4 CONTAINMENT EVALUATION

4.1 Review Objective

The objective of the U.S. Nuclear Regulatory Commission's (NRC's) containment evaluation is to verify that the applicant has adequately evaluated the performance of transportation packages for radioactive material so that the packages (packaging together with contents) meet the regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71, "Packaging and Transportation of Radioactive Material."

4.2 Areas of Review

The NRC staff should review the application to verify that it adequately describes the package and includes adequately detailed drawings. In general, the staff should review the following information to determine the adequacy of the package description:

- description of containment system
  - containment boundary
  - codes and standards
  - special requirements for damaged spent nuclear fuel (SNF)
- general considerations
  - Type AF fissile packages
  - Type B packages
  - combustible-gas generation
- containment under normal conditions of transport
  - Type B transportation packages
  - SNF transportation packages
  - compliance with containment criteria
- containment under hypothetical accident conditions (Type B packages)
  - Type B transportation packages
  - SNF transportation packages
  - compliance with containment criteria
- leakage rate tests for Type B packages
- appendix

4.3 Regulatory Requirements and Acceptance Criteria

Table 4-1 identifies some regulatory requirements associated with the areas of review covered in this SRP chapter. These are not necessarily the only regulations that may apply but are meant to guide the reviewer's initial assessment of whether the applicant provided sufficient information to conduct the safety evaluation.

Table 4-1 Relationship of Regulations and Areas of Review for Transportation Packages								
Areas of Review	**10 CFR Part 71 Regulations**							
	71.31 (a)(1) (a)(2)	**71.31(c)**	**71.33**	**71.35 (a)**	**71.41 (a)**	**71.43 (c)**	**71.43 (d)**	**71.43 (e)**
Description of containment system	●		●	●	●			
Codes and standards		●						
General considerations			●			●	●	●
Containment under normal conditions of transport				●	●			
Containment under hypothetical accident conditions				●	●			
Areas of Review	**10 CFR Part 71 Regulations**							
	71.43 (f)	**71.43 (h)**	**71.51 (a) (1)**	**71.51 (a) (2)**	**71.51 (c)**	**71.63**	**71.71**	**71.73**
Description of containment system					●			
General considerations	●	●			●	●	●	●
Containment under normal conditions of transport			●		●		●	
Containment under hypothetical accident conditions				●	●			●
Note: The bullet (●) indicates the entire regulation as listed in the column heading applies.								

4.3.1 General Requirements

The applicant must describe and evaluate the transportation package in sufficient detail to demonstrate that it meets the relevant containment requirements of 10 CFR 71.31(a)(1), 71.31(a)(2), 71.31(c), 71.33(a)(4), 71.33(a)(5), 71.33(b)(1), 71.33(b)(3), 71.33(b)(5), 71.33(b)(7), and 71.35(a).

The transportation package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the transportation package, in accordance with 10 CFR 71.43(c). If necessary, coordinate with the structural reviewer when reviewing the closing device.

The transportation package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction, in accordance with 10 CFR 71.43(d). If necessary, coordinate with the materials reviewer when reviewing material compatibility.

Any valve or similar device on the transportation package must be protected against unauthorized operation and, except for a pressure-relief valve, must be provided with an enclosure to retain any leakage, as required by 10 CFR 71.43(e).

Shipments containing plutonium must be made with the contents in solid form if the contents contain greater than 0.74 terabecquerel [20 curies] of plutonium, in accordance with 10 CFR 71.63, “Special Requirement for Plutonium Shipments.”

The transportation package shall not have cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the packaging, as required by 10 CFR 71.85(a). Details on acceptance tests for first use of a package are found in the Acceptance Tests and Maintenance section of the application. Discussion on acceptance tests, and any test the NRC deems appropriate [10 CFR 71.93(b)], is found in the corresponding chapter of this SRP.

Each closure device of the transportation package, including any required seals and gaskets, must be properly installed, secure, and free of defects; the package must be in an unimpaired condition and be loaded and closed in accordance with written procedures, as required by 10 CFR 71.87(b), 10 CFR 71.87(c), and 10 CFR 71.87(f). Note that details of procedures are found in the Operating Procedures section of the application, and details on acceptance tests and maintenance procedures are found in the Acceptance Tests and Maintenance section of the application. Discussions on evaluating operating procedures, acceptance tests, and maintenance are found in the corresponding chapters of this SRP.

SNF that has been classified as damaged for storage must be placed in a can designed for damaged fuel or in an acceptable alternative. A can designed for damaged fuel confines gross fuel particles, debris, or damaged assemblies to a known volume within the cask and permits normal handling. Generally, the use of a can would be a factor in the applicant’s criticality, shielding, thermal, material, and structural analyses. For example, it would be a factor in the applicant’s analyses that ensure the requirements of 10 CFR 71.55(e) are met.

The applicant must describe [10 CFR Part 71.31(a)(1)] and evaluate the transportation package to demonstrate that it satisfies the containment requirements of 10 CFR Part 71, Subpart E, “Package Approval Standards,” under the tests and conditions in Subpart F, “Package, Special Form, and LSA-III Tests,” as specified in 10 CFR 71.31(a)(2) and 10 CFR 71.3, “Package Evaluation.”

As noted in 10 CFR 71.19(c), the applicant must ensure that any modifications to a previously approved package are not significant with respect to the safe performance of the containment system.

4.3.2 Containment Under Normal Conditions of Transport

The application must demonstrate that the transportation package satisfies the containment requirements of 10 CFR Part 71, Subpart E, under the conditions and tests of Subpart F, as specified in 10 CFR 71.35(a) and 10 CFR 71.41(a).

The transportation package may not incorporate a feature intended to allow continuous venting during transport, in accordance with 10 CFR 71.43(h).

The transportation package must be designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71, “Normal Conditions of Transport,” there would be no loss or dispersal of radioactive contents and no substantial reduction in the effectiveness of the package, as specified in 10 CFR 71.43(f). This regulation is applicable to Type AF and Type B packages. An additional requirement for Type B packages is specified in 10 CFR 71.51(a).

A Type B transportation package must meet both the containment requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1) under the tests specified in 10 CFR 71.71 and with no dependence on filters or a mechanical cooling system, as specified in 10 CFR 71.51(c).

4.3.3 Containment Under Hypothetical Accident Conditions

The application must demonstrate that the transportation package satisfies the containment requirements of 10 CFR Part 71, Subpart E, under the conditions and tests of Subpart F, as specified in 10 CFR 71.35(a) and 10 CFR 71.41(a).

A Type B transportation package must meet the containment requirements of 10 CFR 71.51(a)(2) for hypothetical accident conditions and with no dependence on filters or a mechanical cooling system, as required by 10 CFR 71.51(c).

4.4 Review Procedures

The containment review of transportation packages for radioactive material should ensure that the containment requirements of 10 CFR Part 71 are satisfied.

The containment review of transportation packages should be based, in part, on the descriptions and evaluations presented in the General Information, Material Evaluation, Structural Evaluation, and Thermal Evaluation sections of the application. Similarly, results of the containment review are considered in the review of Operating Procedures and Acceptance Tests and Maintenance Program. An example of the information flow for the containment review is shown in Figure 4-1. The containment evaluation results could indicate that special conditions in the certificate of compliance (CoC) (i.e., package leakage testing) are required. Verify that these conditions are consistent with the results from the thermal evaluation.

This chapter of the SRP provides review procedures for the containment review of transportation packages. Appendix A, “Description, Safety Features, and Areas of Review for Different Types of Radioactive Material Transportation Packages,” to this SRP describes different types of packaging for different types of contents and provides supplemental discussions and specific guidance related to containment for the particular package types (e.g., uranium hexafluoride (UF6) packages). Note that unirradiated low-enriched uranium (LEU) transportation packages have traditionally fallen under the heading of Type AF fissile transportation packages. However, reprocessed fresh fuel may have content activity that results in a Type B designation; the extent of the review will be dependent on whether the package is designated as Type AF fissile or Type B. Likewise, mixed oxide (MOX) transportation packages, because of the intentional incorporation of plutonium, can only be considered Type B transportation packages, as defined in 10 CFR Part 71.

4.4.1 Description of the Containment System

4.4.1.1 Containment boundary

Review the containment design features presented in the General Information and Containment sections of the application. All drawings, figures, and tables that describe containment features should be consistent with the evaluation.

Verify that the application provides a complete description of the containment boundary, including, as applicable, the containment vessel, welds, O-rings and seals, lids, cover plates,

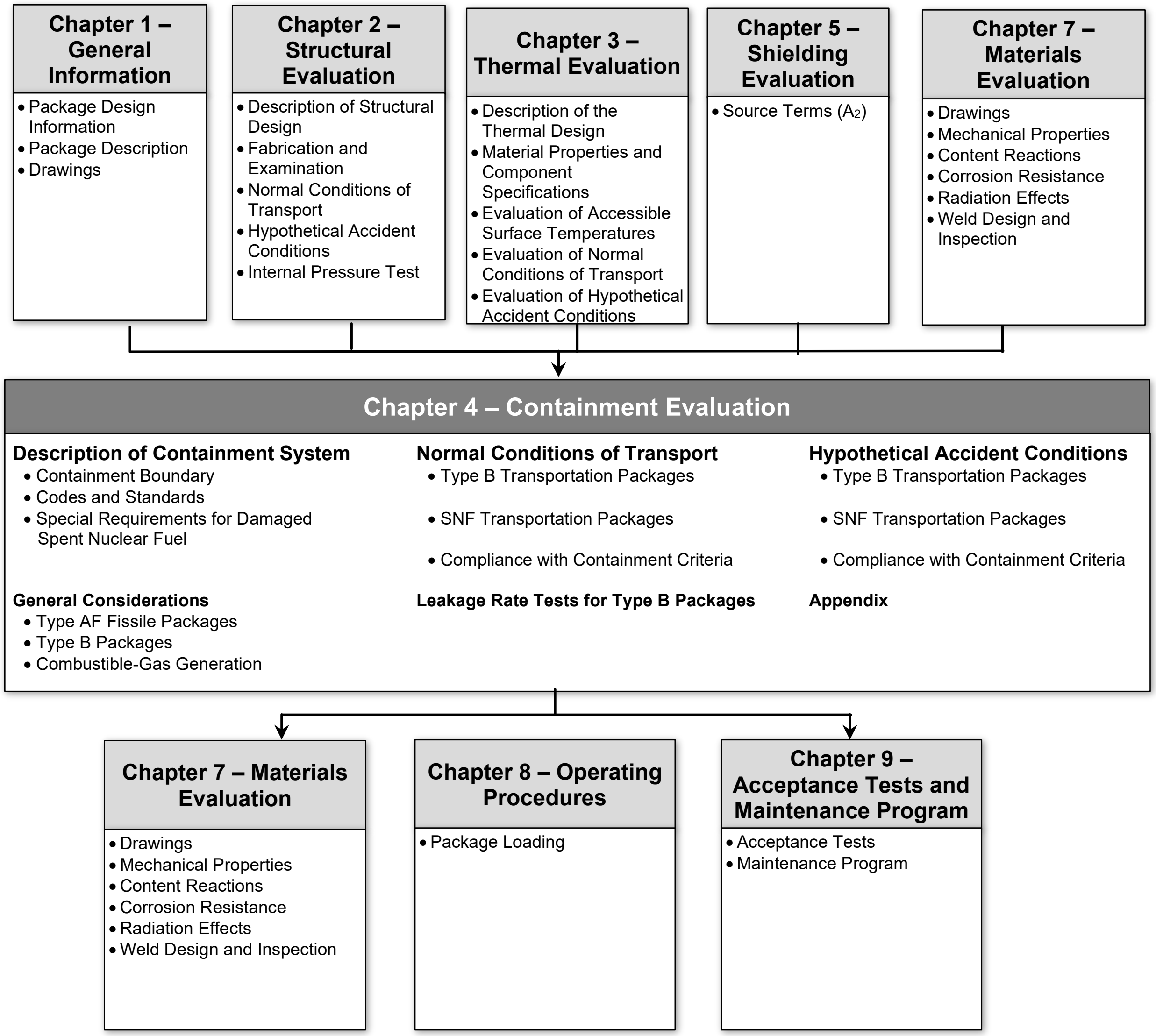

Figure 4-1 Information Flow for the Containment Evaluation

valves, and other closure devices. The application should also describe details associated with the containment boundary, such as codes, standards, and acceptance tests (materials, welds, seals); consult with structural and material disciplines during the review. Figures and sketches should clearly depict the containment boundary. Ensure that all components of the containment boundary are shown in the drawings. The application should provide the containment boundary's free volume, as this information is used in the release calculations discussed below.

Confirm that the following information regarding components of the containment boundary is consistent with that presented in the Structural Evaluation, Material Evaluation, and Thermal Evaluation sections of the application:

- materials of construction
- containment boundary welds

- applicable codes and standards (e.g., American Society of Mechanical Engineers Boiler and Pressure Vessel Code specifications for the vessel)

- bolt torque required to maintain positive closure

- maximum and minimum allowable temperatures of components, including seal material

- maximum and minimum temperatures of components under the tests for normal conditions of transport and hypothetical accident conditions.

Verify that the application describes in detail all containment boundary penetrations and their method of closure. Performance specifications for components such as valves, pressure-relief devices, and O-rings should be documented, and no device may allow continuous venting. Any valve or similar device (e.g., port plugs) on the package must be protected against unauthorized operation and, except for a pressure-relief valve, must be provided with an enclosure to retain any leakage. Cover plates and lids should be recessed or otherwise protected. Compliance with the containment requirements specified in 10 CFR Part 71, including permitted release limits, may not rely on any filter or mechanical cooling system.

Confirm that all containment seals, closure devices, and penetrations, including drain and vent ports, can be leak tested. If fill, drain, or test ports utilize quick-disconnect valves, ensure that such valves do not preclude leak testing of their seals (e.g., cover-plate seals), providing such seals form part of the containment boundary. Plugs can have sealing issues related to reliability from repeated opening and closing (e.g., sealant degradation, galling) such that leak testing should be performed after each installation to confirm there is a seal. Credit may not be taken for closure valves, quick-disconnects, or similar devices because it is assumed that mechanical closure devices (e.g., a valve or quick-disconnect) permit leaks of inert backfill gas (e.g., helium). Practical experience has shown such leaks occur and have been responsible for causing leak paths through the weld. Consequently, welds potentially subjected to helium pressure (by way of leakage through a mechanical closure device) during the welding process must be subsequently helium leak tested.

Verify that the seal material is appropriate for the transportation package. Ensure that no galvanic, chemical, or other reactions will occur between the seal and the packaging or its contents and that the seal will not degrade from irradiation. If penetrations are closed with two seals (e.g., to enable leak testing), verify which seal is defined as the containment boundary. Ensure that dimensions of the seal grooves are proper for the type and size of seals specified. Confirm that the temperature of containment boundary seals will remain within their specified allowable limits under both normal conditions of transport and hypothetical accident conditions. In addition, pursuant to NRC Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks," dated July 5, 1996, confirm that the transportation packages will perform adequately under the operating environments expected (e.g., short-term loading and unloading or long-term storage) during the license period such that no adverse chemical or galvanic reactions are produced.

Verify that the containment system is securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.

4.4.1.2 Codes and standards

Verify that the application identifies established codes and standards applicable to the containment design as required by 10 CFR 71.31(c). Chapter 2, "Structural Evaluation," of this SRP discusses the codes and standards associated with the design, fabrication, testing, inspection, and certification of the containment system (e.g., ASME Boiler and Pressure Vessel Code).

4.4.1.3 Special requirements for damaged spent nuclear fuel

Review the condition and isotopic composition of the SNF or radioactive material proposed for the transportation package. If the contents include damaged fuel, coordinate with the criticality reviewer to verify that it is canned to facilitate handling and that the damaged fuel can confines gross fuel particles to a known subcritical volume under normal conditions of transport and hypothetical accident conditions. Coordinate with the structural and materials reviewers to ensure that the application includes justification for the appropriate material specifications and the design and fabrication criteria for the can. These specifications and criteria should generally be the same as those for containment or criticality support structures, as discussed in Chapter 2 of this SRP. If a screen-type container is used, ensure that the application includes justification for an appropriate mesh size (e.g., mesh size adequately less than fuel fragment size); an acceptance criterion for the mesh can be reviewed in consultation with a materials reviewer.

Note, the determination of the fuel condition should be based, as a minimum, on review of fuel records. Fuel that is known or suspected to be damaged should be visually inspected before loading. If the visual inspection indicates no damage greater that a hairline crack or a pinhole leak, the fuel may be considered undamaged. Additional discussion is provided in Section 7.4.14.1 of this SRP.

4.4.2 General Considerations for Containment Evaluations

4.4.2.1 Type AF fissile packages

Verify that the application specifies that the content under consideration is a Type AF quantity. For Type AF fissile packages, no loss or dispersal of radioactive material is permitted under normal conditions of transport, as specified in 10 CFR 71.43(f). Although 10 CFR Part 71 does not provide numerical release limits for Type AF packages, as it does for Type B packages, the package should confine the contents to a known geometry to ensure subcriticality under both normal conditions of transport and hypothetical accident conditions [per 10 CFR 71.55(e) and 10 CFR 71.59(a)(2)]. Because of the nature of the material, MOX radioactive material and MOX SNF transportation packages are Type B packages and cannot be considered Type AF fissile packages.

4.4.2.2 Type B packages

Type B packages must satisfy the quantified *release* rates of 10 CFR 71.51, "Additional Requirements for Type B Packages." For those packages not tested to a "leaktight" criterion, as defined in American National Standards Institute (ANSI), Institute for Nuclear Materials Management's "American National Standard for Radioactive Materials—Leakage Tests on Packages for Shipment" (ANSI N14.5), verify that the application includes release calculations and identifies the allowable normal conditions of transport and hypothetical accident condition volumetric leakage rates, in accordance with ANSI N14.5 (see NRC Regulatory Guide 7.4, "Leakage Tests on Packages for Shipment of Radioactive Material."). ANSI N14.5 provides an acceptable method to determine the maximum permissible volumetric *leakage* rates based on the allowed regulatory release rates under both normal conditions of transport and hypothetical accident conditions. Ensure that these two volumetric leakage rates are converted to standard air leakage rates, in accordance with ANSI N14.5. The smaller of these air leakage rates is defined as the reference air leakage rate. Typically, the normal conditions leakage rate is the most restrictive. Verify that the Containment section of the application specifies the contents of the package and how the source terms of the contents are used in the release calculations; note that the package content may change with each licensing action. Likewise, verify that the application describes the containment boundary's fill gas (i.e., backfill gas), if used, as this information is used in the release calculations discussed above.

Discussion about release calculations and sample analyses for determining containment criteria for Type B packages are provided in NUREG/CR-6487 "Containment Analysis for Type B Packages Used to Transport Various Contents," issued November 1996, and ANSI N14.5. If the application uses these sample analyses, ensure that the assumptions of that document are applicable to the package under consideration.

Note, the release calculations and analyses discussed above for maximum permissible volumetric leakage rates are unnecessary for transportation packages that are designed and tested to be "leaktight," as defined in ANSI N14.5. This recognizes that the package's containment boundary must remain "leaktight" under normal conditions of transport and hypothetical accident conditions.

Verify that the application describes and justifies the condition of the containment boundary and the contents, especially for content that has been in storage. For fuel content, it is noted that containment is performed by the packaging rather than the fuel cladding.

NRC Information Notice 2016-04, "ANSI N14.5-2014 Revision and Leakage Rate Testing Considerations," dated March 28, 2016, contains information concerning issues that may arise when Type AF and Type B contents are shipped in a Type B package as part of different shipments.

Coordinate with the structural reviewer to ensure that the seal groove and gland design as well as the dimensions and tolerances as noted in engineering drawings are sized for the seal and that the seal and its groove are designed for internal and external (i.e., immersion) pressures. Coordinate with the materials reviewer to ensure that the properties of the seal, especially those that are elastomeric, appropriately consider normal condition and accident condition temperature ranges. In particular, the material for the seal that has high tracer gas permeation may result in difficulties in obtaining accurate leakage rate test results. Note that silicone has a relatively high helium permeation rate.

4.4.2.3 Combustible-gas generation

Confirm that the application demonstrates that any combustible gases generated in the package do not exceed 5 percent by volume, or lower if warranted by the flammable gas, of the free gas volume in any confined region of the package under normal conditions of transport and hypothetical accident conditions. For normal conditions of transport, the application should demonstrate that the 5 percent concentration value, or lower if warranted by the flammable gas, is not generated during a period of 1 year. A condition to the certificate of compliance should be added if a transport period less than 1 year is necessary to ensure that flammable conditions are minimized. Verify that the application justifies the assumptions used in the combustible gas generation calculation, such as choice of “G” values. Information on “G” values and hydrogen generation (e.g., via radiolysis) can be found in NUREG/CR-6673 “Hydrogen Generation in TRU Waste Transportation Packages,” issued May 2000. No credit should be taken for getters, catalysts, or other recombination devices.

4.4.3 Containment Evaluation under Normal Conditions of Transport

4.4.3.1 Type B transportation packages

Confirm that the radionuclides and physical form of the contents evaluated in the Containment section of the application are consistent with those presented in the General Information section of the application. Ensure that the radionuclides include any significant daughter products.

Verify that the application identifies the constituents that comprise the releasable source term, including radioactive gases, liquids, and powder aerosols. If less than 100 percent of the contents are considered releasable, evaluate the justification for the lower fraction.

Verify that the maximum temperature and maximum normal operating pressure are consistent with those determined in the Thermal Evaluation section of the application and with the pressure in the containment vessel based on the conditions of the package under normal transport conditions (e.g., temperature, pressure, release of gases through radiolysis, outgassing, water vapor).

Based on the releasable source term, ensure that the applicant calculated the maximum permissible release rate and the maximum permissible leakage rate in accordance with ANSI N14.5. Using the maximum normal conditions of transport temperature and maximum normal operating pressure, ensure that the maximum permissible leakage rate is converted to the reference air leakage rate in reference cubic centimeters per second, as defined in ANSI N14.5.

Note that for MOX SNF, consider the possibility of increased plutonium isotope levels inherent in MOX. This will influence the mass fraction of fuel that could be released as fines during cladding breach, with a relatively small increase in plutonium-bearing fines resulting in a significantly lower leakage rate acceptance criterion versus LEU SNF (given the A_2 values of the plutonium isotopes). Consideration should be given to defaulting to the ANSI N14.5 “leaktight” criterion.

4.4.3.2 Spent nuclear fuel transportation packages

Verify that the maximum normal operating pressure is consistent with that determined in the Thermal Evaluation section of the application. The pressure in the containment vessel should be based on the conditions of the package under normal transport conditions, including temperature, release of gases and volatiles from fuel rod cladding breaches, and vaporization of contents.

Detailed guidance on procedures for determining the containment criteria is provided in ANSI N14.5 and NUREG/CR-6487.

Confirm that the application fully describes the SNF contents, including fuel type, fuel amount, percent enrichment, burnup, cool time, and decay heat. Confirm that the contents evaluated in the Containment Evaluation section of the application are consistent with those presented in the General Information section of the application. For high burnup fuel, consider fuel fragmentation and releasable fines; coordinate with a materials reviewer about these effects.

Verify that the application identifies the constituents that comprise the releasable source term, including radioactive gases, volatiles, and powders. For SNF packages, the releasable source term is composed of crud on the outside of the fuel rod cladding that can become aerosolized, and fuel fines, volatiles, and gases that are released from a fuel rod in the event of a cladding breach. Source terms, and their bases, for releasable material associated with nonfuel hardware are to be considered; for example, this can include crud that forms on the nonfuel hardware [e.g., burnable poison rod assemblies (BPRAs)]. Although the residual contamination on the inside surfaces of the packaging (from previous shipments) typically can be ignored in the determination of the releasable source term, coordinate with the shielding reviewer whether this issue should be addressed in the Operating Procedures section of the application. Reasonable bounding values for the effective surface activity density (curies per square meter) of the crud on fuel rod cladding are based on experimental determinations. A computer code, such as ORIGEN-S included in the SCALE code system, is used to identify the radionuclides present for a given percent fuel enrichment, burnup, and cool time; Section 5.4.2.1 of this SRP discusses the issues associated with using older codes. Using the individual A2 values for the crud, fines, gases, and volatiles individually, the effective A2 of the releasable source-term mixture can be determined by using the relative release fraction for each contributor and the methods from ANSI N14.5. Table 4-2 gives the release fractions and effective specific activities for the various releasable source-term contributors for SNF with an initial enrichment of 3.2 percent, a burnup of 33,000 megawatt-days per metric ton of initial heavy metal, and a cool time of 5 years. When an applicant uses the release fractions in Table 4-2, ensure that the condition of the fuel described in the application is bounded by the experimental data presented in NUREG/CR-6487. Specifically, these experimental data are based on low-burnup fuel and the release from a single breach of one fuel rod; these data should not be used for SNF described as damaged. The containment and materials reviewers may consider other release fractions for conditions other than those described in NUREG/CR-6487 if the applicant has provided adequate justification.

Based on the mass density, effective specific activity, and effective A2 of the releasable source term, ensure that the maximum permissible release rate and the maximum permissible leakage rate are calculated in accordance with the containment criteria specified in ANSI N14.5. Verify that the maximum permissible leakage rate under normal transport conditions is converted into a reference air leakage rate under standard leak test conditions according to ANSI N14.5 and NUREG/CR-6487.

4.4.3.3 Compliance with containment design criteria

Confirm that the application demonstrates that the package meets the containment requirements in 10 CFR 71.51(a)(1) under normal conditions of transport.

- If compliance is demonstrated by test, verify that the leakage rate of a package subjected to the tests of 10 CFR 71.71 does not exceed the maximum allowable leakage rate for normal conditions. Note, scale-model testing is not a reliable or acceptable method for quantifying the leakage rate of a full-scale package.

Table 4-2 Release Fractions and Specific Activities for the Contributors to the Releasable Source Term for Packages Designed to Transport Irradiated Fuel Rods[a,b]				
Variable	**Pressurized-Water Reactor**		**Boiling-Water Reactor**	
	Normal conditions of transport	**Hypothetical accident conditions**	**Normal conditions of transport**	**Hypothetical accident conditions**
Fraction of crud that spalls off of rods, f_C	0.15	1.0	0.15	1.0
Crud surface activity, S_C [Ci/cm²]	140×10^{-6}	140×10^{-6}	1254×10^{-6}	1254×10^{-6}
Mass fraction of fuel that is released as fines due to a cladding breach, f_F	3×10^{-5}	3×10^{-5}	3×10^{-5}	3×10^{-5}
Specific activity of fuel rods, A_R [Ci/g]	0.60	0.60	0.51	0.51
Fraction of rods that develop cladding breaches, f_B	0.03	1.0	0.03	1.0
Fraction of gases that are released due to a cladding breach, f_G	0.3	0.3	0.3	0.3
Specific activity of gases in a fuel rod, A_G [Ci/g]	7.32×10^{-3}	7.32×10^{-3}	6.28×10^{-3}	6.28×10^{-3}
Specific activity of volatiles in a fuel rod, A_V [Ci/g]	0.1375	0.1375	0.1794	0.1794
Fraction of volatiles that are released due to a cladding breach, f_V	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}

[a]3.2 percent initial enrichment, 33,000 megawatt-days per metric ton of initial heavy metal burnup, 5-year cooling
[b]Applicable only to undamaged fuel. Release fractions for damaged fuel should be justified in the application.
[c]Values in this table are taken from NUREG/CR-6487.

- If compliance is demonstrated by analysis, verify that the structural evaluation shows that the containment boundary, seal region, closure, and closure bolts do not undergo any inelastic deformation and that the materials of the containment system (e.g., seals) are within their maximum and minimum allowable temperature limits when subjected to the conditions in 10 CFR 71.71.

- Demonstration that the packaging meets the maximum allowable leakage rate is verified during acceptance testing of the packaging via the fabrication, periodic, and maintenance leakage rate tests, as discussed in the Acceptance Tests and Maintenance Program section and Operating Procedures section of the application (i.e., pre-shipment leakage rate test). Additional discussion is provided in Section 4.4.5 of this SRP.

4.4.4 Containment Evaluation Under Hypothetical Accident Conditions

The review procedures for containment under hypothetical accident conditions are similar to those under normal conditions of transport and listed in Section 4.4.3 above. This section focuses on the differences relevant to hypothetical accident conditions.

4.4.4.1 Type B transportation packages

The releasable source term, maximum permissible release rate, and maximum permissible leakage rate should be based on package conditions (e.g., temperature, pressure, gas generation by radiolysis) and the 10 CFR Part 71 containment requirements under hypothetical accident conditions. Verify that the temperatures, pressure, and physical conditions of the package (including the contents) are consistent with those determined in the Structural, Material and Thermal Evaluation sections of the application. Ensure that the reference air leakage rate calculated for hypothetical accident conditions is greater than that determined in Section 4.4.3.1 of this SRP for normal conditions of transport. In the rare event that this is not the case, ensure that the containment criteria for the fabrication, periodic, and maintenance leakage rate tests are based on the hypothetical accident condition's reference air leakage rate, rather than normal conditions of transport.

4.4.4.2 Spent nuclear fuel transportation packages

The pressure in the containment vessel should be based on the conditions of the package under hypothetical accident conditions, including temperature, release of gases and volatiles from fuel rod cladding breaches, and vaporization of contents. Pressure contributions from BPRAs should assume all the backfilled helium and generated helium is released in a failed assembly. Verify that this pressure is consistent with that determined in the Thermal Evaluation section of the application.

The releasable source term, maximum permissible release rate, maximum permissible leakage rate, and conversion to the reference air leakage rate should be based on package conditions and the 10 CFR Part 71 containment requirements under hypothetical accident conditions. Verify that the temperatures, pressure, and physical conditions of the package (including the contents) are consistent with those determined in the Structural Evaluation and Thermal Evaluation sections of the application.

Ensure that the reference air leakage rate calculated for hypothetical accident conditions is greater than that determined in Section 4.4.3.2 of this SRP for normal conditions of transport. In the rare event that this is not the case, ensure that the containment criteria for the fabrication, periodic, and maintenance leakage rate tests are based on the hypothetical accident condition's reference air leakage rate, rather than normal conditions of transport.

The containment requirements of 10 CFR 71.51(a)(2) for hypothetical accident conditions shall be applied individually for Krypton-85 and the other radioactive materials. Krypton-85 shall not exceed 10 A2 in a week. The remaining radioactive materials shall not exceed A2 in a week.

The considerations regarding MOX SNF described earlier for the containment criteria for normal conditions of transport also apply to the evaluation of the containment criteria for hypothetical accident conditions.

4.4.4.3 Compliance with containment design criterion

Ensure that the application demonstrates that the package satisfies the containment requirements of 10 CFR 71.51(a)(2) under hypothetical accident conditions. Demonstration is similar to that discussed in Section 4.4.2 and 4.4.3, except that the package should be subjected to the tests of 10 CFR 71.73, "Hypothetical Accident Conditions."

4.4.5 Leakage Rate Tests for Type B Packages

It is noted that leakage rate tests have acceptance criteria and measurement sensitivities that can assure there are no flaws or leak paths that could result in significant release of radioactive contents and inert gases that may be backfilled within the containment boundary. ANSI N14.5 provides information on leakage rate testing of the containment boundary, including acceptance criterion and test sensitivity. Likewise, NRC Information Notice 2016-04 and NRC Regulatory Guide 7.4 contain additional relevant information on leak testing and should be reviewed. Verify that personnel approving leakage rate test procedures and those performing the leakage rate tests are qualified. For example, the American National Standard Institute's "ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel," (ANSI/ASNT CP-189) and the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing" provide the minimum training, education, and experience requirements for nondestructive testing personnel involved with leakage rate testing. An individual who has obtained certification as an ASNT nondestructive testing (NDT) Level III in leak testing has the qualification necessary to develop and approve written instruction for conducting the leakage rate testing as well as the knowledge to consider practical leakage rate testing issues (e.g., isolation of vacuum pump). Using the reference air leakage rate acceptance criterion and pre-shipment leakage rate acceptance criterion, confirm that the allowable leakage rate tests for the following conditions are performed in accordance with ANSI N14.5:

- fabrication
- maintenance
- periodic
- pre-shipment (assembly verification *after* loading of contents)

Verify that the reference air leakage rate acceptance criterion and test sensitivity for the fabrication, maintenance, and periodic leakage rate tests are included in the Acceptance Tests and Maintenance Program review (see Chapter 9, "Acceptance Tests and Maintenance Program Evaluation," of this SRP). Verify that the leakage rate tests of the containment boundary are performed such that subsequent package fabrication procedures (fabrication not related to the containment boundary) do not adversely affect the integrity of the containment boundary. The pre-shipment leakage rate test acceptance criterion and test sensitivity should be included in the operating procedures evaluation. Note that for "rate-of-rise" and "pressure-drop" leakage rate tests, procedures should indicate that the vacuum pump and gas supply be physically removed or powered off, recognizing that a closed valve may not adequately isolate the pump or supply during the pressure measurement phase.

4.4.6 Appendix

Confirm that the appendix, if included, provides a list of references, copies of applicable references if not generally available to the reviewer, test results, and other appropriate supplemental information.

4.5 Evaluation Findings

Prepare evaluation findings upon satisfaction of the regulatory requirements in Section 4.3 of this SRP chapter. If the documentation submitted with the application fully supports positive findings for each of the regulatory requirements, the statements of findings should be similar to the following:

F4-1 The staff has reviewed the applicant's description and evaluation of the containment system and concludes that:

— the application identifies established codes and standards for the containment system

— the package includes a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package

— a package valve or similar device, if present, is protected against unauthorized operation and, except for a pressure-relief valve, is provided with an enclosure to retain any leakage

F4-2 The staff has reviewed the applicant's evaluation of the containment system under normal conditions of transport and concludes that the package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71, "Normal Conditions of Transport," the package satisfies the containment requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1) for normal conditions of transport with no dependence on filters or a mechanical cooling system.

F4-3 The staff has reviewed the applicant's evaluation of the containment system under hypothetical accident conditions and concludes that the package satisfies the containment requirements of 10 CFR 71.51(a)(2) for hypothetical accident conditions, with no dependence on filters or a mechanical cooling system.

The reviewer should provide a summary statement similar to the following:

> Based on review of the statements and representations in the application, the NRC staff concludes that the package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71.

4.6 References

10 CFR Part 71, "Packaging and Transportation of Radioactive Material."

American National Standards Institute, ANSI N14.5-2014, "Radioactive Materials—Leakage Tests on Packages for Shipment," New York, NY.

Regulatory Guide 7.4, U.S. Nuclear Regulatory Commission, "Leakage Tests on Packages for Shipment of Radioactive Material," Agencywide Documents Access and Management System (ADAMS) Accession No. ML112520023.

B&PV Division 3 Code American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code, Section III, Division 3, Containment Systems and Transport Packagings For Spent Nuclear Fuel and High Level Radioactive Waste," New York, NY, 2015.

NRC Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks," OMB No. 3150-0011, U.S. Nuclear Regulatory Commission, July 5, 1996.

NRC Information Notice 2016-04, "ANSI N14.5-2014 Revision and Leakage Rate Testing Considerations," 2016, ADAMS Accession No. ML16063A287.

NUREG/CR-6487, U.S. Nuclear Regulatory Commission, "Containment Analysis for Type B Packages Used to Transport Various Contents," UCRL-ID-124822, Lawrence Livermore National Laboratory, Livermore, CA, November 1996.

NUREG/CR-6673, U.S. Nuclear Regulatory Commission, “Hydrogen Generation in TRU Waste Transportation Packages,” UCRL-ID-13852, Lawrence Livermore National Laboratory, Livermore, CA, May 2000.

Oak Ridge National Laboratory, “SCALE: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design,” ORNL/TM-2005/39, Version 6.1, June 2011.