

DEVELOPMENT AND CERTIFICATION OF A SPECIAL FORM CAPSULE (MODEL III) FOR SEALED SOURCES TO FACILITATE TRANSPORTATION AND STORAGE AS SPECIAL FORM MATERIAL

By

Danny A. Martinez, Cristy L. Abeyta, Leroy E. Leonard,
Shelby J. Leonard, J. Andrew Tompkins

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, safety and national security; 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. In 2000, the OSR Project developed a sealed source overpack 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. A key feature of the SFC was that it could be easily assembled in the field and 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. After successful testing of the Model I and Model II, it was decided to fabricate a third capsule to accommodate the many source sizes. The Model III, with an internal diameter of 1.5 inches was then fabricated and tested. This third model of the LANL SFC has been tested and certified to meet all requirements specified in Title 49 Part 173 of the Code of Federal Regulations, Section 469 (49CFR173.469). Its development expands the capabilities of the OSR Project and Department of Energy (DOE) to efficiently transport and store sealed sources.

Table of Contents

| | |
|--|---|
| Storage as Special Form Material..... | 1 |
| I. INTRODUCTION | 3 |
| II. SCOPE..... | 3 |
| A. SEALED SOURCE | 3 |
| B. SPECIAL FORM | 3 |
| III. DEVELOPMENT..... | 3 |
| IV. GENERAL DESCRIPTION..... | 3 |
| V. FEATURES OF THE SFC | 4 |
| VI. SFC COMPONENT SPECIFICATIONS | 5 |
| VII. SPECIAL FORM TESTING | 5 |
| VIII. TEST CRITERIA | 5 |
| A. IMPACT TEST..... | 5 |
| B. PERCUSSION TEST | 5 |
| C. HEAT TEST..... | 6 |
| D. LEAK-TIGHTNESS DETERMINATION METHOD..... | 6 |
| IX. TEST RESULTS..... | 6 |
| X. FABRICATION | 6 |
| XI. QUALITY ASSURANCE INSPECTION PRIOR TO USE..... | 7 |
| XII. APPLICATION OF LANL SFC..... | 7 |
| A. THERMAL LIMITS FOR THE SFC | 7 |
| XIII. FIELD LOADING PROCEDURE | 8 |
| XIV. CONCLUSION | 8 |
| XV. ACKNOWLEDGEMENTS | 8 |
| XVI. REFERENCES | 8 |

Attachments

- Attachment A. Pacific Testing Laboratories Certificate of Testing
- Attachment B. LANL Drawing 90Y-219998, Revision G, Special Form Capsule

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 Type A, 7A packages, which provide increased flexibility in shipping. In 2000, the OSR Project developed a sealed source overpack 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 and testing of the Model I SFC was documented in LAUR-02-433¹. A key feature of the SFC was that it could be easily assembled in the field and 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. After successful testing of the Model I and II, it was decided an additional capsule to accommodate the many sizes of sources. The Model III, with an internal diameter of 1.5 inches was then fabricated and tested. This third model of the LANL SFC has been tested and certified to meet all requirements specified in Title 49 Part 173 of the Code of Federal Regulations, Section 469 (49CFR173.469²). Its development expands the capabilities of the OSR Project and Department of Energy (DOE) to efficiently transport and store sealed sources.

II. SCOPE

The scope of the project was to develop an additional special form capsule to accommodate the many sizes of sources encountered in the field. The special form capsule also had to be easily sealed in the field. 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 (from *Implementing Guide for Occupational Radiation Protection* (GN5400.9/M1) *Sealed Radioactive Source Accountability and Control*³).

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

After successful testing of the Model I and II, it was decided to fabricate another capsule to accommodate the different sizes of sources. The Model III, with an internal diameter of 1.5 inches, was then fabricated and tested based upon the original design of the Model I. Initial testing resulted in a modification to the design, which incorporated a different ACME threading.

IV. GENERAL DESCRIPTION

The LANL SFC Model III has exterior dimensions of 2.5" OD x 8" long. The housing is fabricated from stainless steel 304 bar stock. The SFC incorporates a tapered plug, made of the same material. A cap utilizing 2 - 4 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 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 capsule components are shown in Figure 1.



Figure 1. Special form capsule components.

V. 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 sealing plug dimensions are controlled because the cap seating depth is the primary indicator of an appropriately sealed capsule. To seal the SFC, the sealing 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 sealing plug surface.

The relieved stem of the cap is sized 0.310" 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 SN# _____ | | |
| CONTENTS _____ | | |
| _____ | | |

Figure 2. Special form capsule laser etching.

VI. SFC COMPONENT SPECIFICATIONS

The LANL SFC consists of three components: the capsule, a sealing plug, and the threaded cap. The capsule consists of a 2.5" OD SS (304) billet 8" in length. An internal cavity 1.5" ID is machined into the billet 7" deep. A female machine screw thread (2 – 4 ACME 2G) 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 2.0° in 1.25" of length and the seat is given a #32 machine finish. The sealing plug is 0.770" in length and is sized to 1.6" OD where it joins the 1.6" ID bore of the housing.

The threaded cap for the SFC consists of a threaded (2 – 4 ACME 2G) 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 0.310" 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.

VII. 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.

VIII. 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 leaktightness be determined following each test. A brief summary of the tests is presented in IX Test Results, and a detailed copy is available upon request.

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 ± 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 1979-02-15⁴, which was prepared in support of ISO 2919⁵. 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 to 25 kN/m² (2 and 3.6 lb/in²) absolute. If no bubbles were observed, the sealed capsule was considered to be leak free.

IX. 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, impact, percussion, and heat, was performed three times using a different capsule every time. Three capsules were used for each of the tests. 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 |
| 002 | Impact | PASS |
| 003 | Impact | PASS |
| 004 | Percussion | PASS |
| 005 | Percussion | PASS |
| 006 | Percussion | PASS |
| 007 | Heat | PASS |
| 008 | Heat | PASS |
| 009 | Heat | PASS |

X. FABRICATION

All capsules are fabricated according to the design specifications in LANL drawing 90Y-220045 (see Attachment B). 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.

XI. QUALITY ASSURANCE INSPECTION PRIOR TO USE

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 a 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.

XII. 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.

A. 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 m², then a 15W/m² 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/m² 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/m² 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.

XIII. 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-170, "Assembly Procedure for the Special Form Capsule, Model I & III"⁷. The procedure provides a quality control process to ensure a compliant seal.

XIV. CONCLUSION

The design of the LANL SFC Model 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 III 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 requirements on July 13, 2000 (see Attachment B). 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.

XV. 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, James 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), Continental Machining and Standard Machining Co. (Albuquerque, NM).

XVI. REFERENCES

1. Development and Certification of a Special Form Capsule for Sealed Sources to Facilitate Transportation and Storage as Special Form Material, LAUR-02-433, February 22, 2002.
2. Code of Federal Regulations Title 49, Part 173.469.
3. *Implementing Guide for Occupational Radiation Protection (GN5400.9/M1) Sealed Radioactive Source Accountability and Control*
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.
6. Assembly Procedure for the Special Form Capsule, Model I & III, OSR-OP-170 Los Alamos National Laboratory, Off-Site Source Recovery Project, N-2, April 2005.



PACIFIC TESTING LABORATORIES, INC.

24950 Avenue Tibbitts, Valencia, CA 91355-3426, USA • (661) 257-1437 • FAX (661) 257-2411

CERTIFICATE OF CONFORMANCE

This certifies that the specimens of Special Form Capsule, manufactured in accordance with Los Alamos National Laboratory (LANL) drawing number 90Y-220045, have been tested to meet the requirements established in 49 CFR 173.469, and have been found to be in compliance with the following specifications:

1. ANSI/HPS N 43.6-1997 Sealed Radioactive Sources, Classification
2. E-WMOSR-004, 1.5" Special Form Radioactive Material Capsule Specification Testing, September 16, 2002

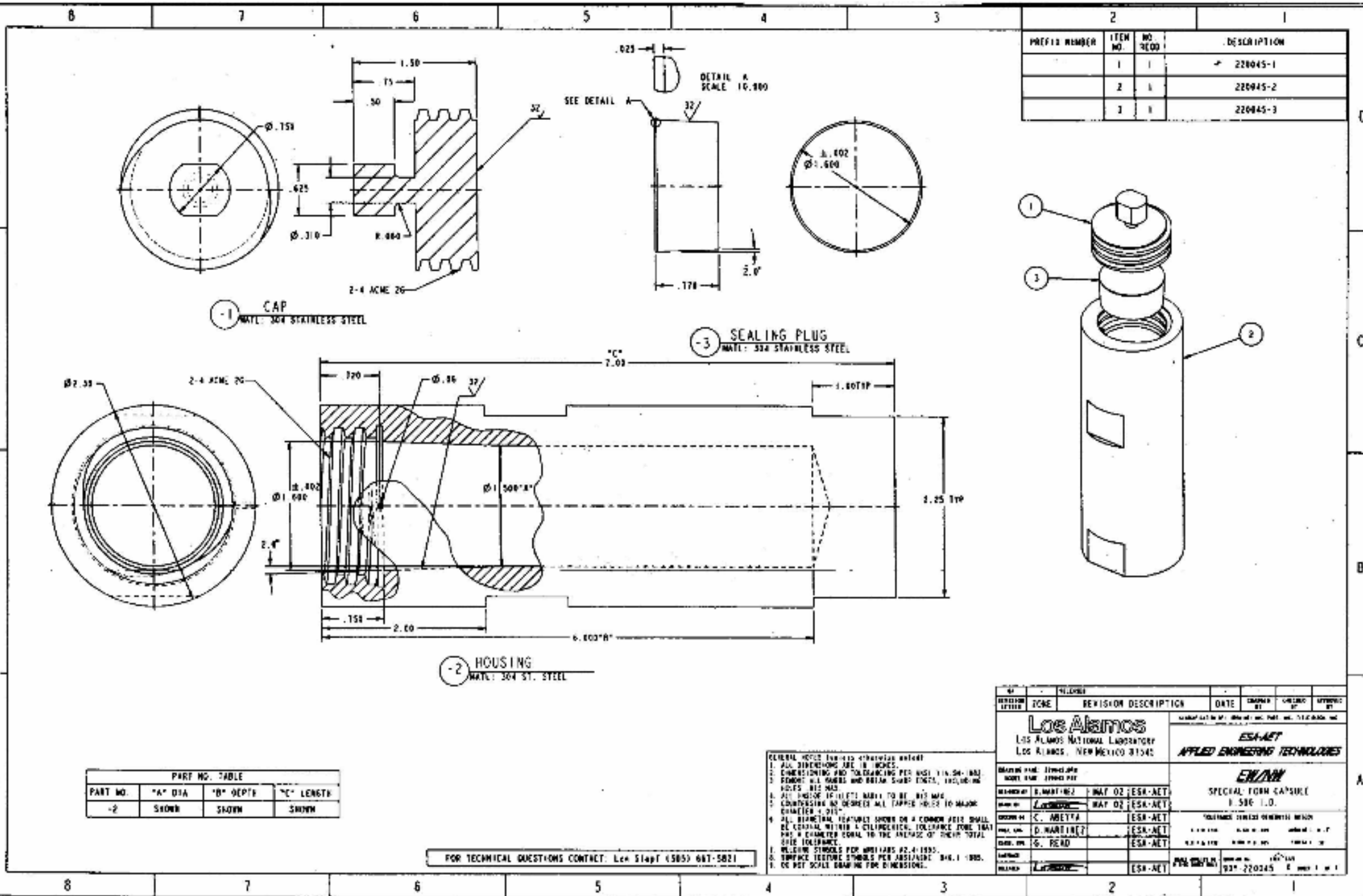
The following physical tests were performed:

1. Heat
2. Percussion
3. Impact
4. Leakage

The leakage-test performed was a vacuum-bubble test, as identified in Annex A, Method A.2.2.1 of ANSI/HPS N43.6-1997. The tests results were compiled in Test Report #25166, and are held on file for review by authorized individuals, upon request.

PACIFIC TESTING LABORATORIES, INC.

Signed:  Date: January 29, 2003
Frank Barrett
Quality Assurance Manager



| PREFIX NUMBER | ITEM NO. | REV. NO. | DESCRIPTION |
|---------------|----------|----------|-------------|
| | 1 | 1 | 220045-1 |
| | 2 | 1 | 220045-2 |
| | 3 | 1 | 220045-3 |

| PART NO. TABLE | | | |
|----------------|---------|-----------|------------|
| PART NO. | "A" DIA | "B" DEPTH | "C" LENGTH |
| -2 | SHOWN | SHOWN | SHOWN |

GENERAL NOTE: UNLESS OTHERWISE NOTED:
 1. ALL DIMENSIONS ARE IN INCHES.
 2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1987.
 3. FINISH: ALL SURFACES AND BREAK SHARP EDGES, INCLUDING HOLES AND RIMS.
 4. ALL HOLE DRILLING SHALL BE TO BE .015 DIA.
 5. CONTOURING AS SHOWN ON ALL TAPPED HOLES TO MAJOR DIAMETER + .015".
 6. ALL SURFICIAL FEATURES SHOWN ON A COMMON FINE SHALL BE CONICAL WITHIN A CYLINDRICAL TOLERANCE ZONE THAT HAS A DIAMETER EQUAL TO THE ANGLE OF THEIR TOTAL SIZE TOLERANCE.
 7. SURFACE FINISH SYMBOLS PER ANSI Z39.1-1995.
 8. SURFACE TOLERANCE SYMBOLS PER ANSI Z39.1-1995.
 9. DO NOT SCALE DRAWING FOR DIMENSIONS.

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

| REV. | DATE | BY | CHKD. | APP'D. | DESCRIPTION |
|------|---------|---------|-------|--------|---------------------------|
| 1 | 10/1/00 | ESR-AET | | | INITIAL DESIGN |
| 2 | 10/1/00 | ESR-AET | | | REVISED TO ADD DIMENSIONS |
| 3 | 10/1/00 | ESR-AET | | | REVISED TO ADD DIMENSIONS |

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

ESR-AET
 APPLIED ENGINEERING TECHNOLOGIES

ESR-AET
 SPECIAL FORM CAPSULE
 1-530 I.D.

| REVISION | DATE | BY | CHKD. | APP'D. | DESCRIPTION |
|----------|---------|---------|-------|--------|---------------------------|
| 1 | 10/1/00 | ESR-AET | | | INITIAL DESIGN |
| 2 | 10/1/00 | ESR-AET | | | REVISED TO ADD DIMENSIONS |
| 3 | 10/1/00 | ESR-AET | | | REVISED TO ADD DIMENSIONS |