A Status Report on the Development and Certification of the Beneficial Uses Shipping System (BUSS) Cask

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INTRODUCTION

In the early 1980s, the U.S. Department of Energy (DOE) implemented a program to encourage beneficial uses of nuclear byproduct materials, such as cesium-137 and strontium-90, created during the production of defense materials. Potential uses of the cesium-137 (^{137}Cs) isotope included sterilizing medical products, maintaining the quality of certain food products, and disinfecting municipal sewage sludge. Strontium-90 (^{90}Sr) is a good heat source and has been used in thermoelectric generators and other products that require a constant supply of heat. During that same period, a proposed facility in Albuquerque, New Mexico, was designed to use cesium-137 to sterilize sewage sludge.

To support the sewage sludge treatment facility, Sandia National Laboratories was funded by the DOE to develop a Nuclear Regulatory Commission (NRC)-certified Type B shipping container to transport cesium chloride (CsCl) or strontium fluoride (SrF_2) capsules produced by the Hanford Waste Encapsulation and Storage Facility (WESF) in the State of Washington. The primary purpose of the Beneficial Uses Shipping System (BUSS) cask is to provide shielding and confinement, as well as impact, puncture, and thermal protection for certified, special form contents during transport under normal and hypothetical accident conditions. The BUSS cask was designed to meet dimensional and weight constraints of the WESF and user facilities. Attaining as-low-as-reasonably-achievable (ALARA) radiation exposures in the design and operation of the transport system was a major design goal. Another goal was to obtain regulatory approval of the design by preparing a safety analysis report for packaging (SARP) (Yoshimura et al. 1993).

PACKAGE DESCRIPTION

The major components of the BUSS cask include the cask body and lid, basket, impact limiters, personnel barrier, and shipping skid. Figure 1 shows an exploded view of the cask system. The cask body is a one-piece, stainless-steel cylindrical forging with envelope dimensions of a 137.8-cm outside diameter and a 124.5-cm length. Eleven integral 10.2-cm-high fins are situated symmetrically around the axial midplane of the cask body. With the lid in place, the cask body has a cylindrical cavity with a diameter of 51.4 cm and a length of 58.4 cm. Besides the opening for the lid, there are two other penetrations into the interior of the cask body that serve as ports for draining, purging, backfilling, and leak testing. Both ports are fitted with a thermal shield, bolted port cover, and recessed metal seal.

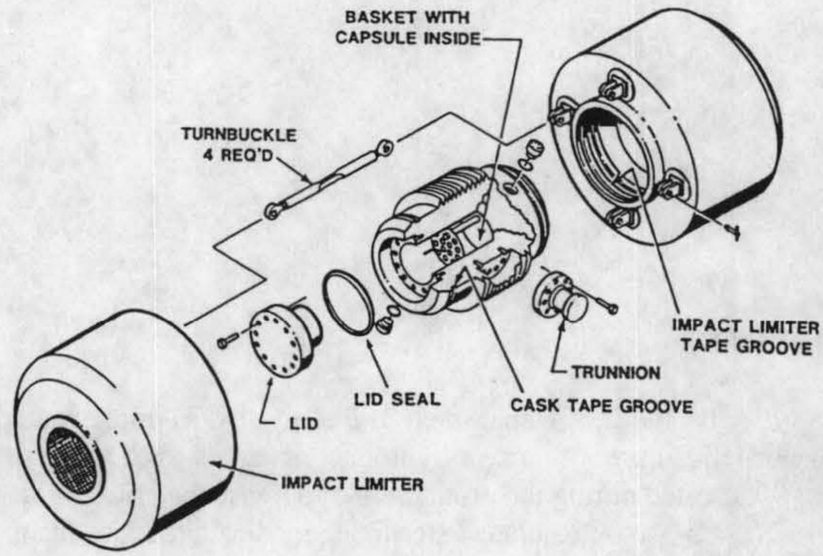

Figure 1. Exploded View of the BUSS Cask

The cask lid is a one-piece, stainless-steel forging with envelope dimensions of a 73.1-cm diameter and a 32.6-cm length. The lid is bolted to the cask body with 12-1/2-inch (3.81-cm) diameter bolts. The lid has a groove and a series of drain holes to facilitate flooding of the cask cavity during immersion in a water-filled pool. Two leak test ports with covers and Helicoflex seals are provided diametrically opposite each other. The lid is equipped with three jacking screws that allow it to be gently lowered onto the cask body. A Helicoflex metal seal is used to provide confinement of helium in the cask cavity. The helium serves to improve the heat transfer from the capsules to the basket and cask structures under normal transport conditions. The design leakage rate for the cask is 1 x 10^{-4} atm cc/s.

Depending on the thermal decay heat of the Cs or Sr capsules to be transported, one of four solid stainless-steel baskets may be used. Baskets are equipped with 4, 6, 12, or 16 holes that function as receptacles for the capsules. Channels and drains are provided for distribution and removal of pool water. Table 1 shows the capsule type, number, and maximum thermal load and activity for a particular basket configuration.

Table 1. Cask Radioactive Material Limits

Basket	Allowable Capsule Type	Maximum Thermal Power Per Capsule (W)	Maximum Total Cask Thermal Power (kW)	Maximum Total Cask Activity (millions of Ci)
16 hole	Cs Cl	250	4.0	0.85
12 hole	Cs Cl	333	4.0	0.85
6 hole	Sr F_2	640	3.9	0.65
4 hole	Sr F_2	850	3.4	0.56

Two impact limiters are provided at each end of the cask. The limiters are constructed of stainless-steel shells and filled with medium-density polyurethane foam. The foam is 46.7-cm thick on the sides and 68.6-cm thick at the ends of the cask. Each limiter is 215 cm in diameter and 99 cm high. Under normal operating conditions, the limiters are held in place by four turnbuckles spaced equally around the cask. Under accident conditions, the limiters are retained by thick, metal tape joints designed to resist large forces and resultant moments created as a result of the short, coupled design of the limiter and cask body. The tape joints were developed as part of the defense program to provide high-strength joining hardware to hold cylindrical structures together. Figure 2 shows a cutaway of the tape joint on the BUSS cask.

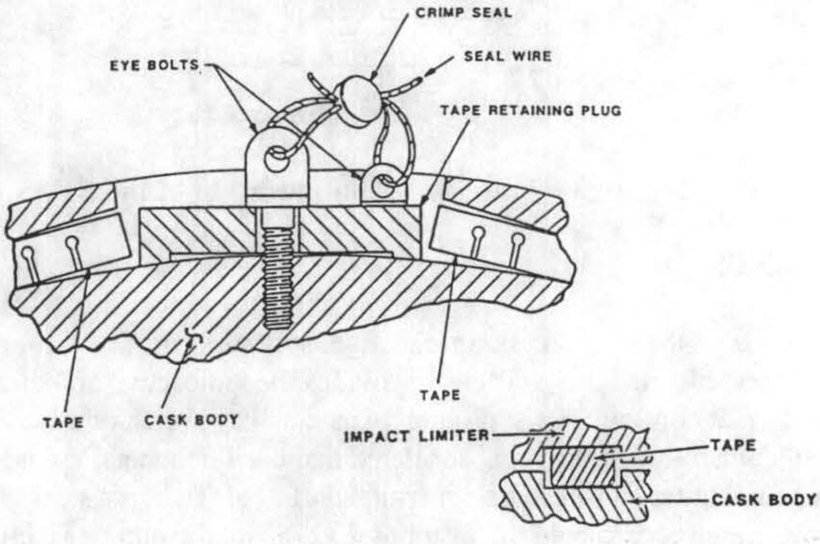

Figure 2. Cutaway of Tape Joint Between the Impact Limiter and Cask

The tiedown and lift features on the cask body include two trunnions and two lift lugs. The two 12.7-cm-diameter by 24.8-cm-long trunnions are located diametrically opposite each other on the midplane of the cask. The two lift lugs are positioned in line along one side of the container. Lifting and handling fixtures were designed and fabricated to facilitate cask operation in storage or irradiation facilities and on transport vehicles.

The personnel barrier, which is necessary to prevent access to hot surfaces, is positioned between the impact limiters and bolted to the transport skid. The personnel barrier defining the accessible surface of the container is approximately 16.5-cm from the outermost cask surface (the trunnions). The barrier is fabricated from aluminum angle and expanded metal sheet.

Figure 3 shows the transport configuration of the cask system with shipping skid and personnel barrier.

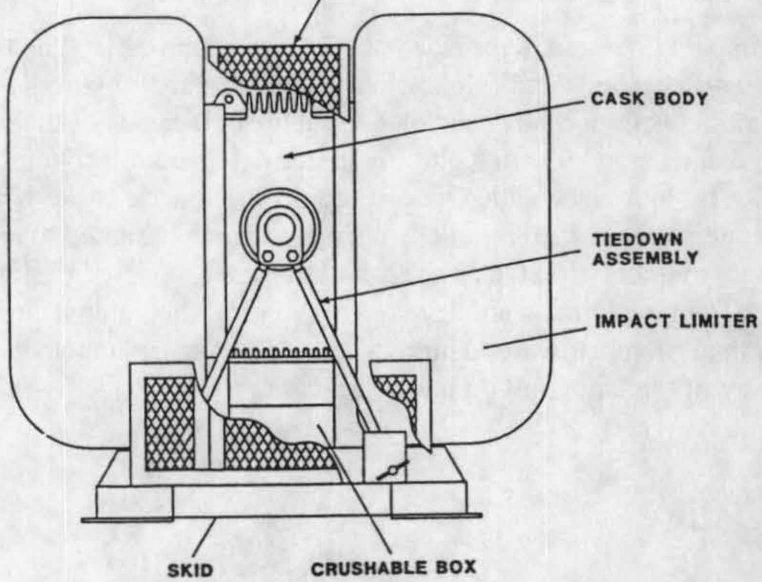

Figure 3. Transport Configuration of the BUSS Cask

CONTENTS

The contents of the BUSS cask are certified, speeial form WESF capsules of melt-cast CsCl or pressed-filled SrF_2. Table 1 provides the radioactive and thermal limits for the various basket configurations. Figure 4 is a cutaway sketch of a typical WESF capsule. The CsCl or SrF_2 are doubly encapsulated in closed-end metal cylinders. For the CsCl, the inner and outer capsules are constructed of 316L stainless steel. For the SrF_2, the inner capsule is constructed of Hastelloy C-276 and the outer capsule is constructed of 316L stainless steel. After fabrication, the capsules must be leak tested using a method with sufficient sensitivity to detect a leak rate (air at standard temperature and pressure of 10^2 atm) of 10^{-8} atm cc/s.

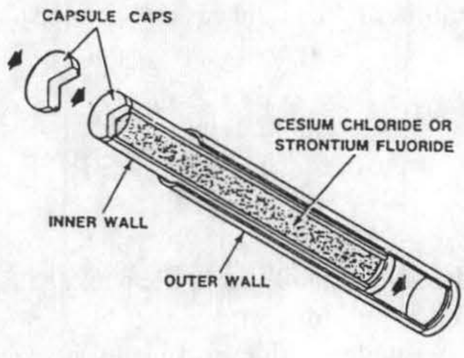

Figure 4. Cutaway of a Typical WESF Capsule

SARP ANALYSES

The BUSS cask development program used state-of-the-art analysis techniques. The design process included evaluation of shielding, structural, thermal, and containment properties for normal transport and hypothetical accident conditions as defined in 10 CFR 71. The results of these analyses are incorporated in the SARP.

The structural assessment included static and dynamic analyses of finite-element representations of the container. Scale models of the packaging (mass model) and impact limiters (replica models) were designed, fabricated, and subjected to structural testing to verify the analysis technique. The principal structural members of the cask included the cask body, lid, bolting hardware, and impact limiters. The greatest impact limiter foam crush (15.5-cm), deceleration (105 g), and peak von Mises stresses (59 MPa) for the 9-m drop test of the BUSS cask were observed to occur in the end-on configuration at -40 degrees C.

The structural response of the BUSS cask to the puncture event was determined by finite-element analysis. The puncture evaluation was performed in three orientations (without impact limiters) to ensure that the most severe accident conditions were analyzed. The orientations included the following:

- Cask side impacting the punch
- Corner of the cask directly below the center of gravity impacting the punch
- Closure end (lid) impacting the punch.

The computer results show that the cask was only moderately stressed and that structural integrity of the cask was maintained. The side puncture produced the highest deceleration of all the structural impact analyses (83 g).

The thermal analyses indicated that the WESF capsule temperatures would remain within design criteria for both normal transport conditions and hypothetical thermal accident conditions. Analyses were performed with helium in the cask cavity for normal transport conditions and with helium or air in the cask cavity for the hypothetical thermal accident conditions.

The shielding assessment included multienergy group, discrete ordinates and Monte Carlo analyses. The radiation transport analyses of the BUSS cask were performed with two goals:

- To evaluate the shielding capabilities of the package for both normal and hypothetical accident conditions
- To determine the energy deposition profiles in the cask and basket for use in the thermal evaluation of the system.

Separate one-, two-, and three-dimensional finite-difference models were developed for use in achieving each goal. The radiation levels calculated for the BUSS cask for both normal and hypothetical accident conditions were within the regulatory limits.

The containment of the radioactive contents of the BUSS cask is provided by the certified, special form WESF capsules. Containment of the system is ensured under conditions of both normal and hypothetical accident conditions by the following:

- Encapsulated contents (special form)
- Cask structural members
- High-quality metallic seals at every penetration into the cask interior.

The capsule containment boundary is virtually unaffected when the cask is subjected to the normal and hypothetical accident conditions specified in 10 CFR 71.

CASK CERTIFICATION

The BUSS cask has been certified by the Packaging Certification Office of the DOE and the NRC for transport of special form WESF cesium chloride or strontium fluoride capsules.

OPERATIONS

The BUSS cask was designed to minimize the number and complexity of the operating procedures to be followed during loading and unloading of the system. This was done to ensure (1) that the system is handled properly during the loading/unloading procedures, (2) that the cask's assembled configuration is correct during transport, and (3) ALARA occupational radiation exposures of personnel are maintained.

The BUSS cask may be loaded and unloaded in either wet or dry conditions. Lifting and handling fixtures were designed and fabricated to permit convenient lifting of the cask from its transport skid, rotation of the cask from the horizontal to vertical position, and removal and installation of the impact limiters.

ABBREVIATED LOADING PROCEDURE

After removing the cask impact limiters and transferring the cask to the handling area, the cask may be loaded under dry conditions, such as in a hot cell or under water.

- In dry conditions (as in a hot cell):
  - Load capsules into basket or load filled basket into cask
  - Install cask lid closure and port covers
  - Evacuate and backfill cavity with helium
  - Leak test the system.

- Under water in a pool:
  - Capsule loading similar
  - Dry cask insides, then evacuate and backfill with helium
  - Leak test the system.

ABBREVIATED UNLOADING PROCEDURE

After removing the cask impact limiters and transferring the cask to the handling area, the cask may be unloaded in a hot cell or under water.

- In dry conditions (such as a hot cell):
  - Remove cask lid and port cover(s)
  - Unload capsules from basket or unload filled basket from cask
  - Remove capsules
  - Replace basket, lid, and port cover(s).

- Under water in a pool
  - Before immersing in pool, loosen lid bolts and port covers
  - Cool cask by immersing in pool
  - Remove lid
  - Unload capsules from basket or unload filled basket from cask
  - Remove capsules
  - Replace basket, lid, and port covers.

ACCEPTANCE TESTING

Several acceptance tests and inspections, each intended to evaluate the performance of different components of the BUSS cask system, were performed before its first use. Some of these tests were performed during the fabrication of the packaging components. The other tests were performed before the cask was first loaded for transport.

During fabrication and prior to first use of the BUSS cask, acceptance testing and inspections were performed by Sandia and Westinghouse/Hanford. Inspections and testing performed included the following:

- Body, lid, and other cask component inspections by Sandia
- Polyurethane foam impact limiters strength testing by Sandia
- Pressure testing (hydro-test) of cask body and lid by Sandia
- Fabrication leak testing of the cask body, lid, and port covers by Sandia
- Shielding testing with isotopic sources by Westinghouse/Hanford
- Thermal testing with isotopic sources by Sandia
- Lid bolt torque testing by Sandia
- Load testing of handling fixtures by Sandia
- Visual inspection by Sandia and Westinghouse/Hanford.

Hardware was labeled by Sandia.

The BUSS cask maintenance and periodic inspection programs are being carried out by the cask user, Westinghouse/Hanford. As part of the process, the procedures in the cask SARP were clarified. The maintenance and periodic inspection programs include the following:

- Periodic (containment integrity) and assembly verification leak testing. (The testing procedure in the SARP was modified as the result of discussions with Westinghouse/Hanford.)
- Helicoflex seals replacement before each use
- Cleaning
- Impact limiter, skid, and cask handling frame weld annual visual inspection
- Torque tests on permanent bolts as defined in the SARP
- Body, lid, and port cover pressure test (hydro-test)
- Impact limiter weighing
- Dye penetrant testing of trunnions and lift lugs
- Seal surface visual inspection
- Load testing of handling equipment.

CESIUM CAPSULE SHIPPING CAMPAIGN

Westinghouse/Hanford and Sandia worked together to prepare the BUSS cask for the Cs capsule shipping campaign between the IOTECH facility in Colorado to the WESF in Washington. A new low-boy trailer was procured by Westinghouse/Hanford for BUSS cask transport. With the new trailer, Sandia modified the shipping skid to accept an integral personnel barrier design. The attachment of the cask skid to the trailer was reviewed by Sandia and Westinghouse. Several sections of the cask SARP were reviewed, modified, and resubmitted as an amendment to the DOE and NRC. Sandia provided training for cask operations and an initial inventory of spare parts. The quality assurance fabrication documentation was reviewed by Westinghouse. Sandia performed supplemental analyses to evaluate the effect of steaming during certain atmospheric conditions.

The IOTECH shipping campaign conducted by Westinghouse/Hanford started on May 19, 1994, and was completed on June 2, 1995. This was nearly 1 year ahead of schedule.

About one cask load of capsules was shipped each month from the IOTECH facility in North Glenn, Colorado, to the Hanford WESF in Washington. Twenty shipments (309 capsules total) were made.

Other shipments underway or planned by Westinghouse/Hanford include transport of 21 Cs capsules from the Pacific Northwest Laboratory and 25 capsules from the Applied Radiant Energy Corporation.

SUMMARY

The BUSS cask was designed as a Type B shipping system for transport of certified, special form WESF CsCl or SrF_2 capsules. A cask SARP was prepared, and both DOE and NRC certification has been received. The cask prototype and ancillary hardware were fabricated and accepted for use. The cask hardware was delivered to Westinghouse/ Hanford, and training and acceptance testing was completed. The cask was successfully used in the transport of Cs capsules to the WESF.

REFERENCES

Yoshimura, H. R., Bronowski, D.R., et al. *Beneficial Uses Shipping System Cask (BUSS), Safety Analysis Report for Packaging (SARP), Volumes I and II*, SAND83-0698, Sandia National Laboratories, Albuquerque, NM (May 1993).

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