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H1616 Supplemental Compliance Test Report

R. E. Glass

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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H1616 Supplemental Compliance Test Report

R. E. Glass
WMD Container Systems
Sandia National Laboratories
P. O. Box 5800
Albuquerque, NM 87185-0483

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MASTER

Abstract

Sandia National Laboratories designed the H1616 container for transport of Type B quantities of radioactive materials. During the most recent recertification cycle, questions were raised concerning the ability of drum type containers with locking rings to survive the hypothetical accident sequence when the puncture test was oriented to specifically attack the locking ring. A series of tests has been performed that conclusively demonstrates that the specially designed locking ring on the H1616 performs adequately in this environment.

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Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

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WMD Container Systems Department
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I. References

Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Materials (10CFR71)
SS393220, Periodic Maintenance and Test, H1616
H1616-TP, H1616 Supplemental Compliance Test Plan
H1616-IP, H1616 Container Supplemental Compliance Test Unit Inspection Procedure
H1616-1-AP, H1616-1 Container Supplemental Compliance Test Unit Assembly Procedure
H1616-1-NCTP, H1616-1 Container Supplemental Compliance Test Unit Normal Compression Test Procedure
H1616-GDTP, H1616 Container Supplemental Compliance Test Unit Guided Drop Test Procedure
H1616-GPTP, H1616 Container Supplemental Compliance Test Unit Guided Puncture Test Procedure
H1616-PFTP, H1616 Container Supplemental Compliance Test Unit Pool Fire Test Procedure
H1616-DP, H1616-1 Container Supplemental Compliance Test Unit Disassembly Procedure
SAND91-2205 Revised, Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages
ANSI N14.5, American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment

II. Introduction

At the direction of DOE/AL NESD (memorandum dated May 9, 1997, H1616 Puncture Testing, from Steven M. Nunley), Sandia planned and executed a series of drop, puncture and fire tests. These tests, as described below, provided additional objective evidence that the H1616 containers comply with the Hypothetical Accident Sequence requirements of 10CFR71. As referenced in Mr. Nunley's memorandum, during the H1616 recertification, a generic question arose concerning the response of drum type containers with locking rings to the combined drop and puncture tests with the orientations of impact designed to assault the locking ring. The data obtained during initial compliance testing of the H1616 demonstrated that the specially designed locking ring on the H1616 was capable of sustaining significant damage without failure. The results of the tests outlined below supplement existing test data and have been incorporated in the Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

In addition to the drop and puncture tests, the panel questioned the analysis of the compression requirement. To resolve that open question, a compression test was performed prior to the drop and puncture tests.

III. Order of Events

The order of events was: (1) receipt and inspection of pedigreed containers, (2) assembly of containment vessels, (3) leak tests of containment vessels, (4) assembly of containers, (5) radiograph containers, (6) compression test, (7) drop tests, (8) post drop test inspections of overpacks, (9) radiograph containers, (10) puncture tests, (11) post puncture inspections, (12) pool fire test, (13) containers disassembly, (14) containment vessels leak tests and (15) incorporate results in the Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages.

IV. Pretest Inspection and Assembly

Four H1616 containers were acquired from the Department of Energy from the existing stockpile and were designated Supplemental Compliance Test Units, SCTU.

All tests were performed with the H1616-1. The use of the H1616-1 ensured that the container with the weaker structure was tested. The minimum package weight was 172 pounds. This weight ensured that the testing bounded the weight of the H1616-2 containment vessel and contents. Simulated contents consisted of 4-inch long sections of 7-5/8 inch diameter steel bar stock. These steel bars weighed approximately 52 pounds and so bound the mass of the actual contents.

Inspection

All containers were accompanied by documents demonstrating that the units fully conformed to the design and were free of radioactive contaminants. Upon receipt of the units, Sandia ensured that the containers were free of radioactive contaminants and inspected the units for damage per Periodic Maintenance and Test, H1616 specification SS393220.

The circumferential center of the locking ring lugs was designated as the 0° location for purposes of inspection and test orientation.

The pre- and post-test inspections of the container included the probable measurement inaccuracies and recorded the equipment used.

Leak Testing

Leak tests were performed in accordance with ANSI N14.5. Leak rates that fell below $1X10^{-7}$ STD cm/s air were recorded as leak tight. All containers were leak tight prior to testing.

V. Normal Conditions Tests

The hypothetical accident conditions tests were preceded by a compression test of SCTU-3 as specified in the normal conditions tests of 10CFR71. This test requires that the container be subjected to a load of at least five times the weight of the package. To meet these conditions an empty H1616 overpack was placed on top of SCTU-3 and a 500-kg mass was placed on top of the empty overpack. The purpose of stacking two containers was to ensure that the load on the SCTU-3 was transmitted, as would be the case if containers were actually stacked five high. This test was performed at ambient temperature for 24 hours.

VI. Hypothetical Accident Sequence Tests

The hypothetical accident sequence tests are specified as (1) 9-m drop, (2) 1-m puncture and (3) pool fire.

All tests were preheated to 160°F and the minimum surface temperature recorded just prior to impact was 157°F. The preheat temperature was selected to simulate the effects of internal heat generation and insolation. Subsequent analyses as reported in the Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages indicate that temperatures resulting from insolation may be as high as 166°F on the drum surface.

The orientations for the drop tests were based on the previous compliance testing as documented in SAND91-2205. A center-of-gravity over corner (CGOC) drop test onto the locking ring lugs (C9, C11 and TMS1) resulted in driving the lugs into the overpack body and hence increased the difficulty of removing the locking ring. The bottom end drop (C6) had no effect on the locking ring. A side drop onto the locking ring lug (TMS2) also drove the lug into the overpack body and increased the difficulty in removing the locking ring. Slapdown on the lug (C5)

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WMD Container Systems Department
Sandia National Laboratories

drove the lug into the overpack body. A side drop away from the lug (C12) and slapdown away from lug (C10) resulted in the localized loss of engagement between the locking ring and the overpack body. The side and slap down drops were the only tests during the compliance sequence that resulted in any loss of engagement between the overpack and the locking ring. Since the loss of engagement was comparable for each test, the side orientation was selected for each of the supplemental compliance drop tests.

These results indicated that the maximum possibility of a puncture test resulting in the loss of the lid is greatest following drop tests on either the side at 45° or 180°. The 45° impact location was chosen to place the lack of engagement area as close as possible to the lugs without driving the lugs into the overpack body. The 180° impact location was chosen to create damage opposite the lug where there would be minimal resistance to rotating the ring off of the lid. The first two packages were oriented bottom down with a single lug over the puncture bar. This orientation resulted in driving the locking ring upward and inducing shear and bending stresses in the bolt.

The third puncture test was not preceded by a drop test. In this test, the puncture bar was normal to a tangent to the lug surface resulting in the container being rotated 10° to 20° counterclockwise from horizontal about the locking ring bolt. This orientation resulted in the lug being impacted in its stiffest position so that the impact energy acts to remove the lid from the overpack as opposed to deforming the lug and driving it into the overpack body.

A fourth unit repeated the impacts of the first unit test with the addition of passive thermal indicators internal to the package for inclusion in a pool fire test. These tests are summarized in Table I.

Robert L. Glass
WMD Container Systems Department
Sandia National Laboratories

Table 1: Hypothetical Accident Conditions Tests

Test	Orientation	Unit
9 m Drop	Side (45°)	SCTU-1
	Side (180°)	SCTU-2
	No test	SCTU-3
	Side (45°)	SCTU-4
Puncture	Bottom down, impact single lug 0° to 10° from vertical	SCTU-1
	Bottom down, impact single lug 0° to 10° from vertical	SCTU-2
	Impact single lug, 10° to 20° from horizontal	SCTU-3
	Bottom down, impact single lug 0° to 10° from vertical	STCU-4
Pool Fire	Vertical	SCTU-2,3,4

Instrumentation

For the pool fire test, six thermocouples were attached to each overpack. The locations of these thermocouples were at mid height every 90° and lid center and bottom center. SCTU-4 included passive thermal indicators located on the flange, body mid-height every 90°, bottom of the containment vessel, mock-up and lid near the valves.

Pass/Fail Criteria

The criterion for successful performance of the package in the compression test is that the container is reusable.

The criterion for successful performance of the package in the hypothetical accident sequence is that the containment vessel remains leaktight.

VII. Results

The results from the compression test were that there was no visible damage to the container and that it remained reusable.

Robert L. Glass
WMD Container Systems Department
Sandia National Laboratories

The test results demonstrated compliance with the accident resistance requirements of 10CFR71. The containment vessel remained leak tight and the highest measured containment vessel temperature was less that 500°F.

Compliance is shown with four types of information: (1) photographic record and visual inspection, (2) dimensional inspection data, (3) temperature data and (4) leak test results.

Photographic Record and Visual Inspection

A visual inspection of SCTU-3 following the compression test detected no visible damage.

For the hypothetical accident sequences, the impact damage incurred in SCTU-1 is shown in Figures 1 and 2. Figure 1 shows that the flat side drop test at the 45° circumferential location resulted in flattening of the overpack along the impact line. There was no observable loosening of the locking ring as the locking ring and overpack body had the same general deformation. The impact of the lug on the puncture bar, as shown in Figure 2, did result in a prying action that rotated the lug away from the overpack body. This impact did not result in the failure of any components of the locking ring and the lid remained attached to the overpack body.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

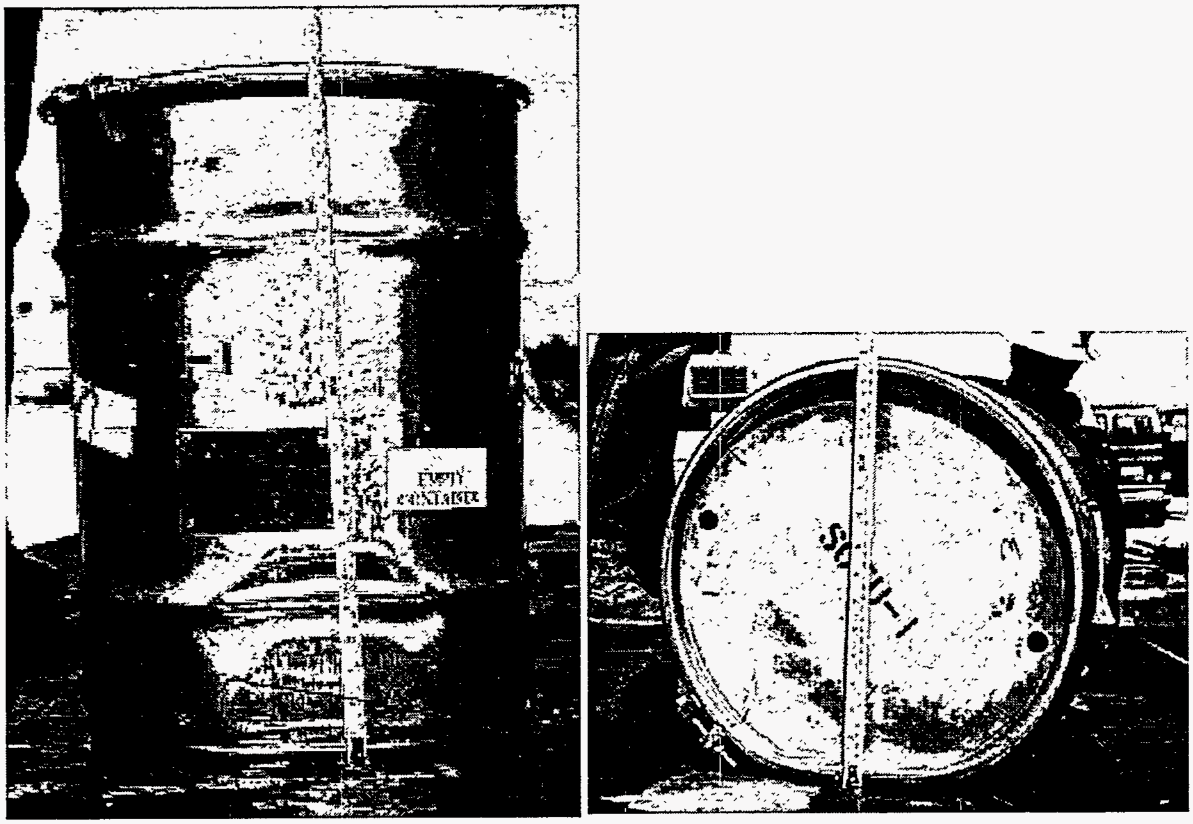

Figure 1: SCTU-1 Side Drop Results

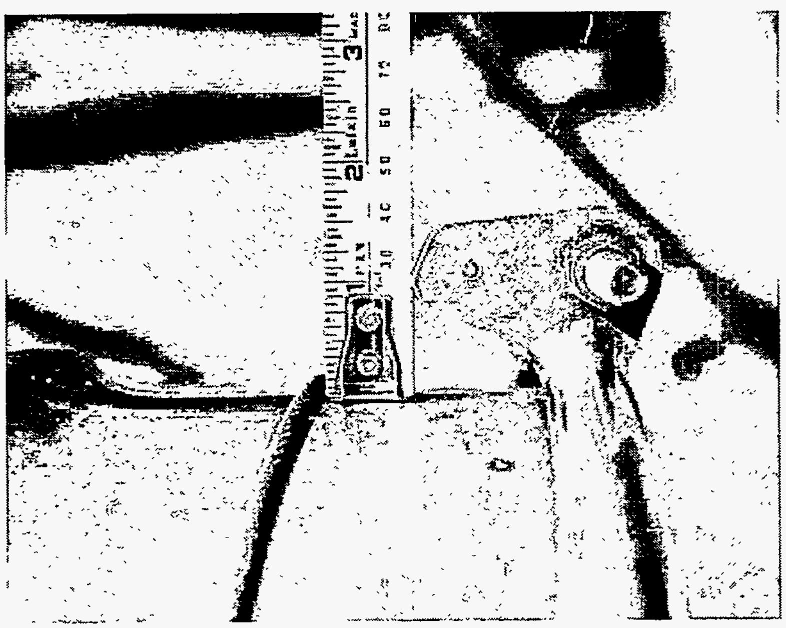

Figure 2: SCTU-1 Puncture Test Lug Deformation

Figure 3 shows the results of the flat side drop at the 180° circumferential location. Again there was a flattening at the impact location, but no discernable loosening of the locking ring. Results from the puncture test were also comparable to those from SCTU-1.

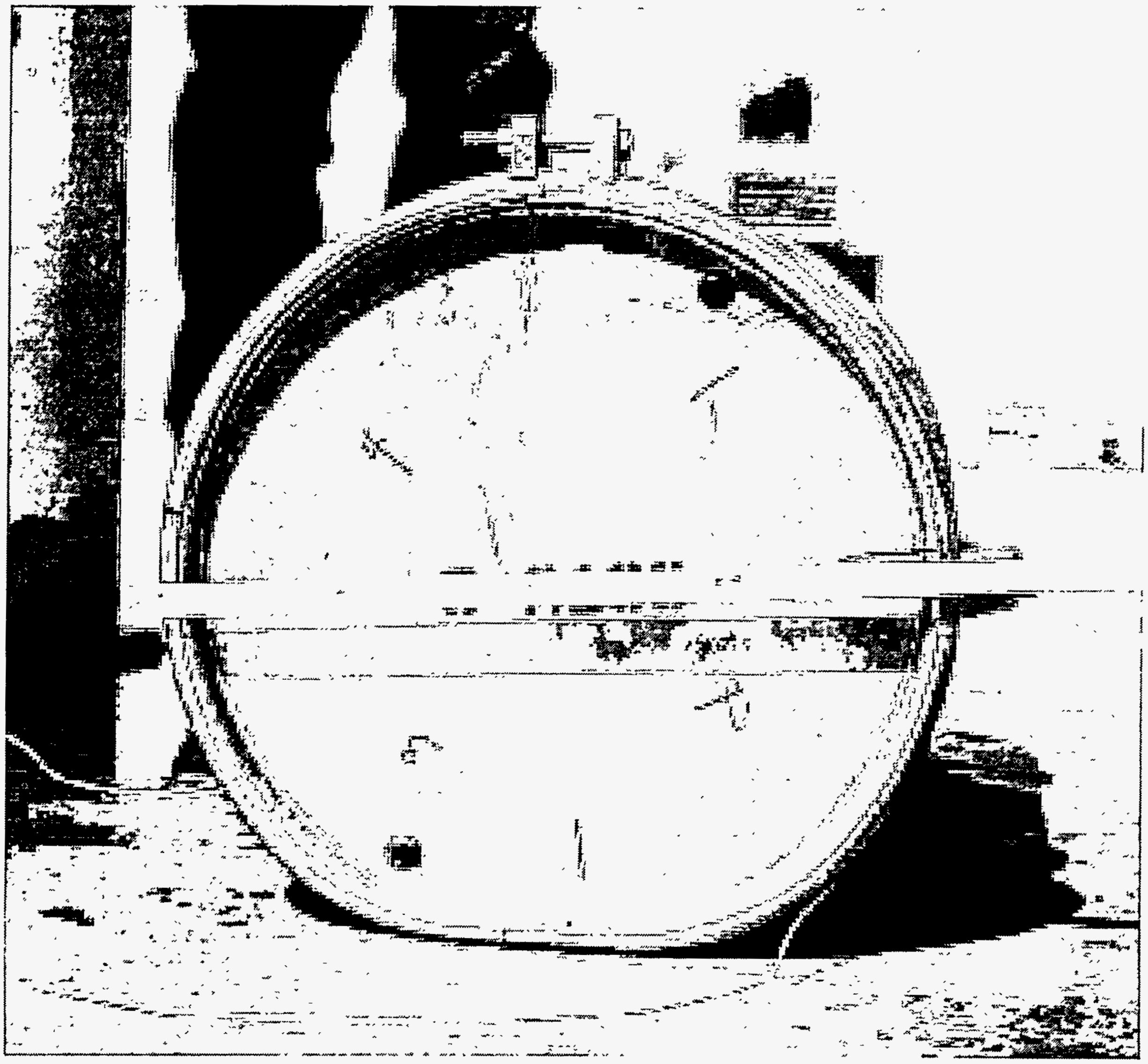

Figure 3: SCTU-2 Side Drop 180° from Lugs

Figures 4 and 5 show the results of the puncture test on SCTU-3. Figure 4 shows the impact on the single lug. Figure 5 shows that the deformation of the lug is smaller than the deformation shown in Figure 2 and again there is no discernable loosening of the locking ring.

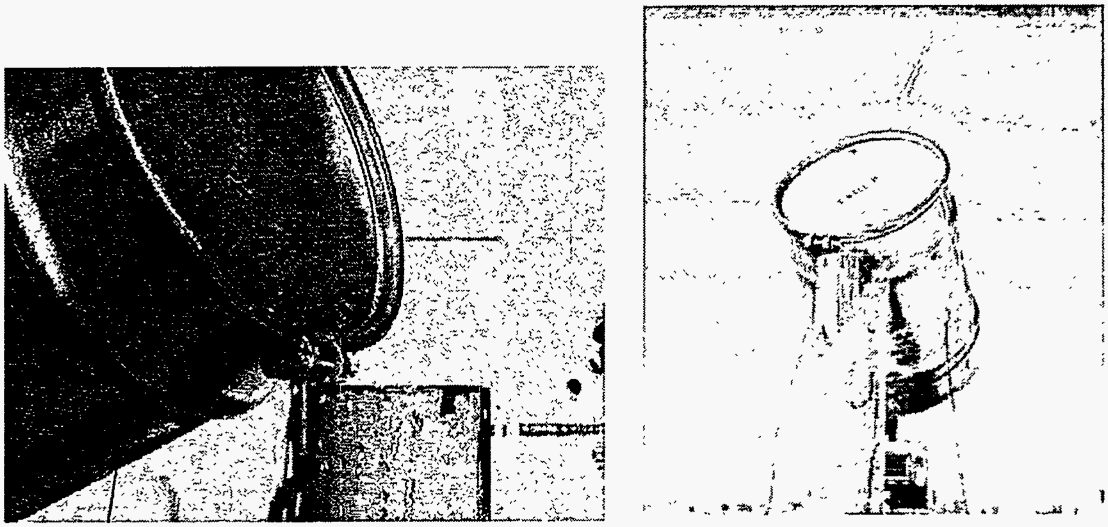

Figure 4: SCTU-3 Impacting the Puncture Bar

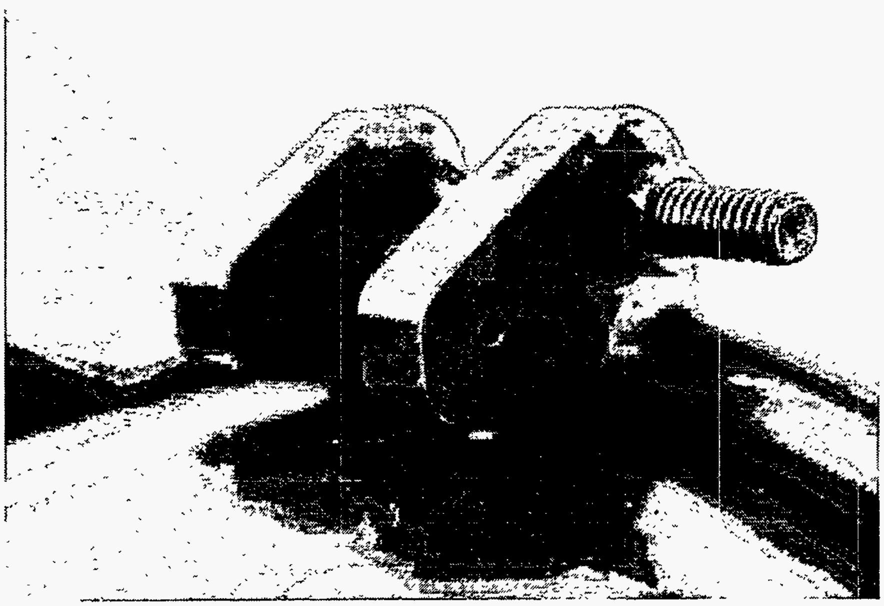

Figure 5: SCTU-3 Lug Deformation from Puncture Test

Figure 6 shows that the damage to SCTU-4 is comparable to that shown in Figure 1 for SCTU-1. Figure 7 captured the lug as it was being deformed during the puncture test. Figure 8 shows the post test deformation. Note that the damage again is comparable to that shown in Figure 2 for SCTU-1.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

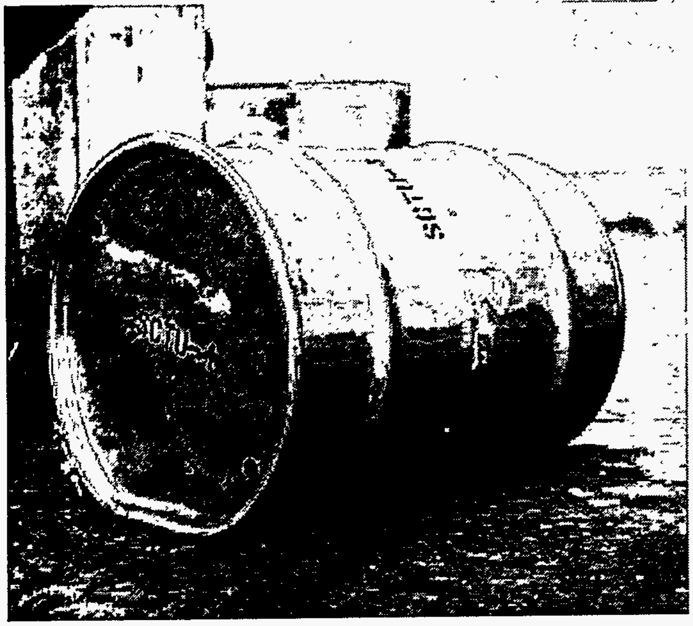

Figure 6: SCTU-4 Drop Test Results

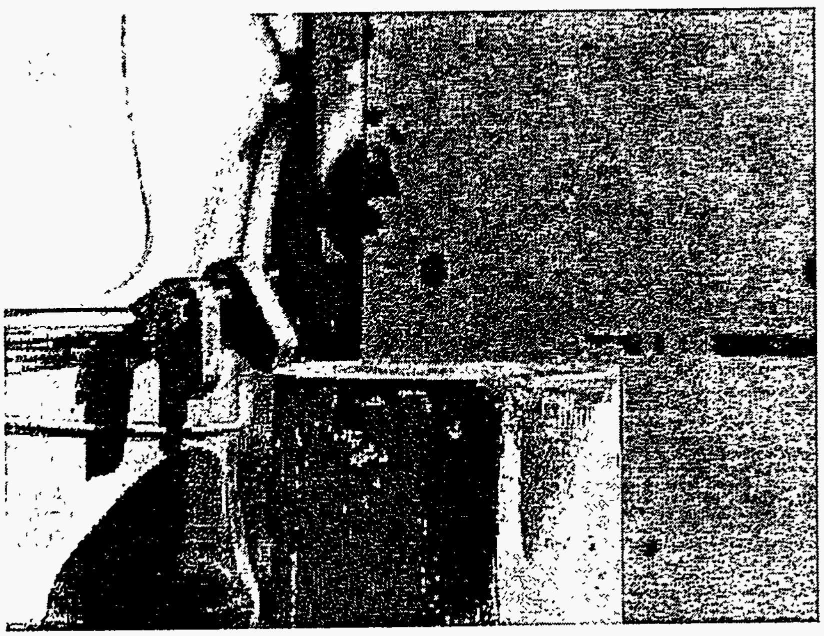

Figure 7: SCTU-4 at Impact

Figure 9 shows a comparison of the deformation of lugs given in the previous figures. SCTU-1 and 4 when subjected to the vertical impact on a single lug had comparable damage. SCTU-3 that was impacted in a stiffer orientation has substantially less deformation.

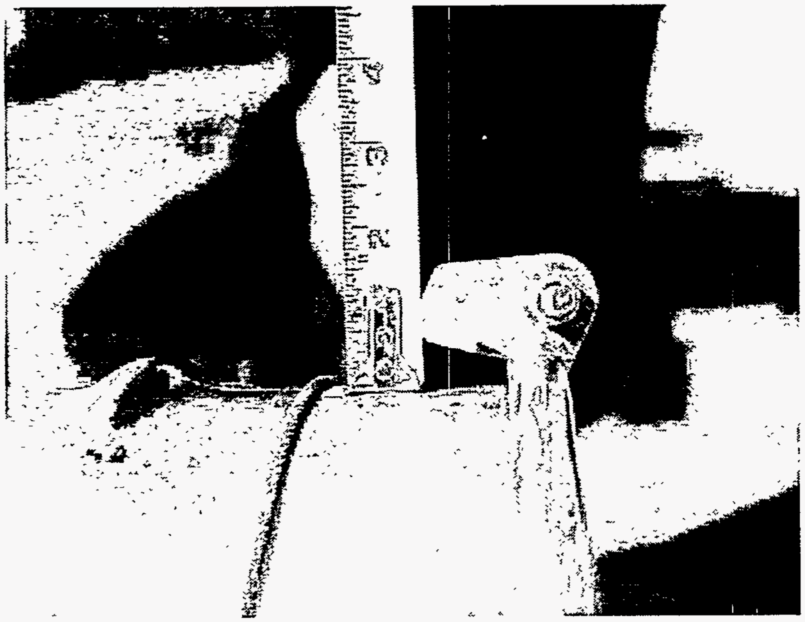

Figure 8: SCTU-4 Lug Deformation

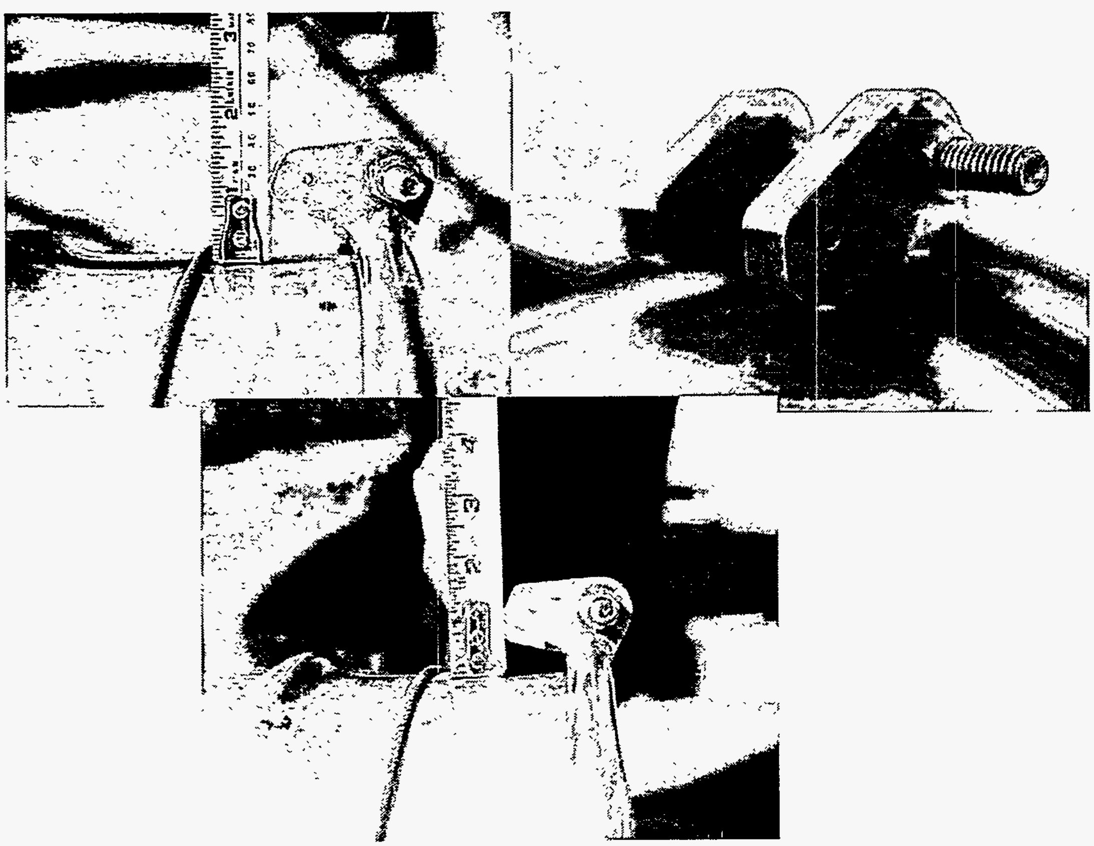

Figure 9: Comparative Lug Deformation

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WMD Container Systems Department
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Figure 10 shows the deformation resulting from the side impacts. All had comparable deformation patterns irrespective of the circumferential impact location and none of the locking rings were loosened by the impacts.

The visual inspection of the locking rings indicated no loss of locking ring engagement, no fractured welds on the impacted lugs and no fractured lug bolts.

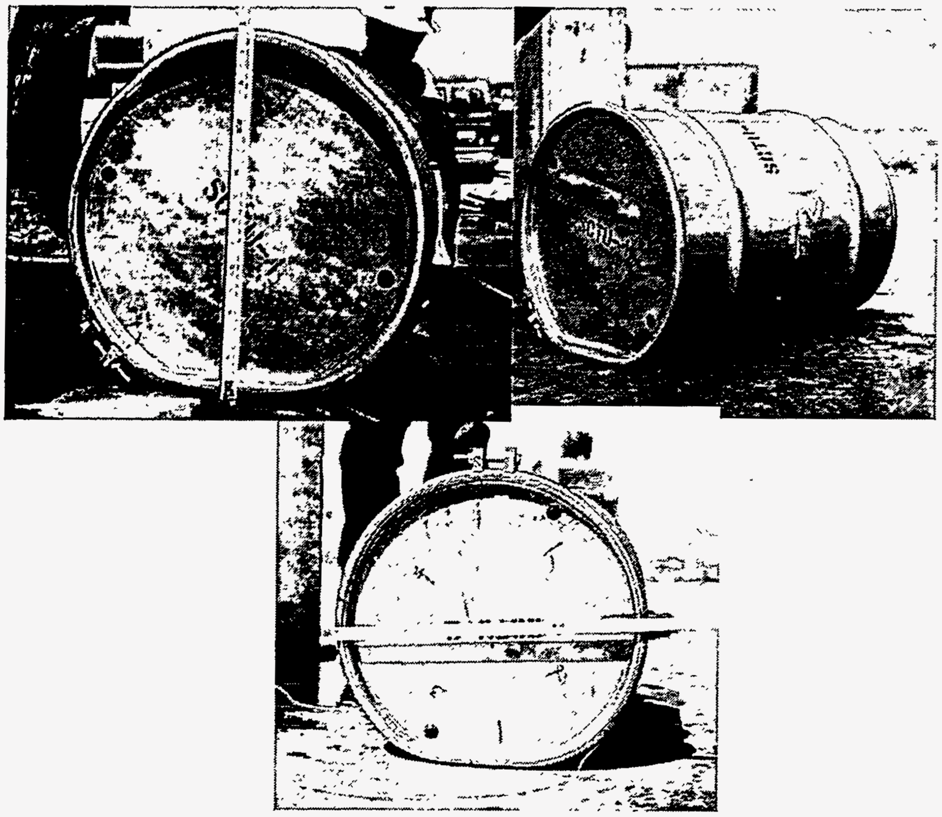

Figure 10: Comparative Drum Deformation

The three supplemental compliance test units configured for the pool fire test are shown in Figure 11. All the units were vertical with the lid up. Since there was no tearing of the stainless steel drum or loosening of the lid, the container orientation was not critical to the test results.

Figure 12 shows the pool fire engulfing the three containers. The data presented in the Temperature Data section will demonstrate that the temperature and time conditions specified in 10CFR71 were met.

Robert E. Glass
WMD Container Systems Department
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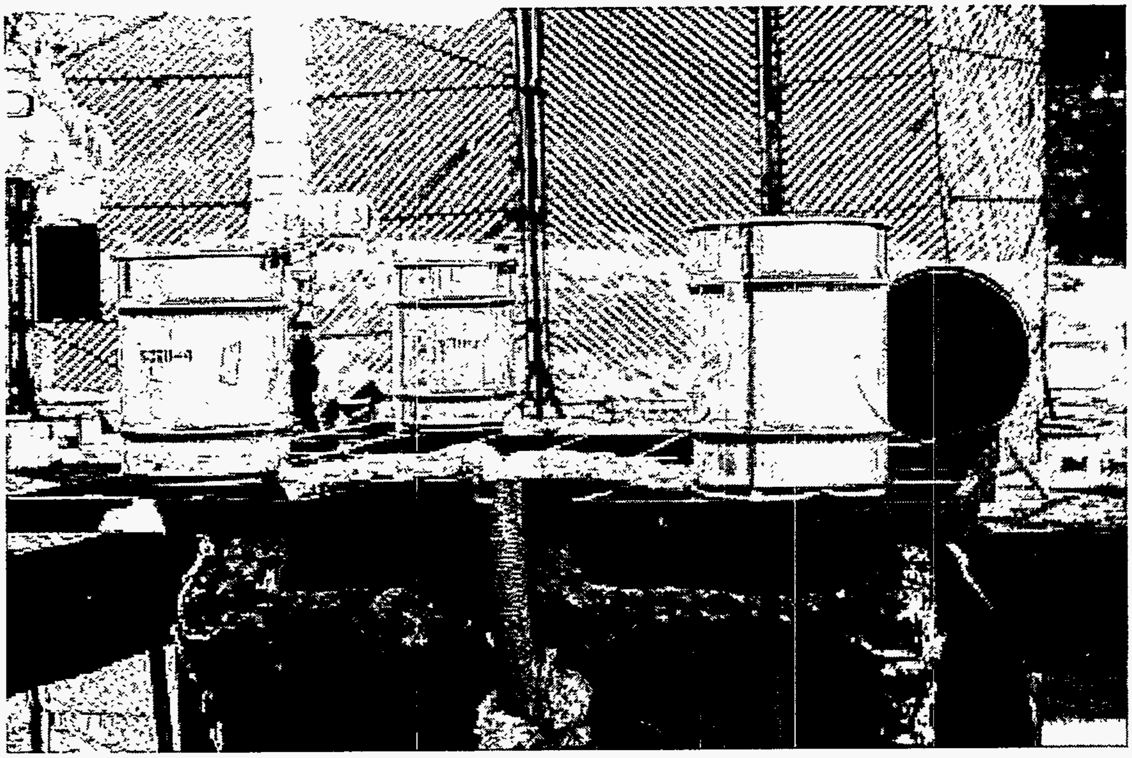

Figure 11: Pool Fire Test Set Up

Figure 12: Pool Fire Test

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WMD Container Systems Department
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After the fire self extinguished, the foam within the containers continued to smolder as shown in Figure 13. After one day, the containers were cool enough to handle. At that point the containers were prepared for leak testing.

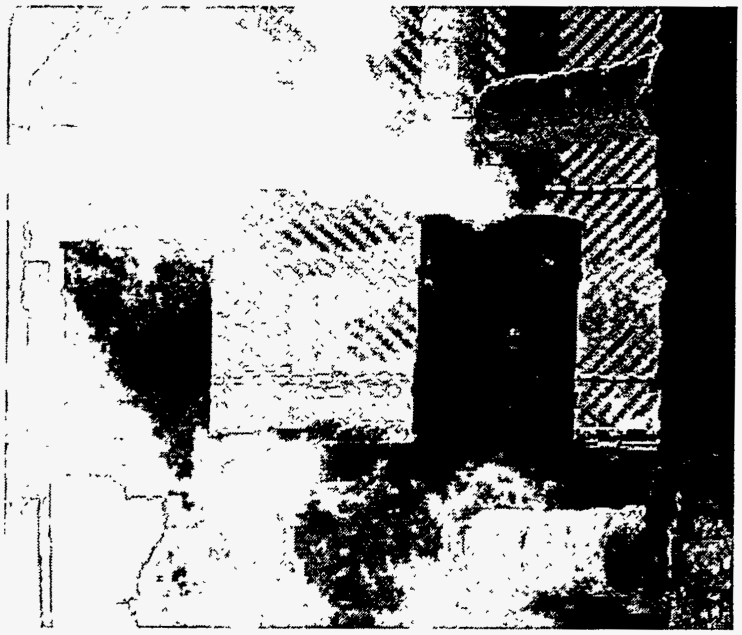

Figure 13: Post Fire Results

Dimensional Inspection Data

The most critical parameters examined after the puncture tests for this sequence of tests are the locking ring deformation and lug gap. The previous compliance tests had demonstrated that no disqualifying damage occurs to the body of the overpack as a result of impact testing. In this particular sequence of tests, the intent was to determine if these tests could damage the locking ring to the extent that either components of the locking ring failed or that sufficient deformation occurred such that confinement of the containment vessel within the overpack was no longer assured.

This report will focus on the measurements taken of the locking ring. In particular, the locking ring diameter was measured every 15 degrees and the gaps between the locking ring lugs and the overpack body were measured. These results are presented below.

Table 2 and Figure 14 show the results of the diameter measurements of SCTU-1 before and after the impact testing. The first column in Table 2 gives the circumferential location in degrees with the midpoint between the lugs designated

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

as the 0° point. All measurements were taken with the locking ring as assembled on the container. The pre-drop measurements show the initial configuration of the locking ring. The post puncture test data shows the configuration of the locking ring after the drop and puncture tests. The final column is the difference between the post test configuration and the pretest configuration. This final column is shown graphically in Figure 14. The maximum change in the diameter is 0.635 inches at the 45° impact point. In addition to the decrease in diameter at the impact point, there is also some ovalization of the ring as demonstrated by the increased diameters away from the impact location.

Table 2: SCTU-1 Locking Ring Deformations

Measurement Location (°)	Pre Drop Test (in.)	Post Puncture Test (in.)	Test Deformation (in.)
0	16.564	16.552	-0.012
15	16.553	16.596	0.043
30	16.554	16.329	-0.225
45	16.559	15.924	-0.635
60	16.560	15.962	-0.598
75	16.563	16.410	-0.153
90	16.565	16.660	0.095
105	16.563	16.675	0.112
120	16.564	16.654	0.09
135	16.561	16.638	0.077
150	16.561	16.623	0.062
165	16.568	16.619	0.051

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

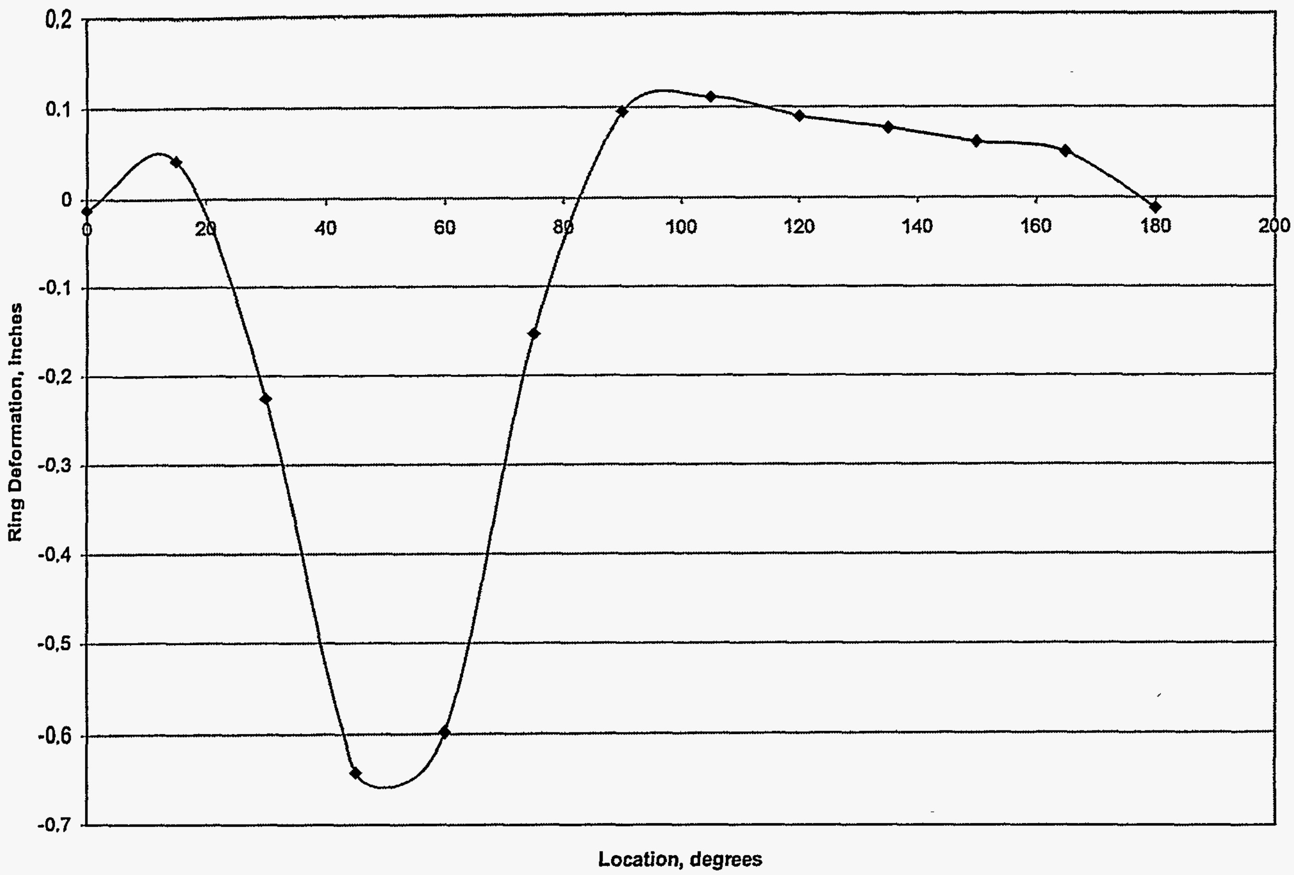

Figure 14: SCTU-1 Ring Deformation

Table 3 shows the effect of the puncture test on the gap between the lug and the overpack body for SCTU-1. The prying action of the puncture bar in this test resulted in increased gaps between the lugs and the overpack body. Both lugs were deformed even though only the right side lug was attacked. The maximum increase in the gap was incurred in the attacked right hand lug. The gap increased from 0.2 to 0.8 inches for a total increase in the gap of 0.6 inches.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

Table 3: SCTU-1 Locking Ring Lug Deformation

Location	Pre Test (in.)	Post Puncture Test (in.)
Right Lug Gap	0.205	0.800
Left Lug Gap	0.160	0.500

Table 4 and Figure 15 show the effects of the impact tests on SCTU-2. This container was impacted at the 180° location. As can be seen in both the Table and the Figure, the maximum deformation is 0.877 along the 0, 180° diameter.

Table 4: SCTU-2 Locking Ring Deformations

Measurement Location (°)	Pre Drop Test (in.)	Post Puncture Test (in.)	Test Deformation (in.)
0	16.573	15.696	-0.877
15	16.575	16.259	-0.316
30	16.573	16.620	0.047
45	16.571	16.664	0.093
60	16.574	16.671	0.097
75	16.578	16.664	0.086
90	16.575	16.669	0.094
105	16.573	16.666	0.093
120	16.573	16.685	0.112
135	16.573	16.691	0.118
150	16.574	16.485	-0.089
165	16.573	15.986	-0.587

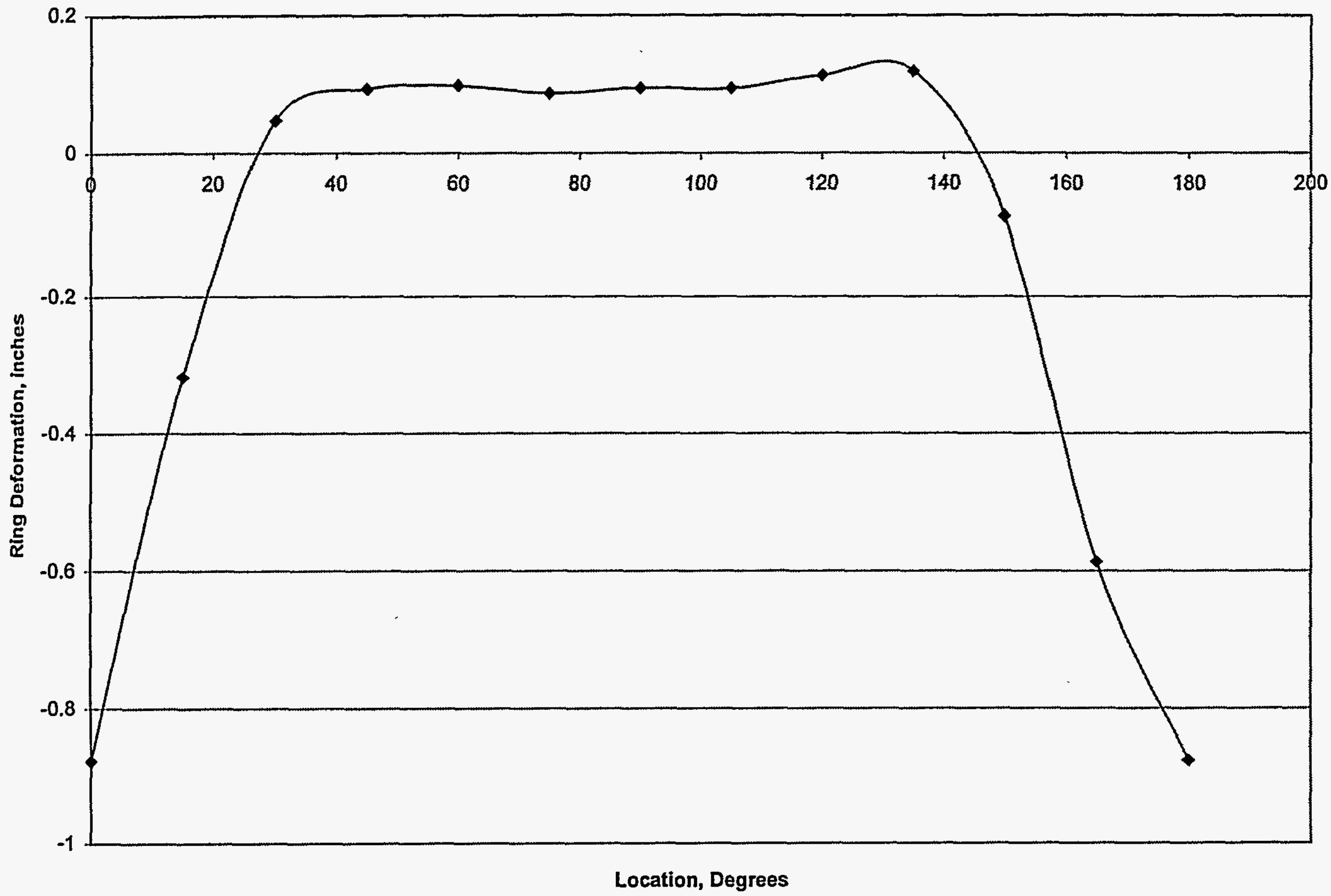

Figure 15: SCTU-2 Ring Deformation

Table 5 shows the effect of the puncture test on the lugs. The maximum increase in the gap for this test is 0.16 inches.

Table 5: SCTU-2 Locking Ring Lug Deformations

Location	Pre Test (in.)	Post Puncture Test (in.)
Right Lug Gap	0.165	0.315
Left Lug Gap	0.155	0.315

Table 6 and Figure 16 show the deformation in the locking ring for SCTU-3. This test consisted of only the puncture test during which the right locking ring lug was impacted normal to the flat surface in an attempt to drive the locking ring off an undamaged container. The results show that there were deformations of up to 0.109 inches. These deformations are much smaller than the other three containers due to the lack of a drop test.

Table 6: SCTU-3 Locking Ring Inspection Results

Measurement Location (°)	Pre Test (in.)	Post Puncture Test (in.)	Puncture Test Deformation (in.)
0	16.591	16.501	-0.090
15	16.594	16.585	-0.009
30	16.590	16.599	0.009
45	16.593	16.603	0.010
60	16.595	16.605	0.010
75	16.585	16.595	0.010
90	16.592	16.567	-0.025
105	16.595	16.528	-0.068
120	16.595	16.594	-0.001
135	16.600	16.590	-0.01
150	16.596	16.558	-0.038
165	16.594	16.485	-0.109

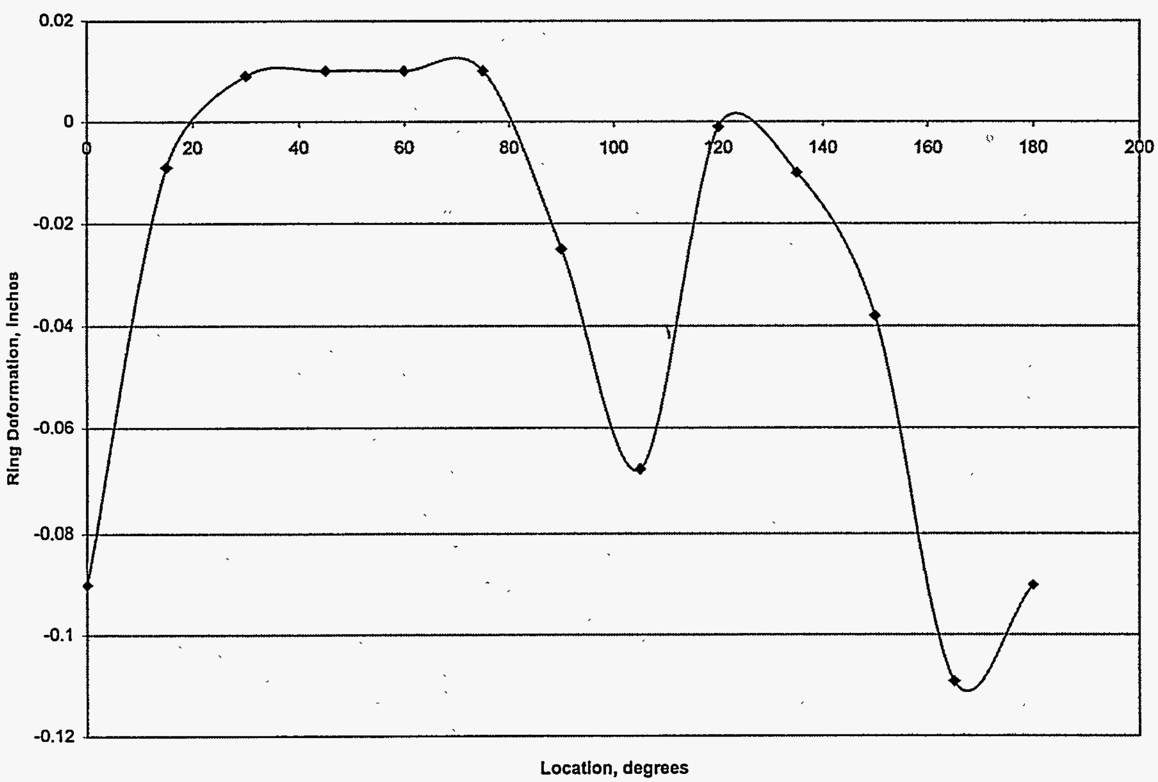

Figure 16: SCTU-3 Ring Deformation

Table 7 shows the effect of the puncture test on the gap between the lug and the overpack body. As expected, the gap was reduced as the lug was driven toward the body of the overpack. The loads and deformations were not of sufficient

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

magnitude to drive the locking ring off and result in loss of confinement for the containment vessel.

Table 7: SCTU-3 Locking Ring Lug Deformations

Location	Pre Test (in.)	Post Puncture Test (in.)
Right Lug Gap	0.210	0.135
Left Lug Gap	0.185	0.165

In Table 8 and Figure 17, a comparison is made between the posttest configurations of all four test units. Figure 17 is graphed with each containers' impact locations designated as 0°. This comparison shows that each of the containers subjected to a drop test (SCTU-1,2,4) had comparable deformations resulting from the impact events. SCTU-3 had much less deformation. SCTU-1 and SCTU-4 had very similar post impact configurations and so having only SCTU-4 in the pool fire was representative of both of those containers.

Table 8: SCTU-1 and 4 Locking Ring Inspection Results

Measurement Location (°)	SCTU-1 Post Test (in.)	SCTU-2 Post Test (in.)	SCTU-3 Post Test (in.)	SCTU-4 Post Test (in.)
0	16.552	15.696	16.501	16.615
15	16.596	16.259	16.585	16.625
30	16.329	16.620	16.599	16.375
45	15.924	16.664	16.603	15.890
60	15.962	16.671	16.605	16.010
75	16.410	16.664	16.595	16.425
90	16.660	16.669	16.567	16.665
105	16.675	16.666	16.528	16.720
120	16.654	16.685	16.594	16.710
135	16.638	16.691	16.590	16.670
150	16.623	16.485	16.558	16.650
165	16.619	15.986	16.485	16.640

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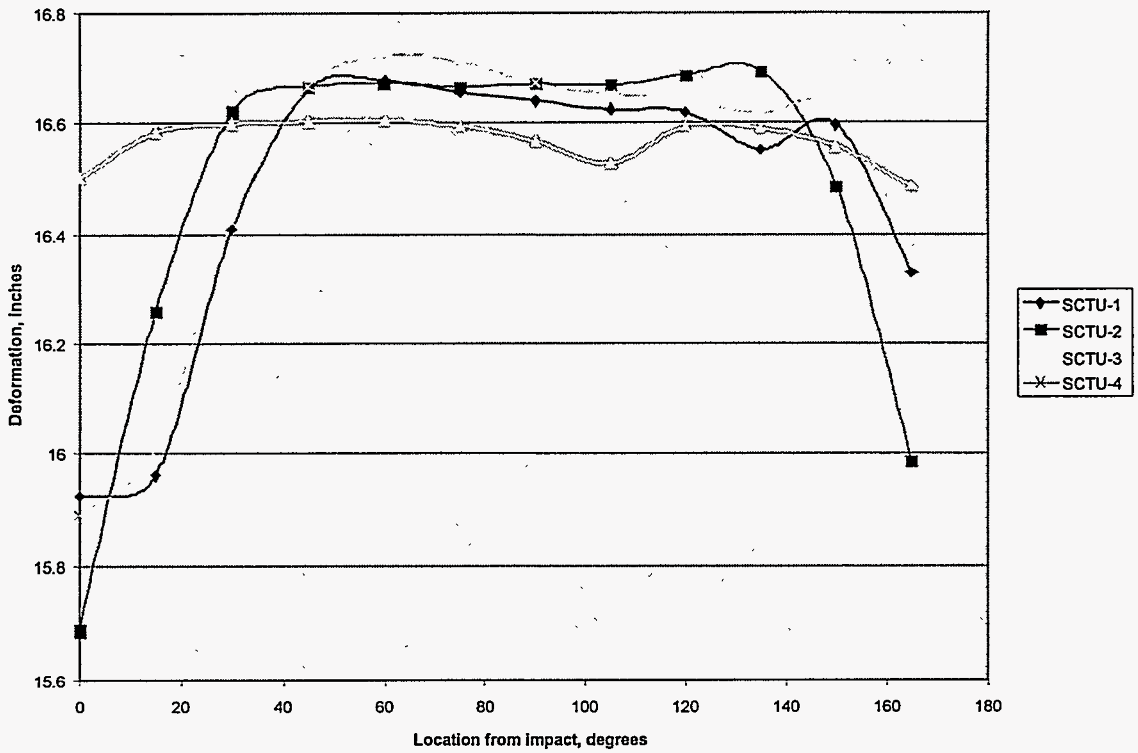

Figure 17: Comparison of Posttest Deformations

Temperature Data

SCTU-2, 3 and 4 were subjected to an all-engulfing pool fire test as defined in 10CFR71. Each of the containers was instrumented with six thermocouples placed on the outside of the drum to monitor skin temperatures. SCTU-4 had passive temperature indicators mounted on the inside of the containment vessel. Table 9 gives the averaged temperature data for the period from 9:37 to 10:07 am. This table shows that the skin temperature of the drums exceeded the regulatory requirement that the fire temperature was at least 800°C for a period of 30 minutes.

Table 9: Time averaged container temperatures

Container	Average Container Temperatures , °C 9:37 to 10:07 am
SCTU-2,3,4	883
SCTU-2	915
SCTU-3	803
SCTU-4	952

Figures 18, 19 and 20 show the temperature histories for each of the containers. These plots show the range of temperature variation within a given pool fire. These range from the tight variation and high temperatures in SCTU-4 to the relatively highly variable, cooler results seen for SCTU-3. In all events, the heat input to each container complied with the regulatory requirements.

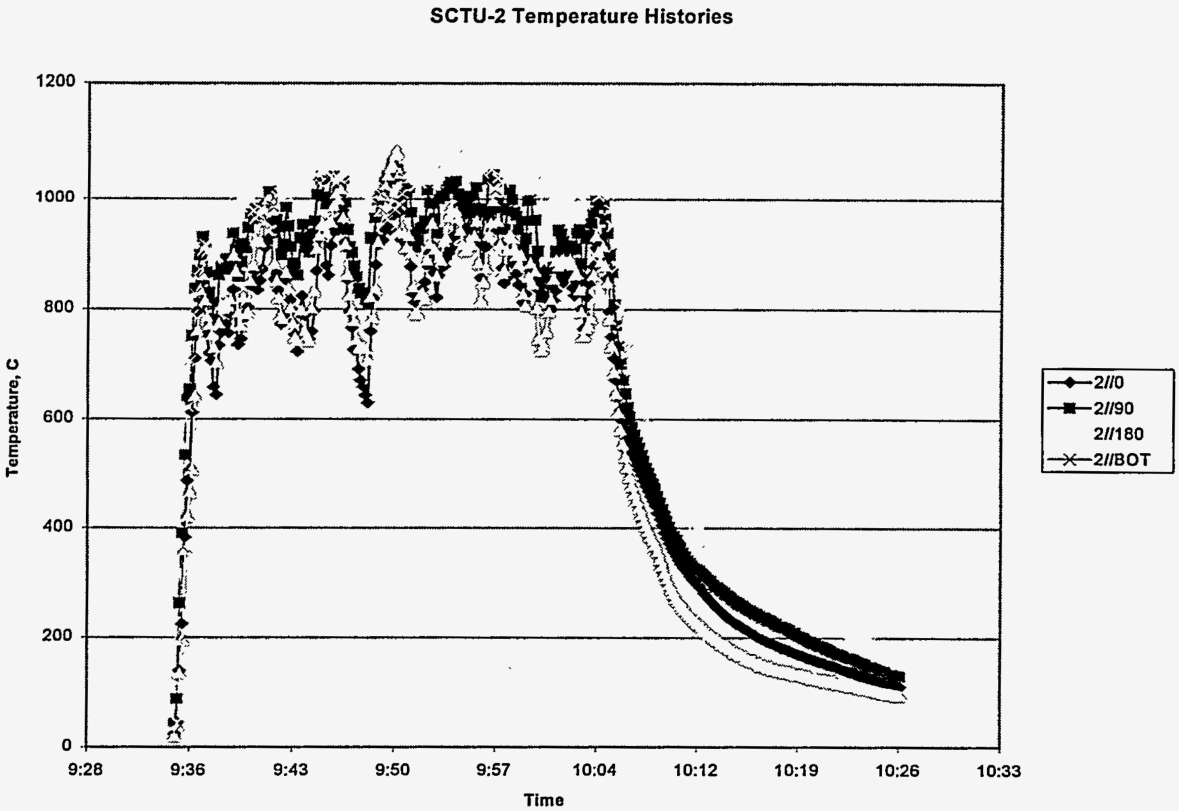

Figure 18: SCTU-2 Pool Fire Test Data

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

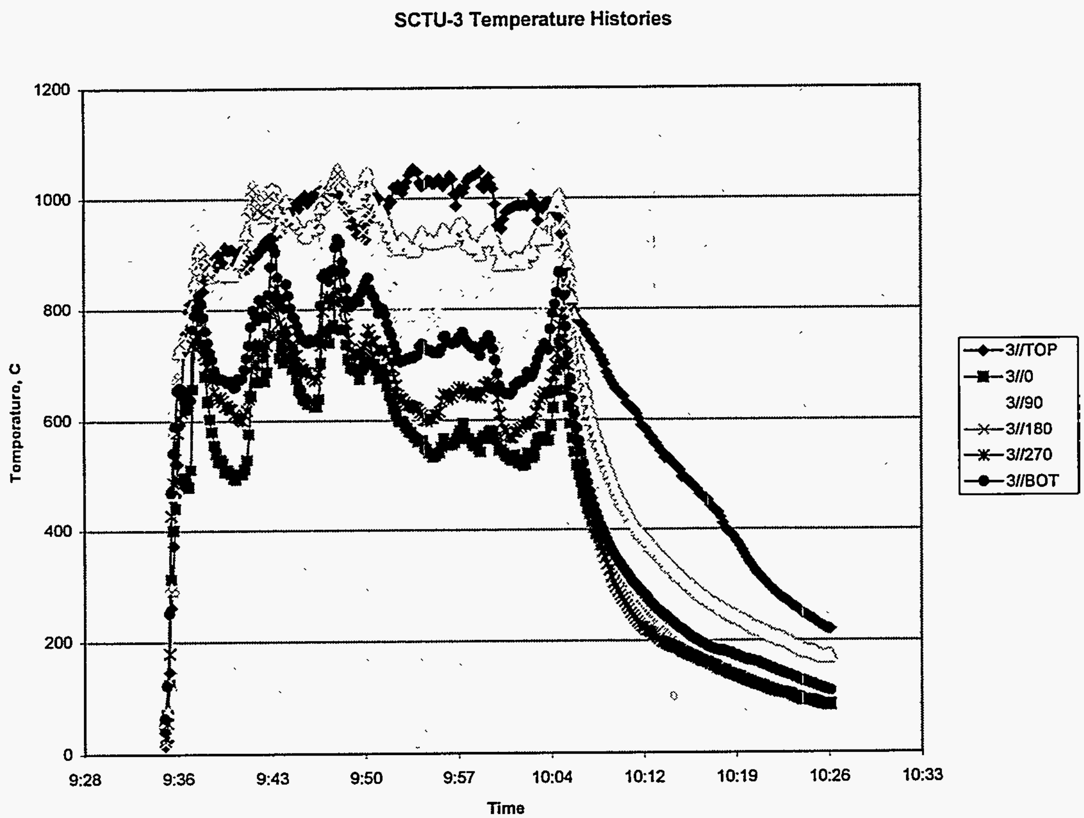

Figure 19: SCTU-3 Pool Fire Test Data

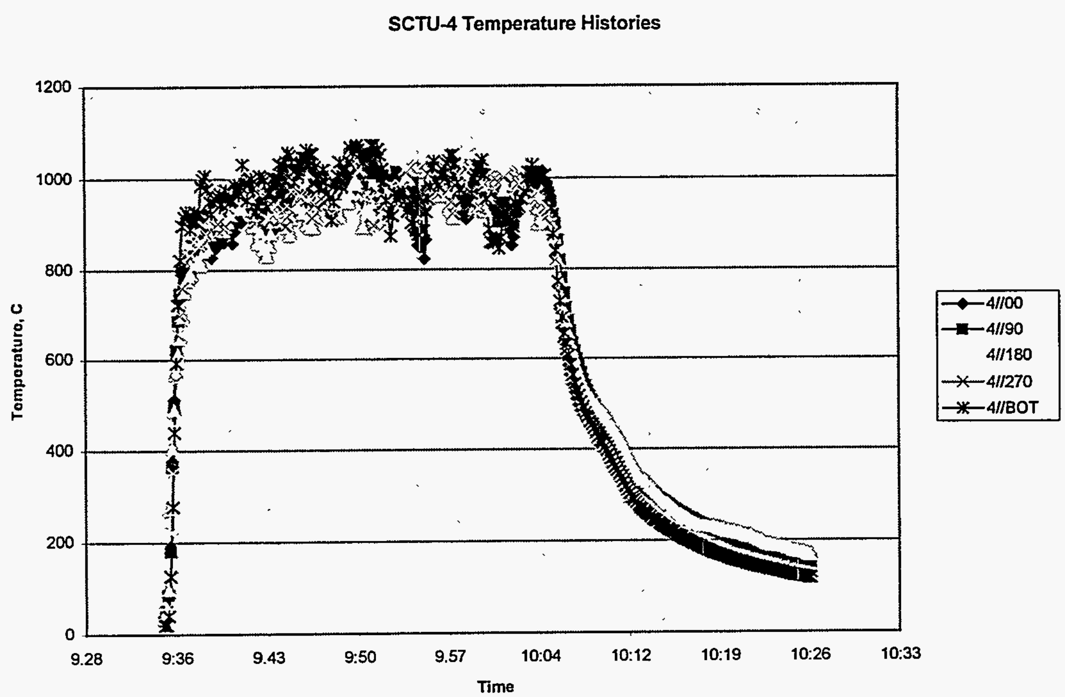

Figure 20: SCTU-4 Pool Fire Test Data

The wind speeds for the pool fire test are shown in Figure 21. These wind speeds are measured outside of the windscreen that protects the fire. As is apparent from the previous temperature histories, these wind speeds did not adversely affect the pool fire.

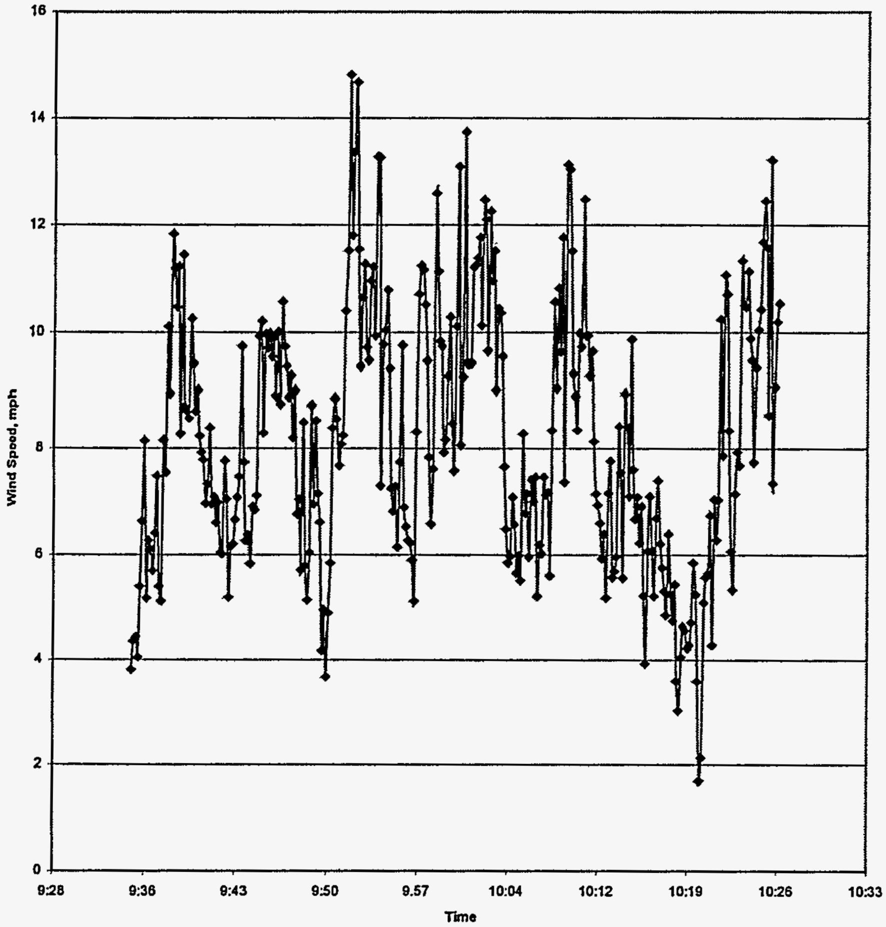

Figure 21: Wind Speed

The internal temperatures are given in Table 10. Note that the range given for temperatures is based on the last black out temperature being the lower temperature and the upper temperature is the next temperature on the passive indicator, so the actual temperature lies within that range.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories

Table 10 : Internal Temperatures, SCTU-4

Location	Temperature Range, °F
Body, flange	410 - 435
Body, flange at 180°	410 - 435
Body, mid wall	450 - 465
Body, mid wall at 90°	465 - 500
Body, mid wall at 180°	465 - 500
Body, bottom	410 - 435
Lid, barrier plate	390 - 410
Lid, curved surface	410 - 435
Mock-up	290 - 300

Leak Test Results

All of the containment vessels were leaktight at the start of testing.

Following the test and disassembly of the overpacks, the containment vessels were leak tested. The leak rates demonstrated that all of the containment vessels were leaktight as defined in ANSI N14.5.

VIII. Conclusion

The results of these sequences of tests provide evidence that the H1616 container meets the requirements of the Code of Federal Regulation, Title 10, Part 71, Packaging and Transportation of Radioactive Materials. Specifically, having been subjected to the hypothetical accident sequence, the containers remained leaktight.

Robert E. Glass
WMD Container Systems Department
Sandia National Laboratories