REMOVAL OF THE CALIFORNIUM SOURCES FROM THE 222-S LABORATORY

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Abstract: This document develops a proposal for removal of two Californium sources from the 222-S Laboratory. Included in this document are assessments of shipping packages and decay calculations.

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REMOVAL OF CALIFORNIUM SOURCES FROM THE 222-S LABORATORY

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Richland, Washington
Under Contract/Release 36473-45**

LIST OF ACRONYMS

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EM	Office of Environmental Management
EnergySolutions	EnergySolutions Federal Services, Inc.
IAEA	International Atomic Energy Agency
NAC	Nuclear Assurance Corporation
NMCA	Nuclear Material Control and Accounting
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
RAMPAC	radioactive materials packaging database
SARP	Safety Analysis Report for Packaging
SP	special permit
WRPS	Washington River Protection Solutions, LLC

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	SUMMARY OF WORK SCOPE PERFORMED	1
2.1	REVIEW OF PROVIDED SOURCE CHARACTERIZATION INFORMATION.....	1
2.2	CONDUCT A REVIEW OF TYPE B PACKAGES	1
2.3	PERFORM AN ASSESSMENT OF THE SRL 4.5-TON CALIFORNIUM SHIPPING .	1
2.4	OPTIONS CONSIDERED.....	2
3.0	RECOMMENDED PLAN.....	2
3.1	OPTION 1 - USE OF AN EXISTING TYPE A PACKAGE	2
3.2	OPTION 2 - MODIFY EXISTING TYPE A PACKAGE.....	2
4.0	SUPPORTING DATA.....	3
4.1	REVIEW OF EXISTING CERTIFIED PACKAGES	3
4.2	ASSESSMENT OF PREVIOUSLY CERTIFIED CALIFORNIUM SHIPPING CASK	3
4.3	ADDITIONAL OPTIONS THAT WERE CONSIDERED.....	4
4.4	RADIOACTIVE MATERIAL INVENTORY	5
4.4.1	Background.....	5
4.4.2	Input Data.....	5
4.4.3	Isotopic Mass Calculations	6
4.4.4	Radioactive Composition and A_1 Calculation on June 1, 2009	8
4.4.5	Conclusions.....	10
5.0	REFERENCES	10
	APPENDIX A - Radcalc Output Files.....	13
	Appendix A.1	13
	Appendix A.2.....	17
	Appendix A.3	21

LIST OF TABLES

Table 1.	Isotopic composition (as determined on January 13, 1999) and assumed nuclear parameters for source SR-CF-3052-OR	6
Table 2.	Isotopic composition (as determined on August 10, 2000) and assumed nuclear parameters for source SR-CF-3053-OR.....	6
Table 3.	Initial Isotopic composition for SR-CF-3052-OR on January 13, 1999.....	7
Table 4.	Initial Isotopic composition for SR-CF-3053-OR on August 10, 2000.....	8
Table 5.	Composition for SR-CF-3052-OR on June 1, 2009 from Radcalc.....	8
Table 6.	Composition for SR-CF-3053-OR on June 1, 2009 from Radcalc.....	9
Table 7.	Composition for SR-CF-3053-OR on February 1, 2010 from Radcalc.....	10

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REMOVAL OF CALIFORNIUM SOURCES FROM THE 222-S LABORATORY

1.0 INTRODUCTION

Washington River Protection Solutions, LLC (WRPS) has requested subcontracted support by EnergySolutions Federal Services, Inc., Northwest Operations (EnergySolutions) to develop a proposal for the removal of two Californium sources from the 222-S Laboratory that is located on the Hanford Site in Richland, Washington. The scope of work for this task is described in the WRPS Statement of Work, Request for Offsite Services Number 36473-45.

2.0 SUMMARY OF WORK SCOPE PERFORMED

2.1 REVIEW OF PROVIDED SOURCE CHARACTERIZATION INFORMATION

The Californium source information provided to EnergySolutions by WRPS was analyzed with the Radcalc 4.1 computer code (FSWO 2009) to establish the shipping requirements. As further discussed in Section 4.4 of this document, one of the Californium sources has decayed to a Type A quantity of radioactive material, and the other source will have decayed to a Type A quantity after February 2010. Therefore, after February 2010, both Californium sources can be shipped in a Type A package.

2.2 CONDUCT A REVIEW OF TYPE B PACKAGES

As discussed in Section 4.1, there are currently no Type B packages that are certified to ship the Californium sources.

2.3 PERFORM AN ASSESSMENT OF THE SRL 4.5-TON CALIFORNIUM SHIPPING CASK

As discussed in Section 4.2, the SRL 4.5-ton Californium shipping cask can no longer be used to ship Type B quantities of radioactive material. However, the cask could be used to ship the sources after February 2010 when both sources have decayed to a Type A quantity of radioactive material. Also, Oak Ridge National Laboratory (ORNL) has other Type A packages that could be used to ship these identified sources.

2.4 OPTIONS CONSIDERED

Several options were considered and are discussed in Section 4.3. The two most promising options are discussed in Section 3.0.

3.0 RECOMMENDED PLAN

3.1 OPTION 1 - USE OF AN EXISTING TYPE A PACKAGE

As noted in Section 4.4, after February 2010 both Californium sources will be decayed to a Type A quantity of radioactive material. This could allow the SRL 4.5-ton Californium shipping cask to be used for shipping the sources to ORNL. The use, availability, and cost of the cask will need to be coordinated with ORNL. This option should be the most cost and schedule effective option as the cask is designed to ship these sources. Initial discussions with the ORNL staff identified below indicate that there are several Type A packages available for shipping the Californium sources. In addition, ORNL staff conveyed that there is an authorization process that must be followed when transferring or returning the Californium sources.

If the ORNL packages are available (yet to be confirmed), the estimated lease costs are less than \$10,000 per month, and the estimated transportation costs are \$6,000 each one way trip between the Hanford Site and the ORNL. Additional information will be provided when contact is made with ORNL.

ORNL Contacts:

Julie Ezold
Cf Source Program Manager
865-574-9594

Darren MalKemus
Cf Source Loan Program
865-574-0437

Paulette McGill
Nuclear Material Control and Accounting (NMCA)
865-574-7022

3.2 OPTION 2 - MODIFY EXISTING TYPE A PACKAGE

A second viable option is to modify an existing Type A package for shipment of the sources after February 2010. EnergySolutions owns several Type A packages that are of the size required to

house the sources and associated shielding material. This option would require the design, analysis, and fabrication of an internal container that would be placed inside the selected Type A package. The design, analysis, and fabrication costs are estimated to be between \$100,000 to \$200,000 and require six to nine months to complete. The Type A package lease costs are estimated to be \$6,000 per month, and transportation costs are estimated to be \$6,000 each, one-way trip.

4.0 SUPPORTING DATA

4.1 REVIEW OF EXISTING CERTIFIED PACKAGES

A search was conducted using the U.S. Department of Energy (DOE), Office of Environmental Management's (EM) radioactive materials packaging (RAMPAC) online database (located at <http://www.rampac.energy.gov>) for any certified Type B packages for shipping sealed sources containing ^{252}Cf . This query did not return any currently certified U.S. Nuclear Regulatory Commission (NRC) or DOE packages. The query returned 35 Competent Authority Certifications for Californium sealed sources, and only one package as having a DOE certification for shipping ^{252}Cf within a special form sealed source. This package is identified as the SRL 4.5-Ton Cf, USA/6642/B() (DOE), and the certification expired effective October 1, 2008.

In addition, the DOE/EM, Packaging Certification Program published the catalog, *DOE Certified Radioactive Materials Transportation Packagings* (DOE 2008). This catalog identifies several Type B, DOE-certified packages. The catalog lists 11 currently certified DOE packages authorized for specified payloads, none of which include ^{252}Cf or which would be suitable for transporting the special form sealed sources requested under a Safety Analysis Reports for Packaging (SARP) payload modification. Two packages, the ORNL TRU Cf (USA/5740/B() (DOE), and the SRL 4.5-Ton Cf (USA/6642/B() (DOE) were listed as authorized prior to October 2008 for shipment of Cf special form radioactive material under their specified SARPs.

The RAMPAC website was also checked for any listings of special permits (SP) with DOE as the holder for ^{252}Cf special form sealed sources, and none were found.

4.2 ASSESSMENT OF PREVIOUSLY CERTIFIED CALIFORNIUM SHIPPING CASK

The SRL 4.5-ton Californium shipping cask was originally used to ship the Californium sources to the Hanford Site in the year 2000. The Certificate of Compliance, USA/6642/B() (DOE), for the cask expired in October 2008, and the cask is no longer authorized to ship Type B quantities of radioactive material. Recertification of the cask as a Type B package is considered to be impractical due to the age of the cask and changes in regulatory requirements. However, the

cask could be certified to ship Type A quantities of radioactive material and could be used to ship the two Californium sources after February 2010.

4.3 ADDITIONAL OPTIONS THAT WERE CONSIDERED

The following additional options were considered:

1. Recertify the expired SRL 4.5-ton Californium shipping cask.

Recertification of the SRL 4.5-ton Californium shipping cask as a Type B package would require a new SARP that would include a detailed justification for why this package would meet current licensing requirements. It is estimated that the preparation of a new SARP could cost from \$500,000 to \$1,000,000 and the entire recertification effort could exceed three years. Due to the age of this package, the likelihood of obtaining approval is considered to be low. Therefore, this option is not considered feasible. Also, if the shipment were scheduled after February 2010, a Type B package would no longer be required.

2. Obtain a U.S. Department of Transportation (DOT) SP to use the expired SRL 4.5-ton Californium shipping cask.

Obtaining an SP to use the SRL 4.5-ton Californium cask could take six to nine months and would not be required after February 2010, which is approximately eight months away. Also, the chance of getting an SP is considered to be low since the package certification expired 1½ years ago.

3. Use the Nuclear Assurance Corporation (NAC) Californium Transport System.

NAC has been working with ORNL to develop and certify a Type B package for the transport of Californium sources. The cask has been under development since 1996; however, recent information from ORNL indicates that development of the package is no longer being funded and certification will not occur within the next few years.

4. Build a new Type B package.

Building a new Type B package would be both cost and schedule prohibitive. This is similar to what NAC was doing (see Item 3, above) and was not successful. Also, if shipping is to be done after February 2010, a Type B package would no longer be required.

5. Search for an International Atomic Energy Agency (IAEA) package.

A search for a suitable IAEA package could be undertaken. However, even if a suitable package could be found, the package would be required to undergo a review by DOT and the review could be as costly as a new package review, which is estimated to cost between \$500,000 and \$1,000,000 and require three to five years of time. Therefore, this option is not considered to be feasible.

4.4 RADIOACTIVE MATERIAL INVENTORY

4.4.1 Background

In 2000, the 222-S laboratory received the two ^{252}Cf neutron sources from ORNL as identified below. These sources are certified as special form per IAEA Certificate of Competent Authority, Special Form Radioactive Materials, Certificate Number USA/0236/S, Rev. 2 (DOT 1996).

- SR-CF-3052-OR, which was assayed at ORNL on June 6, 2000 to obtain a calculated ^{252}Cf mass of $44,059.6 \mu\text{g} \pm 0.21\%$.
- SR-CF-3053-OR, which was assayed at ORNL on August 29, 2000 to obtain a calculated ^{252}Cf mass of $58,683.3 \mu\text{g} \pm .25\%$.

The calculations provided as Appendix A to this document use the initial assay and ^{252}Cf mass to determine the radioactive material inventory and the number of A_1 s for each source on June 1, 2009. The provided information will support shipment of these sources back to ORNL.

4.4.2 Input Data

The input data for the calculations provided in Appendix A of this document is taken from the ORNL information sheets for SR-CF-3052-OR and SR-CF-3053-OR. This information was obtained from Attachments 1 and 2 (respectively) of the WRPS-provided document, *Corrected Activity Estimates for Cf-252 Sources SR-CF-3052-OR and SR-CF-3053-OR* [RPP-CALC-37588, Rev. 0 (dated July 31, 2008)] (Hanni 2008).

Sections 4.4.2.1 and 4.4.2.2 contain a summary of the ORNL input data that is used in the Appendix A information. Additional nuclear data for the daughter nuclides is given in Section 4.4.4. Conclusions of this evaluation are presented in Section 4.4.5.

4.4.2.1 SR-CF-3052-OR Input Data

Table 1 contains the isotopic composition for source SR-CF-3052-OR along with other nuclear data for these isotopes. The relevant dates for this source are January 13, 1999 when the isotopic mass distribution was measured, and June 6, 2000 when the neutron emission rate was measured to determine the mass of the ^{252}Cf component. The measured neutron emission rate was $1.0209 \cdot 10^{11} \text{ n/s} \pm 0.21\%$ for this source. The total estimated uncertainty is $\pm 3\%$. Table 1 also includes the A_1 values from Title 10, Part 71 of the *Code of Federal Regulations* (CFR), "Packaging and Transportation of Radioactive Material," Appendix A, "Determination of A_1 and A_2 ."

Table 1. Isotopic composition (as determined on January 13, 1999) and assumed nuclear parameters for source SR-CF-3052-OR.

Nuclide	Atom % (1/13/1999)	Half-Life ^a years	Atomic Mass ^a	A ₁ ^b Bq
²⁴⁹ Cf	4.32	351.0	249.07485	3.0E+12
²⁵⁰ Cf	10.82	13.08	250.07641	2.0E+13
²⁵¹ Cf	3.31	897.9	251.07959	7.0E+12
²⁵² Cf	81.50	2.645	252.08163	1.0E+11
²⁵³ Cf	0.04	0.049	253.08513	4.0E+13
²⁵⁴ Cf	0.01	0.166	254.08732	1.0E+09

^aFrom FSWO 2009.

^bFrom 10 CFR 71, Appendix A.

4.4.2.2 SR-CF-3053-OR Input Data

Table 2 contains the isotopic composition for source SR-CF-3053-OR along with other nuclear data for these isotopes. The relevant dates for this source are August 10, 2000 when the isotopic mass distribution was measured, and August 29, 2000 when the neutron emission rate was measured to determine the mass of the ²⁵²Cf component. The measured neutron emission rate for this source was $1.3594 \cdot 10^{11}$ n/s $\pm$ 0.25%. The overall estimated uncertainty is $\pm$ 3%. Table 2 also includes the A₁ values from 10 CFR 71, Appendix A.

Table 2. Isotopic composition (as determined on August 10, 2000) and assumed nuclear parameters for source SR-CF-3053-OR.

Nuclide	Atom % (8/10/2000)	Half-Life ^a Years	Atomic Mass ^a	A ₁ ^b Bq
²⁴⁹ Cf	7.15	351.0	249.07485	3.0E+12
²⁵⁰ Cf	14.69	13.08	250.07641	2.0E+13
²⁵¹ Cf	5.05	897.9	251.07959	7.0E+12
²⁵² Cf	73.10	2.645	252.08163	1.0E+11
²⁵³ Cf	≤ 0.01	0.049	253.08513	4.0E+13
²⁵⁴ Cf	≤ 0.01	0.166	254.08732	1.0E+09

^aFrom FSWO 2009.

^bFrom 10 CFR 71, Appendix A.

4.4.3 Isotopic Mass Calculations

4.4.3.1 SR-CF-3052-OR – Initial Mass Composition on January 13, 1999

The initial isotopic masses are evaluated in this section. Table 3 shows the derivation of the initial isotopic masses for the other Californium isotopes based on the calculated ²⁵²Cf mass of 44,059.6 μ g on June 6, 2000. Because the isotopic composition for this source was measured on January 13, 1999, the ²⁵²Cf mass of 44,059.6 μ g on June 6, 2000 will be back-decayed to

establish the initial ^{252}Cf mass on January 13, 1999. The back-decay correction factor for 1.40 years (January 13, 1999 to June 6, 2000) is:

$$\text{Correction Factor} = N_0/N = \exp(\ln(2) \cdot 1.40 \text{ y} / 2.645 \text{ y}) = 1.4433$$

The initial ^{252}Cf mass corrected to January 13, 1999 is 63,591 μg ($=44,059.6 \mu\text{g} \times 1.4433$). The remaining Californium isotope masses are calculated as shown in Table 3.

Table 3. Initial Isotopic composition for SR-CF-3052-OR on January 13, 1999.

Nuclide	Atom % (1/13/1999)	Atomic Mass ^a	Atom % x Atomic Mass	Mass Fraction ^b	Mass grams ^c
^{249}Cf	4.32	249.07485	1076.003	0.042749	0.003331
^{250}Cf	10.82	250.07641	2705.827	0.107501	0.008375
^{251}Cf	3.31	251.07959	831.0734	0.033018	0.002572
^{252}Cf	81.50	252.08163	20544.65	0.816229	0.063591 ^d
^{253}Cf	0.04	253.08513	10.12341	0.000402	0.000031
^{254}Cf	0.01	254.08732	2.540873	0.000101	0.000008
Total	100.00		25170.22	1.000000	0.077909

^aFrom FSWO 2009.

^bMass fraction =

(Atom % x Atomic Mass of isotope)/(Total Atom % x Atomic Mass for all isotopes).

^cMass = Mass ^{252}Cf x (Mass fraction of isotope)/(Mass fraction of ^{252}Cf).

^dMass of ^{252}Cf = 0.063591 grams when back-decayed to January 13, 1999.

4.4.3.2 SR-CF-3053-OR – Initial Mass Composition on August 10, 2000

The initial and decayed isotopic masses are evaluated in this section. Table 4 shows the derivation of the initial isotopic masses for the other Californium isotopes based on the calculated ^{252}Cf mass of 58,683.3 μg on August 29, 2000. Because the isotopic composition for this source was measured on August 10, 2000, the ^{252}Cf mass of 58,683.3 μg will be back-decayed to establish the initial ^{252}Cf mass on 8/10/2000. The back-decay correction factor for 0.052 years (August 10, 2000 to August 29, 2000) is:

$$\text{Correction Factor} = N_0/N = \exp(\ln(2) \cdot 0.052 \text{ y} / 2.645 \text{ y}) = 1.0137$$

The initial ^{252}Cf mass corrected to August 10, 2000 is 59,487 μg ($=58,683.3 \mu\text{g} \times 1.0137$). The remaining Californium isotope masses are calculated as shown in Table 4.

Table 4. Initial Isotopic composition for SR-CF-3053-OR on August 10, 2000.

Nuclide	Atom % (8/10/2000)	Atomic Mass ^a	Atom % x Atomic Mass	Mass Fraction ^b	Mass grams ^c
²⁴⁹ Cf	7.15	249.07485	1780.885	0.070797	0.005607
²⁵⁰ Cf	14.69	250.07641	3673.622	0.146041	0.011565
²⁵¹ Cf	5.05	251.07959	1267.952	0.050406	0.003992
²⁵² Cf	73.10	252.08163	18427.17	0.732554	0.059487 ^d
²⁵³ Cf	≤0.01 ^e	253.08513	2.530851	0.000101	0.000008
²⁵⁴ Cf	≤0.01 ^e	254.08732	2.540873	0.000101	0.000008
Total	100.01		25154.7	1.000000	0.080667

^aFrom FSWO 2009.^bMass fraction =

(Atom % x Atomic Mass of isotope)/(Total Atom % x Atomic Mass for all isotopes).

^cMass = Mass ²⁵²Cf x (Mass fraction of isotope)/(Mass fraction of ²⁵²Cf).^dMass of ²⁵²Cf = 0.059487 grams when back-decayed to August 10, 2000.^eConservatively set to 0.01 atom %.

4.4.4 Radioactive Composition and A₁ Calculation on June 1, 2009

4.4.4.1 SR-CF-3052-OR – Radioactive Composition and A₁ Calculation on June 1, 2009

The initial mass of the Californium isotopes from Table 3 were entered into Radcalc and decayed to June 1, 2009. The resulting mass and activity composition at June 1, 2009 is shown in Table 5 along with the A₁ calculation. There are dozens of daughter products resulting from the decay of the Californium isotopes. Table 5 only lists those isotopes with greater than 1E-5 Ci (3.7E5 Bq) on June 1, 2009. There is less than 1 A₁ (0.832 A₁) at a decay date of June 1, 2009; therefore, this source is designated as a Type A quantity.

Table 5. Composition for SR-CF-3052-OR on June 1, 2009 from Radcalc^a.

Nuclide	Activity Ci	Activity Bq	Mass grams	A ₁ ^b Bq	No. of A ₁ s
Cm-245	1.15E-05	4.25E+05	6.70E-05	9.0E+12	4.73E-08
Cm-246	1.07E-03	3.96E+07	3.48E-03	9.0E+12	4.40E-06
Cm-248	2.40E-04	8.88E+06	5.67E-02	2.0E+10	4.44E-04
Bk-249	1.53E-05	5.67E+05	9.35E-09	4.0E+13	1.42E-08
Cf-249	1.35E-02	4.98E+08	3.29E-03	3.0E+12	1.66E-04
Cf-250	5.28E-01	1.95E+10	4.83E-03	2.0E+13	9.77E-04
Cf-251	4.05E-03	1.50E+08	2.55E-03	7.0E+12	2.14E-05
Cf-252	2.24E+00	8.30E+10	4.19E-03	1.0E+11	8.30E-01
Totals	2.79E+00	1.03E+11	7.51E-02		8.32E-01

^aOnly those isotopes with an activity greater than 1E-5 Ci are shown.^bFrom 10 CFR 71, Appendix A.

The Radcalc output file for this calculation is provided as Appendix A.1. To perform transportation calculations, Radcalc requires a container mass, waste mass, and waste volume to be entered by the user. Arbitrary values were used as input for these parameters since the only transportation quantity of interest was the number of A_1 s, and this calculation is unaffected by those parameters.

4.4.4.2 SR-CF-3053-OR – Radioactive Composition and A_1 Calculations on June 1, 2009 and February 1, 2010

The initial mass of the Californium isotopes from Table 4 were entered into Radcalc and decayed to June 1, 2009. The resulting mass and activity composition at June 1, 2009 is shown in Table 6 along with the A_1 calculation. There are dozens of daughter products resulting from the decay of the Californium isotopes. Table 6 only lists those isotopes with greater than $1\text{E-}5$ Ci ($3.7\text{E}5$ Bq) on June 1, 2009. There is slightly greater than 1 A_1 ($1.18 A_1$) at a decay date of June 1, 2009; therefore, this source is designated as a Type B quantity for this decay time.

Table 6. Composition for SR-CF-3053-OR on June 1, 2009 from Radcalc^a.

Nuclide	Activity Ci	Activity Bq	Mass grams	A_1^b Bq	No. of A_1 s
Cm-245	1.63E-05	6.05E+05	9.52E-05	9.0E+12	6.72E-08
Cm-246	1.30E-03	4.82E+07	4.24E-03	9.0E+12	5.35E-06
Cm-248	2.17E-04	8.01E+06	5.11E-02	2.0E+10	4.01E-04
Bk-249	1.37E-05	5.08E+05	8.38E-09	4.0E+13	1.27E-08
Cf-249	2.26E-02	8.35E+08	5.52E-03	3.0E+12	2.78E-04
Cf-250	7.93E-01	2.93E+10	7.25E-03	2.0E+13	1.47E-03
Cf-251	6.29E-03	2.33E+08	3.96E-03	7.0E+12	3.32E-05
Cf-252	3.17E+00	1.17E+11	5.92E-03	1.0E+11	1.17E+00
Totals	3.99E+00	1.48E+11	7.81E-02		1.18E+00

^aOnly those isotopes with an activity greater than $1\text{E-}5$ Ci are shown.

^bFrom 10 CFR 71, Appendix A.

The Radcalc output file for this calculation is provided as Appendix A.2. To perform transportation calculations, Radcalc requires a container mass, waste mass, and waste volume to be entered by the user. Arbitrary values were used as input for these parameters since the only transportation quantity of interest was the number of A_1 s, and this calculation is unaffected by those parameters.

Table 7 shows the composition at a decay date of February 1, 2010. At this decay time there is less than 1 A_1 ($0.987 A_1$) which means that it may be shipped in a Type A package after February 1, 2010.

Table 7. Composition for SR-CF-3053-OR on February 1, 2010 from Radcalc^a.

Nuclide	Activity Ci	Activity Bq	Mass grams	A ₁ ^b Bq	No. of A ₁ s
Cm-245	1.76E-05	6.50E+05	1.02E-04	9.0E+12	7.22E-08
Cm-246	1.38E-03	5.10E+07	4.49E-03	9.0E+12	5.67E-06
Cm-248	2.20E-04	8.15E+06	5.20E-02	2.0E+10	4.08E-04
Cf-249	2.25E-02	8.34E+08	5.51E-03	3.0E+12	2.78E-04
Cf-250	7.65E-01	2.83E+10	7.00E-03	2.0E+13	1.42E-03
Cf-251	6.28E-03	2.32E+08	3.96E-03	7.0E+12	3.32E-05
Cf-252	2.66E+00	9.84E+10	4.96E-03	1.0E+11	9.84E-01
Totals	3.46E+00	1.28E+11	7.80E-02		9.87E-01

^aOnly those isotopes with an activity greater than 1E-5 Ci are shown.

^bFrom 10 CFR 71, Appendix A.

The Radcalc output file for this calculation is provided as Appendix A.3. To perform transportation calculations, Radcalc requires a container mass, waste mass, and waste volume to be entered by the user. Arbitrary values were used as input for these parameters since the only transportation quantity of interest was the number of A₁s, and this calculation is unaffected by those parameters.

4.4.5 Conclusions

Tables 5 and 6 list the radioactive material inventory on June 1, 2009, for sources SR-CF-3052-OR and SR-CF-3053-OR, respectively. Source SR-CF-3052-OR contains less than 1 A₁ on June 1, 2009 and may be shipped in a Type A package. Source SR-CF-3053-OR contains slightly greater than 1 A₁ on June 1, 2009; however, if this source is shipped after February 1, 2010, it may be shipped in a Type A package because it will contain less than 1 A₁ on February 1, 2010. The radioactive material inventory for source SR-CF-3053-OR on February 1, 2010 is listed in Table 7.

5.0 REFERENCES

10 CFR 71, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

DOE, 2008, *DOE Certified Radioactive Materials Transportation Packages*, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.

DOT, 1996, IAEA Certificate of Competent Authority, Special Form Radioactive Materials, Certificate Number USA/0236/S, Rev. 2, U. S. Department of Transportation, Research and Special Programs Administration, Washington, D.C.

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APPENDIX A – Radcalc Output Files**A.1 - SR-CF-3052-OR on June 1, 2009**

Radcalc 4.1: C:\Program Files\EnergySolutions\Radcalc 4.1\cf source 3052 at 6-1-2009.rad

Performed By: A. V. Savino/

Checked By: J. A. Dewberry/

===== Input Information =====

Comments:**Initial Source Data:**

Isotope	Ci	Gm	TBq
Cf-249	1.362E-02	3.331E-03	5.040E-04
Cf-250	9.153E-01	8.375E-03	3.387E-02
Cf-251	4.078E-03	2.572E-03	1.509E-04
Cf-252	3.410E+01	6.359E-02	1.262E+00
Cf-253	8.980E-01	3.100E-05	3.323E-02
Cf-254	6.795E-02	8.000E-06	2.514E-03

Total Activity:	3.599E+01	1.332E+00
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* Radionuclides with an activity of less than 1E-05 Ci will not be shown in the output.

* Radionuclides with an A1/A2 fraction of less than 0.001 will not be shown in the output.

Container Data:

Container Void Volume:	0	m^3
Container Mass:	1	kg
Mass of solid beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Gross Mass:	2	kg

Waste Data:

Waste Form:	Special	
Waste State:	Solid	
Waste Volume:	1	m^3
Waste Mass:	1	kg
Mass of solid lead:	0	kg
Mass of solid beryllium, graphite, and hydrogenous material enriched with deuterium:	0	kg
Waste Void Volume:	0	m^3

Decay Time Data:

Date to begin source decay:	1/13/1999
Date container sealed:	6/1/2009

===== Radioactive Decay Results =====

Decayed Source:

Isotope	Ci	Gm	TBq
Cm-245	1.150E-05	6.701E-05	4.255E-07
Cm-246	1.069E-03	3.481E-03	3.957E-05
Cm-248	2.401E-04	5.665E-02	8.884E-06
Bk-249	1.531E-05	9.348E-09	5.666E-07
Cf-249	1.347E-02	3.293E-03	4.983E-04
Cf-250	5.280E-01	4.831E-03	1.954E-02
Cf-251	4.046E-03	2.551E-03	1.497E-04
Cf-252	2.245E+00	4.186E-03	8.305E-02

Total Activity:	2.791E+00	1.033E-01
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w/o Daughters:	2.791E+00	1.033E-01
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* Radionuclides with an activity of less than 1E-05 Ci are not shown in the output.

Decay Heat:

Heat Generated on Start Date:	2.466	W
Heat Generated on Seal Date:	0.1804	W

===== Regulatory Requirements Warning =====

Radcalc utilizes numerically based criteria to classify packages against the regulations. Many regulations also include subjective criteria that Radcalc does not consider. The user must check to ensure that all requirements in the regulations are met.

===== DOT Classification Results =====

* DOT classification calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	10960000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	10960000	ALECs	(Number of ALECs)

* This package is not exempt from 49 CFR Subchapter C.

Effective A1s for Mixture:	1.241E+11	Bq
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Type Determination:

Type:	A		(A1s <= 1.0)
A1 Limit Fraction:	0.8321	A1s	(Number of A1s)

* For shipment outside the US, evaluate this package against the 49 CFR 173.435 international limits for Cf-252.

Limited Quantity Determination:

Limited Quantity:	No		(Solid, activity > 0.001 A1)
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Activity:	0.8321	A1
	2.791	Ci
	0.1033	TBq

Fissile:	Yes
Fissile Excepted:	Yes (a)

LSA Determination:

LSA-I:	No		(Fissile excepted, ACEMs > 30 x rad limits)
LSA-II:	No		(Special form)
LSA-III:	No		(Special form)
Specific Activity:	0.0008321	A1/gm	
	0.002791	Ci/gm	

HRCQ Determination:

HRCQ:	No		(A2s <= 3000, Activity <= 1000 TBq)
A1 Limit Fraction:	0.8321	A1s	
Activity:	2.791	Ci	
	0.1033	TBq	

Fissile Determination:

Fissile:	Yes		(Contains fissile isotopes per 49 CFR 173.403)
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Fissile Excepted Determination:

Fissile Excepted:	Yes (a)		(Fissile isotopes <= 2 grams)
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Fissile Mass:	2.382E-08	gm
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Container beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm
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Container Mass:	1000	gm
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Waste lead:	0	gm
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Waste beryllium, graphite, and hydrogenous material enriched with deuterium:	0	gm
--	---	----

Waste Mass:	1000	gm
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Solid Non-Fissile Mass:	0	gm
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Total Uranium Mass:	1.875E-11	gm
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U-233 Mass:	1.117E-17	gm
U-235 Mass:	1.048E-19	gm
Uranium Enrichment:	5.591E-07	%
Total Plutonium Mass:	3.628E-06	gm
Pu-239 Mass:	1.43E-15	gm
Pu-241 Mass:	2.382E-08	gm

Reportable Quantity Determination:

Reportable Quantity:	Yes	(RQs > = 1.0)
RQ Limit Fraction:	77.35	RQs (Number of RQs)

Shipping Papers and Labels:

Isotope	Number of A1s	Fraction of A1s	Cumulative A1s	Cumulative Fraction of A1s
+ Cf-252	0.8305	0.9981	0.8305	0.9981
Cf-250	0.0009768	0.001174	0.8314	0.9992

+ Contains 95% of the total A1s and must be included per 49 CFR 173.433.

* Radionuclides comprising less than 0.1% of the total A1s are not shown in the list.

===== DOE Classification Results =====

* DOE classification calculations are made at the end of the user-specified decay time.

DOE-STD-1027 Category Determination:

Category:	Cat 3	(Cat3s > 1.0, Cat2s <= 1.0)
Cat 2 Limit Fraction:	0.02014	
Cat 3 Limit Fraction:	1.247	

* The DOE-STD-1027 category determination is based on dose-related limits.

The user must apply any criticality-related limits separately.

Dose-Equivalent Curies:

ICRP-72 DE-Ci:	1.283
FGR-11 DE-Ci:	1.168

TRU Waste Determination:

TRU Waste:	Yes	(TRU activity > 100 nCi/gm)
TRU Activity:	18830	nCi/g

WIPP Quantities:

FGE Value:	0.3788
PE-Ci Value:	0.826

===== NRC Classification Results =====

* NRC classification calculations are made at the end of the user-specified decay time.

NRC Container Category:

Container Category:	III	
LSA-I:	No	
LSA-II:	No	
LSA-III:	No	
Total Activity:	2.791	Ci
A1 Limit Fraction:	0.8321	A1s

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A.2 - SR-CF-3053-OR on June 1, 2009

Radcalc 4.1: C:\Program Files\EnergySolutions\Radcalc 4.1\cf source 3053 at 6-1-2009.rad

Performed By: A. V. Savino/

Checked By: J. A. Dewberry/

===== Input Information =====

Comments:

Initial Source Data:

Isotope	Ci	Gm	TBq
Cf-249	2.293E-02	5.607E-03	8.483E-04
Cf-250	1.264E+00	1.157E-02	4.677E-02
Cf-251	6.330E-03	3.992E-03	2.342E-04
Cf-252	3.190E+01	5.949E-02	1.180E+00
Cf-253	2.318E-01	8.000E-06	8.575E-03
Cf-254	6.795E-02	8.000E-06	2.514E-03

Total Activity:	3.349E+01	1.239E+00
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* Radionuclides with an activity of less than 1E-05 Ci will not be shown in the output.

* Radionuclides with an A1/A2 fraction of less than 0.001 will not be shown in the output.

Container Data:

Container Void Volume:	0	m^3
Container Mass:	1	kg
Mass of solid beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Gross Mass:	2	kg

Waste Data:

Waste Form:	Special
Waste State:	Solid
Waste Volume:	1 m^3
Waste Mass:	1 kg
Mass of solid lead:	0 kg
Mass of solid beryllium, graphite, and hydrogenous material enriched with deuterium:	0 kg
Waste Void Volume:	0 m^3

Decay Time Data:

Date to begin source decay:	8/10/2000
Date container sealed:	6/1/2009

===== Radioactive Decay Results =====

Decayed Source:

Isotope	Ci	Gm	TBq
Cm-245	1.634E-05	9.520E-05	6.045E-07
Cm-246	1.302E-03	4.238E-03	4.816E-05
Cm-248	2.165E-04	5.109E-02	8.012E-06
Bk-249	1.373E-05	8.382E-09	5.081E-07
Cf-249	2.256E-02	5.518E-03	8.349E-04
Cf-250	7.926E-01	7.252E-03	2.932E-02
Cf-251	6.287E-03	3.965E-03	2.326E-04
Cf-252	3.172E+00	5.916E-03	1.174E-01

Total Activity:	3.995E+00	1.478E-01
w/o Daughters:	3.995E+00	1.478E-01

* Radionuclides with an activity of less than 1E-05 Ci are not shown in the output.

Decay Heat:

Heat Generated on Start Date:	2.323	W
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Heat Generated on Seal Date: 0.2568 W

===== Regulatory Requirements Warning =====

Radcalc utilizes numerically based criteria to classify packages against the regulations. Many regulations also include subjective criteria that Radcalc does not consider. The user must check to ensure that all requirements in the regulations are met.

===== DOT Classification Results =====

* DOT classification calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	15790000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	15790000	ALECs	(Number of ALECs)

* This package is not exempt from 49 CFR Subchapter C.

Effective A1s for Mixture: 1.257E+11 Bq

Type Determination:

Type:	B		(A1s > 1.0)
A1 Limit Fraction:	1.176	A1s	(Number of A1s)

* For shipment outside the US, evaluate this package against the 49 CFR 173.435 international limits for Cf-252.

Limited Quantity Determination:

Limited Quantity:	No		(Solid, activity > 0.001 A1)
Activity:	1.176	A1	
	3.995	Ci	
	0.1478	TBq	
Fissile:	Yes		
Fissile Excepted:	Yes (a)		

LSA Determination:

LSA-I:	No		(Fissile excepted, ACEMs > 30 x rad limits)
LSA-II:	No		(Special form)
LSA-III:	No		(Special form)
Specific Activity:	0.001176	A1/gm	
	0.003995	Ci/gm	

HRCQ Determination:

HRCQ:	No		(A2s <= 3000, Activity <= 1000 TBq)
A1 Limit Fraction:	1.176	A1s	
Activity:	3.995	Ci	
	0.1478	TBq	

Fissile Determination:

Fissile:	Yes		(Contains fissile isotopes per 49 CFR 173.403)
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Fissile Excepted Determination:

Fissile Excepted:	Yes (a)		(Fissile isotopes <= 2 grams)
Fissile Mass:	2.94E-08	gm	
Container beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Container Mass:	1000	gm	
Waste lead:	0	gm	
Waste beryllium, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Waste Mass:	1000	gm	
Solid Non-Fissile Mass:	0	gm	
Total Uranium Mass:	1.612E-11	gm	
U-233 Mass:	8.271E-18	gm	
U-235 Mass:	8.425E-20	gm	
Uranium Enrichment:	5.226E-07	%	

Total Plutonium Mass:	3.489E-06	gm
Pu-239 Mass:	1.355E-15	gm
Pu-241 Mass:	2.94E-08	gm

Reportable Quantity Determination:

Reportable Quantity:	Yes	(RQs > = 1.0)
RQ Limit Fraction:	114.2	RQs (Number of RQs)

Shipping Papers and Labels:

Isotope	Number of A1s	Fraction of A1s	Cumulative A1s	Cumulative Fraction of A1s
+ Cf-252	1.174	0.9981	1.174	0.9981
Cf-250	0.001466	0.001247	1.175	0.9994

+ Contains 95% of the total A1s and must be included per 49 CFR 173.433.

* Radionuclides comprising less than 0.1% of the total A1s are not shown in the list.

===== DOE Classification Results =====

* DOE classification calculations are made at the end of the user-specified decay time.

DOE-STD-1027 Category Determination:

Category:	Cat 3	(Cat3s > 1.0, Cat2s <= 1.0)
Cat 2 Limit Fraction:	0.02938	
Cat 3 Limit Fraction:	1.813	

* The DOE-STD-1027 category determination is based on dose-related limits.

The user must apply any criticality-related limits separately.

Dose-Equivalent Curies:

ICRP-72 DE-Ci:	1.85
FGR-11 DE-Ci:	1.684

TRU Waste Determination:

TRU Waste:	Yes	(TRU activity > 100 nCi/gm)
TRU Activity:	30390	nCi/g

WIPP Quantities:

FGE Value:	0.6066
PE-Ci Value:	1.191

===== NRC Classification Results =====

* NRC classification calculations are made at the end of the user-specified decay time.

NRC Container Category:

Container Category:	III
LSA-I:	No
LSA-II:	No
LSA-III:	No
Total Activity:	3.995 Ci
A1 Limit Fraction:	1.176 A1s

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A.3 - SR-CF-3053-OR on February 1, 2010

Radcalc 4.1: C:\Program Files\EnergySolutions\Radcalc 4.1\cf source 3053 at 2-1-2010.rad

Performed By: A. V. Savino/

Checked By: J. A. Dewberry/

===== Input Information =====

Comments:

Initial Source Data:

Isotope	Ci	Gm	TBq
Cf-249	2.293E-02	5.607E-03	8.483E-04
Cf-250	1.264E+00	1.157E-02	4.677E-02
Cf-251	6.330E-03	3.992E-03	2.342E-04
Cf-252	3.190E+01	5.949E-02	1.180E+00
Cf-253	2.318E-01	8.000E-06	8.575E-03
Cf-254	6.795E-02	8.000E-06	2.514E-03

Total Activity:	3.349E+01	1.239E+00
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* Radionuclides with an activity of less than 1E-05 Ci will not be shown in the output.

* Radionuclides with an A1/A2 fraction of less than 0.001 will not be shown in the output.

Container Data:

Container Void Volume:	0	m^3
Container Mass:	1	kg
Mass of solid beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Gross Mass:	2	kg

Waste Data:

Waste Form:	Special
Waste State:	Solid
Waste Volume:	1 m^3
Waste Mass:	1 kg
Mass of solid lead:	0 kg
Mass of solid beryllium, graphite, and hydrogenous material enriched with deuterium:	0 kg
Waste Void Volume:	0 m^3

Decay Time Data:

Date to begin source decay:	8/10/2000
Date container sealed:	2/1/2010

===== Radioactive Decay Results =====

Decayed Source:

Isotope	Ci	Gm	TBq
Cm-245	1.757E-05	1.024E-04	6.501E-07
Cm-246	1.378E-03	4.486E-03	5.099E-05
Cm-248	2.204E-04	5.200E-02	8.155E-06
Cf-249	2.253E-02	5.511E-03	8.338E-04
Cf-250	7.649E-01	6.998E-03	2.830E-02
Cf-251	6.283E-03	3.963E-03	2.325E-04
Cf-252	2.661E+00	4.962E-03	9.844E-02

Total Activity:	3.456E+00	1.279E-01
w/o Daughters:	3.456E+00	1.279E-01

* Radionuclides with an activity of less than 1E-05 Ci are not shown in the output.

Decay Heat:

Heat Generated on Start Date:	2.323	W
Heat Generated on Seal Date:	0.2193	W

===== Regulatory Requirements Warning =====

Radcalc utilizes numerically based criteria to classify packages against the regulations. Many regulations also include subjective criteria that Radcalc does not consider. The user must check to ensure that all requirements in the regulations are met.

===== DOT Classification Results =====

* DOT classification calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	13800000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	13800000	ALECs	(Number of ALECs)

* This package is not exempt from 49 CFR Subchapter C.

Effective A1s for Mixture:	1.296E+11	Bq
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Type Determination:

Type:	A		(A1s <= 1.0)
A1 Limit Fraction:	0.9866	A1s	(Number of A1s)

* For shipment outside the US, evaluate this package against the 49 CFR 173.435 international limits for Cf-252.

Limited Quantity Determination:

Limited Quantity:	No		(Solid, activity > 0.001 A1)
Activity:	0.9866	A1	
	3.456	Ci	
	0.1279	TBq	
Fissile:	Yes		
Fissile Excepted:	Yes (a)		

LSA Determination:

LSA-I:	No		(Fissile excepted, ACEMs > 30 x rad limits)
LSA-II:	No		(Special form)
LSA-III:	No		(Special form)
Specific Activity:	0.0009866	A1/gm	
	0.003456	Ci/gm	

HRCQ Determination:

HRCQ:	No		(A2s <= 3000, Activity <= 1000 TBq)
A1 Limit Fraction:	0.9866	A1s	
Activity:	3.456	Ci	
	0.1279	TBq	

Fissile Determination:

Fissile:	Yes		(Contains fissile isotopes per 49 CFR 173.403)
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Fissile Excepted Determination:

Fissile Excepted:	Yes (a)		(Fissile isotopes <= 2 grams)
Fissile Mass:	3.369E-08	gm	
Container beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Container Mass:	1000	gm	
Waste lead:	0	gm	
Waste beryllium, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Waste Mass:	1000	gm	
Solid Non-Fissile Mass:	0	gm	
Total Uranium Mass:	1.993E-11	gm	
U-233 Mass:	1.191E-17	gm	
U-235 Mass:	1.13E-19	gm	
Uranium Enrichment:	5.672E-07	%	
Total Plutonium Mass:	3.979E-06	gm	

Pu-239 Mass:	1.689E-15	gm
Pu-241 Mass:	3.369E-08	gm

Reportable Quantity Determination:

Reportable Quantity:	Yes	(RQs > = 1.0)
RQ Limit Fraction:	106.3	RQs (Number of RQs)

Shipping Papers and Labels:

Isotope	Number of A1s	Fraction of A1s	Cumulative A1s	Cumulative Fraction of A1s
+ Cf-252	0.9844	0.9978	0.9844	0.9978
Cf-250	0.001415	0.001434	0.9858	0.9993

+ Contains 95% of the total A1s and must be included per 49 CFR 173.433.
 * Radionuclides comprising less than 0.1% of the total A1s are not shown in the list.

===== DOE Classification Results =====

* DOE classification calculations are made at the end of the user-specified decay time.

DOE-STD-1027 Category Determination:

Category:	Cat 3	(Cat3s > 1.0, Cat2s <= 1.0)
Cat 2 Limit Fraction:	0.02655	
Cat 3 Limit Fraction:	1.627	

* The DOE-STD-1027 category determination is based on dose-related limits.
 The user must apply any criticality-related limits separately.

Dose-Equivalent Curies:

ICRP-72 DE-Ci:	1.627
FGR-11 DE-Ci:	1.481

TRU Waste Determination:

TRU Waste:	Yes	(TRU activity > 100 nCi/gm)
TRU Activity:	30430	nCi/g

WIPP Quantities:

FGE Value:	0.6062
PE-Ci Value:	1.048

===== NRC Classification Results =====

* NRC classification calculations are made at the end of the user-specified decay time.

NRC Container Category:

Container Category:	III
LSA-I:	No
LSA-II:	No
LSA-III:	No
Total Activity:	3.456 Ci
A1 Limit Fraction:	0.9866 A1s

ENERGY SOLUTIONS			CHECKLIST FOR CHECKING OF ANALYSIS/CALCULATIONS
Document Number/Revision: <u>FSWO-RPT-095, Rev. 0</u>			
Document Title: <u>Removal of Californium Sources from the 222-S Laboratory</u>			
Preparer: <u>A. V. Savino</u>			
Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate and explicitly stated.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☐	☐	☒	Sources of non-standard formula/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety Margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.			
Checker <u>Julie Dewberry</u> / <u>Julie Dewberry</u> Date <u>6/16/09</u>			
NOTE: Any hand calculations, notes or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.			

Subcontractor Calculation Review Checklist.

Page ____ of ____

Subject: FSWO-RPT-095, Rev 0., Removal Of Californium Sources From The 222-S Laboratory

The subject document has been reviewed by the undersigned.

The reviewer reviewed and verified the following items as applicable.

Documents Reviewed: Subject document radioactive source decay calculations and quantitiesAnalysis Performed By: Energy Solutions Federal Services (Savino/Dewberry)

- Design Input ✓
- Basic Assumptions ✓
- Approach/Design Methodology ✓
- Consistency with item or document supported by the calculation ✓
- Conclusion/Results Interpretation ✓
- Impact on existing requirements ✓
- _____

Reviewer (printed name, signature, and date) Gary L Troyer *G L Troyer* 6-Jul-2009Organizational Manager (printed name, signature and date) Greg L Parsons *GL Parsons* 7-25-09

Baune, Heather L

From: Donna Linstrum [djlinstrum@energysolutions.com]
Sent: Wednesday, July 22, 2009 1:19 PM
To: Baune, Heather L
Cc: Donna Linstrum
Subject: RE: Contract 36473-45 - Removal of Cf Sources from 222-S Lab (doc attached)
Attachments: RC41_ESER_GOTS.pdf

Heather,

The information for the software code, version number, and user manual were noted within the documents provided. However, the additional, specific information requested within your message is provided below.

Program Name: Radcalc

Version: 4.1

Release Date: June 5, 2009 (see attached existing software evaluation report)

User Manual Reference: FSWO-SQA-026, Rev. 0. Also included as "User Help Files" as a part of the software code (i.e., drop-down menu)

Verification and Validation: FSWO-VV-029, Rev. 0, "Radcalc 4.1 Verification and Validation Test Report."

Radcalc was developed by EnergySolutions for use by the DOE and its subcontractors free of charge. EnergySolutions has an NQA-1, 2000 Quality Assurance Program that also implements the requirements of DOE Order 414.1C regarding software. The "Software Management Procedure" used for development of this code is QP 3-10, Rev. 9.

Radcalc Version 4.1 is available for download at the following website for registered, approved users. All software quality assurance documentation (very extensive) is available in PDF format via that website by registered, approved users. <https://www.radcalc.energy.gov>

Regards,

Donna Linstrum

EnergySolutions, MSIN: G1-62

(Office) 509-375-9526

(Fax) 509-371-2457

djlinstrum@energysolutions.com

From: Baune, Heather L [mailto:Heather_L_Baune@RL.gov]
Sent: Wednesday, July 22, 2009 10:42 AM
To: Donna Linstrum
Subject: FW: Contract 36473-45 - Removal of Cf Sources from 222-S Lab (doc attached)

Donna,

Per our phone conversation, the following information is requested.

Documentation of computer codes shall include program name, version numbers, release dates, references to user manuals, and program verification data. If the calculation uses software that has

previously been documented and verified in an engineering calculation, that calculation referenced. The new calculation must contain documentation that the previous verification is applicable.

I'd very much appreciate a quick turnaround on this information (in the next day or two) if at all possible.

Please contact me if you have questions.

Thank You,
Heather Baune
372-3393

From: Donna Linstrum [mailto:djlinstrum@energysolutions.com]
Sent: Wednesday, June 17, 2009 9:01 AM
To: Baune, Heather L
Cc: Donna Linstrum; Lippert, Tracy D; Ferrell, Patrick C; Savino, Anthony V
Subject: Contract 36473-45 - Removal of Cf Sources from 222-S Lab (doc attached)

Heather,

The attached files are the released document. I will be sending you the original document via Plant Mail for records retention purposes.

If you have any question, please let me know.

Regards,

Donna Linstrum

Energy Solutions, MSIN: G1-62

(Office) 509-375-9526

(Fax) 509-371-2457

djlinstrum@energysolutions.com

EXISTING SOFTWARE EVALUATION REPORT	
System/Software Name: Radcalc (COTS)	Version: 4.1
Classification Level: A ☐ B ☒ C ☐ D ☐	Major Change ☒ Minor Change ☐
<p>1. Describe purpose of software and software source.</p> <p>Radcalc 4.1 corrects the documented errors, incorporates regulatory interpretations, and incorporates other enhancements identified since the release of Radcalc 4.0. (Ref: EnergySolutions' PR/CRs-023 through -034, -059, and -061 as provided in FSWO-SQA-022, Rev. 1, <i>Radcalc 4.1 Software Requirements Specification</i>.)</p> <p>Radcalc 4.1 capabilities include the following:</p> <ul style="list-style-type: none"> • Performs transportation classifications based on selected DOT definitions and methodologies identified in Title 49, <i>Code of Federal Regulations</i>, "Transportation." • Performs calculations and classification functions using selected methodologies prescribed by the DOE, NRC, U.S. Environmental Protection Agency, and International Commission on Radiological Protection. • Calculates the decay heat rate and activity of radionuclides and their daughter products at the end of a specified time interval. • Calculates the radiolytic hydrogen gas generated in a radioactive waste matrix. • Calculates the helium gas production from radioactive decay. • Incorporates DOE-STD-1027, Change 1, <i>Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports</i>, to classify packages using the Category 2 and Category 3 facility limits. • Includes a complete set of DE-Ci values compiled from ICRP Publication 72, <i>Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients</i>, and FGR11/EPA-520/1-88-020, <i>Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion</i>. • Incorporates Revision 2 of the <i>Contact-Handled Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC)</i> as the source of FGE values. • Incorporates revisions to WIPP PE-Ci requirements current to Revision 6.2 of DOE/WIPP-02-3122, <i>Contact-Handled Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant</i>. DOE/WIPP-02-3122 defines "TRU" differently than the more standard definition established in DOE Manual 435.1-1 Chg 1, <i>Radioactive Waste Management Manual</i>. This includes updating ²³⁹Pu-equivalent curie (PE-Ci) database values for ²³³U and ²³⁷Np, and adding 60 other transuranic (TRU) isotopes to the calculation. <p>As identified within the software quality assurance documentation, Radcalc 4.1 requires a set of user-supplied input parameters to perform its calculations.</p> <p>Radcalc 4.1 is a Secure Socket Layer (SSL), web-based software application that is available (free of charge) to registered/authorized users as defined and granted by the U.S. Department of Energy (DOE), Office of Packaging and Transportation (EM-63). Radcalc is distributed with database viewers</p>

EXISTING SOFTWARE EVALUATION REPORT

System/Software Name: Radcalc (COTS)

Version: 4.1

that allow registered/authorized users to access the Radcalc nuclear, transportation classification and G-value database values on an isotope-by-isotope basis. Registered/authorized users may download the software and obtain all software quality assurance documentation from:

<https://www.radcalc.energy.gov>

2. Describe mathematical models and design basis.

The two documents identified below identify the mathematical models and design basis of Radcalc 4.1. The implementation document identifies the source code files for the software program.

- FSWO-SQA-023, 2009, *Radcalc Software Design Description*, Rev. 0, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- FSWO-SQA-025, 2009, *Radcalc Implementation Document*, Rev. 0, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.

3. Describe/List primitive baseline configuration items.

The relevant software quality assurance documents, as applicable to Radcalc 4.1 (dated March 26, 2009), are listed below. Registered/approved users have access to the listed documents via the Radcalc 4.1 website to these listed documents. These documents are available in PDF format.

- EnergySolutions, 2009, "Safety Software Quality Plan," Radcalc 4.1, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington, February 2009.
- FSWO-SQA-021, Rev. 0, *Radcalc Version 4.1 Project Risk Evaluation Report*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
***See below for project specific RER**
- FSWO-SQA-022, Rev. 1, *Radcalc Software Requirements Specification (Current to Radcalc 4.1)*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- FSWO-SQA-023, Rev. 0, *Radcalc Software Design Description (Current to Radcalc 4.1)*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- FSWO-SQA-025, Rev. 0, *Radcalc 4.1 Implementation Document*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- FSWO-SQA-026, Rev. 0, *Radcalc 4.1 User Manual*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington. (Information is also included a drop-down menu within the software itself.)
- FSWO-V V-028, Rev. 0, *Radcalc 4.1 Verification and Validation Plan and Test Procedure*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- FSWO-V V-029, Rev. 0, *Radcalc 4.1 Verification and Validation Test Report*, EnergySolutions Federal Services, Inc., Northwest Operations, Richland, Washington.
- PR/CR's are tracked by the baseline software configuration control as identified in QP 3-10, Rev. 9,

<h2 style="text-align: center;">EXISTING SOFTWARE EVALUATION REPORT</h2>	
System/Software Name: Radcalc (COTS)		Version: 4.1	
<p><i>Software Management.</i></p> <ul style="list-style-type: none"> *Project-Specific Risk Evaluation Report – A standalone project RER for Radcalc will not be prepared unless contractually directed otherwise. A generic RER has been prepared for all COTS/GOTS software that is classed as Acquired Safety Level B. Refer to FSWO-SQA-018, <i>Project Risk Management Evaluation for Acquired Software Classified as Safety Level B.</i> 			
<p>3a. If documentation from Item 3 is not available, justify exceptions and specify compensatory actions required to demonstrate acceptance for use.</p> <ul style="list-style-type: none"> Explain the need for continued use of the software. Explain the consequence of not using the software. Describe the risk associated with continued use of the software. Describe interior actions taken to mitigate the risk. Describe actions to be implemented. Identify implementation due date. <p>There are no exceptions. All software quality assurance documentation identified in Item 3 is adequately provided and available.</p>			
<p>4. Describe adequacy of existing design and user documentation to support software operation/maintenance including necessary user training:</p> <p>The design and user documentation that are applicable to Radcalc 4.1 are listed in Item 3. In addition, the Radcalc software integrates a drop-down "help" menu.</p> <p>Radcalc is designed, codified, tested, documented, and maintained by EnergySolutions for the DOE-HQ/EM-63 via a contract through Project Enhancement Corporation (PEC). Both EnergySolutions Document Control and PEC have software quality assurance documentation and backup CDs of the Radcalc 4.1 code and installation files for website use. PEC has the contractual responsibility to maintain all record copy documentation/media for Radcalc 4.1.</p> <p>The development of Radcalc 4.1 was in accordance with the requirements identified in QP 3-10, Rev. 9. Industry standard programming techniques appropriate for the software and hardware systems used by Radcalc were used. Software developers incorporated innovations to improve the value of the software to DOE and end users. IEEE recommended standards were used as guides.</p> <p>EnergySolutions has provided user training as needed to both groups and individuals. EnergySolutions has provided user support for error correction in accordance with QP 3-10.</p> <p>The contractual requirements for EnergySolutions' involvement with regard to continued support and/or development for Radcalc activities is currently unknown. It is expected that DOE orders and standards shall apply to the extent doing so is contractually required; meets DOE and other customer requirements, priorities, or expectations; and is sufficiently funded.</p>

EXISTING SOFTWARE EVALUATION REPORT		
System/Software Name: Radcalc (COTS)		Version: 4.1
<p>5. Describe adequacy of existing test documentation to demonstrate acceptable performance based on defined software requirements. (Define new test cases required to fully demonstrate performance and to support regression testing.)</p> <p>Radcalc 4.1 was verified and validated (V&V) in accordance with QP 3-10, Rev. 9. The V&V documentation is identified in Item 3, and includes the test plan/procedure and report information.</p>		
Existing Software Evaluation Report Review/Approval		
	Print/Sign	Approval Date
System Engineer	A. V. Savino / <i>Anthony V. Savino</i>	06/05/2009
Independent Technical Reviewer	J. A. Reeves / <i>John A. Reeves</i>	06/05/2009
System Manager	D. J. Linstrum / <i>Dina J. Linstrum</i>	06/05/2009
Line Manager (Req'd for 3a only)	N/A	

FSWO-059 11/07