3-60B Type-B Shipping Cask Enhanced Operational Features to Facilitate Leakage Rate Testing - 15585

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ABSTRACT

Energy*Solutions* is fabricating a new 3-60B Type B Shipping Cask that will be ready for use in spring 2015, designed for shipping Type B quantities of activated and/or non-fuel-bearing reactor or accelerator components. Energy*Solutions*, in consult with Leak Testing Specialists, Inc., has implemented an improved design of the 3-60B cask closures to better facilitate periodic and maintenance leakage rate testing and to allow end users to more easily perform pre-shipment leakage rate testing to confirm proper assembly of the cask closures.

A typical Type B cask closure lid design incorporates a double O-ring configuration, where the inner O-ring provides containment and the outer O-ring is used for leakage rate testing of the containment O-ring seal. Leakage rate testing of a double O-ring configuration is typically accomplished by filling the cask cavity with helium, pulling a vacuum on the annular space between the two O-rings and monitoring for helium leakage through the containment O-ring. One issue is the potential for helium saturation of the O-ring elastomeric material, which can result in leakage rate test failures. The cask cavity volume is typically large, and takes a significant amount of time to fill with helium. As a result, the saturation time for certain elastomeric compounds may be exceeded, leading to potential false-negative leakage rate testing results. To avoid this, that the cask cavity typically is loaded with sealed container(s) to reduce the free volume and the fill time.

The improved 3-60B cask closure lid incorporates a triple O-ring seal configuration that facilitates maintenance leak rate testing of the closure lid containment O-ring seal and eliminates the issues discussed above. The triple O-ring configuration uses the middle O-ring as the containment seal, with the inner and outer test O-rings creating relatively small annular volumes for testing purposes. These small annular volumes are quick to fill, minimizing the issue of Helium saturation of the O-ring material. This seal configuration also makes it possible to detect and replace a damaged O-ring seal during loading operations, or dress a damaged sealing surface, and perform the required maintenance leakage rate testing of the replacement O-ring at the plant site without the need to unload the cask and send it to a maintenance facility.

Also, a second test port has been added to each O-ring annulus to allow leakage rate testing to be accomplished using a formal system calibration that complies with the requirements and recommendations of ASME Section V, Article 10 [4], ANSI N14.5-97 [2], and ANSI N14.5-2014 [3]. This provides a simple, reliable, and accurate means to perform leakage rate testing with a test confidence level that cannot be achieved without the second test port.

The improved closure and test port design simplifies and shortens the time required to perform leakage testing, resulting in reduced operating costs, greater schedule security, and dose savings for the cask users.

INTRODUCTION

The 3-60B package is a general–purpose Type B (U)-96 transport package that is certified by the U.S. Nuclear Regulatory Commission (NRC), Certificate of Compliance (CoC) No.71-9321 [1]. It consists of a cylindrical shipping cask with an impact limiter attached at each end. The 3-60B package, which is transported by truck in a horizontal orientation, has a maximum allowable gross weight of 80,000 pounds and a maximum payload weight of 9,500 pounds. The general arrangement of the 3-60B package is shown in Figure 1. The 3-60B package is approved to transport a maximum of 3,000A_2 or 1,110 TBq (30,000 Ci), whichever is less, of by-product, source, or special nuclear material in several forms, including de-watered inorganic solids and resins, and activated and/or contaminated non-fuel-bearing reactor or accelerator components packaged in secondary containers. The 3-60B package can be loaded wet or dry.

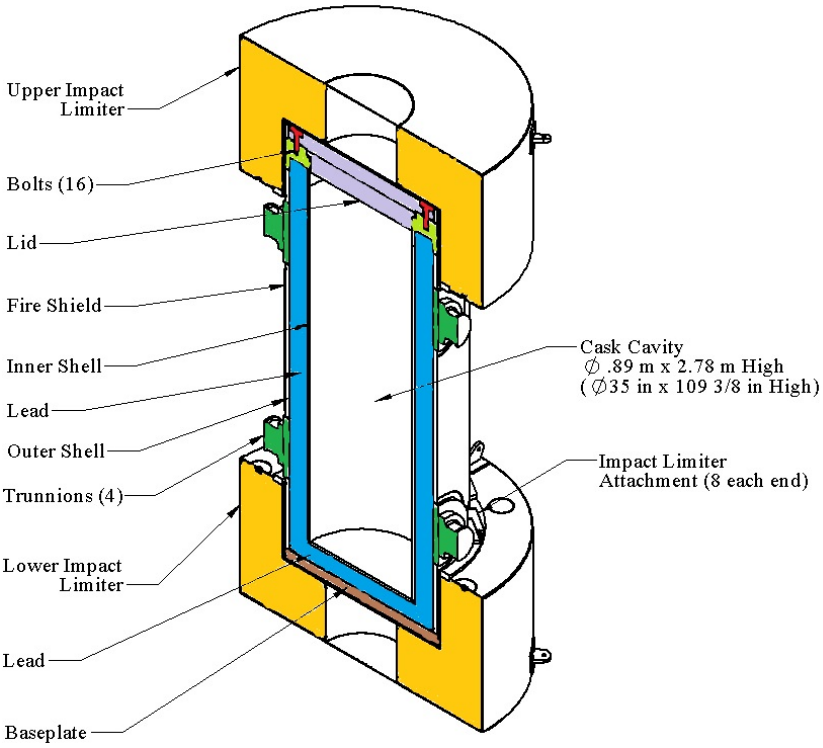

Figure 1 – 3-60B Packaging General Arrangement

The containment system for the 3-60B package is comprised of the closure lid, vent, drain, and test ports, the cask inner shell and base plate, and associated welds and closure seals. Elastomeric O-ring seals are used on the closure lid, the vent and drain ports, and test ports to provide a leak-tight seal of the package closures.

To assure the integrity of the 3-60B package containment system, fabrication acceptance leakage rate tests, periodic maintenance leakage rate tests, and pre-shipment leakage rate tests are required. The fabrication acceptance leakage rate test is required prior to use of each newly fabricated 3-60B package to demonstrate that all containment boundary component base materials, welds, and closures satisfy the leakage rate criteria. Maintenance leakage rate testing of all 3-60B package containment seals is required prior to returning the package to service following maintenance, repair, or replacement of any components of the containment system to confirm that the performance of the containment system has not been degraded. Periodic leakage rate testing is performed within a 12-month period prior to every shipment to confirm that the containment capabilities of the package have not been deteriorated over an extended period of use. Finally, pre-shipment leakage rate testing of all containment seals, even those that are not opened during loading operations, is required before each shipment of a loaded package to verify that the containment system is properly assembled for shipment. Fabrication acceptance, periodic, and maintenance leakage rate testing are performed to verify that the containment system satisfies the ANSI N14.5-97 [2] and ANSI N14.5-2014 [3] leaktight acceptance criterion of 1 x 10^{-7} ref-cm^3/s,

whereas the pre-shipment leakage rate test, which requires no detectable leakage when tested to a sensitivity of 1 x 10^{-3} ref-cm^3/s, verifies that the package is properly assembled prior to transport.

Leakage rate testing is a vital step in the safe operation of a shipping cask. However, leakage rate testing can be time-consuming and problematic for packages with poorly designed leak testing features and procedures. If a package fails a leakage rate test, significant effort may be required to investigate and resolve the issue. Therefore, packaging design features that improve the ease and reliability with which leakage rate testing may be performed can result in a significant reduction in loading time and occupational exposure for cask shipments. With this in mind, Energy*Solutions*, in consult with Leak Testing Specialists, Inc., a recognized leader and expert in leak testing of Type B transportation packages, has added design alternatives to the 3-60B cask closures to better facilitate periodic and maintenance leakage rate testing and to allow end users to more easily perform pre-shipment leakage rate testing to confirm proper assembly of the cask closures.

In January 2014, Energy*Solutions* submitted an application to NRC to amend the 3-60B CoC to include several new design features to facilitate cask fabrication, use, testing, and operation and to upgrade the package containment criteria to leak-tight. NRC approval of the 3-60B CoC amendment request is expected in early 2015. The first 3-60B package is currently being fabricated and will be available for use in May 2015. Once available, the 3-60B will provide an alternative for shipments previously made in the TN-RAM package.

Many of the design features added to the 3-60B package in the pending CoC amendment request will greatly enhance the ease with which package fabrication, periodic, maintenance, and pre-shipment leakage rate tests are accomplished.

ISSUES WITH DOUBLE O-RING SEALS ON CASK CLOSURE LIDS

A typical Type B cask closure lid design incorporates a double O-ring configuration, where the inner O-ring provides containment and the outer O-ring facilitates leakage rate testing of the containment O-ring seal. Leakage rate testing of a double O-ring configuration is typically accomplished by filling the cask cavity with helium gas, pulling a vacuum on the annular space between the two O-rings and monitoring for helium gas leakage through the containment O-ring. One common issue with this type of closure is the potential for the O-ring elastomer to saturate with helium gas prior to completing the test, which typically results in test failure.

The extent to which a design is susceptible to this issue is a function of the package closure design, containment seal elastomeric compound, and leakage rate testing requirements and procedure. Silicone rubber is an elastomeric compound that is commonly used for Type B package containment seals for its radiation resistance, physiologically neutron properties, and wide service temperature range. However, silicone rubber has a relatively high helium gas permeability rate. Experience shows that a typical silicone rubber O-ring can become saturated with helium gas in less than 8 minutes. Thus, silicone rubber O-ring seals may not be suitable for a large package if the leak testing procedure requires the cavity to be filled with helium gas because it may take longer than 8 minutes to fill the entire cavity volume.

In practice, measures can be taken to accomplish helium leakage rate testing of a large package with a double O-ring configuration, such as placing a sealed container inside the cask cavity to minimize the free volume that must be filled with helium gas or attaching a bag to the inside of the containment seal to limit the test volume (if permitted by the CoC). When leakage rate testing is performed at a maintenance facility, these approaches are usually not a problem, since the additional support equipment (sealed containers) are available, and the task is usually not on critical path. However, if a lid containment O-ring needs to be replaced at a utility site during loading operations, this is a different situation. The radioactive contents of the cask would need to be unloaded to allow a sealed container to be placed inside the cask

cavity in order to perform the leakage rate testing. However, this approach is not practical during loading operations at a utility site for several reasons. First, cask loading operations are usually performed with strict timeline controls. Any major time delays in cask loading operations are very disruptive and costly to a utility. Secondly, unloading a previously loaded shipping cask will result in increased occupational exposure and not support ALARA. Finally, some of the equipment required to perform helium leakage rate testing (e.g., a sealed cavity filler) is normally not readily available at a utility site because this testing is normally done at a cask maintenance facility. Transporting, maintaining, and tracking these items adds to the logistical challenges.

Elastomeric compounds with a lower helium permeability rate, such as ethylene propylene-diene rubber (EPDM), can be used for the package containment O-rings and/or the alternate design features may be added to facilitate leakage rate testing. Energy*Solutions* is using this latter approach for the 3-60B package as discussed below.

IMPROVED TRIPLE O-RING DESIGN

The 3-60B cask closure lid incorporates a triple O-ring seal configuration that greatly facilitates helium maintenance leak rate testing of the closure lid and the containment O-ring seal and eliminates the issues discussed above for the double O-ring configuration. See Figure 2. For the triple O-ring configuration, the middle O-ring is the containment seal, and the inner and outer test O-rings create relatively small annular volumes for testing purposes. The annular regions on either side of the containment O-ring are both equipped with two diametrically opposed test ports that are used to perform leakage rate testing. To perform the leakage rate test of the containment O-ring, a vacuum is drawn on the outer annular volume, and a mass spectrometer leak detector is used to monitor that volume for helium leakage. The inner annular volume is evacuated, then backfilled with helium gas. The leakage rate across the containment O-ring closure is measured by the mass spectrometer leak detector. Because these annular volumes are small and can be quickly be filled with helium gas, the triple O-ring configuration minimizes the potential of a leakage rate failure due to helium gas permeation through the containment O-ring.

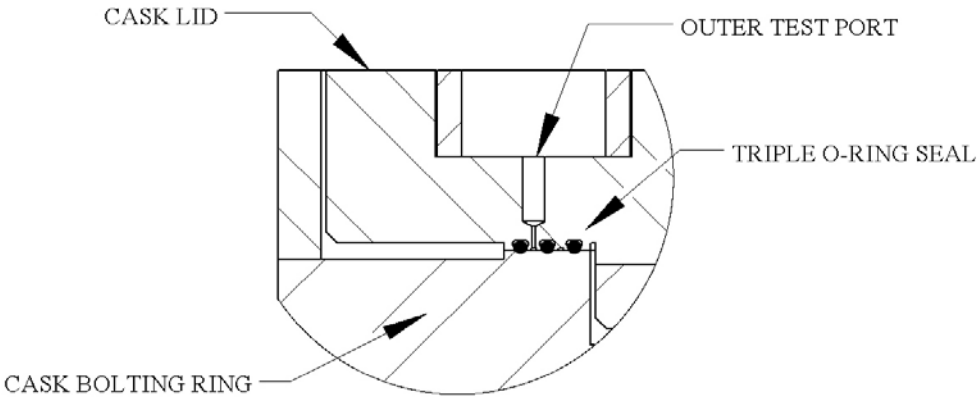

Figure 2 – Triple O-Ring Seal on 3-60B Shipping Cask

The triple O-ring seal configuration also makes it possible to replace a damaged O-ring seal during loading operations at a utility site and perform the required maintenance leakage rate testing of the replacement O-ring without the need to unload the cask and send it to a maintenance facility. After replacing a containment O-ring seal, the maintenance leakage rate test is performed as described above. Although maintenance leakage rate testing is typically performed at a cask maintenance facility, and is not expected to be performed at the utility sites, this capability is a significant benefit of the 3-60B

cask design because it can avoid potentially costly delays in the shipping schedule and minimize occupational exposure.

SYSTEM CALIBRATION CAPABILITY

Another major design improvements made to the 3-60B shipping cask is the addition of a second test port to each O-ring annulus on the closure lid and vent port plugs. This allows leakage rate testing to be accomplished using a full system calibration that complies with the requirements and recommendations of ASME Section V, Article 10 – 2013 [4], ANSI N14.5-97 [2], and ANSI N14.5-2014 [3]. This provides a simple, reliable, and accurate means to perform leakage rate testing with a test confidence level that cannot be achieved without the second test port.

System calibration is the calibration of an entire leak testing system including the leak detector, test object, interconnecting hardware, and ambient environment to verify sensitivity and test timing of the entire system. This approach provides a simple, reliable, and accurate means to perform leakage rate testing that reliably eliminates many potential sources of error or "false" test results caused by unintentional errors in operation, test equipment failure, changes in equipment model or variations in pre- and post-test conditions. The system calibration technique provides positive evidence in each test record that the test equipment is in communication with the entire test volume and is properly sensing for helium at the time of the critical test measurements.

A typical test setup for the pre-shipment leakage rate test using the two test ports for system calibration is shown in Figure 3. The test is performed by connecting a test manifold and gas supply to one test port and a leak standard (calibrated to 1 x 10^{-3} ref-cm^3/s) to the other test port. The system is charged with test gas to an initial pressure and allowed to stabilize. Once stabilized, a pre-measurement calibration is performed by closing the valve to the gas supply, and then recording the elapsed time (Δt_1) for the test pressure to decrease by the specified amount (e.g., 10 divisions on the pressure gauge). The valve to the calibrated leak is then closed and the test pressure is monitored for an elapsed time of at least Δt_1 to assure there is no detectable change in test pressure (i.e., pressure drop must be less than 1 division on the pressure gauge). Following the pressure drop test, the valve to the calibrated leak is opened to perform a post-measurement calibration, similar to the pre-measurement calibration. The pre-shipment leakage rate test is acceptable if no detectable leakage occurs during the test and if the pre- and post-measurement leakage rates are within ±30% of one another.

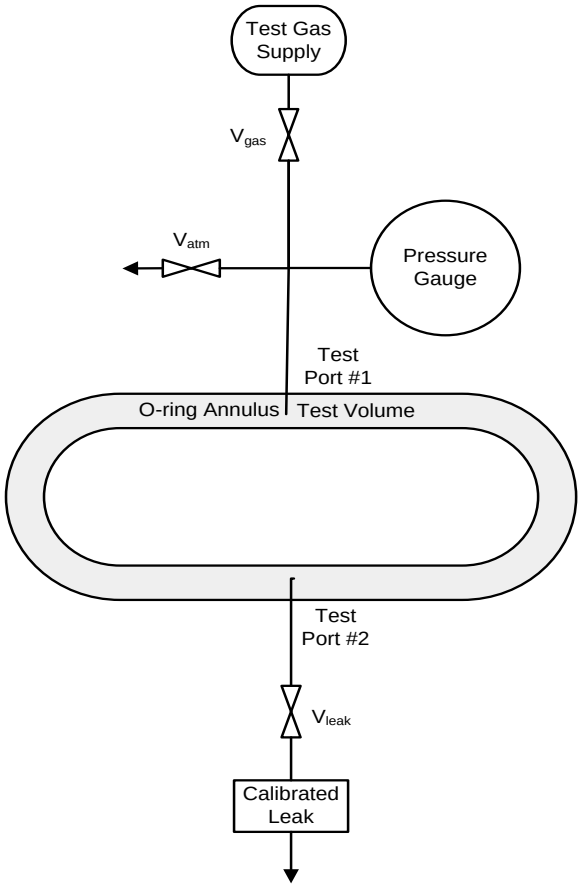

Figure 3 - Typical 3-60B Cask Pre-Shipment Leakage Rate Test Configuration

In a similar manner, the dual test ports can be utilized to perform the fabrication acceptance, maintenance, and periodic leakage rate tests of the containment O-ring seals based on an ASME Section V, Article 10 [4], Appendix IX compliant helium hood test using leakage rate test configuration similar to that shown in Figure 4.

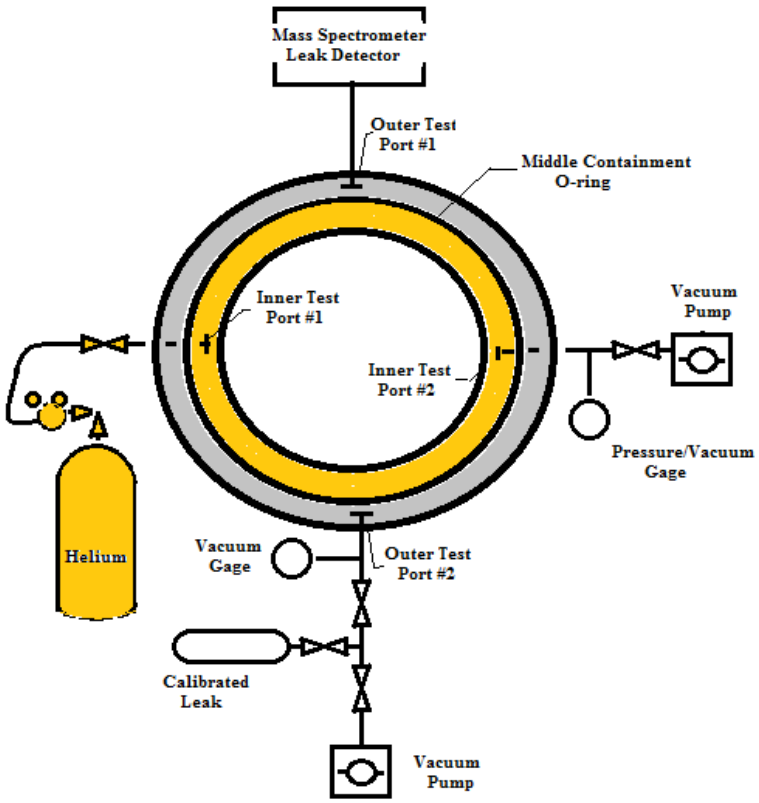

Figure 4 - Typical 3-60B Cask Periodic/Maintenance Leakage Rate Test Configuration

CONCLUSION

Energy*Solutions*, in consult with Leak Testing Specialists, Inc., has implemented an improved design of the 3-60B cask closures to better facilitate periodic and maintenance leakage rate testing and to allow end users to more easily perform pre-shipment leakage rate testing to confirm proper assembly of the cask closures. This is a direct result of involving leak testing engineers early in the design phase.

The triple o-ring design creates small annular volumes which are quick to fill and eliminates issues the helium saturation of the o-ring material. This simplifies operations in the field by eliminating the need to fill the cask cavity with sealed containers to reduce the free volume.

With the addition of a second test port in each respective annular volume allows end user to take advantage of the latest system calibration methods in leak rate testing.

The improved closure and test port design simplifies and shortens the time required to perform leakage testing, resulting in both cost and dose savings for the cask users.

REFERENCES

1. Energy*Solutions* 3-60B Shipping Cask Certificate of Compliance for (CoC) No. 71-9321
2. ANSI N14.5, “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment”, 1997
3. ANSI N14.5, “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment”, 2014
4. ASME Section V, Article 10, “Nondestructive Examination”, 2013