	5.64E-01	1.05E-07
Ni-63	6.85E+04	8.10E+02	8.46E-02 *	1.00E+02	6.85E-01	4.25E-08
Mn-54	7.80E+02	2.70E+01	2.89E-02 *	1.00E+01	7.80E-02	1.45E-08
Sb-125	3.61E+02	2.70E+01	1.34E-02	1.00E+01	3.61E-02	6.71E-09
Cs-137	1.85E+02	1.62E+01	1.14E-02	1.00E+00	1.85E-01	5.73E-09
Ce-144	5.58E+01	5.40E+00	1.03E-02	1.00E+00	5.58E-02	5.19E-09
Fe-55	5.28E+03	1.08E+03	4.89E-03	1.00E+02	5.28E-02	2.45E-09
Pu-241	4.18E+00	1.62E+00	2.58E-03	1.00E+00	4.18E-03	1.30E-09
Co-57	4.05E+02	2.70E+02	1.50E-03	1.00E+02	4.05E-03	7.53E-10
Zn-65	7.08E+01	5.40E+01	1.31E-03	1.00E+01	7.08E-03	6.59E-10
Pu-238	1.63E-02	2.70E-02	6.05E-04	1.00E-02	1.63E-03	3.04E-10
C-14	4.26E+01	8.10E+01	5.26E-04	1.00E+01	4.26E-03	2.64E-10
Pu-239	1.10E-02	2.70E-02	4.06E-04	1.00E-02	1.10E-03	2.04E-10
Sr-90	3.24E+00	8.10E+00	4.00E-04	1.00E-01	3.24E-02	2.01E-10
Cm-243	5.38E-03	2.70E-02	1.99E-04	1.00E-02	5.38E-04	1.00E-10
Am-241	5.35E-03	2.70E-02	1.98E-04	1.00E-02	5.35E-04	9.95E-11
Sr-89	5.44E-01	1.62E+01	3.36E-05	1.00E+01	5.44E-05	1.69E-11
H-3	1.77E+01	1.08E+03	1.64E-05	1.00E+02	1.77E-04	8.24E-12
Ni-59	5.64E+02	No A2	0.00E+00	1.00E+02	5.64E-03	0.00E+00

Sums: mCi: 8.88E+04 Type A: 1.01E+00 RQ: 2.41E+00 LSA: 5.06E-07

Compare LSA Fraction to LSA II (solid) limit of <= 1E-4

* Nuclides included in 95% of the hazard fraction as per 49 CFR 173.433(g)