# Transportation Operations Experience Involving Suspected Leaking Cesium Capsules*

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## BACKGROUND

In May 1988, contamination and elevated radioactivity in a storage pool were detected at the Decatur, Georgia, facility of Radiation Sterilizers, Inc. (RSI). The contamination and pool activity were traced to the $^{137}Cs$ capsules which were used at the facility to sterilize commercial products by irradiation. Since the pool and facility were not designed or licensed for handling unencapsulated material, an immediate project was initiated to stabilize and clean up the facility. One of the first tasks of the project was to identify and remove the one or more leaking capsules, each of which contained approximately 30,000 ci of $^{137}Cs$.

While there was some difficulty in determining exactly which capsules were releasing radioactivity, arrangements for the off-site transportation of a limited number of capsules were made in parallel with the leaking source identification effort. Shipment off-site was necessary in order to allow evaluation of the capsules to determine the nature and cause of the leak, as well as to assist in the stabilization and recovery operations.

## THE SEARCH FOR A PACKAGE

The search for a preferred package concept concentrated on finding a package design that would meet all regulatory requirements, including overall contents limits on activity, form (nonspecial form $^{137}Cs$ as cesium chloride), and decay heat loading (approximately 200 W per capsule). Additionally, the maximum allowable package diameter was limited to approximately 65 in. due to the size of the roof opening through which the package had to be lowered. A great preference was given to package designs that would not require amendments to their U.S. Nuclear Regulatory Commission (NRC) Certificates of Compliance (CoC) since time was critical. Also important in the package selection were: expected ease of operations in a 20-ft deep pool, availability of packagings, and cost-effectiveness.

A review team was formed to provide expertise in package design and certification, capsule handling, logistics, and transportation operations. The team identified several options but concluded that

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no package designs existed with suitable NRC certification to ship the capsules without first placing the capsule into overpacks.

The use of the General Electric Model 600 cask was recommended and implemented. The package design approval was sufficiently broad to include the capsules, provided that they were "contained in a metal encasement of such material as to withstand the combined effects of the internal heat load and the 1475$^{o}$F fire with the closure pre-tested for leak tightness." The package was also suitable dimensionally, was operationally suited to underwater loading, and one packaging was available for use. No amendment to the CoC would be necessary provided that a suitable encapsulation and handling system could be designed that would meet the CoC requirements and allow drying of the capsule while the system was underwater.

## DEVELOPMENT OF INNER PACKAGING AND LOADING SYSTEM

The selection of the Model 600 cask substantially reduced the inner packaging regulatory design burden since the only substantive requirement was one of proper material selection and drying of the capsule. However, the conditions that prevailed at the RSI facility and the uncertainty of capsule condition presented a number of design challenges. The design effort embraced not only the "metal encasement" or capsule overpack (CO) for the suspect source, but also the system for preparing the CO for shipment.

### Design Criteria

The CoC requirements were interpreted to apply to the CO when it was protected within the Model 600 cask. The leak tightness requirement was interpreted to mean bubble-tight. ANSI N14.5 indicates that the detection sensitivity of a bubble test is in the range of 10E-3 to 10E-4 $cm^2/s$, depending on test parameters. Although not a CoC requirement, the NRC specified in its review that the design should include positive closure devices on all penetrations and there should be protection of these devices from mechanical assault.

Operational design criteria included requirements that: (1) the CO had to be remotely handled, loaded and closed underwater; (2) the CO had to be purged of water and dried; (3) the vented water, and possibly steam, had to be contained in a shippable canister since this effluent was potentially contaminated; and (4) all containers had to be sealed and tested for leakage while underwater. Of course, radiation safety was a constant design consideration throughout the effort.

### System Design

The system consisted of: the CO; the condensate trap; and the manifolding, valving, tubing, tools and ancillary equipment required to make it all function. Approved procedures were also part of the system. The test pressure of the overpack was 150 psig vs the calculated in-transit thermal accident pressure of 98 psig. The test pressure of the trap was 50 psig vs and operating pressure would be only slightly above atmospheric. The peak design temperature for the overpack was 600°F.

The CO was designed to accept one cesium capsule. The canister body consisted of a 4-in. OD x 0.180-in. wall x 24-in.-long tube welded to a 6-in square x 0.25-in.-thick base plate. Welded to the upper end of the tube was a 6-in. Conflat (or Del-Seal) flange. The overpack closure or lid consisted of a mating 6-in Conflat blank flange with two penetrations and a crimp-sealing device for each penetration. The drain penetration was a dip tube extending to the overpack bottom with a vent penetration only extending through the closure flange. Handling and closure protection appliances were fixed to the closure and body as appropriate. All overpack construction, except for the seal, bolts, and crimping lines, was 300 series stainless steel.

The Conflat flange uses sixteen 5/16-24 UNF bolts; however, tests indicated that eight uniformly spaced bolts would provide sufficient seal loading; two of the available holes were used for guide pin mounting. The Conflat comes from the vacuum industry and uses a guillotine principle for sealing. Circular knife-edges on the mating flanges embed themselves into a non-reusable copper gasket when the flange bolts are tightened, thus forming a bubble-tight (or better) seal.

The crimp-sealing devices of the initial CO design were unique. Each of the closure penetrations had a 0.25-in. soft copper tube section coupling it, via Swagelok fittings, to the flexible polyethylene tubing used to interconnect the various system components. Each copper tube section passed through a crimper that consisted of an anvil and a movable double knife-edge assembly. A bolt drove the knife-edge assembly onto the tube, crimping it in two locations about 1-in. apart; the tube was supported by the anvil. Sixty ft-lb of torque was sufficient to effect a crimp seal that was, at a minimum, bubble-tight.

The Condensate Trap (CT) was designed to collect the water and condensed vapors vented from the CO and permitted them to be monitored for the presence of radioactivity. If monitoring showed small amounts of activity, the effluent could be discharged to the pool ion-exchange cleanup system. If large amounts of activity were detected, the CT could also be used as a shipping canister. The CT had a built-in heater that permitted evaporative removal of the water, thus leaving dry cesium behind. When the contents were dry, the CT could be loaded into the Model 600 cask and shipped for disposal.

The condensate trap construction was 300 series stainless steel with the exception of three copper penetration connection tubes. There was no removable closure; rather, the CT was all welded. The body was an 8-in. schedule 40 pipe section x 8 in. long. Top and bottom heads were 10-in. square x 0.25 in. thick plates. A heater well entered the body from the side along a radius close to the CT bottom and contained a replaceable 500 W cartridge heater. The top head had three penetrations, one with a bottom dip tube. One of the penetrations was a CO effluent/gas inlet, the dip tube was a liquid discharge, and the third was a gas discharge. All three penetrations had crimp-seal devices, as previously described.

### Fabrication and Testing

The CO and the CT were fabricated following good industry practices. Certificates accompanied the materials, welding was performed by experienced craftsmen, and the welds were liquid penetrant tested. The CO was hydrostatically tested at 150 psig and air bubble tested at 50 psig. The CT was hydrostatically tested and air bubble tested at 50 psig.

### Loading/Purging System Design and Operation

The basic steps for loading and drying of the capsules were relatively straightforward and included

1. The system was assembled and tested for leak tightness before being placed in the pool. The CO closure was removed prior to placement in the pool.

2. The CO body (with a new gasket) and the CT were placed on an underwater stand and were keyed to it to prevent rotation during tightening and crimping operations. The suspected leaking cesium capsule was placed into the CO using a long-handled tool. The closure was installed with a long-handled tool, and the closure bolts were uniformly tightened to 15 ft-lb using an extension wrench.

3. The CO was then pressurized with nitrogen, forcing the contained water into the CT. During this operation, the Conflat flange gasket was leak checked visually for bubble-tightness. Prolonged purging in conjunction with the decay heat load assisted in the drying process. The CT was isolated from the CO by closing the appropriate valves after the effluent transfer and purge operations.

4. When the CO was dry, the crimping devices were actuated and checked for leakage using a pressure decay method calculated in accordance with ANSI N14.5. Following crimp leak tightness verification, the outboard sections of copper tubing were broken free and the CO became available for transfer to the Model 600 cask.

5. The CT could be processed as previously described depending on the amount of activity contained in the effluent it collected. In actual practice, no radioactivity was detected in the CT and its contents were discharged to the pool ion-exchange system.

The fundamental activities described above were detailed in a 15-page procedure that was developed to assure that the correct tooling and personnel were available and to minimize the risk associated with handling a leaking capsule. The procedure was rigorously followed throughout the loading process. Modifications to the system and procedures were made as experience was gained and operational requirements changed. For example, after the first shipment, two COs were mounted on a single base plate and shipped in the Model 600 cask.

## THE FIRST SHIPMENT

During preparation for the first shipment, several areas of concern were identified that had to be resolved before the shipment could be accomplished. These included: (1) containing the potentially contaminated CO effluent under water, (2) ensuring that the water was removed from the overpack, (3) verifying that the overpack was sealed, and (4) ensuring that the system could be operated 20 ft under water. Several tests of individual components and the complete loading system were completed to give operating personnel experience and to prove the equipment would operate as designed. In addition to the detailed procedures that were developed to guide the operators, a detailed Packaging and Transportation Plan was developed to explain the overall activities. This plan proved invaluable in identifying the functions necessary to accomplish the transportation and served as the basis for allocating organizational responsibilities. It also served as a foundation for a schedule of the activities and as a checklist to monitor progress. A detailed approach was needed to inform the state and federal agencies of exactly was going to happen and to obtain their concurrence.

Leak testing the crimp seals involved applying a known pressure (100 psi) to the seal for a given period of time (65 min) with the other side of the seal at approximately atmospheric pressure. The pressurized side of the seal was monitored for a pressure decay of no more than 0.5 psi in the 65-min period. This proved to be a very small pressure change over a considerable period of time and was difficult to reproduce reliably. Suitable test equipment was difficult to obtain (a digital, calibrated pressure transducer was needed); the flexible lines used tended to expand over time, providing volume increases that could be interpreted as indications of leakage; and the time required to be in the pool area (which was very warm and required anticontamination clothing). Since two crimps had to be tested for each CO, the total time required was considerable (including several test failures due to leakage at fittings, expansion of the flexible tubing, etc.).

When water was found in the overpack as the capsule was removed at Oak Ridge National Laboratory (ORNL), an investigation was undertaken to determine the cause. It was puzzling that the water was in the CO after preliminary cold testing had proven the equipment and procedures were adequate for purging it. While no single cause was positively identified, several possible mechanisms were identified, including: water remaining in the flexible lines after the drying operation (which subsequently drained back into the CO prior to crimping); insufficient drying time; and the possibility of a leaking CO seal that could have allowed water to reenter the CO after drying but prior to loading into the transport cask.

The final resolution to the problems encountered in the drying was to develop a vacuum drying system to both dry and leak test the CO. The NRC agreed that a vacuum system would adequately address the problems that had occurred and would provide sufficient leak-testing.

Problems encountered in the transportaton operations of the shipment included the coordination of activities between the various contractors on-site (including the scheduling of riggers and a mobile crane, media notifications, final vehicle preparation, and shipping paper preparation). The attention afforded by local media interest and the assurances required by the regulatory agencies added a dimension not normally encountered in making similar material shipments.

Once the carrier's equipment and driver was on-site, some minor . descrepancies required correction (e.g., a discharged fire extinguisher) but the transportation was without further incident.

## DESIGN AND OPERATIONAL IMPROVEMENTS

### The Second Shipment

The primary improvement implemented prior to the second shipment involved the addition of the vacuum system to perform final drying and to verify that the CO was dry. This was accomplished by adding a third line from the CO to a vacuum system capable of supplying a vacuum of less than the vapor pressure (VP) of water at the pool water temperature. By applying vacuum less than the VP of water, holding for a short time to allow the water to evaporate, and then isolating the system of interest from the vacuum pump, it was possible to quickly observe the system pressure and any pressure rise. If the pressure did not rise, the overpack was dry. This also served to identify any leaks in the system since any in-leakage of water would also have resulted in a pressure rise.

The system developed for the second shipment included two overpacks and required valving to enable the loading and shipment of two capsules in one Model 600 package. Also added to the processing system was an additional gas/liquid separator to prevent contamination from coming to the top of the pool and monitored filters at pool level to identify problems before they became critical. Check valves were added in several locations to prevent backflow of contamination to pool level and a procedural change made to ensure that the lid seal remained in place. Because of the additional valves and lines in this system and the requirement to operate 20 ft below water, it was necessary to fabricate and install coiled lines on the system to reduce the length of lines floating in the pool that might hinder the operators. The revised system is depicted in Fig. 1.

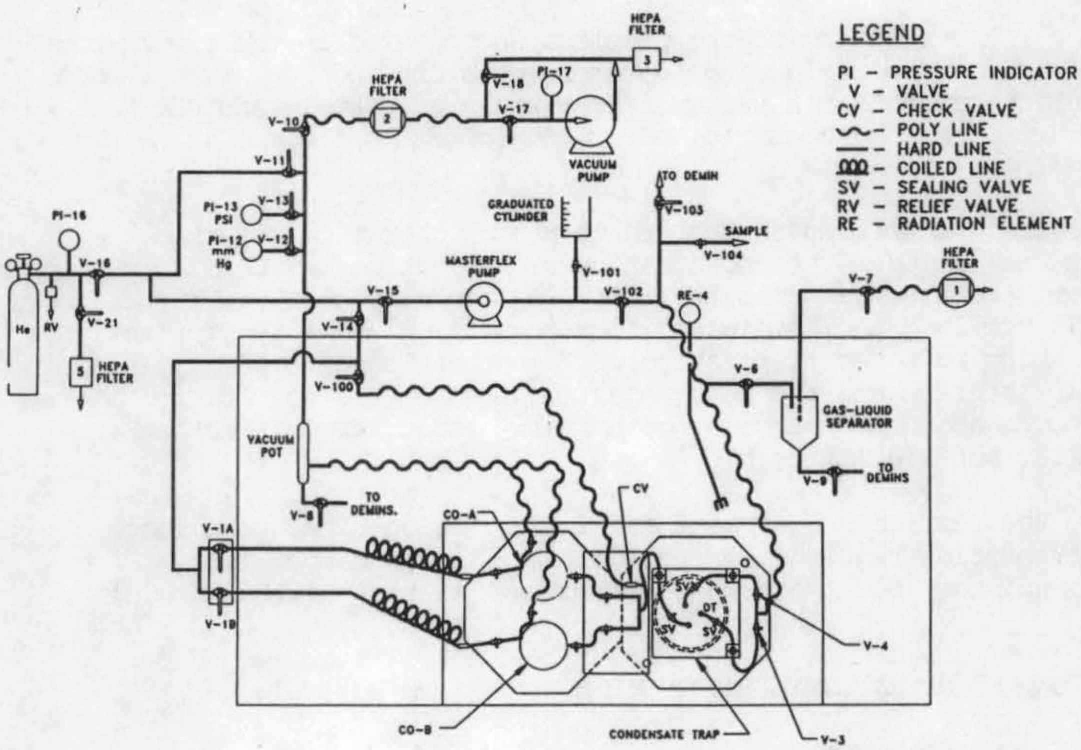


Fig. 1. Revised loading/drying system layout.

Because of the major changes required to the procedures to incorporate additional equipment and equipment changes, a procedure summary was developed and a potential problem analysis prepared in consultation with the operators to identify potential areas, preventative actions, and contingency actions. This document was invaluable in training the operators who used the new system and three levels of testing were completed before operations began. A test to prove the drying capability of the vacuum system, a full-scale test outside the pool operating area, and a complete test of the procedure in the pool using a dummy capsule were also performed.

## The Third Shipment

During preparations for the third shipment, discussions with the operators led to requests for changes to the procedures and equipment design to make the operation smoother and to remove the potential for some handling mishaps. The dip tube that had been connected to the overpack lid was relocated to the side of the cylinder to prevent the possibility of moving or damaging the soft copper gasket on the top of the overpack during lid emplacement. Also added was a gasket protector funnel which guided the capsule during loading into the CO. The metal bellows valves used in the second shipment to replace the crimpers had been mounted to the lid and were moved to the side of the overpack for the third shipment.

This greatly reduced the amount of flexible line floating in the water since the lines were no longer connected to the lid. The modified CO design is shown in Fig. 2.

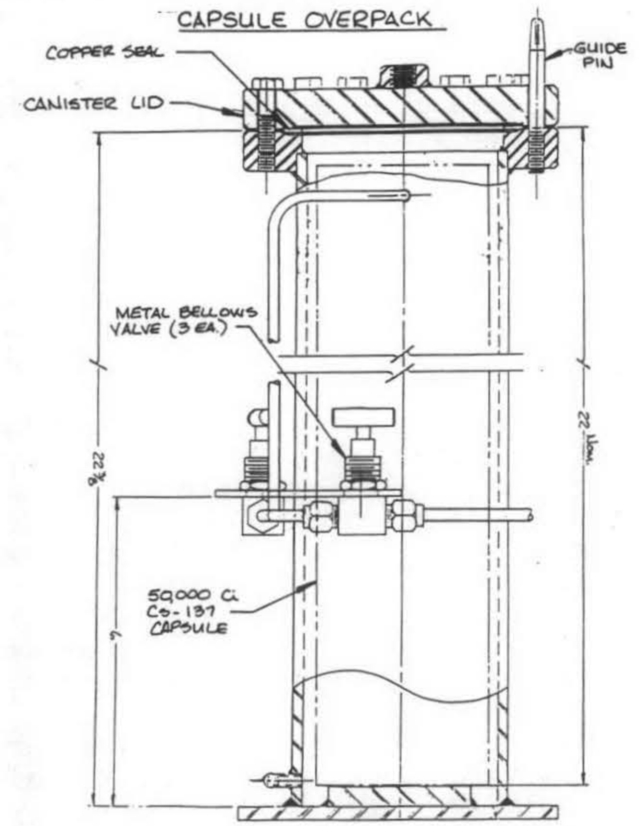


Fig. 2. Modified capsule overpack design.

Since the equipment and procedural modifications were not major and experienced operators were used for the third shipment, training involved only a review of procedures, flowsheets, and the problem analysis. As familiarity with the equipment and procedures on the part of contractors, DOE, and regulatory agencies increased, operations and regulatory approvals began to occur with much greater ease and confidence.

The logistics and transportation operations preparatory activities were the same as the second shipment. However, a delay in the planned shipping date was encountered when the mobile crane was not available. It was not deemed desirable to change to another crane and crew since the personnel used in the past were trained in the operations to be performed. Transport operations went as planned except for some last minute difficulties resulting from the unexpected use of a new driver and tractor. Minor repairs were needed to the tractor, and new training and medical certificates for the driver were required. The vehicle identification number on the lease and insurance certification did not agree with the numbers on the tractor, and a new lease and a new insurance certificate were obtained. Three local television stations were present to cover the activities taking place outside the building, indicating that there had been no reduction in media interest concerning the shipments.

All shipments transited Georgia with no stops or problems. The first two shipments transited Tennessee with no problems also; however, the Tennessee Public Service Commission advised that they wanted to inspect the third shipment upon entry into the state of Tennessee. The driver was advised to pull into the Cleveland, Tennessee, rest stop for inspection. This inspection resulted in no adverse findings, and the shipment proceeded to Oak Ridge National Laboratory without any problems.

## CONCLUSIONS

As a result of the three shipments that have been made, several observations can be made concerning ways to ease similar operations. It should be noted that some of the circumstances regarding these shipments are unique (such as state and federal agency responsibilities and roles, media interest, and initial urgency). However, many of the circumstances are similar to those encountered in a number of operations. It was found that packaging operations could be significantly improved by:

- involving operating personnel in the development of equipment design and procedures, including the use of a team approach with operators and design personnel;
- emphasizing equipment design and procedures that maximize the use of techniques that are easily and quickly verified;
- thorough and planned training for all operations personnel; and
- thorough documentation or required functions, assigned responsibilities, and procedures

It was also found that transportation operations could significantly benefit from advanced planning that included:

- identifying and assigning responsibilities for each function or service that is required;
- identifying, scheduling, and verifying availability of rigging capabilities, and carrier services;
- coordinating and identifying information needs with state and federal agencies as far in advance as possible; and
- verifying compliance of service providers (such as required documentation of carrier personnel and equipment).

By taking the few extra precautions that are needed to absolutely ensure compliance with applicable regulations, the organization in charge can go a long way toward ensuring a trouble free operation.