7. PACKAGE OPERATIONS

Chapter 7 describes the RT-100 operations during loading and preparation for shipment. These operations delineate the fundamental steps needed to ensure that the RT-100 is properly prepared for transport, and ensure that the operations are consistent with the previous sections of this application.

RT-100 loading and preparation operations are consistent with maintaining occupational radiation exposures as low as reasonably achievable (ALARA), as required by the "Standards for Protection Against Radiation" in 10 CFR 20.1101(b) [Ref. 8]. RT verifies that the operating controls and procedures meet the requirements of 10 CFR Part 71; furthermore, the operating procedures are adequate to ensure the RT-100 is operated in a manner consistent with the procedures and requirements of this Safety Analysis Report. The RT operating controls and procedures ensure the transportation safety with respect to the United States (US) requirements for transportation packages for radioactive material.

A separate operations manual is to be prepared for the RT-100 to describe the operational steps in greater detail. The regulatory requirements for the operating controls and procedures evaluation from 10 CFR Part 71 [Ref. 2] include the following issues:

- Application identifies the established codes and standards used for the operating procedures in accordance to 10 CFR Part 71 Section 71.31(c) [Ref. 2].
- Application for a fissile material is not applicable for the RT-100 since it will not be used for fissile material transport.
- RT-100 shall be transported as a Type B shipment B(U)-96 exclusive use shipment.
- The shipper shall ensure that the routine determination of 10 CFR 71.87 [Ref. 2] is met prior to each shipment. Prior to delivery of a package to a carrier, RT will send to the consignee any special instructions needed to safely open the package and use it in accordance with 10 CFR 20.1906(e) [Ref. 8] and 10 CFR Part 71 Section 71.89 [Ref. 2].
- The operating procedures meet the regulatory requirements listed in the Preparation of Empty Package for Transport Section.
- The operating procedures are adequate to ensure that the package will be operated in accordance with the Safety Analysis Report.

Input from the other sections of this application are used to develop the RT-100 operational controls and procedures. Information flow for the operating procedures evaluation is shown in Figure 7-1.

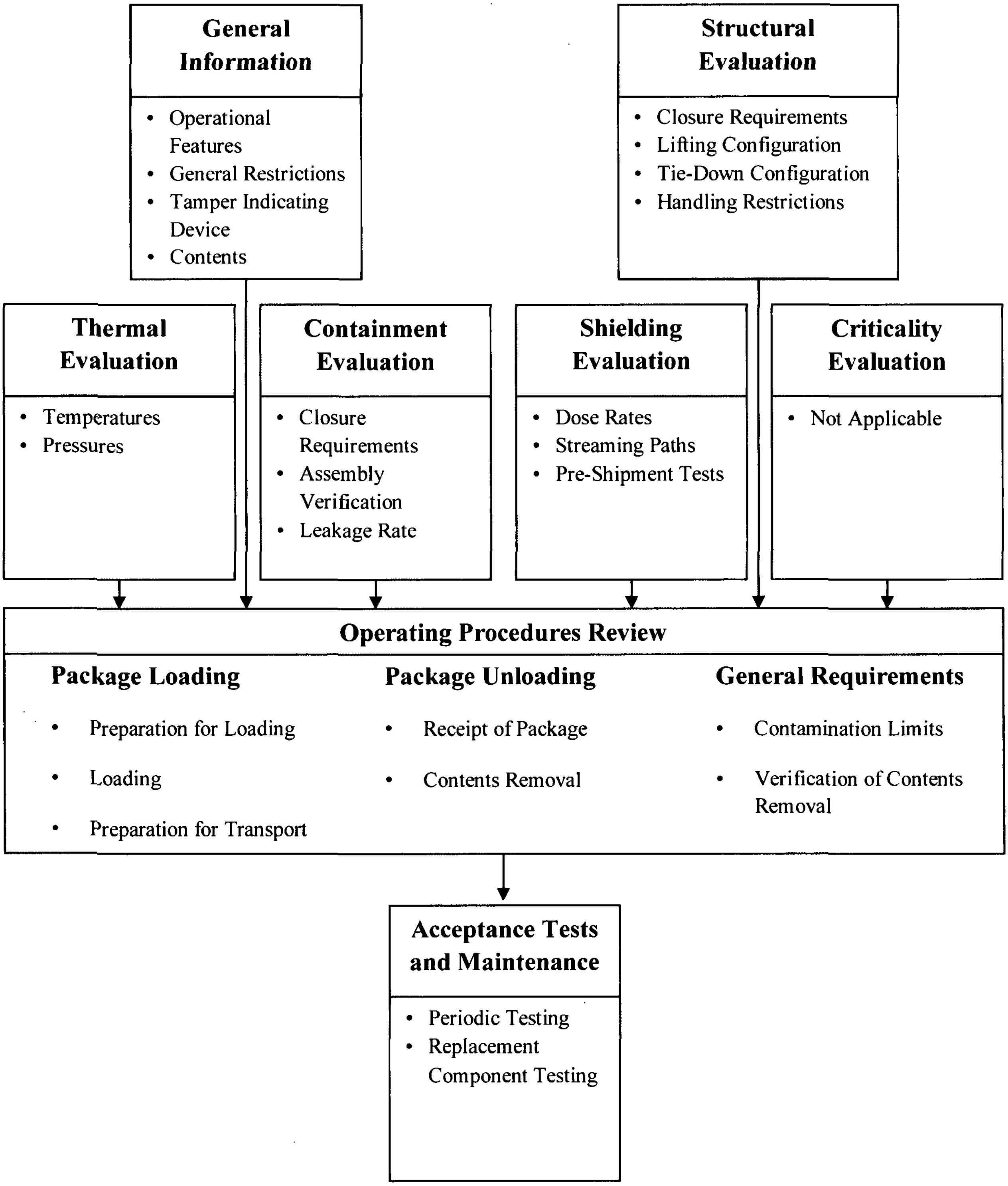


Figure 7-1 Information Flow for the Operating Procedures Review

7.1 Package Loading

Section 7.1 describes loading-related preparations, tests, and inspections of the package. These actions include the inspections made before loading the package to ensure the package is not damaged, and that radiation and surface contamination levels are within allowable limits.

The procedures for loading of the RT-100 are defined as follows:

- 7.1.1 Preparation for Loading
- 7.1.2 Loading of the RT-100
- 7.1.3 Preparation for Transport

7.1.1 Preparation for Loading

The following actions are taken prior to loading operations:

1. RT-100 is surveyed for surface contamination to ensure it is within allowable limits. If the package exceeds contamination limits, the RT-100 must be decontaminated prior to the next step.
2. A visual inspection is performed to determine if any component damage has occurred that would prevent safe performance of the package under NCT and HAC. Any damaged/out-of-specification components are repaired or replaced.
3. A pre-loading briefing is conducted with the loading team with the purpose of reviewing all procedures, and ensuring everyone is cognizant of the loading requirements and the associated safety measures. Pre-loading actions include appropriate ALARA measures and contamination control.
4. The package contents data is reviewed to ensure the contents meet the Certificate of Compliance.
5. The following conditions must be met for safe handling of the RT-100:
    - All operating instructions/procedures outlined in the Safety Analysis Report must be followed.
    - RT-100 shall not be lifted via the lifting rings on the upper impact limiter.
    - RT-100 shall only be lifted in the vertical position.
    - RT-100 shall not be placed in an upside down position at any time.
    - RT-100 shall not be handled while tied down.

Loading of the RT-100 can take place on or off the trailer, and with or without the lower impact limiter attached. Additionally, loading can take place via the primary or secondary lid. Figure 7.1.1-1 illustrates the process flow for these steps. Subsequent sections describe these steps in greater detail. If the RT-100 remains on the trailer, the trailer and lower impact limiter must be protected against contamination during the procedure.

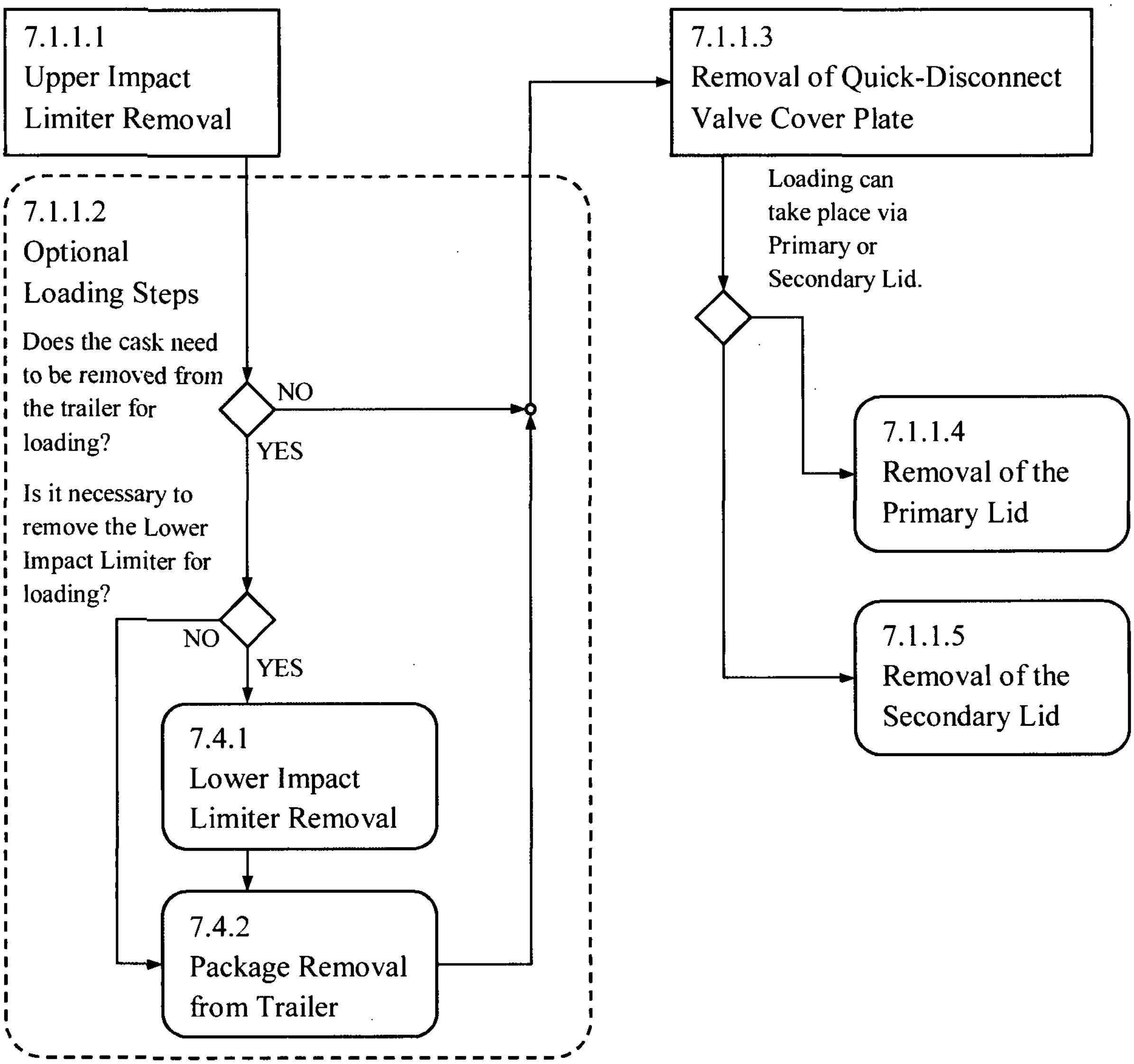


Figure 7.1.1-1 Preparation for Loading Process Flowchart

7.1.1.1 Upper Impact Limiter Removal

Remove the upper impact limiter by following these steps:

1. Remove tamper indicating seal from the upper impact limiter aligning pin.
2. Remove the cotter pin from each upper impact limiter bolt.
3. Using appropriate tools loosen and remove all head nuts (12 Hex Head Nuts, M36) which secure the impact limiter to the cask body.
4. Install three lifting rings to the upper impact limiter. Remove the impact limiter using an appropriate lifting device attached to the three (3) lifting rings.

NOTE: To prevent damage, the impact limiter shall be handled and stored with care. It must be placed on a clean, flat surface in a position so that the studs and aligning pins do not touch the ground.

7.1.1.2 Optional Loading Steps

- Lower Impact Limiter Removal: Refer to the actions described in Section 7.4.1.
- Package Removal from Trailer: Refer to the actions described in Section 7.4.2.

7.1.1.3 Removal of Quick-Disconnect Valve Cover Plate

CAUTION: In the event of failure of the quick disconnect valve, radioactive material may be released when opening the vent port cover plate. Use caution to consider potential release of material consistent with the form of the cask contents.

Before opening the primary or secondary lid, internal and external pressure must be balanced to ensure safety, contamination control and to easily remove the lid(s). This is accomplished following these steps:

1. With appropriate tools, loosen and remove all bolts (6 Socket Head Cap Screws, M10x30) which secure the quick-disconnect valve cover plate to the primary lid.
2. Manually install and hand tighten two (2) of the six (6) bolts previously removed from the quick-disconnect valve cover plate into two (2) threaded holes specially designed for this purpose. Remove the cover plate using the bolts.
3. Vent the cask cavity by connecting the quick-disconnect valve to a leak tight ventilation system.

NOTES:

- Treat the quick-disconnect valve cover plate, its cavity surfaces, bolts and O-rings as potentially contaminated.
- The quick-disconnect valve cover plate must be set down with caution to prevent damage.
- Any defective bolts or O-rings, or those showing signs of deterioration shall be replaced with components meeting the specifications in the RT100 NM 1000-F Bill of Material (Chapter 1, Appendix 1.4, Attachment 1.4-1).

- If components are replaced, a Maintenance Leak Test shall be performed on each new inner seal in accordance with Section 8.2.2.1. This must be done prior to loading the cask.

7.1.1.4 Removal of the Primary Lid

Remove the primary lid by following these steps:

1. Remove all the bolts (32 Hex Head Cap Screws, M48x170) securing the lid to the cask body.
2. Insert the three (3) lid lifting rings in the threaded holes designed for this purpose on the upper side of the primary lid.
3. Remove primary lid using suitable lifting equipment attached to the three lifting rings.
4. Inspect all bolt threads, hole threads, and O-rings for damage.

NOTES:

- Treat the primary lid, cask cavity surfaces, bolts, and O-rings as potentially contaminated.
- The primary lid shall be handled and stored with care in order to prevent damage.
- Any defective bolt or O-ring, or those showing signs of deterioration shall be replaced with components meeting the specifications in the RT100 NM 1000-F Bill of Material (Chapter 1, Appendix 1.4, Attachment 1.4-1).
- If a component is replaced, a Maintenance Leak Test shall be performed on each new inner seal in accordance with Section 8.2.2.1. This must be done prior to loading the cask.
- Replaced by a Robatel Technologies authorized individual.
- Removal of the secondary lid is not necessary to remove the primary lid.

7.1.1.5 Removal of the Secondary Lid

Remove the secondary lid by following these steps:

1. Remove all the bolts (18 Hex Head Cap Screws, M36x120) securing the secondary lid to the primary lid.
2. Insert the three (3) lid lifting rings in the threaded holes designed for this purpose in the upper side of the secondary lid.
3. Remove secondary lid using suitable lifting equipment attached to the three lifting rings.
4. Inspect all bolt threads, hole threads, and O-rings for damage.

NOTES:

- Treat the secondary lid, cask cavity surfaces, bolts, and O-rings as potentially contaminated.
- The secondary lid shall be handled and stored with care in order to prevent damage.
- Any defective bolt or O-ring, or those showing signs of deterioration shall be replaced with components meeting the specifications in the Bill of Material (Appendix 1.4).
- If a component is replaced, a Maintenance Leak Test shall be performed on each new inner seal in accordance with Section 8.2.2.1. This must be done prior to loading the cask.
- Replaced by a Robatel Technologies authorized individual.

7.1.2 Loading of the RT-100

Section 7.1.2 addresses the actions for loading of the RT-100. Figure 7.1.2-1 describes the process flow for these steps. Subsequent sections describe these steps in detail.

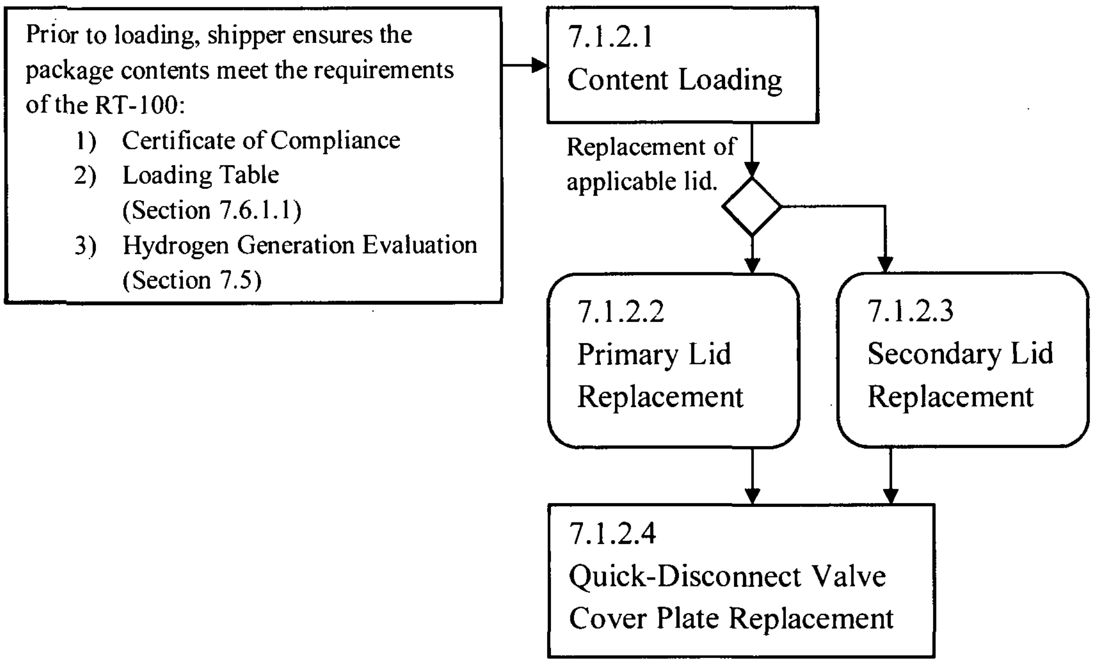


Figure 7.1.2-1 Loading of the RT-100 Process Flowchart

7.1.2.1 Content Loading

Load the cask by following these steps:

1. Prior to loading of the RT-100, the following conditions shall be met:
   a. Package contents meet the requirements of the RT-100 Certificate of Compliance
   b. Package contents meet the requirements of Appendix 7.6 and its loading table addressed in Section 7.6.1.1
   c. Package contents meet the requirements of the hydrogen generation evaluation described in Section 7.5
2. Ensure the contents, secondary container, and packaging are chemically compatible (i.e., will not react to produce flammable gases).
3. Inspect RT-100 interior for any damage, loose material or moisture. Clean seal surfaces.
4. Radioactively contaminated liquids may be pumped out or removed using absorbent material.
5. Removal of any material from inside the cask is performed under the supervision of qualified health physics personnel, and in accordance with health & safety requirements.
6. Pre-position any shoring necessary to shore/brace the liner during normal transit.
7. Place disposable liner, drums, or other containers into the pre-positioned shoring; install additional shoring or bracing as necessary to restrict movement of contents during normal transport.

8. Process liner as necessary and cap the liner as required.
9. Clean and inspect lid seal surfaces.

7.1.2.2 Primary Lid Replacement

The primary lid is attached by following these steps:

1. Inspect and clean (if necessary) the two (2) seal surfaces (on the cask body and on the primary lid).
2. Inspect and clean (if necessary) the two (2) primary lid O-rings for reuse. Contact RT if any damage, crack, or condition is noted that can prevent O-rings from sealing properly.
3. If not already present, install the three (3) lifting rings on the primary lid in the threaded holes designed for this purpose.
4. Place the primary lid on the cask. The lid is positioned by an aligning pin to ensure the proper placement of the primary lid on the cask body.
5. Lubricate (if necessary) the thirty-two (32) bolt and hole threads.
6. Install the bolts with washers.
7. Tighten the bolts using the "star pattern" method to ensure evenly distributed pressure on the primary lid and cask body.
   a. Use an initial torque of 400 N-m ± 10%.
   b. Use a final torque of 850 N-m ± 10%.
8. Remove the three (3) lifting rings from the primary lid.
9. Conduct a Pre-Shipment Leak Test of primary lid O-ring as written in either Section 8.2.2.2 or Section 8.2.2.3.

7.1.2.3 Secondary Lid Replacement

The secondary lid is attached by following these steps:

1. Inspect and clean (if necessary) the two (2) seal surfaces (on the top of the primary lid and on the bottom of the secondary lid).
2. Inspect and clean the two (2) secondary lid O-rings for reuse. Contact RT if any damage, crack, or condition is noted that can prevent O-rings from sealing properly.
3. If not already present, install the three (3) lifting rings on the secondary lid in the threaded holes designed for this purpose.
4. Place the secondary lid on the primary lid. The lid is positioned by an aligning pin to ensure the proper placement of the secondary lid on the primary lid.
5. Lubricate (if necessary) the eighteen (18) bolt and hole threads.
6. Install the bolts with washers.
7. Tighten the bolts using the "star pattern" method to ensure evenly distributed pressure on the secondary and primary lids.
   a. Use an initial torque of 150 N-m ± 10%.
   b. Use a final torque of 350 N-m ± 10%.
8. Remove the three (3) lifting rings from the secondary lid.

9. Conduct a Pre-Shipment Leak Test of secondary lid O-ring as written in either Section 8.2.2.2 or Section 8.2.2.3.

7.1.2.4 Quick-Disconnect Valve Cover Plate Replacement

The quick-disconnect valve cover plate is replaced in the following manner:

1. Inspect and clean the two (2) quick-disconnect valve cover plate O-rings. Contact RT if any damage, crack, or any condition is noted that can prevent O-rings from proper sealing.
2. Install two (2) of the previously removed cover plate bolts (Socket Head Cap Screw, M10x30) in the threaded holes on the cover plate. Manually place the cover plate on the primary lid. Subsequently, remove these two (2) bolts.
3. Lubricate (if necessary) the six (6) quick-disconnect valve cover plate bolt and hole threads.
4. Secure the quick-disconnect valve onto the primary lid using plate bolts and washers.
5. Tighten bolts using the "star pattern" method to ensure consistent pressure on the quick-disconnect valve and primary lid.
   a. Tighten the bolts by hand to compress the O-rings (no specific torque required).
   b. Use a final torque of 27 N-m ± 10%.
6. Conduct a Pre-Shipment Leak Test of quick-disconnect valve cover plate O-ring as written in either Section 8.2.2.2 or Section 8.2.2.3.

7.1.3 Preparation for Transport

The following general requirements are completed prior to final transport of the RT-100:

1. Contamination survey completed on the external surfaces to confirm that non-fixed (removable) radioactive contamination is as low as reasonably achievable, and is within the limits specified in 49 CFR 173.443 [Ref. 3], as required by 10 CFR 71.87 [Ref. 2]. If contamination is within limits, preparation for transport may be conducted. If contamination exceeds the limits, the RT-100 must be decontaminated until the contamination limits are met.
2. Measure the exterior gamma radiation levels following RIS 13-04 to ensure these do not exceed 200 millirem per hour (2 mSv/h) at any point on the vertical planes projected from the outer edges of the trailer, on surface of the impact limiter at the axial center line if the package, and on the lower external surface of the trailer, 10 millirem per hour (0.1 mSv/h) at any point 2 meters (6.6 feet) from the vertical planes projected by the outer edges of the trailer (excluding the underside of the trailer) and 2 millirem per hour (0.02 mSv/h) in the tractor cab, in accordance with 49 CFR 173.441 and 10 CFR 71.47. Measurements shall be made at the axial mid-plane of the cask and below the cask end on the lower external surface of the trailer. Also measure the neutron radiation to ensure there is not unexpected neutron sources in the content.
   - Caution: Ensure calibration is current and address radiation detector uncertainty when measuring pre-shipment dose rates.

3. If necessary, install the lower impact limiter and load the package on the trailer:
   - Replacement of Lower Impact Limiter: Refer to Section 7.4.3
   - Reloading the Package onto the Trailer: Refer to Section 7.4.4

Figure 7.1.3-1 describes the process flow for transport preparation. Subsequent sections describe these steps in greater detail.

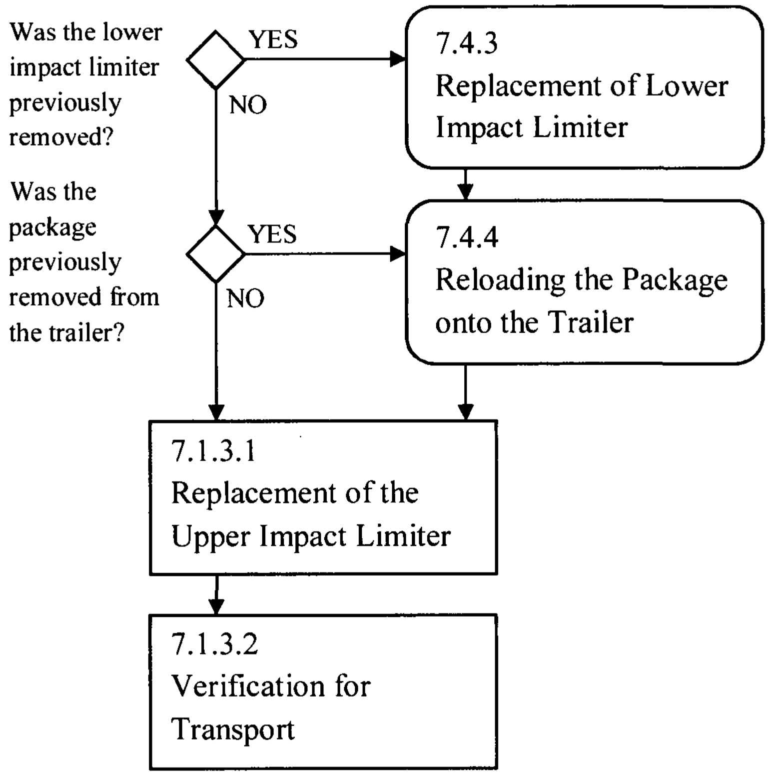


Figure 7.1.3-1 Preparation for Transport Process Flowchart

7.1.3.1 Replacement of Upper Impact Limiter

Install the upper impact limiter using the following steps:

1. Inspect and clean the top surface of the cask.
2. Inspect each threaded stud for cleanliness, defects and lubrication – replace if necessary in accordance with Section 7.4.5.3.
3. Lift the upper impact limiter using an appropriate lifting device fixed to its three (3) lifting rings.
4. Position the upper impact limiter using the two (2) aligning pins.
5. Lower the upper impact limiter slowly and cautiously to prevent any damage to threaded studs and aligning pins.
6. Disconnect the lifting device from the upper impact limiter.
7. Disconnect or render inoperable the 3 lifting rings on the upper impact limiter.
8. Secure the cask to the upper impact limiter by installing twelve (12) head nuts on the

threaded studs. The head nuts do not require any specific torque. The nuts must be in contact with the cask attachment ring.

9. Install a cotter pin on each threaded stud.
10. Install a tamper indicating seal on the upper impact limiter aligning pin.

7.1.3.2 Verification for Transport

The following actions are confirmed prior to shipment of a loaded package.

- Licensed consignee who expects to receive the package containing materials in excess of Type A quantities specified in 10 CFR 20.1906(a) [Ref. 8] meets and follows the requirements of 10 CFR 20.1906 [Ref. 8], as applicable.
- Before delivery of a package to a carrier for transport, the shipper shall ensure that any special instructions needed to safely open the package have been sent to, or otherwise made available to, the consignee for the consignee's use in accordance with 10 CFR 20.1906(e) [Ref. 8].
- Trailer placarding and cask labeling meet DOT specifications (49 CFR 172).
- Provisions of 10 CFR 71.87 [Ref. 2] are met.
- Radiation dose rates are in accordance with 10 CFR 71.47 [Ref. 2]
  - $\leq$ 200 mrem/hr at package surface.
  - $\leq$ 10 mrem/hr at 2 meters from the vertical side of the trailer.
  - $\leq$ 2 mrem/hr at the cab of the tractor
- No temperature survey is required. The thermal evaluation demonstrates that the temperature requirement of 10 CFR 71.43(g) [Ref. 2] is met.
- Security seals are properly installed as required by 10 CFR 71.43(b) [Ref. 2]
- Inspect the exterior of the cask for damage prior to shipping a loaded package. Contact RT if damage is present.
- Ensure that the RT-100 is correctly tied-down to the trailer.

7.2 Package Unloading

Section 7.2 addresses the unloading operations for the RT-100.

The procedures for unloading the RT-100 are defined as follows:

7.2.1 Receipt of Package from Carrier
7.2.2 Removal of Contents

7.2.1 Receipt of Package from Carrier

The following actions are taken upon receipt of the RT-100 from the carrier:

1. User shall follow the applicable requirements of 10 CFR 20.1906 [Ref. 8] "Procedures for Receiving and Opening Packages" when the package contains radioactive material in excess of Type A quantities. Corresponding packages are identified by review of the shipping papers.

2. Any special instructions provided by the shipper in accordance with 10 CFR 71.89 [Ref. 2] are reviewed and followed.
3. Perform visual examination of the unopened cask. Any damage is reported to the shipper and actions taken to replace or repair any components that would jeopardize the integrity of the RT-100.
4. Inspect the tamper indicating seal at the upper impact limiter aligning pin. Shipper is notified and the shipment may be rejected by the consignee if the tamper seal has been removed or tampered with in any way. At consignee discretion, the consignee may proceed to accept the RT-100 contents if the tamper indicating seal was damaged during shipment.
5. Conduct contamination and radiation dose rate surveys to determine if the levels are compliant with the DOT and NRC. If either of these surveys exceeds the limits, the shipper is notified immediately, and the shipper collaborates with consignee; or the appropriate regulatory authorities and DOT, to resolve the issue.
6. Measure the exterior gamma radiation levels following RIS 13-04 to ensure these do not exceed 200 millirem per hour (2 mSv/h) at any point on the vertical planes projected from the outer edges of the trailer, on surface of the impact limiter at the axial center line if the package, and on the lower external surface of the trailer, 10 millirem per hour (0.1 mSv/h) at any point 2 meters (6.6 feet) from the vertical planes projected by the outer edges of the trailer (excluding the underside of the trailer) and 2 millirem per hour (0.02 mSv/h) in the tractor cab, in accordance with 49 CFR 173.441 and 10 CFR 71.47. Measurements shall be made at the axial mid-plane of the cask and below the cask end on the lower external surface of the trailer. Also measure the neutron radiation to ensure there is not unexpected neutron sources in the content.

7.2.2 Removal of Contents

Unloading is conducted with the RT-100 in a vertical position in an approved licensed radioactive materials facility. If desired, the RT-100 may be removed from the trailer and the lower impact limiter may be removed. Follow the instructions in Section 7.4 for these optional steps.
The following procedures are used to remove the contents from the RT-100:

1. Remove the upper impact limiter in accordance with Section 7.1.1.1.
2. Remove the quick-disconnect valve cover plate and balance the interior and exterior pressures in accordance with Section 7.1.1.3.
   - <u>Caution</u>: In the event of failure of the quick disconnect valve, radioactive material may be released when opening the vent port cover plate. Use caution to consider potential release of material consistent with the form of the cask contents.
3. Remove applicable lid (handle as contaminated):
   - Removal of the Primary Lid: Section 7.1.1.4
   - Removal of the Secondary Lid: Section 7.1.1.5
4. Use appropriate equipment to remove the contents.

5. Inspect RT-100 interior for any damage, loose material, or moisture. Clean seal surfaces. Contact RT in case of damaged O-ring.

NOTES:

- Care should be taken not to damage the cask or the sealing surfaces.
- Remove any material from inside the cask under the supervision of qualified health physics personnel, and by following appropriate health & safety protocols.
- Radioactively contaminated liquids may be pumped or removed by absorbent material.

7.3 Preparation of Empty Package for Transport

Section 7.3 describes the operations used to certify that the empty package is safe for transportation in accordance with 49 CFR 173.428, "Empty Class 7 (Radioactive) Material Packaging" [Ref. 4].

These operations must be completed before shipment of the empty RT-100:

1. Confirm the cavity is empty of contents as far as practicable
2. Survey the lid, quick connect cover and interior:
   - Decontaminate if the limits of 49 CFR 173.428(d) [Ref. 4] are exceeded.
3. Replace and secure the applicable lid:
   - Primary Lid Replacement 7.1.2.2
   - Secondary Lid Replacement 7.1.2.3
4. Replace and secure the quick-disconnect valve cover in accordance with Section 7.1.2.4.
5. Decontaminate the exterior surfaces of the cask, as necessary.
6. If previously removed, replace lower impact limiter in accordance with Section 7.4.3.
7. If previously removed, replace RT-100 on the trailer in accordance with Section 7.4.4.
8. Replace upper impact limiter in accordance with Section 7.1.3.1.
9. Inspect the exterior and confirm it is undamaged and unimpaired.

7.4 Other Operations

Section 7.4 describes provisions for any special operational controls.

7.4.1 Lower Impact Limiter Removal

The lower impact limiter may be removed by following these steps:

1. Remove the cotter pin from each lower impact limiter threaded stud.
2. Using appropriate tools loosen and remove all the head nuts which secure the impact limiter to the cask body.
3. Remove the cask from the trailer following the sequence described in Section 7.4.2.
4. Install three lifting rings to the lower impact limiter using three (3) 120° distant studs.
5. Remove the impact limiter using an appropriate lifting device attached to the three (3) lifting rings.

NOTE: To prevent damage, the impact limiter shall be handled and stored with care. It must be placed on a clean, flat surface in a position so that the studs and aligning pins do not touch the ground.

7.4.2 Package Removal from Trailer

The RT-100 may be removed from the trailer by following these steps:

1. Verify transport trailer is in appropriate area for unloading.
2. Disconnect tie-down system and render the holes inoperable so that they cannot be used for lifting of the packaging.
3. If not already complete, remove upper impact limiter in accordance with Section 7.1.1.1.
4. Inspect condition of the cask lifting pocket welds.
5. Install Lifting Yoke. (RT-100 Lifting Yoke must be handled with its two (2) suitable lifting rings connected to the lifting crane.)
   a. Engage two (2) lifting yoke arms in the cask lifting pockets (Figure 7.4.2-1).
   b. Connect arms in the lifting pockets by inserting the pin in each arm (Figure 7.4.2-2).
   c. Secure lifting yoke arms by inserting lock pin in the pin hole below the cask lifting pockets, and secure the lock pin with a cotter pin (Figure 7.4.2-3).
6. With or without the lower impact limiter attached, lift the RT-100 cask from the transport trailer (Figure 7.4.2-4).
7. Place the RT-100 cask (and lower impact limiter) in an approved storage area. Care should be taken to prevent the cask assembly and the lifting equipment from any damage.
8. Disconnect the lifting yoke from the cask.

Figure 7.4.2-1 Lifting Yoke Arm Positioned on Cask

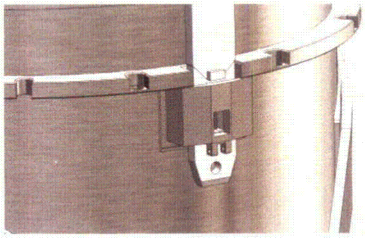


Figure 7.4.2-2 Lifting Yoke Connections

Figure 7.4.2-3 Lifting Yoke Secured with Locking Pin

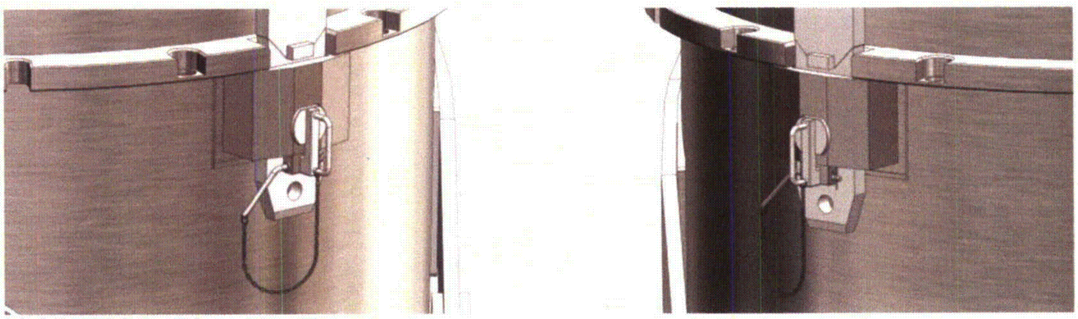
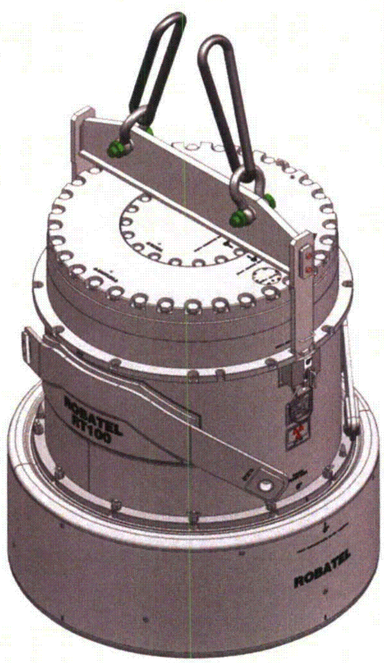


Figure 7.4.2-4 Assembled Cask Ready to Lift
(shown with Lower Impact Limiter installed)



7.4.3 Replacement of Lower Impact Limiter

Replace the lower impact limiter by following these steps:

1. Verify that the lower impact limiter is correctly positioned and located in an appropriate area for installing the cask. The installation of the lower impact limiter can be conducted with the limiter already positioned on the transport trailer.
2. Inspect and clean the lower impact limiter surface.
3. Inspect each threaded stud for cleanliness, defects and lubrication – replace if necessary in accordance with Section 7.4.5.3.
4. Install the lifting yoke on the cask as written in Section 7.4.2 (upper impact limiter shall not be installed on the cask).
5. Lift cask with appropriate lifting equipment.
6. Inspect and clean (if necessary) bottom surface of cask.
7. Position the cask body using the two (2) lower impact limiter aligning pins.
8. Using caution, slowly lower the cask body to prevent any damage to the lower impact limiter and the cask body.
9. Secure cask on the lower impact limiter by installing the twelve (12) nuts on the threaded studs. The head nuts do not require any specific torque. The nuts must be in contact with the cask attachment ring.
10. Install a cotter pin on each of the 12 threaded studs.

7.4.4 Reloading the Package onto the Trailer

The RT-100 may be reloaded onto the trailer by following these steps:

1. Verify the transport trailer is located in an appropriate area for loading. Figure 7.4.4-1 shows an example trailer illustration.
2. Install the lifting yoke on the cask as written in Section 7.4.2 (upper impact limiter shall not be installed on the cask).
3. Lift the RT-100 cask onto the transport trailer as shown in Figure 7.4.4-2. Position the tie-down arms along the trailer as shown in Figure 7.4.4-2.
4. Disconnect the lifting yoke from the cask as described in Section 7.4.2.
5. The lifting pockets must be rendered inoperable prior to transport. Acceptable options for this step include: inserting the lifting pins in the lifting pockets and securing with the lock pins, or inserting and securing dedicated pins into the lifting pockets.
6. Install the upper impact limiter as described in Section 7.1.3.1.
7. Connect the four (4) tie-down arms to the trailer by the tie-down equipment.
8. Tighten the tie-down equipment to ensure no movement of the RT-100 in any direction.

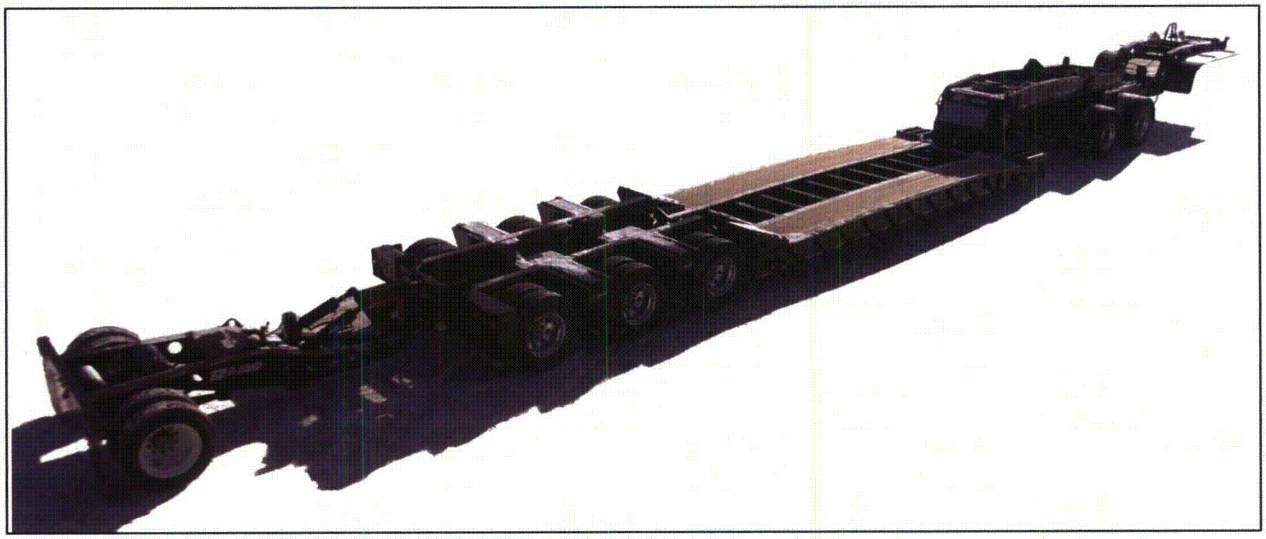


Figure 7.4.4-1 Example Trailer Illustration

Figure 7.4.4-2 Loading of the RT-100 on Transportation Trailer

7.4.5 Tightening of Components

Section 7.4.5 addresses issues associated with components that require tightening.

7.4.5.1 Tightening Torques

Table 7.4.5-1 provides descriptive information and torque values for lid bolts. Table 7.4.5-2 provides descriptive information and torque values for other parts.

Table 7.4.5-1 Lid Bolt Tightening Torques

Description	Dimensions	Qty.	Tightening Torque [N-m]	Tolerance
Primary lid bolts	HHCS M48x170	32	850	± 10%
Secondary lid bolts	HHCS M36x120	18	350	± 10%
Quick disconnect valve disconnect valve cover plate bolts	SHCS M10x30	6	27	± 10%

Table 7.4.5-2 Tightening Torques - Other Parts

Description	Dimensions	Qty.	Tightening Torque [N-m]	Tolerance
Primary Lid Aligning Pin	M42	1	850	± 10%
Secondary Lid Aligning Pin	M24	1	200	± 10%
Impact Limiter Studs	M36	24	N/A[1]	-
Impact Limiter Nuts	HM36	24	N/A[1]	-
Quick Disconnect Valve Cover Plate Leak Test Port Plug	M10	1	10	± 10%
Quick Disconnect Valve	G 3/8	1	50	± 10%
Primary and Secondary Lid Leak Test Port Plug	M20	2	100	± 10%

[1] The lower and upper impact limiter nuts do not require any specific torque to ensure function. They are hand-torqued when assembled. Thus, no control of the tightening torque on these nuts is necessary.

7.4.5.2 Threaded Bolts – Tightening Methods and Equipment

Threaded bolts and parts must be tightened to the torque limits specified in Table 7.4.5-1 and Table 7.4.5-2, using a wrench that displays the torque applied during tightening.

1. Bolts and bolt holes are cleaned prior to use.
2. Bolt holes are lubricated before bolts are placed into position for tightening.
3. Bolts and nuts are lubricated before tightening.
4. Bolts on the primary and secondary lids are tightened via the "star pattern" in a minimum of two stages:
   a. Use an initial torque of approximately 50% of required torque.
   b. Use a final torque of the full required torque.

7.4.5.3 Replacement of the Impact Limiter Threaded Studs

The impact limiter threaded studs may be replaced in the following manner:

1. Remove the spring pin securing the threaded stud.
2. Unscrew the threaded stud and remove it.
3. Install a new threaded stud and tighten it by hand to align the stud and the embossing holes (no specific torque required).
4. Install a new spring pin to secure the threaded stud.

7.5 Hydrogen Buildup in RT-100 Transport Cask

The RT-100 is designed for a maximum decay heat of 200 Watts, as described in Section 1.2.2.8. The rate of hydrogen gas generation must also be considered when evaluating the heat load. The method for calculating the hydrogen gas generation is described in Section 4.4. Two evaluation methods are described in the following sections – a simplified model (Section 7.5.1) which is used for most shipments but is limited to certain restrictions, and an analytical model (Section 7.5.2) used for other cases. An example calculation using the analytical model is detailed in Section 7.5.3.

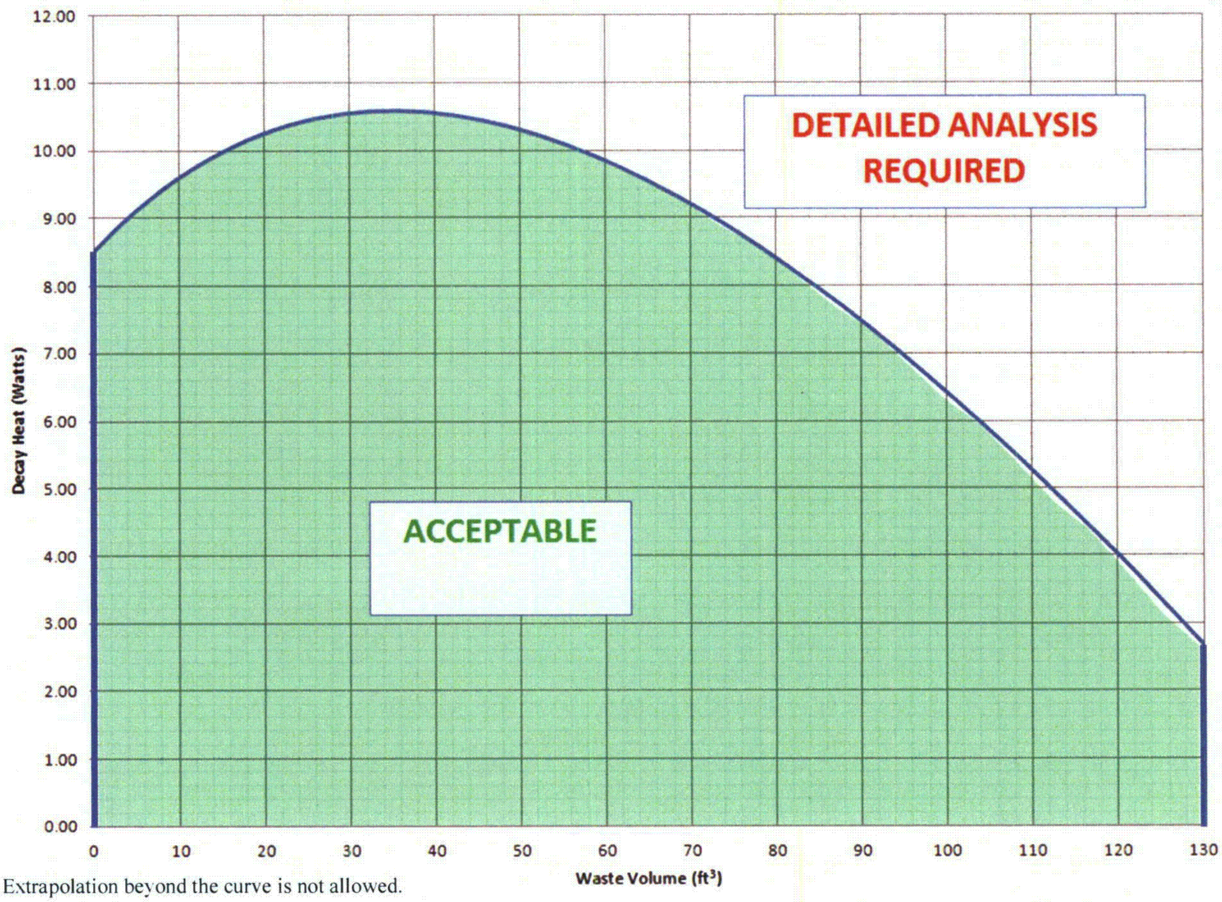
Package material and content that can generate flammable gas shall be appropriately assigned as part of the ionic resin bead waste or polyethylene container when using the Loading Curve (Figure 7.5-1 and Table 7.5.1-1) or detailed analysis (Section 7.5.2) to determine acceptable hydrogen gas generation-related parameters of shipping time and decay heat. For example, waste filters (made of material other than polypropylene or polyethylene) shall be grouped as ionic bead waste and wood shoring would be grouped as part of the polyethylene container. If filters are made of polyethylene or polypropylene, they are to be included in the secondary container volume for the hydrogen gas generation detailed analysis.

7.5.1 Hydrogen Gas Generation – Simplified Model used to develop Loading Curve

Using the equations derived in Chapter 4, Section 4.4, the decay heat limit versus waste volume can be determined for a limit of 5% in the cavity free volume. Figure 7.5-1 provides a curve illustrating the waste volume to decay heat value that would result in the generation of a flammable gas mixture within 10 days assuming that all decay heat is absorbed by the waste material and the polyethylene container. The calculation assumes that the hydrogen generation occurs over a period of time that is twice the allowable shipping time. For most shipments, this simplified graphical model (Loading Curve) can be used to determine the maximum heat load.

Use the following procedure to confirm the decay heat of the cask contents meet the requirements of NUREG/CR-6673 [Ref. 16]:

1. Confirm <u>all</u> the restrictions listed in Table 7.5.1-1 are met. Confirm the secondary container is listed in Table 7.5.1-2, or is a container of equivalent material volume. Confirm the shoring volume does not exceed the allowable volume. If these restrictions cannot be met, the analytical model described in Section 7.5.2 must be used.
2. Identify the waste volume (V_{WASTE}) in cubic feet.
3. Use the Loading Curve shown in Figure 7.5-1 to find the maximum allowable decay heat ($D_{H,max}$) in Watts.
4. Confirm that the cask contents have a decay heat (D_H) that is less than the maximum allowable decay heat ($D_{H,max}$).



Extrapolation beyond the curve is not allowed.

Figure 7.5-1 Package Loading Curve for Hydrogen Generation – Decay Heat Limit Versus Waste Volume

Table 7.5.1-1 Conditions for using Package Loading Curve (Excerpt from Table 4.4.4-1)

Condition for Shipper to use Loading Curve	
1	Waste consisting of resins and filters from commercial power plants
2	Waste has been dewatered or grossly dewatered
3	No limit on moisture content of resin
4	Use of a liner (or equivalent) listed in Table 7.5.1-2 with maximum shoring volume as specified
5	Shipment time not greater than 10 days
6	Loading at temperature not exceeding 38 °C and standard pressure (1 atm)
7	Secondary containers are passively vented within the cask cavity during shipment.
8	Filters in the waste are not made of polyethylene or polypropylene.
9	Waste Volume not greater than 130 ft^3.

Table 7.5.1-2 Secondary Container and Allowable Shoring Volumes (Excerpt from Table 4.4.3-6)

Secondary Container	Volume Occupied by Container		Allowable Shoring Volume	
	(ft³)	(cm³)	(ft³)	(cm³)
PL 6-80 MT	9.28	2.63E+05	20.82	5.90E+05
PL 6-80 MTIF	9.74	2.76E+05	20.36	5.76E+05
PL 6-80 FR	10.21	2.89E+05	19.89	5.63E+05
PL 6-80 FP/FEDX	11.60	3.28E+05	18.50	5.24E+05
PL 8-120 MT	11.14	3.15E+05	18.96	5.37E+05
PL 8-120 MTIF	11.60	3.28E+05	18.50	5.24E+05
PL 8-120 FR	12.06	3.42E+05	18.04	5.11E+05
PL 8-120 FP/FEDX	13.46	3.81E+05	16.64	4.71E+05
PL 8-120 CMT	13.36	3.78E+05	16.74	4.74E+05
PL 14-150	14.85	4.20E+05	15.25	4.32E+05
PL 10-160 MT	12.99	3.68E+05	17.11	4.84E+05
PL 10-160 MTIF	13.64	3.86E+05	16.46	4.66E+05
PL 10-160 FR	13.92	3.94E+05	16.18	4.58E+05
PL 10-160 FP/FEDX	15.31	4.34E+05	14.79	4.19E+05
NUHIC-55	2.78	7.88E+04	27.32	7.74E+05
NUHIC-136	11.14	3.15E+05	18.96	5.37E+05
Radlok 500	12.62	3.57E+05	17.48	4.95E+05
EL-50	16.87	4.78E+05	13.23	3.75E+05
EL-142	27.02	7.65E+05	3.08	8.72E+04
L 6-80 MT	2.27	6.42E+04	27.83	7.88E+05
L 6-80 CMT	2.61	7.38E+04	27.49	7.79E+05
L 6-80 IN-SITU	7.94	2.25E+05	22.16	6.28E+05
L 6-80 FP	2.38	6.74E+04	27.72	7.85E+05
L 6-80 FP/FEDX	2.78	7.86E+04	27.32	7.74E+05
L 8-120 MT	2.72	7.70E+04	27.38	7.75E+05
L 8-120 CMT	3.06	8.67E+04	27.04	7.66E+05
L 8-120 IN-SITU	9.52	2.70E+05	20.58	5.83E+05
L 8-120 FR	2.83	8.03E+04	27.27	7.72E+05
L 8-120 FP/FEDX	3.00	8.51E+04	27.10	7.67E+05
ES-50	0.57	1.61E+04	29.53	8.36E+05
ES-142	2.49	7.06E+04	27.61	7.82E+05

7.5.2 Hydrogen Gas Generation – Analytical Model used for Detailed Analysis

If Figure 7.5-1 is not applicable to a shipment, or if further analysis is required, the equations given in Section 4.4.5 can be used to determine the maximum allowable decay heat. Equation 4.8 and Equation 4.9 are given below for reference:

Equation 4.8

Determination of maximum shipping time based on a known decay heat:

$$t_{max} = \frac{(2.5A_N P_0)(4.6E6 - V_C - 0.8911V_{WASTE})(0.8911V_{WASTE} + V_C)}{(R_g T_0 D_H)[0.6336V_{WASTE} G_{Ti}(\alpha_i - 0.05) + V_C G_{TC}(\alpha_C - 0.05) + 0.2575V_{WASTE} G_{TW}(\alpha_W - 0.05)]}$$

Equation 4.9

Determination of the maximum decay heat based on a known shipment time:

$$D_{H,max} = \frac{(2.5A_N P_0)(4.6E6 - V_C - 0.8911V_{WASTE})(0.8911V_{WASTE} + V_C)}{(R_g T_0 t)[0.6336V_{WASTE} G_{Ti}(\alpha_i - 0.05) + V_C G_{TC}(\alpha_C - 0.05) + 0.2575V_{WASTE} G_{TW}(\alpha_W - 0.05)]}$$

where:

t_{max}	=	maximum allowable shipping time for a given decay heat to ensure the hydrogen generated during shipment does not exceed 5% [s]
$D_{H,max}$	=	maximum allowable decay heat for a given shipping time to ensure the hydrogen generated during shipment does not exceed 5% [eV/s]
A_N	=	Avogadro's constant [6.022×10^{23} molecules/gmol]
R_g	=	gas law constant [82.05 cm^3·atm/gmol·K]
P_0	=	pressure when the container is sealed [atm]
T_0	=	temperature when the container is sealed [K]
t	=	shipment time [s]
D_H	=	decay heat of cask contents [eV/s]
V_C	=	volume occupied by the secondary container, shoring, and polyethylene or polypropylene filters in the waste [cm^3]
V_{WASTE}	=	volume occupied by the ionic resin and stainless steel filters in the waste material [cm^3]
G_{Ti}	=	total radiolytic G value for the ionic resin and stainless steel filters [molecules/100eV]
G_{TC}	=	total radiolytic G value for the secondary container, shoring, and polyethylene or polypropylene filters in the waste [molecules/100eV]
G_{TW}	=	total radiolytic G value for water in waste [molecules/100eV]
α_i	=	fraction of G_{Ti} that is equivalent to G_{FGi}, flammable gas released, for the ionic resin and stainless steel filters
α_C	=	fraction of G_{TC} that is equivalent to G_{FGC}, flammable gas released, for the secondary container, shoring, and polyethylene or polypropylene filters in the waste
α_W	=	fraction of G_{TW} that is equivalent to G_{FGW}, flammable gas released, for water in the waste

NOTE: Use of Equation 4.8 and Equation 4.9 are valid only when the conditions listed in Table 7.5.2-1 are met. Shipments are allowed only if the conditions in Table 7.5.2-1 are met.

Table 7.5.2-1 Conditions for Shipper to use the Detailed Analysis (From Table 4.4.5-1)

1	Waste consists of resins and filters from commercial power plants.
2	Waste has been grossly dewatered.
3	Secondary containers are passively vented within the cask cavity during shipment.

Use the following procedure to confirm the decay heat of the cask contents meet the requirements of NUREG/CR-6673 [Ref. 16]:

1. Determine the values of the variables P_0, T_0, V_C, and V_{WASTE}. Initial pressure (P_0) and initial temperature (T_0) may be measured by the user at the time of loading. The volume occupied by the secondary container, shoring, and polyethylene or polypropylene filters in the waste (V_C) and the volume occupied by the ionic resin and stainless steel filters in the waste material (V_{WASTE}) are known.
2. Determine the values of the variables G_{Ti}, G_{TC}, G_{TW}, α_i, α_C, and α_W. G-values (G_{Ti}, G_{TC}, G_{TW}) and α fractions (α_i, α_C, α_W) must be justified by the user based on waste characterization. These variables must be adjusted for the transport temperature of 80 °C, as described in Section 4.4.1.3, in order to meet the requirements of NUREG/CR-6673 [Ref. 12]. The values must also be adjusted for the appropriate alpha/gamma radiation distribution. One example of this adjustment is provided in Table 7.5.2-2 for the same G-values in the bounding case loading curve for the 80% gamma/20% alpha decay heat distribution.
3. Use one of the following methods (a *or* b).
    a. Take the decay heat of the cask contents (D_H) and solve Equation 4.8 for the maximum allowable shipping time (t_{max}). Confirm the shipment time (t) will be less than the maximum allowable shipping time (t_{max}).
    b. Take the shipment time (t) and solve Equation 4.9 for the maximum allowable decay heat ($D_{H,max}$). Confirm the actual decay heat of the contents (D_H) is less than the maximum allowable decay heat ($D_{H,max}$).

Table 7.5.2-2 G-values and α-Fractions for a Range of Alpha/Gamma Decay Heat Distributions (Excerpt from Table 4.4.5-2)

Gamma Frac	Alpha Frac	Material	G (net gas), G_T		α	
0.0	1.0	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	3.65	α_i	0.81
		Water	G_{TW}	1.60	α_W	1.00[16]
0.1	0.9	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	3.40	α_i	0.82
		Water	G_{TW}	1.49	α_W	1.00[16]
0.2	0.8	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	3.14	α_i	0.82
		Water	G_{TW}	1.37	α_W	1.00[16]
0.3	0.7	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	2.88	α_i	0.83
		Water	G_{TW}	1.26	α_W	1.00[16]
0.4	0.6	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	2.62	α_i	0.84
		Water	G_{TW}	1.14	α_W	1.00[16]
0.5	0.5	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	2.37	α_i	0.85
		Water	G_{TW}	1.03	α_W	1.00[16]
0.6	0.4	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	2.11	α_i	0.87
		Water	G_{TW}	0.91	α_W	1.00[16]
0.7	0.3	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	1.85	α_i	0.89
		Water	G_{TW}	0.80	α_W	1.00[16]
0.8	0.2	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	1.59	α_i	0.91
		Water	G_{TW}	0.68	α_W	1.00[16]
0.9	0.1	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	1.34	α_i	0.95
		Water	G_{TW}	0.57	α_W	1.00[16]
0.95	0.05	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	1.21	α_i	0.97
		Water	G_{TW}	0.51	α_W	1.00[16]
1.0	0.0	Polyethylene	G_{TC}	5.06	α_C	1.00
		Resin	G_{Ti}	1.08	α_i	1.00
		Water	G_{TW}	0.45	α_W	1.00[16]

[16] For water, the α value is set to 1.0.

7.5.3 Hydrogen Gas Generation – Analytical Model Example

An example calculation using the analytical model developed in Section 7.5.2 is shown below. The following two variables are constants are known:

A_N = 6.022E23 molecules/gmol
R_g = 82.05 cm^3·atm/gmol·K

In this example, the user has input the following parameters:

P_0 = 1 atm
T_0 = 89 °F = 305 K
t = 8 days = 691200 s
V_C = 30.1 ft^3 = 8.52E05 cm^3
V_{WASTE} = 70.0 ft^3 = 1.98E06 cm^3

These variables are substituted into the maximum allowable decay heat equation as shown:

$$D_{H,max} = \frac{(2.5A_NP_0)(4.6E6 - V_C - 0.8911V_{WASTE})(0.8911V_{WASTE} + V_C)}{(R_gT_0t)[0.6336V_{WASTE}G_{Ti}(\alpha_i - 0.05) + V_CG_{TC}(\alpha_C - 0.05) + 0.2575V_{WASTE}G_{TW}(\alpha_W - 0.05)]}$$

$$= \frac{[(2.5)(6.022E23)(1)] \times [4.6E6 - 8.52E5 - (0.8911)(1.98E6)] \times [(0.8911)(1.98E6) + 8.52E5]}{[(82.05)(305)(691200)][0.6336(1.98E6)G_{Ti}(\alpha_i - 0.05) + (8.52E5)G_{TC}(\alpha_C - 0.05) + 0.2575(1.98E6)G_{TW}(\alpha_W - 0.05)]}$$

$$= \frac{[1.51E24] \times [1.98E6] \times [2.62E6]}{[1.73E10][(1.25E6)G_{Ti}(\alpha_i - 0.05) + (8.52E5)G_{TC}(\alpha_C - 0.05) + (5.10E5)G_{TW}(\alpha_W - 0.05)]}$$

Additionally, the user knows the decay heat distribution of the waste stream is 95% gamma. Using the information provided in Table 7.5.2-2, the user inputs the following G-values and α fractions. (Note that the values listed in Table 7.5.2-2 have already been adjusted for bounding NCT temperature.)

G_{Ti} = 1.21 molecules/100eV
G_{TC} = 5.06 molecules/100eV
G_{TW} = 0.51 molecules/100eV
α_i = 0.97
α_C = 1.00
α_W = 1.00

With further substitution, the maximum allowable decay heat ($D_{H,max}$), may be calculated:

$$= \frac{[1.51E24] \times [1.98E6] \times [2.62E6]}{[1.73E10][(1.25E6)(1.21)(0.97 - 0.05) + (8.52E5)(5.06)(1 - 0.05) + (5.10E5)(0.51)(1 - 0.05)]}$$

$$= \frac{[7.81E36]}{[1.73E10][(1.40E6) + (4.10E6) + (2.47E5)]}$$

$$D_{H,max} = 7.87 \times 10^{19}\frac{eV}{s} = 12.61\ Watts$$

7.6 Appendix

The following appendices are included for Chapter 7 instruction and information. Additional steps and conditions of use for the RT-100 are as follows:

1. The maximum content density is 1.0 g/cm^3. The weight of free water must be excluded in this determination. The source strength density must be ensured at any point of the content. Average density by dividing the total activity by total weight is not acceptable.
2. No neutron emitting nuclides, except in trace amounts.
3. The weight of water must be excluded when determining the Ci/gram of content limit.
4. The source concentration must not exceed the Curies per gram limit determined using the method and the loading tables as prescribed in Appendix 7.6 of this Chapter and no concentration or shift during normal conditions of transport.
5. The user/shipper must analyze the constituent radioactive nuclides of the content on a per-gram basis.
6. The user/shipper must determine the allowable content based on the loading tables provided in Section 7.6.1.1.
7. The user/shipper must ensure the per gram activities at any point within the content does not exceed the limit that is specified according to the loading table.
8. The allowable content must be determined based on dry resin or filter media. Any potential concentration of sources during loading and transport is not permitted.
9. The radioactive content is not to exceed 1.0 g/cm^3 and the nuclear physical characteristics, i.e., the gamma attenuation coefficient of the content must not be smaller than that of the carbon material resin.
10. A comprehensive dose rate measurement is performed prior to transport of the package as described in Section 7.1.3.
11. A comprehensive dose rate measurement is preformed after arrival at the destination as described in Section 7.2.1.
12. Compare pre-shipment dose rate measurements to dose rate measurements at the arrival of the package. Stop any further shipment if the measured dose rates show significant differences from the pre-shipment measurement values.

7.6.1 RT-100 Loading Table Discussion

The dose rate compliance of the RT-100 cask is ensured by: first, determining the percent of each radionuclide activity relative to its maximum allowable value, and then summing up this dose rate percentage for all radionuclides and assuring that the sum does not exceed 100%. In addition, the activity for the package shall be less than 3000 A_2, the total decay heat output shall be less than 200 watts, and the actual content activity concentration of neutron emitters shall be less than 3.5 milliCuries/kg. This compliance is facilitated by employing a loading table that is completed by the shipper of the RT-100. The loading table has ten columns as follows:

- "Actual Content Nuclide" – Radionuclide entered by user into the loading table. Qualification of the content loaded into the RT-100 cask is under the responsibility of the shipper/user.

- "Maximum Allowable Activity Concentration" – The maximum allowed activity for the isotope being entered into the RT-100 transport cask, in milliCuries/kg, that is based on the methodology described in Section 5.4.4 and presented in Table 7.6.1-6.

- "Actual Content Activity Concentration" – The maximum activity concentration of the isotope to be placed in the RT-100 transport entered by the user in units of milliCuries/kg. This value should be the maximum for any waste stream placed in the cask. The user shall ensure that the bulk density of the resin or filter media does not exceed 1 g/cm^3.

- "% of Maximum" – The percent of maximum column represents the percentage of the activity concentration entered by the user for the isotope in question versus the maximum allowable activity concentration established by the methodology described in Section 5.4.4.

- "A2" – The total activity equivalent to 1 A_2 in Curies for isotope entered by the user.

- "Activity(i) / A2(i)" – The total A_2 quantity for the isotope entered by the user.

- "Q Value" – The amount of heat energy released per unit activity, in Watts/milliCurie, for the isotope entered by the user.

- "Heat Load" – The total heat load contribution, in Watts, for the activity concentration and mass entered by the user for the isotope.

- "Neutron Emitter?" – This column indicates whether the Radionuclide entered by the user is a neutron emitter (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{248}Cm, ^{241}Am, or ^{252}Cf).

- "Actual Content Activity Concentration" – For neutron emitters, the previously entered activity concentration is shown in this column.

The total waste inventory volume and mass is entered into the first two rows in cubic feet and kilograms (in the yellow cells in Table 7.6.1-1). The "Actual Content Activity Concentration (milliCuries/kg)" and "Actual Content Nuclide" columns (columns in yellow in Table 7.6.1-1) is where the user inputs the activity concentration and radionuclides in the package.

Once total mass in kilograms, total activity concentration in milliCuries/kg, and radionuclides are input into the table, the rest is automatically updated. The "% of Maximum" column is the ratio of the results in "Actual Content Activity Concentration (milliCuries/kg)" column divided by the values in "Maximum Allowable Activity Concentration (milliCuries/kg)" column.

The "Maximum Allowable Activity Concentration (milliCuries/kg)" column contains the maximum activity per kilogram allowed for each isotope based on the NCT and HAC dose rate limits and the most conservative response functions (mrem/hr/Curie) generated by MCNP calculations. The "% of Maximum" column is summed at the end of the column. If the sum is greater than 100%, than the inventory dose rate would potentially exceed the NCT or HAC dose rate limits, which would make the package not acceptable. If the sum is less than or equal to 100%, the package would generate an acceptable dose rate under NCT and HAC conditions. The "A2 (Curie)" column contains the A_2 activity value in Curies for the isotope. The "Activity (i) / A2(i)" column is the ratio of the activity entered by the user divided by the A_2 value for the isotope. The "Activity (i) / A2(i)" column is summed. If the value is under 3000 A_2, the inventory total activity is below the containment limit.

The third test is determining the total heat load of the inventory. Each radionuclide's activity is multiplied by the value in the "Q Value (Watts/milliCurie)" column and the result is automatically entered into the "Heat Load (Watts)" column. At the end of the column, the results are summed and compared to the 200 Watt limit. If it is below the limit, the package is acceptable under heat load limitations.

The final test is to ensure the neutron emitter limit of 3.5 milliCuries/kg is not exceeded. If the user-entered radionuclide is a neutron emitter, it is indicated in the "Neutron Emitter?" column. For these radionuclides, the "Actual Content Activity Concentration" is shown. At the end of the column, the results are summed and compared to the limit of 3.5 milliCuries/kg. If the sum is below the limit, the package is considered to contain only trace amounts of neutron-emitting radionuclides.

At the end of each evaluation, a marker indicating if the inventory passes a particular set of

criteria (for example the cell beside "Passed Shielding Criteria") is provided. If the cell turns green and states "TRUE", then the inventory passes that particular set of criteria. If the cell turns red and states "FALSE", then the inventory has failed that particular set of criteria. An inventory must pass all four criteria (shielding, containment, heat load, and neutron limit) in order to be shipped in an RT-100 cask.

Notes for the RT-100 Loading Table:

- Each radionuclide in the resin mixture is listed by row.
- The sum of column 4 (% of max) should be less than 100% for dose rate regulatory compliance and the sum of column 6 (C(i)/A(i)) should be less than 3000 A_2 for containment regulatory compliance.
- The sum of column eight should be less than 200 Watts in order to satisfy the heat load limit.
- A basic procedure has been provided in Section 7.6.1.1.
- Several examples have been provided in Section 7.6.1.2, Section 7.6.1.3, and Section 7.6.1.4.
- Example of RT-100 Loading Table format provided below in Table 7.6.1-1.

Table 7.6.1-1 RT-100 Loading Table Illustration

	Waste Vol (ft^3)	Actual Content Loading Evaluation							
	Content Mass (kg)								
Gamma Emitting Nuclides		Shielding Evaluation		Containment Evaluation		Heat Load Evaluation		Neutron Emitter† Evaluation	
Actual Content Nuclide	Maximum Allowable Activity Concentration (milliCuries/kg)	Actual Content Activity Concentration (milliCuries/kg)	% of Maximum	A2 (Curie)	Activity(i) / A2(i)	Q Value (Watts/mCi)	Heat Load (Watts)	Neutron Emitter?	Actual Content Activity Concentration (milliCuries/kg)
ac225	5.06E+05	0.00E+00	0.00	0.16	0.00E+00	3.49E-05	0.00E+00	N	
ag108m	2.12E+03	0.00E+00	0.00	19	0.00E+00	9.70E-06	0.00E+00	N	
ag110	3.68E+04	0.00E+00	0.00	0.54	0.00E+00	7.18E-06	0.00E+00	N	
ag110m	4.84E+02	0.00E+00	0.00	11	0.00E+00	1.67E-05	0.00E+00	N	
am241	6.02E+07	0.00E+00	0.00	0.027	0.00E+00	3.34E-05	0.00E+00	Y	0.00E+00
am242	5.83E+11	0.00E+00	0.00	0.54	0.00E+00	1.15E-06	0.00E+00	N	
am243	2.81E+06	0.00E+00	0.00	0.027	0.00E+00	3.47E-05	0.00E+00	N	
au199	4.09E+04	0.00E+00	0.00	16	0.00E+00	1.38E-06	0.00E+00	N	
ba140	3.43E+04	0.00E+00	0.00	8.1	0.00E+00	2.92E-06	0.00E+00	N	
be7	1.93E+05	0.00E+00	0.00	540	0.00E+00	2.00E-06	0.00E+00	N	
c14	5.83E+11	0.00E+00	0.00	81	0.00E+00	2.93E-07	0.00E+00	N	
cd109	5.83E+11	0.00E+00	0.00	54	0.00E+00	1.17E-07	0.00E+00	N	
ce139	2.50E+04	0.00E+00	0.00	54	0.00E+00	1.47E-06	0.00E+00	N	
ce141	4.14E+04	0.00E+00	0.00	16	0.00E+00	1.46E-06	0.00E+00	N	
ce144	1.80E+05	0.00E+00	0.00	5.4	0.00E+00	7.99E-06	0.00E+00	N	
cm241	1.16E+04	0.00E+00	0.00	27	0.00E+00	4.05E-06	0.00E+00	N	
cm242	4.05E+08	0.00E+00	0.00	0.27	0.00E+00	3.65E-05	0.00E+00	Y	0.00E+00
cm243	3.16E+04	0.00E+00	0.00	0.027	0.00E+00	3.66E-05	0.00E+00	Y	0.00E+00
cm244	8.69E+08	0.00E+00	0.00	0.054	0.00E+00	3.50E-05	0.00E+00	Y	0.00E+00
cm245	3.76E+04	0.00E+00	0.00	0.024	0.00E+00	3.33E-05	0.00E+00	N	
cm246	5.83E+11	0.00E+00	0.00	0.024	0.00E+00	3.28E-05	0.00E+00	N	
co57	1.99E+04	0.00E+00	0.00	270	0.00E+00	8.52E-07	0.00E+00	N	
co58	6.96E+03	0.00E+00	0.00	27	0.00E+00	5.99E-06	0.00E+00	N	
co60	2.50E+02	0.00E+00	0.00	11	0.00E+00	1.54E-05	0.00E+00	N	
cr51	1.98E+05	0.00E+00	0.00	810	0.00E+00	2.20E-07	0.00E+00	N	
cs134	6.03E+03	0.00E+00	0.00	19	0.00E+00	1.02E-05	0.00E+00	N	
cs136	1.09E+02	0.00E+00	0.00	14	0.00E+00	1.22E-05	0.00E+00	N	
cs137	7.95E+04	0.00E+00	0.00	16	0.00E+00	5.04E-06	0.00E+00	N	
cs144	5.27E+00	0.00E+00	0.00	0.54	0.00E+00	3.00E-05	0.00E+00	N	
cu64	6.61E+03	0.00E+00	0.00	27	0.00E+00	1.86E-06	0.00E+00	N	
eu154	9.69E+01	0.00E+00	0.00	16	0.00E+00	9.08E-06	0.00E+00	N	
eu155	9.11E+04	0.00E+00	0.00	81	0.00E+00	7.77E-07	0.00E+00	N	
fe55	1.63E+09	0.00E+00	0.00	1100	0.00E+00	3.40E-08	0.00E+00	N	
fe59	7.11E+02	0.00E+00	0.00	24	0.00E+00	7.74E-06	0.00E+00	N	
h3	5.83E+11	0.00E+00	0.00	1100	0.00E+00	3.37E-08	0.00E+00	N	
hf181	1.36E+04	0.00E+00	0.00	14	0.00E+00	4.34E-06	0.00E+00	N	
hg203	2.45E+04	0.00E+00	0.00	27	0.00E+00	1.99E-06	0.00E+00	N	
i124	5.54E+01	0.00E+00	0.00	27	0.00E+00	7.75E-06	0.00E+00	N	
i125	5.83E+11	0.00E+00	0.00	81	0.00E+00	3.49E-07	0.00E+00	N	
i129	5.83E+11	0.00E+00	0.00	Unlimited		4.68E-07	0.00E+00	N	
i131	1.71E+04	0.00E+00	0.00	19	0.00E+00	3.40E-06	0.00E+00	N	
in113m	3.11E+04	0.00E+00	0.00	54	0.00E+00	2.29E-06	0.00E+00	N	
k40	2.42E+02	0.00E+00	0.00	24	0.00E+00	3.76E-06	0.00E+00	N	
kr85	2.62E+06	0.00E+00	0.00	270	0.00E+00	1.50E-06	0.00E+00	N	
la140	1.63E+01	0.00E+00	0.00	11	0.00E+00	1.68E-05	0.00E+00	N	
mn54	1.65E+04	0.00E+00	0.00	27	0.00E+00	4.98E-06	0.00E+00	N	

Table 7.6.1-1 RT-100 Loading Table Illustration (Continued)

mo99	9.03E+03	0.00E+00	0.00	16	0.00E+00	4.01E-06	0.00E+00	N	
na24	3.38E+00	0.00E+00	0.00	5.4	0.00E+00	2.77E-05	0.00E+00	N	
nb94	6.40E+02	0.00E+00	0.00	19	0.00E+00	1.02E-05	0.00E+00	N	
nb95	2.59E+03	0.00E+00	0.00	27	0.00E+00	4.80E-06	0.00E+00	N	
ni59	3.30E+06	0.00E+00	0.00	Unlimited		4.36E-08	0.00E+00	N	
ni63	5.83E+11	0.00E+00	0.00	810	0.00E+00	1.02E-07	0.00E+00	N	
np237	5.86E+05	0.00E+00	0.00	0.054	0.00E+00	2.85E-05	0.00E+00	N	
pa233	3.22E+04	0.00E+00	0.00	19	0.00E+00	2.54E-06	0.00E+00	N	
pm144	3.14E+03	0.00E+00	0.00	19	0.00E+00	9.35E-06	0.00E+00	N	
po210	7.99E+07	0.00E+00	0.00	0.54	0.00E+00	3.21E-05	0.00E+00	N	
pr144	6.75E+02	0.00E+00	0.00	0.54	0.00E+00	7.34E-06	0.00E+00	N	
pu238	1.62E+09	0.00E+00	0.00	0.027	0.00E+00	3.31E-05	0.00E+00	Y	0.00E+00
pu239	1.14E+08	0.00E+00	0.00	0.027	0.00E+00	3.11E-05	0.00E+00	Y	0.00E+00
pu240	2.60E+08	0.00E+00	0.00	0.027	0.00E+00	3.11E-05	0.00E+00	Y	0.00E+00
pu241	3.67E+09	0.00E+00	0.00	1.6	0.00E+00	3.18E-08	0.00E+00	N	
pu242	6.96E+08	0.00E+00	0.00	0.027	0.00E+00	2.95E-05	0.00E+00	Y	0.00E+00
rb86	1.82E+03	0.00E+00	0.00	14	0.00E+00	4.51E-06	0.00E+00	N	
ru103	1.83E+04	0.00E+00	0.00	54	0.00E+00	3.33E-06	0.00E+00	N	
ru106	1.57E+03	0.00E+00	0.00	5.4	0.00E+00	9.65E-06	0.00E+00	N	
sb122	3.62E+03	0.00E+00	0.00	11	0.00E+00	5.94E-06	0.00E+00	N	
sb124	2.19E+01	0.00E+00	0.00	16	0.00E+00	1.33E-05	0.00E+00	N	
sb125	1.29E+04	0.00E+00	0.00	27	0.00E+00	3.16E-06	0.00E+00	N	
sc46	7.66E+01	0.00E+00	0.00	14	0.00E+00	1.26E-05	0.00E+00	N	
se75	1.14E+04	0.00E+00	0.00	81	0.00E+00	2.41E-06	0.00E+00	N	
sn113	1.09E+06	0.00E+00	0.00	54	0.00E+00	1.66E-07	0.00E+00	N	
sn113m	5.83E+11	0.00E+00	0.00	0.54	0.00E+00	3.87E-07	0.00E+00	N	
sn117m	2.25E+04	0.00E+00	0.00	11	0.00E+00	1.86E-06	0.00E+00	N	
sr85	1.15E+04	0.00E+00	0.00	54	0.00E+00	3.12E-06	0.00E+00	N	
sr89	5.83E+11	0.00E+00	0.00	16	0.00E+00	3.46E-06	0.00E+00	N	
sr90	3.64E+08	0.00E+00	0.00	8.1	0.00E+00	6.70E-06	0.00E+00	N	
tc99	5.83E+11	0.00E+00	0.00	24	0.00E+00	5.02E-07	0.00E+00	N	
tc99m	2.24E+04	0.00E+00	0.00	110	0.00E+00	9.35E-07	0.00E+00	N	
te123m	2.37E+04	0.00E+00	0.00	27	0.00E+00	1.46E-06	0.00E+00	N	
te132	2.17E+04	0.00E+00	0.00	11	0.00E+00	1.98E-06	0.00E+00	N	
th228	3.85E+06	0.00E+00	0.00	0.027	0.00E+00	2.07E-04	0.00E+00	N	
u233	2.67E+07	0.00E+00	0.00	0.16	0.00E+00	2.91E-05	0.00E+00	N	
xe131m	1.02E+06	0.00E+00	0.00	1100	0.00E+00	9.61E-07	0.00E+00	N	
xe133	2.72E+07	0.00E+00	0.00	270	0.00E+00	1.09E-06	0.00E+00	N	
y88	1.02E+01	0.00E+00	0.00	11	0.00E+00	1.60E-05	0.00E+00	N	
zn65	2.34E+03	0.00E+00	0.00	54	0.00E+00	3.50E-06	0.00E+00	N	
zr95	2.62E+03	0.00E+00	0.00	22	0.00E+00	5.04E-06	0.00E+00	N	
		Gamma Sum (%)	0.00	Gamma Sum (A2)	0.00	Gamma Sum (Watts)	0.00	Neutron Sum (mCi/kg)	0.00
		Limit (% of 95% of the NCT and HAC dose rate criteria)	100	Limit (A2)	3000	Limit (Watts)	200	Limit‡ (Neutron Sum, mCi/kg)	3.50
		Passed Shielding Criteria	TRUE	Passed Containment Criteria	TRUE	Passed Heat Load Criteria	TRUE	Passed Neutron Limit Criteria	TRUE

7.6.1.1 RT-100 Loading Table Procedure

Step 1: In top left corner of the Loading Table, input the inventory volume and mass in cubic feet and kilograms (the cells are highlighted in yellow). Verify that the bulk density of the resin or filter media does not exceed 1 g/cm^3 at any point of the content. The weight of water must be excluded when determining the Ci/gram of radioactive content limit. Resin or filter media having a bulk density above 1 g/cm^3 cannot be shipped in the RT-100 cask.

Step 2: Input an isotope in the first column of the loading table. Format is element symbol in lower case letters, followed by mass number with no spaces or dashes (i.e. i129 or eu154). Input radionuclide's activity concentration (in milliCuries/kilogram) in the "Actual Content Activity Concentration (milliCuries/kilogram)" column. The activity concentration input for each isotope should be the maximum for any waste stream placed in the cask.

Step 3: Repeat process until all isotopes and associated activity concentrations are listed. As each new isotope and concentration is entered, a new row is displayed. If "N/A" appears in any of the columns for the isotope entered, the isotope is not applicable to the RT-100 Loading Table or it is incorrectly input into the spreadsheet.[17]

Step 4: Once all relevant inventory inputs (inventory mass, radioisotopes, and activity concentration of each radioisotope) are entered into the table, check cells at the end of the evaluation columns, beside "Passed Criteria" cells. If cell beside passed criteria is green and states "TRUE", inventory has passed that particular set of criteria (for example, passed the shielding criteria). If cell beside criteria is red and states "FALSE", inventory has failed that particular set of criteria.

Step 5: An inventory **must pass all** test criteria before it can be shipped in an RT-100 cask.

7.6.1.2 Turkey Point Source Term Example Evaluation

The following is a sample from stored spent resin and used filters in High Integrity Containers (HIC's) from Turkey Point Units 3 & 4 Low Level Waste Facility [Ref. 9]. Sample results were increased by three standard deviations in order to generate a conservative source term, within 99% confidence interval. Based on Reference 9, mass of a particular Turkey Point HIC's contents was on the order of 2060 kg. Sample results were entered into the RT-100 Loading Table and the results are shown in Table 7.6.1-2.

The spent resin and used filter inventory from Turkey Point generates a value of 3.42% in the "%

[17] If "N/A" appears in containment column but the isotope passes the shielding evaluation, the isotope is not in Table A-1 of Appendix A of 10 CFR 71. Look up the radiation type of the isotope. Based on Table A-3 of Appendix A of 10 CFR 71, enter 0.54 Ci for A2 of beta or gamma emitters and 0.0024 Ci for alpha emitters.

of Maximum" column, which is below 100%. The inventory satisfies the dose rate regulatory compliance. The total inventory A_2 value is 8.37 A_2, which is below the 3000 A_2 limit. The inventory satisfies the containment limit. The total power output is 1.13 Watts, which is below the 200 Watts limit. The actual content activity concentration of neutron emitters is 0.00 milliCuries/kilogram, which is below the limit of 3.5 milliCuries/kilogram. Therefore, this package's inventory would be considered acceptable.

Table 7.6.1-2 Turkey Point Loading Table Example

	Waste Vol (ft^3)	Actual Content Loading Evaluation							
2060.00	Content Mass (kg)								
Gamma Emitting Nuclides		Shielding Evaluation		Containment Evaluation		Heat Load Evaluation		Neutron Emitter† Evaluation	
Actual Content Nuclide	Maximum Allowable Activity Concentration (milliCuries/kg)	Actual Content Activity Concentration (milliCuries/kg)	% of Maximum	A2 (Curie)	Activity(i) / A2(i)	Q Value (Watts/mCi)	Heat Load (Watts)	Neutron Emitter?	Actual Content Activity Concentration (milliCuries/kg)
h3	5.83E+11	1.45E-03	0.00	1100	2.72E-06	3.37E-08	1.01E-07	N	
c14	5.83E+11	1.25E-03	0.00	81	3.18E-05	2.93E-07	7.55E-07	N	
fe55	1.63E+09	8.40E+00	0.00	1100	1.57E-02	3.40E-08	5.88E-04	N	
ni63	5.83E+11	4.68E+01	0.00	810	1.19E-01	1.02E-07	9.80E-03	N	
sr89	5.83E+11	1.73E-03	0.00	16	2.23E-04	3.46E-06	1.23E-05	N	
sr90	3.64E+08	1.46E-02	0.00	8.1	3.71E-03	6.70E-06	2.01E-04	N	
tc99	5.83E+11	4.10E-03	0.00	24	3.52E-04	5.02E-07	4.24E-06	N	
pu241	3.67E+09	4.52E-03	0.00	1.6	5.82E-03	3.18E-08	2.96E-07	N	
i129	5.83E+11	4.40E-05	0.00	Unlimited		4.68E-07	4.24E-08	N	
mn54	1.65E+04	9.17E-01	0.01	27	7.00E-02	4.98E-06	9.41E-03	N	
co57	1.99E+04	2.23E-01	0.00	270	1.70E-03	8.52E-07	3.92E-04	N	
co58	6.96E+03	1.00E+00	0.01	27	7.63E-02	5.99E-06	1.23E-02	N	
co60	2.50E+02	7.28E+00	2.91	11	1.36E+00	1.54E-05	2.31E-01	N	
sb125	1.29E+04	5.19E-01	0.00	27	3.96E-02	3.16E-06	3.38E-03	N	
cs134	6.03E+03	2.69E+01	0.45	19	2.92E+00	1.02E-05	5.65E-01	N	
cs137	7.95E+04	2.84E+01	0.04	16	3.66E+00	5.04E-06	2.95E-01	N	
ce144	1.80E+05	1.88E-01	0.00	5.4	7.17E-02	7.99E-06	3.10E-03	N	
cm242	4.05E+08	2.84E-05	0.00	0.27	2.17E-04	3.65E-05	2.13E-06	Y	2.84E-05
pu238	1.62E+09	9.97E-05	0.00	0.027	7.61E-03	3.31E-05	6.81E-06	Y	9.97E-05
pu239	1.14E+08	5.47E-05	0.00	0.027	4.17E-03	3.11E-05	3.50E-06	Y	5.47E-05
am241	6.02E+07	8.45E-05	0.00	0.027	6.45E-03	3.34E-05	5.81E-06	Y	8.45E-05
cm243	3.16E+04	9.16E-05	0.00	0.027	6.99E-03	3.66E-05	6.91E-06	Y	9.16E-05
		Gamma Sum (%)	3.42	Gamma Sum (A2)	8.37	Gamma Sum (Watts)	1.13	Neutron Sum (mCi/kg)	0.00
		Limit (% of 95% of the NCT and HAC dose rate criteria)	100	Limit (A2)	3000	Limit (Watts)	200	Limit‡ (Neutron Sum, mCi/kg)	3.50
		Passed Shielding Criteria	TRUE	Passed Containment Criteria	TRUE	Passed Heat Load Criteria	TRUE	Passed Neutron Limit Criteria	TRUE

7.6.1.3 St. Lucie Loading Table

The following is source term information for a typical St. Lucie HIC source term [Ref. 10]. Two sets of sample results were increased by three standard deviations in order to generate a conservative source term, within 99% confidence interval. If multiple samples are taken from a shipment, the maximum activity concentration values for each isotope should be used in the RT-100 Loading Table. Based on Reference 10, mass of a particular St. Lucie HIC's contents was on the order of 1950 kg. The maximum values for each isotope from the two samples were inputted into the RT-100 Loading Table and the results are shown in Table 7.6.1-3.

The spent resin and used filter inventory from St. Lucie generates a value of 9.78% in the "% of Maximum" column, which is below 100%. The inventory satisfies the dose rate regulatory compliance. The total inventory A_2 value is 1.70 A_2, which is below the 3000 A_2 limit. The heat load is 0.23 Watts, which is below the 200 Watt limit. The actual content activity concentration of neutron emitters is 0.00 milliCuries/kilogram, which is below the limit of 3.5 milliCuries/kilogram. Therefore, this package's inventory would be considered acceptable.

Table 7.6.1-3 St. Lucie Loading Table Example

	Waste Vol (ft^3)	Actual Content Loading Evaluation							
1950.00	Content Mass (kg)								
Gamma Emitting Nuclides		Shielding Evaluation		Containment Evaluation		Heat Load Evaluation		Neutron Emitter† Evaluation	
Actual Content Nuclide	Maximum Allowable Activity Concentration (milliCuries/kg)	Actual Content Activity Concentration (milliCuries/kg)	% of Maximum	A2 (Curie)	Activity(i) / A2(i)	Q Value (Watts/mCi)	Heat Load (Watts)	Neutron Emitter?	Actual Content Activity Concentration (milliCuries/kg)
h3	5.83E+11	3.90E-03	0.00	1100	6.91E-06	3.37E-08	2.57E-07	N	
c14	5.83E+11	1.55E-02	0.00	81	3.73E-04	2.93E-07	8.86E-06	N	
fe55	1.63E+09	3.65E+00	0.00	1100	6.47E-03	3.40E-08	2.42E-04	N	
ni63	5.83E+11	3.00E+01	0.00	810	7.22E-02	1.02E-07	5.94E-03	N	
sr89	5.83E+11	9.20E-03	0.00	16	1.12E-03	3.46E-06	6.20E-05	N	
sr90	3.64E+08	2.86E-03	0.00	8.1	6.89E-04	6.70E-06	3.74E-05	N	
tc99	5.83E+11	2.70E-03	0.00	24	2.19E-04	5.02E-07	2.64E-06	N	
pu241	3.67E+09	4.00E-03	0.00	1.6	4.88E-03	3.18E-08	2.48E-07	N	
i129	5.83E+11	2.45E-04	0.00	Unlimited		4.68E-07	2.23E-07	N	
cr51	1.98E+05	1.46E+00	0.00	810	3.51E-03	2.20E-07	6.27E-04	N	
mn54	1.65E+04	8.35E-01	0.01	27	6.03E-02	4.98E-06	8.11E-03	N	
co57	1.99E+04	3.21E-01	0.00	270	2.32E-03	8.52E-07	5.34E-04	N	
co58	6.96E+03	1.59E+00	0.02	27	1.15E-01	5.99E-06	1.86E-02	N	
fe59	7.11E+02	9.00E-02	0.01	24	7.31E-03	7.74E-06	1.36E-03	N	
co60	2.50E+02	3.92E+00	1.57	11	6.95E-01	1.54E-05	1.18E-01	N	
zn65	2.34E+03	1.28E-01	0.01	54	4.62E-03	3.50E-06	8.73E-04	N	
nb94	6.40E+02	4.20E-02	0.01	19	4.31E-03	1.02E-05	8.34E-04	N	
zr95	2.62E+03	1.21E-01	0.00	22	1.07E-02	5.04E-06	1.19E-03	N	
nb95	2.59E+03	2.15E-01	0.01	27	1.55E-02	4.80E-06	2.01E-03	N	
ru103	1.83E+04	1.37E-01	0.00	54	4.95E-03	3.33E-06	8.89E-04	N	
ru106	1.57E+03	2.90E-01	0.02	5.4	1.05E-01	9.65E-06	5.45E-03	N	
ag108m	2.12E+03	5.20E-02	0.00	19	5.34E-03	9.70E-06	9.83E-04	N	
ag110m	4.84E+02	1.30E-01	0.03	11	2.30E-02	1.67E-05	4.23E-03	N	
sb124	2.19E+01	3.60E-02	0.16	16	4.39E-03	1.33E-05	9.31E-04	N	
sb125	1.29E+04	3.32E-01	0.00	27	2.40E-02	3.16E-06	2.05E-03	N	
cs134	6.03E+03	4.20E-02	0.00	19	4.31E-03	1.02E-05	8.35E-04	N	
cs137	7.95E+04	1.72E-01	0.00	16	2.10E-02	5.04E-06	1.69E-03	N	
la140	1.63E+01	1.29E+00	7.93	11	2.29E-01	1.68E-05	4.22E-02	N	
ce141	4.14E+04	2.92E-01	0.00	16	3.56E-02	1.46E-06	8.33E-04	N	
ce144	1.80E+05	5.70E-01	0.00	5.4	2.06E-01	7.99E-06	8.88E-03	N	
am241	6.02E+07	4.10E-05	0.00	0.027	2.96E-03	3.34E-05	2.67E-06	Y	4.10E-05
cm242	4.05E+08	1.56E-05	0.00	0.27	1.13E-04	3.65E-05	1.11E-06	Y	1.56E-05
cm243	3.16E+04	2.44E-04	0.00	0.027	1.76E-02	3.66E-05	1.74E-05	Y	2.44E-04
pu238	1.62E+09	5.70E-05	0.00	0.027	4.12E-03	3.31E-05	3.68E-06	Y	5.70E-05
pu239	1.14E+08	5.90E-05	0.00	0.027	4.26E-03	3.11E-05	3.58E-06	Y	5.90E-05
		Gamma Sum (%)	9.78	Gamma Sum (A2)	1.70	Gamma Sum (Watts)	0.23	Neutron Sum (mCi/kg)	0.00
		Limit (% of 95% of the NCT and HAC dose rate criteria)	100	Limit (A2)	3000	Limit (Watts)	200	Limit‡ (Neutron Sum, mCi/kg)	3.50
		Passed Shielding Criteria	TRUE	Passed Containment Criteria	TRUE	Passed Heat Load Criteria	TRUE	Passed Neutron Limit Criteria	TRUE

7.6.1.4 Additional Examples

Two additional examples have been generated to show the maximum Co-60 loading for the RT-100 and an arbitrary example showing a load that fails the RT-100 Loading Table. Table 7.6.1-4 shows the maximum Co-60 inventory allowed due to shielding limits. The activity concentration is at 100% under the "% of Maximum" column. Table 7.6.1-5 shows the effect of inputting two radionuclides that individually would pass the compliance tests, but having both radionuclide quantities in the cask would generate a dose rate that would fail either NCT or HAC shielding conditions. This is illustrated by the red "FALSE" cell due to shielding sum is 100.73%, which is above the 100% limit. The inventory in Table 7.6.1-5 would not be acceptable in an RT-100 Transport Cask.

Table 7.6.1-4 Maximum Co-60 Loading Table Example

	Waste Vol (ft^3)	Actual Content Loading Evaluation							
2988.58	Content Mass (kg)								
Gamma Emitting Nuclides		Shielding Evaluation		Containment Evaluation		Heat Load Evaluation		Neutron Emitter† Evaluation	
Actual Content Nuclide	Maximum Allowable Activity Concentration (milliCuries/kg)	Actual Content Activity Concentration (milliCuries/kg)	% of Maximum	A2 (Curie)	Activity(i) / A2(i)	Q Value (Watts/mCi)	Heat Load (Watts)	Neutron Emitter?	Actual Content Activity Concentration (milliCuries/kg)
co60	2.50E+02	2.50E+02	100.00	11	6.79E+01	1.54E-05	1.15E+01	N	
		Gamma Sum (%)	100.00	Gamma Sum (A2)	67.94	Gamma Sum (Watts)	11.52	Neutron Sum (mCi/kg)	0.00
		Limit (% of 95% of the NCT and HAC dose rate criteria)	100	Limit (A2)	3000	Limit (Watts)	200	Limit‡ (Neutron Sum, mCi/kg)	3.50
		Passed Shielding Criteria	TRUE	Passed Containment Criteria	TRUE	Passed Heat Load Criteria	TRUE	Passed Neutron Limit Criteria	TRUE

Table 7.6.1-5 Failed Loading Table Example

	Waste Vol (ft^3)	Actual Content Loading Evaluation							
3000.00	Content Mass (kg)								
Gamma Emitting Nuclides		Shielding Evaluation		Containment Evaluation		Heat Load Evaluation		Neutron Emitter† Evaluation	
Actual Content Nuclide	Maximum Allowable Activity Concentration (milliCuries/kg)	Actual Content Activity Concentration (milliCuries/kg)	% of Maximum	A2 (Curie)	Activity(i) / A2(i)	Q Value (Watts/mCi)	Heat Load (Watts)	Neutron Emitter?	Actual Content Activity Concentration (milliCuries/kg)
co60	2.50E+02	2.33E+02	93.18	11	6.35E+01	1.54E-05	1.08E+01	N	
cs137	7.95E+04	6.00E+03	7.55	16	1.13E+03	5.04E-06	9.07E+01	N	
		Gamma Sum (%)	100.73	Gamma Sum (A2)	1188.55	Gamma Sum (Watts)	101.51	Neutron Sum (mCi/kg)	0.00
		Limit (% of 95% of the NCT and HAC dose rate criteria)	100	Limit (A2)	3000	Limit (Watts)	200	Limit‡ (Neutron Sum, mCi/kg)	3.50
		Passed Shielding Criteria	FALSE	Passed Containment Criteria	TRUE	Passed Heat Load Criteria	TRUE	Passed Neutron Limit Criteria	TRUE

Table 7.6.1-6 Radionuclide Activity Concentration Limits

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
na24	3.38E-06	NCT
bi208	3.76E-06	NCT
cs144	5.27E-06	NCT
y88	1.02E-05	NCT
la140	1.63E-05	NCT
sb124	2.19E-05	NCT
eu156	2.26E-05	NCT
sc48	2.67E-05	NCT
la138	3.87E-05	NCT
tb156	4.10E-05	NCT
ag106m	4.45E-05	NCT
lu169	4.55E-05	NCT
na22	5.38E-05	NCT
sb120m	5.51E-05	NCT
i124	5.54E-05	NCT
br82	5.93E-05	NCT
lu172	6.68E-05	NCT
ta182	6.93E-05	NCT
ca47	7.23E-05	NCT
sc46	7.66E-05	NCT
te131m	7.96E-05	NCT
eu152	8.35E-05	NCT
as72	8.49E-05	NCT
tm172	9.32E-05	NCT
eu154	9.69E-05	NCT
cs136	1.09E-04	NCT
pm148	1.10E-04	NCT
ge69	1.25E-04	NCT
tb160	1.56E-04	NCT
sn125	1.82E-04	NCT
rh102m	1.88E-04	NCT
gd147	1.93E-04	NCT
tc96	2.23E-04	NCT
sr83	2.25E-04	NCT
k40	2.42E-04	NCT
co60	2.50E-04	NCT
as76	2.84E-04	NCT
nb92	3.41E-04	NCT

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
np238	3.49E-04	NCT
am240	4.09E-04	NCT
tb158	4.32E-04	NCT
pm148m	4.79E-04	NCT
ag110m	4.84E-04	NCT
ho166m	5.45E-04	NCT
pa232	5.96E-04	NCT
sb126	6.14E-04	NCT
nb94	6.40E-04	NCT
rb84	6.41E-04	NCT
tm168	6.65E-04	NCT
pr144	6.75E-04	NCT
fe59	7.11E-04	NCT
rh99	7.83E-04	NCT
tm165	8.21E-04	NCT
zr89	1.18E-03	NCT
rh102	1.23E-03	NCT
as71	1.37E-03	NCT
ru106	1.57E-03	NCT
tc95m	1.59E-03	NCT
rb86	1.82E-03	NCT
tc98	1.97E-03	NCT
ag108m	2.12E-03	NCT
ho166	2.17E-03	NCT
ir194m	2.25E-03	NCT
zn65	2.34E-03	NCT
cs132	2.34E-03	NCT
lu171	2.56E-03	NCT
nb95	2.59E-03	NCT
zr95	2.62E-03	NCT
tb153	2.83E-03	NCT
te121m	3.15E-03	NCT
ag105	3.32E-03	NCT
sb127	3.61E-03	NCT
sb122	3.62E-03	NCT
pm144	3.14E-03	NCT
cd115m	4.17E-03	NCT
kr79	4.27E-03	NCT
pm146	4.35E-03	NCT

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	**Max. Ci/g**	**Condition**
gd149	4.88E-03	NCT
i126	5.10E-03	NCT
tc99m	2.24E-02	HAC
cs134	6.03E-03	NCT
os185	6.57E-03	NCT
cu64	6.61E-03	NCT
pm143	6.71E-03	NCT
co58	6.96E-03	NCT
as74	7.27E-03	NCT
ba131	7.28E-03	NCT
br77	9.13E-03	NCT
ce143	9.23E-03	NCT
pm151	1.27E-02	NCT
lu176	1.12E-02	HAC
se75	1.14E-02	HAC
y87	1.16E-02	HAC
cm241	1.16E-02	HAC
sr85	1.15E-02	HAC
te121	1.15E-02	HAC
rb83	1.23E-02	HAC
rh101	1.30E-02	HAC
sb125	1.29E-02	HAC
hf181	1.36E-02	HAC
mn54	1.65E-02	NCT
y91	1.80E-02	NCT
i131	1.71E-02	HAC
xe127	1.73E-02	HAC
ru103	1.83E-02	HAC
yb169	1.97E-02	HAC
co57	1.99E-02	HAC
au198	2.01E-02	HAC
ru97	2.01E-02	HAC
ta183	2.04E-02	HAC
np239	2.04E-02	HAC
ba133	2.04E-02	HAC
sn123	2.46E-02	NCT
zr88	2.05E-02	HAC
zn72	2.06E-02	HAC
te132	2.17E-02	HAC

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
cf249	2.18E-02	HAC
bi210m	2.20E-02	HAC
hf182	2.22E-02	HAC
rh101m	2.23E-02	HAC
sn117m	2.25E-02	HAC
hf175	2.30E-02	HAC
u235	2.32E-02	HAC
te123m	2.37E-02	HAC
hg203	2.45E-02	HAC
cm247	2.45E-02	HAC
cf251	2.48E-02	HAC
ce139	2.50E-02	HAC
pu246	2.54E-02	HAC
mo99	9.03E-03	NCT
sc47	2.93E-02	HAC
cs129	2.97E-02	HAC
ag110	3.68E-02	NCT
in113m	3.11E-02	HAC
u237	3.13E-02	HAC
cm243	3.16E-02	HAC
pa233	3.22E-02	HAC
pt191	3.21E-02	HAC
tb155	3.46E-02	HAC
cd115	3.40E-02	HAC
ba140	3.43E-02	HAC
er172	3.72E-02	HAC
lu177m	3.73E-02	HAC
cm245	3.76E-02	HAC
np236	3.88E-02	HAC
cu67	4.00E-02	HAC
in114m	4.87E-02	NCT
au199	4.09E-02	HAC
ce141	4.14E-02	HAC
ga67	4.31E-02	HAC
tm167	4.47E-02	HAC
ar37	4.49E-02	HAC
th227	5.64E-02	HAC
ra223	5.77E-02	HAC
pu237	6.27E-02	HAC

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
nd147	6.37E-02	HAC
sn126	6.59E-02	HAC
cs137	7.95E-02	HAC
sm153	6.61E-02	HAC
os191	6.88E-02	HAC
te129m	8.36E-02	NCT
nb95m	7.52E-02	HAC
rh105	8.17E-02	HAC
eu155	9.11E-02	HAC
re189	9.10E-02	HAC
gd153	9.29E-02	HAC
th229	9.61E-02	HAC
os193	1.08E-01	HAC
lu177	1.12E-01	HAC
hf172	1.20E-01	HAC
ba135m	1.28E-01	HAC
yb175	1.69E-01	HAC
ce144	1.80E-01	HAC
eu149	1.91E-01	HAC
be7	1.93E-01	HAC
cr51	1.98E-01	HAC
xe133m	1.99E-01	HAC
pa231	2.09E-01	HAC
re186	2.10E-01	HAC
ir192	2.36E-01	HAC
ag111	2.47E-01	HAC
pm149	3.21E-01	NCT
xe129m	4.35E-01	HAC
ra224	4.99E-01	HAC
ac225	5.06E-01	HAC
kr81	5.11E-01	HAC
ra226	5.69E-01	HAC
np237	5.86E-01	HAC
pt195m	6.57E-01	HAC
as77	7.12E-01	HAC
xe131m	1.02E+00	HAC
sn113	1.09E+00	HAC
th231	1.60E+00	HAC
dy166	1.70E+00	HAC

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
kr85	2.62E+00	HAC
ni59	3.30E+00	NCT
am243	2.81E+00	HAC
w188	3.13E+00	HAC
nb91	3.47E+00	HAC
th228	3.85E+00	HAC
es254	4.48E+00	HAC
tb161	4.57E+00	HAC
u230	6.10E+00	HAC
te125m	7.07E+00	HAC
th234	7.08E+00	HAC
am242m	1.20E+01	HAC
rn222	1.50E+01	HAC
w181	1.72E+01	HAC
la137	1.73E+01	HAC
pt193m	1.78E+01	HAC
es253	1.90E+01	HAC
u232	2.54E+01	HAC
u233	2.67E+01	HAC
xe133	2.72E+01	HAC
th230	2.84E+01	HAC
te127m	3.73E+01	HAC
ac227	4.82E+01	HAC
u234	5.50E+01	HAC
am241	6.02E+01	HAC
po210	7.99E+01	NCT
pd103	6.91E+01	HAC
th232	7.27E+01	HAC
cd113m	8.69E+01	HAC
u236	9.99E+01	HAC
w185	1.07E+02	HAC
v49	1.07E+02	HAC
pu239	1.14E+02	HAC
cf252	1.34E+02	HAC
pu236	1.44E+02	HAC
u238	1.86E+02	HAC
pu240	2.60E+02	HAC
sr90	3.64E+02	NCT
cl36	3.35E+02	HAC

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	Max. Ci/g	Condition
cm242	4.05E+02	HAC
ca41	4.10E+02	HAC
sm145	5.73E+02	HAC
pu242	6.96E+02	HAC
pm147	7.00E+02	HAC
cm244	8.69E+02	NCT
er169	1.53E+03	HAC
pu238	1.62E+03	NCT
fe55	1.63E+03	HAC
pu241	3.67E+03	HAC
bi210	1.96E+04	HAC
bk249	5.28E+04	HAC
pr143	2.15E+05	NCT
tc97	5.81E+05	HAC
ca45	5.83E+05	HAC
ge71	5.83E+05	HAC
nb93m	5.83E+05	HAC
mo93	5.83E+05	HAC
tc97m	5.83E+05	HAC
cd109	5.83E+05	HAC
sn119m	5.83E+05	HAC
sn121m	5.83E+05	HAC
te123	5.83E+05	HAC
i125	5.83E+05	HAC
i129	5.83E+05	HAC
cs131	5.83E+05	HAC
pm145	5.83E+05	HAC
sm151	5.83E+05	HAC
tb157	5.83E+05	HAC
dy159	5.83E+05	HAC
tm170	5.83E+05	HAC
tm171	5.83E+05	HAC
os194	5.83E+05	HAC
pt193	5.83E+05	HAC
tl204	5.83E+05	HAC
pb205	5.83E+05	HAC
pb210	5.83E+05	HAC
ra225	5.83E+05	HAC
ra228	5.83E+05	HAC

Project	RT-100 Transport Cask	
Task	Maximum Curies Per Gram Limits	
Gamma Emitting Radionuclides		
Radionuclide	**Max. Ci/g**	**Condition**
np235	5.83E+05	HAC
cm246	5.83E+05	HAC
cm248	5.83E+05	HAC
cf250	5.83E+05	HAC
se72	5.83E+05	HAC
as73	5.83E+05	HAC
te118	5.83E+05	HAC
sb119	5.83E+05	HAC
nd140	5.83E+05	HAC
yb166	5.83E+05	HAC
h3	5.83E+05	HAC
ni63	5.83E+05	HAC
sr89	5.83E+05	HAC
tc99	5.83E+05	HAC
sn113m	5.83E+05	HAC
am242	5.83E+05	HAC
c14	5.83E+05	HAC

7.7 References

1. Robatel Technologies, LLC, Quality Assurance Program for Packaging and Transportation of Radioactive Material, 10 CFR 71 Subpart H, Dated January 31, 2012 and NRC Approved on March 21, 2012
2. U.S. Nuclear Regulatory Commission, 10 CFR Part 71--PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL, and the following specific Sections:

71.31(c)	71.45	71.47	71.47(b)(1)	71.89
71.87	71.47(b-d)	71.35(c)	71.43(g)	

3. U.S. Department of Transportation, Hazard Communications for Class 7 (Radioactive) Materials – Package and Vehicle Contamination Limits, 49 CFR 173.443.
4. U.S. Department of Transportation, Empty Class 7 (Radioactive) Materials Packaging, 49 CFR 173.428.
5. ANSI N14.5-1997, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," American National Standards Institute, Inc., 11 West 42nd Street, New York, NY, www.ansi.org.
6. U.S. Nuclear Regulatory Commission, REGULATORY GUIDE 7.9 – Standard format and content of Part 71 applications for approval of packages for radioactive material, dated March 2005
7. U.S. Nuclear Regulatory Commission, "Guide for Preparing Operating Procedures for Shipping Packages," NUREG/CR-4775, July 1988.
8. U.S. Nuclear Regulatory Commission, 10 CFR Part 20--STANDARDS FOR PROTECTION AGAINST RADIATION, and the following specific Sections:

20.1101(b)	20.1906	20.1906(e), 20.1906(a)

9. LLW-11-026, "Turkey Point Unit 3 & 4 Low Level Waste Facility PTN Source Term Information", P. A. Miktus, September 7, 2011.
10. LLW-09-002, "St. Lucie Unit 1 & 2 Low Level Waste Facility RFI Response", B. Bedford, December 2, 2009.
11. [Withdrawn]
12. NUREG/CR-6673, "Hydrogen Generation in TRU Waste Transportation Packages," Anderson, B., Sheaffer, M., & Fischer, L., Lawrence Livermore National Laboratory, Livermore, CA, May 2000.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Initially, RT employs an Assessment Test program to meet the requirements of 10 CFR Part 71 [Ref. 2], Subpart G. The RT Package Maintenance Program ensures the RT- 100 meets its Certificate of Compliance requirements throughout the package service life. Both the acceptance tests and maintenance programs are conducted in accordance with the RT Quality Assurance Program [Ref. 1]. Figure 8-1 shows flow of information for acceptance test and maintenance programs.

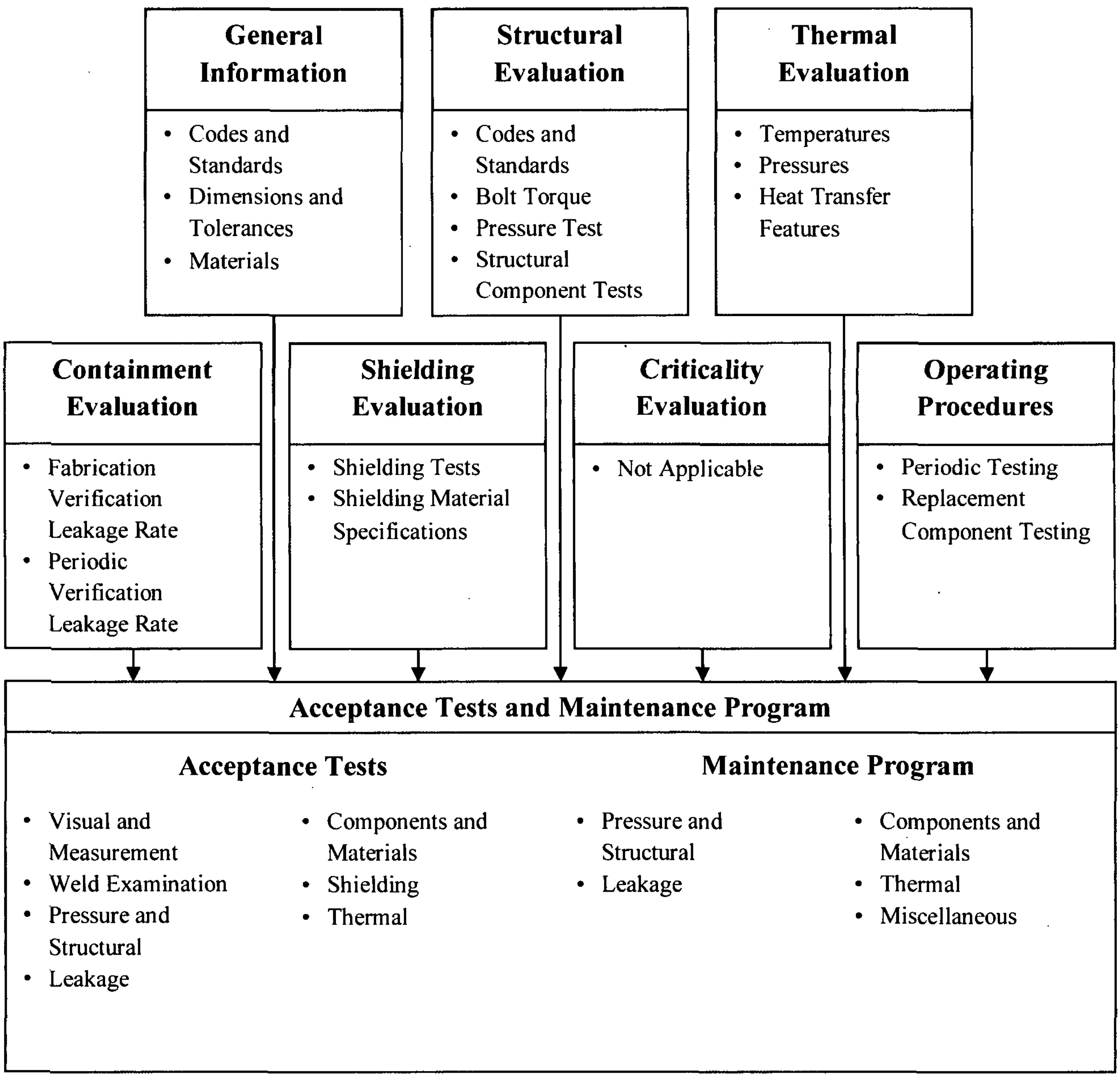


Figure 8-1 Information Flow for the Acceptance Tests and Maintenance Program Review

8.1 Acceptance Tests

Requirements for the acceptance testing include the following criteria:

- The SAR identifies codes, standards, and provisions of the quality assurance program used for the acceptance testing of the packaging in accordance with 10 CFR 71.31(c) and 71.37(b) [Ref. 2]. The SAR is prepared and the RT-100 is fabricated in accordance with the RT Quality Assurance Program [Ref. 1], approved by the USNRC on 21 March 2012.
- The fabrication of the RT-100 is verified to be in accordance with the approved design and in accordance with 10 CFR 71.85(c) [Ref. 2].
- The RT-100 is inspected for cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce its effectiveness; inspection is conducted in accordance with 10 CFR 71.85(a) [Ref. 2].
- Prior to lead pouring, measure the average clearance annular gap between the inner and outer shell of the cask body. Using a gauge, verify that the annular gap is above 86 mm at every point between the two shells. After lead pouring, the maximum annular gap between the lead and the inner and outer shell shall not exceed 0.1 cm.
- Since the RT-100 maximum normal operating pressure exceeds 35 kPa (5 psi) gauge, prior to first use the cask will be tested at an internal pressure at least 150% of the maximum normal operating pressure to verify its ability to maintain structural integrity at that pressure in accordance with 10 CFR 71.85(b) [Ref. 2].
- The RT-100 is conspicuously and durably marked with its model number, serial number, gross weight, and a package identification number assigned by the NRC in accordance with 10 CFR 71.85(c) [Ref. 2].
- Robatel Technologies, LLC performs all tests required by the NRC in accordance with 10 CFR 71.93(b) [Ref. 2].
- RT-100 is fabricated in accordance with drawings provided in Chapter 1, Appendix 1.4.

General Notes

- A pre-shipment leak test is performed after the contents have been loaded, per ANSI N14.5 [Ref. 6], as mentioned in Table 4.3-1.
- All disassembled parts will be reassembled in accordance with requirement stated in Chapter 7. In particular, this requirement applies to bolt/nut tightening, and torques applied.
- Cleanliness of sealing surfaces is of highest priority during package disassembly and assembly. This requirement particularly applies to O-rings and seal surfaces.
- O-rings are replaced within a 12 month period of use in accordance with Regulatory Guide 7.9 [Ref. 3] and NUREG-1609 [Ref. 4].
  - The RT-100 has two (2) O-rings associated with each of the primary lid, secondary lid, and quick-disconnect valve.
  - Replaced O-rings are leak tested.

8.1.1 Visual Inspections and Measurements

Throughout the fabrication process, confirmation by visual inspection and measurement are required to verify that the RT-100 packaging dimensionally conforms to the drawings RT100 PE 1001-1, Rev. H and RT100 PE 1001-2, Rev. H provided in Chapterl, Appendix 1.4. In addition, the packaging is to be visually inspected for any adverse conditions in materials or fabrication that would prevent the package from being assembled or operated in accordance with requirements outlined in Chapter 7, or tested in accordance with the requirements of Chapter 8. Visual and non-destructive examination shall be performed by ASNT or COFREND certified inspectors.

8.1.2 Weld Examinations

Containment boundary welds are identified in drawing RT100 PRS 1011, Rev. E in Chapter 1, Appendix 1.4. The following welds on this drawing are classified as containment boundary welds: S.1011.01, S.1011.02, and S.1011.03. These welds are required to be inspected and meet the acceptance requirements of ASME Code, Section III, Division I, Subsection ND, Article ND-5000 [Ref. 5].

The weld maps RT100 PRS 1011, Rev. E, RT100 PRS 1013, Rev. C, RT100 PRS 1031, Rev. D and RT100 PRS 1032, Rev. D listed in Chapter 1, Appendix 1.4, provide the examination criteria for each weld. Radiographic testing, dye penetrant testing, and/or visual testing is performed in accordance with applicable ASME standards. The Containment Boundary welds are also inspected by radiographic examination. Non-destructive examination shall be performed by ASNT or COFREND certified inspectors.

8.1.3 Structural and Pressure Tests

A pressure test of the containment system is performed as required by 10 CFR 71.85 [Ref. 2]. As described in Chapter 3, Section 3.3.2.5, Maximum Normal Operating Pressure for the RT-100 cavity is 182.71 kPa. Per 10 CFR 71.85(b) [Ref. 2], the containment system shall be tested at an internal pressure at least 50% higher than the actual maximum normal operating pressure, or 274 kPa. However, for conservatism, the minimum test pressure is set to 300 kPa. The hydrostatic test pressure is held for a minimum of 10 minutes. Afterward, the primary lid and secondary lid closures are examined for leakage.

Except from temporary connections, leaks are remedied, and the test and inspection are repeated. After depressurization and draining, the cask cavity and seal areas are visually inspected for cracks and deformation. Any cracks or deformation are remedied, and the test and inspection repeated.

8.1.4 Leakage Tests

Section 8.1.4 describes the leakage tests to be performed on the RT-100 prior to its initial use. Refer to Section 8.3 and Table 8.3-1 for a summary of the leak test types.

Testing performed on the cask body containment boundaries during fabrication:

8.1.4.1 Cask Containment Boundary

8.1.4.1.1 Cask Body Leak Testing – Prior to Lead Pouring

8.1.4.1.2 Primary Lid Assembly Including Secondary Lid and Cover Plate – Prior to Final Assembly

Verification testing performed on the cask after final assembly:

8.1.4.2 Primary and Secondary Lid Containment O-Rings Helium Leak Testing

8.1.4.3 Quick Disconnect Valve Helium Leak Testing

8.1.4.4 Quick Disconnect Valve Cover Plate Containment O-Rings Helium Leak Testing

Note Regarding Test Personnel Qualifications

Detailed procedures following the instructions below are to be approved by personnel certified in ASNT NDT or COFREND Level III leak testing. The use of COFREND certified personnel instead of ASNT certified personnel is accepted for leakage testing for the RT-100, based on the equivalence note 102885 EQN 001 Rev. C [Ref. 12].

Note Regarding Test Duration

For each helium test, the duration must be calculated by test personnel. The Test Duration is a function of the System Response Time and the Helium Penetration Time.

The System Response Time is defined as the time from admitting helium to a test assembly with a known leak, until the measured leakage rate increases to 2×10^{-7} cm^3/s above background. For the Primary Lid O-ring, which has the longest response time, the time has been experimentally determined to be less than 20 seconds.

The Helium Penetration Time is defined as the time from admitting helium to a test assembly, until the measured leakage rate of helium gas permeating through the seal under test increases to a rate of 2×10^{-7} cm^3/s above background. For the Vent Port Cover Plate O-ring, which has the shortest penetration time, the time has been experimentally determined to be approximately 5 minutes.

The Test Duration should be such that:

$$2 \times System\ Response\ Time < Test\ Duration < 80\%\ Helium\ Penetration\ Time$$

$$40\ sec < Test\ Duration < 240\ sec$$

In order to meet the above criterion, the Test Duration is specified as approximately 2 minutes.

8.1.4.1 Cask Containment Boundary

8.1.4.1.1 Cask Body Leak Testing – Prior to Lead Pouring

Testing of the cask body containment boundary is performed prior to the lead shield pour to allow access to all containment welds. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 table A1 test A.5.3 [Ref. 6] to demonstrate compliance with the ANSI N14.5 leaktight criteria. Figure 8.1.4-1 shows a general diagram of the test apparatus. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 [Ref. 7] or equivalent.

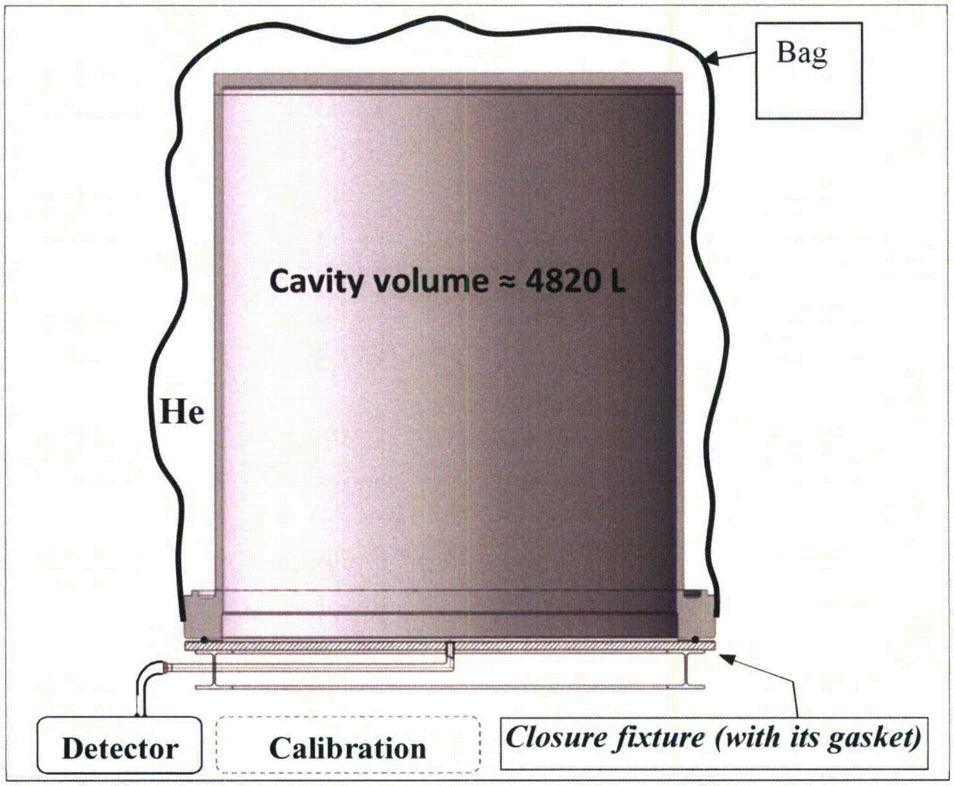


Figure 8.1.4-1 Cask Body Containment Boundary Test Apparatus

- *Test Personnel Qualifications*
  Test personnel shall be ASNT NDT or COFREND Level II certified in leakage testing.
- *Frequency*
  Cask body containment boundaries are tested only once during fabrication.
- *Components to be tested*
  The body containment boundary includes the inner shell, the cask forged bottom, and the upper flange.
- *Testing Procedure*
  1. Assemble the cask body with a substitute sealed plate used in place of the cask lid.
     Note: The material in contact with the cask must be chemically compatible with the cask body material (stainless steel) and the test gas (helium).

2. Place the entire vessel in a bag taped on the outer surface of the upper flange, as shown in Figure 8.1.4-1.
3. Create a vacuum in the cask cavity (0.01 atm abs or less).
4. Fill the bag with helium to a partial pressure of at least 25% of the total gas pressure.
5. Measure the helium flow signal detected in the interspace. The test duration will be approximately 2 minutes as described in Section 8.1.4.

- *Acceptance Criteria*
  Refer to Table 8.3-1 and Table 8.3-2 for test acceptance criteria.
- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

8.1.4.1.2 Primary Lid Assembly Including Secondary Lid and Cover Plate – Prior to Final Assembly

Testing of the Primary Lid Assembly is performed prior to final assembly of the Cask. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 table A1 test A.5.3 [Ref. 6] to demonstrate compliance with the ANSI N14.5 leaktight criteria. Figure 8.1.4-2 shows a general diagram of the test apparatus. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 [Ref. 7] or equivalent.

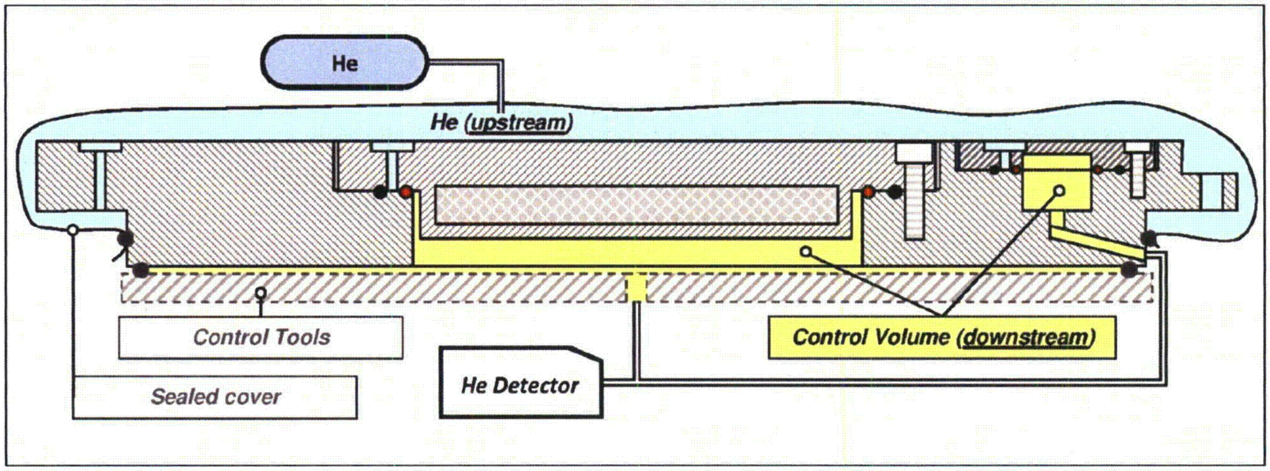


Figure 8.1.4-2 Primary Lid Assembly Containment Boundary Test Apparatus

- *Test Personnel Qualifications*
  Test personnel shall be ASNT NDT or COFREND Level II certified in leakage testing.
- *Frequency*
  Cask body containment boundaries are tested only once during fabrication.
- *Components to be tested*
  The Primary Lid Assembly Containment Boundary includes the Primary Lid, Secondary Lid, and Quick-Disconnect Valve Cover Plate.

- *Testing Procedure*
  1. Remove the Quick-Disconnect Valve.
  2. Assemble the Primary Lid per Chapter 7, Section 7.1.2.3, Secondary Lid Replacement, and 7.1.2.4, Quick-Disconnect Valve Cover Plate Replacement. The bolts must be torqued to the specifications listed in Table 7.4.5-1.
  3. Attach to the Primary Lid Assembly a control tool as shown in Figure 8.1.4-2.
     Note: The material in contact with the lid assembly must be chemically compatible with the primary lid assembly material (stainless steel) and the test gas (helium).
  4. A sealing cover is arranged above the primary lid assembly as shown in Figure 8.1.4-2, and sealed just below the closure bolt flange.
     Note: The sealing cover should not be placed over the opening leading to the Quick-Disconnect Valve Cover Plate.
  5. Create a vacuum in the control volume (0.01 atm abs or less).
  6. Fill the bag with helium to a partial pressure of at least 25% of the total gas pressure.
  7. Measure the helium flow signal detected in the control volume. The test duration will be approximately 2 minutes as described in Section 8.1.4.
- *Acceptance Criteria*
  Refer to Table 8.3-1 and Table 8.3-2 for test acceptance criteria.
- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

8.1.4.2 Primary and Secondary Lid Containment O-Rings Helium Leak Testing

Verification of the primary and secondary lid containment boundaries is performed prior to its initial use, periodically every 12 months, and after maintenance. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 table A1 test A.5.3 [Ref. 6] to demonstrate compliance with the ANSI N14.5 leaktight criteria. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 [Ref. 7] or equivalent.

- *Test Personnel Qualifications*
  Test personnel shall be ASNT NDT or COFREND Level II certified in leakage testing.
- *Frequency*
  This test is performed prior to initial use, periodically every 12 months, and after maintenance involving O-rings or bolts.
- *Components to be tested*
  The components tested are the inner O-rings in the primary lid or the secondary lid.
- *Testing Procedure*
  1. Assemble the cask lids per Chapter 7, Section 7.1.2.2, Primary Lid Replacement, and 7.1.2.3, Secondary Lid Replacement. The bolts must be torqued to the specifications listed in Table 7.4.5-1.

2. Remove the quick disconnect valve cover plate, per Chapter 7, Section 7.1.1.3.
3. Remove the leak test port plug on either the primary or secondary lid, whichever containment boundary is to be tested. Attach the vacuum pump and the leak detection equipment to the port.
4. Pull a vacuum in the O-ring interspace (0.01 atm abs or less).
5. Fill the internal cavity with helium through the vent port (min helium partial pressure 25% of total pressure).
6. Measure the helium flow signal detected in the interspace. The test duration will be approximately 2 minutes as described in Section 8.1.4.

- *Acceptance Criteria*
  Refer to Table 8.3-1 and Table 8.3-2 for test acceptance criteria.
- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

8.1.4.3 Quick Disconnect Valve Helium Leak Testing

As described in Section 4.1.2, the RT-100 does not rely on any valve or pressure relief device to meet the containment requirements. The Quick Disconnect valve is protected by the vent port cover plate, as shown in Figure 4.1.2-1. Therefore, it is not necessary for the Quick Disconnect Valve to meet the ANSI N14.5 leaktight criteria. However, as an additional safety precaution, the Quick Disconnect valve is leak tested as described below.

Verification of the quick disconnect valve is performed prior to its initial use, periodically every 12 months, and after maintenance. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 table A1 test A.5.3 [Ref. 6]. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 [Ref. 7] or equivalent.

- *Test Personnel Qualifications*
  Test personnel shall be ASNT NDT or COFREND Level II certified in leakage testing.
- *Frequency*
  This test is performed prior to initial use, periodically every 12 months, and after maintenance involving the quick disconnect valve.
- *Components to be tested*
  The component tested is the quick-disconnect valve.
- *Testing Procedure*

1. The quick-disconnect valve must be assembled and torqued to the specification listed in Table 7.4.5-2.
2. Install a bag on the vent port hole under the primary lid as shown in Figure 8.1.4-3.
   Note: Alternately, the primary lid may be assembled to the cask body without the secondary lid, and the cavity filled with helium via the primary lid opening as shown

in Figure 8.1.4-4.

3. Remove the quick disconnect valve cover plate, per Chapter 7, Section 7.1.1.3.
4. Install a vacuum clutch over the vent port. Pull a vacuum of 0.01 atm abs or less.
5. Fill the bag (or alternatively the containment vessel) with helium (min helium partial pressure 25% of total pressure).
6. Measure the helium flow signal detected in the interspace. The test duration will be approximately 2 minutes as described in Section 8.1.4.

- *Acceptance Criteria*

  Refer to Table 8.3-1 for test acceptance criteria.

- *Actions to be taken if test fails*

  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

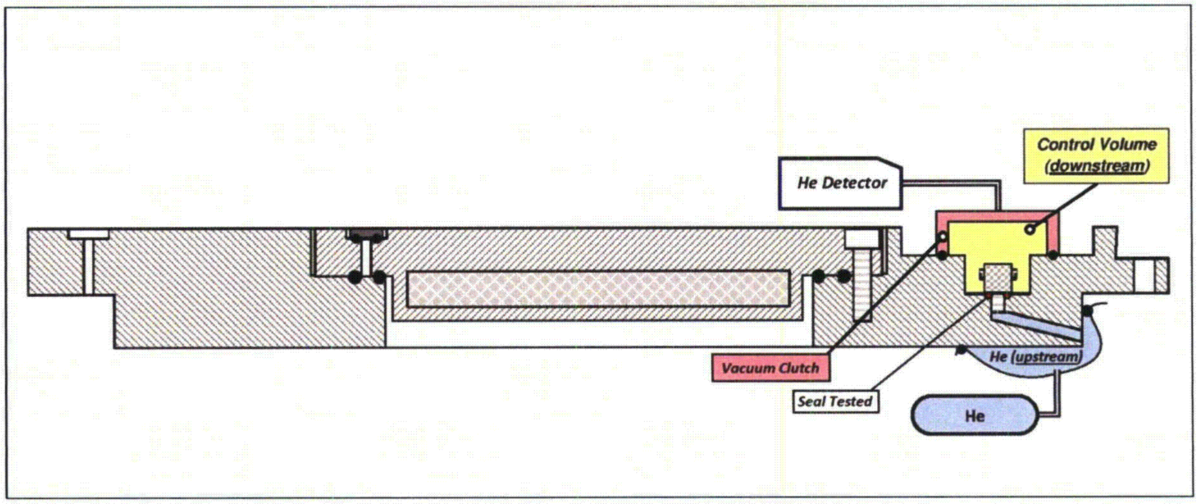


Figure 8.1.4-3 Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve

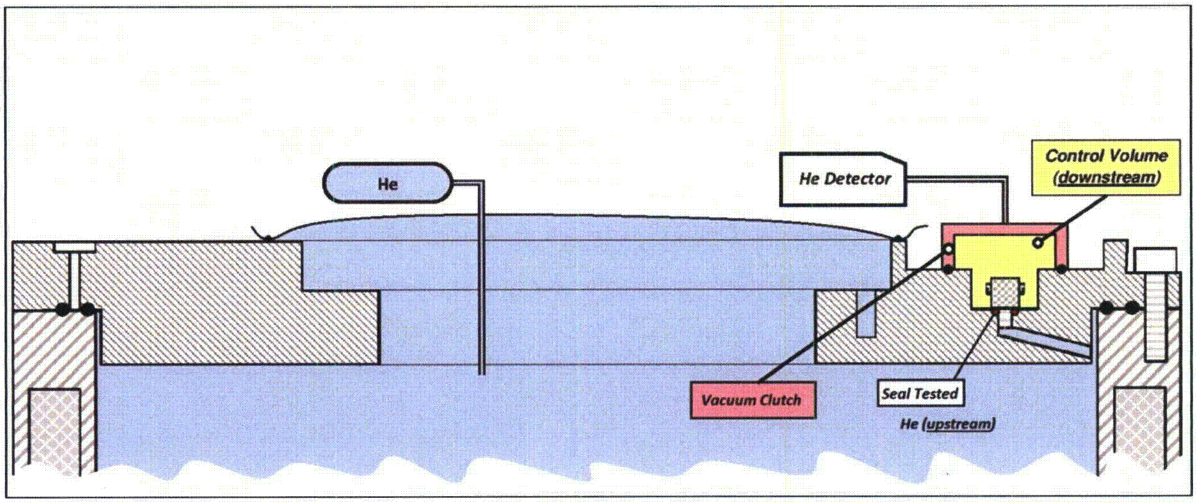


Figure 8.1.4-4 Alternate Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve

8.1.4.4 Quick Disconnect Valve Cover Plate Containment O-Rings Helium Leak Testing

Verification of the quick disconnect valve cover plate containment boundary is prior to its initial use, periodically every 12 months, and after maintenance. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 table A1 test A.5.3 [Ref. 6] to demonstrate compliance with the ANSI N14.5 leaktight criteria. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 [Ref. 7] or equivalent.

- *Test Personnel Qualifications*
  Test personnel shall be ASNT NDT or COFREND Level II certified in leakage testing.
- *Frequency*
  This test is performed prior to initial use, periodically every 12 months, and after maintenance involving the O-rings or bolts.
- *Components to be tested*
  The component tested is the inner O-ring seal in the quick disconnect valve cover plate.
- *Testing Procedure*
  1. Install a bag on the vent port hole under the primary lid as shown in Figure 8.1.4-5. Note: Alternately, the primary lid may be assembled to the cask body without the secondary lid, and the cavity filled with helium via the primary lid opening as shown in Figure 8.1.4-6.
  2. Remove the quick disconnect valve.
  3. Assemble the cover plate per Chapter 7, Section 7.1.2.4 Quick Disconnect Valve Cover Plate Replacement. The bolts must be torqued to the specifications listed in Table 7.4.5-1.
  4. Remove the quick disconnect valve cover plate leak test plug. Attach the vacuum pump and the leak detection equipment to the port.
  5. Pull a vacuum in the O-ring interspace (0.01 atm abs or less).
  6. Fill the bag (or alternatively the containment vessel) with helium (min helium partial pressure 25% of total pressure).
  7. Measure the helium flow signal detected in the interspace. The test duration will be approximately 2 minutes as described in Section 8.1.4.
- *Acceptance Criteria*
  Refer to Table 8.3-1 and Table 8.3-2 for test acceptance criteria.
- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

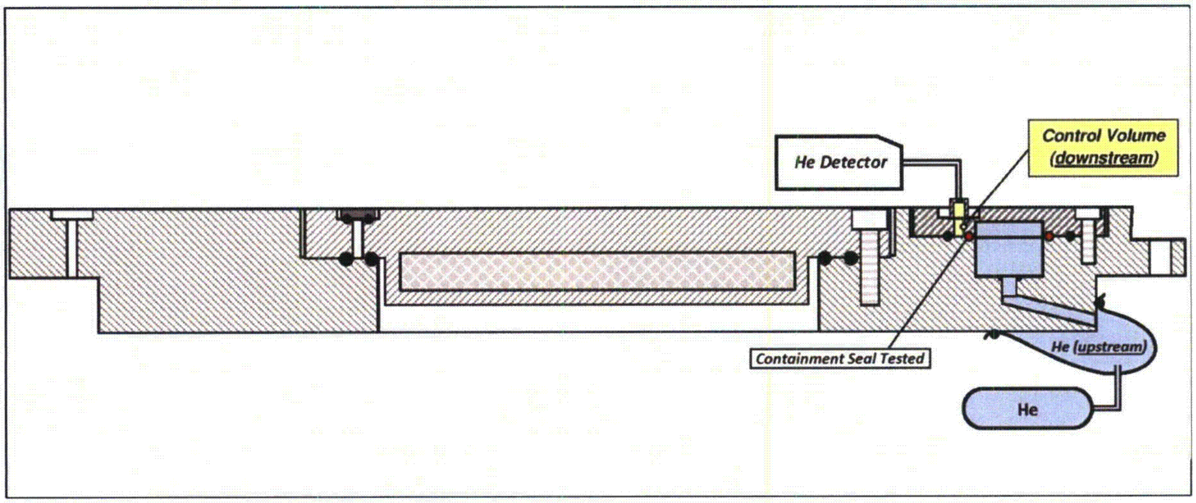


Figure 8.1.4-5 Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve Cover Plate

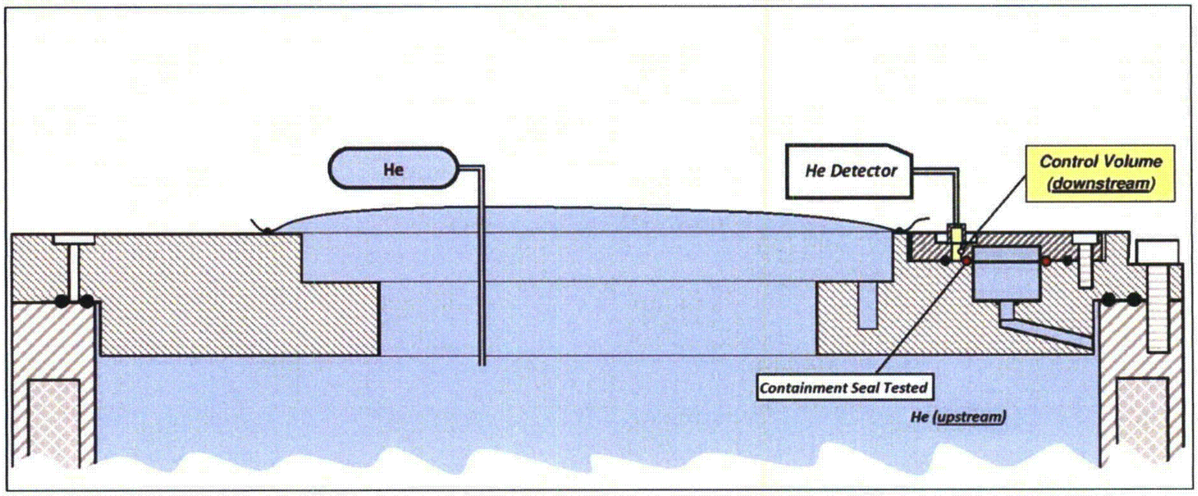


Figure 8.1.4-6 Alternate Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve Cover Plate

8.1.5 Component and Material Tests

The RT-100 is fabricated using industry wide procurement practices for the materials. All materials undergo extensive testing to meet the ASME standards of the material specifications. These specifications (including ASME standards) are part of the procurement process to ensure component materials meet or exceed nuclear industry practices.

To confirm that acceptance criteria are met, materials used for the fabrication of the RT-100 are procured in accordance with RT Quality Assurance Program [Ref. 1] standards. Materials not meeting these standards are replaced. Any materials replacing the originally purchased component parts are subject to the same testing to ensure conformance with specifications.

Where possible, materials for the RT-100 are procured in accordance with ASME/ASTM standards. In certain cases materials may be procured to other standards, such as DIN or ISO. For these materials, a Commercial Grade Dedication (CGD) Plan is prepared to ensure the material meets all specifications critical to safety; such CGD Plans may include independent analyses to confirm supplier material specifications. The CGD Plan is prepared in accordance with RT Quality Assurance Program [Ref. 1] requirements. The following sections give additional information regarding CGD Plan characteristics:

8.1.5.1 Foam
8.1.5.2 O-Ring
8.1.5.3 Ceramic Paper
8.1.5.4 Fusible Plugs
8.1.5.5 Carbon Steel and Alloy Steel Fasteners
8.1.5.6 Stainless Steel Fasteners
8.1.5.7 Thread Inserts
8.1.5.8 Quick Disconnect Valve

8.1.5.1 Foam

The impact limiter foam is procured from General Plastics (GP), series FR3700. The density tolerance is specified as ±10%. GP provides in its documentation the mechanical characteristics of the foam. As GP is a NQA-1 company, the critical characteristics of the foam are not retested.

8.1.5.2 O-Ring

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

8.1.5.3 Ceramic Paper

Proprietary Information Content Withheld Under 10 CFR 2.390

8.1.5.4 Fusible Plugs

The fusible plugs used for the RT-100 are made of polyethylene. The critical characteristic of the fusible plugs is the melting temperature, which shall be less than 160°C. This temperature is based on Robatel Industries' experience with other material plugs.

The melting temperature requirement is based on the ability of the plug to vent the pyrolysis gases produced during decomposition of the polyurethane impact limiter foam in the

hypothetical fire accident. Polyurethanes do not break down below 475 K, or 202°C [Ref. 10]. Since the melting temperature of the fusible plug is less than the decomposition temperature of the impact limiter foam, the gases will be vented.

Another thermoplastic material can be used provided the fusible plugs have a melting temperature below 160°C.

8.1.5.5 Carbon Steel and Alloy Steel Fasteners

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Content Withheld Under 10 CFR 2.390

Proprietary Information Content Withheld Under 10 CFR 2.390

8.1.5.8 Quick Disconnect Valve

The quick disconnect valve used in the RT-100 is a Staubli HCB 08.1152/IC/JE, made of stainless steel, and supplied with an EPDM O-ring. The critical characteristic of the valve is its leakage rate. As previously described in Section 8.1.4.3, when assembled, the quick disconnect valve is leak tested.

8.1.6 Shielding Tests

The RT-100 is designed to provide sufficient shielding to meet or exceed NRC and DOT requirements for a Type B (U)-96 package. Specifically, the RT-100 design includes gamma radiation shielding to meet 10 CFR Part 71 [Ref. 2] during both NCT and HAC.

Shielding integrity of the RT-100 is tested using nondestructive examination techniques (e.g., gamma scanning method) to ensure there are neither direct radiation streams nor voids greater than the acceptance criteria in the lead shield annulus. The acceptance criterion is defined as follows: measurements indicate that no lead layer is less than the minimum specified on the drawing. Any results not meeting this requirement are remedied, and the test and inspection are repeated.

To ensure that the minimum lead thickness is poured, prior to lead pouring, a gauge of 86 mm is utilized to verify that at any point, the distance between the cask inner and outer shell is at least 86 mm. See Appendix 8.3, Section 8.3.1 for further information regarding the lead pouring process.

8.1.7 Thermal Tests

No thermal acceptance testing is required for the RT-100. Refer to the thermal evaluation of the RT-100 described in Chapter 3, Section 3.3, Thermal Evaluation under Normal Conditions of Transport and 3.4 Thermal Evaluation under HAC of the SAR.

8.1.8 Miscellaneous Tests

No miscellaneous tests are to be performed on the RT-100 package.

8.2 Maintenance Program

The RT-100 is subjected to routine inspection and periodic maintenance to ensure its compliance with this SAR and standards required by the NRC. In addition, requirements of the RT Quality Assurance Program [Ref. 1] are employed to direct required maintenance periods. Defective items are replaced or remedied, and tested as appropriate.

- The SAR identifies codes, standards, and provisions of the quality assurance program used for the maintenance of the RT-100 in accordance with 10 CFR 71.31(c) [Ref. 2], and 71.37(b) [Ref. 2]. The RT Quality Assurance Program [Ref. 1] addresses all criteria of 10 CFR 71 [Ref. 2].
- The RT-100 is maintained in an unimpaired physical condition other than superficial defects in accordance with 10 CFR 71.87(b) [Ref. 2]. Any major changes to the RT-100 result in an evaluation for repair/ replacement of damaged parts.
- The RT-100 is not designed to transport fissile material in accordance with 10 CFR 71.87(g) [Ref. 2] and thus, the presence of any moderator or neutron absorber in a fissile material package is not applicable.
- RT shall perform any and all tests deemed appropriate by the NRC in accordance with 10 CFR 71.93(b) [Ref. 2]. NRC is permitted to perform tests on the RT-100 that it deems necessary.
- A maintenance program is part of the operational procedures to ensure that the package performs as intended throughout its service life.

Any RT-100 that does not comply with the specifications and verifications of the SAR is taken out of service until the corrective action(s) have been completed. All corrective actions are reported to RT, NRC, and approved RT-100 Users.

8.2.1 Structural and Pressure Tests

No routine or periodic structural or periodic testing will be performed on the RT-100 transportation cask.

The RT-100 lifting fixture shall be tested annually in accordance with ANSI N14.6 [Ref.8] requirements to verify continuing compliance.

Each containment weld is inspected from the inner surface using dye penetrant methods to detect cracks. Any results not meeting the ASME Code, Section III, Division I, Subsection ND, Article ND-5000 [Ref. 5] requirement are remedied, and the test and inspection are repeated.

8.2.2 Leakage Tests

Section 8.2.2 describes leakage tests to be performed on the RT-100 during its use. This section is subdivided into testing performed after annual inspection or maintenance, and testing performed prior to each shipment. Refer to Appendix 8.3, Section 8.3.1 and Table 8.3-1 for a summary of the leak test types.

Note: Procedures described below are approved by ASNT NDT or COFREND Level III certified personnel in leakage testing.

8.2.2.1 Periodic and Maintenance Leak Test

Leak testing of the RT-100 must be performed after completion of annual inspection and after maintenance or repair. These tests are identical to those performed on the RT-100 prior to its initial use. Refer to the following applicable subsections of Section 8.1.4 for details:

- 8.1.4.2 Primary and Secondary Lid Containment O-Rings Helium Leak Testing
- 8.1.4.3 Quick Disconnect Valve Helium Leak Testing
- 8.1.4.4 Quick Disconnect Valve Cover Plate Containment O-Rings Helium Leak Testing

8.2.2.2 Pre-Shipment Leak Test – Gas Pressure Rise Option

A pre-shipment leakage test is required before each shipment of Type B material quantities to verify proper integrity of the containment system. The following test method is a gas-pressure rise approach in accordance with ANSI N14.5-1997 table A1 test A.5.2 [Ref. 6]. Test equipment shall be calibrated and traceable to an appropriate standard.

Note: As an alternative to the pressure rise method, the pre-shipment leak test can be performed following the pressure drop method described in Section 8.2.2.3.

- *Test Personnel Qualifications*

  Trained and qualified personnel shall perform leakage testing in accordance with written procedures and document the results. The American Society of Nondestructive Testing (ASNT) Recommended Practices or Standards provide acceptable qualification requirements for NDE personnel. Applicable Codes and Standards or design criteria controlling the qualification of NDE personnel shall be utilized to establish the applicable ASNT qualification requirement and edition or to specify an equivalent alternative requirement.

- *Frequency*
  Testing is performed prior to each shipment of Type B material.
- *Components to be tested*
  The vent port cover plate O-ring seals, and the primary or secondary lid O-ring seals, depending on which lid was removed prior to content loading.
  Caution: Users of the RT-100 shall be aware that containment boundary components (detailed in Figure 4.1.2-1) could have been opened during a prior shipment of Type A contents, but a pre-shipment leakage rate test might not have been performed. The user must verify that an unopened lid has been previously leak tested in accordance with the Certificate of Compliance. If this verification cannot be made, the appropriate containment boundary seal must be leak tested.
- *Testing Procedure*
  1. Assemble the cask lids per Chapter 7, Section 7.1.2.2, Primary Lid Replacement, 7.1.2.3, Secondary Lid Replacement, and Section 7.1.2.4, Quick-Disconnect Valve Cover Plate Replacement. The bolts must be torqued to the specifications listed in Table 7.4.5-1.
  2. Remove the applicable leak test port plug.
  3. Ensure that the O-ring on the test manifold is in good condition and lubricated. Connect the vacuum pump test assembly to the appropriate test port. The test assembly should consist of a vacuum pump isolated by a valve, with a gauge indicating the system pressure.
  4. Accurately determine and record the control volume. The control volume includes the volume of the interspace between the O-rings as given in Table 8.2.2-1, plus the volume associated with the measuring instrumentation manifold.

Table 8.2.2-1 Volume of the Interspaces between the O-rings

Interspace Location	Volume [cm³]	Volume [m³]
Primary Lid	70.0	0.000070
Secondary Lid	35.0	0.000035
Quick-Disconnect Valve Cover Plate	3.5	0.0000035

  5. Determine and record the pressure gauge resolution, p.
  6. Measure and record the base metal temperature of the cask lid, T_{amb}.
     Note: Test should be carried out, where possible, in isothermal conditions. Small temperature variations can lead to large pressure variations.
  7. Calculate the minimum required test duration, H_{min}, following the method described in the *Acceptance Criteria* section below.
  8. Create a vacuum in the interspace between the O-rings.
     Note: Absolute pressure of 30 ~ 90 mbar is recommended. Lower absolute pressure may lead to outgassing of the interspace surfaces requiring longer pumping

time to reach a sensitivity of 10^{-3} ref·cc/sec.

Note: Vacuum conditioning of the O-ring seals may be required.

9. Isolate the pump. Physically disconnect the pump and/or turn the pump off.
10. Wait for the vacuum pressure to stabilize, with an absolute pressure of 30 ~ 90 mbar before starting the test.
11. Record the start time, t_1, and start pressure, P_1.
12. After the test duration, H, record the end time, t_2, and end pressure, P_2. Ensure that the test duration is greater than the minimum required test duration, H_{min}.
13. Calculate the pressure change during the test, ΔP. Ensure that the pressure change is less than or equal to the pressure gauge resolution, p.

    Note: This test procedure confirms functionality of the containment seal and the control seal simultaneously. In the event of test failure, either O-ring may be responsible for the leakage.
14. Replace the applicable leak test port plug.

- *Acceptance Criteria*

The preshipment leakage rate test need not be more sensitive than 1×10^{-3} ref-cm^3/s [Ref. 6], as shown in Table 8.3-1. This corresponds to a minimum sensitivity, S_{min}, under standard conditions of 1.01×10^{-4} Pa-m^3/s. The test is carried out by the pressure rise method. Using formula B.14 given in Annex B of ANSI N14.5-1997, the test duration, H, must be greater than the minimum required test duration, H_{min}:

$$H > H_{min} = \frac{V_C \cdot p}{S_{min}} \cdot \frac{T_{std}}{T_{amb}}$$

where: H = actual test duration [s]
H_{min} = minimum required test duration [s][18]
S_{min} = minimum required sensitivity [1.01×10^{-4} Pa-m^3/s]
p = minimum measurable pressure [Pa] for the test, or gauge resolution
V_C = control volume [m^3]
T_{std} = standard temperature [298 K]
T_{amb} = base metal temperature of the cask lid [K] measured during the test

Over the calculated test duration, there can be no measurable pressure rise. I.e., the minimum measurable pressure rise, ΔP, must be less than or equal to the gauge resolution, p:

$$\Delta P = P_2 - P_1 \leq p$$

where: P_1 = pressure [Pa] at the start of the test, t_1 being the start time [s]
P_2 = pressure [Pa] at the end of the test, t_2 being the end time [s]
ΔP = change in pressure [Pa] during the test
p = minimum measurable pressure [Pa] for the test, or gauge resolution

[18] Regardless of gauge resolution, the minimum required test duration shall be at least 10 seconds.

- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

Note: The pre-shipment leak test is not required before a shipment if the contents meet the definition for low specific activity materials or surface contaminated objects as stated in 10 CFR 71.4 [Ref. 2] and also, meet the exemption standard for low specific activity materials or surface contaminated objects as stated in 10 CFR 71.14(b)(3)(i) [Ref. 2].

8.2.2.3 Pre-Shipment Leak Test – Gas Pressure Drop Option

A pre-shipment leakage test is required before each shipment of Type B material quantities to verify proper integrity of the containment system. The following test method is a gas-pressure drop approach in accordance with ANSI N14.5-1997 table A1 test A.5.1 [Ref. 6]. Test equipment shall be calibrated and traceable to an appropriate standard.

Note: As an alternative to the pressure drop option, the pre-shipment leak test can be performed following the pressure rise method described in Section 8.2.2.2.

- *Test Personnel Qualifications*
  Trained and qualified personnel shall perform leakage testing in accordance with written procedures and document the results. The American Society of Nondestructive Testing (ASNT) Recommended Practices or Standards provide acceptable qualification requirements for NDE personnel. Applicable Codes and Standards or design criteria controlling the qualification of NDE personnel shall be utilized to establish the applicable ASNT qualification requirement and edition or to specify an equivalent alternative requirement.
- *Frequency*
  Testing is performed prior to each shipment of Type B material.
- *Components to be tested*
  The vent port cover plate O-ring seals, and the primary or secondary lid O-ring seals, depending on which lid was removed prior to content loading.
  Caution: Users of the RT-100 shall be aware that containment boundary components (detailed in Figure 4.1.2-1) could have been opened during a prior shipment of Type A contents, but a pre-shipment leakage rate test might not have been performed. The user must verify that an unopened lid has been previously leak tested in accordance with the Certificate of Compliance. If this verification cannot be made, the appropriate containment boundary seal must be leak tested.
- *Testing Procedure*
  1. Assemble the cask lids per Chapter 7, Section 7.1.2.2, Primary Lid Replacement,

7.1.2.3, Secondary Lid Replacement, and Section 7.1.2.4, Quick-Disconnect Valve Cover Plate Replacement. The bolts must be torqued to the specifications listed in Table 7.4.5-1.

2. Remove the applicable leak test port plug.
3. Ensure that the O-ring on the test manifold is in good condition and lubricated. Connect the pump test assembly to the appropriate test port. The test assembly should consist of a pump isolated by a valve, with a gauge indicating the system pressure.
4. Accurately determine and record the control volume. The control volume includes the volume of the interspace between the O-rings as given in Table 8.2.2-1, plus the volume associated with the measuring instrumentation manifold.
5. Determine and record the pressure gauge resolution, p.
6. Measure and record the base metal temperature of the cask lid, T_{amb}.
   Note: Tests should take place at isothermal conditions, if at all possible, as temperature changes lead to corresponding pressure changes.
7. Calculate the minimum required test duration, H_{min}, following the method described in the *Acceptance Criteria* section below.
8. Pressurize the cavity in the interspace between the O-rings.
   Note: Minimum absolute pressure of 1.67 atm [24.5 psia] is recommended. Another pressure differential may be used provided the cask user converts the reference leak rate for the new test conditions in accordance with NUREG/CR-6847 Section 2.2.6. Refer to Section 4.3.2 for details regarding the conversion of equivalent air leakage rates.
9. Isolate the pump. Physically disconnect the pump and/or turn the pump off.
10. Wait for the pressure to stabilize, with an absolute pressure of 1.67 ~ 1.75 atm [24.5 ~ 25.7 psia] before starting the test.
    Note: Another pressure differential may be used provided the cask user converts the reference leak rate for the new test conditions in accordance with NUREG/CR-6847 Section 2.2.6. Refer to Section 4.3.2 for details regarding the conversion of equivalent air leakage rates.
11. Record the start time, t_1, and the start pressure, P_1.
12. After the test duration, H, record the end time, t_2, and end pressure, P_2. Ensure that the test duration is greater than the minimum required test duration, H_{min}.
13. Calculate the pressure change during the test, ΔP. Ensure that the pressure change is less than or equal to the pressure gauge resolution, p.
    Note: This test procedure confirms functionality of the containment seal and the control seal simultaneously. In the event of test failure, either O-ring may be responsible for the leakage.
14. Replace the applicable leak test port plug.

- *Acceptance Criteria*

The preshipment leakage rate test need not be more sensitive than 1×10^{-3} ref-cm^3/s

[Ref. 6], as shown in Table 8.3-1. This corresponds to a minimum sensitivity, S_{min}, of 1.01×10^{-4} Pa-m^3/s, when the pressure in the test cavity is 1.67 atm and atmospheric pressure is 1 atm. The test is carried out by the pressure drop method. Using formula B.14 given in Annex B of ANSI N14.5-1997, the test duration, H, must be greater than the minimum required test duration, H_{min}:

$$H > H_{min} = \frac{V_C \cdot p}{S_{min}} \cdot \frac{T_{std}}{T_{amb}}$$

where: H = actual test duration [s]
H_{min} = minimum required test duration [s][19]
S_{min} = minimum required sensitivity [1.01×10^{-4} Pa-m^3/s]
p = minimum measurable pressure [Pa] for the test, or gauge resolution
V_C = control volume [m^3]
T_{std} = standard temperature [298 K]
T_{amb} = base metal temperature of the cask lid [K] measured during the test

Over the calculated test duration, there can be no measurable pressure rise. I.e., the minimum measurable pressure rise, ΔP, must be less than or equal to the gauge resolution, p:

$$\Delta P = P_1 - P_2 \leq p$$

where: P_1 = pressure [Pa] at the start of the test, t_1 being the start time [s]
P_2 = pressure [Pa] at the end of the test, t_2 being the end time [s]
ΔP = change in pressure [Pa] during the test
p = minimum measurable pressure [Pa] for the test, or gauge resolution

- *Actions to be taken if test fails*
  Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

Note: The pre-shipment leak test is not required before a shipment if the contents meet the definition for low specific activity materials or surface contaminated objects as stated in 10 CFR 71.4 [Ref. 2] and also, meet the exemption standard for low specific activity materials or surface contaminated objects as stated in 10 CFR 71.14(b)(3)(i) [Ref. 2].

8.2.3 Component and Material Tests

Section 8.2.3 describes periodic tests and replacement schedules for components. This section is subdivided into routine component inspection and annual component inspection.

8.2.3.1 Routine Component Inspection

Maintenance during normal use is performed to ensure that the RT-100 continues to meet design specifications and functions. Each time the RT-100 goes through the cycle of loading and

[19] Regardless of gauge resolution, the minimum required test duration shall be at least 10 seconds.

unloading, the following components are visually inspected:

- Fasteners: Inspect threaded studs, bolts, nuts, washers, secure pins, and thread inserts. Clean and lubricate; replace as necessary.
- Subcomponents: Inspect the condition of the primary lid, secondary lid, quick disconnect valve cover plate, upper impact limiter and lower impact limiter.
- Welds: Inspect the condition of cask attachment ring welds and cask lifting pocket welds.
- Seals: Inspect the RT-100 seals and check maintenance records to ensure the seals are within the 12 month replacement period. If replacement is necessary, contact RT and perform a leakage rate test after seal replacement.
- Labels: Inspect and record the readability of the RT-100 labeling. Repair if necessary.

8.2.3.2 Annual Component Inspection

Inspections, tests and maintenance are performed every twelve (12) months of cask service as required in accordance with the SAR and NRC compliance requirements. The following steps are performed to ensure all components are in proper working order:

1. The exterior surfaces of the cask are visually inspected for damage and the results of the survey are documented. The major components and items to be inspected include the following items:
   - Upper and Lower impact limiters
   - RT-100 body
   - Condition of the fusible plugs in the impact limiters
   - Condition and readability of RT-100 markings
2. Following procedures in Chapter 7, the RT-100 is disassembled into its components:
   - Upper and Lower impact limiters
   - Primary and Secondary lids
   - Quick disconnect valve cover plate
   - Quick disconnect valve
   - Leak test port plugs
   - Cask body
   - Primary lid, secondary lid, and vent port cover plate O-rings
3. Cask visible exterior surface welds and interior cavity welds are visually inspected for defects.
4. The primary lid, secondary lid and quick-disconnect valve cover plate sealing surfaces are cleaned.
5. New inner and outer containment boundary O-rings are installed according to the recommendation of NUREG-1609 [Ref. 4].

8.2.4 Thermal Tests

No thermal tests are required for the RT-100. At least every four (4) years, testing is performed on the cask body lifting elements (lifting pockets). At the same time, examination of the inner shell visible welds parts on the cask body is performed in addition to the periodic maintenance every twelve (12) months.

8.2.5 Miscellaneous Tests

Threaded inserts may be used to repair threaded bolts holes. At a minimum, each repaired bolt hole will be tested for proper installation by assembling the joint components where the insert is used and ensuring the bolt can be tightened to the required torque. Refer to Tables 7.4.5-1 and 7.4.5-2 for applicable torque requirements.

If a threaded hole for lifting components is repaired, a load test shall be performed. The affected component must be able to withstand a load equal to 150% of the maximum service load. Each threaded insert shall be visually inspected after testing to ensure that there is no visible damage or deformation to the insert.

RT does not envision any other miscellaneous test being required of the RT-100.

8.3 Appendix

8.3.1 Summary of Leak Test Requirements

Table 8.3-1 RT-100 Leakage Test Types

Section	Component(s) to be tested	ANSI N14.5 table A1 test type	Test Frequency	Test Gas	Max. Leak Rate	Min. Sensitivity
8.1.4.1.1	Inner Shell Containment Boundary	A.5.3	Only once during fabrication	Helium	Table 8.3-2	
8.1.4.1.2	Primary Lid Assembly Containment Boundary	A.5.3	Only once during fabrication	Helium	Table 8.3-2	
8.1.4.2	Inner O-ring seals in the primary lid or the secondary lid	A.5.3	Performed prior to initial use, periodically every 12 months, and after maintenance	Helium	Table 8.3-2	
8.1.4.3	Quick-disconnect valve	A.5.3	Performed prior to initial use, periodically every 12 months, and after maintenance	Helium	No Leakage	$1x10^{-3}$ ref·cm^3/sec
8.1.4.4	Inner O-ring seal in the quick disconnect valve cover plate	A.5.3	Performed prior to initial use, periodically every 12 months, and after maintenance	Helium	Table 8.3-2	
8.2.2.2	Vent port cover plate O-ring seals, and the primary or secondary lid O-ring seals	A.5.2	Prior to each shipment of Type B material	N/A (vacuum)	No Leakage	$1x10^{-3}$ ref·cm^3/sec
8.2.2.3	Vent port cover plate O-ring seals, and the primary or secondary lid O-ring seals	A.5.1	Prior to each shipment of Type B material	Air	No Leakage	$1x10^{-3}$ ref·cm^3/sec

Table 8.3-2 Allowable Helium Leakage Rates

Helium Partial Pressure	Max. Leak Rate[1]	Min. Sensitivity
0.25 atm	2.672E-08 cm^3/sec	1.336 E-08 cm^3/sec
0.45 atm	5.137E-08 cm^3/sec	2.569 E-08 cm^3/sec
0.65 atm	8.185E-08 cm^3/sec	4.093 E-08 cm^3/sec
0.85 atm	1.263E-07 cm^3/sec	0.632 E-07 cm^3/sec
1.00 atm	1.897E-07 cm^3/sec	0.949 E-07 cm^3/sec

[1] Max. Leak Rate is taken from Table 4.3.1-2 at T=273K

8.3.2 Minimum Lead Thickness and Gap Determination

Proprietary Information Content Withheld Under 10 CFR 2.390

Proprietary Content Withheld Under 10 CFR 2.390

8.4 References

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