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July 24, 2018
FS–18–0176

ATTN: Document Control Desk
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission
Washington, DC 20555–0001

SUBJECT: 1) BRR Package Amendment Request, Docket No. 71-9341 and EPID No. L-2018-LLA-0028

2) Letter from Nishka Devaser to Philip Noss of June 26, 2018, transmitting a Request for Additional Information (RAI)

Dear Mr. Devaser:

Orano Federal Services LLC (Orano FS) hereby submits Revision 12 of the Safety Analysis Report (SAR) for the BRR Package, which includes changes made in response to the NRC RAI referenced above.

Our response to the RAI is provided in Attachment A. Minor changes were also made to one of the licensing drawings. All changes are discussed and justified in Attachment A. Revisions made to the SAR are marked with a change bar in the margin and show Revision 12 in the header. Note that pages not changed will show various earlier revision numbers in the header.

As a reminder, Orano FS would also like to request correction of a typographical error we discovered in the Certificate of Compliance (CoC), Revision 5, issued by the NRC on July 21, 2016. In Table 1.4 of the CoC, for TRIGA Fuel ID 201, the fuel OD should be corrected from 1.44 inches to 1.41 inches, consistent with the dimension given in Table 1.2-1 of the BRR package SAR. Of note, this discrepancy has no safety consequences.

Included with this letter is one paper copy of the SAR update pages and one CD containing the PDF file "BRRC SAR Complete Rev. 12.pdf" (37,620 kb, 777 pages). The CD is contained within an envelope labeled, "BRR package SAR Revision 12, Electronic Copy of Document, Docket 71-9341 EPID No. L-2018-LLA-0028".

To update a paper copy of the SAR, replace the cover sheet, Table of Contents, drawing 1910-01-01-SAR, and pages 5.6-2 through 5.6-7. An extra cover sheet and spine sheet are provided to update the binder.

NMSS20

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Should you have any questions regarding this submittal, please contact me at (233) 552-1321 or via email (phil.noss@orano.group).

Yours Truly,

Phil Noss

Philip Noss
Licensing Manager
Orano Federal Services LLC

Copies:

Attention: Nishka Devaser, Project Manager (incl. changed pages and CD)
U. S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD 20852

Donald Darrington, Idaho National Laboratory (incl. changed pages and CD)

Ken Wahlquist, Idaho National Laboratory (incl. changed pages and CD)

Dr. Ethan Balkin, DOE-SC Isotope Programs (incl. changed pages and CD)

Richard J. Smith, Project Manager, Orano Federal Services LLC

Tess Klatt, Contracts, Orano Federal Services LLC

Attachments:

Attachment A, Response to RAI, BRR Package Amendment, Docket 71-9341, L-2018-LLA-0028

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Attachment A

Response to RAI, BRR Package Amendment Docket 71-9341, L-2018-LLA-0028

Shielding Evaluation

1. Demonstrate how the calculated dose rates for the package containing the 1 kCi source at discrete locations can be scaled up to represent a package configuration that contains different sources with varying strengths.

   The applicant stated in Section 5.6.2.1 of the SAR (ADAMS Accession No. ML 18044A 164) that a 1 kCi Co-60 source is modeled and scaled as needed to match the Co-60 payload of the different package configurations. Source intensity, gamma energy release rate, and total source decay heat for the 1 kCi modeled Co-60 source are shown in Table 5.6-2 alongside scaled values for Type 1 and Type 2 payloads. However, the configurations are not uniform. Therefore, it is not clear to the staff how the scaling is performed for the nonuniform source configuration.

   The staff requests that the applicant provide an explanation, with justification, on how the model using a 1 kCi source can be scaled up when the source is not uniform. This information is needed to verify compliance with the external dose rate regulations in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

Response: While various Co-60 isotope production target activities are present in the bounding Type 1 and Type 2 isotope production target payloads, only a 1 kCi Co-60 source is modeled in ORIGEN since the necessary characteristics for subsequent analysis (source intensity, total decay heat, and gamma energy release rate) scale proportional to activity. A 1 kCi Co-60 source was only selected for modeling in ORIGEN due to the ease of multiplicative scaling. As detailed below, the characteristics of the 1 kCi Co-60 source are scaled at various points to explicitly model different activity Co-60 isotope production targets. In both shielding and thermal modeling, the non-uniformity of the Type 1 and Type 2 payloads is accounted for. As a result, all MCNP-calculated dose rates and gamma heating rates do not require scaling. While Table 5.6-2 only shows the properties of the ORIGIN-modeled 1 kCi Co-60 source alongside scaled up totals for the Type 1 and Type 2 payloads, it is not intended to be a comprehensive representation of all scaling used in analysis of the isotope

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production target payloads. SAR Section 5.6.2.1, *Gamma Source*, has been revised for clarity. There are no other changes to the SAR text.

Revisions to drawing 1910-01-01-SAR

In reviewing the SAR, it was found necessary to make some minor changes to SAR drawing 1910-01-01-SAR, Rev. 5. These are detailed as follows:

a) Make threaded inserts mandatory in the closure bolt attachment holes and lifting attachment bolt holes, instead of optional.

Discussion and Justification: Item 24 on the drawing is a heavy duty insert which may be used in the (12) closure bolt attachment holes and in the (4) lifting attachment bolt holes. Previously, item 24 has shown flag note 30, which made them optional. With this change, flag note 30 has been removed from item 24, making the thread inserts mandatory. In addition, on sheet 4 of the drawing, in zones D-1 and C-1, the associated bolt hole callouts have been revised accordingly. Note that flag note 30 is retained as-is, since it can refer to other threaded holes on the cask. This change is considered desirable to ensure that all future casks fabricated must include these strong inserts. Of note, the single existing BRR cask has always included these same (item 24) thread inserts in all of the corresponding holes.

b) Revise the inner diameter and height of the personnel barrier.

Discussion and Justification: A review of the drawing showed that the fitup between the personnel barrier (see sheet 3) and the cask could be improved by increasing the inner diameter from (45.6) inches to (46.0) inches and reducing the height from (50.3) inches to (49.8) inches. These small changes will have no affect on the function of the component.

c) Correct a drafting error.

Discussion and Justification: During the finalization and plotting of Rev. 5 of this drawing, the CAD software allowed the lower impact limiter attachment lugs to "drift" out of position. This can be seen on sheet 2, zone B-2 of Rev. 5, where the incorrect reference dimension (45.7) is shown. On all prior revisions of the drawing, the correct dimension of (45.3) is shown. This drafting/plotting error has been corrected. It had no effect on any safety evaluation.

The revised drawing is provided as Rev. 6.

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BEA Research Reactor Package

Safety Analysis Report
Docket 71–9341

Revision 12
July 2018

DOCKET 71–9341

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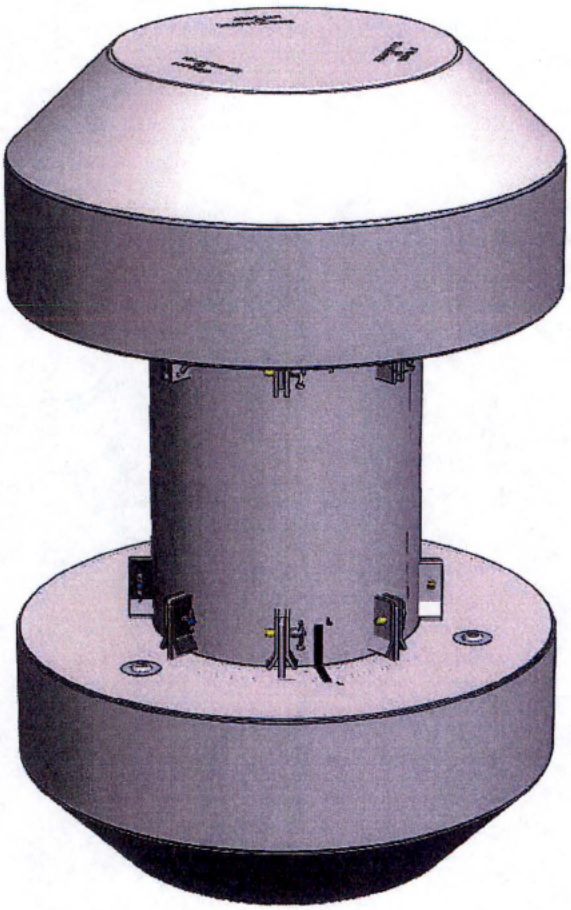
BEA Research Reactor Package



Safety Analysis Report

Revision 12

Orano Federal Services LLC

July 2018

DOCKET 71–9341

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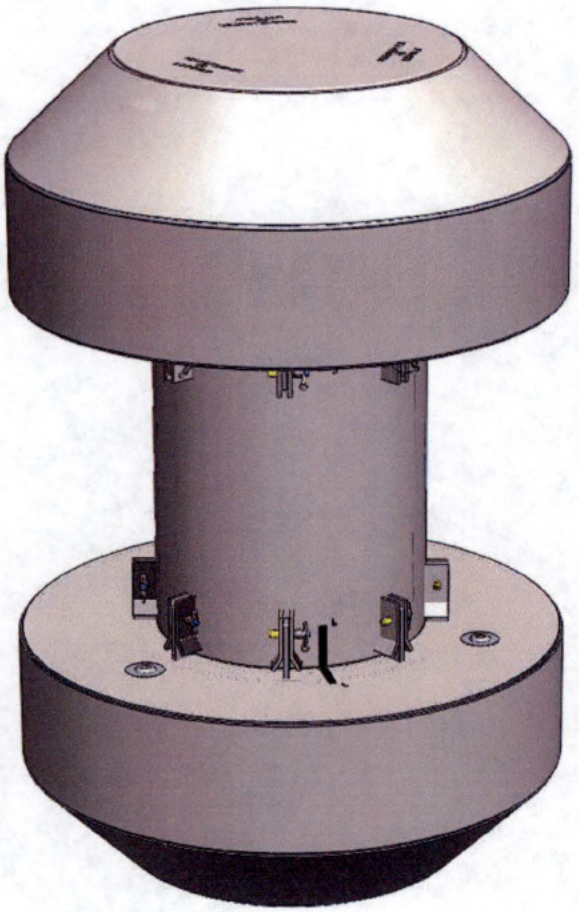
BEA Research Reactor Package



Safety Analysis Report

Revision 12

Orano Federal Services LLC

July 2018

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TABLE OF CONTENTS

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DWG NO 1910-01-01-SAR REV 6 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

1. INTERPRET DRAWING PER ASME Y14.5M. INTERPRET WELDS PER ANSI/AWS A2.4.
2. THREADS PER ANSI B1.1.
3. THE PACKAGE SHALL BE IDENTIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF 10 CFR 71.85(c) USING A STAINLESS STEEL NAMEPLATE.
4. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME SECTION IX.
5. ALL WELDS SHALL BE VISUALLY EXAMINED IN ACCORDANCE WITH AWS D1.6.
6. INDICATED WELDS SHALL BE LIQUID PENETRANT INSPECTED ON THE FINAL PASS IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NB, ARTICLE NB-5000, AND SECTION V, ARTICLE 6.
7. INDICATED WELDS SHALL BE RADIOGRAPH INSPECTED IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NB, ARTICLE NB-5000, AND SECTION V, ARTICLE 2.
8. INDICATED WELDS SHALL BE ULTRASONICALLY INSPECTED IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NB, ARTICLE NB-5000, AND SECTION V, ARTICLE 4.
9. ALL ITEMS MADE FROM SHEET MATERIAL MAY BE MADE FROM TWO OR MORE PIECES, AND JOINED WITH COMPLETE PENETRATION WELDS, INSPECTED IN ACCORDANCE WITH G/N 28.
10. ASTM A240, A276 OR A479 ARE OPTIONAL MATERIAL FORMS THAT MAY BE SUBSTITUTED FOR ANY ASTM A240, A276 OR A479, TYPE 304 STAINLESS STEEL.
11. OPTION: LEAD MAY BE PER FEDERAL SPECIFICATION QQ-L-171E, GRADE A OR C.
12. CAST MATERIAL SHALL BE RADIOGRAPH AND LIQUID PENETRANT INSPECTED IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NB, ARTICLE NB-2570, AND SECTION V, ARTICLES 2 AND 6.
13. FORGED MATERIAL SHALL BE ULTRASONICALLY AND LIQUID PENETRANT INSPECTED IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NB, ARTICLE NB-2540, AND SECTION V, ARTICLES 4 AND 6.
14. WHEN MATERIAL OPTION ASTM A182, GRADE F304 IS USED, INSPECT PER G/N 13.
15. WHEN MATERIAL OPTION ASTM A182, GRADE F304 IS USED, INSPECT PER G/N 13. WHEN MATERIAL OPTION ASTM A451, GRADE CPF8A IS USED, INSPECT PER F/N 12.
16. WELDMENT OF END CASTINGS (I/N 15 AND I/N 16) TO INNER AND OUTER SHELLS (I/N 17 AND I/N 18) SHALL COMPLY WITH TOLERANCE REQUIREMENTS OF ASME CODE, SECTION III, DIVISION 1, SUBSECTION NE, ARTICLE NE-4220.
17. O-RING MATERIAL, ACCEPTANCE TESTS, AND ACCEPTABLE DEVIATIONS IN PROPERTIES ARE PER SECTION 8.1.5.2 OF THE SAFETY ANALYSIS REPORT.
18. ELECTROLESS NICKEL PLATE TO A THICKNESS OF .0005 - .0010 INCHES IN ACCORDANCE WITH SAE-AMS 2404, REVISION F, CLASS 1 OR MIL-DTL-26074, REVISION F, CLASS 1, GRADE B.
19. PRIOR TO ASSEMBLY, OPTIONALLY COAT EACH O-RING WITH A THIN COAT OF VACUUM GREASE.
20. TIGHTEN CLOSURE BOLTS TO A TORQUE OF 200-240 FT-LB, USING A CROSSING PATTERN. COAT THREADS WITH A LOW-HALOGEN, NICKEL BASED NUCLEAR GRADE LUBRICANT PRIOR TO ASSEMBLY.
21. TIGHTEN PORT PLUG BOLT TO 8-10 FT-LB TORQUE.
22. TIGHTEN DRAIN PLUG BOLT TO 18-22 FT-LB TORQUE.
23. THE DESIGN PRESSURE IS 25 PSIG. THE CONTAINMENT BOUNDARY SHALL BE PRESSURE TESTED TO A MINIMUM OF 125% OF THE DESIGN PRESSURE AS REQUIRED BY SECTION 8.1.3.2 OF THE SAFETY ANALYSIS REPORT.
24. THE CONTAINMENT BOUNDARY SHALL BE LEAKAGE RATE TESTED TO DEMONSTRATE A LEAKAGE RATE NOT TO EXCEED 1.0E-7 REFERENCE CUBIC CENTIMETERS PER SECOND, AIR, PER ANSI N14.5, AS REQUIRED BY SECTION 8.1.4 OF THE SAFETY ANALYSIS REPORT.
25. A SHIELDING INTEGRITY TEST SHALL BE PERFORMED PER SECTION 8.1.6 OF THE SAFETY ANALYSIS REPORT.
26. LABEL TO BE MACHINED ENGRAVE, IMPRESSION STAMP, OR EQUIVALENT, CHARACTERS 3/8-INCH HIGH MINIMUM.
27. AN ANNULAR REGION OF LEAD UP TO 1/2 INCH SQUARE MAY BE REMOVED ADJACENT TO THE WELD TO PREVENT LEAD CONTAMINATION. SPACE MAY BE FILLED WITH CERAMIC ROPE OR EQUIVALENT. A WELD BACKING BAR MAY BE USED.
28. EXCEPT AS INDICATED, AND EXCLUDING SEAL, TACK, AND INTERMITTENT WELDS, AND ASSEMBLY A4, ALL WELDS SHALL BE LIQUID PENETRANT INSPECTED ON THE FINAL PASS IN ACCORDANCE WITH ASME CODE, SECTION III, DIVISION 1, SUBSECTION NF, ARTICLE NF-5000, AND SECTION V, ARTICLE 6.
29. LEAD SHEETS SHALL BE ULTRASONICALLY INSPECTED TO ENSURE NO VOIDS GREATER THAN 10% OF SHEET THICKNESS. SHEETS SHALL FILL THE CAVITY AND BE TIGHTLY FIT AND FORCEFULLY INSTALLED. ALL REMAINING GAPS SHALL BE PACKED WITH FITTED LEAD SCRAPS OR COMPRESSED LEAD WOOL.
30. THREAD INSERTS ARE OPTIONAL.
31. INSTALL ITEM 31 (PIPE) AFTER FINAL CLOSURE WELD OF SHIELD PLUG COMPLETED.
32. FOR UNDIMENSIONED FILLET WELDS, THE MINIMUM FILLET WELD LEG SIZE IS EQUAL TO THE THICKNESS OF THE THINNER BASE METAL BEING JOINED.
33. SPACERS, MADE FROM 12-GAUGE SHEET METAL (I/N 21), ARE LOCATED AS REQUIRED AROUND OUTER SHELL OD TO MAINTAIN GAP BETWEEN THERMAL SHIELD AND CASK BODY. SPACERS MAY BE ATTACHED USING CONTINUOUS OR INTERMITTENT FILLET WELDS.
34. PLATE THICKNESS GREATER THAN THOSE SPECIFIED IN THE LIST OF MATERIAL MAY BE USED IN ORDER TO ENSURE THE MINIMUM MILL PLATE THICKNESS AFTER MACHINING.
35. WEATHER SEAL MAY BE INSTALLED BETWEEN THE BRR CASK ASSEMBLY (ITEM A2) AND THE LOWER IMPACT LIMITER ASSEMBLY (ITEM 2).

(CONTINUED ON SHEET 3)

LIST OF MATERIALS

A4	A3	A2	A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
			X	A1		BRR PACKAGE ASSEMBLY	
		X		1	A2	BRR CASK ASSEMBLY	
	X			1	A3	SHIELD PLUG	
X				1	A4	PERSONNEL BARRIER ASSEMBLY	
			1	1	1910-01-02-SAR-A1	UPPER IMPACT LIMITER ASSEMBLY	
			1	2	1910-01-02-SAR-A2	LOWER IMPACT LIMITER ASSEMBLY	
			16	3	CL-16-BLPT	BALL LOCK PIN, 1 DIA, STAINLESS STEEL	CARR LANE OR EQUIV
17		1		4		O-RING, 17.88 +/- 1% ID X .375 +/- .007	BUTYL, RAINIER RUBBER R0405-70
17		1		5		O-RING, 20.125 +/- 1% ID X .375 +/- .007	BUTYL, RAINIER RUBBER R0405-70
17		2		6	NAS 1523C6N	SEALING WASHER, .38 ID	BUTYL, RAINIER RUBBER R0405-70
17		1		7	NAS 1523C10N	SEALING WASHER, .63 ID	BUTYL, RAINIER RUBBER R0405-70
		12		8		WASHER, .17 THK X 1.06 ID X 1.6 OD	ASTM A564, GRADE 630, COND H1025
		1		9		DUST COVER, BODY	ASTM B16 UNS C36000, H02 TEMPER
		2		10		DUST COVER, LID	ASTM B16 UNS C36000, H02 TEMPER
		1		11		ALIGNMENT PIN, .75 DIA	ASTM A276, UNS S21800
18		12		12		SHCS, 1-8UNC-2A X 2.5 LG	ASTM A320, TYPE L43
		1		13		SHCS, 5/8-11UNC-2A	ASTM B16 UNS C36000, H02 TEMPER
		2		14		SHCS, 3/8-16UNC-2A	ASTM B16 UNS C36000, H02 TEMPER
14 12		1		15		CASTING, UPPER BODY	ASTM A351, GR CF8A OR ASTM A182, GRADE F304
14 12		1		16		CASTING, LOWER BODY	ASTM A351, GR CF8A OR ASTM A182, GRADE F304
14 12		1		17		CASTING, INNER SHELL	ASTM A451, GR CPF8A OR ASTM A182, GRADE F304
34 15		1		18		PLATE, OUTER SHELL, 2.0 THK	ASTM A240, TYPE 304 OR ASTM A182 GRADE F304 OR ASTM A451, GRADE CPF8A
		1		19		ANGLE, 1 X 1 X 1/8	ASTM A276, TYPE 304
11		AR		20		LEAD, POURED	ASTM B29
		AR		21		SHEET, .105 THK (12 GA)	ASTM A240, TYPE 304
11	AR	AR		22		LEAD, SHEET	ASTM B29
	1	AR		23		PLATE, 1.0 THK	ASTM A240, TYPE 304
		16		24	KNH1608JMX-SY	HEAVY DUTY INSERT, 1-8UNC-2B X 1.4 LG	KEENSERT OR EQUIV

(CONTINUED ON SHEET 3)

REV	DESCRIPTION
6	SEE ECN NO. 1910-01-01-SARR5-E1, E2 & E3
5	SEE ECN NO. 1910-01-01-SARR4-E1 & E2
4	SEE ECN NO. 1910-01-01-SARR3-E1
3	SEE ECN NO. 1910-01-01-SARR2-E1
2	SEE ECN NO. 1910-01-01-SARR1-E1
1	SEE ECN NO. 1910-01-01-SARR0-E1

REVISION HISTORY

	NAME/SIGNATURE	DATE
EM	DSH DSHillstream	7/11/18
RE	P.NOSS P.Noss	7/11/18
TECH CHK	D. WICK	7/11/2018
DFTG CHK	D. WICK	7/11/2018
DRAWN	Q. LE	7/9/2018

NA | NA | NEXT ASSY | FINAL ASSY

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009 (REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

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Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

DWG TITLE
BRR PACKAGE ASSEMBLY
SAR DRAWING

MACHINE TOLERANCES:
FRACTION ± 1/4 — 2 PLACE DECIMAL ± .06
ANGLES ± 2° — 1 PLACE DECIMAL ± .2
WELD & FORMED TOLERANCES:
FRACTION ± 1/4 — 2 PLACE DECIMAL ± .12
ANGLES ± 2° — 1 PLACE DECIMAL ± .3

SCALE: NOTED | WT. ~ LBS
REV: 6 | SHEET 1 OF 5
DWG SIZE D | DWG NO. 1910-01-01-SAR
CADFILE: 19100101SAR6.SLDDRW
DWG - 3001275-006

[redacted]

SECTION B-B

TOP VIEW

[redacted]

SECTION A-A
(IMPACT LIMITERS AND PERSONNEL BARRIER REMOVED FOR CLARITY)
SCALE: 1/8

ASSEMBLY A1
SCALE: 1/8

[redacted]

SECTION L-L
SCALE: 1/2

DETAIL J
SCALE: 1/2

PERSONNEL BARRIER ASSEMBLY (A4) 38
SCALE: 1/8

SECTION K-K
SCALE: 1/1

LIST OF MATERIALS (CONTINUED)

A4	A3	A2	A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
	1	32		25		PLATE, 1/2 THK	ASTM A240, TYPE 304
34		1		26		PLATE, 2.0 THK	ASTM A240, TYPE 304
30	1		3	27	KNH813J	HEAVY DUTY INSERT, 1/2-13UNC-2B X .7 LG	KEENSERT OR EQUIV
	1			28		PLATE, 1 1/2 THK	ASTM A240, TYPE 304
	1			29		PLATE, 3/8 THK	ASTM A240, TYPE 304
	1			30		BAR, RD, 1.5 DIA	ASTM A276, TYPE 304
	1			31		PIPE, 3/4 SCH 40S	ASTM A312 OR A376, GR TP304
36	AR			32		EXPANDED SHEET, 3/4 #13	ASTM F1267, TYPE I OR TYPE II CLASS 3
	AR			33		SHEET, .135 (10 GA)	ASTM A240, TYPE 304
	16			34		SEAMLESS TUBE, Ø1 OD X .25 WALL	ASTM A511 GR MT304
	8			35		ANGLE, 1 X 1 X 1/8 THK	ASTM A276, TYPE 304
	32			36		PLASTIC PAD	ACETAL
	64			37		FLAT HEAD SCREW, 1/4-20 UNC-2A	STAINLESS STEEL
	8			38		PAD, .5 THK	FOAM RUBBER
	8			39		SHCS, 3/8-16 UNC-2A	STAINLESS STEEL
	16			40		FLAT WASHER, Ø3/8 NOM.	STAINLESS STEEL
	8			41		LOCK WASHER, Ø3/8 NOM.	STAINLESS STEEL
	8			42		HEX NUT, 3/8-16 UNC	STAINLESS STEEL

NOTES, UNLESS OTHERWISE SPECIFIED: (CONTINUED)

36 ITEM 32 MAY BE MADE FROM STANDARD OR FLATTENED EXPANDED METAL. ITEM SHALL HAVE A MINIMUM 75% OPEN AREA. APPEARANCE OF ITEM HAS BEEN ALTERED.

37 ATTACH USING LOCTITE 30537 ADHESIVE OR OTHER ADHESIVE DESIGNED TO ADHERE RUBBER TO METAL.

35 PERSONNEL BARRIER USED WHEN TRANSPORTING ISOTOPE TARGETS ONLY.

39 EXPANDED METAL BARRER SHEET (ITEM 32) TACK WELDED TO EDGE STRIPS (ITEM 33) AT REGULAR INTERVALS.

40 INSTALL FASTENERS HAND TIGHT.

[redacted]

ASSEMBLY A2
SCALE: 1 / 6

SEAL
TYP

[redacted]

SECTION C-C
SCALE: 1/6

SECTION D-D
SCALE: 1/2

[redacted]

SHIELD PLUG (A3) 34
SCALE: 1/2

CLOSURE LID
SCALE: 1 / 2

[redacted]

SECTION F-F
SCALE: 1/2

SECTION G-G
SCALE: 1/1

[redacted]

outer rows (10 holes per row). All plates are 0.5-in thick except for the topmost support plate, which is 1.25-in thick. All components are stainless steel except for a 6-in diameter aluminum bar within the central tube.

5.6.1.2 Summary Table of Maximum Radiation Levels

The package is shipped vertically-oriented under exclusive use requirements using an open (flat-bed) transport vehicle, with no credit taken for the use of a personnel barrier. The requirements for exclusive use under normal conditions for transport (NCT) and hypothetical accident conditions (HAC), per 10 CFR 71.47(b) and 10 CFR 71.51(a)(2), are summarized and applied as follows:

Limits for Normal Conditions for Transport

- 200 mrem/hr on the external surface of the package
- 200 mrem/hr for the projected outer surfaces of the transport vehicle (trailer side edges, assumed 4 feet from cask centerline, and the top and bottom surfaces of the impact limiters)
- 10 mrem/hr at any point 2 meters from the projected side surfaces of the transport vehicle
- 2 mrem/hr in any normally occupied space (assumed 25 feet from the package centerline)

Limits for Hypothetical Accident Conditions

- 1000 mrem/hr at any point 1 meter from the outer surfaces of the package (i.e. the cask only as no credit for the impact limiters is taken during HAC)

A summary of the maximum dose rates for isotope production target payloads are shown in Table 5.6-1 for NCT and HAC. Under NCT, the maximum package surface dose rate is 172.9 mrem/hr, the maximum vehicle surface dose rate is 57.3 mrem/hr, the maximum dose rate 2 meters from the vehicle surface is 3.1 mrem/hr, and the dose rate at the occupied location is 0.5 mrem/hr. Under HAC, the maximum dose rate at 1 meter from the vehicle surface is 25.4 mrem/hr.

Table 5.6-1 – Summary of Maximum Total Dose Rates (Exclusive Use) for Isotope Production Target Payloads

Normal Conditions of Transport	Package Surface (mrem/hr)			Vehicle Surface (mrem/hr)		
Radiation	**Top**	**Side**	**Bottom**	**Top**	**Side**	**Bottom**
Gamma (Total)	57.3	172.9	17.6	57.3	23.4	17.6
10 CFR 71.47 (b) Limit	200	200	200	200	200	200

Normal Conditions of Transport	2 Meters from Vehicle Surface (mrem/hr)			Occupied Location (mrem/hr)
Radiation	**Top**	**Side**	**Bottom**	**25 ft from cask center**
Gamma (Total)	-	3.1	-	0.5
10 CFR 71.47 (b) Limit	10	10	10	2

Hypothetical Accident Conditions	1 Meter from Package Surface (mrem/hr)		
Radiation	**Top**	**Side**	**Bottom**
Gamma (Total)	25.4	15.3	9.3
10 CFR 71.51 (a)(2) Limit	1000	1000	1000

5.6.2 Source Specification

Only Co-60 sources are modeled. Co-60 is a gamma and beta emitter, though from a package shielding standpoint, only gamma emissions contribute to dose rates. All source term data is calculated using the ORIGEN module of the SCALE 6.2.1 code package [11]. Isotope production targets are assumed to have no axial variation in gamma source strength. Systematic movement of targets during irradiation cycles within the ATR ensures minimal axial variation in source strength.

5.6.2.1 Gamma Source

Only a 1 kCi Co-60 source is modeled in ORIGEN. The source characteristics of the 1 kCi source are scaled as necessary to model different sources with varying strengths since the selected characteristics change proportionally with source strength. The 1 kCi source is selected for modeling in ORIGEN due to the ease of multiplicative scaling. Source intensity, gamma energy release rate, and total source decay heat for the 1 kCi modeled Co-60 source are shown in Table 5.6-2 alongside scaled total values for Type 1 and Type 2 payloads (see Section 5.6.3.1, *Configuration of Source and Shielding*, for payload descriptions). Table 5.6-2 is not a comprehensive representation of all source characteristic scaling. Gamma energy release rates are output by ORIGEN in units of MeV/sec and converted to units of watts using the conversion factor of 1.602×10^{-13} watts/(MeV/sec).

The gamma energy spectrum is taken from the ORIGEN discrete gamma data file (based on ENDF/B-VII.1 evaluations) and is shown in Table 5.6-3. Note that the sum of discrete gamma probabilities is greater than one since Co-60, on average, emits more than one gamma per decay.

5.6.2.2 Neutron Source

No neutron sources are utilized.

Table 5.6-2 – Co-60 Source Term Characteristics

Payload	Co-60 Activity (kCi)	Source Intensity (γ/s)	Total Decay Heat (W)	Gamma Energy Release Rate (W)
-	1	7.3948E+13	15.4	14.8
Type 1	82	6.0637E+15	1264.2	1217.0
Type 2	80	5.9158E+15	1233.4	1187.3

Table 5.6-3 – Co-60 Discrete Gamma Spectrum

Gamma Energy (MeV)	Probability of Gamma per Co-60 Decay
7.5100E-04	1.6946E-06
8.5234E-04	8.055E-07
8.7689E-04	1.3826E-08
8.8364E-04	5.6638E-07
7.4178E-03	3.1894E-05
7.4358E-03	6.2286E-05
8.2223E-03	3.9005E-06
8.2246E-03	7.6481E-06
8.2879E-03	3.3435E-09
8.2881E-03	4.8594E-09
3.4714E-01	7.5E-05
8.2610E-01	7.6E-05
1.1732E+00	0.9985
1.3325E+00	0.99983
2.1586E+00	1.2E-05
2.5057E+00	2E-08

5.6.3 Shielding Model

5.6.3.1 Configuration of Source and Shielding

All relevant design features of the BRR package are modeled in MCNP. Some assembly hardware (for example, the loading collar) and minor component geometry features (such as chamfers or small holes) are considered to have an insignificant effect on final results and are not modeled. The key dimensions relevant to the modeled cask, target basket, and target holder

(including targets) are summarized in Table 5.3-1, Table 5.6-4, and Table 5.6-5, respectively. The modeled package, target basket, and target holder are shown in Figure 5.6-1, Figure 5.6-2, and Figure 5.6-3, respectively. New-design targets are shown in Figure 5.6-4 while old-design targets are shown in Figure 5.6-5. The old-design target model geometry is representative of the two groups of old-design targets. Some details are not included in the dimension tables but may be inferred from the figures.

The shielding model used in analysis of the irradiated fuel payloads was developed prior to the completion of the packaging drawings. Inconsistencies between the model and the packaging drawings as well as lead slump and shrinkage are discussed in Section 5.3.1, *Configuration of Source and Shielding*.

The only geometry change made to the irradiated fuel payloads shielding model is the refinement of the impact limiters to include chamfered corners. This addition was made to ensure dose rates are measured as close as possible to the source. All air outside of the package in the irradiated fuel payloads model has been converted to void to simplify variance reduction.

The Type 1 payload may consist of up to 10 new-design or old-design targets. The maximum individual target activity is 14.1 kCi, while the maximum total payload activity is 82 kCi. Targets must be loaded into the inner row of target basket holes (the outer row is blocked by the loading collar, not modeled) and arranged, using a loading plan, into five zones of two (adjacent) holes each. The maximum activity within each zone is 22 kCi. The worst-case shielding and heating configuration is shown in Figure 5.6-6. Starting from the ~11 o'clock position and progressing clockwise, the source strengths are 4.9 kCi, 14.1 kCi, 7.9 kCi, 14.1 kCi, 14.1 kCi, 7.9 kCi, 14.1 kCi, and 4.9 kCi. This configuration is used for the joint NCT/HAC dose rate model as well as the thermal model.

The Type 2 payload may consist of up to 20 targets (old-design only). The maximum individual target activity is 4 kCi, resulting in a maximum possible activity of 80 kCi. There are no additional restrictions on how these targets may be loaded. The worst-case shielding and heating configuration, shown in Figure 5.6-7, is a fully loaded target basket of maximum activity targets. This configuration is used for the joint NCT/HAC dose rate model as well as the thermal model.

New-design and old-design targets can be transported in the BRR package at the same time, but the two cases modeled represent the bounding possible configurations (since the outer row is blocked whenever targets of activity greater than 4 kCi are transported). Joint NCT/HAC dose rate models have all target holders and targets shifted upwards the maximum amount possible to maximize package top dose rates. Thermal models have all target holders and targets in the expected positions for normal transport (i.e. the package is right-side up).

5.6.3.2 Material Properties

The target basket and target holders are manufactured out of stainless steel, with the exception of the aluminum rod inside the target basket central tube. The cask is constructed of stainless steel and lead. The isotope production targets are manufactured out of aluminum with embedded cobalt pellets. The new-design target rods include an internal helium-filled cavity, modeled at atmospheric pressure.

The stainless steel, dry air, and lead compositions and densities are the same as those used in the irradiated fuel payload shielding analysis, detailed in Section 5.3.2, *Material Properties*. The aluminum composition and density utilized is obtained from [12] and provided in Table 5.6-6.

Cobalt and helium are modeled as pure with densities of 8.9 g/cm^3 [13] and 0.000166 g/cm^3 [12], respectively.

The old-design target rods are modeled as a homogenous aluminum-cobalt mixture to account for the presence of the embedded cobalt pellets without explicit modeling. The 4158 cobalt pellets (per target rod) are 0.0394-in diameter, 0.0394-in long cylinders, while the modeled aluminum target rod is a 0.417-in diameter, 16-in long bored cylinder with a wall thickness of 0.125 inches. The calculation of the mixture density and elemental composition is performed using the aluminum listed in Table 5.6-6 and pure cobalt. The resulting homogenous mixture is, by mass, 29% cobalt and 71% aluminum with a density of 3.37 g/cm^3. The resulting mixture composition is shown in Table 5.6-7.

All empty space within the cask is modeled as dry air. Empty space outside the cask is modeled as void. The impact limiters are also modeled as void.

Table 5.6-4 – Key Target Basket Model Dimensions

Item	Dimension (in)
Overall height	53.45
Central tube outer diameter	6.5
Central tube thickness	0.25
Support plate diameter	15.63
Bottom, lower middle, and upper middle plate thickness	0.5
Top plate thickness	1.25
Inner target hole alignment diameter	9.0
Outer target hole alignment diameter	13.0
Top plate target hole diameter	1.375
Upper middle plate target hole diameter	1.125
Aluminum bar diameter	5.9
Aluminum bar height	50.5

Table 5.6-5 – Key Target Holder and Target Model Dimensions

Item	Dimension (in)
Target Holder	
Overall height	23.74, modeled as 23.94
Tubing outer diameter	0.875
Tubing thickness	0.065
Collar and cap hexagonal minimal diameter	1.13
Collar height	2.0
Cap height	3.50
Grapple plate height	3.20, modeled as 3.40
New-Design Target	
Overall height	16.015
Overall diameter	0.460
Source region height	14.765
Pellet alignment diameter	0.335
Pellet diameter	0.043
Helium cavity diameter	0.28
Old-Design Target (0.5" outer diameter modeled)	
Overall Height	16.0
Source rod outer diameter	0.417
Source rod thickness	0.125
Housing outer diameter	0.4775
Housing inner diameter	0.430
Source region height	15.0
Source region depth	0.0394