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DEVELOPMENT AND CERTIFICATION OF A CAPSULE FOR SEALED SOURCE ENCAPSULATION (LA-UR-07-6980)

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ABSTRACT

The OSR Project has developed a sealed source encapsulation to provide a method to assure US DOT special form containment of radioactive sealed sources during transport. This encapsulation is called the LANL Special Form Capsule (SFC). The capsule was designed to meet both project specific design requirements and the testing requirements specified in the Code of Federal Regulations 49 CFR 173.469[1]. A key feature of the SFC was that it could be easily assembled in the field. Its development expanded the projects capabilities to efficiently transport and store sealed sources. Sealed sources that are special form can be shipped using US DOT 7A, Type A packages, which provide for increased flexibility in shipping.

We describe the development of the special form capsule, the in-house testing as well as the independent laboratory testing performed to certify the container. Quality assurance issues associated with the fabrication and the assembly will also be discussed.

The special form container is available in three sizes referred to as the Model I, II, and III. Each container utilizes the same sealing concept. The capsule is selected to optimize the payload volume.

I. INTRODUCTION

The Off-Site Source Recovery (OSR) Project at Los Alamos National Laboratory (LANL) recovers and manages excess and unwanted radioactive sealed sources and other radioactive materials that present a risk to public health, safety and national security. Due to their age, a lack of available manufacturer data and unknown origin, or the potential for leakage, some of the radioactive sealed sources targeted for recovery by the OSR Project do not meet US Department of Transportation (US DOT) Type A requirements. Sealed sources that are special form can be shipped using US DOT 7A, Type A packages, which provide increased flexibility in shipping. In 2000, the OSR Project developed a sealed source encapsulation called the LANL Special Form Capsule (SFC) Model I to provide a method to ensure US DOT special form containment of radioactive sealed sources during transport. The development of the SFC allowed sealed sources which did not have current special form certification or documentation for domestic transport to be made special form by field encapsulation in a LANL SFC. The development and testing of the Model I SFC was documented in LA-UR-02-433[2]. A key feature of the SFC was that it could be easily assembled in the field. After successful testing of the Model I, two larger capsules, the Model II and III, were developed. The development and testing of the Model II and III SFC was documented in LA-UR-05-2942[3] and LA-UR-05-3283[4]. Their development expanded the

capabilities of the OSR Project and Department of Energy (DOE) to efficiently transport and store sealed sources. All three models of the LANL SFC have been tested and certified to meet all requirements specified in 49 CFR 173.469.

II. SCOPE

The scope of the engineering effort was to develop a sealed source encapsulation for radioactive materials or sources offered for domestic transport under 49 CFR. Use of this encapsulation would qualify the package as special form. The special form capsule must be easily sealed in the field and be fabricated in various sizes to accommodate the full physical size and isotopic range of sealed sources likely to be encountered by the OSR Project. The following definitions are applicable:

A. SEALED SOURCE Radioactive material that is contained in a sealed capsule, sealed between layers of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to the use of the source. (Guide for Occupational Radiation Protection (GN5400.9/M1) Sealed Radioactive Source Accountability and Control[5])

B. SPECIAL FORM Class 7 Radioactive material that satisfies the following conditions:

1. it is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule;
2. the piece or capsule has at least one dimension not less than 5 millimeters (0.2 inch); and
3. it satisfies the test requirements of 49 CFR 173.469.

III. DEVELOPMENT

A special form capsule, the SFC-7, was first patented by Radiation Service Organization, Inc. (RSO) in 1989 (Patent # 5042679). This patent expired on November 9, 1999. As the work of the OSR Project accelerated in the later 1990s, an increased need arose to field-qualify sealed sources as special form. However, the size limitations of the SFC-7 restricted its usefulness. After discussions with the RSO staff, it was agreed the LANL would take on the task of expanding the RSO design into a suite of SFCs that would serve a large size range of sealed sources. Using the original concept from RSO, the OSR Project designed and fabricated several prototype capsules and tested them in-house against the special form requirements in 49 CFR 173.469. In the SFC-7 design, the plug had been fabricated using brass, while the housing was fabricated from stainless steel 304 bar stock. The first prototype design failed the heat test due to the difference in the thermal expansion co-efficient. For that reason, the tapered plug for the next prototype was fabricated using the same material as the housing, stainless steel 304 bar stock. The capsule fabricated using the revised design passed the heat test. After further research and study, 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 transferred to the plug. The ACME thread is a specialty thread, which provides clearance on all diameters for free movement, while contributing high strength. This element of design provides a high quality part, which is less susceptible to failure. Once the final prototype had been successfully tested at LANL, a suite of capsules were fabricated and sent to Pacific Testing Laboratory (PTL) for testing against the special form requirements in 49 CFR 173.469.

IV. GENERAL DESCRIPTION

The LANL SFC's are fabricated from SS 304 bar stock. A cap, utilizing ACME 2G threads, is used to apply pressure on the tapered plug forming a seal against the inner wall. The cap incorporates a knob that shears off during assembly. The thickness of the throat on the cap was experimentally determined such that when it sheared off there was sufficient pressure applied on the taper plug to achieve a seal. The final containment cannot be opened without destroying the capsule. The capsule components are shown in Figure 1.

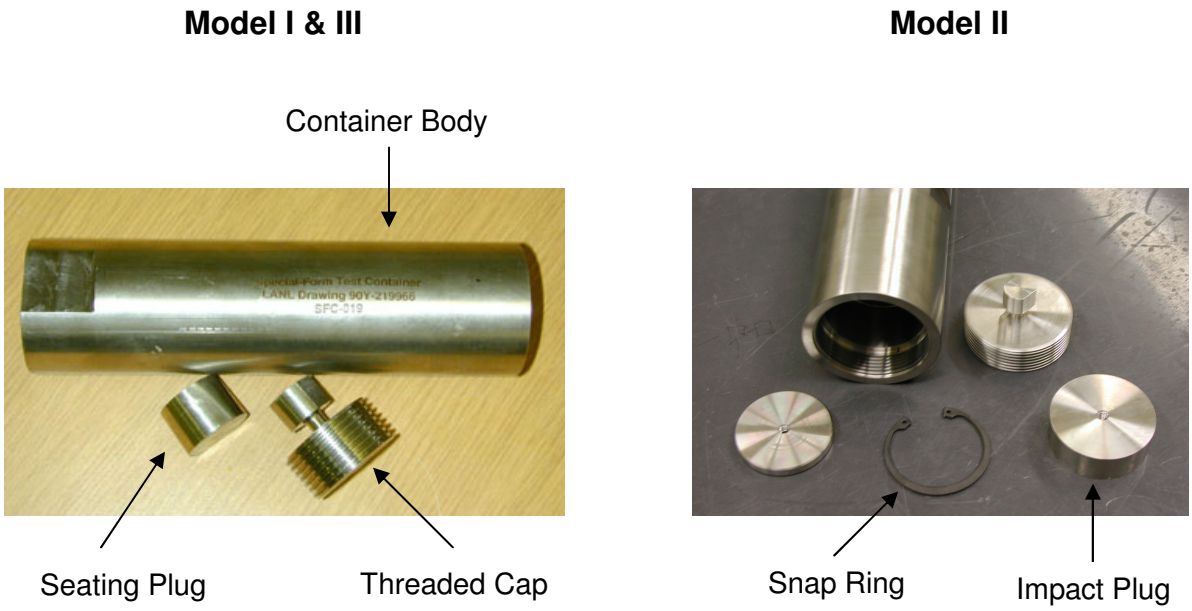

Figure 1. Special form capsule components

V. FEATURES OF THE SFC

The physical dimensions of the three SFC's are shown in Table 1. The Model I and III are available in various lengths. The walls of the housing are 0.5" thick or greater. The sealing plug is longer and slightly larger in diameter on the large end than its tapered seat to ensure that, when placed loosely in the seat, at least 0.020" projects above the upper face of the seat. The dimensions of the sealing plug and its mating surfaces on the housing are controlled to a tight tolerance because the cap seating depth is the primary indicator of an appropriately sealed capsule. The threaded cap incorporates a stem which has been sized to shear off at 45, 65 and 75 ft-lb respectively for the Model I, III and II capsules. Once the stem is sheared, the sealing plug is firmly seated in the capsule. The sealing surfaces provide a metal-to-metal seal. The threaded cap remains in place and serves to protect and retain the sealing plug within the capsule. After the stem is sheared flush with the surface of the cap, the assembly cannot be opened and reused without destroying the capsule. The Model II SFC incorporates an impact limiting disk and snap ring. This feature was added to prevent the packaged material from impacting the sealing plug should the capsule be dropped.

The SFC serial numbers are unique and intended to identify the individual capsules. The serial numbers have been laser etched on the capsules and include appropriate safety information. A section is reserved on the capsule where package information can be etched. A traveler sheet, which includes quality assurance information, is generated for each SFC. This traveler is packaged with the container.

TABLE 1

SFC	Internal Depth	Overall Length	ID	OD	Weight (grams)
Model I					
Type 2	4.5”	7.0”	1.0”	2.0”	2389
Type 6	2.5”	5.0”	1.0”	2.0”	1781
Type 5	1.5”	4.0”	1.0”	2.0”	1475
Type 4	0.5”	3.0”	1.0”	2.0”	1165
Model II	8.5”	11.75”	2.062”	3.0”	6290
Model III	4.5”	7.0”	1.5”	2.5”	3353
Model III	8.5”	11.75”	1.5”	2.5”	5304

VI. SPECIAL FORM TESTING

During the development phase of the SFC, a suite of in-house tests was conducted to verify the adequacy of the design. Various sealing concepts were evaluated. Once the design was validated, capsules were fabricated, assembled, and sent to PTL in Valencia, CA, for independent testing.

VII. TEST CRITERIA

The capsules were tested to the requirements of “special form radioactive material,” as defined in 49 CFR 173.469(b)-(1)-(4). 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 specified that the leak-tightness be determined following each test. The tests are described below:

A. IMPACT TEST

The impact test [49 CFR 173.469 (b) (1)] required that the sealed specimen be dropped onto the target from a minimum height of 9 m. The target was 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. After the test was performed, each capsule was examined visually and subjected to a leakage test.

B. PERCUSSION TEST

The percussion test [49 CFR 173.469 (b) (2)] 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 $\pm$ 0.3) mm. The lead, of hardness number 3.5 to 4.5 on the Vickers scale and not more than 25 mm thick, covered an area greater than that 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. After the test was performed, each capsule was examined visually and subjected to a leakage test.

C. HEAT TEST

The heat test [49 CFR 173.469 (b) (4)] required that the test 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 allowed to cool. After testing was performed, each capsule was examined visually and subjected to a leakage test.

D. LEAK-TIGHTNESS DETERMINATION METHOD

Following each of the above tests, 49 CFR 173.469 specifies that the leak-tightness or indispersibility of the specimen must be determined. For Class 7 (radioactive) materials the method used can be as prescribed in the International Organization for Standardization (ISO) Technical Report 1979-02-15[6], which was prepared in support of ISO 2919[7]. Analytical reagent-grade ethylene glycol, water, or silicon oil was used as the leak-test fluid in a vacuum chamber. The air content of the fluid was lowered by evacuating the chamber for one minute and then returning it to atmospheric pressure. The capsule was then submerged completely to a depth of 5 cm (2 in) below the fluid level. The pressure in the chamber was reduced to between 15 - 25 kN/m2 (2 - 3.6 lb/in2) absolute. If no bubbles were observed, the sealed capsule was considered to be leak free.

VIII. TEST RESULTS

Each test, impact, percussion, and heat, was performed three times using a different capsule every time. Each of the capsules was evaluated for leakage as described above before and after each individual test. The Model I, II, and III SFC's passed the tests specified in 49 CFR 173.469(b)-(1)-(4).

IX. FABRICATION

All capsules are fabricated according to the design specifications in LANL drawings 90Y-219966 Revision E, 90Y-219998 Revision H and 90Y-220045 Revision A. Fabrication is conducted in compliance with the quality assurance specifications in 10 CFR 71 subpart H and the additional quality assurance requirements specified in LANL Quality Assurance Supplement, Form-838c.

X. QUALITY ASSURANCE

Critical components, which include the sealing plug and the mating surface of the capsule, are thoroughly examined for any defects upon receipt from the manufacturer. Possible defects include nicks, scratches, and nonconformance with dimensional requirements as specified in the LANL drawing. 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 feeler gauge or dial gauge. 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. If the gap measurement following assembly falls between the two QA gap measurements, a leak tight assembly is assured.

XI. APPLICATION OF LANL SFC

The materials intended for encapsulation by the LANL SFC are limited to metal clad sealed sources or leaking sealed sources containing dry solids. In general, use of the SFC by LANL will be for radioactive sources containing the following alpha-emitting isotopes: Pu-238, Pu-239, Am-241, Np-237, Cm-244, and Ra-226 with a total weight of 2500 grams for the Model II and 1000 grams for the Model III. However, the potential radioactive contents of this capsule are limited only by the potential for pressurization of the capsule and/or the heat generated in the capsule by radioactive decay. Adequate void space should be left to assure that pressure build-up due to an inner container leak would not significantly challenge the integrity of the capsule.

XII. FIELD LOADING PROCEDURE

A set of tools and accessories has been developed to enable efficient loading and closing of the capsule in the field to reduce external radiation dose to workers while ensuring a quality seal. For encapsulation of neutron sources, polyethylene shielding is included among the accessories to minimize radiation dose and to comply with ALARA (as low as reasonably achievable) policies. The capsules must be assembled in strict accordance with their respective assembly procedures. The procedure provides a quality control process to ensure a compliant seal.

XIII. CONCLUSION

The design of the LANL SFC Model I, II and III has been tested and certified to meet all requirements specified by the US DOT in 49 CFR 173.469 (ANSI N43.6 Annex E) for special form material. Note that the LANL SFC Model II can be fabricated in lengths up to 19 inches without additional testing. PTL issued a certificate indicating that the SFC meets US DOT requirements. The design characteristics of the capsule and the successful testing allow us to state that the capsules meet the requirements of ANSI N43.6 Annex E, ISO 2919, and ISO 1979-02-15.

XIV. ACKNOWLEDGEMENTS

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XV. REFERENCES

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