Radioactive Material Package-Testing Capabilities at Sandia National Laboratories*

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INTRODUCTION

Evaluation and certification of radioactive and hazardous material transport packages can be accomplished by subjecting these packages to normal transport and hypothetical accident test conditions as defined in Title 10, Code of Federal Regulations, Part 71 (10 CFR 71) (NRC 1994). The regulations allow package designers to certify packages using analysis, testing, or a combination of analysis and testing. Testing can be used to substantiate assumptions used in analytical models and to demonstrate package structural and thermal response. Regulatory test conditions include impact, puncture, crush, penetration, water spray, immersion, and thermal environments. Testing facilities are used to simulate the required test conditions and provide measurement response data.

Over the past four decades, comprehensive testing facilities have been developed at Sandia National Laboratories to perform a broad range of verification and certification tests on hazardous and radioactive material packages or component sections. Sandia's facilities provide an experience base that has been established during the development and certification of many package designs. These unique facilities, along with innovative instrumentation data collection capabilities and techniques, simulate a broad range of testing environments (Hohnstreiter et al. 1992). In certain package designs, package testing can be an economical alternative to complex analysis to resolve regulatory questions or concerns.

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COYOTE AERIAL CABLE FACILITY

The Coyote aerial cable facility is one of the primary testing facilities used to perform impact, puncture, and dynamic crush testing of transportation packaging. This facility incorporates a novel application of rocket power and free fall to provide a means of duplicating impact tests under controlled conditions. Test units can be impacted at velocities approaching 244 m/s (800 ft/s) at impact angles from vertical to approximately 30 degrees from horizontal. The facility consists of a 1,524-m (5,000-ft) wire cable suspended across a mountain canyon. The cable can support proportionately heavier package weights at lower elevations. The allowable package weight at 9 m (30 ft) exceeds 23,000 kg (50,000 lb). Various impact targets are located along the canyon floor parallel to the cable. The target at this facility (Figure 1) is considered unyielding for test objects weighing up to 91 tonnes (100 tons). Some recent tests are discussed below.

Structural Evaluation Test Unit

The impact event in the hypothetical accident sequence of 10 CFR 71 for radioactive material transport packages is a 9-m (30-ft) drop onto an essentially unyielding target, resulting in an impact velocity of 13.4 m/s (44 ft/s). The purpose of the Structural Evaluation Test Unit (SETU) program evaluates the structural response of a test package subjected to impacts more severe than the regulatory 9-m (30-ft) impact. Several types of structural response are considered: the behavior of the package containment boundary, including the bolted closure and O-rings; loss of shielding capability due to lead slump; and the deceleration loading of package contents that may result in damage. The SETU program provides data suitable for use in risk assessments on the degree of package damage from severe impact accidents. Figure 2 shows the SETU test unit after impacting the unyielding surface at 13.4 m/s (44 ft/s).

Rocky Flats Pipe Overpack Payload Container

The Rocky Flats pipe overpack payload container provides a barrier against migration of high-activity plutonium waste transported within the TRUPACT-II container. For low-level wastes, the TRUPACT-II design assumes plutonium is free to migrate, thereby requiring a low limit on the amount of plutonium that may be shipped within a single container. It is cost-prohibitive to transport higher-activity wastes in these limited quantities. The pipe overpack payload container prevents migration, as demonstrated by a series of 9-m (30-ft) impact tests. Three tests subjected two-drum stacks of pipe overpack payload containers to axial impacts onto an unyielding target, and the other test subjected 14 pipe overpack payload containers to a side impact. In all tests the containers prevented plutonium migration. Figure 3 shows the TRUPACT-II inner containment vessel with 14 pipe overpack payload containers elevated 9-m (30-ft) above the unyielding target.

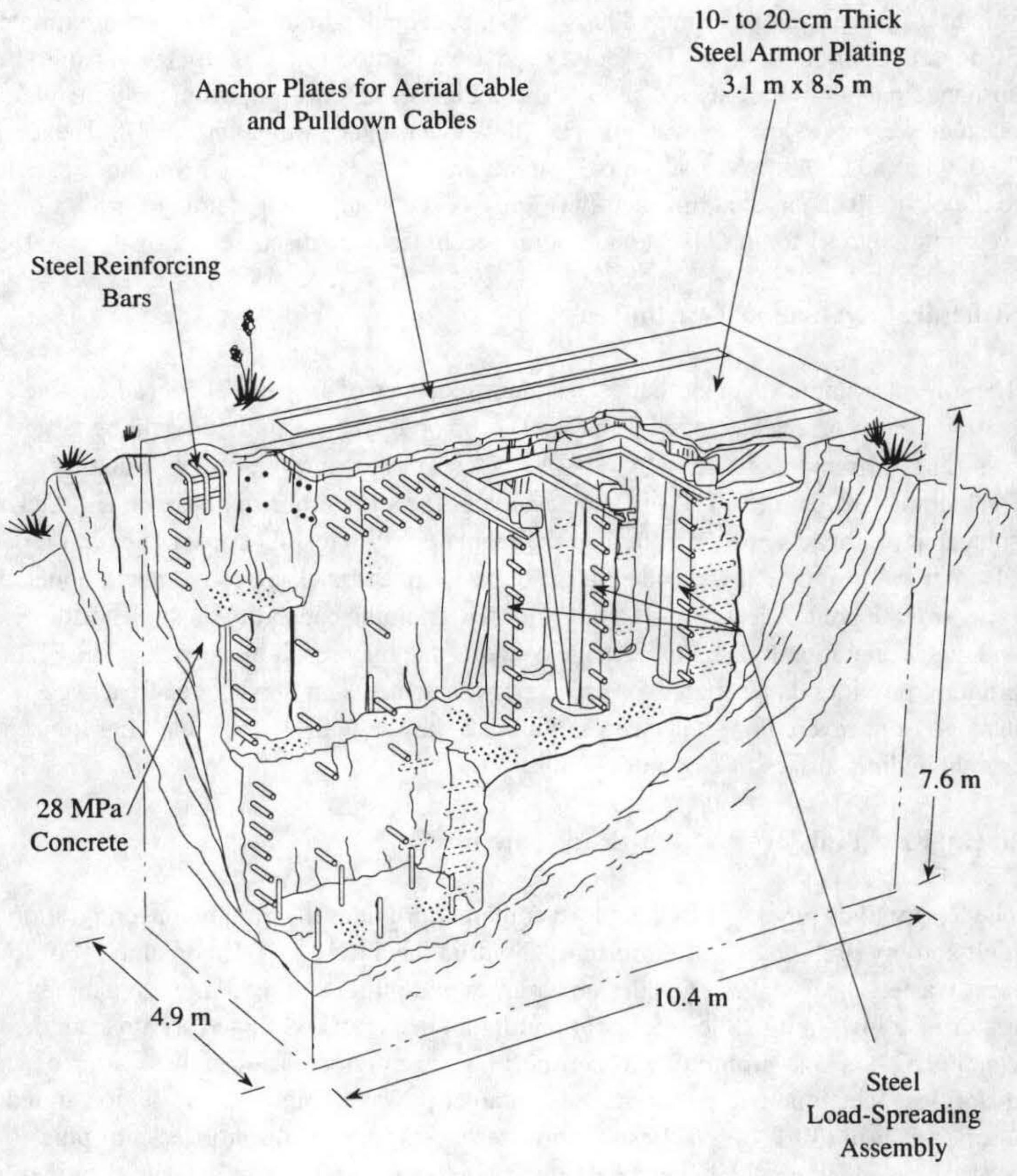

Figure 1. Unyielding target at the aerial cable facility.

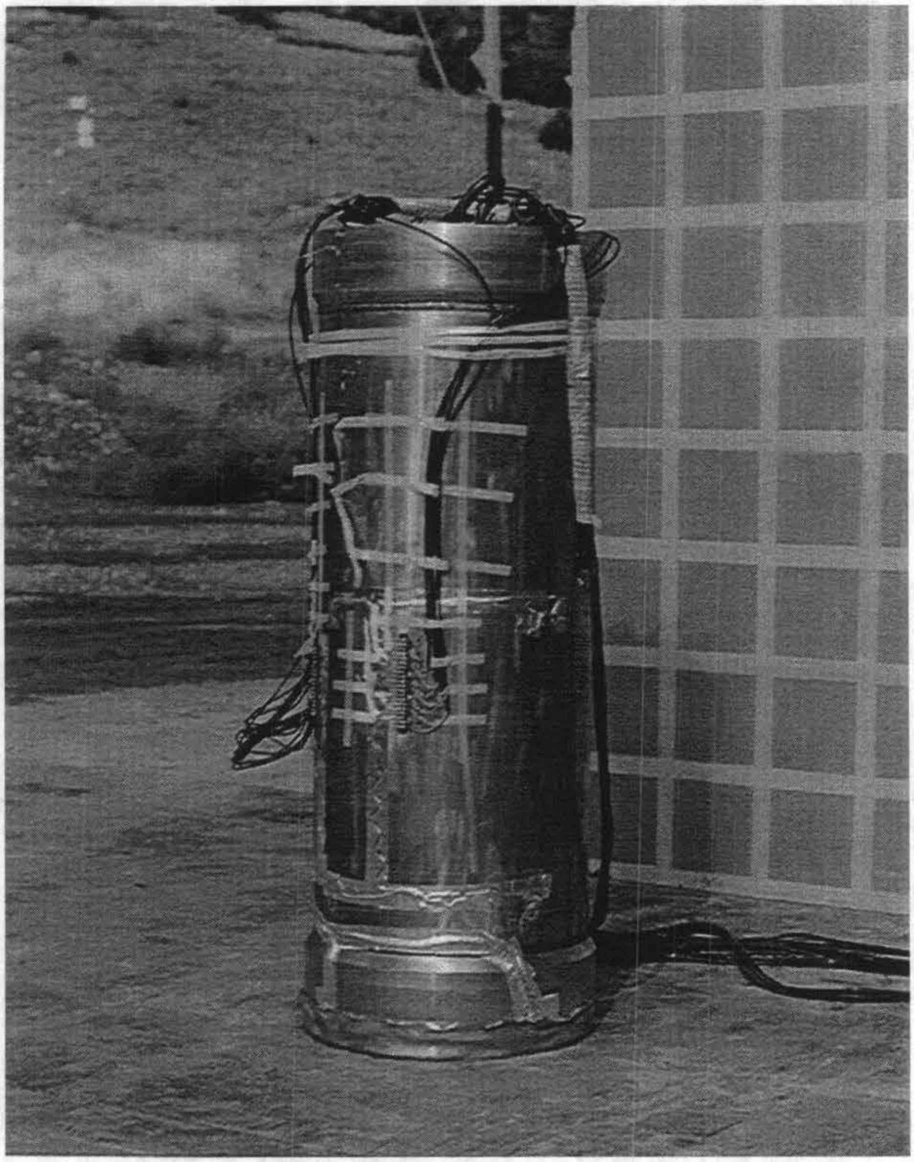

Figure 2. SETU test unit after impacting unyielding target.

SLED TRACK FACILITIES

Extra-regulatory or horizontal impact tests are performed using one of the two rocket sled track facilities. The 3,050-m (10,000-ft) sled track facility can be used in a mono or dual rail configuration. Peak velocities of greater than 2,000 m/s (6,500 ft/s) have been achieved at the facility. The 610-m (2000-ft) sled was used for full-scale truck and railcar impact tests conducted for the U.S. Department of Energy. The test systems are accelerated along standard gauge tracks by a rocket-powered pusher sled. These sleds can accelerate the test system to velocities of 200 m/s (650 ft/s). At one end of the track is a simulated bridge abutment; at the other end, various impact targets can be constructed to support the required test conditions.

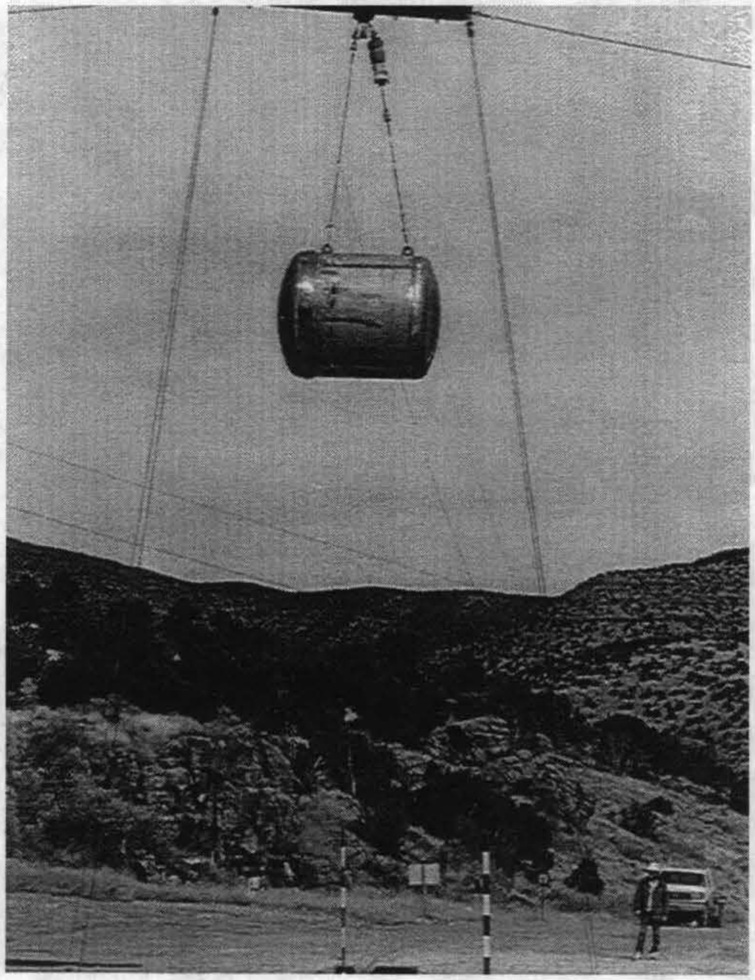

Figure 3. TRUPACT-II inner containment vessel elevated above the target.

DROP TOWER FACILITIES

Impact testing of packages weighing up to 680 kg (1,500 lb) can be performed at the 56-m (185-ft) drop tower. This facility provides free-fall or guided drop with vertical velocities approaching 30 m/s (98 ft/s). This system consists of two cables stretched vertically between anchors on the ground and the top of the tower. A carriage can be hoisted and released from any height up to the top of the tower. Explosive cable cutters or other mechanical release methods are used to release the test item from the carriage just above the unyielding target. The short free flight ensures the precise orientation of the package at impact. This facility is primarily used for impact and dynamic crush testing of scale models or small full-scale packages.

Water impact and immersion testing can be performed at the 91-m (300-ft) water impact facility, a trapezoidal freshwater pool constructed adjacent to the drop tower. The pool is 15.2 m (50 ft) deep. The tower can support packages weighing up to 2,700 kg (6,000 lb) with free-fall impact velocities or rocket-assisted impact velocities that approach 200 m/s (700 ft/s). Immersion testing can be performed on large packages using cranes or other lifting mechanisms.

THERMAL TESTING FACILITIES

Sandia has subjected containers to pool fires that simulate postulated transportation accident environments for over 30 years. The open pool fire facility can be adjusted to a maximum size of 9 m (30 ft) by 18 m (60 ft) for performing free-burning fires for a maximum fire duration of 2 hours. Packages weighing up to 135 tonnes (149 tons) can be supported at heights up to a few meters above the pool surface. Extensive measurements have been performed to qualify the temperatures, heat flux levels, and gas velocities in pool fire tests. The heat flux levels in these fires have been shown to meet the regulatory requirements. Figure 4 shows the On-Site Container developed by Sandia for U.S. Army transport of obsolete munitions during an open pool fire.

The wind-shielded fire test facility is an enclosed pool fire facility. The facility was designed to provide the thermal environment of a large open pool fuel fire while meeting current air-quality requirements. This indoor facility eliminates the effects of weather during the test.

Simulated fire tests can be conducted in Sandia's radiant heat facility using a fast response electric furnace. The simulated fire test provides a controlled level of either temperature or heat flux. The temperature can be adjusted up to 1,100°C (2,012°F) to match existing regulations, and the heat flux is adjustable to up to 200 kW/m^2. The rise time to reach test temperature can be as low as 30 seconds. Test packages up to 1 m in diameter and 1 m long have been tested.

SEARAM

Other testing has been performed at remote locations using Sandia's testing capabilities. DOE's SeaRAM (for Sea Radioactive Materials) program (Sandia Lab News 1995) is developing technical tools to help assess the safety of transporting radioactive materials by sea. Recent tests examined how an engine room fire (the most common type of ship fire) or an accidental blaze within a cargo hold might affect specialized casks used to contain nuclear materials during transport. Fires set inside the cargo hold of a Coast Guard merchant ship measured how heat from the flame transferred to nearby simulated nuclear materials shipping containers. To take the measurements, the Sandia researchers placed calorimeters simulating casks in the ship's hold and in an adjacent hold. Then they

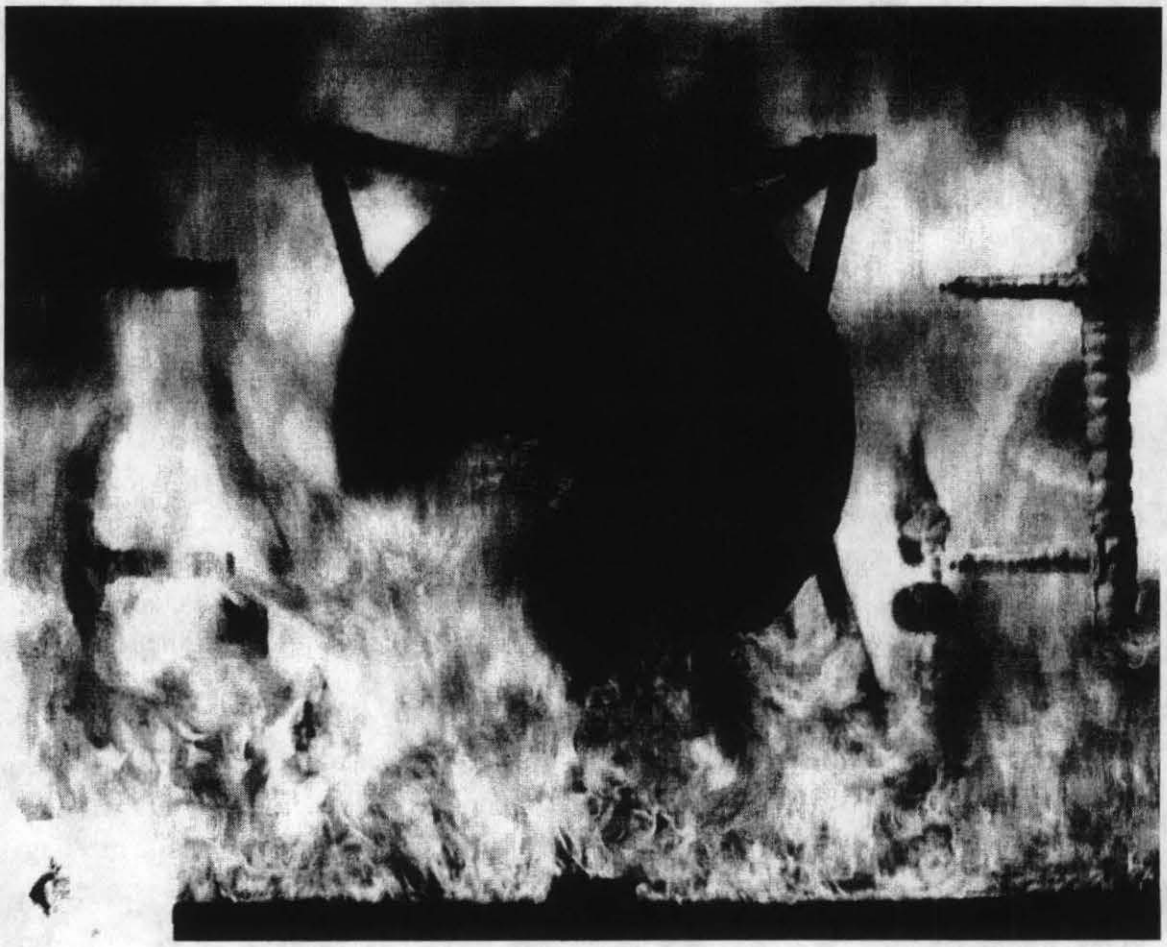

Figure 4. Sandia's On-Site Container during an open pool fire.

conducted four fire tests: two hydrocarbon (heptane) spray fires and two wood ("crib") fires. Thermal transfer data gathered during the tests will be compared to analytical results from Sandia computer models. The goal of the program is to develop computational models to predict thermal transfer in a variety of other accident scenarios.

DATA COLLECTION AND PROCESSING

SNL provides a full range of data collection and processing facilities for both telemetry and hard-wired instrumentation. In addition to data collection capabilities at each facility, systems such as the Mobile Instrumentation Data Acquisition System (MIDAS) support package testing. This unique self-contained mobile system is capable of acquiring and processing up to 72 channels of piezoresistive or voltage-based transient structural data. In addition, up to 200 channels of temperature data can be collected and processed. MIDAS has been developed and documented in accordance with a quality assurance program meeting current regulatory drivers to ensure accurate and reliable response measurements.

High-speed photometrics are used to document impact and subsequent package response during testing. Frame rates (film speeds) range from real time (24 frames per second) up to 250,000 frames per second. Nominal frame rates for package testing extend to approximately 10,000 frames per second. These high-speed film data are time-coded to allow correlation with instrumentation measurement data.

SUMMARY

Sandia's four decades of experience, unique testing facilities, and sophisticated data collection and processing capabilities combine to support design, evaluation, and certification of radioactive and hazardous material transport packages. Sandia responds to new challenges in transport package testing, as shown by the innovative SeaRAM and SETU programs. Package testing at Sandia is also used to develop quality computer modeling and calculation codes as evidenced by recent dynamic crush impact testing (Hoffman and Ammerman 1995). Sandia's unique testing facilities can serve the needs of the international package testing community.

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