PACTEC

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Test Report for Compacted Drums TR-017

Prepared for:
Washington TRU Solutions, LLC

Contract # 106311 Task 7

PacTec Job # 20307

PacTec Document TR-017 Rev. 0
March 2004

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Packaging Technology, Inc.			
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TABLE OF CONTENTS

1.0 INTRODUCTION

This Test Report is in support of TRUPACT-II licensing activities pertaining to the proposed loading and shipment of compacted drum "pucks" in 55-gallon, 85-gallon, and 100-gallon drum overpack configurations.

This testing program is intended to demonstrate to the Nuclear Regulatory Commission (NRC) that compacted drum pucks, when appropriately configured with spacers installed within the drums in a TRUPACT-II packaging, can withstand the regulatory Hypothetical Accident Conditions (HAC) 30-foot free drop test described in 10 CFR §71.73 (Reference 1) without loss of position of the drum overpack lids or a reduction in the axial spacing under the assumed distances used in the current criticality evaluation. The free drop is onto a flat, essentially unyielding, horizontal surface with the package striking the surface in a position to maximize the damage expected.

Two sizes of compacted drums assemblies were tested: (1) 30-gallon pucks inside 55-gallon drum overpacks, and (2) 55-gallon pucks inside 100-gallon drum overpacks. Of note, the 55-gallon drum overpacks and 100-gallon drum overpacks will bound the 85-gallon drum overpack configuration. The ability of the drum overpacks to adequately withstand the above-specified free drop condition was demonstrated by dropping a TRUPACT-II Inner Containment Vessel (ICV) assembly loaded with puck-filled drum overpacks. The TRUPACT-II Outer Containment Assembly (OCA), with its energy absorbing polyurethane foam, is conservatively omitted from this testing. The puck-filled drum overpacks included three different configurations to determine the adequacy of using no spacers (baseline), a metal grate spacer, or a grout-filled spacer.

The test plan, test engineering and quality assurance (QA) oversight were conducted by Packaging Technology, Inc. (PacTec), in accordance with the PacTec 10 CFR 71, Subpart H QA Program, under the direction of Washington TRU Solutions, LLC (WTS). All tests were conducted at Westinghouse Engineered Products Department (WEPD) in Carlsbad, New Mexico. Drops were performed on an unyielding surface (Reference 8). Testing was documented via video and still photography (see Appendix D) to provide a visual record of events.

2.0 REFERENCES

1. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material*, 01-01-02 Edition.

2. International Atomic Energy Agency (IAEA), Safety Standards Series No. TS-G-1.1 (ST-2), *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, International Atomic Energy Agency, Vienna, 2002.

3. WTS Drawing No. 165-F-015-W Rev. NEW, *GRATE SPACER, 100-GAL DRUM ASSEMBLY.*

4. WTS Drawing No. 165-F-013-W Rev. NEW, *GROUT SPACER, 100-GAL DRUM ASSEMBLY.*

5. WTS Drawing No. 165-F-014-W Rev. NEW, *GRATE SPACER, 55-GAL DRUM ASSEMBLY.*

6. WTS Drawing No. 165-F-012-W Rev. NEW, *GROUT SPACER , 55-GAL DRUM ASSEMBLY.*

7. Packaging Technology, Inc., 2003, *Test Plan for Compacted Drums*, TP-037, Revision 0.

8. Westinghouse Electric Co., 1998, *Engineering Specification for Drop Test Pad for Type A Performance Testing*, ES-A-001, Revision 0.

9. WTS, 2003, *TRUPACT-II Safety Analysis Report,* Rev. 20, Section 6.3.1.4, Case D Contents Model.

10. Packaging Technology, Inc., 2004, DVD, *T-2 Compacted Drum Drop.*

3.0 TEST PLAN

All testing was conducted in accordance with *Test Plan for Compacted Drums*, TP-037, Revision 0 (Reference 7). Test spacers were fabricated in accordance with WTS drawings (References 3 – 6), and other test items were fabricated per the sketches provided in the test plan. Prior to testing, key characteristics of the test items were verified to ensure that the test items met drawing and/or test plan design/material/configuration requirements (see Appendix A). Written data sheets per TP-037 were used and the completed data sheets are included in Appendix B. Deviations from the plan are discussed where appropriate in this report, and are also summarized in Appendix C. These deviations were the result of lessons-learned as the testing progressed. All deviations were approved by the test engineer, QA representative, and WTS witness as required by the test plan, TP-037, Revision 0, Section 7.0 (Reference 7).

4.0 ACCEPTANCE CRITERIA

The purpose of the compacted drum drop testing was to determine whether adequate spacing will remain between the top and bottom overpack drum/puck combination in each axial set following the regulatory Hypothetical Accident Conditions 30-foot free drop test described in 10 CFR §71.73. The testing included a comparison of the performance of the "no spacer" configuration with the "grout" and "grate" spacer configurations, with direct measurements used to determine the axial spacing between the bottom puck in the top overpack drum, and the top puck in the bottom overpack drum.

The necessary axial drum spacing is defined in the current criticality evaluation presented in the *TRUPACT-II Safety Analysis Report,* Rev. 20, Section 6.3.1.4, Case D Contents Model (Reference 9). In summary, the criticality analysis model includes two cylinders of fissile material with 0.06 inch thick steel representing 50% of the thickness of the steel in the lid of the lower puck and overpack drum, 0.15 inch thick polyethylene representing 50% of the thickness of the TRUPACT-II ICV payload assembly slip-sheet and reinforcing plate, and another 0.06 inch thick layer of steel representing 50% of the thickness of steel in the bottom of the upper puck and overpack drum. In addition, the contents model also incorporates a 0.50 inch of separation between the pucks when the packing fraction of polyethylene in the pucks exceeds 70%.

Therefore, the post drop test evaluation needed to confirm that a total of 0.12 inch of steel, 0.15 inch of polyethylene, and an additional 0.50 inch separation existed following the drop testing. The test plan provided a means to determine the 0.50 inch spacing, by taking differential measurements of the facing (top to bottom) axial pucks and corresponding drum pan sections, obtain a resultant sum, and then subtract the slip-sheet, reinforcing plate, and drum pan thickness. Acceptance criteria would be met if the resultant spacing exceeded 0.50 inch. Overpack drum lids may become unattached from their corresponding drum body, but must remain in relative position over the drum. In addition, the slipsheets must remain between the pucks in axially adjacent drums.

5.0 DESCRIPTION OF TEST ARTICLES AND FACILITIES

Test preparation, drop testing and dimensional evaluation was conducted at Westinghouse Engineered Products Department (WEPD), Carlsbad, NM, from February 2 – 5, 2004.

Packaging Technology, Inc. (PacTec) provided project management, contract management and oversight of fabrication and test services, test engineering and Quality Assurance Engineer (QAE) support to the subject drop test in accordance with their NRC 10 CFR 71, Subpart H Quality Assurance (QA) Program. Key test item characteristics were verified by the PacTec test engineer and QAE prior to assembly of the test articles, as reported in Appendix A. In addition, a fabrication data package for the WEPD-prepared test articles was completed as required by the PacTec QA program.

WEPD provided the test facility, drop test pad, crane and personnel to conduct the testing. The WEPD drop test pad meets IAEA (Reference 2) requirements, as documented by *Engineering Specification for Drop Test Pad for Type A Performance Testing*, ES-A-001 (Reference 8). WEPD fabricated and/or prepared the following test items:

- Modified ICV test articles, in accordance with Section 5.3 of Test Plan TP-037 (Reference 7). Two ICVs were configured: one for 100-gallon drums, the other for 55-gallon drums. Modifications included the welding of stiffener plates on the bottom of the ICV to spread the impact load across the bottom and thus simulate the effect of dropping the ICV inside the Outer Containment Vessel (OCV, as discussed in TP-037, Section 6.2.1). The locking rings were not used; therefore, the lids were welded to the ICV bodies. The lower aluminum honeycomb spacer was used in the bottom of the 100-gallon ICV test article, whereas an upper aluminum honeycomb spacer (there is only approximately one inch difference in axial height between the spacers) was used in the bottom of the 55-gallon ICV test article. Both ICV test articles utilized a wooden spacer at the top, which provided a conservatively rigid support to restrain the palleted drum sets. Standard production pallets and polyethylene reinforcement plates and slip-sheets were utilized in the test.
- Surrogate drum payload pucks, in accordance with the Test Plan TP-037 (Reference 7). These concrete/steel pucks were used in the 55-gallon drum test articles to simulate the size and weight of crushed 30-gallon drum payload pucks.

- 100-gallon grate spacers, fabricated in accordance with WTS Drawing No. 165-F-015-W (Reference 3).
- 100-gallon grout spacers, fabricated in accordance with WTS Drawing No. 165-F-013-W (Reference 4).
- 55-gallon grate spacers, fabricated in accordance with WTS Drawing No. 165-F-014-W (Reference 5).
- 55-gallon grout spacers, fabricated in accordance with WTS Drawing No. 165-F-012-W (Reference 6).
- 100-gallon removable head drums, prepared in accordance with Section 5.1 of the Test Plan TP-037 (Reference 7). The drums and their corresponding crushed 55-gallon payload pucks, known as documented surrogate waste drums (DSW), were supplied by the Idaho National Engineering and Environmental Laboratory (INEEL). The lids and bodies were nominally 0.055-inch thick, carbon steel. Drums were clearly marked to track their position: drums 1L – 3L were in the bottom row; drums 1U – 3U were in the upper row. Two, 100-gallon drum overpacks (1U, 1L) had only DSW drums installed. Two, 100-gallon drum overpacks (2U, 2L) had a grated spacer installed at their bottom, prior to loading DSW drums. Two, 100-gallon drum overpacks (3U, 3L) had a grouted spacer installed at their bottom, prior to loading DSW drums. See Figure 1 for drum positioning.
- 55-gallon removable head drums, prepared in accordance with Section 5.2 of the Test Plan TP-037 (Reference 7). The lids and bodies were nominally 0.046-inch thick, carbon steel. Drums were clearly marked to track their position: drums 1L – 7L were in the bottom row; drums 1U – 7U were in the upper row. Six, 55-gallon drum overpacks had only surrogate pucks installed (1L, 2L, 3L, 4L, 5L, 5U). Two, 55-gallon drum overpacks had a grated spacer installed at their bottom, prior to loading surrogate pucks (6L, 6U). Two, 55-gallon drum overpacks had a grouted spacer installed at their bottom, prior to loading surrogate pucks (7L, 7U). The remaining four, 55-gallon drums were empty (1U, 2U, 3U, 4U), acting as dunnage to maintain the initial drum configuration. See Figure 2 for drum positioning.

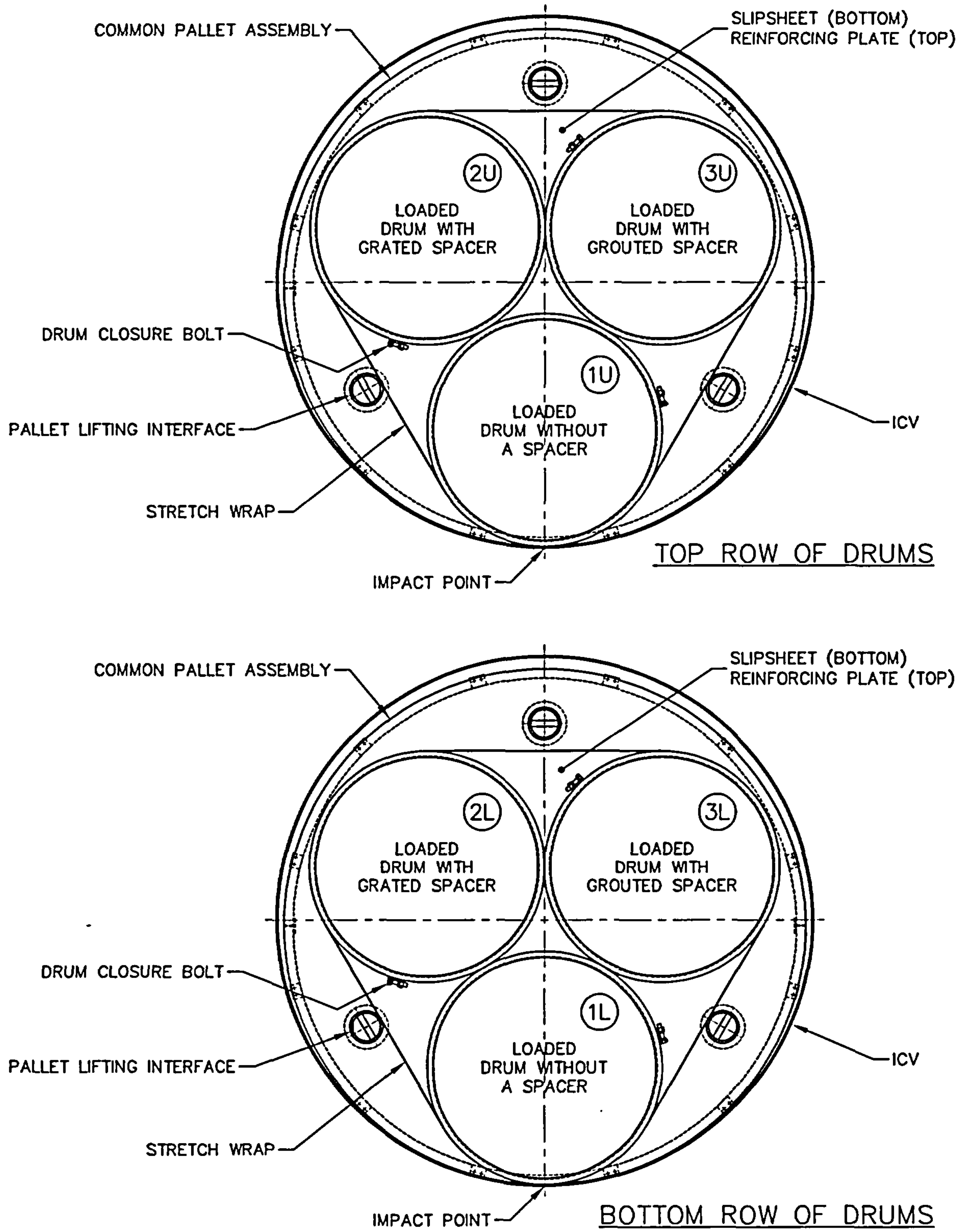
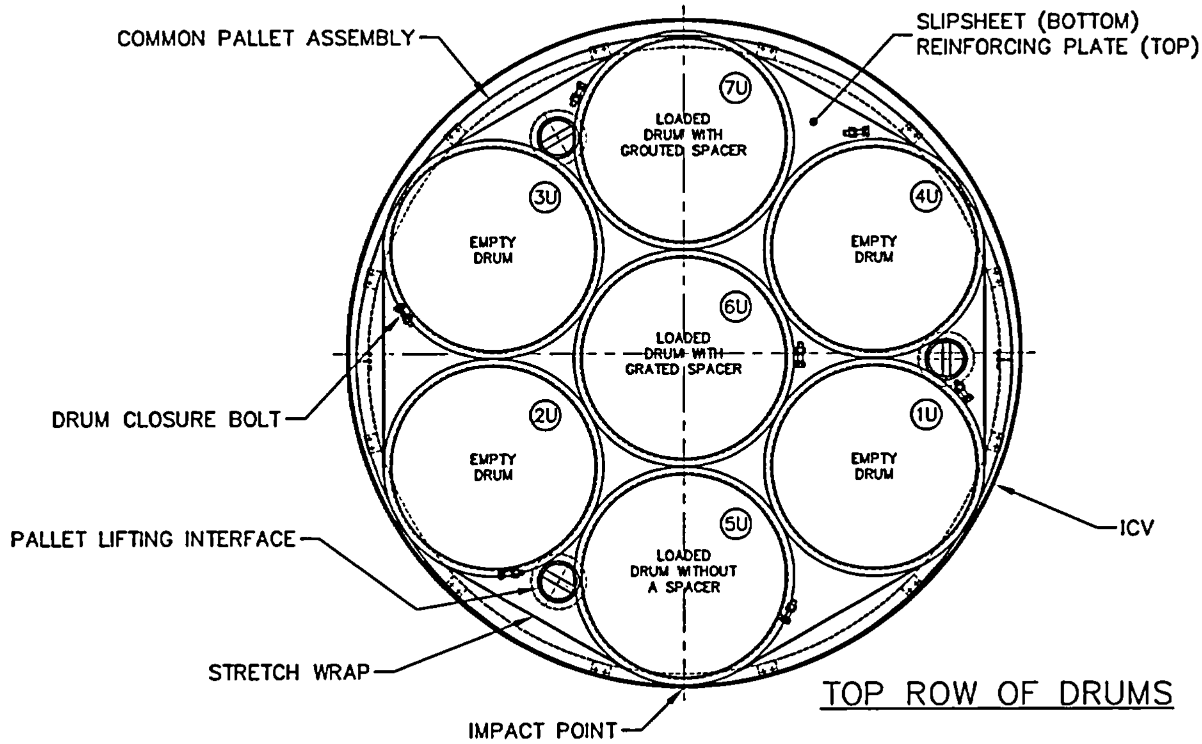
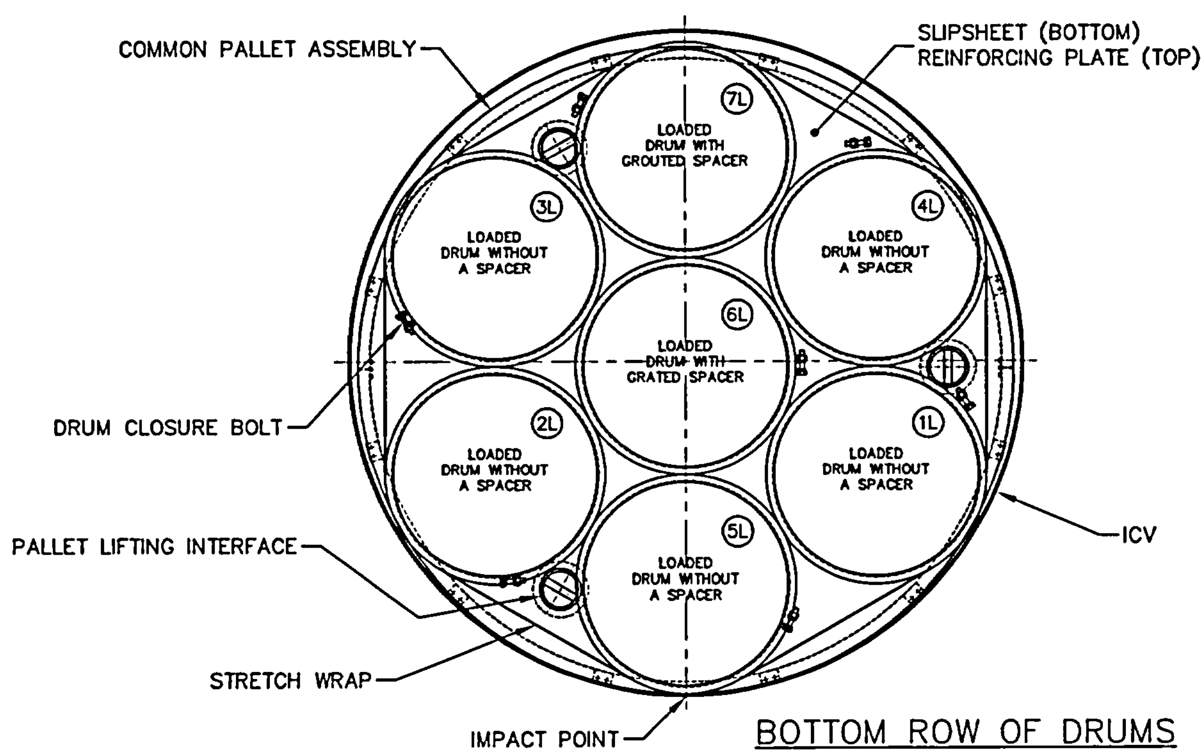


Figure 1 – Pre-Drop Orientation of 100-Gallon Drum Overpacks



TOP ROW OF DRUMS



BOTTOM ROW OF DRUMS

Figure 2 – Pre-Drop Orientation of 55-Gallon Drum Overpacks

As specified in the test plan, all test unit assembly and payload items were weighed with a calibrated scale in accordance with Section 7.1 of TP-037. Appendix A, Data Sheets 1.1 and 1.2 provides the individual component weights of the 100-gallon test units and 55-gallon test units, respectively. All individual drum overpack assemblies approached but did not exceed 1,000 lb, as limited by the TRUPACT-II SAR. See Table 1 for a weight summary.

Table 1 – Test Unit Weight Summary

100-Gallon Test Unit	
ICV and Related Components	2,962 lbs
6, 100-Gallon Drum Overpack Assemblies	5,680 lbs
Total Test Unit Weight	8,642 lbs
55-Gallon Test Unit	
ICV and Related Components	2,948 lbs
14, 55-Gallon Drum Overpack Assemblies	9,962 lbs
Total Test Unit Weight	12,910 lbs

6.0 SUMMARY OF TESTING RESULTS

The following is a summary of the test results, in the general order of their completion. See Appendix B, *Data Sheets*, for detailed notes and observations. Approved deviations from the plan are summarized in Appendix C. Video coverage of the drops is available (Reference 10); selected digital photos of key points in the testing are provided in Appendix D.

6.1 Preparation Prior to Free Drop Tests

The 100-Gallon and 55-Gallon Test Units were prepared as discussed in Section 5.0 above. Marks were made on each test unit ICV prior to welding the lid, to specify the correct impact point for the side drop (see Figures 1 and 2).

Six, 100-gallon drum overpacks were installed inside the ICV of the 100-Gallon Test Unit in a standard configuration: 3 drums on a lower, polyethylene slip-sheet and restrained by an upper, flat polyethylene reinforcing plate, and 3 drums on a lower, polyethylene slip-sheet and restrained by an upper, flat polyethylene reinforcing plate, all wrapped with plastic stretch wrap to stabilize the assembly on a standard pallet. The orientation of the differently configured drums, as installed within an ICV, is shown in Figure 1.

Fourteen, 55-gallon drum overpacks were installed inside the ICV of the 55-Gallon Test Unit in a standard configuration: 7 drums on a lower, polyethylene slip-sheet and restrained by an upper, flat polyethylene reinforcing plate, and 7 drums on a lower, polyethylene slip-sheet and restrained by an upper, flat polyethylene reinforcing plate, all wrapped with plastic stretch wrap to stabilize the assembly on a standard pallet. The orientation of the differently configured drums, as installed within an ICV, is shown in Figure 2.

6.2 Thirty Foot Free Drop Tests

Thirty foot free drops of the 100-Gallon and 55-Gallon Test Units were conducted in accordance with TP-037, Sections 7.2 and 7.3, respectively. For both Test Units, the vertical drop preceded the horizontal drop, for a total of four drops (two drops for each Test Unit). The ICVs were not opened between drops. An inclinometer was used to ensure the Test Unit ICVs were square on the drop pad within 2°. Drop testing temperature ranged from 43°F to 45°F, and wind speed was essentially calm (less than 5 mph).

For all four drops, the Test Units struck the drop pad squarely, with no significant rolling or secondary impacts. The vertical drop of the 100-Gallon Test Unit landed at a very slight angle, but not to such a degree that there was a concern about loss of axial loading in the internal drum overpacks.

Damage to the Test Unit ICVs was noted in the corresponding data sheet for each drop test (Appendix B, Data Sheets 2.1 through 3.2). As expected, damage to the exterior of the ICVs was generally of a buckling nature for the vertical drops, and of a crushing nature for the horizontal drops. There was no release of internal components and all lid welds remained in place, thus indicating maximum loading to the drum overpacks (i.e., no excessive loss of energy attributed to gross failure of the ICV).

6.3 Post-Test Disassembly and Evaluation

Following drop testing, the 100-Gallon and 55-Gallon Test Units were disassembled, with photographic coverage to document condition of each item upon removal from the ICV (see Appendix D). In general, the damage to the drum overpacks in both Test Units was severe – the vertical drop produced significant crushing of the bottom layer of drum overpacks; the side drop produced significant bending and "curling" of the drum lids to the point that openings were observed. In no case were any drum lids completely lost. All drum overpack lids remained on top of their corresponding drum body, albeit with significant openings from the side drop, thus meeting Section 4.0 criteria for no loss of lid position. In addition, all polyethylene reinforcement plates and slip-sheets remained in position, with no rips or loss of thickness based on visual observation.

The bottom honeycomb spacers crushed approximately 20% for the 100-Gallon Test Unit, and approximately 50% for the 55-Gallon Test Unit. This was determined by comparing the measured residual height of the spacer after the drop (Appendix B, Post Drop Notes Data Sheet) with the height provided on the TRUPACT-II drawing of the spacer. As the total weight of the 55-Gallon drum overpack assemblies were roughly twice that of the 100-Gallon drum overpack assemblies (see Table 1), this result generally indicates that both Test Units produced similar g-loads to the internals in the drop test.

Section 7.4 of test plan TP-037 provided a detailed procedure for differential measurement of the top-to-bottom axial spacing between the drum overpack payload pucks. An attempt was made to utilize this procedure, starting with the 100-Gallon Test Unit's top drum with grated spacer (drum 2U) and top drum with grouted spacer (drum 3U). Appendix B, Data Sheets 4.2 and 4.3, reports the measurements. It became apparent, due to the non-uniform damage caused by the side drop, that the differential measurement technique of the test plan would provide ambiguous results. This was especially the case for the "no spacer" drums, as the tops and bottoms suffered significant non-symmetric bending damage.

Therefore, an approved modification to the test plan was implemented, to take direct measurements of the spacers themselves. Both Test Unit's grate and grout spacers suffered only superficial damage from the tests (e.g., slight bending of plate; spalling of grout). As noted in Appendix A, both the grout and grate spacers remained at or near their as-fabricated height of 0.9 to 1.1 inch (slightly exceeding the nominal 0.89 inch dimension given by the drawings), with no significant change observed from the pre-drop measurements.

Further direct measurements were made on the drums to determine high-low heights for the lower drum rows (see last page of Appendix B). Also, measurements were made to determine "coining effects" and distances of the internal payload pucks from the top of the drums. It was apparent, from the measurements and observations, that the "no spacer" drums nested together in the vertical drop to the point that residual spacing of greater than 0.5 inch could not be assured. For example, the payload puck in the lower 55-gallon "no spacer" drum (drum 5L) was essentially in contact with the inside surface of the drum lid.

The conclusion was drawn that either the grate or grout spacers should be used to ensure adequate axial spacing under HAC, for both the 100-Gallon and 55-Gallon configurations. The post-drop condition of the spacers (no change in height after drop), combined with the intact drum lids/bottoms, slip sheets and reinforcing plates, indicates that the design criteria of Section 4.0 would be met. Greater than 0.50 inch additional spacing can be assured with the spacers, as the thickness of the spacer's steel pan (nominally 0.1345 inch, References 3 - 6) provides the steel thickness assumed in the criticality analysis (0.12 inch, minimum, Reference 9) and the remaining thickness of the grout or grate insert to the pan (nominally 0.75 inch, References 3 - 6) provides 0.25 inch more than the 0.50 inch minimum additional separation that is required by the criticality analysis (Reference 9).

7.0 APPENDICIES

A. Test Item QA Verification Data and Post-Drop Spacer Height

B. Data Sheets

C. Deviations from Test Plan

D. Test Photos

APPENDIX A
Test Item QA Verification Data and Post-Drop Spacer Height

(2 SHEETS TOTAL)

Load cell LCD-007 due 2/19/04
12" calipers CD-086 due 9/9/04

Project 20307, Quality Categorization of Drop Test Items, January 27, 2004, Page 2

1" Mic MO-036 due 2/19/04
3" throat Mic MO-038 due 5/12/04

Test Item Characteristics for Verification [Lower & uppers]

After Drop.

Test Item	Reference	Characteristics to be Verified
55-Gallon Grate Spacer	WTS Drawing 165-F-014-W	1. Plate diameter: 18.00-in 18.125, ~~18.0625~~ 18-1/16" 2. Plate height: 0.89-in < .920 - 1" w/Air 385 3. Plate thickness: 10-ga .132 4. Grate diameter: 16.5-in 5. Plate material: by CMTR 6. Grate material: by CMTR or COC or similar data 7. Grate dimensions: ¾ x 1/8-in bearing bar, ¼-in cross bar 8. Welds in place
55-Gallon Grout Spacer	WTS Drawing 165-F-012-W	1. Plate diameter: 18.00-in -18 1/8, 18 1/8 - 17 15/16 - 18 1/16 2. Plate height: 0.89-in .80 - 1.020 3. Plate thickness: 10-ga 4. Grout material: by CMTR or COC or similar data 5. Verify 7-day cure Poured Mon/1st Mon
100-Gallon Grate Spacer	WTS Drawing 165-F-015-W	1. Plate diameter: 26.00-in 26.0 - 26 1/8 2. Plate height: 0.89-in 1.0 - 1.050 w/Air 385 3. Plate thickness: 10-ga .132 4. Grate diameter: 24.5-in 24.5 5. Plate material: by CMTR 6. Grate material: by CMTR or COC or similar data 7. Grate dimensions: ¾ x 1/8-in bearing bar, ¼-in cross bar 8. Welds in place
100-Gallon Grout Spacer	WTS Drawing 165-F-013-W	1. Plate diameter: 26.00-in 26.0 - 26 1/8 2. Plate height: 0.89-in .90 - 1.025 3. Plate thickness: 10-ga 4. Grout material: by CMTR or COC or similar data 5. Verify 7-day cure poured last Mon
Modified TRUPACT-II ICV	Test Plan TP-037, Figures 10 & 11	1. Reinforce plate height: 10-in at side, 1-in at center 10" & 1½" 2. Reinforce plate thickness: 3/8-in 3. Reinforce plate radius: 34-in 4. Configuration of reinforcement correct; welds in place 5. Lifting devices in accordance with Options 1 or 2 or WTS approved equivalent; any welds full length, ¼-in fillet minimum 6. Internal components to ICV (e.g., honeycomb, pallet, etc.) correct and in serviceable condition
55-Gallon Drums	Test Plan TP-037, Section 5.2	1. Body 18-ga minimum .046 2. Lid 16-ga minimum .046 3. Meets UN Spec: by COC or similar data 4. Confirm drums are in good condition (no significant damage, holes, or rust)
100-Gallon Drums	Test Plan TP-037, Section 5.1	1. Obtain body and lid thickness for records .055/.055 2. Confirm drums are in good condition (no significant damage, holes, or rust) and include compacted drum payloads
Payload Weight Pucks	Test Plan TP-037, Figure 4	1. Diameter: 18-in (verify sample) 2. Height: 7-1/4 to 7-1/2-in (verify sample) 7 7/16 - 7 5/16 3. Weight: 235 to 240 lbs, may be verified collectively when loaded in drums
ICV Wood Spacer	Test Plan TP-037, Figure 13	1. Center height: 11-1/4-in 2. Side height: 8-7/8-in sloped to 7-7-8-in 3. Center to side: 20-1/2-in 4. Square: 48-in on a side 5. Diagonal length: 26-13/16-in 6. Dimensioned lumber centered on ¾-in plywood

upper grate 55
.9 - 1.05

upper grate 100
.1.0 - 1.1

upper grout 100
1.0 - 1.1

upper grout 55
.9 - 1.0

HGU-001
due 2/3/05

Test Eng.
R.J. Smith
2/4/04

QAE:
[illegible]
2/4/04

[1]Apply tolerances as specified in corresponding reference document, otherwise consider dimensions as nominal.

PacTec

Summary of Post-Drop Spacer Height[1]

Spacer Type	Pre-Drop Heights (inches)[2] Average, for top and bottom spacers	Post-Drop Heights (inches)[2] Range, for top spacers only
55-Gallon Grate Spacers	0.920 – 1.000	0.90 – 1.05
55-Gallon Grout Spacers	0.900 – 1.020	0.90 – 1.00
100-Gallon Grate Spacers	1.000 – 1.050	1.00 – 1.10
100-Gallon Grout Spacers	0.900 – 1.025	1.00 – 1.10

[1]Raw measurement data shown in previous page of this appendix, dated 2/4/04.

[2]Significant figures vary depending on type of measurement instrument used.

APPENDIX B
Data Sheets

(10 SHEETS TOTAL)

DATA SHEET 1.1 – Component Weights, 100-Gallon Drum Overpacks

Instrumentation Records[1]

Load Cell/Scale Description	Serial Number	Calibration Due Date
Load Cell	LCD-007	8/19/04
N/A	N/A	N/A
N/A	N/A	N/A

ICV Component Weights (lbs)

Lid	Body	Upper Spacer	Lower Spacer	Pallet – 4 slipsheets	Total Assembly
583	2032	71	80	196	2962

Lower Row, Drum Overpack Weights [2] (lbs) 4 slipsheets

Without Spacer, No 1	With Grated Spacer, No 2	With Grouted Spacer, No. 3	Total
905	944	980	2829

Upper Row, Drum Overpack Weights [2] (lbs)

Without Spacer, No. 1	With Grated Spacer, No 2	With Grouted Spacer, No. 3	Total
~~897~~ 904	947	1000	2851

Test Engineer and Witness Records

Signature	Printed Name	Date
Test Engineer Signature: [signature]	Richard J. Smith	2/3/04
Witness Signature: [signature]	Kevin King	2/3/04

Notes:

① If multiple load cells/scales are utilized, denote the corresponding component(s) that each load cell/scale was used to measure.

② Drum overpack weights include the weight of a 100-gallon drum, documented surrogate waste (DSW) drums, and a spacer (if used).

DATA SHEET 1.2 – Component Weights, 55-Gallon Drum Overpacks

Instrumentation Records①

Load Cell/Scale Description	Serial Number	Calibration Due Date
Load Cell	LCD-007	8/19/04
N/A	N/A	N/A
N/A	N/A	N/A

ICV Component Weights (lbs)

Lid	Body	Upper Spacer	Lower Spacer	Pallet	Total Assembly
582	1991	74	85	216	2948

Lower Row, Drum Overpack Weights ②(lbs) including 4 slipsheets.

Without Spacer, No. 1	Without Spacer, No. 2	Without Spacer, No. 3	Without Spacer, No. 4
960	969	966	~~969~~ 960

Without Spacer, No. 5	With Grated Spacer, No. 6	With Grouted Spacer, No. 7	Total
970	984	994	6803

Upper Row, Drum Overpack Weights ②(lbs)

~~Without Spacer~~ EMPTY, No. 1	~~Without Spacer~~ EMPTY, No. 2	~~Without Spacer~~ EMPTY, No. 3	~~Without Spacer~~ EMPTY, No. 4
51	51	51	51

Without Spacer, No. 5	With Grated Spacer, No. 6	With Grouted Spacer, No. 7	Total
979	979	997	~~3144~~ 3159

Test Engineer and Witness Records

Test Engineer Signature	Printed Name	Date
[signature]	Richard J. Smith	2/3/04

Witness Signature	Printed Name	Date
[signature]	Kevin King	2/3/04

Notes:

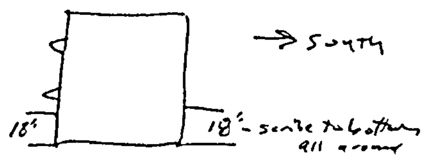
① If multiple load cells/scales are utilized, denote the corresponding component(s) that each load cell/scale was used to measure.

② Drum overpack weights include the weight of a 55-gallon drum, surrogate pucks (if used), and a spacer (if used).

DATA SHEET 2.1 – Test 1 with 100-Gallon Drum Overpacks, 30-Foot Vertical End Drop

Pre-Test Records

Record the Drop Configuration Using the Space Below



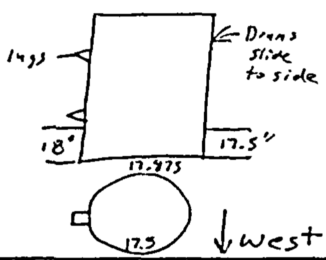
30'	*Drop Height*
0°	*Longitudinal Angle (0° = horizontal)*
N/A	*Circumferential Angle (0° = down; see Figure 8)*

Test Records

Ambient Temperature (°F)	Ambient Wind Speed/Direction (mph)	Test Time (hh:mm:ss)
44° F	0 - 2 mph	2/4/04 9:45 AM

Post-Test Records

Record Visible Damage Using the Space Below



Record Additional Comments Below or on a Separate Page

Buckeled side max 17.5" at bottom SW corner

No lid welds cracked.

Test Engineer and Witness Records

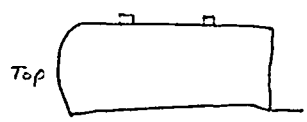
Signature	Printed Name	Date
[signature] *Test Engineer Signature*	Richard J. Smith *Printed Name*	2/4/04 *Date*
[signature] *Witness Signature*	Kevin King *Printed Name*	2/4/04 *Date*

DATA SHEET 2.2 – Test 2 with 100-Gallon Drum Overpacks, 30-Foot Horizontal Side Drop

Pre-Test Records

Record the Drop Configuration Using the Space Below

→ South



30' — *Drop Height*

0° — *Longitudinal Angle (0° = horizontal)*

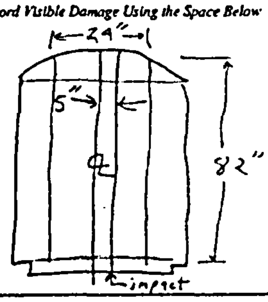
0° — *Circumferential Angle (0° = down; see Figure 8)*

Test Records

45°	0 – 2 mph	2/4/04 10:20 am
Ambient Temperature (°F)	*Ambient Wind Speed/Direction (mph)*	*Test Time (hh:mm:ss)*

Post-Test Records

Record Visible Damage Using the Space Below



Record Additional Comments Below or on a Separate Page

24" x 82" damage zone

Depth to be calc'd : 2 dym

5" from ℄ to impact "line"

No broken welds.

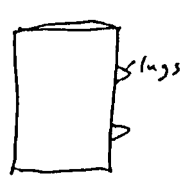
Test Engineer and Witness Records

[signature]	Richard J. Smith	2/4/04
Test Engineer Signature	*Printed Name*	*Date*
[signature]	Kevin King	2/4/04
Witness Signature	*Printed Name*	*Date*

DATA SHEET 3.1 – Test 1 with 55-Gallon Drum Overpacks, 30-Foot Vertical End Drop

Pre-Test Records

Record the Drop Configuration Using the Space Below



30′
Drop Height

0°
Longitudinal Angle (0° = horizontal)

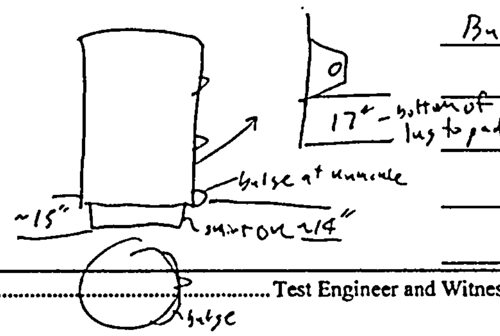
N/A
Circumferential Angle (0° = down; see Figure 9)

Test Records

44° F	0-2 mph	2/4/04 10:43 AM
Ambient Temperature (°F)	*Ambient Wind Speed/Direction (mph)*	*Test Time (hh:mm:ss)*

Post-Test Records

Record Visible Damage Using the Space Below



Record Additional Comments Below or on a Separate Page

Buckled ~ 8" above skirt weld.

No broken welds

Test Engineer and Witness Records

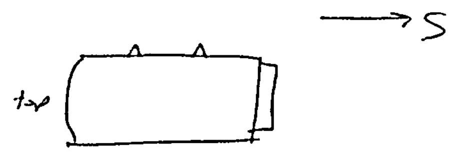
[signature]	Richard J. Smith	2/4/04
Test Engineer Signature	*Printed Name*	*Date*
[signature]	Kevin King	2/4/04
Witness Signature	*Printed Name*	*Date*

Test Plan for Compacted Drums TP-037, Rev. 0
December 2003

DATA SHEET 3.2 – Test 2 with 55-Gallon Drum Overpacks, 30-Foot Horizontal Side Drop

Pre-Test Records

Record the Drop Configuration Using the Space Below



30'
Drop Height

wet top
to bottom
impacts

~0°
Longitudinal Angle (0° = horizontal)

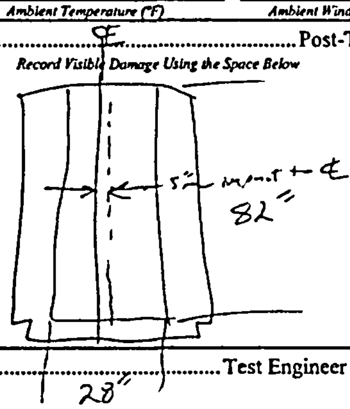
0°
Circumferential Angle (0° = down; see Figure 9)

Test Records

43° F	0-5 mph	2/4/04 11:12 AM
Ambient Temperature (°F)	*Ambient Wind Speed/Direction (mph)*	*Test Time (hh:mm:ss)*

Post-Test Records

Record Visible Damage Using the Space Below



Record Additional Comments Below or on a Separate Page

Buckled bottom rib on skirt
No broken welds
Drum ribs bulging thru.

Test Engineer and Witness Records

[signature]	Richard J. Smith	2/4/04
Test Engineer Signature	*Printed Name*	*Date*
[signature]	Kevin King	2/4/04
Witness Signature	*Printed Name*	*Date*

Page A-7
file: TP-037 R0

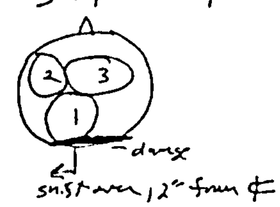
CONTINUATION DATA SHEET

Page 1 of 1

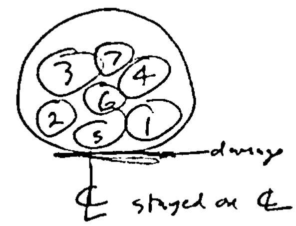
Post Drop Notes

Test Record

100-gal post drop



55-gal post drop



Observations on both ICVs:

- All poly sheets remained in place.
- All drum lids remained on top of its respective drum.
- Residual ht of 100-gal bottom honeycomb = 9.25"
- Residual ht of 55-gal bottom honeycomb = 6.5"

Test Engineer and Witness Records

Test Engineer Signature	Printed Name	Date
[signature]	Richard J. Smith	2-4-04

Witness Signature	Printed Name	Date
[signature]	Kevin King	2/4/04

Note: This form is not part of Test Plan TP-037; it is for continuation of TP-037 data sheets as necessary

DATA SHEET 4.2 – Axial Measurements, 100-Gallon Drum Overpacks with Grated Spacers

Instrumentation Records

Linear Measurement Device Description	Serial Number	Calibration Due Date
12" Height Gage	HGU-001	2/3/05

Bottom Drum, Puck Inside Drum (in) [see Step 1 in Figure 14]

Axial Measurement No. 1	Axial Measurement No. 2	Axial Measurement No. 3	(A) Average

Bottom Drum, Puck Outside Drum (in) [see Step 2 in Figure 14]

Axial Measurement No. 1	Axial Measurement No. 2	Axial Measurement No. 3	(B) Average

Top Drum, Puck Inside Drum (in) [see Step 1 in Figure 15] order: 1

Axial Measurement No. 1	Axial Measurement No. 2	Axial Measurement No. 3	(C) Average
4.925	5.320	6.025	5.4233

Top Drum, Puck Outside Drum (in) [see Step 2 in Figure 15] 2

Axial Measurement No. 1	Axial Measurement No. 2	Axial Measurement No. 3	(D) Average
3.91	RJS 2/4/04 3.84	4.22	3.99

Total Axial Spacing (in)

(A) Bottom Drum with Puck Inside Drum	–	(B) Bottom Drum with Puck Outside Drum	=	(E) Bottom Drum Upper Spacing
5.4233	–	3.99 RJS 2/9/04 ~~4.22~~ KK 2/5/04	=	1.433 RJS 2/9/04 ~~1.20~~ KK 2/9/04
(C) Top Drum with Puck Inside Drum		(D) Top Drum with Puck Outside Drum		(F) Top Drum Lower Spacing
	+		=	
(E) Bottom Drum Upper Spacing		(F) Top Drum Lower Spacing		Total Axial Spacing

Test Engineer and Witness Records

Test Engineer Signature	Printed Name	Date
[signature]	Richard J. Smith	2/4/04

Witness Signature	Printed Name	Date
[signature]	Kevin King	2/4/04

DATA SHEET 4.3 – Axial Measurements, 100-Gallon Drum Overpacks with Grouted Spacers

Instrumentation Records

Linear Measurement Device Description	*Serial Number*	*Calibration Due Date*

Bottom Drum, Puck Inside Drum (in) [see Step 1 in Figure 14]

Axial Measurement No. 1	*Axial Measurement No. 2*	*Axial Measurement No. 3*	*(A) Average*

Bottom Drum, Puck Outside Drum (in) [see Step 2 in Figure 14]

Axial Measurement No. 1	*Axial Measurement No. 2*	*Axial Measurement No. 3*	*(B) Average*

Top Drum, Puck Inside Drum (in) [see Step 1 in Figure 15] order: 3

6.1	6.3	6.2	6.2
Axial Measurement No. 1	*Axial Measurement No. 2*	*Axial Measurement No. 3*	*(C) Average*

Top Drum, Puck Outside Drum (in) [see Step 2 in Figure 15] 4

4.7	4.5	4.6	4.6
Axial Measurement No. 1	*Axial Measurement No. 2*	*Axial Measurement No. 3*	*(D) Average*

Total Axial Spacing (in)

	–		=	
(A) Bottom Drum with Puck Inside Drum		*(B) Bottom Drum with Puck Outside Drum*		*(E) Bottom Drum Upper Spacing*
6.2	–	4.6	=	1.6
(C) Top Drum with Puck Inside Drum		*(D) Top Drum with Puck Outside Drum*		*(F) Top Drum Lower Spacing*
	+		=	
(E) Bottom Drum Upper Spacing		*(F) Top Drum Lower Spacing*		*Total Axial Spacing*

Test Engineer and Witness Records

[signature]	Richard J. Smith	2/4/04
Test Engineer Signature	*Printed Name*	*Date*
[signature]	Kevin King	2/4/04
Witness Signature	*Printed Name*	*Date*

Taken with Tape Measure: High – Low

		High – Low
100 Gal. Height after Drop	1L	33" – 29 1/2"
	2L	32" – 28 1/4
	3L	32" – 29 1/2"

		High – Low
DIA after Drop	1L	33" – ~~25~~ 22 1/4"
	2L	31" – 31"
	3L	32" – 25 1/4

55 Gal. Height after Drop	1L	37" – 33"
	2L	37" – 34"
	3L	34" – 33"
	4L	34" – 34"
	5L	34" – 32"
	6L	34" – 32 1/2"
	7L	32" – 31"

* Joined due to drop

DIA after Drop	1L	22" – 19"
	2L	21" – 19"
	3L	23" – 21"
	4L	24" – 23"
	5L	26" – 17 1/2"
	6L	24" – 18"
	7L	24" – 24"

Top View Shapes

Bottom of drum estimated coining effect after drop

100 Gal.	2U	2U ~~approx~~ ≈ 3/8" – 1"
55 Gal	7U	7U ≈ 3/8" – 1"

Flattest upper drum sections (at bottom)

Before: After:

Distance from puck to top lid after drop

55 Gal.	5L	3" to peak of distortion of lid
		Lid in contact w/puck for majority of lid surface
	6L	puck in contact w/lid
	7L	puck 1" from lid

Kevin King, QAE/PacTec
[signature] 2/5/04

Richard Smith, Test Eng. PacTec
[signature] 2/5/2004

APPENDIX C
Deviations from Test Plan

(1 SHEET TOTAL)

CONTINUATION DATA SHEET

Page 1 of 1

Notes & Modifications to Test Plan

Test Record

- used 18, 4" avg length welds on 100-gal ICV. welds larger than 3/16" (~3/8-1/4). Full 6" lug weld length on 55-gal ICV.
- Welded in (tack) bottom spacer clips. -100gal ICV
- 55-gal bottom spacer is actually a top honeycomb spacer; sits on clips (not clipped in).
- For axial measurements, drums were cut closer than 5" (~2").
- Used minimum axial measurement for data pt#1, then did 2 more @ ~120°.
- After eval. of top grate & grout spacers for 100-gal axial measurements, we decided to take direct measurement of thickness of all spacers (55 & 100gal). The "no spacer" cases were ambiguous and/or difficult to measure as side drop generally resulted in very non-uniform deflections.
- WEPD QA did not take axial measurements per their traveler. WTS authorized PacTec QAE to take measurements.

[signature] STEVEN A. PORTER 02.04.04

Test Engineer and Witness Records

[signature]	Richard J. Smith	2/4/04
Test Engineer Signature	Printed Name	Date
[signature]	Kevin King	2/4/04
Witness Signature	Printed Name	Date

Note: This form is not part of Test Plan TP-037; it is for continuation of TP-037 data sheets as necessary

APPENDIX D
Test Photos

(26 SHEETS TOTAL)

Figure 1 – Surrogate Drum Payload Pucks

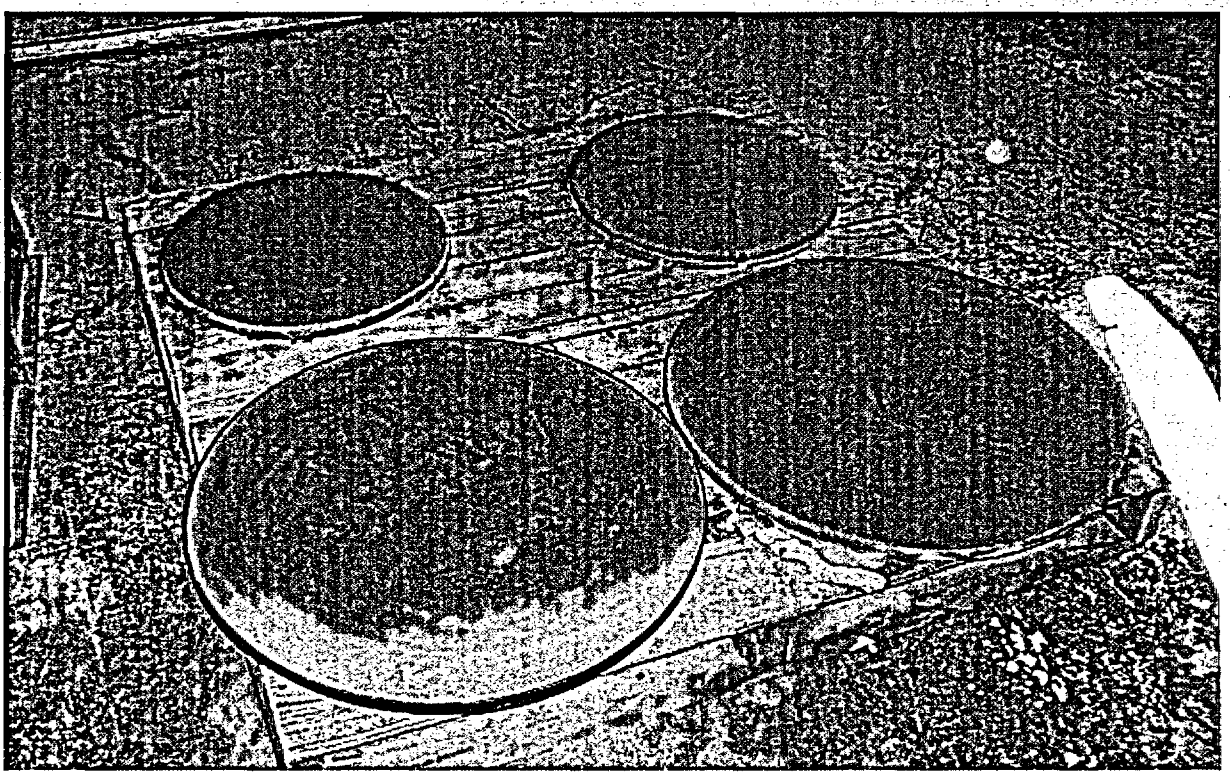


Figure 2 – 55-Gallon and 100-Gallon Grout Spacers

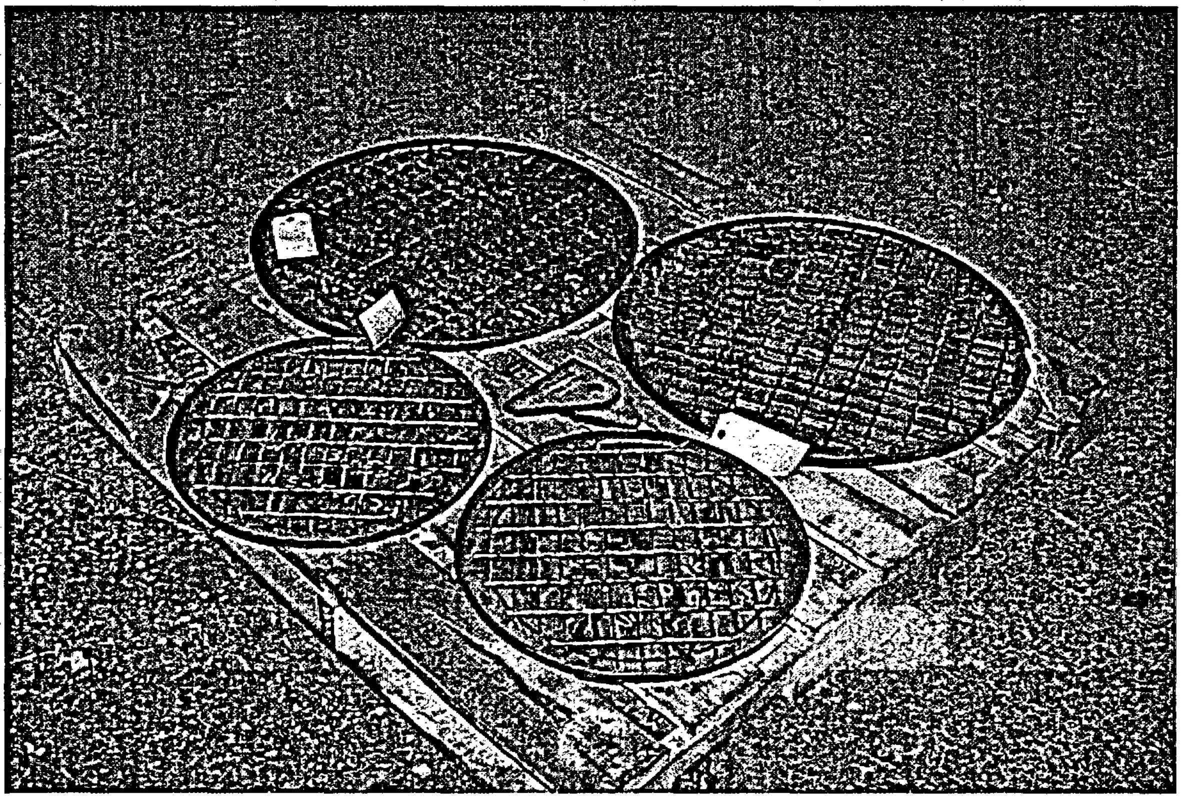


Figure 3 – 55-Gallon and 100-Gallon Grate Spacers

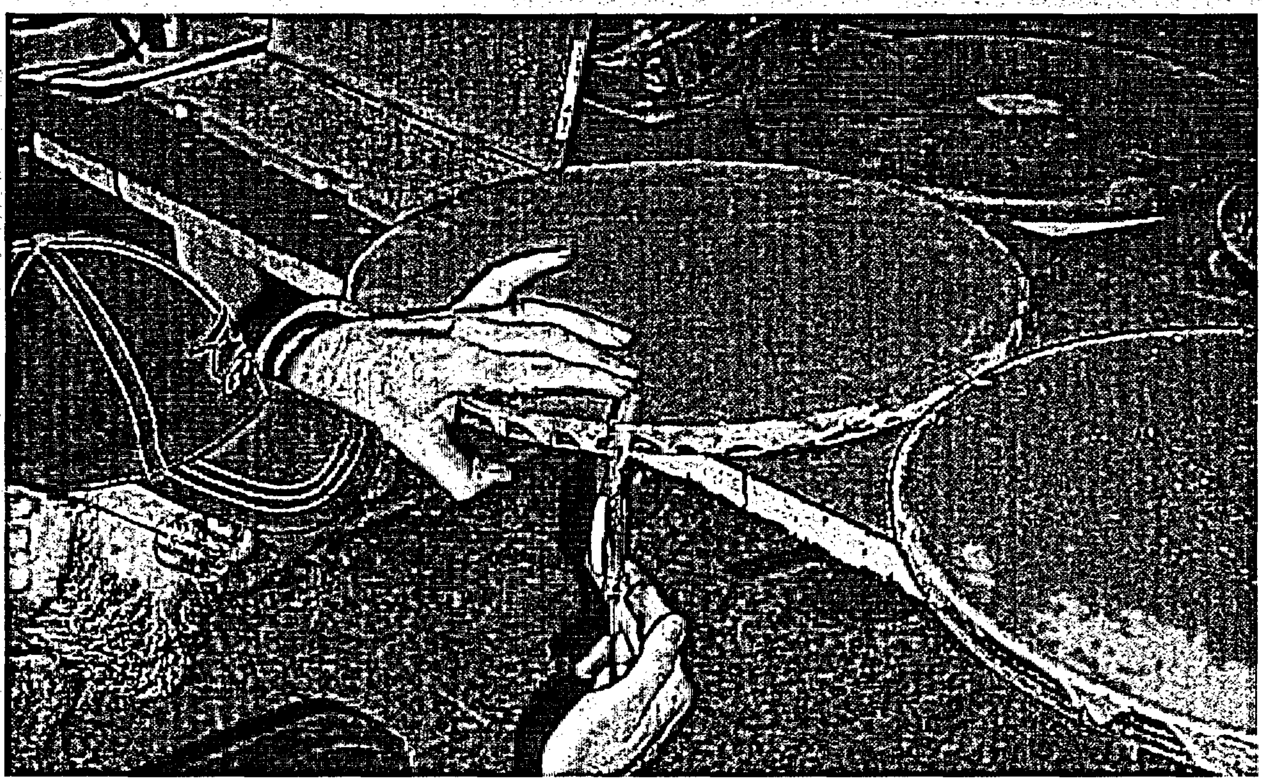


Figure 4 – Measuring Pre-Drop Spacer Thickness

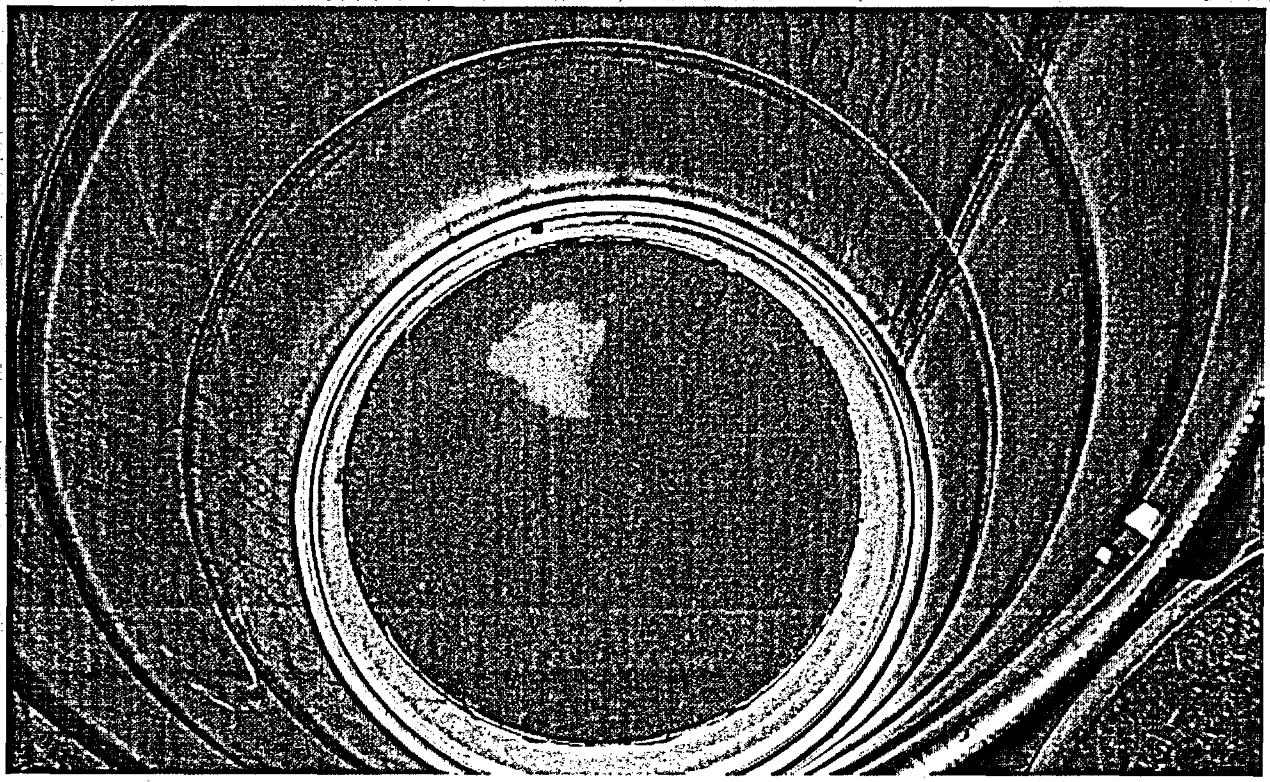


Figure 5 – Installation of Grout Spacer in 55-Gallon Drum

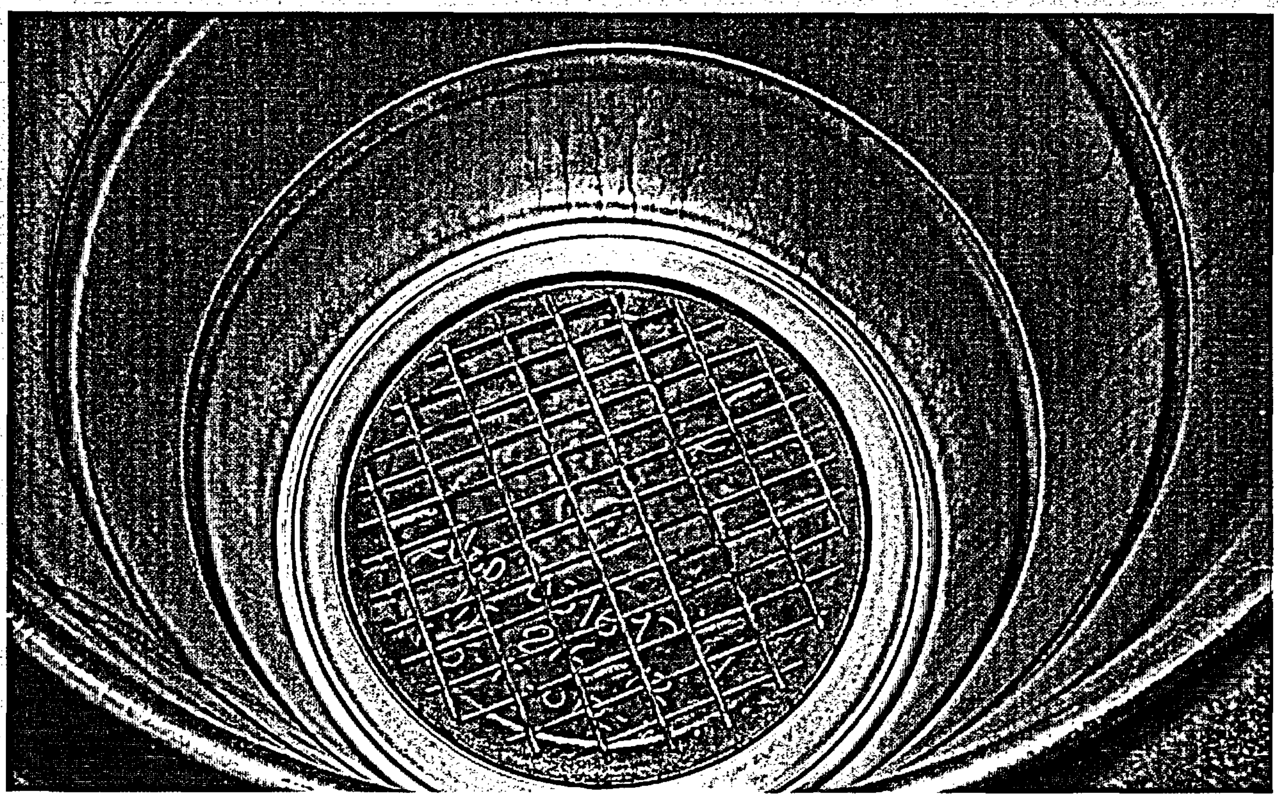


Figure 6 – Installation of Grate Spacer in 55-Gallon Drum

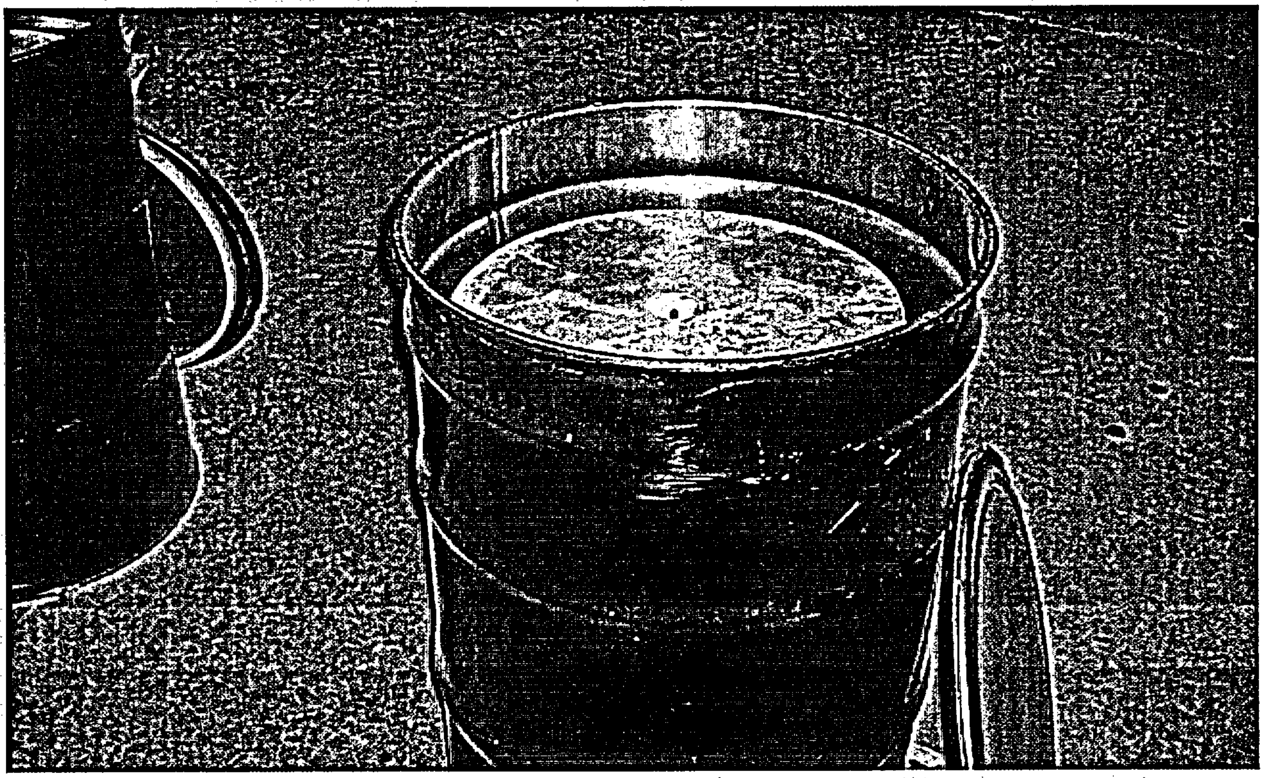


Figure 7 – Installation of Pucks in 55-Gallon Drum

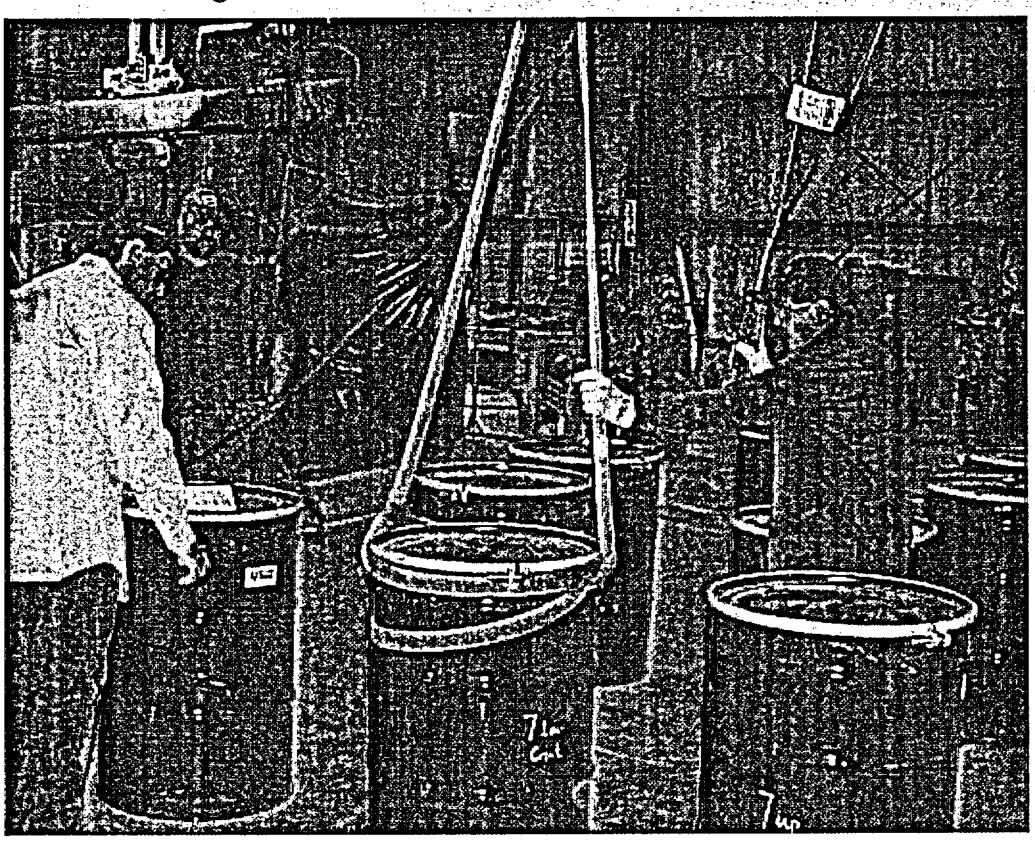


Figure 8 – Measuring 55-Gallon Drum Weights

Figure 9 – Loaded 55-Gallon Test Drums

Figure 10 – 100-Gallon Drums

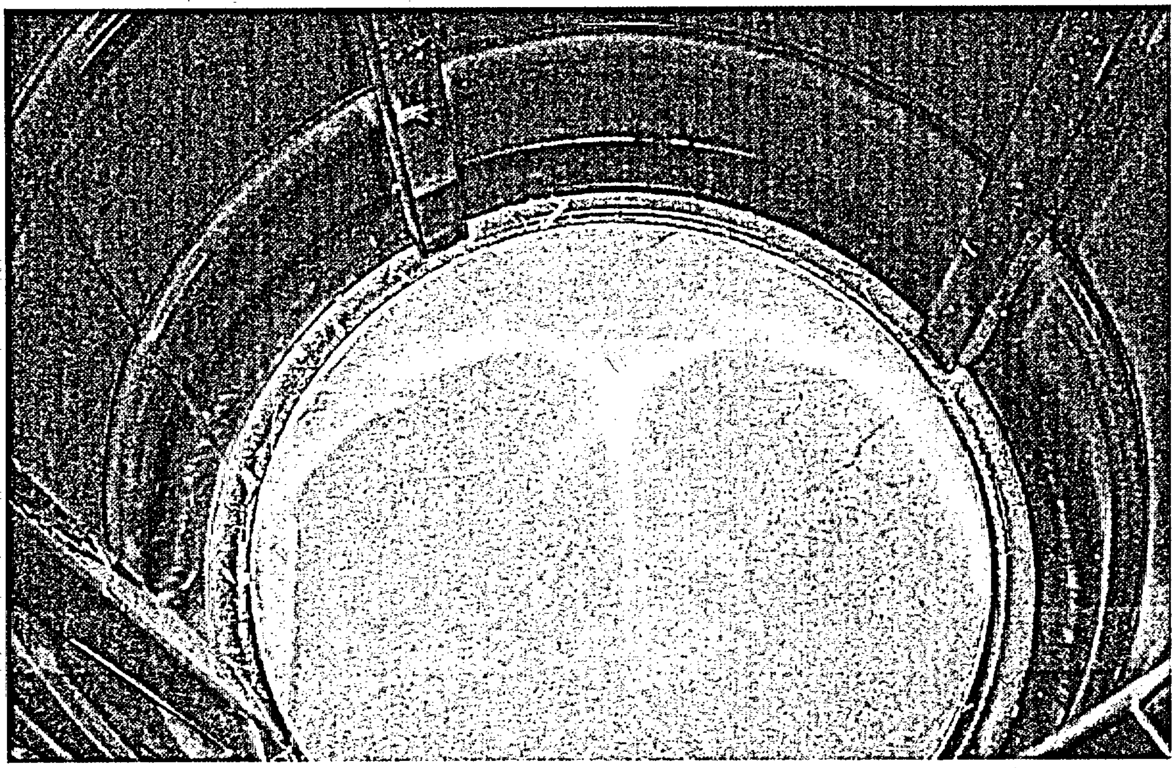


Figure 11 – Installation of Grout Spacers in 100-Gallon Drums

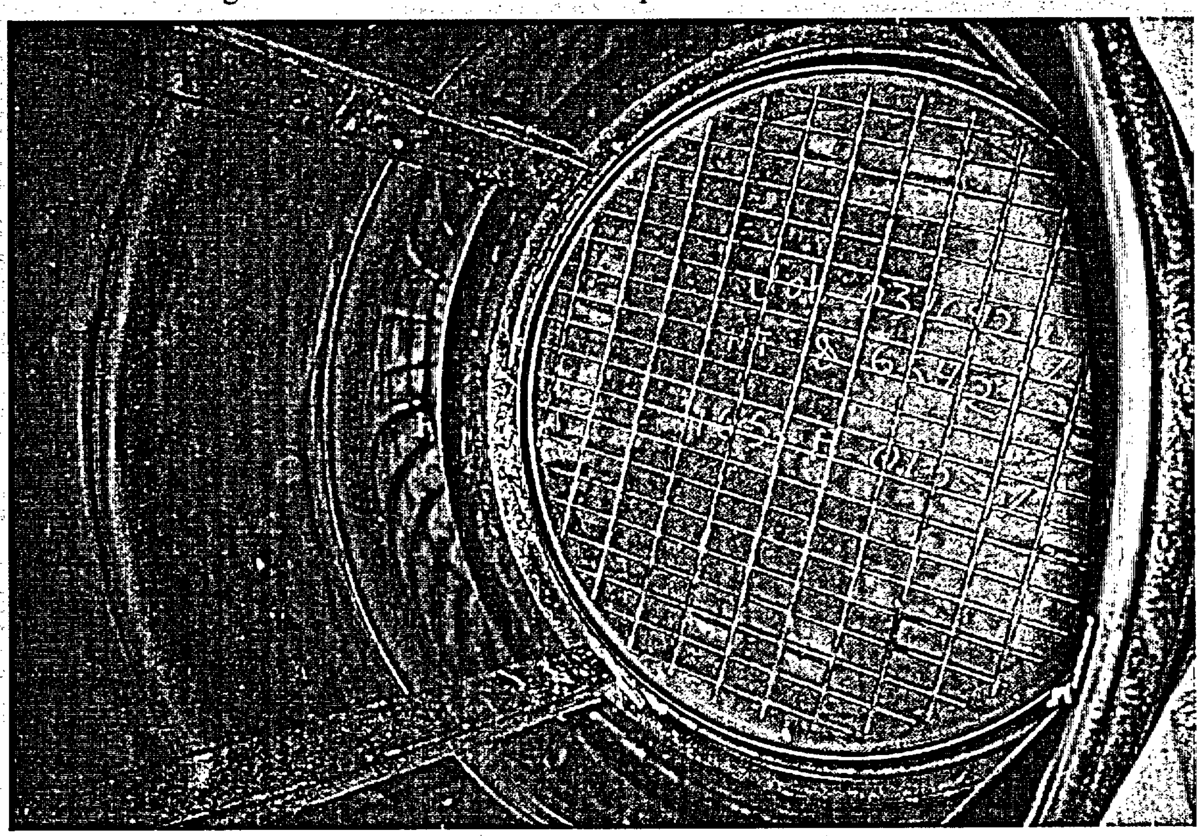


Figure 12 - Installation of Grate Spacers in 100-Gallon Drums

Figure 13 – Compacted Drum Puck Payload for 100-Gallon Drums

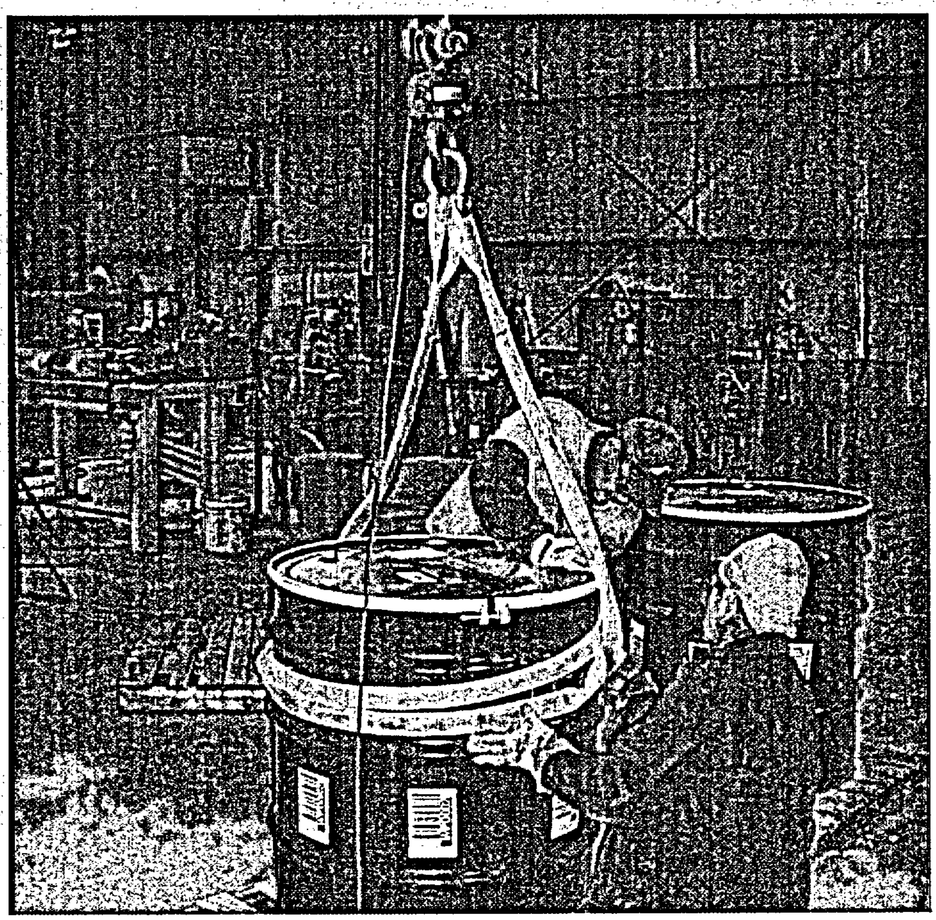


Figure 14 – Measuring 100-Gallon Drum Weights

Figure 15 – Loaded 100-Gallon Test Drums

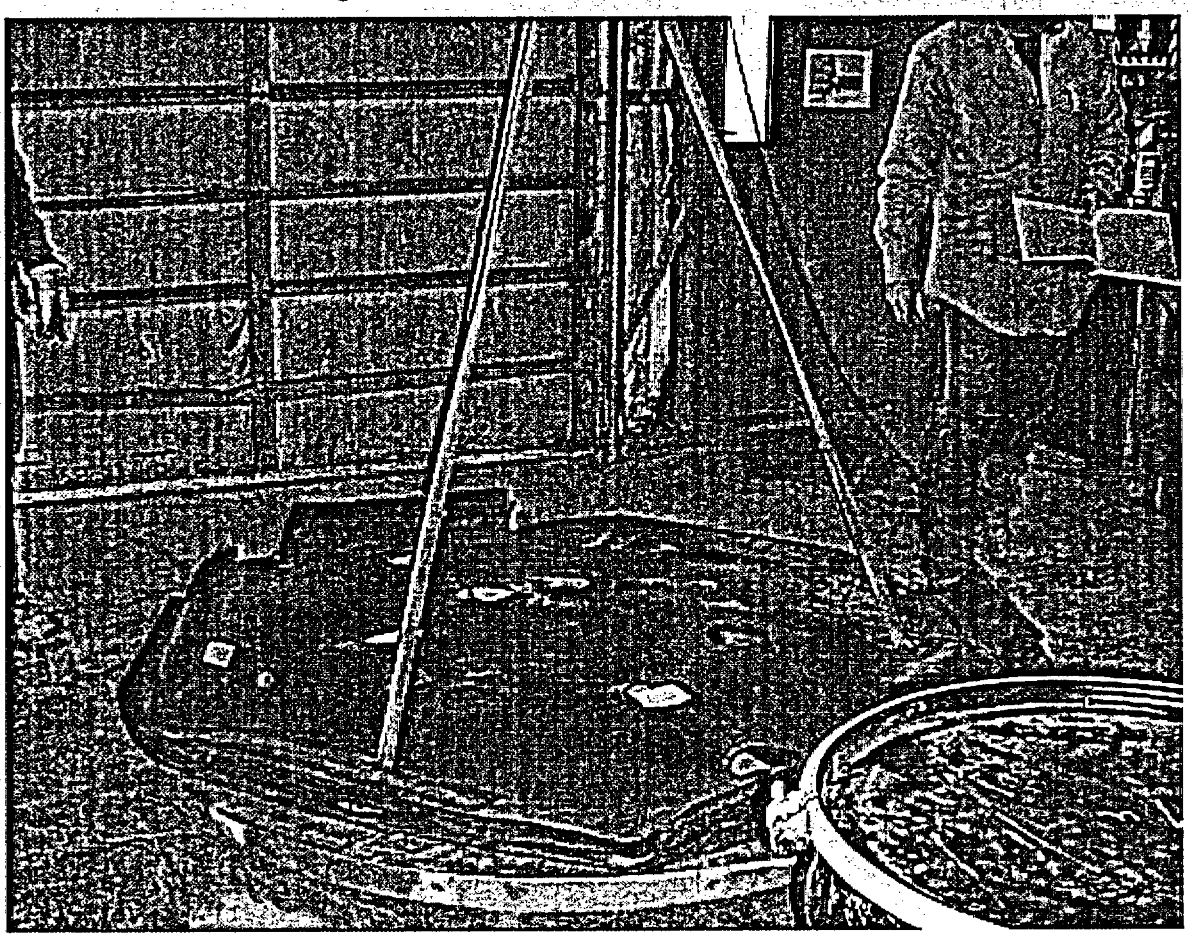


Figure 16 – Weighing Pallet, Reinforcement Plates and Slip Sheets

Figure 17 – 55-Gallon Test Drums on Pallet with Reinforcement Plates and Slip Sheets

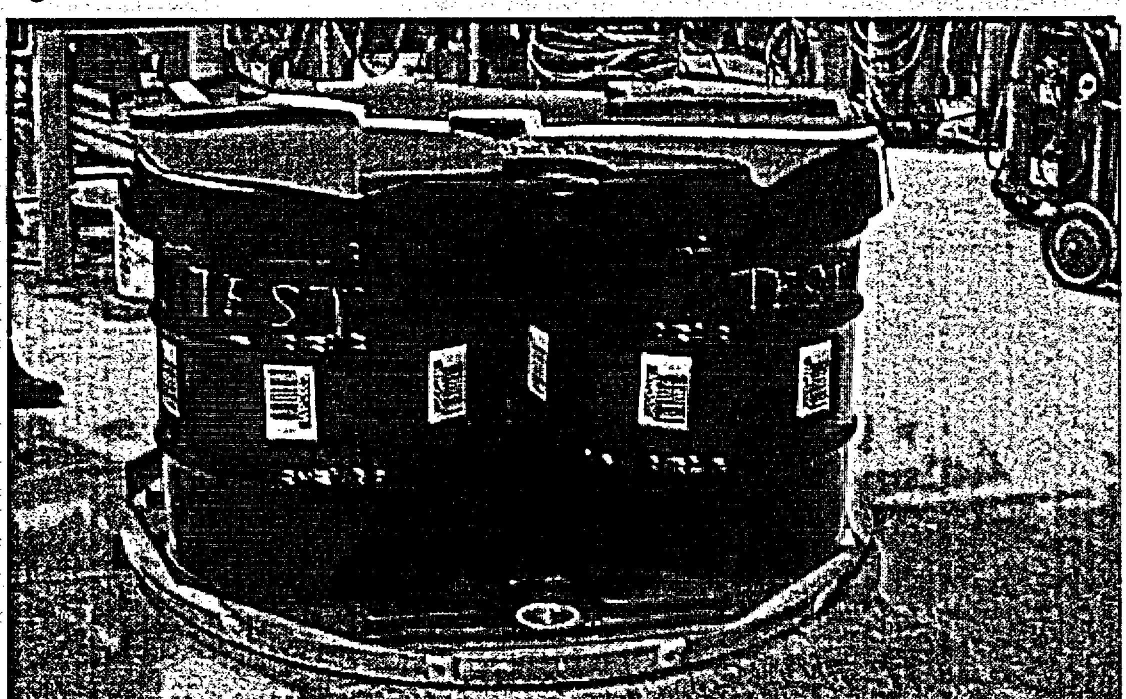


Figure 18 - Installation of 100-Gallon Test Drums on Pallet with Reinforcement Plate and Slip Sheet

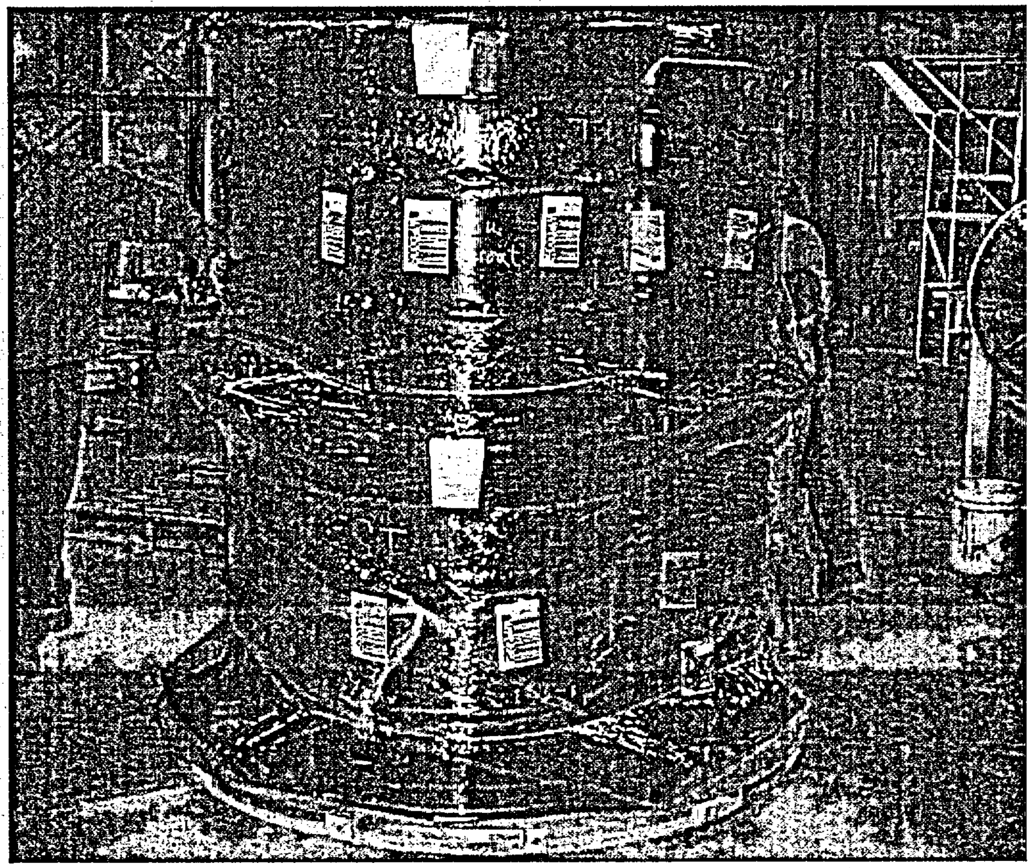


Figure 19 – 100-Gallon Test Drums on Pallet with Reinforcement Plates and Slip Sheets

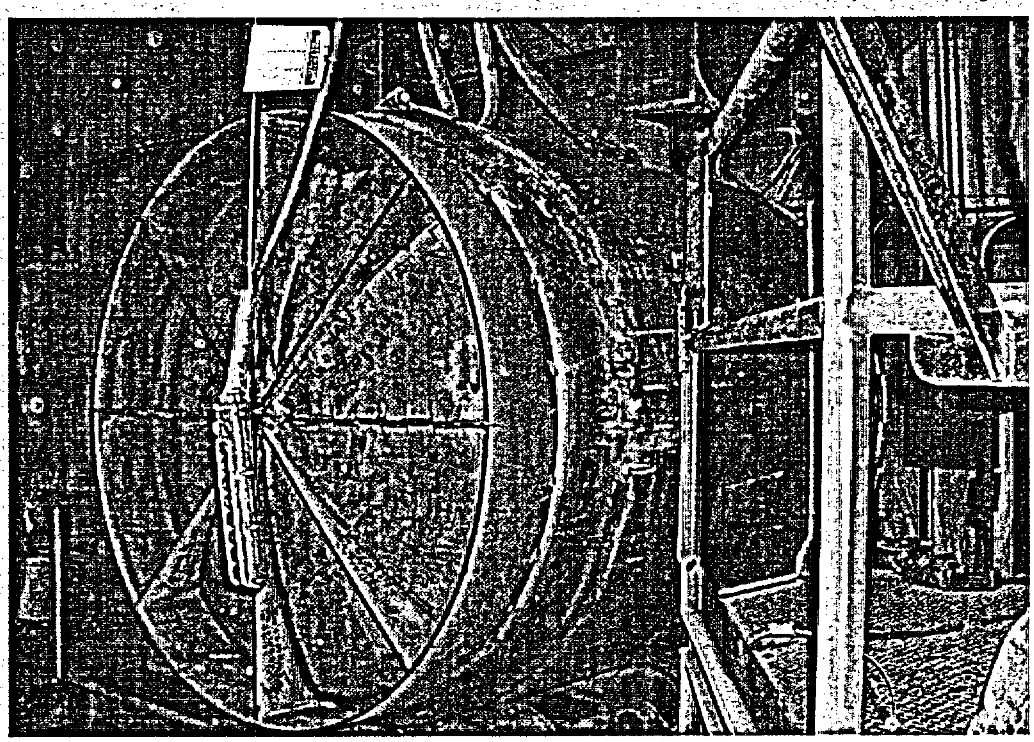


Figure 20 – In-Process Modification of ICV Test Unit

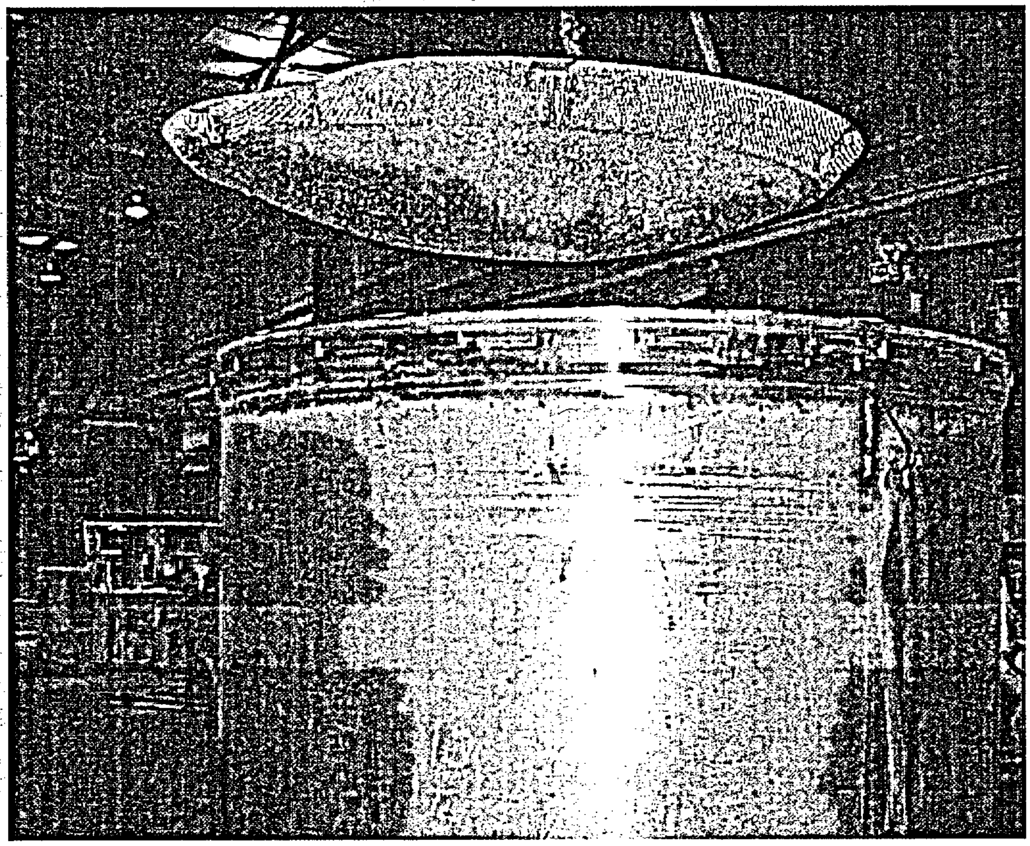


Figure 21 – Installation of Honeycomb Spacer in ICV

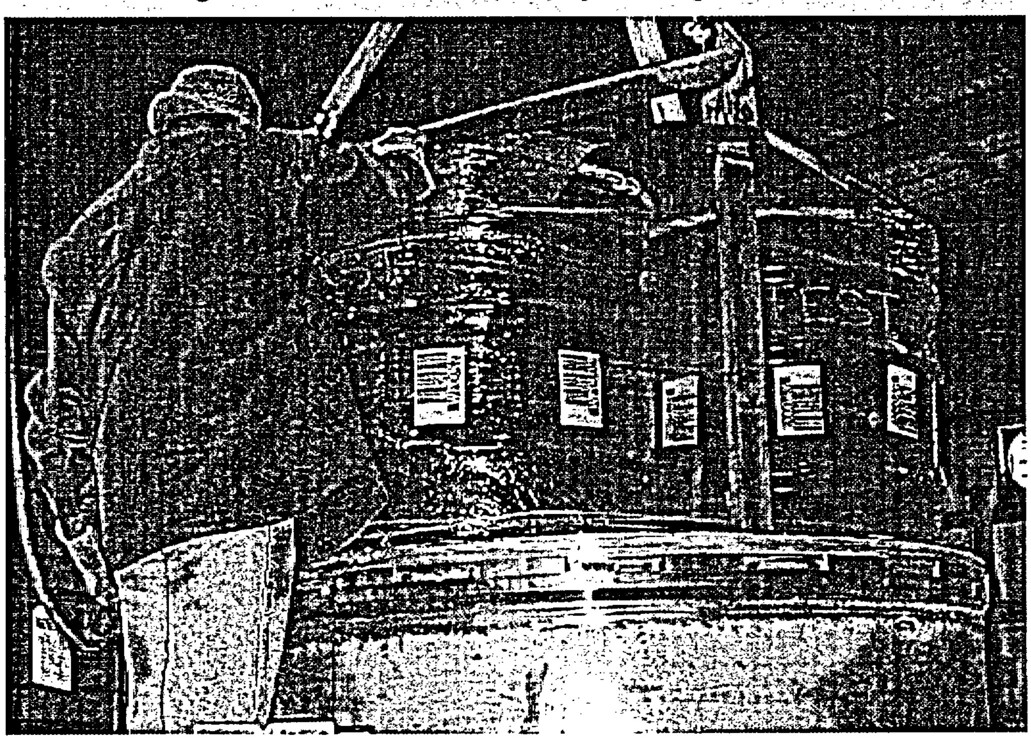


Figure 22 – Installation of Test Drums in ICV

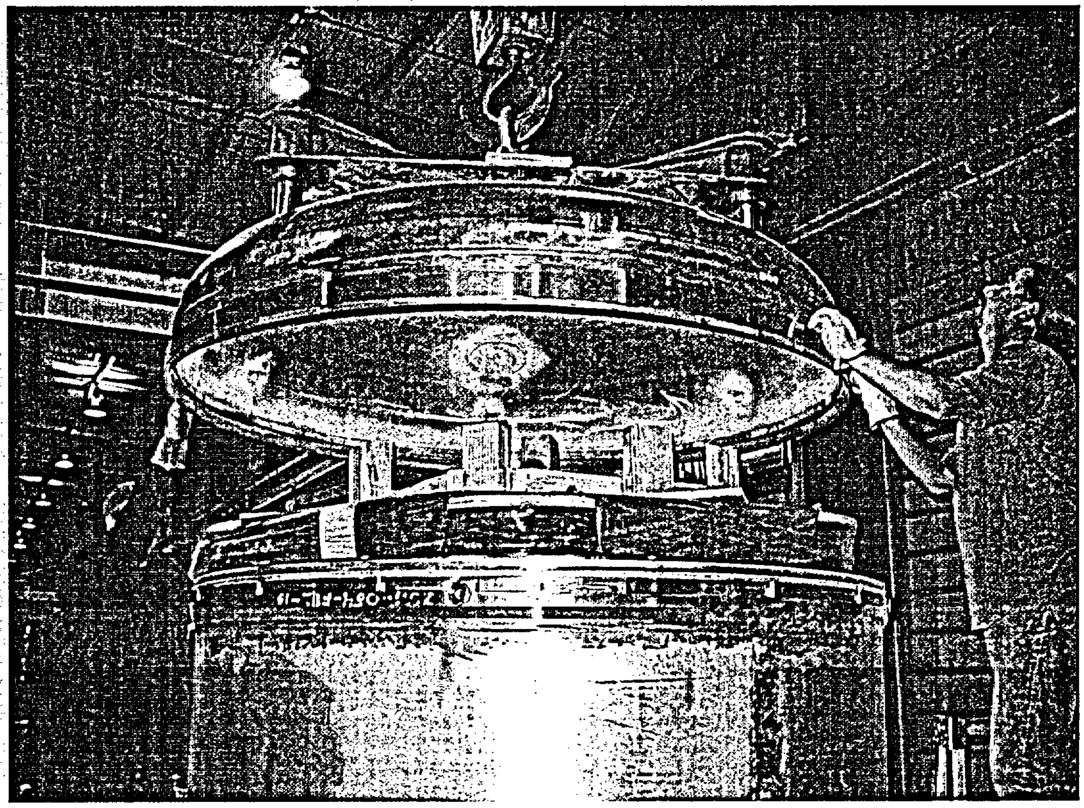


Figure 23 – Installation of Wood Spacer and ICV Lid

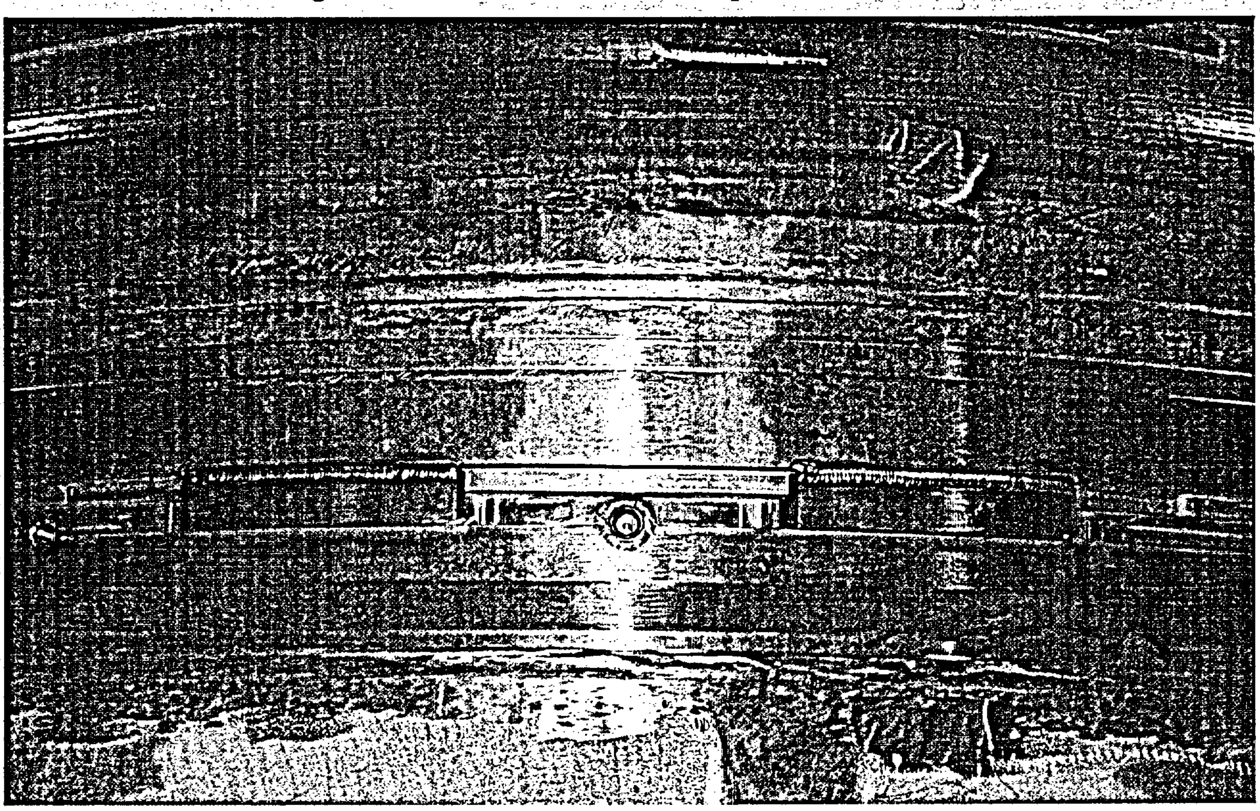


Figure 24 – ICV Lid Welds

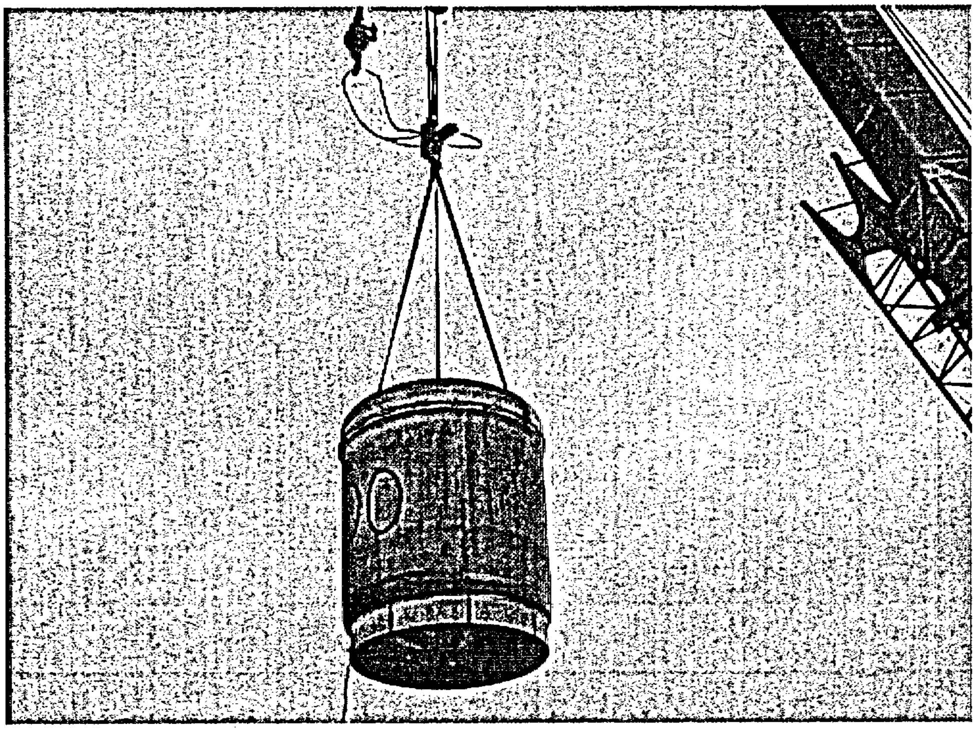


Figure 25 – Vertical Drop Test of 100-Gallon Test Unit

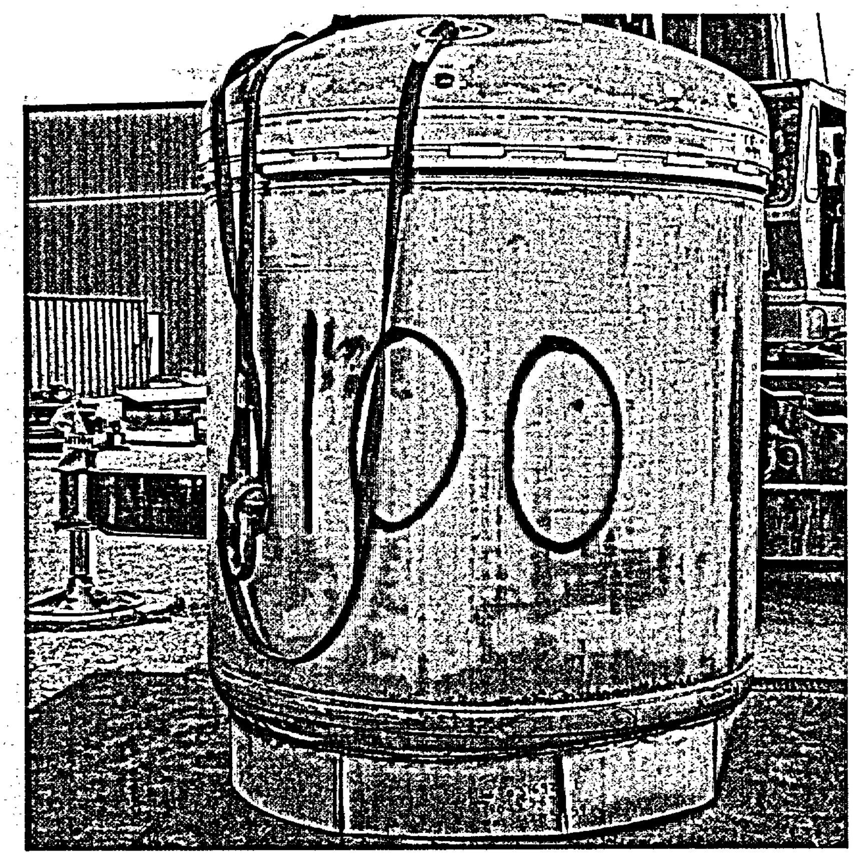


Figure 26 – Post Vertical Drop Condition of 100-Gallon Test Unit

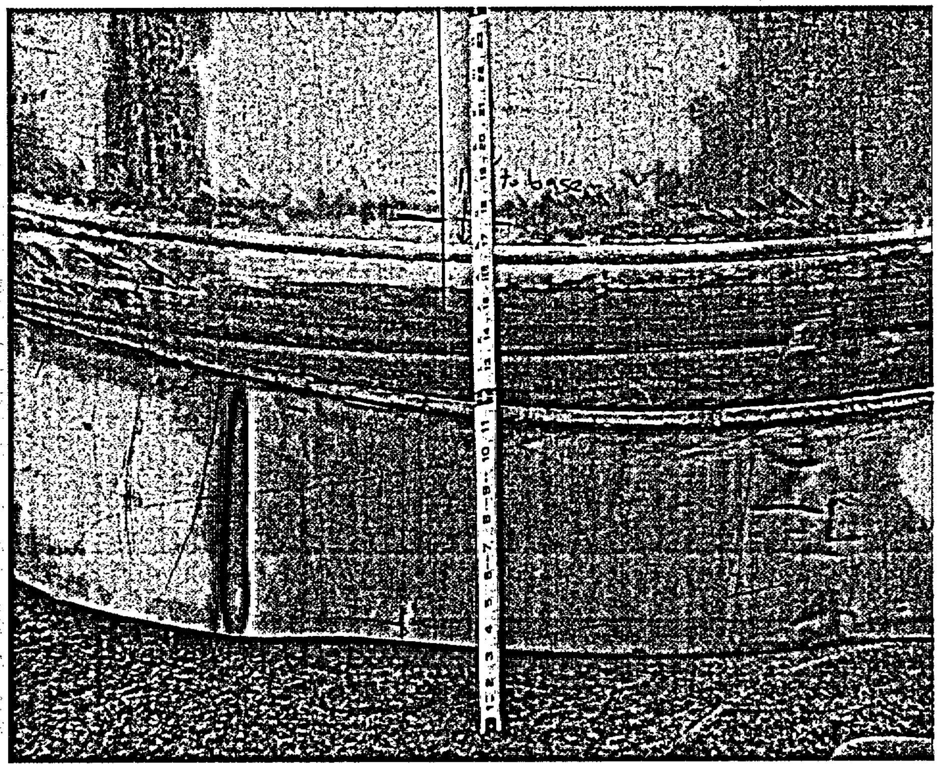


Figure 27 – Post Vertical Drop Deformation of 100-Gallon Test Unit

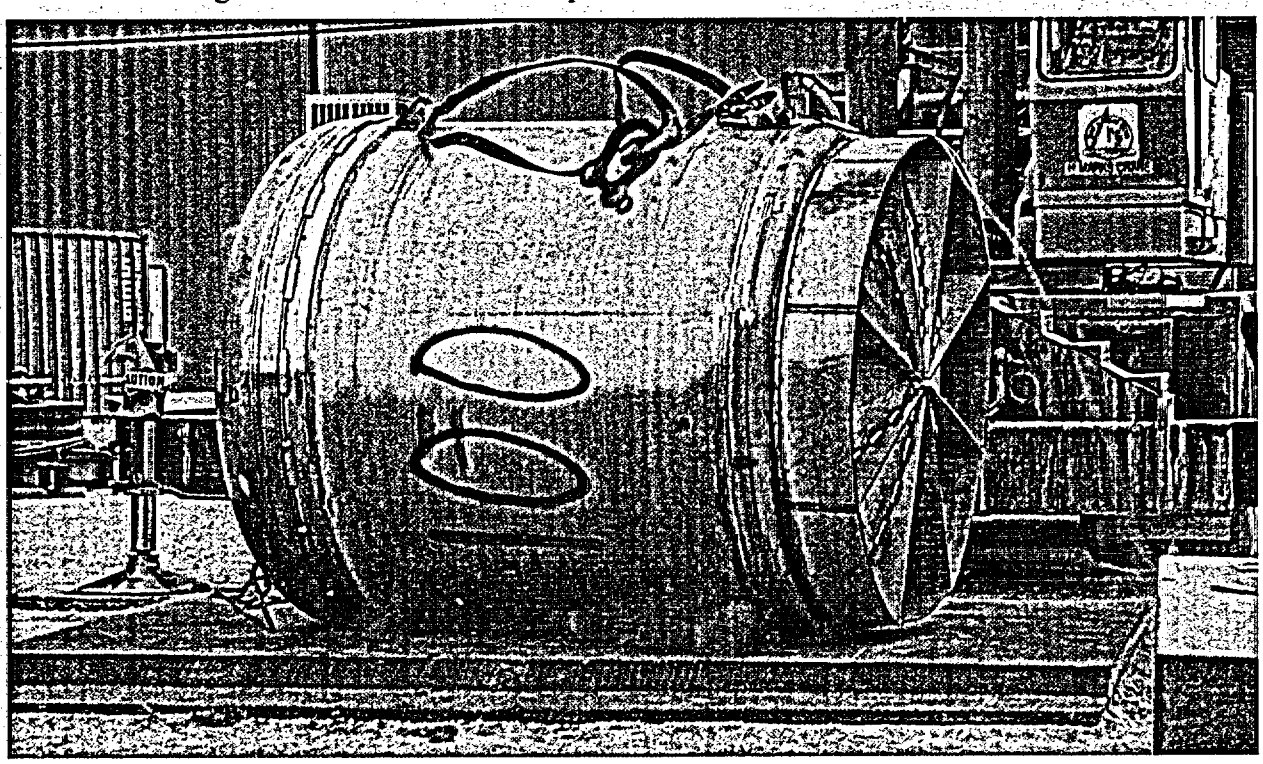


Figure 28 – Horizontal Drop Impact of 100-Gallon Test Unit

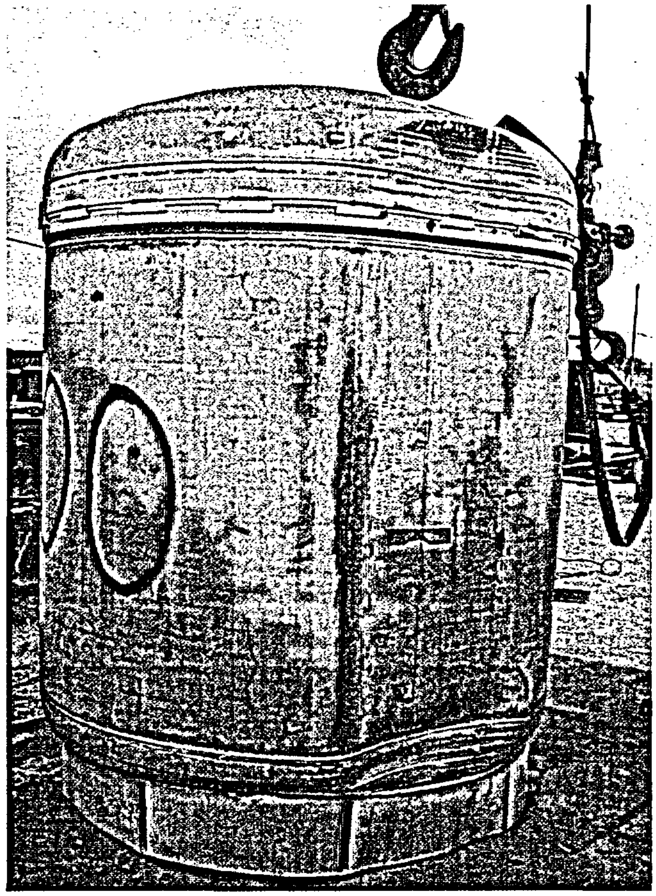


Figure 29 – Post Horizontal Drop Deformation of 100-Gallon Test Unit

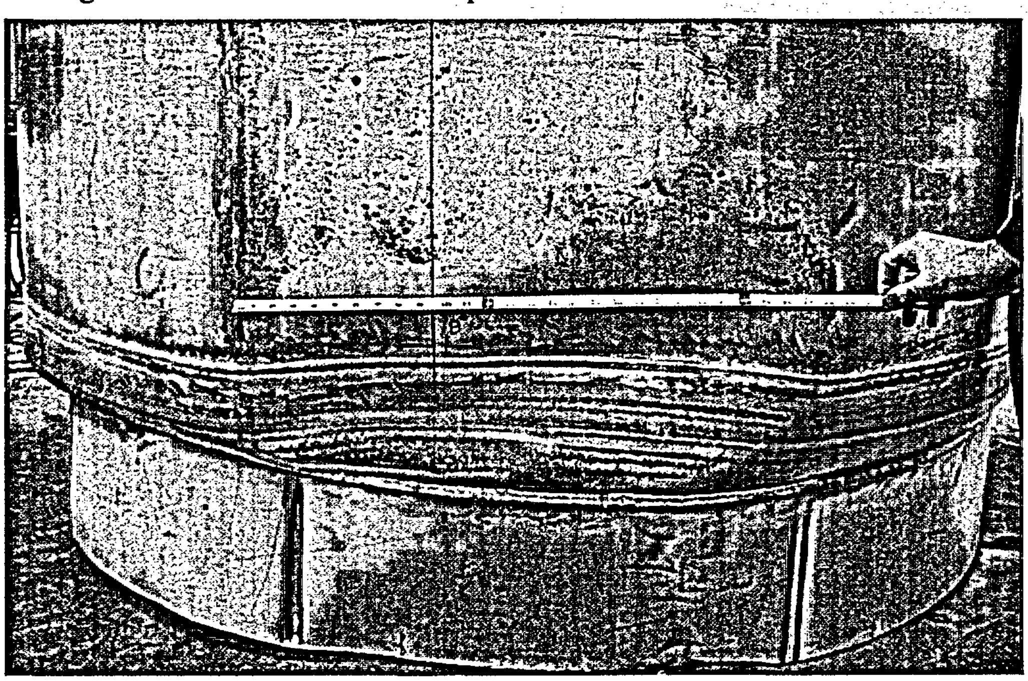


Figure 30 – Measurement of Horizontal Drop Deformation of 100-Gallon Test Unit

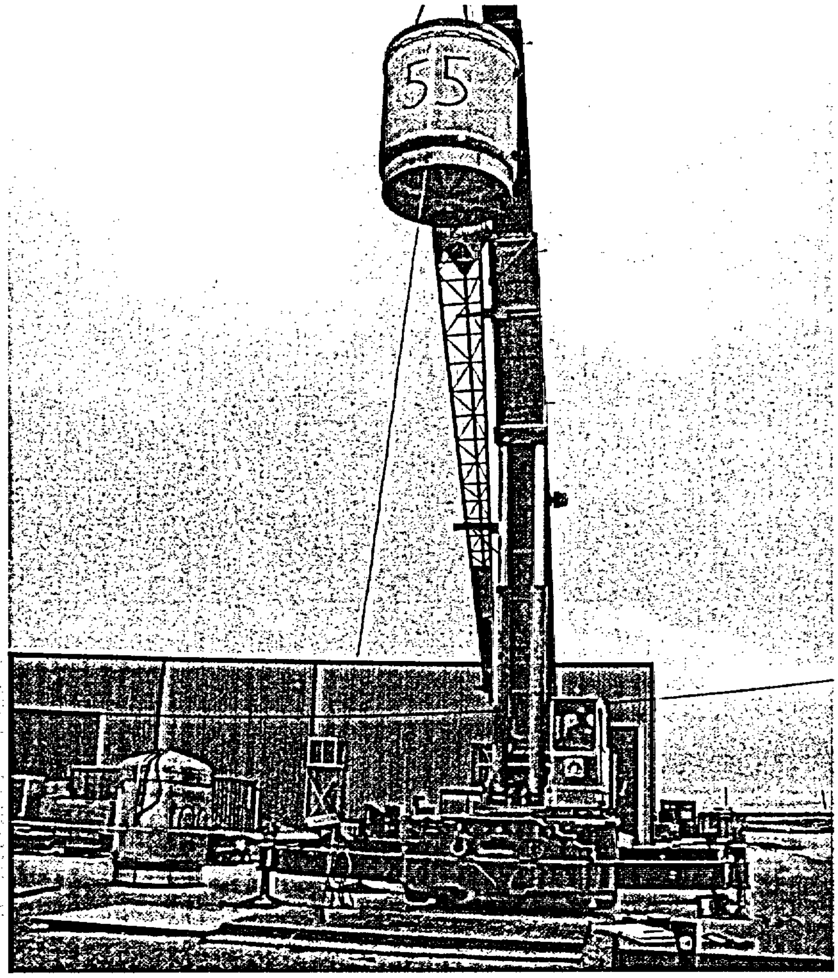


Figure 31 – Vertical Drop Test of 55-Gallon Test Unit

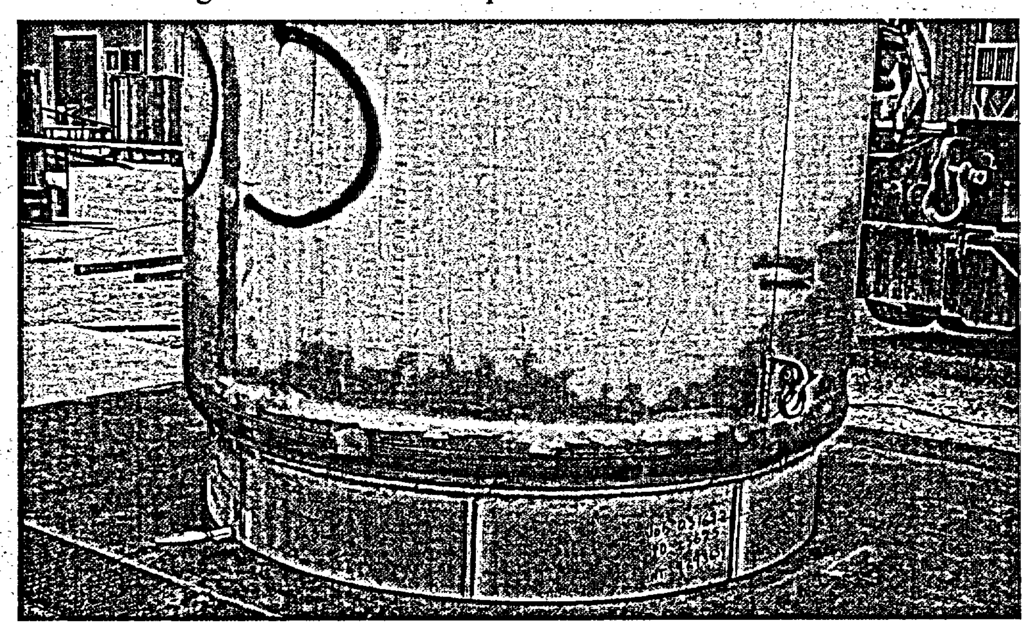


Figure 32 – Post Vertical Drop Deformation of 55-Gallon Test Unit

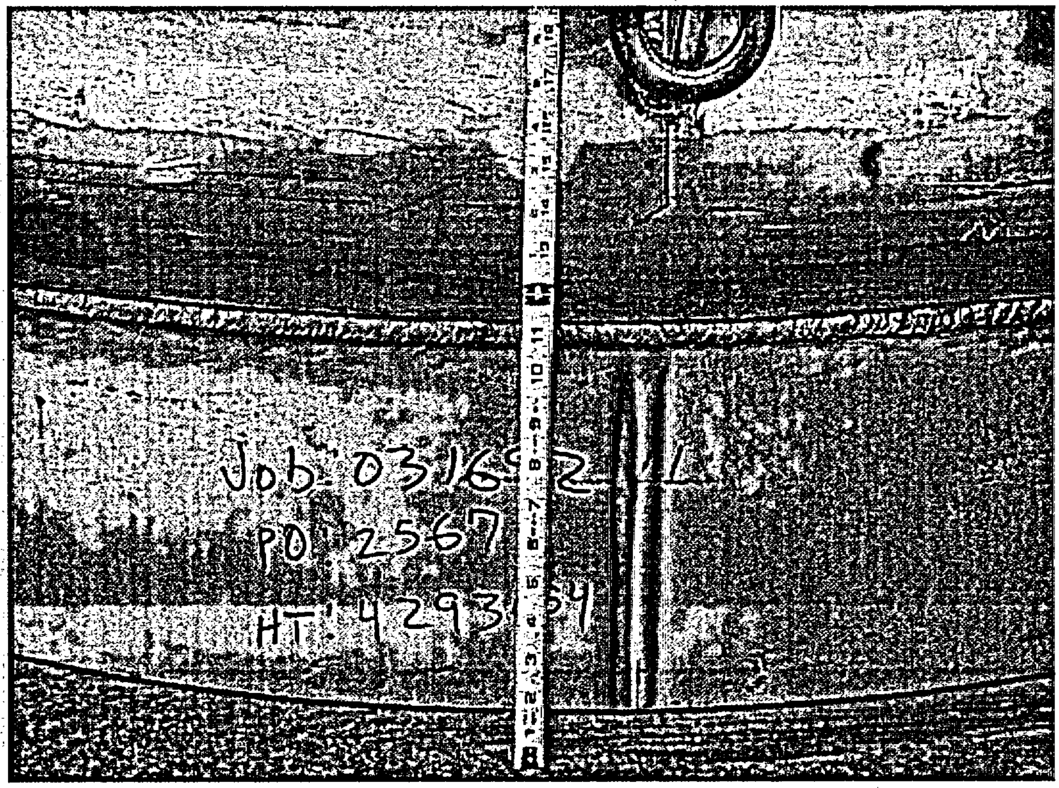


Figure 33 – Measurement of Vertical Drop Deformation of 55-Gallon Test Unit

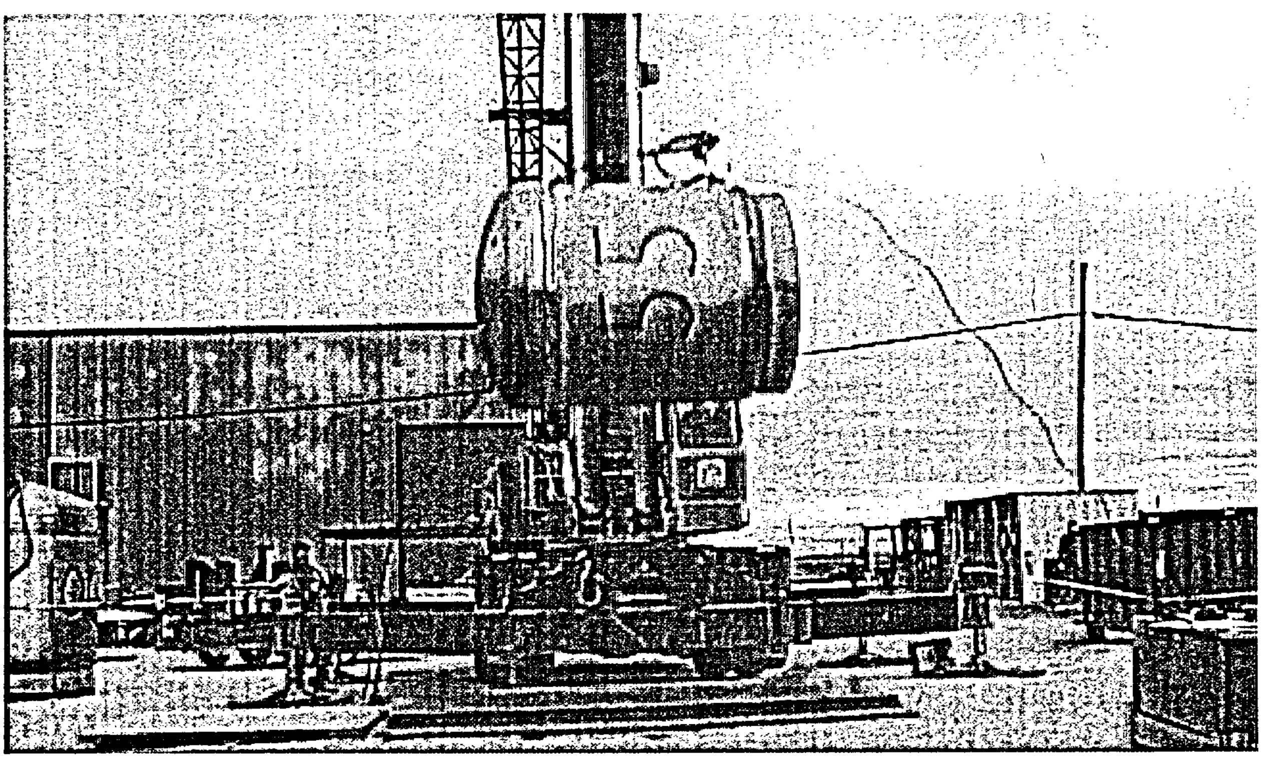


Figure 34 – Horizontal Drop Test of 55-Gallon Test Unit

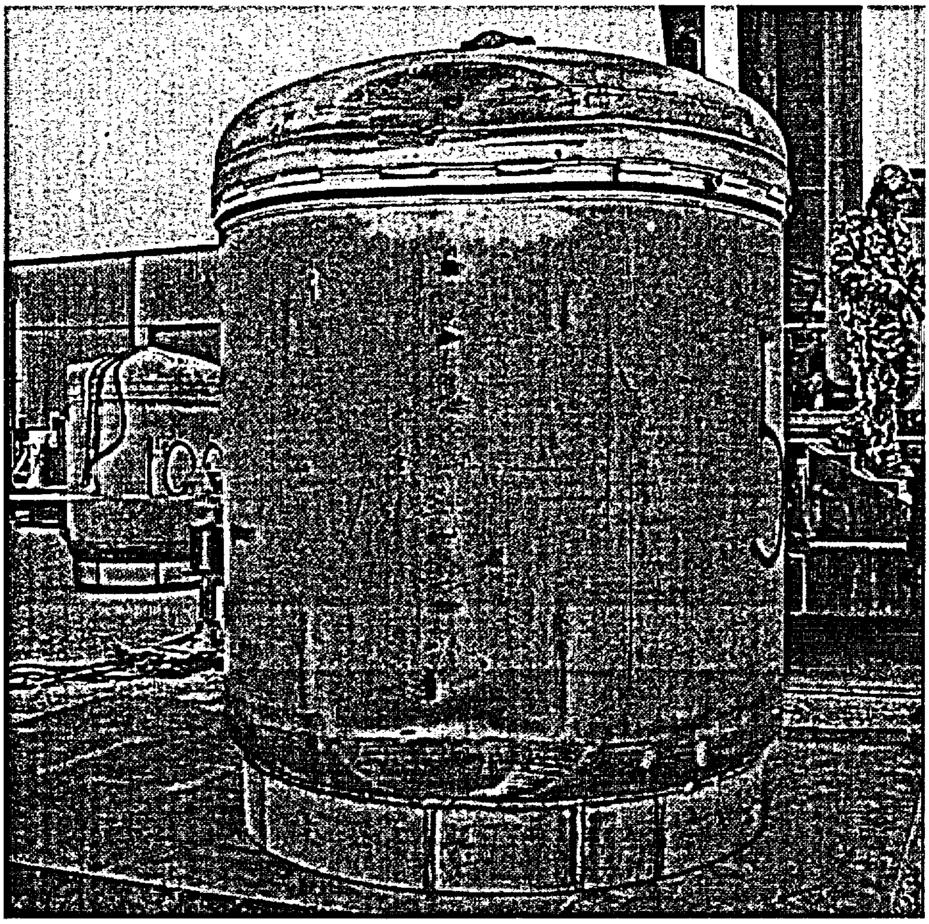


Figure 35 – Post Horizontal Drop Deformation of 55-Gallon Test Unit

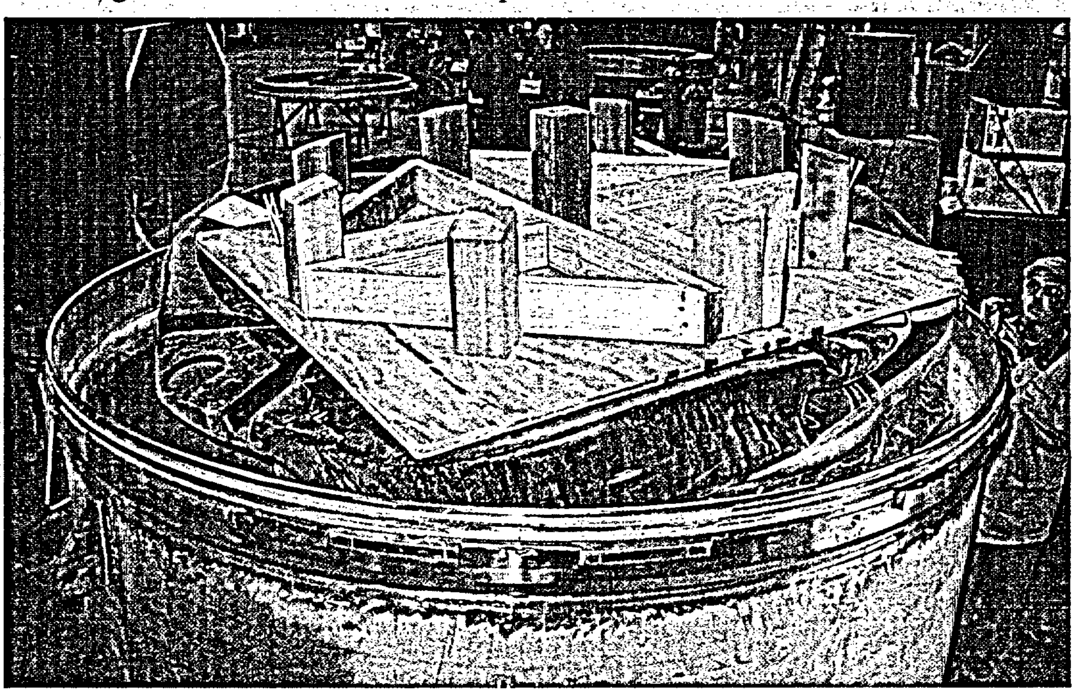


Figure 36 – 100-Gallon ICV After Lid Removal

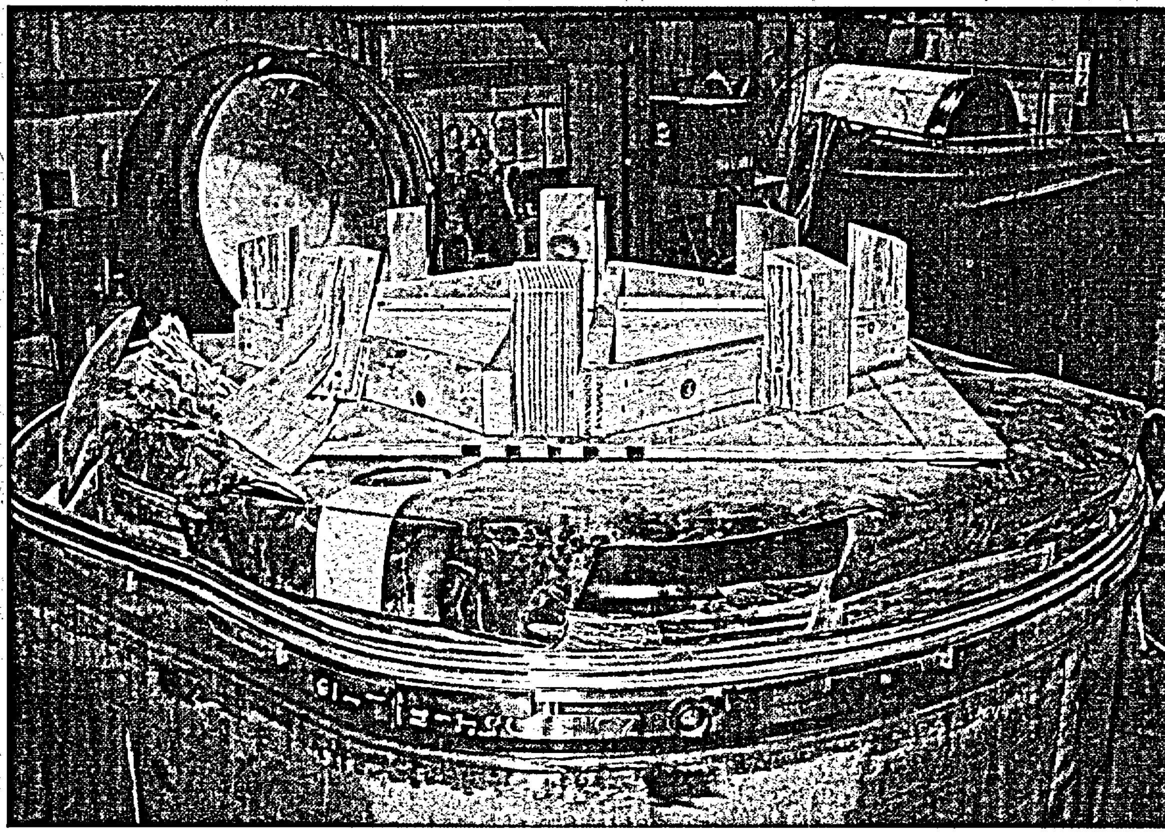


Figure 37 – 55-Gallon ICV After Lid Removal

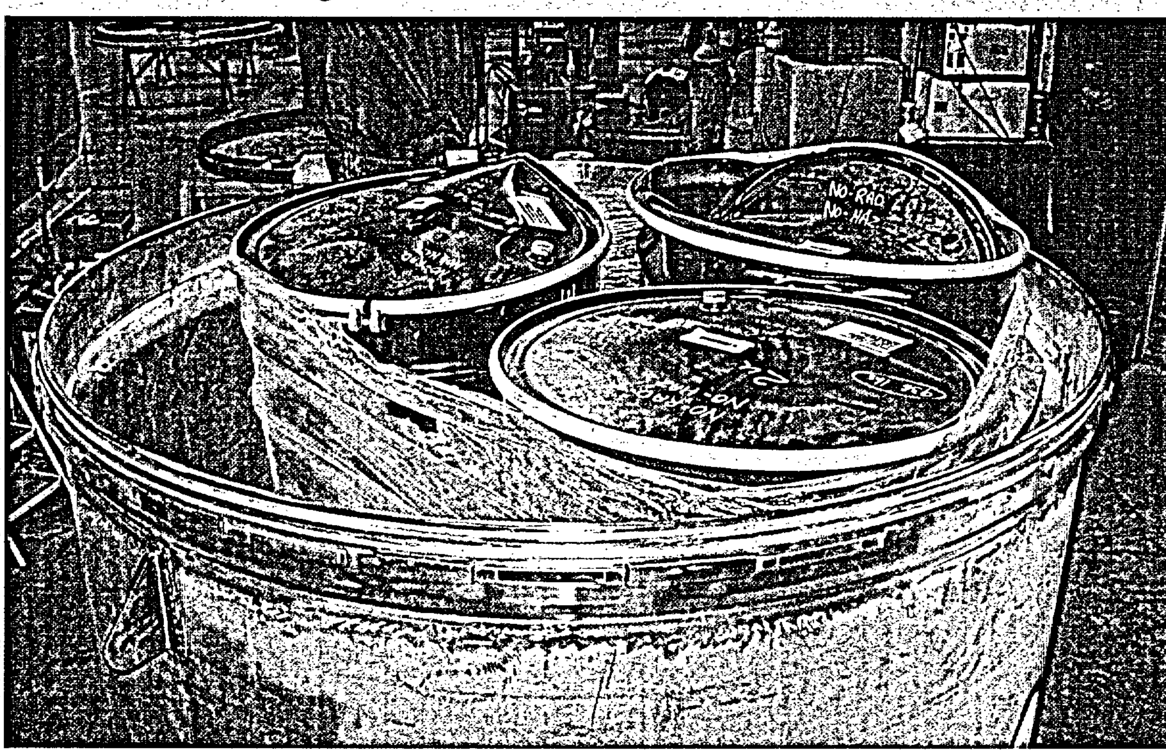


Figure 38 – Post Drop Condition of Upper 100-Gallon Drum Layer

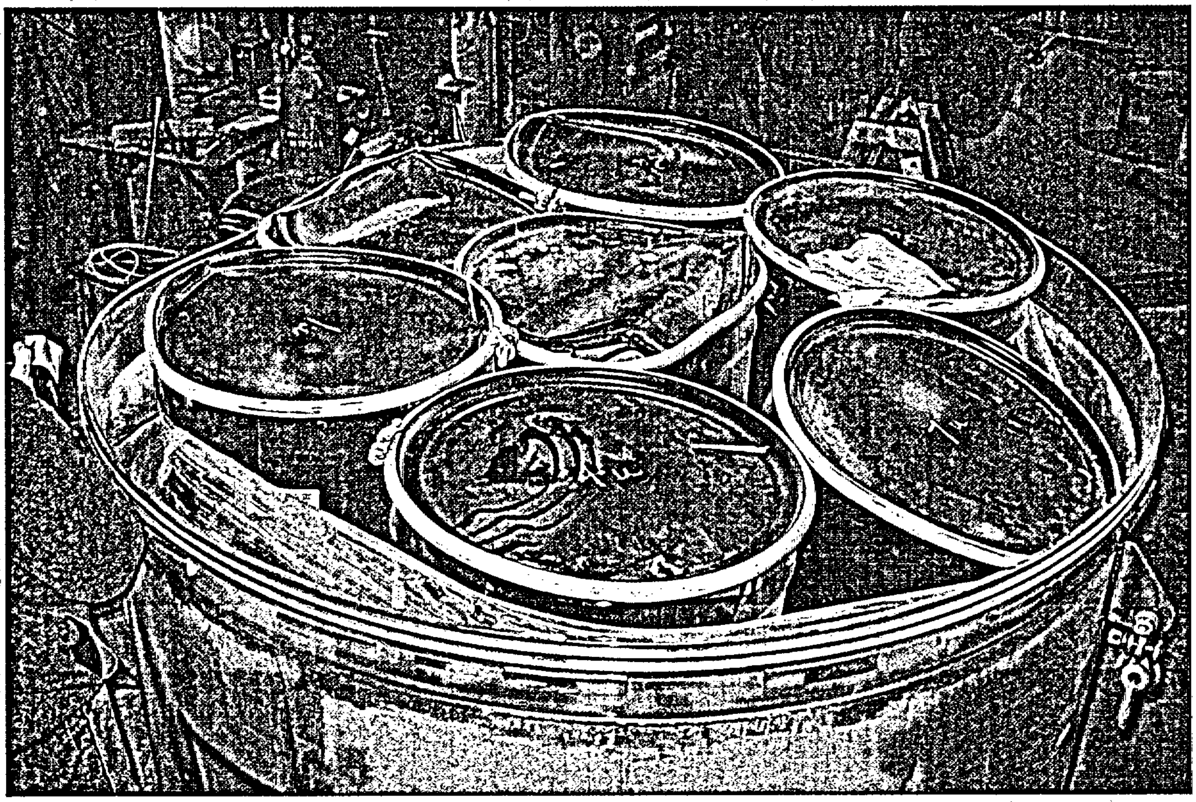


Figure 39 – Post Drop Condition of Upper 55-Gallon Drum Layer

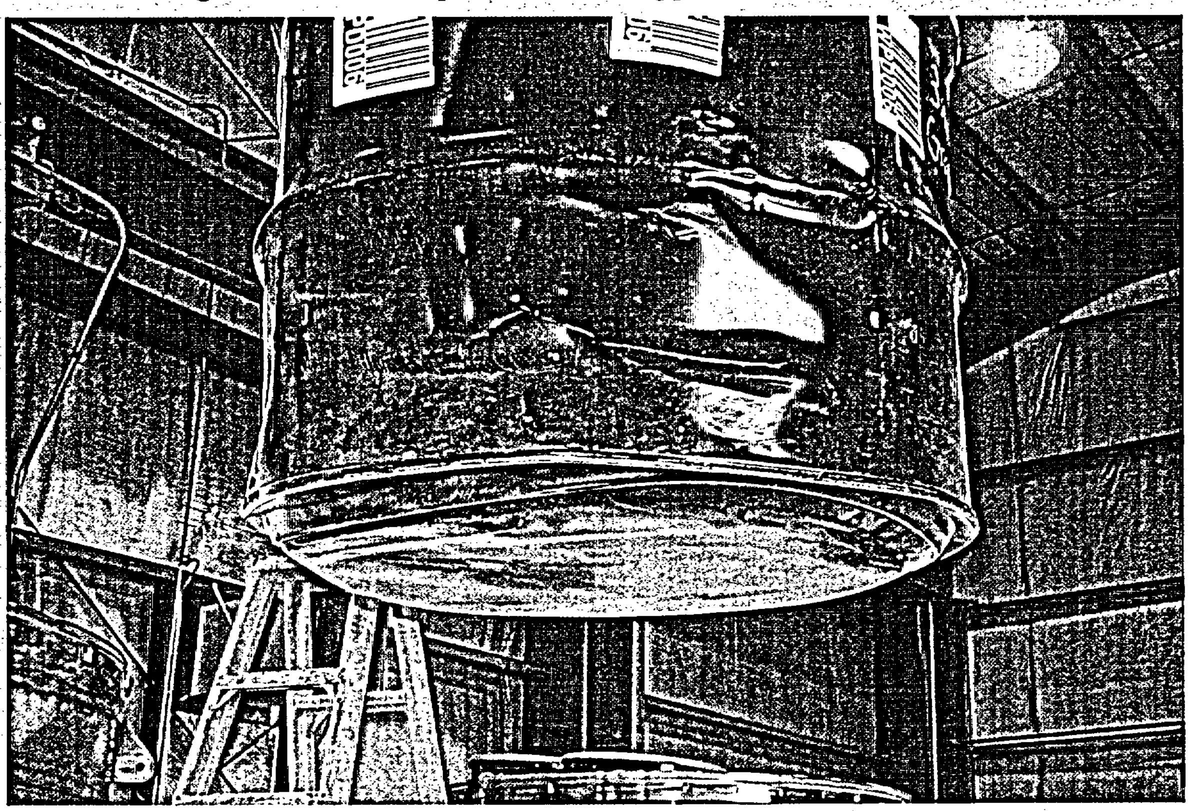


Figure 40 – Typical Coining Effect in Bottom of Upper Layer 100-Gallon Drum

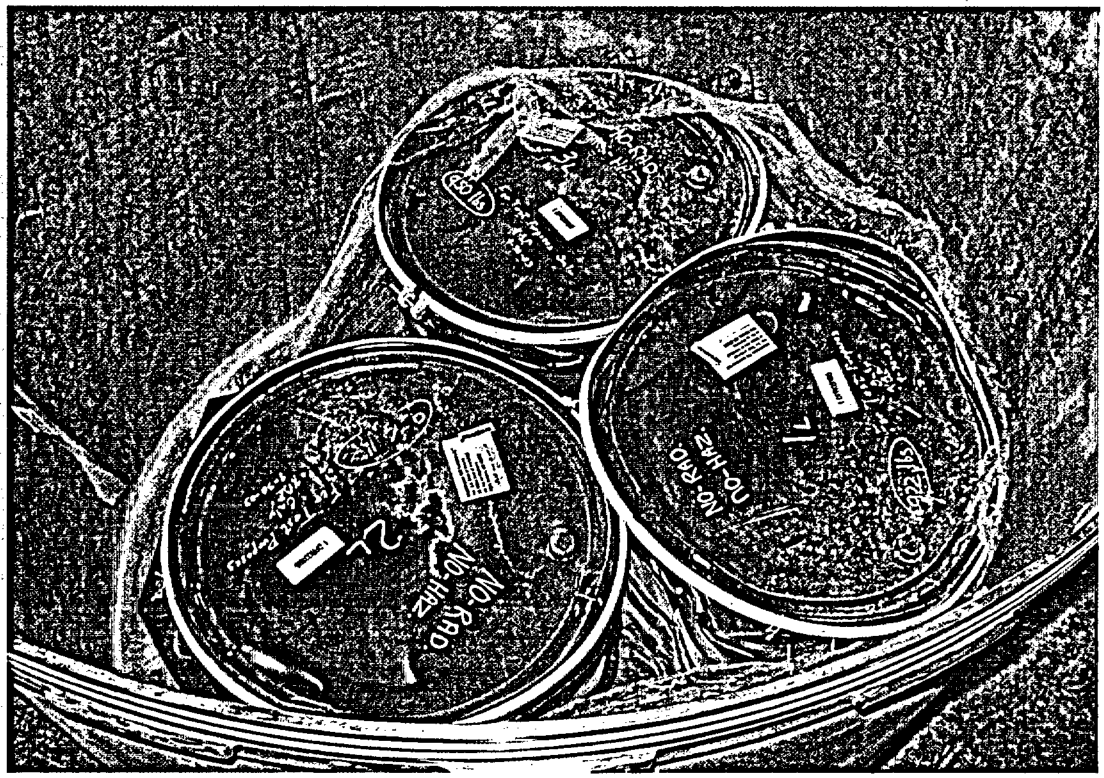


Figure 41 – Post Drop Condition of Lower 100-Gallon Drum Layer

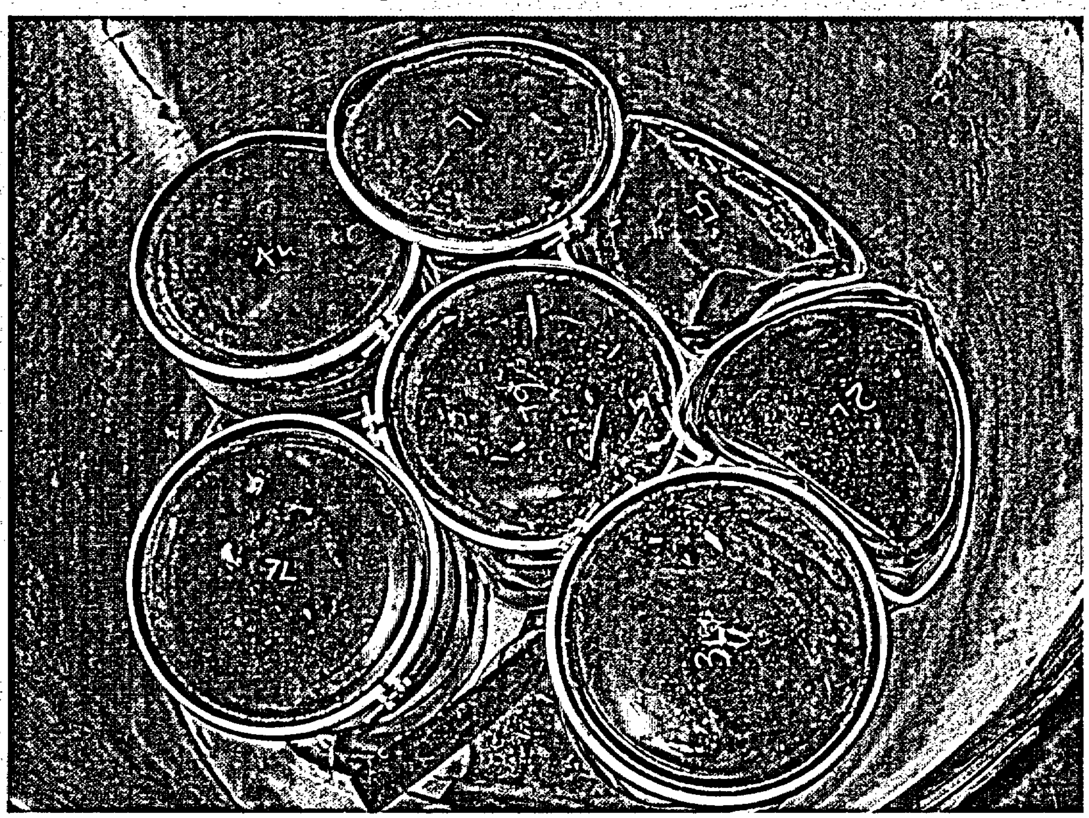


Figure 42 – Post Drop Condition of Lower 55-Gallon Drum Layer

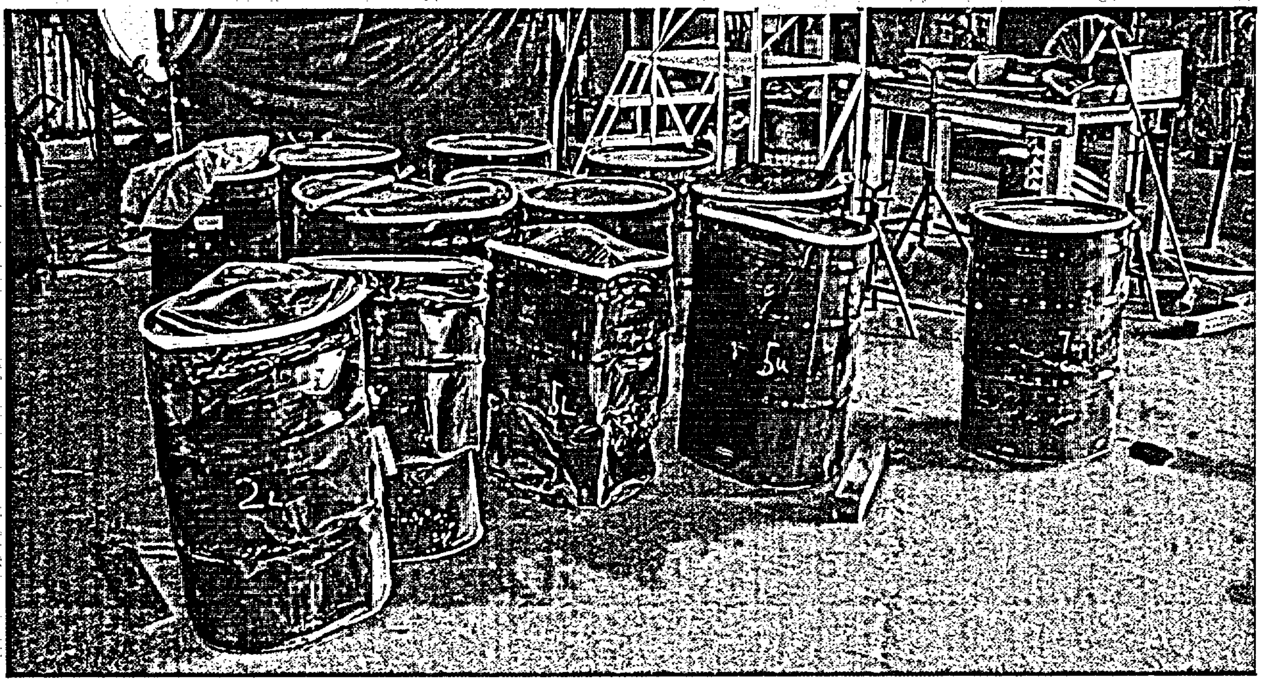


Figure 43 – Typical 55-Gallon Drum Damage

Figure 44 – Measurement of Lower Drum Height Reduction

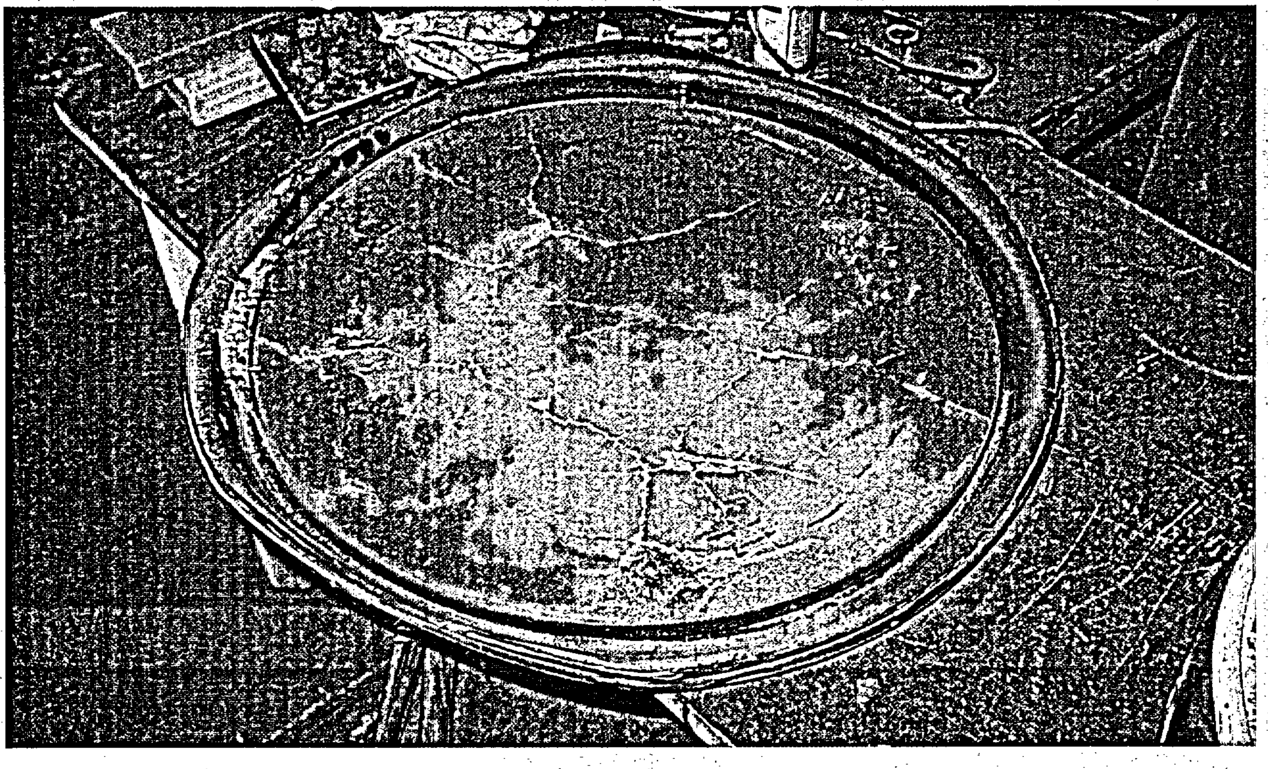


Figure 45 – Typical Post Drop Grout Spacer Condition

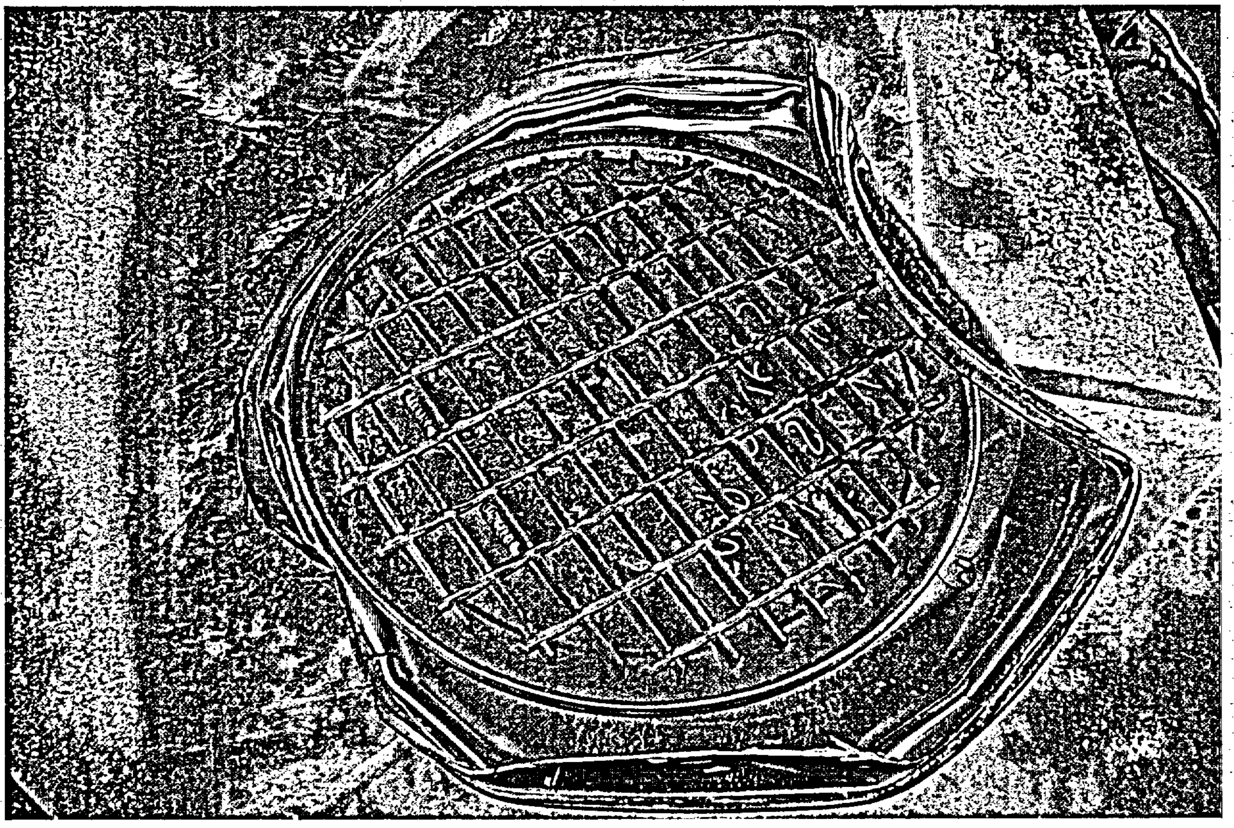


Figure 46 – Typical Post Drop Grate Spacer Condition

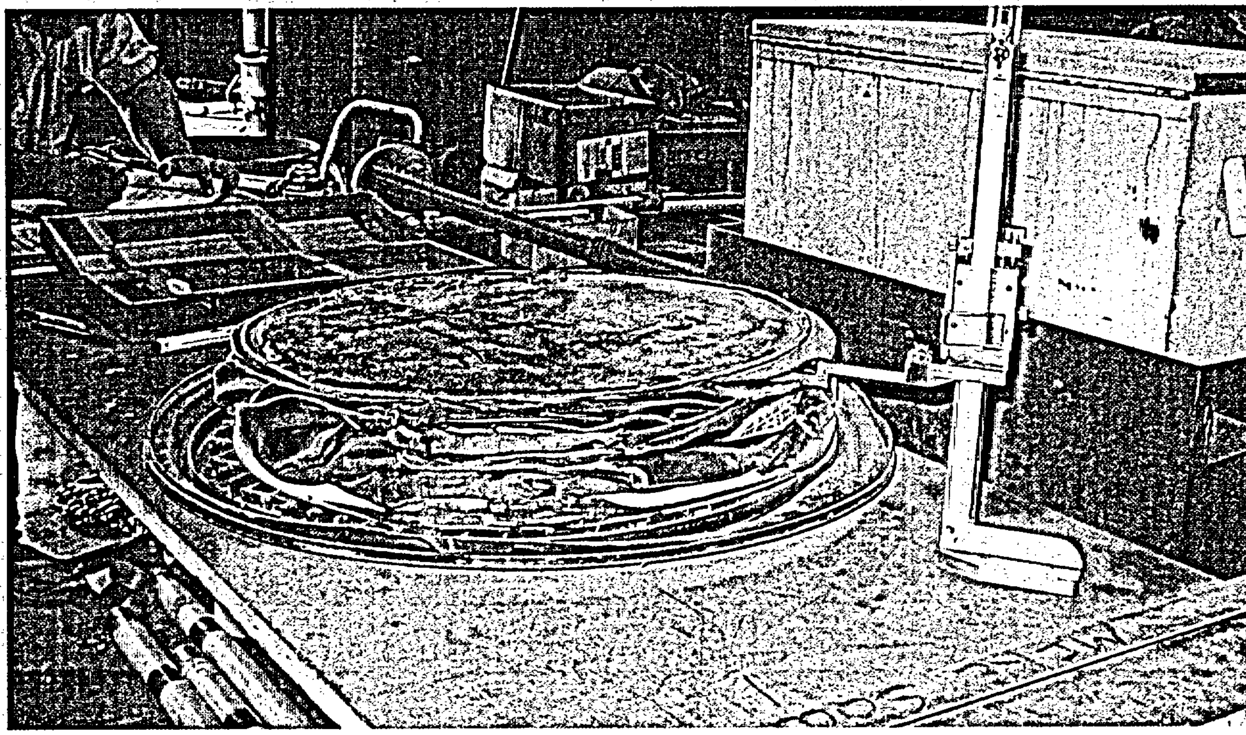


Figure 47 – Differential Measurement of Spacer and Drum Pan Deflection, Per Test Plan

Figure 48 – Direct Measurement of Spacer Heights

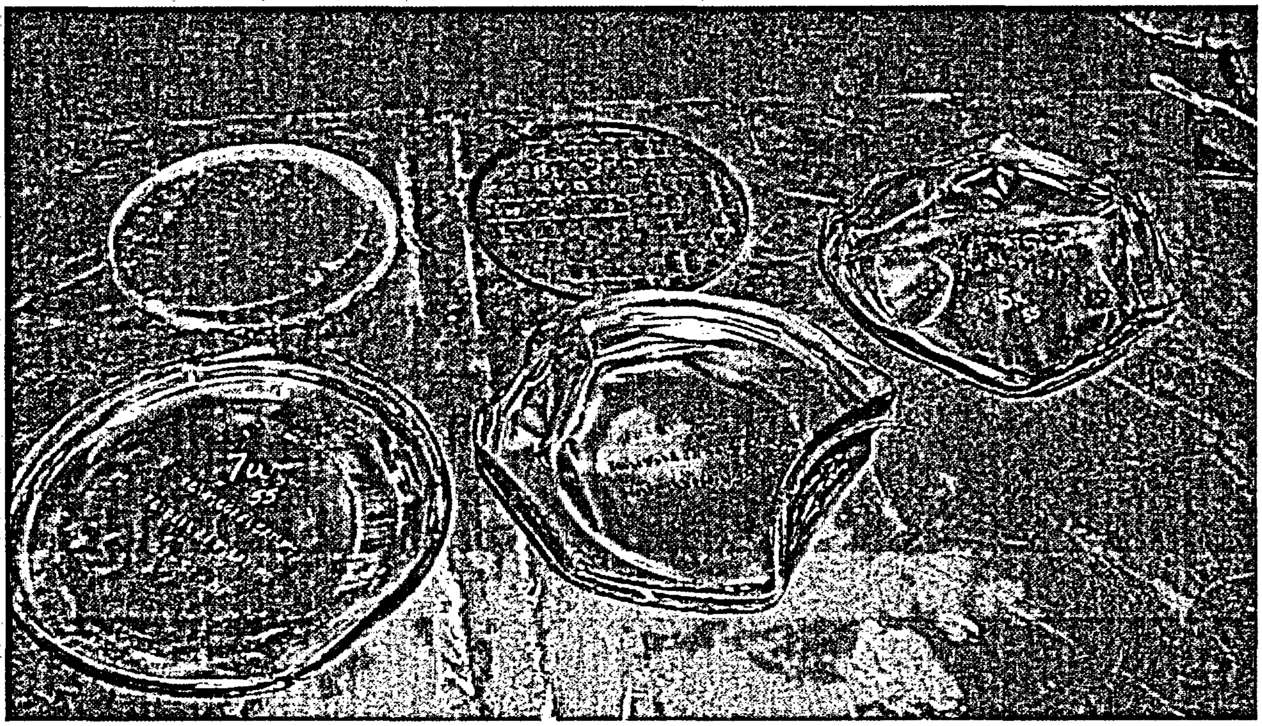


Figure 49 – Typical Spacer and Drum Pan Condition

Figure 50 – Imprint of Upper Drum to Lower Drum Lid

Figure 51 – Opening of No-Spacer Lower Drum, Note Position of Puck Against Lid

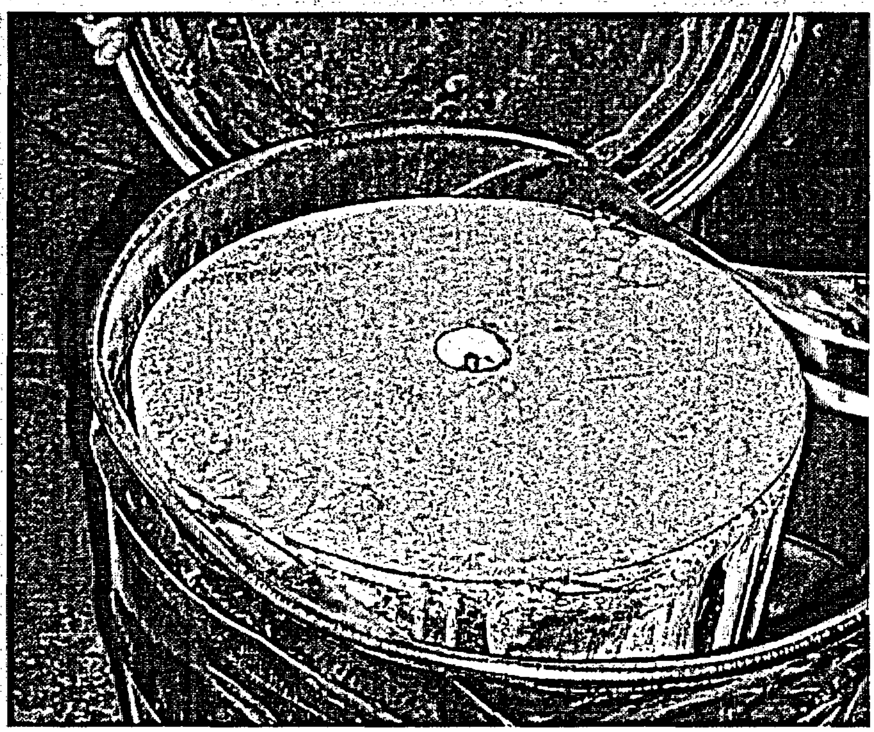


Figure 52 – Position of Payload Puck in Lower Drum