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WEST VALLEY DEMONSTRATION PROJECT FULL-SCALE CANISTER IMPACT TESTS

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ABSTRACT

Five West Valley Nuclear Services (WVNS) high-level waste (HLW) canisters were impact tested during 1994 to demonstrate compliance with the drop test requirements of the Waste Acceptance Product Specifications. The specifications state that the canistered waste form must be able to survive a 7-m (23 ft) drop unbreached. The 10-gauge (0.125 in. wall thickness) stainless steel canisters were approximately 85% filled with simulated vitrified waste and weighed about 2100 kg (4600 lb). Each canister was dropped vertically from a height of 7 m (23 ft) onto an essentially unyielding surface. The integrity of the canister was determined by the application and analysis of strain circles, dimensional measurements, and helium leak testing. The canisters were also visually inspected before and after the drop for physical damage.

After the impact, very little deformation of the canisters was observed. The strain circles deformed in the axial direction less than 3% and up to 7% in the hoop direction. The canisters on average showed a slight diameter increase of approximately 2% (1 to 2 cm) in the area nearest to the bottom head. The diameter only increased an average of 0.8% (0.5 cm) at the 76-cm elevation. The canister height decreased by an average of 0.4% (1.2 cm). Helium leak testing of each weld showed either no detectable leaks or very slight leaks much less than the acceptance criteria of 10^{-4} atm cc/sec. Each of the canisters passed the "straightness" test in which the canisters were fit into an inspection sleeve, a straight cylinder with a 63.5-cm (25 in) diameter, after the impact.

The results of the impact test verify that the canisters survived the 7-m drops unbreached. Therefore, these results demonstrate that the reference canister meets the drop test specification of the Waste Acceptance Product Specification.

INTRODUCTION

Pacific Northwest Laboratory (PNL)* has conducted impact tests of canisters filled with simulated HLW glass since 1975. The canisters have varied in design and have been dropped from heights ranging from 0.3 m to 31.7 m (1 ft to 104 ft). A specially constructed drop pad was built to provide an essentially unyielding surface. The purpose of the tests is to demonstrate that the canistered waste form can withstand a drop onto a flat, essentially unyielding surface and remain unbreached.

In 1994, WVNS sponsored PNL to impact test five of the production-typical design canisters that will be used by the West Valley Demonstration Project to contain HLW glass. Each canister was dropped vertically, from a height of 7 m (23ft) with the bottom of the canister parallel to the impact pad. The canisters were examined before and after the drop for dimensional deformation and leak tightness.

TESTING AND RESULTS

This section describes the impact test facility and the pre- and post-impact tests that were used to evaluate the canister integrity. All of the procedures and facilities involved in the drop test were developed and used during previous canister impact tests.

* PNL is operated by Battelle Memorial Institute for the U.S. Department of Energy

Initial examination

Five canisters were sent to PNL from WV in two different shipments. The canisters are approximately 3 m (118 in.) long with a 61-cm (24 in.) diameter. Two of the canisters were filled with simulated HLW glass at PNL in 1993 and the other three at WVNS during FACTS Testing in 1986. The three FACTS test canisters were decontaminated with a solution of cerium (IV) and nitric acid. The canister lids were attached by a complete seal weld with the WVNS prototypic welder to ensure that any leaks detected in the helium leak test would not be due to failure of a canister lid weld. The canister lids have two taps with fittings attached that were kept plugged except during the helium leak test.

Upon arrival, the canisters were visually inspected for damage, sketched, and photographed. The initial inspection revealed minor dents, abrasions, and some rusting where the surfaces had been abraded. Some of the light scratches detected resulted from the metal banding used to attach the canisters to the skids. The initial conditions of the canisters were determined to be acceptable for canister drop testing.

Impact Test Facility

A specially constructed pad is required for impact tests. The PNL impact pad is located in the Hanford 300 Area, north of the 350 Building. The pad consists of a steel plate supported by a reinforced concrete foundation designed to minimize deflection when impacted with an object equal in weight to the heaviest canister. The target plate is 20 cm (8-in.), 1.8 m by 3.2 m (70 in. by 10 ft 5 in.), surrounded by a 61 cm (2-ft) apron of 2.54 cm (1-in.) steel on concrete. The reinforced concrete base is 1.8 m (6 ft) deep, 3 m by 4.4 m (10 ft by 14 ft 5 in). The approximate mass of the impact pad is slightly over 99,000 kgs (220,000 lbs).

The target section is anchored at several points into the concrete base so that the plate and the concrete form a single unit. Two separate 2.4 m by 3 m (8-ft by 10-ft) plywood backdrops are located behind the pad at 90° to each other. The backdrops are painted with a white and black checkerboard pattern of 0.3048 m (1-ft) squares. These squares are used in conjunction with high-speed photographs taken during the impact to verify the impact angle. The drop test site is shown in Figure 1.

Impact Test Procedure

A truck-mounted crane was used to hoist the canisters above the impact pad. The canisters were rigged with two wire chokers wrapped around the flange 180° from each other. The chokers were attached to a shackle and then to a quick release device. The shackle was wrapped with softening material to minimize any damage that might occur if the shackle hit the canister during testing. The canister was held several inches off the ground while the vertical orientation was checked with a level. The canister position was adjusted by lowering the canister and adjusting the position of the wire chokers. After a vertical orientation was determined, a 7-m line was attached to the bottom of the canister. The canister was then raised until the bottom of the line just touched the impact pad. The position of line was verified and then the line was removed. The high-speed cameras were started just before the canister was released. Figure 2 shows a canister in the raised position just before release. Upon impact, each canister bounced approximately 15 to 46 cm (6 to 18 in.) above the pad. Three canisters remained upright, and two fell sideways. A photograph of a canister after impact is shown in Figure 3.

The canisters showed little obvious deformation after the bottom impacts. After the impact, all of the canisters had bulged areas approximately 30 cm (12 in.) from the bottom head. Canisters WV-71A and WV-33A fell sideways into the gravel and had significant secondary impact dents where the upper section of the canister, above the glass level, impacted the gravel.

Strain Circle Application and Analysis

Strain circles were applied to the bottom 61 cm (24 in.) of the canisters at 90° increments in 15-cm (6 in.) strips up the sides of each canister. Strain circles are precise diameter circles that are applied to the surface of metal. The circles can be of various sizes, and the circles can be arranged in various patterns. In this test, a strain circle diameter of 0.5 cm (0.20 in.) was used with the circles arranged in a rectangular grid with 0.64-cm (0.25 in.) spacing between circle centers. The strain circles are applied to the surface with an electrochemical process, which does not effect the properties of the metal or create any stress risers. By knowing the original diameter of the circles and measuring the diameters of the circles after the metal surface is deformed, the surface strains can be determined. The use of strain circles permits strains due to deformations of the canisters to be determined over rather large areas without extensive instrumentation.

After impact testing, each of the four strain circle regions were visually examined and preliminary strain circle diameter measurements were made to determine the most highly strained regions. Generally, maximum strains were observed in a region 15 cm (6 in.) to 20 cm (8 in.) up the side wall from the bottom. The strain levels and surface deformations tended to vary from canister to canister and appeared to be related to the manner in which the glass inside the canister fractured. For several canisters, the strain circle data indicates that the glass appeared to fracture across the bottom corner and push a wedge of glass outward. The end of this wedge was 15 to 20 cm up from the bottom. This was the region of the canister wall that showed the highest localized strains. For other canisters, there was no evidence of this type of glass fracture, and the canisters appeared to undergo mostly axisymmetric deformations.

The diameters of strain circles were read from regions of each canister judged to be most affected by the drop. After the initial screening to determine the worst case deformations, a line of strain circles containing the most highly deformed circles was measured. This line extended from near the bottom to at least 25 cm (10 in.) from the bottom. Most of the strain circles on the bottom of the canister were very difficult to read due to impact damage. However, those that were readable indicated strains ranging from 1% to 3%. Above 10 in. from the bottom, the strains were generally unvarying and smaller than the strains measured lower on the side wall.

In the axial direction, both compressive and tensile strains were measured. Generally, the trend was for compressive strains in the axial direction. However, due to localized bending of the side wall some tensile strains were evident. The strains for the selected circles that were read are not entirely representative of the entire canister since we focused on the regions with the largest strains. Therefore, the average axial strains would be more compressive than is indicated by the data. All axial strains measured with the strain circles were in the range of minus 5% to plus 3% strain.

In the hoop direction, all measured strains were greater than or equal to zero. A maximum hoop strain of 7% was recorded. All of the canisters tended to become shorter in length and larger in diameter as a result of the drop test. Even above the region where we stopped reading the strain circles, the canisters had a small but detectable amount of positive hoop strain.

Canister Dimensions

As an indication of the extent of deformation after the impact, each of the canisters' diameter and height were measured before and after the impact test and then compared.

The diameter of the lower section of the canister was measured with a 0.61 m (24-in.) micrometer. The diameter measuring points were first scribed onto the canister surface. A vertical line was drawn through the approximate center of the canister serial number and was designated as the 0° reference point. From the 0° reference, vertical lines were drawn around the canister designating 45°, 90°, 135°, 180°, 225°, 270°, and 315°. Horizontal lines were drawn every 5.1 cm (2 in.) up from the bottom. Then a micrometer was used to determine the diameter of the canister at 0°, 45°, 90°, and 135° at the 2-in. elevations.

The canister heights were measured at eight different locations in 45° increments around the canister. The canisters were also weighed before impact with a dynamometer.

After the bottom impacts, the heights and diameters were remeasured. The canisters showed little obvious deformation in both diameter and height. All of the canisters showed a slight diameter increase of approximately 1.27 cm (2%) in the area nearest to the bottom head. At the 76.2 cm (30-in.) elevation, the canister diameters only increased an average of 0.5 cm (0.8%). The canister height decreased by an average of 1.2 cm (0.4%). These small changes were expected. Other drop tests have demonstrated that the energy of the impact is absorbed by the glass contained in the canister and not by the canister.[1]

Helium Leak Test

Helium leak testing was performed before impact to ensure that all of the canister welds were leak tight. The tests were performed in accordance with ASME Section V, Article 10 (Hood Method). The leak rate was non-detectable for all of the canisters except WV 35A, which had a leak rate of 2.14×10^{-8} atm cc/sec at the top circumferential weld. The maximum leak rate allowable is 1×10^{-4} atm cc/sec per the WVNS Waste Qualification specifications.

The initial leak testing evaluated all welds and used the two fittings on the canister lid. After the impact, a hole was drilled into the canister wall 18 cm (7 in.) from the bottom of the canister, and a 1.27 cm (1/2-in.) fitting was attached. Each canister was evacuated with a vacuum pump. After evacuation, a helium standard was allowed to leak into the canister through the bottom nozzle. If the standard is detected by a mass spectrometer at the nozzle on the canister flange, there is a path through the glass for the helium to flow.

After ensuring that a path through the glass was present, the canister was again evacuated. The evacuated canisters were then enclosed in a plastic bag (or hood). The space between the bag and the canister was filled with helium. Any helium leak would be detected by the mass spectrometer.

All five West Valley canisters passed the requirements of a helium leak rate of less than 1×10^{-4} atm cc/sec. After the impact, three of the canisters still showed no detectable leaks, and the other two had leak rates that were in the range of 10^{-8} atm cc/sec. The helium leak rates before and after impact are summarized in Table I.

Table I. Helium Leak Test Results.

Canister Number	Leak Rate Before Impact (atm cc/sec)	Leak Rate After Impact (atm cc/sec)
WV 33A	no detectable leaks	no detectable leaks
WV 35A	2.14×10^{-8}	8.96×10^{-8}
WV 38A	no detectable leaks	6.61×10^{-8}
WV 70A	no detectable leaks	no detectable leaks
WV 71A	no detectable leaks	no detectable leaks

CONCLUSIONS

Five West Valley canisters filled with simulated HLW glass were vertically dropped from a height of 7 m (23 ft) onto a specially built impact pad. The structural integrity of each canister was then evaluated with helium leak testing, strain circle analysis, and dimensional measurements. The following observations and conclusions resulted from the evaluations:

- All five of the canisters were able to withstand a 7-m (23 ft) impact to their bottom head without breaching.
- The maximum amount of axial and hoop strain observed on the bottom section of the five impacted canisters was 3% and 7%, respectively, which is less than 13% of the typical 304L stainless steel strain to failure value of 56%.

•Significant denting of the upper portion of the canisters occurred when two canisters (WV-33A and WV-71A) fell onto their sides after impacting the pad. Several small hairline cracks were observed in the dented area of the canister WV-71A. The cracks were superficial and did not breach the canister.
•The highest amount of deformation occurred 10 to 25 cm (4 to 10 in.) from the bottom head of the canisters. The amount of deformation present on each canister did not exceed the overall dimensional specifications for canister transportation or repository storage. The canisters easily fit into a 63.5-cm (25 in.) diameter inspection cylinder after the impact.

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1. Olson, K. M. and J. M. Alzheimer. "Defense Waste Processing Facility Canister Impact Testing." PNL-6812, Pacific Northwest Laboratory (1989).