Division of Spent Fuel Storage and Transportation
Interim Staff Guidance - ISG-18, Rev. 1

Issue: The Design and Testing of Lid Welds on Austenitic Stainless Steel Canisters as the Confinement Boundary for Spent Fuel Storage

Introduction:

The purpose of this ISG is to address the design and testing of the various closure welds ("lid welds") associated with the redundant closure of all-welded austenitic stainless steel canisters:

> As an acceptable confinement boundary under 10 CFR Part 72.236(e) (Ref. 1) for purposes of demonstrating no credible leakage of radioactive material during storage and satisfying the dose limits under normal and off-normal conditions in 10 CFR Parts 72.104(a) and 72.106(b).

This staff guidance is not a regulatory requirement. Instead, it is one acceptable method for meeting the applicable regulatory requirements. It is provided to reduce applicant burden and staff review effort. Use of this guidance by applicants is optional. Other means for satisfying the appropriate regulatory requirements may be proposed for staff review. However, deviation from this guidance in whole or in part may result in more lengthy staff review schedules. This guidance does not apply to Part 71 transport designs, and has not been considered for such applications. This ISG does not address the testing of the welds comprising a storage cask body.

Discussion:

10 CFR 72.236(e) states: "The spent fuel storage cask (*note: also called "canister"*) must be designed to provide redundant sealing of confinement systems." For a welded canister design, the staff has accepted closure designs employing redundant lids or covers, each with independent field welds. Thus, a potential leak path must breach two independent welds, sequentially, before the confinement system would be compromised.

The construction codes (e.g., the American Society for Mechanical Engineers Boiler and Pressure Vessel Code) specify the types of non-destructive examinations (NDE) required for the confinement boundary welds during canister fabrication and loading operations. In addition to the code required NDE, a helium leakage test of the confinement boundary is considered necessary to satisfy regulatory requirements. Whereas bolted lid canister designs incorporate a helium monitoring system during storage, the welded closure designs must rely on weld integrity to assure continued confinement effectiveness. Consequently, at least one of the redundant welded closures must be helium leakage tested per the method of ANSI N14.5 (Ref. 2), with the following exception permitted. The configuration of the lid welds and the confinement boundary are discussed in more detail in the technical guidance of this ISG.

When the large, multi-pass weld* joining the canister shell to the structural lid of an austenitic stainless steel spent fuel canister is executed and examined consistent with the guidance provided in ISG-15 (Ref. 3), the staff has reasonable assurance that no flaws of significant size will exist such that they could impair the structural strength or confinement capability of this weld. For a spent nuclear fuel canister, such a flaw would be the result of improper fabrication or welding technique, as service-induced flaws under normal and off-normal conditions of storage are not credible. Any such fabrication flaws would be reasonably detectable during the in-process and post-weld examination techniques described by ISG-15.

Based on evaluation, the described techniques of ISG-15 should detect any such flaw which could lead to a failure or credible leakage of radioactive material. Therefore, the staff believes that there is reasonable assurance that no credible leakage of radioactive material would occur through the structural lid to canister shell weld of an austenitic stainless steel canister, and that helium leakage testing of this specific multi-pass weld is unnecessary provided the weld is executed and examined in accordance with ISG-15.

Conversely, it is the staff position that other welds associated with the lid assemblies of spent fuel canisters must be subject to the helium leakage test of ANSI N14.5, in addition to the ASME Code Section III (Ref. 4) required pressure test and surface NDE which would demonstrate compliance with 10 CFR 72.236. This revision to ISG-18 expands the guidance to address all welds associated with the redundant closures of a spent fuel canister and describes how each individual closure weld must be considered from the overall design and testing standpoint.

Revision 1 adds discussion and staff review guidance for the:

1. Helium leakage test for closure welds.
2. Design and examination criteria to be met before any closure weld may be exempted from the helium leakage test.
3. Criteria for helium leakage testing of any closure weld which may be pressurized during the welding process.
4. ASME Code, Section III, hydrostatic test requirement.
5. ASME Code Case N-595.
6. Criteria for limiting root pass thickness.

Technical Review Guidance:

General Guidance

The staff should verify that the cask design under review is in compliance with the guidance of this document.

1. This guidance only applies to canisters of all-welded construction, fabricated from austenitic stainless steel, employing redundant welds for the confinement closure.

* Under this guidance, the term “multi-pass weld” means a weld with three or more individual layers of weld metal. Each layer may be composed of a single weld bead or several adjacent weld beads of common thickness. The minimum of three layers will minimize the probability of a weld flaw propagating through the weld layers resulting in a leakage path.

2. The welded canister (i.e., the confinement boundary) must be helium leakage tested in accordance with ANSI N14.5 and ISG-15, except as specified by this guidance.

3. Closure welds must conform with the guidance of ISG-15, and/or the guidance of this instruction, as appropriate.

4. “Structures, systems, and components important to safety must be designed… to withstand postulated accidents.” [10 CFR 72.122(b)].

5. Records documenting the lid welds shall comply with the provisions of 10 CFR Part 72.174, “Quality Assurance Records,” and ISG-15. Records storage should comply with ANSI N45.2.9, “Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants” (Ref. 5).

6. Activities related to inspection, evaluation, documentation of fabrication, and lid welding shall be performed in accordance with an NRC-approved quality assurance program as required in 10 CFR Part 72, Subpart G, “Quality Assurance.”

Specific Guidance

The use of helium leakage testing for dry cask storage was established to provide assurance that:

1. No leakage occurred after the closure welds of the cask system were executed. This was viewed as necessary since no active or passive methods are employed to confirm or monitor the presence of helium within an all-welded spent fuel canister over its licensed lifetime. “No leakage” in this case means measured leakage rate performed per ANSI N14.5, at a predetermined sensitivity that shows hypothetical doses would not exceed 10 CFR Part 72 limits.

2. If the weld(s) meets the criteria of ANSI N14.5, the staff has assurance that radio-nuclide leakage would not exceed the regulatory dose limits in 10 CFR Parts 72.104 and 72.106.

3. No oxygen in-leakage could occur, assuring the presence of the inert helium atmosphere which prevents oxidation and corrosion induced degradation of the spent fuel assemblies and enhances cooling of the spent fuel.

Helium Leakage Test - Large Weld Exception Criteria

In order for any closure weld to be exempt from the helium leakage testing to demonstrate compliance with 10 CFR 72.236, the staff should verify that all of the following conditions are satisfied:

1. The weld must be multi-pass, with a minimum weld depth comprised of at least 3 distinct weld layers.

2. Each layer of weld may be composed of one or more adjacent weld beads.

3. The layer must be complete across the width of the weld joint.

4. If only three weld layers comprise the full thickness of the weld, each layer must be PT examined.

5. For more than three weld layers, not all weld layers need to be PT examined. The maximum weld deposit depth allowed before a PT examination is necessary is based upon flaw-tolerance calculations in accordance with ISG-15. Note: This criteria does not supercede the flaw acceptance criteria of any construction code. Instead, this criteria is used to establish the maximum allowable weld deposit depth before an in-process PT examination is necessary.

6. Regardless of conditions (4) or (5) above, at least three different weld layers must be examined, e.g., the root pass, a mid-layer, and the cover pass.

7. The weld cannot have been executed under conditions where the root pass might have been subjected to pressurization from the helium fill in the canister itself. When executing vent and drain connection cover plate welds, it should not be assumed that the fill and drain closure valves, quick-disconnects, or similar, are leak tight. It is assumed that mechanical closure devices (e.g. a valve or quick-disconnect) permit helium leaks. Field experience has shown that 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 leakage tested.

Helium Leakage-Testing of the Confinement Boundary

The redundant weld requirement for the confinement system closure creates two closure boundaries. The staff should verify that at least one of the redundant boundaries is helium leakage tested, or, some closure welds leakage tested and the remaining closure welds of the same boundary designed so that the “large weld” exemption criteria of the preceding section are met. Only a boundary which is testable or meets the large weld exemption criteria, per this guidance, should be considered the confinement boundary of the redundant closures. Refer to sketches A and B and the following narrative for application of this criteria to two currently approved designs.

Leakage Testing a Single Lid With Cover Plate Design - Sketch A

In sketch A, the dotted line marked (1) defines one closure boundary. Starting on the left side of the sketch, the closure boundary can be traced from the canister wall, up through the large, multi-pass weld joining the canister wall to the heavy section, combined shield and structural lid. The boundary continues through the lid to the small weld joining the heavy lid to the vent-and-drain port cover plate, and back to the heavy lid. The remainder of this boundary (and sketch) is assumed to be symmetrical with or similar to the half-sketch portion that is shown, for all cases.

The large, canister-shell-to-lid weld is exempted from the helium leakage test. This is because the canister-shell-to-lid weld is a large, multi-pass weld meeting the flaw tolerance and other guidance of ISG-15 and the appropriate portions of this guidance. Note that this weld is executed prior to filling the canister with helium (use of purge or backing gas for welding operations is not considered filling or pressurizing).

Before the remaining welds of this first closure boundary are executed, the canister is drained, dried, purged, and filled with helium to the design operating pressure. The helium line connection is closed off and the vent and drain port cover plates fitted and welded into place. Since the vent-and-drain port cover plate weld may have potentially been pressurized from underneath due to assumed leakage from the closure valve, it must be helium leakage tested in accordance with the methods described in ANSI N14.5. If there are other cover plates and welds, they shall also be helium leakage tested.

This first closure boundary maintains confinement integrity because one weld meets the large weld exemption criteria and the other weld was leakage tested. Thus, this first closure boundary meets the staff guidance by ensuring at least one of the two redundant closure boundaries is leakage tested or conforms to the large weld exemption criteria.

The second boundary, delineated by the dotted line 2 in Sketch A, can be traced from the canister wall on the left side of the sketch up through the cover plate fillet weld joining the canister wall to the structural lid cover plate. The boundary continues through the cover plate to the fillet weld joining the cover plate to the canister lid. The weld joining the cover plate to the canister wall and lid cannot be helium leakage tested since there is no feasible means to do so. Since this second boundary does not meet all the criteria for a confinement boundary, it may not be designated as the confinement boundary. The first closure boundary is thereby designated the confinement boundary in this design, as it meets all the applicable criteria for a confinement boundary.

Leakage Testing a Dual Lid Design - Sketch B

In sketch B, the dotted line marked (1) defines one of the redundant closure boundaries. It may be traced from the canister wall on the left side of the sketch. The boundary proceeds through the weld joining the canister wall to the shield lid, then through the shield lid. It continues through the small weld joining the vent-and-drain port cover plate back to the shield lid again.

This closure boundary may satisfy the leakage test guidance by several methods, depending on the details of the weld design. The canister shell to shield lid weld may be designed several ways. The weld may be a small seal weld which would necessitate subsequent helium leakage testing. Conversely, it could be a large, multi-pass weld consistent with the guidance of ISG-15. In that case, the weld would qualify for the leakage test exemption. Either way, note that this weld (canister to shield lid weld) is executed prior to filling and pressurizing the canister with helium (use of purge or backing gas for welding operations is not considered filling or pressurizing).

Next, the canister is drained, dried, purged, and filled with helium to the design operating pressure. The helium line connection is closed off. The vent-and-drain port cover plates are fitted and welded into place. Since the vent-and-drain port cover plate weld may have potentially been pressurized from underneath due to assumed leakage through the closure valve, it must be helium leakage tested with the methods described in ANSI N14.5. The vent-and-drain-port cover plate welds may be tested either individually or in combination with the helium leakage test of another weld.

This first closure boundary maintains confinement integrity because one weld was either tested, or, meets the large weld exemption criteria. The other weld was leakage tested. Thus, this closure boundary demonstrates compliance with regulatory requirements and is consistent with staff guidance by ensuring at least one of the two redundant closures is leakage tested or exempted by conformance to the exemption guidance of ISG-15. This cover may therefore be designated as the confinement boundary.

The secondary boundary, delineated by dotted line 2 in sketch B, can be traced from the canister wall on the left side of the sketch up through the canister wall-to-structural lid weld and into the structural lid. This large canister shell-to-lid weld is exempted from the helium leakage test, because the canister shell-to-lid weld is a large, multi-pass weld meeting the flaw tolerance and other guidance of ISG-15, and the appropriate portions of this guidance.

For this lid design, the second closure also qualifies for designation as the confinement boundary, because it meets the large weld exemption criteria of this guidance and the guidance in ISG-15. In this case, the designer has the freedom to designate either of the redundant closures as the confinement boundary. However, only one of the two closures is credited as the confinement boundary.

Hydrostatic Testing

Closure welds must be hydrostatically or pneumatically tested in accordance with ASME Code Section III requirements to the extent practicable.

ASME Code Case N-595-4

ASME Code Case N-595-4 (and all earlier versions) (Ref. 6) is not endorsed by the NRC staff, per Regulatory Guide (RG) 1.193 (Ref. 7), and consequently is not permitted as an alternative to the Code requirements.

Criteria for Limiting Root Pass Thickness

Cask lid welding is governed in part by the limiting flaw size analysis, per the guidance in ISG-15. The method prescribed in ISG-15 controls the depth of weld deposit for the intermediate passes before the required PT examination is performed. However, the root pass thickness is not addressed by the guidance of ISG-15, as a single layer root pass was assumed. Occasionally, multi-layer root passes are employed to smooth the weld surface to avoid false positives from the PT.

A multi-layer root pass is acceptable provided a flaw size analysis is used to limit the weld deposit depth. Stress analysts should note that the intermediate layer critical flaw size calculation assumes an internal flaw, not a surface connected flaw. For the root pass calculation, a surface connected flaw must be assumed. Surface connected flaws have a higher stress intensity factor than internal flaws. This will result in a smaller critical flaw size. Consequently, the permissible weld deposit thickness will also be smaller than for the intermediate weld pass case.

The staff should verify that if the licensee desires to use a thicker root pass, they must limit the amount of weld deposit to the ratio of the fracture toughness K values (or, J values) for the different flaw types (buried K divided by surface K) multiplied by the maximum weld deposit depth allowed by the ISG-15 calculation method. This will limit the depth of the root pass to the critical flaw size for a surface connected flaw. Thus, if a licensee desires to use a thicker weld deposit for the root pass, then a limiting flaw size analysis establishes a structural basis that is consistent with the intent of ISG-15. Alternative approaches may be proposed. Any alternative approach must consider the flaw tolerance of the weld and limit weld deposit depth to less than the critical flaw depth so that a PT may be performed before proceeding with additional weld deposit depth.

The staff recognizes that for stainless steel, K, or even J, is not entirely correct for evaluating failure in austenitic stainless steel due to the large capacity for plastic deformation. Generally, the result is failure due to net section stress, not fracture. However, the stress intensity ratio suggested above is acceptable for this purpose.

Regulatory Basis:

The systems, structures, and components (SSCs) important to safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function to be performed [10 CFR 72.122(a)].

The high-level radioactive waste.....must be packaged.....without the release of radioactive materials to the environment or radiation exposures in excess of [10 CFR] part 20 limits. The package must be designed to confine the high-level radioactive waste for the duration of the license [10 CFR 72.122(h)(5)].

Radiation shielding and confinement features must be provided sufficient to meet the requirements in parts 72.104 and 72.106 [10 CFR 72.236(d)].

The spent fuel storage cask must be designed to provide sealing of confinements systems [10 CFR 72.236(e)].

The spent fuel storage cask must be inspected to ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce its confinement effectiveness [10 CFR 72.236(j)].

The spent fuel storage cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the NRC, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions [10 CFR 72.236(l)].

The independent spent fuel storage installation must be designed to provide conformance to Parts 72.104 and 72.106 which define criteria for radioactive material in effluents and direct radiation limits.

Applicability:

This guidance applied to dry cask storage system reviews conducted in accordance with NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems” (January 1997); and NUREG-1567, “Standard Review Plan for Spent Fuel Storage Facilities” (March 2000).

Recommendation:

The staff recommends that the appropriate chapters of NUREG-1536 and NUREG-1567 be revised to incorporate the above guidance related to the canister lid welds of austenitic stainless steel canisters.

Approved **/RA/** October 3, 2008
E. William Brach, Director Date
Division of Spent Fuel Storage
and Transportation

References

1. U.S. Code of Federal Regulations (CFR), “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,” Title 10, Part 72, January 1, 2007.

2. American National Standards Institute, ANSI N14.5-1997, “Radioactive Materials - Leakage Tests on Packages for Shipment,” 1997.

3. U.S. NRC, Spent Fuel Storage and Transportation Division, Interim Staff Guidance - 15 (ISG-15), “Materials Evaluation,” January, 2001.

4. American Society of Mechanical Engineers (ASME) “Boiler and Pressure Vessel Code,” Section III, Division 1, Subsection NB.

5. ANSI N45.2.9 "Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants," 1979.

6. American Society of Mechanical Engineers (ASME), “Cases of ASME Boiler and Pressure Vessel Code,” Code Case N-595-4, 2004.

7. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.193, “ASME Code Cases Not Approved for Use,” Revision 1, August 2005.

Enclosure 2

1. Sketch A, “Leakage Testing a Single Lid with Cover Plate Design”.

2. Sketch B, “Leakage Testing a Dual Lid Design”.