The Development of the Russian Fissile Material and U.S. Pit Containers*

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BACKGROUND

Sandia National Laboratories has developed two container designs for the storage and transportation of radioactive materials resulting from weapons dismantlement. Each of these packages was designed to perform under similar conditions and to prevent release of contents under comparable accident conditions. There are contents specific requirements that led to differences in the final design, though the overall protection of contents is similar.

The U.S. Defense Nuclear Agency directed the development of the Russian Fissile Material Container. This program is an integral part of the Cooperative Threat Reduction program. The goal of the container program is to provide a minimum of 10,000 containers. Sandia was responsible for the design and testing of the containers. The U.S. Defense Nuclear Agency is responsible for the production of containers.

At the request of the U.S. Department of Energy (DOE), Sandia developed a Type B container for the transport of dismantled U.S. weapons components. This program takes advantage of the experience gained during the development of the Russian Fissile Material container. The goal of this program is to provide 17,000 containers that meet the current and proposed requirements of Title 10, Code of Federal Regulations, Part 71, as well as contents specific requirements.

Sandia has teamed with other DOE laboratories and agencies in developing the US Pit Container. Specifically, Los Alamos National Laboratories and Lawrence Livermore National Laboratories are responsible for the development of fixtures for their specific component systems and analyses of normal conditions, shielding and criticality; Allied Signal Kansas City is providing technical support in materials testing and production; and Mason-Hanger Pantex, as the user facility, is providing input into leak testing, marking, and facilities interface requirements.

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RUSSIAN FISSILE MATERIAL CONTAINER

The Russian Fissile Material Container program involved three phases: (1) technical exchanges between the Russians and U.S. to define the container requirements, (2) development of a design that satisfies those requirements and (3) the fabrication of 10,000+ containers. The first two phases have been completed and DNA is procuring 10,000+ containers.

Technical exchanges occurred in December 1992, June 1993, August 1993 and May 1994. The December 1992 exchange resolved that the containers should meet the accident resistance and normal conditions requirements as referenced in the AT-400R Container Requirements, dated August 31, 1993 and defined in the International Atomic Energy Agency's (IAEA) Safety Series No. 6: Regulations for the Safe Transport of Radioactive Material and that both a welded closure design and a bolted closure design were required. The June 1993 exchange addressed facilities concerns and a conceptual design that remained leak-tight following the hypothetical accident sequence and provided the acceptable thermal response during storage. At the August 1993 exchange, Sandia demonstrated the test facilities that would be used for compliance testing, presented preliminary test results and documented the final requirements document. The May 1994 exchange presented the design approved for production and provided an opportunity for the Russians to see the facilities involved in the first article production. The Russians reviewed and commented on the compliance test plan and procedures.

The requirements document provides a statement of general use, configuration control, performance requirements and test requirements. The general statement outlines the use for the container. The configuration section was based on the prototype design. It specifies the type of overpack, the need for both welded and bolted containment vessels, attachments for handling and container internal capacity and external dimensions. The performance requirements specify which IAEA sections pertain to the design and the failure criteria for those tests. It further specifies the need for tamper resistant features. The test requirements section specifies the test configuration required to appropriately simulate the Russian contents, specifies data requirements and defines the storage environment for the container.

The container designs, as shown in Figures 1 and 2, consist of a protective overpack, an insert cover housing and either a welded or bolted closure containment vessel. The protective overpack is a composite structure. The cross section from exterior to interior consists of (1) a stainless steel drum with bolted lid, (2) a ceramic paper insulation, (3) a high density polyurethane foam, (4) a molded ceramic paper insulation and (5) an inner stainless steel liner. This drum provides for corrosion resistance and protects the ceramic insulation and foam from damage during normal handling. The drum also provides confinement for the foam and insert cover housing during the hypothetical accident sequence. The closure for the drum consists of a stainless steel ring welded to the interior of the drum. This ring has 12 threaded holes for bolting the lid in place. The lid consists of a stainless steel ring dimensioned to fit within the drum and welded to a stainless steel sheet. The thermal and structural protection provided by the overpack is performed primarily by the high density polyurethane foam. The inner liner of the overpack consists of formed stainless steel. The liner provides for protection and confinement of the foam during normal handling and accident conditions. The liner also provides a heat transfer path that reduces the internal temperatures during storage and transportation.

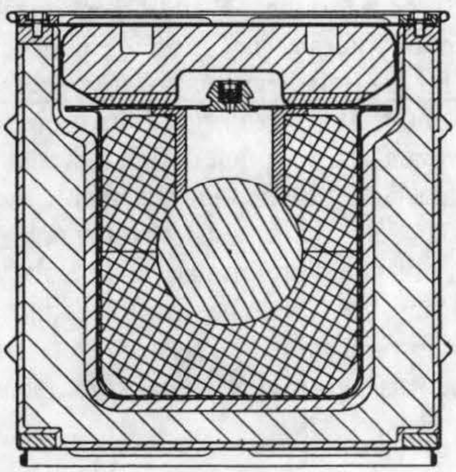

Figure 1: Russian Fissile Material Container - Welded Closure

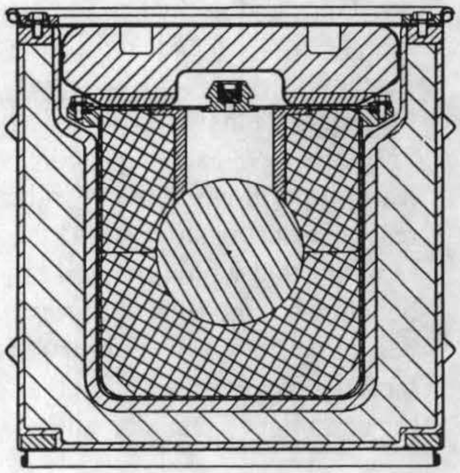

Figure 2: Russian Fissile Material Container - Bolted Closure

The insert cover housing provides the same protection as the overpack and it also consists of the same high-density foam enclosed in a stainless steel shell. The stainless steel shell also provides a heat path to reduce the internal temperatures during storage and transportation.

The containment vessel is either a welded vessel (AT-401R) or a vessel with a bolted closure and elastomeric seal (AT-402R). The AT-401R incorporates a welded closure with the capability of being opened and rewelded closed three times. This is accomplished with the extended flange. The body is welded to a stainless steel closing plate to form the AT-401R containment vessel assembly. The closing plate includes a fitting providing access to the interior of the containment vessel for leak testing, sampling and backfill. The fitting mates with a copper gasket. The gasket is formed to the sealing surface by the compressive action of a stainless steel plug to ensure a leak-tight seal.

The AT-402R containment vessel has a bolted closure. The flange includes an O-ring groove, 12 threaded holes and a shear shoulder to preclude sliding of the closing plate during impact. The containment vessel assembly is then made up by bolting the closing plate weldment to the containment vessel and compressing the O-ring to seal the assembly.

The performance specifications cover three types of tests. These are (1) normal conditions, (2) hypothetical accident sequence and (3) Russian specific tests. The first two specified IAEA tests and defined criteria for compliance with Russian requirements. The third category lists tests associated with Russian storage or operational concerns.

The development test program provided input used in defining the design. Development was terminated in December 1993 and preparations began for testing first article production units. The first of these units was used to demonstrate the normal conditions tests to the Russians in May 1994. Changes have been negotiated with DNA since May 1994 to improve performance and simplify fabrication processes. The compliance tests were begun in June 1995 and completed in October 1995. The complete compliance test sequence is given in Table I. Table I specifies the test unit and the sequence of tests to which that unit was subjected. CTU specifies a Compliance Test Unit, 401 specifies a welded closure, 402 specifies the bolted closure and the -XX specifies the number of the unit.

The table shows that 13 welded closure units were tested and 10 bolted closure units. Each type of container (bolted and welded) was subjected to a complete sequence of dynamic crush, puncture and pool fire tests in each of three orientation. The bolted closure was also subjected to a drop, puncture and pool fire sequence. For these tests, all of the temperature requirements were met and the packages remained leak-tight following the tests.

The normal conditions test sequence was performed on a bolted closure unit (CTU402-2). All of the criteria for deformation and water ingress were satisfied. The insolation test demonstrated compliance with the temperature limits for both the containment vessel and surface temperatures. The normal vibration tests simulated both road and rail transport. In the case of CTU402-4, the vibration test was used as a preconditioning test for the accident test sequence. In all cases, the normal conditions tests met the requirements.

In addition to these IAEA defined tests, the containers were subjected to tests to examine the response of the container to normal and extreme conditions of storage. These tests included extreme thermal tests (fire propagation, 1050°C), a normal heat transfer tests (normal thermal), a decontamination test (high pressure water spray) and a corrosion test. The container met the requirements of these tests.

The design of the Russian Fissile Material Container is complete. The affirmation report will be complete this month and sent to the DOE for review. DNA is currently producing containers for use in Russia.

Table I: Compliance Test Sequence

Test Unit	Test Sequence
CTU401-1	Free Drop Side, Free Drop CGOC, Free Drop End, Immersion
CTU401-2	Insolation
CTU401-3	Vibration
CTU401-4	Crush Side, Puncture Side, Pool Fire
CTU401-5	Crush End, Puncture End, Pool Fire
CTU401-6	Crush Side, Puncture Side, Pool Fire
CTU401-7	Crush CGOC, Puncture CGOC, Pool Fire
CTU401-8	Fire Propagation
CTU401-9	Fire Propagation
CTU401-10	Normal Thermal
CTU401-11	End Drop, End Puncture, Pool Fire
CTU401-12	Three rewelds, CGOC Crush, CGOC Puncture, Pool Fire
CTU401-13	Corrosion
CTU402-1	Water Spray, Water Spray, Stacking, Water Spray, Free Drop Side, Water Spray, Free Drop CGOC, Water Spray, Free Drop End, Water Spray, Penetration Lid, Water Spray, Penetration Closure, Water Spray, Penetration Side
CTU402-2	Insolation
CTU402-3	Fastener Life Cycle, Immersion
CTU402-4	Vibration, Crush Side, Puncture Side, Pool Fire
CTU402-5	Crush CGOC, Puncture CGOC, Pool Fire
CTU402-6	Crush End, Puncture End, Pool Fire
CTU402-7	Crush CGOC, Puncture CGOC, Pool Fire
CTU402-8	1050°C Radiant Heat
CTU402-9	High Pressure Water Spray, Normal Thermal
CTU402-10	Side Drop, Side Puncture, Pool Fire

US PIT CONTAINER

The U.S. packaging requirements were significantly different from the Russian requirements. In particular, the U.S. container required a larger volume and the packing scheme provided for substantially less internal structural support. The thermal requirements for the U.S. container also specified different storage conditions.

The design of the US Pit Container is shown in Figure 3. The container consists of the protective overpack, two insert assemblies and the containment vessel. The test results indicate that this packaging will meet the requirements of 10CFR71 as well as the specific project requirements.

The overpack consists of a steel/foam/steel composite wall. The performance of the overpack is similar to the Russian Fissile Material Container. The US Pit Container does not require the use of the ceramic paper insulation due to the use of an intumescing foam.

The larger size of the US Pit Container, in combination with the thermal requirements, required enhanced heat transfer during normal storage. This was accomplished with a thicker liner and two insert assemblies.

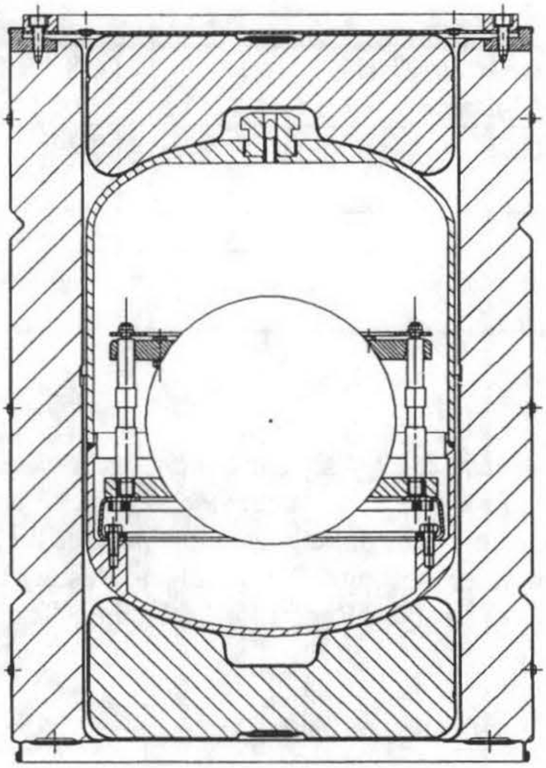

Figure 3: US Pit Container

The thermal and structural protection provided by the overpack is performed primarily by the high-density polyurethane foam. This intumescing polyurethane foam provides the required shock mitigation and thermal properties. Typical properties of each of the foams are provided in Table II. The foam provides the structure required to limit the deformation of the containment vessel during the drop and dynamic crush events. The foam also provides for thermal protection of the containment vessel during the fire. This protection is provided through three mechanisms. The foam is a good insulator at temperatures up to approximately 180°C. When the FR3725 foam reaches high temperatures it intumesces to seal impact-induced cracks against the ingress of hot combustion gases and air and finally it forms a low density char. The NCFI24-125VS foam does not intumesce and hence requires the additional ceramic paper insulation.

The containment vessel consists of two 6.3 mm thick stainless steel shells with elliptical heads. After installing the contents, the two shells joined by welding. The top of the containment vessel includes a stainless steel tube with a fitting requested by Pantex. The fitting and tube allow for the leak testing and backfill of the containment vessel during assembly. Following assembly, the stainless steel tubing is crimped and welded to provide the closure. The tubing can then be used to sample the containment vessel contents for the life of the container. A removable stainless steel fitting is then threaded in place to protect the tubing during a bare vessel 9 m drop test.

Table II: Thermal and Structural Properties of Polyurethane Foams [Wenski, 1995]

Property	Russian Fissile Material Container - NCFI 24-125VS	US Pit Container - FR3725
Thermal Conductivity, W/mK, 24°C	0.234	0.245
Intumescence	8.9	>100%
Compressive Strength, MPa, 10%	16.0	16.8

PROTOTYPE TESTING

From April 1994 through December 1994 six empty containers were subjected to a variety of normal and accident conditions tests. The purpose of these tests was to provide information for the development of the packaging and to provide the technical basis for the acquisition of units for compliance testing. The compliance testing is currently under way at Sandia to support the Safety Analysis Report for Packaging. Table III summarizes the prototype test program.

Table III: US Pit Container Prototype Tests

Unit	Test Description	Test Date
Prototype 1	1.2 m drop onto overpack lid	4/6/94
Prototype 1	1.2 m side drop test	4/6/94
Prototype 1	1.2 m CGOC drop test	4/6/94
Prototype 1	9 m CGOC drop test	4/6/94
Prototype 1	9 m drop onto overpack lid	4/7/94
Prototype 1	9 m side drop test	4/7/94
Prototype 1	9 m CGOC dynamic crush test	4/7/94
Prototype 1	1 m side puncture test	4/8/94
Prototype 1	800°C radiant heat test	4/15/94
Prototype 2	normal thermal	4/29-5/5/94
Prototype 3	9 m side dynamic crush test	7/21/94
Prototype 3	800°C radiant heat test	8/2/94
D400-EVD	9 m bare vessel fitting down drop test	12/5/94
D400-EVDC	9 m bare vessel side dynamic crush test	12/6/94
D400-Hydro	hydrostatic test	12/6/94

The results indicated that the packaging response, to both the normal and accident conditions, was within the design parameters. The 1.2 m drop data, filtered at 1 kHz, indicated a rigid body deceleration of 280 g. The same accelerometer response for the 9 m drop indicated a rigid body deceleration of 1400 g. In each of these cases, the response of the package limits deformation to the container with the result that much of the shock is transmitted to the containment vessel. Following the three 1.2 m drops, the three 9 m drops and the single dynamic crush test, prototype 1 was subjected to a radiant heat test. During this test, the overpack surface was heated to over 800°C and held at that temperature for 30 minutes. These results showed that the containment vessel temperatures remained below 260°C. This temperature presents no threat to the containment vessel due to the welded closure.

During the normal thermal test, the container was held in a 38°C environment with an internal heat source until all the components came to thermal equilibrium. The equilibrium temperature for the mock-up was 64°C and the containment vessel was 57°C.

The final series of tests were the bare containment vessel tests. In each of these tests, the containment vessel was subjected to environments far in excess of those anticipated to occur as the results of the compliance testing. These tests were the bare vessel drop, dynamic crush and hydrostatic tests. Each of the impact tests, while resulting in significant deformation of the containment vessel, demonstrated that containment was maintained.

The hydrostatic test was an attempt to take the containment vessel to failure. In fact, due to equipment limitations the test was terminated at an internal pressure of 15 MPa with no indication of leakage.

SUMMARY

Two containers have been developed for the transportation and long-term storage of materials being generated during the dismantlement of U.S. and Russian weapons. Each of these containers provides a leak-tight stainless steel containment vessel. Each of the containers relies upon a protective overpack consisting of a steel/foam/steel construction with an insert assembly to provide packing and a thermal path from the containment vessel to the overpack exterior.

The differences in the containers are driven by specific storage and handling requirements. The Russian container required a welded vessel that could be opened rewelded closed three times. This requirement led to the external flange. The use of polypropylene packing permitted a thinner wall due to the substantive internal structural support.

The U.S. container required larger internal dimensions with no internal structural support for the containment vessel. These requirements led to a substantially thicker containment vessel wall section. The requirement to survive bare vessel drop tests led to the use of elliptical heads.

REFERENCES

Wenski, E. G. Summary Report on 30 lb. foams for the AT400A Container Project, May 1995