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THE S300 SPECIAL FORM SOURCE OVERPACK

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ABSTRACT

To transport certain plutonium-beryllium neutron sources, a Type AF fissile material packaging was needed. Since the sources were destined for final disposal, they were first packaged in strong, leak tight special form capsules. The demands on the packaging were thereby reduced such that a simple shielded drum would suffice. The packaging chosen was based on the pipe overpack, designed as a container for use within the TRUPACT-II shipping package.

Type AF packages are required to maintain criticality control of the fissile material while subjected to the full hypothetical accident sequence of tests. In this case, it was also required to maintain the leak tight integrity of the special form capsule. The novel licensing approach taken in the case of the S300 was to propose that the packaging was progressively expendable, and that each accident event could permanently eliminate a portion of the packaging structure. The key assertion, as demonstrated by the Safety Analysis Report, was that, regardless of what happened to the packaging overpack, the special form capsule would never experience an accident condition which was more severe than that experienced during qualification testing of the special form capsule. This was accomplished without any additional physical testing. This paper will discuss the details of the licensing demonstration.

INTRODUCTION

The Off-Site Source Recovery Project at Los Alamos National Laboratory (LANL), as part of the National Nuclear Security Administration's (NNSA) Office of Global Threat Reduction, recovers and manages excess and unwanted radioactive sealed sources that present a risk to public health and safety, and for which no disposal options currently exist. Primary focus has been on neutron sources of the Americium-Beryllium (AmBe) and Plutonium-Beryllium (PuBe) types. The sources are collected and shipped for temporary storage at LANL, with eventual disposal at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Sealed sources that lack the appropriate certifications or are known to be leaking can be transported by placement within a field-closable special form capsule (SFC). As special form, the source can be shipped in a neutron-shielded Type A package. The S300 package, based on a shielded 55-gallon drum, was developed and certified for this purpose.

However, there are two difficulties with this approach when plutonium is present:

- 10 CFR 71.23 [1] provides a general license for transport of PuBe sources, but there is no comparable provision in IAEA regulations (TS-R-1) [2]. If international transport is needed, the Part 71.23 general license does not apply.
- In the case where Pu-239 is the isotope, 10 CFR 71.23(d)(3) limits the Pu-239 to 120g for non-exclusive use and 240g for exclusive use. If greater quantities need to be transported, a Type A package cannot be used.

For these cases, a Type AF package (Type A package with approved fissile content) is required. In the U.S., Type AF packages, unlike ordinary Type A packages, are licensed by the U.S. Nuclear Regulatory Commission (NRC). The S300 Type A package was licensed as a Type AF without further testing. This was accomplished by showing that the package met all of the hypothetical accident requirements delineated in 10 CFR 71.73.

THE S300 TYPE A PACKAGE

The S300 Type A package has existed since 2002 for transport of neutron sources in special form. It meets all U.S. Department of Transportation (DOT) requirements for Type A packaging as delineated by Title 49 CFR. It also has obtained approval from the NRC for use as a payload container within the TRUPACT-II. A cross-section of the S300 is shown in Figure 1. Components of the S300 are identified in Figure 2. (Figures are grouped at the end of the paper.)

The S300 is based on a standard, 55-gallon steel drum. Within the drum is a close-fitting, rigid poly liner which protects a thick layer of cane fiberboard dunnage. Nested within a cavity of cane fiberboard is a 12-inch steel pipe component, consisting of a Type 304 stainless steel pipe section body, a flat closed end, and a flat bolted lid. Within the pipe component is an approximately four-inch (100 mm) thick, high-density polyethylene shield insert (not shown in Figure 2).

A cross section of the inner 12-inch pipe component and shield insert are shown in Figure 3. The payload cavity is 3.5 inches (90 mm) in diameter and 13 inches (330 mm) long. Into this cavity is placed the SFC, containing the sealed neutron source. The SFC is shown in Figures 4 and 5.

This package configuration was successfully evaluated against the relevant requirements of 49 CFR parts 173 and 178 [3], including physical vibration and free drop testing of prototype units.

SPECIAL FORM CAPSULE (SFC)

Under the Type AF package certification, the S300 can transport two different special form capsules, designated as “Model II” and “Model III.” Each capsule is of essentially identical design, with differences only in relative size. The Model II and Model III were developed to provide field-closable capsules that met the requirements for special form as delineated in 10 CFR 71.75.

Made entirely of Type 304 stainless steel, they consist of a cylindrical body, a tapered sealing plug, and a threaded cap as shown in Figures 4 and 5.

After placing the sealed source(s), an impact disk, and snap ring inside a capsule, a tapered plug is inserted and retained by a threaded cap. Upon continued tightening of the threaded cap, the shearable cap stem shears off, with the result being a leak tight capsule that cannot be reopened. Prototype specimens of both versions of the capsule demonstrated leak-tightness after being subjected to all physical tests required by 10 CFR 71.75. The Model II and Model III capsules are approved special form sources under the following IAEA Certificates of Competent Authority:

- Model II – USA/0696/S-96
- Model III – USA/0695/S-96

TYPE AF LICENSING STRATEGY

The goal of the project was to obtain a Type AF license for the S300 without further prototype testing. As it stood at the outset, the S300 had been tested and evaluated to the DOT requirements, but not to the much more stringent requirements of the hypothetical accident conditions (HAC) of 10 CFR 71.73. (The DOT requirements for Type A are very similar to the normal conditions of transport (NCT) tests of 10 CFR 71.71.) To obtain approval for the S300 as a Type AF package, the strategy was to demonstrate in the safety analysis report (SAR) that the S300 packaging could protect the SFC from conditions more severe than it experienced in the physical testing for special form approval. It could then be assured that, since the SFC was leak tight under special form test conditions, it would be leak tight under the Part 71 hypothetical accident conditions.

The proposed safety demonstration also addressed criticality control and shielding. Both are relevant to the neutron sources due to their use of fissile Pu-239 and to their production of neutrons. First, for criticality, it was shown that an infinite array of bare SFCs is subcritical under worst-case moderation, giving the package a criticality safety index (CSI) of zero. Second, the bare capsule dose rate at 1-m was below 10 mSv/h. In fact, the contents were limited to 206g of Pu-239 for non-exclusive use or 350g for exclusive use by the dose rate limits under NCT of 2 mSv/h, surface.

THE LICENSING DEMONSTRATION

The licensing demonstration depended on the similarity which exists between the special form tests of Part 71.75 and the HAC tests of Part 71.73. Principally, this similarity consists in a free drop from 30 ft (9 m) onto an unyielding surface, and in a heat or fire test, having an ambient temperature of 1,475 °F (800 °C). At the conclusion of special form testing, the SFC was leak tight. Therefore, it follows that the SFC would be leak tight following the HAC accident sequence as long as the S300 packaging protected it from structural or thermal conditions any more severe than it experienced in the special form test sequence. In fact, since an infinite array of bare capsules is subcritical, and since a bare capsule meets accident condition dose rate limits, it is not necessary that any of the S300 packaging components (excluding the SFC) actually survive the accident sequence intact. In this way, the components of the S300 can be considered progressively expendable.

The licensing demonstration was structured to consider each of the HAC events in sequence, including a conservative estimate of the worst-case consequences of the event. These considerations will now be reviewed in detail:

- *Free Drop.* Part 71.73(c)(1) requires a free drop of the specimen through a distance of 30 ft (9 m) onto a flat, horizontal, unyielding surface. Although the S300 was not drop tested, it was possible to show from prior testing of drums containing a similar pipe component that the pipe component and its lid would remain intact. The deformation of the drum and of the cane fiberboard also ensured that the impact experienced by the SFC was less severe than occurred during special form qualification testing of the capsule, in which the bare capsule struck the ground from 30 ft (9 m). Therefore, the HAC free drop event was bounded by the equivalent special form qualification free drop. However, there is data in the literature which indicates that the lid of a standard 55-gallon drum may become detached in the worst-case impact orientation. Therefore, it was conservatively assumed that the intact pipe component, containing the SFC, was ejected from the drum following the free drop event.

- *Crush.* Part 71.73(c)(2) requires the impact of a 1,100 lb (500 kg) plate falling from a height of 30 ft (9 m) onto the specimen which is resting on the unyielding surface. An intact drum could easily withstand this impact without damage to the SFC, but due to the conservative assumption regarding the outcome of the prior free drop, it was necessary to evaluate the impact of the plate on a bare pipe component. Again, a physical test of this nature was not performed on the pipe component. Instead, it was shown using conservative hand calculations that the polyethylene shield insert would protect the SFC from excessive loads. However, it was also assumed that the impact of the plate on the pipe component, lying on the unyielding surface, could lead to failure of the lid bolts and consequent removal of the lid. Due to the postulated loss of the pipe component lid, the bare SFC was now assumed to have fallen out of the pipe component and shield insert body.

- *Puncture.* Part 71.73(c)(3) requires that the specimen be dropped through a distance of 40 inches (1 m) onto a six-inch (150-mm) diameter, flat-ended, mild steel puncture bar. Due to the assumed removal of the SFC from the pipe component, it was necessary to evaluate the puncture test on the bare capsule. However, due to the small size of the capsule, the flat top of the bar was equivalent to the unyielding, flat surface onto which the SFC was dropped from a height of 30 ft (9 m) during special form qualification testing. Therefore, the puncture test was easily bounded by the special form qualification free drop test.

- *Thermal.* Part 71.73(c)(4) requires exposure of the specimen to a fully engulfing hydrocarbon fire having an average flame temperature of at least 1,475 °F (800 °C) for 30 minutes. In contrast, the thermal test required under special form qualification, Part 71.75(b)(4), requires that the capsule be heated to a temperature of 1,475 °F (800 °C) for 10 minutes.

  The HAC test specifies an environment, whereas the special form test specifies a specimen material temperature and duration. As noted above, all of the S300 packaging components were assumed to be removed by the free drop and crush tests, and the SFC was exposed to the HAC thermal test as a bare capsule. Conservative hand calculations were used to show that the SFC reaches the flame temperature of 1,475 °F (800 °C) just 11 minutes before the end of the 30 minute fire test duration, which is essentially identical to the material temperature of 1,475 °F (800 °C) for 10 minutes required by the special form qualification test. Therefore, the HAC thermal test did not expose the capsule to a condition more severe than it had been exposed to in special form qualification testing.

- *Immersion.* Part 71.73(c)(6) requires immersion of the specimen under a head of water of at least 50 ft (15 m). In this case, an undamaged S300 would need to be considered, but regardless of the response of the S300 packaging components to immersion, the problem resolved into one of external pressure on the SFC. There was no equivalent special form qualification test; however, it was possible to show that the relatively modest pressure of 21.7 psig (150 kPa) would have no effect on the SFC, especially considering that the pressure would act in the direction to push the tapered sealing plug deeper into its seat. Therefore it was shown the immersion test would have no significant effect on the SFC.

Thus, at the conclusion of all of the HAC tests, it is seen that the Model II or Model III capsules would not experience conditions more severe than experienced in special form qualification testing, and that the capsules would remain leak tight and subcritical after the HAC accident sequence.

CONCLUSIONS

The S300 Type AF package received an NRC Certificate of Compliance and an DOT Certificate of Competent Authority (USA/9329/AF) without additional prototype testing by showing that the consequences of the HAC accident sequence would be no more severe than the test conditions to which the capsules had already been exposed during special form qualification testing. Since the bare capsule was subcritical in an optimally moderated infinite array, and since the dose rate was within acceptable HAC limits, it was possible to view the S300 packaging components as expendable. Using conservative assumptions regarding accident damage, it was shown that, even though the S300 packaging might not survive the accident sequence intact, the leak tight capability of the SFC was maintained.

ACKNOWLEDGMENTS

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REFERENCES

1. Title 10, Code of Federal Regulations, Part 71, *Packaging and Transportation of Radioactive Material*.
2. TS-R-1, *Regulations for the Safe Transport of Radioactive Material*, International Atomic Energy Agency (IAEA).
3. Title 49, Code of Federal Regulations, Part 173, *Shippers—General Requirements for Shipments and Packagings*, and Part 178, *Specifications for Packagings*.

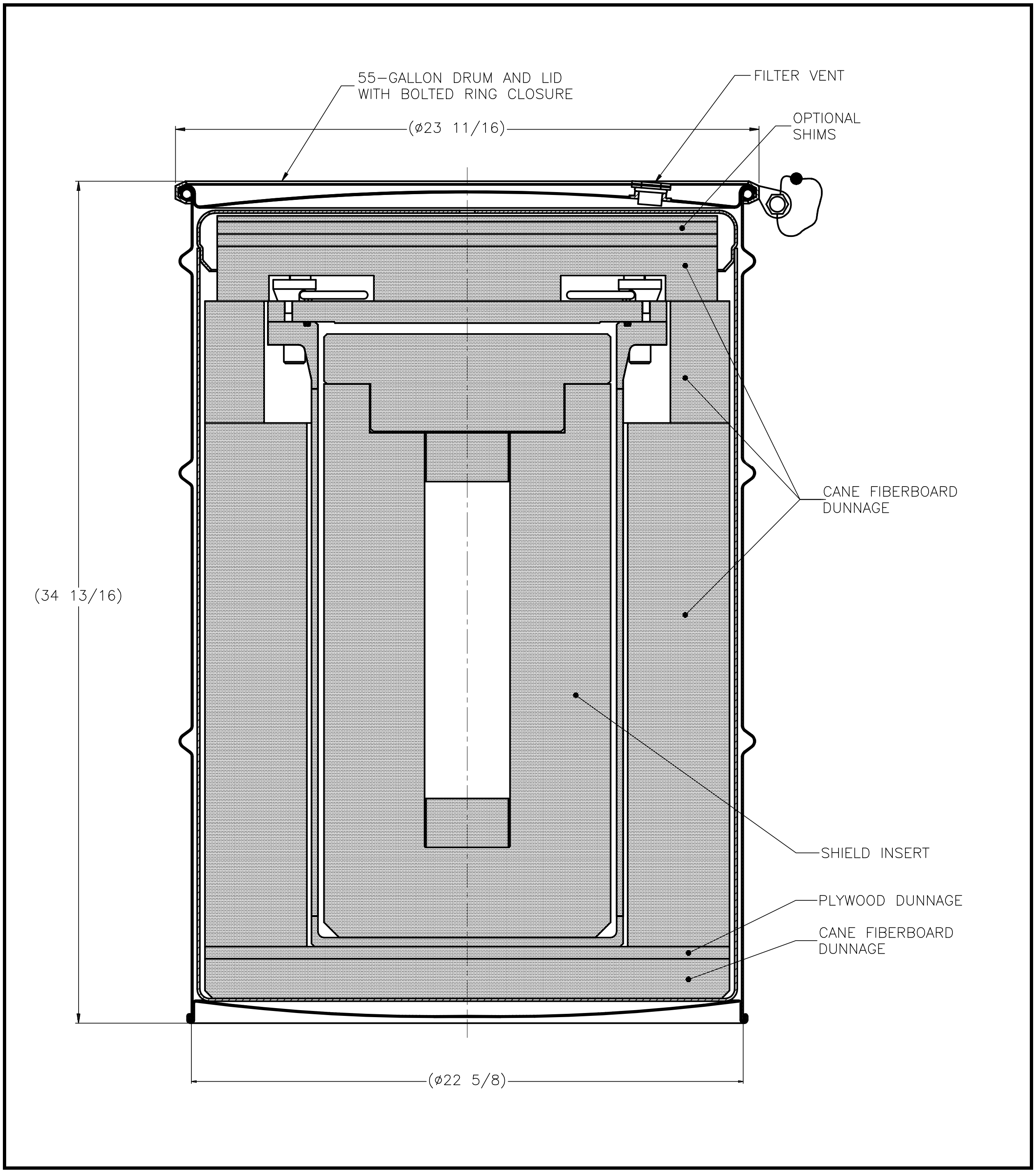

Figure 1. Cross Section of the S300

Figure 2. Components of the S300

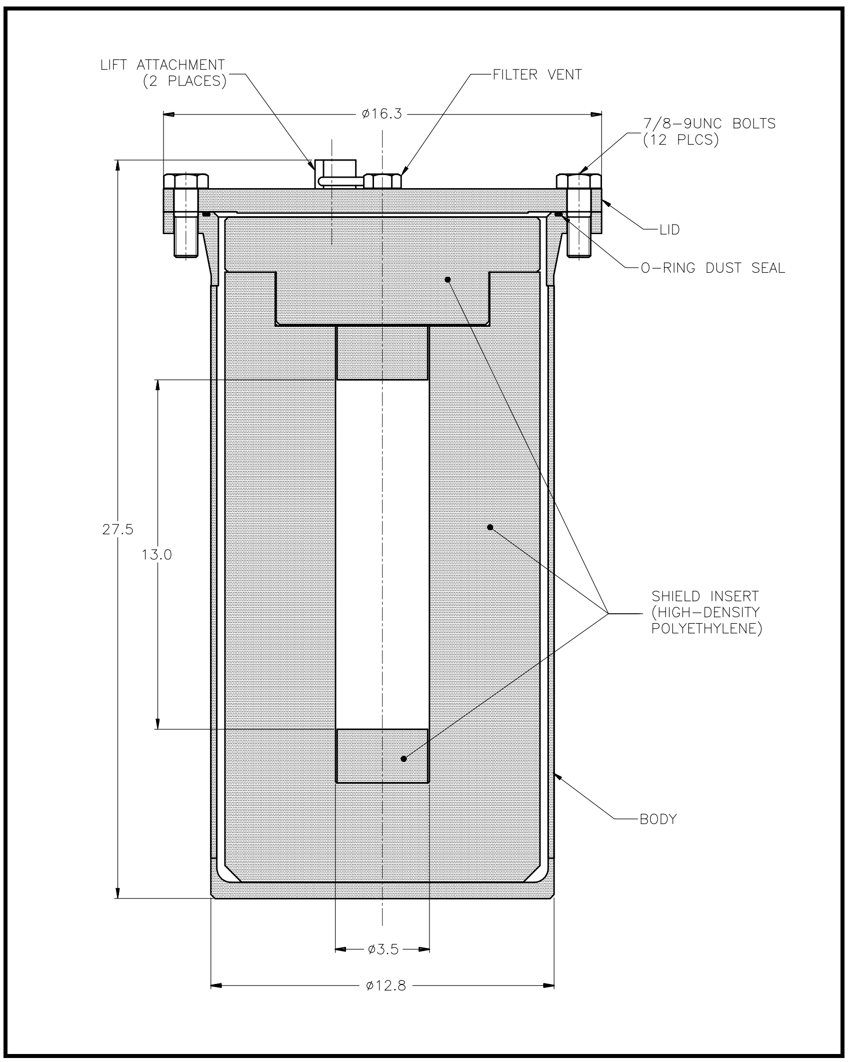

Figure 3. Cross Section of the 12-inch Pipe Component

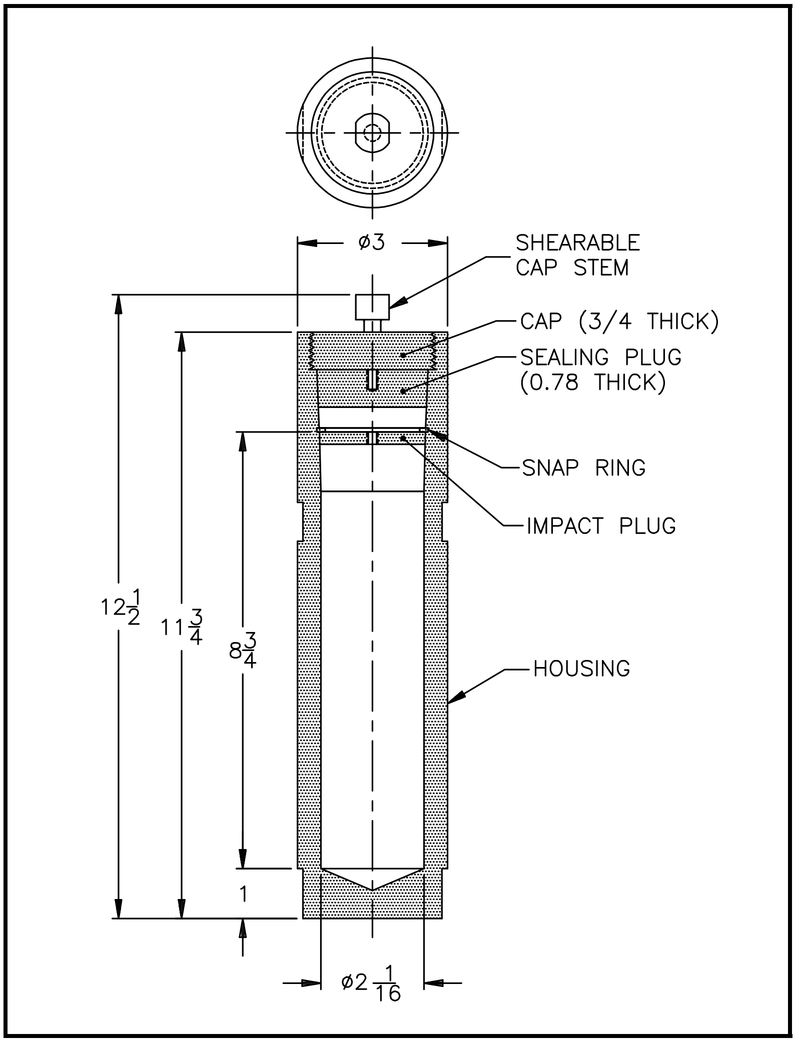

Figure 4. Cross-section of the Model II Special Form Capsule

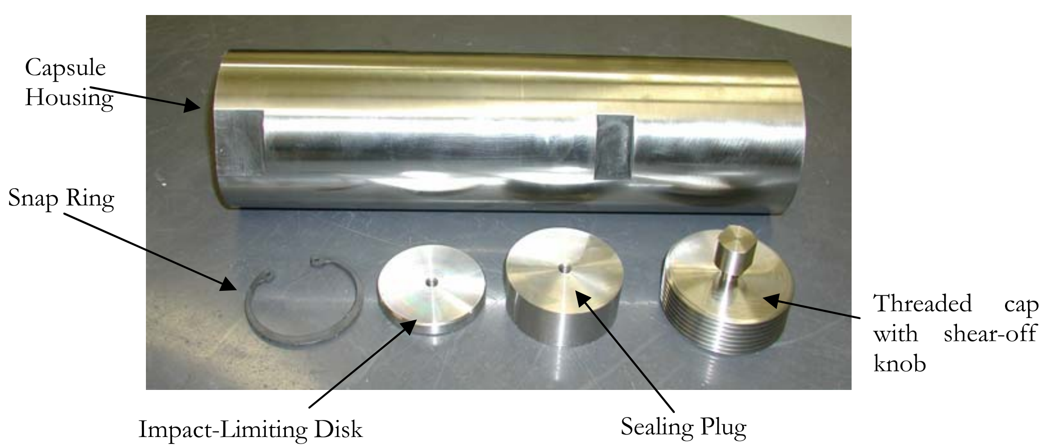

Figure 5. Components of the Model II Special Form Capsule