Appendix 3.5.3, Excerpted from Safety Analysis Report for the Century Champion Type B Package Thermal Test

Introduction

The Century Industries Versa-Pac Shipping Container is an evolutionary package design based on the design and testing of the Century Industries Champion Type B package. Due to the similarity in both package designs, tests involving the Century Industries Champion, although not directly applicable, can be used to support the safety basis of the Versa-Pac design as supplemented by further analysis and tests. Tests involving the Champion package that are applicable to the design of the Versa-Pac include drop tests, thermal and immersion tests. The thermal test further indicates the lack of the thermal stresses in the design. The design similarities are further presented with attachment of the test results for the Champion package.

Design Comparison

Both packages share the same basic structural components in that they have an inner and outer liner of sheet metal that is surrounded by vertical and horizontal stiffeners. Both package designs use the same ceramic fiber blanket insulation between the inner and outer liners and also surrounding the radial portion of the containment boundary. Both designs have approximately the same polyurethane foam in their respective bottom and top portions of the container. Both designs are based on an inner structure that slides into an outer drum. Therefore, both package designs should have a similar thermal response including thermal stresses. However, the temperature profiles may be different as further discussed.

The package designs differ in the type of insulation that surrounds the inner containment area. The Champion surrounds the containment area with polyurethane foam that is poured in place while the Versa-Pac utilizes ceramic fiber blanket insulation within the same area.

The Champion utilizes a leak testable inner vessel as the primary containment with a secondary blind cap flange on top of the main sealing flange while the Versa-Pac uses only a ½" blind flange with a high temperature fibrous sleeve at the containment boundary.

Thermal Test

Figure 3.5.3-1 shows the Century Champion Package rigging for the thermal test. Figure 3.5.3-2 displays a typical view of the package during the 30 minute 1475^{o}F thermal test phase. Figure 3.5.3-3 displays the package upon completion of the thermal testing prior to conduct of the immersion test.

Summary of Results

The metallic components of the package, as shown in Figure 3.5.3-3, do not show any signs of failure or fatigue at the conclusion of the thermal test. This demonstrates that thermal stresses induced during thermal testing are low and within the structural capacity of the components. The polyurethane insulation is considered to be a sacrificial component, and in performing its function its structure is broken down by the heat of the fire. However, the polyurethane components (including the internal polyurethane plug utilized in the Versa-Pac) do provide load-carrying capability for the packaging, and the steel components provide the strength and structure required to maintain the packaging intact following the event. The 30 minute thermal test including the post-test natural cool-down did not cause any seam or closure separation in the package. The package structure including outer closure drum does not shown any signs of failure or fatigue. These observations from the testing of the Century Champion are directly applicable to the Versa-Pac design since their outer structures are identical. Therefore, the Versa-Pac design is not anticipated to be subject to deleterious thermal stresses during the required 30 minute thermal test at 1475^{o}F.

Pages 14 and 15 of the Champion Safety Analysis Report are provided as pages 5 and 6 to Appendix 3.5.3. The test results indicate that during a 44-minute fire exposure, the lower portion of the inner vessel attained a maximum temperature of 450^{o}F. Testing of the Versa-Pac would be expected to produce similar results since the structures and thermal insulation are similar to the Champion. The analytical analysis presented in Section 3.0, Thermal Evaluation, indicate a maximum temperature to the contents of 552^{o}F for the Versa-Pac using a 3-inch polyurethane foam plug in the top of the containment vessel. With the plug removed, the analytical results approach 600^{o}F. The analytical results seem reasonable and are generally performed to bound actual thermal tests with sufficient margin to ensure the design meets the requirements. Therefore, the lower temperature experienced in the fire testing of the Champion seems reasonable. In an actual fire test of the Versa-Pac, the maximum temperature at the containment boundary would be expected to be less than 600^{o}F. A lower temperature is anticipated since the Versa-Pac design uses a fiberglass thermal break in the area of the containment boundary closure.

Figure 3.5.3-1 Champion Package on Test Stand – View from Thermocouple Shielding Tube

Figure 3.5.3-2 Champion Package during Thermal Testing Phase

Figure 3.5.3-3 Champion Package Post-Thermal Test

9.2.3.4 Drop Test 4

Figure D-30 shows Drop Test 4 (puncture test, side orientation). Pre-test conditions were:

a) Drop Angle 0° (measured horizontally)

b) Drop Height 40 in. to impact face

The shipping container was released cleanly and impacted the puncture bar in the proper location and orientation. The container remained on its side after impacting the cylindrical puncture bar (see Figure D-32). Deformation data of the exterior was measured and recorded by Fire Technology personnel. Video was taken of the drop event and color photographs showing the extent of damage were taken and are included with this report.

All testing was completed successfully, and all phases of this testing were witnessed by SwRI QA/QC and NSF and Century Industries personnel.

After all drops were completed the CI-1 shipping container was placed in a conditioning chamber overnight and the test article was exposed to warm heat. The test article was exposed to ambient air at a temperature of 140°F ± 10°F for more than 15 hours prior to the fire test.

9.3 Pool Fire Performance Evaluation Test

The CI-1 shipping container was transported to the remote test site in Sabinal, Texas, and the pool fire test described in Title 10 CFR 71.73 (c)(4) was performed on January 28, 2004. Messrs. Mike Arnold and Rick McVey representing Century Industries, Mr. Preston Foster representing BMX Technologies, and Mr. Joseph Pugh representing Nuclear Fuel Services were present to witness the tests. Following initial startup procedures and transfer of 950 gal of diesel fuel to the burn pan, the data acquisition equipment was verified and the fuel was ignited to begin the 30-min pool fire test. Based on visual observation and flame temperatures, it was decided by Century Industries and SwRI to extend the fire exposure due to the lack of complete fire engulfment to the shipping container. An additional 310 gallons of diesel fuel was added for the additional 14 min of burn to compensate for the incomplete engulfment and low flame temperatures. A total of 1260 gallons of diesel fuel was used for the 44 min burn period. A larger pool fire may mitigate these adverse affects. Table 3 lists the significant observations during the pool fire exposure and post-test cool down period.

Following extinguishment, temperature data was recorded during the cool down period. During the cool down, the test article was protected from precipitation and wind effects to eliminate enhanced cooling of the test article.

Table 3. Pool Fire Test Observations.

TIME (Min:Sec)	OBSERVATIONS
0:00	Test started. Flames fully developed across pool surface.
1:00	CI-1 shipping container engulfed by flames. Light southeast wind blowing flames northwest. Shipping container mostly engulfed by flames.
17:00	Plug melted and off-gassing from side of container at plug location.
30:00	Decision was made to extend time of exposure.
32:30	Additional 310 gallons of diesel started. Ended with 1260 gallons of diesel fuel.
38:00	Off-gassing burning from crease on bottom of container and off-gassing not burning from plug location.
44:15	Fuel beginning to burn out.
46:30	Residual burning continues on container.
47:00	Off-gassing at TC outlet port and at crease. Both continue to burn.
48:00	No visible flames in pool.
55:00	Temperature monitoring of shipping container continuing (5-10 min stop between burn and cool-down period).

Time-temperature profiles and test condition graphs taken during the pool fire exposure and cool down period are shown in Figures 10 through 15. The average flame temperature recorded by the TCs used to measure the pool fire was 1350°F and the average wind speed during the test was 3.1 mph. During the 44-min fire exposure, TC Nos. 5 and 8 attained maximum temperatures of 450°F and 303°F, respectively. TC Nos. 5 and 8 were located on the lower portion of the inner vessel. As a result of the crush tests, a tear developed at the base of the 55-gal drum. It is SwRI's opinion that the tear provided ventilation, allowing the foam to decompose and burn, causing the elevated temperatures recorded by TC Nos. 5 and 8. Tabular data for the test conditions TC measurements appear in Appendix E.

9.4 Hydrostatic Immersion Test

On January 29, 2004, the CI-1 shipping container was transported back to SwRI's main campus facility and delivered to the Test and Evaluation Section of the Department of Structural Engineering. The weight of the container as received from the off-site test facility was 386 lbs. The reduction of weight of 4 lb was due to the consumption of the insulation during the fire exposure.