ENSURING THE 50 YEAR LIFE OF A FISSILE MATERIAL CONTAINER

R. E. Glass (1) and T. L. Towne (1)

(1) Sandia National Laboratories*, Albuquerque, NM USA

Summary

Sandia was presented with an opportunity in 1993 to design containers for the long term storage and transport of fissile material. This program was undertaken at the direction of the US Department of Energy and in cooperation with Lawrence Livermore National Laboratory and Los Alamos National Laboratory which were tasked with developing the internal fixturing for the contents. The hardware is being supplied by Allied Signal Federal Manufacturing and Technologies, and the packaging will occur at Mason and Hangar Corporation's Pantex Plant. The unique challenge was to design a container that could be sealed with the fissile material contents; and, anytime during the next 50 years, the container could be transported with only the need for the pre-shipment leak test. This required not only a rigorous design capable of meeting the long term storage and transportation requirements, but also resulted in development of a surveillance program to ensure that the container continues to perform as designed over the 50-year life.

This paper addresses the design of the container, the testing that was undertaken to demonstrate compliance with US radioactive materials transport regulations, and the surveillance program that has been initiated to ensure the 50-year performance.

Design

The design of the container required the proper selection of materials, closure mechanism, and leak test capability. The first criterion in materials selection was the performance of the packaging in both normal and hypothetical accident conditions. To meet these rigorous criteria, the ability of the package to remain leak tight while being subjected to the drop, crush, puncture, and fire criteria was paramount. In addition to these criteria, it was also important to ensure that the materials did not deteriorate over the 50-year life of the packaging. This meant that the materials used in the construction of the container while being stored in a radiation field at elevated temperatures, do not experience any significant degradation of material properties.

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Following the selection of materials, it was important to determine the method of closure. The requirement that the container be capable of being transported following 50 years of storage, in combination with the requirement to maintain an inert internal environment, led to the selection of a welded closure. Elastomeric o-rings were deemed unsuitable for long-term storage due to the limited shelf life of the materials.

Initial leak testing occurs through a fitting that is attached to a 3/8 inch stainless steel backfill tube that is welded to the interior wall of the containment vessel. The initial test verifies the leak tightness of the girth weld and containment vessel body. A purge and backfill process then fills the container with an inert atmosphere. The backfill tube is then crimped and welded to provide the hermetic seal, and a final leak test is performed on the purge and backfill tube. Future leak testing is then performed in an evacuated envelope with a mass spectrometer used to detect the inert backfill gas. The tube can be perforated with a laser and a sample of the gas taken to ensure that the backfill gas remains in the container; then the laser is defocused to reweld the hole. An ultrasonic inspection of the girth weld, prior to transport, demonstrates the structural integrity of the weld.

A cross section of the container is shown in Figure 1. The AT-400A container has the following four major components: (1) a protective overpack, (2) insert assemblies, (3) containment vessel, and (4) internal fixturing. The protective overpack consists of a standard stainless steel drum and liner filled with a high density polyurethane foam. The overpack is closed with 16 silver-plated stainless steel cap screws. Internal to the overpack are two stainless steel clad foam insert assemblies. The insert assemblies provide structural and thermal protection for the containment vessel. The containment vessel consists of a stainless steel weldment of an upper and lower shell. The lower shell provides attachment points for the internal fixturing. The upper shell provides access to the containment vessel through a backfill tube. The internal fixturing consists of metal components designed to provide the thermal and structural response required by the contents. The containment vessel and fixtures are cleaned to ensure that no organic materials remain within the containment boundary. The final assembly processes for the containment vessel are: (1) the welding together of the upper and lower shells, (2) the back filling and leak testing of the containment vessel with an inert gas, and (3) the crimping and welding of the backfill tube.

Materials and fabrication processes were selected to minimize the possibility of corrosion of the stainless steel components. The drum, liner, insert covers, and all containment vessel components are 304L, and the filler material for the welds is 308L. To minimize corrosion, as the stainless steel components were fabricated, machining was only performed with the use of cutting fluids that had minimal levels of sulfur and chlorine; and, during the handling of the parts, contact was restricted to nonferrous materials. This care is also exercised during packaging operations.

The next material to be selected was the impact limiting foam. A high density polyurethane foam was selected. While this material has been used extensively in packaging applications, the foam was subjected to tests to detect leachable chlorides, since leachable chlorides are corrosive. The foam was found to be free of detectable levels. The foam supplier also supplied data demonstrating that the foam, when subjected to levels of radiation greater than were anticipated for the 50-year life of the container, would incur no significant degradation.

A three-year accelerated aging study, conducted at elevated temperatures with samples of the foam, also detected no significant changes.

Normal and Hypothetical Accident Sequence Testing

Testing of the containers was performed on prototype units, development units and compliance units. Prototypes of the container were subjected to a series of normal conditions and hypothetical accident sequence tests, both empty and with contents, to demonstrate proof of concept. During the development testing, hypothetical accident sequence tests subjected each container to three drops, three dynamic crushes, and three puncture tests. These tests helped determine the most damaging orientations for the compliance tests, and due to the accumulated damage of the test, exceeded the regulatory requirements.

Also during the development testing, bare containment vessel tests were performed to evaluate the response of the containment vessel to severe environments. In particular, a bare containment vessel was subjected to hydrostatic and dynamic crush testing. The hydrostatic test failed the girth weld through ductile tearing at approximately 3750 psi. For the dynamic crush test, a containment vessel was machined to reduce the wall thickness at the weld by 25%. The containment vessel was then subjected to three dynamic crush tests with the first impact at the fill tube end and then two side impacts separated by 90 degrees. These three tests resulted in a containment vessel that was roughly cubical. Even with all the deformation, the containment vessel remained leak tight.

The compliance testing was performed to provide evidence that the container complies with the requirements of Title 10, Code of Federal Regulations, Part 71 (10CFR71). These tests used the final internal fixturing design and simulated the maximum mass of the radioactive contents. The normal conditions tests are given in Table I, the hypothetical accident sequence tests are given in Table II, and the sequence of tests that each container went through are summarized in Table III. The tests are the system engineering tests, the system compliance tests, and the shelf-life unit tests. The system engineering tests, designated SEU-XX, focused on the performance of the internal support structure as the packaging was subjected to regulatory impact events (1.2 m drop, 9 m drop, dynamic crush and puncture). The system compliance tests, designated SCU-XX, subjected the packaging and simulated contents to prescribed regulatory tests. The SCU series demonstrated that the package provides containment and limits internal temperatures throughout the hypothetical accident sequence and normal conditions tests. The shelf-life units, designated SLU-XX will repeat the compliance tests with production hardware. These tests will ensure that the container production and packaging processes are producing packages of comparable quality to the compliance test units.

The results of the SEU sequence of tests demonstrated that the internal fixturing maintained its integrity through the hypothetical accident sequence and limited the contents loading to acceptable levels during the normal conditions tests.

The results of the SCU sequence of tests showed that the package met the regulatory requirements and that the temperatures of the contents were within acceptable levels. The containment boundary remained leak tight following all tests. Figure 2 is representative of the accumulated damage that occurs to the container as a result of the 9 m drop and dynamic crush tests. The overpack is deformed somewhat, and there was a loss of three cap screws from the overpack lid. There is no visual deformation of the containment vessel. The additional damage that occurs in the puncture test is a marking and slight flattening of the impact point. The fire test results in significant amounts of foam decomposition and deposition of the resulting tars on the containment vessel. The temperature limits on the contents are not exceeded, there is no visible deformation of the containment vessel, and the containment boundary remains leak tight.

Surveillance

In addition to the processes outlined above, the AT-400A container will be surveyed during its storage life to ensure that no significant changes occur during use. This surveillance program includes a new materials testing program to establish the initial condition of the container components; a stockpile testing program to periodically sample the stockpile of containers and to test the same parameters that were established during the new materials testing program; and finally, a systems level test program in which shelf-life units, will be pulled from the stockpile and subjected to the extreme normal environments. These test programs focus on the critical parameters for container performance. For example, foam samples that will be obtained from the overpacks and insert assemblies will be subjected to the same qualifying tests established during production such as density, thermal conductivity, and compressive strength. Similar tests will be performed to ensure the integrity of the welds and to determine that corrosion is not occurring in the base materials.

New material laboratory testing (NMLT) and stockpile laboratory testing (SLT) consists of: general container evaluation during disassembly and inspection; containment vessel gas sample analysis; test and evaluation of the containment vessel welds; and overpack and insert assembly foam properties determination. The NMLT and SLT programs incorporate destructive (DT) and non-destructive testing (NDT).

Table IV illustrates the NMLT, SLT and System Level Test sampling rates and test types over the 50 -year design life of the AT-400A as a function of cycle duration.

The focus of the destructive testing is on the long term performance of the foam and the welds. The foam data replicates all of the foam qualification testing done by the manufacturer during the production of the overpacks and insert assemblies. In addition to evaluating the foam qualification data, thermogravimetric analysis (TGA) is used to ensure that the thermal decomposition of the foam is not changing over time. The girth weld data evaluates the strength of the weld and potential changes to the corrosion resistance. The backfill tube data also examines the corrosion resistance and evaluates the quality of the laser gas sampling reweld characteristics.

The system level test consists of vibration and temperature preconditioning of a shelf-life unit followed by a four foot drop test. Following completion of the system level test, the shelf-life unit will be subjected to the complete series of destructive and nondestructive testing specified for the general container evaluation. Table V lists the destructive testing.

Conclusion

The AT-400A was designed for 50 year storage and transport of fissile material. The compliance testing demonstrated that the container remains leak tight throughout the normal and hypothetical accident conditions as specified for Type B containers in the US Code of Federal Regulations.

The materials and processes used in the manufacture of the AT-400A were selected to minimize the effects of aging on the container. In conjunction with the rigor of the design, an extensive surveillance program has been put in place that will ensure that change in the characteristics of the container resulting from the long term storage of fissile materials is detected. The surveillance program includes three levels. The first level consists of the new material laboratory testing that establishes the baseline properties based on evaluation of new production containers. The second level is the stockpile laboratory testing. The stockpile laboratory testing involves both destructive and nondestructive testing of the containers to monitor the containment vessel backfill gas, evaluate the containment vessel welds and to determine the properties of the foam in the overpack and inserts. The final level of testing is the system level test. The system level test will evaluate the response of the container to the extreme normal environments.

The combination of the rigorous design and the surveillance program will ensure that the fissile [illegible] fe of the A' [illegible]

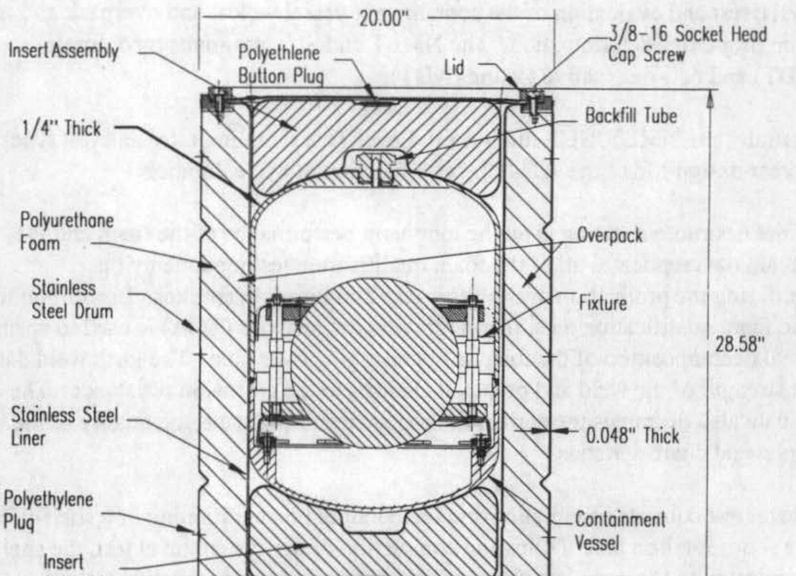

Figure 1: Cross Section of the AT-400A Container

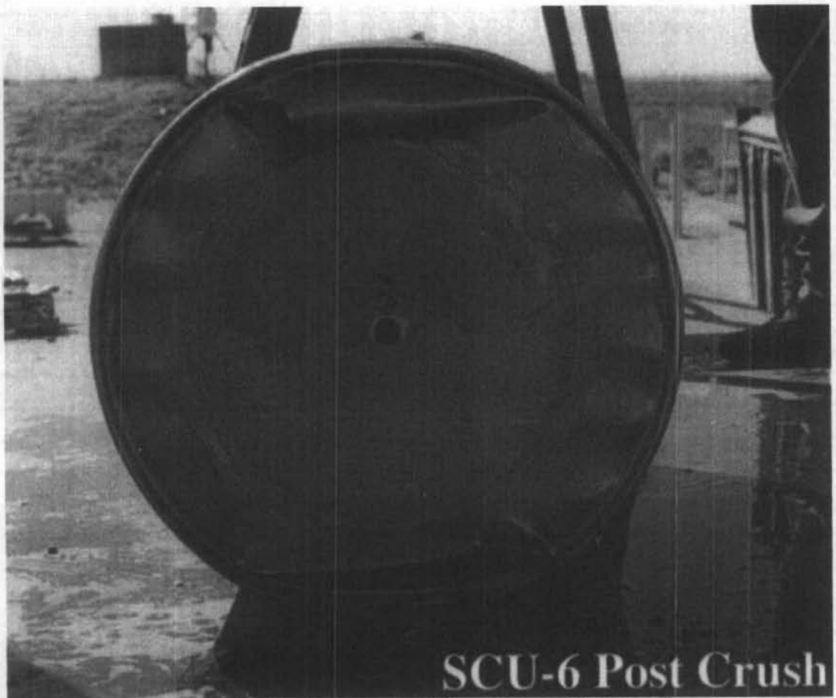

Figure 2: Cumulative damage through 9m drop and dynamic crush tests

Table I: Normal Conditions Tests

Test	Orientation	Unit	Initial Temperature
Water Spray		SCU-7/ SLU-2	Ambient
Stacking		SCU-7/ SLU-2	Ambient
1.2 m Drop	Lid down	SEU-14	-20°F
	Side	SEU-15	-20°F
	Lid up	SEU-16	-20°F
	CGOC	SEU-17	-20°F
	Lid down	SCU-6/ SLU-1	-20°F
	CGOC	SCU-7/ SLU-2	Ambient
	Lid down	SCU-7/ SLU-2	Ambient
	Side	SCU-7/ SLU-2	Ambient
Penetration	Lid	SCU-7/ SLU-2	Ambient
	Closure	SCU-7/ SLU-2	Ambient
	Side	SCU-7/ SLU-2	Ambient
Thermal		SEU-18	100°F
		SEU-19	100°F
Vibration		SCU-7/ SLU-2	Ambient
Corrosion		SCU-7/ SLU-2	95°F

Table II: Accident Conditions Tests

Test	Orientation	Unit	Initial Temperature
Immersion		SCU-6/SLU-1	Ambient
9 m Drop	Lid down	SEU-14	-20°F
	CGOC	SCU-6 /SLU-1	-20°F
Crush	Lid down	SEU-14	-20°F
	Side	SCU-6/ SLU-1	-20°F
Puncture	Lid down	SEU-14	-20°F
	Lid gap	SCU-6/ SLU-1	-20°F
Pool Fire		SCU-6/ SLU-1	140°F

Table III: Verification Sequential Tests

Unit	Order of Tests
SEU-14	1.2 m drop, 9 m drop, dynamic crush, puncture
SEU-15	1.2 m side drop
SEU-16	1.2 m drop
SEU-17	1.2 m drop
SEU-18	Normal thermal
SEU-19	Normal thermal
SCU-6	Immersion, 1.2 m drop, 9 m drop, dynamic crush, puncture, pool fire
SCU-7	Stacking, water spray, 1.2 m drop, water spray, 1.2 m drop, water spray, 1.2 m drop, penetration, penetration, penetration, vibration, corrosion
SLU-1	Immersion, 1.2 m drop, 9 m drop, dynamic crush, puncture, pool fire, fissile material immersion
SLU-2	Stacking, water spray, 1.2 m drop, water spray, 1.2 m drop, water spray, 1.2 m drop, penetration, penetration, penetration, vibration, corrosion

Table IV: System Level Test Sampling Rates for Twelve Month Cycle

Cycle	Test Type	Number of Samples	Test Breakdown
1	NMLT	6	6 DT
2 Thru end of Production	NMLT SLT	4	2 DT* 2 NDT
Post Production	SLT *	4	2 DT * 2 NDT

* System Level Test Starts in Cycle 2 and then one sample every four years.

Table V: Surveillance Destructive Testing

Component	Measurement	Remarks
		FOAM DATA
Insert Assembly	Compression	ASTM-D-1621 on 2x2x2" Samples Insert Assemblies
Overpack	Compression	ASTM-D-1621 on 2x2x2" Samples. Base, Middle and Top of Overpack
Overpack	Compression	ASTM-D-1621 on 2x2x2" Samples
Insert Assembly	Density (15 lbs/ft^3)	ASTM-D-1622 Upper and Lower Insert Assemblies
Overpack	Density (30 lbs/ft^3)	ASTM-D-1622Base, Middle and Top of Overpack
Insert Assembly	Intumescence	Use 9952037 B3 on 2x2x2" Samples. Insert Assemblies
Overpack	Intumescence	Use 9952037 B3 on 2x2x2" Samples. Base, Middle and Top of Overpack
Insert Assembly	Thermal Conductivity	ASTM C-518 on 4x4x2" Samples. Insert Assemblies **Δ Density x 0.0097.
Overpack	Thermal Conductivity	ASTM C-518 on 4x4x2" Samples. **D Density x 0.0097. Base, Middle and Top of Overpack
Insert Assembly	TGA	O&I 7-9955.2 Record weight loss to ±1% at 800^o C. (8 mg Sample) Air Flow. Base, Middle and Top of Overpack
Overpack	TGA	O&I 7-9955.2 Record weight loss to ±1% at 800^o C. (8 mg Sample) Air Flow. Base, Middle and Top of Overpack
		WELD DATA
Girth Weld	Weld Penetration	SS706213 O&I 96-208
Girth Weld	Weld Bend Face	SS706178 O&I 96-208
Girth Weld	Weld Bend Root	SS706178 O&I 96-208
Girth Weld	Weld Tensile Strength	SS706178 O&I 95-281 Tensile Strength
Girth Weld	Void/Inclusion	SS706213
Girth Weld	Delta Ferrite	SE 2433.1
Backfill Tube	Delta Ferrite	SE 2433.1
CV Tube	Laser Hole	Diameter
CV Tube	Laser Hole	Material Thickness

**Thermal Conductivity is dependent on Density. The Δ Density is difference between the Nominal (15 or 30 lbs/ft^3) minus the calculated Density.