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Development and Certification of a Special Form Capsule for Sealed Sources to Facilitate Transportation and Storage as Special Form Material

By

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Abstract

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 and safety and for which no disposal options currently exist. 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 Type A, 7A packages, which provide increased flexibility in shipping. The OSR Project has developed a sealed source overpack called the LANL Special Form Capsule (SFC) Model 1 to provide a method to ensure US DOT special form containment of radioactive sealed sources during transport. Sealed sources which do not have current special form certification or documentation for domestic transport can be made special form by field encapsulation in a LANL SFC. The LANL SFC has been developed to meet the needs of the OSR Project and Department of Energy (DOE) requirements for efficiently shipping sealed sources. It has been tested and certified to meet all requirements specified in 49CRF173.469.

1.0 INTRODUCTION

The Off-Site Source Recovery (OSR) Project at Los Alamos National Laboratory (LANL) recovers and manages radioactive sealed sources and other radioactive materials that present a risk to public health and safety, present a potential loss of control by a US Nuclear Regulatory Commission (NRC) or agreement state licensee, are excess and unwanted, are a Department of Energy (DOE) responsibility under the Low-Level Radioactive Waste Policy Amendments Act (Public Law 99-240)[1], or are DOE-owned. The OSR Project focuses on the problem of excess and unwanted sources in both the public and private sectors for which there is no disposal option because the material exceeds the limits for Class C waste specified in 10 CFR 61.55[2]. As of 2001, the OSR Project estimates that from 6,000 to 18,000 sealed transuranic sources may require recovery over the lifetime of the project. The project was undertaken to reduce potential health and safety risks from unwanted radioactive material with no disposal path and to enable the DOE to meet its obligation under Public Law 99-240.

The OSR Project has implemented a large-scale national recovery of unwanted radioactive sealed sources. A major element of the project is transportation of sealed sources from their present locations to interim storage sites. Safe and cost-effective recovery of sealed sources to a DOE site or other storage location requires efficient packaging and transport of the sealed 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[3]. For isotopes of particular interest to the OSR Project, i.e., plutonium (Pu)-238, Pu-239 and americium (Am)-241, the A_1 limit (special form) is 10,000 times greater than the A_2 limit (normal form). Due to the age or circumstances under which these excess sealed sources are found, special form documentation is often unavailable. The OSR Project works to research and reconstruct special form documentation for the sealed sources it recovers; however, it is not always possible. Therefore, a method to create special form in the field would prove very helpful to the efficiency of transport.

Early in the history of the OSR Project, it was recognized that some method to qualify suspect or leaking sources as special form was needed. During a recovery in 1994, the OSR Project found a capsule, the SFC-7, which had been developed and patented by Radiation Service Organization, Inc. (RSO) in 1989. RSO had developed the SFC-7 to facilitate shipments of radium (Ra)-226 sources as special form in Type A packages for disposal. Shipment as Type A allowed 200 times more Ra-226 activity to be packaged and transported in a single container. The OSR Project used the SFC-7 in the field to qualify a Pu-238/beryllium source as special form, which allowed the efficient recovery of the source to LANL. 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

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1 U.S. Congress, 1985. *Low-Level Radioactive Waste Policy Amendments Act of 1985.* Public Law 99-240, Made the DOE responsible for disposal of any low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste, as defined by 10CFR61.55, in effect on 1-26-83.

2 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.

3 Code of Federal Regulations Title 49, Part 173, Describes general requirements for shipments and packagings of hazardous and radiological materials.

limitations of the SFC-7 restricted its usefulness. After discussions with the RSO staff, it was agreed that 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.

The SFC-7 was modified and improved by the Engineering Science Applications, Energy and Process Engineering (ESA-EPE) group at LANL. Test specimens of the final design (LANL SFC Model 1) were fabricated and sent to an independent testing laboratory, Pacific Testing Laboratories (PTL) in Valencia, California, where they were tested to determine whether the new design met the DOT requirements for special form and could be certified.

2.0 SCOPE

The scope of the project was to develop a sealed source overpack, which provided for radioactive materials or sources offered for domestic transport under 49 CFR to qualify as special form. The special form capsule had to 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:

Sealed Source	Radioactive material that is contained in a sealed capsule, sealed between layers of nonradioactive 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 (from *Implementing Guide for Occupational Radiation Protection* (GN5400.9/M1) *Sealed Radioactive Source Accountability and Control*).
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.

3.0 DEVELOPMENT

As mentioned above, a special form capsule, the SFC-7, was first patented by RSO in 1989 (Patent # 5042679). This patent expired on November 9, 1999. Using the original concept from RSO, the OSR Project designed and fabricated several prototype capsules and tested them in-house at LANL 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 coefficient. 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 transfer to the plug. The ACME thread is a specialty thread that provides clearance on all diameters for free movement while contributing high strength. This element of design provides a high-quality part that is less susceptible to failure. Once the final prototype had been successfully tested in-house, several Model 1 SFCs were fabricated for testing by PTL.

4.0 GENERAL DESCRIPTION

The LANL SFC Model 1 has exterior dimensions of 2” OD x 7” long, although it is currently available in 3 additional lengths. The housing is fabricated from stainless steel 304 bar stock. The SFC incorporates a tapered plug, made of the same material. A cap utilizing 11/2-10 ACME 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 as part of the sealing process to a final containment that cannot be opened without machining, which would result in the destruction of the capsule. The design is detailed in LANL drawing 90Y-219966 Revision D (Attachment A) and is shown in Figure 1.

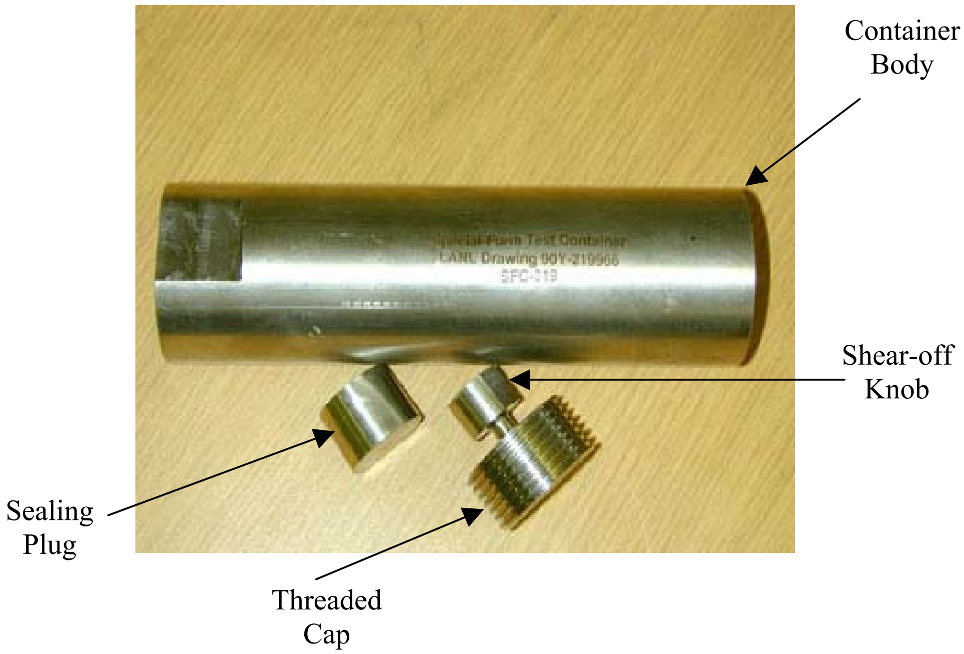

Figure 1. Special form capsule components.

5.0 FEATURES OF THE SFC

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 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 of the cylinder until the face of the cap is resting on the seal plug surface.

The relieved stem of the cap is sized 0.275” OD 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 about 250 lb. of external force to extract, following removal of the threaded cap. It would require 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 stem is sheared flush with the surface of the cap, the assembly cannot be opened and reused without destroying the capsule.

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 traveler sheet, which includes quality assurance information, is generated for each SFC and is packaged with it in a sealed plastic bag prior to use. 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 ____________________

CONTENTS ____

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6.0 SFC COMPONENT SPECIFICATIONS

The LANL SFC consists of three components: the capsule, a sealing plug, and the threaded cap. The capsule consists of a 2” OD SS (304) billet 7” in length. An internal cavity 1” ID is machined into the billet 6” deep. A female machine screw thread (11/2 – 10 ACME) is machined into the open end of the billet 0.75” deep. A seat for the sealing plug is machined into the billet below the threaded section.

The sealing plug is tapered 0.025” in 0.75” of length and the seat is given a #32 machine finish. The sealing plug is 0.770” in length and is sized to 1.000” OD where it joins the 1.000” ID bore of the housing.

The threaded cap for the SFC consists of a threaded (11/2 – 10 ACME) disc 0.75” thick, topped by a 0.75” OD x 0.75” long stem. The stem is sized to 0.625” OD and then further relieved to an OD of 0.275” for a distance of 0.25” above where it joins the threaded disc of the cap. Flats are then machined into the remaining portion of the stem to allow a wrench to apply torque.

7.0 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. Once the design was validated, capsules were fabricated, assembled, and sent to PTL in Valencia, CA, for independent testing.

8.0 TEST CRITERIA

The capsules were tested to the requirements of "special form radioactive material," as defined in 49 CFR 173.469(b)-(1)-(4)[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 leaktightness be determined following each test. A brief summary of the tests is presented in 9.0 Test Results, and a detailed copy is available upon request.

8.1 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.

8.2 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 ± 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.

8.3 BENDING TEST

A bending test [49 CFR 173.469 (b) (3)] 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. For Model 1 of the LANL SFC, the length to minimum width ratio was 6. These test criteria would allow fabrication of Model 1 of the LANL SFC in any length up to 19 inches before the bending test would be required. It was considered highly improbable that an SFC greater

4 Code of Federal Regulations Title 49, Part 173, Describes general requirements for testing of special form radioactive material.

than 19 inches would be of use. Therefore, this test was considered unnecessary for Model 1 as designed.

8.4 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.

8.5 LEAKTIGHTNESS DETERMINATION METHOD

Following each of the above tests, 49 CFR 173.469 specifies that the leaktightness 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[5], which was prepared in support of ISO 2919[6]. The capsules were ensured to be at ambient temperature, and then immersed 5 cm (2 inches) below water level in a water bath, at a temperature between 363 and 368^{o}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 x 10^{-6} Pa-m^3/s and was considered to be leak free.

9.0 TEST RESULTS

The test results are presented in Table 1. The following table summarizes the number of tests that were performed on the capsules. Each test was done using a different capsule. Three capsules were used for each of the tests: impact, percussion, and heat. Each of the capsules was evaluated for leakage as described above before and after each individual test.

Table 1. Test results.

SFC #	Test	Results
001	Impact	PASS
004	Impact	PASS
007	Impact	PASS
005	Percussion	PASS
009	Percussion	PASS
012	Percussion	PASS
003	Heat	PASS
006	Heat	PASS
010	Heat	PASS

5 Sealed Radioactive Sources – Leak Test Methods, International Organization for Standardization, Technical Report 4826, Published 1979-02-15.
6 Radiation Protection – Sealed Radioactive Sources – General Requirements and Classification, International Organization for Standardization, ISO 2919, Second edition, 1999-02-15.

10.0 FABRICATION

During the leakage determination following a nonrequired test, two SFCs were found to have failed. Careful evaluation of the capsules revealed that the plugs in these two capsules were pressed deeper into the seats than the design specified. This indicated a problem in the dimensional tolerance of the fabricated parts. Therefore, three more SFCs were fabricated using tighter controls on mating parts. The new tolerances required a minimum of 0.020" of the plug to project into the threaded section, ensuring complete transfer of force from the threaded cap to the plug. The three capsules were then sent to PTL in May 1999, for additional testing. All three capsules passed. The fabrication drawings were revised to incorporate tighter tolerances on critical components. In addition, a thorough quality assurance plan was implemented to eliminate future problems.

All capsules are now fabricated according to the design specifications in LANL drawing 90Y-219966, Revision D (Attachment 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 QA Supplement, Form-838c.

11.0 QUALITY ASSURANCE INSPECTION PRIOR TO 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 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, see Figure 2. 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, this will ensure a leak tight assembly.

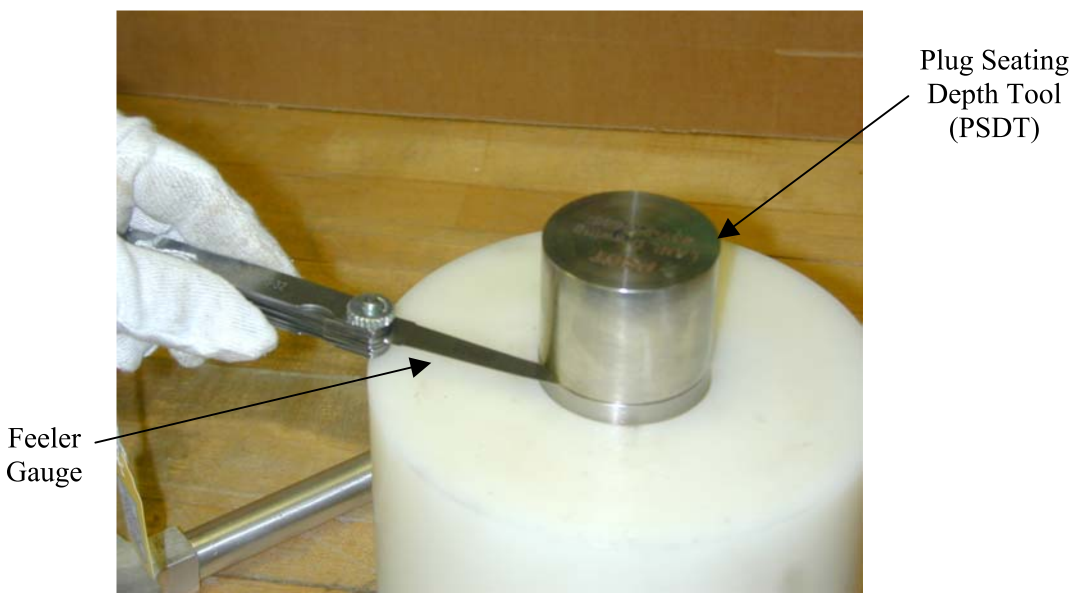

Figure 2. Use of QA tool.

12.0 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. 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.

12.1 CAPSULE PRESSURIZATION

To establish practical guidelines for limitations on capsule contents posed by internal pressure and internal heat generation, limits have been calculated for a variety of isotopes. Pressure limitations were calculated using the American Society of Mechanical Engineers (ASME) Pressure Vessel Code[7] and the appropriate void volume. Since the SFC is an *overpack*, there will always be an internal void volume between the inside of the SFC and the radioactive material being encapsulated. This volume provides for helium gas buildup from decay. The greater the void volume, the longer the time period before internal pressurization challenges the SFC. The curves shown in Figure 3 illustrate the effect of internal pressurization on service life. Void volume per unit of activity (cc/initial Ci) determines the service life limited by internal pressurization of the capsule. The limiting internal pressure calculated by the Pressure Vessel Code is 4,356 psi, which is the maximum internal pressure with a safety factor (SF) of 4 at 800^{o}C. These curves provide a guideline only, and users of the SFC are encouraged to perform their own calculations to ensure that they have provided for an adequate void volume.

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7 ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Design and Fabrication of Pressure Vessels, 1995.

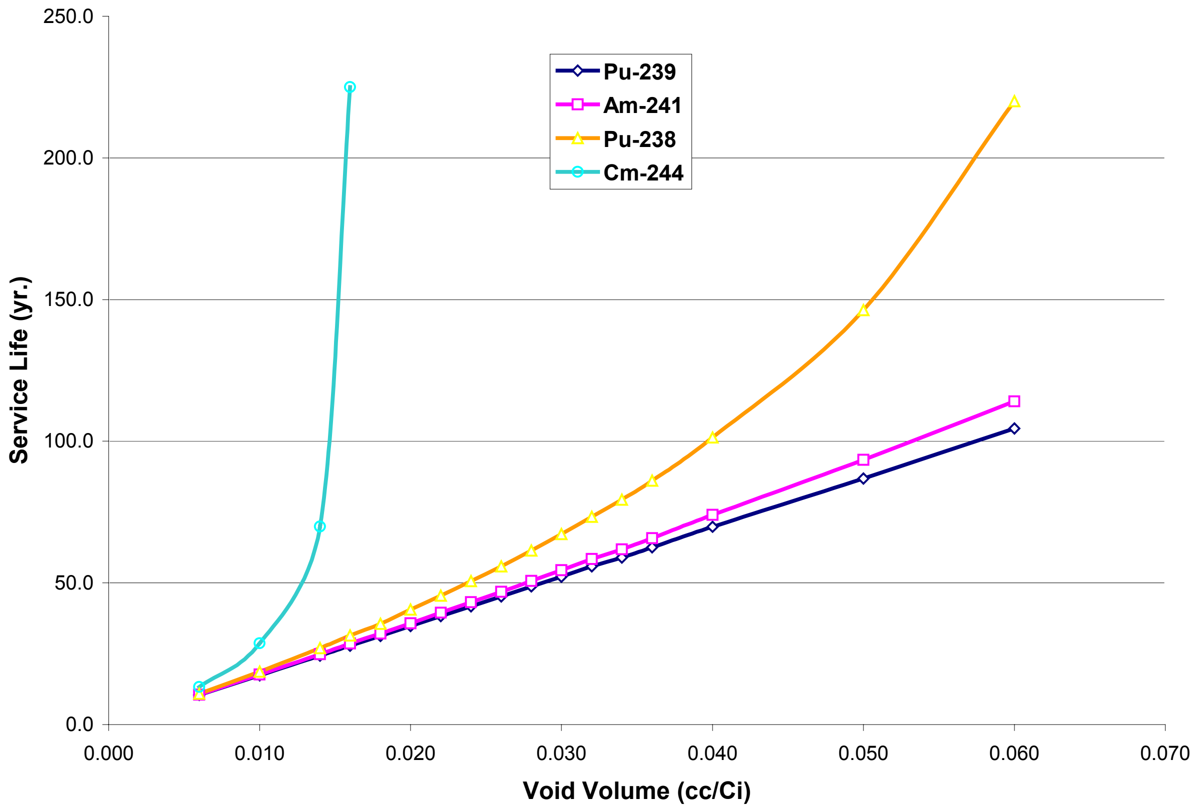

Figure 3. SFC service life limitations caused by internal pressure buildup shown as a function of the void volume and encapsulated isotope.

Determination of the service life required the calculation of the volume of gas generated by alpha decay at specific time intervals for specific void volume/initial activity ratios. The calculation of the gas generated is essentially the integrated total alpha decay of the radioactivity present and evaluation of the alpha particle release as free gas in the void volume. As illustrated above, this was done for several void volume/activity ratios in order to illustrate the effects of pressure buildup on the capsule service life. For example, the relatively short half-life of Cm-244 ensures that the rate of decrease in the material exceeds the potential for pressure buildup at volume to activity ratios greater than 0.014 and thus will never impose a restrictive service life limit.

12.2 THERMAL LIMITS FOR THE SFC

Thermal limits for US DOT Class 7 packages are detailed in 49 CFR: 173.410, 173.442, and 173.448. In summary, the two most restrictive packaging requirements are

1. The temperature of the accessible package surface must not be greater than 50°C (122°F), when the air temperature is 38°C (100°F), which is a net 12°C (21.6°F) temperature increase. For shipments by air, insulation cannot be considered.
2. The average surface heat flux of the package does not exceed 15 watts per square meter without special stowage provision and the immediately surrounding cargo is not in sacks or bags or another form that would impede air circulation for heat removal.

Regarding the implications of requirement number 1, a simple conductive heat flow model (Fourier) of the SFC will demonstrate that 90 watts of heat generated by radioactive decay will increase the SFC surface temperature by about 12°C (21.6°F) in free air. Thus, the SFC in an un-insulated state will increase in temperature only by about 12°C, which would meet the thermal requirements of number 1. However, under most instances of transport, the SFC would not be "the accessible package surface." The SFC will be shipped inside an external shipping container.

If the standard shipping package is a 55-gallon drum, with surface area of 2.11 m^2, then a $15W/m^2$ limit would allow packaging of radioactive material emitting 31.6W of decay heat. This 31.6W limit is about 1/3 of the limit calculated above (90-W). Clearly the $15W/m^2$ without special stowage provision is more restrictive and will be the limitation used by LANL when shipping in a 55-gallon drum. Other packaging geometries should be specifically evaluated to determine the thermal limit for the SFC.

It should be noted that the thermal limits described above are a packaging requirement and not a special form requirement. Neither a 12°C temperature rise nor a $15W/m^2$ thermal flux will present any significant physical challenge to 300 series stainless steel at ambient or the elevated (800°C) temperature at which the SFC has been tested. The potential effects of higher thermal loading should be specifically evaluated in conjunction with the specific packaging geometries and materials to be used.

13.0 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 in a manner that ensures 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 the procedures described in OSR-OP-160, "Assembly Procedure for the Special Form Capsule"[8]. The procedure provides a quality control process to ensure a compliant seal.

14.0 CONCLUSION

The design of the LANL SFC Model 1 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 1 can be fabricated in lengths up to 19 inches without additional testing. Pacific Testing Laboratories issued a certificate indicating that the SFC meets US DOT

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8 Assembly Procedure for the Special Form Capsule, OSR-OP-160, LANL, OSR Project, E-WMOSR, July 2001.

requirements on July 13, 2000 (see Attachment C). 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.

15.0 ACKNOWLEDGEMENTS

The authors acknowledge the many people involved in the design, testing, and fabrication of the LANL Special Form Capsule. We are indebted to Radiation Service Organization, Inc., Laurel, MD, for their original work. The United States Department of Energy funded this work. Thanks especially to Robert Campbell (US DOE, EM-22) Washington, DC, Jim Orban (US DOE) Albuquerque, NM, and Joel Grimm (US DOE) Albuquerque, NM for their support of this work. The LANL SFC has been developed and qualified for use as special form containment by LANL with the participation of and contribution from Pacific Testing Laboratories (Valencia, CA), Hand Precision Machining and Jona Machining (Los Alamos, NM).

16.0 REFERENCES

1. U.S. Congress, 1985. *Low-Level Radioactive Waste Policy Amendments Act of 1985.* Public Law 99-240.

2. Code of Federal Regulations Title 10, Part 61.55.

3. Code of Federal Regulations Title 49, Part 173.435.

4. Code of Federal Regulations Title 49, Part 173.463

5. Sealed Radioactive Sources – Leak Test Methods, International Organization for Standardization, Technical Report 4826, Published 1979-02-15.

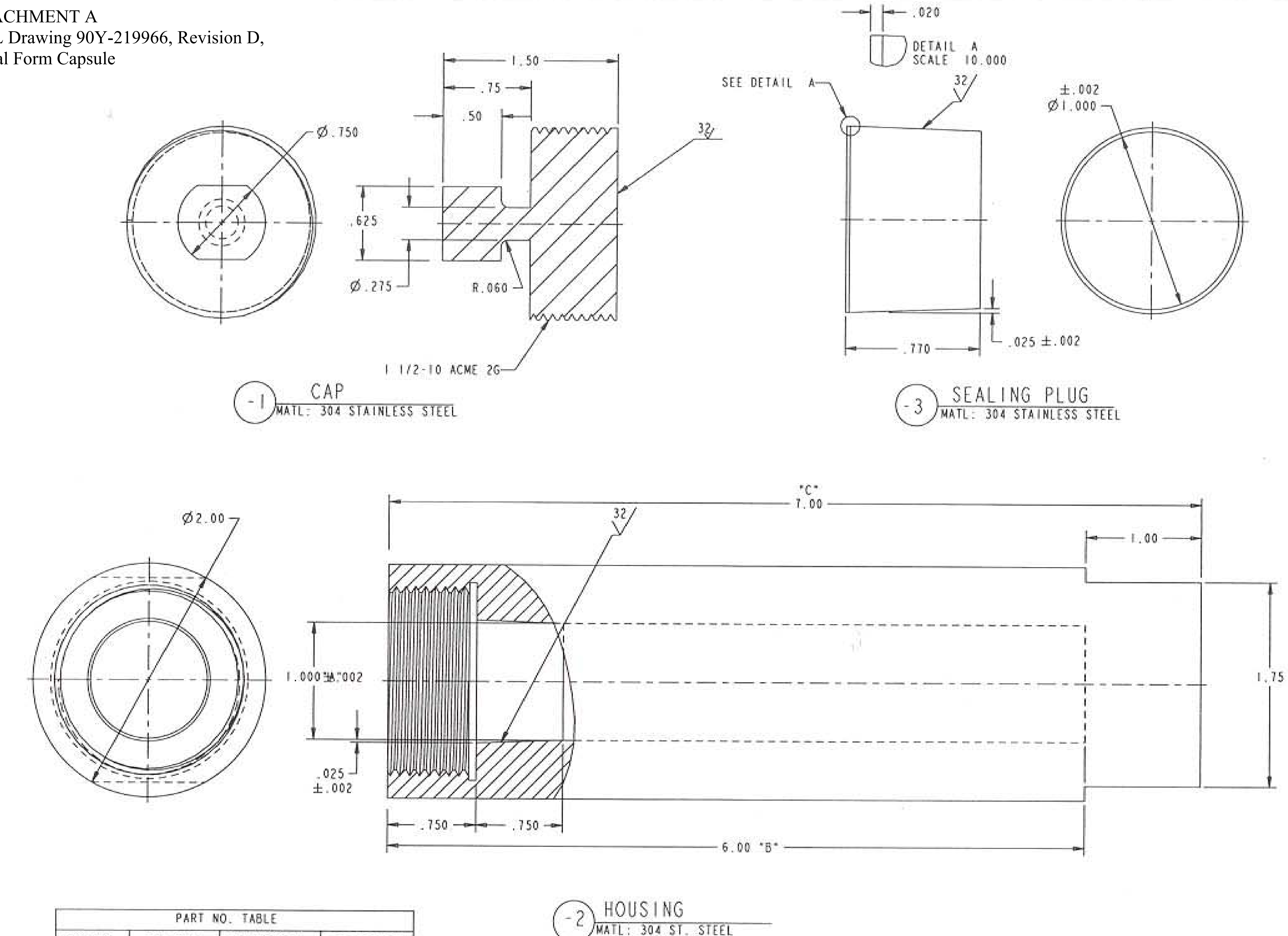
6. Radiation Protection – Sealed Radioactive Sources – General Requirements and Classification, International Organization for Standardization, ISO 2919, Second edition, 1999-02-15.

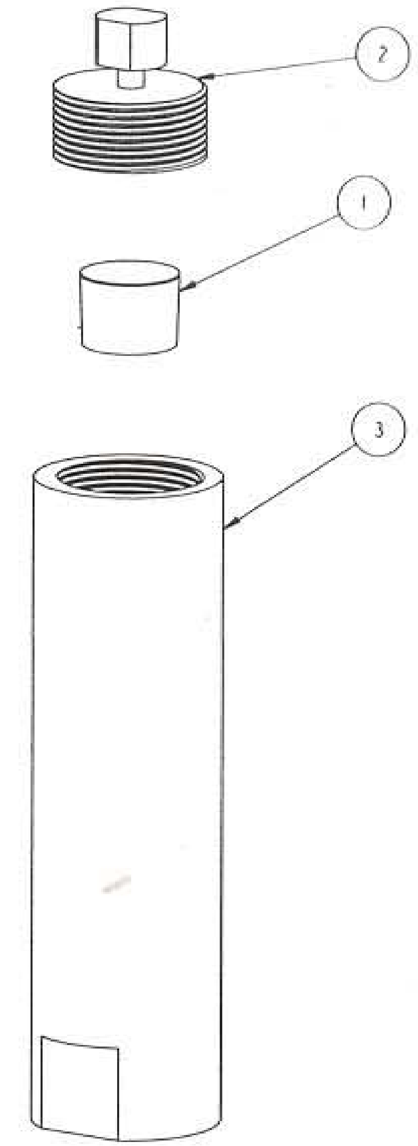
7. ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Design and Fabrication of Pressure Vessels, 1995.

8. Assembly Procedure for the Special Form Capsule, OSR-OP-160 Los Alamos National Laboratory, Off-Site Source Recovery Project, E-WMOSR, July 2001.

ATTACHMENT A
LANL Drawing 90Y-219966, Revision D,
Special Form Capsule

PREFIX NUMBER	ITEM NO.	NO. REQD	DESCRIPTION
	1	1	219966-3
	2	1	219966-1
	3	1	219966-2





PART NO. TABLE			
PART NO.	"A" DIA	"B" LENGTH	"C" LENGTH
-2	SHOWN	SHOWN	SHOWN
-4	1.0"	2"	3"
-5	1.0"	3"	4"
-6	1.0"	4"	5"
-7	1.0"	11.5"	12.5"
-8	1.0"	12.0"	13.0"
-9	1.0"	15.25"	16.25"
-10	1.0"	17.75"	18.75"

FOR TECHNICAL QUESTIONS CONTACT: Len Stapf (505) 667-5821

GENERAL NOTES (unless otherwise noted)
1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. REMOVE ALL BURRS AND BREAK SHARP EDGES, INCLUDING HOLES .015 MAX.
4. ALL INSIDE (FILLET) RADII TO BE .015 MAX.
5. COUNTERSINK 82 DEGREES ALL TAPPED HOLES TO MAJOR DIAMETER +.015".
6. ALL DIAMETRAL FEATURES SHOWN ON A COMMON AXIS SHALL BE COAXIAL WITHIN A CYLINDERICAL TOLERANCE ZONE THAT HAS A DIAMETER EQUAL TO THE AVERAGE OF THEIR TOTAL SIZE TOLERANCE.
7. WELDING SYMBOLS PER ANSI/AWS A2.4-1993.
8. SURFACE TEXTURE SYMBOLS PER ANSI/ASME B46.1 1985.
9. DO NOT SCALE DRAWING FOR DIMENSIONS.

REVISION LETTER	ZONE	REVISION DESCRIPTION	DATE	CHANGED BY	CHECKED BY	APPROVED BY
D		ADDED -7 THRU -10	JUL 01	LHS		
C		DELETED BLEED HOLE	SEPT 00	LHS		
B		ADDED 32 FIN TO -2 & -3	AUG 00	LHS		
A		GEN REV & ADDED SIZE TABLE FOR -2	JUL 00	LHS		
0A	-	RELEASED				

Los Alamos
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545

CLASSIFICATION OF DRAWING UNC. PART UNC. TITLE BLOCK UNC

ESA-EPE
ENERGY & PROCESS ENGINEERING

DRAWING NAME: 219966.DRW
MODEL NAME: 219966.PRT

DESIGNED BY	D.MARTINEZ	JAN 00	ESA-EPE
DRAWN BY	[signature]	JAN 00	ESA-EPE
CHECKED BY	C. ABEYTA	JAN 00	ESA-EPE
PROJ. ENG.	D.MARTINEZ	JAN 00	ESA-EPE
CLASS. RVW.	G. READ	JAN 00	ESA-EPE
CUSTOMER	L.LEONARD	JAN 00	E-WMOSR
RELEASED	[signature]	JAN 00	ESA-EPE

LANL
SPECIAL FORM CAPSULE
MODEL 1

TOLERANCE (UNLESS OTHERWISE NOTED)

DRAWING No. 90Y 219966 D SHEET 1 OF 1

$P_H = (t^2/CD^2)*S$ 6261 psi P_H = Head stress limited maximum internal pressure

0.770	t = thickness of plug (inches)
0.750	C = 0.75, geometry factor
1.000	D= plug OD (inches)
7920	S= allowable stress (304 SS, psi at 800C)

$P_S = (t_{plug}/2D)*S$ 4356 psi P_S = shear stress limited maximum internal pressure

0.770	t_{plug} =minimum plug thickness (inches)
0.700	D= plug OD (inches)
7920	S= allowable stress (304 SS, psi at 800C)

$P_C = (SEt_r)/(R+0.6t_r)$ 4950 psi P_C = Circumferential stress limited, maximum internal P

1.000	E = joint efficiency factor
0.500	t_r = wall thickness at the welded end of capsule (inches)
0.500	R = 1/2 * D
7920	S= allowable stress (304 SS, psi at 800C)

$P_L = (2SEt_r)/(R-0.4t_r)$ 13200 psi P_L = Longitudinal stress limited, maximum internal P

1.000	E = joint efficiency factor
0.500	t_r = wall thickness at the welded end of capsule (inches)
0.500	R = 1/2 * D
7920	S= allowable stress (304 SS, psi at 800C)

P_H =	6261	psi	P_H = Head stress limited maximum internal pressure
P_S =	4356	psi	P_S = shear stress limited maximum internal pressure
P_c =	4950	psi	P_c = Circumferential stress limited, maximum internal pressure
P_L =	13200	psi	P_L = Longitudinal stress limited, maximum internal pressure

It should be noted that P_S (4,350 psi) is the limiting maximum internal pressure value, based on shear stress in the capsule head plug. Analysis of the threaded portion of the Cap indicates that 15,690 psi would be required to cause a shear failure of the Threaded Cap portion of the SFC 1.

"There is to be acknowledeged for the head stress analysis here employed the requirement that, as stated in the Code, discussion regarding Fig. UG-34(q), design of the welded joint against failure in shear must be based on a factor of safety of at least 4 (p. 24)." Reference: Monsanto application for C of C to US DOT on MRC 2720 series capsules (US/0043/S), 12-10-81. Capsule stresses are analyzed using the methods specified in *Rules for Construction of Pressure Vessels, Division 1, 1971 Edition, Boiler and Vessel Code, Section VIIII.*

Load to produce failure in shear of threaded cap portion of SFC 1
(Refer to LANL Drawing 90Y219966, mod. 1)

The first requirement of the cap is that the threaded portion engage the body of the SFC to a depth sufficient to prevent stripping of the threads. The required minimum depth of engagement is calculated as follows:

L_e = length of engagement = the depth to which a thread machine screw must be engaged to prevent stripping of the threads (as opposed to fracture of a screw) as a mode of failure.
L_e = (2Ai)/(3.1416Kn max[0.5 + 0.57735n(Es min - Kn max)] = 0.69"

The SFC has a depth of engagement of 0.75", which exceeds the 0.69" minimum calculated above.

n =	threads per inch	= 10 threads/inch
D =	basic major diameter of the thread	= 1.500"
K_n max =	maximum minor diameter of the internal thread	= 1.400"
E_s min =	minimum pitch diameter of the external thread	= 1.490"

Load to Shear threads on the Threaded Cap of the SFC

P = direct tensile load (lb. force)
S = ultimate tensile strength (psi, @800 C) = 7920 psi
Ai = tensile stress area = 0.7854 x $(D-(0.9743/n))^2$ = 1.55 in^2

P = S x Ai = 7920 psi x 1.55 in^2 = 12,237 lb. force

Internal Pressure Required to generate this force

Pressure internal = P/Area of plug = 12,237 lb.force / 0.78 in^2 = 15,690 psi of internal pressure

Private communication from D. Martinez, LANL/ESA-EPE (6-8-00): Empirical data indicate that 250 lb. force is required to start shearing process on externally pulling plug from its seat. Seal plug area is equal to Asplug = 3.1416 x $(0.5)^2$ = 0.785 in^2. The minimum interior pressure required to generate that force is equal to 250 lbf/0.785 in^2 = 318 psi. This does not take into consideration the force necessary to remove the screw threaded cap that seated the plug.

PACIFIC TESTING LABORATORIES, INC.
24950 Avenue Tibbetts, Valencia, CA 91355-3426, USA • TEL: (661) 257-1437 • FAX: (661) 257-2411

CERTIFICATE OF TESTING FOR USDOT SPECIAL FORM CAPSULE
LANL DRAWING 90Y-219966

This certifies that the specimens of Special Form Radioactive Material Capsules, manufactured in accordance with the above-cited drawing, have been tested to meet the requirements established in 49CFR173.469, and have been found to be in compliance with, the following specifications:

1) ANSI/HPS N 43.6-1997 Sealed Radioactive Sources, Classification

2) ESA-EPE-ADM-013.0 Revision 1 Special Form Radioactive Material Capsule Specification Testing, Approved February 28, 2000

The following physical tests were performed:

1) Impact
2) Percussion
3) Bending
4) Heat

Test results are compiled in Test Report #20545, and are held on file for review by authorized individuals, upon request.

Signed: ______________________
Frank Barrett
Quality Control Manager

Dated: 7-13-00

Signed: ______________________
Michael Shin
Laboratory Director

Dated: 7-13-00