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Hanford Immobilized High-Level Waste Canister Drop Testing

G. B. Josephson
J. M. Alzheimer

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Test Specification: 24590-HLW-TSP-RT-04-001 Rev. 0
Test Plan: TP-RPP-WTP-321
Test Exception: 24590-HLW-TEF-RT-05-00002;
24590-HLW-TEF-RT-05-00003
Material Acceptance Plan: 24590-WTP-MAP-AS-05-00005
Test Procedure: TPR-RPP-WTP-319; TPR-RPP-WTP-320;
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Test Instruction: TI-RPP-WTP-356; TI-RPP-WTP-357; TI-RPP-WTP-358;
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Welding Procedure: PNNL Facilities & Operations Welding Manual, ADM-023

R&T Focus Area: Waste Form Qualification

Test Scoping Statement: B-63

10/31/05
for W. L. Tamosaitis

ACCEPTED FOR
WTP PROJECT USE

Battelle—Pacific Northwest Division
Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by Test Specification 24590-HLW-TSP-RT-04-001 Rev. 0 and Test Plan TP-RPP-WTP-321 Rev. 0. The work and any associated testing followed the quality assurance requirements outlined in the Test Specification/Plan. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

Gordon H. Beeman, Manager
WTP R&T Support Project

10/18/05
Date

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Acronyms and Abbreviations

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BNI	Bechtel National Incorporated
COG	center of gravity
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
HLW	high-level waste
IAEA	International Atomic Energy Agency
IHLW	immobilized high-level waste
MAP	Materials Acceptance Plan
MSLD	mass spectrometer leak detector
ORP	Office of River Protection
PNWD	Battelle—Pacific Northwest Division
QARD	Quality Assurance Requirements Document
WASRD	Waste Acceptance System Requirements Document
WVDP	West Valley Demonstration Project

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Test Summary

Two prototypic immobilized high-level waste (IHLW) canisters were filled with non-radioactive IHLW simulant glass, drop tested from 7 meters, and subsequently examined and leak tested. One canister, HT002, had a 3/8-in. wall thickness; the other canister, HT503, had a 10-gage (0.135-in.) wall thickness. Both canisters passed Waste Acceptance System Requirements Document (WASRD) 4.8.8 requirements (DOE 2002).

Additionally, the canisters were measured before and after the drop, and overall canister deformations were quantified. Both canisters were axially compressed from the drop, and the diameters of the canisters near the bottom expanded. The 10-gage wall canister had greater deformation than the thicker (3/8-in.) wall canister. Deformations of the 3/8-in. wall canister were sufficiently small that it was not readily apparent that the canister had been dropped. Deformations of the 10-gage wall canister were clearly visible. The drop impact formed many horizontal "wrinkles" or bulges in the wall around the lower half of the canister.

Strain circles were added in strips in eight sections around the bottoms of the canister walls and on the reverse-dished canister bottoms. Some of the bulges formed in sections that had been marked by strain circles. The largest strains measured by the strain circles were still low (<1%) and could not be statistically differentiated from zero within the accuracy of the method ±3%. Typical strains to failure for 304L stainless steel are on the order of 40%. The conclusion from the strain circles is that no area of the canisters was strained close to failure.

Objectives

Objectives for the test are summarized in Table S.1.

Table S.1. Test Objectives and Test Descriptions

Test Objective	Objective met? (Y/N)	Description
Waste Compliance with WASRD (4.8.8)	Y	Canister survived 7-meter drop onto unyielding surface without evidence of breach and passed leak test (see Section 3).
Engineering data—canister measurements (diameter, length, bow and warp)	Y	Measurements conducted before and after drop. Deformations from impact determined (see Section 4 and 5).
Engineering data—strain circles	Y	Strain circles applied to sections of canister wall and on canister bottom. Strain circles measured before and after drop. Strains were small (~1%), less than the tolerance of the method, and much less than typical strain-to-failure for 304L stainless steel (see Section 6).

Test Objective	Objective met? (Y/N)	Description
Engineering data—helium leak test	Y	Helium leak test port installed. Helium leak tests conducted before and after test drop. Canister leakage rate was “non-detectable” before and after drop. Canister was “leak-tight” by WASRD standard, $<1\times10^{-4}$ ref-cc/sec (see Section 3).
Engineering data—inspections	Y	Canisters were inspected upon receipt, before drop test and after drop test. All surfaces of canisters were photographed before and after drop test. Only observable “damage” was bulges (“wrinkles”) on walls of 10-gage canister (see Figures 4.11, 5.2, 5.3, and 5.4).
Engineering data—bottom drop	Y	Canister angle upon impact was 0° from vertical (±0.25°) (see Section 2.1.4).
Engineering data—video record	Y	High-speed (500 frames/sec) video records of both canister test drops were taken from orthogonal directions. High speed videos plus regular speed video of technical aspects of the test drops were taken. Videos are compiled into a video documentary of the test drops (frames from the video are Figures 2.8, 2.9, and 5.4).

Test Exceptions

Table S.2. Test Exceptions and Test Descriptions

Test Exception	Description/Impact
24590-HLW-TEF-RT-05-00002	The test exception deleted the requirement to determine and mark the center-of-gravity for each canister. The change did not impact the objectives of the test. Other changes clarified the report requirements and contacts. These changed the administration of the project, but not the objectives.
24590-HLW-TEF-RT-05-00003	The test exception expanded the defined scope so that two canisters would be drop tested, a 3/8-in. wall canister and a 10-gage wall canister. This test exception expanded the objectives of the test in that two canister designs would be tested for conformance to WASRD 4.8.8. Previously, only one canister would initially be tested. The test exception allowed a wider tolerance for the drop test height, based upon a propagation of errors analysis that indicated the planned tolerance was not achievable. The change did not impact the test objectives.

Results and Performance against Success Criteria

Table S.3. Success Criteria and Results

Success Criteria	Did results meet success criteria?
Dropped canister passes helium leak test, $<1\times10^{-4}$ ref-cc/sec.	Yes, both canisters passed helium leak test, $< 1\times10^{-4}$ ref-cc/sec.
Dropped canister shall not lose glass contents based on visual examination of canister and drop pad.	Yes, there was no visible breach of either canister or glass lost through the canister walls, lid, or bottom. **Note:** Some glass was lost during the first drop test, canister HT002 (3/8-inch wall), through a port that was installed to facilitate helium leak testing. The port is not part of the canister design that was being tested. The port was more firmly sealed for the second canister drop HT503 (10-gage wall) and no glass was lost.

Quality Requirements

Application of WTP Project-SP Quality Assurance Requirements

Battelle Pacific Northwest Division's (PNWD) Quality Assurance Program is based upon the requirements as defined in the United States Department of Energy (USDOE) Order 414.1A, Quality Assurance and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A -- Quality Assurance Requirements (a.k.a. the Quality Rule). PNWD has chosen to implement the requirements of DOE Order 414.1A and 10 CFR 830, Subpart A by integrating them into the Laboratory's management systems and daily operating processes. The procedures necessary to implement the requirements are documented through PNWD's Standards-Based Management System (SBMS).

PNWD implements the WTP Project-SP quality requirements by performing work in accordance with the PNWD *Bechtel National, Inc. Support Program Quality Assurance Program* (QAP). This work was performed to the quality requirements of NQA-1-1989 Part I, Basic and Supplementary Requirements, NQA-2a-1990, Part 2.7 and DOE/RW-0333P, Rev 13, Quality Assurance Requirements and Descriptions (QARD) (DOE 2003). These quality requirements are implemented through PNWD's *Waste Treatment Plant Support Project (WTPSP) Quality Assurance Requirements and Description Manual*.

A matrix that cross-references the NQA-1, NQA-2a and QARD requirements with the PNWD's procedures for this work is given in Appendix A Table A.1. It includes justification for those requirements not implemented.

TABLE A.1 is the same as Table 2, Quality Assurance Requirements, in the project test plan, TP-RPP-WTP-321.

In addition to the Quality assurance requirements listed above the progress of the canister testing was incorporated into a Materials Acceptance Plan (MAP), 24590-WTP-MAP-AS-05-00005, that included witness and hold point inspections of the canister and testing records at defined stages during the testing. The MAP witness and hold points are included in Table A.2 of Appendix A.

WTP Project R&T Test Conditions

Table S.4. Research and Technology Test Conditions

R&T Test Conditions (Test Spec. ref.)	Were Test Conditions Followed?
Witness and Hold Points (6.2.1)	Yes, all witness and hold points were conducted as per the Materials Acceptance Plan (MAP), 24590-WTP-MAP-AS-05-00005.
Inspections (6.3.1.1)	Yes, canisters were inspected upon receipt, before drop test and after drop test. All surfaces of canisters were photographed before and after drop test. Only observable "damage" was bulges ("wrinkles") on walls of 10-gage canister after drop test (see Figure 5.2).
Canister measurements (6.3.1.1, 6.3.3.1)	Yes, measurements (diameter, length, and warp) conducted before and after drop. Deformations from impact determined (see Sections 4 and 5).
Strain circles (6.3.1.2)	Yes, strain circles applied to sections of canister wall and on canister bottom. Strain circles measured before and after drop. Strains were small (~1%), less than the tolerance of the method, and much less than typical strain-to-failure for 304L stainless steel (see Section 6).
Helium leak test (6.3.1.3, 6.3.1.4, 6.3.3.2)	Yes, helium leak test port installed. Helium leak tests conducted before and after test drop. Canister leakage rate was "non-detectable" before and after drop. Canister was "leak-tight" by WASRD standard, $<1\times10^{-4}$ ref-cc/sec (see Section 3).
Photographs (6.3.1.5, 6.3.3.3)	Yes, all surfaces of canisters were photographed before and after drop test. Only observable "damage" was bulges ("wrinkles") on walls of 10-gage canister (see Figure 5.2).
Bottom drop (6.3.2.1)	Yes, canister angle upon impact was 0° from vertical (±0.25°) (see Section 2.1.4).
Drop from 7 m (6.3.2.2)	Yes, canister height was 7 m -0/+3 cm; Drop pad met International Atomic Energy Agency (IAEA) requirements for an "unyielding" surface (see Sections 2.2, 2.3).
Video record (6.3.2.3, 6.3.2.4)	Yes, high-speed (500 frames/sec) video records of both canister test drops were taken from orthogonal directions. High speed videos plus regular speed video of technical aspects of the test drops. Videos are compiled into a video documentary of the test drops. (Frames from the video are Figures 2.8, 2.9, and 5.4.) Canister angle at impact determined using individual frames

R&T Test Conditions (Test Spec. ref.)	Were Test Conditions Followed?
	of the videos immediately before impart (see Figures 2.8 and 2.9).
Test Plan (6.3.2.5)	Yes, Test Plan identifies measurements, inspections, and test conditions.
Drop Pad examination (6.3.2.6)	Yes, drop pad was examined for glass fragments after each test drop (see Section 3.2). **Note:** Some glass was lost during the first drop test, canister HT002 (3/8-inch wall), through a port that was installed to facilitate helium leak testing. The port is not part of the canister design that was being tested. The port was more firmly sealed for the second canister drop HT503 (10-gage wall), and no glass was lost.

Simulant Use

N/A.

These tests used prototypic canisters filled with HLW glass simulant. No testing is planned for canisters containing actual waste because the tests are on the canister, not the waste. The use of glass simulants should not impact the canister testing results.

Discrepancies and Follow-on Tests

None.

1.0 Introduction

Since 1975, Battelle has conducted impact tests on canisters filled with simulated immobilized high-level waste (IHLW). Canisters have been dropped from heights ranging from 0.3 m to 31.7 m (1 ft to 100 ft) in a number of different orientations. Following impact, the canisters underwent tests that have contributed to the safety analysis of transporting and handling high-level waste (HLW) canisters. Among the tests were measurements of canister deformation and canister integrity by helium leak testing.

As part of its IHLW Product Compliance Plan (Nelson 2004), Bechtel National Incorporated (BNI) contracted PNWD to conduct drop tests on two prototypic IHLW canisters to demonstrate that the canisters could withstand a drop from 7 m (23 ft) as required by WASRD 4.8.8 (DOE 2002). The canisters were dropped flat onto the bottom of the canister according to Test Specification 24590-HLW-TSP-RT-04-001, *Immobilized High-Level Waste Canister Drop Tests* (Larson 2004), and Test Exceptions 24590-HLW-TEF-RT-05-00002 (Larson 2005a) and 24590-HLW-TEF-RT-00003 (Larson 2005b). The canister drop testing with associated activities and documentation were conducted in compliance with the requirements of DOE/RW-0333P, *Quality Assurance Requirements and Description* (QARD) Rev.13 (DOE 2003). These quality requirements were implemented through PNWD's *Waste Treatment Plant Support Project (WTPSP) Quality Assurance Requirements and Description Manual* (PNWD 2004). A matrix that cross-references the QARD requirements with the PNWD's procedures for this work is given in Appendix A, Table A.1.

In addition to the Quality assurance requirements listed above the progress of the canister testing was incorporated into a *Materials Acceptance Plan (MAP), 24590-WTP-MAP-AS-05-00005* (BNI 2005), that included witness and hold point inspections of the canister and testing records at defined stages during the testing. The MAP witness and hold points are included in Table A.2 of Appendix A.

The main criterion for success was that the canister would not leak after the test drop as demonstrated by a leak rate of less than 1×10^{-4} ref-cc/sec (DOE 2002). Additionally, the canisters were to be free of visible breach or loss of waste glass. Measurements of the canister length, diameter, and distortion (straightness) were made before and after the canister drop to quantify the amount of canister deformation caused by the impact.

The test canisters were 0.6 m (2 ft) diameter and 4.6 m (15 ft) high. The two test canisters were made of 304L stainless steel and represented designs with different canister wall thicknesses, one with a 3/8-in. wall thickness and one with a 10-gage wall thickness (measuring ~0.135 in.). Figure 1.1 shows the canister design.

Canister HT002 (3/8-in. wall) weighed 3706 kg; and canister HT503 (10-gage wall) weighed 3533 kg. In addition to the weight of the filled canister, each drop included additional weight that added to the total impact energy. Each canister had a lid welded on to it to make it leak-tight (5 kg), plus the weight of the lifting collar (43 kg), rigging (20 kg), and rubber padding (9 kg). The total dropped weight included the weight of the canister plus 77 kg.

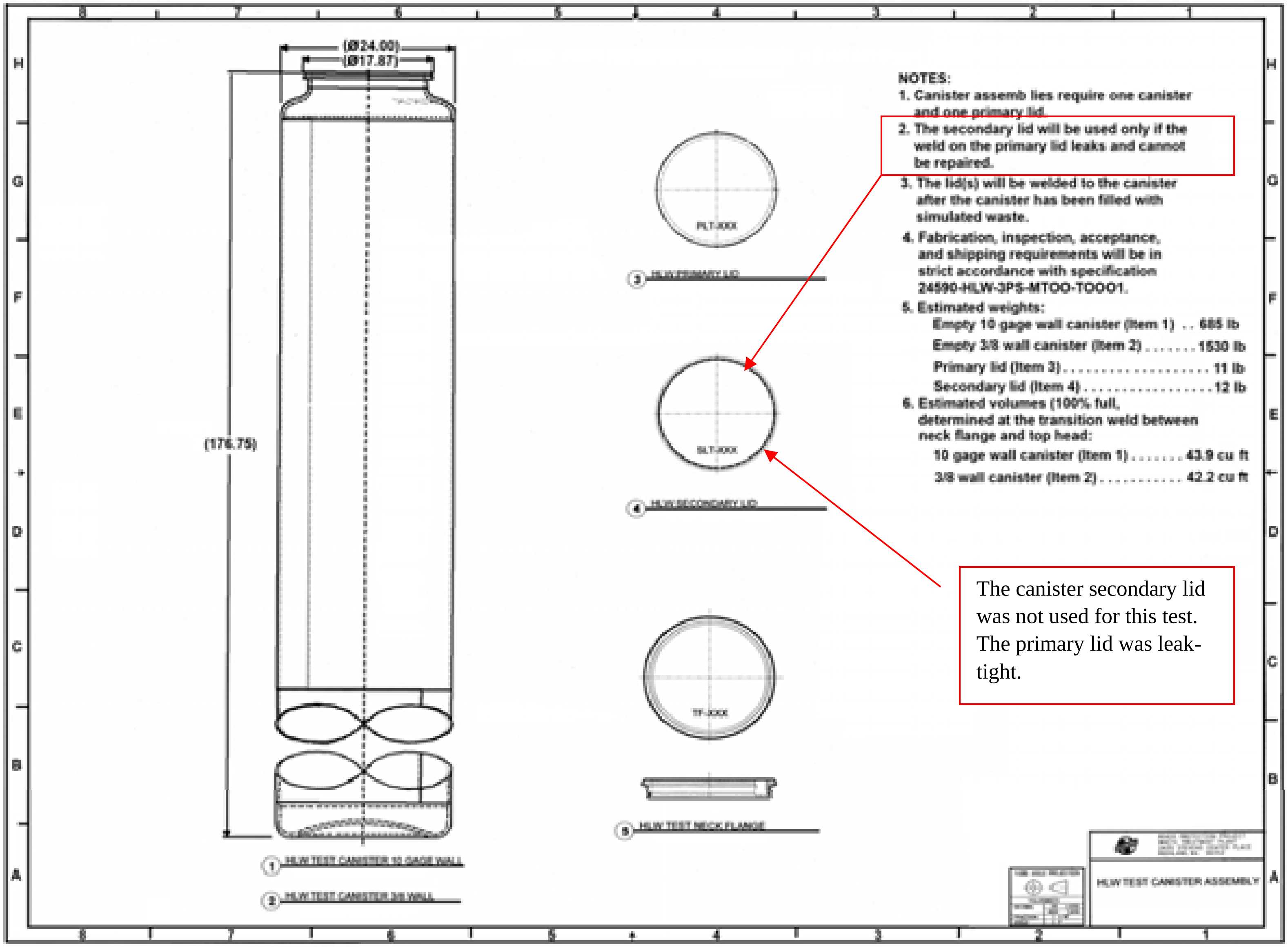


Figure 1.1. WTP Project IHLW Canister

2.0 Canister Drop Test Description

The canister drop was conducted to achieve three key requirements:

1) The canister was to have a “flat bottom” impact.
2) The drop height was to be at least 7 m (23 ft), but not excessively greater than 7 meters.
3) The drop pad was to qualify as an “unyielding” surface as specified by the International Atomic Energy Agency (IAEA).

2.1 “Flat bottom” (vertical) Impact

Three aspects of the drop were critical to achieve a “flat bottom” drop:

1) Canister hanging angle
2) Swinging
3) Canister release.

2.1.1 Canister Hanging Angle

Previous canister drops employed straps cinched around the canister body or top flange to suspend the canister. Trial and error adjustments to the straps allowed the riggers to achieve an orientation near target angles, limited by time, patience, and skill of the rigger. Drops that were to be “flat” were able to achieve an orientation within 1.5° of vertical (Farnsworth and Alzheimer 1987) by carefully adjusting the hanging straps so that the canister hung vertically before dropping. On some occasions, the canister drops were sufficiently flat that the canister remained upright after dropping 7 m (23 ft) (Olson and Alzheimer 1989).

This project employed a lifting collar to suspend the canister to achieve the “flat bottom” drop. There were two main drivers:

1) The adjustments needed to be made quickly and precisely. Both test drops were conducted as part of a program with a fixed time schedule. It was considered that the “trial and error” nature of adjusting hanging straps could cause delays. A collar could be fixed before the program so that adjustments would not be necessary.
2) To provide more precise and controlled adjustments than were possible by “trial and error” loosening and re-cinching straps.

Originally, the project intended to use an existing lifting collar provided by the WTP Project that had been manufactured to facilitate handling the canisters. This collar weighed about 220 lbs and was designed to attach around the neck of the canister and lift under the canister’s top flange. Upon close scrutiny of the design, it was determined that the collar would have to be firmly fixed to the top flange, or the collar would crash down onto the neck of the canister upon impact and damage the canister.

Engineering design of modifications to the existing collar indicated that a very heavy and bulky retainer system would be needed to provide sufficient strength to hold the heavy collar in place against the intense gravitational (*g*) forces from the drop impact. The retainer system would also require drilling several bolt holes into the WTP collar, changing the original design. The intense *g* forces from the heavy collar also raised questions about potential damage to the thin walled canister that could not adequately be addressed. Therefore, a new and lighter lifting assembly was designed and fabricated to conduct the drop. The collar design is shown in Figure 2.1. Figure 2.2 shows the lifting collar in use with the canister in horizontal and vertical positions.

The lifting collar used two swivel rings 180° opposite one another. The swivel rings allowed the center of gravity (COG) to hang directly below the swivels. If the COG was not in the plane of the swivels, the canister would not hang vertical. In that case, the collar could be rotated on the flange until the COG was in-line with the swivels. The collar had to be adjusted once to achieve verticality for the first drop and did not need to be adjusted for the second drop. Verticality in the perpendicular plane was then achieved by adjusting the turnbuckles. Through these two methods of adjustment, the canister could be adjusted to perfectly vertical within the precision of the measurement instrument.

Verticality was measured using a 152.4 cm (60-in.) calibrated level; centering the bubble between the level's marks (see Figure 2.3). Deviations at the end of the level as small as 0.64 cm (0.25 in.) caused a discernable movement of the bubble away from center. A deviation of 0.64 cm (0.25 in.) over 152.4 cm (60 in.) equates to an angular change of 0.24°, the limits of precision for this test.

$$\sin(0.24^0) = \frac{0.25''}{60''} \tag{2.1}$$

A "flat bottom" drop implies that the bottom of the canister would impact the drop pad squarely. Before the canister hanging angle was measured, the canister was placed onto a drop pad that had previously been ascertained as level, and the verticality of the canister wall was verified when the canister bottom was flat on the drop pad. The side-walls of both canisters (HT002 and HT503) were vertical when measured with the level, and the canister was resting on the drop pad. The bottoms of both canisters were square to the side-walls.

2.1.2 Swinging

The canister could act like a pendulum swinging on the cable from the end pulley of the crane. If the canister were swinging, then it may not impact the pad vertically even if it were suspended perfectly from the cable and hook. The angle of the canister swinging on the end of the cable moves with periodic motion described by:

$$Angle = A\cos(\frac{2\pi \times t}{T} + \delta)\ ^{(a)} \tag{2.2}$$

where A = maximum angular displacement, degrees
t = elapsed time, seconds
T = period of one full swing (back and forth), seconds
δ = original position in swing (e.g., farthest to the left).

(a) The equation for periodic motion is an approximation that is accurate only for relatively small angles of displacement, which is correct for this application.

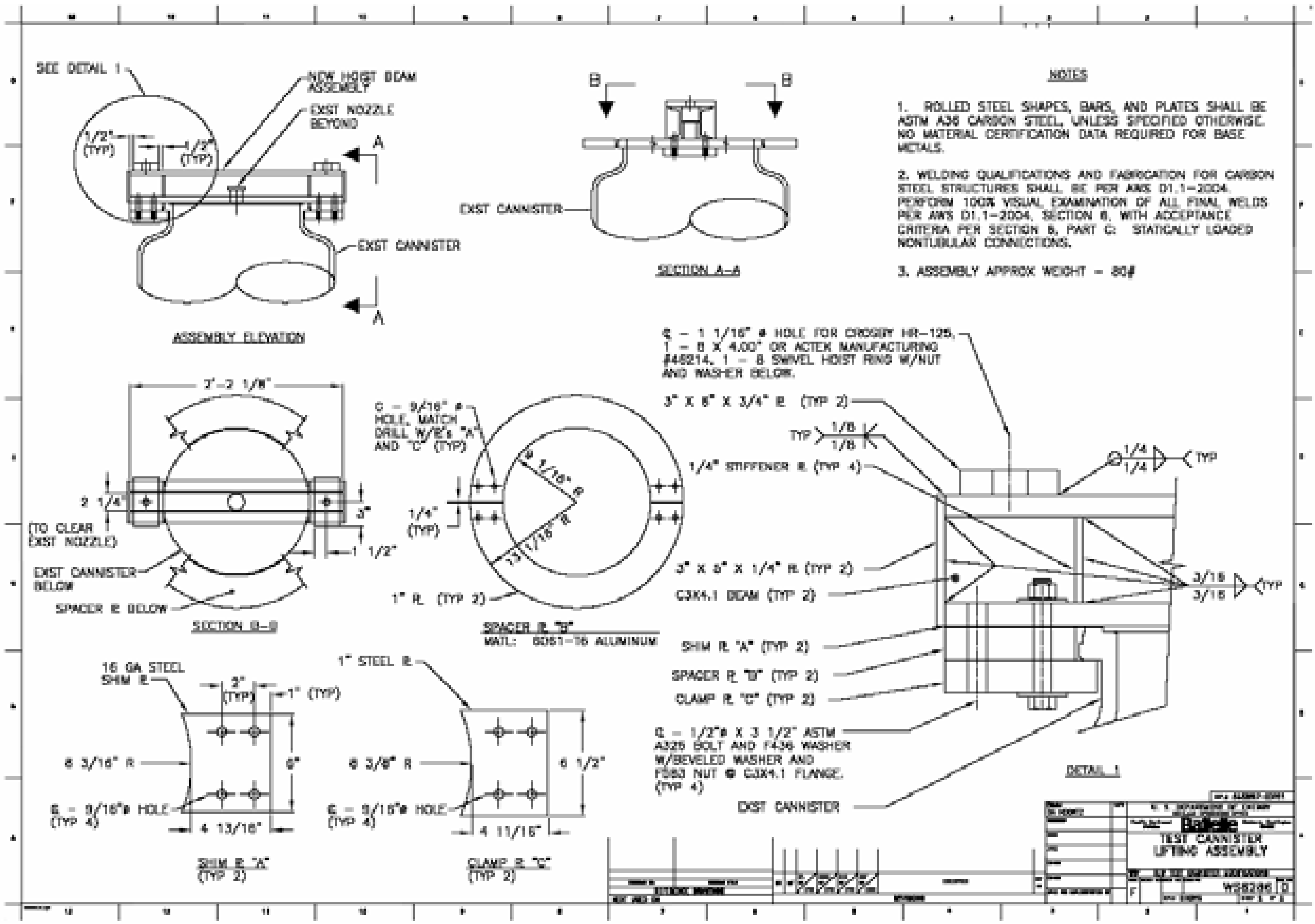
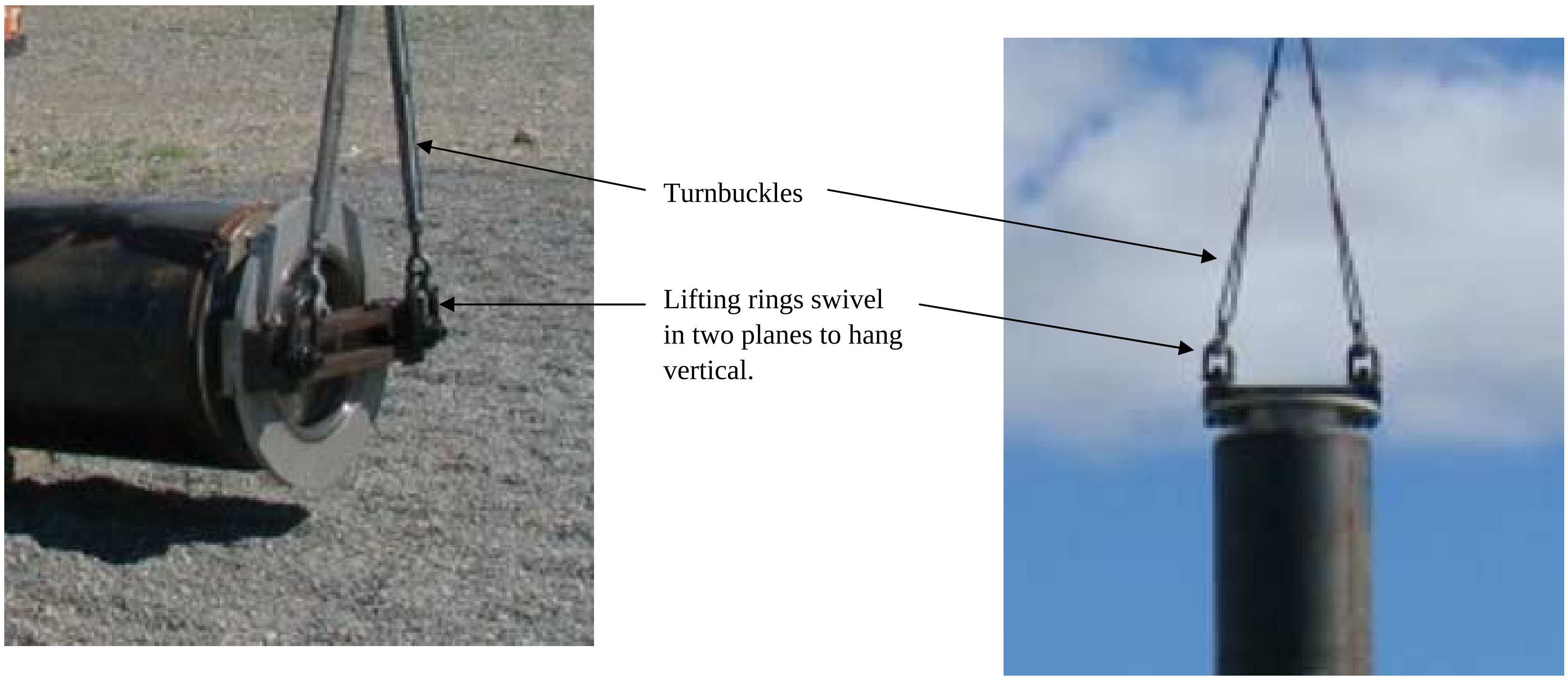


Figure 2.1. Lifting Collar Fabrication Drawing



Canister in horizontal position. Collar is clamped onto canister flange. Aluminum ring around flange assures collar will not slip when tipping canister between horizontal and vertical positions.

Canister in vertical position, hanging with COG vertically under plane of lifting ring. Collar may be rotated until COG is in line with lifting rings. Final vertical adjustment is made by adjusting turnbuckles to achieve verticality in plane of lifting rings.

Figure 2.2. Canister Drop Lifting Collar

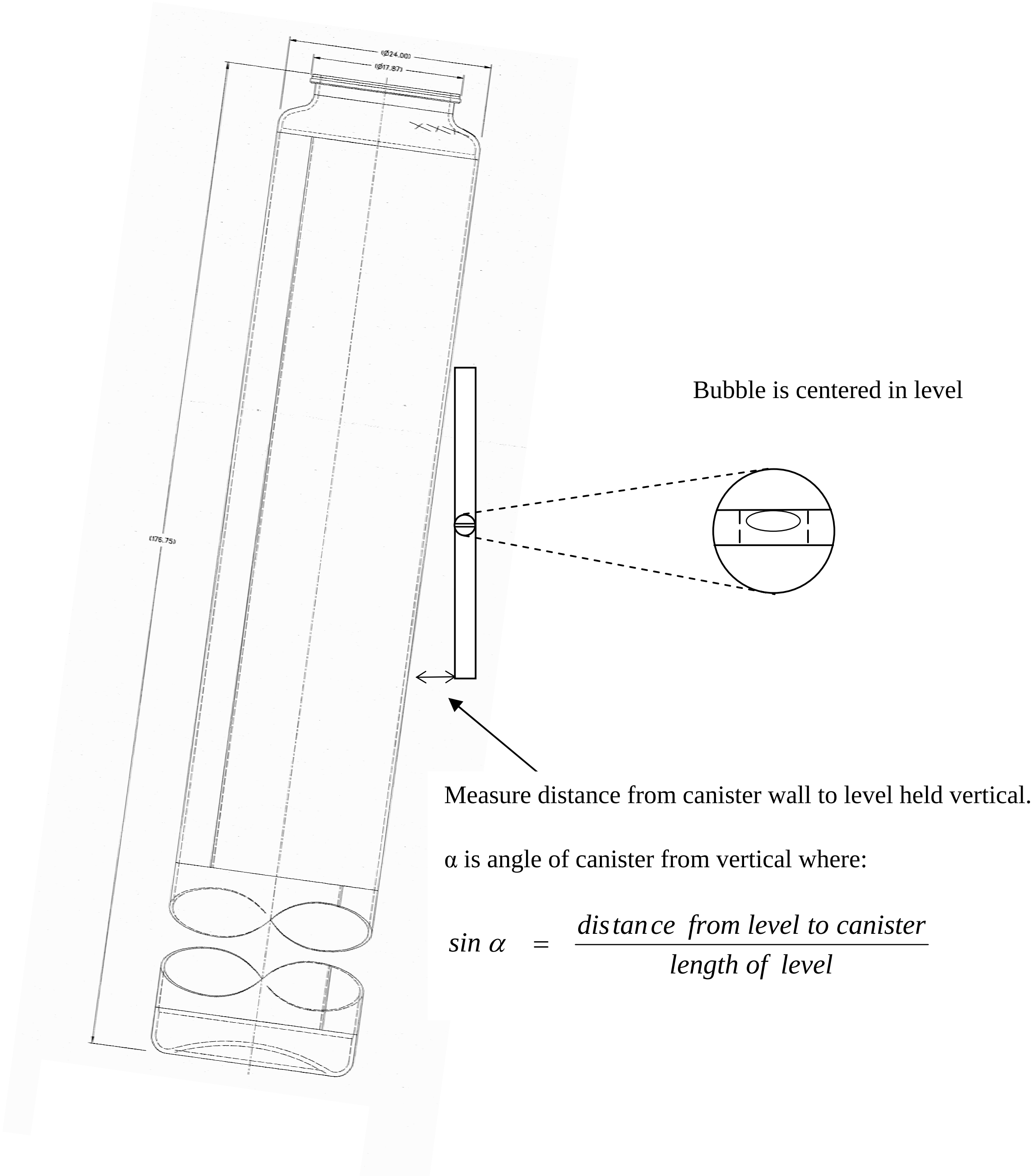


Figure 2.3. Measuring Canister Angle

The angular velocity is the first time derivative of the angular position:

$$Angular\ velocity = -A\sin\left(\frac{2\pi \times t}{T} + \delta\right) \times \frac{2\pi}{T} \qquad (2.3)$$

When the canister is released, it accelerates by gravity until it impacts the drop pad. Ignoring air resistance, the time to impact will be 1.195 sec for a 7-m (23-ft) drop. During that period, the canister continues to rotate at the same angular velocity it had at the instant of release. Figure 2.4 shows the periodic angle of the canister during a full swing and the impact angle of the canister if it were released at time, t.

Figure 2.4 shows that if the canister were released at the wrong instant within the swing, the canister could potentially impact at an angle exceeding the maximum swing. According to Figure 2.4, releasing the canister 2.5 seconds after it reached its swing maximum (1 degree) caused the canister to impact the pad with an angle of 1.5 degrees.

This test sought to achieve an impact angle as close as possible to vertical and with a maximum deviation of 1 degree. Therefore, the swing angle of the canister was measured using a transit immediately before the drop, and the allowable swing was limited so that angular velocity after release would not carry the canister outside of the 1 degree allowable impact angle. Figure 2.5 shows that to ensure a maximum impact angle no greater than 1 degree, the canister swing angle had to be limited to less than 0.66 degrees.[a]

Figure 2.6 shows the swing angle being verified to be <0.66 degrees just before the release of Drop Test 1.

During both test drops, favorable wind conditions limited the canister swinging to immeasurably small swing angles. Canister swinging did not impact the drop test.

2.1.3 Canister Release Mechanism

After the verticality of the canister attachment was established and the swing limited, there was a third critical action to ensure a vertical impact. The canister had to be released without imparting torque, thus causing it to rotate. This was achieved by holding the rigging with a hook that could swing freely and release the rigging without imparting any lateral force to the canister. Until the moment of release, the hook was held in a closed position with a trigger. The trigger was retracted using a pneumatic cylinder powered with 100 to 125 psig air. Figure 2.7 shows a diagram of how the release hook operated and a photograph of the release hook. The release hook was designed and manufactured by Washington Chain and Supply Inc., of Seattle, WA.

(a) Precise timing of the release could theoretically be used to obtain a 0-degree impact angle. However, this method was considered to be impractical because the signal to release had to be confirmed by several people, and the timing was not considered to be precisely controllable.

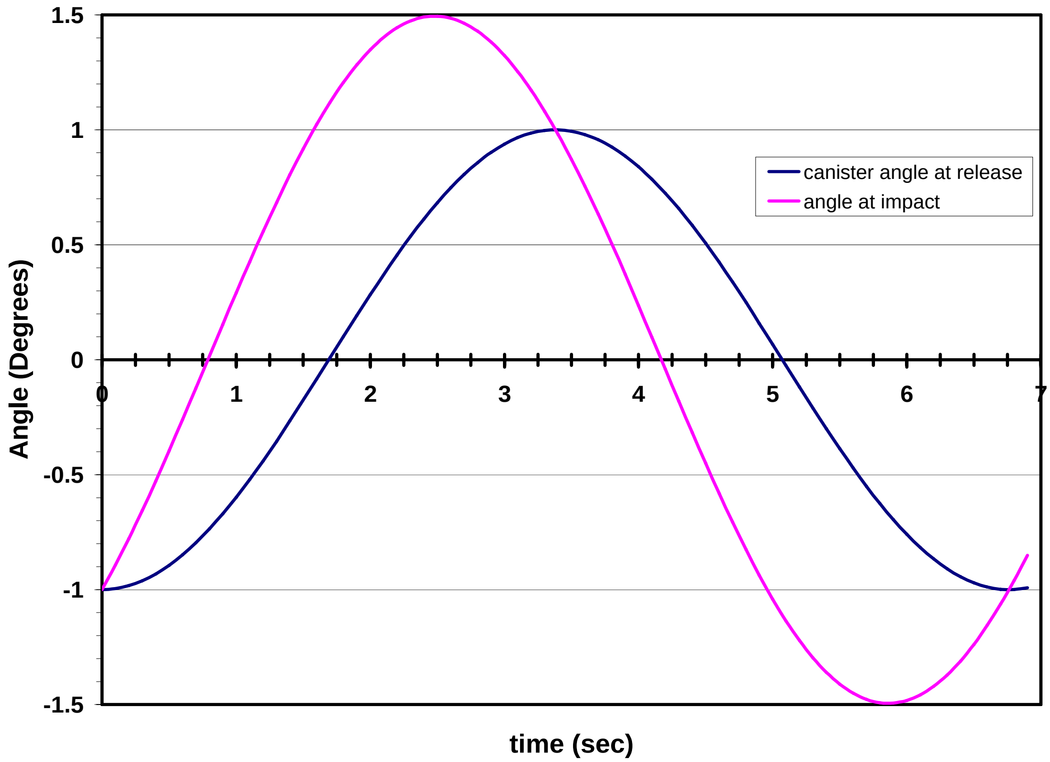


Figure 2.4. Canister Swing Angle and Impact Angle vs Time

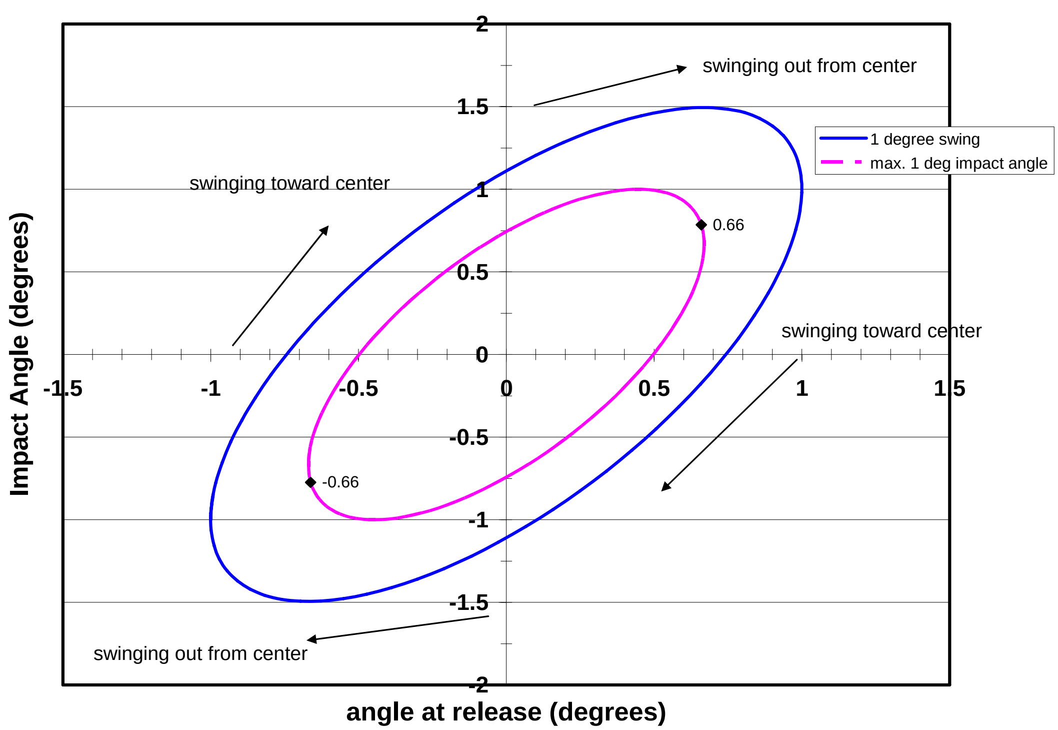
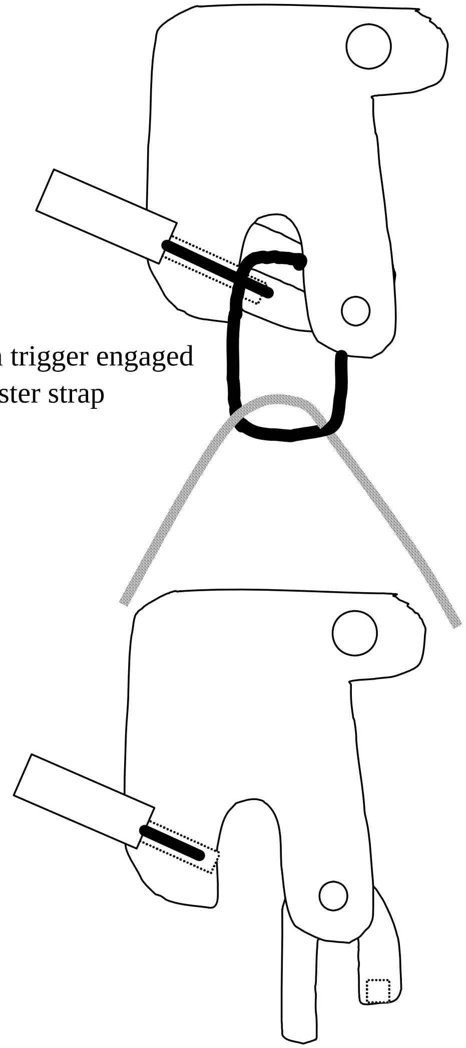


Figure 2.5. Canister Impact Angle vs. Angle at Release

Figure 2.6. Canister Swing Verified to be Within 0.66 Degrees Using Two Transits Viewing the Canister from Perpendicular Angles

Washington Chain and Supply Inc. Model CSRH-182
Quick Release Hook

Release with trigger engaged
holding canister strap



Release with trigger retracted

Figure 2.7. Release Hook Mechanism and Operation

2.1.4 Canister Impact Angle Results

The canister drops were recorded using high speed (500 frames per second) video cameras that created a computer video record of the drop. Two high-speed video cameras, oriented perpendicular to one another, were used to record each drop against a 3-m (10-ft) wide × 2.4-m (8-ft) tall backboard with a 1-foot checkerboard grid pattern. The grid pattern was aligned to have vertical and horizontal lines using the calibrated level. The drop angle of the canister, α, was calculated by measuring the horizontal displacement of the canister image against the backboard at two heights.

$$\tan\alpha = \frac{horizontal\ displacement, x}{vertical\ displacement, y} \tag{2.4}$$

The total angle of the canister from vertical (θ) was calculated from the angle of the canister viewed through each camera.

$$\tan^2\theta = \tan^2\alpha + \tan^2\beta \tag{2.5}$$

where α is the angle from vertical measured from one camera, and β is the angle from vertical measured from the other camera. See Appendix B for derivation of drop angle, Equation 2.5.

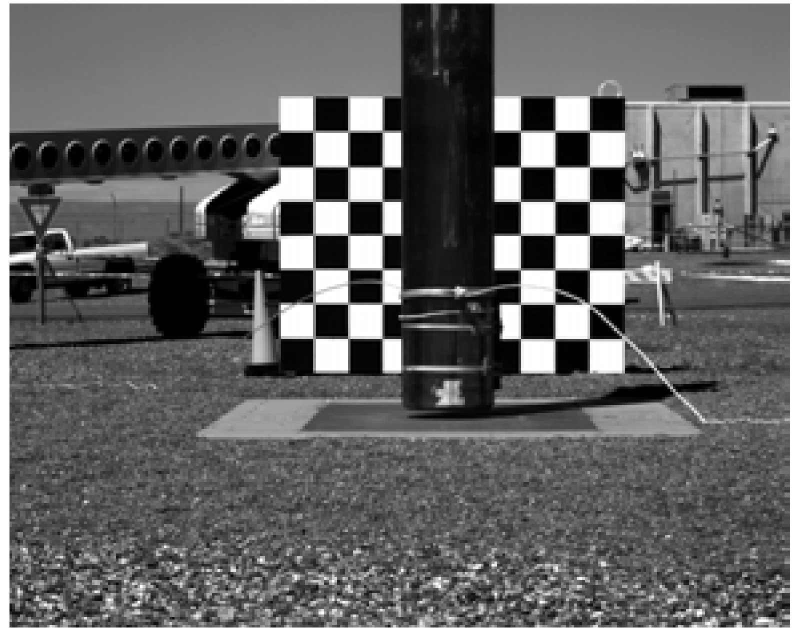
Figure 2.8 shows the angle of the first canister drop immediately before impact (HT002, 3/8-in. wall) from each camera vantage. Figure 2.9 shows the angle of the second canister drop (HT503, 10-gage wall) from each camera vantage.

Both canister drops appear indistinguishably close to perfectly vertical, 0°. To determine the canister angle at impact, the video frames immediately before impact were used as pictures. The pictures were enlarged and printed on 11×17 paper using a 600 dpi printer. Using this method, there was still no distinguishable deviation from vertical for either drop. The measurements could be made to within 0.5 mm, which relates to a precision of ±0.25° for the method.

Appendix C describes a second method used to estimate the canister angle at impact. The second method used pixel-by-pixel mapping software. Data using the pixel mapping method are for information only, not official data.

Canister HT002 viewed from southern camera immediately before impact.

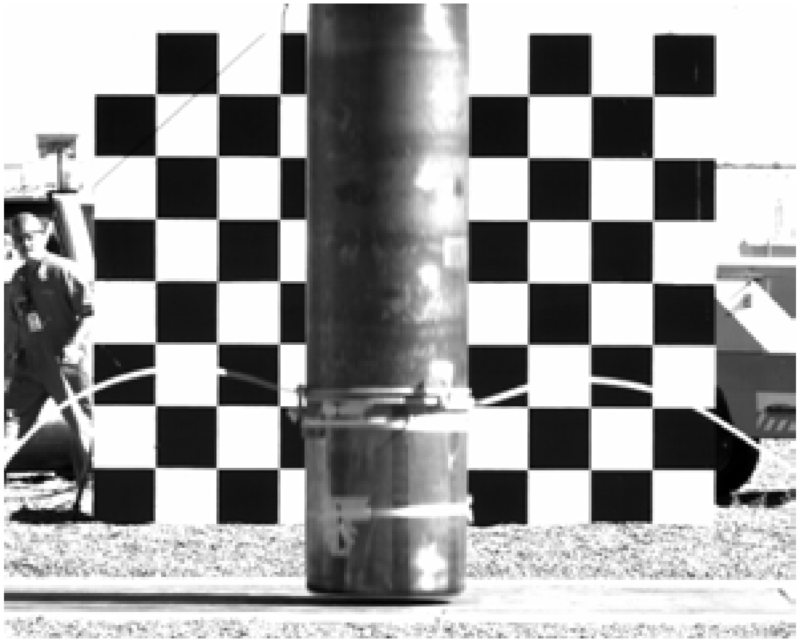
The camera was 64 ft. from impact and 83 ft. from the back-board.



Canister HT002 viewed from eastern camera immediately before impact.

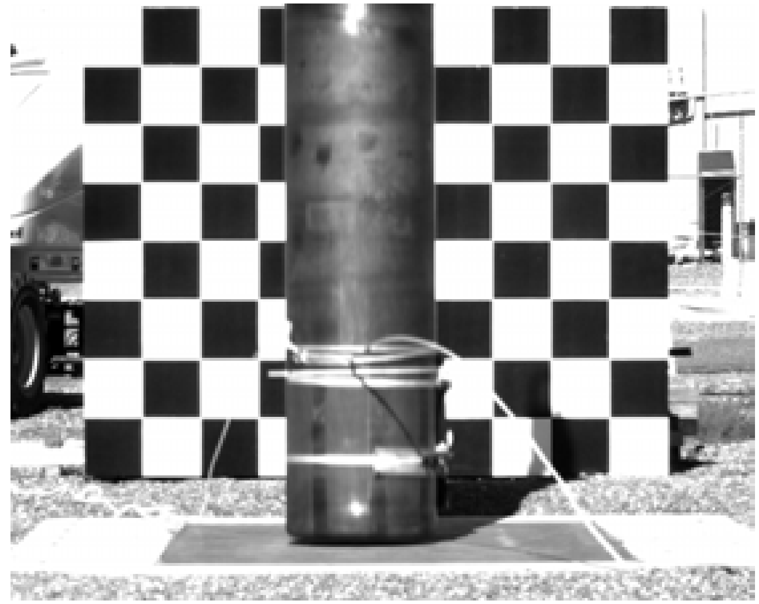
The camera was 56 ft. from impact and 76 ft from the backboard.

Figure 2.8. Canister Angle Immediately Before Impact, HT002, 3/8-in. Wall Canister



Canister HT503 viewed from southern camera immediately before impact.

The camera was 65 ft. from impact and 84 ft. from the back-board.



Canister HT503 viewed from eastern camera immediately before impact.

The camera was 65 ft. from impact and 85 ft from the backboard.

Figure 2.9. Canister Angle Immediately Before Impact, HT503, 10-Gage Wall Canister

2.2 7 Meter Drop Height

The WASRD specifies that the drop be from 7 m (23 ft). This was interpreted to mean that the drop had to be from at least 7 m (23 ft). It could be higher, but causing increased risk that the additional drop energy could cause an unwarranted failure.

The drop height was established by attaching a pre-measured non-stretching plastic tape with a 16-oz. plumb bob to the side of the canister 20 cm (7.9 in.) from the bottom. The tape was pre-measured using a calibrated tape measure and marked. The canister was lifted to a height such that the plumb bob just cleared the drop pad. Two templates (0.5 cm and 1.0 cm [0.2 in. and 0.4 in.] thick) were placed on the drop pad next to the plumb bob. The height of the plumb bob above the drop pad was compared to the two templates and the canister height adjusted so the plumb bob was off the ground but not above the higher template. This verified that the canister height was >7 m (23 ft). The overall length of the tape was 7.21 m (23.65 ft) to allow for attaching the tape 20 cm (7.87 in.) up the side of the canister and allowing 1 cm (0.39 in.) for potential accumulated measurement errors. The precision of the drop height was estimated to be 7 m -0/+3 cm (23 ft -0/+1.2 in.). (See Appendix D for estimate of measurement errors.)

Figure 2.10 shows the tape and plumb bob to set the canister height. After the height was finally established, the plumb bob was pulled from the canister and the templates removed from the drop pad.

2.3 Drop Pad was an "Unyielding" Surface

The IAEA has defined that an unyielding surface shall have at least 4 cm (1.57 in.) of steel floated onto concrete. The combined mass shall be >10× the mass of the dropped object (IAEA 1990, Para. A-618; IAEA 2002, Sec. VII, Para. 717.2, p. 167). The drop pad used for these tests had a mass of concrete and 19-cm-thick (7.5-in.-thick) steel totaling 100,680 kg or >27× the canister mass. Appendix E includes details of the drop pad design calculations. The drop pad was installed in the 300 Area at the corner of Nebraska and Arizona streets in 1986.

Two wooden backboards (3 m wide × 2.4 m tall [10-ft wide × 8-ft tall]) are also part of the drop pad facilities, though not actually attached to the drop pad. One backboard is located north of the drop pad and the other is perpendicular to the first, west of the drop pad. The backboards are painted with a checkerboard pattern. The backboards were leveled using the calibrated level to provide vertical and horizontal reference to determine the canister angle immediately before impact.

For this project, the backboards were moved to be approximately 6 m (20 ft) away from the point of impact so that the canister could not fall over and hit the backboard, potentially damaging the canister wall.

Figure 2.11 shows the drop pad facility.

Figure 2.10. Canister Drop Height Established with Pre-Measured Tape and Plumb Bob

Drop Pad Area Looking Northwest

Figure 2.11. Drop Pad Facility

3.0 Canisters Passed Drop Test

To demonstrate compliance with WASRD 4.8.8 the HLW canisters shall be capable of withstanding a drop of 7 meters onto a flat, essentially unyielding surface without breaching or dispersing radionuclides. For this test, the “Success Criteria” to pass the Canister Drop Test were:

1) the canister would be “leak tight” after the drop as determined by a helium leak test, and
2) glass was not dispersed from a breached canister as determined by a visual inspection of the canister and drop pad area.

3.1 Helium Leak Test

The primary standard that the canister passed the drop test was that the canister remained “leak tight” after the test. The WASRD requires that the gas leak rate be less than 1×10^{-4} ref-cc/sec, where “ref-cc/sec” is defined as a volume of 1 cm^3 of dry air per second at a pressure of 1 atmosphere absolute and 25ºC (WASRD 4.8.6). For this test, helium was used as the “leaking” gas rather than air. Based on leak equations from American National Standards Institute (ANSI) N14.5, an equivalent helium leak rate to the specification would be less than 1.3×10^{-4} atm-cm^3/sec at 1 atm (ANSI 1998). (See Appendix F for derivations of equivalent helium gas leak rate.)

Before the canisters were dropped, each canister was leak tested to verify that the canister was initially “leak tight” and also to provide evidence that if a leak were present near the bottom of the canister (most likely location for failure) that the leak would be detected. The canisters were leak tested by Cogema Engineering Corporation of Richland, WA, using the “hood technique” consistent with *ASME Boiler and Pressure Vessel Code*, Section V, Article 10 (ASME 1995).

Figure 3.1 schematically portrays the “hood technique.”

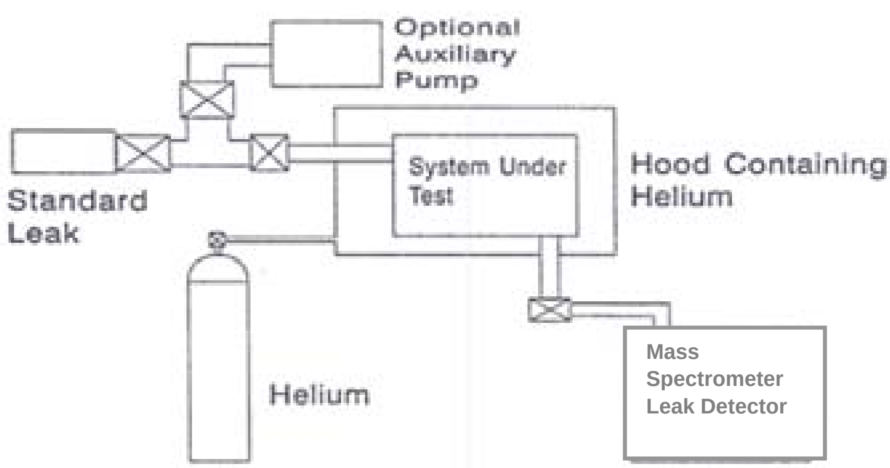


Figure 3.1. Helium Leak Test “Hood Technique”

The hood technique has the following steps (Cogema 2003):

1) Before evacuating the canister, the mass spectrometer leak detector (MSLD) was calibrated with a 2.2×10^{-8} atm-cc/sec calibrated leak using the division method to determine the machine sensitivity. The machine sensitivity for each of the examinations was 1.0×10^{-11} atm-cc/sec/division or better. The MSLD is specifically tuned to measure helium molecules with a molecular mass of 4.

2) The item is evacuated using the optional auxiliary pump and then the MSLD.

3) A standard leak of helium near the allowable limit is added into the canister near the bottom and the MSLD output monitored. The helium is added near the bottom of the canister to verify that if a leak were present it would, indeed, flow through the glass-filled canister to the MSLD. The time to reach a stable helium concentration is also measured. For this test, Cogema used a standard helium leak of 3.3×10^{-5} atm-cc/sec. The standard leak provides a Type II calibration for the MSLD, establishing the MSLD output proportional to a known leak.

4) After the helium is cleared out of the system, the entire canister was enclosed in a ”hood” (plastic sheeting) and the volume within the hood filled with helium.

5) The output of the MSLD is monitored for at least the time established in Step 3) for helium to reach the MSLD. The helium leak rate is determined from the MSLD output proportional to the output for the standard leak.

Figure 3.2 shows Cogema technicians conducting the helium leak test. Canister HT002 (3/8-in. wall) is in the plastic sheet, “hood.”

To facilitate the helium leak test, a ½-in. NPT Weld-o-let was previously welded to each canister approximately 43 cm (17 in.) up the canister wall, and a ¼-in. hole was tapped through the canister wall. The glass appeared intact and adhered to the wall where the drill penetrated. Nevertheless, the standard leak flowed the length of the canister and was detected by the MSLD within 90 sec and reached a stable level within 20 min.

Both canisters HT002 (3/8-in. wall) and HT503 (10-gage wall) were verified to be “leak tight” before the drop test. After the drop test, both canisters still had undetectable He leak rates, $<2\times10^{-8}$ atm-cc/sec—well below the allowable limit, 1.3×10^{-4} atm-cc/sec.

Both canisters passed the helium leak test requirement.

3.2 Visual Observation

In addition to the helium leak test, the integrity of the canister(s) was established by visual examination of the canister for signs of breach and examination of the drop pad for fragments of glass.

Canister HT002 (3/8-in. wall) was dropped first. After the drop, the canister appeared remarkably undamaged. There was no buckling or any signs of a breach. However, examination of the drop pad revealed some fragments of glass. Further examination revealed that the sealing plug from the top helium leak check port had been ejected upon impact. The plug was held in place with a friction-fit O-ring. The shock from the impact, evidently, was too great for the friction fit.

Close examination of the video record showed the plug being ejected from the port. Examination of subsequent frames also showed particles in the air above the canister, which are most likely pieces of glass from the canister being ejected through the open test port. See Figure 3.3.

For the second test drop (HT503, 10-gage wall), the port plug was securely taped in place and was not ejected upon impact. No fragments of glass were found on the drop pad after the second drop. Visual examination of the canister showed that the canister wall had many bumps and bulges from the impact, but no evidence of a breach through the canister wall.

Figure 3.2. Helium Leak Check Using "Hood" Technique

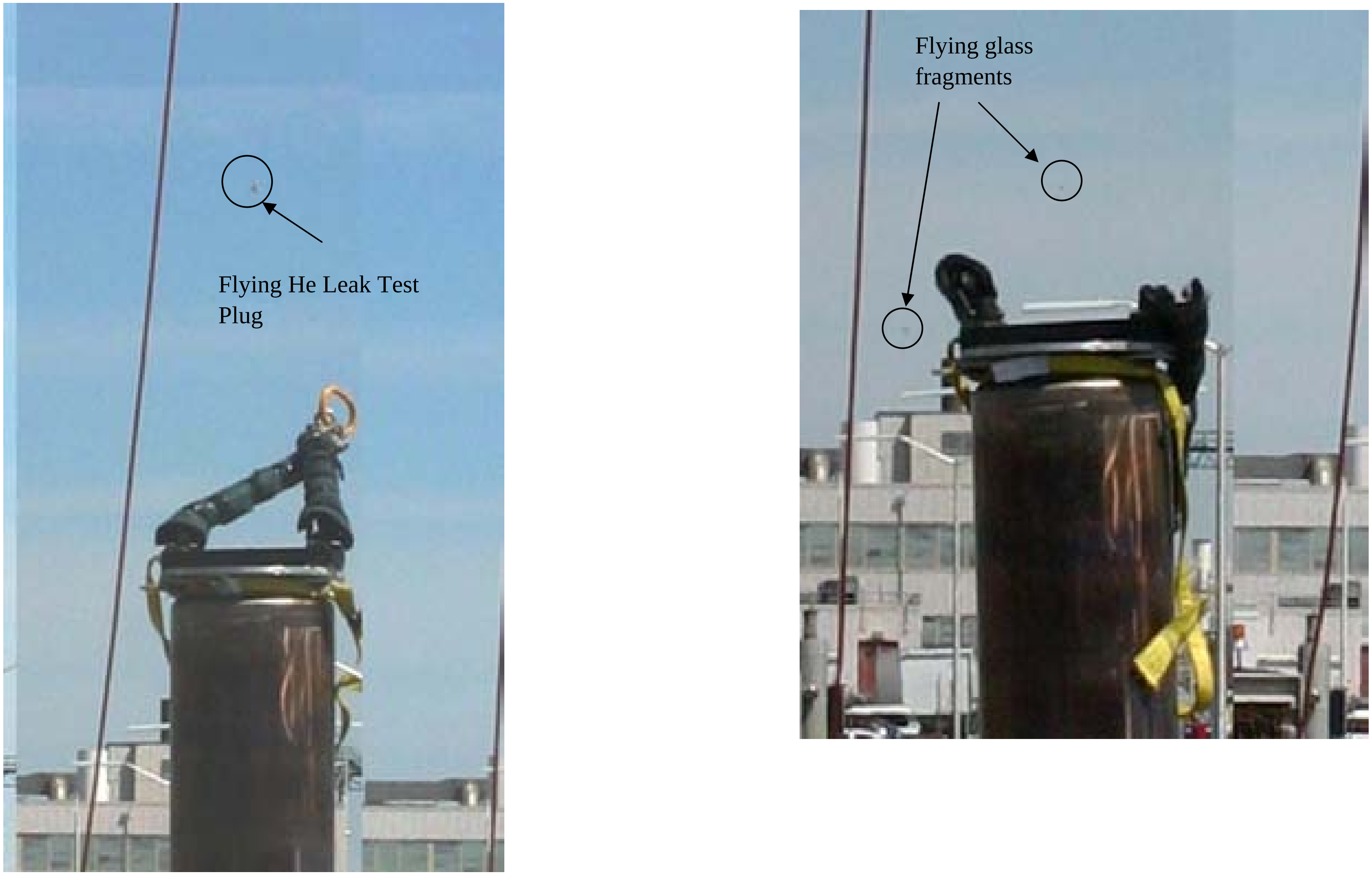


Figure 3.3. Helium Leak Test Plug Ejected Upon Impact During First Drop Test

4.0 Canister Measurements

To aid WTP Project evaluation of the canister design, characteristic measurements of each canister were taken before and after the test drop. Before the test drop the canisters were marked with axial lines at 45° arcs around the circumference of the canister. The overall length of the canister was measured along each axial line from the top flange to the canister bottom. Circumferential lines were marked across each axial line at prescribed distances from the canister bottom. Marks were made at 5-cm (2-in.) intervals for the bottom 75 cm (29.5 in.), at 15-cm (6-in.) intervals between 75-cm (29.5 in.) and 225-cm (88.6-in.) elevations, and at 30-cm (11.8-in.) intervals between 225 cm (88.6 in.) and the top of the canister. The distances from the canister lid to the bottom edge of each mark were measured before and after the test drop.

The canister design employed a 1.3-cm (0.5-in.) thick reverse-dished bottom. Lines were drawn across the reverse-dished bottom between opposing axial lines, and marks were made at each 1/8th diameter across the bottom of the canister.

Four types of measurements were made to characterize the canister based upon these marks:

1) Diameter—the diameter of the canister was measured between each intersection of circumferential and axial lines and the intersection 180° opposite.
2) Length—the distances from a straight edge across the canister lid to the bottom edge of each intersection of axial line and circumferential line, and to a straight edge across the canister bottom were measured.
3) Canister reverse dish—the distances between a straight-edge across the bottom of the canister and the surface of the reverse-dished bottom at each mark were measured before and after the drop.
4) Bow and warp—the canister was centered between two straight lines, and the distance between the straight line and the canister surface was measured at 15-cm (6-in.) intervals along each axial line. These measurements could be used to determine whether the canister was bowed, warped, or out of round.

Figures 4.1 through 4.4 depict the markings and canister measurement methods.

The transcribed data sheets from the measurements (pre-drop and post-drop) for canister HT002 (3/8-in. wall) are in Appendix G, Tables G.1–G.10. The transcribed data sheets from the measurements for canister HT503 (10-gage) are in Appendix H, Tables H.1-H.13.

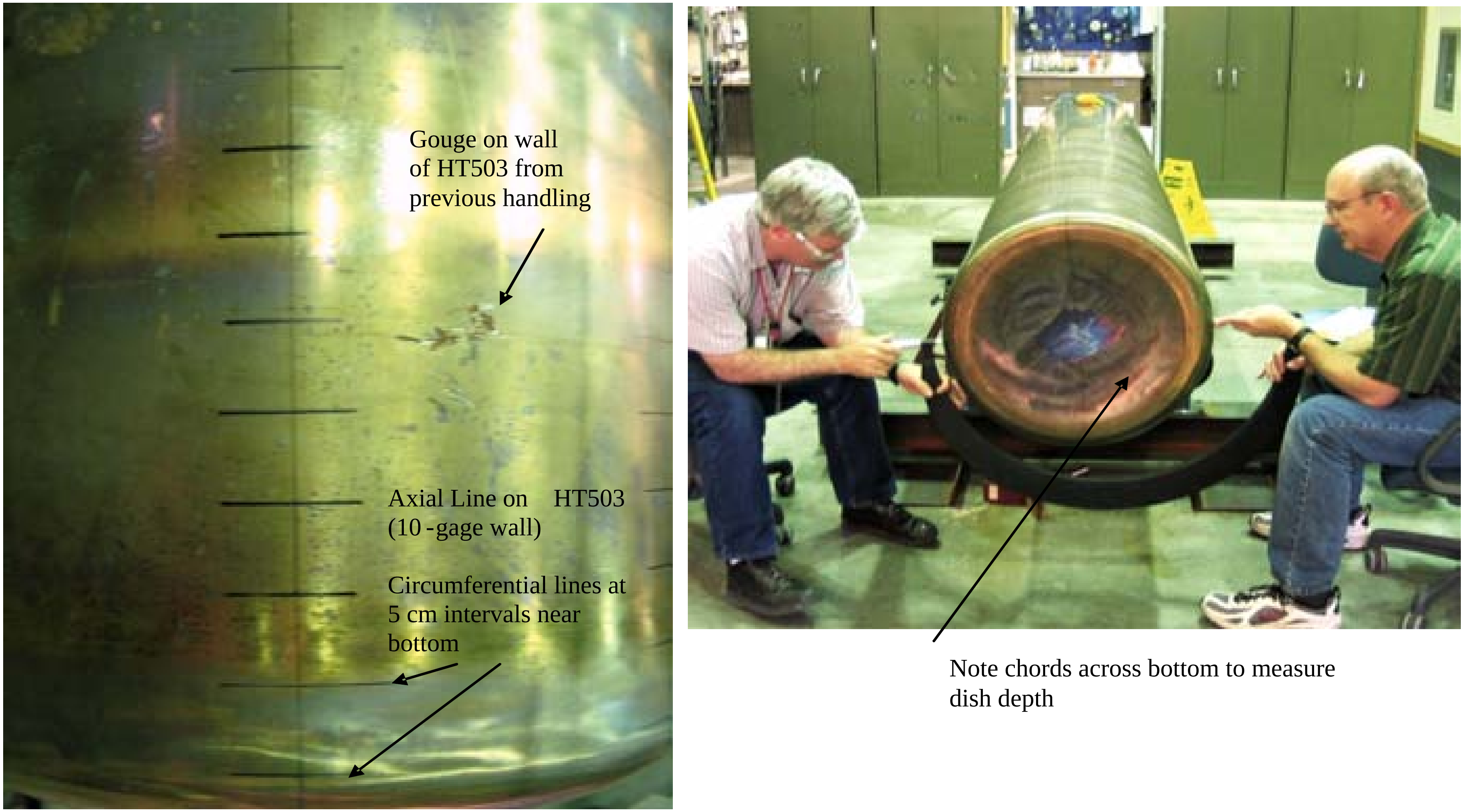


Figure 4.1. Canister Markings

Figure 4.3. Measuring Canister Length

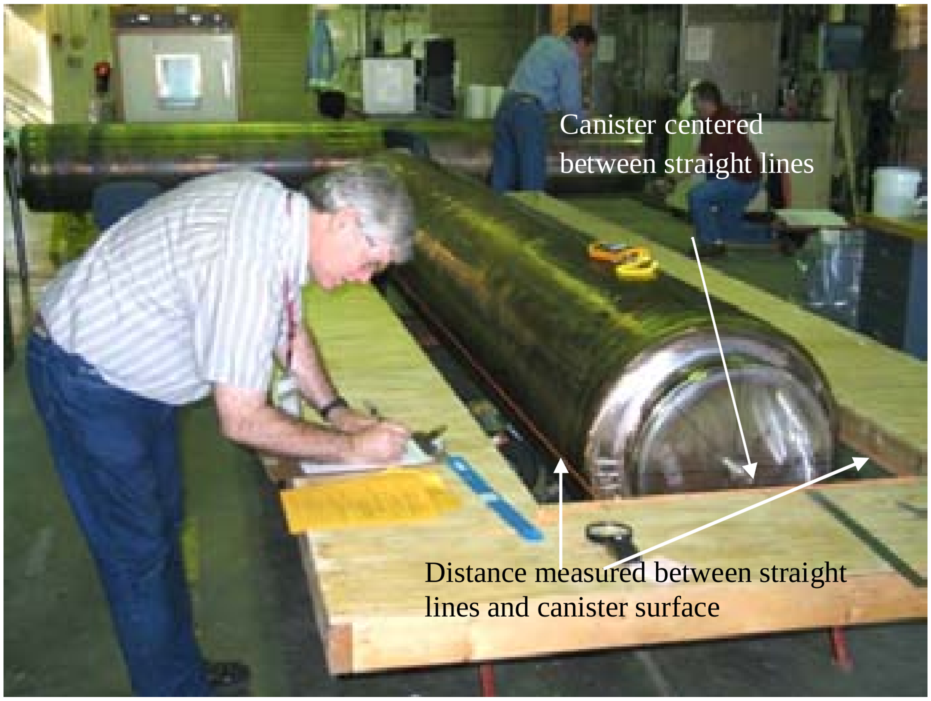


Figure 4.4. Measuring Bow and Warp Using Template with Straight Lines

After the test drop post-drop measurements were conducted at the same marked locations as the pre-drop measurements. Comparisons of the pre-drop and post-drop measurements indicate that both canisters, HT002 and HT503, were axially compressed and increased in diameter from the force of the impact as shown below.

	Maximum increase in canister diameter	Length Reduction
HT002 (3/8-in. wall)	0.57 cm (0.22 in.) @ 5 cm (2 in.) above bottom	1.4 cm
HT503 (10-gage wall)	1.1 cm (0.43 in.) @ 35 cm (13.78 in.) above bottom	2.3 cm

Previous bottom drops from 7 meters of West Valley Demonstration Project (WVDP) canisters and Defense Waste Processing Facility (DWPF) canisters also caused reductions in the overall canister lengths and increases in the canister diameters near the bottom. Data from previous drops of WVDP canisters and DWPF canisters are included in Table 4.1 with data from this testing.

Table 4.1. Canister Changes in Length and Diameter from 7-Meter Drop

Canister	Δ length	Δ diameter
HT002, 3/8-in. wall	-1.4 cm	+0.57 cm
HT503, 10-gage wall	-2.3 cm	+1.1 cm
West Valley Demonstration Project canister (bottom drop) (Whittington and Alzheimer 1994)	-1.2 cm	+1.2 cm
Defense Waste Processing Facility canister (bottom drop) (Olson and Alzheimer 1989)	-0.89 cm	+1.25 cm

The increases in diameter for the 10-gage canister were similar to the diameter increases observed for the WVDP and DWPF canisters. The increase in diameter for the 3/8-in. wall canister was significantly less and actually occurred below the weld to the canister bottom head, which was ½-in. thick.

The diameters were measured at four circumferential positions at each marked elevation above the canister bottom. The increases in diameter (average for four measurements) at each elevation are shown in Figure 4.5 for both canisters.

The diameters before and after the test drop for HT002 (3/8-in. wall) and HT503 (10-gage wall) are illustrated in Figures 4.6 and 4.7, respectively. Both canisters show a reduced diameter near the center weld. The effect was not a result of the drop, but existed as a “pre-drop” condition for both canisters. The reduced diameter near the center weld is included only as an observation.

For each canister, the distances from a straight edge placed across the canister lid to each elevation mark[a] were measured along each of the eight axial lines. The average change in length along the eight axial lines marked on each canister is shown in Figure 4.8 for HT002 and HT503.

Both WTP canisters employed a reverse-dished bottom head (½-in. thick), which was 12.7 cm (5 in.) high and welded to the canister wall. The distances from points marked on the canister reverse-dished bottom head and a straight edge across the bottom edge were measured before and after the drop. The WTP canister showed very little deformation of the reverse-dished bottom head upon impact. Figures 4.9 and 4.10 show the profile of the bottom head before and after impact for canisters HT002 (3/8-in. wall) and HT503 (10-gage wall), respectively. Figure 4.11 shows the bottoms of canisters HT002 and HT503 after drop impact.

To determine whether the canisters had any bow or warp, either from manufacture or deformation during filling, the distances from a taut line to the surface of the canister were measured along each axial line and its opposing axial line 180° opposite. After a set of measurements were taken, the canister was rotated 45° and re-centered between the taut lines. A non-linear change in distances from the canister surface to the taut line would indicate a bow or warp of the canister. Figures 4.12 and 4.13 show that the walls of each canister were straight, without any measurable bow or warp.

[a] The elevation marks were made with felt marker and were about 1/8” wide. For greater accuracy, the edge of the mark closest to the canister bottom was the precise measured location.

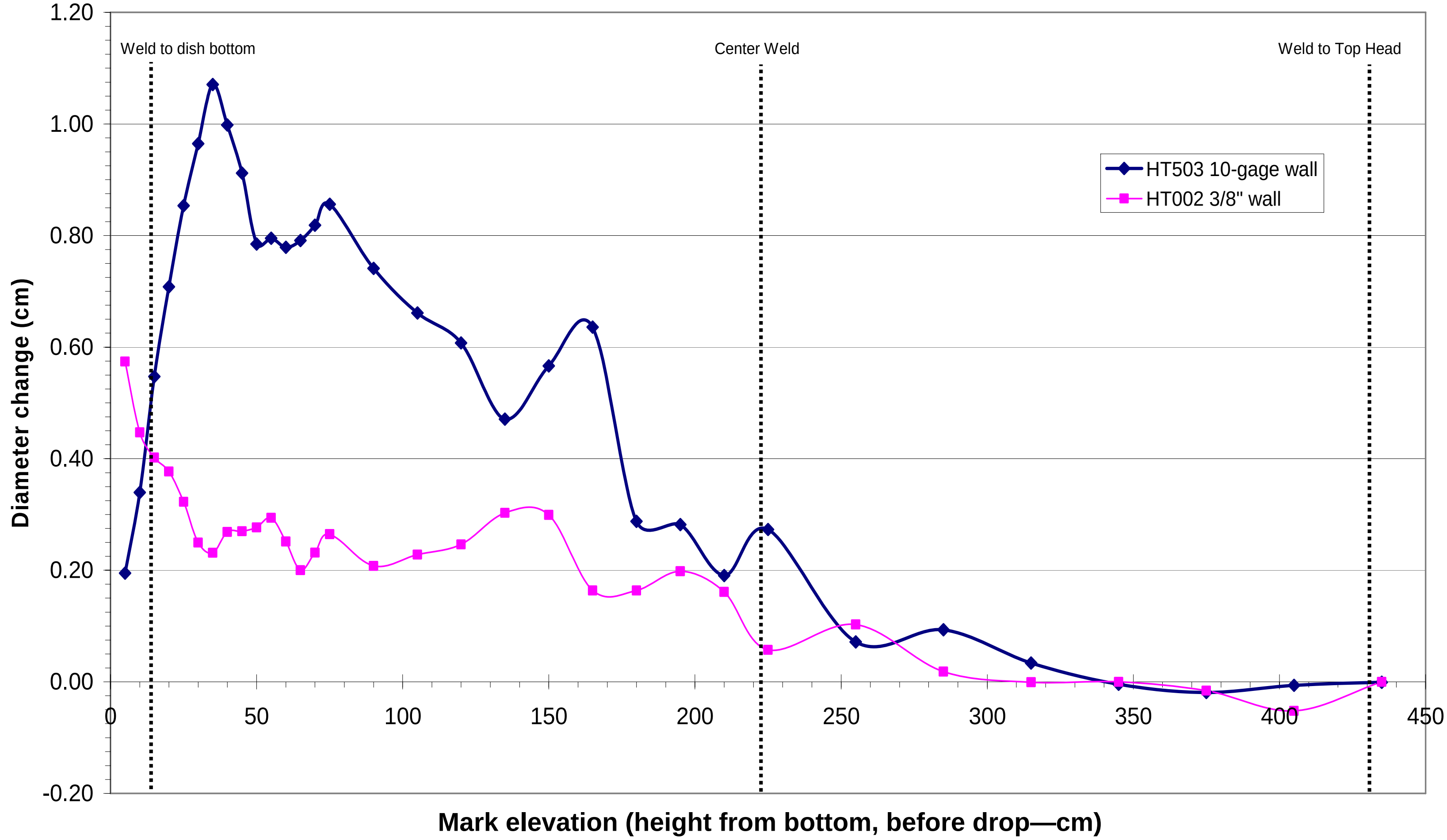


Figure 4.5. Change in Canister Diameter (post drop-pre drop)

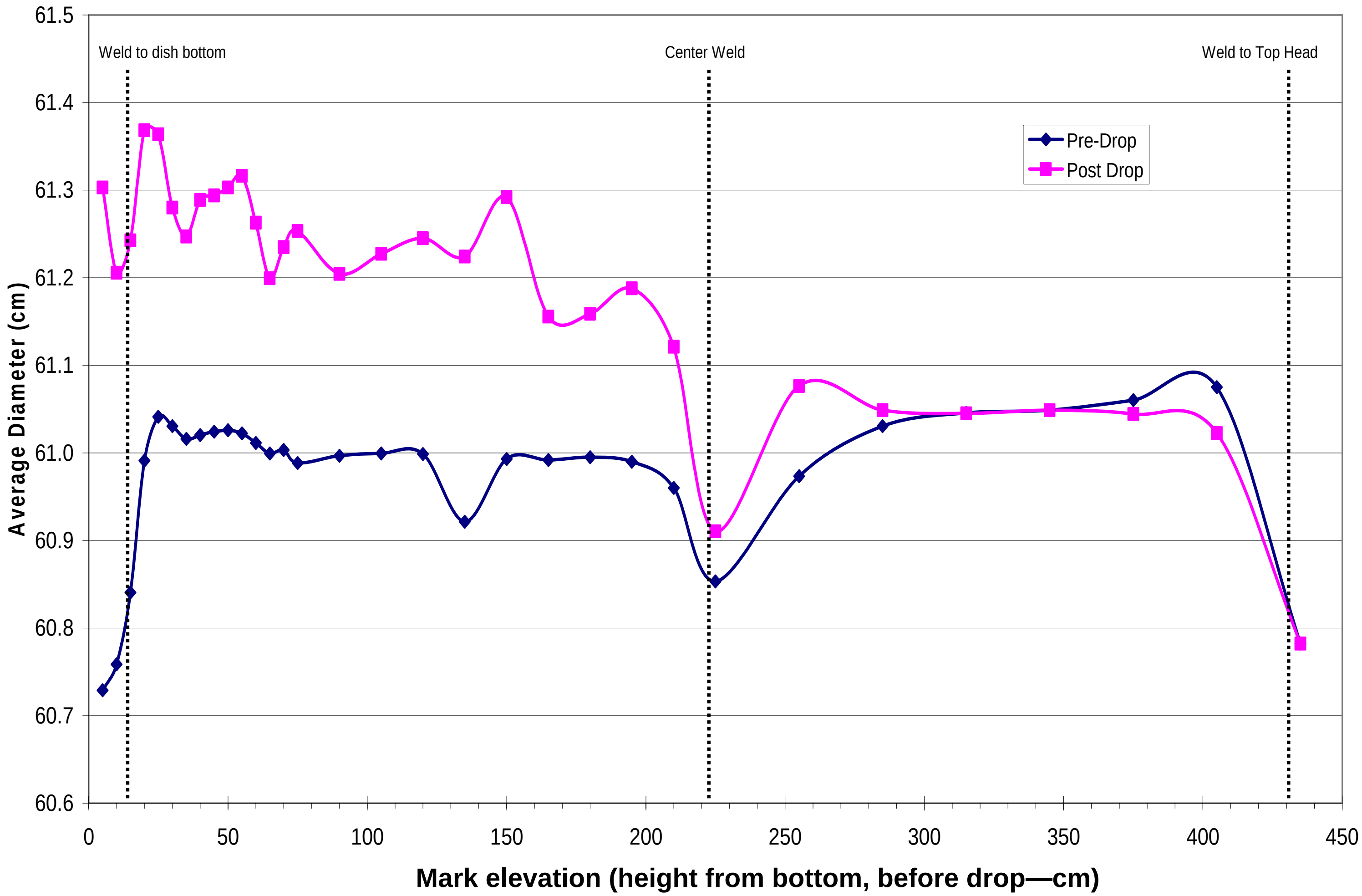


Figure 4.6. Canister Diameters Pre-Drop and Post-Drop, 3/8-in. Wall

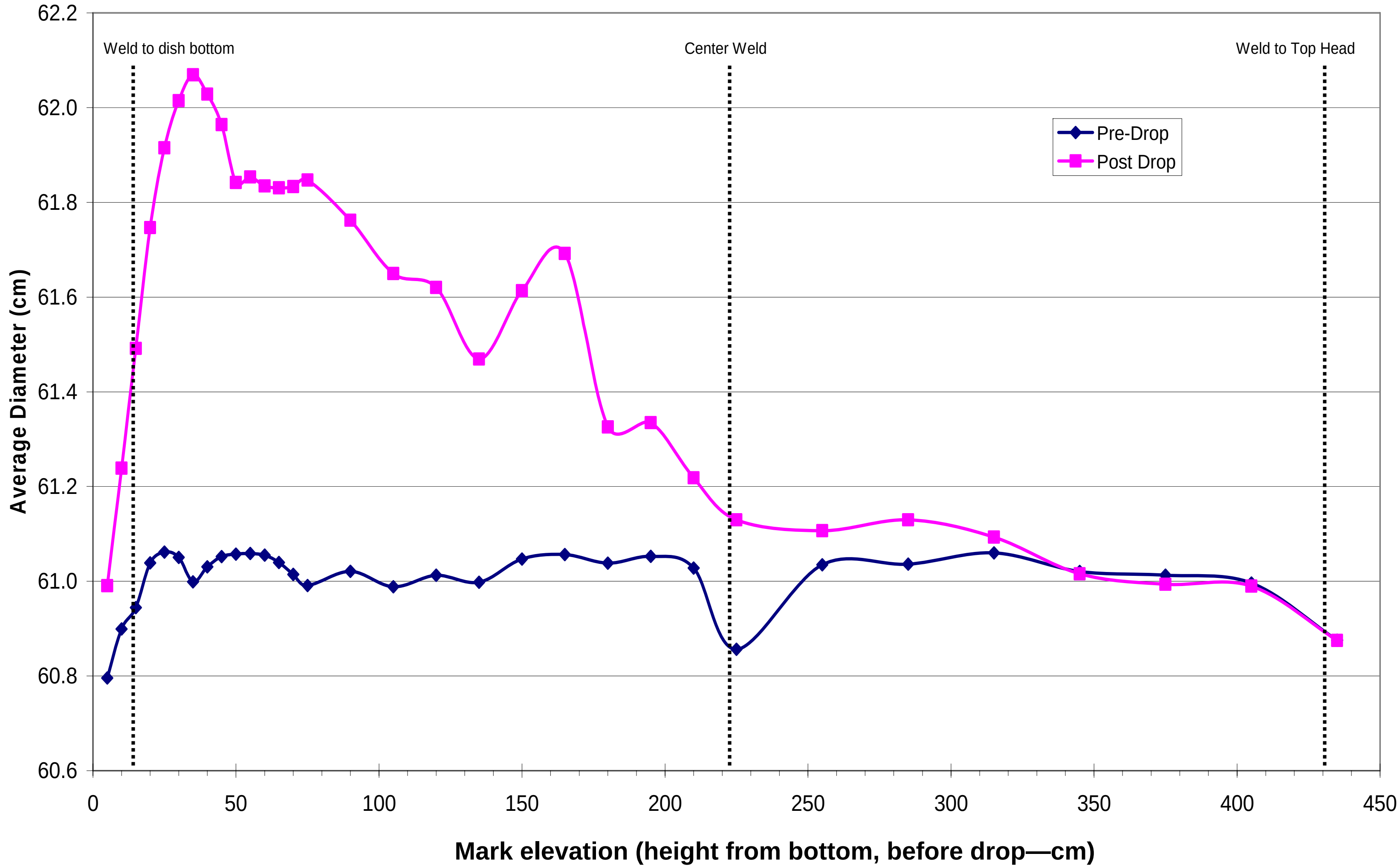


Figure 4.7. Canister Diameters Pre-Drop and Post-Drop, 10-gage Wall

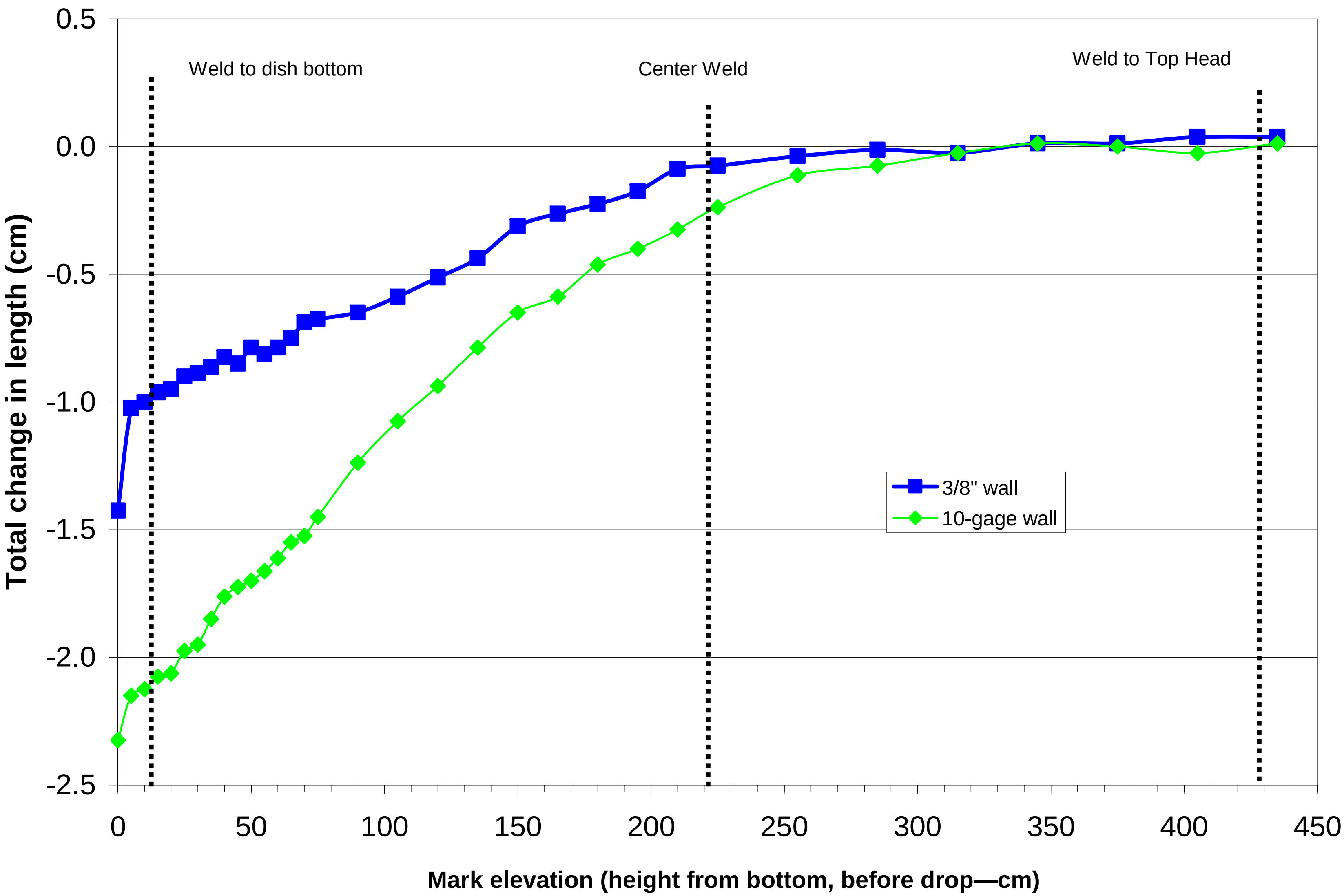


Figure 4.8. Change in Length of Canister

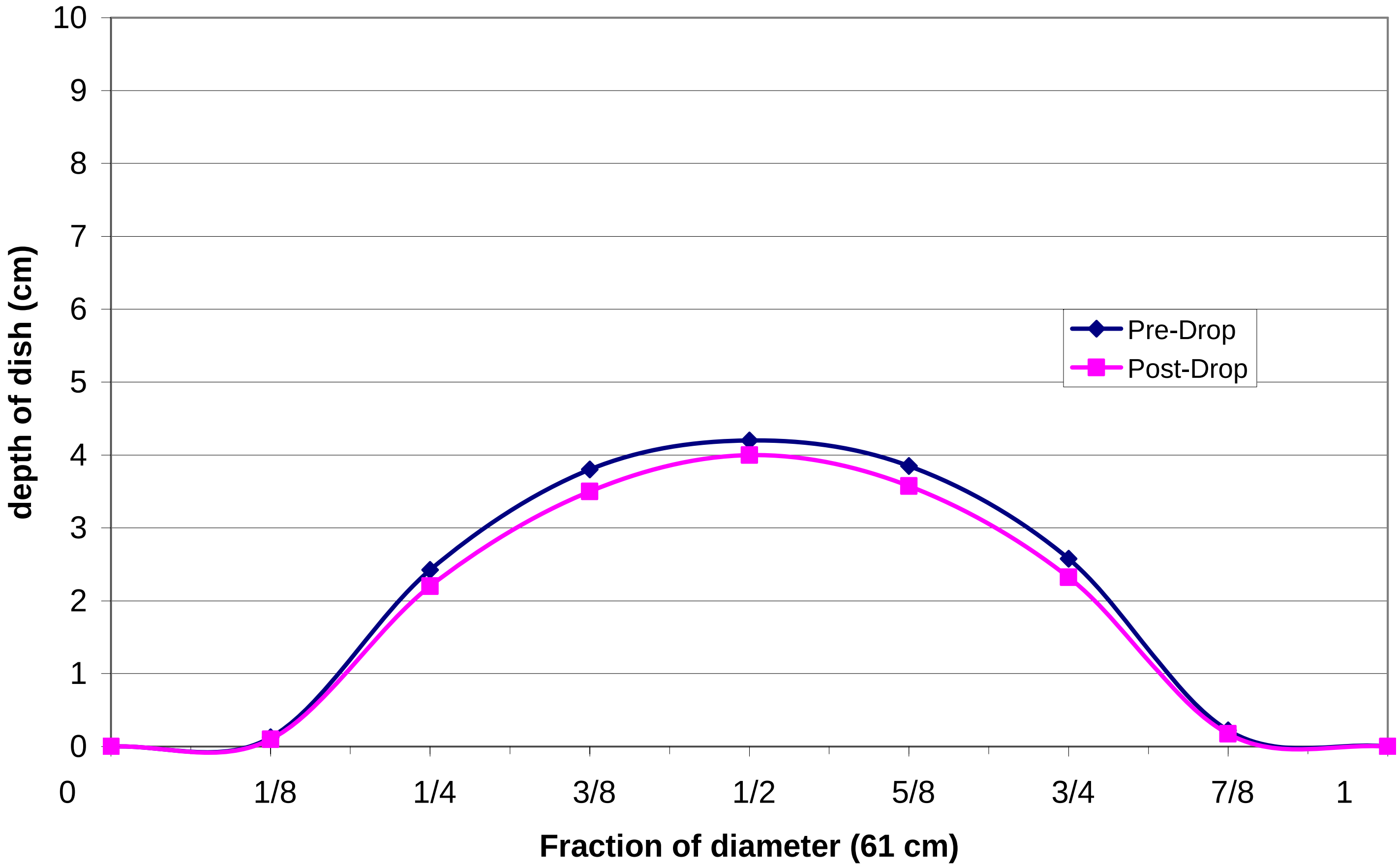


Figure 4.9. Dish Profile HT002

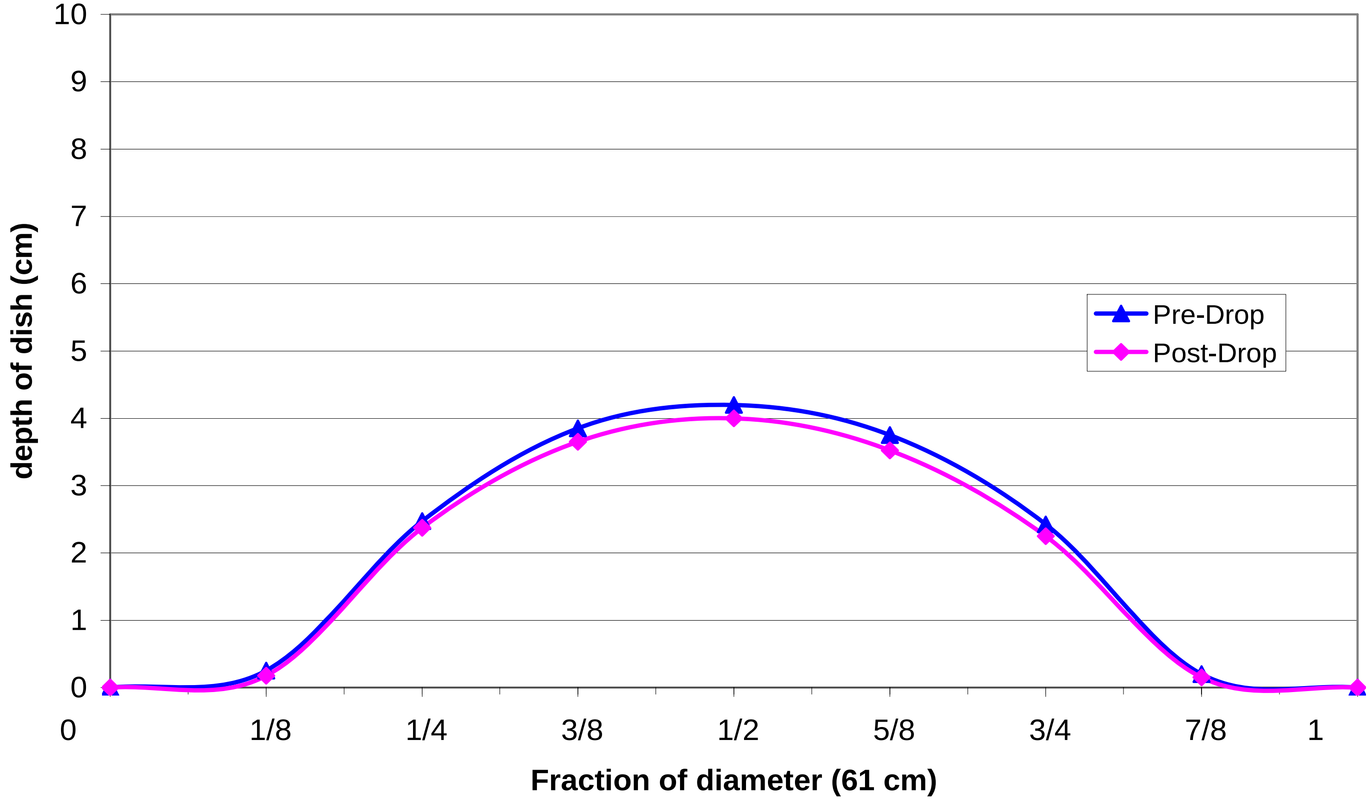


Figure 4.10. Dish Profile HT503

Bottom of HT002 (3/8-in. wall) after drop

Bottom of HT503 (10-gage wall) after drop

Figure 4.11. Canister Bottoms after Drop Test Impact

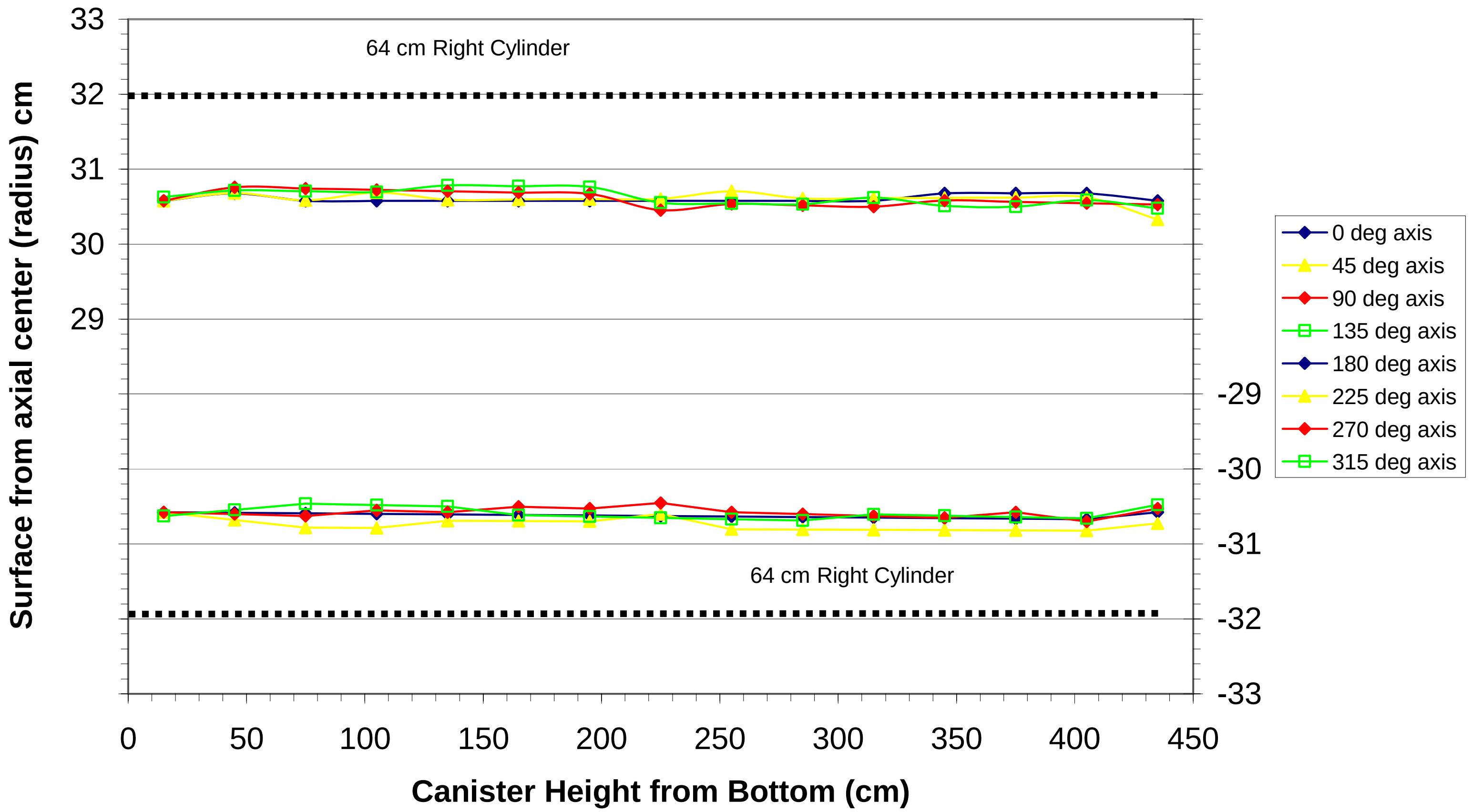


Figure 4.12. Bow and Warp Canister HT002

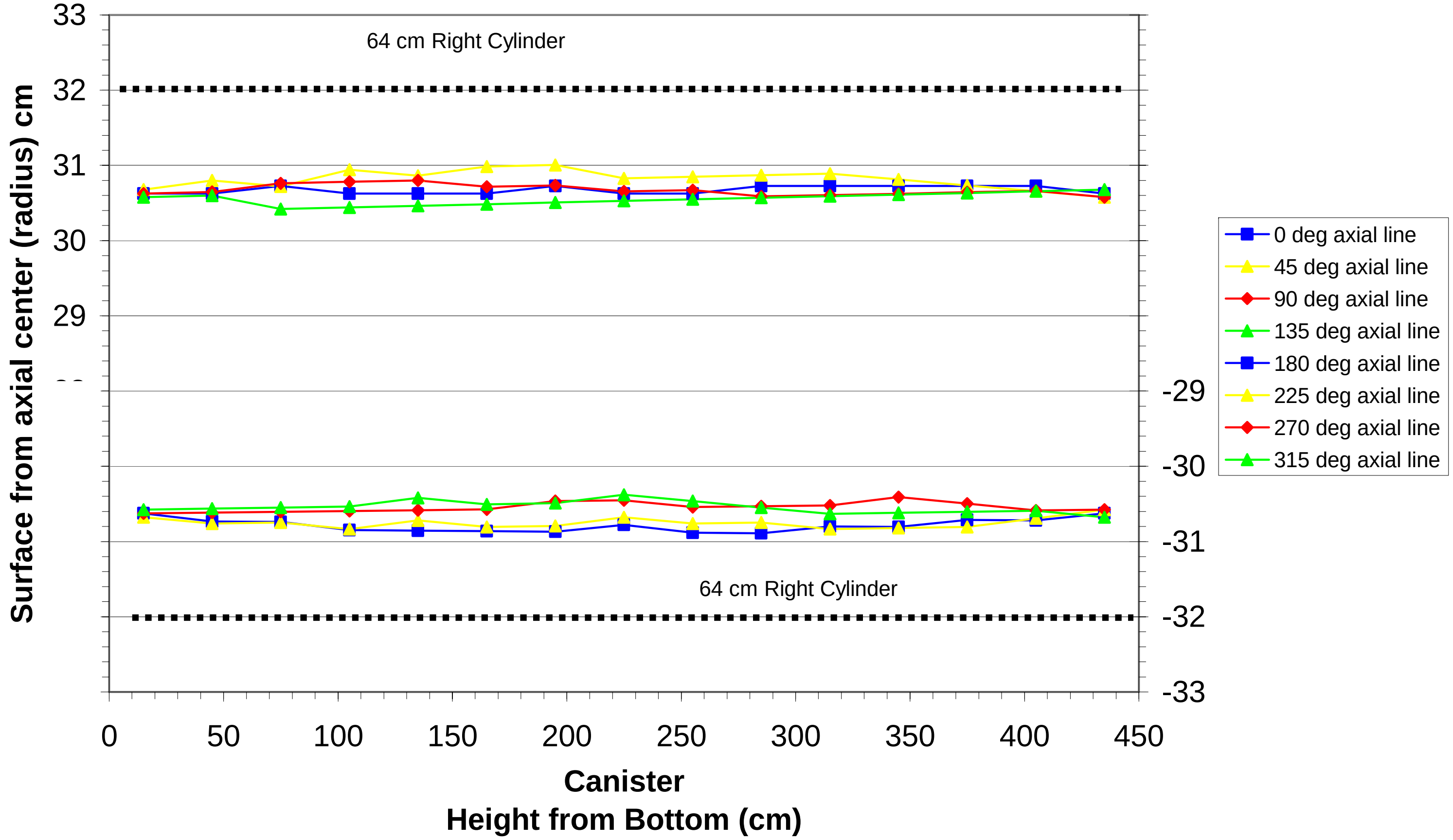


Figure 4.13. Bow and Warp Canister HT503

5.0 Canister Deformation from Impact

The canister diameter, length, and dish-profile measurements provide a quantitative measure of canister deformation from impact. The thick-walled canister, HT002 (3/8-in. wall), appeared essentially identical before and after impact. The thin-walled canister, on the other hand, showed considerable deformation of the canister wall. Small circumferential bulges (i.e. similar to wrinkles) were formed in the canister wall by the impact and were distributed over the bottom half of the canister. One prominent bulge formed immediately above the canister center weld, but no bulges were above that elevation. The shape of the bulges were smooth curves similar to what one would get by pushing together the ends of a sheet of paper lying on the desk (see Figure 5.1).

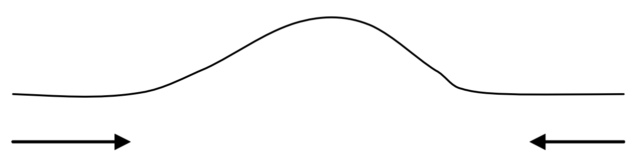
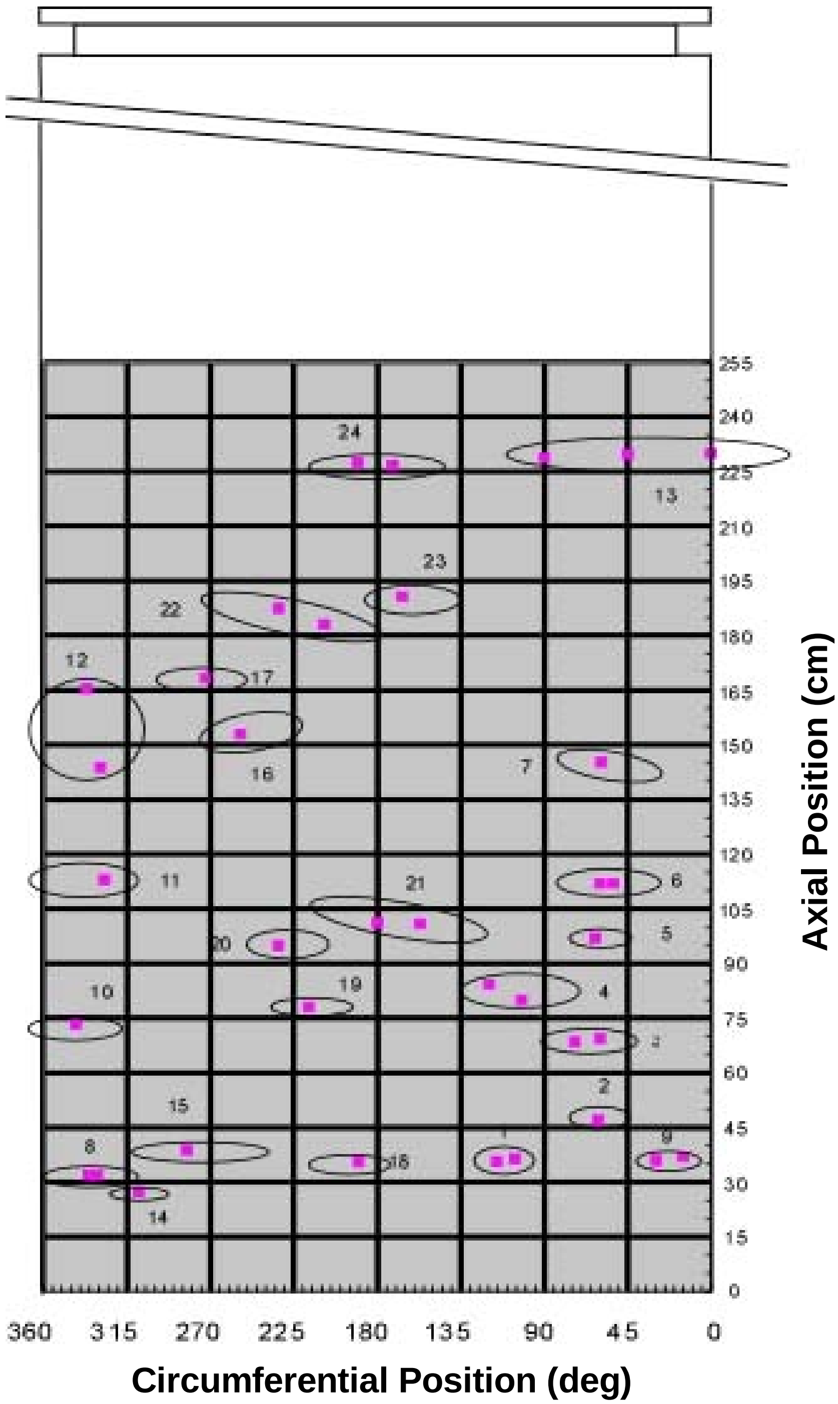


Figure 5.1. Example of Bulge Shape of Deformed Canister Wall After Drop

Figure 5.2 shows some of the bulges that were created by the impact on HT503 (10-gage wall). Twenty four of the most noticeable bulges were marked and measured by measuring the canister diameter at one or two points within the bulge. Also, distances from a taut line to the highest point of each bulge were measured using the template for the bow and warp measurements (Fig. 4.4). From these measurements, the height of the bulges above the "unstrained" canister surface was calculated. Figure 5.3 maps the approximate location of the bulges and shows the height of each bulge.

Figure 5.4 shows a sequence of three consecutive frames from the high-speed video recording of the HT503 (10-gage wall) test drop. The first frame is immediately before impact, and the next two frames show bulges, "wrinkles," forming on the canister wall as the energy of impact is being dissipated. The total elapsed time is 2/500th of a second.

Figure 5.2. Bulges on HT503 from Drop Impact



Anomaly Location	Height of bulge above "unstressed" canister wall (cm)
1-1	0.4
1-2	0.3
2-1	0.6
3-1	0.6
3-2	0.7
4-1	0.9
4-2	0.7
5-1	0.3
6-1	0.6
6-2	0.7
7-1	0.6
8-1	0.6
8-2	0.5
9-1	0.5
9-2	0.7
10-1	0.2
11-1	0.1
12-1	0.4
12-2	0.0
13-0	0.3
13-45	0.4
13-90	0.7
14-1	0.4
15-1	0.3
16-1	1.0
17-1	No data
18-1	0.8
19-1	0.3
20-1	0.1
21-1	1.4
21-2	1.2
22-1	0.2
22-2	0.4
23-1	0.5
24-1	0.6
24-2	0.5

Figure 5.3. Map of Bulges on HT503 (10-gage wall)

(canister wall opened up and laid flat like a wall map)

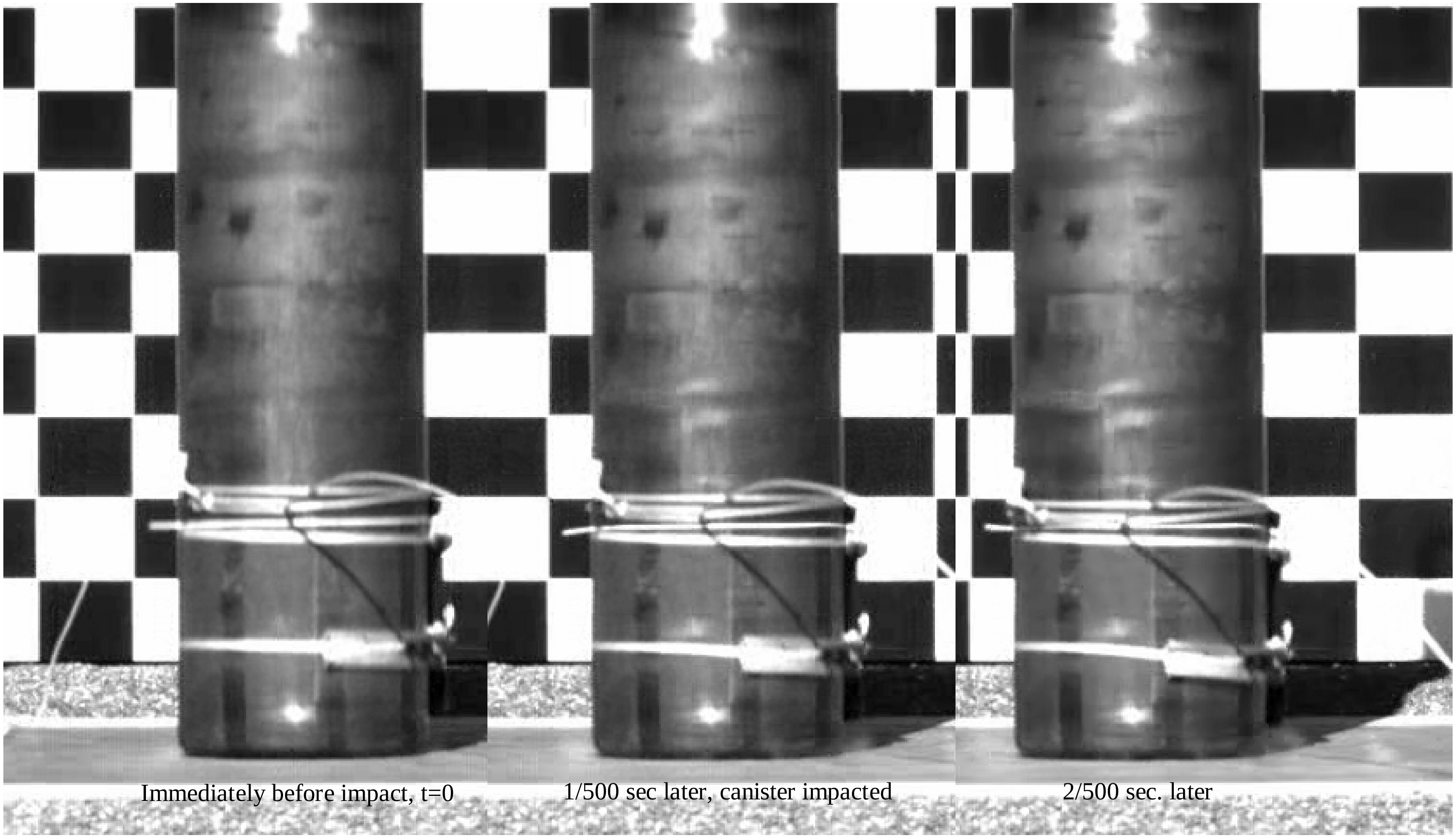


Figure 5.4. Bulges Forming on HT503

6.0 Strain-Circle Application and Analysis

Strain circles are precise diameter circles that are applied to the surface of metal and are commonly used for characterizing the deformation strains in sheet metal. These circles can be of various sizes, and the circles can be arranged in various patterns. For our application, 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.) between circle centers. The strain circles were applied to the canister surface using an electrochemical process that does not impact the overall strength properties of the metal. The surface strains can be determined by knowing the original diameter of the circles and measuring the diameters of the circles after the metal surface is deformed. The use of strain circles permits strains caused by deformation of the canisters to be determined over large areas without extensive instrumentation.

To apply the strain circles, the canister surface was first cleaned. This included buffing with 320-grit abrasive paper followed by washing with clean water. A stencil with the strain-circle pattern was then attached to the canister. One lead from an electrical power supply was grounded to the canister. A special pad with a metal backing was attached to the other power supply lead. An electrolyte was applied to the pad and the pad rolled over the stencil surface. The electrolyte and electrical current combined to selectively oxidize the surface of the metal wherever the stencil permitted current flow. A neutralizing solution was applied to the surface immediately to prevent further oxidation.

Strain circles were applied to eight patches on the canister side walls near the bottom. Seven of these patches were approximately 15 cm (6 in.) wide and 61 cm (24 in.) long. The long axis of these patches was oriented along the long axis of the canister. Each of these patches began as close to the bottom of the canister sidewall as reasonably achievable. The patches were uniformly spaced around the circumference of the canister. The initial patch was placed approximately 2.54 cm (1 in.) away from the zero degree line axial line, and subsequent patches placed at 45° intervals around the canister. The eighth patch was approximately 15 cm (6 in.) wide and 20 cm (8 in.) long to accommodate the bottom helium leak detection port. The location and orientation of the strain-circle patches are shown in Figure 6.1. Patches of strain circles were also placed on the bottom of the canisters between the reference marks. Photographs of typical strain-circle patches are shown in Figure 6.2.

Before dropping the canisters, a statistically significant portion of the strain circles had their diameters read to establish a baseline, undeformed, dimension of the strain circles for post drop calculations. A validation study had previously been completed that demonstrated that the accuracy of the strain-circle procedure is ±3 percent. The results of this study are included in Appendix I.

After impact testing, eight regions on each canister had the diameters of their strain circles read. Each of these regions was three strain circles wide and 24 strain circles long. The long axis of each region was parallel to the axis of the canister. For the thinner walled canister, one region was selected for each of the eight patches. The regions selected were at features of interest such as bulges or "scratches." A preliminary survey of the strain circles indicated that no strains were present in any of the applied strain circles that exceeded the demonstrated accuracy of the method (3 percent). For the thicker walled canister, all of the regions where strain-circle diameters were read extended from very near the bottom of the canister upward. One region was from each of the eight patches. Again, no strains were detected on any of the canister strain circles in excess of the demonstrated accuracy. All strain circles in each selected region were read by two independent staff.

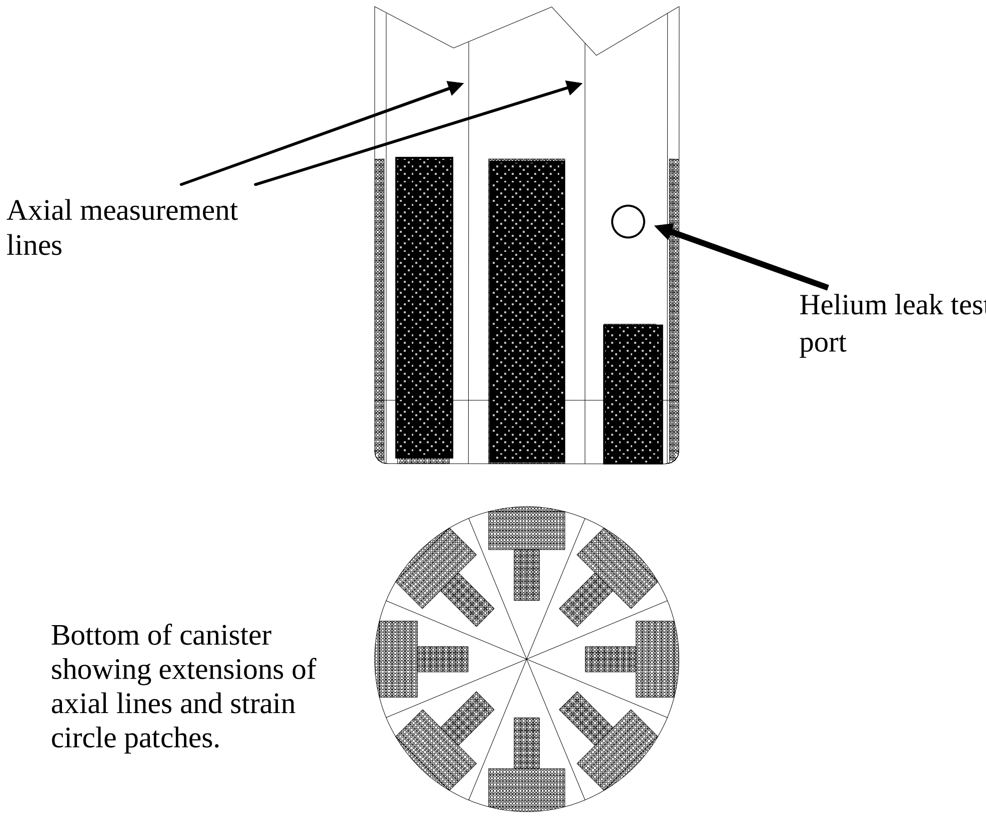
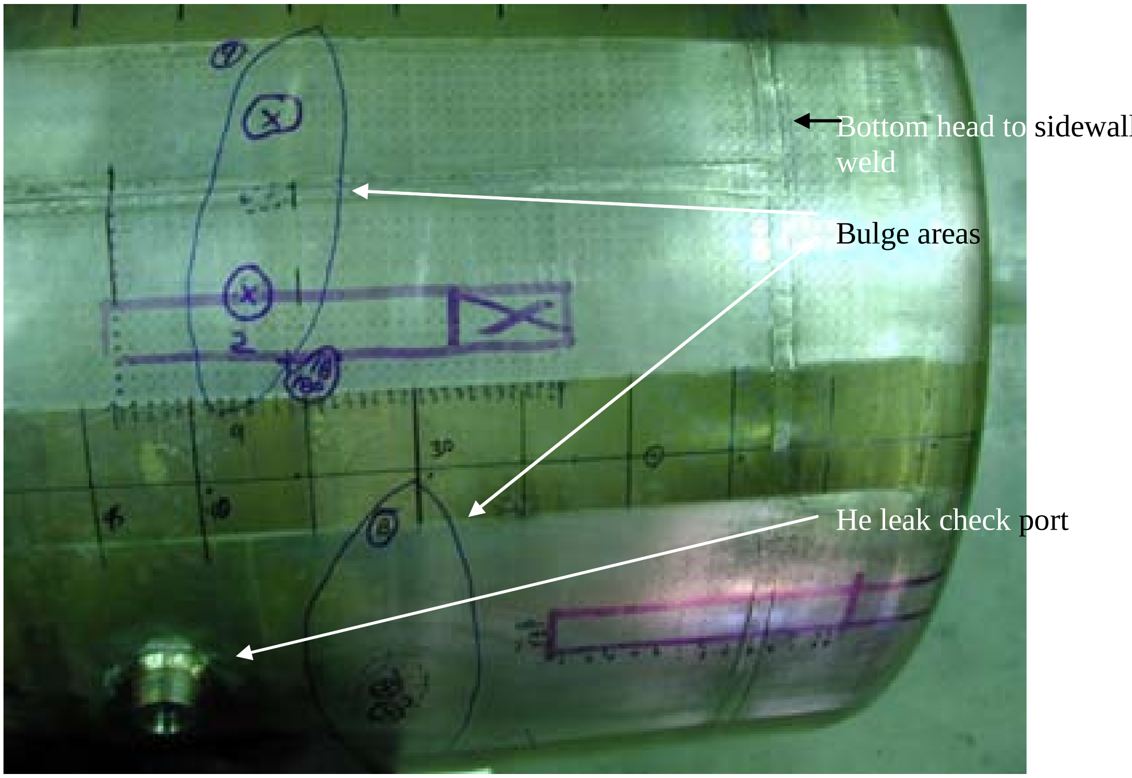


Figure 6.1. Strain-Circle Locations and Orientations

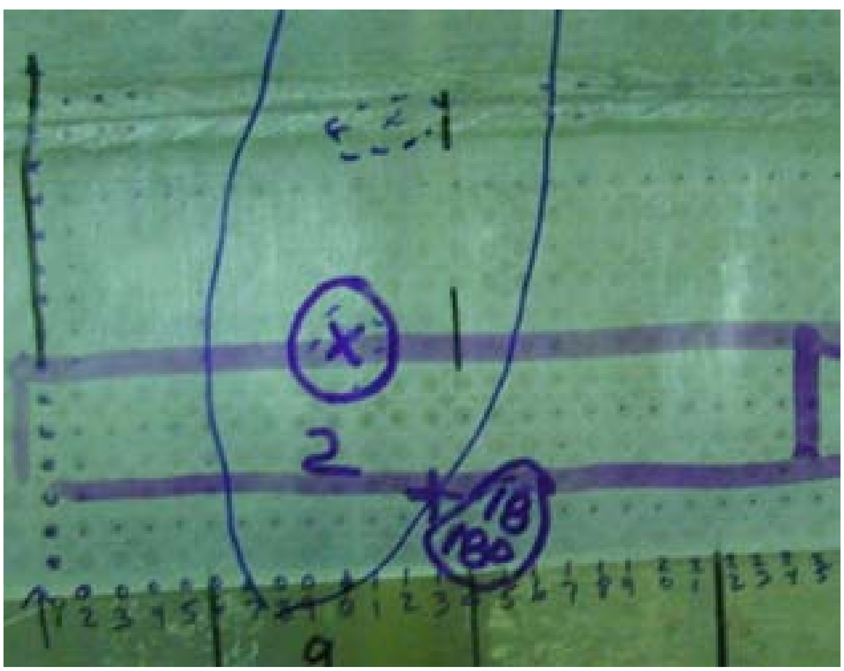
Preliminary readings of strains in the bottom patches indicated no strain, so quantitative data were only collected from the eight axial patches on the canister wall. Data from all of the strain-circle readings are included in Appendix J. The data are identified by the two axial lines that border the patch being read. For example, 0-45 indicates the patch of strain circles between the 0° and 45° axial lines.

Figure 6.2 is a picture of the area of strain circles read on HT503 (10-gage wall) and the bulge in the area of strain circles.

Figure 6.3 is a plot of the plastic deformation (strain) from one of the regions with the most interesting and largest measured strains. This was in the vicinity of one of the bulges. In each region, three neighboring rows of strain circles were read, each row containing 24 circles. Figure 6.3 contains three plots of plastic deformation (strain), one for each of the rows.

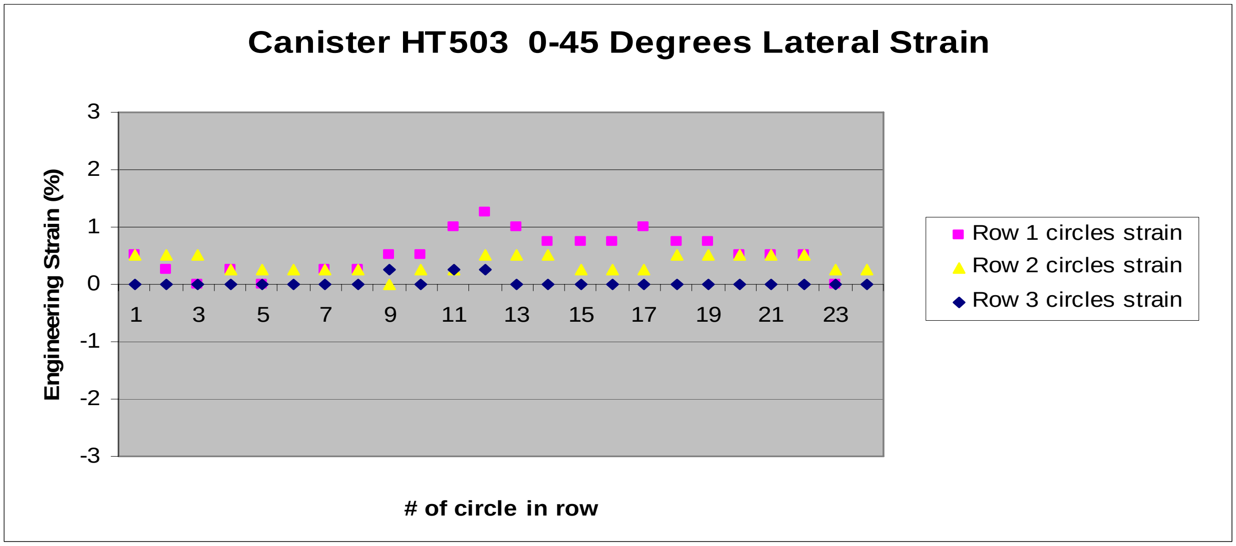


Patch on Sidewall of HT503 (including bulge from drop)



Close up of bulge in Strain circle area. No measurable strains by strain circle method.

Figure 6.2. Strain-Circle Area on HT503 (10-gage wall)



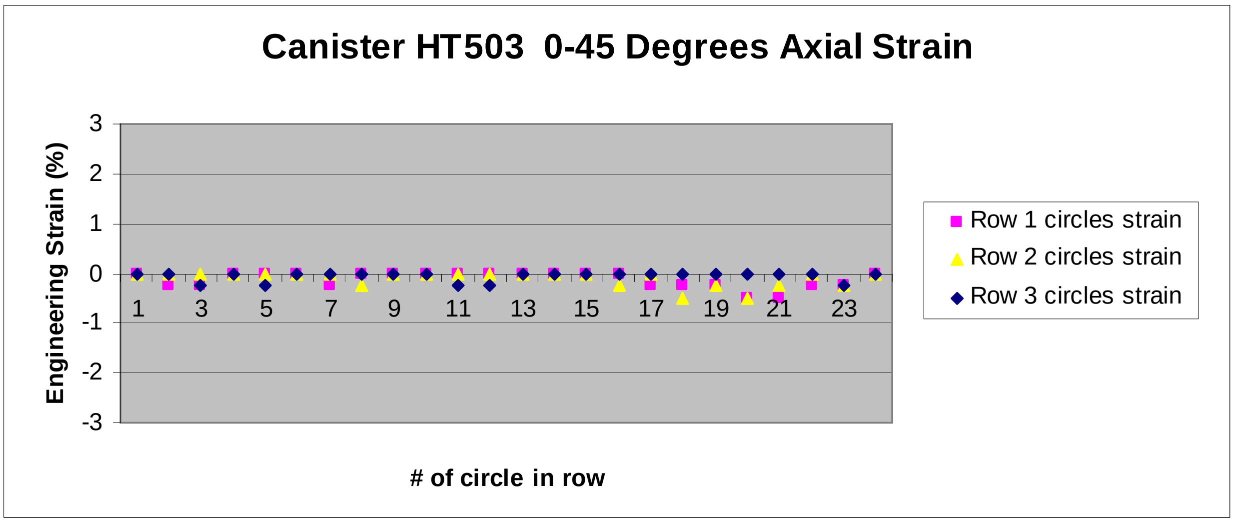


Figure 6.3. Largest Measured Strains on Canister HT503 (10-gage wall)

While the strains are low (less than 2 percent), there is a detectable trend in the data. There tended to be a slight (less than 1 percent) compressive strain in the axial direction and a slight tensile strain in the lateral (hoop) direction. Both measured strains, though slight, are consistent with the overall changes in canister dimensions. The length was reduced by impact (axial compression) and the diameter increased (lateral expansion).

None of the strains measured with the strain circles could statistically be differentiated from zero. All of the plastic deformations (strains) as measured would indicate that failure of the canister caused by strain-to-failure of the canister wall is very unlikely. While strain-to-failure data for the specific canister material were not available, typical values for strain-to-failure for 304 stainless steel is typically in excess of 40 percent.

Plots of the other strain circles read on HT503 show less strain. Strains measured on HT002 are even less. Plots of all measured strains are in Appendix K.

7.0 Conclusions

Two IHLW canisters were drop tested from a height of 7 m (23 ft) in a vertical orientation to achieve as close as possible a flat bottom impact. Both canisters impacted the drop pad in a vertical orientation with no measurable angle from perpendicular. Both canisters passed the drop test. They passed the helium leak test with a leakage at least 4 orders of magnitude below the allowable limit, 1.3×10^{-4} atm-cc/sec, which equates to the WASRD standard to be "leak tight", 1×10^{-4} ref-cc/sec.[a] Neither canister showed signs of breach.

The deformation of the 10-gage wall canister was similar to deformations of other IHLW canisters previously tested (WVDP and DWPF). The 10-gage wall canister had a similar increase in diameter near the bottom of the canister, 1.2 cm (0.47 in.), and reduction in canister length, -0.89 cm (-0.35 in.). The thicker walled canister displayed less deformation than the 10-gage wall. Both canisters displayed approximately the same small compression of the reverse-dished bottom.

Strain-circle analysis indicated that there were no statistically significant strains (<3%) even in the areas where bulges appeared on the thin-walled canister. No areas were strained anywhere near typical failure limits, which are around 40% inelastic strain.

[a] The WASRD requirement for "leak-tight" cites a leak rate for a reference gas, which is air at 1 atmosphere pressure and 25C. See Section 3.1 for definition.

Appendix A

Quality Assurance Requirements

Appendix A: Quality Assurance Requirements

Table A.1. PNWD WTP Support Project Quality Assurance Requirements

QARD Section	Yes	No	Implementing Procedure Title	Justification for Exclusion
1	X		Waste Treatment Plant Support Project(WTPSP) Manual Section 1.1, Organization QA-RPP-WTP-101, Communication and Commitment (Interface) Control QA-RPP-WTP-1501, Nonconforming Items	
2	X		WTPSP Manual Section 2.1, Quality Assurance Program QA-RPP-WTP-205, Quality Assurance Plans QA-RPP-WTP-201, Indoctrination and Training QA-RPP-WTP-208, Applying QA Controls (Grading) QA-RPP-WTP-902, Control of Special Processes WTPSP Manual Section 18.1, Audits	
3		X	WTPSP Manual Section 3.1 QA-RPP-WTP-301, Hand Calculations	Design activities will not be performed; however, hand calculations may be performed as per procedure QA-RPP-WTP-301.
4	X		WTPSP Manual Section 4.1 QA-RPP-WTP-401, Purchase Requisitions	
5	X		WTPSP Manual Section 5.1 QA-RPP-WTP-501, Preparation, Review and Approval of QA Implementing Procedures QA-RPP-WTP-1102, Generating, Reviewing, Approving, and Issuing Test Plans QA-RPP-WTP-1103, Generating, Reviewing, Approving, and Issuing Test Procedures and Instructions QA-RPP-WTP-1104, Report Generation, Review, Approval, and Publication	
6	X		WTPSP Manual Section 6.1 QA-RPP-WTP-601, Document Control QA-RPP-WTP-602, Document Change Control	
7	X		WTPSP Manual Section 7.1 QA-RPP-WTP-401, Purchase Requisitions	
8		X	WTPSP Manual Section 8.1	This task will not involve working with samples. Canisters use pre existing identifications.
9	X		WTPSP Manual Section 9.1 QA-RPP-WTP-902, Control of Special Processes	
10	X		WTPSP Manual Section 10.1	Inspections, helium leak checks, will be a procured service and will not be performed by PNWD. PNNL will perform other inspections of the canisters.
11	X		WTPSP Manual Section 11.1 QA-RPP-WTP-1101, Scientific Investigation QA-RPP-WTP –604, Independent Technical Review	
12	X		WTPSP Manual Section 12.1 QA-RPP-WTP-1201, Calibration Control System	
13	X		WTPSP Manual Section 13.1	Special handling and shipping precautions are needed to avoid scratching, denting, or damaging the canister before it is drop tested. Precautions to be included in directions to lifting, rigging, and transportation crew.
14		X	WTPSP Manual Section 14.1	This task will not involve the use of items that require inspection, testing, or operational status indicators
15	X		WTPSP Manual Section 15.1 QA-RPP-WTP-1501, Nonconforming Items	
16	X		WTPSP Manual Section 16.1 QA-RPP-WTP-1601, Trend Analysis QA-RPP-WTP-1602, Corrective Action	
17	X		WTPSP Manual Section 17.1 QA-RPP-WTP-1701, Records System QA-RPP-WTP-1704, Laboratory Record Books	
18		X	WTPSP Manual Section 18.1 QA-RPP-WTP-1801, Internal Audits	Responsibility of Project Management

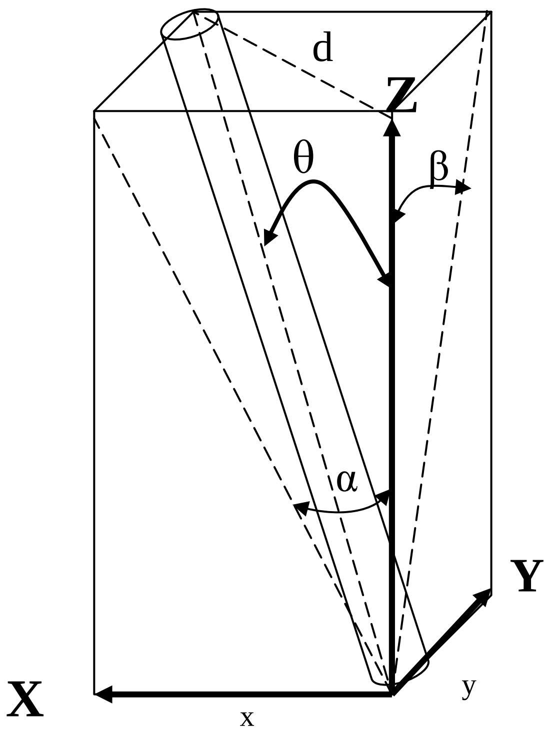
Table A.2 WTP Project Materials Acceptance Plan Hold and Witness Points

#	Attribute/Activity	H/W
1	Does not apply to PNWD	
2	Confirm canister preparation for Testing: • Canister measurements are complete and recorded. • Strain circles are etched and locations documented.	W
3	Pressure Testing as follows: • Pre-Canister Drop Helium Leak Test (HLT) of 100% of all canister surfaces except the leak test port areas. • Personnel Qualifications are current and in accordance with SNT- TC-IA requirements.	H
4	Witness the Canister Drop Test	H
5	Confirm canister inspection after drop testing to include: • Canister measurements are complete and recorded. • Strain measurements are complete and recorded.	W
6	Pressure Testing as follows • Post-Canister Drop Helium Leak Test (HLT) of 100% of all canister surfaces except the leak test port areas. • Personnel Qualifications are current and in accordance with SNT -TC-IA requirements.	H
7	Final Source Verification has confirmed that all witness and hold points have been satisfactorily completed and that the equipment/material conforms to specified requirements to the extent prescribed in this MAP and the referenced SQ Procedure.	H
8	Release for Shipment is authorized	H
9	Does not apply to PNWD	

Appendix B

Canister Angle Derivation

Appendix B: Canister Angle Derivation



θ—is the angle of the canister from vertical
α—is the angle of the canister seen by the camera looking at the XZ plane
β—is the angle of the canister seen by the camera looking at the YZ plane
x—is the distance the canister is displaced in the XZ plane.
y—is the distance the canister is displaced in the YZ plane.
d—is the distance the canister is displaced from vertical.

Eq. 1) $\tan\theta = \frac{d}{Z}$ Eq. 2) $\tan^2\theta = \frac{d^2}{Z^2}$

Eq. 3) $\tan\alpha = \frac{x}{Z}$ therefore: $x = Z * \tan\alpha$

Eq. 4) $\tan\beta = \frac{y}{Z}$ therefore: $y = Z * \tan\beta$

Eq. 5) $x^2 + y^2 = d^2$

substituting for x, y in Eq. 5) gives Eq.6) $d^2 = Z^2 * (\tan^2\alpha + \tan^2\beta)$

Substituting for Eq. 6) into Eq. 2

Eq. 7) $\tan^2\theta = \tan^2\alpha + \tan^2\beta$

Appendix C

Canister Angle by Pixel Method

Appendix C: Canister Angle by Pixel Method

To improve the precision for measuring the canister angle, the video frame was displayed using computer software that provided pixel-by-pixel coordinate mapping. The image was displayed on a 1280×1024 pixel video monitor with a 0.3-mm dot pitch. Then a point at the edge of the canister near the top and a point at the edge of the canister near the bottom of the canister were mapped. Three of the four camera images showed a horizontal displacement of only one pixel.[a] The fourth camera showed zero pixel horizontal displacement. Using this method and employing Eqs. 3, 4, and 7 from Appendix B, the canister drop angles were estimated to be:

3/8-in. wall Canister (HT002) — 0.08°
10-gage wall Canister (HT503) — 0.23°

Drop 1 HT002 (3/8" Wall)

	point 1 x	point 1 y	point 2 x	point 2 y	Angle (deg)
Camera 1 (East)	768	969	769	263	-0.08
Camera 2 (South)	643	813	643	418	0
			Total Angle:		**0.08**

Drop 2 HT503 (10-gauge Wall)

	point 1 x	point 1 y	point 2 x	point 2 y	Angle (deg)
Camera 1 (East)	244	438	243	90	0.16
Camera 2 (South)	236	459	237	106	-0.16
			Total Angle:		**0.23**

(a) As part of the set-up, the camera was "leveled" so that the vertical lines of the backboard displayed as vertical in the video image.

Appendix D

Estimated Height Error Propagation

Appendix D: Estimated Height Error Propagation

Estimated Propagation of Height error		
	errors	
	+/-	
	cm	
measurement error of tape/plumb bob length--	0.25	
accuracy of measurement on canister--	0.25	
accuracy to attach tape--	0.25	
thermal expansion of tape--		
glasss coefficient is 9E-6 per degree C.		
for 20F temperature change--expansion of 7meter (700 cm) is:	0.07	cm
potential accumulated errors	0.82	cm
Target Length for Tape:		
Minimum Height of Drop	700	cm
Location on can	20	cm
Length to measure plumb bob	**721**	**cm**
Maxium height of drop	**703**	cm
Tape length	721	cm
height of tape on can	20	cm
height of jig	1	cm
accumulated errors	0.82	cm
accuracy of lift (plumb bob off ground but not above jig viewed through binoculars)	1	cm

Appendix E

Drop Pad Design Calculations

Appendix E: Drop Pad Design Calculations

(FOR INFORMATION ONLY)

KAISER ENGINEERS HANFORD	CALCULATION IDENTIFICATION AND INDEX	WO/Job No. B203A0 Date 4/10/86

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline (03) STRUCTURAL

Project No. & Name IMPACT PAD DESIGN

Calculation Item IMPACT PAD DESIGN

These calculations apply to:

Dwg. No. H-3-48996 Rev. No. 0

Dwg. No. Rev. No.

Other (Study, CDR) Rev. No.

The status of these calculations is:

- ☐ Preliminary Calculations
- ☒ Final Calculations
- ☐ Check Calculations (On Calculation Dated)
- ☐ Void Calculation (Reason Voided

Incorporated in Final Drawings? ☒ Yes ☐ No

This calculation verified by independent "check" calculations? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	W.J. Moore 4/10/86		
	K.C. Tu 4/13/86		
Approved by	D G Lien 5/5/86		
Checked Against Approved Vendor Data			

INDEX

Design Analysis Page No.	Description
1	SIZE OF CONCRETE BASE
	DESIGN OF PLYWOOD BACKDROP AND SUPPORTS
	DESIGN CONNECTION OF BACKDROP POST TO CONCRETE IMPACT PAD
	Vert. ai Spring Constant

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Page No. 1 of 5
Revision 0

PNL	WO/Job No. B203A0	
Subject Impact Pad Design	Date 4/9/86	By W.J. MAGRUDER
	Checked	By
Location 300 AREA	Revised	By

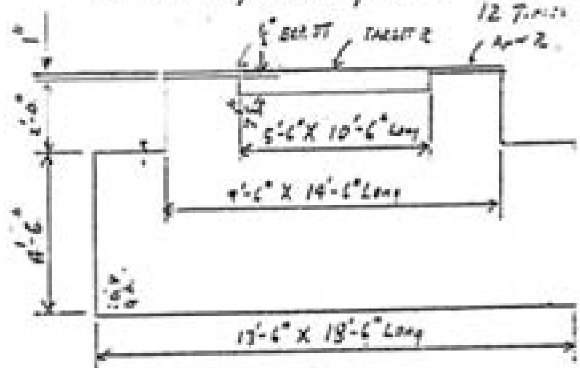
OBJECTIVE: Design an impact test pad with steel target plate and concrete base

Design Criteria: Statement of work (SOW 264956, Rev 0)

SIZE OF CONCRETE BASE

From the SOW, section A, item 2 "The maximum falling mass of a test container is 6000 Kg."

From the SOW, section A, item 8 "The concrete base shall have a mass no less than 12 times the maximum falling mass."



CROSSECTION
Scale: ¼" = 1'-0"

VOLUME CONCRETE

Top portion $(4'-6")(14'-6")(2'-0") = 275.5$ ft
− Target R $(5'-6")(10'-6")(7\tfrac{1}{2}") = (-36.1$ ft
+ EXP. JT.

Bottom portion $(13'-6")(18'-6")(4'-6") = 1123.9$ ft
Total Volume conc. $= 1363.3$ ft

steel $= 36.1\,ft^3 \times 785 \times 62.4 = 17,683$ lb

Weight of concrete $= 150\ lb/ft^3$

$1363.3\,ft^3\,(150\ lb/ft^3) = 204,495$ lb.

222,178 lb
110 tons.

Max falling mass $= 6000$ Kg or $13,227.7$ lbs

$\dfrac{204,495 \text{ lbs conc}}{13,227.7 \text{ lbs falling mass}} = 15.5$ which is greater than 12 times the falling mass required by the statement of work.

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HANFORD

DESIGN ANALYSIS

Revision ϕ

Client PNL	WO/Job No. B203A0
Subject Impact Pad Design	Date 4/10/86 · By W.J. MAGRUDER
	Checked April 86 · By K. C. Tu
Location 300 AREA	Revised · By

DESIGN OF PLYWOOD BACKDROP AND SUPPORTS

Design Criteria: Statement of work (SOW) – 8-ft high by 10 ft long plywood backdrop

Telephone conversation with Dave Koontz (4/8/86)
Back Drop only needs to be designed to carry the wind loads at the Hanford site.

Ref: SDC 4.1 Basic wind speed = 70 MPH

Ref: UNIFORM BUILDING CODE 1985 section 2311

design wind pressure $p = C_e C_q q_s I$

where C_e = Combined Height + gust factor from Table 23-G
$= 1.2$ with exposure C

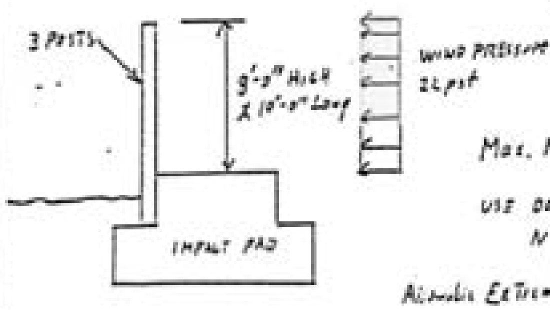
$p = 1.2(1.4)(13\ psf)\ 1.0 = 21.8\ psf$

use 22 PSF

C_q = Pressure coeff. from Table 23-H
$= 1.4$ for

q_s = Wind stagnation pressure from Table 23-F
$= 13$ PSF for 70 MPH basic wind speed

I = Importance factor
$= 1.0$



SECTION
NO SCALE

Max. Moment on post = $(22\ psf)\ 8'\left(\frac{10'}{3}\right)(4') = 2346.7$

USE DOUGLAS FIR-LARCH WOOD POSTS
No. 2 Grade by Western wood products Assoc.

Allowable Extreme Fiber Stress in bending $F_b = 1200$ psi

6 x 6 POST $S = 27.73\ in^3$

$f_b = \frac{M}{S} = \frac{2346.7^{ft\text{-}lb}(12)}{27.73\ in^3} = 1015$ psi < 1200 psi OK

USE (2) 6 x 6 POSTS

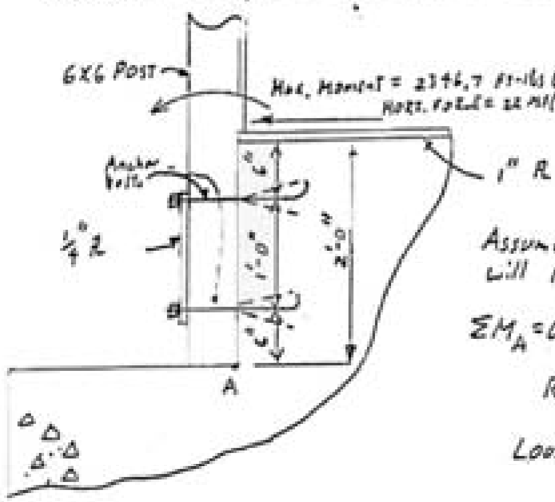
KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Page No. ____ of 5
Revision ϕ
3 of 5

Client: PNL	WO/Job No. B20380		
Subject: Impact Pad Design	Date 4/17/86	By W. J. MAGRUDER	
	Checked [illegible] 86	By K. C. Tu	
Location: 300 Area	Revised	By	

Connection Design of Backdrop Post To Concrete Impact Pad



PARTIAL SECTION
3/4" = 1'-0"

Assume that the top two anchor bolts will resist the entire wind load.

$$\Sigma M_A = 0 = 2346.7\ \text{ft-lbs}(12) + 587^{\#}(15'') - R_A\, 13''$$

$$R_A = 2379.7\ \text{lbs}$$

$$\text{Load on each anchor} = \tfrac{1}{2} R_A = \tfrac{1}{2}(2379.7) = 1190\ \text{lbs}$$

use 5/8" dia embedded anchor bolts
Tensile strength = 13,560 lbs > 1190 lbs

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Revision ___ 4 of 5

Client PNL	WO/Job No B223A2
Impact Pad Design	Date 4/4/86 By K. C. T.
	Checked 4/22/86 By W. J. Magruder
Location 300 AREA	Revised By

Vertical Spring Constant

See "Vibrations of Soils and Foundations" by F.E. Richart, Jr., J. R. Hall, Jr., & R. D. Woods P. 350

$k_z = \frac{G}{1-\nu} \beta_z \sqrt{4cd}$

$2d = 18.5'$

$2c = 13.5'$

$\frac{d}{c} = 1.37$

$\beta_z = 2.18$

$G = 1700$ KSF — From "Seismic Evaluation and Recommended Modifications for 291-Z Bldg & Stack" By URS, ... 1980

$\nu_s = .37$

$k_z = \frac{1700}{1-.37} 2.18 \sqrt{18.5 \times 13.5} = 92,965$ K/ft

Equivalent radius

$2\pi r_0 = 2(18.5+13.5)$

$r_0 = 10.19'$

Depth to Radius Ratio

$\frac{H}{r_0} = \frac{5.83}{10.19} = 0.57$

$\frac{K_{zH}}{k_z} = 1.32$ fig 10-17 page 352

$K_{zH} = 1.32 \times 92,965 = 122,713$ K/ft

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Revision ϕ 5 of 5

C: PNL	WO/Job No. B25340	
Subject: Impact Pad Design	Date 4/4/85	By K. C. Tee
	Checked 4/30/86	By W. S. Magruder
Location: 307 AREA	Revised	By

Steel $\rlap{/}{P}$ 65" x 125" x 8.5"

$$= \frac{P}{\delta} = \frac{AE}{L} = \frac{65 \times 125 \times 29000}{8.5} = 27.72 \times 10^6 \ {}^{k}/_{in}$$

$$= 332 \times 10^6 \ {}^{k}/_{ft}$$

Concrete

$$K_c = \frac{18.5 \times 13.5 \times 57\sqrt{3000} \times 12^2}{5.83} = 19,246,047 \ {}^{k}/_{in} = 230976568 \ {}^{k}/_{ft}$$

$$K = \frac{1}{\frac{1}{K_{su}} + \frac{1}{K_{\rlap{/}{P}}} + \frac{1}{K_c}} = 122,660 \ {}^{k}/_{ft} \quad = \frac{F}{\delta}$$

The maximum falling mass of a test container

$$M g = 6000 \, kg \times 2.2046 = 13,228^{\#}$$

The free-fall height

$$H = 9_m \times 3.28 = 29.52'$$

Potential Energy = Work

Assume container deforms 2"

and target plate deform δ'

$$13.228 \left(29.52 + \frac{2}{12} + \delta\right) = \frac{1}{2} F \delta + F\left(\frac{2}{12}\right)$$

$F = K\delta$ = [illegible]

$$13.228 \left(29.69 + \delta\right) = \frac{1}{2} 122,660 \delta^2 + \frac{122,660}{6} \delta$$

$\delta = 0.0182' \times 12 = 0.218"$ [illegible]

$F = 0.0182 \times 122660 = 2231^{k}$ [illegible]

Appendix F

Equivalent Helium Leak Rates

Appendix F: Equivalent Helium Leak Rate

Equations and approach copied from ANSI N14.5-1997, Sec. B.3 (ANSI 1997)

Correlation approach is to calculate a "hole" that will leak air at the prescribed rate under standard conditions and then calculate the He leak rate through the same hole using the molecular weight and viscosity of helium.

Air Leakage: $Q = La \times P$ atm-cm^3/sec

$La=(Fc+Fm)*(Pu-Pd)$ cm^3/sec

$Fc= (2.49\times10^6 * D^4)/ (a*u)$

$Fm= (3.81\times10^3*D^3*(T/M)^{0.5})/(a*Pa)$

Q: Total air leakage for test, requirement is <1E-04 atm-cm^3/sec. For 1 atm driving force Q=La.

La: air leakage rate cm^3/sec at pressure

Fc: coefficient for continuum flow, cm3/atm-sec

Fm: coefficient for free molecular flow, cm3/atm-sec

Pu, Pd: fluid pressure, atm; upstream and downstream, respectively.

D: equivalent diameter of leak hole, cm

a: length of leak path (thickness of canister wall), 0.342 cm (0.1345 in.)

u: viscosity of gas; .0185 cP for air; .0198 cP for He

T: temperature in Kelvin (298K)

Pa: average pressure between inside and outside; 0.5 atm

M: molecular wt.; air 29; He_4

for Air	u=	0.0185	M=	29
guess D cm	Fc	Fm	La	
0.001	0.000394	7.14E-05	4.65E-04	
0.0005	2.46E-05	8.93E-06	3.35E-05	
0.0007	9.45E-05	2.45E-05	1.19E-04	
0.00067	7.93E-05	2.15E-05	1.01E-04	
0.000669	7.88E-05	2.14E-05	1.00E-04	

For Helium use same diameter hole but different M and u

	u=	0.0198	M=	4
D cm	Fc	Fm	La	
0.000669	7.37E-05	5.76E-05	1.31E-04	

Helium leak equivalent is **1.3E-4 cm3/sec for a 1 atm driving pressure.**

Appendix G

Canister HT002 (3/8-in. wall) Measurements

Appendix G: Canister HT002 (3/8-in. wall) Measurements

Table G.1. Pre-Drop Diameters for HT002 (3/8-in. wall)

Data Sheet 357-2 *Canister Diameter Measurements*				
measurement tolerance-- +/- 0.025 cm				
Post Drop ☐	Can ID: HT002	Micrometer ID: 441-47-01-01		
	Can wall: 3/8 in.			
Pre Drop ☒ X		Cal Date: 3/31/2005		
		Exp. Date: 3/31/2006		
measurements by: WC Buchmiller/ WA Wilcox				
	Axial Lines			
Circumferential Lines	**0º/180º**	**45º/225º**	**90º/270º**	**135º/315º**
+5cm Circumferential line	60.73	60.73	60.75	60.73
+10cm Circumferential line	60.73	60.75	60.78	60.78
+15cm Circumferential line	60.80	60.85	60.83	60.88
+20cm Circumferential line	60.95	61.00	61.00	61.03
+25cm Circumferential line	61.00	61.05	61.05	61.05
+30cm Circumferential line	60.98	61.05	61.05	61.05
+35cm Circumferential line	60.98	61.03	61.05	61.00
+40cm Circumferential line	60.98	61.05	61.05	61.00
+45cm Circumferential line	60.98	61.05	61.08	61.00
+50cm Circumferential line	60.98	61.08	61.10	60.98
+55cm Circumferential line	60.95	61.08	61.10	60.95
+60cm Circumferential line	60.95	61.08	61.08	60.93
+65cm Circumferential line	60.90	61.05	61.05	60.98
+70cm Circumferential line	60.90	61.05	61.08	60.98
+75cm Circumferential line	60.90	61.05	61.08	60.93
+90cm Circumferential line	60.90	61.08	61.05	60.98
+105cm Circumferential line	60.90	61.10	61.03	61.00
+120cm Circumferential line	60.90	61.08	61.00	61.00
+135cm Circumferential line	60.85	60.83	61.00	61.00
+150cm Circumferential line	60.85	61.08	61.00	61.05
+165cm Circumferential line	60.88	61.05	61.03	61.03

Data Sheet 357-2 *Canister Diameter Measurements*				
measurement tolerance-- +/- 0.025 cm				
+180cm Circumferential line	60.90	61.05	61.00	61.03
+195cm Circumferential line	60.85	61.03	61.00	61.08
+210cm Circumferential line	60.90	61.08	61.00	60.88
+225cm Circumferential line	60.78	60.93	60.78	60.93
+255cm Circumferential line	60.93	61.20	60.90	60.85
+285cm Circumferential line	60.98	61.20	60.95	61.00
+315cm Circumferential line	61.05	61.23	60.98	60.93
+345cm Circumferential line	61.05	61.25	60.95	60.95
+375cm Circumferential line	61.05	61.25	60.98	60.98
+405cm Circumferential line	61.10	61.23	61.03	60.95
+435cm Circumferential line	60.83	60.78	60.78	60.75

Table G.2. Post-Drop Diameters for HT002 (3/8-in. wall)

Data Sheet 357-2 *Canister Diameter Measurements*				
measurement tolerance-- +/- 0.025 cm				
Post Drop [X]	Can ID	**HT002**	Micrometer ID	441-47-01-01
Pre Drop [ ]	Can wall	3/8 in.	Cal Date	3/31/2005
			Exp. Date	3/31/2006
measurements by: WC Buchmiller/ MD Johnson				
	Axial Lines			
Circumferential Lines	**0º/180º**	**45º/225º**	**90º/270º**	**135º/315º**
+5cm Circumferential line	61.45	61.13	61.18	61.45
+10cm Circumferential line	61.33	61.08	61.10	61.33
+15cm Circumferential line	61.30	61.20	61.13	61.33
+20cm Circumferential line	61.40	61.38	61.33	61.35
+25cm Circumferential line	61.38	61.38	61.35	61.38
+30cm Circumferential line	61.30	61.25	61.23	61.33
+35cm Circumferential line	61.25	61.23	61.23	61.28
+40cm Circumferential line	61.25	61.30	61.30	61.30
+45cm Circumferential line	61.23	61.30	61.35	61.30
+50cm Circumferential line	61.25	61.30	61.40	61.25
+55cm Circumferential line	61.30	61.35	61.40	61.20
+60cm Circumferential line	61.23	61.38	61.33	61.13
+65cm Circumferential line	61.15	61.30	61.23	61.13
+70cm Circumferential line	61.18	61.28	61.25	61.23
+75cm Circumferential line	61.20	61.33	61.30	61.20
+90cm Circumferential line	61.10	61.23	61.28	61.20
+105cm Circumferential line	61.08	61.35	61.23	61.25
+120cm Circumferential line	61.13	61.25	61.33	61.30
+135cm Circumferential line	61.10	61.30	61.23	61.28
+150cm Circumferential line	61.18	61.30	61.35	61.33
+165cm Circumferential line	61.03	61.23	61.15	61.23
+180cm Circumferential line	61.10	61.23	61.15	61.18
+195cm Circumferential line	61.05	61.20	61.18	61.33
+210cm Circumferential line	61.00	61.23	61.05	61.23

Data Sheet 357-2 *Canister Diameter Measurements*				
measurement tolerance-- +/- 0.025 cm				
+225cm Circumferential line	60.85	61.00	60.83	60.98
+255cm Circumferential line	61.00	61.25	60.93	61.15
+285cm Circumferential line	61.00	61.20	60.95	61.03
+315cm Circumferential line	61.08	61.23	60.98	60.93
+345cm Circumferential line	61.05	61.25	60.95	60.95
+375cm Circumferential line	61.05	61.25	60.98	60.93
+405cm Circumferential line	61.10	61.08	60.95	60.95
+435cm Circumferential line	60.83	60.78	60.78	60.75

Table G.3. Pre-Drop Length Measurements HT002 (3/8-in. wall)

Data Sheet 357-4 *Canister Length Measurements*

measurement tolerance-- cm (xxx.x)

Post Drop	☐	Can ID	HT002	Tape Measure ID	PNL-99-65-002
		Can wall	3/8 in.		
Pre Drop	X			Cal Date	3/30/2005
				Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

Circumferential Lines	Axial Lines 0º	45º	90º	135º
+0cm Circumferential line	449.3	449.2	449.3	449.2
+5cm Circumferential line	444.3	444.3	444.3	444.3
+10cm Circumferential line	439.3	439.4	439.3	439.3
+15cm Circumferential line	434.3	434.3	434.3	434.3
+20cm Circumferential line	429.3	429.3	429.2	429.3
+25cm Circumferential line	424.3	424.3	424.2	424.3
+30cm Circumferential line	419.3	419.3	419.3	419.2
+35cm Circumferential line	414.3	414.3	414.2	414.2
+40cm Circumferential line	409.3	409.3	409.2	409.2
+45cm Circumferential line	404.3	404.2	404.3	404.3
+50cm Circumferential line	399.3	399.3	399.3	399.2
+55cm Circumferential line	394.3	394.3	394.3	394.3
+60cm Circumferential line	389.3	389.2	389.3	389.3
+65cm Circumferential line	384.3	384.3	384.3	384.2
+70cm Circumferential line	379.3	379.3	379.3	379.2
+75cm Circumferential line	374.3	374.3	374.3	374.3
+90cm Circumferential line	359.3	359.3	359.3	359.2
+105cm Circumferential line	344.3	344.3	344.3	344.2
+120cm Circumferential line	329.3	329.3	329.3	329.2
+135cm Circumferential line	314.3	314.3	314.3	314.2
+150cm Circumferential line	299.3	299.3	299.3	299.2
+165cm Circumferential line	284.3	284.3	284.3	284.2

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance-- cm (xxx.x)				
+180cm Circumferential line	269.4	269.3	269.3	269.2
+195cm Circumferential line	254.3	254.3	254.3	254.2
+210cm Circumferential line	239.3	239.3	239.3	239.2
+225cm Circumferential line	224.4	224.3	224.3	224.2
+255cm Circumferential line	194.4	194.3	194.3	194.2
+285cm Circumferential line	164.3	164.3	164.3	164.2
+315cm Circumferential line	134.4	134.4	134.3	134.2
+345cm Circumferential line	104.3	104.3	104.3	104.3
+375cm Circumferential line	74.3	74.3	74.3	74.3
+405cm Circumferential line	44.3	44.3	44.3	44.3
+435cm Circumferential line	14.4	14.2	14.2	14.2

Table G.4. Pre-Drop Length Measurements HT002 (3/8-in. wall)

Data Sheet 357-4 *Canister Length Measurements*

measurement tolerance-- cm (xxx.x)

Post Drop [ ]	Can ID	HT002	Tape Measure ID	PNL-99-65-002
	Can wall	3/8 in.		
Pre Drop [X]			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

Circumferential Lines	Axial Lines 180º	225º	270º	315º
+0" Circumferential line	449.3	449.3	449.3	449.3
+5cm Circumferential line	444.3	444.3	444.3	444.3
+10cm Circumferential line	439.3	439.3	439.3	439.3
+15cm Circumferential line	434.3	434.3	434.3	434.3
+20cm Circumferential line	429.3	429.3	429.2	429.3
+25cm Circumferential line	424.3	424.4	424.3	424.3
+30cm Circumferential line	419.3	419.2	419.3	419.3
+35cm Circumferential line	414.3	414.3	414.2	414.2
+40cm Circumferential line	409.3	409.3	409.2	409.2
+45cm Circumferential line	404.3	404.3	404.2	404.3
+50cm Circumferential line	399.2	399.2	399.2	399.2
+55cm Circumferential line	394.2	394.2	394.2	394.3
+60cm Circumferential line	389.3	389.3	389.3	389.3
+65cm Circumferential line	384.2	384.2	384.2	384.2
+70cm Circumferential line	379.2	379.2	379.2	379.2
+75cm Circumferential line	374.3	374.3	374.3	374.3
+90cm Circumferential line	359.3	359.2	359.2	359.3
+105cm Circumferential line	344.2	344.2	344.3	344.3
+120cm Circumferential line	329.2	329.2	329.2	329.3
+135cm Circumferential line	314.3	314.2	314.2	314.3
+150cm Circumferential line	299.3	299.2	299.2	299.3
+165cm Circumferential line	284.3	284.3	284.3	284.2

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance-- cm (xxx.x)				
+180cm Circumferential line	269.3	269.3	269.2	269.3
+195cm Circumferential line	254.3	254.3	254.3	254.3
+210cm Circumferential line	239.3	239.2	239.2	239.3
+225cm Circumferential line	224.3	224.3	224.3	224.3
+255cm Circumferential line	194.3	194.3	194.3	194.3
+285cm Circumferential line	164.3	164.2	164.2	164.2
+315cm Circumferential line	134.3	134.3	134.3	134.3
+345cm Circumferential line	104.3	104.2	104.3	104.3
+375cm Circumferential line	74.3	74.3	74.2	74.2
+405cm Circumferential line	44.3	44.2	44.2	44.2
+435cm Circumferential line	14.3	14.2	14.2	14.2

Table G.5. Post-Drop Length Measurements HT002 (3/8-in. wall)

Data Sheet 357-4 *Canister Length Measurements*

measurement tolerance-- cm (xxx.x)

Post Drop: X	Can ID	HT002	Tape Measure ID	PNL-99-65-002
	Can wall	3/8 in.		
Pre Drop:			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ MD Johnson

Circumferential Lines	**Axial Lines** 0º	45º	90º	135º
+0cm Circumferential line	447.6	447.9	448.0	447.9
+5cm Circumferential line	443.2	443.2	443.4	443.3
+10cm Circumferential line	438.3	438.3	438.4	438.3
+15cm Circumferential line	433.3	433.2	433.4	433.3
+20cm Circumferential line	428.3	428.2	428.4	428.3
+25cm Circumferential line	423.4	423.3	423.5	423.4
+30cm Circumferential line	418.4	418.5	418.5	418.3
+35cm Circumferential line	413.4	413.4	413.5	413.3
+40cm Circumferential line	408.5	408.4	408.5	408.4
+45cm Circumferential line	403.4	403.4	403.5	403.4
+50cm Circumferential line	398.4	398.5	398.6	398.4
+55cm Circumferential line	393.5	393.4	393.6	393.4
+60cm Circumferential line	388.5	388.4	388.6	388.4
+65cm Circumferential line	383.5	383.4	383.6	383.5
+70cm Circumferential line	378.6	378.5	378.7	378.5
+75cm Circumferential line	373.6	373.6	373.7	373.6
+90cm Circumferential line	358.6	358.5	358.8	358.6
+105cm Circumferential line	343.7	343.6	343.8	343.6
+120cm Circumferential line	328.7	328.8	328.9	328.7
+135cm Circumferential line	313.9	313.9	314.0	313.7
+150cm Circumferential line	299.0	299.0	299.2	298.9

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance-- cm (xxx.x)				
+165cm Circumferential line	284.1	284.1	284.2	284.0
+180cm Circumferential line	269.2	269.2	269.2	269.0
+195cm Circumferential line	254.2	254.2	254.3	254.1
+210cm Circumferential line	239.2	239.2	239.4	239.2
+225cm Circumferential line	224.3	224.2	224.4	224.1
+255cm Circumferential line	194.3	194.3	194.4	194.2
+285cm Circumferential line	164.3	164.3	164.4	164.2
+315cm Circumferential line	134.3	134.4	134.4	134.3
+345cm Circumferential line	104.3	104.3	104.4	104.3
+375cm Circumferential line	74.3	74.3	74.4	74.3
+405cm Circumferential line	44.3	44.2	44.5	44.3
+435cm Circumferential line	14.4	14.2	14.4	14.2

Table G.6. Post-Drop Length Measurements HT002 (3/8-in. wall)

Data Sheet 357-4 *Canister Length Measurements*

measurement tolerance-- cm (xxx.x)

Post Drop [X]	Can ID	HT002	Tape Measure ID	PNL-99-65-002
	Can wall	3/8 in.		
Pre Drop [ ]			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ MD Johnson

Circumferential Lines	Axial Lines 180º	225º	270º	315º
+0" Circumferential line	448.0	448.0	447.8	447.6
+5cm Circumferential line	443.2	443.3	443.3	443.3
+10cm Circumferential line	438.2	438.4	438.3	438.3
+15cm Circumferential line	433.3	433.4	433.4	433.4
+20cm Circumferential line	428.3	428.4	428.4	428.3
+25cm Circumferential line	423.4	423.5	423.4	423.3
+30cm Circumferential line	418.4	418.3	418.4	418.3
+35cm Circumferential line	413.4	413.4	413.4	413.3
+40cm Circumferential line	408.4	408.5	408.4	408.3
+45cm Circumferential line	403.4	403.5	403.5	403.3
+50cm Circumferential line	398.4	398.5	398.5	398.3
+55cm Circumferential line	393.4	393.4	393.5	393.4
+60cm Circumferential line	388.4	388.6	388.6	388.5
+65cm Circumferential line	383.5	383.6	383.4	383.4
+70cm Circumferential line	378.5	378.5	378.6	378.5
+75cm Circumferential line	373.6	373.6	373.7	373.6
+90cm Circumferential line	358.6	358.6	358.6	358.6
+105cm Circumferential line	343.7	343.7	343.6	343.7
+120cm Circumferential line	328.7	328.7	328.7	328.7
+135cm Circumferential line	313.8	313.8	313.7	313.8
+150cm Circumferential line	298.9	298.9	298.8	298.9

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance-- cm (xxx.x)				
+165cm Circumferential line	284.0	284.0	283.8	283.9
+180cm Circumferential line	269.0	269.0	268.9	269.0
+195cm Circumferential line	254.0	254.0	254.0	254.1
+210cm Circumferential line	239.1	239.1	239.1	239.1
+225cm Circumferential line	224.2	224.2	224.2	224.2
+255cm Circumferential line	194.3	194.2	194.2	194.2
+285cm Circumferential line	164.2	164.2	164.1	164.2
+315cm Circumferential line	134.2	134.2	134.2	134.3
+345cm Circumferential line	104.3	104.3	104.2	104.3
+375cm Circumferential line	74.3	74.2	74.2	74.3
+405cm Circumferential line	44.3	44.3	44.2	44.3
+435cm Circumferential line	14.3	14.2	14.2	14.3

Table G.7. Pre-Drop Canister Dish Measurements HT002 (3/8-in. wall)

Data Sheet 357-5 *Canister Dish Measurements*

measurement tolerance--cm (x.x)

Post Drop	☐	Can ID	HT002	Ruler ID	PNL-66-02-001
		Can wall	3/8 in.		
Pre Drop	X			Cal Date	3/30/2005
				Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

	Radial Line			
Radial Position[a]	0º/180º	45º/225º	90º/270º	135º/315º
7.6cm (7.6cm in from outer edge)[b]	0.2	0.1	0.1	0.1
15.2cm	2.5	2.4	2.4	2.4
22.9cm	3.8	3.8	3.8	3.8
30.5cm (center)	4.2	4.2	4.2	4.2
38.1cm	3.9	3.9	3.8	3.8
45.7cm	2.5	2.6	2.6	2.6
53.3cm(~7.6cm in from outer edge)[b]	0.1	0.3	0.2	0.3

(a) All radial positions and radial lines were located and marked before the canister drop.
(b) For example, on the 0º/180º radial line, the 7.6cm Radial Position would be 7.6cm in along the Radial Line between the 0º axial line and the 180º axial line as drawn on the canister and along the canister bottom. The 7.6cm Radial Position, on the 0º/180º radial line, would be closest to the 0º axial line and the 53.3cm Radial Position, on the 0º/180º radial line, closest to the 180º axial line.

Table G.8. Post-Drop Canister Dish Measurement HT002 (3/8-in. wall)

Data Sheet 357-5 *Canister Dish Measurements*

measurement tolerance--cm (x.x)

Post Drop [X]

Pre Drop [ ]

Can ID: HT002

Can wall: 3/8 in.

Ruler ID: PNL-66-02-001

Cal Date: 3/30/2005

Exp. Date: 3/30/2006

measurements by: WC Buchmiller/ MD Johnson

	Radial Line			
Radial Position[a]	0º/180º	45º/225º	90º/270º	135º/315º
7.6cm (7.6cm in from outer edge[b])	0.1	0.1	0.1	0.1
15.2cm	2.1	2.2	2.2	2.3
22.9cm	3.4	3.6	3.5	3.5
30.5cm (center)	4.0	4.0	4.0	4.0
38.1cm	3.6	3.6	3.6	3.5
45.7cm	2.3	2.4	2.4	2.2
53.3cm(~7.6cm in from outer edge[b])	0.1	0.2	0.2	0.2

[a] All radial positions and radial lines were located and marked prior to the canister drop
[b] For example, on the 0º/180º radial line, the 7.6cm Radial Position would be 7.6cm in along the Radial Line between the 0º axial line and the 180º axial line as drawn on the canister and along the canister bottom. The 7.6cm Radial Position, on the 0º/1

Table G.9. Pre-Drop Canister Distortion Measurements HT002 (3/8-in. wall)

Data Sheet 357-6 *Canister Distortion Measurements*

(Taut line – Outer edge to Axial Line on Canister Wall) tolerance--cm (x.x)

Post Drop	☐	Can ID	**HT002**	Rule ID	PNL-66-02-001
		Can Wall	**3/8 in.**		ID
Pre Drop	X			Cal Date	3/30/2005
				Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

Axial Lines

Circumferential Lines	**0º/**	**180º**	**45º/**	**225º**	**90º/**	**270º**	**135º/**	**315º**
+15cm Circumferential line	3.2	3.2	3.2	3.2	3.4	3.0	3.4	2.9
+45cm Circumferential line	3.1	3.2	3.1	3.1	3.2	3.0	3.3	3.0
+75cm Circumferential line	3.2	3.2	3.2	3.0	3.2	3.0	3.3	3.1
+105cm Circumferential line	3.2	3.2	3.1	3.0	3.2	3.1	3.3	3.1
+135cm Circumferential line	3.2	3.2	3.2	3.1	3.2	3.1	3.2	3.1
+165cm Circumferential line	3.2	3.2	3.2	3.1	3.2	3.2	3.2	3.0
+195cm Circumferential line	3.2	3.2	3.2	3.1	3.2	3.2	3.2	3.0
+225cm Circumferential line	3.2	3.2	3.2	3.2	3.4	3.3	3.4	3.0
+255cm Circumferential line	3.2	3.2	3.1	3.0	3.3	3.2	3.4	3.0
+285cm Circumferential line	3.2	3.2	3.2	3.0	3.3	3.2	3.4	3.0
+315cm Circumferential line	3.2	3.2	3.2	3.0	3.3	3.2	3.3	3.1
+345cm Circumferential line	3.1	3.2	3.2	3.0	3.2	3.2	3.4	3.1
+375cm Circumferential line	3.1	3.2	3.2	3.0	3.2	3.3	3.4	3.1
+405cm Circumferential line	3.1	3.2	3.2	3.0	3.2	3.2	3.3	3.1
+435cm Circumferential line	3.2	3.3	3.5	3.1	3.2	3.4	3.4	3.3

Table G.10 Post-Drop Canister Distortion Measurements HT002 (3/8-in. wall)

Data Sheet 357-6 *Canister Distortion Measurements*

(Taut line – Outer edge to Axial Line on Canister Wall) tolerance--cm (x.x)

Post Drop [X]

Can ID **HT002**

Rule ID PNL-66-02-001

ID

Can Wall **3/8 in.**

Pre Drop [ ]

Cal Date 3/30/2005

Exp. Date 3/30/2006

measurements by: WC Buchmiller/ MD Johnson

Circumferential Lines	**Axial Lines** 0°/	180°	45°/	225°	90°/	270°	135°/	315°
+15cm Circumferential line	2.7	3.2	2.9	2.6	3.3	2.7	3.4	2.6
+45cm Circumferential line	2.9	3.1	3.1	2.6	3.4	2.6	3.2	2.7
+75cm Circumferential line	3.0	3.1	3.1	2.6	3.3	2.8	3.3	2.9
+105cm Circumferential line	3.1	3.1	3.2	2.6	3.3	2.8	3.2	2.8
+135cm Circumferential line	3.1	3.0	3.1	2.7	3.3	2.7	3.2	2.9
+165cm Circumferential line	3.2	3.0	3.1	2.8	3.3	2.8	3.1	2.9
+195cm Circumferential line	3.1	3.0	3.1	2.9	3.2	2.9	3.1	2.9
+225cm Circumferential line	3.2	3.1	3.1	3.0	3.3	3.1	3.1	3.1
+255cm Circumferential line	3.1	3.2	2.9	3.0	3.3	3.1	3.0	2.9
+285cm Circumferential line	3.1	3.2	2.9	3.0	3.4	3.0	3.2	2.9
+315cm Circumferential line	3.1	3.0	2.9	3.0	3.2	3.0	3.2	3.0
+345cm Circumferential line	3.1	3.1	2.9	3.0	3.3	3.0	3.3	2.9
+375cm Circumferential line	3.1	3.1	3.0	2.9	3.3	3.1	3.3	3.0
+405cm Circumferential line	3.1	3.1	3.1	2.8	3.2	3.1	3.2	2.9
+435cm Circumferential line	3.2	3.2	3.3	3.1	3.4	3.2	3.3	3.1

Appendix H

Canister HT503 (10-gage wall) measurements

Appendix H: Canister HT503 (10-gage wall) measurements

Table H.1. Pre-Drop Diameters for HT503 (10-gage wall)

Data Sheet 424-2 *Canister Diameter Measurements*

measurement tolerance-- +/- 0.025 cm

Post Drop	☐	Can ID	HT503	Micrometer ID	441-47-01-01
		Can wall	10 gage		
Pre Drop	X			Cal Date	3/31/2005
				Exp. Date	3/31/2006

measurements by: WC Buchmiller/ WA Wilcox

	Axial Lines			
Circumferential Lines	**0º/180º**	**45º/225º**	**90º/270º**	**135º/315º**
canister bottom	-	-	-	-
+5cm Circumferential line	60.80	60.83	60.78	60.80
+10cm Circumferential line	60.90	60.95	60.88	60.88
+15cm Circumferential line	60.93	61.08	60.88	60.88
+20cm Circumferential line	61.03	61.23	60.95	60.95
+25cm Circumferential line	61.05	61.28	60.98	60.93
+30cm Circumferential line	61.08	61.28	60.95	60.90
+35cm Circumferential line	61.03	61.23	60.93	60.85
+40cm Circumferential line	61.08	61.25	60.95	60.83
+45cm Circumferential line	61.10	61.28	61.00	60.85
+50cm Circumferential line	61.10	61.28	61.03	60.85
+55cm Circumferential line	61.13	61.28	61.03	60.83
+60cm Circumferential line	61.13	61.25	61.05	60.78
+65cm Circumferential line	61.13	61.25	61.03	60.75
+70cm Circumferential line	61.10	61.20	61.05	60.70
+75cm Circumferential line	61.13	61.18	61.03	60.65
+90cm Circumferential line	61.23	61.20	61.05	60.60
+105cm Circumferential line	61.18	61.25	60.98	60.55
+120cm Circumferential line	61.20	61.30	60.95	60.58

Data Sheet 424-2 *Canister Diameter Measurements*				
measurement tolerance-- +/- 0.025 cm				
+135cm Circumferential line	61.18	61.30	60.93	60.58
+150cm Circumferential line	61.23	61.40	60.95	60.63
+165cm Circumferential line	61.18	61.48	60.95	60.63
+180cm Circumferential line	61.15	61.48	60.93	60.60
+195cm Circumferential line	61.23	61.45	60.90	60.63
+210cm Circumferential line	61.15	61.40	60.88	60.68
+225cm Circumferential line	60.95	61.15	60.73	60.60
+255cm Circumferential line	61.23	61.33	60.85	60.75
+285cm Circumferential line	61.25	61.33	60.83	60.75
+315cm Circumferential line	61.23	61.38	60.78	60.85
+345cm Circumferential line	61.18	61.30	60.78	60.85
+375cm Circumferential line	61.13	61.13	60.88	60.93
+405cm Circumferential line	61.10	61.00	60.98	60.93
+435cm Circumferential line	60.90	60.88	60.88	60.85
canister top				

Table H.2. Post-Drop Diameters for HT503 (10-gage wall)

Data Sheet 424-2 *Canister Diameter Measurements*

measurement tolerance--+/- 0.025 cm

Post Drop	X	Can ID	HT503	Micrometer ID	441-47-01-01
		Can wall	10 gage		
Pre Drop				Cal Date	3/31/2005
				Exp. Date	3/31/2006

measurements by: WC Buchmiller/ MD Johnson

Circumferential Lines	**Axial Lines** 0º/180º	45º/225º	90º/270º	135º/315º
canister bottom	-	-	-	-
+5cm Circumferential line	61.00	61.00	60.83	61.13
+10cm Circumferential line	61.23	61.20	61.23	61.30
+15cm Circumferential line	61.48	61.50	61.40	61.58
+20cm Circumferential line	61.75	61.88	61.55	61.83
+25cm Circumferential line	61.93	62.03	61.70	62.00
+30cm Circumferential line	62.10	62.13	61.78	62.08
+35cm Circumferential line	62.10	62.20	61.78	62.23
+40cm Circumferential line	62.05	62.23	62.08	61.78
+45cm Circumferential line	62.00	62.23	61.90	61.75
+50cm Circumferential line	61.85	62.10	61.83	61.58
+55cm Circumferential line	61.95	62.03	61.85	61.58
+60cm Circumferential line	62.00	61.95	61.78	61.63
+65cm Circumferential line	61.88	61.98	61.80	61.68
+70cm Circumferential line	61.83	62.03	61.83	61.65
+75cm Circumferential line	61.85	62.13	61.85	61.58
+90cm Circumferential line	61.90	61.85	61.85	61.45
+105cm Circumferential line	62.00	61.90	61.58	61.13
+120cm Circumferential line	61.80	61.95	61.58	61.15
+135cm Circumferential line	61.60	61.83	61.50	60.98
+150cm Circumferential line	61.73	61.95	61.55	61.25
+165cm Circumferential line	61.60	61.80	61.38	62.00
+180cm Circumferential line	61.40	61.80	61.23	60.88

Data Sheet 424-2 *Canister Diameter Measurements*				
measurement tolerance--+/- 0.025 cm				
+195cm Circumferential line	61.55	61.68	61.23	60.90
+210cm Circumferential line	61.33	61.55	61.20	60.83
+225cm Circumferential line	61.20	61.33	61.03	60.98
+255cm Circumferential line	61.30	61.38	60.95	60.83
+285cm Circumferential line	61.33	61.43	60.88	60.93
+315cm Circumferential line	61.28	61.45	60.80	60.88
+345cm Circumferential line	61.20	61.30	60.75	60.83
+375cm Circumferential line	61.13	61.13	60.85	60.88
+405cm Circumferential line	61.10	61.00	60.98	60.90
+435cm Circumferential line	60.90	60.88	60.88	60.85
canister top				

Table H.3. Pre-drop Canister Diameters for HT503 (10-gage wall)

Data Sheet 424-3 *Canister Diameter Measurements*

At Surface Anomalies

Post Drop [ ]	Can ID HT503
	Micrometer ID 441-47-01-01
	Can wall 10 gage
Pre Drop [X]	Cal Date 3/31/2005
	Exp. Date 3/31/2006

measurements by: WC Buchmiller/ WA Wilcox

Circumferential Position	Axial Position Description	Diam. cm	Anomaly Description
12.8 cm right of 90° deg axial	9.0 cm below 225 cm line	61.85	Bulge below circumferential weld at mid-height
10.6 cm right of 90° deg axial	4.3 cm below 225 cm line	61.73	Diameter appears less near weld likely due to girdling effect by weld. Measurement does not include weld.

Table H.4. Post-Drop Canister Diameters Across Bulges HT503 (10-gage wall)

Data Sheet 424-3 *Canister Diameter Measurements*

At Surface Anomalies

Post Drop [x]

Can ID HT503

Micrometer ID 441-47-01-01

Can wall 10 gage

Cal Date 3/31/2005

Pre Drop [ ]

Exp. Date 3/31/2006

measurements by: WC Buchmiller/ MD Johnson

Anomaly	**Axial Position (cm)**	**Arc Length (cm)**	**from (degree)**	**towards (degree)**	**Conv. cm to degrees**	**Calculated Circumferential Position (degrees)**	**Diameter across anomaly cm**
1-1	36.5	8.5	90	135	16	106	61.83
1-2	35.8	13.6	90	135	26	116	61.83
2-1	47.1	8.5	45	90	16	61	62.08
3-1	69.4	8.0	45	90	15	60	62.05
3-2	68.5	8.7	90	45	16	74	62.13
4-1	80.0	6.5	90	135	12	102	62.03
4-2	84.3	8.2	135	90	15	120	61.75
5-1	97.0	9.4	45	90	18	63	61.95
6-1	112.1	4.2	45	180	8	53	62.08
6-2	112.0	8.1	45	180	15	60	62.08
7-1	145.3	7.6	45	180	14	59	62.08
8-1	32.0	13.0	0	315	24	336	62.25
8-2	32.0	15.6	0	315	29	331	62.28
9-1	36.0	8.2	45	0	15	30	62.58
9-2	37.0	16.0	45	0	30	15	62.58
10-1	73.4	9.4	0	315	18	342	61.55
11-1	113.0	17.7	0	315	33	327	61.45
12-1	143.8	16.5	0	315	31	329	61.40
12-2	165.5	12.5	0	315	23	337	61.68
13-0	230.0	0.0	0	0	0	0	61.70
13-45	229.7	0.0	0	45	45	45	61.98
13-90	228.8	0.0	0	90	90	90	61.45

Data Sheet 424-3 *Canister Diameter Measurements*							
At Surface Anomalies							
14-1	27.3	3.4	315	270	6	309	62.13
15-1	38.8	6.7	270	315	13	283	61.93
16-1	153.0	8.7	270	225	16	254	61.73
17-1	168.4	1.4	270	315	3	273	61.38
18-1	35.6	5.4	180	225	10	190	62.55
19-1	78.1	4.3	225	180	8	217	62.13
20-1	94.9	4.4	225	270	8	233	62.08
21-1	101.2	0.0	0	180	180	180	62.48
21-2	101.0	12.3	180	135	23	157	62.25
22-1	185.7	4.3	225	270	8	233	61.83
22-2	183.1	8.7	225	180	16	209	62.00
23-1	190.7	7.1	180	135	13	167	61.43
24-1	227.5	5.6	180	225	11	191	61.75
24-2	226.7	4.4	180	135	8	172	61.45

Table H.5. Pre-Drop Canister Length Measurements HT503 (10-gage wall)

Data Sheet 424-4 *Canister Length Measurements*

measurement tolerance--cm (xxx.x)

Post Drop [ ]	Can ID	HT503	Tape Measure ID	PNL-99-65-002
	Can wall	10-gage		
Pre Drop [X]			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

Circumferential Lines	**0º**	**45º** (Axial Lines)	**90º**	**135º**
+0cm Circumferential line	449.4	449.4	449.4	449.3
+5cm Circumferential line	444.4	444.6	444.5	444.4
+10cm Circumferential line	439.4	439.6	439.5	439.3
+15cm Circumferential line	434.4	434.6	434.6	434.4
+20cm Circumferential line	429.5	429.6	429.5	429.3
+25cm Circumferential line	424.4	424.5	424.5	424.4
+30cm Circumferential line	419.5	419.6	419.5	419.3
+35cm Circumferential line	414.5	414.5	414.5	414.3
+40cm Circumferential line	409.3	409.4	409.4	409.3
+45cm Circumferential line	404.4	404.5	404.4	404.4
+50cm Circumferential line	399.4	399.5	399.5	399.4
+55cm Circumferential line	394.4	394.5	394.5	394.4
+60cm Circumferential line	389.3	389.4	389.5	389.4
+65cm Circumferential line	384.4	384.4	384.4	384.3
+70cm Circumferential line	379.4	379.5	379.5	379.4
+75cm Circumferential line	374.4	374.4	374.4	374.4
+90cm Circumferential line	359.3	359.3	359.5	359.3
+105cm Circumferential line	344.4	344.4	344.4	344.3
+120cm Circumferential line	329.3	329.4	329.5	329.4
+135cm Circumferential line	314.4	314.4	314.5	314.4
+150cm Circumferential line	299.4	299.5	299.5	299.4

Data Sheet 424-4 *Canister Length Measurements*				
measurement tolerance--cm (xxx.x)				
+165cm Circumferential line	284.4	284.4	284.5	284.5
+180cm Circumferential line	269.4	269.5	269.4	269.3
+195cm Circumferential line	254.4	254.4	254.5	254.5
+210cm Circumferential line	239.4	239.3	239.4	239.5
+225cm Circumferential line	224.4	224.4	224.4	224.4
+255cm Circumferential line	194.4	194.4	194.5	194.5
+285cm Circumferential line	164.4	164.4	164.4	164.4
+315cm Circumferential line	134.4	134.4	134.5	134.5
+345cm Circumferential line	104.4	104.4	104.4	104.4
+375cm Circumferential line	74.4	74.4	74.4	74.4
+405cm Circumferential line	44.3	44.4	44.4	44.4
+435cm Circumferential line	14.3	14.3	14.6	14.4

Table H.6. Pre-Drop Canister Length Measurements HT503 (10-gage wall)

Data Sheet 357-4 *Canister Length Measurements*

measurement tolerance--cm (xxx.x)

Post Drop ☐	Can ID	HT503	Tape Measure	PNL-99-65-002
				ID
	Can wall	10-gage		
Pre Drop ☒ X			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

		Axial Lines		
Circumferential Lines	**180º**	**225º**	**270º**	**315º**
+0" Circumferential line	449.4	449.3	449.3	449.4
+5cm Circumferential line	444.3	444.4	444.4	444.5
+10cm Circumferential line	439.3	439.4	439.5	439.4
+15cm Circumferential line	434.3	434.5	434.5	434.4
+20cm Circumferential line	429.3	429.4	429.5	429.4
+25cm Circumferential line	424.5	424.5	424.5	424.4
+30cm Circumferential line	419.3	419.4	419.5	419.4
+35cm Circumferential line	414.3	414.4	414.5	414.4
+40cm Circumferential line	409.3	409.4	409.5	409.4
+45cm Circumferential line	404.4	404.4	404.5	404.4
+50cm Circumferential line	399.5	399.5	399.5	399.5
+55cm Circumferential line	394.4	394.5	394.5	394.4
+60cm Circumferential line	389.3	389.4	389.5	389.4
+65cm Circumferential line	384.3	384.4	384.5	384.4
+70cm Circumferential line	379.3	379.4	379.5	379.4
+75cm Circumferential line	374.4	374.4	374.5	374.5
+90cm Circumferential line	359.5	359.5	359.5	359.3
+105cm Circumferential line	344.3	344.4	344.4	344.4
+120cm Circumferential line	329.5	329.5	329.4	329.4
+135cm Circumferential line	314.4	314.4	314.4	314.4
+150cm Circumferential line	299.4	299.5	299.4	299.5

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance--cm (xxx.x)				
+165cm Circumferential line	284.4	284.5	284.5	284.4
+180cm Circumferential line	269.3	269.4	269.4	269.4
+195cm Circumferential line	254.5	254.5	254.5	254.5
+210cm Circumferential line	239.4	239.4	239.4	239.5
+225cm Circumferential line	224.3	224.4	224.4	224.4
+255cm Circumferential line	194.4	194.5	194.5	194.5
+285cm Circumferential line	164.4	164.5	164.5	164.4
+315cm Circumferential line	134.4	134.5	134.5	134.4
+345cm Circumferential line	104.2	104.3	104.4	104.3
+375cm Circumferential line	74.3	74.4	74.4	74.5
+405cm Circumferential line	44.3	44.3	44.4	44.4
+435cm Circumferential line	14.4	14.4	14.4	14.4

Table H.7. Post-drop Canister Length Measurements HT503 (10-gage wall)

Data Sheet 424-4 *Canister Length Measurements*

measurement tolerance--cm (xxx.x)

Post Drop [X]	Can ID	HT503	Tape Measure	PNL-99-65-002
				ID
	Can wall	10-gage		
Pre Drop [ ]			Cal Date	3/30/2005
			Exp. Date	3/30/2006
measurements by: WC Buchmiller/ MD Johnson				
		Axial Lines		
Circumferential Lines	**0º**	**45º**	**90º**	**135º**
+0cm Circumferential line	447.0	447.3	447.3	447.2
+5cm Circumferential line	442.2	442.5	442.6	442.4
+10cm Circumferential line	437.4	437.5	437.5	437.4
+15cm Circumferential line	432.4	432.6	432.6	432.4
+20cm Circumferential line	427.4	427.6	427.6	427.4
+25cm Circumferential line	422.2	422.5	422.5	422.5
+30cm Circumferential line	417.6	417.6	417.6	417.5
+35cm Circumferential line	412.7	412.7	412.7	412.5
+40cm Circumferential line	407.6	407.6	407.7	407.6
+45cm Circumferential line	402.7	402.7	402.7	402.6
+50cm Circumferential line	397.7	397.8	397.8	397.7
+55cm Circumferential line	392.8	392.8	392.8	392.7
+60cm Circumferential line	387.8	387.8	387.8	387.7
+65cm Circumferential line	382.9	382.9	382.9	382.7
+70cm Circumferential line	377.8	378.0	377.9	377.9
+75cm Circumferential line	372.9	373.0	373.0	372.9
+90cm Circumferential line	358.0	358.1	358.3	358.4
+105cm Circumferential line	343.0	343.2	343.5	343.5
+120cm Circumferential line	328.2	328.5	328.6	328.8
+135cm Circumferential line	313.4	313.7	313.8	313.9
+150cm Circumferential line	298.7	298.9	298.9	298.9

Data Sheet 424-4 *Canister Length Measurements*				
measurement tolerance--cm (xxx.x)				
+165cm Circumferential line	283.8	283.9	283.9	283.9
+180cm Circumferential line	268.5	269.5	268.9	268.8
+195cm Circumferential line	254.0	254.0	254.0	254.1
+210cm Circumferential line	239.0	238.9	239.0	239.1
+225cm Circumferential line	224.1	224.1	224.1	224.2
+255cm Circumferential line	194.3	194.4	194.3	194.4
+285cm Circumferential line	164.3	164.4	164.3	164.3
+315cm Circumferential line	134.4	134.4	134.4	134.5
+345cm Circumferential line	104.3	104.4	104.5	104.4
+375cm Circumferential line	74.4	74.4	74.4	74.4
+405cm Circumferential line	44.3	44.4	44.3	44.4
+435cm Circumferential line	14.3	14.4	14.6	14.5

Table H.8. Post-drop Canister Length Measurements HT503 (10-gage wall)

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance--cm (xxx.x)				
Post Drop [X]	Can ID	HT503	Tape Measure ID	PNL-99-65-002
	Can wall	10-gage		
Pre Drop [ ]			Cal Date	3/30/2005
			Exp. Date	3/30/2006
measurements by: WC Buchmiller/ MD Johnson				
		Axial Lines		
Circumferential Lines	**180º**	**225º**	**270º**	**315º**
+0" Circumferential line	447.2	447.1	446.5	446.7
+5cm Circumferential line	442.2	442.3	442.1	442.0
+10cm Circumferential line	437.2	437.3	437.1	437.0
+15cm Circumferential line	432.4	432.4	432.2	432.1
+20cm Circumferential line	427.3	427.4	427.1	427.2
+25cm Circumferential line	422.5	422.6	422.7	422.4
+30cm Circumferential line	417.2	417.5	417.4	417.5
+35cm Circumferential line	412.4	412.5	412.5	412.6
+40cm Circumferential line	407.6	407.6	407.5	407.7
+45cm Circumferential line	402.6	402.8	402.7	402.8
+50cm Circumferential line	397.8	397.8	397.8	397.8
+55cm Circumferential line	392.7	392.8	392.9	392.8
+60cm Circumferential line	387.7	387.8	387.9	387.8
+65cm Circumferential line	382.7	382.8	382.9	382.9
+70cm Circumferential line	377.8	377.9	378.0	377.9
+75cm Circumferential line	372.9	373.0	373.1	373.0
+90cm Circumferential line	358.1	358.2	358.2	358.0
+105cm Circumferential line	343.4	343.4	343.3	343.1
+120cm Circumferential line	328.7	328.6	328.3	328.2
+135cm Circumferential line	313.7	313.7	313.4	313.4

Data Sheet 357-4 *Canister Length Measurements*				
measurement tolerance--cm (xxx.x)				
+150cm Circumferential line	298.8	298.8	298.7	298.7
+165cm Circumferential line	283.8	283.9	283.8	283.9
+180cm Circumferential line	268.8	268.9	269.0	269.0
+195cm Circumferential line	254.1	254.2	254.1	254.1
+210cm Circumferential line	239.1	239.2	239.2	239.2
+225cm Circumferential line	224.1	224.1	224.1	224.4
+255cm Circumferential line	194.3	194.4	194.4	194.3
+285cm Circumferential line	164.3	164.4	164.4	164.4
+315cm Circumferential line	134.3	134.5	134.5	134.4
+345cm Circumferential line	104.2	104.3	104.4	104.4
+375cm Circumferential line	74.3	74.4	74.4	74.5
+405cm Circumferential line	44.3	44.3	44.3	44.4
+435cm Circumferential line	14.3	14.4	14.4	14.4

Table H.9. Pre-Drop Canister Dish Measurements HT503 (10-gage wall)

Data Sheet 424-5 *Canister Dish Measurements*

measurement tolerance--cm (x.x)

Post Drop ☐	Can ID	HT503	Ruler	PNL-66-02-001 ID
	Can wall	10-gage		
Pre Drop ☒			Cal Date	3/30/2005
			Exp. Date	3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

	Radial Line			
Radial Position[a]	0º/180º	45º/225º	90º/270º	135º/315º
7.6cm (7.6cm in from outer edge[b])	0.2	0.3	0.3	0.2
15.2cm	2.4	2.5	2.5	2.5
22.9cm	3.8	3.8	3.9	3.9
30.5cm (center)	4.2	4.2	4.2	4.2
38.1cm	3.9	3.7	3.7	3.7
45.7cm	2.5	2.4	2.4	2.4
53.3cm(~7.6cm in from outer edge[b])	0.2	0.2	0.2	0.2

[a] All radial positions and radial lines were located and marked prior to the canister drop
[b]For example, on the 0º/180º radial line, the 7.6cm Radial Position would be 7.6cm in along the Radial Line between the 0º axial line and the 180º axial line as drawn on the canister and along the canister bottom. The 7.6cm Radial Position, on the 0º/1

Table H.10. Post-Drop Canister Dish Measurements HT503 (10-gage wall)

Data Sheet 424-5 *Canister Dish Measurements*				
measurement tolerance--cm (x.x)				
Post Drop [X]	Can ID	HT503	Ruler ID	PNL-66-02-001
	Can wall	10-gage		
Pre Drop [ ]			Cal Date	3/30/2005
			Exp. Date	3/30/2006
measurements by: WC Buchmiller/ MD Johnson				
	Radial Line			
Radial Position[a]	0º/180º	45º/225º	90º/270º	135º/315º
7.6cm (7.6cm in from outer edge[b])	0.1	0.2	0.2	0.2
15.2cm	2.3	2.4	2.4	2.4
22.9cm	3.6	3.7	3.7	3.6
30.5cm (center)	4.0	4.1	4.0	3.9
38.1cm	3.7	3.6	3.4	3.4
45.7cm	2.4	2.3	2.2	2.1
53.3cm(~7.6cm in from outer edge[b])	0.2	0.2	0.1	0.1

[a] All radial positions and radial lines were located and marked prior to the canister drop

[b]For example, on the 0º/180º radial line, the 7.6cm Radial Position would be 7.6cm in along the Radial Line between the 0º axial line and the 180º axial line as drawn on the canister and along the canister bottom. The 7.6cm Radial Position, on the 0º/1

Table H.11. Pre-Drop Canister Distortion Measurements HT503 (10-gage wall)

Data Sheet 424-6 *Canister Distortion Measurements*

(Taut line – Outer edge to Axial Line on Canister Wall) tolerance--cm (x.x)

Post Drop	☐	Can ID **HT503**	Rule ID PNL-66-02-001 ID
		Can Wall **10-gage**	
Pre Drop	X		Cal Date 3/30/2005
			Exp. Date 3/30/2006

measurements by: WC Buchmiller/ WA Wilcox

Circumferential Lines	**Axial Lines** 0º/	180º	45º/	225º	90º/	270º	135º/	315º
+15cm Circumferential line	3.2	3.1	2.9	3.3	2.8	3.5	3.0	3.4
+45cm Circumferential line	3.2	3.0	2.8	3.2	2.8	3.5	3.0	3.4
+75cm Circumferential line	3.1	3.0	2.9	3.2	2.7	3.5	3.2	3.4
+105cm Circumferential line	3.2	2.9	2.7	3.1	2.7	3.5	3.2	3.4
+135cm Circumferential line	3.2	2.9	2.8	3.2	2.7	3.5	3.2	3.5
+165cm Circumferential line	3.2	2.9	2.7	3.1	2.8	3.5	3.2	3.4
+195cm Circumferential line	3.1	2.9	2.7	3.1	2.8	3.6	3.2	3.4
+225cm Circumferential line	3.2	3.0	2.9	3.2	2.9	3.6	3.2	3.5
+255cm Circumferential line	3.2	2.9	2.9	3.1	2.9	3.5	3.2	3.4
+285cm Circumferential line	3.1	2.9	2.9	3.1	3.0	3.5	3.2	3.3
+315cm Circumferential line	3.1	3.0	2.9	3.0	3.0	3.5	3.2	3.2
+345cm Circumferential line	3.1	3.0	3.0	3.0	3.0	3.6	3.2	3.2
+375cm Circumferential line	3.1	3.1	3.1	3.0	3.0	3.5	3.2	3.2
+405cm Circumferential line	3.1	3.1	3.2	3.1	3.0	3.4	3.2	3.2
+435cm Circumferential line	3.2	3.2	3.3	3.2	3.1	3.4	3.2	3.1

Table H.12. Post-drop Canister Distortion Measurements HT503 (10-gage wall)

Data Sheet 424-6 *Canister Distortion Measurements*

(Taut line – Outer edge to Axial Line on Canister Wall) tolerance--cm (x.x)

Post Drop [X]

Pre Drop [ ]

Can ID **HT503**

Can Wall **10-gage**

Rule ID PNL-66-02-001 ID

Cal Date 3/30/2005

Exp. Date 3/30/2006

measurements by: WC Buchmiller/ MD Johnson

Axial Lines

Circumferential Lines	**0°/**	**180°**	**45°/**	**225°**	**90°/**	**270°**	**135°/**	**315°**
+15cm Circumferential line	3.0	2.7	2.5	3.1	2.6	3.0	2.7	3.0
+45cm Circumferential line	2.7	2.6	2.2	2.8	2.3	2.9	2.7	2.9
+75cm Circumferential line	2.8	2.6	2.3	2.8	2.1	3.1	2.7	3.0
+105cm Circumferential line	2.9	2.3	2.3	3.0	2.4	3.2	2.8	3.2
+135cm Circumferential line	3.0	2.5	2.4	2.8	2.4	3.2	2.9	3.4
+165cm Circumferential line	3.0	2.5	2.5	2.9	2.5	3.2	2.9	3.0
+195cm Circumferential line	3.1	2.4	2.7	2.8	2.4	3.3	2.9	3.4
+225cm Circumferential line	3.2	2.6	0.0	2.9	2.5	3.3	2.9	3.3
+255cm Circumferential line	3.2	2.7	2.8	2.9	2.7	3.3	3.1	3.3
+285cm Circumferential line	3.0	2.6	2.9	2.7	2.9	3.3	3.1	3.1
+315cm Circumferential line	3.0	2.7	2.9	2.7	3.0	3.2	3.1	3.1
+345cm Circumferential line	3.0	2.8	3.0	2.7	3.0	3.3	3.2	3.1
+375cm Circumferential line	3.0	2.9	3.0	2.7	3.0	3.2	3.2	3.0
+405cm Circumferential line	3.0	2.9	3.2	2.6	3.2	3.0	3.3	2.9
+435cm Circumferential line	3.1	3.0	3.4	2.6	3.2	3.0	3.4	3.0

Table H.13. Post-drop Canister Distortion Measurements HT503 (10-gage wall)

Data Sheet 424-6 *Canister Distortion Measurements*

At Surface Anomalies

Post Drop [x]

Can ID HT503

Micrometer ID 441-47-01-01

Can wall 10 gage

Cal Date 3/31/2005

Pre Drop [ ]

Exp. Date 3/31/2006

measurements by: WC Buchmiller/ MD Johnson

Anomaly	Axial Position (above bottom) (cm)	Arc Length (cm)	from (degree)	towards (degree)	Calculated Circum-ferential Position (degrees)	Distance from taut line to anomaly (cm)	Height of anomaly above "unstressed" canister wall
1-1	36.5	8.5	90	135	106	2.7	0.4
1-2	35.8	13.6	90	135	116	2.8	0.3
2-1	47.1	8.5	45	90	61	2.5	0.6
3-1	69.4	8.0	45	90	60	2.5	0.6
3-2	68.5	8.7	90	45	74	2.4	0.7
4-1	80.0	6.5	90	135	102	2.2	0.9
4-2	84.3	8.2	135	90	120	2.4	0.7
5-1	97.0	9.4	45	90	63	2.8	0.3
6-1	112.1	4.2	45	180	53	2.5	0.6
6-2	112.0	8.1	45	180	60	2.4	0.7
7-1	145.3	7.6	45	180	59	2.5	0.6
8-1	32.0	13.0	0	315	336	2.5	0.6
8-2	32.0	15.6	0	315	331	2.6	0.5
9-1	36.0	8.2	45	0	30	2.6	0.5
9-2	37.0	16.0	45	0	15	2.4	0.7
10-1	73.4	9.4	0	315	342	2.9	0.2
11-1	113.0	17.7	0	315	327	3.0	0.1
12-1	143.8	16.5	0	315	329	2.7	0.4
12-2	165.5	12.5	0	315	337	3.1	0.0
13-0	230.0	0.0	0	0	0	2.8	0.3

Data Sheet 424-6 *Canister Distortion Measurements*							
At Surface Anomalies							
13-45	229.7	0.0	0	45	45	2.7	0.4
13-90	228.8	0.0	0	90	90	2.4	0.7
14-1	27.3	3.4	315	270	309	2.7	0.4
15-1	38.8	6.7	270	315	283	2.8	0.3
16-1	153.0	8.7	270	225	254	2.1	1.0
17-1	168.4	1.4	270	315	273	NA	
18-1	35.6	5.4	180	225	190	2.3	0.8
19-1	78.1	4.3	225	180	217	2.8	0.3
20-1	94.9	4.4	225	270	233	3.0	0.1
21-1	101.2	0.0	0	180	180	1.7	1.4
21-2	101.0	12.3	180	135	157	1.9	1.2
22-1	185.7	4.3	225	270	233	2.9	0.2
22-2	183.1	8.7	225	180	209	2.7	0.4
23-1	190.7	7.1	180	135	167	2.6	0.5
24-1	227.5	5.6	180	225	191	2.5	0.6
24-2	226.7	4.4	180	135	172	2.6	0.5

Appendix I

Strain-Circle Application and Analysis Method Validation Tests

Appendix I: Strain-Circle Application and Analysis Method Validation Tests

This appendix reports the results of the strain-circle application and analysis method validation tests that were conducted to quantify the accuracy of the strain-circle method for determining strains for the WTP canister drop tests. Tensile specimens were fabricated from 10-gage 304 stainless steel sheet. Using the manufacturer's instructions and strain-circle stencil, strain circles were applied to the tensile specimens. Diameters of strain circles on five specimens were measured using both a calibrated calipers and the strain-circle template. Four tensile specimens were then stretched approximately 5%, 15%, 25%, and 35%, respectively. The specimens are shown in Figure I.1. After stretching, these specimens and one unstretched specimen again had strain-circle diameters measured using the calibrated calipers and the template. Figure I.2 shows the template and one of the tensile specimens. Figure I.3 shows how the template was used, and Figure I.4 shows how the strain circles were measured using the calipers. Strains from both the caliper measurements and the template measurements were calculated and compared. An estimated accuracy of the template measurement method was established.

Using data from both the calibrated calipers and the strain-circle template, strains were calculated for 24 strain circles on each of the five tensile specimens. Both axial and lateral strains were measured. A total of 240 strain calculations were made for each method. Figure I.5 shows a comparison of the results for the two methods. Strains ranged from approximately negative 15 percent to a positive 35 percent. The solid black line on the plot has a slope of one (caliper strain equals template strain). It can be seen that the data points are generally evenly distributed above and below the line. The dotted lines in the plot are plus and minus five percent lines and envelope all but one of the 240 points. The standard deviation of all points is less than 1.5 percent. Figure I.6 shows the same data with the dotted lines representing plus and minus two standard deviations or three percent. Seventy five percent (180 of 240) of the data points were within one standard deviation, 93 percent (224 of 240) are within two standard deviations, and all but one data point are within three standard deviations. Two standard deviations (3%) is the value we will use for our claimed accuracy.

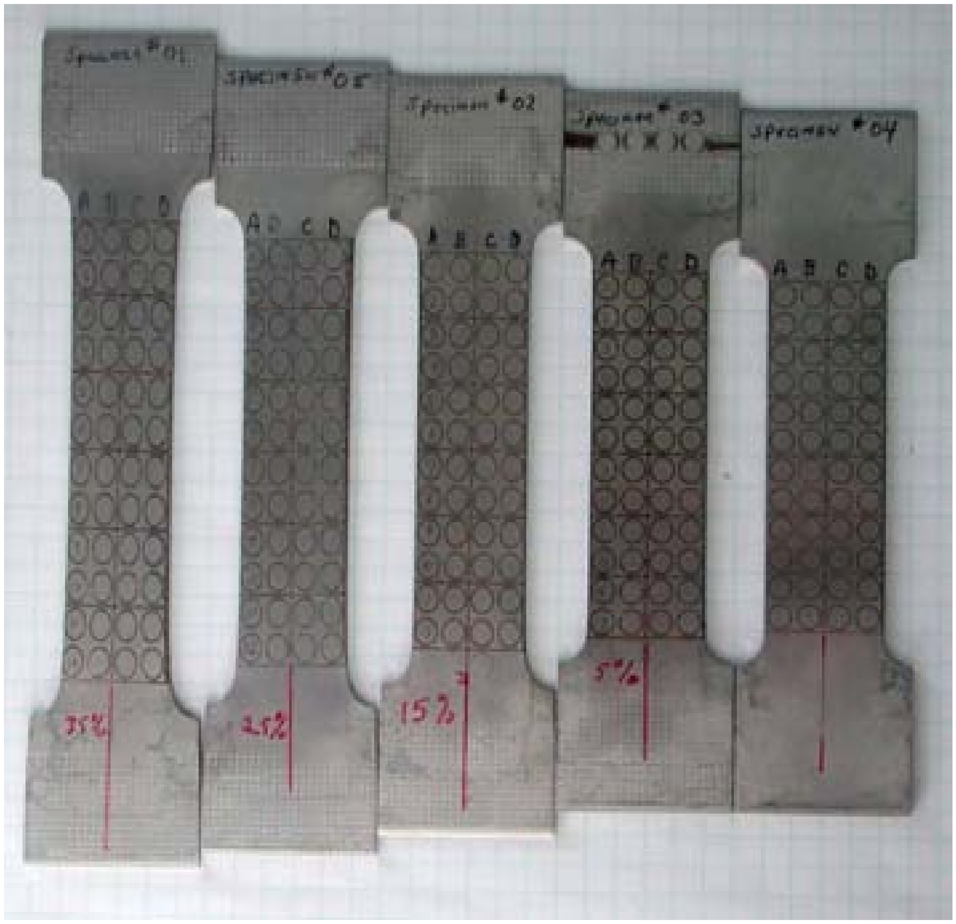


Figure I.1. Tensile Specimens

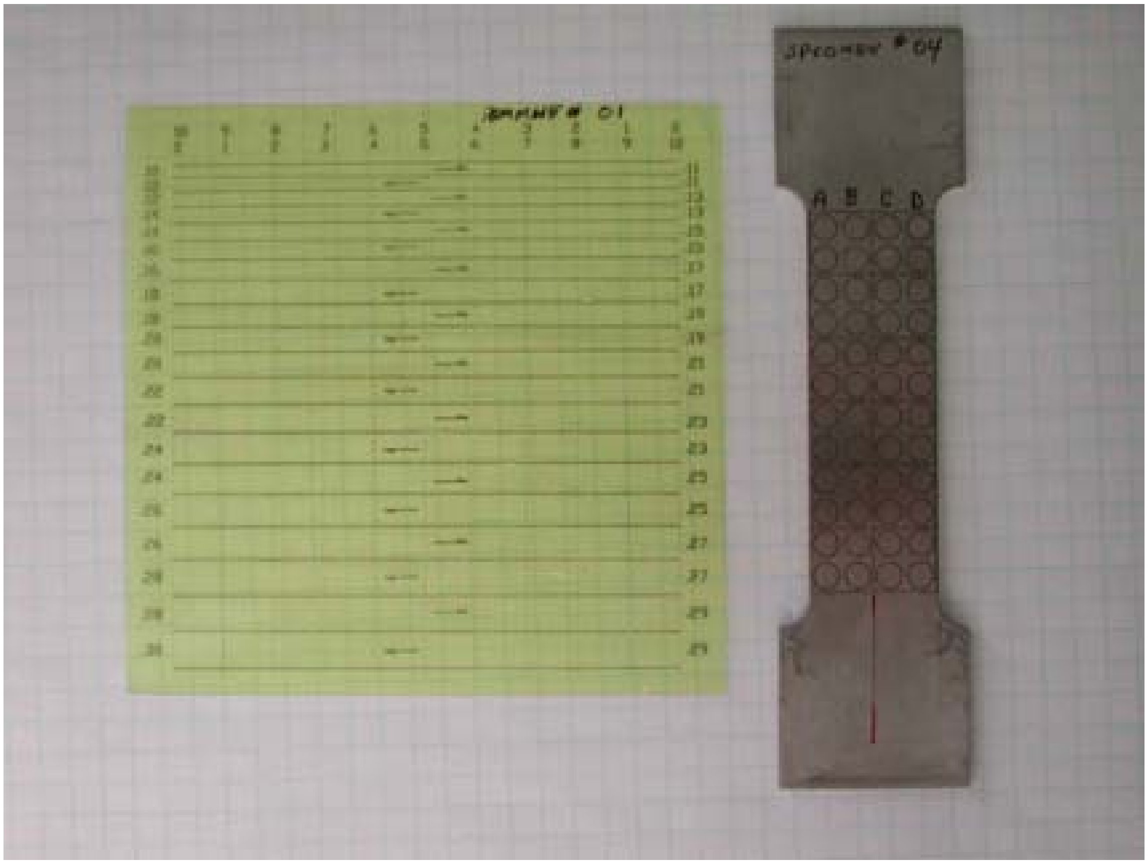


Figure I.2. Tensile Specimen with Template

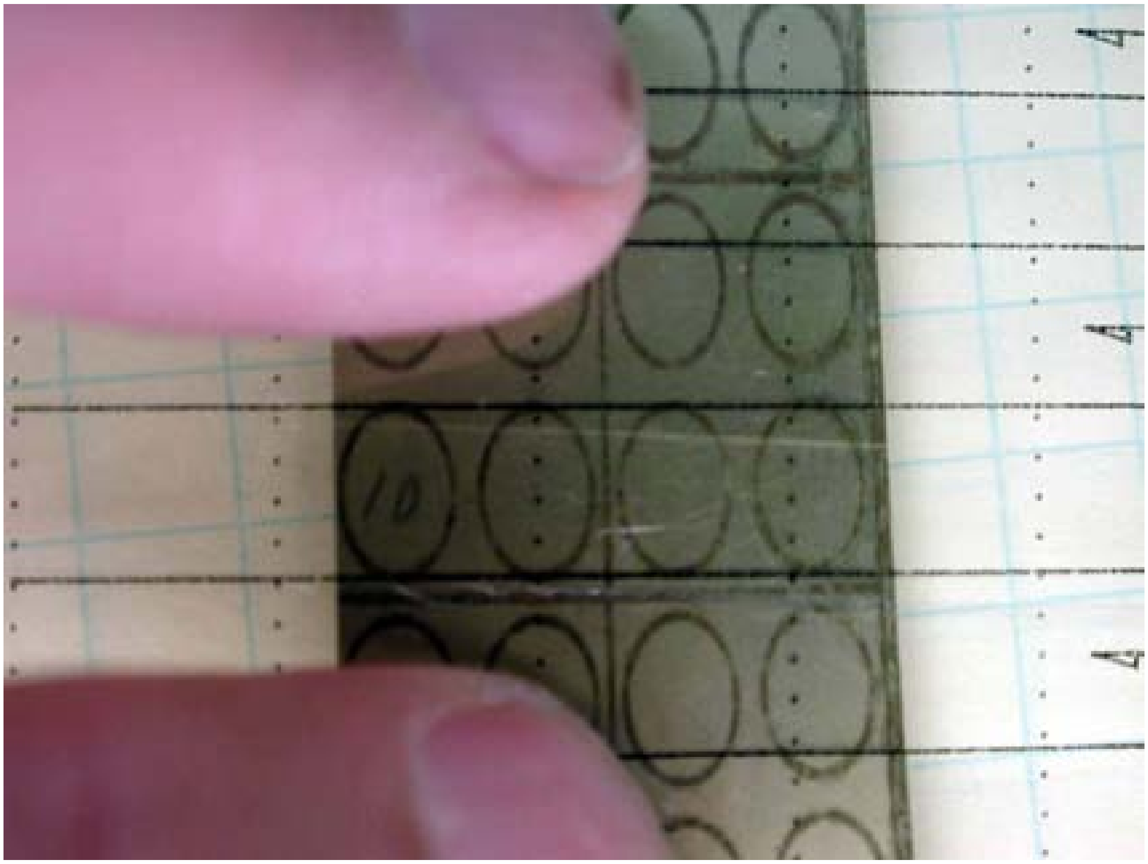


Figure I.3. Measuring Strain Circle with Template

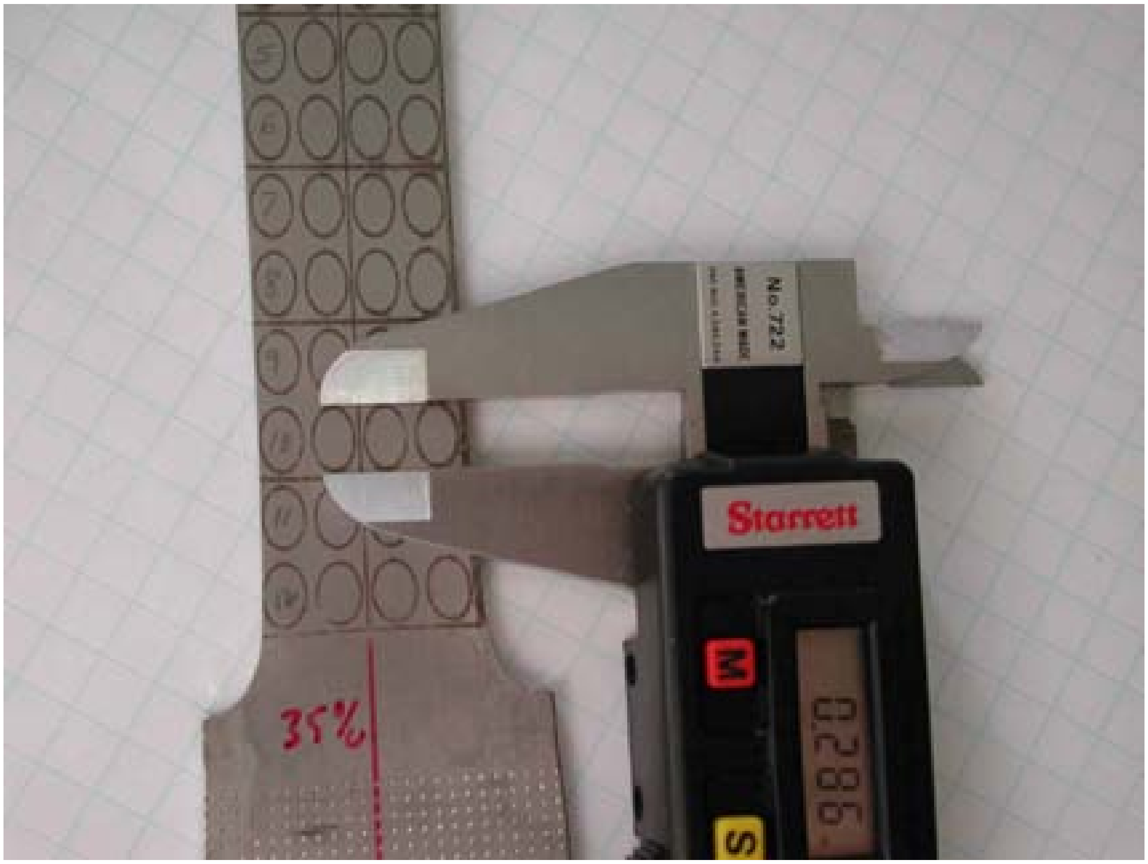


Figure I.4. Measuring Strain Circle with Caliper

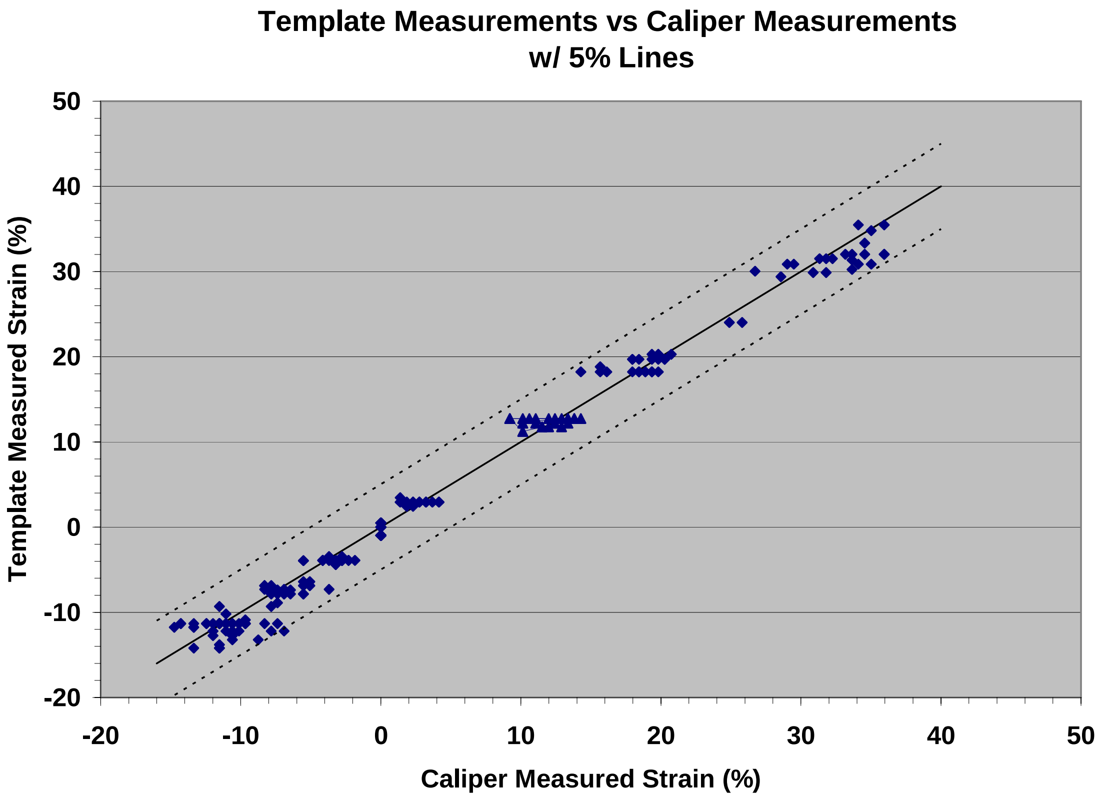


Figure I.5. Data with Five Percent Lines

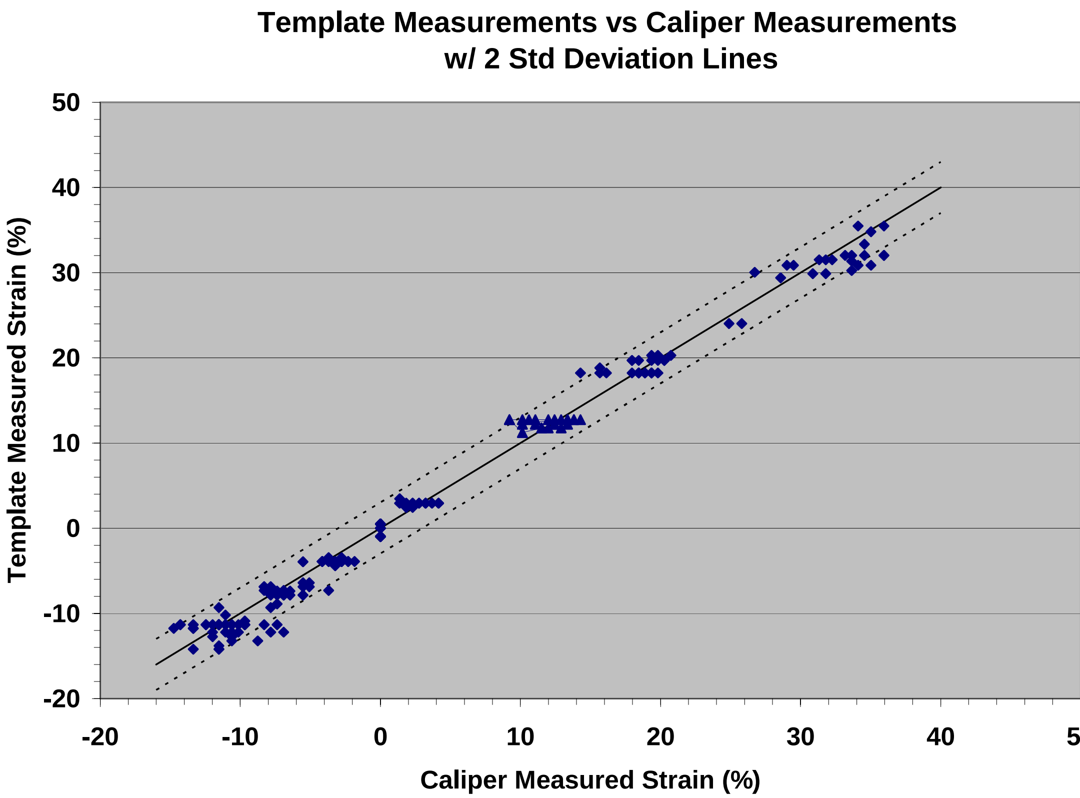


Figure I.6. Data with Two Standard Deviation Lines

Appendix J

Strain-Circle Measurements

Appendix J: Strain-Circle Measurements

Canister HT503		Max=	0.205	2.5						
		Min=	0.198	-1						
min	0.198	0.200	0.200	0.199						
max	0.202	0.205	0.201	0.200						
stdev	0.00046	0.00081	0.00010	0.00010						
avg	0.19993	0.20034	0.20001	0.19999						
	First Axial	First Lateral	Second Axial	Second Lateral			First Axial	First Lateral	Second Axial	Second Lateral
0-45 degrees					45-90 degrees					
D1	0.200	0.202	0.200	0.200	G1		0.200	0.200	0.200	0.200
D2	0.199	0.201	0.200	0.200	G2		0.200	0.200	0.200	0.200
D3	0.199	0.200	0.200	0.200	G3		0.200	0.200	0.200	0.200
D4	0.200	0.201	0.200	0.200	G4		0.200	0.200	0.200	0.200
D5	0.200	0.200	0.200	0.200	G5		0.200	0.200	0.200	0.200
D6	0.200	0.200	0.200	NR	G6		0.200	0.200	0.200	0.200
D7	0.199	0.201	0.200	0.200	G7		0.200	0.200	0.200	0.200
D8	0.200	0.201	0.200	0.200	G8		0.200	0.200	0.200	0.200
D9	0.200	0.202	0.200	0.200	G9		0.200	0.200	0.200	0.200
D10	0.200	0.202	0.200	0.200	G10		0.200	0.200	0.200	0.200
D11	0.200	0.204	0.200	0.200	G11		0.200	0.200	0.200	0.200
D12	0.200	0.205	0.200	0.200	G12		0.200	0.201	0.200	0.200
D13	0.200	0.204	0.200	0.200	G13		0.200	0.199	0.200	0.200
D14	0.200	0.203	0.200	0.200	G14		0.200	0.200	0.200	0.200
D15	0.200	0.203	0.200	0.200	G15		0.200	0.200	0.200	0.200
D16	0.200	0.203	0.200	0.200	G16		0.200	0.200	0.200	0.200
D17	0.199	0.204	0.200	0.200	G17		0.200	0.200	0.200	0.200
D18	0.199	0.203	0.200	0.200	G18		0.200	0.200	0.200	0.200
D19	0.199	0.203	0.200	0.200	G19		0.200	0.199	0.200	0.200
D20	0.198	0.202	0.200	0.200	G20		0.200	0.200	0.200	0.200
D21	0.198	0.202	0.200	0.200	G21		0.200	0.200	0.200	0.200
D22	0.199	0.202	0.200	0.200	G22		0.200	0.200	0.200	0.200
D23	0.199	0.200	0.200	0.200	G23		0.200	0.200	0.200	0.200
D24	0.200	0.200	0.200	NR	G24		0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
0-45 degrees					45-90 degrees				
E1	0.200	0.202	0.200	0.200	H1	0.200	0.200	0.200	0.200
E2	0.200	0.202	0.200	0.200	H2	0.200	0.200	0.200	0.200
E3	0.200	0.202	0.200	0.200	H3	0.200	0.200	0.200	0.200
E4	0.200	0.201	0.200	0.200	H4	0.200	0.200	0.200	0.200
E5	0.200	0.201	0.200	0.200	H5	0.200	0.200	0.200	0.200
E6	0.200	0.201	0.200	0.200	H6	0.200	0.200	0.200	0.200
E7	0.200	0.201	0.200	0.200	H7	0.200	0.200	0.200	0.200
E8	0.199	0.201	0.200	0.200	H8	0.200	0.200	0.200	0.200
E9	0.200	0.200	0.200	0.200	H9	0.200	0.200	0.200	0.200
E10	0.200	0.201	0.200	0.200	H10	0.200	0.200	0.200	0.200
E11	0.200	0.201	0.200	0.200	H11	0.200	0.200	0.200	0.200
E12	0.200	0.202	0.200	0.200	H12	0.200	0.200	0.200	0.200
E13	0.200	0.202	0.200	0.200	H13	0.200	0.200	0.200	0.200
E14	0.200	0.202	0.200	0.200	H14	0.200	0.200	0.200	0.200
E15	0.200	0.201	0.200	0.200	H15	0.200	0.200	0.200	0.200
E16	0.199	0.201	0.200	0.200	H16	0.200	0.200	0.200	0.200
E17	0.200	0.201	0.200	0.200	H17	0.200	0.200	0.200	0.200
E18	0.198	0.202	0.200	0.200	H18	0.200	0.200	0.200	0.200
E19	0.199	0.202	0.200	0.200	H19	0.200	0.200	0.200	0.200
E20	0.198	0.202	0.200	0.200	H20	0.200	0.200	0.200	0.200
E21	0.199	0.202	0.200	0.200	H21	0.200	0.200	0.200	0.200
E22	0.200	0.202	0.200	0.200	H22	0.200	0.200	0.200	0.200
E23	0.199	0.201	0.200	0.200	H23	0.200	0.200	0.200	0.200
E24	0.200	0.201	0.200	0.200	H24	0.200	0.200	0.200	0.200
F1	0.200	0.200	0.200	0.200	I1	NR	0.200	0.200	0.200
F2	0.200	0.200	0.200	0.200	I2	0.200	0.200	0.200	0.200
F3	0.199	0.200	0.200	0.200	I3	0.200	0.200	0.200	0.200
F4	0.200	0.200	0.200	0.200	I4	0.200	0.200	0.200	0.200
F5	0.199	0.200	0.200	0.200	I5	0.200	0.200	0.200	0.200
F6	0.200	0.200	0.200	0.200	I6	0.200	0.200	0.200	0.200
F7	0.200	0.200	0.200	0.200	I7	0.200	0.200	0.200	0.200
F8	0.200	0.200	0.200	0.200	I8	0.200	0.200	0.200	0.200
F9	0.200	0.201	0.200	0.200	I9	0.200	0.200	0.200	0.200
F10	0.200	0.200	0.200	0.200	I10	0.200	0.200	0.200	0.200
F11	0.199	0.201	0.200	0.200	I11	0.200	0.200	0.200	0.200
F12	0.199	0.201	0.200	0.200	I12	0.200	0.200	0.200	0.200
F13	0.200	0.200	0.200	0.200	I13	0.200	0.200	0.200	0.200
F14	0.200	0.200	0.200	0.200	I14	0.200	0.200	0.200	0.200
F15	0.200	0.200	0.200	0.200	I15	0.201	0.200	0.200	0.200
F16	0.200	0.200	0.200	0.200	I16	0.200	0.200	0.200	0.200
F17	0.200	0.200	0.200	0.200	I17	0.200	0.200	0.200	0.200
F18	0.200	0.200	0.200	0.200	I18	0.200	0.200	0.200	0.200
F19	0.200	0.200	0.200	0.200	I19	0.200	0.200	0.200	0.200
F20	0.200	0.200	0.200	0.200	I20	0.200	0.200	0.200	0.200
F21	0.200	0.200	0.200	0.200	I21	0.200	0.200	0.200	0.200
F22	0.200	0.200	0.200	0.200	I22	0.200	0.200	0.200	0.200
F23	0.199	0.200	0.200	0.200	I23	0.200	0.200	0.200	0.200
F24	0.200	0.200	0.200	0.200	I24	0.200	0.200	0.200	0.200

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
90-135 degrees					135-180 degrees				
J1	0.200	0.200	0.200	0.200	M1	0.200	0.200	0.200	0.200
J2	0.200	0.200	0.200	0.200	M2	0.200	0.200	0.200	0.200
J3	0.200	0.200	0.200	0.200	M3	0.200	0.200	0.200	0.200
J4	0.200	0.200	0.200	0.200	M4	0.200	0.200	0.200	0.200
J5	0.200	0.200	0.200	0.200	M5	0.200	0.200	0.200	0.200
J6	0.200	0.200	0.200	0.200	M6	0.200	0.200	0.200	0.200
J7	0.200	0.200	0.200	0.200	M7	0.200	0.200	0.200	0.200
J8	0.200	0.200	0.200	0.200	M8	0.200	0.200	0.200	0.200
J9	0.200	0.200	0.200	0.200	M9	0.200	0.200	0.200	0.200
J10	0.200	0.200	0.200	0.200	M10	0.200	0.200	0.200	0.200
J11	0.200	0.200	0.200	0.200	M11	0.200	0.200	0.200	0.200
J12	0.200	0.200	0.200	0.200	M12	0.200	0.200	0.200	0.200
J13	0.200	0.200	0.200	0.200	M13	0.200	0.200	0.200	0.200
J14	0.200	0.200	0.200	0.200	M14	0.200	0.200	0.200	0.200
J15	0.200	0.200	0.200	0.200	M15	0.200	0.200	0.200	0.200
J16	0.200	0.200	0.200	0.200	M16	0.200	0.200	0.200	0.200
J17	0.200	0.200	0.200	0.200	M17	0.200	0.200	0.200	0.200
J18	0.200	0.200	0.200	0.200	M18	0.200	0.200	0.200	0.200
J19	0.200	0.200	0.200	0.200	M19	0.200	0.200	0.200	0.200
J20	0.200	0.200	0.200	0.200	M20	0.200	0.200	0.200	0.200
J21	0.200	0.200	0.200	0.200	M21	0.200	0.200	0.200	0.200
J22	0.200	0.200	0.200	0.200	M22	0.200	0.200	0.200	0.200
J23	0.200	0.200	0.200	0.200	M23	0.200	0.200	0.200	0.200
J24	0.200	0.200	0.200	0.200	M24	0.200	0.200	0.200	0.200
K1	0.200	0.200	0.200	0.200	N1	0.200	0.200	0.200	0.200
K2	0.200	0.200	0.200	0.200	N2	0.200	0.200	0.200	0.200
K3	0.200	0.200	0.200	0.200	N3	0.200	0.200	0.200	0.200
K4	0.200	0.200	0.200	0.200	N4	0.200	0.200	0.200	0.200
K5	0.200	0.200	0.200	0.200	N5	0.200	0.200	0.200	0.200
K6	0.200	0.200	0.200	0.200	N6	0.200	0.200	0.200	0.200
K7	0.200	0.200	0.200	0.200	N7	0.200	0.200	0.200	0.200
K8	0.200	0.200	0.200	0.200	N8	0.200	0.200	0.200	0.200
K9	0.200	0.200	0.200	0.200	N9	0.200	0.200	0.200	0.200
K10	0.200	0.200	0.200	0.200	N10	0.200	0.200	0.200	0.200
K11	0.200	0.200	0.200	0.200	N11	0.200	0.200	0.200	0.200
K12	0.200	0.200	0.200	0.200	N12	0.200	0.200	0.200	0.200
K13	0.200	0.200	0.200	0.200	N13	0.200	0.200	0.200	0.200
K14	0.200	0.200	0.200	0.200	N14	0.200	0.200	0.200	0.200
K15	0.200	0.200	0.200	0.200	N15	0.200	0.200	0.200	0.200
K16	0.200	0.200	0.200	0.200	N16	0.200	0.200	0.200	0.200
K17	0.200	0.200	0.200	0.200	N17	0.200	0.200	0.200	0.200
K18	0.200	0.200	0.200	0.200	N18	0.200	0.200	0.200	0.200
K19	0.200	0.200	0.200	0.200	N19	0.200	0.200	0.200	0.200
K20	0.200	0.200	0.200	0.200	N20	0.200	0.200	0.200	0.200
K21	0.200	0.200	0.200	0.200	N21	0.200	0.200	0.200	0.200
K22	0.200	0.200	0.200	0.200	N22	0.200	0.200	0.200	0.200
K23	0.200	0.200	0.200	0.200	N23	0.200	0.200	0.200	0.200
K24	0.200	0.200	0.200	0.200	N24	0.200	0.200	0.200	0.200

	First Axial	**First Lateral**	**Second Axial**	**Second Lateral**		**First Axial**	**First Lateral**	**Second Axial**	**Second Lateral**
90-135 degrees					135-180 degrees				
L1	0.200	0.200	0.200	0.200	O1	0.200	0.200	0.200	0.200
L2	0.200	0.200	0.200	0.200	O2	0.200	0.200	0.200	0.200
L3	0.200	0.200	0.200	0.200	O3	0.200	0.200	0.200	0.200
L4	0.200	0.200	0.200	0.200	O4	0.200	0.200	0.200	0.200
L5	0.200	0.200	0.200	0.200	O5	0.200	0.200	0.200	0.200
L6	0.200	0.200	0.200	0.200	O6	0.200	0.200	0.200	0.200
L7	0.200	0.200	0.200	0.200	O7	0.200	0.200	0.200	0.200
L8	0.200	0.200	0.200	0.200	O8	0.200	0.200	0.200	0.200
L9	0.200	0.200	0.200	0.200	O9	0.200	0.200	0.200	0.200
L10	0.200	0.200	0.200	0.200	O10	0.200	0.200	0.200	0.200
L11	0.200	0.200	0.200	0.200	O11	0.200	0.200	0.200	0.200
L12	0.200	0.200	0.200	0.200	O12	0.200	0.200	0.200	0.200
L13	0.200	0.200	0.200	0.200	O13	0.200	0.200	0.200	0.200
L14	0.200	0.200	0.200	0.200	O14	0.200	0.200	0.200	0.200
L15	0.200	0.200	0.200	0.200	O15	0.200	0.200	0.200	0.200
L16	0.200	0.200	0.200	0.200	O16	0.200	0.200	0.200	0.200
L17	0.200	0.200	0.200	0.200	O17	0.200	0.200	0.200	0.200
L18	0.200	0.200	0.200	0.200	O18	0.200	0.200	0.200	0.200
L19	0.200	0.200	0.200	0.200	O19	0.200	0.200	0.200	0.200
L20	0.200	0.200	0.200	0.200	O20	0.200	0.200	0.200	0.200
L21	0.200	0.200	0.200	0.200	O21	0.200	0.200	0.200	0.200
L22	0.200	0.200	0.200	0.200	O22	0.200	0.200	0.200	0.200
L23	0.200	0.200	0.200	0.200	O23	0.200	0.200	0.200	0.200
L24	0.200	0.200	0.200	0.200	O24	0.200	0.200	0.200	0.200
	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
180-225 degrees					225-270 degrees				
P1	0.200	0.200	0.200	0.200	S1	0.200	0.200	0.200	0.200
P2	0.200	0.200	0.200	0.200	S2	0.200	0.200	0.200	0.200
P3	0.200	0.200	0.200	0.200	S3	0.200	0.200	0.200	0.200
P4	0.200	0.200	0.200	0.200	S4	0.200	0.200	0.200	0.200
P5	0.200	0.200	0.200	0.200	S5	0.200	0.200	0.200	0.200
P6	0.200	0.200	0.200	0.200	S6	0.200	0.200	0.200	0.200
P7	0.199	0.200	0.200	0.200	S7	0.200	0.200	0.200	0.200
P8	0.200	0.200	0.200	0.200	S8	0.200	0.200	0.200	0.200
P9	0.200	0.200	0.200	0.200	S9	0.200	0.200	0.200	0.200
P10	0.200	0.200	0.200	0.200	S10	0.200	0.200	0.200	0.201
P11	0.200	0.200	0.200	0.199	S11	0.200	0.200	0.200	0.200
P12	0.200	0.200	0.200	0.200	S12	0.199	0.201	0.200	0.200
P13	0.200	0.201	0.200	0.200	S13	0.200	0.201	0.200	0.200
P14	0.200	0.201	0.200	0.200	S14	0.200	0.200	0.200	0.200
P15	0.200	0.201	0.200	0.200	S15	0.200	0.200	0.200	0.200
P16	0.200	0.200	0.200	0.200	S16	0.200	0.200	0.200	0.200
P17	0.200	0.200	0.200	0.200	S17	0.200	0.200	0.200	0.200
P18	0.199	0.200	0.200	0.199	S18	0.200	0.200	0.200	0.200
P19	0.199	0.200	0.200	0.200	S19	0.199	0.200	0.200	0.200
P20	0.200	0.200	0.200	0.200	S20	0.200	0.200	0.200	0.200
P21	0.200	0.200	0.200	0.200	S21	0.200	0.200	0.200	0.200
P22	0.200	0.200	0.200	0.200	S22	0.200	0.200	0.200	0.200
P23	0.200	0.200	0.200	0.200	S23	0.200	0.200	0.200	0.200
P24	0.200	0.200	0.200	0.200	S24	0.200	0.200	0.200	0.200

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
180-225 degrees					225-270 degrees				
Q1	0.200	0.200	0.201	0.200	T1	0.200	0.200	0.200	0.200
Q2	0.200	0.200	0.200	0.200	T2	0.200	0.200	0.200	0.200
Q3	0.200	0.200	0.200	0.200	T3	0.200	0.200	0.200	0.200
Q4	0.200	0.200	0.200	0.200	T4	0.200	0.200	0.200	0.200
Q5	0.200	0.200	0.200	0.200	T5	0.200	0.200	0.200	0.200
Q6	0.200	0.200	0.200	0.200	T6	0.200	0.200	0.200	0.200
Q7	0.200	0.200	0.200	0.200	T7	0.200	0.200	0.200	0.200
Q8	0.200	0.200	0.200	0.200	T8	0.200	0.200	0.200	0.200
Q9	0.200	0.200	0.200	0.200	T9	0.201	0.200	0.200	0.200
Q10	0.200	0.200	0.200	0.200	T10	0.200	0.200	0.200	0.200
Q11	0.200	0.200	0.200	0.200	T11	0.201	0.200	0.200	0.200
Q12	0.200	0.201	0.200	0.200	T12	0.200	0.200	0.200	0.200
Q13	0.200	0.202	0.200	0.200	T13	0.200	0.200	0.200	0.200
Q14	0.200	0.201	0.200	0.200	T14	0.200	0.200	0.200	0.200
Q15	0.200	0.200	0.200	0.200	T15	0.201	0.200	0.200	0.200
Q16	0.200	0.200	0.200	0.200	T16	0.200	0.200	0.200	0.200
Q17	0.200	0.200	0.200	0.200	T17	0.201	0.200	0.200	0.200
Q18	0.200	0.200	0.200	0.200	T18	0.201	0.200	0.200	0.200
Q19	0.200	0.200	0.200	0.200	T19	0.201	0.200	0.200	0.200
Q20	0.200	0.200	0.200	0.200	T20	0.200	0.200	0.200	0.200
Q21	0.200	0.200	0.200	0.200	T21	0.201	0.200	0.200	0.200
Q22	0.200	0.200	0.200	0.200	T22	0.200	0.200	0.200	0.200
Q23	0.200	0.200	0.200	0.200	T23	0.200	0.200	0.200	0.200
Q24	0.200	0.200	0.200	0.200	T24	0.200	0.200	0.200	0.200
R1	0.200	0.200	0.200	0.200	U1	0.199	0.200	0.200	0.200
R2	0.200	0.200	0.200	0.200	U2	0.200	0.200	0.200	0.200
R3	0.200	0.200	0.200	0.200	U3	0.200	0.200	0.200	0.200
R4	0.200	0.200	0.200	0.200	U4	0.200	0.200	0.200	0.200
R5	0.200	0.200	0.200	0.200	U5	0.200	0.200	0.200	0.200
R6	0.200	0.200	0.200	0.200	U6	0.200	0.200	0.200	0.200
R7	0.200	0.200	0.200	0.200	U7	0.200	0.200	0.200	0.200
R8	0.200	0.200	0.200	0.200	U8	0.200	0.200	0.201	0.200
R9	0.200	0.200	0.200	0.200	U9	0.200	0.200	0.200	0.200
R10	0.200	0.200	0.200	0.200	U10	0.200	0.200	0.200	0.200
R11	0.200	0.200	0.200	0.200	U11	0.200	0.200	0.200	0.200
R12	0.200	0.200	0.200	0.200	U12	0.200	0.200	0.200	0.200
R13	0.200	0.200	0.200	0.200	U13	0.200	0.200	0.200	0.200
R14	0.199	0.200	0.200	0.200	U14	0.200	0.200	0.200	0.200
R15	0.200	0.200	0.200	0.200	U15	0.200	0.200	0.200	0.200
R16	0.199	0.200	0.200	0.200	U16	0.200	0.200	0.200	0.200
R17	0.200	0.200	0.200	0.200	U17	0.200	0.200	0.200	0.200
R18	0.200	0.200	0.201	0.200	U18	0.200	0.200	0.200	0.200
R19	0.199	0.200	0.200	0.200	U19	0.200	0.200	0.200	0.200
R20	0.200	0.200	0.200	0.200	U20	0.200	0.200	0.200	0.200
R21	0.200	0.200	0.200	0.200	U21	0.200	0.200	0.200	0.200
R22	0.200	0.200	0.200	0.200	U22	0.200	0.200	0.200	0.200
R23	0.200	0.200	0.200	0.200	U23	0.200	0.200	0.200	0.200
R24	0.200	0.200	0.200	0.200	U24	0.200	0.200	0.200	0.200

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
270-315 degrees					315-0 degrees				
V1	0.199	0.200	0.200	0.200	Y1	0.200	0.200	0.200	0.200
V2	0.200	0.200	0.200	0.200	Y2	0.200	0.200	0.200	0.200
V3	0.200	0.200	0.200	0.200	Y3	0.200	0.200	0.200	0.200
V4	0.200	0.200	0.200	0.200	Y4	0.200	0.200	0.200	0.200
V5	0.200	0.200	0.200	0.200	Y5	0.200	0.200	0.200	0.200
V6	0.199	0.200	0.200	0.200	Y6	0.200	0.200	0.200	0.200
V7	0.200	0.200	0.200	0.200	Y7	0.201	0.200	0.200	0.200
V8	0.200	0.200	0.200	0.200	Y8	0.201	0.200	0.200	0.200
V9	0.200	0.200	0.200	0.200	Y9	0.201	0.200	0.200	0.200
V10	0.200	0.200	0.200	0.200	Y10	0.200	0.200	0.200	0.200
V11	0.199	0.200	0.200	0.200	Y11	0.201	0.200	0.200	0.200
V12	0.199	0.200	0.200	0.200	Y12	0.200	0.200	0.200	0.200
V13	0.200	0.200	0.200	0.200	Y13	0.200	0.200	0.200	0.200
V14	0.200	0.200	0.200	0.200	Y14	0.200	0.200	0.200	0.200
V15	0.200	0.200	0.200	0.200	Y15	0.201	0.200	0.200	0.200
V16	0.200	0.200	0.200	0.200	Y16	0.200	0.200	NR	NR
V17	0.200	0.200	0.200	0.200	Y17	0.200	0.200	0.200	0.200
V18	0.201	0.200	0.200	0.200	Y18	0.200	0.200	NR	NR
V19	0.200	0.200	0.200	0.200	Y19	0.200	0.200	0.200	0.200
V20	0.201	0.200	0.200	0.200	Y20	0.200	0.200	0.200	0.200
V21	0.202	0.200	0.200	0.200	Y21	0.200	0.200	0.200	0.200
V22	0.200	0.200	0.200	0.200	Y22	0.200	0.200	0.200	0.200
V23	0.200	0.200	0.200	0.200	Y23	0.200	0.200	0.200	0.200
V24	0.200	0.200	0.200	0.200	Y24	0.200	0.200	0.200	0.200
W1	0.201	0.200	0.200	0.200	Z1	0.200	0.200	0.200	0.200
W2	0.201	0.200	0.201	0.200	Z2	0.201	0.200	0.201	0.200
W3	0.200	0.200	0.200	0.200	Z3	0.200	0.200	0.200	0.200
W4	0.200	0.200	0.200	0.200	Z4	0.201	0.200	0.200	0.200
W5	0.200	0.200	0.200	0.200	Z5	0.200	0.200	0.200	0.200
W6	0.200	0.200	0.200	0.200	Z6	0.200	0.200	0.200	0.200
W7	0.200	0.200	0.200	0.200	Z7	0.200	0.200	0.200	0.200
W8	0.200	0.200	0.200	0.200	Z8	0.200	0.200	0.200	0.200
W9	0.200	0.200	0.200	0.200	Z9	0.200	0.200	0.200	0.200
W10	0.200	0.200	0.200	0.200	Z10	0.200	0.200	0.200	0.200
W11	0.200	0.200	0.200	0.200	Z11	0.201	0.200	0.200	0.200
W12	0.200	0.200	0.200	0.200	Z12	0.200	0.200	0.200	0.200
W13	0.200	0.200	0.200	0.199	Z13	0.200	0.200	0.200	0.200
W14	0.200	0.200	0.200	0.200	Z14	0.200	0.200	0.200	0.200
W15	0.200	0.200	0.200	0.200	Z15	0.202	0.200	0.200	0.200
W16	0.200	0.200	0.200	0.200	Z16	NR	0.200	NR	NR
W17	0.200	0.200	0.200	0.200	Z17	0.200	0.200	0.200	0.200
W18	0.200	0.200	0.200	0.200	Z18	0.200	0.200	NR	NR
W19	0.201	0.200	0.200	0.200	Z19	0.200	0.200	0.200	0.200
W20	0.200	0.200	0.200	0.200	Z20	0.200	0.200	0.200	0.200
W21	0.200	0.200	0.200	0.200	Z21	0.200	0.200	0.200	0.200
W22	0.201	0.200	0.200	0.200	Z22	0.200	0.200	0.200	0.200
W23	0.200	0.200	0.200	0.200	Z23	0.200	0.200	0.200	0.200
W24	0.200	0.200	0.200	0.200	Z24	0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
270-315 degrees					315-0 degrees				
X1	0.200	0.200	0.200	0.200	beta1	0.200	0.200	0.200	0.200
X2	0.202	0.202	0.200	0.200	beta2	0.200	0.200	0.200	0.200
X3	0.200	0.200	0.200	0.200	beta3	0.200	0.200	0.200	0.200
X4	0.201	0.201	0.200	0.200	beta4	0.200	0.200	0.200	0.200
X5	0.201	0.201	0.200	0.200	beta5	0.200	0.200	0.200	0.200
X6	0.201	0.201	0.200	0.200	beta6	0.200	0.200	0.200	0.200
X7	0.200	0.200	0.200	0.200	beta7	0.200	0.200	0.200	0.200
X8	0.200	0.200	0.200	0.200	beta8	0.200	0.200	0.200	0.200
X9	0.200	0.200	0.200	0.200	beta9	0.200	0.200	0.200	0.200
X10	0.200	0.200	0.200	0.200	beta10	0.200	0.200	0.200	0.200
X11	0.200	0.200	0.200	0.200	beta11	0.200	0.200	0.200	0.200
X12	0.200	0.200	0.200	0.200	beta12	0.200	0.200	0.200	0.200
X13	0.200	0.200	0.200	0.200	beta13	0.200	0.200	0.200	0.200
X14	0.200	0.200	0.200	0.200	beta14	0.200	0.200	0.200	0.200
X15	0.201	0.201	0.200	0.200	beta15	0.200	0.200	0.200	0.200
X16	0.200	0.200	0.200	0.200	beta16	0.200	0.200	NR	NR
X17	0.200	0.200	0.200	0.200	beta17	0.200	0.200	0.200	0.200
X18	0.200	0.200	0.200	0.200	beta18	0.200	0.200	NR	NR
X19	0.200	0.200	0.200	0.200	beta19	0.200	0.200	0.200	0.200
X20	0.200	0.200	0.200	0.200	beta20	0.200	0.200	0.200	0.200
X21	0.200	0.200	0.200	0.200	beta21	0.200	0.200	0.200	0.200
X22	0.200	0.200	0.200	0.200	beta22	0.200	0.200	0.200	0.200
X23	0.201	0.201	0.200	0.200	beta23	0.200	0.200	0.200	0.200
X24	0.200	0.200	0.200	0.200	beta24	0.200	0.200	0.200	0.200

NR—not recorded

Canister HT002		Max=	0.201	0.5					
		Min=	0.199	-0.5					
min	0.200	0.200	0.199	0.200					
max	0.200	0.200	0.201	0.200					
	0.00000	0.00000	0.00012	0.00000					
	0.20000	0.20000	0.20001	0.20000					
	First Axial	**First Lateral**	**Second Axial**	**Second Lateral**		**First Axial**	**First Lateral**	**Second Axial**	**Second Lateral**
315-0 degrees					315-270 degrees				
A1	0.200	0.200	0.200	0.200	D1	0.200	0.200	0.200	0.200
A2	0.200	0.200	0.200	0.200	D2	0.200	0.200	0.200	0.200
A3	0.200	0.200	0.200	0.200	D3	0.200	0.200	0.200	0.200
A4	0.200	0.200	0.200	0.200	D4	0.200	0.200	0.200	0.200
A5	0.200	0.200	0.200	0.200	D5	0.200	0.200	0.200	0.200
A6	0.200	0.200	0.200	0.200	D6	0.200	0.200	0.200	0.200
A7	0.200	0.200	0.200	0.200	D7	0.199	0.200	0.200	0.200
A8	0.200	0.200	0.200	0.200	D8	0.200	0.200	NR	NR
A9	NR	NR	0.200	0.200	D9	0.200	0.200	0.200	0.200
A10	0.200	0.200	0.200	0.200	D10	0.200	0.200	0.200	0.200
A11	NR	0.200	0.200	0.200	D11	0.200	0.200	NR	0.200
A12	NR	NR	0.200	0.200	D12	0.200	0.200	0.200	0.200
A13	0.200	0.200	0.200	0.200	D13	0.200	0.200	0.200	0.200
A14	0.200	0.200	0.200	0.200	D14	0.200	0.200	0.200	0.200
A15	0.200	0.200	0.200	0.200	D15	0.200	0.200	0.200	0.200
A16	0.200	0.200	0.200	0.200	D16	0.200	0.200	0.200	0.200
A17	0.200	0.200	0.200	0.200	D17	0.200	0.200	0.200	0.200
A18	0.200	0.200	0.199	0.200	D18	0.200	0.200	0.200	0.200
A19	0.200	0.200	0.200	0.200	D19	0.200	0.200	0.200	0.200
A20	0.200	0.200	0.200	0.200	D20	0.200	0.200	0.200	0.200
A21	0.200	0.200	0.200	0.200	D21	0.200	0.200	0.200	0.200
A22	0.200	0.200	0.200	0.200	D22	0.200	0.200	0.200	0.200
A23	0.200	0.200	0.200	0.200	D23	0.200	0.200	0.200	0.200
A24	0.200	0.200	0.200	0.200	D24	0.200	0.201	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
315-0 degrees					315-270 degrees				
B1	0.200	0.200	0.200	0.200	E1	0.200	0.200	0.200	0.200
B2	0.200	0.200	0.200	0.200	E2	0.200	0.200	0.200	0.200
B3	0.200	0.200	0.200	0.200	E3	0.200	0.200	0.200	0.200
B4	0.200	0.200	0.200	0.200	E4	0.200	0.200	0.200	0.200
B5	0.200	0.200	0.200	0.200	E5	0.200	0.200	0.200	0.200
B6	0.200	0.200	0.200	0.200	E6	0.200	0.200	0.200	0.200
B7	0.200	0.200	0.200	0.200	E7	0.200	0.200	0.200	0.200
B8	0.200	0.200	0.200	0.200	E8	0.200	NR	NR	NR
B9	0.200	0.200	NR	NR	E9	0.200	0.200	0.200	0.200
B10	0.200	0.200	0.200	0.200	E10	0.200	0.200	0.200	0.200
B11	0.200	0.200	0.200	0.200	E11	0.200	0.200	NR	0.200
B12	NR	NR	NR	NR	E12	0.200	0.200	0.200	0.200
B13	0.200	0.200	0.200	0.200	E13	0.200	0.200	0.200	0.200
B14	0.200	0.200	0.200	0.200	E14	0.200	0.200	0.200	0.200
B15	0.200	0.200	0.200	0.200	E15	0.200	0.200	0.200	0.200
B16	0.200	0.200	0.200	0.200	E16	0.200	0.200	0.200	0.200
B17	0.200	0.200	0.200	0.200	E17	0.200	0.200	0.200	0.200
B18	0.200	0.200	0.200	0.200	E18	0.200	0.200	0.200	0.200
B19	0.200	0.200	0.200	0.200	E19	0.200	0.200	0.200	0.200
B20	0.200	0.200	0.200	0.200	E20	0.200	0.200	0.200	0.200
B21	0.200	0.200	0.200	0.200	E21	0.200	0.200	0.200	0.200
B22	0.200	0.200	0.201	0.200	E22	0.200	0.200	0.200	0.200
B23	0.200	0.200	0.201	0.200	E23	0.200	0.200	0.200	0.200
B24	0.200	0.200	0.201	0.200	E24	0.200	0.200	0.200	NR
C1	0.200	0.200	0.200	0.200	F1	0.200	0.200	0.200	0.200
C2	0.200	0.200	0.200	0.200	F2	0.200	0.200	0.200	0.200
C3	0.200	0.200	0.200	0.200	F3	0.200	0.200	0.200	0.200
C4	0.200	0.200	0.200	0.200	F4	0.200	0.200	0.200	0.200
C5	0.200	0.200	0.200	0.200	F5	0.200	0.200	0.200	0.200
C6	0.200	0.200	0.200	0.200	F6	0.200	0.200	0.200	0.200
C7	0.200	0.200	0.200	0.200	F7	0.200	0.200	0.200	0.200
C8	0.200	0.200	0.200	0.200	F8	0.200	0.200	0.200	NR
C9	0.200	0.200	NR	NR	F9	0.200	0.200	0.200	0.200
C10	0.200	0.200	0.200	0.200	F10	0.200	0.200	0.200	0.200
C11	0.200	0.200	0.200	0.200	F11	0.200	0.200	0.200	0.200
C12	0.200	NR	NR	NR	F12	0.200	0.200	0.200	0.200
C13	0.200	0.200	0.200	0.200	F13	0.200	0.200	0.200	0.200
C14	0.200	0.200	0.200	0.200	F14	0.200	0.200	0.200	0.200
C15	0.200	0.200	0.200	0.200	F15	0.200	0.200	0.200	0.200
C16	0.200	0.200	0.200	0.200	F16	0.200	0.200	0.200	0.200
C17	0.200	0.200	0.200	0.200	F17	0.200	0.200	0.200	0.200
C18	0.200	0.200	0.200	0.200	F18	0.200	0.200	0.200	0.200
C19	0.200	0.200	0.200	0.200	F19	0.200	0.200	0.200	0.200
C20	0.200	0.200	0.200	0.200	F20	0.200	0.200	0.200	0.200
C21	0.200	0.200	0.200	0.200	F21	0.200	0.200	0.200	0.200
C22	0.200	0.200	0.200	0.200	F22	0.200	0.200	0.200	0.200
C23	0.200	0.200	0.200	0.200	F23	0.200	0.200	0.200	0.200
C24	0.200	0.200	0.200	0.200	F24	0.200	0.200	NR	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
270-225 degrees					225-180 degrees				
G1	0.200	0.200	0.200	0.200	J1	0.200	0.200	0.200	0.200
G2	0.200	0.200	0.200	0.200	J2	0.200	0.200	0.200	0.200
G3	0.200	0.200	0.200	0.200	J3	0.200	0.200	0.200	0.200
G4	0.200	0.200	0.200	0.200	J4	0.200	0.200	0.200	0.200
G5	0.200	0.200	0.200	0.200	J5	0.200	0.200	0.200	0.200
G6	0.200	0.200	0.200	0.200	J6	0.200	0.200	0.200	0.200
G7	0.200	0.200	0.200	0.200	J7	NR	NR	NR	NR
G8	0.200	0.200	0.200	NR	J8	0.200	0.200	0.200	0.200
G9	0.200	0.200	0.200	0.200	J9	0.200	0.200	0.200	0.200
G10	0.200	0.200	0.200	0.200	J10	NR	NR	0.200	NR
G11	0.200	0.200	0.200	0.200	J11	0.200	0.200	0.200	0.200
G12	0.200	0.200	0.200	0.200	J12	0.200	0.200	0.200	0.200
G13	0.200	0.200	0.200	0.200	J13	0.200	0.200	0.200	0.200
G14	0.200	0.200	0.200	0.200	J14	0.200	0.200	0.200	0.200
G15	0.200	0.200	0.200	0.200	J15	0.200	0.200	0.200	0.200
G16	0.200	0.200	0.200	0.200	J16	0.200	0.200	0.200	0.200
G17	0.200	0.200	0.200	0.200	J17	0.200	0.200	0.200	0.200
G18	0.200	0.200	0.200	0.200	J18	0.200	0.200	0.200	0.200
G19	0.200	0.200	0.200	0.200	J19	0.200	0.200	0.200	0.200
G20	0.200	0.200	0.200	0.200	J20	0.200	0.200	0.200	0.200
G21	0.200	0.200	0.200	0.200	J21	0.200	0.200	0.200	0.200
G22	0.200	0.200	0.200	0.200	J22	0.200	0.200	0.200	0.200
G23	0.200	0.200	0.200	0.200	J23	0.200	0.200	0.200	0.200
G24	0.200	0.200	NR	0.200	J24	0.200	0.200	0.200	0.200
H1	0.200	0.200	0.200	0.200	K1	0.200	0.200	0.200	0.200
H2	0.200	0.200	0.200	0.200	K2	0.200	0.200	0.200	0.200
H3	0.200	0.200	0.200	0.200	K3	0.200	0.200	0.200	0.200
H4	0.200	0.200	0.200	0.200	K4	0.200	0.200	0.200	0.200
H5	0.200	0.200	0.200	0.200	K5	0.200	0.200	0.200	0.200
H6	0.200	0.200	0.200	0.200	K6	0.200	0.200	0.200	0.200
H7	0.200	0.200	0.200	0.200	K7	NR	NR	NR	NR
H8	0.200	0.200	0.200	0.200	K8	0.200	0.200	0.200	0.200
H9	0.200	0.200	0.200	0.200	K9	0.200	0.200	0.200	0.200
H10	0.200	0.200	0.200	0.200	K10	NR	NR	0.200	NR
H11	0.200	0.200	0.200	0.200	K11	0.200	0.200	0.200	0.200
H12	0.200	0.200	0.200	0.200	K12	0.200	0.200	0.200	0.200
H13	0.200	0.200	0.200	0.200	K13	0.200	0.200	0.200	0.200
H14	0.200	0.200	0.200	0.200	K14	0.200	0.200	0.200	0.200
H15	0.200	0.200	0.200	0.200	K15	0.200	0.200	0.200	0.200
H16	0.200	0.200	0.200	0.200	K16	0.200	0.200	0.200	0.200
H17	0.200	0.200	0.200	0.200	K17	0.200	0.200	0.200	0.200
H18	0.200	0.200	0.200	0.200	K18	0.200	0.200	0.200	0.200
H19	0.200	0.200	0.200	0.200	K19	0.200	0.200	0.200	0.200
H20	0.200	0.200	0.200	0.200	K20	0.200	0.200	0.200	0.200
H21	0.200	0.200	0.200	0.200	K21	0.200	0.200	0.200	0.200
H22	0.200	0.200	0.200	0.200	K22	0.200	0.200	0.200	0.200
H23	0.200	0.200	0.200	0.200	K23	0.200	0.200	0.200	0.200
H24	0.200	0.200	NR	0.200	K24	0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
270-225 degrees					225-180 degrees				
I1	0.200	0.200	0.200	0.200	L1	0.200	0.200	0.200	0.200
I2	0.200	0.200	0.200	0.200	L2	0.200	0.200	0.200	0.200
I3	0.200	0.200	0.200	0.200	L3	0.200	0.200	0.200	0.200
I4	0.200	0.200	0.200	0.200	L4	0.200	0.200	0.200	0.200
I5	0.200	0.200	0.200	0.200	L5	0.200	0.200	0.200	0.200
I6	0.200	0.200	0.200	0.200	L6	0.200	0.200	0.200	0.200
I7	0.200	0.200	0.200	0.200	L7	NR	0.200	NR	NR
I8	0.200	0.200	0.200	0.200	L8	0.200	0.200	0.200	0.200
I9	0.200	0.200	0.200	0.200	L9	0.200	0.200	0.200	0.200
I10	0.200	0.200	NR	0.200	L10	NR	NR	0.200	NR
I11	0.200	0.200	0.200	0.200	L11	0.200	0.200	0.200	0.200
I12	0.200	0.200	0.200	0.200	L12	0.200	0.200	0.200	0.200
I13	0.200	0.200	0.200	0.200	L13	0.200	0.200	0.200	0.200
I14	0.200	0.200	0.200	0.200	L14	0.200	0.200	0.200	0.200
I15	0.200	0.200	0.200	0.200	L15	0.200	0.200	0.200	0.200
I16	0.200	0.200	0.200	0.200	L16	0.200	0.200	0.200	0.200
I17	0.200	0.200	0.200	0.200	L17	0.200	0.200	0.200	0.200
I18	0.200	0.200	0.200	0.200	L18	0.200	0.200	0.200	0.200
I19	0.200	0.200	0.200	0.200	L19	0.200	0.200	0.200	0.200
I20	0.200	0.200	0.200	0.200	L20	0.200	0.200	0.200	0.200
I21	0.200	0.200	0.200	0.200	L21	0.200	0.200	0.200	0.200
I22	0.200	0.200	0.200	0.200	L22	0.200	0.200	0.200	0.200
I23	0.200	0.200	NR	0.200	L23	0.200	0.200	0.200	0.200
I24	0.200	0.200	NR	0.200	L24	0.200	0.200	0.200	0.200

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
180-135 degrees					135-90 degrees				
M1	0.200	0.200	0.200	0.200	P1	0.200	0.200	0.200	0.200
M2	0.200	0.200	0.200	0.200	P2	0.200	0.200	0.200	0.200
M3	0.200	0.200	0.200	0.200	P3	0.200	0.200	0.200	0.200
M4	0.200	0.200	0.200	0.200	P4	0.200	0.200	0.200	0.200
M5	0.200	0.200	0.200	0.200	P5	0.200	0.200	0.200	0.200
M6	0.200	0.200	0.200	0.200	P6	0.200	0.200	0.200	0.200
M7	0.200	0.200	0.200	0.200	P7	0.200	0.200	0.200	0.200
M8	NR	NR	0.200	0.200	P8	0.200	0.200	NR	NR
M9	0.200	0.200	NR	NR	P9	0.200	0.200	NR	NR
M10	NR	NR	0.200	0.200	P10	0.200	0.200	0.200	0.200
M11	0.200	0.200	NR	0.200	P11	0.200	0.200	0.200	0.200
M12	0.200	0.200	0.200	NR	P12	0.200	0.200	0.200	NR
M13	0.200	0.200	0.200	0.200	P13	0.200	0.200	0.200	0.200
M14	0.200	0.200	0.200	0.200	P14	0.200	0.200	0.200	0.200
M15	0.200	0.200	0.200	0.200	P15	0.200	0.200	0.200	0.200
M16	0.200	0.200	0.200	0.200	P16	0.200	0.200	0.200	0.200
M17	0.200	0.200	0.200	0.200	P17	0.200	0.200	0.200	0.200
M18	0.200	0.200	0.200	0.200	P18	0.200	0.200	0.200	0.200
M19	0.200	0.200	0.200	0.200	P19	0.200	0.200	0.200	0.200
M20	0.200	0.200	0.200	0.200	P20	0.200	0.200	0.200	0.200
M21	0.200	0.200	0.200	0.200	P21	0.200	0.200	0.200	0.200
M22	0.200	0.200	0.200	0.200	P22	0.200	0.200	0.200	0.200
M23	0.200	0.200	0.200	0.200	P23	0.200	0.200	0.200	0.200
M24	0.200	0.200	0.200	0.200	P24	0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
180-135 degrees					135-90 degrees				
N1	0.200	0.200	0.200	0.200	Q1	0.200	0.200	0.200	0.200
N2	0.200	0.200	0.200	0.200	Q2	0.200	0.200	0.200	0.200
N3	0.200	0.200	0.200	0.200	Q3	0.200	0.200	0.200	0.200
N4	0.200	0.200	0.200	0.200	Q4	0.200	0.200	0.200	0.200
N5	0.200	0.200	0.200	0.200	Q5	0.200	0.200	0.200	0.200
N6	0.200	0.200	0.200	0.200	Q6	0.200	0.200	0.200	0.200
N7	0.200	0.200	0.200	0.200	Q7	0.200	0.200	0.200	0.200
N8	NR	NR	0.200	0.200	Q8	0.200	0.200	0.200	0.200
N9	0.200	0.200	NR	0.200	Q9	0.200	0.200	NR	NR
N10	NR	NR	0.200	0.200	Q10	0.200	0.200	NR	0.200
N11	0.200	0.200	NR	NR	Q11	0.200	0.200	0.200	0.200
N12	0.200	0.200	0.200	0.200	Q12	0.200	0.200	0.200	NR
N13	0.200	0.200	0.200	0.200	Q13	0.200	0.200	0.200	0.200
N14	0.200	0.200	0.200	0.200	Q14	0.200	0.200	0.200	0.200
N15	0.200	0.200	0.200	0.200	Q15	0.200	0.200	0.200	0.200
N16	0.200	0.200	0.200	0.200	Q16	0.200	0.200	0.200	0.200
N17	0.200	0.200	0.200	0.200	Q17	0.200	0.200	0.200	0.200
N18	0.200	0.200	0.200	0.200	Q18	0.200	0.200	0.200	0.200
N19	0.200	0.200	0.200	0.200	Q19	0.200	0.200	0.200	0.200
N20	0.200	0.200	0.200	0.200	Q20	0.200	0.200	0.200	0.200
N21	0.200	0.200	0.200	0.200	Q21	0.200	0.200	0.200	0.200
N22	0.200	0.200	0.200	0.200	Q22	0.200	0.200	0.200	0.200
N23	0.200	0.200	0.200	0.200	Q23	0.200	0.200	0.200	0.200
N24	0.200	0.200	0.200	0.200	Q24	0.200	0.200	0.200	0.200
O1	0.200	0.200	0.200	0.200	R1	0.200	0.200	0.200	0.200
O2	0.200	0.200	0.200	0.200	R2	0.200	0.200	0.200	0.200
O3	0.200	0.200	0.200	0.200	R3	0.200	0.200	0.200	0.200
O4	0.200	0.200	0.200	0.200	R4	0.200	0.200	0.200	0.200
O5	0.200	0.200	0.200	0.200	R5	0.200	0.200	0.200	0.200
O6	0.200	0.200	0.200	0.200	R6	0.200	0.200	0.200	0.200
O7	0.200	0.200	0.200	0.200	R7	0.200	0.200	0.200	0.200
O8	NR	NR	0.200	0.200	R8	0.200	0.200	0.200	0.200
O9	0.200	0.200	0.200	NR	R9	0.200	0.200	NR	NR
O10	NR	NR	0.200	0.200	R10	0.200	0.200	NR	0.200
O11	0.200	0.200	NR	NR	R11	0.200	0.200	0.200	0.200
O12	0.200	0.200	NR	0.200	R12	0.200	0.200	0.200	NR
O13	0.200	0.200	0.200	0.200	R13	0.200	0.200	0.200	0.200
O14	0.200	0.200	0.200	0.200	R14	0.200	0.200	0.200	0.200
O15	0.200	0.200	0.200	0.200	R15	0.200	0.200	0.200	0.200
O16	0.200	0.200	0.200	0.200	R16	0.200	0.200	0.200	0.200
O17	0.200	0.200	0.200	0.200	R17	0.200	0.200	0.200	0.200
O18	0.200	0.200	0.200	0.200	R18	0.200	0.200	0.200	0.200
O19	0.200	0.200	0.200	0.200	R19	0.200	0.200	0.200	0.200
O20	0.200	0.200	0.200	0.200	R20	0.200	0.200	0.200	0.200
O21	0.200	0.200	0.200	0.200	R21	0.200	0.200	0.200	0.200
O22	0.200	0.200	0.200	0.200	R22	0.200	0.200	0.200	0.200
O23	0.200	0.200	0.200	0.200	R23	0.200	0.200	0.200	0.200
O24	0.200	0.200	0.200	NR	R24	0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
90-45 degrees					45-0 degrees				
S1	0.200	0.200	0.200	0.200	V1	0.200	0.200	0.200	0.200
S2	0.200	0.200	0.200	0.200	V2	0.200	0.200	0.200	0.200
S3	0.200	0.200	0.200	0.200	V3	0.200	0.200	0.200	0.200
S4	0.200	0.200	0.200	0.200	V4	0.200	0.200	0.200	0.200
S5	0.200	0.200	0.200	0.200	V5	0.200	0.200	0.200	0.200
S6	0.200	0.200	0.200	0.200	V6	0.200	0.200	0.200	0.200
S7	0.200	0.200	0.200	0.200	V7	0.200	0.200	0.200	0.200
S8	0.200	0.200	0.200	0.200	V8	0.200	0.200	0.200	0.200
S9	0.200	0.200	0.200	0.200	V9	0.200	0.200	0.200	0.200
S10	0.200	0.200	0.200	0.200	V10	0.200	0.200	0.200	NR
S11	0.200	0.200	0.200	0.200	V11	0.200	0.200	0.200	0.200
S12	0.200	0.200	NR	0.200	V12	0.200	0.200	0.200	0.200
S13	0.200	0.200	NR	0.200	V13	0.200	0.200	NR	0.200
S14	0.200	0.200	0.200	0.200	V14	0.200	0.200	0.200	0.200
S15	0.200	0.200	0.200	0.200	V15	0.200	0.200	0.200	0.200
S16	0.200	0.200	0.200	0.200	V16	0.200	0.200	0.200	0.200
S17	0.200	0.200	0.200	0.200	V17	0.200	0.200	0.200	0.200
S18	0.200	0.200	0.200	0.200	V18	0.200	0.200	0.200	0.200
S19	0.200	0.200	0.200	0.200	V19	0.200	0.200	0.200	0.200
S20	0.200	0.200	0.200	0.200	V20	0.200	0.200	0.200	0.200
S21	0.200	0.200	0.200	0.200	V21	0.200	0.200	0.200	0.200
S22	0.200	0.200	0.200	0.200	V22	0.200	0.200	0.200	0.200
S23	0.200	0.200	0.200	0.200	V23	0.200	0.200	0.200	0.200
S24	0.200	0.200	0.200	0.200	V24	0.200	0.200	0.200	0.200
T1	0.200	0.200	0.200	0.200	W1	0.200	0.200	0.200	0.200
T2	0.200	0.200	0.200	0.200	W2	0.200	0.200	0.200	0.200
T3	0.200	0.200	0.200	0.200	W3	0.200	0.200	0.200	0.200
T4	0.200	0.200	0.200	0.200	W4	0.200	0.200	0.200	0.200
T5	0.200	0.200	0.200	0.200	W5	0.200	0.200	NR	0.200
T6	0.200	0.200	0.200	NR	W6	0.200	0.200	0.200	0.200
T7	0.200	0.200	0.200	0.200	W7	0.200	0.200	0.200	0.200
T8	0.200	0.200	0.200	0.200	W8	0.200	0.200	0.200	0.200
T9	0.200	0.200	0.200	NR	W9	0.200	0.200	0.200	0.200
T10	0.200	0.200	0.200	NR	W10	0.200	0.200	0.200	0.200
T11	0.200	0.200	0.200	0.200	W11	0.200	0.200	0.200	0.200
T12	0.200	0.200	0.200	0.200	W12	0.200	0.200	NR	0.200
T13	0.200	0.200	0.200	0.200	W13	0.200	0.200	NR	0.200
T14	0.200	0.200	0.200	0.200	W14	0.200	0.200	0.200	0.200
T15	0.200	0.200	0.200	0.200	W15	0.200	0.200	0.200	0.200
T16	0.200	0.200	0.200	0.200	W16	0.200	0.200	0.200	0.200
T17	0.200	0.200	0.200	0.200	W17	0.200	0.200	0.200	0.200
T18	0.200	0.200	0.200	0.200	W18	0.200	0.200	0.200	0.200
T19	0.200	0.200	0.200	0.200	W19	0.200	0.200	0.200	0.200
T20	0.200	0.200	0.200	0.200	W20	0.200	0.200	0.200	0.200
T21	0.200	0.200	0.200	0.200	W21	0.200	0.200	0.200	0.200
T22	0.200	0.200	0.200	0.200	W22	0.200	0.200	0.200	0.200
T23	0.200	0.200	0.200	0.200	W23	0.200	0.200	0.200	NR
T24	0.200	0.200	0.200	0.200	W24	0.200	0.200	0.200	0.200

NR—not recorded

	First Axial	First Lateral	Second Axial	Second Lateral		First Axial	First Lateral	Second Axial	Second Lateral
90-45 degrees					45-0 degrees				
U1	0.200	0.200	0.200	0.200	X1	0.200	0.200	0.200	0.200
U2	0.200	0.200	0.200	0.200	X2	0.200	0.200	0.200	0.200
U3	0.200	0.200	0.200	0.200	X3	0.200	0.200	0.200	0.200
U4	0.200	0.200	0.200	0.200	X4	0.200	0.200	0.200	0.200
U5	0.200	0.200	0.200	0.200	X5	0.200	0.200	0.200	0.200
U6	0.200	0.200	0.200	0.200	X6	0.200	0.200	0.200	0.200
U7	0.200	0.200	0.200	0.200	X7	0.200	0.200	0.200	0.200
U8	0.200	0.200	0.200	0.200	X8	0.200	0.200	0.200	0.200
U9	0.200	0.200	0.200	NR	X9	0.200	0.200	0.200	0.200
U10	0.200	0.200	0.200	NR	X10	0.200	0.200	0.200	NR
U11	0.200	0.200	0.200	0.200	X11	0.200	0.200	0.200	0.200
U12	0.200	0.200	NR	0.200	X12	0.200	0.200	NR	0.200
U13	0.200	0.200	0.200	0.200	X13	0.200	0.200	NR	0.200
U14	0.200	0.200	0.200	0.200	X14	0.200	0.200	0.200	NR
U15	0.200	0.200	0.200	0.200	X15	0.200	0.200	0.200	0.200
U16	0.200	0.200	0.200	0.200	X16	0.200	0.200	0.200	0.200
U17	0.200	0.200	0.200	0.200	X17	0.200	0.200	0.200	0.200
U18	0.200	0.200	0.200	0.200	X18	0.200	0.200	0.200	0.200
U19	0.200	0.200	0.200	0.200	X19	0.200	0.200	0.200	0.200
U20	0.200	0.200	0.200	0.200	X20	0.200	0.200	0.200	0.200
U21	0.200	0.200	0.200	0.200	X21	0.200	0.200	0.200	0.200
U22	0.200	0.200	0.200	0.200	X22	0.200	0.200	0.200	0.200
U23	0.200	0.200	0.200	0.200	X23	0.200	0.200	0.200	0.200
U24	0.200	0.200	0.200	0.200	X24	0.200	0.200	0.200	0.200

NR—not recorded

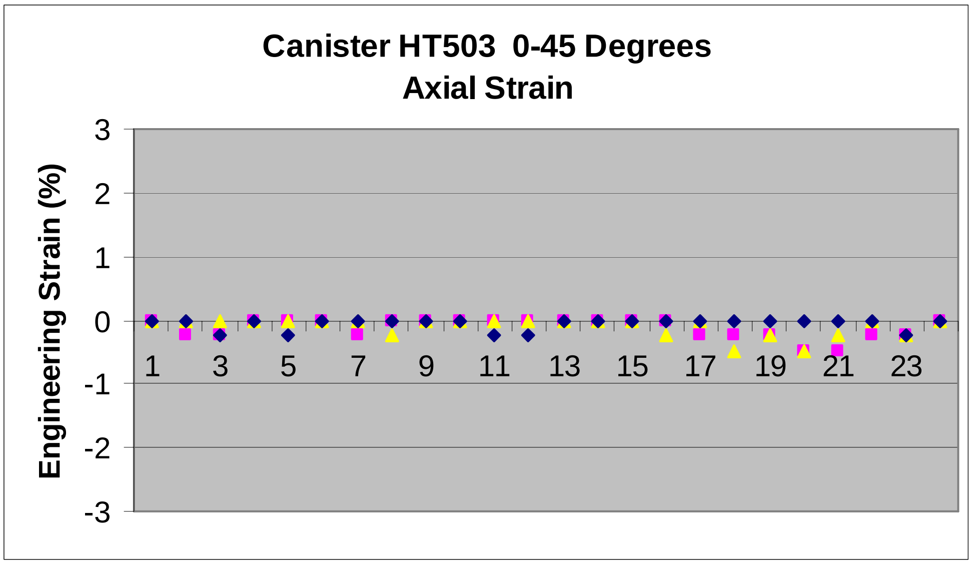
Appendix K

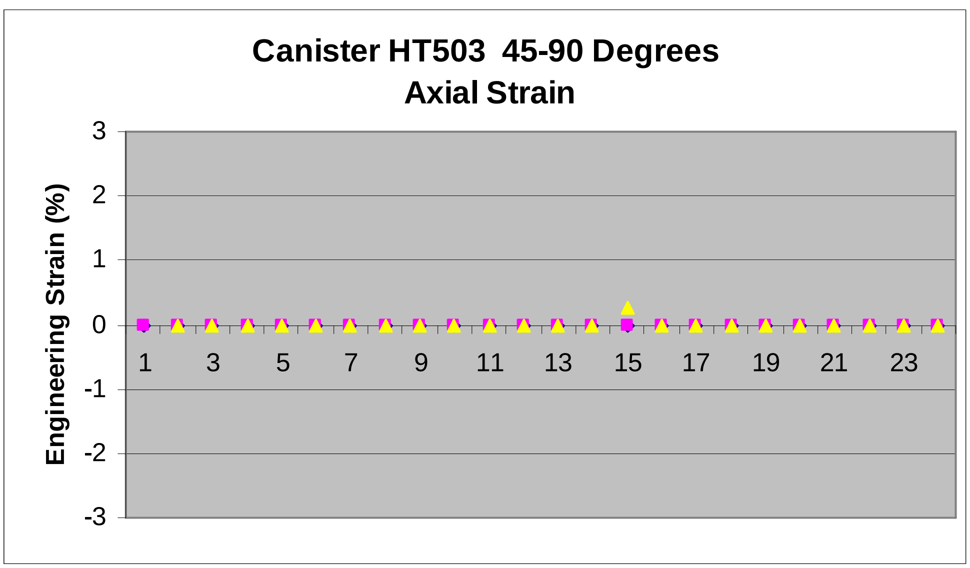
Plots of Strain-Circle Data

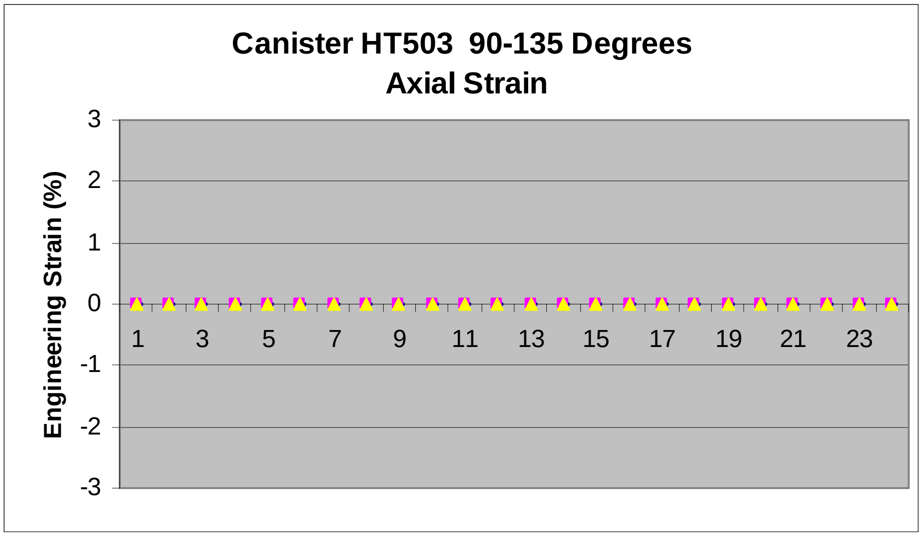
Appendix K: Plots of Strain-Circle Data

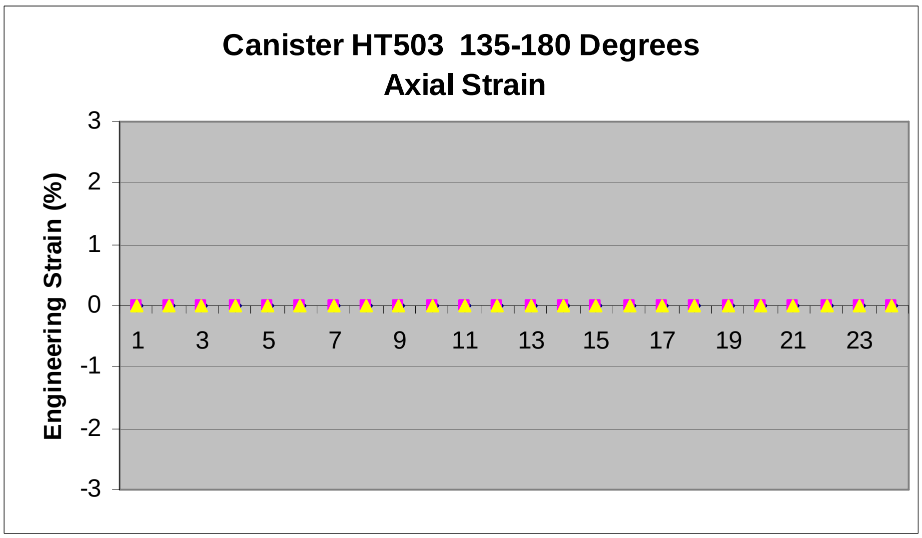
Plots show data for all circles in a section.
Sections of strain circles contain three rows.
Each row contains 24 strain circles.

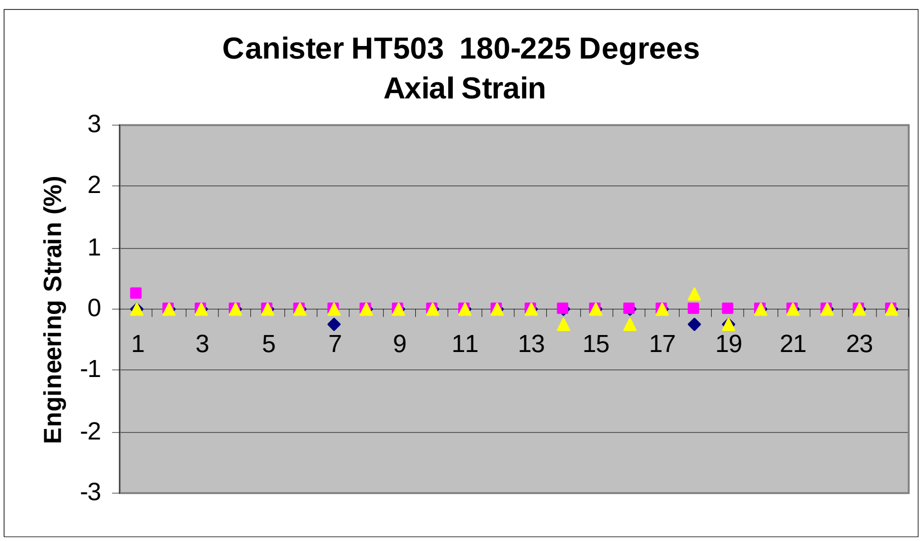
Is for first row of strain circles
Is for second row of strain circles
Is for third row of strain circles

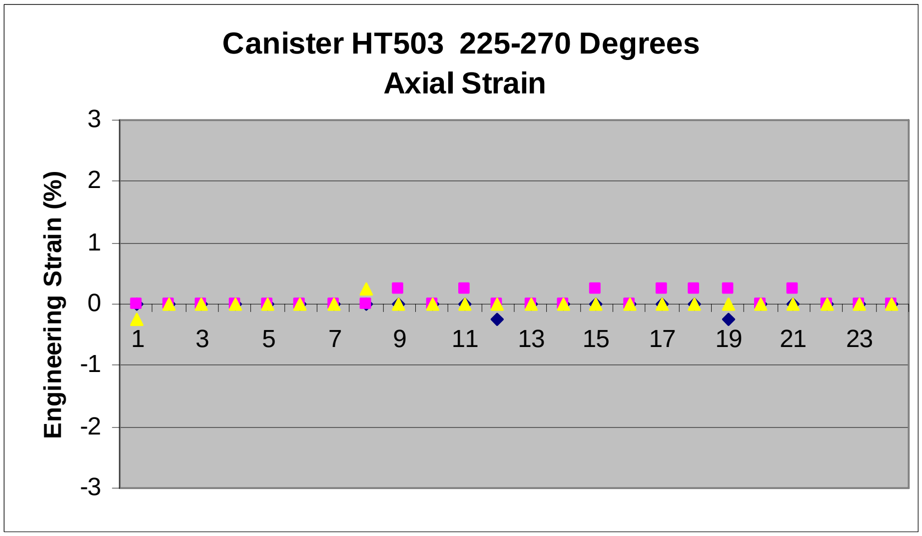


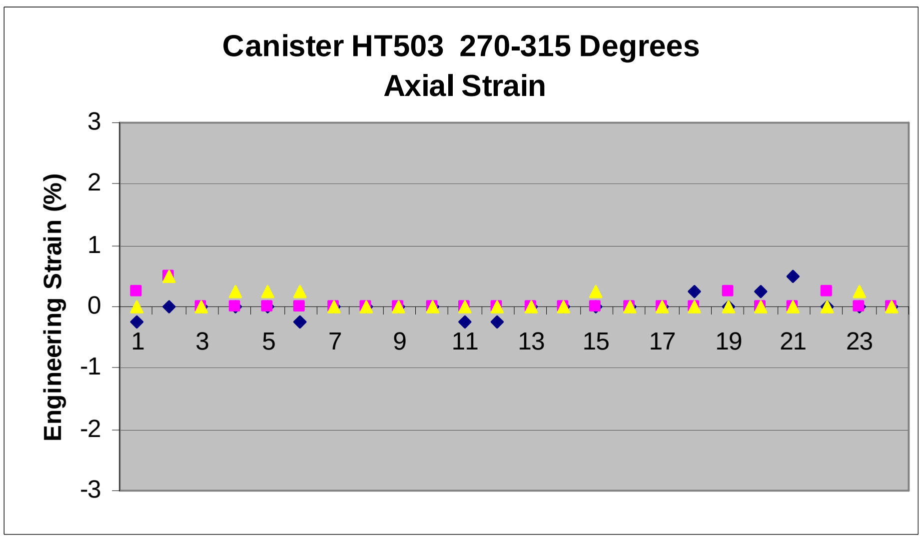


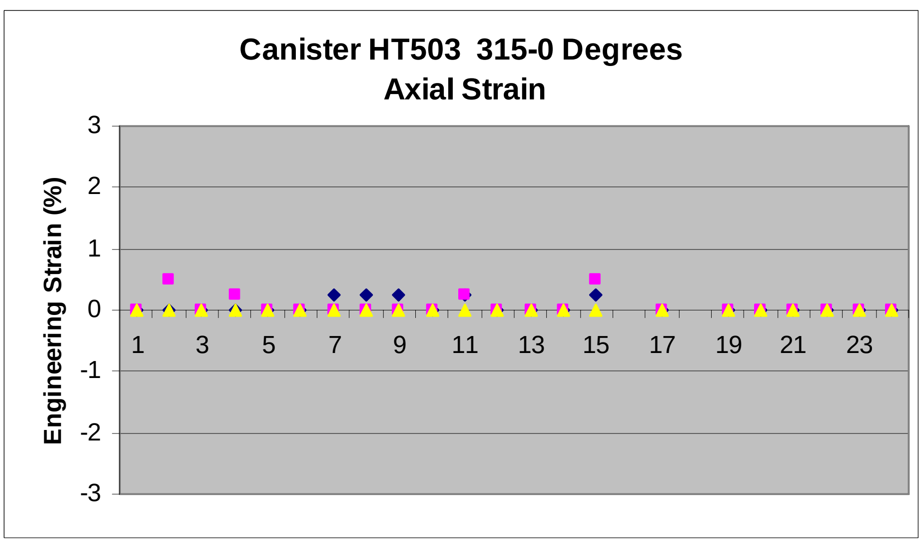

Canister HT503 90-135 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 135-180 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 180-225 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 225-270 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 270-315 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 315-0 Degrees
Axial Strain
Engineering Strain (%)
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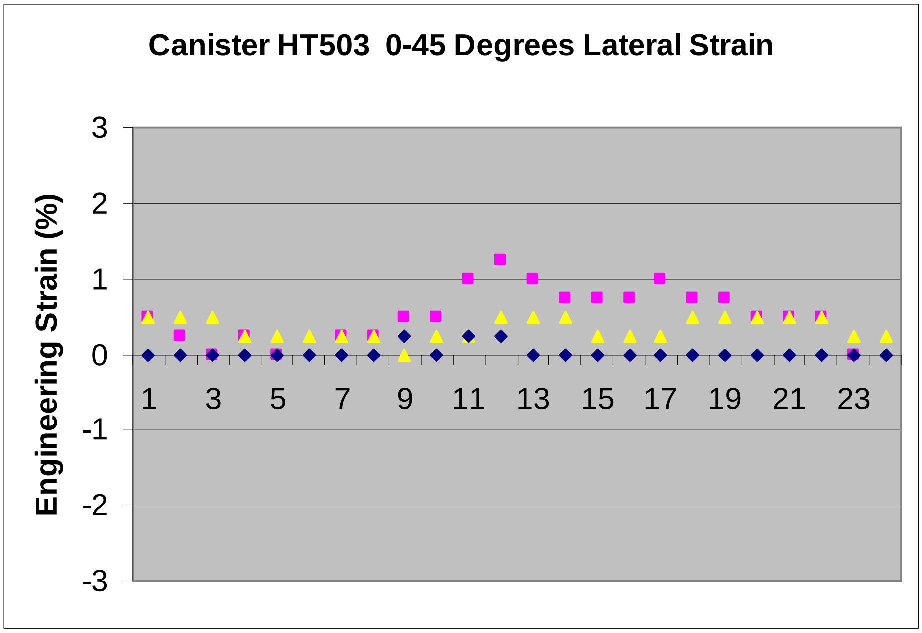
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 0-45 Degrees Lateral Strain
Engineering Strain (%)
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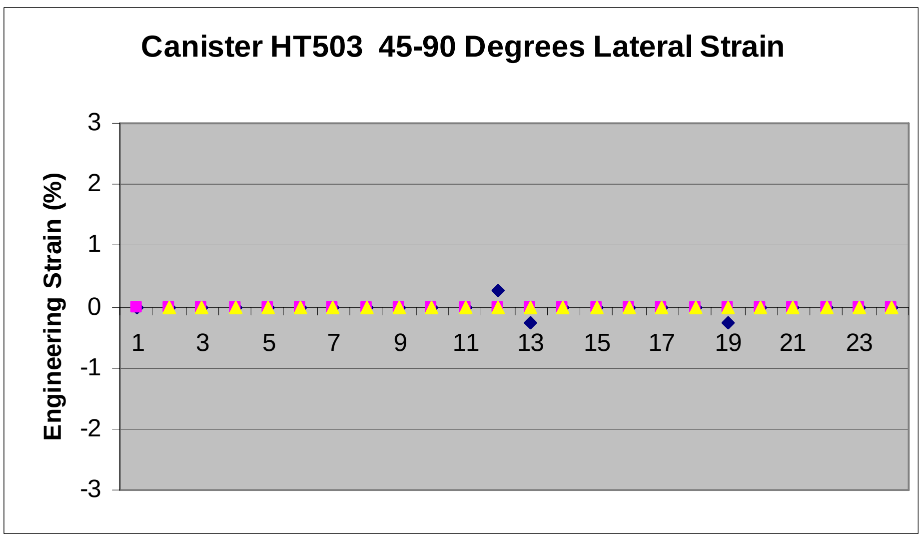
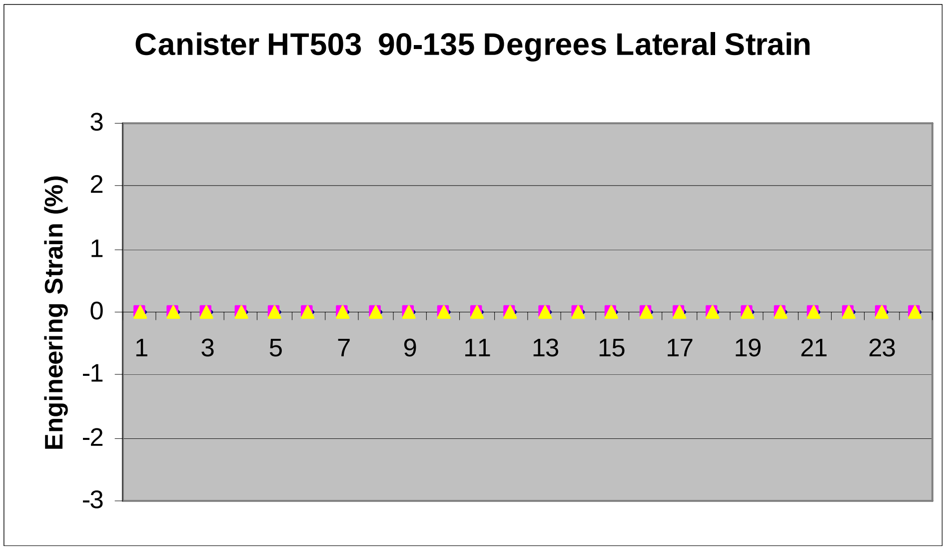
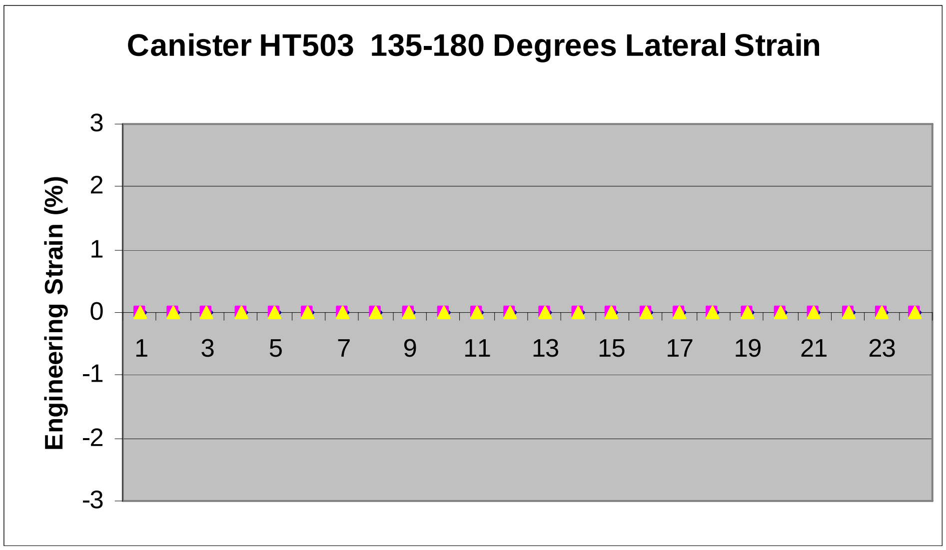
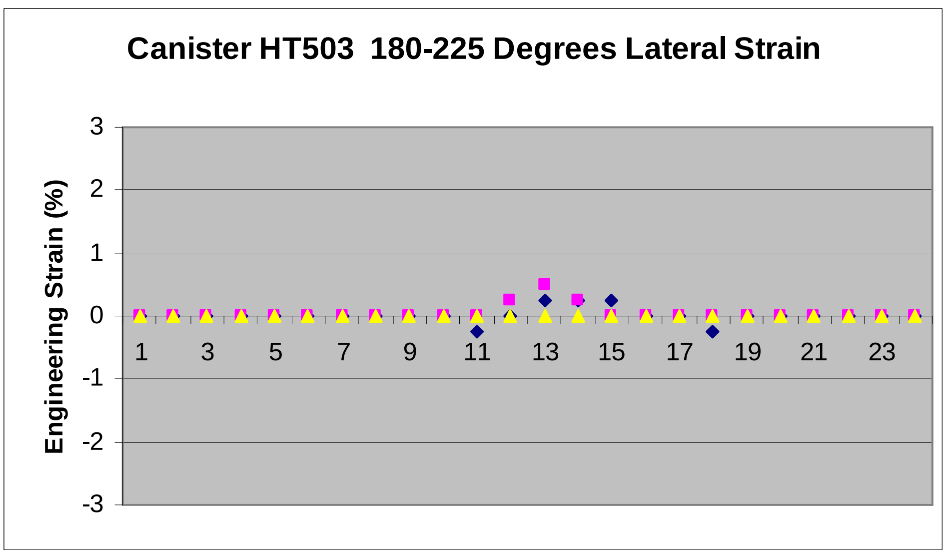
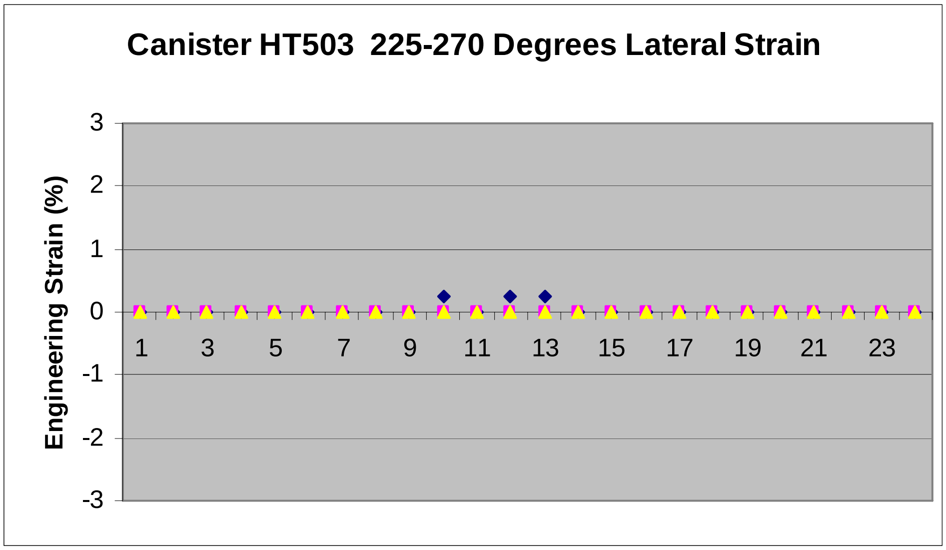
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

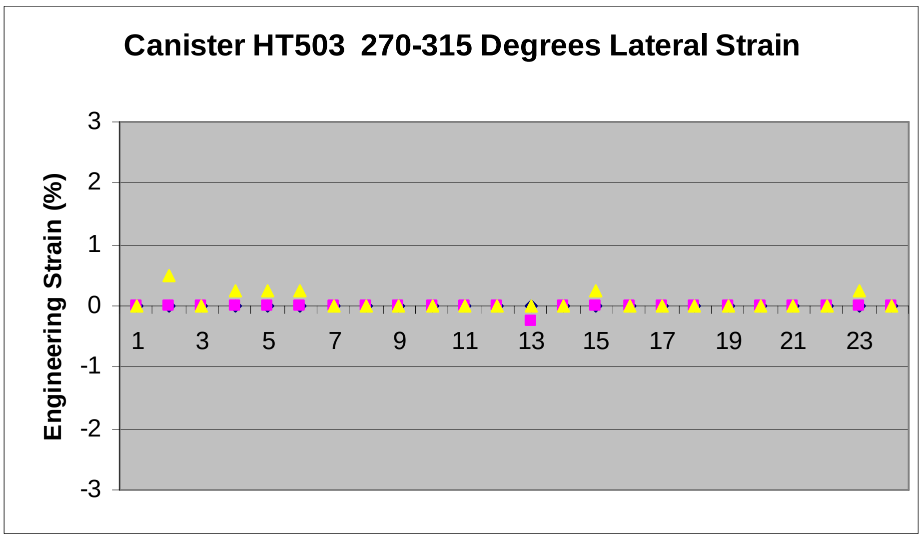

Canister HT503 45-90 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

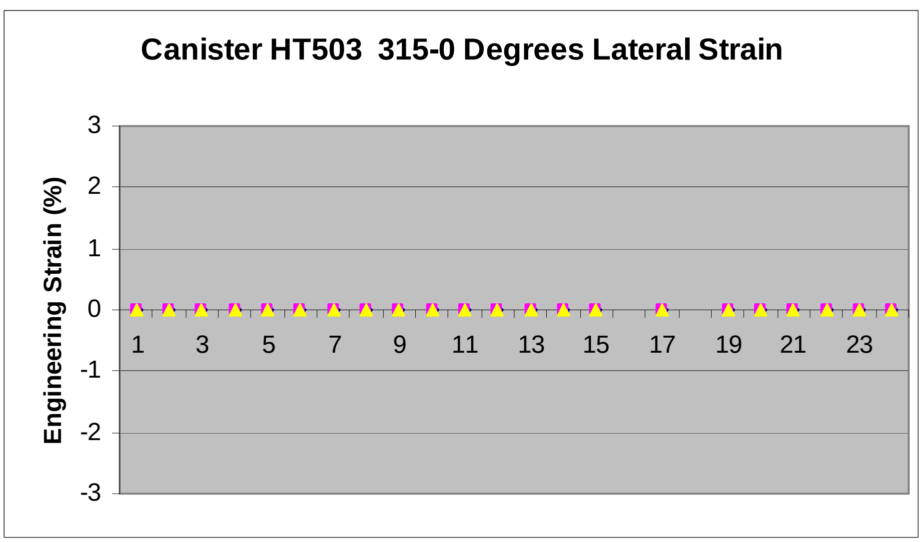

Canister HT503 90-135 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 135-180 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 180-225 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 225-270 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 270-315 Degrees Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT503 315-0 Degrees Lateral Strain
Engineering Strain (%)
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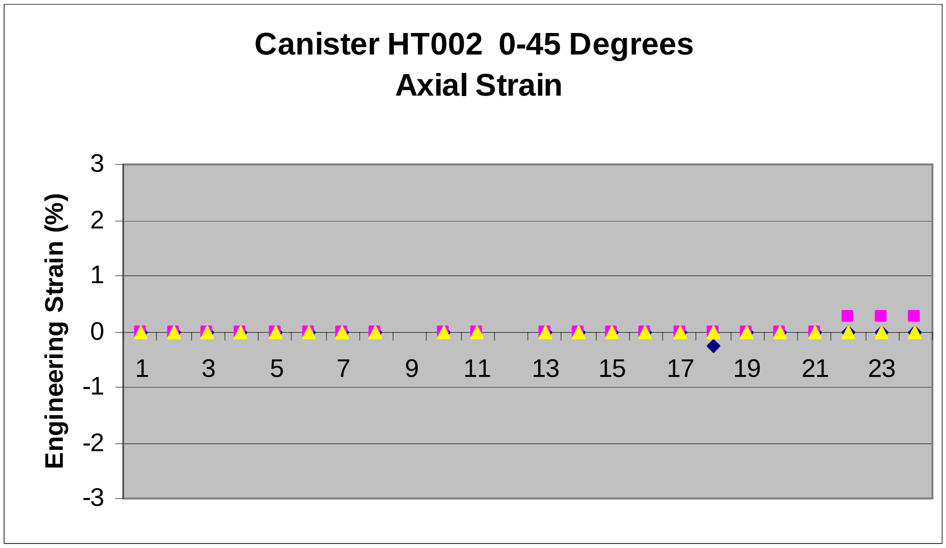
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 0-45 Degrees
Axial Strain
Engineering Strain (%)
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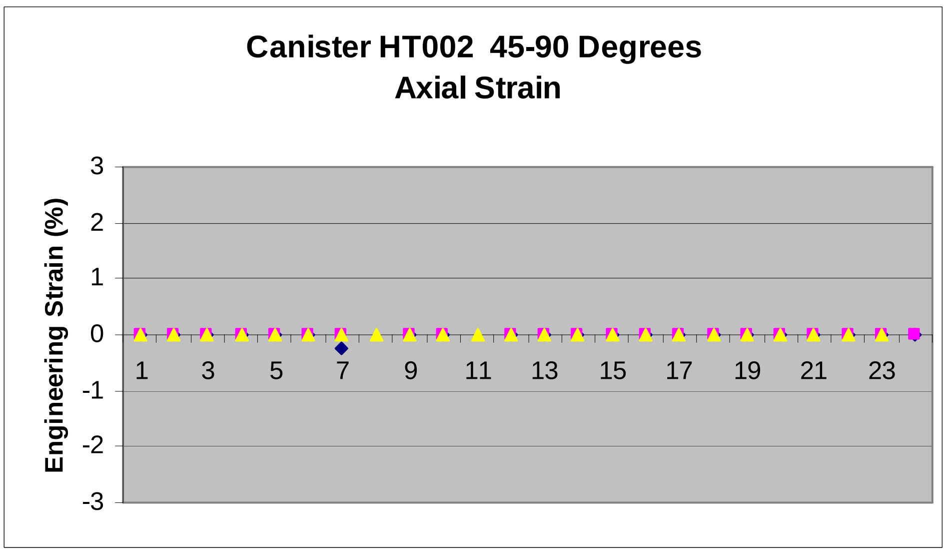
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 45-90 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
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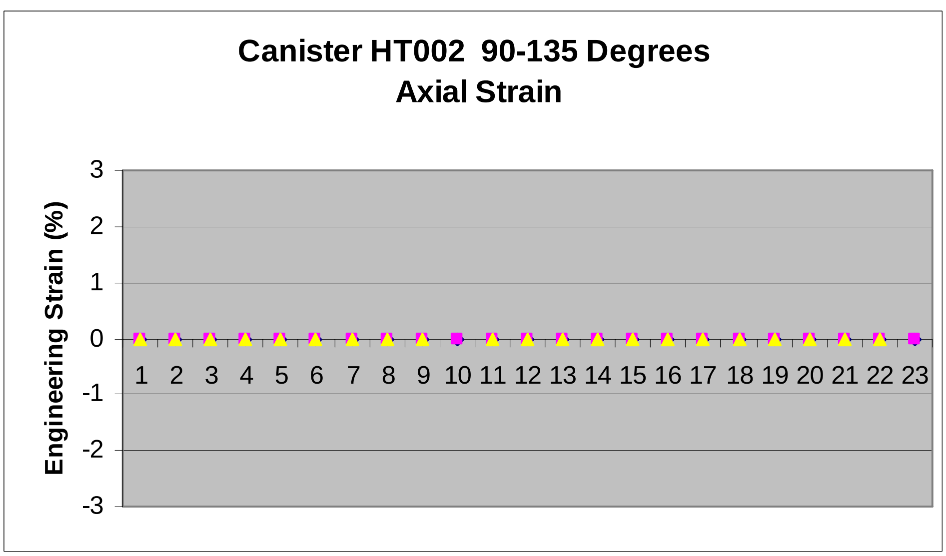
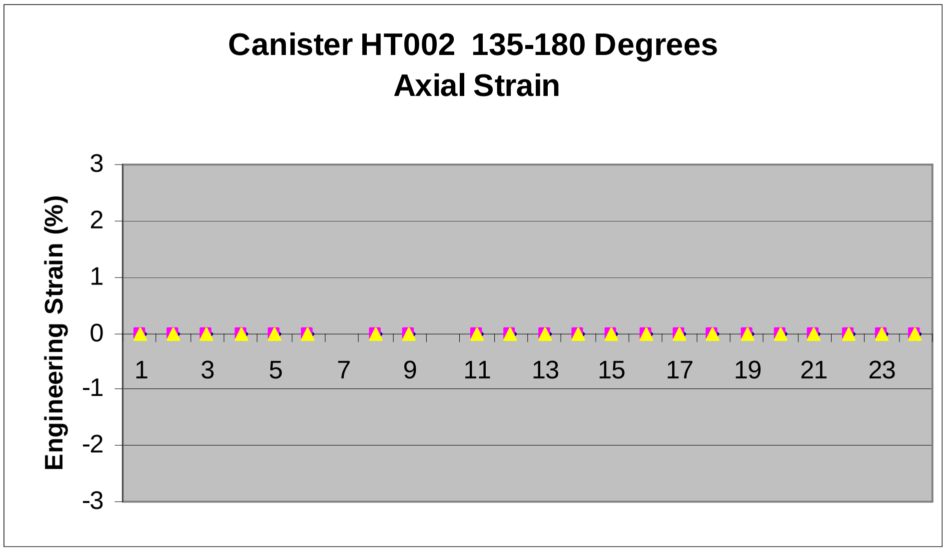
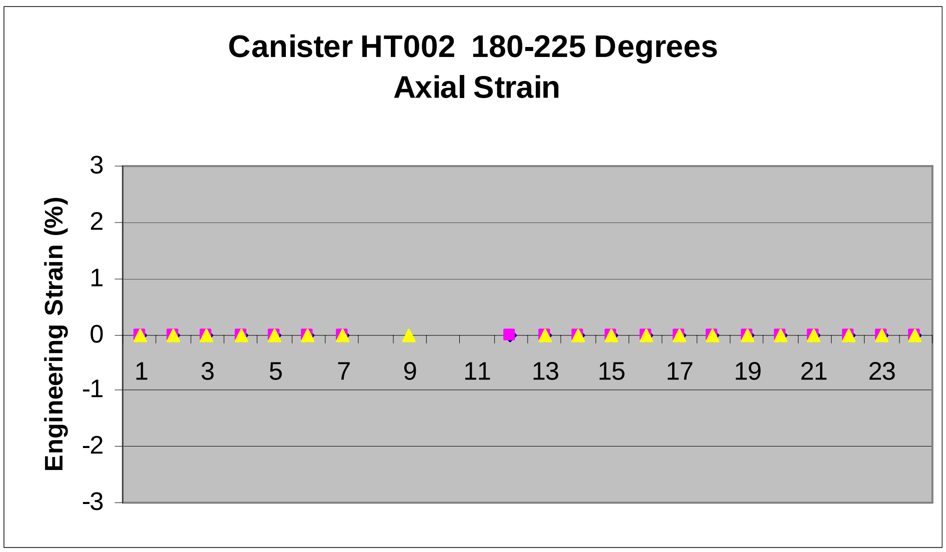
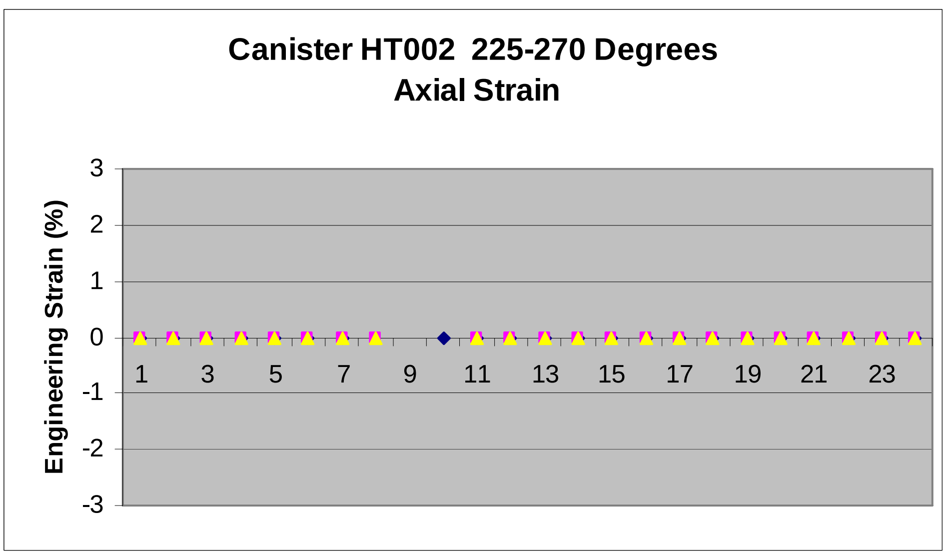
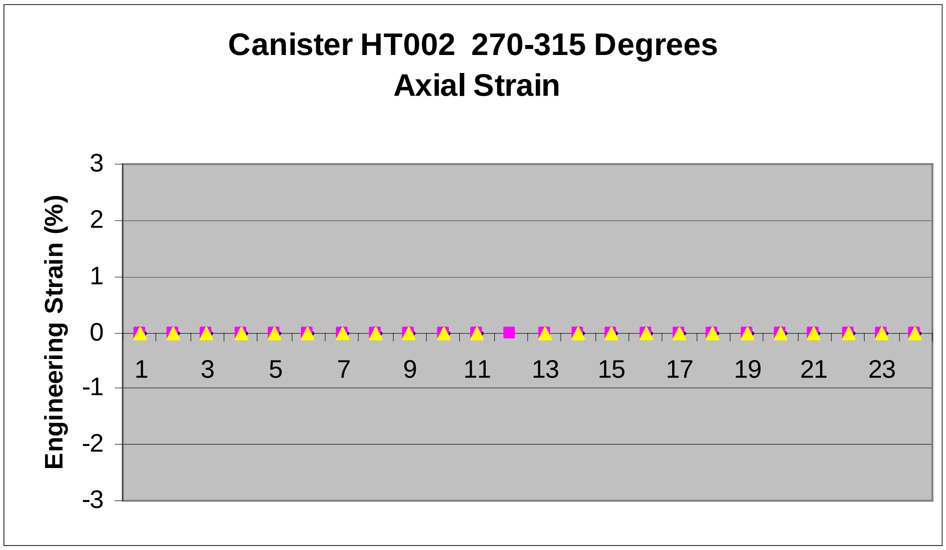
9
11
13
15
17
19
21
23

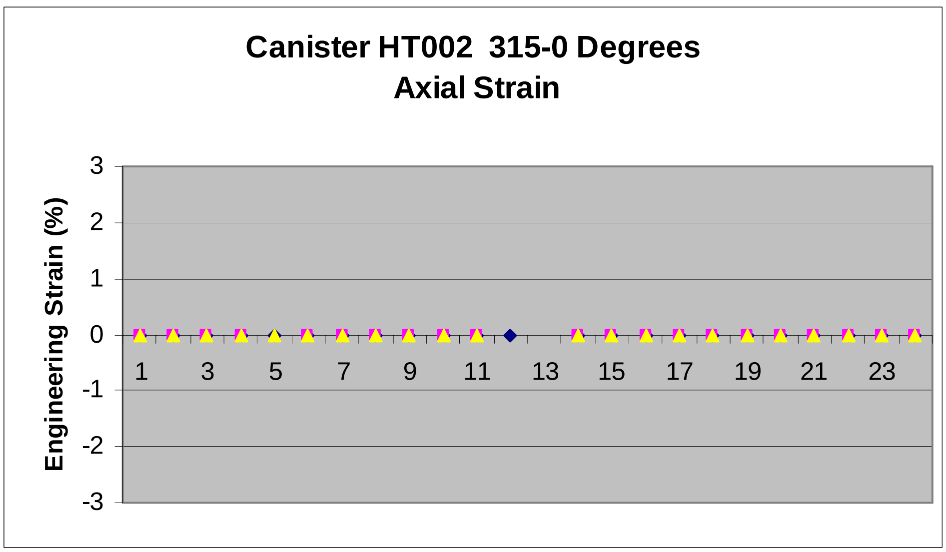

Canister HT002 90-135 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

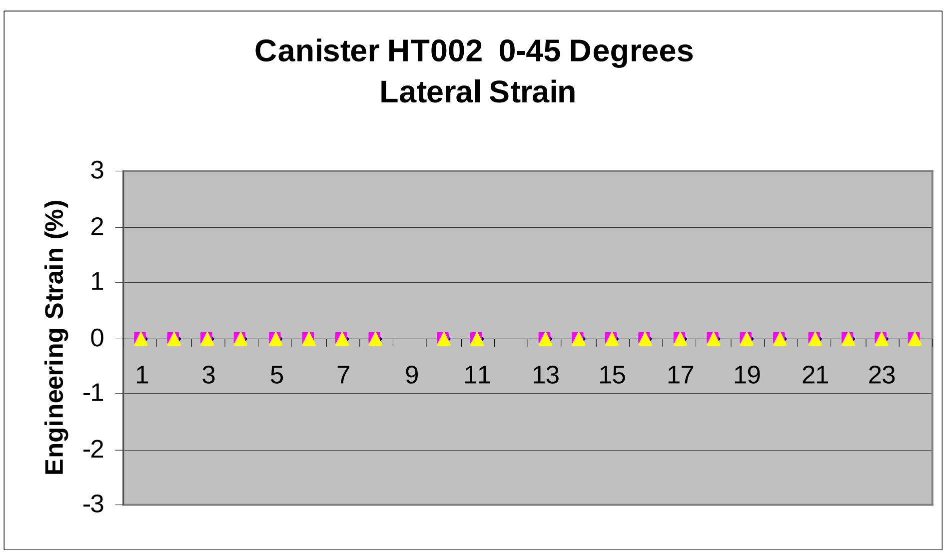

Canister HT002 135-180 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

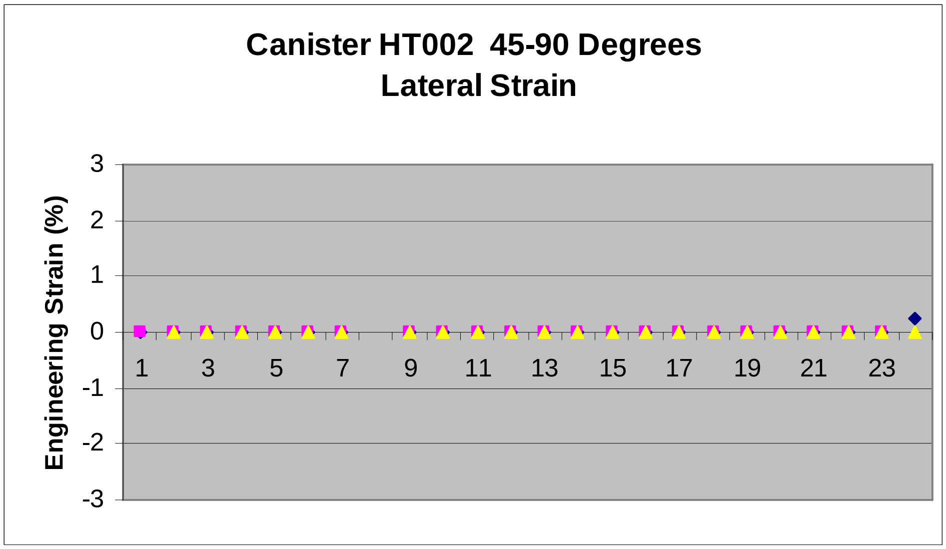

Canister HT002 180-225 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

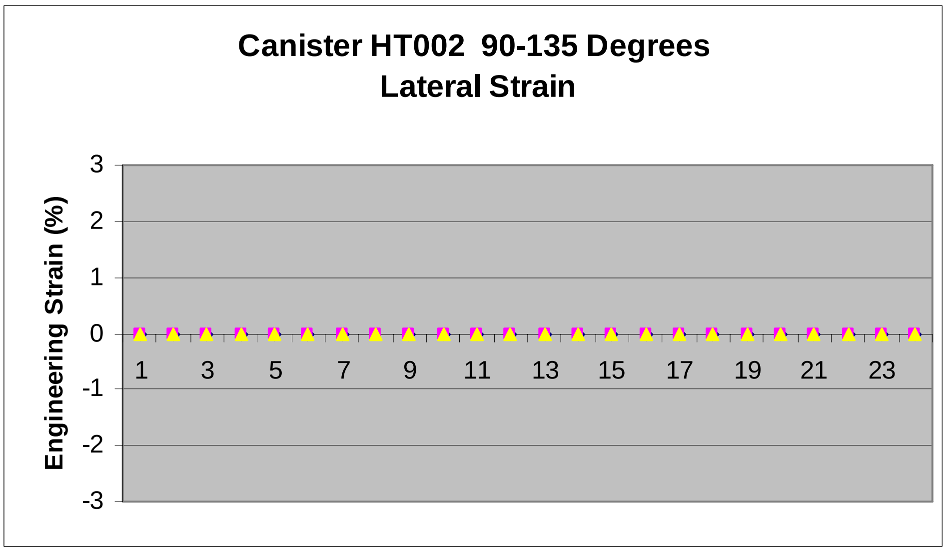

Canister HT002 225-270 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

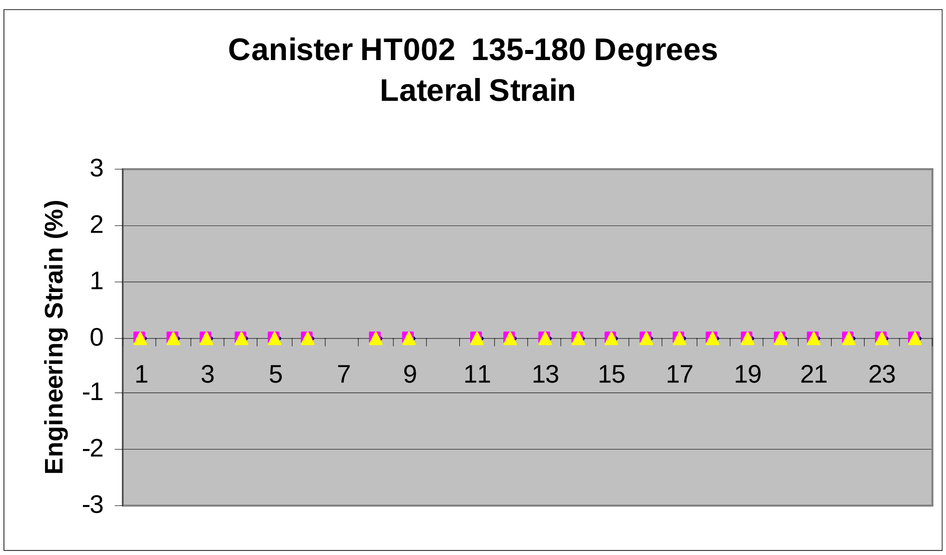

Canister HT002 270-315 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

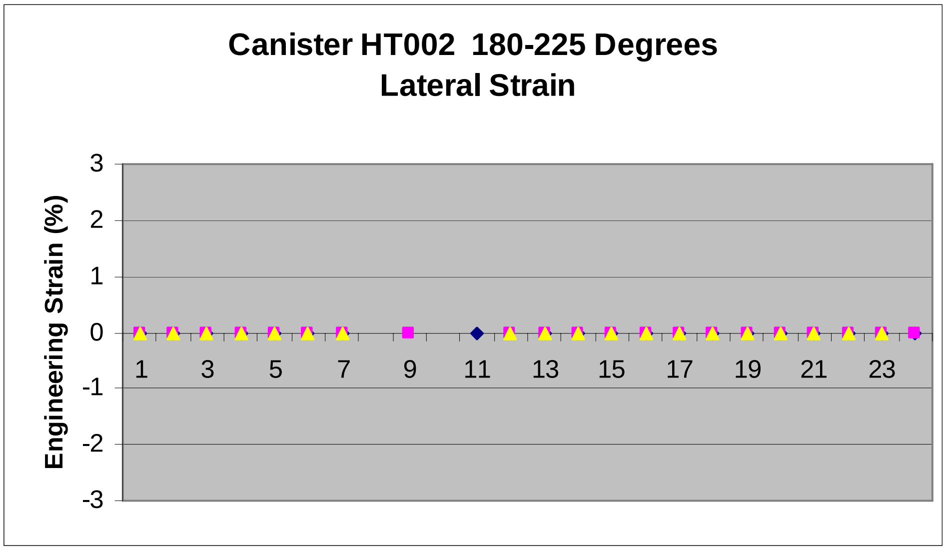

Canister HT002 315-0 Degrees
Axial Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

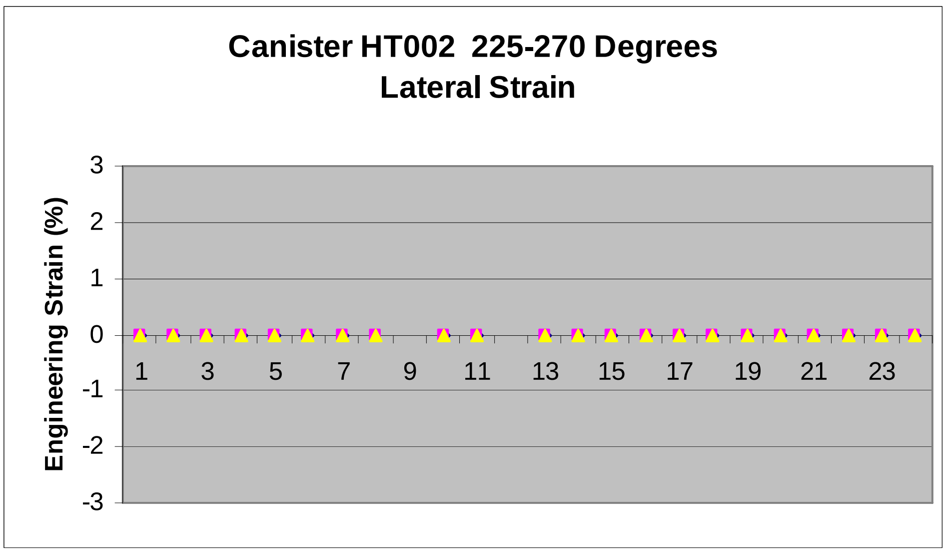

Canister HT002 0-45 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

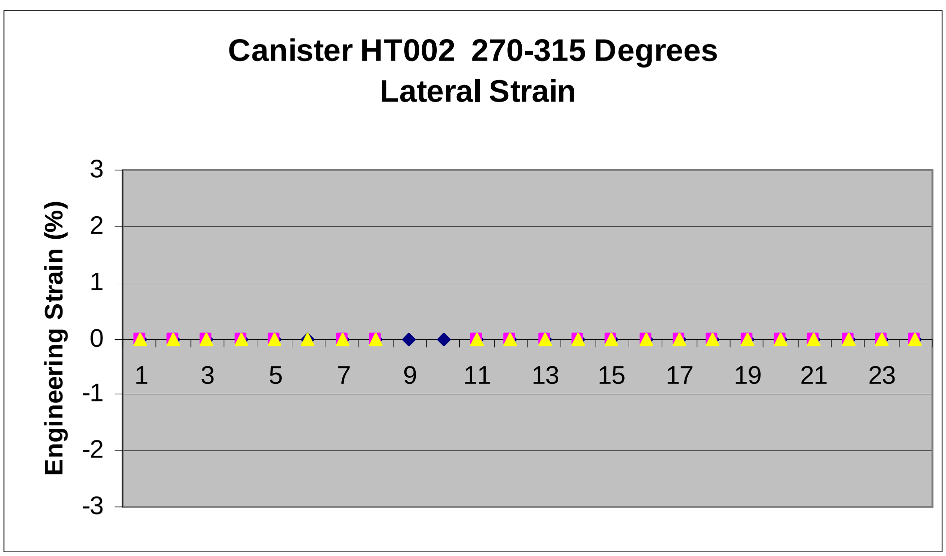

Canister HT002 45-90 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23

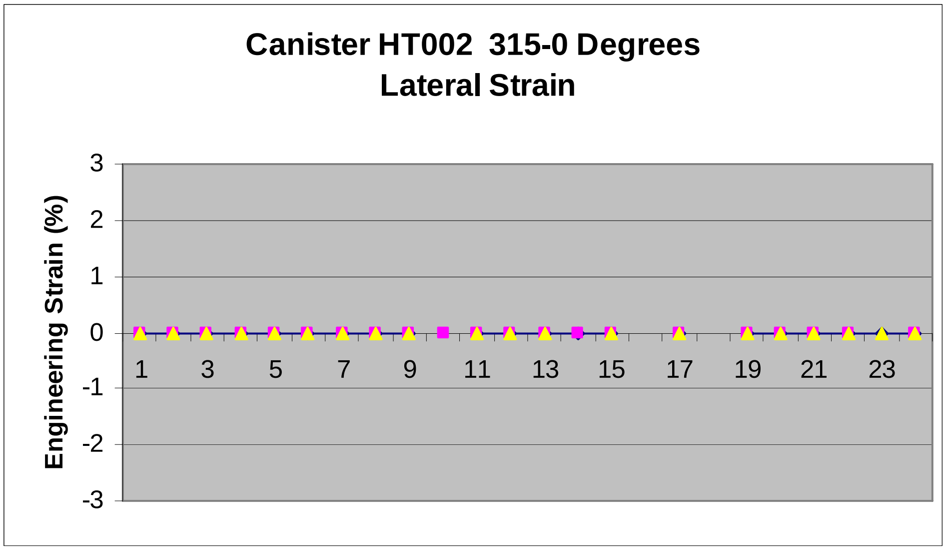

Canister HT002 90-135 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 135-180 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 180-225 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 225-270 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 270-315 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
3
5
7
9
11
13
15
17
19
21
23


Canister HT002 315-0 Degrees
Lateral Strain
Engineering Strain (%)
3
2
1
0
-1
-2
-3
1
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23

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