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The Off-Site Source Recovery Program's Special Form Capsule: Making Radioactive Material Sealed Sources Easier and Safer to Ship

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ABSTRACT

The Off-Site Source Recovery Program (OSRP) is a U.S. Government activity sponsored by the NNSA's Office of Global Material Security to remove excess, unwanted, abandoned, or orphaned radioactive sealed sources that pose a potential risk to national security, health, and safety. Shipping radioactive sealed sources can be incredibly difficult: they can be contaminated or special form status may have expired, causing the cost of the shipment to greatly increase or, in some cases, eliminating the ability to ship the sources altogether. Encapsulating radioactive sealed sources in a Special Form Capsule (SFC) can resolve many of these problems. However, because OSRP visits numerous sites under a variety of working conditions, a field-sealable SFC that can be closed without power tools or any specialty equipment was needed. Expanding on previous efforts, OSRP perfected an SFC that can be closed by hand with simple tools. Once closed, the capsules can be shipped under special form limits rather than the much more conservative normal form limits. There are currently six different capsules that vary in width and depth, giving users a choice of how best to encapsulate their radioactive sealed sources. These capsules have successfully been used in the field for over 15 years, allowing OSRP to ship thousands of sources around the world safely and securely. The paper will detail the history of these capsules from design, testing, and certification of the various models, and other designs that are currently being pursued.

INTRODUCTION

The Off-Site Source Recovery Program (OSRP) is a U.S. Government activity sponsored by the National Nuclear Security Administration's (NNSA) Office of Global Material Security and is managed at Los Alamos National Laboratory (LANL) through the Nuclear Engineering and Nonproliferation Division. OSRP has an NNSA sponsored mission to remove excess, unwanted, or disused radioactive sealed sources that pose a potential risk to national security, health, and safety.

The initial scope of OSRP included any sealed sources comprising Great than Class C (GTCC) low-level radioactive waste specified in 10 CFR 61.55[1]. However, since September 11, 2011, the mission expanded from environmental concerns to address broader public safety and national security requirements. Since 1997, OSRP has been able to recover more than 42,500 sources totaling more than 1.3 million Curies.

HISTORY

As OSRP implemented large-scale recoveries of unwanted radioactive sealed sources, transportation started becoming a bottleneck. After every recovery, the sources needed to be transported from their present location to interim storage sites. Safe and cost-effective recoveries require efficient packaging and transport of the sources.

Radioactive sealed sources in Special Form can be transported in DOT Type A containers in quantities up to the A_1 limit reported in 49 CFR 173.435[2]. For isotopes of particular interest to OSRP (Pu-238, Pu-239, and Am-241, for example) the Special Form (A_1) limit is 10,000 greater than the Normal Form (A_2) limit. OSRP works with many sealed sources that, because of either age or other circumstances, do not have special form documentation available. The Program works to research and re-construct special form documentation for the sealed sources it recovers, however, it is not always possible. Therefore a method to create special form sources in the field would prove very helpful to the efficiency of transport.

Early in the history of OSRP, it was recognized that some method to qualify suspect or leaking sources as special form was needed. During a recovery in 1994, OSRP found a capsule, the SFC-7, which had been developed and patented by Radiation Service Organization, Inc. (RSO, Inc.) in 1989. RSO, Inc. had developed the SFC-7 to facilitate shipments of Ra-226 sources for disposal. OSRP used the SFC-7 in the field to qualify a Pu-238/Be source as special form, which allowed the efficient recovery of the source to LANL. As the work of OSRP accelerated in the late 1990's, an increased need arose to field-qualify sealed sources as special form. However, the size of the SFC-7 restricted its usefulness. After discussions with RSO, Inc., it was agreed that LANL would take on the task of expanding the RSO, Inc. design into a suite of SFCs that would serve a large range of sealed sources.

The SFC-7 was modified, improved, and expanded by the Engineering Science Applications Energy and Process Engineering (ESA-EPE) group at LANL. Test specimens of the final designs were fabricated and sent to an independent testing laboratory, Pacific Testing

Laboratories (PTL) in Valencia, California. At PTL they were tested to determine whether the new design met the DOT requirements for special form so the design could be certified.

DEVELOPMENT

The SFC-7 was first patented by RSO in 1989 (Patent # 5042679). This patent expired on November 9th, 1999. Using the original concept from RSO, Inc., OSRP designed, fabricated, and tested several prototype capsules. The prototypes were first tested in-house at LANL against the special form requirements in 49 CFR 173.469. The original SFC-7 design had a plug that was fabricated using brass, while the housing was fabricated from stainless steel 304. This first prototype design failed the heat test due to the difference in the thermal expansion coefficient. The next prototype was fabricated using the same material for both the plug and the housing.

After further research, it was discovered that the threaded portion of the housing and cap could also be improved. It was decided to incorporate ACME threads to enhance the force transfer to the plug. The ACME thread is a specialty thread that provides clearance on all diameters for free movement while contributing high strength and means it is less susceptible to failure.

While one, very large model of SFC would fit almost any sealed source, the decision was made to make several models. By using a variety of internal diameters and heights, sources recovered by OSRP can be efficiently packaged and transported. Three base models of SFC were made that ranged in internal diameter: I, II, and III (Table 1). The Model I and III also come in a range of internal height. The Model II has an internal diameter of 2.062" which means that it can fit sources that are exactly 2" in diameter or that are slightly damaged or corroded. The Model II can also be used to re-encapsulate a Model I, which may be helpful if OSRP is consolidating sources or if the Model I has failed in the field.

Table 1. Special Form Container Dimensions

SFC Model	Internal Height	Overall Length	ID	OD	Weight (g)	Content Weight Limit (g)
Model I Type 2	4.18"	7.0"	1.0"	2.0"	2389	300
Model I Type 4	0.18"	3.0"	1.0"	2.0"	1165	80
Model I Type 5	1.18"	4.0"	1.0"	2.0"	1475	235
Model I Type 6	2.18"	5.0"	1.0"	2.0"	1781	390
Model II	8.5"	11.75"	2.062"	3.0"	6290	2500
Model III	4.0"	7.0"	1.5"	2.5"	3353	100
Model III-2	8.75"	11.75"	1.5"	2.5"	5303	1700

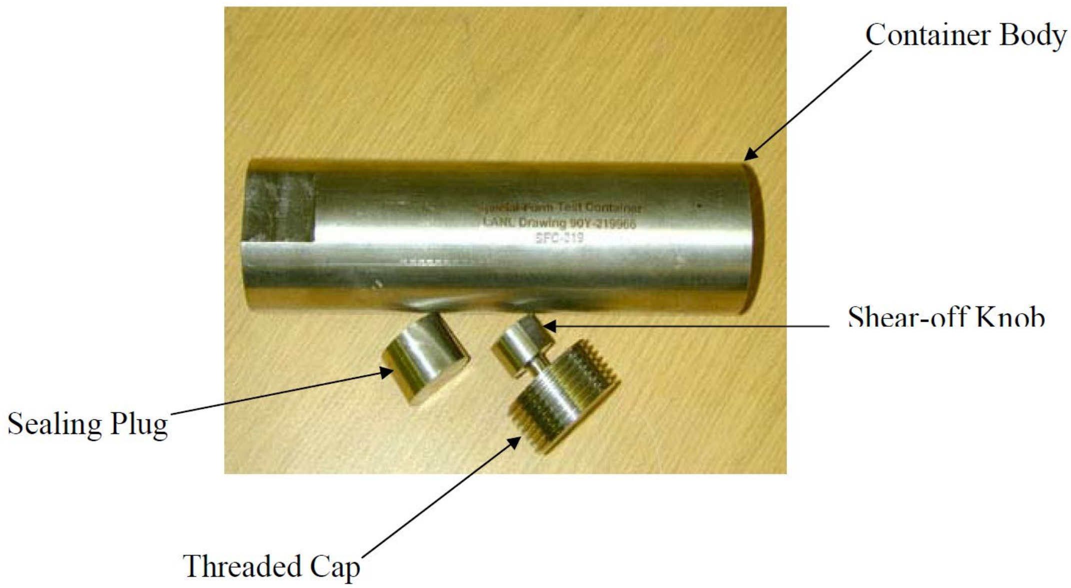

Figure 1 Salient Features of the SFC

SALIENT FEATURES OF THE SFC

The walls of the housing are 0.5” thick or greater. The sealing plug is tapered to insure that, when placed loosely in the seat, at least 0.020” projects above the upper face of the seat. The seal plug dimensions are controlled because the cap seating depth is one indicator of an appropriately sealed capsule. To seal the SFC, the seal plug is placed in the seat. The threaded cap is then advanced into the female thread until the face of the cap is resting on the seal plug surface.

The stem or knob of the cap is sized 0.275” to require a minimum of 40 ft-lb of torque prior to the shearing of the stem from the cap. Once the stem is sheared, the sealing plug is firmly seated in the capsule. The sealing surfaces provide a metal-to-metal seal. Once seated, the plug requires 250 lb of external force to extract, following the removal of the threaded cap. This requires 318 psi of pressure within the SFC to generate the same force. The threaded cap remains in place and serves to protect and retain the sealing plug within the capsule. After the steam is sheared flush with the surface of the cap, the assembly cannot be opened and reused without destroying the capsule.

Each SFC has a serial number which is unique and can be used to identify the model, type, and individual capsule. The serial numbers have been laser etched on the capsules and include appropriate safety information. A traveler sheet, which includes quality assurance information, is generated for and packaged with each SFC. A section is reserved on the capsule in order to etch content information. A typical LANL SFC displays the following information:

DANGER – RADIOACTIVE MATERIALS
IF FOUND, NOTIFY CIVIL AUTHORITIES

LANL US DOT SPECIAL FORM CAPSULE SN# ____________

CONTENTS ______________________________________

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TESTING

The capsules were tested to the requirements of special-form radioactive material as defined in 49 CFR 173.469(b)(1)-(4)[3]. All tests, except the heat and leakage tests, were carried out at ambient temperature and were done using a capsule fabricated according to drawing specifications. A different capsule was used for each of the tests. In order to evaluate the performance of the capsules, the test criteria specifies that the leak-tightness be determined following each test.

Impact Test

This test required that the sealed specimen be dropped onto the target from a minimum height of 9 m. The target is a flat, horizontal surface of such mass and rigidity that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen.

Percussion Test

This test required that the specimen be placed on a sheet of lead, supported by a smooth solid surface and then be struck by the flat face of a steel billet to produce an impact equivalent to that resulting from a free drop of 1.4 kg through 1 m. The flat face of the billet must be 25 mm in diameter with the edges rounded off to a radius of 3.0 +/- 0.3 mm. The lead must be of hardness number 3.5 to 4.5 on the Vickers scale and not more than 25 mm thick. The area of the lead must be larger than the area covered by the specimen. A fresh surface of lead was used for each impact. The billet struck the specimen so as to cause maximum damage

Bending Test

This test is required only for long, slender sources with both a minimum length of 10 cm and a length-to-minimum-width ratio of not less than 10. The SFCs tested have ratios ranging from 1.5 (Model I Type 4) to 4.7 (Model III-2), therefore this test was not conducted.

Heat Test

This test requires that the specimen be heated in air to a temperature of not less than 800°C, held at that temperature for a period of 10 minutes, and then be allowed to cool.

Visual Examination and Leak-Tightness Determination

After each test was performed, each specimen was visually inspected for damage. 49 CFR 173.469 specifies that the leak-tightness or indispensability of the specimen must be determined after each test. For Class 7 (Radioactive) materials the method used can be as prescribed in the International Organization for Standardization (ISO) Technical Report 1979-02-15[4], which was prepared in support of ISO 2919[5]. The capsules were assured to be at ambient temperature, and then immersed 5 cm (2") below water level in a water bath at a temperature between 363 and 368 K. The water bath was observed for a period of 2 minutes to see if any bubbles emanated from the source. If no bubbles were observed, the sealed capsule was considered to have a leak rate less than 1.33×10^{-6} Pa-m^3/s and was considered to be leak-free. This leak test was conducted before and after each other test.

Testing Conclusions and Lessons Learned

Once each type and model of the SFC was tested and examined, it was given a pass or fail. As stated above, when the testing first started, the plug and body were of dissimilar metals and during the heat test expanded at different rates. During testing, several SFCs were found to have failed because the plugs were pressed deeper into the seats than the design specified. This issue was solved by requiring tighter tolerances on mating parts.

Some longer, Model II capsules initially failed because during the drop test, the material inside the capsule would gather enough force to hit the plug out of place. This was solved by adding a snap ring and impact limiter, so that the material in the capsule wouldn't hit the plug.

FIELD USE

Critical components, which include the tapered plug and the mating surface of the capsule, are thoroughly examined for any defects upon receipt from the manufacture. Possible defects include nicks, scratches, and non-conformance with dimensional requirements. In addition, quality assurance (QA) measurements of critical components of each individual capsule assembly are made using a QA tool called the Plug Seating Depth Tool (PSDT) and a dial micrometer. The threaded cap is hand tightened on the capsule body with and without the tapered plug in place and the gap measurements between the PSDT and the top of the capsule are recorded.

To use in the field, OSRP has developed an in-depth procedure. The steps involve verifying the QA measurements, loading the capsule with approved content, and closing the capsule. Once the capsule is closed, the measurements are compared with the original QA measurements to confirm that the plug has traveled far enough into the seat that the capsule is adequately sealed.

A set of accessories has been developed to enable efficient loading of the capsule in the field to reduce external radiation dose to workers. For encapsulation of neutron sources, polyethylene shielding is included among the accessories to minimize radiation dose and to comply with ALARA policies. While the capsules must be assembled in strict accordance with OSRP procedures, some of the specially made accessories can be swapped out with tools found in the field. For instance: the SFC closure kit provided by OSRP has a specially designed collapsible wrench for shearing off the knob on the cap. However, an impact wrench may also be used since the knob will shear off once the appropriate torque is reached.

FUTURE DESIGNS

OSRP is currently working on two designs for the future: the Model IV and Model X. The Model IV will be 4” in internal diameter and in varying lengths. The Model X will be 1” in internal diameter and up to 28” long. The Model IV will be welded shut as opposed to plug sealed like the current generation of SFCs. These two models will also be custom made when needed, rather than produced in large batches. The Model X, like the Model II, will have an impact limiter because of the force the internal material exerts on the sealing plug during the drop test.

BENEFITS

The major benefit of OSRP’s Special Form Capsules is that it takes what might have been a Type B shipment and turns it into a Type A shipment. Type B shipments are costly and specialized; for some licensees, a Type B shipment may be an impossibility. For OSRP, when working with older, corroded, or orphaned sources, this makes shipment and disposal much easier.

The Off-Site Source Recovery Program, while a U.S. Government sponsored program, travels around the world, helping to secure radiological material and advise on its storage. Some of the areas OSRP has visited are not as developed as the United States. This makes the fact that the SFC can be sealed without power and in the field, an invaluable tool.

Other than shipping, the SFC offers benefits in shielding and storage. The SFC provides an easy way to consolidate sources, but the dose rates may be challenging. The thick stainless steel walls of the SFC provides some shielding and the compact size means that shielding can be done easily. This can be a key benefit when packaging many smaller sources into the capsule. If a source is leaking, repackaging it into an SFC makes the source safer and the likelihood of contamination smaller.

The SFCs are currently being used not only by OSRP but by several companies that it has trained. These companies use the SFCs to safely and securely transport radioactive material. The SFCs can currently be used with over 15 different isotopes and up to the A_1 limit of material with those isotopes. With material special formed, shipments that might have been impossible can be completed in an economical, efficient, and safe manner.

REFERENCES

[1] Code of Federal Regulations Title 10, Part 61.55, Describes the method of classification for land disposal of radioactive wastes and provides a definition for Class A, B, and C wastes which are suitable for shallow land burial waste disposal sites. Wastes which exceed the limits established for Class-C are defined as not suitable for shallow land burial disposal techniques.

[2] Code of Federal Regulations Title 49, Part 173, Describes general requirements for shipments and packagings of hazardous and radiological materials

[3] Code of Federal Regulations Title 49, Part 173, Paragraph (b), Subparagraphs (1) through (4) Describe specific tests a specimen must be subjected to

[4] Sealed Radioactive sources – Leak test methods, International Organization for Standardization, Technical Report 4826, Published 1979-02-15

[5] Radiation protection – Sealed radioactive sources – General requirements and classification, International Organization for Standardization, ISO 2919, Second edition, 1999-02-15