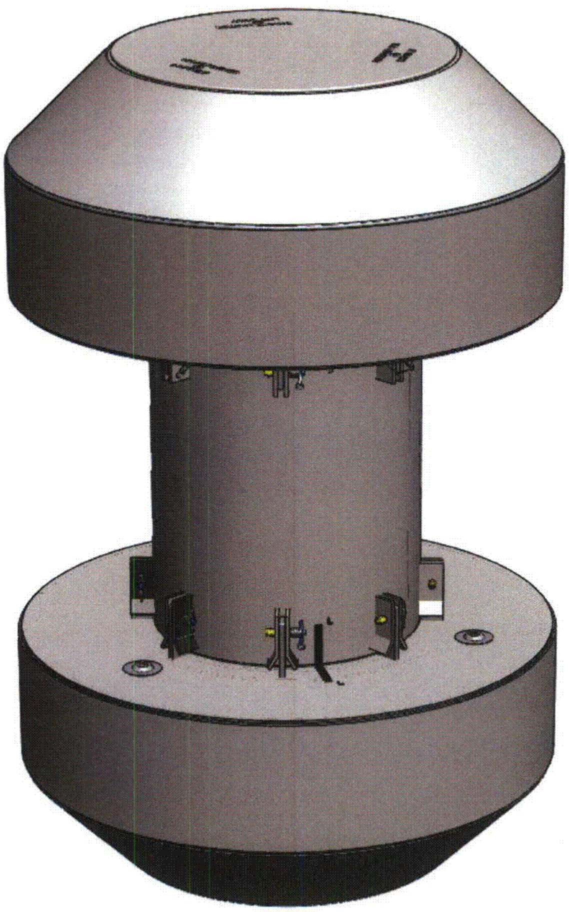
DOCKET 71–9341

BEA Research Reactor Package



Safety Analysis Report

Revision 4

AREVA Federal Services LLC

December 2010

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in–place through the upper end structure, and is nominally 8 inches thick. The shield at the bottom is made from lead sheet material that is packed firmly into place, and is 7.7 inches thick. The bottom lead cavity is closed using a one inch thick plate secured with a full penetration groove weld, see Zone A6/7 of sheet 3 of drawing 1910–01–01–SAR.

The removable shield plug is located at the top of the payload cavity. The outer shell is made from Type 304 plate material of 1/2–inch, 3/8–inch, 1–inch, and 1½–inch thickness. See Zone D2 of sheet 4 of drawing 1910–01–01–SAR. The cavity is filled with lead sheet material that is packed firmly into place. The total thickness of the plug is 11.2 inches, and the lead thickness is 9.7 inches. The plug rests on a shoulder located approximately half way along the length of the plug. A corresponding shoulder is located in the upper end structure of the cask body to support the shield plug. A 3/4–inch diameter pipe passes through the plug to ensure proper draining and drying of the cask. The pipe is oriented approximately diagonally to prevent a deleterious shine path. The shield plug is lifted using a central, 1/2–13 UNC threaded hole.

The closure lid is made from 2–inch thick, ASTM A240, Type 304 stainless steel plate. It is attached to the cask using 12, 1–8 UNC bolts made of ASTM A320, Grade L43 material, with hardened steel washers. The bolts are plated with electroless nickel per MIL–DTL–26074 Rev. F Class 1 Grade B, and tightened to a torque of 220 ± 20 ft-lb. The mating holes in the cask body may be optionally fitted with heavy duty thread inserts. The mating surface of the lid features a step relief located at the bolt circle. This relief prevents any contact from occurring between the lid and the body outside of the bolt circle, thus preventing prying loads from being applied to the closure bolts. The closure lid includes two O–ring seals made from butyl rubber of 3/8–inch cross sectional diameter. The inner O–ring is the containment seal, and the outer is the test seal. The seals are retained in dovetail grooves in the lid. The O–ring material (including the sealing washers, see below) is made from Rainier Rubber R-0405–70, and subject to the tests given in Section 8.1.5.2.

The BRR package provides a single level of leaktight containment. The containment boundary of the BRR package consists of the following elements. Unless noted, all elements are made of ASTM Type 304 stainless steel in various product forms.

- The lower massive end structure (including the passage to the drain port)
- The inner cylindrical shell
- The upper massive end structure
- The containment elastomer O–ring seal (the inner seal in the closure lid)
- The closure lid
- The vent port in the closure lid including elastomer sealing washer
- The drain port in the lower end structure including elastomer sealing washer

The containment boundary is shown in Figure 1.2-12.

As noted above, the BRR package features two ports that are part of the containment boundary: a vent port in the closure lid, and a drain port in the lower end structure. Both ports are closed with threaded plugs made of ASTM B16 brass and sealed with butyl rubber sealing washers. A

threaded brass cover is used to protect the port plugs. A seal test port is located between the containment O–ring seal and test O–ring seals, and is not part of containment.

1.2.1.2 Impact Limiters

Impact limiters are attached to each end of the BRR package, having essentially identical design, and are shown in drawing 1910–01–02–SAR. Each limiter is 78 inches in diameter and 34.6 inches long overall, with a conical section 15 inches long towards the outer end. The impact limiter design consists of Type 304 stainless steel shells and approximately 9 lb/ft^3 polyurethane foam. The external shells (except for the end plate) are 1/4 inches thick, and the internal shells (that interface with the cask body) are 1/2 inches thick. The outer end plate is 1/2 inches thick. The closure end impact limiter features three reinforced, 1/2–13UNC holes for lifting of the impact limiter only. An optional drain tube, aligned along the long axis of the cask, may be included in the lower impact limiter. The polyurethane foam is rigid, closed–cell, and is poured in place. On the side that mates with the cask, the annular sheet features three plastic melt–out plugs designed to relieve pressure in the HAC fire event. The attachment of the impact limiters to the cask body is described in Section 1.2.1.1, *Cask Body*.

1.2.1.3 Baskets

There are four baskets used with the BRR package, one for each type of fuel transported, and are shown in drawing 1910–01–03–SAR. The baskets are made from welded construction using Type 304 stainless steel in plate, bar, pipe, and tubular forms. Each basket has a diameter of 15.63 inches and a length of 53.45 inches, and features a number of cavities that fit the size and shape of the fuel. The cavities are sized to minimize free play between the fuel and the basket, while ensuring free insertion and removal of the elements. The baskets are open on the top, and the fuel is located at the top end, nearest the shield plug. The baskets are designed to freely drain water when the cask is lifted out of the spent fuel pool.

1.2.1.3.1 MURR

The MURR basket consists of an outer rolled shell, an inner pipe, and thick radial plates that form eight pie–shaped cavities for the fuel in a circular array. The bottom of the fuel cavities is formed by a 3/8–inch thick plate that is welded to the inside of the shell. The lifting bar divides the interior of the inner tube in half and prevents loading any fuel within the inner tube. The MURR basket is shown in Figure 1.2-4.

1.2.1.3.2 MITR–II

The MITR-II basket consists of a cylindrical weldment supported by a 14 inch diameter pedestal. Twenty-nine (29) flat plates of variable thicknesses are machined and stacked to create eight (8) diamond shaped fuel cavities. Fuel cavities are arranged symmetrically about the center axis of the basket. The top plate of the weldment is machined to prevent the loading of fuel into the central cavity of the basket. The bottom plate of the weldment provides support for the fuel and allows for drainage of water from the fuel cavities. The MITR–II basket is shown in Figure 1.2-5.

DWG NO 1910-01-01-SAR REV 4 SH 1

Figure Withheld Under 10 CFR 2.390

AREVA	AREVA Federal Services LLC Packaging Projects Tacoma, WA 98402
DWG TITLE	BRR PACKAGE ASSEMBLY SAR DRAWING
SCALE: SHOWN	WT. - LBS
REV: 4	SHEET 1 OF 4
SIZE D	DWG NO. 1910-01-01-SAR

A

2

1

Figure Withheld Under 10 CFR 2.390

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AREVA	AREVA Federal Services LLC Packaging Projects Tacoma, WA 98402
DWG TITLE	BRR PACKAGE IMPACT LIMITER SAR DRAWING
SCALE: NOTED	WT. ~ [illegible]
REV: 1	SHEET 1 OF 2
DWG SIZE: D	DWG NO. 1910-01-02-SAR
CADFILE: [illegible]	[illegible]

Figure Withheld Under 10 CFR 2.390

Figure Withheld Under 10 CFR 2.390

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Packaging Projects
Tacoma, WA 98402

DWG TITLE
BRR PACKAGE FUEL BASKETS
SAR DRAWING

SCALE: SHOWN	WT. ~ LBS	
REV: 4	SHEET 1 OF 3	
DWG SIZE D	DWG NO. 1910-01-03-SAR	

Figure Withheld Under 10 CFR 2.390

Figure Withheld Under 10 CFR 2.390

A comparison of the calculated ('Calc') and full-scale equivalent test ('Actual') impact limiter performance is given in Table 2.12.5-24. A negative sign in the '% Less' columns indicates that the test result was lower than the calculated value.

2.12.5.4 Analysis of Optional Drain Tube

An optional drain tube may be included in the lower impact limiter. The drain tube is made from Type 304 stainless steel tube with an outer diameter of 5/8" and a wall thickness of 0.05 ± 0.02 inches.

The lower end of the drain tube is welded to the penetration in the impact limiter shell with a weld nominally equal to the thickness of the tube wall thickness.

The upper end of the tube is inserted over a transitional fitting which is welded to the inner shell of the impact limiter. This fitting is sized to allow for free axial movement between the tube and fitting. This arrangement prevents any axial load from being applied to the tube from the weight of the cask during normal use.

Under free end drop conditions, the tube is intended to crush along with the impact limiter foam. With an ultimate tensile stress of σ_U = 75 ksi, the maximum force applied by the tube may be calculated with the maximum cross-sectional area.

$$A = \frac{\pi}{4}\left[d_o^2 - d_i^2\right] = 0.123\ in^2$$

where the outer diameter of the tube is d_o = 0.63 inches, and the minimum inner diameter is d_i = 0.49 inches for a maximum wall thickness of 0.07 inches. A conservative upper bound compressive load will therefore be:

$$F = \sigma_U A = 9{,}225\ lb$$

For a package weight of 32,000 lbs, this applies an insignificant acceleration of 0.3g. This result is rather conservative as it ignores buckling of the tube and assumes uniform flow of the material at a value equal to the ultimate stress.

A bounding value for the HAC end drop impact of 120g (See Section 2.7.1.1, *Impact Forces and Deformation*) was used to bound the full-scale equivalent end drop test result of 58g (from Table 2.12.5-23.) Therefore the loading due to the drain tube on the package is of negligible concern.

2.12.5.5 Conclusion

The impact limiter evaluation is used to establish a bounding impact magnitude for stress analysis in other sections of this SAR. The maximum impact occurs in the cold temperature case. For NCT, the maximum overall impact is equal to 32.9g in the 90° orientation, from which a bounding impact for all orientations of 40g is taken. For HAC, the maximum overall impact is 86.8g in the 15° secondary slapdown impact, and a very conservative value of 120g is used as a bounding impact for all orientations.

The maximum strain occurs under HAC in the hot temperature case, and equals 83.2% in the 15° secondary slapdown case.

8. Hold at temperature for 8 hours. Create a hard vacuum between the two test O-rings to confirm their integrity. A helium leakage rate test was not performed due to the tendency toward rapid saturation of the O-rings with helium at elevated temperature.
9. Chill the fixture to -20 °F, maintaining the inner ring in the shifted position.
10. Perform a final helium leakage rate test with the fixture still at -20 °F.

For each test, the maximum and minimum compressions were calculated using the dimensions of the fixture and of the test O-rings. The principal result of these tests was a demonstration that the subject rubber compound is capable of maintaining a leaktight condition at -20 °F with a minimum compression of 14.9% subsequent to an 8 hour soak at 400 °F. Details of the five small fixture tests are given in Table 2.12.7-1, adapted from Table 2.10.7-1 of [2]. Note that the term 'disk' in the table corresponds to the term 'inner ring' used in this description.

The second set of tests was performed in 1999, and are documented in Section 2.10.7.4A of [2]. These tests served to lower the minimum compression value at which a leaktight condition was demonstrated to be maintained. The tests used the same small test fixture, modified to allow it to achieve a lower minimum compression. The same test procedure was followed, except that all tests were run at a temperature of 400 °F. The principal result of these tests was a demonstration that the subject rubber compound is capable of maintaining a leaktight condition at -20 °F with a minimum compression of 12.9% subsequent to an 8 hour soak at 400 °F. Details of the three tests are given in Table 2.12.7-2, adapted from Table 2.10.7.4A-2 of [2].

2.12.7.2 Performance Tests Associated with the RTG Package

2.12.7.2.1 Face Seal Tests

O-ring tests were also performed in support of the Radioisotope Thermoelectric Generator (RTG) package certification (DOE Docket 94-6-9904). The results are reported in Section 2.10.6 of [3]. In these tests, a face-type fixture was used which permitted four different compressions to be tested at once. Unlike the TRUPACT-II testing, and consistent with the conditions in a face-type configuration, the O-rings were not mechanically moved or disturbed throughout the test. The fixture consisted of an inner plate having three concentric grooves on each side. Each groove had a different depth and contained an O-ring made from butyl compound R-0405-70 as described above. The inner and outer O-rings on each side were the test specimens; the center O-rings were used only to support leakage rate testing of the test specimens. The O-rings were compressed by outer plates which were set off from the inner plate by shims which, along with the groove depths, controlled the amount of compression of each test O-ring. The nominal test O-ring cross-sectional diameter was 0.275 inches. The minimum compression created by the fixture was 10%, which was uniform around the entire circumference of the fixture. Compressions of 12%, 14%, and 15.5% were tested at the same time. The dimensions of the fixture and of the test specimens, and the resulting compression values, are shown in Table 2.12.7-3.

The time/temperature sequence was as follows:

1. Assemble the test fixture at ambient conditions and perform a helium leakage rate test.
2. Chill the fixture to -40 °F and perform a helium leakage rate test.

3. Heat the fixture to 380 °F, and hold for 24 hours. Confirm integrity of the test O-rings by placing a hard vacuum on the test cavity (less than 0.2 mbar).
4. Allow the fixture to cool to 350 °F, and hold for 144 hours. The total time at elevated temperature is 168 hours, or one full week. Confirm integrity of the test O-rings by placing a hard vacuum on the test cavity (less than 0.2 mbar).
5. Cool the fixture to -20 °F and perform a final helium leakage rate test.

Each of the helium leakage rate tests demonstrated a leakage rate below the leaktight criterion of 1×10^{-7} ref-cc/sec, air, as defined by [1]. Of note, only the results from the outer O-ring tests (10% and 14% compression) were available at the time of publication of [3]. The successful completion of the inner O-ring tests (12% and 15.5% compression) was confirmed in [4].

2.12.7.2.2 Bore Seal Tests

Further O-ring tests were performed by Westinghouse Hanford Company in association with the RTG package, and documented in [5] and [6][2]. In these tests, the same bore-type fixture was used as that used for the TRUPACT-II tests described in Section 2.12.7.1, *Performance Tests Associated with the TRUPACT-II Package*. The procedure differed slightly in that a cold shift (step no. 5 from Section 2.12.7.1) was not performed. The test sequence was as follows:

1. Assemble the fixture at ambient conditions, and shift the inner ring fully to one side, generating minimum compression on one side and maximum on the other. Perform a helium leakage rate test.
2. Chill the fixture to -40 °F and perform a helium leakage rate test.
3. Heat to the specified elevated temperature and hold for the specified time. At the end of the hold time, perform a helium leakage rate test (saturation with helium at the high temperature was not reported to have had an effect on the helium leakage rate test).
4. Chill the fixture to -20 °F and perform the final helium leakage rate test.

For each test, the maximum and minimum compressions were calculated using the dimensions of the fixture and of the test O-rings. A number of different time/temperature tests were run, showing leaktight performance of the butyl material for 430 °F for one hour [6], 375 °F for 25 hours [6], and 350 °F for 168 hours [5]. Data is summarized in Table 2.12.7-4.

2.12.7.3 Long Term Performance of Butyl Rubber Seals

The tests of the Rainier Rubber R-0405-70 compound described in this appendix were performed at relatively high temperatures for relatively short times, consistent with the HAC fire event. Demonstration of the performance of the material at the lower temperature and longer duration associated with the NCT hot environment is made by extrapolation of this data.

Reference 7 uses thermogravimetric analysis to predict the relative lifetimes of some elastomers. One of the results of this study is to show that elastomer lifetime is linear when plotted on a log-

[2] Note that some of the test reports refer to the material as 'RR-0405-70' while in some instances, 'R-0405-70' is used. Both refer to the same compound, where 'RR' is used for uncured material, and 'R' for a cured product form. All testing was performed on cured material.

lifetime (ordinate) vs. 1000/Temp (K) (abscissa) scales. This is shown in figure 3 of [7], which is reproduced as Figure 2.12.7-1. The curve for butyl will not necessarily have the same slope or be placed in the same position relative to the scales as is shown in the figure. The position and slope for butyl will need to be established using the test data. Then, using linear extrapolation, its performance at longer lifetimes can be found. Note, since the abscissa is based on the inverse of temperature, temperature is actually decreasing along the abscissa towards the right, even though the values of 1000/Temp (K) are increasing. Consequently, the longest lifetimes correlate to the lowest temperature, as expected.

Figure 2.12.7-2 shows several time/temperature data points from the tests discussed above, along with the best-fit line through the data. For consistency, only data from the bore-type test fixture are considered. Note that this is not a locus of exact failure points (points defining the border between pass/fail), but of tests that passed (i.e., met the leaktight requirements of [1]). The possibility exists that some or all of these tests were "undertests", i.e., were not tested to the extreme limit of the material. Because the margin to failure may be different for each test, the actual locus of borderline results (zero-margin pass) may have a shallower slope than the best-fit curve to the data. If that curve were used to extrapolate upward to longer lifetimes, it might over predict the acceptable temperature (recall that temperature is decreasing to the right).

For the BRR package, it is desired to determine the acceptable temperature for leaktight performance for a duration of one year (8,760 hours). The most conservative extrapolation (the lowest acceptable temperature) will be generated from the data curve fit having the shallowest (conservative) slope. To find the shallowest slope, a data point for a test failure (450 °F for 8 hours) is introduced, as shown in Figure 2.12.7-3. This is taken from the TRUPACT-II test results shown in Table 2.12.7-1. The straight line between this failure point and the longest-term successful data point (350 °F for 168 hours) has the shallowest slope which is consistent with the known data points. This can be concluded from the following observations:

1. The 450 °F/8 hour data point cannot be an undertest, since it is a known failure. Therefore, the actual zero-margin pass temperature must lie to the right of, but not to the left of, the test data point.
2. The 350 °F/168 hour data point is likely somewhat undertested. Therefore, the actual zero-margin pass temperature must lie to the left of, but not to the right of, the test data point.
3. Consequently, the actual locus of zero-margin performance could be steeper than, but could not be shallower than, the line formed by joining the 450 °F/8 hour and 350 °F/168 hour data points.

The equation of the line connecting these two data points is:

$$\mathrm{Log}_{10}(\mathrm{hrs}) = 5.396(1000/T(K)) - 9.775$$

Using this expression, the maximum leak tight temperature for 8,760 hours (one year) is 249 °F. Therefore, the R-0405-70 butyl material can be held at at least 249 °F for one full year (constant temperature night/day) and is expected to be leak tight per ANSI N14.5. This is the most conservative extrapolation that can be made from the known data and is essentially equal to the long term limit for the butyl material of 250 °F which is stated in Section 3.2.2, *Technical Specification of Components*.

2.12.7.4 Summary

The butyl rubber compound used for the BRR package containment seals was tested in both a bore-type and a face-type test fixture at low compression and elevated temperature. In the bore-type testing, the O-rings were demonstrated to be helium leaktight at a temperature of -20 °F after a soak at 400 °F for 8 hours at a minimum compression of 11.9%. In the face-type testing, the O-rings were demonstrated to be helium leaktight at a temperature of -20 °F after a soak at 380 °F for 24 hours followed by a soak at 350 °F for 144 hours at a minimum compression of 10%. These compression and temperature/time conditions exceed the severity of those experienced in the BRR package. In addition, the seals are expected to be leaktight after one full year at a constant temperature of at least 249 °F. Because this value was conservatively obtained, the value of 250 °F used in Section 3.2.2, *Technical Specification of Components* is acceptable. The minimum compression of the BRR package containment seal O-ring is calculated in Section 4.1.3, *Seals*, and the maximum temperature under NCT and HAC is discussed in Chapter 3, *Thermal Evaluation.*

Table 2.12.7-1 – TRUPACT–II O-ring Seal Performance Test Results (1989)⑦

Test Number	O-ring Seal Cross-Sectional Diameter (inches)				Stretch (%)		Maximum Gap (inches)		Minimum Compression (%)				Soak Temperature and Helium Leakage Rate Test Results ④				
	O-ring Seal No. 1		O-ring Seal No. 2				Disk	Disk	Disk Centered		Disk Offset		Disk Centered		Disk Offset		
	Min	Max	Min	Max	Min	Max	Center	Offset	Min	Max	Min	Max	Ambient	-40 °F	-20 °F	8 hrs⑤	-20 °F
1	0.387	0.397	0.387	0.396	2.0	4.1	0.026	③	22.1	25.6	14.9	20.0	Yes	Yes	Yes	350 °F	Yes
2	0.388	0.398	0.387	0.398	2.0	4.1	0.029	0.050	21.3	25.1	15.7	19.7	Yes	Yes	⑥	450 °F	No
3	0.387	0.397	0.387	0.399	2.0	4.1	0.027	0.052	21.9	25.8	15.2	19.4	Yes	Yes	Yes	400 °F	Yes
4	②	②	②	②	2.0	4.1	0.027	0.053	21.9	25.8	**14.9**	19.1	Yes	Yes	Yes	**400 °F**	**Yes**
5	②	②	②	②	2.0	4.1	0.026	0.050	22.1	26.0	15.7	19.9	Yes	Yes	Yes	400 °F	Yes

Notes:

① Material for all O-ring seal test specimens was butyl rubber compound R-0405-70, Rainier Rubber Co., Seattle, WA.

② Not measured; calculations assume the worst case range as taken from Tests Numbers 1 - 3 (i.e., Ø0.387 minimum to Ø0.399 maximum).

③ Range of values is 0.048 in. minimum to 0.053 in. maximum due to an indirect method of gap measurement (used for this test only).

④ A "Yes" response indicates that helium leakage rate testing demonstrated a leaktight condition as defined in [1], i.e., the leakage rate was less than or equal to 1×10^{-7} ref-cc/sec, air. In all cases, measured leak rates were less than or equal to 2.0×10^{-8} ref cc/s, helium, for tests with a "Yes" response.

⑤ No helium leakage rate tests were performed at elevated temperatures due to O-ring seal permeation and saturation by helium gas. The ability of the test fixture to establish a rapid, hard vacuum between the O-ring seals was used as the basis for leakage rate test acceptance at elevated temperatures. All tests rapidly developed a hard vacuum, with the exception of Test Number 2 at an elevated temperature of 450 °F, which slowly developed a vacuum.

⑥ Initial leakage rate of 1.0×10^{-5} ref cc/s, helium; became leaktight approximately one minute later.

⑦ Adapted from Table 2.10.7-1 of [2].

Table 2.12.7-2 – Supplementary TRUPACT–II O-ring Seal Performance Test Results (1999)④

Test No.	Disk Centered % Comp.		Disk Offset % Comp.		Helium Leak Tight②				
	O-ring #1	O-ring #2	O-ring #1	O-ring #2	Ambient Temp.	-40 °F	-20 °F (Disk Offset)	Hot Soak (Disk Offset)③	-20 °F (Disk Offset)
1	18.5	17.9	12.7	12.0	Yes	Yes	Yes	Held Vacuum	Yes
2	20.8	20.0	12.9	**11.9**	Yes	Yes	Yes	Held Vacuum	**Yes**
3	19.2	19.2	12.1	12.1	Yes	Yes	Yes	Held Vacuum	Yes

Notes:

① Material for all O-ring seal test specimens was butyl rubber compound R-0405-70, Rainier Rubber Co., Seattle, WA.

② Seal is considered to be leaktight if the actual leakage rate is less than or equal to 8×10^{-8} atm-cc/sec.

③ Hot soak was 8 hours at a uniform temperature of 400 °F.

④ Adapted from Table 2.10.7.4A-2 of [2].

Table 2.12.7-3 – RTG O-ring Face Seal Performance Test Parameters③

Fixture Side	Outer groove depth, in.	Inner groove depth, in.	Shim Thickness, in.	Outer O-ring X-section, in.	Inner O-ring X-section, in.	Outer O-ring compression, %	Inner O-ring compression, %
Side A	0.2053	0.2000	0.044	0.2770	0.2773	10	12
Side B	0.2075	0.2033	0.031	0.2776	0.2774	14	15.5

Notes:

① Material for all O-ring seal test specimens was butyl rubber compound R-0405-70, Rainier Rubber Co., Seattle, WA.

② Each of the four test O-ring seals were leaktight per [1] when tested at a temperature of -20 °F following the time/temperature sequence of 380 °F for 24 hours followed by 350 °F for 144 hours.

③ Adapted from Table 4.1-1 and Table 4.1-2 of [3].

Table 2.12.7-4 – RTG O-ring Bore Seal Performance Test Parameters

Test No.	Min Compression, %	Max Compression, %	Max Temperature, °F	Hold Time, hours	Data Source
4	17.5	30.5	350	168	Table 3 of [5]
4B	17.8	31.3	375	25	Table 3 of [6]
3	19.2	32.3	430	1	Table 3 of [6]

Notes:

① Material for all O-ring seal test specimens was butyl rubber compound R-0405-70, Rainier Rubber Co., Seattle, WA.

② O-ring seals were leaktight per [1] when tested initially at room temperature, at a temperature of -40 °F, again at the stated maximum temperature at the end of the hold time, and finally when chilled to -20 °F.

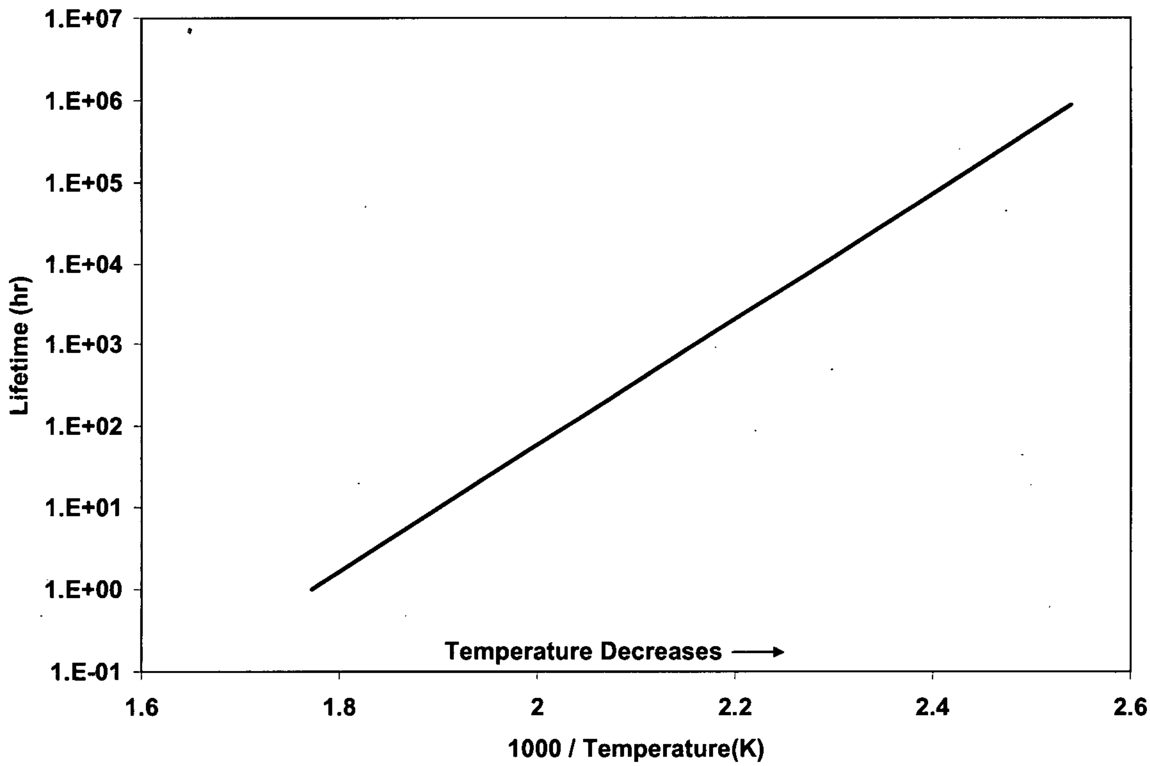

Figure 2.12.7-1 – Elastomer Time-Temperature Behavior (adapted from Figure 3 of [7])

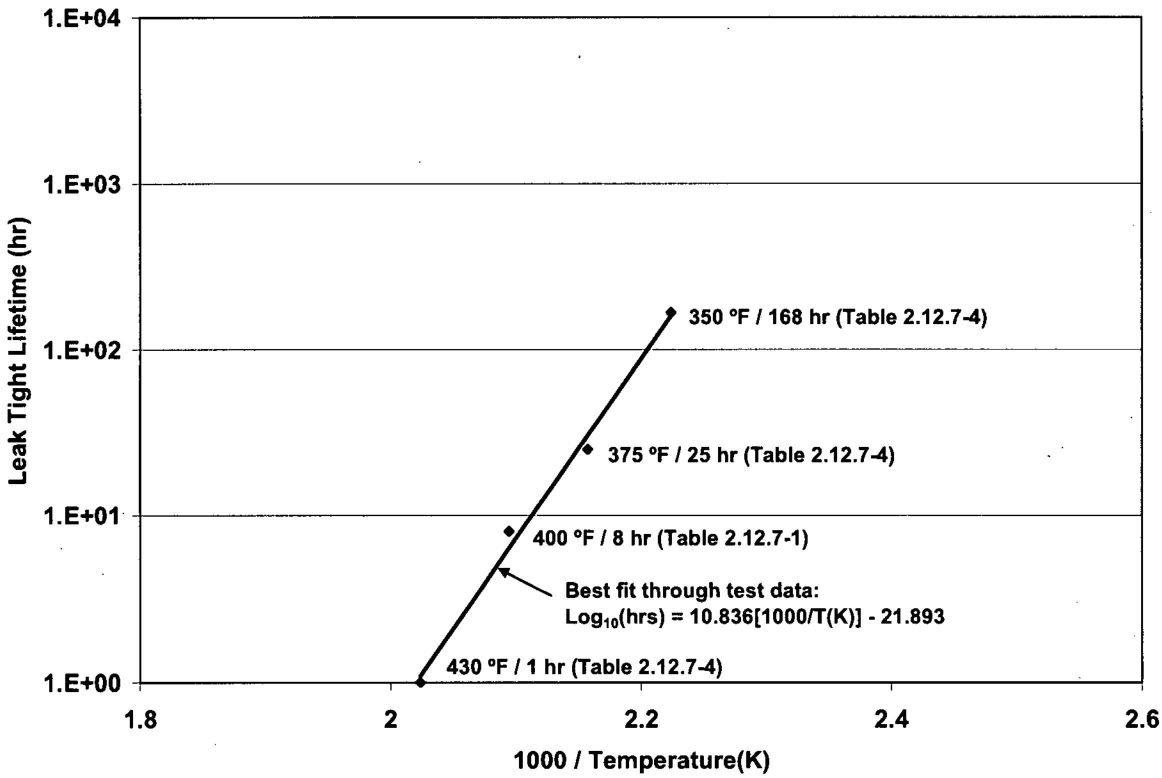

Figure 2.12.7-2 – R-0405-70 Test Data and Best Fit Curve

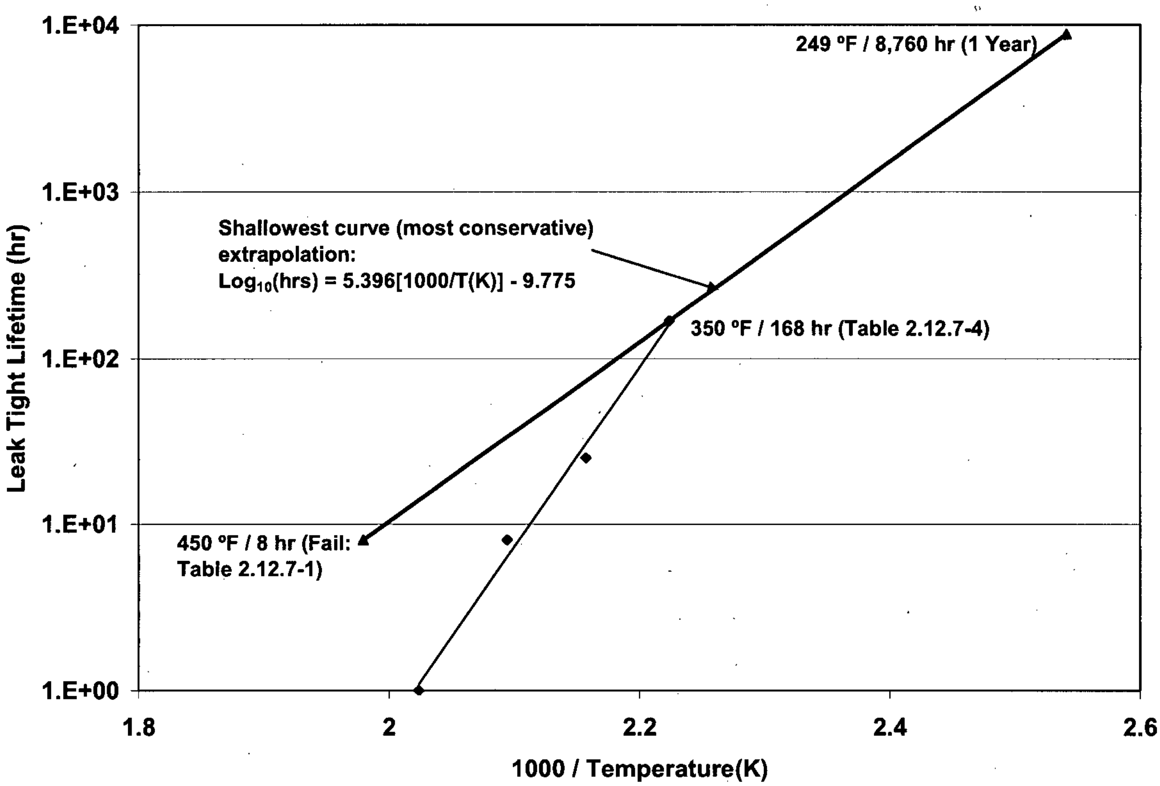

Figure 2.12.7-3 – Conservative Extrapolation to One Year

2.12.7.5 References

1. ANSI N14.5-1997, *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment*, American National Standards Institute (ANSI), Inc.
2. *Safety Analysis Report for the TRUPACT-II Shipping Package*, USNRC Docket 71-9218, Revision 18, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.
3. DOE Docket No. 94-6-9904, *Radioisotope Thermoelectric Generator Transportation System Safety Analysis Report for Packaging*, WHC-SD-RTG-SARP-001, prepared for the U.S. Department of Energy Office of Nuclear Energy under Contract No. DE-AC06-87RL10930 by Westinghouse Hanford Company, Richland, WA.
4. Westinghouse Hanford Company, *RTG Transportation System Packaging O-ring Material Thermal Validation Test Report for Face Seal Test Fixture*, WHC-SD-RTG-TRP-010, Rev 0.
5. Westinghouse Hanford Company, *Radioisotope Thermoelectric Generator (RTG) Transportation System Packaging O-ring Material Thermal Validation Test Report*, WHC-SD-RTG-TRP-001, Rev. 1.
6. Westinghouse Hanford Company, *Radioisotope Thermoelectric Generator (RTG) Transportation System Packaging O-ring Material Elevated Temperature Test Report*, WHC-SD-RTG-TRP-002, Rev. 0.
7. Nigrey, P. J., *Prediction of Packaging Seal Life Using Thermoanalytical Techniques*, Proceedings of the 12th International Conference on the Packaging and Transportation of Radioactive Materials, PATRAM 98, Vol. 4, p. 1730.

Table 3.1-1 – Maximum Temperatures for NCT and HAC Conditions

Location / Component ①	NCT Hot Conditions, °F	Accident Conditions, °F	Maximum Allowable	
			Normal	Accident
Fuel Element Plate	350	451	400	1,100
Fuel Element Side Plate	348	449	400	1,100
Fuel Basket	334	437	800	800
Inner Shell	237	393	800	800
Lead	234	482	620	620
Outer Shell	216	704	800	2,700
Thermal Shield	185	1,256	800	2,700
Lower End Structure	205	335	800	800
Upper End Structure	222	485	800	800
Shield Plug	230	317	620 ②	620 ②
Cask Lid	218	306	800	800
Closure/Vent Port Elastomeric Seals	217	306	250	400
Drain Port Elastomeric Seal	202	373	250	400
Upper Impact Limiter				
- Max. Foam	217	-	300	N/A
- Avg. Foam	147	-	300	N/A
- Shell	217	1,475	250 ③	2,700 ④
Lower Impact Limiter				
- Max. Foam	200	-	300	N/A
- Avg. Foam	142	-	300	N/A
- Shell	200	1,475	250 ③	2,700 ④
Max. Accessible Surface without Insolation	185 ⑤	-	185	N/A
Cask Cavity Bulk Gas	259	388	N/A	N/A

Notes: ① Results based on either a payload of eight (8) MURR fuel elements dissipating 158 W each or a payload of eight (8) MITR-II fuel elements dissipating 150 W each and helium as the backfill gas.

② Temperature criterion based on melting point of the enclosed lead shielding.

③ Temperature criterion based on long term temperature limit for shell coating.

④ Temperature criterion based on melting point for the shell. No criteria for the polyurethane foam since its thermal decomposition serves as it principal means of providing thermal protection during the HAC event.

⑤ Maximum temperature occurs at the root of the upper cask impact limiter attachment lugs.

Table 3.3-1 – NCT Temperatures for BRR Packaging with MURR Fuel

Component	Temperature (°F) ①		
	NCT Hot ④	NCT Hot without Solar	Max. Allowable
MURR Fuel Plate	350	331	400
MURR Side Plate	348	329	400
MURR Fuel Basket	334	315	800
Inner Shell	237	216	800
Lead	233	213	620
Outer Shell	216	195	800
Thermal Shield	185	182	800
Lower End Structure	205	184	800
Upper End Structure	220	200	800
Shield Plug	225	205	620 ②
Cask Lid	216	197	800
Closure/Vent Port Elastomeric Seals	216	197	250
Drain Port Elastomeric Seal	202	181	250
Upper Impact Limiter			
- Max. Foam	215	196	300
- Avg. Foam	146	132	300
- Shell	215	196	250 ③
Lower Impact Limiter			
- Max. Foam	200	179	300
- Avg. Foam	142	127	300
- Shell	200	179	250 ③
Max. Accessible Surface	-	185 ⑤	185
Cask Cavity Bulk Gas	259	239	N/A

Notes: ① Results assume a payload of eight (8) MURR fuel elements dissipating 158 W each and helium as the backfill gas.

② Temperature criterion based on melting point of the enclosed lead shielding.

③ Temperature criterion based on long term temperature limit for shell coating.

④ Results conservatively based on an earlier design for the cask and impact limiter attachment lugs. See Appendix 3.5.3 for a description of the design change and the conservative impact of ignoring the design change for NCT Hot modeling.

⑤ Maximum temperature occurs at the root of the upper cask impact limiter attachment lugs.

Table 3.3-2 – NCT Hot Temperatures for BRR Packaging with MITR-II Fuel

Component ①	Temperature (°F)	
	8 Elements @ 150 W Each④	Max. Allowable
MITR-II Fuel Plate	348	400
MITR-II Side Plate	347	400
MITR-II Fuel Basket	331	800
Inner Shell	237	800
Lead	234	620
Outer Shell	216	800
Thermal Shield	185	800
Lower End Structure	197	800
Upper End Structure	222	800
Shield Plug	230	620 ②
Cask Lid	218	800
Closure/Vent Port Elastomeric Seals	217	250
Drain Port Elastomeric Seal	194	250
Upper Impact Limiter		
- Max. Foam	217	300
- Avg. Foam	147	300
- Shell	217	250 ③
Lower Impact Limiter		
- Max. Foam	192	300
- Avg. Foam	140	300
- Shell	192	250 ③
Cask Cavity Bulk Gas	254	N/A

Notes: ① Results assume a payload of eight (8) MITR-II fuel elements dissipating 150 W each and helium as the backfill gas.

② Temperature criterion based on melting point of the enclosed lead shielding.

③ Temperature criterion based on long term temperature limit for shell coating.

④ Results conservatively based on an earlier design for the cask and impact limiter attachment lugs. See Appendix 3.5.3 for a description of the design change and the conservative impact of ignoring the design change for NCT Hot modeling.

Table 3.4-1 – HAC Temperatures

Component	Temperature (°F) ①			
	End of Fire	Peak	Post-fire Steady State	Max. Allowable
MURR Fuel Plate	344	451	326	1,100
MURR Side Plate	341	449	324	1,100
MURR Fuel Basket	326	437	310	800
Inner Shell	301	393	211	800
Lead	471	482	207	620
Outer Shell	704	704	200	2,700
Thermal Shield	1,256	1,256	180	2,700
Lower End Structure	318	335	182	800
Upper End Structure	485	485	198	800
Shield Plug	234	317	201	620 ②
Cask Lid	215	306	196	800
Closure/Vent Port Elastomeric Seals	212	306	196	400
Drain Port Elastomeric Seal	365	373	195	400
Upper Impact Limiter				
- Max. Foam	-	-	-	N/A③
- Avg. Foam	-	-	-	N/A③
- Shell	1,475	1,475	195	2,700 ③
Lower Impact Limiter				
- Max. Foam	-	-	-	N/A③
- Avg. Foam	-	-	-	N/A③
- Shell	1,475	1,475	190	2,700 ③
Cask Cavity Bulk Gas	305	388	257	N/A

Notes: ① Results assume a payload of eight (8) MURR fuel elements dissipating 158 W each and helium as the backfill gas.

② Temperature criterion based on melting point of the enclosed lead shielding.

③ Temperature criterion based on melting point for the shell. No criteria for the polyurethane foam since its thermal decomposition serves as it principal means of providing thermal protection during the HAC event.

4.4 Leakage Rate Tests for Type B Packages

4.4.1 Fabrication Leakage Rate Tests

During fabrication, the containment boundary is leakage rate tested as described in Section 8.1.4, *Fabrication Leakage Rate Tests*. The fabrication leakage rate tests are consistent with the guidelines of Section 7.3 of ANSI N14.5. This leakage rate test verifies the containment integrity of the BRR packaging to a leakage rate not to exceed 1×10^{-7} ref–cm^3/s, air.

4.4.2 Maintenance/Periodic Leakage Rate Tests

Annually, or at the time of damaged containment seal replacement or sealing surface repair, the containment O–ring seal and the vent port and drain port sealing washers are leakage rate tested as described in Section 8.2.2, *Maintenance/Periodic Leakage Rate Tests*. The maintenance/periodic leakage rate tests are consistent with the guidelines of Section 7.4 of ANSI N14.5. This test verifies the sealing integrity of the containment seals to a leakage rate not to exceed 1×10^{-7} ref–cm^3/s, air.

4.4.3 Preshipment Leakage Rate Tests

Prior to shipment of the loaded BRR package, the containment O–ring seal and the vent port and drain port sealing washers are leakage rate tested per Section 8.2.2, *Maintenance/Periodic Leakage Rate Tests*. The preshipment leakage rate tests are consistent with the guidelines of Section 7.6 of ANSI N14.5. This test verifies the sealing integrity of the containment seals to a leakage rate not to exceed 1×10^{-7} ref–cm^3/s, air.

7.0 PACKAGE OPERATIONS

7.1 Procedures for Loading the Package

This section delineates the procedures for loading a payload from the BRR packaging. Hereafter, reference to specific BRR packaging components may be found in Appendix 1.3.3, *Packaging General Arrangement Drawings*.

7.1.1 Preparation for Loading

1. Remove the BRR package tie–down cover from the upper impact limiter.
2. Attach rigging to the upper impact limiter using the three (3) 1/2–13 UNC threaded holes marked as impact limiter lift points.
3. Remove the (8) eight ∅1–inch ball lock pins from each upper impact limiter attachment.
4. Using an overhead crane (or equivalent), lift and remove the upper impact limiter from the cask body.
5. Secure the lift adaptor to the cask body using the four (4) 1– 8UNC bolts. If rigging is used, secure the swivel hoist rings in place using swivel hoist ring 1-8UNC fasteners. Tighten the bolts/fasteners to 220 ±20 ft–lb torque.
6. Remove the (8) eight ∅1–inch ball lock pins from each lower impact limiter attachment.
7. Lift the cask body from the lower impact limiter, and place it on the facility transport equipment.
8. Secure the cask body to the facility transport equipment, and remove the rigging from the lift adaptor.

7.1.2 Loading of Contents

The BRR package is designed to be loaded either in a pool of water (wet) or in a hot cell (dry), as delineated in the following sections.

7.1.2.1 Wet Loading

1. Remove the twelve (12) 1–8UNC socket head cap screws (SHCSs) that retain the closure lid.
2. Install three (3) hoist rings (or equivalent) into the three (3) 1/2–13 UNC threaded holes in the closure lid.
3. Lift and remove the closure lid from the cask body. Store the closure lid in a manner to minimize potential damage to the O–ring seals and sealing surfaces.
4. Install and secure the sealing surface protector to the cask body.
5. Using the center 1/2–13 UNC threaded hole in the shield plug as a lift point, remove the shield plug from the cask body.
6. If not previously installed, install the appropriate fuel basket into the cask body cavity.

7. Remove the drain port dust cover and then the drain port plug. Install an appropriate fitting to the drain port.
8. Using an overhead crane (or equivalent), and attached to the lift adaptor, lift the cask body with the fuel basket from the facility transport equipment and position over the spent fuel pool staging area.
9. Slowly lower the cask body into the pool until the cavity is flooded, and the cask body is secure in the facility fuel loading station.
10. Load a fuel element into each fuel channel in the fuel basket. Up to eight (8) fuel elements may be loaded into the MURR, MITR-II, or ATR baskets. Up to nineteen (19) fuel elements may be loaded into the TRIGA basket.
11. Using the center 1/2–13 UNC threaded hole as a lift point, lower the shield plug into the cask body cavity. Visually verify that the shield plug is properly seated, and reposition if necessary.
12. If required, install the shield plug restraint, or optionally, install the shield plug restraint once the cask body has been raised to the working level.
13. Lift the loaded cask body from the spent fuel pool while spraying exposed portions with clean demineralized water. Perform a radiological survey of the cask body as it is raised out of the pool.
14. Open the drain fitting to drain the pool water from the cavity. Continue draining the cavity until no appreciable water is noted. Optionally, the cavity may be drained after securing the cask body in the facility work area.
15. Close the drain fitting, and remove the connecting plumbing from the drain fitting.
16. Lift the loaded cask body out of the spent fuel pool area and secure it in the facility work area.
17. Remove the sealing surface protector and, if installed, the shield plug restraint from the shield plug and cask body.
18. Remove and discard both main O–ring seals (if present), and clean and inspect the sealing surfaces in the closure lid and the mating surfaces on the cask body. If damage is present which is sufficient to impair containment integrity (scratches or dents, etc.), repair the damaged surfaces per Section 8.2.3.2, *Sealing Area Routine Inspection and Repair*.
19. Install two new (unused) O-rings in the appropriate grooves in the closure lid. As an option, sparingly apply vacuum grease to the O–ring seals and/or sealing surfaces.
20. Install the closure lid on the cask body, using the alignment pin to guide the closure lid into position.
21. Visually inspect the closure SHCSs for wear or damage that could impair their function and, if necessary, replace or repair per the requirements of the drawings in Appendix 1.3.3, *Packaging General Arrangement Drawings*.
22. Install the twelve (12) 1–8UNC SHCSs to secure the closure lid to the cask body. Using a star pattern, tighten the closure SHCSs to 220 ±20 ft–lb torque (lubricated).
23. Remove the vent port dust cover, vent port plug, test port dust cover, and test port plug.
24. Remove the drain port fitting from the drain port.

25. Remove and discard the vent, test, and drain port sealing washers from their respective port plugs (if present), and clean and inspect each sealing surface. If damage is present which is sufficient to impair containment integrity (scratches or dent, etc.), repair the damaged surfaces per Section 8.2.3.2, *Sealing Area Routine Inspection and Repair.*
26. Install the drain port plug and a new (unused) sealing washer in the drain port. Tighten the drain port plug to 20 ±2 ft–lb torque.
27. Using the vent port tool, install the vent port plug with a new (unused) sealing washer. Ensure that the vent port plug is loose enough to allow airflow through the vent port.
28. Install the test port plug and a new (unused) sealing washer in the closure lid approximately finger-tight.
29. Connect a vacuum pump and a shutoff valve to the vent port tool and evacuate the cavity until the internal pressure is 1 – 2 torr. Isolate the vacuum pump from the cask body cavity by closing the shutoff valve and shutting off the vacuum pump, closing the shutoff valve and venting the suction line to atmosphere, or other appropriate means that does not maintain a vacuum on the outlet of the shutoff valve.
30. Monitor the cavity pressure for a minimum of 30 minutes. If the cavity pressure does not exceed 3 torr at the end of the time period, proceed to Step 34.
31. If the pressure exceeds 3 torr, open the port tool to re–pressurize the cask body cavity to atmospheric pressure. Repeat Steps 29 and 30.
32. If after eight (8) hours of vacuum drying with air and the pressure exceeds 3 torr, disconnect the vacuum pump from the vent port tool and connect a source of helium gas.
33. Provide a helium atmosphere inside the cask payload cavity by backfilling with helium gas to a pressure of slightly greater than atmospheric pressure, i.e., +1, -0 psig. Repeat Steps 29 and 30.
34. Disconnect the vacuum pump from the vent port tool and connect a source of helium gas.
35. Provide a helium atmosphere inside the cask payload cavity by backfilling with helium gas to a pressure of slightly greater than atmospheric pressure, i.e., +1, -0 psig.
36. Disconnect the helium gas source from the vent port tool.
37. Using the vent port tool, tighten the vent port plug to 9 ±1 ft–lb torque.
38. Perform leakage rate testing on the containment O-ring seal and the drain and vent port sealing washers per Section 8.2.2.2, *Helium leakage Rate Testing the Main Containment O-ring Seal*, Section 8.2.2.3, *Helium Leakage Rate Testing the Drain Port Sealing Washer*, and Section 8.2.2.4, *Helium Leakage Rate Testing the Vent Port Sealing Washer.*
39. At the conclusion of all leakage rate testing, install the drain port dust cover, the test port dust cover, and vent port dust cover.

7.1.2.2 Dry Loading

Steps 1 – 6 may be performed either inside or outside of the hot cell. A transfer cask may be used in place of the hot cell for this procedure. The cask must remain upright at all times.

1. Remove the twelve (12) 1–8UNC socket head cap screws (SHCSs) that retain the closure lid.
2. Install three (3) hoist rings (or equivalent) into the three (3) 1/2–13 UNC threaded holes in the closure lid.
3. Lift and remove the closure lid from the cask body. Store the closure lid in a manner to minimize potential damage to the O–ring seals and sealing surfaces.
4. Install and secure the sealing surface protector to the cask body.
5. Using the center 1/2–13 UNC threaded hole in the shield plug as a lift point, remove the shield plug from the cask body.
6. If not previously installed, install the appropriate fuel basket into the cask body cavity.
7. If steps 1 – 6 were performed outside of the hot cell, reinstall shield plug in cask.
8. Mate the cask opening with the hot cell. If necessary, place the cask body inside the hot cell.
9. If required, remove the shield plug.
10. Load a fuel element into each fuel channel in the fuel basket. Up to eight (8) fuel elements may be loaded into the MURR, MITR-II, or ATR baskets. Up to nineteen (19) fuel elements may be loaded into the TRIGA basket.
11. Using the center 1/2–13 UNC threaded hole as a lift point and a remote lift adapter, lower the shield plug into the cask body cavity. Visually verify that the shield plug is properly seated, and reposition if necessary.
12. Optionally, install the shield plug restraint.
13. If the cask was placed within the hot cell remove the loaded cask body from the hot cell. Perform a radiological survey of the cask body as it is removed.
14. If the cask was mated to the hot cell, disconnect the cask from the hot cell. Perform a radiological survey of the cask body as it is removed.
15. Remove the sealing surface protector and, if installed, the shield plug restraint from the shield plug and cask body.
16. Remove and discard both main O–ring seals (if present), and clean and inspect the sealing surfaces in the closure lid and the mating surfaces on the cask body. If damage is present which is sufficient to impair containment integrity (scratches or dents, etc.), repair the damaged surfaces per Section 8.2.3.2, *Sealing Area Routine Inspection and Repair*.
17. Install two new (unused) O-rings in the appropriate grooves in the closure lid. As an option, sparingly apply vacuum grease to the O–ring seals and/or sealing surfaces.
18. Install the closure lid on the cask body, using the alignment pin to guide the closure lid into position.
19. Visually inspect the closure SHCSs for wear or damage that could impair their function and, if necessary, replace or repair per the requirements of the drawings in Appendix 1.3.3, *Packaging General Arrangement Drawings*.
20. Install the twelve (12) 1–8UNC SHCSs to secure the closure lid to the cask body. Using a star pattern, tighten the closure SHCSs to 220 ±20 ft–lb torque (lubricated).

21. Remove the vent port dust cover, vent port plug, test port dust cover, and test port plug.
22. Remove the drain port dust cover and drain port plug.
23. Remove and discard the vent, test, and drain port sealing washers from their respective port plugs (if present), and clean and inspect each sealing surface. If damage is present which is sufficient to impair containment integrity (scratches or dent, etc.), repair the damaged surfaces per Section 8.2.3.2, *Sealing Area Routine Inspection and Repair.*
24. Install the drain port plug and a new (unused) sealing washer in the drain port. Tighten the drain port plug to 20 ±2 ft–lb torque.
25. Using the vent port tool, install the vent port plug with a new (unused) sealing washer. Ensure that the vent port plug is loose enough to allow airflow through the vent port.
26. Install the test port plug and a new (unused) sealing washer in the closure lid approximately finger-tight.
27. Connect a vacuum pump and a shutoff valve to the vent port tool and evacuate the cavity until the internal pressure is 1 – 2 torr. Isolate the vacuum pump from the cask body cavity by closing the shutoff valve and shutting off the vacuum pump, closing the shutoff valve and venting the suction line to atmosphere, or other appropriate means that does not maintain a vacuum on the outlet of the shutoff valve.
28. Monitor the cavity pressure for a minimum of 30 minutes. If the cavity pressure does not exceed 3 torr at the end of the time period, proceed to Step 32.
29. If the pressure exceeds 3 torr, open the port tool to re–pressurize the cask body cavity to atmospheric pressure. Repeat Steps 27 and 28.
30. If after eight (8) hours of vacuum drying with air and the pressure exceeds 3 torr, disconnect the vacuum pump from the vent port tool and connect a source of helium gas.
31. Provide a helium atmosphere inside the cask payload cavity by backfilling with helium gas to a pressure of slightly greater than atmospheric pressure, i.e., +1, -0 psig. Repeat Steps 27 and 28.
32. Disconnect the vacuum pump from the vent port tool and connect a source of helium gas.
33. Provide a helium atmosphere inside the cask payload cavity by backfilling with helium gas to a pressure of slightly greater than atmospheric pressure, i.e., +1, -0 psig.
34. Disconnect the helium gas source from the vent port tool.
35. Using the vent port tool, tighten the vent port plug to 9 ±1 ft–lb torque.
36. Perform leakage rate testing on the containment O-ring seal and the drain and vent port sealing washers per Section 8.2.2.2, *Helium leakage Rate Testing the Main Containment O-ring Seal*, Section 8.2.2.3, *Helium Leakage Rate Testing the Drain Port Sealing Washer*, and Section 8.2.2.4, *Helium Leakage Rate Testing the Vent Port Sealing Washer.*
37. At the conclusion of all leakage rate testing, install the drain port dust cover, the test port dust cover, and vent port dust cover.

7.1.3 Preparation for Transport

1. Utilizing the lift adaptor, or optional rigging, lift and lower the cask body into the lower impact limiter that is located on the transport trailer. Ensure that the cask body is aligned with the impact limiter alignment stripe for correct circumferential location.
2. Install the (8) eight ∅1–inch ball lock pins into each lower impact limiter attachment.
3. Remove the (4) four 1 – 8 UNC bolts that attach the lift adaptor to the cask body. Remove the lift adaptor or rigging hardware. The lifting holes may be optionally plugged.
4. Lift and lower the upper impact limiter onto the cask body. Ensure that the upper impact limiter is aligned with the cask body stripe for correct circumferential location.
5. Install the (8) eight ∅1–inch ball lock pins into each upper impact limiter attachment.
6. Install the tamper–indicating device (security seal) in the appropriate upper impact limiter attachment location.
7. Remove the rigging from the upper impact limiter lift points. The lifting holes may be optionally plugged.
8. Install the BRR package tie–down cover over the upper impact limiter, and secure the cover to the semi–trailer using the tie–down attachments. Optionally, install weather seal on bottom impact limiter.
9. Monitor external radiation for each loaded BRR package per the requirements of 49 CFR §173.441.
10. Determine that surface contamination levels for each loaded BRR package is per the requirements of 10 CFR §71.87(i) and 49 CFR §173.443.
11. Determine the transport index for each loaded BRR package per the requirements of 49 CFR §173.403.
12. Complete all necessary shipping papers in accordance with Subpart C of 49 CFR 172 [3].
13. BRR package marking shall be in accordance with 10 CFR §71.85(c) and Subpart D of 49 CFR 172. Package labeling shall be in accordance with Subpart E of 49 CFR 172. Package placarding shall be in accordance with Subpart F of 49 CFR 172.

7.2 Procedures for Unloading the Package

This section delineates the procedures for unloading a payload from the BRR packaging. Hereafter, reference to specific BRR packaging components may be found in Appendix 1.3.3, *Packaging General Arrangement Drawings*.

7.2.1 Receipt of Package from Carrier

1. Remove the BRR package tie–down cover from the upper impact limiter.
2. Verify that the tamper–indicating device (security seal) has not been tampered with or removed.
3. Attach rigging to the upper impact limiter using the three (3) 1/2–13 UNC threaded holes marked as impact limiter lift points.
4. Remove the tamper–indicating device (security seal) and the (8) eight ∅1–inch ball lock pins from each upper impact limiter attachment.
5. Using an overhead crane (or equivalent), lift and remove the upper impact limiter from the cask body.
6. Secure the lift adaptor to the cask body using the (4) four 1– 8UNC bolts. If rigging is used, secure the swivel hoist rings in place using swivel hoist ring 1-8UNC fasteners. Tighten the bolts to 220 ±20 ft–lb.
7. Remove the (8) eight ∅1–inch ball lock pins from each lower impact limiter attachment.
8. Lift the loaded cask body from the lower impact limiter, and place it on the facility transport equipment.
9. Secure the cask body to the facility transport equipment, and remove the rigging from the lift adaptor.

7.2.2 Removal of Contents

The BRR package is designed to be unloaded either in a pool of water (wet) or in a hot cell (dry), as delineated in the following sections. The unloading procedures may require removal of the lift adapter to facilitate gas sampling or other testing. If the lift adapter is removed for this purpose, reinstall per Paragraph 7.2.1, step 6 upon completion of sampling or testing.

7.2.2.1 Wet Unloading

1. Remove the vent port dust cover and connect a vent port tool to the vent port. Connect a gas sampling device to the vent port tool.
2. Loosen and remove the vent port plug using the vent port tool so that a gas sample may be extracted from the cavity .
3. Following verification of no contamination in the gas sample, vent the cavity to atmosphere to equalize cavity pressure.

4. Install three (3) hoist rings (or equivalent) into the three (3) 1/2–13 UNC threaded holes in the closure lid.
5. Remove the twelve (12) 1–8UNC socket head cap screws (SHCSs) that secure the closure lid.
6. Lift and remove the closure lid from the cask body. Store the closure lid in a manner to minimize potential damage to the O–ring seals and sealing surfaces.
7. Install and secure the sealing surface protector to the cask body.
8. Optionally, install the shield plug restraint over the shield plug in the cask body.
9. Remove the drain port dust cover and then the drain port plug. Install an appropriate fitting to the drain port.
10. Using appropriate rigging and an overhead crane (or equivalent) attached to the lift adaptor, lift the loaded cask body from the facility transport equipment and position over the spent fuel pool staging area.
11. If installed, remove the shield plug restraint, or optionally, remove the restraint after the cask body is secured in the facility fuel unloading station.
12. Slowly lower the cask body into the pool until the cavity is flooded, and secure the loaded cask body in the facility fuel unloading station.
13. Using the center 1/2–13 UNC threaded hole in the shield plug as a lift point, remove the shield plug from the cask body.
14. Remove the fuel elements from the basket and place in the facility's receiving station.
15. Using the center 1/2–13 UNC threaded hole as a lift point, lower the shield plug into the cask body cavity. Visually verify that the shield plug is properly seated, and reposition if necessary.
16. Optionally, install the shield plug restraint. The shield plug restraint may be installed once the cask body has been raised to the working level.
17. Lift the cask body from the spent fuel pool while spraying exposed portions with clean demineralized water. Perform a radiological survey of the cask body as it is raised out of the pool.
18. Open the drain fitting to drain the pool water from the cavity. Continue draining the cavity until no appreciable water is noted. Optionally, the cavity may be drained after securing the cask body in the facility work area.
19. Close the drain fitting, and remove the connecting plumbing from the drain fitting.
20. Lift the cask body out of the spent fuel pool area and secure it in the facility work area.
21. Remove the sealing surface protector and, if installed, the shield plug restraint from the shield plug and cask body.
22. Install the closure lid on the cask body, using the alignment pin to guide the closure lid into position.

23. Install the twelve (12) 1–8UNC SHCSs to secure the closure to the cask body. Using a star pattern, tighten the closure SHCSs to 220 ±20 ft–lb torque (lubricated).
24. Install the vent port plug and tighten to 9 ±1 ft–lb torque. Install the vent port dust cover.
25. Install the drain port plug and tighten to 20 ±2 ft–lb torque. Install the drain port dust cover.
26. Assemble the impact limiters onto the package and secure the package to the transport trailer as described in Section 7.1.3, *Preparation for Transport*. A tamper–indicating device is not required.

7.2.2.2 Dry Unloading

Steps 1 – 9 may be performed either inside or outside of the hot cell. A transfer cask may be used in place of the hot cell for this procedure. The cask must remain upright at all times

1. Remove the vent port dust cover and connect a vent port tool to the vent port. Connect a gas sampling device to the vent port tool.
2. Loosen and remove the vent port plug using the vent port tool so that a gas sample may be extracted from the cavity.
3. Following verification of no contamination in the gas sample, vent the cavity to atmosphere to equalize cavity pressure.
4. Install three (3) hoist rings (or equivalent) into the three (3) 1/2–13 UNC threaded holes in the closure lid.
5. Remove the twelve (12) 1–8UNC socket head cap screws (SHCSs) that retain the closure lid.
6. Lift and remove the closure lid from the cask body. Store the closure lid in a manner to minimize potential damage to the O–ring seals and sealing surfaces.
7. Install and secure the sealing surface protector to the cask body.
8. Optionally, install the shield plug restraint over the shield plug in the cask body.
9. Install a remote lift adaptor in the center 1/2–13 UNC threaded hole of the shield plug.
10. Mate the cask opening with the hot cell. If required, place the loaded cask body into the hot cell.
11. Remove the shield plug restraint (if installed) and lift the shield plug from the cask body.
12. Remove the fuel elements from the basket and place in the facility's receiving station.
13. Replace the shield plug into the cask body cavity. Optionally, install the shield plug restraint.
14. Remove or disconnect the unloaded cask body from the hot cell.
15. Remove the remote lift adaptor from the shield plug.
16. Remove the shield plug restraint (if installed) and remove the sealing surface protector.
17. Install the closure lid on the cask body, using the alignment pin to guide the closure lid into position.

18. Install the twelve (12) 1–8UNC SHCSs to secure the closure to the cask body. Using a star pattern, tighten the closure SHCSs to 220 ±20 ft–lb torque (lubricated).
19. Install the vent port plug and tighten to 9 ±1 ft–lb torque. Install the vent port dust cover.
20. If used, install the drain port plug and tighten to 20 ±2 ft–lb torque. Install the drain port dust cover.
21. Assemble the impact limiters onto the package and secure the package to the transport trailer as described in Section 7.1.3, *Preparation for Transport*. A tamper–indicating device is not required.

7.4 Appendix

7.4.1 References

1. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material*, 01–01–08 Edition.
2. Title 49, Code of Federal Regulations, Part 173 (49 CFR 173), *Shippers–General Requirements for Shipments and Packagings*, 10–01–08 Edition
3. Title 49, Code of Federal Regulations, Part 172 (49 CFR 172), *Hazardous Materials Tables and Hazardous Communications Regulations*, 10–01–08 Edition.