TEST REPORT

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Lockheed Martin Energy Systems
Bear Creek Rd.
Oak Ridge, TN 37831

REPORT NO. 45918-01
OUR JOB NO. 45918
YOUR P. O. NO. 84YLFP22
CONTRACT N/A
PAGE 1 of 52 PAGE REPORT
DATE February 21, 1997

VIBRATION TESTING
OF AN
ES-2 SHIPPING CONTAINER

For

Lockheed Martin Energy Systems, Inc.
Oak Ridge, TN

STATE OF ALABAMA
COUNTY OF MADISON } SS

R. L. Porter, Department Manager, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted testing and is to the best of his knowledge true and correct in all respects.

SEAL

SUBSCRIBED and sworn to before me this 25th day of Feb, 1997

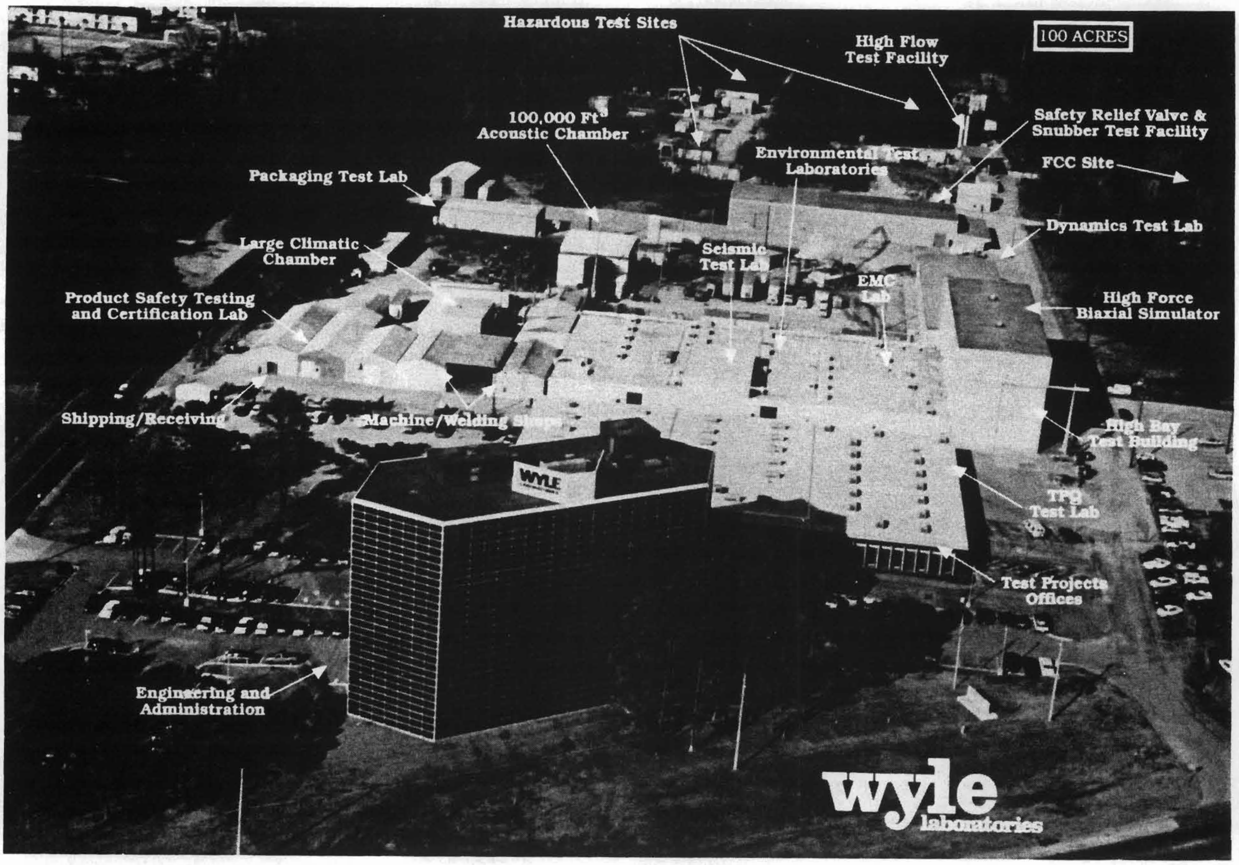
Notary Public in and for the State of Alabama at large
My Commission expires September 1, 1997

PREPARED BY 2/24/97
John Wakefield, Project Engineer

APPROVED BY 2-24-97
D. P. Sandlin, Engineering Supervisor

WYLE Q. A. 2-26-97
R. G. Thomas, Q.A. Manager

(pap)



AERIAL VIEW OF WYLE/HUNTSVILLE

TABLE OF CONTENTS

ATTACHMENTS

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1.0 INTRODUCTION

1.1 Scope

This report describes the test procedures followed and the results obtained during the performance of Vibration Testing on an ES-2 Shipping Container. Performance of testing was from January 7 to January 10, 1997.

1.2 References

- Lockheed Martin Energy Systems (LMES) Request for Quotation dated September 24, 1996
- Wyle Laboratories' Quotation Letter No. 542/3020-01/JK
- Lockheed Martin Energy Systems' Purchase Order No. 84YLFP22
- Wyle Laboratories' Quality Assurance Program, Revision 1
- ANSI/NCSL Z540-1 "Calibration Laboratories and Measuring and Test Equipment, General Requirements"
- ISO 10012-1, "Quality Assurance Requirements for Measuring Equipment"
- MIL-STD-45662A, "Calibration System Requirements"

1.3 Test Specimen Description

The following item was subjected to test:

ES-2 Shipping Container, S/N 12002

The ES-2 Shipping Container consisted of a main container, a top plug, and an inner container with exterior foam padding (See Photograph 2 in Attachment A). Two convenience cans with weights sealed inside them had been placed into the inner container, prior to shipment to Wyle Laboratories, to simulate an actual load weight and setup, and were not considered to be part of the unit under test.

2.0 REQUIREMENTS

The ES-2 Shipping Container shall be subjected to Vibration Testing in accordance with Lockheed Martin Energy Systems' Request for Quotation dated September 24, 1996. One ES-2 Container shall be utilized as the test unit for all testing.

3.0 TEST PERFORMANCE AND RESULTS

The ES-2 Shipping Container was subjected to Vibration Testing in accordance Lockheed Martin Energy Systems (LMES) Request for Quotation dated September 24, 1996, and the directives of the LMES personnel present at the test site. LMES Representatives were present to perform post-test checkouts of the test unit. Prior to the start of testing, a snap-shock accelerometer was mounted inside the test unit by LMES personnel. All data obtained from this accelerometer before, during, and after testing was retained by LMES.

3.1 Sinusoidal Vibration

The ES-2 Shipping Container was first subjected to Sinusoidal Vibration. Performance of testing was on January 7, 1996.

The test unit was set up on the vibration table in its vertical axis and subjected to Sinusoidal Vibration from 10 to 500 Hz at 0.96 grms with a 1-Hz step frequency. From 10 to 250 Hz, the 34-second frequency dwells were performed in 1-Hz steps. Starting at 250 Hz, the step was changed to 2 Hz at the direction of the LMES Representative. The total test time was approximately 3 hours and 47 minutes. Following the completion of the Sinusoidal Vibration Test, the test unit was opened by LMES personnel and inspected for damage.

The ES-2 Shipping Container successfully completed the Sinusoidal Vibration Test. A photograph of the test setup is presented in Attachment A. A Vibration Test Data Sheet and Data Plots are presented in Attachment B. Tabulated Data containing the Dwell Frequency, positive and negative g Peak Levels for the control and response accelerometers, and Tape Start Time for the respective Dwell Frequency is presented in Attachment C. An Instrumentation Equipment sheet for the Test Setup is presented in Attachment D.

3.2 Random Vibration

Following the completion of the Sinusoidal Vibration, the test unit was subjected to Random Vibration. Performance of testing was from January 8 to January 10, 1997.

The test unit was reassembled into its normal shipping configuration, returned to the vibration table, and subjected to random vibration from 10 to 500 Hz at 0.96 grms for 40 hours.

3.0 TEST PERFORMANCE AND RESULTS (Continued)

3.2 Random Vibration (Continued)

At the direction of the LMES Representative, the test unit was allowed to continue vibration following the completion of the 40-hour run time to allow time to videotape the test unit while it was still under test. The test was then terminated at the direction of the LMES Representative. Total test time was approximately 41 hours, 58 minutes.

Following the completion of the test, the test unit was removed from the vibration table, opened by LMES personnel, and inspected for damage. Wear spots on the test unit were noted in the following places:

- On the top plug, with a corresponding wear spot on the inside of the main container lid.
- In the bottom of the main container where the inner container rests.
- Around the inside circumference of the main container where the pressure test plug on the inner container rubbed against the main container wall.
- Around the circumference of the aluminum inner sleeve insert of the inner container along the flange weld.

None of these wear spots were deemed significant enough by LMES personnel to warrant a failure of the test unit.

When the inner container was opened, severe damage was noted to the two convenience cans inside the inner container. This damage and the noted wear spots are documented in Notice of Anomaly No. 1. Photographs of the wear spots and damaged convenience cans appear in Attachment A.

A Post-Test Functional Pressure Check was performed on the inner container by LMES personnel. The results of this Pressure Check were retained by LMES.

The ES-2 Shipping Container successfully completed the Random Vibration Test. A photograph of the test setup is presented in Attachment A. A Vibration Test Data Sheet and Data Plots are presented in Attachment B. An Instrumentation Equipment sheet for the Test Setup is presented in Attachment D.

4.0 QUALITY ASSURANCE

All work performed on this test program was completed in accordance with Wyle Laboratories' Quality Assurance Program.

5.0 TEST EQUIPMENT AND INSTRUMENTATION

All instrumentation, measuring and test equipment used in the performance of this test program were calibrated in accordance with Wyle Laboratories' Quality Assurance Program which complies with the requirements of ANSI/NCSL Z540-1, ISO 10012-1, and Military Specification MIL-STD-45662A. Standards used in performing all calibrations are traceable to the National Institute of Standards and Technology (NIST) by report number and date. When no national standards exist, the standards are traceable to international standards or the basis for calibration is otherwise documented.

ORIGINAL

NOTICE OF ANOMALY

DATE: February 3, 1997

NOTICE NO: 1 P.O. NUMBER: 84YLFP22 CONTRACT NO: N/A
CUSTOMER: Martin Marietta Energy WYLE JOB NO: 45918
NOTIFICATION MADE TO: Gerald Byington NOTIFICATION DATE: Jan. 10, 1997
NOTIFICATION MADE BY: John Wakefield VIA: Verbal

CATEGORY: ■ SPECIMEN ☐ PROCEDURE ☐ TEST EQUIPMENT DATE OF ANOMALY: Jan. 10, 1997
PART NAME: ES-2 Shipping Container PART NO. N/A
TEST: Vibration (Vertical Axis Only) I.D. NO. N/A
SPECIFICATION: Wyle Quotation No. 542/3020-01/JK PARA. NO. N/A

REQUIREMENTS:

The ES-2 Shipping Container shall be inspected for damage following the completion of the 40-hour Sine-On-Random Vibration Test.

DESCRIPTION OF ANOMALY:

The following results were noted following the completion of the 40-hour Sine-On-Random Vibration Test:

- There is a one-inch wear spot on the top plug, with a corresponding wear spot on the inside of the main container lid.
- There are slight wear spots in the bottom of the main container where the inner container rests.
- There is a 3/4-inch wear strip around the inside circumference of the main container where the pressure test plug on the inner container rubbed against the main container wall.
- Wear was noted around the circumference of the aluminum inner sleeve insert of the inner container along the flange weld.
- Two convenience cans inside the inner container were severely damaged.

DISPOSITION - COMMENTS - RECOMMENDATIONS:

The test results were noted by Martin Marietta Energy (MME) personnel. No wear spots were deemed significant enough by MME personnel to warrant a failure of the test unit. The convenience cans with weights sealed inside to simulate an actual load weight and setup were placed inside the test unit prior to Vibration Testing at Wyle Laboratories. These were not considered part of the unit under test, though the damage to the convenience cans was noted by MME personnel.

RESPONSIBILITY TO ANALYZE ANOMALIES AND COMPLY WITH 10 CFR PART 21: ■ CUSTOMER ☐ WYLE

VERIFICATION:

TEST WITNESS: Gerald Byington
REPRESENTING: Martin Marietta Energy
QUALITY ASSURANCE: [signature] 2-3-97

PROJECT ENGINEER: [signature] 2/3/97 John Wakefield
PROJECT MANAGER: [signature] 2/3/97 R. L. Porter
INTERDEPARTMENTAL COORDINATION:

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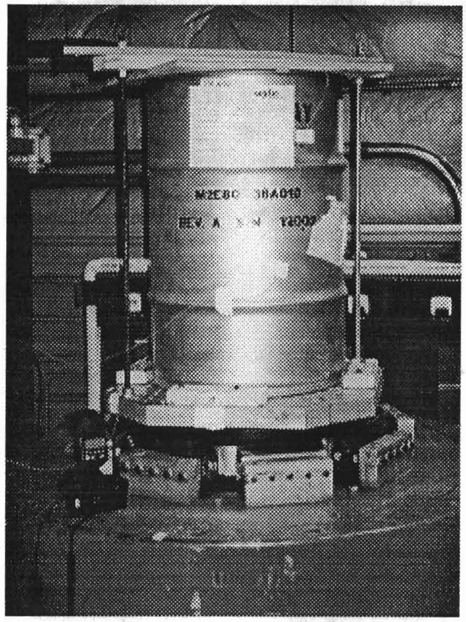
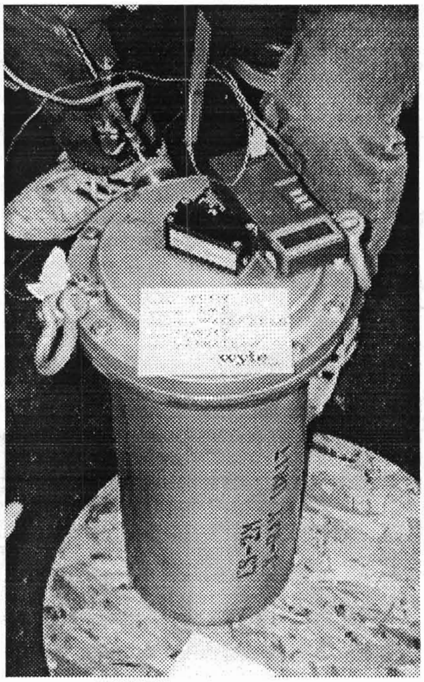
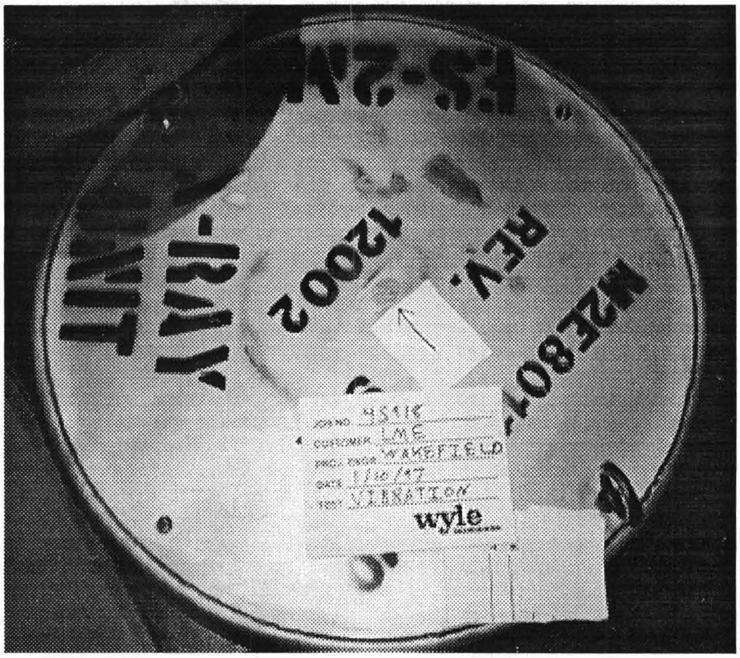


Photograph No. 1
Typical Vibration Test Setup

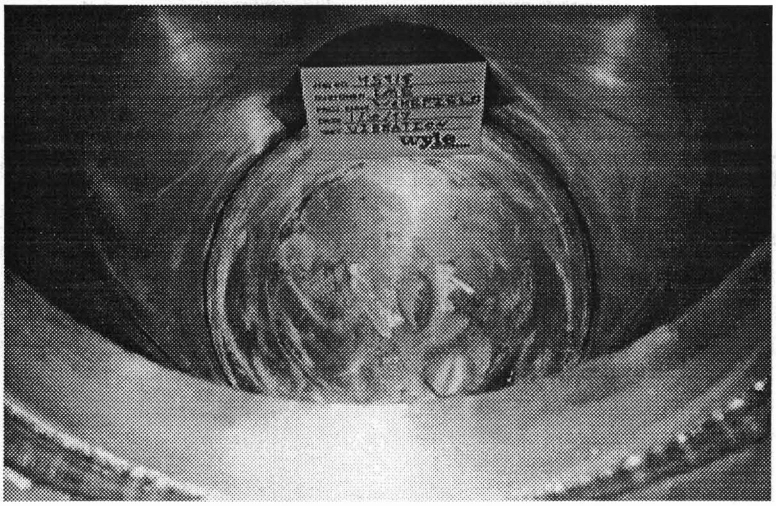
Photograph No. 2
ES-2 Shipping Container, Unpackaged Configuration



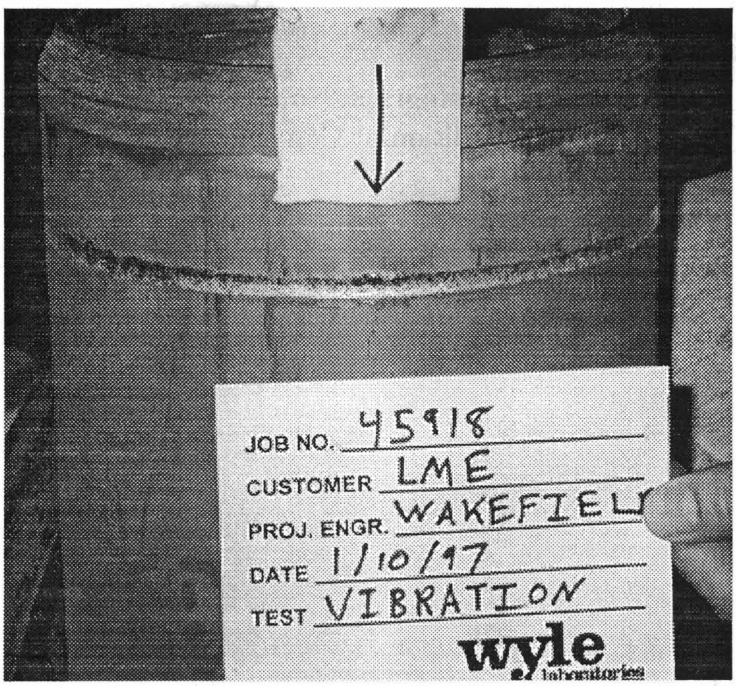
Photograph No. 3
LMES Pressure Check Setup



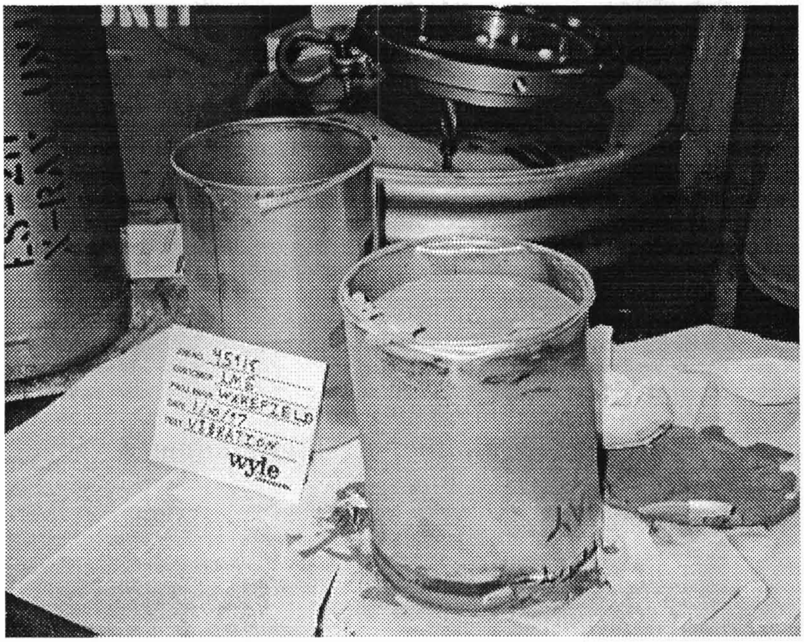
Photograph No. 4
Wear Spot on Top Plug



Photograph No. 5
Wear Spots in Bottom of Main Container



Photograph No. 6
Wear Strip on Aluminum Sleeve



Photograph No. 7
Post-Test Condition of Convenience Cans

ATTACHMENT B

VIBRATION TEST DATA SHEET AND DATA PLOTS

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VIBRATION TEST DATA SHEET

Customer Lockheed Martin Spec. LMES RFQ dated 4/24/96 Specimen Drum (ES-2 Shipping Container)

Job No. 45918-00 Method N/A Part No. N/A Specimen Temp. Amb.

GSI Yes ☐ No ☒ Procedure N/A S/N 12002 Photo Yes ☒ No ☐

Test Title Sine Vibration and Random Vibration

Date	Time	Axis					RANDOM			TOTAL	Test Time (min)	COMMENTS	NAME
				Freq. (cps)	Disp. ("da)	Accel (± g)	Freq. (cps)	PSD (g^2/cps)	Slope dB/oct	Accel. (grms)			
												TEST REQUIREMENT	
1/7/97	14:55	Vert.		10-500		.96					277.8	Run #1 - 34 sec/freq.	SLG
1/8/97	12:09	Vert.					10	.023				Run #2 - 40 hr (minimum) random	
							500	.00046		.961	2517		SLG

WH-1028A

Signed Stacy George 1/20/97 Approved [signature] 1/31/97

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Sinusoidal Vibration Test Data Plots

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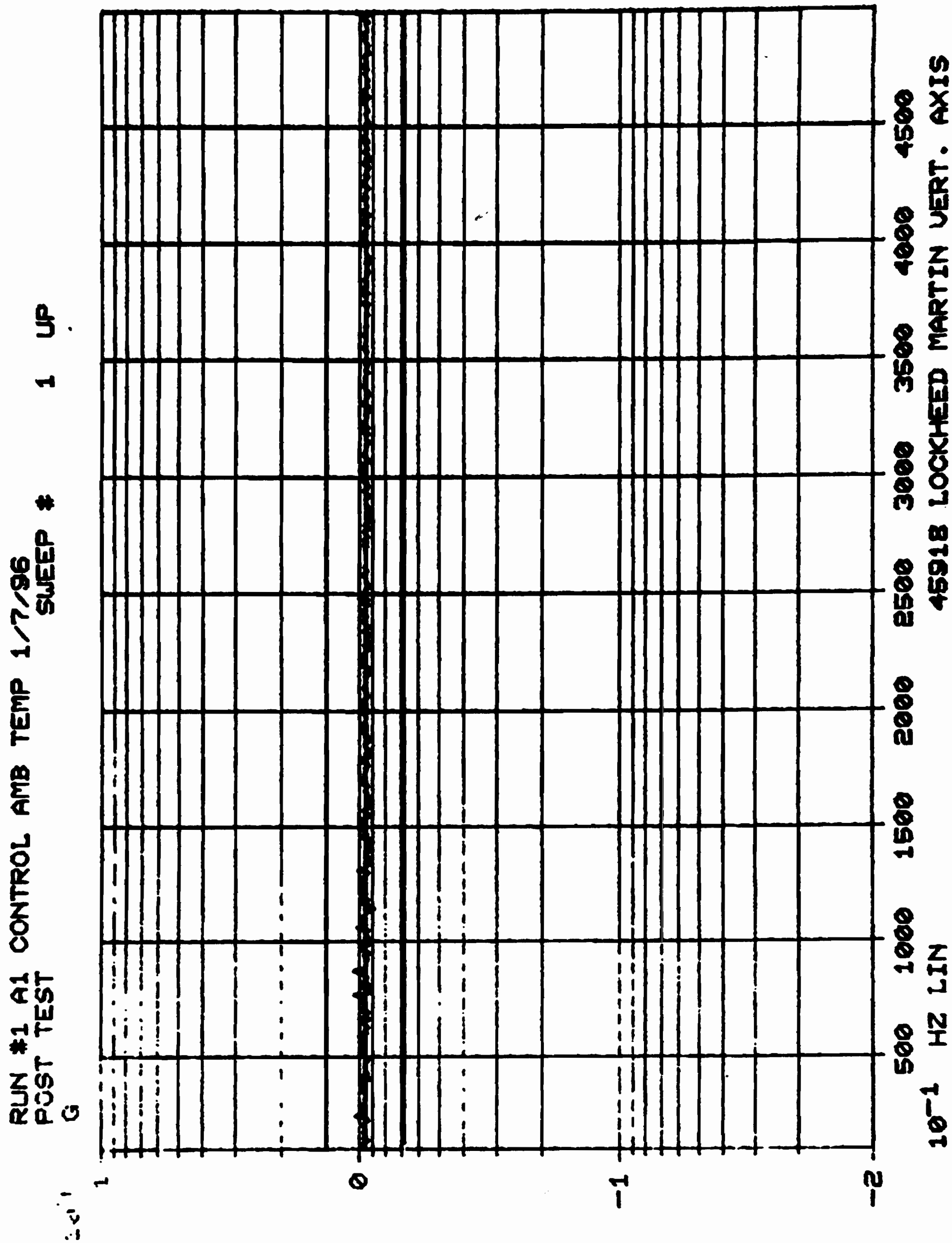
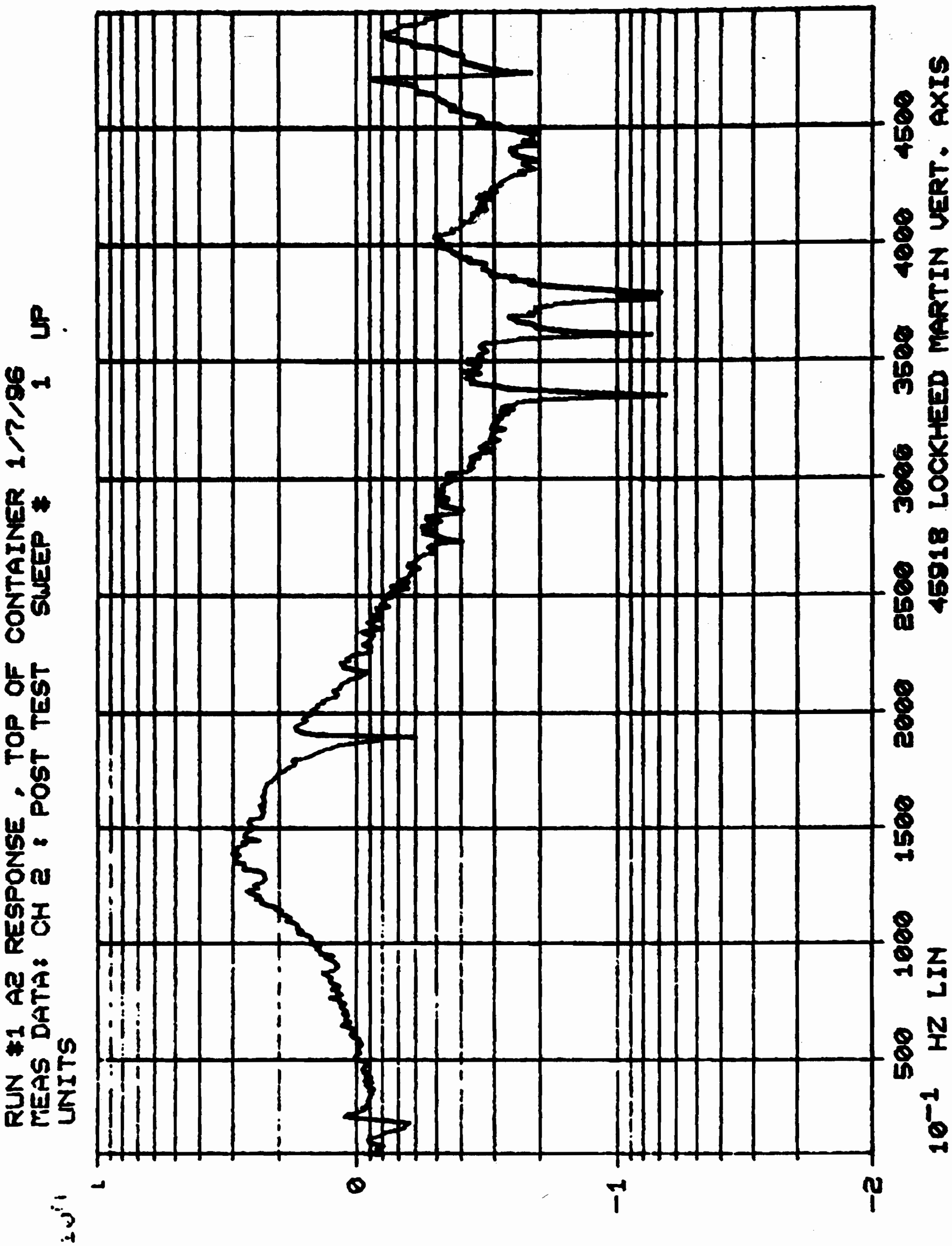

RUN #1 A1 CONTROL AMB TEMP 1/7/96
POST TEST
SWEEP # 1 UP
G
1
0
-1
-2
10^{-1}
500
1000
1500
2000
2500
3000
3500
4000
4500
HZ LIN
45918 LOCKHEED MARTIN VERT. AXIS


RUN #1 A2 RESPONSE , TOP OF CONTAINER 1/7/96
MEAS DATA: CH 2 : POST TEST SWEEP # 1 UP
UNITS
1
0
-1
-2
10^-1
500
1000
1500
2000
2500
3000
3500
4000
4500
HZ LIN
45918 LOCKHEED MARTIN VERT. AXIS

Random Vibration Test Data Plots

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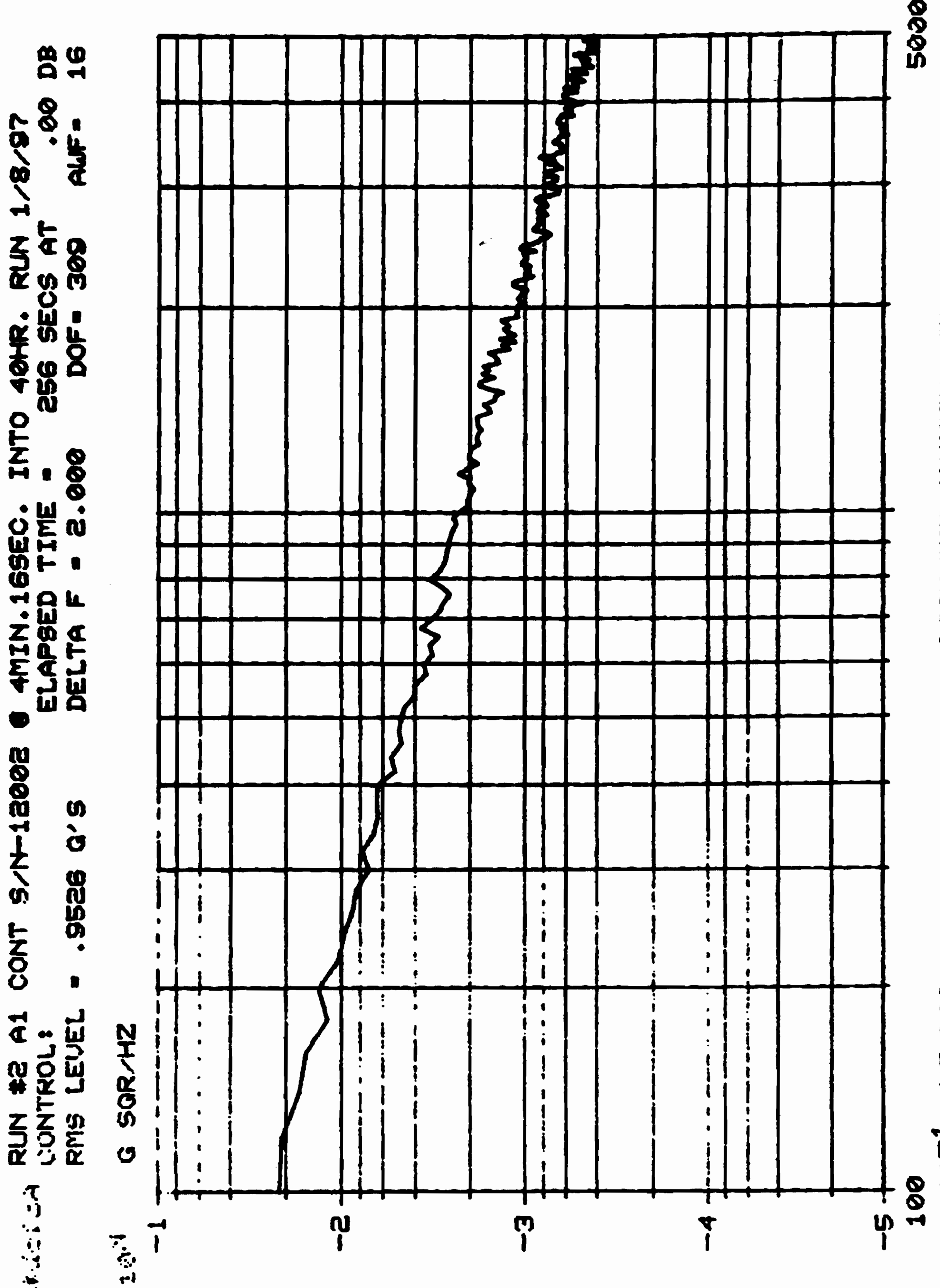
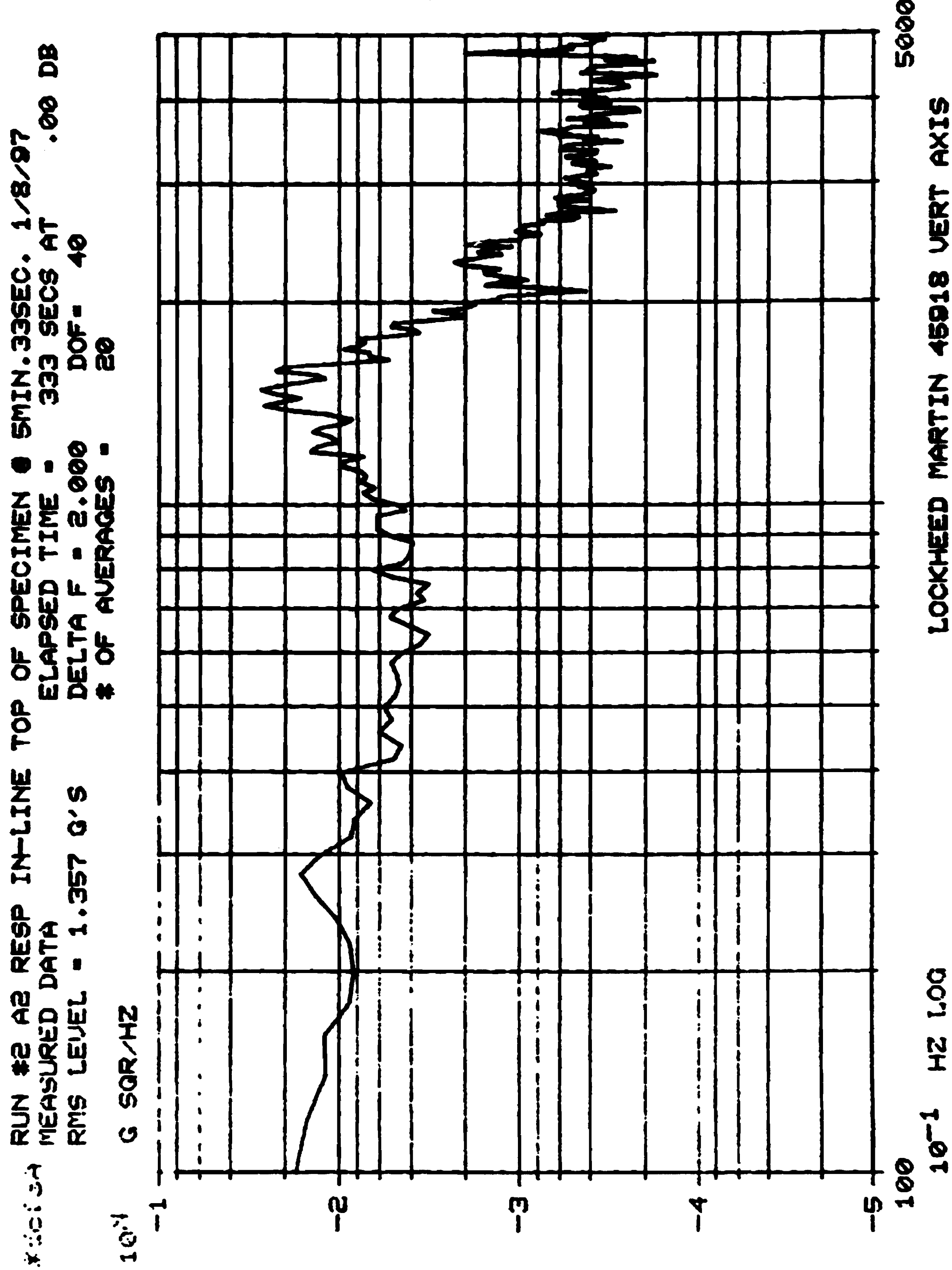
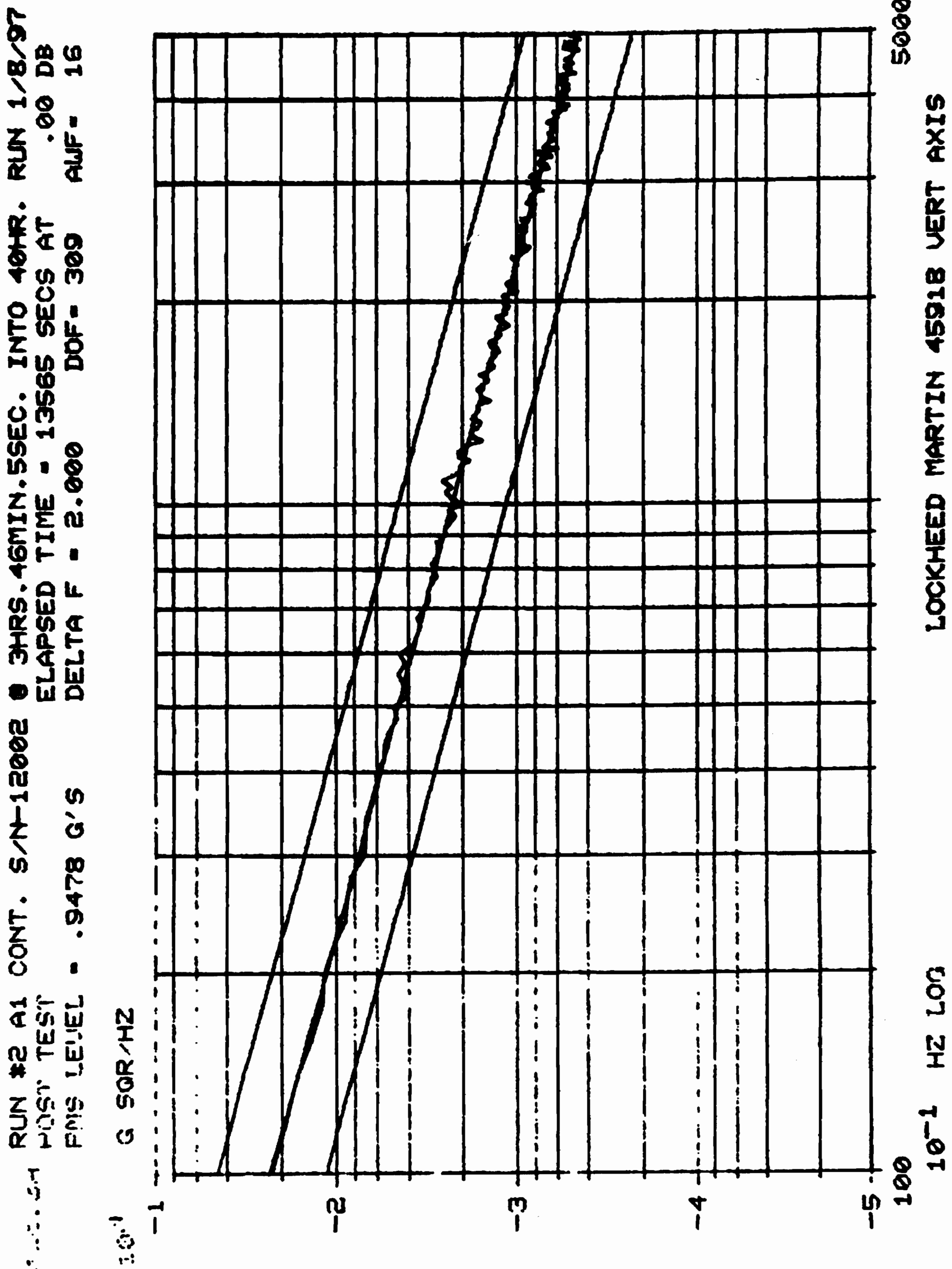
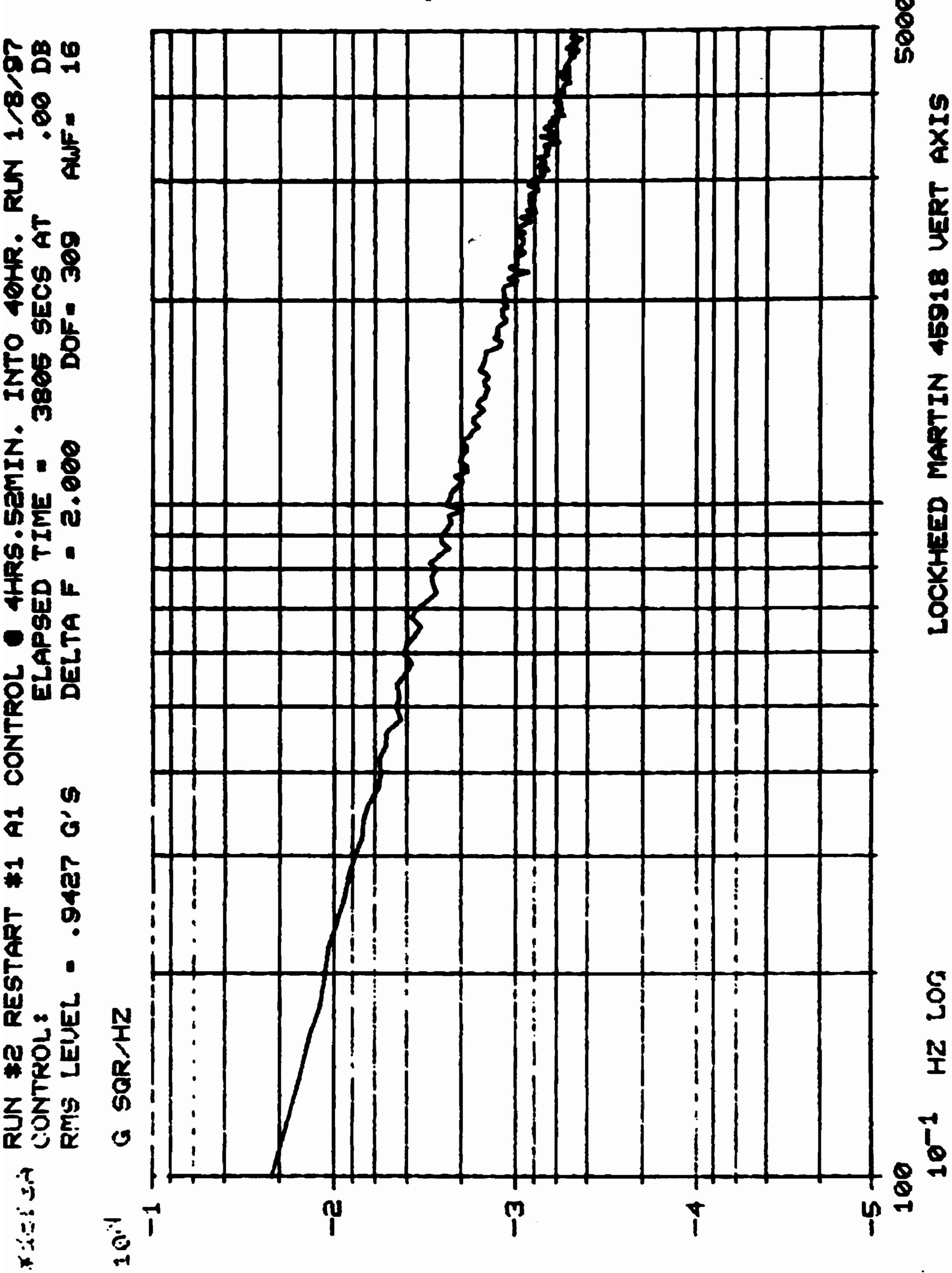
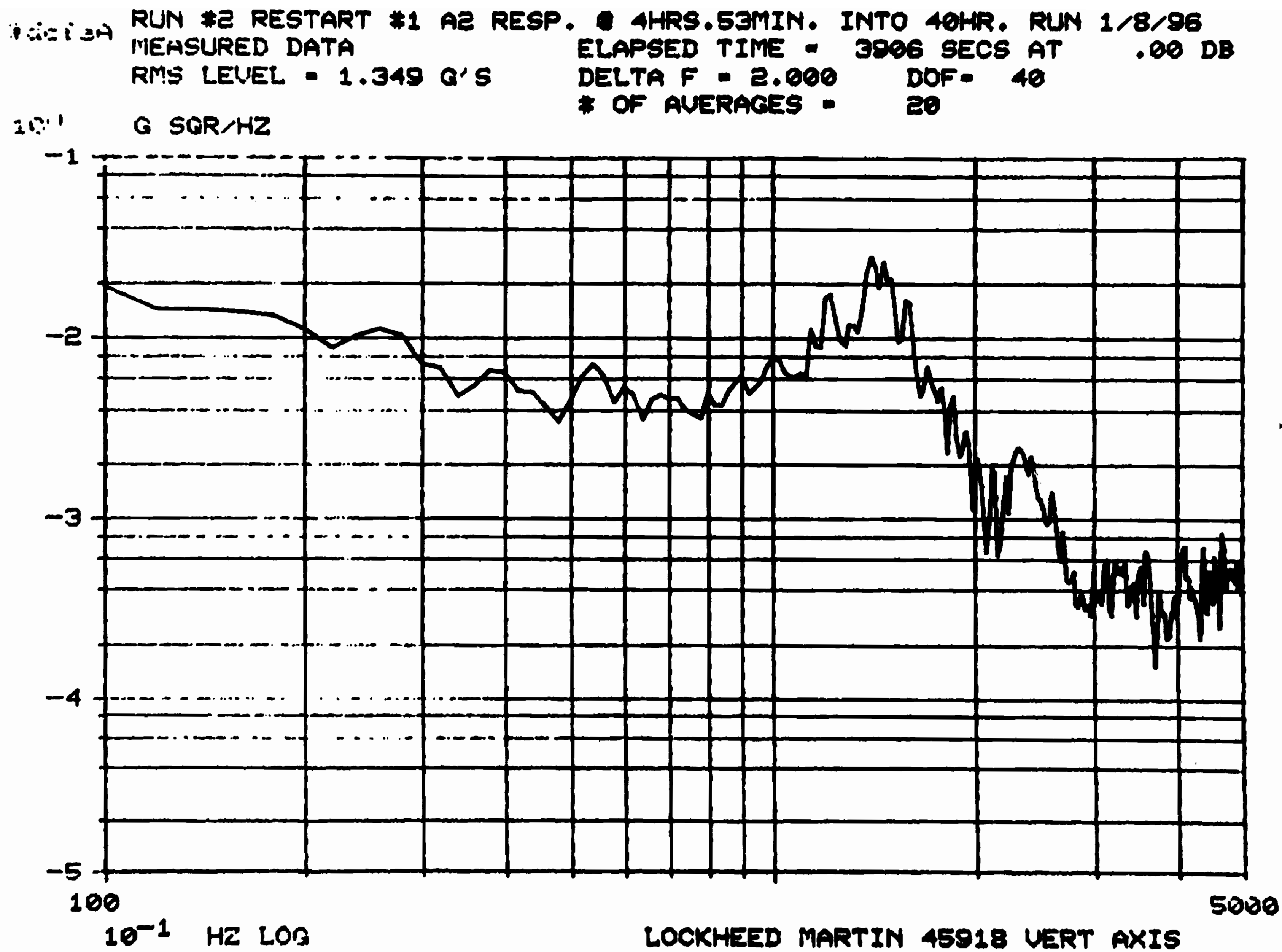
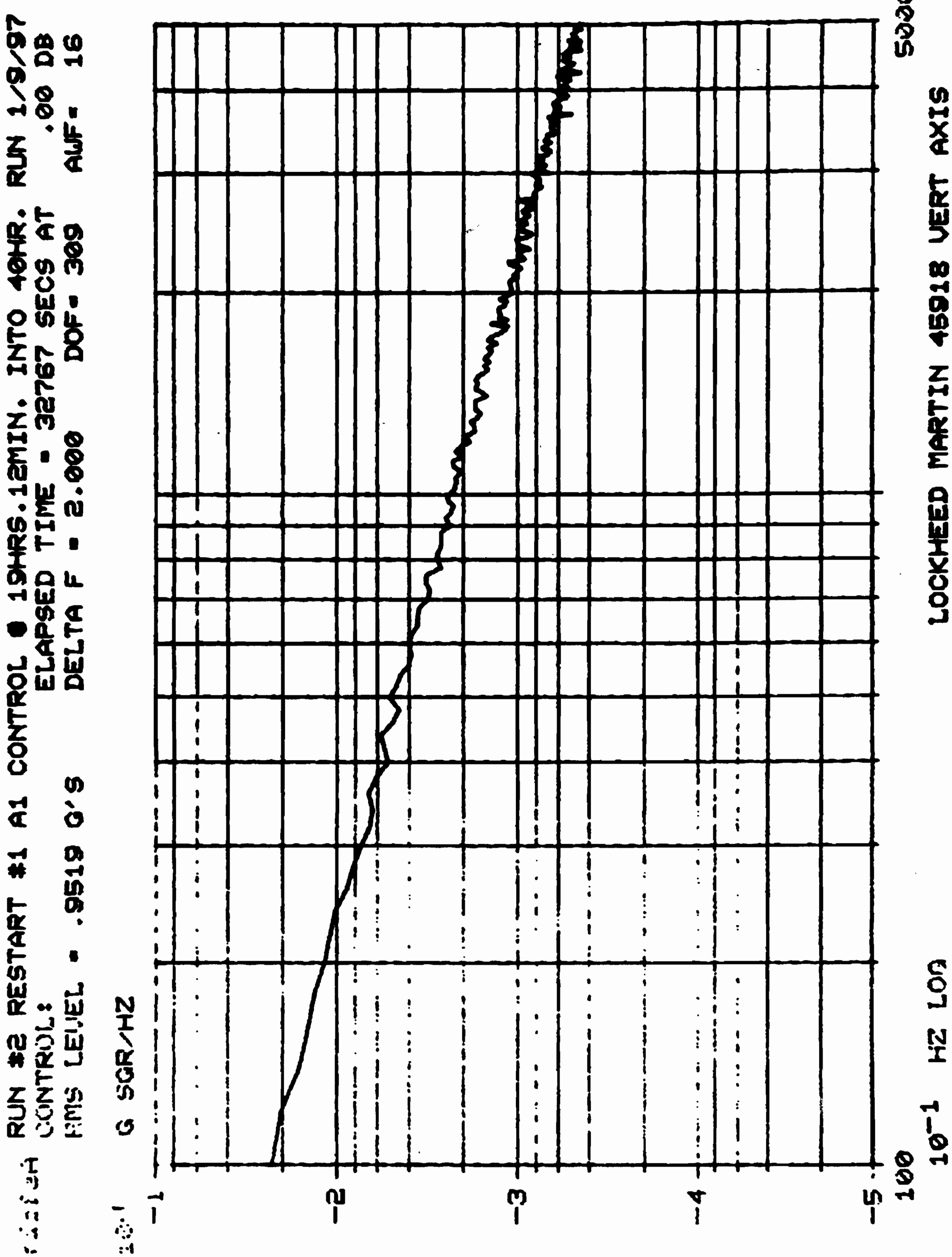

RUN #2 A1 CONT S/N-1200B @ 4MIN.16SEC. INTO 40HR. RUN 1/8/97
CONTROL: ELAPSED TIME = 256 SECS AT .00 DB
RMS LEVEL = .9528 G'S DELTA F = 2.000 DOF= 300 AWF= 16
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
10-1 HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS

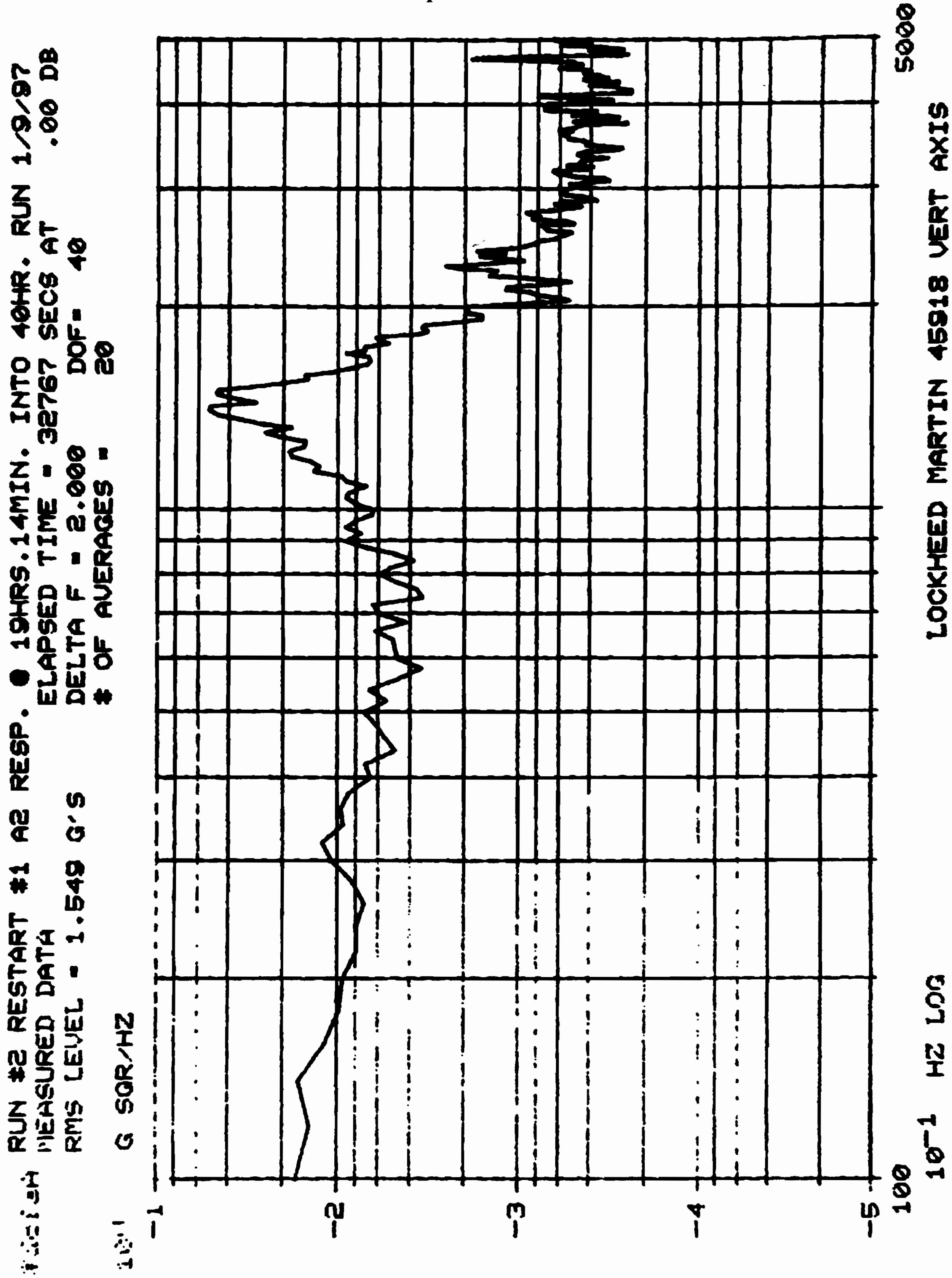

RUN #2 A2 RESP IN-LINE TOP OF SPECIMEN @ 5MIN.33SEC. 1/8/97
MEASURED DATA
ELAPSED TIME = 333 SECS AT .00 DB
RMS LEVEL = 1.357 G'S
DELTA F = 2.000
DOF= 40
# OF AVERAGES = 20
G SQR/HZ
10^1
-1
-2
-3
-4
-5
100
10^-1
HZ LOG
5000
LOCKHEED MARTIN 45918 VERT AXIS

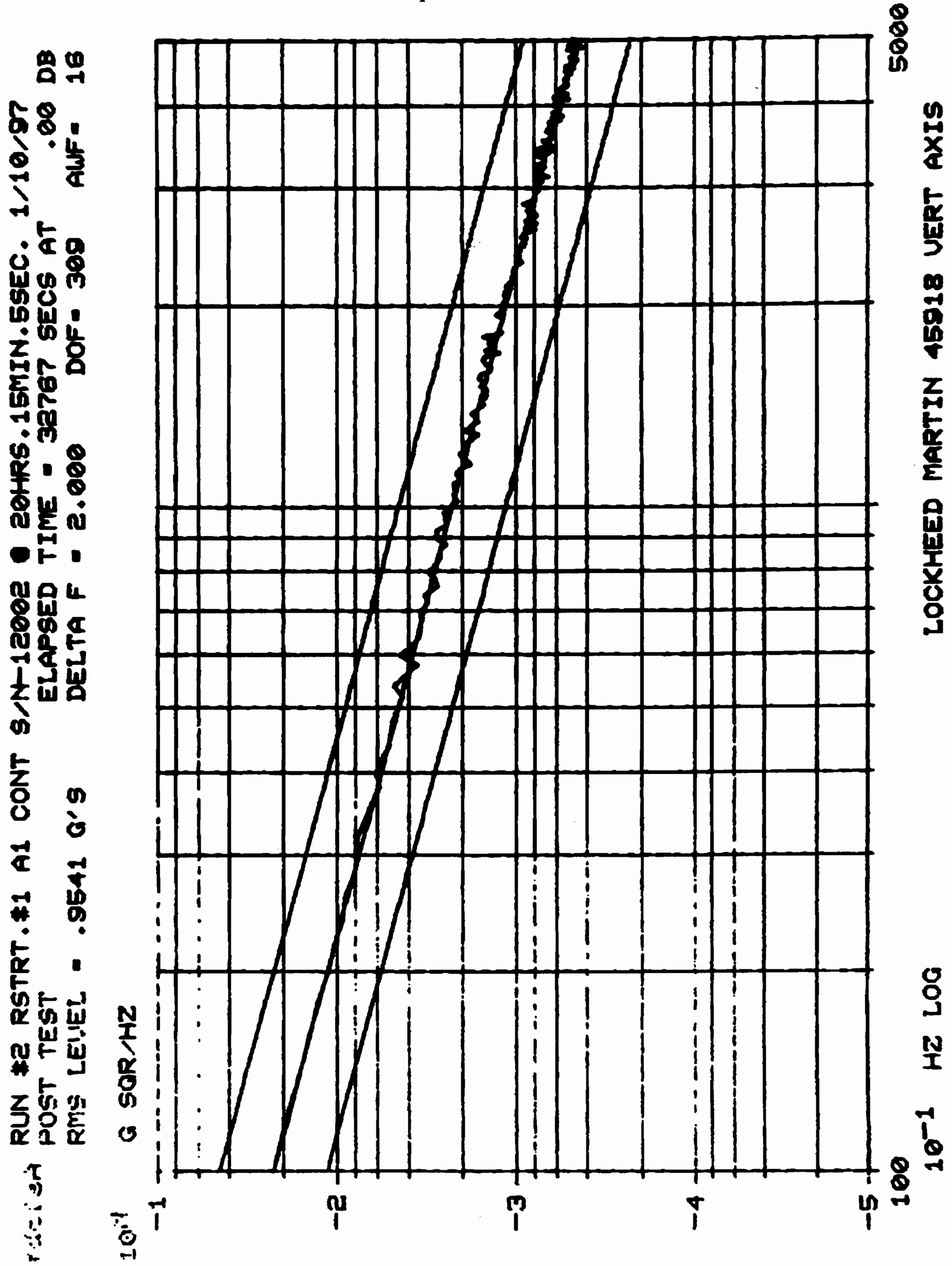

RUN #2 A1 CONT. S/N-12002 @ 3HRS.46MIN.5SEC. INTO 40HR. RUN 1/8/97
POST TEST ELAPSED TIME = 13565 SECS AT .00 DB
RMS LEVEL = .9478 G'S DELTA F = 2.000 DOF= 309 AWF= 16
G SQR/HZ
10^{-1}
-1
-2
-3
-4
-5
100
5000
HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS

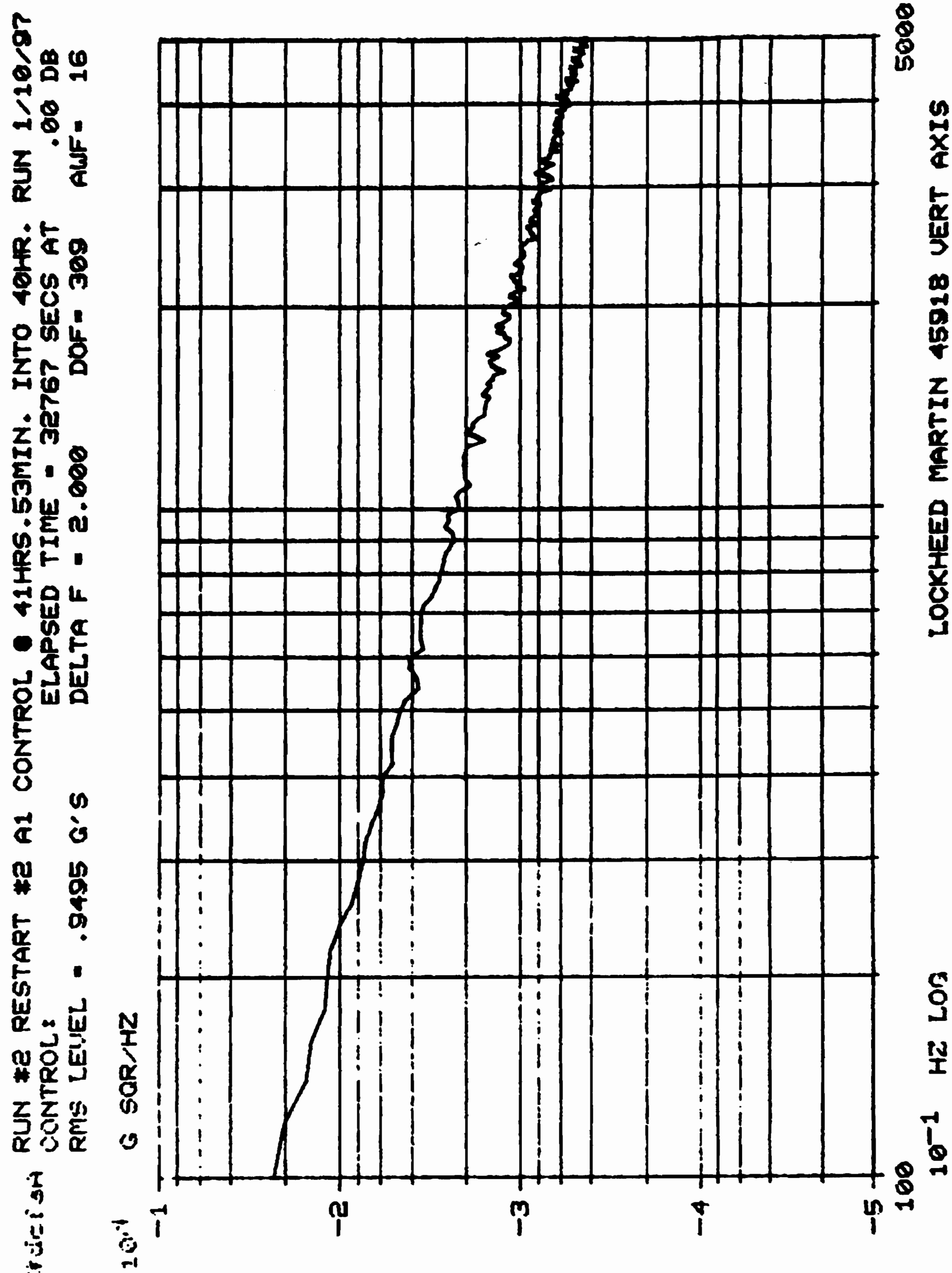

RUN #2 RESTART #1 A1 CONTROL @ 4HRS.52MIN. INTO 40HR. RUN 1/8/97
CONTROL:
ELAPSED TIME = 3805 SECS AT .00 DB
RMS LEVEL = .9427 G'S
DELTA F = 2.000
DOF= 309
AWF= 16
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
10^-1 HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS

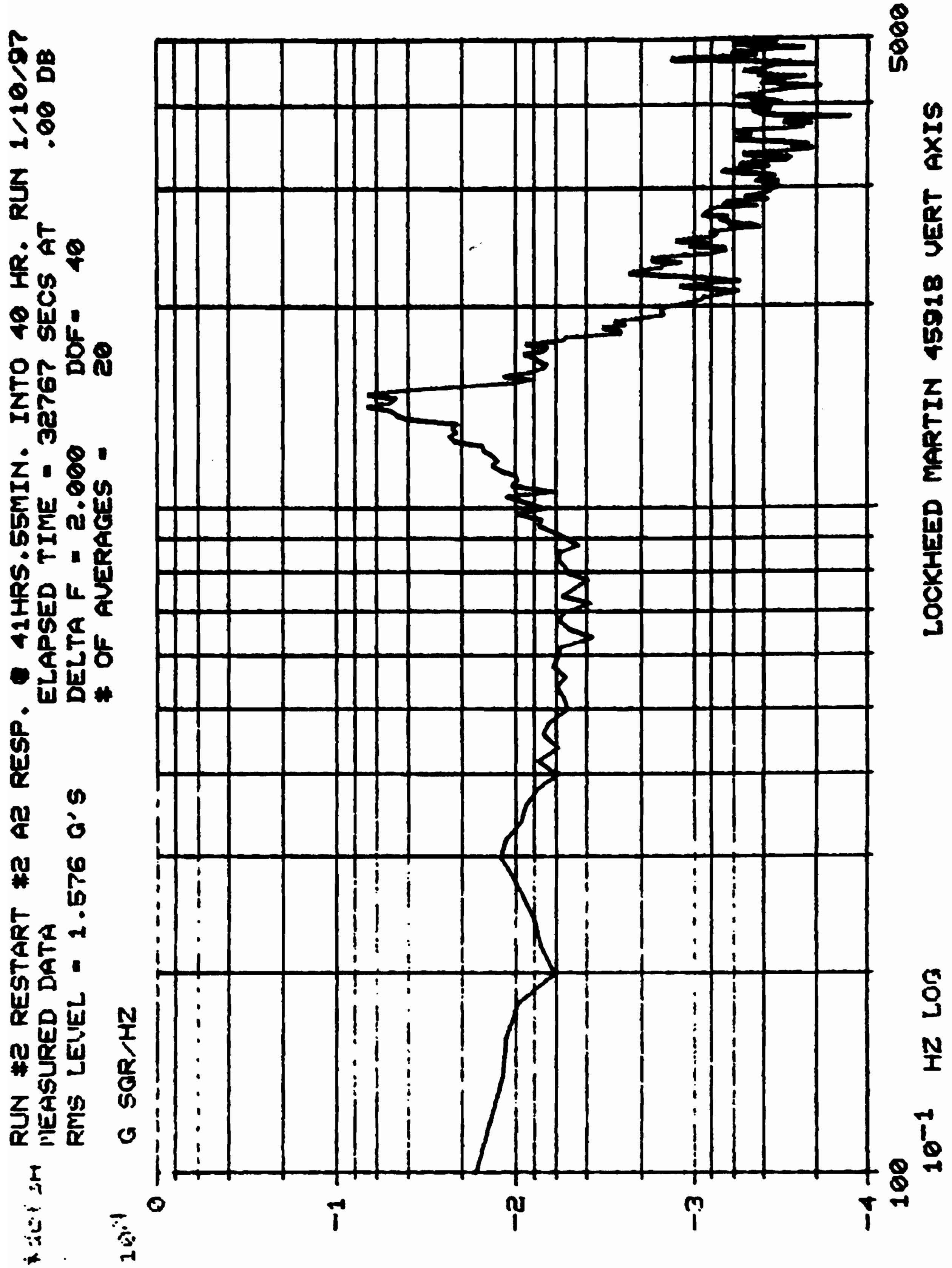

RUN #2 RESTART #1 A2 RESP. @ 4HRS.53MIN. INTO 40HR. RUN 1/8/96
MEASURED DATA
ELAPSED TIME = 3906 SECS AT .00 DB
RMS LEVEL = 1.349 G'S
DELTA F = 2.000
DOF= 40
# OF AVERAGES = 20
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
10^-1 HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS

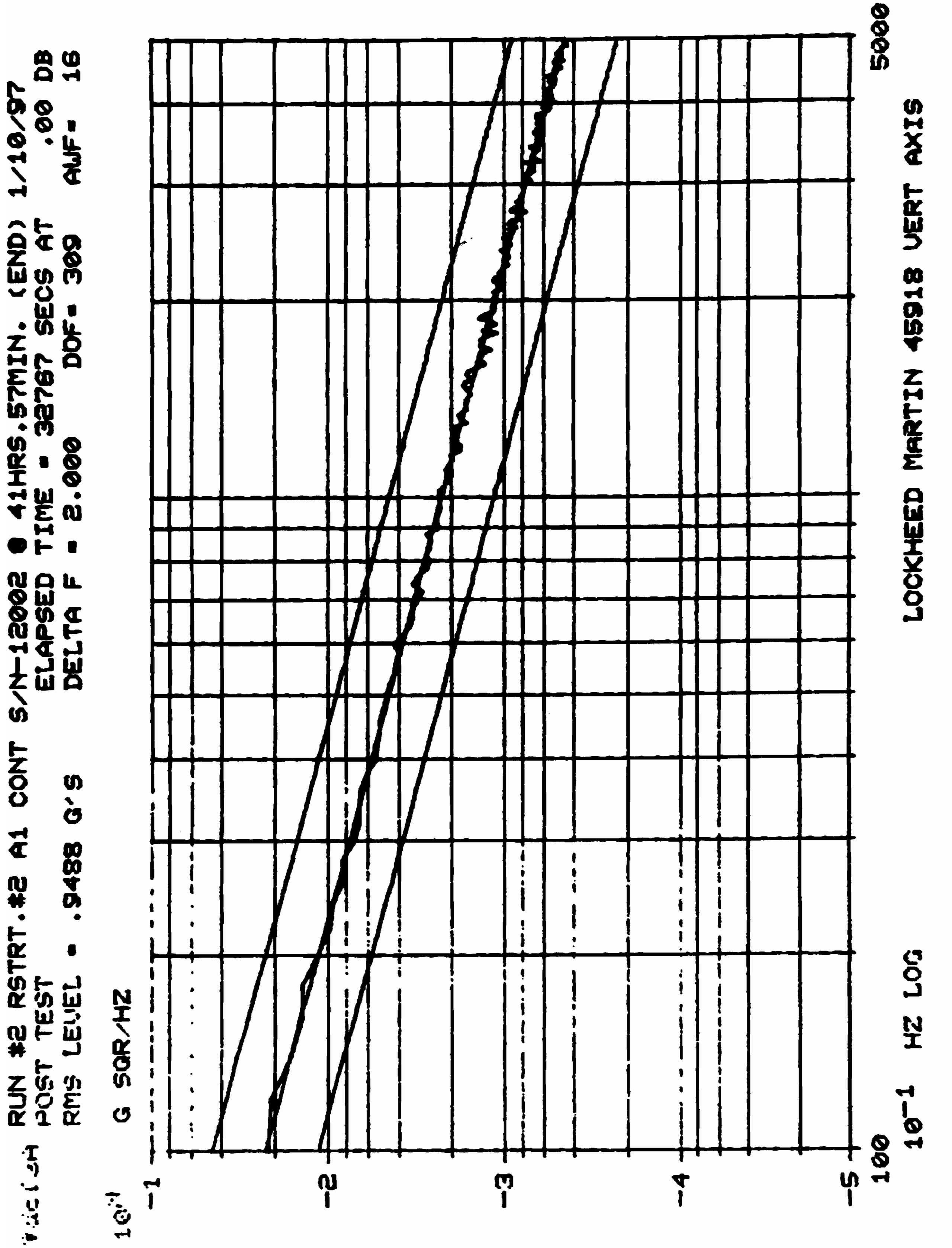

RUN #2 RESTART #1 A1 CONTROL @ 19HRS.12MIN. INTO 40HR. RUN 1/9/97
CONTROL: ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = .9519 G'S DELTA F = 2.000 DOF= 309 AWF= 16
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
10^-1 HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS


RUN #2 RESTART #1 A2 RESP. @ 19HRS.14MIN. INTO 40HR. RUN 1/9/97
MEASURED DATA
ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = 1.549 G'S
DELTA F = 2.000
DOF= 40
# OF AVERAGES = 20
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
10^{-1} HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS


RUN #2 RSTRT.#1 A1 CONT S/N-12002 @ 20HRS.15MIN.5SEC. 1/10/97
POST TEST ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = .9541 G'S DELTA F = 2.000 DOF= 309 AWF= 16
G SQR/HZ
10^1
-1
-2
-3
-4
-5
100
10^-1 HZ LOG
5000
LOCKHEED MARTIN 45918 VERT AXIS


RUN #2 RESTART #2 A1 CONTROL @ 41HRS.53MIN. INTO 40HR. RUN 1/10/97
CONTROL:
ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = .9495 G'S
DELTA F = 2.000
DOF= 309
AWF= 16
G SQR/HZ
10
-1
-2
-3
-4
-5
100
10^-1 HZ LOG
5000
LOCKHEED MARTIN 45918 VERT AXIS


RUN #2 RESTART #2 A2 RESP. @ 41HRS.55MIN. INTO 40 HR. RUN 1/10/97
MEASURED DATA
ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = 1.576 G'S
DELTA F = 2.000
DOF= 40
# OF AVERAGES = 20
G SQR/HZ
0
-1
-2
-3
-4
100
10^-1 HZ LOG
5000
LOCKHEED MARTIN 45918 VERT AXIS


RUN #2 RSTRT.#2 A1 CONT S/N-12002 @ 41HRS.57MIN. (END) 1/10/97
POST TEST
ELAPSED TIME = 32767 SECS AT .00 DB
RMS LEVEL = .9488 G'S
DELTA F = 2.000
DOF= 309
AWF= 16
G SQR/HZ
-1
-2
-3
-4
-5
100
5000
HZ LOG
LOCKHEED MARTIN 45918 VERT AXIS

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ATTACHMENT C

SINUSOIDAL VIBRATION TEST TABULATED DATA

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Sinusoidal Vibration Recorded Data								
							3.33	
Frequency	g	peak	g	peak	Tape Start		Calculated g peak	
(Hz)	A1 Control Accel		A2 Container Accel		Time		A2 Container Accel	
	Pos.	Neg.	Pos.	Neg.			Pos.	Neg.
			(Multiply by 3.33)					
10	0.9	1	0.26	0.3	1452		0.8658	0.999
11	0.93	1.05	0.29	0.28	1452		0.9657	0.9324
12	1	1.05	0.26	0.29	1453		0.8658	0.9657
13	1	1.04	0.29	0.28	1454		0.9657	0.9324
14	1	1.02	0.27	0.27	1454		0.8991	0.8991
15	1	1.05	0.28	0.29	1455		0.9324	0.9657
16	1.05	1.05	0.28	0.32	1455		0.9324	1.0656
17	1	1.05	0.31	0.32	1456		1.0323	1.0656
18	1	1.02	0.31	0.34	1457		1.0323	1.1322
19	1	1.07	0.27	0.3	1457		0.8991	0.999
20	1.05	1.05	0.27	0.31	1458		0.8991	1.0323
21	1	1.05	0.28	0.3	1458		0.9324	0.999
22	1.05	1.05	0.27	0.28	1459		0.8991	0.9324
23	1.1	1.05	0.29	0.32	1500		0.9657	1.0656
24	1.05	1.05	0.3	0.3	1500		0.999	0.999
25	1.1	1.1	0.28	0.3	1501		0.9324	0.999
26	1.05	1.1	0.37	0.32	1501		1.2321	1.0656
27	1.15	1.15	0.53	0.5	1502		1.7649	1.665
28	1.15	1.1	0.48	0.42	1502		1.5984	1.3986
29	1.05	1.1	0.47	0.42	1503		1.5651	1.3986
30	1.05	1.05	0.36	0.32	1504		1.1988	1.0656
31	1.05	1.05	0.34	0.32	1504		1.1322	1.0656
32	1.05	1.05	0.32	0.3	1505		1.0656	0.999
33	1.05	1.05	0.31	0.31	1506		1.0323	1.0323
34	1.1	1.1	0.31	0.31	1506		1.0323	1.0323
35	1.1	1.1	0.31	0.31	1507		1.0323	1.0323
36	1.05	1.05	0.31	0.3	1508		1.0323	0.999
37	1.05	1.05	0.3	0.29	1508		0.999	0.9657
38	1.05	1.05	0.31	0.3	1509		1.0323	0.999
39	1.04	1.05	0.3	0.28	1509		0.999	0.9324
40	1.1	1.05	0.31	0.31	1510		1.0323	1.0323
41	1.1	1.1	0.32	0.31	1511		1.0656	1.0323
42	1.1	1.05	0.34	0.32	1511		1.1322	1.0656
43	1.05	1.1	0.31	0.31	1512		1.0323	1.0323
44	1.1	1.05	0.32	0.31	1513		1.0656	1.0323
45	1.1	1.05	0.33	0.31	1513		1.0989	1.0323
46	1.1	1.06	0.33	0.3	1514		1.0989	0.999
47	1.1	1.1	0.33	0.33	1514		1.0989	1.0989
48	1.1	1.05	0.33	0.32	1515		1.0989	1.0656
49	1.1	1.1	0.35	0.34	1515		1.1655	1.1322
50	1.1	1.1	0.34	0.33	1516		1.1322	1.0989
51	1.15	1.1	0.33	0.33	1516		1.0989	1.0989
52	1.1	1.1	0.33	0.33	1517		1.0989	1.0989
53	1.05	1.05	0.32	0.32	1518		1.0656	1.0656

54	1.05	1.05	0.32	0.32	1519		1.0656	1.0656
55	1.05	1.05	0.33	0.32	1519		1.0989	1.0656
56	1.1	1.05	0.33	0.32	1520		1.0989	1.0656
57	1.05	1.05	0.33	0.33	1520		1.0989	1.0989
58	1.1	1.1	0.33	0.33	1521		1.0989	1.0989
59	1.1	1.1	0.34	0.33	1522		1.1322	1.0989
60	1.05	1.05	0.32	0.31	1522		1.0656	1.0323
61	1.1	1.1	0.36	0.35	1523		1.1988	1.1655
62	1.1	1.05	0.36	0.36	1524		1.1988	1.1988
63	1.05	1.05	0.36	0.36	1524		1.1988	1.1988
64	1.1	1.05	0.36	0.35	1525		1.1988	1.1655
65	1.05	1.05	0.36	0.35	1525		1.1988	1.1655
66	1.05	1.05	0.36	0.35	1526		1.1988	1.1655
67	1.05	1.05	0.37	0.36	1527		1.2321	1.1988
68	1.1	1.1	0.38	0.37	1527		1.2654	1.2321
69	1.1	1.1	0.35	0.34	1528		1.1655	1.1322
70	1.1	1.05	0.38	0.38	1528		1.2654	1.2654
71	1.1	1.05	0.37	0.36	1529		1.2321	1.1988
72	1.05	1.05	0.37	0.36	1530		1.2321	1.1988
73	1.05	1.05	0.38	0.36	1530		1.2654	1.1988
74	1.05	1.05	0.37	0.36	1531		1.2321	1.1988
75	1.05	1.05	0.38	0.36	1531		1.2654	1.1988
76	1.05	1.05	0.38	0.37	1532		1.2654	1.2321
77	1.1	1.05	0.4	0.38	1532		1.332	1.2654
78	1.1	1.05	0.42	0.41	1533		1.3986	1.3653
79	1.1	1.05	0.43	0.41	1533		1.4319	1.3653
80	1.05	1.05	0.43	0.41	1534		1.4319	1.3653
81	1.05	1.05	0.43	0.4	1535		1.4319	1.332
82	1.05	1	0.38	0.37	1535		1.2654	1.2321
83	1.05	1	0.42	0.39	1536		1.3986	1.2987
84	1.05	1	0.41	0.4	1537		1.3653	1.332
85	1.05	1	0.42	0.4	1537		1.3986	1.332
86	1.05	1	0.43	0.42	1538		1.4319	1.3986
87	1.1	1.05	0.41	0.39	1539		1.3653	1.2987
88	1.05	1	0.44	0.43	1539		1.4652	1.4319
89	1.05	1	0.44	0.42	1540		1.4652	1.3986
90	1.05	1	0.44	0.45	1540		1.4652	1.4985
91	1.05	1	0.44	0.45	1541		1.4652	1.4985
92	1.1	1	0.42	0.43	1541		1.3986	1.4319
93	1.05	1	0.44	0.45	1542		1.4652	1.4985
94	1.05	1	0.45	0.47	1542		1.4985	1.5651
95	1.1	1.05	0.48	0.49	1543		1.5984	1.6317
96	1.05	1	0.5	0.49	1544		1.665	1.6317
97	1.05	1	0.54	0.53	1544		1.7982	1.7649
98	1.05	1	0.56	0.52	1545		1.8648	1.7316
99	1.05	1	0.55	0.53	1546		1.8315	1.7649
100	1.1	1	0.55	0.53	1546		1.8315	1.7649
101	1.1	1.05	0.55	0.55	1547		1.8315	1.8315
102	1.05	1	0.55	0.54	1547		1.8315	1.7982

103	1.05	1	0.56	0.55	1548		1.8648	1.8315
104	1.05	1	0.58	0.56	1549		1.9314	1.8648
105	1.05	1	0.63	0.58	1549		2.0979	1.9314
106	1.05	1	0.66	0.61	1550		2.1978	2.0313
107	1.05	1	0.67	0.62	1551		2.2311	2.0646
108	1.1	1	0.67	0.6	1551		2.2311	1.998
109	1.1	1.05	0.68	0.61	1552		2.2644	2.0313
110	1.05	1	0.71	0.69	1552		2.3643	2.2977
111	1.05	1	0.69	0.67	1553		2.2977	2.2311
112	1.05	1	0.69	0.67	1554		2.2977	2.2311
113	1.05	1	0.73	0.71	1554		2.4309	2.3643
114	1.05	1.05	0.76	0.76	1555		2.5308	2.5308
115	1.1	1.05	0.76	0.8	1556		2.5308	2.664
116	1.1	1.05	0.83	0.84	1556		2.7639	2.7972
117	1.1	1.05	0.82	0.86	1557		2.7306	2.8638
118	1.1	1.05	0.83	0.9	1558		2.7639	2.997
119	1.1	1.05	0.83	0.91	1558		2.7639	3.0303
120	1.1	1.05	0.82	0.88	1559		2.7306	2.9304
121	1.1	1.1	0.84	0.92	1559		2.7972	3.0636
122	1.1	1.05	0.86	0.95	1600		2.8638	3.1635
123	1.1	1.05	0.86	0.95	1600		2.8638	3.1635
124	1.1	1.1	0.87	1	1601		2.8971	3.33
125	1.1	1.1	0.85	0.95	1601		2.8305	3.1635
126	1.1	1.05	0.82	0.95	1602		2.7306	3.1635
127	1.1	1.05	0.72	0.9	1602		2.3976	2.997
128	1.1	1.1	0.73	0.91	1603		2.4309	3.0303
129	1.05	1.1	0.72	0.88	1604		2.3976	2.9304
130	1.1	1.1	0.75	0.81	1604		2.4975	2.6973
131	1.1	1.05	0.76	0.8	1605		2.5308	2.664
132	1.1	1.1	0.79	0.81	1605		2.6307	2.6973
133	1.1	1.05	0.89	0.81	1606		2.9637	2.6973
134	1.1	1.05	0.89	0.94	1607		2.9637	3.1302
135	1.1	1.1	0.9	1.15	1607		2.997	3.8295
136	1.1	1.1	0.85	1.3	1608		2.8305	4.329
137	1.1	1.1	0.9	1.4	1609		2.997	4.662
138	1.1	1.1	0.9	1.4	1609		2.997	4.662
139	1.1	1.1	0.85	1.35	1610		2.8305	4.4955
140	1.1	1.05	0.9	1.45	1610		2.997	4.8285
141	1.1	1.1	0.85	1.4	1611		2.8305	4.662
142	1.1	1.05	0.8	1.4	1612		2.664	4.662
143	1.1	1.05	0.8	1.35	1612		2.664	4.4955
144	1.1	1.05	0.8	1.45	1613		2.664	4.8285
145	1.1	1.1	0.8	1.4	1613		2.664	4.662
146	1.1	1.05	0.8	1.4	1614		2.664	4.662
147	1.1	1.05	0.75	1.35	1614		2.4975	4.4955
148	1.1	1.1	0.7	1.25	1615		2.331	4.1625
149	1.1	1.1	0.7	1.25	1616		2.331	4.1625
150	1.1	1.1	0.65	1.15	1616		2.1645	3.8295
151	1.1	1.1	0.65	1.15	1617		2.1645	3.8295

152	1.1	1.05	0.65	1.1	1618		2.1645	3.663
153	1.1	1.05	0.65	1.1	1618		2.1645	3.663
154	1.1	1.1	0.65	1.05	1619		2.1645	3.4965
155	1.1	1.1	0.65	1	1619		2.1645	3.33
156	1.1	1.05	0.65	0.95	1620		2.1645	3.1635
157	1.1	1.05	0.65	0.95	1621		2.1645	3.1635
158	1.1	1.1	0.66	0.94	1621		2.1978	3.1302
159	1.1	1.05	0.66	0.9	1622		2.1978	2.997
160	1.1	1.1	0.66	0.89	1622		2.1978	2.9637
161	1.1	1.05	0.67	0.89	1623		2.2311	2.9637
162	1.05	1.05	0.69	0.88	1624		2.2977	2.9304
163	1.1	1.05	0.74	0.85	1624		2.4642	2.8305
164	1.1	1.05	0.71	0.83	1625		2.3643	2.7639
165	1.1	1.05	0.72	0.82	1626		2.3976	2.7306
166	1.1	1.05	0.7	0.81	1626		2.331	2.6973
167	1.1	1.05	0.7	0.81	1627		2.331	2.6973
168	1.1	1.05	0.72	0.82	1627		2.3976	2.7306
169	1.05	1	0.73	0.79	1628		2.4309	2.6307
170	1.1	1.05	0.72	0.78	1629		2.3976	2.5974
171	1.05	1	0.72	0.78	1629		2.3976	2.5974
172	1.1	1	0.7	0.76	1630		2.331	2.5308
173	1.05	1	0.69	0.75	1630		2.2977	2.4975
174	1.1	1.05	0.66	0.72	1631		2.1978	2.3976
175	1.05	1.05	0.65	0.71	1632		2.1645	2.3643
176	1.05	1.05	0.63	0.69	1632		2.0979	2.2977
177	1.05	1	0.63	0.67	1633		2.0979	2.2311
178	1.05	1	0.61	0.66	1633		2.0313	2.1978
179	1.1	1.05	0.59	0.65	1634		1.9647	2.1645
180	1.1	1.05	0.56	0.62	1635		1.8648	2.0646
181	1.1	1.05	0.56	0.61	1635		1.8648	2.0313
182	1.05	1.05	0.55	0.57	1636		1.8315	1.8981
183	1.1	1.05	0.53	0.56	1636		1.7649	1.8648
184	1.05	1.05	0.53	0.54	1637		1.7649	1.7982
185	1.1	1.05	0.5	0.5	1638		1.665	1.665
186	1.1	1.05	0.47	0.47	1638		1.5651	1.5651
187	1.1	1.05	0.43	0.44	1639		1.4319	1.4652
188	1.1	1.05	0.4	0.41	1639		1.332	1.3653
189	1.05	1.05	0.39	0.37	1640		1.2987	1.2321
190	1.05	1	0.36	0.33	1641		1.1988	1.0989
191	1.1	1.05	0.35	0.26	1641		1.1655	0.8658
192	1.1	1.05	0.55	0.54	1642		1.8315	1.7982
193	1.1	1.05	0.58	0.62	1643		1.9314	2.0646
194	1.1	1.05	0.58	0.62	1643		1.9314	2.0646
195	1.1	1.05	0.56	0.65	1644		1.8648	2.1645
196	1.05	1.05	0.54	0.62	1644		1.7982	2.0646
197	1.05	1.05	0.54	0.62	1645		1.7982	2.0646
198	1.1	1.05	0.54	0.62	1646		1.7982	2.0646
199	1.1	1.05	0.54	0.6	1646		1.7982	1.998
200	1.1	1.05	0.53	0.59	1647		1.7649	1.9647

201	1.1	1.05	0.51	0.58	1647		1.6983	1.9314
202	1.1	1.05	0.5	0.56	1648		1.665	1.8648
203	1.1	1.05	0.5	0.54	1649		1.665	1.7982
204	1.1	1.05	0.49	0.52	1649		1.6317	1.7316
205	1.1	1.05	0.48	0.5	1650		1.5984	1.665
206	1.1	1.05	0.48	0.5	1650		1.5984	1.665
207	1.1	1.1	0.47	0.48	1651		1.5651	1.5984
208	1.1	1.1	0.47	0.49	1651		1.5651	1.6317
209	1.1	1.05	0.47	0.49	1652		1.5651	1.6317
210	1.1	1.05	0.46	0.47	1653		1.5318	1.5651
211	1.1	1.05	0.46	0.46	1653		1.5318	1.5318
212	1.1	1.05	0.45	0.46	1654		1.4985	1.5318
213	1.1	1.05	0.42	0.45	1655		1.3986	1.4985
214	1.1	1.05	0.42	0.43	1655		1.3986	1.4319
215	1.1	1.05	0.41	0.41	1656		1.3653	1.3653
216	1.1	1.05	0.41	0.41	1656		1.3653	1.3653
217	1.1	1.05	0.4	0.4	1657		1.332	1.332
218	1.05	1.05	0.38	0.38	1658		1.2654	1.2654
219	1.1	1.05	0.42	0.43	1658		1.3986	1.4319
220	1.1	1.05	0.45	0.45	1659		1.4985	1.4985
221	1.1	1.05	0.45	0.45	1659		1.4985	1.4985
222	1.1	1.05	0.44	0.45	1700		1.4652	1.4985
223	1.05	1.05	0.42	0.43	1700		1.3986	1.4319
224	1.05	1.05	0.42	0.43	1701		1.3986	1.4319
225	1.1	1.05	0.42	0.42	1702		1.3986	1.3986
226	1.1	1.05	0.4	0.4	1702		1.332	1.332
227	1.1	1.05	0.4	0.39	1703		1.332	1.2987
228	1.1	1.05	0.39	0.38	1704		1.2987	1.2654
229	1.05	1.05	0.38	0.38	1704		1.2654	1.2654
230	1.05	1.05	0.39	0.39	1705		1.2987	1.2987
231	1.1	1.05	0.39	0.39	1705		1.2987	1.2987
232	1.1	1.05	0.38	0.38	1706		1.2654	1.2654
233	1.1	1.05	0.38	0.38	1706		1.2654	1.2654
234	1.1	1.05	0.39	0.36	1707		1.2987	1.1988
235	1.1	1.05	0.38	0.36	1708		1.2654	1.1988
236	1.1	1.05	0.38	0.36	1708		1.2654	1.1988
237	1.1	1.05	0.37	0.35	1709		1.2321	1.1655
238	1.1	1.05	0.38	0.36	1709		1.2654	1.1988
239	1.05	1.05	0.38	0.36	1710		1.2654	1.1988
240	1.1	1.05	0.38	0.36	1710		1.2654	1.1988
241	1.1	1.05	0.37	0.35	1711		1.2321	1.1655
242	1.1	1.05	0.36	0.35	1712		1.1988	1.1655
243	1.1	1.05	0.35	0.34	1712		1.1655	1.1322
244	1.1	1.05	0.35	0.34	1713		1.1655	1.1322
245	1.1	1.05	0.35	0.34	1713		1.1655	1.1322
246	1.1	1.05	0.34	0.33	1714		1.1322	1.0989
247	1.1	1.05	0.33	0.32	1714		1.0989	1.0656
248	1.1	1.05	0.33	0.33	1715		1.0989	1.0989
249	1.05	1.05	0.34	0.33	1716		1.1322	1.0989

250	1.05	1.05	0.33	0.33	1716		1.0989	1.0989
Start Frequency Step of 2 Hertz								
252	1.1	1.05	0.33	0.32	1717		1.0989	1.0656
254	1.1	1.05	0.32	0.31	1718		1.0656	1.0323
256	1.1	1.05	0.32	0.31	1718		1.0656	1.0323
258	1.1	1.05	0.3	0.3	1719		0.999	0.999
260	1.1	1.05	0.31	0.29	1720		1.0323	0.9657
262	1.1	1.05	0.31	0.28	1720		1.0323	0.9324
264	1.1	1.05	0.3	0.27	1721		0.999	0.8991
266	1.1	1.05	0.29	0.26	1722		0.9657	0.8658
268	1.1	1.05	0.29	0.27	1722		0.9657	0.8991
270	1.1	1.05	0.29	0.26	1723		0.9657	0.8658
272	1.1	1.05	0.28	0.25	1723		0.9324	0.8325
274	1.1	1.05	0.25	0.21	1724		0.8325	0.6993
276	1.1	1.05	0.27	0.25	1725		0.8991	0.8325
278	1.1	1.05	0.28	0.27	1726		0.9324	0.8991
280	1.1	1.05	0.29	0.27	1726		0.9657	0.8991
282	1.1	1.05	0.28	0.26	1727		0.9324	0.8658
284	1.1	1.05	0.27	0.25	1728		0.8991	0.8325
286	1.1	1.05	0.25	0.23	1728		0.8325	0.7659
288	1.1	1.05	0.26	0.26	1729		0.8658	0.8658
290	1.1	1.05	0.26	0.28	1729		0.8658	0.9324
292	1.1	1.05	0.27	0.26	1730		0.8991	0.8658
294	1.1	1.05	0.26	0.27	1731		0.8658	0.8991
296	1.05	1.05	0.25	0.26	1731		0.8325	0.8658
298	1.1	1.05	0.26	0.26	1732		0.8658	0.8658
300	1.1	1.05	0.25	0.25	1733		0.8325	0.8325
302	1.1	1.05	0.25	0.24	1733		0.8325	0.7992
304	1.1	1.05	0.24	0.23	1734		0.7992	0.7659
306	1.1	1.1	0.23	0.23	1735		0.7659	0.7659
308	1.1	1.05	0.22	0.22	1735		0.7326	0.7326
310	1.1	1.05	0.22	0.21	1736		0.7326	0.6993
312	1.1	1.05	0.22	0.21	1737		0.7326	0.6993
314	1.1	1.05	0.2	0.2	1737		0.666	0.666
316	1.1	1.1	0.2	0.2	1738		0.666	0.666
318	1.1	1.1	0.21	0.2	1738		0.6993	0.666
320	1.1	1.05	0.2	0.2	1739		0.666	0.666
322	1.1	1.05	0.2	0.22	1740		0.666	0.7326
324	1.1	1.05	0.2	0.2	1740		0.666	0.666
326	1.1	1.05	0.21	0.21	1741		0.6993	0.6993
328	1.1		0.19	0.2	1742		0.6327	0.666
330	1.1	1.05	0.2	0.2	1742		0.666	0.666
332	1.1	1.1	0.19	0.2	1743		0.6327	0.666
334	1.1	1.1	0.18	0.18	1744		0.5994	0.5994
336	1.1	1.1	0.15	0.13	1745		0.4995	0.4329
338	1.1	1.05	0.16	0.18	1745		0.5328	0.5994
340	1.1	1.05	0.19	0.21	1746		0.6327	0.6993

342	1.1	1.05	0.21	0.24	1747		0.6993	0.7992
344	1.1	1.1	0.22	0.24	1747		0.7326	0.7992
346	1.1	1.05	0.22	0.24	1748		0.7326	0.7992
348	1.1	1.05	0.22	0.24	1749		0.7326	0.7992
350	1.1	1.05	0.23	0.24	1749		0.7659	0.7992
352	1.1	1.05	0.23	0.24	1750		0.7659	0.7992
354	1.1	1.05	0.22	0.24	1751		0.7326	0.7992
356	1.1	1.05	0.21	0.24	1751		0.6993	0.7992
358	1.1	1.05	0.2	0.23	1752		0.666	0.7659
360	1.1	1.05	0.19	0.22	1753		0.6327	0.7326
362	1.1	1.05	0.14	0.16	1753		0.4662	0.5328
364	1.1	1.05	0.18	0.19	1754		0.5994	0.6327
366	1.1	1.05	0.19	0.19	1755		0.6327	0.6327
368	1.1	1.05	0.2	0.21	1756		0.666	0.6993
370	1.1	1.05	0.2	0.21	1756		0.666	0.6993
372	1.1	1.05	0.18	0.2	1757		0.5994	0.666
374	1.1	1.05	0.18	0.19	1758		0.5994	0.6327
376	1.1	1.05	0.16	0.17	1758		0.5328	0.5661
378	1.1	1.1	0.14	0.15	1759		0.4662	0.4995
380	1.1	1.05	0.15	0.14	1759		0.4995	0.4662
382	1.1	1.05	0.15	0.15	1800		0.4995	0.4995
384	1.1	1.05	0.17	0.17	1801		0.5661	0.5661
386	1.1	1.05	0.19	0.19	1801		0.6327	0.6327
388	1.1	1.05	0.2	0.21	1802		0.666	0.6993
390	1.1	1.05	0.21	0.21	1803		0.6993	0.6993
392	1.1	1.05	0.23	0.25	1803		0.7659	0.8325
394	1.1	1.05	0.23	0.22	1804		0.7659	0.7326
396	1.1	1.05	0.24	0.24	1805		0.7992	0.7992
398	1.1	1.05	0.24	0.24	1805		0.7992	0.7992
400	1.1	1.05	0.26	0.26	1806		0.8658	0.8658
402	1.1	1.05	0.26	0.26	1807		0.8658	0.8658
404	1.1	1.1	0.28	0.27	1807		0.9324	0.8991
406	1.1	1.05	0.26	0.25	1808		0.8658	0.8325
408	1.1	1.05	0.23	0.24	1809		0.7659	0.7992
410	1.1	1.05	0.25	0.23	1809		0.8325	0.7659
412	1.1	1.05	0.25	0.21	1810		0.8325	0.6993
414	1.1	1.05	0.25	0.21	1811		0.8325	0.6993
416	1.1	1.05	0.25	0.21	1811		0.8325	0.6993
418	1.1	1.1	0.25	0.22	1812		0.8325	0.7326
420	1.1	1.05	0.21	0.2	1813		0.6993	0.666
422	1.1	1.05	0.23	0.24	1813		0.7659	0.7992
424	1.1	1.05	0.23	0.21	1814		0.7659	0.6993
426	1.1	1.05	0.22	0.19	1815		0.7326	0.6327
428	1.1	1.05	0.2	0.2	1815		0.666	0.666
430	1.1	1.05	0.2	0.19	1816		0.666	0.6327
432	1.1	1.05	0.2	0.19	1817		0.666	0.6327
434	1.1	1.05	0.19	0.17	1817		0.6327	0.5661
436	1.1	1.05	0.19	0.17	1818		0.6327	0.5661
438	1.1	1.05	0.18	0.18	1819		0.5994	0.5994
440	1.1	1.05	0.2	0.2	1819		0.666	0.666

442	1.1	1.05	0.21	0.22	1820		0.6993	0.7326
444	1.1	1.05	0.19	0.19	1821		0.6327	0.6327
446	1.1	1.05	0.19	0.18	1821		0.6327	0.5994
448	1.1	1.05	0.18	0.18	1822		0.5994	0.5994
450	1.1	1.05	0.19	0.19	1822		0.6327	0.6327
452	1.1	1.05	0.21	0.2	1823		0.6993	0.666
454	1.1	1.05	0.23	0.22	1824		0.7659	0.7326
456	1.1	1.05	0.24	0.22	1824		0.7992	0.7326
458	1.1	1.05	0.25	0.23	1825		0.8325	0.7659
460	1.1	1.1	0.27	0.25	1826		0.8991	0.8325
462	1.1	1.05	0.28	0.26	1826		0.9324	0.8658
464	1.1	1.05	0.29	0.29	1827		0.9657	0.9657
466	1.1	1.05	0.3	0.29	1828		0.999	0.9657
468	1.1	1.05	0.32	0.32	1828		1.0656	1.0656
470	1.1	1.1	0.35	0.33	1829		1.1655	1.0989
472	1.1	1.05	0.41	0.28	1830		1.3653	0.9324
474	1.1	1.05	0.22	0.18	1830		0.7326	0.5994
476	1.1	1.05	0.25	0.21	1831		0.8325	0.6993
478	1.1	1.05	0.25	0.24	1831		0.8325	0.7992
480	1.1	1.05	0.25	0.25	1832		0.8325	0.8325
482	1.1	1.05	0.25	0.26	1833		0.8325	0.8658
484	1.1	1.05	0.25	0.27	1833		0.8325	0.8991
486	1.1	1.05	0.29	0.31	1834		0.9657	1.0323
488	1.1	1.05	0.35	0.39	1835		1.1655	1.2987
490	1.1	1.05	0.37	0.4	1835		1.2321	1.332
492	1.1	1.05	0.34	0.38	1836		1.1322	1.2654
494	1.1	1.05	0.33	0.35	1837		1.0989	1.1655
496	1.1	1.05	0.31	0.32	1837		1.0323	1.0656
498	1.1	1.05	0.27	0.28	1838		0.8991	0.9324
500	1.1	1.05	0.25	0.26	1839		0.8325	0.8658

ATTACHMENT D

INSTRUMENTATION EQUIPMENT SHEET

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INSTRUMENTATION EQUIPMENT SHEET

F 1

DATE: 01/07/97
TECHNICIAN: S. GEORGE

JOB NUMBER: 45918-00
CUSTOMER: LOCKHEED MARTIN

TEST AREA: DYN LAB
TYPE TEST: VIBRATION

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	HARD COPY UNIT	TEKTRONIX	4631	B174940	112119	MULTI	MFG	07/23/96	01/17/97
2	TERMINAL	TEKTRONIX	4612	N/A	100589	MULTI	MFG	03/08/96	03/07/97
3	VIB CONT SYSTEM	H/P	5427A366	2120A00409	100291	MULTI	MFG	11/22/96	11/21/97
4	AMPL CHARGE	ENDEVCO	2735	GR29	092925	GAIN	1.5%	07/24/96	01/20/97
5	AMPL CHARGE	ENDEVCO	2735	GS26	096748	GAIN	1.5%	08/22/96	02/18/97
6	OSCILLOSCOPE	TEKTRONIX	2213A	B013724	101481	60 MHZ	3%	09/25/96	03/24/97
7	DIG MTR	KEITHLEY	179A	480740	108696	DCV	.04%	10/29/96	04/25/97
8	ACCEL	BRUEL & KJAER	4366	1104925	101755	2KGSV/5KGSK	5%	10/18/96	01/16/97
9	ACCEL	ENDEVCO	2213C	3755	081375	1KGSV/2KGSK	5%	11/11/96	02/07/97
10	TORQUE	S. RICHMOND	M25-I	N/A	112715	25 IN/LBS	5% FS	07/27/96	01/23/97
11	STOP WATCH	EXTECH	365530	112296	112296	9HR/59MIN/59SEC	.5 SEC	08/07/96	02/03/97

This is to certify that the above instruments were calibrated using state-of-the-art techniques with standards whose calibration is traceable to the National Institute of Standards and Technology.

INSTRUMENTATION Stacy S George 1/7/97

CHECKED & RECEIVED BY [signature] 1/7/97

Q.A. [signature] 1/7/97

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US006299950B1

(12) **United States Patent**
Byington et al.

(10) **Patent No.: US 6,299,950 B1**
(45) **Date of Patent: *Oct. 9, 2001**

(54) **FIREPROOF IMPACT LIMITER AGGREGATE PACKAGING INSIDE SHIPPING CONTAINERS**

(75) Inventors: **Gerald A. Byington**, Knoxville; **Raymon Edgar Oakes, Jr.**, Kingston; **Matthew Rookes Feldman**, Knoxville, all of TN (US)

(73) Assignee: **BWXT Y12 LLC**, Oak Ridge, TN (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/940,295**

(22) Filed: **Sep. 30, 1997**

(51) **Int. Cl.**[7] **G21F 5/00**; G21C 19/00

(52) **U.S. Cl.** **428/34.5**; 252/478; 250/506.1; 376/272; 976/323; 976/333; 976/344

(58) **Field of Search** 352/478; 428/34.4, 428/34.5, 34.6; 264/71; 250/506.1; 376/272; 976/320, 323, 324, 333, 344, 350, 353

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,982,134	9/1976	Housholder et al.	250/506
4,612,046	9/1986	Orcutt	75/96
5,385,873	1/1995	MacNeill	501/95
5,626,665	5/1997	Barger et al.	106/706
5,658,634	8/1997	Ragland et al.	428/75

FOREIGN PATENT DOCUMENTS

1460196A * 12/1976 (GB).

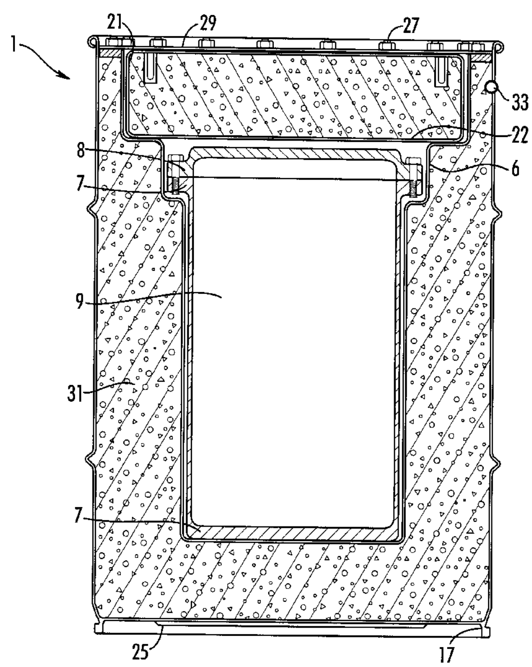
* cited by examiner

Primary Examiner—Rena L. Dye
(74) *Attorney, Agent, or Firm*—J. Herbert O'Toole; Hardaway/Mann IP Group

(57) **ABSTRACT**

The invention is a product and a process for making a fireproof, impact limiter, homogeneous aggregate material for casting inside a hazardous material shipping container, or a double-contained Type-B nuclear shipping container. The homogeneous aggregate material is prepared by mixing inorganic compounds with water, pouring the mixture into the void spaces between an inner storage containment vessel and an outer shipping container, vibrating the mixture inside the shipping container, with subsequent curing, baking, and cooling of the mixture to form a solidified material which encapsulates an inner storage containment vessel inside an outer shipping container. The solidified material forms a protective enclosure around an inner storage containment vessel which may store hazardous, toxic, or radioactive material. The solidified material forms a homogeneous fire-resistant material that does not readily transfer heat, and provides general shock and specific point-impact protection, providing protection to the interior storage containment vessel. The material is low cost, may contain neutron absorbing compounds, and is easily formed into a variety of shapes to fill the interior void spaces of shipping containers.

6 Claims, 4 Drawing Sheets



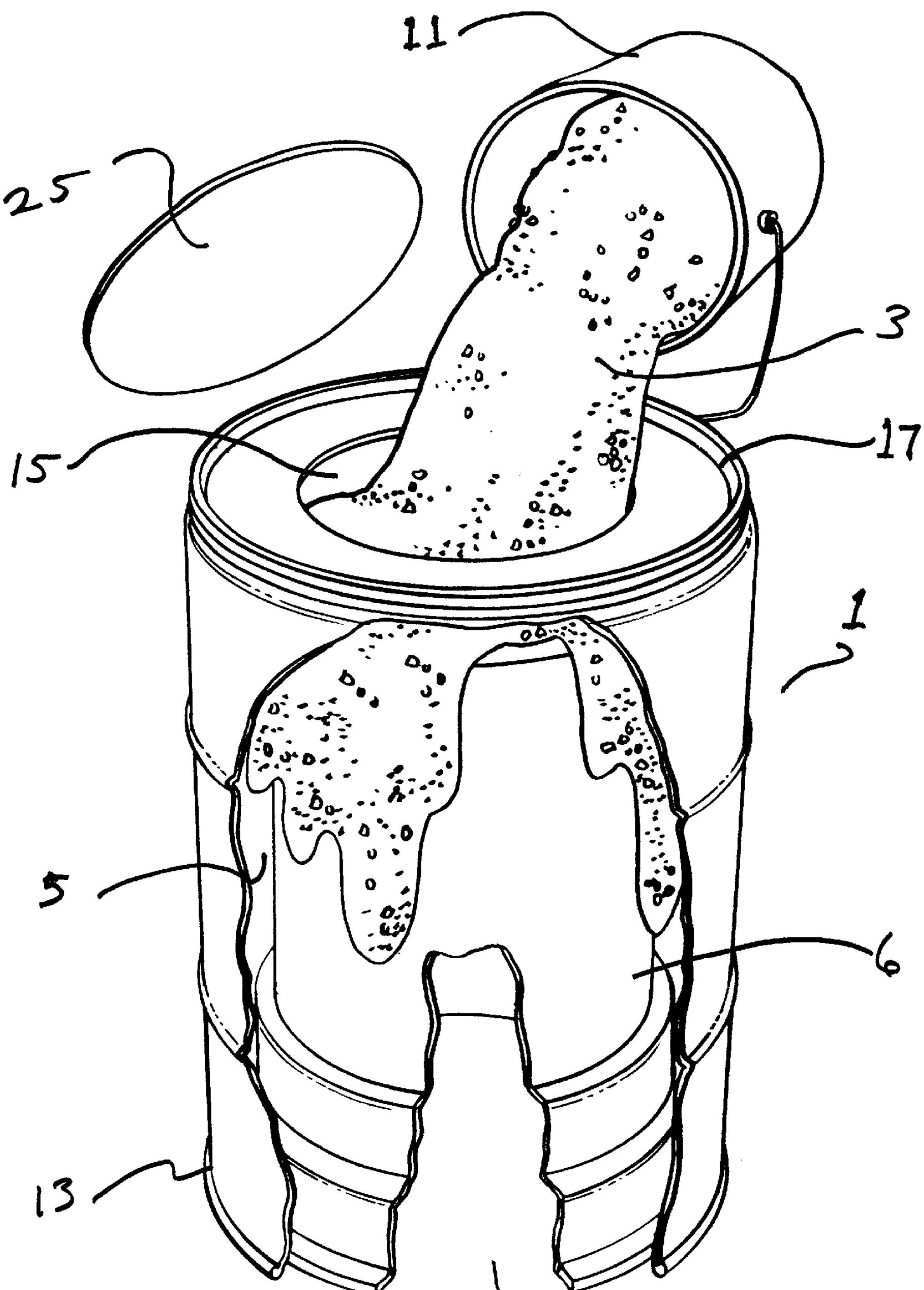


Fig. 1

FIG. 1A

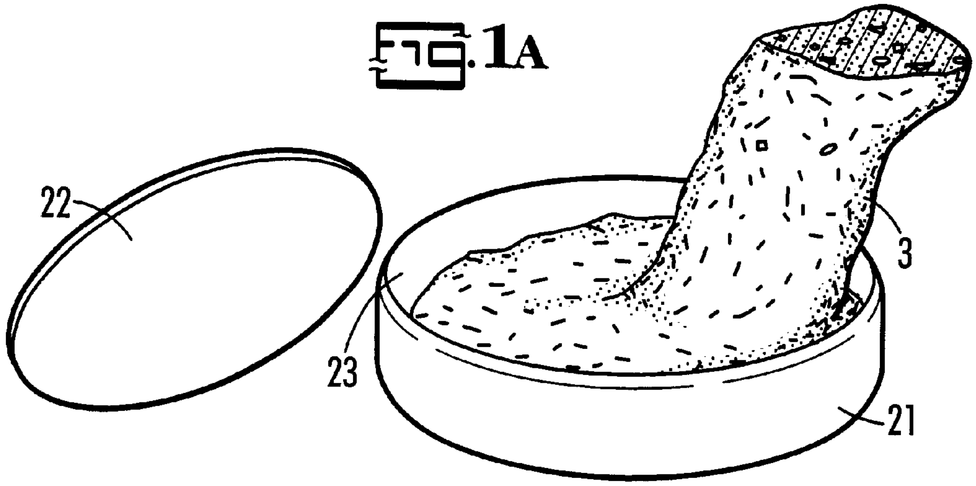
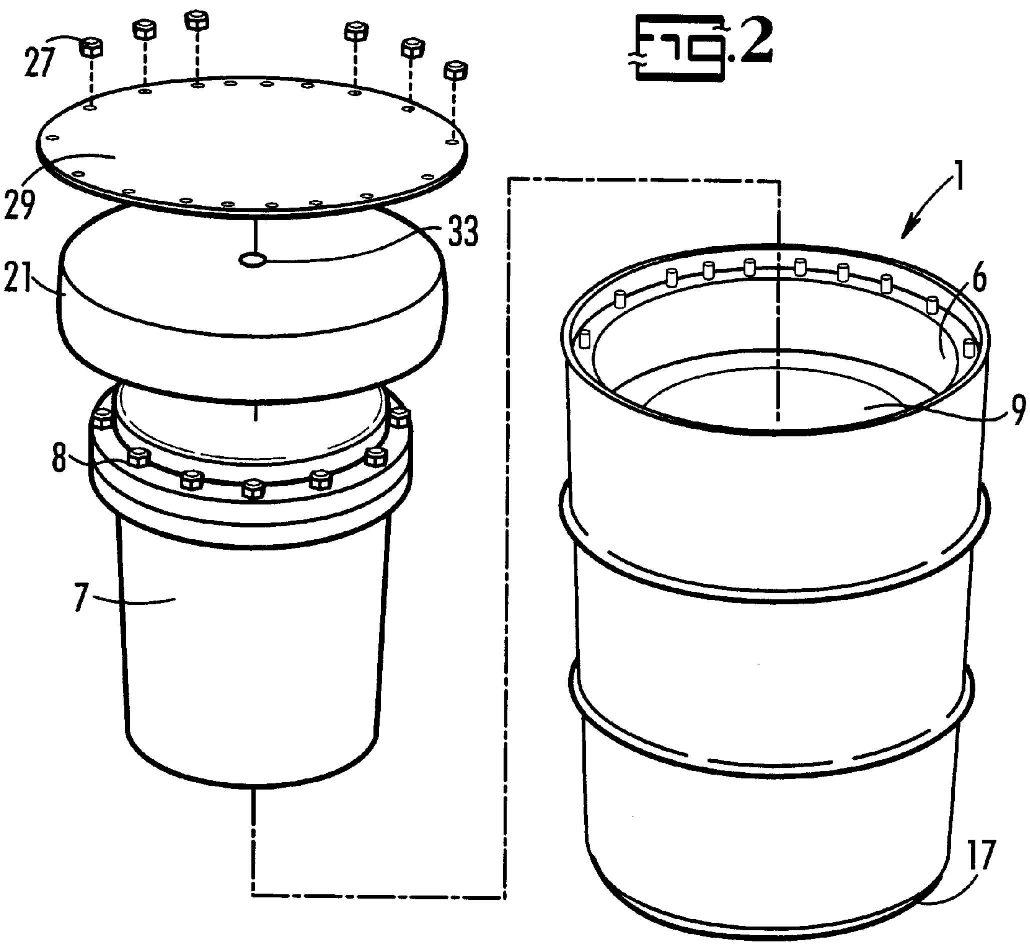


FIG. 2



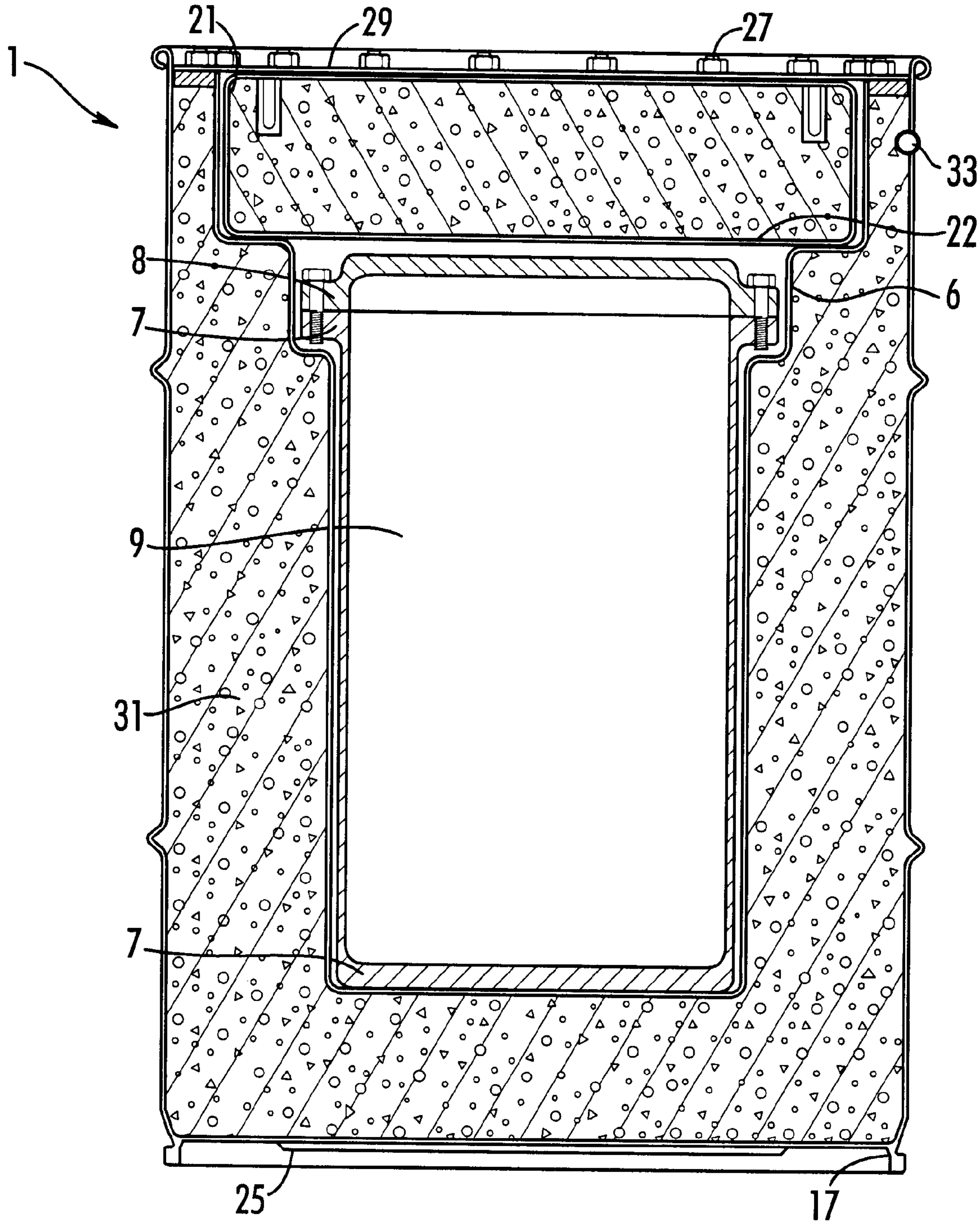


Fig.3

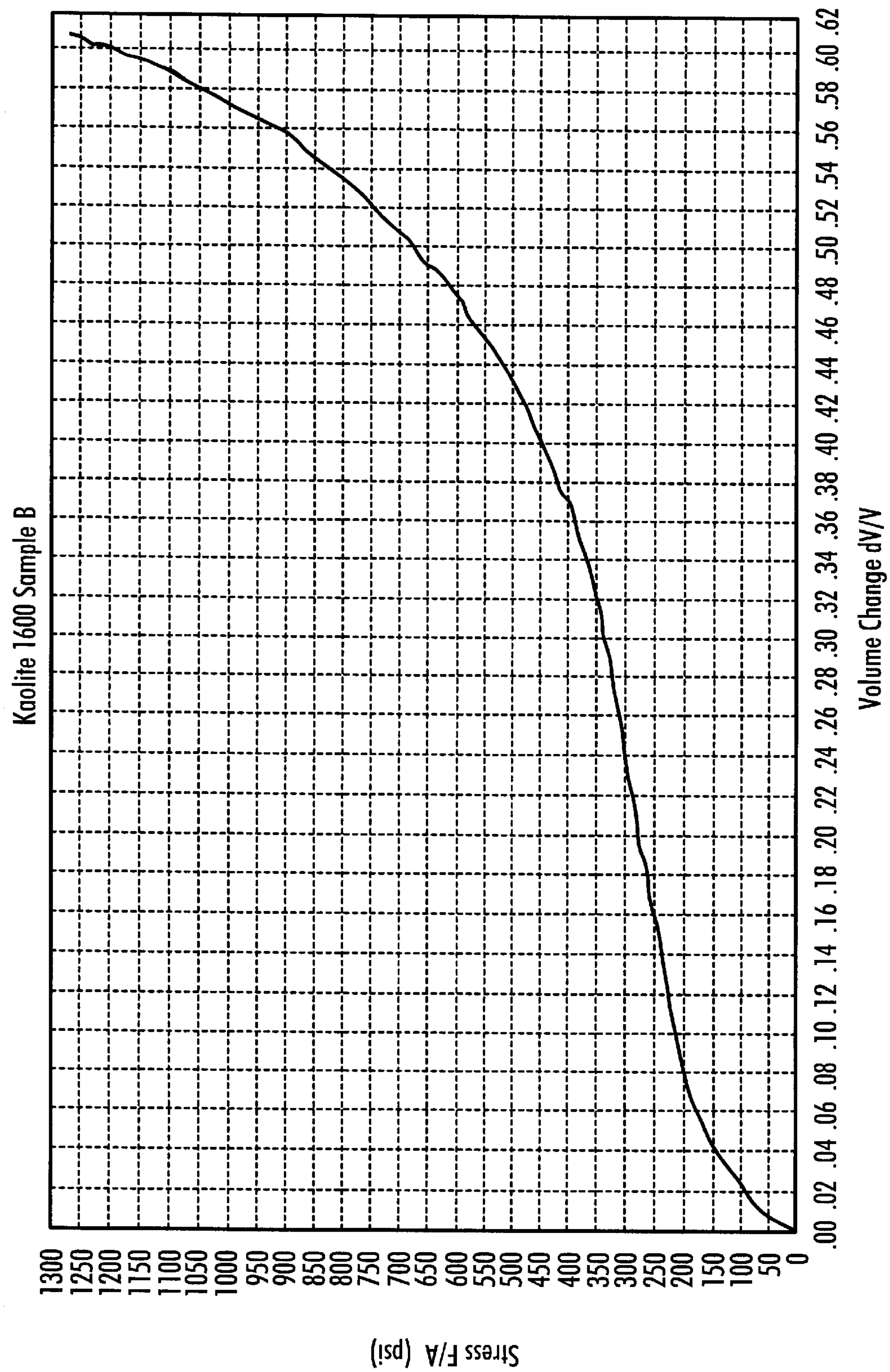

Kaolite 1600 Sample B
Volume Change dV/V
Stress F/A (psi)
.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34 .36 .38 .40 .42 .44 .46 .48 .50 .52 .54 .56 .58 .60 .62
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300

FIG. 4

FIREPROOF IMPACT LIMITER AGGREGATE PACKAGING INSIDE SHIPPING CONTAINERS

United States Government has rights in this invention pursuant to Contract No. DE-AC05-84OR21400 between the U.S. Department of Energy and Lockheed Martin Energy Systems, Inc.

BACKGROUND OF THE INVENTION

The invention relates generally to a packaging for shipping containers. Specifically, the present invention relates to a product for preventing damage to an interior containment vessel from impacts to exterior shipping containers. The invention is more specifically related to a product which is fireproof, castable, crushable, and non-toxic, which provides protection for nuclear material and/or other hazardous materials inside an interior containment vessel, when the exterior container is utilized for shipping of hazardous or radioactive materials.

Shipping containers with single, double, and triple containment have been utilized extensively in the nuclear materials and hazardous waste shipping industry. There continues a need for a product that provides shock and fire-resistant material for placement inside the exterior container, to protect and cradle the interior containment vessel. Ragland, et al., U.S. Pat. No. 5,658,634, describes a thin laminated metal foil and nonwoven fiber material that provides insulation for automotive systems. Barger, et al., U.S. Pat. No. 5,626,665, describes a cementitious system which utilizes low amounts of water plus calcined clay and other materials to produce high strength cement. MacNeill, U.S. Pat. No. 5,385,873, describes a high temperature resistant material containing ceramic fibers and inorganic vermiculite to withstand the high temperatures within catalytic converters. Orcutt, U.S. Pat. No. 4,612,046, describes an insulating composition formed from a mixture of Kaolite™ and amorphous quenched slag, to thermally insulate the exposed surface of molten metal in a cast vessel or furnace vessel. Householder, et al., U.S. Pat. No. 3,982,134, describes a container for nuclear materials transport that has on the interior, a pressure vessel, gamma radiation protection, insulating material, and neutron absorbing shielding in the form of beads or globules of water encapsulated in plastic. The prior art provides for materials that are heat insulating, shock protective, or radiation shielding when placed in separate layers into the interior of a nuclear materials shipping container. These and other materials, when added to containers, have shortcomings based on the inability to provide a light-weight, low-cost, heat insulating, shock protective, and radiation shielding material that can be castable inside the interior void spaces of a nuclear materials shipping container. Thus there exists room for improvement within the art.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a process for making a product for encapsulating containers for shipping.

It is a further object of this invention to provide a process for making a product for encapsulating containers of nuclear materials and/or hazardous materials for shipping.

It is a further object of the present invention to provide a process of encapsulating a container for shipping.

It is an additional object of this invention to provide a product for encapsulating containers for shipping that is not flammable.

It is a further additional object of this invention to provide a rigid product that provides shock and impact protection to encapsulated containers by compaction of the rigid product.

It is yet a further and more particular object of this invention to provide a product that insulates an encapsulated container.

It is yet an additional and more particular object of this invention to provide a product that serves as a radiation absorber to reduce the amount of radiation measured at the exterior surface of the shipping container.

These and other objects of the present invention are accomplished by a process for making an aggregate product, and the aggregate product composed of a rigid homogeneous aggregate material utilizing portland cement and inorganic vermiculite. The material made by the process is non-flammable, provides both thermal insulation and impact protection to any containment vessel that the material surrounds.

The above and other objects of the present invention are also accomplished by a process of protecting a containment vessel inside a container for shipping nuclear materials, comprising the steps of: mixing a portland cement material with an inorganic vermiculite and water; pouring the mixture into the interior voids of an outer container for shipping; vibrating the mixture inside the outer container for shipping; curing the vibrated mixture at ambient temperature inside the exterior container for shipping; baking the cured mixture inside the exterior container for shipping at elevated temperatures; cooling the baked mixture to ambient temperature; welding a cover plate over the fill hole; and assembling the shipping package.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention's features and advantage will become apparent from a reading of the following detailed description, given with reference to the various figure of drawing, in which:

FIG. **1** is a view of the aggregate product of the present invention in a mixing container;

FIG.**1***a* is a view of the aggregate product poured into a top plug unit;

FIG. **2** is a cross-sectional view of the aggregate product poured into the exterior container of the present invention;

FIG. **3** is a cross-sectional view of the solidified product of the present invention inside a double-containment nuclear shipping container; and

FIG. **4** is a graph of the compressive stress and fractional volume change when compressive stress is applied to the solidified product of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with this invention, it has been found that a protective material is needed that is fire-resistant and is crushable to serve as an shock absorbing and impact limiting material for insertion into the void spaces **5** formed between the inside walls of a shipping container **1**, and the outer walls of a containment vessel **7** for hazardous and/or nuclear materials. In accordance with FIGS. **1**–**4**, the preferred embodiment for the present invention is a fireproof, impact limiting, homogeneous aggregate material (HAM)**3**. The homogeneous aggregate material **3** is in a granular form when dry, and is in a porable form after water is mixed in (see FIG. **2**), until the mixture is poured into a shipping container, vibrated and allowed to stand, cure and solidify for numerous days, and baked at high temperatures for numerous days, forming a solid mass inside the shipping container (see FIG. **3**) after a cover plate is welded over the fill hole.

The homogeneous aggregate material is a combination of portland cement and inorganic vermiculite. The material of the present invention does not contain hydrocarbon compounds as does the prior art. Most existing, commonly-used, internal packaging materials utilized in hazardous and/or radioactive shipping containers, contain some type of carbon, or hydrocarbon-based, internal packaging and insulating material which is flammable after the appropriate combustion temperature is reached during test scenarios. The internal impact limiting and insulating material **3** (HAM) is placed in the void spaces **5** of an outer container **1** which occur between:

(a) the interior surface **6** of the walls of the outer shipping container **1**;

(b) the walls of an interior encapsulating jacket **6** or stainless steel liner of material that covers the exterior surface of the internal nuclear material containment vessel **7** placed inside the outer shipping container **1**; and

(c) the top lid **29** and top plug unit **21** that seals the upper portion of the shipping container **1**.

The homogeneous aggregate material **3** is also placed in the void space **5** in the top plug unit **21** of the shipping container **1**. The top plug unit **21** forms an upper barrier for impact absorption and insulation from the top of the interior containment vessel **7**, then a drum lid **8** is bolted onto the top of the outer shipping container **1** (see FIGS. **2** and **3**). The lid **8** of the interior containment vessel **7** has separate bolts, and O-ring seals made of ethylene-propylene material, for sealing of the lid **8** of the interior vessel **7** onto the interior containment vessel **7**.

The invention provides for utilization of a homogeneous aggregate material **3** as an internal containment vessel **7** packing or encapsulating material, which solves numerous problems incurred by the use of hydrocarbon-based packaging materials because the invention is fireproof, shock absorbent, and castable into any shape, providing additional safety to reduce the possibility of a worst-case breach of nuclear material transport containers.

The homogeneous aggregate material **3** is composed of two main inorganic components. One of the main inorganic components is portland cement, which is typically composed of: lime, alumina, silica, iron oxide, tetracalcium aluminoferrate, tricalcium aluminate, tricalcium silicate, and dicalcium silicate in varying amounts, along with small amounts of magnesia, sodium, potassium, and sulfur. The other main component of the homogeneous aggregate material is an inorganic vermiculite, which is mixed with the portland cement.

One type of inorganic vermiculite and portland cement mixture utilized in tests is commercially available from Thermal Ceramics, Inc., of Augusta, GA, under the trade name of Kaolite™ 1600. The inorganic mixture tested was composed of:

approximately 10% aluminum oxide (alumina),

approximately 37% of silicon dioxide (silica),

approximately 6.7% of ferric oxide,

approximately 1.2% of titanium oxide,

approximately 30% of calcium oxide,

approximately 13.1% of magnesium oxide, and

approximately 2% of sodium monoxide.

The portland cement and inorganic vermiculite aggregates form a homogeneous, rigid mass after water is added and the mixture is allowed to stand in a shipping container and cure for approximately two days, followed by a high temperature baking for approximately two days.

One preferred embodiment of the process of mixing and forming the homogeneous aggregate material **3** in an outer shipping container **1**, for protection of the interior containment vessel **7**, includes the following steps in reference to FIGS. **1–3**.

(A) Provide a stainless steel shipping container **1** weighing approximately 95 pounds and having approximately 5.0 cubic feet of void space **5** between the outer shipping container **1**, and the walls of an interior encapsulating jacket **6** or stainless steel liner, into which an inner containment vessel **7** is placed. The void space **5** is to be filled with the wet mixture **35** of inorganic vermiculite, portland cement and water, for a wet cast weight of approximately 400 pounds.

(B) Mix approximately 122 pounds of inorganic vermiculite and portland cement with approximately 183 pounds of water slowly in a mixer container **11** until thoroughly mixed (see FIG. **1**).

(C) Place the drum shipping container **1** upside down **13** onto a shaking or vibrating table (not shown). Shake or vibrate the shipping container **1** at approximately 1.5 to 2 times the wet cast weight (750 pound-force) at 2,000 vibrations per minute, while pouring the wet mixture **35** into the drum shipping container void space **5** through a bottom pour hole **15** (see FIG. **2**).

(D) Continue the vibrations for a time period of at least five minutes after the drum of the shipping container **1** is full.

(E) Shake or vibrate the shipping container **1** at approximately 750 pound-force at 2,000 vibrations per minute, while pouring the wet mixture **35** into the bottom pour hole **15** in the bottom surface or bottom head **17** of the outer shipping container **1**, and vibrate for at least 5 minutes after filling.

(F) While the mixture **35** is solidifying inside the shipping container **1** (see next step), a similar wet mixture **35** of inorganic vermiculite, portland cement, and water is poured into the top plug unit **21**, through an opening, into the void space **23** (see FIG. **1A**), while vibrating the top plug unit **21** for at least 5 minutes after filling.

(G) Allow the mixture to solidify within the shipping container **1** and within the top plug unit **21**, over approximately 24 to 48 hour period, at room temperature. The temperature of at least approximately 60, and up to approximately 90 degrees fahrenheit is preferable.

(H) Bake the solidified mixture **31** (FIG. **3**), inside the shipping container **1**, and in the top plug unit **21**, in a gas-fired or forced convection fresh air circulating electric furnace (not shown), over at least approximately 48 hours, beginning at 200 degrees fahrenheit for approximately 4 hours, and increasing the temperatures by approximately 75 degrees every hour, until approximately 500 degrees is reached, with baking at approximately 500 degrees for approximately 36 to 40 hours, for a total bake period of approximately 48 hours.

(I) Cool the solidified and baked mixture **31** within the shipping container **1**, and within the top plug unit **21**, to approximately room temperature. The finished weight for the solidified and baked mixture **31** in the shipping container **1** is approximately 245 pounds, and the finished density is approximately 30 pounds per cubic foot.

(J) Weld a bottom cover plate **25** over the bottom pour hole **15** in the outer shipping container **1** (see FIGS. **1** and **3**).

(K) Weld the fill hole cover plate **22** over the top pour opening in the top plug unit **21** (see FIG. **1***a*).

(L) Assemble the finished shipping container **1** (FIG. **3**) in the following order; load the containment vessel **7** with the radioactive and/or hazardous materials, seal the containment vessel top **8**, and fasten with bolts, lower the assembled containment vessel **7** into the interior encapsulating jacket **6** inside the outer containers center void **9** (now filled with solidified homogeneous material **31**, place the top plug unit **21** over the containment vessel **7**, install the shipping container lid **29** with its fasteners **27**.

After baking, cooling, and assembly of the shipping container, the homogeneous aggregate material has approximately 4–5 pounds per cubic foot of residual water bound in the solidified material, potentially serving as a neutron absorbing and heat dissipating component of the homogeneous aggregate material **31**.

A second embodiment for shipping containers utilized for transport of neutron emitting nuclear materials, is the addition of natural boron, enriched boron, compounds containing boron (i.e. boron carbide), or compounds containing gadolinium, cadmium, europium, hafnium, samarium, indium alloys, or other neutron absorbing compounds mixed into the homogeneous aggregate material. The addition of boron compounds, or other neutron absorbing compounds, to the mixture before solidification, provides a nonvolatile neutron absorbing additive to the homogeneous aggregate material **3**. The above described steps of mixing, pouring, curing, baking, and cooling are utilized, with the boron compounds, or other neutron absorbing compounds, mixed into the mixture of portland cement, vermiculite, and water at the mixing step, before the wet mixture is poured into the voids of the shipping container. The percentage of boron, boron containing compounds, or other neutron absorbing compounds added to the wet mixture is variable and is dependent on the radioactivity of the materials stored in the inner containment vessel. As explained earlier, the baked and cooled homogeneous aggregate material **3** has approximately 4–5 pounds per cubic foot of water remaining in the solidified material, potentially serving as a neutron absorbing component of the homogeneous aggregate material **3**.

The benefits of the homogeneous aggregate material **3** are numerous when compared to the prior art. Current packaging and shock-inhibiting materials utilize hydrocarbon- or carbon-based materials for the interior voids **5** of shipping containers **1** containing interior nuclear material containment vessels **7**. The carbon-based materials will eventually burn and release toxic fumes, or may add to the internal heating of a containment vessel **7** of nuclear materials. The silicon, aluminum, ferric, magnesium and calcium composition of inorganic vermiculite and portland cement will not burn when cured and hardened inside a shipping container **1**. The cured mass of homogeneous aggregate material provides a castable, non-flammable, packaging material that serves as a thermal insulator for any enclosed containment vessel **7** of hazardous chemical and/or nuclear materials. The cured mass has a very low capacity to store heat, therefore providing outstanding insulating properties from exposures to high or low temperatures. The cured mass does not expand appreciably when heated to high temperatures. The melting temperature of the cured mass is approximately 2335 degrees fahrenheit, which is higher than the stainless steel outer container **1** that is typically utilized for transport of nuclear materials.

Testing results for the solidified, cured, and baked homogeneous aggregate material **3** inside a shipping container **1** have verified the insulating capabilities of the claimed invention. Testing has subjected stainless steel shipping containers **1**, with an internal containment vessel **7** surrounded by the solidified, cured, and baked homogeneous aggregate material **31** encapsulated by a ductile jacket **6**, to temperatures of 1525 degrees Fahrenheit at the outer surface of the walls of the shipping container **1** for over 34 minutes. The ductile jacket **6** is composed of the stainless steel interior wall and the exterior wall of the drum shipping container (see FIG. **2**) **1**. The maximum temperature measured on the interior wall **6** of the encapsulated material was approximately 215 degrees Fahrenheit, with a maximum measured temperature at the exterior of the containment vessel **1** of 150 degrees Fahrenheit. The heat is also dissipated by some of the approximate 4–5 pounds per cubic foot of water left inside the HAM after curing and baking, that evaporates during the fire test, venting steam away through vent holes from the interior wall that protects the containment vessel. Vent holes in the containment vessel **7** and shipping container **1** are drilled after the HAM **3** is cured, and fusible plastic hole plugs **33** are placed in the vent holes. In summary, internal nuclear and/or other hazardous containment vessels **1** are protected from destructive temperatures at the containment vessel lids **8**, which have O-ring seals which deteriorate over 350 degrees Fahrenheit, by the homogeneous aggregate material, placed inside the shipping container **1** and serving as an encapsulating jacket **6** around the containment vessel **7**.

A second major benefit is the impact limiting properties of the homogenous aggregate material **3** when solidified in a ductile jacket **6** within the shipping container **1**, provides a brittle structure that is frangible when subjected to impacts (see FIG. **4**). As the shipping container **1** is subjected to impacts, the brittle structure of the HAM fractures, crushes, and powders, dissipating the force around the interior containment vessel **7**. Because the brittle homogenous aggregate material **3** directs fractures from the impact in many different directions, the HAM **3** does not delaminate along one specific plane. The stress-strain curve (see FIG. **4**) shows the energy absorbing capabilities of the brittle structure of the homogenous aggregate material **3** formed into an encapsulating jacket **6**. Therefore, the encapsulating jacket **6**, and the brittle structure of the homogenous aggregate material **3**, provides insignificant pathways for flames, radiation of heat, or hot gasses to reach the internal containment vessel **7**.

A third and less obvious benefit of the homogeneous aggregate material **3** is that the inorganic vermiculite material is non-toxic in a dry condition, and is castable into a multitude of shapes when water is added, with the final form being non-toxic also. During curing of the aggregate material inside the shipping container **1**, and during any thermal testing for package certification purposes of the shipping container **1** with the aggregate material inside, the only offgas formed is water vapor, which is non-toxic. As discussed above, the cured inorganic mass does not burn, and no toxic offgasses such as hydrocarbons or tars are formed when the cured mass approaches its melting temperature.

A fourth benefit of the homogeneous aggregate material **3** is the low cost for the materials, and the low cost to prepare a rigid mass of the material. Costs of $12.00 to $14.00 per cubic foot have been calculated for the raw materials, which is significantly less than current rigid polyurethane foam and high-density fiberboard insulation utilized for Type-B nuclear and/or hazardous material shipping containers **1**. As emphasized above, insulating material with hydrocarbon- or carbon-based materials, such as wood, polyurethane foam, and high-density fiberboard insulation, are prone to ignite above each material's combustion temperature, which requires complete removal and cleaning of a container containing hydrocarbon-based insulation when subjected to high, ignition temperatures. The invention of homogeneous aggregate material **3** does not ignite, and will not require interior cleaning of a container utilizing the material when subjected to high temperatures up to the material's melting point, which is above the melting point of the exterior stainless steel shipping container **1**.

A fifth benefit of the homogeneous aggregate material **3** encapsulated inside a stainless steel shipping container **1** is the low cost to maintain the shipping container **1**. The organic compounds described earlier for use as impact limiting and thermal insulating materials tend to age and breakdown when exposed to severe temperature, humidity changes, and rough handling, will require periodic replacement. Replacement of the impact limiting and thermal insulating material generates a recurring maintenance cost for the life of the shipping package **1**. The homogeneous aggregate material **3** of the present invention, when placed inside the exterior shipping container **1**, has been subjected to over 42,000 miles of simulated endurance vibration testing with a fully loaded containment vessel **7**. Radiographs have shown that the internal structure of the homogeneous aggregate material **3** will fracture, crush, and be reduced to powder from the endurance vibration and impact testing. Additional thermal (direct flame or indirect heating) testing on this container **1** has shown no significant loss of effectiveness in its impact limiting and thermal insulating properties, when incorporated with the internal homogeneous aggregate material **3**. Therefore, there is no projected cost to replace the internal contents of the exterior shipping container **1**, even if the structure of the internal homogeneous aggregate material fractures. There is no appreciable loss of reduction of properties of the internal homogeneous aggregate material **3** within the shipping container **1** over the life of the shipping container **1**.

Although the present invention has been described in considerable detail with reference to a preferred version thereof, other versions are possible. For example, the materials of the apparatus may utilize a different inorganic vermiculite composition, or a similar composition of a non-carbon based, homogeneous aggregate of materials which include a solidifying agent such as portland cement. The percentage of alumina, silica, and other non-carbon oxide compounds may be varied from the percentages described above.

The configuration of the inorganic homogeneous aggregate material can be of any shape when solidified, providing impact protection and crush limitations for any stress on the exterior shipping container **1** in any direction. The shape of the material conforms to the shape of the container in which the material is cured (see FIG. **3**). The solidified inorganic homogeneous aggregate material **3** fills the void spaces **5** between the interior contaminent vessel **7**, and the exterior walls of the outer shipping container **1**. The containment vessel **7** is placed inside the outer container **1** with the top plug **21** over the containment vessel's lid **8**. By this method of encapsulating a container **1** with a rigid, nonflammable, inorganic matrix of crushable material, the internal containment vessel's high hazard materials is protected from temperature extremes and from impacts to the exterior shipping container **1**.

The process mixing and curing steps can be varied by allowing for additional mixing and vibrating time for the mixture inside the shipping container **1**, and by providing a longer curing and heating time without detriment to the final rigid form of the inorganic homogeneous aggregate material **3**.

Many variations will undoubtedly become apparent to one skilled in the art upon a reading of the above specification with reference to the drawings. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

What is claimed is:

1. A shipping container comprising:

1) an outer container having a wall, a bottom, a dismountable cover and a hollow interior;

2) a liner having sides and a bottom being smaller in every dimension than said outer container;

3) an inner container having a wall, a bottom, a dismountable cover and a hollow interior, said inner container being smaller in every dimension than said liner; and

4) a thermally insulating and energy-absorbing material disposed between said inner container and said outer container in all directions, said thermally insulating and energy-absorbing material consisting essentially of a mixture of
   a) vermiculite;
   b) portland cement;
   c) water; and
   d) air, constituting a void volume;

said mixture having been dried after being packed between said liner and said outer container to contain not more than 5 pounds per cubic feet of water and to exhibit a compressive stress no greater than 500 psi over a range of 10 to 40% compressive strain.

2. A container according to claim **1** wherein that portion of said thermally insulating and energy absorbing material disposed between the cover of said inner container and the cover of said outer container is removable.

3. A shipping container according to claim **1** wherein said thermally insulating and energy absorbing material has a density of approximately 30 pounds per cubic foot.

4. A shipping container according to claim **1** wherein said thermally insulating and energy absorbing material further comprises a component having a high neutron absorption cross section.

5. A shipping container according to claim **4** wherein said component having a high neutron absorption cross section is selected from the group consisting of boron, boron compounds, gadolinium, gadolinium compounds, cadmium, cadmium compounds, europium, europium compounds, hafnium, hafnium compounds, samarium, samarium compounds, and indium alloys.

6. A shipping container according to claim **1** further comprising at least one pressure relief valve in said outer container.

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OAK RIDGE NATIONAL LABORATORY

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ORNL/NTRC-005
Rev. 0

TEST REPORT OF THE ES-2100 PACKAGE

June 25, 2003
Revision 0

NATIONAL TRANSPORTATION RESEARCH CENTER

UT-BATTELLE

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Nuclear Science and Technology Division

Test Report of the ES-2100 Package

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June 25, 2003

Prepared for the
Y-12 Plant Complex
Nuclear Packaging Program

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Test Report of the ES-2100 Package

ABSTRACT

This test report describes a series of both drop and thermal tests performed on four test units of the ES-2100 shipping package from December of 2002 through April of 2003. These tests were performed to ensure compliance with the requirements of Title 10, Code of Federal Regulations (CFR), Part 71.71, *Normal Conditions of Transport* (NCT), Title 10, CFR, Part 71.73, *Hypothetical Accident Conditions* (HAC), and International Atomic Energy *Regulations for the Safe Transport of Radioactive Material 1996 Edition (TS-R-1)*, and to document the test activities to be included in the ES-2100 Safety Analysis Report for Packaging (SARP). This package is designed to contain Uranium oxide powders.

1 INTRODUCTION

Four ES-2100 packagings with surrogate contents were tested to demonstrate compliance with selected requirements of Title 10, Code of Federal Regulations (CFR), Part 71.71, *Normal Conditions of Transport* (NCT), Title 10, CFR, Part 71.73, *Hypothetical Accident Conditions* (HAC), and International Atomic Energy *Regulations for the Safe Transport of Radioactive Material 1996 Edition (TS-R-1)*. The packagings, each containing steel shot as a surrogate for the actual contents made up the test units and were identified by numbers TU-1-12/02, TU-2-12/02, TU-3-12/02, and TU-4-12/02. Hereafter in this report the test units are identified simply by their TU-X designation.

The test units were initially subjected to a series of drops that involved Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) tests. After the drop tests were completed, each of the four test units were then subjected to the thermal test specified as part of the HAC. Section 3 describes the drop tests performed on the test units. Section 4 describes the thermal tests that these same test units were subjected to.

Table 1-1 provides a test matrix that summarizes all of the tests performed on each individual test unit along with the orientation of each test unit when it was dropped tested.

Table 1-1. Summary of physical and thermal tests for ES -2100 package

Test	TU-1 (horizontal attitude)	TU-2 (CG-over-top-edge attitude)	TU-3 (horizontal attitude)	TU-4 (CG-over-top-edge attitude)
NCT 1.2 m (4 ft.) drop	X	X	X	X
HAC 9m (30 ft.) drop	X	X		
HAC 9m (30 ft.) dynamic crush	X	X	X	X
HAC punch	X	X	X	X
HAC puncture at CV lid joint	X			
Thermal test to 800°C (1475°F)	X	X	X	X
0.9 m (3 ft.) immersion	X	X	X	X

2 DESCRIPTION OF THE SHIPPING PACKAGE

The ES-2100 is a 55-gal, stainless steel drum that is 22-1/2 inches in diameter and 34-3/4 inches tall fabricated from 16-gauge, 304 stainless steel. The package has an integral annular liner that is filled with Kaolite 1600™, a mixture of cement and vermiculite, cast in place. The stainless steel structural member used to attach the annular liner shell to the drum forms the base for the 18 threaded studs that are used to secure the drum lid in place. Inside the annular liner shell is placed a polyurethane insert that provides some cushioning for the containment vessel (CV). Four equally spaced vent holes are placed around the top of the drum to allow for venting of steam generated during a thermal accident. A top plug, also fabricated from stainless steel and filled with Kaolite 1600™, sits above the CV and isolates the drum lid from the containment vessel (see Figure 2-1).

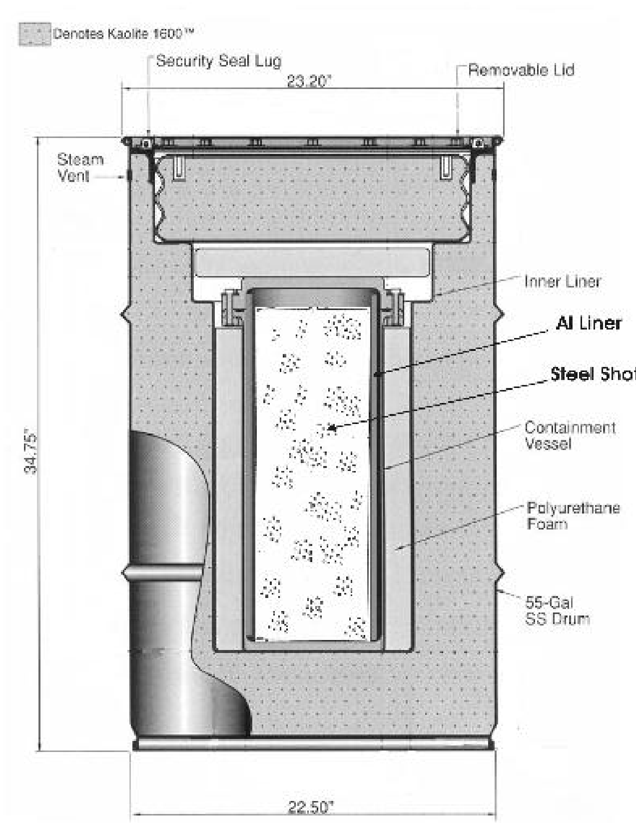


Figure 2-1 Cutaway view of the ES -2100 showing surrogate contents of steel shot.

The stainless steel CV is 21-1/4 inches tall, 8-5/8 inches in diameter, and has a Monel reinforcing nut ring that increases flange strength and also prevents gauling of lid bolts. The CV is sealed with two ethylene-propylene elastomeric O-rings, the inner one of which provides part of the containment boundary. The lid is held in place with twelve 3/8-inch bolts. There are no penetrations or fittings into the containment vessel. The vessel lid is fabricated with a sampling port that allows a pressure check of the gas space between the two O-rings to determine that the vessel is sealed to DOT operational requirements.

2.1 PREPARATION FOR TEST UNIT ASSEMBLY

Data sheets documenting information on pre- and post-test activities have been generated and are presented in the Appendices. All data sheets that refer to TU-1 are presented in Appendix A. Similarly Appendices B, C, and D contain data sheets that apply to TU-2, TU-3, and TU-4 respectively.

2.1.1 O-Ring Leak Check Test

The O-ring seal of the CV assembly was leak tested using a CALT 5 leak check system manufactured by Croft and Associates. The leak check was performed on all test units in accordance with ANSI N14.5-1997 using the manufacturer's leak testing procedure for the CALT 5 leak test device. The test sensitivity was at least 1×10^{-5} ref-cc/sec. (see Figure 2-2).

Figure 2-2 Checking the leak rate of an ES-2100 containment vessel with a CALT 5 leak tester.

The leakage rate resulting from the tests are documented on Test Form 1A, Assembly of the CV, in Appendices A-D. A summary of the measured leak rates is given in Table 2-1.

Table 2-1. Measured leak rate for the CV of each test unit.

Drum ID	TU-1	TU-2	TU-3	TU-4
Leak Rate, std-cc/sec air	8.08E-05	6.84E-05	6.28E-05	8.87E-05

2.1.2 Radiography of Test Units

Prior to assembly, each test unit was radiographed to determine if there were any voids in the Kaolite 1600™ that had been created when that material was cast in the package. The gamma ray source consisted of 33 curies of Ir-192. The film was 14 inches tall and 17 inches wide. To look in all parts of the Kaolite 1600™ the film was placed around the outer surface of the drum so that the film overlapped on the ends; the source was placed in the cavity of the package.

Exposure time was limited to about 50 seconds for the side and bottom shots and 135 seconds for the plug. To cover the entire circumference of the package, 5 separate pieces of film were required. To cover the entire height of the drum, three rows were required. Thus, 15 pieces of film were required for each drum. One shot was taken through the bottom and three films were used to x-ray the removable plug. Thus, it took 19 radiographs to completely examine the Kaolite 1600™ in each drum. Results of the radiography for the test units were recorded on Test Form 2A in Appendices A-D.

Radiographs of each test unit revealed some small, incidental, cracks in the Kaolite 1600™ which were located in the thinnest section of the annular liner at the top of the drum where the steam vents are located (see Figure 2.1). It is likely that these very thin gaps were formed as the Kaolite 1600™ cured after being poured. The cracks are small enough to be of no concern for the thermal test.

The actual radiographs are in the master data file that has been provided to the Y-12 sponsors.

2.1.3 Application of Temperature Labels

Prior to assembly, an array of maximum temperature blackout labels was applied to 16 locations on each CV and an additional 16 labels were affixed to the inside surface of each drum. Several of the temperature labels can be seen on the CV in Figure 2-2 and an additional number can be seen on the inside surface of the drum in Figure 2-3. Two more labels were loosely placed in the middle of the surrogate payload, the steel shot.

The temperature labels are designed with 16 indicating spots that range from 125º F to 500º F, in 25º increments. Each label was affixed at a specific location and an additional strip of Teflon™ tape was placed over the label to ensure it would remain in place during the thermal test.

Figure 2-3 Preparation of drum with affixed temperature labels.

2.2 DESCRIPTION OF TEST UNITS

The test units were full-scale ES-2100 packagings. An aluminum sleeve was designed to be placed inside the CV which was, in turn, loaded with a mockup of the Uranium oxide powder payload. This surrogate payload consisted of 460 grit (approximately 0.04 to 0.07 inches in diameter) steel blasting shot contained in plastic bags. Figure 2-4 shows the items that were individually weighed and then placed inside the drum prior to testing.

All test units had temperature indicators affixed to the CV as well as the inside surface of the drum liner prior to assembly for testing. The locations of the temperature indicators are discussed in Section 4.

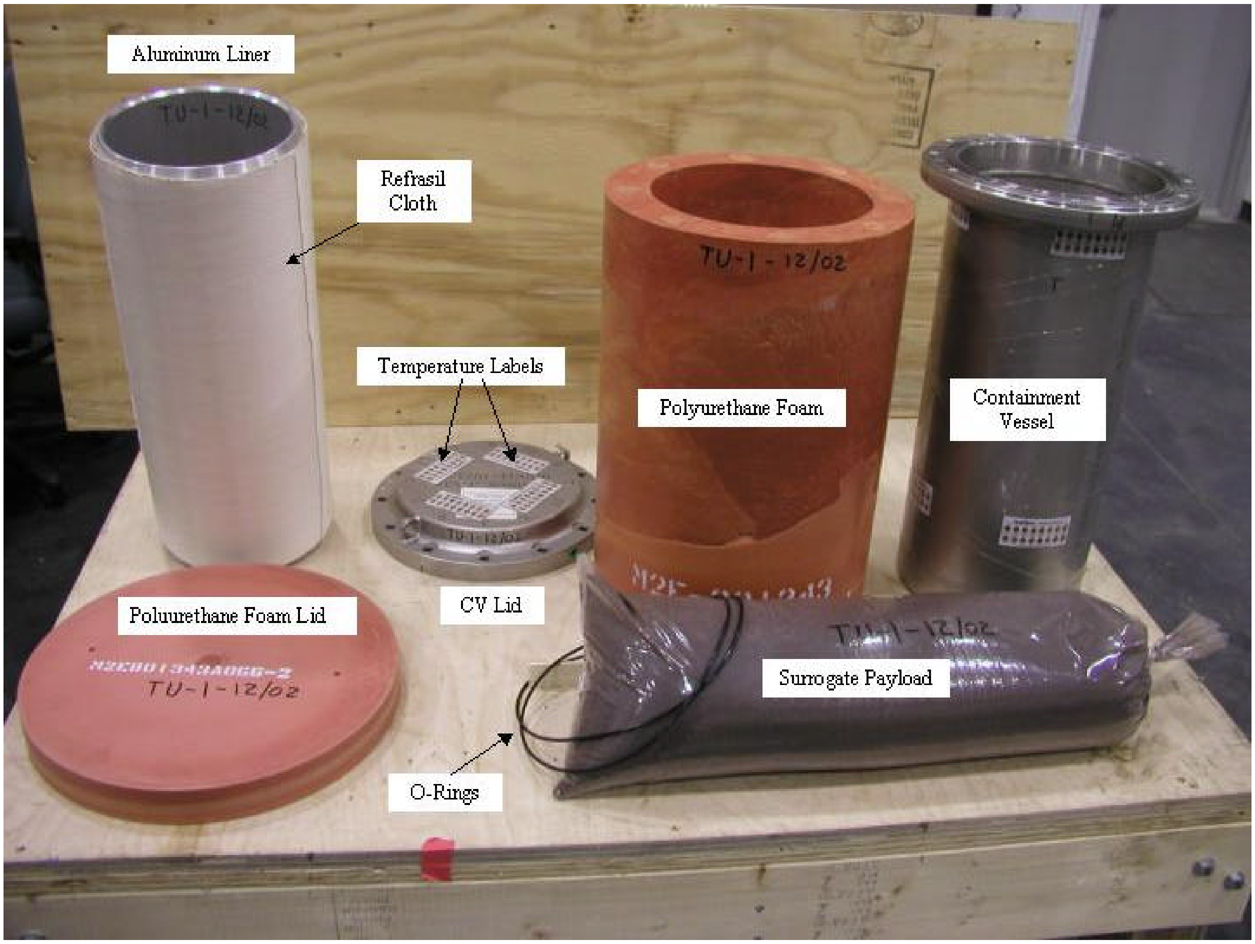


Figure 2-4 Internals prior to being placed inside ES -2100 drum.

The vertical seam of the outside drum of all test units was marked with a 0º vertical reference line and the other three quadrants were marked with a vertical line at 90º, 180º, and 270º as measured around the top perimeter of the package in a counterclockwise direction looking down onto the top of the package. A horizontal line was also marked around the circumference of each outer drum at 16-1/4 inches above the lower edge of the outer drum which defined the center-of-gravity plane of each package. The intersection of the vertical lines and the circumferential line provided CG "targets" on each quarter of the outer drum surface.

Results of weighing the components of the package were recorded on Test Form 3 in Appendices A-D. The total weight of each package is given in Table 2-2.

Table 2-2. Test weight of each test unit.

Item	TU-1	TU-2	TU-3	TU-4
Test weight, lb.	453	447	449	451

2.3 PACKAGE ASSEMBLY

Before assembly began, the components of each CV was given a visual inspection, the results of which were documented in Test Forms 1A. The weights of the various components making up the package was taken and recorded on Test Form 3. The assembly of each test unit was documented on Test Form 2. These test forms are presented in Appendices A-D.

An aluminum liner was designed to be installed inside each of the four CV's. This liner provided the base to wrap two layers of Refrasil insulating cloth so as to provide a thermal barrier between the inner wall of the CV and the steel shot test load. This insulation is intended to prevent the test load from acting as a heat sink during the thermal testing. In addition, two discs of Refrasil, sized to cover the bottom inner surface of the CV, were placed on the bottom inner surface of the CV and two more discs of Refrasil, sized to cover the top inner surface of the CV lid, were placed on the inner surface of the CV lid. Once wrapped, the aluminum liner was then placed inside the CV.

A plastic bag was placed inside the aluminum liner after the liner was installed in the CV. Approximately 56.7 kg (125 lb) of steel shot was then poured into the plastic bag. The polyurethane foam was placed inside the drum cavity and the loaded CV was placed inside the polyurethane foam.

3 REGULATORY DROP TEST REQUIREMENTS

Four test units were subjected to a variety of physical tests required by regulatory authorities. All four units were dropped 1.2 m (4 ft) as described in the DOT regulations for NCT test requirements. Two of the four were then subjected to the 9 m (30 ft) HAC drop test followed by a 9 m (30 ft) HAC dynamic crush test as required by the Nuclear Regulatory Commission under certain conditions. The IAEA regulations require that a package be tested either with a 9 m drop test OR subjected to a 9 m crush test, not both. With this in mind, the other two test units were only subjected to the HAC crush test after being put through the NCT drop test. All four test units were then subjected to the HAC punch test. One test unit, TU-1, was dropped a second time onto the punch so as to impact directly adjacent to the flange of the CV. These drop tests are discussed in more detail in this Section.

3.1 DROP TESTS

The drop tests were carried out at the National Transportation Research Center (NTRC) in Knoxville, Tennessee and were conducted by Oak Ridge National Laboratory staff members of the Transportation Technology Group of the Nuclear Science and Technology Division.

As noted in Table 1-1, all four test units, TU-1, TU-2, TU-3, and TU-4, were initially subjected to the 1.2 m (4 ft) Normal Condition of Transport (NCT) drop test. All NCT drop impacts were made onto the seam of the packages, the area that is considered the weakest.

The 10CFR-71.73 HAC compliance testing was performed using TU-1 and TU-2. These two packages were subjected to the 9 m (30 ft) free fall drop test followed by the 9m (30 ft.) dynamic crush test. 10CFR-71.73 requires that the package subjected to the 9 m (30 ft) free fall drop followed by the 9m (30 ft) dynamic crush to be in a position for which maximum damage is expected in this latter test. Previous experience and modeling of the ES-2100 indicated that the side orientation and package center of gravity (CG) over the top edge are the most damaging orientations for these tests. For the 9 m (30 ft) dynamic crush test, the portion of the package damaged in the previous NCT and HAC tests was set on the drop pad and the 500 kg (1102 lbs) crush weight was dropped to impact on the opposite (i.e., the undamaged) side, or edge (in the case of the CG-over-corner test) of the package. (See Figure E-19)

The TS-R-1 HAC compliance testing, required by the International Atomic Energy Agency (IAEA) was performed using test units TU-3 and TU-4. The IAEA requires either (not both) a 9m (30 ft) drop or a dynamic crush test be applied to a package. Previous experience and modeling of the ES-2100 indicated that the side orientation and CG-over-the-top-edge are the most damaging orientations for these packages. For the 9m (30ft) dynamic crush test on these TU-3, the portion of the package that had been damaged in the previous NCT test was set on the impact pad and the 500 kg (1102 lbs) crush weight was dropped on the opposite (i.e., the undamaged) side. In the case of TU-4, the undamaged bottom was placed on the impact pad and the package was balanced such that the 500 kg crush weight would impact the previously damaged edge of the lid.

Following the above-noted tests, all four Test Units were subjected to the HAC punch test. For this punch test, each unit was dropped onto a 15-cm (6-inch) diameter steel punch in a horizontal attitude so that the impact occurred on the seam of the outer drum of each package. In addition, TU-1 was subjected to a second HAC punch test in which it was dropped onto the punch in a horizontal attitude so that the impact occurred immediately adjacent to the flange of the CV contained within the drum. In practice, the package struck the punch at the junction of the top rolling hoop and the 0° line (the seam).

3.1.1 NCT Drop Test Results

Of the four test units that were put through the NCT tests, TU-1 and TU-3 were dropped in a horizontal attitude from a height of 4 ft. Figure 3-1 shows the drop height measurement being made prior to releasing the TU-1 package. The outer drum was slightly flattened along the 0° line. The width of the flattened drum surface was taken at four different positions: the top ring, the top rolling hoop, the bottom rolling hoop, and the drum bottom. These dimensional measurements are given in Table 3-1.

Prior to impact, the drum diameter, as measured at the top ring from the 0° line to the 180° line on the undamaged drum, was determined to be 23-5/8 inches. Following the NCT drops, this diameter was measured to be 23-1/4 inches on TU-1 and 23-1/4 inches on TU-3 (see Test Form 4 in Appendices A and C).

Figure 3-1 Measuring the drop height of TU-1 for the NCT drop test.

Table 3-1. Width of flat at specific locations along the height of the drum from NCT test*.

Position	Top Ring	Top Hoop	Bottom Hoop	Drum Bottom
TU-1 Measurement, in.	4-1/4	5-1/8	6-3/16	5-1/4
TU-3 Measurement, in.	4-5/8	4-11/16	6-1/2	4

* All dimensional measurements were taken with a ruler whose smallest division was 1/16 inch.

Additional detailed sketches of the damage and measurements to these packages are given in the Test Form 4 data sheets in Appendices A and C for packages TU-1 and TU-3, respectively.

Units TU-2 and TU-4 were dropped from a height of 4 feet on their top with their center-of-gravity positioned directly above the junction of the top edge and the vertical 0° line of the drum. The angle of the drum prior to release was measured to be 34.6° from the vertical for both drums. Figure 3-2 shows the drop height measurement being made prior to releasing the TU-4 package. Also seen in this figure is the vertical 180° line marked on the outside of the package and part of the clamp that was attached to the bottom of the drum. This hoisting arrangement permitted the drum, with a single-point suspension, to hang with the CG directly over the top edge.

Impacting on the top edge of the package produced a flat area in the top ring of about 7-5/8 inches and bend down approximately ¼ inch from its original position. The package then fell over and slightly flattened the bottom when it hit the impacting surface. Figure 3-3 shows the damage to the top ring, at the 0º line, caused by the impact.

Figure 3-2 Measuring the drop height to the top of TU-4 for the NCT drop test.

Because the top ring flattened as well as bent, the diameter of the package diminished from an original diametric measurement of 23-9/16 to 23-7/16 inches in package TU-2 and from 23-9/16 to 23-1/2 inches in package TU-4. Additional detailed sketches of the damage and measurements of these packages is given in the Test Form 4 data sheets in Appendices B and D for packages TU-2 and TU-4 respectively.

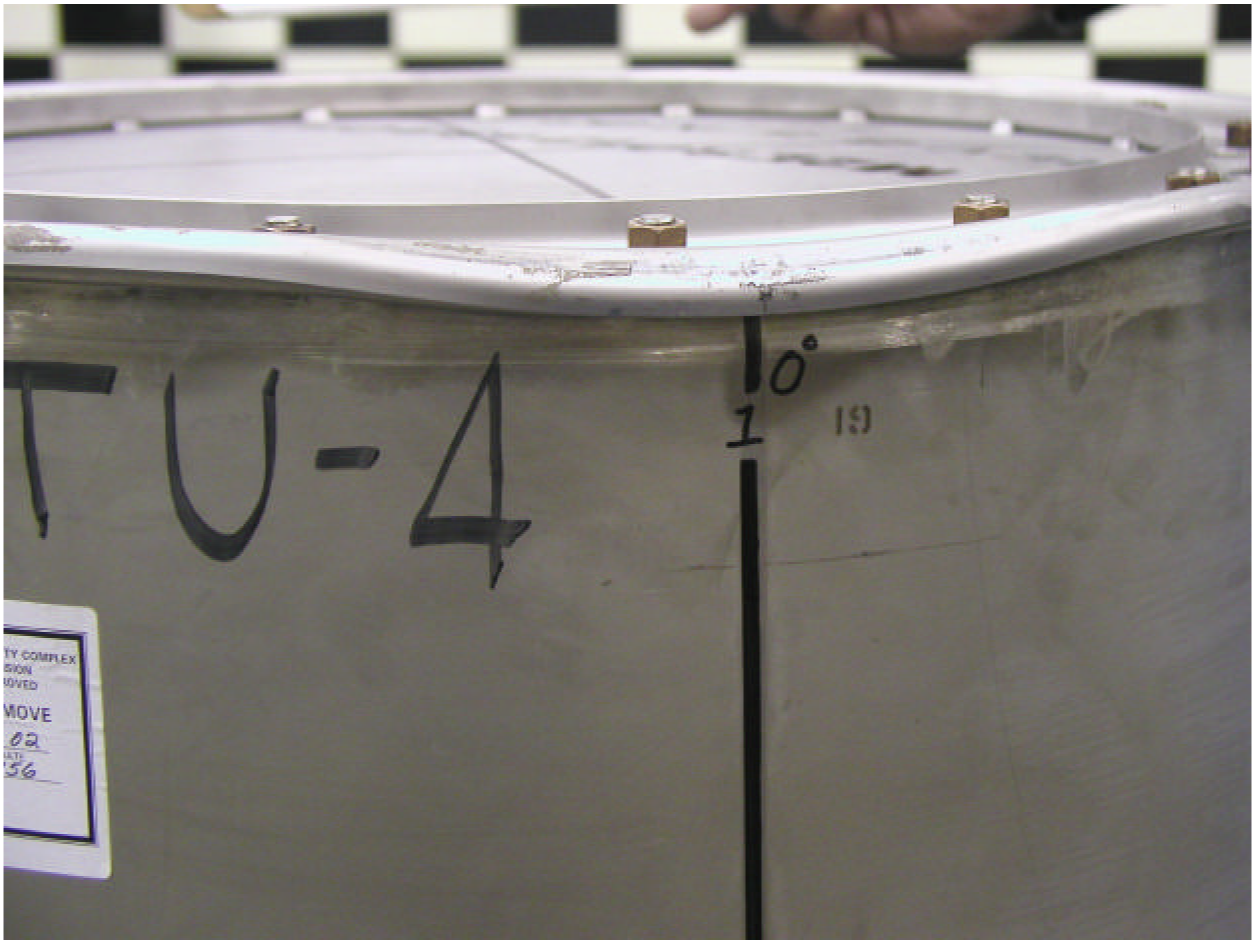


Figure 3-3 Photo of the damage to the top ring on the closure of TU-4 resulting from the NCT drop test.

3.1.2 HAC Drop Test Results

Following the NCT drops of all four packages, test units TU-1 and TU-2 were put through the 9 m (30 ft) Hypothetical Accident Condition (HAC) drop test. In the case of TU-1 the package was dropped in a horizontal attitude (the measured angle of the package prior to the drop was 0.8° from horizontal) and oriented to impact on the 0° line that had been damaged in the NCT drop.

The setup for the 9 m (30 ft) horizontal drop of TU-1 is shown in Figure 3-4. Extra light stands seen in the photo were brought in to provide sufficient illumination for the 500 frames per second high speed motion pictures that were taken of the drop and impact.

Figure 3-4 Photo showing the test setup for the HAC 9-m free drop of TU-1.

Figure 3-5 shows the package, which was rolled over following the impact, to expose the damage that was caused by the drop test. The view shows the bottom edge, which wrinkled significantly, and the flattening of the impacted side. Table 3-2 indicates the widths of the resultant flat that were measured at four different locations along the height of the package.

Table 3-2. Width of flat at specific locations along the height of TU-1 from HAC 9-m free drop test.

Position	Top Ring	Top Hoop	Bottom Hoop	Drum Bottom
The 0° side, Measurement, in.	8-1/16	9-1/8	11-7/8	11

Note the flat produced at the bottom end of the package is over 35% greater than the similar measurement at the top ring. This difference is primarily due to the fact that the top closure is structurally more rigid than is the bottom and therefore would not be expected to deform as much as the bottom in a horizontal impact. The diameter of the drum as measured at the top ring from the 0° line to the opposite 180° line was measured to be 22-3/4 inches as compared to the undamaged drum diameter of 23-9/16 inches.

Figure 3-5 Results of dropping the TU-1 package from 9-m onto the solid unyielding surface.

In the case of TU-2, the package was hung from a steel bracket clamped to the bottom rim of the package such that the package hung with its CG directly above the same top edge of the package that had initially impacted in the NCT drop test for this test unit. The angle of the package when suspended was 34.6° from vertical. Figure 3-6 shows the drop test setup for TU-2 once it was raised to its 9 m (30 ft) drop height.

Figure 3-6 Photo showing the test setup for the HAC 9-m drop of TU-2.

The results of the impact when TU-2 was dropped onto the unyielding target are shown in Figure 3-7. Note that the top edge crushed down toward the bottom of the drum producing several wrinkles in the steel outer shell above the name plate that had been welded onto the package and which helped stiffen the outer shell at that point. However, the bolt ring helped stiffen the lid and the height of the drum at the 0° line was measured to be 32-7/16 inches as compared to an undamaged height of 35-1/16 inches. The imprint of the impacting surface is clearly seen in the photo on the edge of the ring and the width of the imprint was measured to be 12-13/16 inches from end to end. In addition, all lid bolts remained in place.

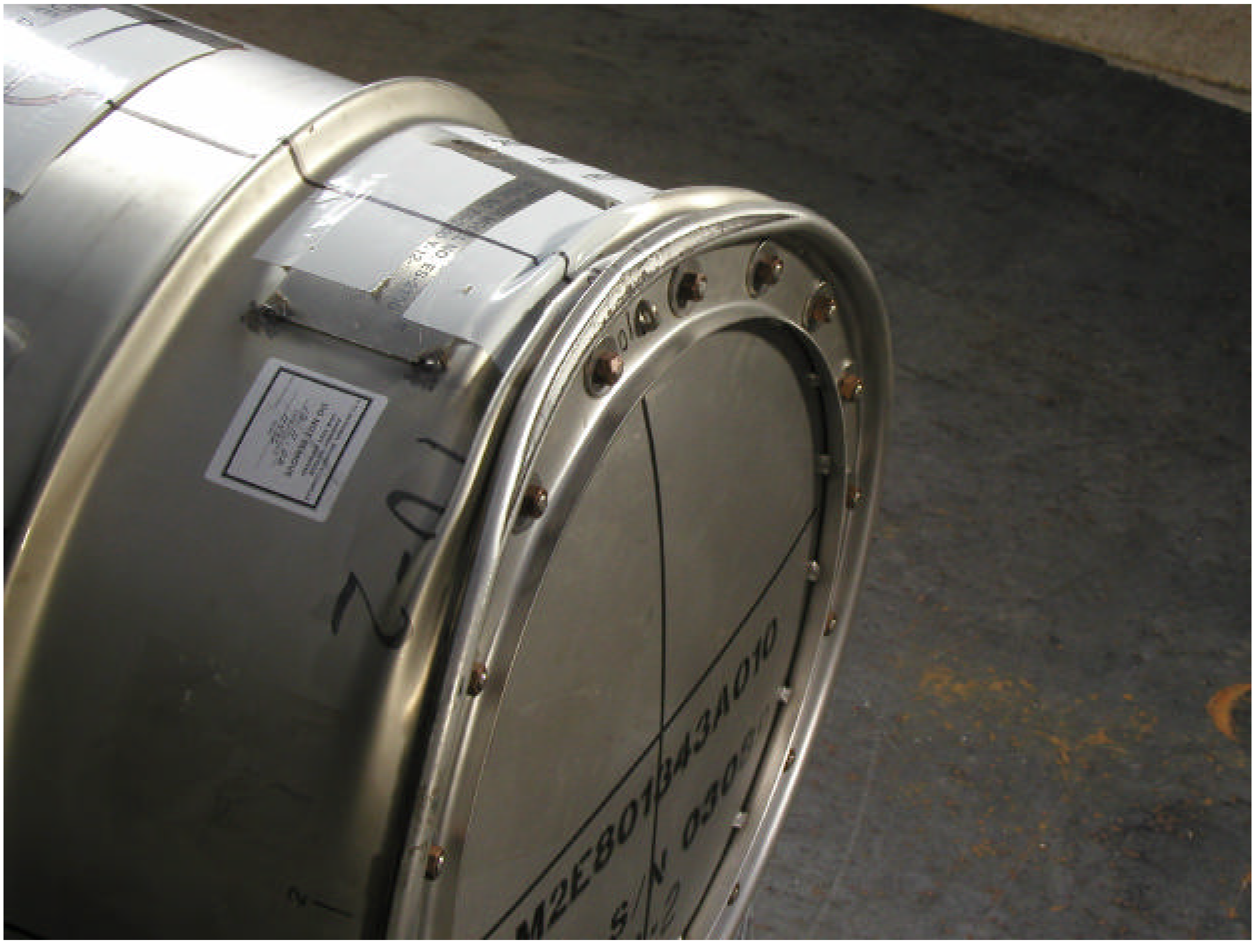


Figure 3-7 Results of dropping TU-2 in a CG-over-corner drop from 9 m.

3.1.3 HAC Dynamic Crush Tests

All four test units were subjected to the dynamic crush test. This test consisted of placing the test units on the unyielding impact pad and dropping a 500 kg (1102 lb) weight onto the package from a 9 m (30 ft) drop height.

3.1.3.1 NRC-required crush tests

When a package weighs less than 500 kg, has an overall density is less than 1000kg/m^3 (62.4 lb/ft^3), and the proposed radioactive contents will be greater than 1000 A_2 not as special form, the NRC requires the dynamic crush test to follow the 9-m free drop test. Since these packages weighed approximately 204 kg (450 lb), TU-1 and TU-2 were both put through the dynamic crush test after being subjected to the 9-m free drop test.

Test Unit TU-1 was placed on its side on the impact pad with the 0° line (which had been damaged in the previous 9-m free drop) down against the steel surface. The 500-kg weight was raised to a height of 9 m above the undamaged 180° line on the drum and released.

Figure 3-8 shows the damage caused to the 180° line area of the drum as viewed from the drum top and the 500-kg impacting weight in the background. Note that the drum is flattened more at the bottom than at the top of the drum demonstrating that the

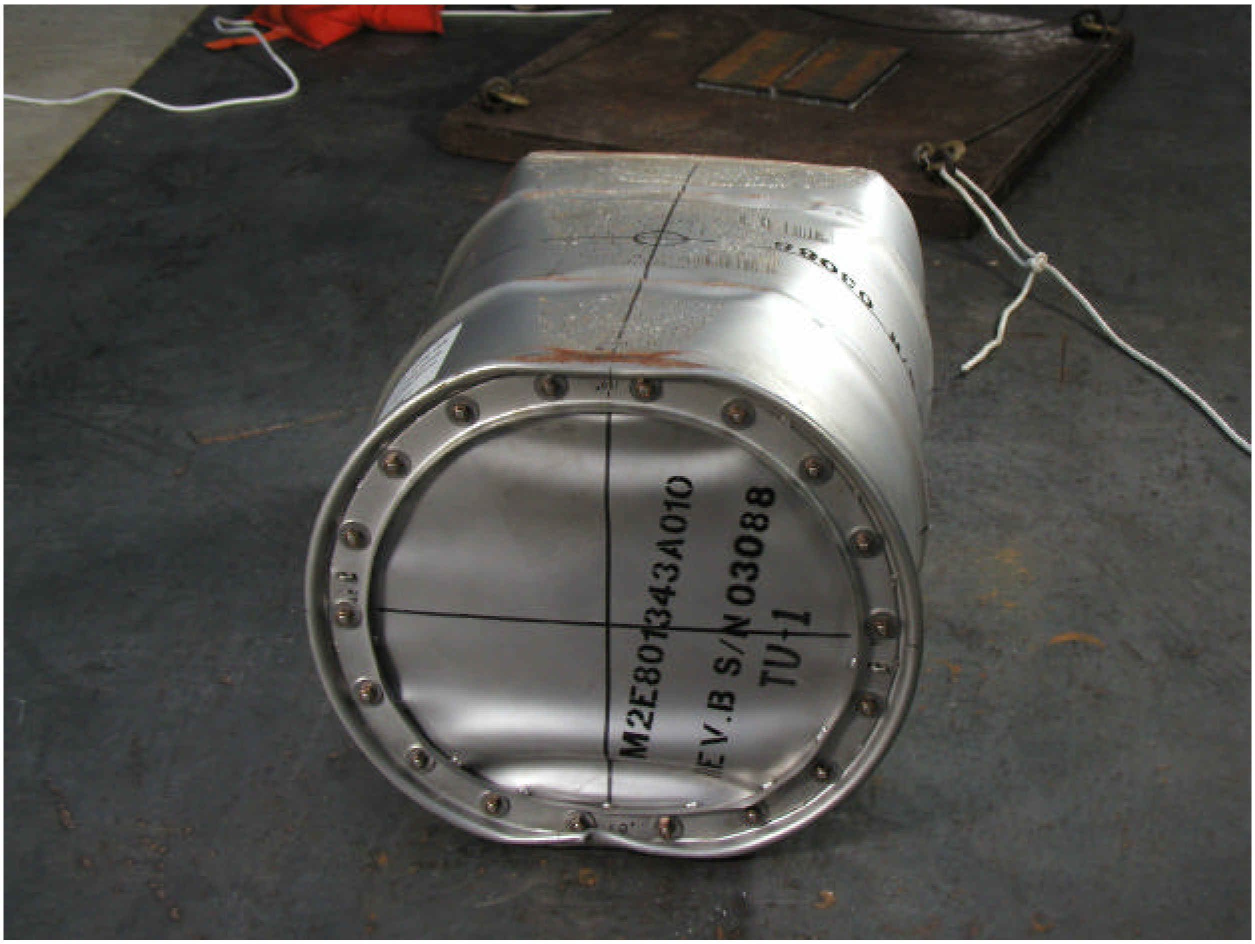


Figure 3-8 Results of the dynamic crush test as viewed from the top end of TU-1.

top is more rigid and able to withstand a side impact with less deformation than the bottom. And while most of the damage to the 0° line was received from the 9-m free drop test, some additional damage was caused by the impact in the crush test. Note the small tear in the top ring at the 0° side in the lower portion of this photo.

Following the test, the package was set on its bottom and a variety of dimensional measurements were made. Details are presented in Test Form 6 in Appendix A and are summarized below.

Table 3-3 presents the measurements of the flattened areas that were produced at four different locations on the 0° side and the 180° side of TU-1. The flattened dimensions on the 0° side shown in Table 3-3 may be compared to similar measurements noted in Table 3-2 that were made at the same location on TU-1 following the 9-m free drop, the difference being attributable to the effect of the crush test as measured on the seam side of the package.

Table 3-3. Width of flattened areas at specific locations along the height of TU-1 following the crush test.

Position	Top Ring	Top Hoop	Bottom Hoop	Drum Bottom
The 0° side, Measurement, in.	9-5/8	11-13/16	16-1/5	17-3/4
The 180° side, Measurement, in.	8-1/4	10-3/4	15	17

Diameter measurements were also made on TU-1 following the crush test. These measurements were made between the 0° line and the 180° line as well as between the 90° line and the 270° line at three different height locations on the package. The measurements are noted in Table 3-4 and are compared with diameter measurements that were made on an undamaged package.

Table 3-4. Diameter measurements at specific locations along the height of TU-1 following the crush test.

Position	Top ring	Middle	Drum bottom
Diameter between 0° - 180° line, inches	21-1/8	19-5/8	15-7/8
Diameter between 90° - 270° line, inches	23-15/16	23-11/16	23-1/16
Undamaged package diameter, inches	23-5/8	22-5/8	22-1/4

Test unit TU-2 was tested by setting it on the impact pad in the CG-over-corner attitude that it had been dropped in from 9-m and discussed in Section 3.1.2. To do this the package had to be balanced on its edge with its already damaged top end resting on the impact pad and the bottom of the package in an upward position. To balance the package, two thin nylon cords that were anchored to the impact pad were attached to a strap that had been tightened around the diameter of the package. These cords could be adjusted in length to get the package to balance properly. Figure 3-9 shows the test setup after the package had been balanced and just prior to the release of the 500 kg steel plate.

Figure 3-9 Test setup for the dynamic crush test of TU-2.

A plumb bob attached to the end of a 9-m steel wire and taped to the middle of the underside of the steel plate can be seen suspended right above the desired point of impact on the corner of the package. The plumb bob is also used to obtain the correct drop height for all 9-m drop tests.

The impact of the steel plate produced a flattened surface on the edge of the bottom of the package and increased the flattened area on the top of the package that was sitting on the impact pad.

The damaged area of the bottom of the package is shown in Figure 3-10. The damage extends from the bottom rolling hoop to almost the middle of the bottom of the package. That flattened dimension is approximately 14 inches.

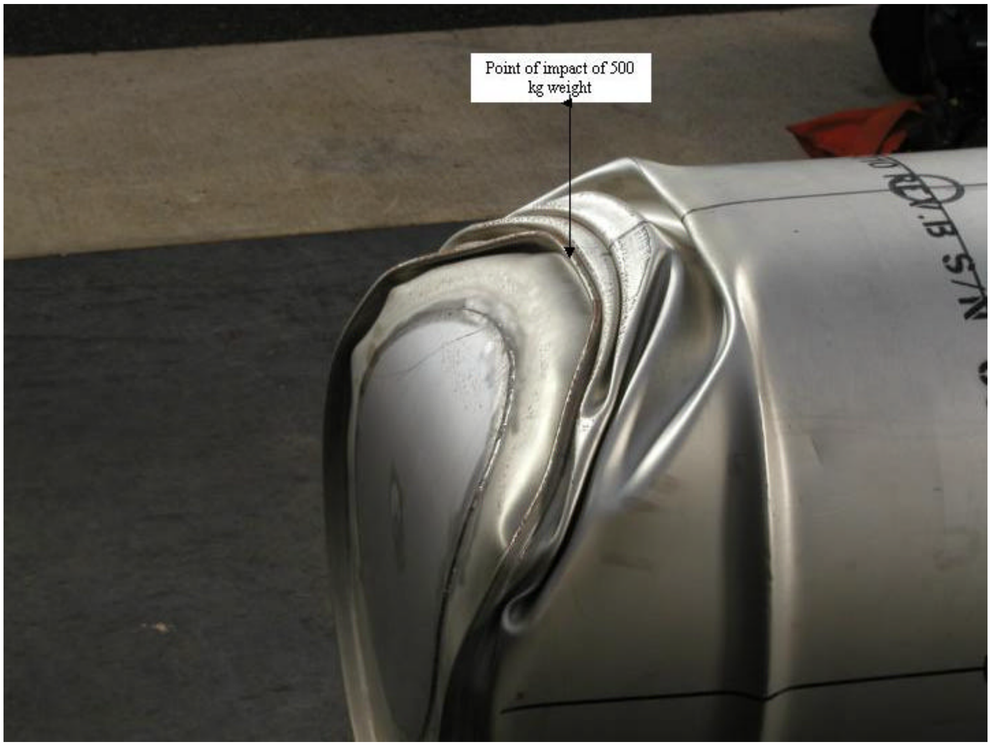


Figure 3-10 Damaged bottom of TU-2 resulting from the dynamic crush test.

The damaged area of the top of the package is shown in Figure 3-11. This damage is much less due to the heavier structural members in the lid area. Note that in this photo there is a slight change to the originally straight 90° line drawn on the side of the package starting at about the top rolling hoop. The angle was measured to be approximately 7° from its original vertical position and was caused by the compression of the steel drum at the top rolling hoop at the 0° line at the time of impact of the steel plate on the package. This compression, in turn, caused the entire top of the package to bend slightly. The physical damage to the lid area is rather minor. Details of the damage are sketched on Test Form 6 in Appendix B.

Figure 3-11 Damaged top of TU-2 resulting from the dynamic crush test.

3.1.3.2 IAEA-required crush tests

The HAC impact tests required by the IAEA for packages weighing less than 500 kg specify that they will be subjected *either* to a free-drop test from 9 m or they will be subjected to a crush test identical to that required by the NRC. Test units TU-3 and TU-4 were not exposed to the 9-m free drop test but, following the NCT test, were subjected to the HAC crush test.

Test unit TU-3 was placed on the impact pad with the 0° line down resting against the steel surface of the impact pad. The 0° line identifies the area that had been slightly flattened in the NCT drop test of this unit, as discussed in Section 3.1.1. For this crush test, the 500-kg weight was raised to a height of 9 m above the undamaged 180° line on the drum and released. Figure 3-12 shows the damage to the lid end resulting from the impact.

The impact caused the package along the 180° line to be flattened and increased the flattened surface along the 0° line that had been resting on the surface of the impact pad. Table 3-5 presents the measurements of the flats that were produced at four different locations on the 0° side and the 180° side of TU-3. The flat dimensions on the 0° side shown in Table 3-5 may be compared to similar measurements noted in Table 3-1 that were made at the same location on TU-3 following the NCT 4-ft drop test. The measurement data for this crush test were recorded on Test Form 6 in Appendix C.

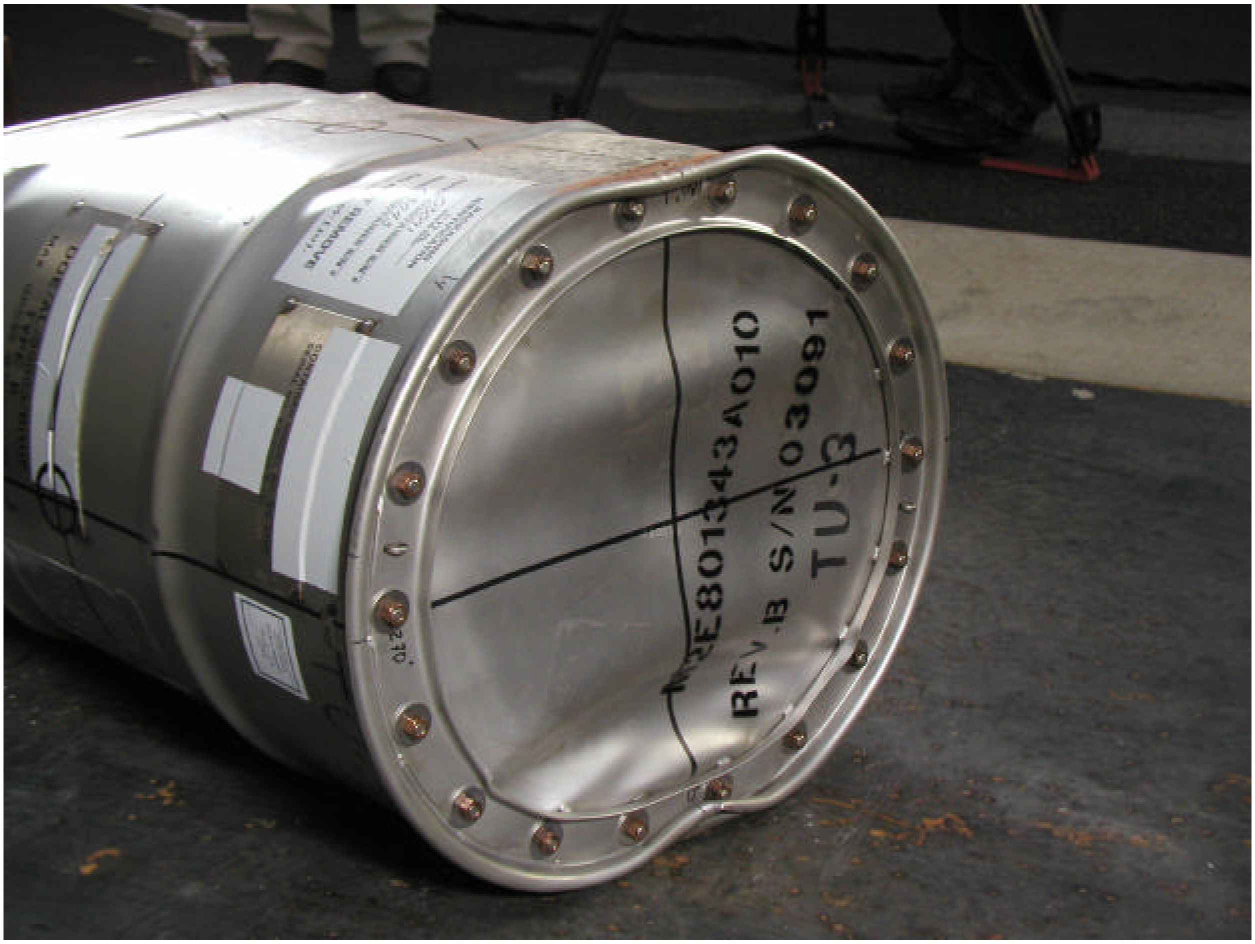


Figure 3-12 Results of the dynamic crush test as viewed from the top end of TU-3.

Table 3-5. Width of flattened areas at specific locations along the height of TU-3 following the crush test.

Position	Top Ring	Top Hoop	Bottom Hoop	Drum Bottom
The 0° side, Measurement, in.	10	11-3/4	14	15-3/4
The 180° side, Measurement, in.	7-7/8	10-1/2	15	16-3/4

Diameter measurements were also made on TU-3 following the crush test. These measurements were made between the 0° line and the 180° line as well as between the 90° line and the 270° line at three different height locations on the package. The measurements are noted in Table 3-6 and are compared with diameter measurements that were made on an undamaged package.

Table 3-6. Diameter measurements at specific locations along the height of TU-3 following the crush test.

Position	Top ring	Middle	Drum bottom
Diameter between 0° - 180° line, inches	21-1/4	19-7/8	17-1/4
Diameter between 90° - 270° line, inches	23-15/16	23-5/8	22-7/8
Undamaged package diameter, inches	23-9/16	22-5/8	22-1/4

TU-4 was readied for the crush test by setting it on the impact pad in the CG-over-corner attitude. To do this the package had to be balanced on the impact pad. However, contrary to the positioning arrangement used in testing the TU-2 package (in which the already damaged lid was set on the impact pad) this package was arranged with the undamaged bottom placed on the impact pad and the damaged top end in an upward position where it would receive the direct impact of the steel plate. To balance the package, two thin nylon cords that were anchored to the impact pad were also attached to a strap that had been tightened around the upper part of the package. These cords could be adjusted in length to get the package to balance properly. This arrangement is shown in Figure 3-13.

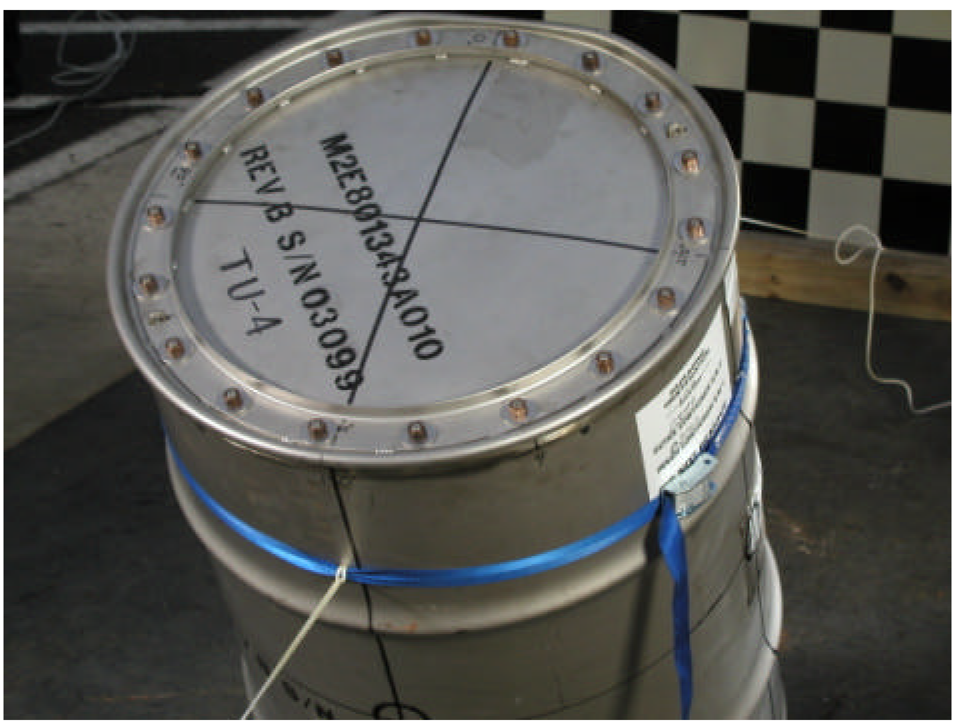


Figure 3-13 Setup for the crush test for TU-4.

Note that the edge of the top ring that had been damaged in the NCT drop tests discussed in Section 3.1.1 and shown in Figure 3-3 is at the top of the photo in Figure 3-13 and is positioned to be impacted by the steel plate in the test.

Figure 3-14 shows the resulting damage to the top of the package following the impact of the steel plate on the package. The impact caused the steel drum at the 0° line and the top rolling hoop to buckle and fold. This is a structurally weaker area caused by the presence of the rolling hoop in the drum. The impact also caused the top lid of the package to crush along the 0° line with the result that this side of the drum shortened slightly.

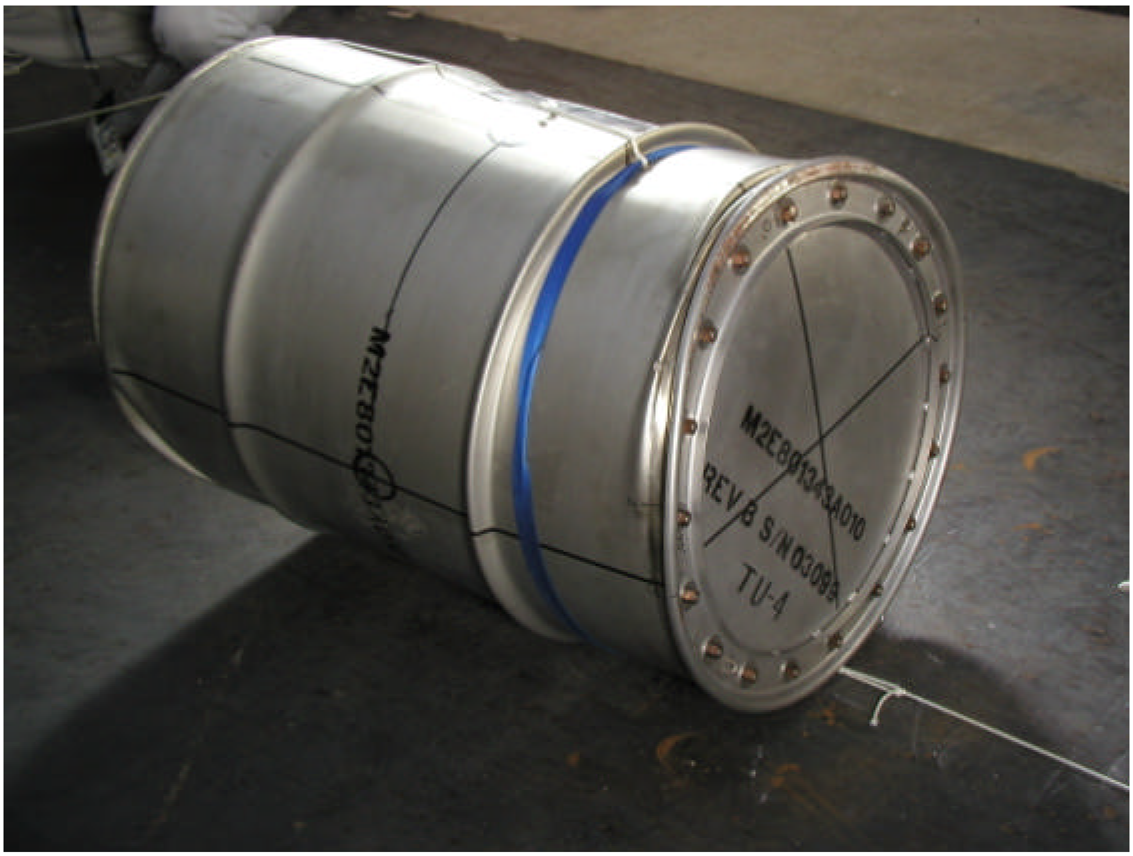


Figure 3-14 Results of the dynamic crush test as viewed from the top end of TU-4.

Figure 3-15 shows the damage caused on the bottom the package that had been its point of balance on the impact pad. The crush is much more severe than was produced on the top, shortening the height of the package on the 180° line more than occurred on the 0° line. Table 3-7 presents the length of the 0° line and the 180° line and compares those dimensions to the height of an undamaged package.

Table 3-7. Height of the TU-4 at specific locations following the crush test.

Drum	0° Line	180° Line	Undamaged package
Height, inches	31-5/8	28	35-1/16

Note that in Figure 3-15 the 270° line appears to be slightly bent at the top rolling hoop. This angle was measured to be 4°. This is interesting since this is the same area that TU-2 produced a bend in the drum as a result of the crush test, but TU-4 was set up on the drop pad upside-down from the position of the TU-2 test unit. The difference in the angles produced (7° for TU-2 as compared with 4° for TU-4) is understandable since the TU-2 test unit underwent a 9-m HAC free drop test and thus sustained more damage prior to being subjected to the crush test.

Figure 3-15 Results of the dynamic crush test as viewed from the bottom end of TU-4.

3.1.4 HAC Puncture Tests

All four test units were subjected to the HAC dynamic puncture test and TU-1 was dropped twice. In this series of tests each package was positioned so its lowest surface would impact the punch in a horizontal orientation. Each package was raised to a height of 1 m (40-inches) above a 15-cm (6-inch) diameter steel punch that had been bolted to a steel impacting surface of the inside drop pad at the NTRC. With the exception of the second puncture test performed on TU-1, each was aligned with the center-of-gravity of the package directly over the punch and then dropped.

TU-1 had previously been dropped in a horizontal attitude on the 0° line from 9 m and then subjected to a crush test with a 500 kg steel plate being dropped onto the bottom edge at the 180° line. This produced two flattened surfaces in opposite sides of the drum that were not parallel, but slightly wedge shaped (see Figure 3-8 of Figure E-20 in

Appendix E). Thus when the flattened lower surface was placed on the horizontal floor, the top surface was sloped at a 7.7° angle. When this package was raised to 1 m above the punch, the angle on the top surface was measured to be 7.5°, which meant that the bottom was within 0.2° of being horizontal. The package was then dropped onto the punch.

The resulting impact produced an indentation in the side of the steel drum, but did not puncture it (See Figure 3-16). The damage was observed to cover a circular-shaped area approximately 23 cm (9 inches) in diameter. A straightedge was laid across the indentation along the 0° line and the depth of the indentation was measured to be about 1.4 cm (9/16 inch). The diameter of the drum was measured from the center of the punch mark and the 0° line to the 180° line and found to be 18-7/8 inches. The original diameter of the drum was about 22-1/2 inches. The dimensional data for this test was recorded on Test Form 7 in Appendix A.

Figure 3-16 Damage produced in the first puncture test of TU-1.

Following the first punch test that impacted on the 0º line, TU-1 was rotated 180° around its longitudinal axis and subjected to a second puncture test. Again, the package was adjusted so the flattened lower surface was horizontal but the impact would occur on the 180° line at a point which was about 10-5/8 inches from the top of the package, just adjacent to the location of the flange of the inner containment vessel. When this package was raised to 1 m above the punch, the angle on the top surface was measured to be 7.3°, which meant that the bottom was within 0.4° of being horizontal. The test unit was raised and dropped onto the punch.

The resulting impact produced an indentation in the side of the steel drum, but did not puncture it (See Figure 3-17). The damage was observed to cover a circular-shaped area approximately 27.3 cm (10-3/4 inches) in diameter. A straightedge was laid across the indentation along the 180° line and the depth of the indentation was measured to be about 1.3 cm (1/2 inch). The diameter of the drum was measured from the center of the punch mark and the 180° line to the 0° line and found to be 18-7/8 inches. The original diameter of the drum at the top rolling hoop was 23-3/8 inches. The dimensional data for this test was recorded on Test Form 7A in Appendix A.

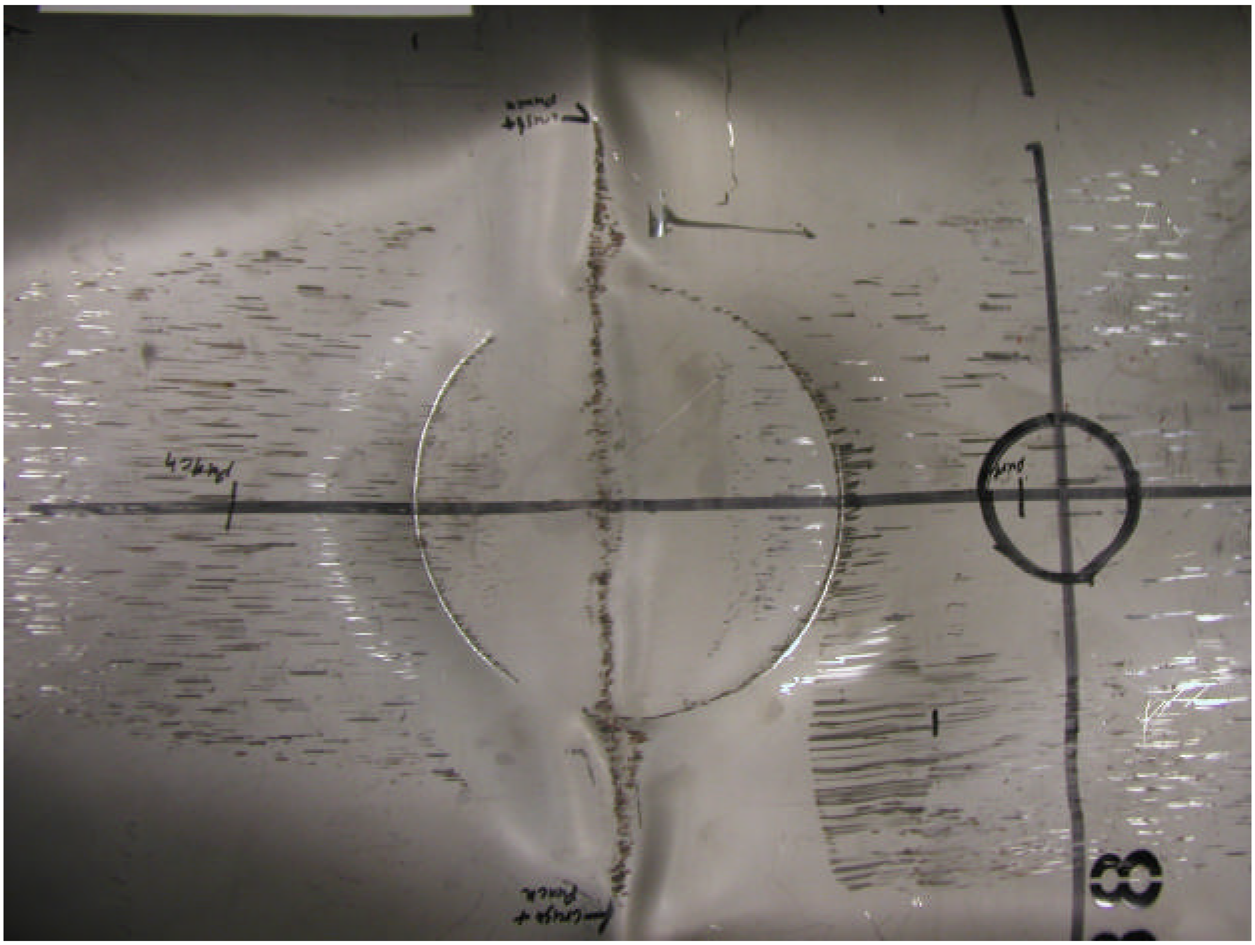


Figure 3-17 Damage produced in the second puncture test of TU-1.

TU-2 was subjected to the puncture test by orienting the package horizontally such that the impact would occur on the 0° line and in line with its center-of-gravity. In this case the package had been previously dropped on its top edge and subjected to the crush test in that same CG-over-corner orientation. These edge impacts left the middle of the package at the 0° line relatively undamaged. The package was raised 1 m above the punch and then dropped.

The resulting impact produced an indentation in the side of the steel drum, but did not puncture it (see Figure 3-18). The damage was observed to cover a slightly oval-shaped area with a major diameter of approximately 23 cm (9 inches) and a minor diameter of about 22 cm (8-5/8 inches). A straightedge was laid across the indentation along the 0° line and the depth of the indentation was measured to be about 1.6 cm (5/8 inch). The diameter of the drum was measured from the center of the punch mark on the 0° line to the 180° line and found to be 53.5 cm (21-1/16 inches). The original diameter of the drum was about 22-1/2 inches measured at the same location. Data for the punch test of TU-2 is given on Test Form 7 data sheet in Appendix B.

Figure 3-18 Measuring the indentation produced in the puncture test of TU-2.

TU-3 had previously been dropped in a horizontal attitude on the seam (line 0°) from 9 m and then subjected to a crush test with a 500 kg steel plate being dropped onto the 180° line. This resulted in the two flattened surfaces produced in the sides of the drum that were not parallel, but slightly wedge shaped (see Figure 3-12). Thus when the flattened lower surface was placed on the horizontal floor, the top surface was sloped at a 7.1° angle. When this package was raised to 1 m above the punch, the top angle was adjusted and measured to be 7.1°, which meant that the bottom was horizontal. The package was then dropped onto the punch.

The resulting impact produced an indentation in the side of the steel drum, but did not puncture it (See Figure 3-19). The damage was observed to cover a circular-shaped area approximately 25 cm (10-inches) in diameter. A straightedge was laid across the indentation along the 0° line and the depth of the indentation was measured to be about 1.3 cm (1/2-inch). The diameter of the drum was measured from the center of the punch mark and the 0° line to the 180° line and found to be 19-1/4 inches. The original diameter of the drum was about 22-1/2 inches. Data for the punch test of TU-3 is given on Test Form 7 data sheet in Appendix C.

Figure 3-19 Damage produced from previous tests plus the punch test of TU-3.

TU-4 was subjected to the puncture test by orienting the package horizontally such that the impact would occur on the 0° line and in line with its center-of-gravity. In this case the package had been previously dropped on its top edge in a NCT test and subjected to the HAC dynamic crush test. These edge impacts left the middle of the package at the 0° line relatively undamaged. The package was raised 1 m above the punch and then dropped.

The resulting impact produced an indentation in the side of the steel drum, but did not puncture it (see Figure 3-20). The damage was observed to cover a slightly oval-shaped area with a major diameter of approximately 24 cm (9-1/2 inches) and a minor diameter of about 22 cm (8-5/8 inches). A straightedge was laid across the indentation along the 0° line and the depth of the indentation was measured to be about 1 cm (3/8-inch). The diameter of the drum was measured from the center of the punch mark and the 0° line to the 180° line and found to be 55.6 cm (21-7/8 inches). The original diameter of the drum was about 22-1/2 inches.

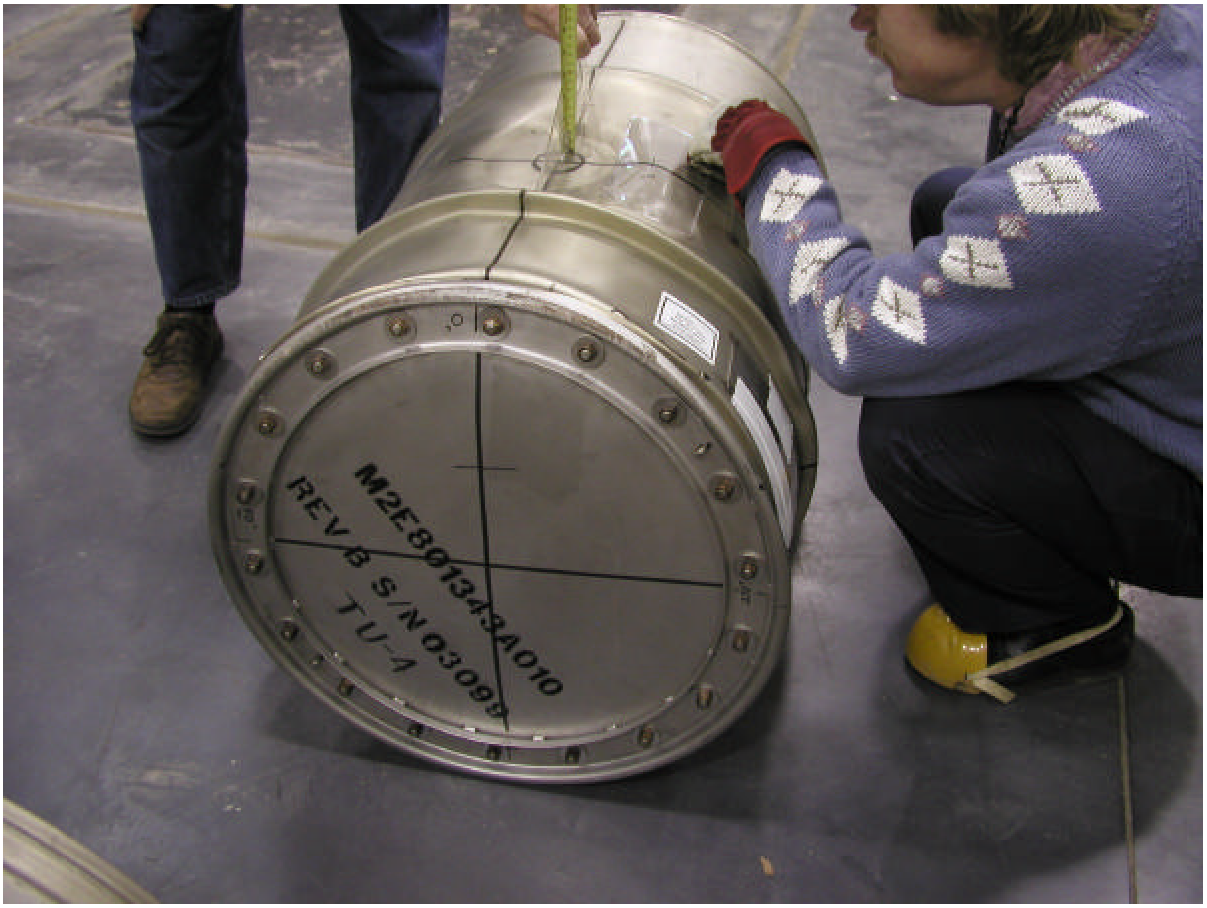


Figure 3-20 Damage produced from previous tests plus the punch test of TU-4.

Data for the punch test of TU-4 is given on Test Form 7 data sheet in Appendix D.

4 THERMAL TESTS

The thermal testing of the ES-2100 was performed in the gas fired Furnace, No. 3179, at the Alstom Power Facility in Chattanooga, Tennessee. The furnace has an approximate volume of 2640 ft^3 with six burners that have the capability of producing up to 2 million BTUs/hour each. The furnace has one thermocouple controller and an over-temperature thermocouple.

As discussed in Sections 4.1 and 4.2, prior to the beginning of the HAC thermal testing, the furnace was properly characterized and each test package was pre-heated. Thermocouples were attached to both the furnace and the test units in order to prepare for the thermal testing. Temperature indicators were also attached into and on each test unit, as previously identified in Section 2.3.1, and placed into each bag of blasting shot that served as a surrogate payload.

4.1 FURNACE SETUP

Prior to the beginning of the thermal testing, the furnace was characterized for temperature and heat recovery times. In order to monitor the temperature and heat recovery times, twelve thermocouples were installed on the furnace walls and door, three thermocouples were installed on the 11' x 7' steel plate that lay on the floor, and two thermocouples were attached to the test stand that was welded to the steel plate. The distribution of these thermocouples is indicated in Figure 4-1, Figure 4-2, and Figure 4-3 respectively. The furnace soaked at temperature of 1550 ^{o}F for 24 hours prior to begin the thermal testing. After the first test, the furnace allowed to soak for at least 60 minutes prior to the next test. The furnace controller temperature was continuously monitored on the furnace strip chart.

To minimize the cooling effect on the furnace, workers practiced loading and unloading test packages to and from the cold furnace to assure that the furnace door would not remain open more than 90 seconds. The longest time the door was open during the thermal testing was 73 seconds.

Figure 4-1 Installation of thermocouple under retainer clip.

Figure 4-2 Testing thermocouple after installation.

Figure 4-3 Thermocouples installed and ready to put into furnace.

4.2 PACKAGE SETUP

As identified in Section 2.3.1, Application of Temperature Labels, and as indicated in Figure 2-3, all test units were assembled with numerous temperature labels in preparation for thermal testing.

Additionally, all of the test units were preheated to over 38°C (100°F) by placing the four test units in a 6’x 6’ x 6’ environmental chamber. The environment chamber was heated by a torpedo-type kerosene space heater which is controlled by a mechanical bulb thermostat with a control range of 100°F to 200°F. The temperature in the environmental chamber was set at 66°C (150°F) for approximately 24 hours and then a minimum of 41°C (105°F) for at least the next 24 hours. The specific temperatures and durations have been documented as an appendix to this test report.

Six thermocouples were attached to the exterior surface of each package after preheating. Metal retainer clips were welded to the drums as shown in Figure 4-1 to hold the thermocouples in place. The thermocouple tips were inserted underneath the metal clips, and the wrapped around the metal clips. In order to eliminate any radiant viewing factor between the thermocouples and the furnace walls, the tips and metal clips were covered with a ceramic coating.

4.3 HAC THERMAL TESTING & RESULTS

4.3.1 HAC Thermal Testing

Thermal testing required that the package be exposed to an 800°C (1475°F) thermal source or greater for a minimum of 30 minutes. No test unit was loaded into the furnace until 13 of the 15 thermocouples on the furnace walls and the two attached to the support stand reached a reading of 800°C (1475°F). All packages were placed in the preheated furnace on the support stand positioned with the long axis horizontal, the package lids facing the right wall of the furnace (when facing the furnace door), and the drum side-seam (0^o on the package) facing down. The thermal test for each test unit did not begin until the furnace thermocouples recovered to a temperature above 800°C (1475°F) and five of the six thermocouples on the package had attained a temperature of at least 800°C (1475°F). The packages were exposed to the radiation environment for a minimum of 30 minutes and the temperature recording was set to record data every 30 seconds. Figure 4-4 shows TU-3 as it is about to be unloaded from the furnace.

Figure 4-4 Removing TU-3 from Furnace.

Each test package was removed from the furnace and placed on a stand where it was not exposed to artificial cooling. All packages were allowed to cool naturally to room temperature. All data concerning the thermal testing of each test unit was recorded on Test Form 8A.

The furnace was allowed to reheat for a minimum of one hour between each individual test. Between tests, the furnace controller temperature data recorded continuously on the strip chart.

4.3.2 Thermal Test Results

As previously stated, thermocouples were attached to both the furnace and test units for monitoring purposes. Figure 4-5 through Figure 4-12 indicate the temperatures the furnace and test units experienced as each test was performed.

A description of the results for each test unit is provided below. Table 4-1 provides the maximum temperature readings from specified areas within the ES-2100 package. The results from all temperature labels are recorded on Test Form 8D for each test unit.

Table 4-1. Maximum Temperature Label Readings per ES -2100 Components

Test Unit #	Max. Temp. Inside Surrogate Material	Max. Temp. on Outside of CV	Max. Temp Inside ES-2100 Drum	Location of Max Temp. in Drum
1	150^o F	175^o F	500^o F	Bottom of Plug@180^o & 270^o
2	150^o F	175^o F	500^o F	Bottom of Plug@180^o
3	175^o F	225^o F	500^o F	Bottom of Plug@90^o & 180^o
4	150^o F	175^o F	475^o F	Bottom of Plug@180^o

TU-1 - As a result of the thermal testing of Test Unit #4, the highest temperature inside the surrogate material was 150^o F. All temperature labels around the outside of the CV were exposed to 175^o F heat. With respect to the range of temperatures encountered inside the ES-2100 drum, the temperature range varied from 175^o F at the bottom of the drum to 500^o F on the bottom of the plug and at the 180^o to the 270^o locations. After Test Unit #1 was removed from the furnace, it was placed on a test stand to cool naturally. After a few minutes from being removed from the furnace, smoke was notice venting from the TID holes and a smell of burning foam was noticed. Subsequently, a brownish orange liquid seeped from the bottom TID attachment hole.

TU-2 - As a result of the thermal testing of Test Unit #4, the highest temperature inside the surrogate material was 150^o F. All temperature labels around the outside of the CV were exposed to 175^o F heat. With respect to the range of temperatures encountered inside the ES-2100 drum, the range varied from 175^o F at the bottom of the drum to 500^o F on the bottom of the plug at the 180^o location. The results from all temperature labels are recorded on Test Form 8D. After Test Unit #1 was removed from the furnace, it was placed on a test stand to cool naturally. After twenty minutes from being removed from the furnace, smoke was noticed venting from the TID holes and stopped after approximately 40 minutes. A smell of burned foam was also noticed. Approximately one hour after the package was removed from the furnace, a brownish orange liquid began seeping from the bottom TID attachment hole and stopped approximately 40 minutes later.

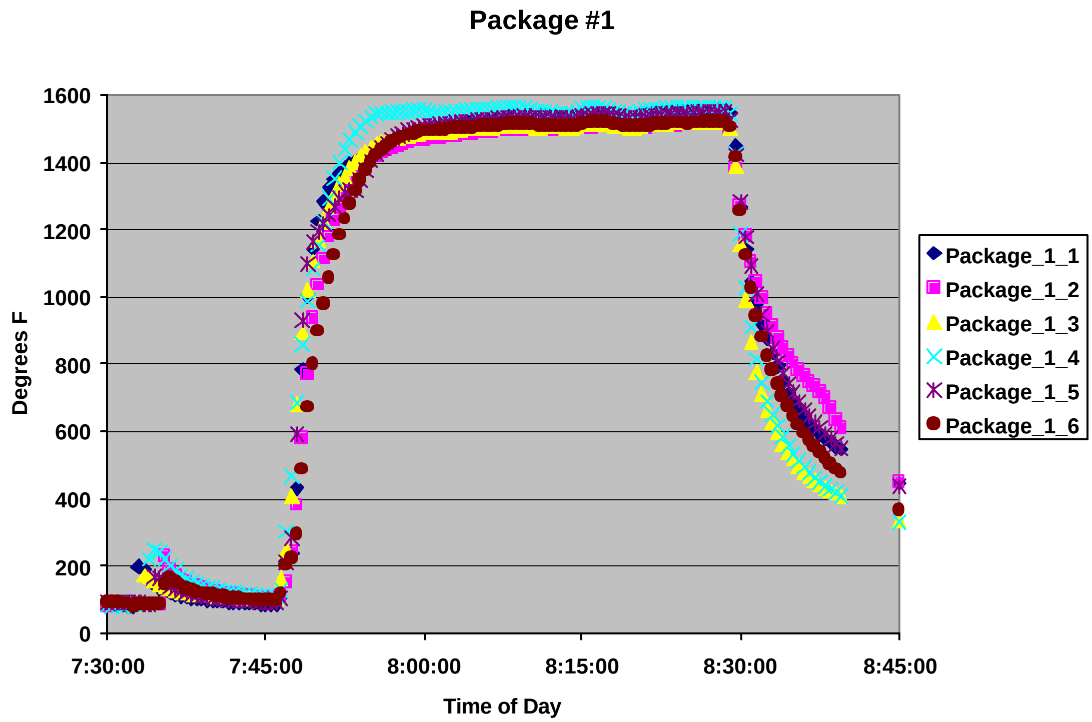


Figure 4-5 Package TU-1 Thermocouple Temperature Curves.

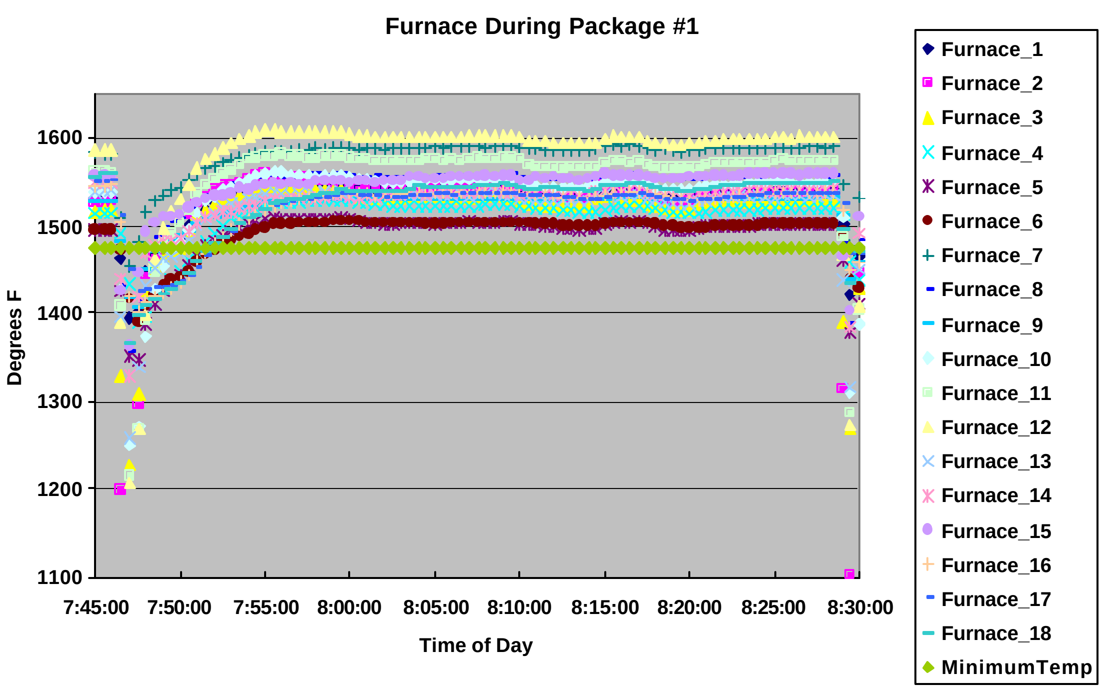


Figure 4-6 Furnace Thermocouple Temperature Curves During Burning of TU-1.

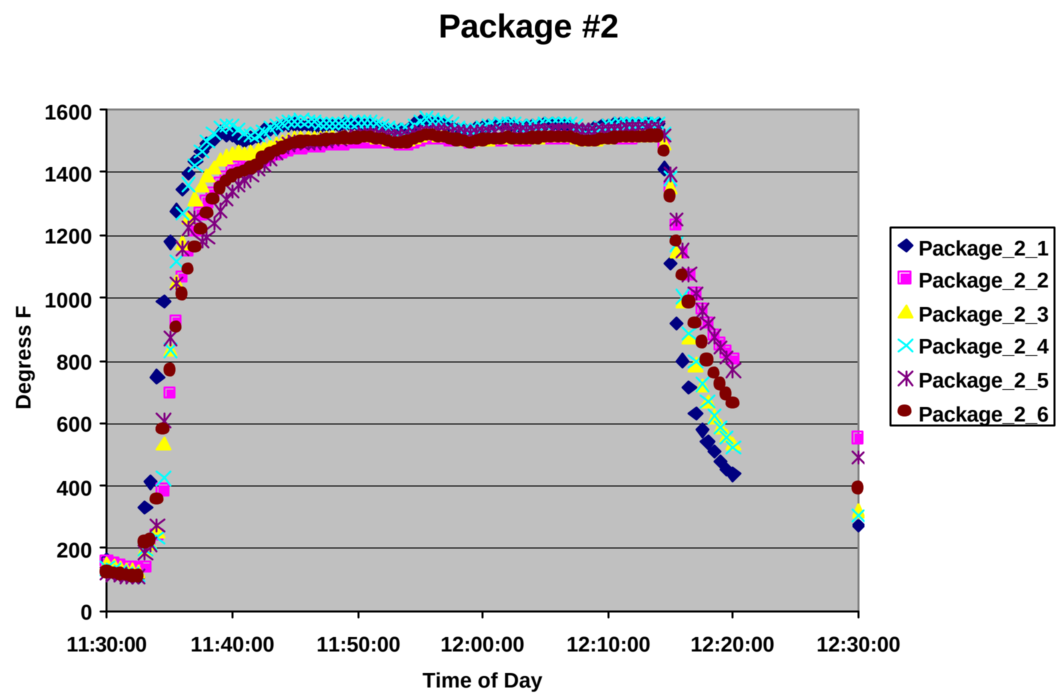


Figure 4-7 Package TU-2 Thermocouple Temperature Curves.

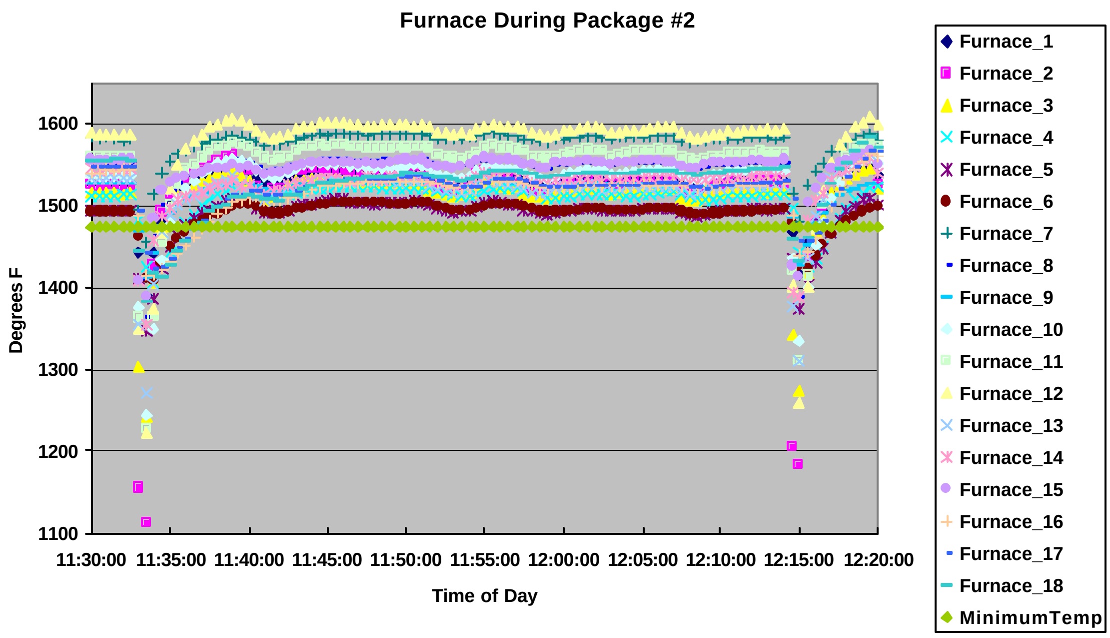


Figure 4-8 Furnace Thermocouple Temperature Curves During Burning of TU-2.

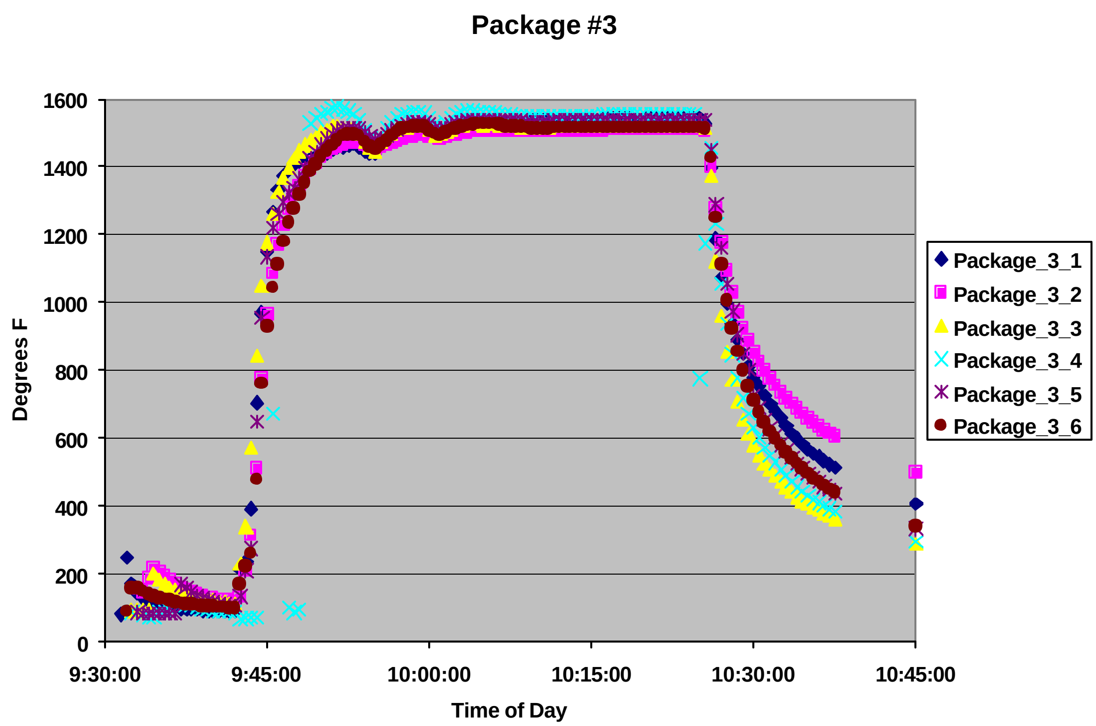


Figure 4-9 Package TU-3 Thermocouple Temperature Curves.

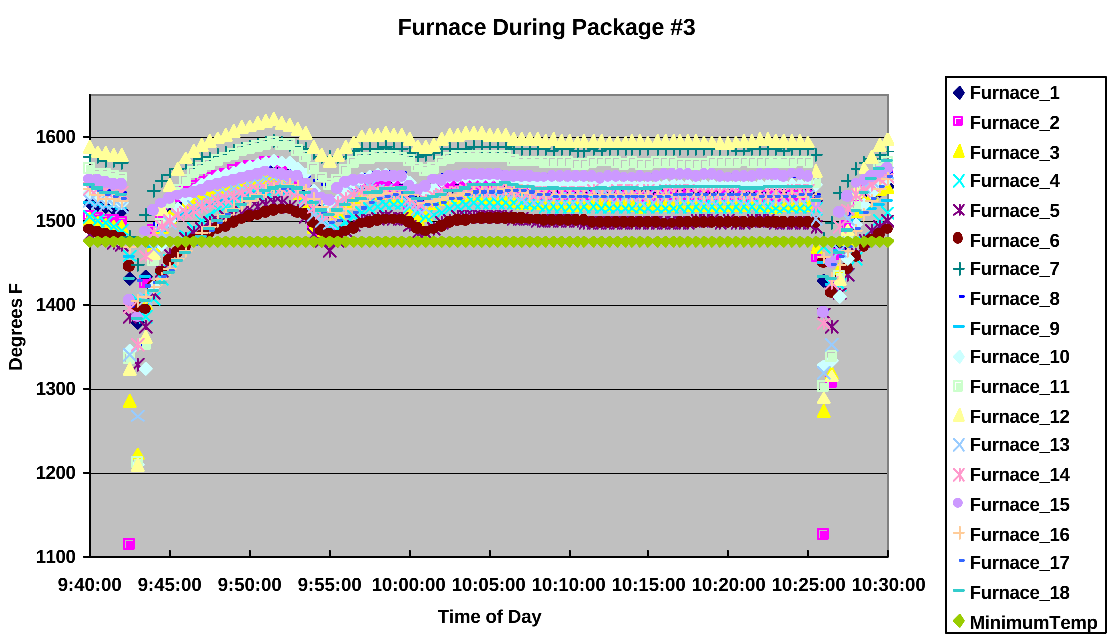


Figure 4-10 Furnace Thermocouple Temperature Curves During Burning of TU-3.

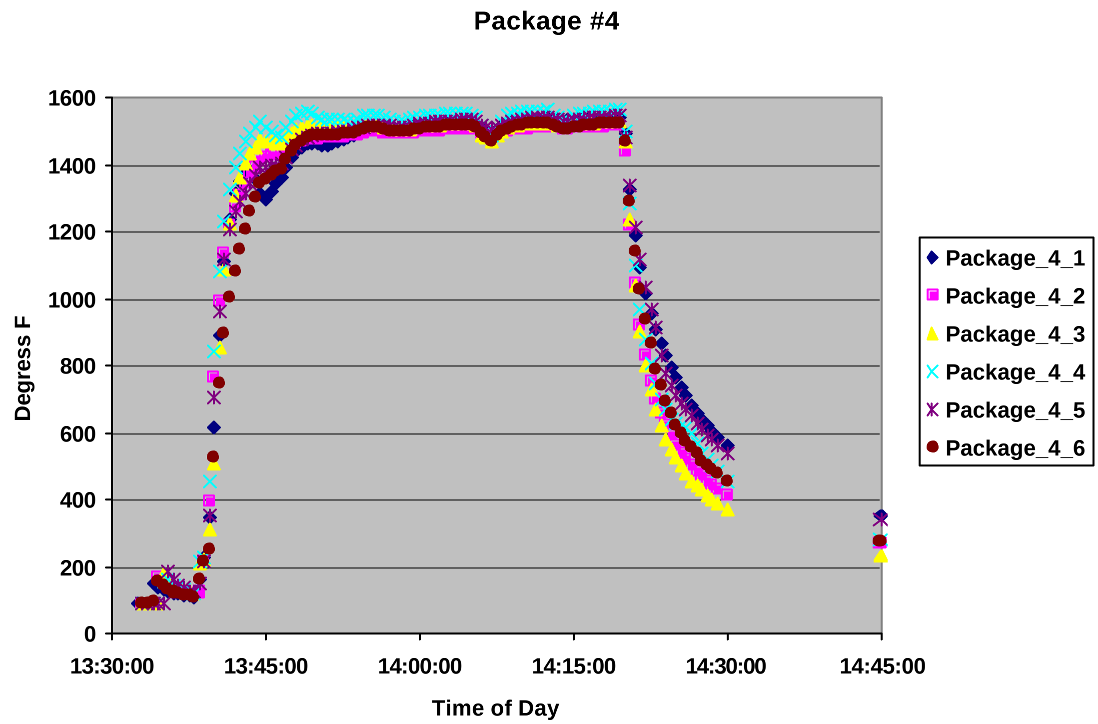


Figure 4-11 Package TU-4 Thermocouple Temperature Curves.

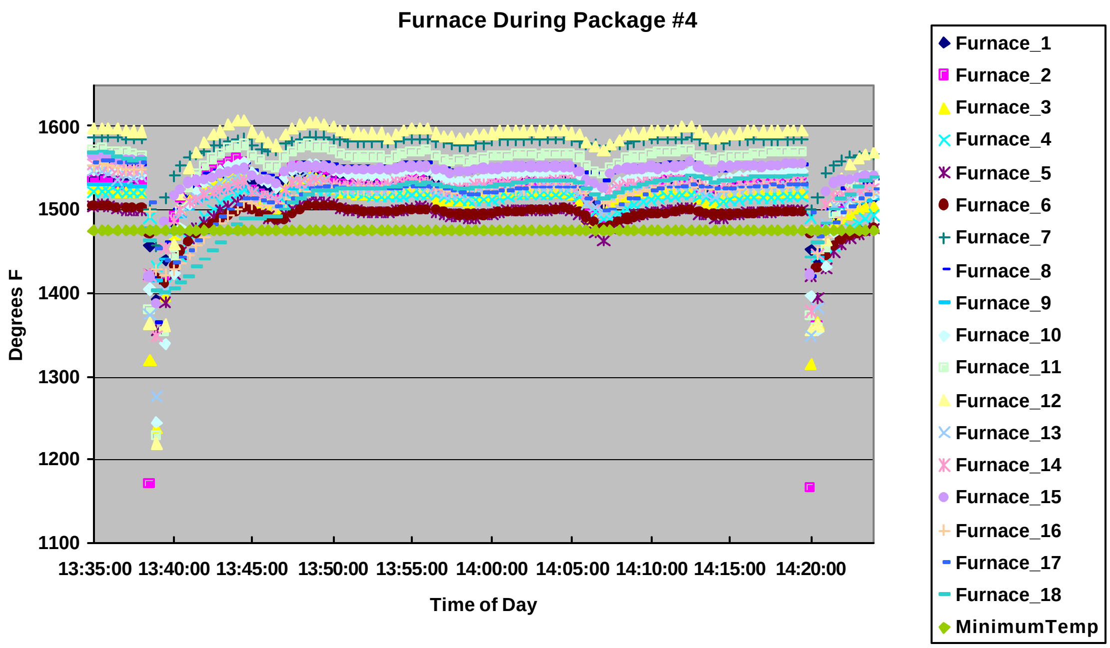


Figure 4-12 Furnace Thermocouple Temperature Curves During Burning of TU-4.

TU-3 - As a result of the thermal testing of Test Unit #3, the highest temperature inside the surrogate material was 175^o F. The highest temperature recorded on the outside of the CV was 225^o F. The temperature was recorded at the top of the CV and locates 90^o, 180^o, and 270^o. With respect to the range of temperatures encountered inside the ES-2100 drum, the range varied from 200^o F at the bottom of the drum to 500^o F on the bottom of the plug and at the 90^o and 180^o locations. The results from all temperature labels are recorded on Test Form 8D. After Test Unit #3 was removed from the furnace, it was placed on a test stand to cool naturally. Immediately after being removed from the furnace, smoke was noticed venting from the TID holes and stopped after approximately 39 minutes. A smell of burned foam was also noticed and a brownish orange liquid began seeping from the bottom TID attachment hole.

TU-4 - As a result of the thermal testing of Test Unit #4, the highest temperature inside the surrogate material was 150^o F. All temperature labels around the outside of the CV were exposed to 175^o F heat. With respect to the range of temperatures encountered inside the ES-2100 drum, the range varied from 225^o F at the bottom of the drum to 475^o F on the bottom of the plug and at the 180^o location. The results from all temperature labels are recorded on Test Form 8D. After Test Unit #3 was removed from the furnace, it was placed on a test stand to cool naturally. Approximately twenty minutes from being removed from the furnace, smoke was noticed venting from the TID holes and stopped after approximately 35 minutes. A smell of burned foam was also noticed.

4.4 POST-HAC CONDITIONS TESTING

After cooling for several days, the test packages were disassembled and inspected. The post-thermal weights of each test unit, top plug, and containment vessel were recorded on Test Form 3. The drums were disassembled and photographed for record. Each test unit was visually inspected, and the condition of the package and any observations were recorded on the test forms and photographs.

All four CV units underwent leak and immersion testing that were recorded on Test Form XX. The CV O-rings were successfully leak tested to an operational leak check ($<1\times10^{-3}$ ref-cc/sec). As shown in Table 4-2 no leaks were indicated.

Table 4-2. Post Test Measured leak rate for the CV of each test unit.

Drum ID	TU-1	TU-2	TU-3	TU-4
Leak Rate, std-cc/sec air	9.33E-05	7.22E-05	1.03E-04	1.68E-04

All CVs were immersed under a head of water of at least 0.9 m (3 ft.). The exterior of each CV was dried. After the immersion test, a fitting was installed in the lid of each CV and a leak checked to $< 1X10^{-7}$ ref-cc/sec using a helium leak test apparatus was successfully performed on the entire containment boundary of each CV. Figure 4-13 through Figure 4-16 show the He leak rate curve for each test unit. No leaks were indicated.

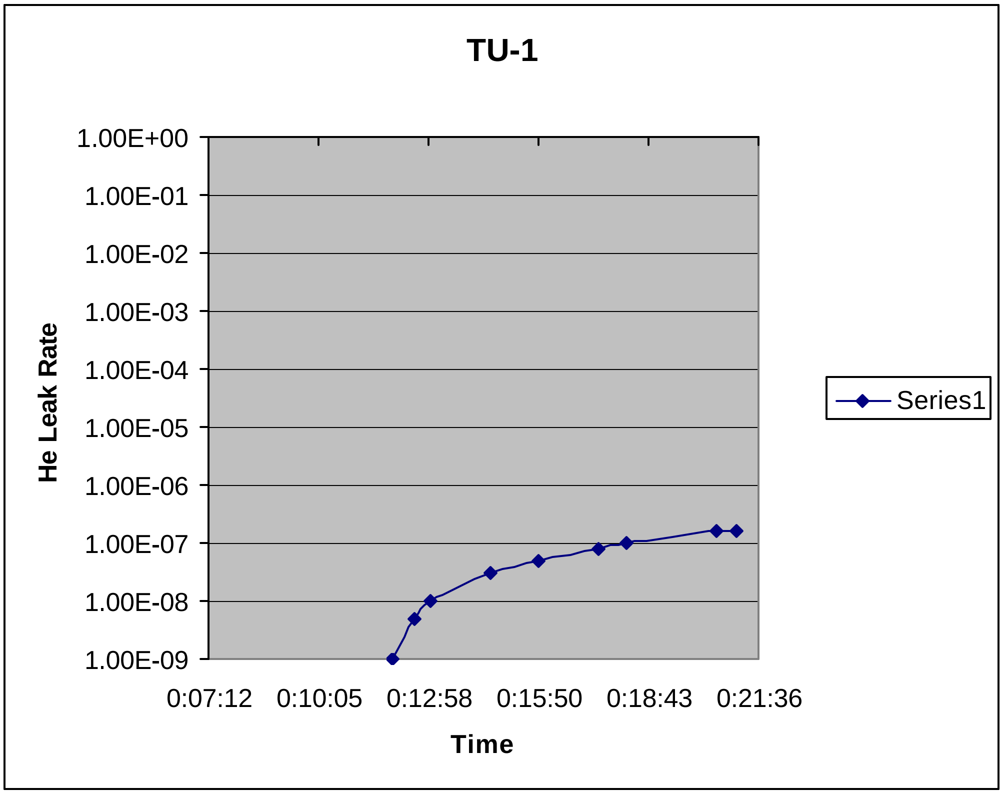


Figure 4-13 He Leak Rate Detected vs Time for TU-1.

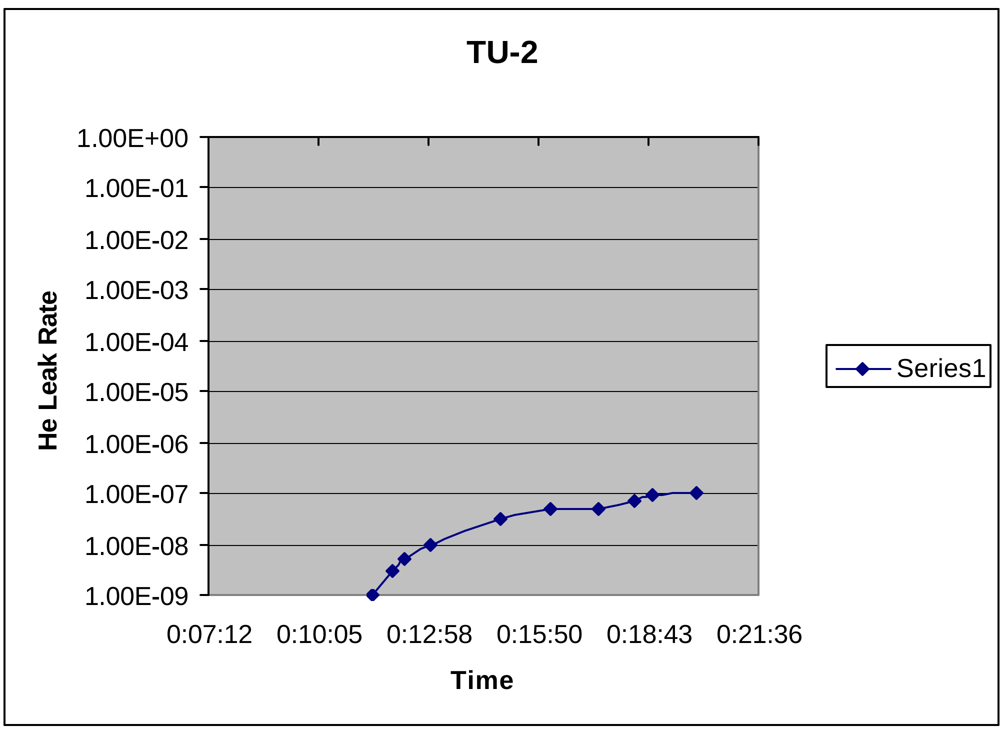


Figure 4-14 He Leak Rate Detected vs Time for TU-2.

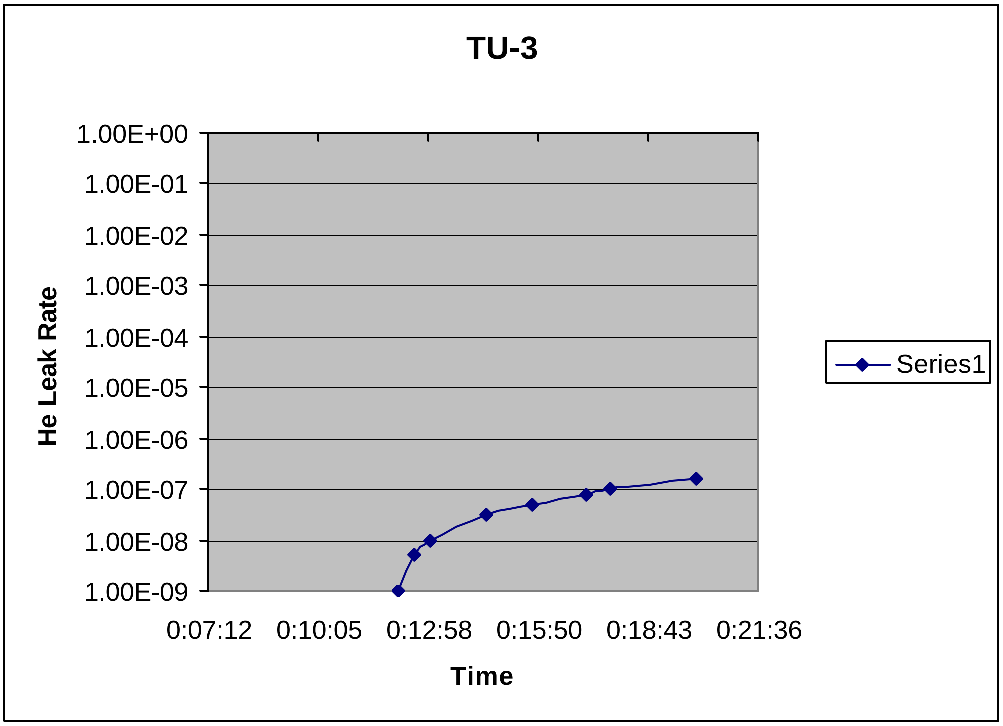


Figure 4-15 He Leak Rate Detected vs Time for TU-3.

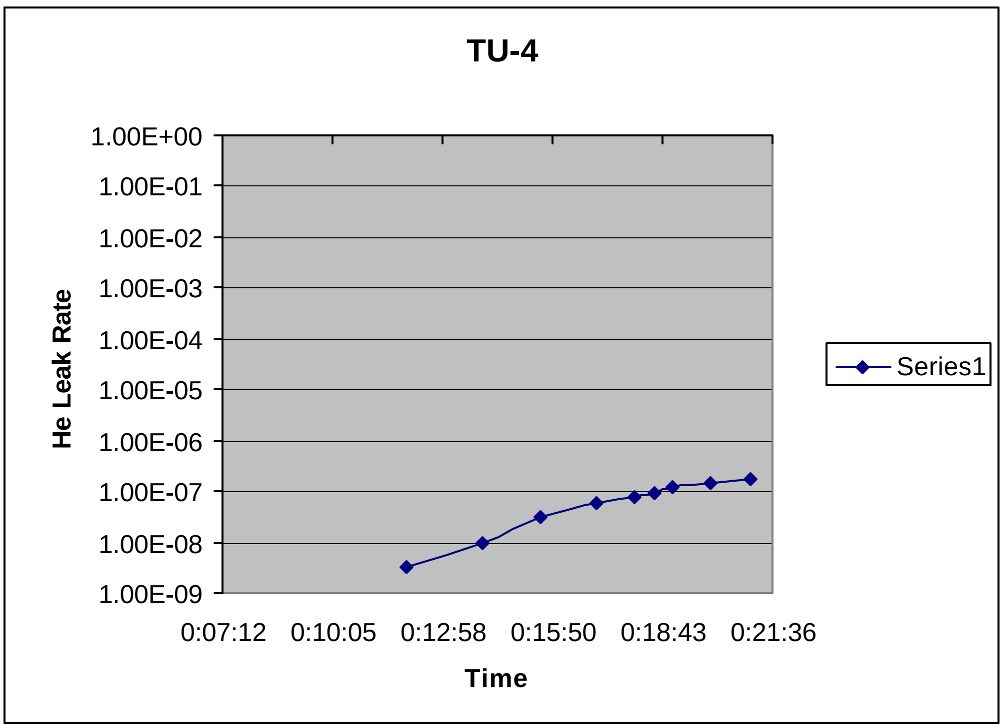


Figure 4-16 He Leak Rate Detected vs Time for TU-4.

The CVs were then opened. The CV contents were examined and found to have no evidence of water leaking past the seal.

Appendix A

Data Sheets for TU-1

TEST FORM 1A
ASSEMBLY OF THE CV

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-1-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
MBH	CV test unit serial number: 03009
MBH	All containment vessel (CV) components have been visually inspected to ensure they are present and in good condition.
MBH	Temperature indicators have been affixed to the surface of the CV as indicated Figure 3.2 and on Test Form 6D.
MBH	None of the temperature indicators indicate exposure to a temperature in the measured range.
MBH	The container and lid have been clearly marked as " TU- 1".
MBH	A vertical line has been marked on the side of the container and lid with a permanent marker to indicate alignment the two components.
MBH	The CV O-rings and sealing surfaces have been inspected for defects and found acceptable.
MBH	Refrasil insulation cloth was applied to the inside of the CV. — applied to lid & bottom only MBH
MBH	The stainless steel sleeve was inserted after the Refrasil cloth was installed. Sleeve is wrap w/ Refrasil and inserted MBH
MBH	Two (2) temperature labels are in the center of the shot.
MBH	The aluminum sleeve, weighing 23 pounds with the Refrasil, was installed in the CV. Steel shot weighing 103 pounds was installed inside the aluminum sleeve. The shot plus the weight of the sleeve weighs 125 ± 1 pounds. The plastic bag containing the shot has been closed with stranded tape and the bag has been trimmed leaving 1 inch of excess bag.
MBH	The lid has been installed on the container and the previously applied vertical markings align. The washers and bolts have been installed. The initial torque of the bolts was 9 ± 1 ft.-lbs. and applied in the sequence etched on the CV lid. A second torque of the bolts was applied at 18 ± 1 ft.-lbs. A re-torque of 18 ± 1 ft.-lbs. was again applied. All torque as applied was in the sequence etched on the CV lid. Ambient temperature at closure is 19 °C (67 °F). Torque wrench # 4010082626 Calibration Expiration Date 12/4/03
MBH 12/7/02	The CV assembly has been leak tested with the Calt#5 per the Manufacturer's Instructions Manual. Leak Tester Cert. # M201288 Expiration Date: 8/18/03 Leakage Value: 8.08×10^{-5} std-cc/sec air
MBH	Mark the top of the CV lid with 0, 90, 180 and 270-degree locations with a permanent marker.
MBH	The CV assembly has been weighed and the weight has been recorded on Form 3.
MBH	Photographs of the assembly have been taken*.

Comments: Picture of all marked components; Picture w/ Refrasil in CV lid; Picture w/ shot loaded in CV; Picture of finished CV

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/6/02 — Testing Technician / Date
L. B. Gaffert 12/6/02 — Witness / Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-1-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
MBH	The exterior of the drum has been clearly marked "TU-1".
	Record the drum serial number: B088
MBH	Each urethane foam insert has been clearly marked "TU-1"
	The center-of-gravity markings have been applied to the drum as shown.
* MBH	Mark the 0, 90, 180, 270 degree locations on the Drum Lid, Top Plug, and the inner and outside walls of the drum with a permanent marker. The "0" location is the vertical, outside-wall seam of the drum. 12/4/02
MBH	The plastic Leak Check port plug has been removed
MBH	The CV assembly has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
MBH	The Drum Top Plug was weighed and the weight has been recorded on Form 3.
MBH	The Drum Top Plug has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
MBH	The Drum Lid with no gasket has been installed with the 0 degree mark rotated and aligned with the 0° degree mark on the drum.
N/A	A security seal has been attached to the drum.
MBH	The drum lid washers are placed over the lugs and the drum lid nuts were initially installed and torque to 10 ± 1 ft.-lbs. The nuts were then tightened a second time to a torque of 10 ± 1 ft-lbs. No torque sequence is required to be followed.
	Torque wrench # 4010282626 Calibration Expiration Date 12-4-03
MBH	The test package assembly has been weighed and the weight recorded on Form 3.
MBH	Photographs of the assembly have been taken*.

Comments: __________

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/10/02 — Testing Technician, Date

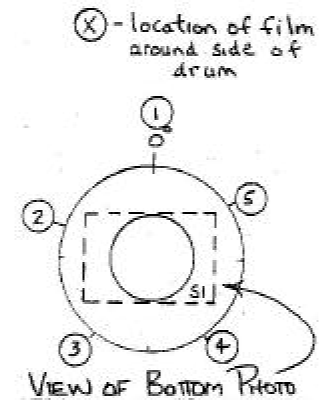
L. B. Shappert 12/10/02 — Witness, Date

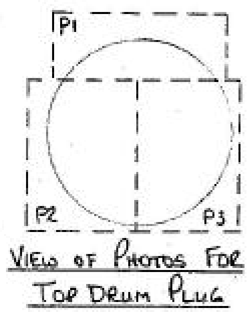
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

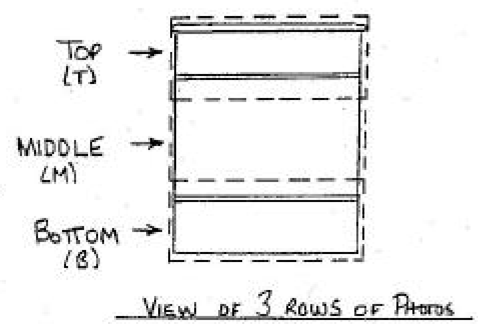
TEST FORM 2A
RADIOGRAPH DRUM LINER

Test Plan TTG/TP/ES-2100, Rev.2
Test Unit TU-1-12/02
Test Location 3017 @ ORNL

VERIFIED	TASK
mBH	The test unit has been clearly marked "TU-___"
mBH	Record the test unit serial number: 03088
mBH	Record the history of the drum, i.e. as built dropped, etc.
	History: new drum – to be used for testing
mBH	Date test unit is radiographed: 12/5/02
mBH	* Still photographs are to be taken as indicated below: Three rows [top (T), middle (M) and bottom(B)] of five pictures per row were taken and numbered T1-T5, M1-M5, and B1 - B5. Three pictures of the Drum Top Plug (P) were taken and numbered P1-P3. One picture of the bottom was taken and numbered S1.







Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk — Testing Technician — Date 12/10/02

[signature] — Witness — Date 12/10/02

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 3
COMPONENT WEIGHTS

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-1-12/02
Test Location NTRC Rm. L-110

PRE-DROP TEST WEIGHTS				POST THERMAL TEST WEIGHTS			
PART NAME	WEIGHT	BY	DATE	PART NAME	WEIGHT	BY	DATE
CV (lid & body) w/ bolts	66 lbs.	MBH	12/6/02				
CV mass (shot)	103 lbs.	MBH	12/6/02				
CV sleeve	23 lbs.	MBH	12/6/02				
CV assembly	192 lbs.	MBH	12/6/02	CV assembly	192 lbs.	YBS	5/5/03
* Drum isolation Foam	13 lbs.	MBH	12/6/02	Drum isolation Foam	13 lbs.	YBS	5/7/03
Drum Top Plug	32 lbs.	MBH	12/10/02	Drum Top Plug	31 lbs.	YBS	5/7/03
Test package Ass'y	453 lbs.	MBH	12/10/02	Test package Ass'y	452 lbs.	RG	4-29-03

EQUIPMENT

PRE-DROP TEST:		POST THERMAL TEST:	
Scale: X502322	Expiration Date: 10/14/03	Scale: X502323	Expiration Date: 10-14-03
Accuracy: ± 1 lb.		Accuracy: ± 1 lb	
Scale: X502322	Expiration Date: 10/14/03	Scale: X502322	Expiration Date: 10-14-03
Accuracy: ± 1 lb		Accuracy: ± 1 lb.	

Comments: * NOTE: TEST PLAN REV. 2 & TEST FORM 3, REV 2 REQUIRE THE DRUM FOAM LID & DRUM FOAM CYLINDER TO BE WEIGHED SEPARATELY. BOTH WERE WEIGHED TOGETHER AND THE CV WAS ASSEMBLED PRIOR TO THE REV 2a. THE Y-12 PACKAGING ENGINEER HAS WAIVED THE SEPARATE WEIGHING REQUIREMENT AS LONG AS EACH COMPONENT IS WEIGHED SEPARATELY AFTER THERMAL TESTING. ABD 12/11/02

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk — Testing Technician — 12/10/02 (Date)
A. B. [signature] — Witness — 12/10/02 (Date)

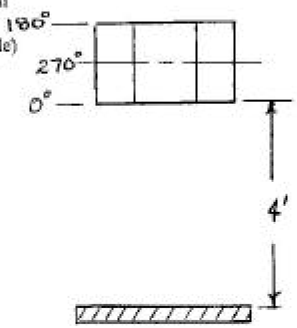
TEST FORM 4 Test Plan TTG/TP/ES-2100-02 Rev. 1

1.2m (4 ft) FREE FALL DROP Test Unit TU-1-12/02

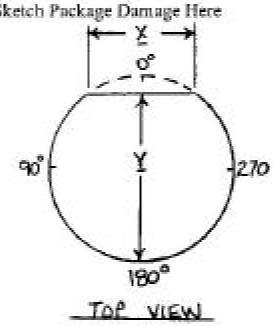
Test Location NTRC Indoor drop pad Rm L-110

VERIFIED	TASK
mBH	Still and video cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken
mBH	Attitude of the Test Unit shall be 0.0° (computed angle) Tolerance ± 2°
mBH	Measured attitude of the Test Unit 0.6°
mBH	Level number 311-006-04 Exp. Date 6-03
mBH	The Test Unit has been raised so that the lowest point is 1.2m (4 ft) above an essentially unyielding, horizontal impact surface.
mBH	Measuring device 4' METAL RULE
mBH	Ambient temperature at the time of the test: °C (69.4F)
mBH	The Test Unit was dropped from a minimum of 1.2m (4 ft) onto the drop pad
mBH	Videos* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Drop Setup Here FLAT DROP



Sketch Package Damage Here



Testing Damage Observations: SEE PHOTOGRAPHS

POSITION	"X"	"Y"
TOP RING	4 1/4"	23 1/4 (23 9/16 NORMAL DIA.)
TOP HOOP	5 1/8"	? NOT MEASURED
BOTTOM HOOP	6 5/16	? " "
BOTTOM - DRUM (NOT CHIME)	5 1/4	? " "

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/11/02 L.B. Shappert 12/11/02

Testing Technician Date Witness Date

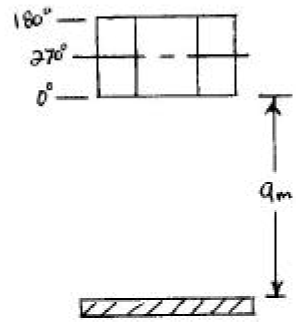
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM #5
9m (30 ft) FREE FALL DROP

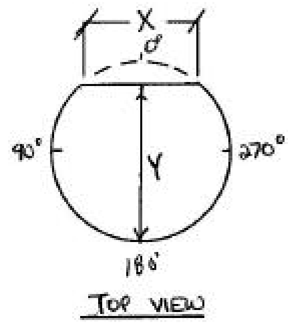
Test Plan TTG/TP/ES-2100-02, Rev.2
Test Unit TU-1 - 12/02
Test Location: NTRC Outside Drop Pad
12/12/02

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photos and video of the drop
MBH	Photographs of the arrangements for the drop have been taken.
MBH	Ambient temperature of the test: ____°C, (40 °F) at the time of 9:25 am
MBH	The angle of the Test Unit is 0.0° as specified in Figure 4.3. The measured drop angle is 0.8°. Measuring device: 311-034-501 Calibration expiration date: 6-03
MBH	The Test Unit has been raised so that the lowest point is 30 1/2" above an essentially unyielding, horizontal impact surface. Measuring device: TTG 9m measurement wire Calibration expiration date: ________
MBH	The Test Unit was dropped in free fall from a minimum of 9m (30 ft) onto the drop pad.
MBH	Videos and high speed films* of the drop were made
MBH	Photographs* of the resulting damage were taken

Sketch Test Setup Here FLAT



Sketch Package Damage Here



Testing Damage Observations:

POSITION	"X"	"Y"	ORIGINAL
TOP RING	8 7/16	22 3/4"	23 9/16"
TOP HOOP	9 7/8"	NOT MEASURED	23 3/8"
BOTTOM HOOP	11 7/8"	NOT MEASURED	23 3/8
BOTTOM DRUM (CHIME)	11	NOT MEASURED	22 1/4

Comments: ____________

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk — Testing Technician — 12/12/02 (Date)
L. B. Shappert — Witness — 12/12/02 (Date)

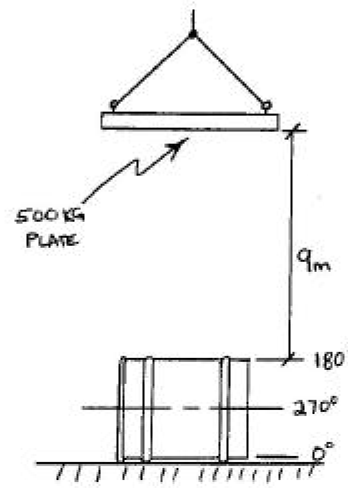
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

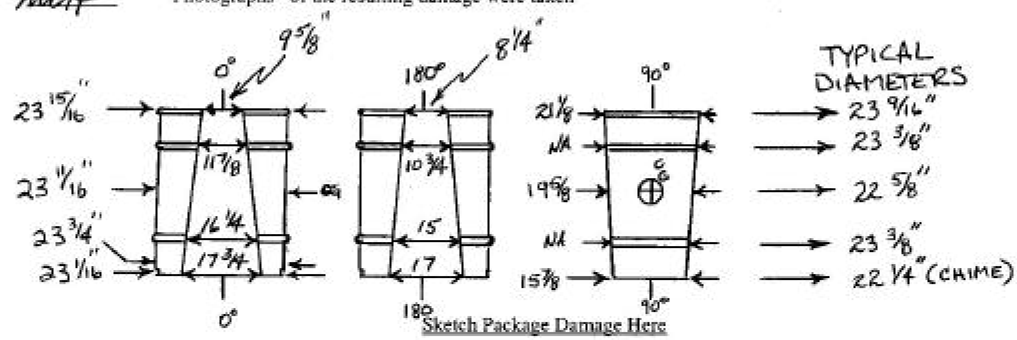
TEST FORM 6
9m (30 ft) DYNAMIC CRUSH TEST

Test Plan TTG/TP/ES-2100-02, Rev.2
Test Unit TU-1-12/02
Test Location: NTRC Outside Drop Pad

VERIFIED	TASK
mBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
mBH	Still , video and high speed cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken.
mBH	Ambient temperature of the test: ____°C, (42°F) at the time of 11:25am
mBH	The test unit has been placed on an essentially unyielding surface in the orientation shown in Figure 4.5. The measured drop angle is 0.0. Measuring device: 311-006-501 Calibration expiration date: 6-03
mBH	The 500kg (1100 lb) steel plate has been raised so that the lowest point is 30 1/2" above the highest point on the test unit and the CG of the Crush Plate is centered over the CG of test unit ± 4 in. Measuring device: TTG 9 m measurement wire
mBH	The steel plate was released to fall onto the test unit from a height of at least 9m (30 ft).
mBH	Videos and high speed films* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Test Setup Below





Sketch Package Damage Here

Testing Damage Observations & Comments:
DIMENSIONS INDICATED ON 0° & 180° PROFILE VIEWS WERE TAKEN ACROSS THE DAMAGED FLAT SURFACES.

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	12/16/02	L. B. Sheppard	12/16/02
Testing Technician	Date	Witness	Date

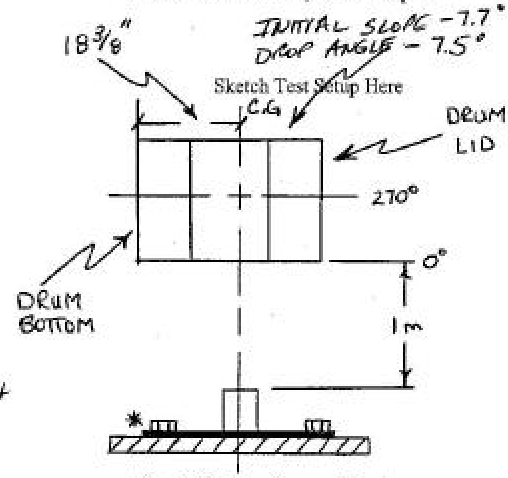
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 7
1 m (40 in) PUNCTURE DROP

12/17/02
Test Plan:TTG/TP/ES-2100-02, Rev.2
Test Unit TU-1-12/02
Test Location: NTRC, Inside Drop Pad

VERIFIED	TASK
mBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
mBH	Still, video and high speed cameras are setup to take photo and video of the drop.
mBH	Ambient temperature of the test: ____°C, (72°F) at the time of 1:10 PM
mBH	The test drop angle of this unit is 0° on bottom; 7.7 on top as specified by Figure 4.8. The measured drop angle is 0° @ bottom; 7.5 on top mBH. Measuring device: 311-006-301. Calibration expiration date: 6-03
⁴⁄	
mBH	The Test Unit has been raised so that the lowest point is 1 m above the steel bar. Measuring device: TTG 1m STICK. Calibration expiration date: ________

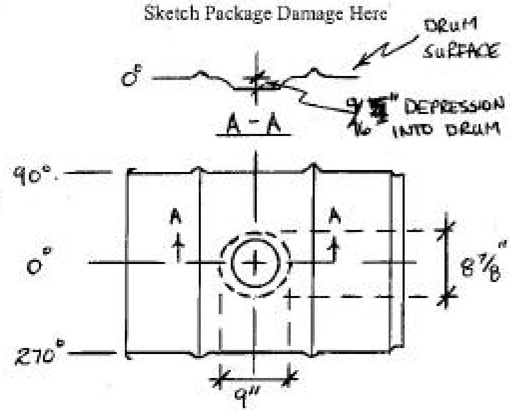
Sketch Test Setup Here



Testing Damage Observations: DRUM DIM.

LOCATION	ORIG DIA	AFTER DROP	DAMAGED AREA
POINT OF IMPACT	22.5"	18 7/8"	~~9" x 8 7/8"~~ mBH ≈ 9" Ø

Sketch Package Damage Here



Comments: * PUNCH BAR PLATE IS BOLTED DOWN W/ 4 - 1 INCH BOLTS. BOLTS ARE TORQUE TO 200 FT-LB. TORQUE WRENCH K-4804 — CAL. EXP. DATE: 11/26/03 PUNCH HIT BOTTOM (0°) OF DRUM WHICH IS PERPENDICULAR TO PUNCH.

I certify that the above tasks have been performed and that the observations and comments are correct.

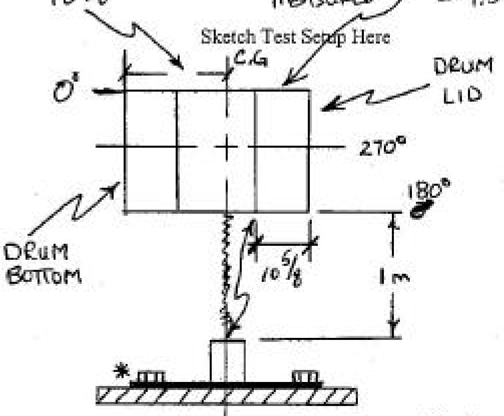
Mark B. Hawk	1/24/03	L.B. Sheppard	1/24/03
Testing Technician	Date	Witness	Date

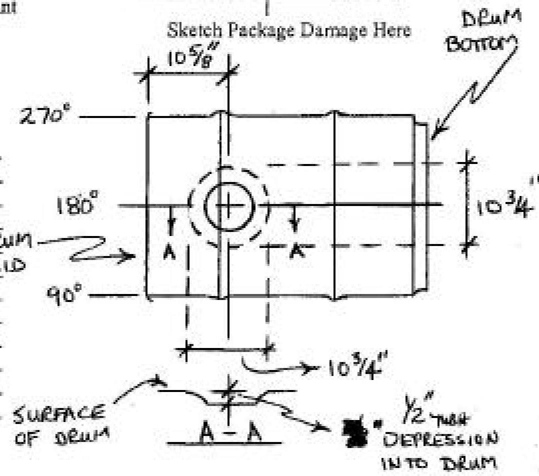
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 7A
1 m (40 in) PUNCTURE DROP

12/17/02
Test Plan: TTG/TP/ES-2100-02, Rev.2
Test Unit TU-1-12/02
Test Location: NTRC, Inside Drop Pad
ORIGINAL ANGLE -7.7°
MEASURED -7.3°

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photo and video of the drop.
MBH	Ambient temperature of the test: ____°C, (72°F) at the time of 1:25PM
MBH	The test drop angle of this unit is 00° BOTTOM -7.7 as specified by Figure 4.8. The measured drop angle is 00/7.3 Measuring device: ____ Calibration expiration date: ____
MBH	The Test Unit has been raised so that the lowest point is 1 m above the steel bar. Measuring device: 311-024-501 Calibration expiration date: 6-03





Testing Damage Observations:

LOCATION	DRUM ORG DIA	DRUM DIM AFTER DROP	DAMAGED AREA
FLANGE OF C.V.	22.5"	18-7/8"	10 3/4" Ø

Comments: * PUNCH BAR PLATE IS BOLTED DOWN W/ 4 - 1 INCH BOLTS. BOLTS ARE TORQUE TO 200 FT-LB. TORQUE WRENCH K-4804 — CAL. EXP. DATE: 11/26/03 DROP WAS ON TOP ROLLING HOOP ON THE 180° AXIS - APPROXIMATELY WHERE CV LID WOULD BE.

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date
Mark B. Hawk	1/24/03	L. B. Shappert	1/24/03

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8A
THERMAL TESTING

Test Plan ______
Test Unit TU-1
Test Location 415 Om

VERIFIED	TASK
PTS	The Test Unit has been prepared in accordance with the Test Plan. Forms 1A and 2 are complete and the pre-test weights are recorded on Form 3.
PTS	All thermocouples have been installed on the exterior of drum, furnace and test stand in accordance with the Test Plan, Figures ___, ___, ___, ___ and ___.
PTS	All thermocouples have been surveyed to ensure they are working. (Any malfunctions or erratic performance will be addressed in the comments section below.)
PTS	The thermocouple recorder(s) is set to read every 30 seconds.
PTS	*Photographs of the arrangements for the test have been taken.
PTS	The test package has been preheated to over 38 °C (100 °F). Measuring device: Thermal monitoring system Calibration expiration date: ______
PTS	Furnace has reached the minimum soak point temperature of 800 °C (1475 °F), and has soaked at this temperature for a minimum of 8 hours. The furnace set point temperature has been adjusted to [illegible] °C (1530 °F) at least one hour prior to each test. Time: 742 am/pm Date: 4-25-03
PTS	The unit has been placed in the furnace, on the support stand, with the damaged area up at: 0° down. Time: 747 am/pm Date: 4-25-03 Open furnace door time: 73 seconds
PTS	The 31 minute timed test began when 5 out of 6 test unit thermocouples reached the test temperature of 800 °C (1475 °F), as specified in the test plan. Time: 758 am/pm Date: 4-25-03 End @ 8:28 30:05 on timer
PTS	Immediately following the timed test (minimum of 30 minutes at 800 °C) the test unit is taken out of the furnace and allowed to cool naturally. Time: 829 Out of furn am/pm Date: 4-25-03 Ambient Temperature ______ °C (63.4 °F)
PTS	The unit stopped outgassing (flames) at No outgassing observed outgassing/burnout lapsed time was ______ minutes.
PTS	The thermocouple recorder shall be set to record the internal thermocouples at 15 minute intervals for at least 12 hours.

Comments: Original strip chart paper record from furnace controller is included in test records

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature] ______ [signature] 4/25/03
Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TTG/TP/ES-2100-02 Rev. 2 12/10/2002 10

TEST FORM 8D
TEMPERATURE INDICATOR READINGS

Test Plan ________
Test Unit TU-1-12/02
Test Location ________

A visual inspection of each temperature indicator on the ES-2100 package consisting of those indicators inside the CV stainless steel shot, outside the CV, and on the ES-2100 drum liner shall be made. The values of the blackouts which occurred shall be recorded below. Dimensions identified under the "Height" column are the dimensions from the bottom of the CV or drum liner to the bottom of the temperature indicators.

RECORD BLACKOUT TEMPERATURES AT THESE LOCATIONS:

ES-2100 TEMPERATURE INDICATOR NUMBER LOCATION CHART

Figure 3.2 – INSIDE OF CV, STEEL SHOT TEMPERATURE @ 12"

12	1 150°F	2 150°F

Figure 3.2 – ON THE OUTSIDE OF THE ES-2100 CV

Row/ Height, inches	0°	90°	180°	270°
Bottom	3 175 °F	4 175 °F	5 175 °F	6 175 °F
4.2	7 175 °F	8 175 °F	9 175 °F	10 175 °F
16.8	11 175 °F	12 175 °F	13 175 °F	14 175 °F
Top	15 175 °F	16 175 °F	17 175 °F	18 175 °F

Figure 3.3 – ON THE INSIDE OF THE ES-2100 DRUM INNER LINER

Row/ Height, inches	0°	90°	180°	270°
Bottom	19 175 °F	20 200 °F	21 225 °F	22 225 °F
5	23 225 °F	24 250 °F	25 225 °F	26 250* °F
12.7	27 225 °F	28 225 °F	29 ** °F	30 250* °F
1ST Ledge	31 <125 °F	32 300 °F	33 450 °F	34 375 °F
Plug Bottom	35 375 °F	36 375 °F	37 500 °F	38 500 °F

Comments: * Damaged near dots of interest
** Torn off during removal

I certify that the above tasks have been performed and that the observations and comments are correct.

L.B. Shappert 4/30/03 — Testing Technician, Date
R.D. [illegible] 4/30/03 — Witness, Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 13 - **OPERATIONAL LEAK TEST**

Test Plan ES-2100

Test Unit TU-1-12/02

VERIFIED	TASK
______	Post Assembly Leak Test ______ Post Test Leak Test X
______	A leak test in accordance with the CALT5 Manufacturer's Instructions Manual was performed on the CV assembly.
	Leak Tester Cert. #________ Expiration Date: ________ Leakage Value: _____ ref-cc/sec air

Attach CALT5 Printout Here

See Printout

$$Lr = \frac{V * Ts}{3600 * H * Ps}\left(\frac{P1}{T1} - \frac{P1}{T1}\right) ref - cc/sec$$

$$Lr = \frac{Vcm3 * 298°K}{3600 * \frac{M\ min}{60\ min} * 1atm}\left(\frac{P1atm}{T1°K} - \frac{P2atm}{T2°K}\right) ref - cc/sec$$

$$Lr = \frac{5.333\ cm3 * 4.96667}{6\ min}\left(\frac{\frac{1874.24\ mBar}{1013.25\ mBar/atm}}{(25\ °C + 273)°K} - \frac{\frac{1867.78\ mBar}{1013.25\ mBar/atm}}{(25\ °C + 273)°K}\right) ref - cc/sec$$

$$Lr = \frac{5.333\ cm3 * 4.96667}{6\ min}\left(\frac{1.8497 atm}{298\ °K} - \frac{1.8433 atm}{298\ °K}\right) ref - cc/sec$$

4.412059 .000021141

$Lr = 9.33 \times 10^{-5}\ ref - cc/sec$

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date: 6-24-03	Witness	Date: 6/24/03

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

n

System Date THU 07 JUN 1990 15:22:05
CALT No: 0052 Transducer No: 835279
Days since last calibration: ~~521~~ 1-27-03

ORNL
CALT5 - Version V1.43

Pressure Drop
*** LEAKAGE TEST ***

Test Reference No: CI95001
Design/Serial Nos: F313/3009
Comment: Lid Seal
Interspace Volume: 5.333 cc
Settling Time: 5 mins
Test Duration: 6 mins
Temperature: 25°C
Temperature ratio: 1.000
μ ratio: 1.000
Pass Rate (SLR): 1.0E-04 bar cc/sec
Allowable δP : -17 mbar

**** RESULTS ****

	Pressure mbar	Date/Time
Atmos:	975.07	
Start:	1874.24	07 JUN 1990 15:28:11
Final:	1867.78	07 JUN 1990 15:34:11

Leakage Rate: 3.8E-05 bar cc/sec

PASS

Standard conditions:
Temperature: 25°C
Up stream pressure: 1013 mbar
Down stream pressure: 0 mbar

Sig: [signature] Date: 5-5-03
(Tested by)

Sig: L.B. Shappert Date: 5/5/03
(Supervisor)

Appendix B

Data Sheets for TU-2

TEST FORM 1A
ASSEMBLY OF THE CV

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-2-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
mBH	CV test unit serial number: 03017
mBH	All containment vessel (CV) components have been visually inspected to ensure they are present and in good condition.
mBH	Temperature indicators have been affixed to the surface of the CV as indicated Figure 3.2 and on Test Form 6D.
mBH	None of the temperature indicators indicate exposure to a temperature in the measured range.
mBH	The container and lid have been clearly marked as " TU- 2 ".
mBH	A vertical line has been marked on the side of the container and lid with a permanent marker to indicate alignment the two components.
mBH	The CV O-rings and sealing surfaces have been inspected for defects and found acceptable.
mBH	* Refrasil insulation cloth was applied to the inside of the CV.
mBH	** The stainless steel sleeve was inserted after the Refrasil cloth was installed.
mBH	Two (2) temperature labels are in the center of the shot.
mBH	The aluminum sleeve, weighing 23 pounds with the Refrasil, was installed in the CV. Steel shot weighing 102 pounds was installed inside the aluminum sleeve. The shot plus the weight of the sleeve weighs 125 ± 1 pounds. The plastic bag containing the shot has been closed with stranded tape and the bag has been trimmed leaving 1 inche of excess bag.
mBH	The lid has been installed on the container and the previously applied vertical markings align. The washers and bolts have been installed. The initial torque of the bolts was 9 ± 1 ft.-lbs. and applied in the sequence etched on the CV lid. A second torque of the bolts was applied at 18 ± 1 ft.-lbs. A re-torque of 18 ± 1 ft.-lbs. was again applied. All torque as applied was in the sequence etched on the CV lid. Ambient temperature at closure is 19 °C (67 °F).
	Torque wrench # 4010282626 Calibration Expiration Date 12/4/03
mBH 12/7/02	The CV assembly has been leak tested with the Calt#5 per the Manufacturer's Instructions Manual. Leak Tester Cert. # M201288 Expiration Date: 8/18/03 Leakage Value: 6.84 x10^{-5} std-cc/sec air
mBH	Mark the top of the CV lid with 0, 90, 180 and 270-degree locations with a permanent marker.
mBH	The CV assembly has been weighed and the weight has been recorded on Form 3.
mBH	Photographs of the assembly have been taken*.

Comments: Pictures ① marked components; ② CV w/ shot loaded; ③ Finished CV ④ CV bottom temp labels
* Refrasil is applied to bottom of CV and bottom of CV lid
** Refrasil is applied to exterior of sleeve prior to installing into CV.

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk 12/6/02 — Testing Technician, Date
L. B. Toppert 12/6/02 — Witness, Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-2-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
MBH	The exterior of the drum has been clearly marked "TU-_".
MBH	Record the drum serial number: 03 089
MBH	Each urethane foam insert has been clearly marked "TU-_"
	The center-of-gravity markings have been applied to the drum as shown.
MBH	Mark the 0, 90, 180, 270 degree locations on the Drum Lid, Top Plug, and the inner and outside walls of the drum with a permanent marker. The "0" location is the vertical, outside-wall seam of the drum. LJY 12/4/02
MBH	The plastic Leak Check port plug has been removed
MBH	The CV assembly has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
MBH	The Drum Top Plug was weighed and the weight has been recorded on Form 3.
MBH	The Drum Top Plug has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
MBH	The Drum Lid with no gasket has been installed with the 0 degree mark rotated and aligned with the 0° degree mark on the drum.
N/A	A security seal has been attached to the drum.
MBH	The drum lid washers are placed over the lugs and the drum lid nuts were initially installed and torque to 10 ± 1 ft.-lbs. The nuts were then tightened a second time to a torque of 10 ± 1 ft-lbs. No torque sequence is required to be followed.
	Torque wrench # 4010282626 Calibration Expiration Date 12/4/03
MBH	The test package assembly has been weighed and the weight recorded on Form 3.
MBH	Photographs of the assembly have been taken*.

Comments: ____________________

I certify that the above tasks have been performed and that the observations and comments are correct.

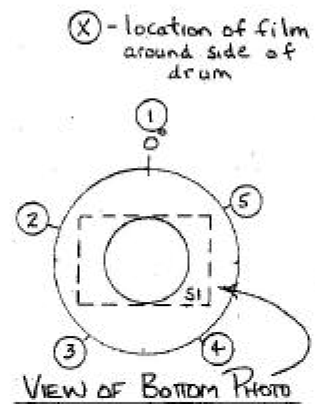
Mark B. Hawk	12/10/02	[signature]	12/10/02
Testing Technician	Date	Witness	Date

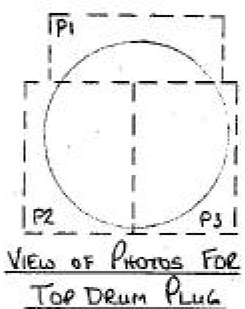
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

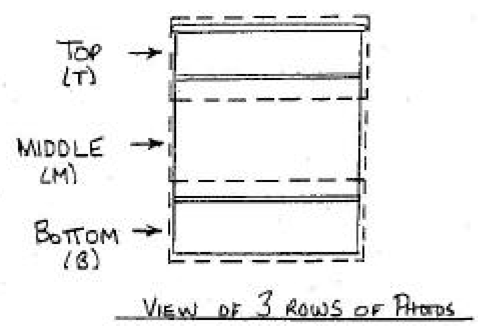
TEST FORM 2A
RADIOGRAPH DRUM LINER

Test Plan TTG/TP/ES-2100, Rev.2
Test Unit TU-2-12/02
Test Location @ ORNL 3017 mbH

VERIFIED	TASK
mbH	The test unit has been clearly marked "TU-___"
mbH	Record the test unit serial number: 03089
mbH	Record the history of the drum, i.e. as built dropped, etc.
	History: new drum – to be used for testing purposes
mbH	Date test unit is radiographed: 12/6-7/02
mbH	* Still photographs are to be taken as indicated below: Three rows [top (T), middle (M) and bottom(B)] of five pictures per row were taken and numbered T1-T5, M1-M5, and B1 - B5. Three pictures of the Drum Top Plug (P) were taken and numbered P1-P3. One picture of the bottom was taken and numbered S1.







Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	12/10/02	Richard D McLellan	12/10/02
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 3
COMPONENT WEIGHTS

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-2-12/02
Test Location NTRC Rm. L-110

PRE-DROP TEST WEIGHTS / **POST THERMAL TEST WEIGHTS**

PART NAME	WEIGHT	BY	DATE	PART NAME	WEIGHT	BY	DATE
CV (lid & body) w/BOLTS	66 lbs.	MBH	12/6/02				
CV mass (shot)	102 lbs.	MBH	12/6/02				
CV sleeve	23 lbs.	MBH	12/6/02				
CV assembly	191 lbs.	PTG	12-6-02	CV assembly	191 lbs.	LBS	5/5/03
* Drum isolation Foam	13 lbs.	MBH	12/6/02	Drum isolation Foam	13 lbs.	LBS	5/7/03
Drum Top Plug	32 lbs.	MBH	12/10/02	Drum Top Plug	32 lbs.	LBS	5/7/03
Test package Ass'y	447 lbs.	MBH	12/10/02	Test package Ass'y	445 lbs.	LBS	4/29/03

EQUIPMENT

PRE-DROP TEST:

Scale: X 502322 Expiration Date: 10/14/03

Accuracy: ± 1 lb.

Scale: _____ Expiration Date: _____

Accuracy: ± _____

POST THERMAL TEST:

Scale: _____ Expiration Date: _____

Accuracy: ± _____

Scale: _____ Expiration Date: _____

Accuracy: ± _____

Comments: * NOTE: TEST PLAN, REV. 2 & TEST FORM REV 2 REQUIRE THE DRUM FOAM LID & DRUM FOAM CYLINDER TO BE WEIGHED SEPARATELY. BOTH WERE WEIGHED TOGETHER AND THE CV WAS ASSEMBLED PRIOR TO THE REV. 2A. THE Y-12 PACKAGING HAS WAIVED THE SEPARATE WEIGHING AS LONG AS EACH COMPONENT IS WEIGHED SEPARATELY AFTER THERMAL TEST. ATH 12/11/02

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk 12/10/02 L.B. Slaggart 12/10/02

Testing Technician Date Witness Date

TEST FORM 4 Test Plan TTG/TP/ES-2100-02 Rev. 1

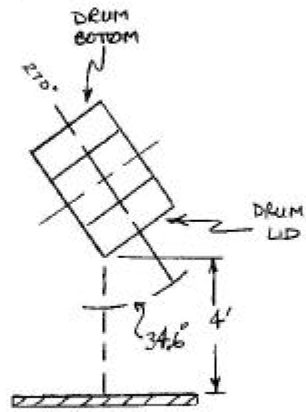
1.2m (4 ft) FREE FALL DROP Test Unit TU-1 - 12/02

Test Location NTRC Indoor drop pad Rm L-110

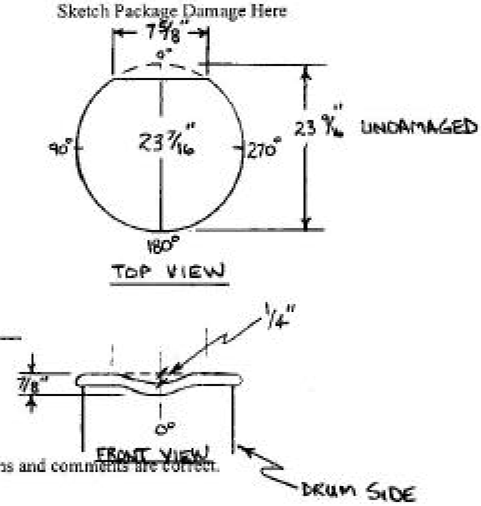
11:05am 12/11/02

VERIFIED	TASK
mBH	Still and video cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken
mBH	Attitude of the Test Unit shall be 34.6 (computed angle) Tolerance ±
mBH	Measured attitude of the Test Unit 35.1° Level number 311-006-501 Exp. Date 6-03
mBH	The Test Unit has been raised so that the lowest point is 1.2m (4 ft) above an essentially unyielding, horizontal impact surface. Measuring device
mBH	Ambient temperature at the time of the test: °C (69 °F)
mBH	The Test Unit was dropped from a minimum of 1.2m (4 ft) onto the drop pad
mBH	Videos* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Drop Setup Here



Sketch Package Damage Here



Testing Damage Observations: ______________________

Comments: ______________________

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	12/11/02	L. B. Stappert	12/11/02
Testing Technician	Date	Witness	Date

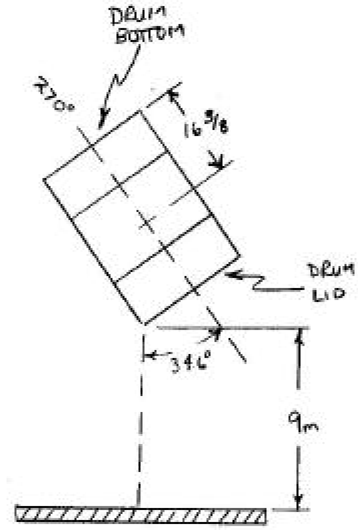
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 5
9m (30 ft) FREE FALL DROP

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-2-12/02
Test Location NTRC Outdoor drop pad

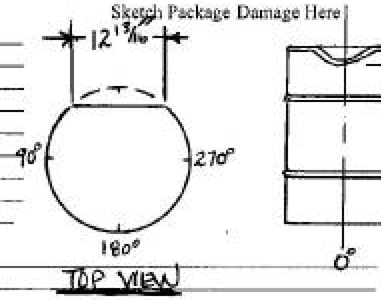
VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-drop test weights are recorded on Form 3.
MBH	Still video and high speed cameras are setup
MBH	Photographs of the arrangements for the drop have been taken
MBH	Photographs of the arrangements for the drop have been taken Ambient temperature of the test: ____°C, (41 °F) at the time of 9:45 am
MBH	The test drop angle of this unit is 34.6° as specified in Figure 4.4. The measured drop angle is 35.2 Measuring device: 311-024-501 Calibration expiration date: 6-03
MBH	The Test Unit has been raised so that the lowest point is 30' 1/2" above an essentially unyielding, horizontal impact surface. Measuring device: TTG 9 m measurement wire.
MBH	The Test Unit was dropped in free fall from a minimum of 9m (30 ft) onto the drop pad
MBH	Videos and high speed films* of the drop were made
MBH	Photographs* of the resulting damage were taken

Sketch Test Setup Here CG/CORNER



Testing Damage Observations:

Sketch Package Damage Here



Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date
Mark B. Hawk	12/12/02	L. B. Shappert	12/12/02

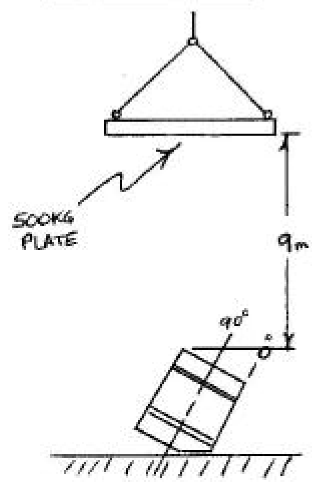
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

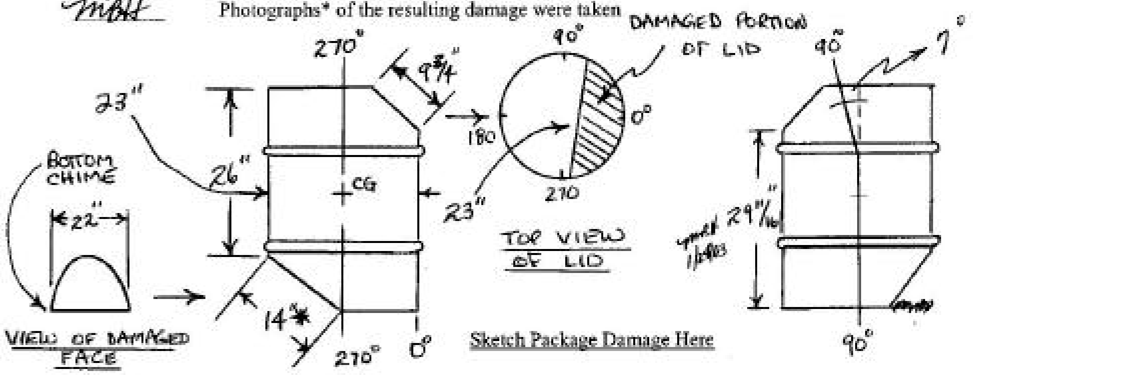
TEST FORM 6
9m (30 ft) DYNAMIC CRUSH TEST

Test Plan TTG/TP/ES-2100-02, Rev.2
Test Unit TU-2-12/02
Test Location: NTRC Outside Drop Pad

VERIFIED	TASK
mBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
mBH	Still , video and high speed cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken.
mBH	Ambient temperature of the test: ____°C, (43 °F) at the time of 1:15P.
mBH	The test unit has been placed on an essentially unyielding surface in the orientation shown in Figure 4 7. The measured drop angle is 34.2. mBH Measuring device: 311-006-501 Calibration expiration date: 6-03
mBH	The 500kg (1100 lb) steel plate has been raised so that the lowest point is 30' 1/2" above the highest point on the test unit and the CG of the Crush Plate is centered over the CG of test unit ± 4 in. Measuring device: TTG 9 m measurement wire
mBH	The steel plate was released to fall onto the test unit from a height of at least 9m (30 ft).
mBH	Videos and high speed films* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Test Setup Below





Sketch Package Damage Here

Testing Damage Observations & Comments:
IMPACT POINT WAS UNDAMAGED BOTTOM CHIME @180°. PREVIOUSLY DAMAGED CORNER @ 0° AND ON LID WAS AGAINST DROP PAD.

* NOTE: 14" DIMENSION IS ACCURATE FROM BELOW BOTTOM HOOP TO BOTTOM OF DRUM; HOWEVER DAMAGE AT THE DRUM BOTTOM DOES NOT EXTEND TO CENTERLINE OF DRUM.

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/16/02 — Testing Technician, Date

L.B. Shappert 12/16/02 — Witness, Date

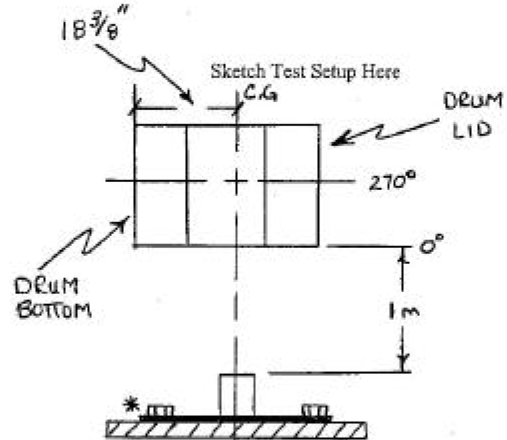
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 7
1 m (40 in) PUNCTURE DROP

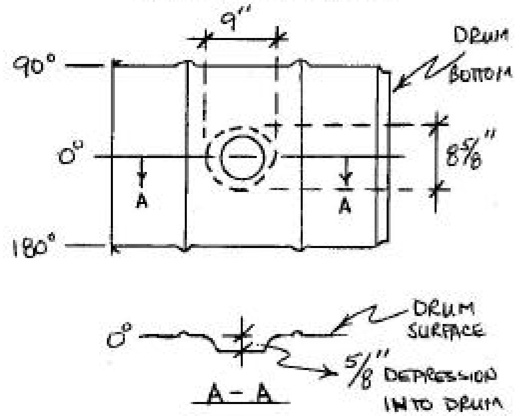
Test Plan:TTG/TP/ES-2100-02, Rev.2 12/17/02
Test Unit TU-2-12/02
Test Location: NTRC, Inside Drop Pad

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photo and video of the drop.
MBH	Ambient temperature of the test: ____°C, (7 °F) at the time of 2:05 PM
MBH	The test drop angle of this unit is 0.2° as specified by Figure 4.8. The measured drop angle is 0.2. Measuring device: 311-006-501 Calibration expiration date: 6-03
MBH	The Test Unit has been raised so that the lowest point is 1m above the steel bar. Measuring device: TTG meter stick Calibration expiration date: —

Sketch Test Setup Here



Sketch Package Damage Here



Testing Damage Observations:

LOCATION	DRUM ORIG. DIA.	DRUM DIM AFTER DROP	DAMAGED AREA
PT. OF IMPACT	22.5"	21 1/16"	9" x 8 5/8"

Comments: * PUNCH BAR PLATE IS BOLTED DOWN W/ 4 - 1 INCH BOLTS. BOLTS ARE TORQUE TO 200 FT-LB. TORQUE WRENCH K-4804 — CAL. EXP. DATE: 11/26/03

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	1/24/03	L. B. Shappert	1/24/03
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8A
THERMAL TESTING

Test Plan ________
Test Unit TU-2
Test Location Albert

VERIFIED	TASK
PTS	The Test Unit has been prepared in accordance with the Test Plan. Forms 1A and 2 are complete and the pre-test weights are recorded on Form 3.
PTS	All thermocouples have been installed on the exterior of drum, furnace and test stand in accordance with the Test Plan, Figures ___, ___, ___, ___ and ___.
PTS	All thermocouples have been surveyed to ensure they are working. (Any malfunctions or erratic performance will be addressed in the comments section below.)
PTS	The thermocouple recorder(s) is set to read every 30 seconds.
PTS	*Photographs of the arrangements for the test have been taken.
PTS	The test package has been preheated to over 38 °C (100 °F). Measuring device: thermal monitoring system Exrn Ch#136 Calibration expiration date: ________
PTS	Furnace has reached the minimum soak point temperature of 800 °C (1475 °F), and has soaked at this temperature for a minimum of 8 hours. The furnace set point temperature has been adjusted to ___ °C (1460 °F) at least one hour prior to each test. Time: 1131 am/pm Date: 4-25-03 11:32 door opening
PTS	The unit has been placed in the furnace, on the support stand, with the damaged area up at: Time: 1133 am/pm Date: 4-25-03 Open furnace door time: 67 seconds
PTS	The 31 minute timed test began when 5 out of 6 test unit thermocouples reached the test temperature of 800 °C (1475 °F), as specified in the test plan. Time: 1143 am/pm Date: 4-25-03 30:09 min run
PTS	Immediately following the timed test (minimum of 30 minutes at 800 °C) the test unit is taken out of the furnace and allowed to cool naturally. Time: 1214 am/pm Date: 4-25-03 Ambient Temperature ___ °C (65.7) 12:14 out of furnace
PTS	The unit stopped outgassing (flames) at No outgassing observed. outgassing/burnout lapsed time was ________ minutes. Outgassing @ 1234 Stopped @ 1314
PTS	The thermocouple recorder shall be set to record the internal thermocouples at 15 minute intervals for at least 12 hours. Some small dripping observed

Comments: Original strip chart paper record from furnace controller is included in test records
Outgassing observed @ 1234 Smells like foam

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature] 4-25-03 [signature] 4/25/03
Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8D
TEMPERATURE INDICATOR READINGS

Test Plan ________
Test Unit TU-2 – 12/2
Test Location ________

A visual inspection of each temperature indicator on the ES-2100 package consisting of those indicators inside the CV stainless steel shot, outside the CV, and on the ES-2100 drum liner shall be made. The values of the blackouts which occurred shall be recorded below. Dimensions identified under the "Height" column are the dimensions from the bottom of the CV or drum liner to the bottom of the temperature indicators.

RECORD BLACKOUT TEMPERATURES AT THESE LOCATIONS:

ES-2100 TEMPERATURE INDICATOR NUMBER LOCATION CHART

Figure 3.2 – INSIDE OF CV, STEEL SHOT TEMPERATURE @ 12"

12	1 190 °F	~~190~~ 2 180 °F

Figure 3.2 – ON THE OUTSIDE OF THE ES-2100 CV

Row/ Height, inches	0°	90°	180°	270°
Bottom	3 175 °F	4 175 °F	5 175 °F	6 175 °F
4.2	7 175 °F	8 175 °F	9 175 °F	10 175 °F
16.8	11 175 °F	12 175 °F	13 175 °F	14 175 °F
Top	15 175 °F	16 175 °F	17 175 °F	18 175 °F

Figure 3.3 – ON THE INSIDE OF THE ES-2100 DRUM INNER LINER

Row/ Height, inches	0°	90°	180°	270°
Bottom	19 225 °F	20 225 °F	21 225 °F	22 225 °F
5	23 250 °F	24 250 °F	25 250 °F	26 225 °F
12.7	27 225 °F	28 250 °F	29 250 °F	30 225 °F
1ST Ledge	31 <125 °F	32 325 °F	33 375 °F	34 350 °F
Plug Bottom	35 375 °F	36 375 °F	37 500 °F	38 450 °F

Comments: ________

I certify that the above tasks have been performed and that the observations and comments are correct.

L.B. Shappert 4/30/03 — Testing Technician, Date

RD Michelhaugh Jr 4/30/03 — Witness, Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 13 - **OPERATIONAL LEAK TEST**

Test Plan ES-2100

Test Unit TU-2-12/02

VERIFIED	TASK
______	Post Assembly Leak Test ______ Post Test Leak Test X
______	A leak test in accordance with the CALT5 Manufacturer's Instructions Manual was performed on the CV assembly.

Leak Tester Cert. #__________ Expiration Date: __________ Leakage Value: ______ ref-cc/sec air

Attach CALT5 Printout Here

See Printout

$$Lr = \frac{V * Ts}{3600 * H * Ps}\left(\frac{P1}{T1} - \frac{P1}{T1}\right) ref - cc/\sec$$

$$Lr = \frac{Vcm3 * 298°K}{3600 * \frac{M\min}{60\min} * 1atm}\left(\frac{P1atm}{T1°K} - \frac{P2atm}{T2°K}\right) ref - cc/\sec$$

$$Lr = \frac{5.417\ cm3 * 4.96667}{6\ \min}\left(\frac{\frac{1716.37\ mBar}{1013.25\ mBar/atm}}{(25\ °C + 273)°K} - \frac{\frac{1711.52\ mBar}{1013.25\ mBar/atm}}{(25\ °C + 273)°K}\right) ref - cc/\sec$$

$$Lr = \frac{5.417\ cm3 * 4.96667}{6\ \min}\left(\frac{1.6939\ atm}{298\ °K} - \frac{1.6891\ atm}{298\ °K}\right) ref - cc/\sec$$

4.484075 .000016107

$$Lr = 7.22 \times 10^{-5}\ ref - cc/\sec$$

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature]	6-24-03	[signature]	6/24/03
Testing Technician	Date	Witness	Date

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

11

System Date SAT 02 JUN 1990 11:37:35
CALT No: 0052 Transducer No: 835279
Days since last calibration: ~~516~~ 1-27-03

ORNL
CALT5 - Version V1.43

Pressure Drop
** LEAKAGE TEST **

Test Reference No: CI95001
Design/Serial Nos: F313/3017
Comment: Lid Seal
Interspace Volume: 5.417 cc
Settling Time: 5 mins
Test Duration: 6 mins
Temperature: 25°C
Temperature ratio: 1.000
μ ratio: 1.000
Pass Rate (SLR): 1.0E-04 bar cc/sec
Allowable δP : -13 mbar

*** RESULTS ***
Pressure mbar Date/Time

Atmos: 980.25
Start: 1716.37 02 JUN 1990 11:44:00
Final: 1711.52 02 JUN 1990 11:49:59

Leakage Rate: 3.7E-05 bar cc/sec

PASS

Standard conditions:
Temperature: 25°C
Up stream pressure: 1013 mbar
Down stream pressure: 0 mbar

Sig: JC Copeland Date: 4-30-03
(Tested by)

Sig: [signature] Date: 4-30-03
(Supervisor)

Appendix C

Data Sheets for TU-3

TEST FORM 1A
ASSEMBLY OF THE CV

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-3-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
mBH	CV test unit serial number: 03043
mBH	All containment vessel (CV) components have been visually inspected to ensure they are present and in good condition.
mBH	Temperature indicators have been affixed to the surface of the CV as indicated Figure 3.2 and on Test Form 6D.
mBH	None of the temperature indicators indicate exposure to a temperature in the measured range.
mBH	The container and lid have been clearly marked as " TU-3".
mBH	A vertical line has been marked on the side of the container and lid with a permanent marker to indicate alignment the two components.
mBH	The CV O-rings and sealing surfaces have been inspected for defects and found acceptable.
mBH	* Refrasil insulation cloth was applied to the inside of the CV.
mBH	** The stainless steel sleeve was inserted after the Refrasil cloth was installed.
mBH	Two (2) temperature labels are in the center of the shot.
mBH	The aluminum sleeve, weighing 24 pounds with the Refrasil, was installed in the CV. Steel shot weighing 101 pounds was installed inside the aluminum sleeve. The shot plus the weight of the sleeve weighs 125 ± 1 pounds. The plastic bag containing the shot has been closed with stranded tape and the bag has been trimmed leaving 1 inche of excess bag.
LBS	The lid has been installed on the container and the previously applied vertical markings align. The washers and bolts have been installed. The initial torque of the bolts was 9 ± 1 ft.-lbs. and applied in the sequence etched on the CV lid. A second torque of the bolts was applied at 18 ± 1 ft.-lbs. A re-torque of 18 ± 1 ft.-lbs. was again applied. All torque as applied was in the sequence etched on the CV lid. Ambient temperature at closure is ____ °C (68 °F). ***
	Torque wrench # 4010282626 Calibration Expiration Date 12/04/03
mBH 12/7/02	The CV assembly has been leak tested with the Calt#5 per the Manufacturer's Instructions Manual. Leak Tester Cert. # M201288 Expiration Date: 8/18/03 Leakage Value: 6.28 x10^-5 std-cc/sec air
mBH	Mark the top of the CV lid with 0, 90, 180 and 270-degree locations with a permanent marker.
mBH	The CV assembly has been weighed and the weight has been recorded on Form 3.
mBH	Photographs of the assembly have been taken*.

Comments: Picture of: ① all marked components ② CV w/shot loaded; ③ finished CV ④ CV bottom templabels
* Refrasil is applied to bottom of CV and bottom of CV lid
** Refrasil is applied to exterior of sleeve prior to installing into CV.
*** First leak check failed; CV-O-rings where removed & cleaned. Refrasil found on O-ring (inner); lid retorque per above. mBH 12/7/02

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/6/02 L.B. Sleppert 12/06/02
Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-3-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
mBH	The exterior of the drum has been clearly marked "TU-_".
mBH	Record the drum serial number: 03091
mBH	Each urethane foam insert has been clearly marked "TU-__"
	The center-of-gravity markings have been applied to the drum as shown.
mBH	Mark the 0, 90, 180, 270 degree locations on the Drum Lid, Top Plug, and the inner and outside walls of the drum with a permanent marker. The "0" location is the vertical, outside-wall seam of the drum. LBS 12/4/02
mBH	The plastic Leak Check port plug has been removed
mBH	The CV assembly has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
mBH	The Drum Top Plug was weighed and the weight has been recorded on Form 3.
mBH	The Drum Top Plug has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
mBH	The Drum Lid with no gasket has been installed with the 0 degree mark rotated and aligned with the 0° degree mark on the drum.
N/A	A security seal has been attached to the drum.
mBH	The drum lid washers are placed over the lugs and the drum lid nuts were initially installed and torque to 10 ± 1 ft.-lbs. The nuts were then tightened a second time to a torque of 10 ± 1 ft-lbs. No torque sequence is required to be followed.
	Torque wrench #4010282626 Calibration Expiration Date 12-4-03
mBH	The test package assembly has been weighed and the weight recorded on Form 3.
mBH	Photographs of the assembly have been taken*.

Comments: ______

I certify that the above tasks have been performed and that the observations and comments are correct.

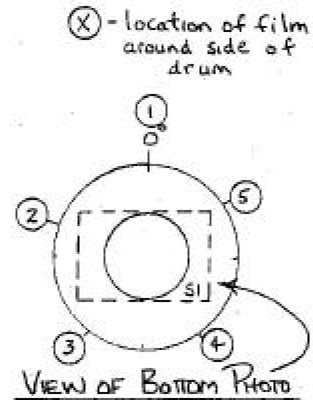
Mark B. Hawk	12/10/02	L.B. Shappert	12/10/02
Testing Technician	Date	Witness	Date

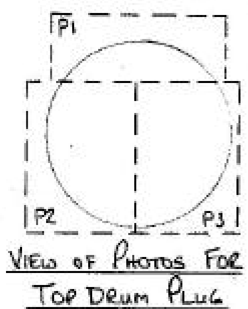
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

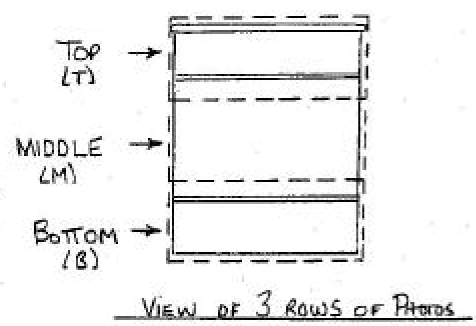
TEST FORM 2A
RADIOGRAPH DRUM LINER

Test Plan TTG/TP/ES-2100, Rev.2
Test Unit TU-3-12/02
Test Location 3017 @ ORNL

VERIFIED	TASK
mBH	The test unit has been clearly marked "TU-___"
mBH	Record the test unit serial number: 03091
mBH	Record the history of the drum, i.e. as built dropped, etc.
	History: new drum - to be used for testing
mBH	Date test unit is radiographed: 12/7-9/02
mBH	* Still photographs are to be taken as indicated below: Three rows [top (T), middle (M) and bottom(B)] of five pictures per row were taken and numbered T1-T5, M1-M5, and B1 - B5. Three pictures of the Drum Top Plug (P) were taken and numbered P1-P3. One picture of the bottom was taken and numbered S1.







Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	12/10/02	Robert D Malo[illegible]	12/10/02
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 3
COMPONENT WEIGHTS

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-3-12/02
Test Location NTRC Rm. L-110

PRE-DROP TEST WEIGHTS | **POST THERMAL TEST WEIGHTS**

PART NAME	WEIGHT	BY	DATE	PART NAME	WEIGHT	BY	DATE
CV (lid & body) w/bolts	66 lbs.	MBH	12/6/02				
CV mass (shot)	101 lbs.	MBH	12/6/02				
CV sleeve	24 lbs.	MBH	12/6/02				
CV assembly	191 lbs.	MBH	12/6/02	CV assembly	191 lbs.	LBS	5/5/03
* Drum isolation Foam	13 lbs.	MBH	12/6/02	Drum isolation Foam	13 lbs.	LBS	5/7/03
Drum Top Plug	31 lbs.	MBH	12/10/02	Drum Top Plug	31 lbs.	LBS	5/7/03
Test package Ass'y	449 lbs.	MBH	12/10/02	Test package Ass'y	448 lbs.		

EQUIPMENT

PRE-DROP TEST: | POST THERMAL TEST:

Scale: X502322 Expiration Date: 10/14/03 | Scale: ____ Expiration Date: ____

Accuracy: ± 1 lb | Accuracy: ± ____

Scale: ____ Expiration Date: ____ | Scale: ____ Expiration Date: ____

Accuracy: ± ____ | Accuracy: ± ____

Comments: *NOTE: TEST PLAN REV 2 & TEST FORM 3 REV 2 REQUIRE THE DRUM FOAM LID & DRUM FOAM CYLINDER TO BE WEIGHED SEPARATELY. BOTH WERE WEIGHED TOGETHER AND THE CV WAS ASSEMBLED PRIOR TO THE REV 2A. THE Y-12 PACKAGING ENGINEER HAS WAIVED THE SEPARATE WEIGHING REQUIREMENT, AS LONG AS EACH COMPONENT IS WEIGHED SEPARATELY AFTER THERMAL TESTING. STK 12/11/02

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk 12/10/02 — Testing Technician, Date

L. B. Sluyput 12/10/02 — Witness, Date

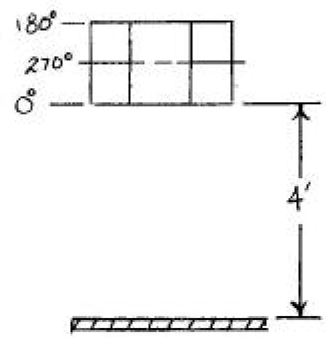
TEST FORM 4
1.2m (4 ft) FREE FALL DROP

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-3-12/02
Test Location NTRC Indoor drop pad Rm L-110

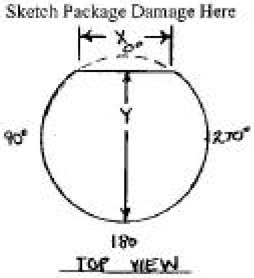
VERIFIED — TASK — 10:35am 12/11/02

VERIFIED	TASK
mBH	Still and video cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken
mBH	Attitude of the Test Unit shall be 0.0° (computed angle) Tolerance ± 2°
mBH	Measured attitude of the Test Unit 0.8° Level number 311-006-501 Exp. Date 6-03
mBH	The Test Unit has been raised so that the lowest point is 1.2m (4 ft) above an essentially unyielding, horizontal impact surface.
mBH	Measuring device
mBH	Ambient temperature at the time of the test: °C (69 °F)
mBH	The Test Unit was dropped from a minimum of 1.2m (4 ft) onto the drop pad
mBH	Videos* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Drop Setup Here FLAT DROP



Sketch Package Damage Here



Testing Damage Observations: 2nd nut to left of 0° (clockwise) is loose (finger tight).

POSITION	"X"	"Y"
TOP RING	4-5/8"	23 1/4 (23-9/16" - NORMAL DIA.)
TOP HOOP	4-13/16"	NOT MEASURED
BOTTOM HOOP	6-1/2"	NOT MEASURED
BOTTOM of DRUM (NOT CHIME)	4"	NOT MEASURED

Comments: ______

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature] 12/11/02 [signature] 12/11/02
Testing Technician — Date — Witness — Date

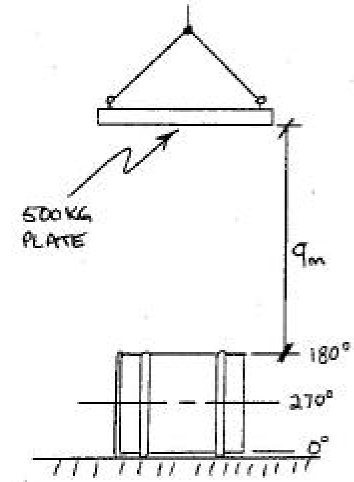
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

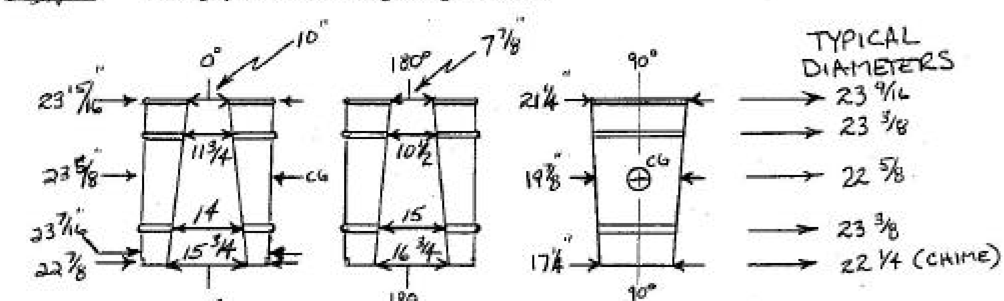
TEST FORM 6
9m (30 ft) DYNAMIC CRUSH TEST

Test Plan TTG/TP/ES-2100-02, Rev.2
Test Unit TU-3-12/02
Test Location: NTRC Outside Drop Pad

VERIFIED	TASK
mBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
mBH	Still, video and high speed cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken.
mBH	Ambient temperature of the test: ____°C, (41 °F) at the time of 10:55am
mBH	The test unit has been placed on an essentially unyielding surface in the orientation shown in Figure 45. The measured drop angle is 0.__. Measuring device: 311-006-501 Calibration expiration date: 6-03
mBH	The 500kg (1100 lb) steel plate has been raised so that the lowest point is 30'½" above the highest point on the test unit and the CG of the Crush Plate is centered over the CG of test unit ± 4 in. Measuring device: TTG 9 m measurement wire
mBH	The steel plate was released to fall onto the test unit from a height of at least 9m (30 ft).
mBH	Videos and high speed films* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Test Setup Below





Sketch Package Damage Here

Testing Damage Observations & Comments:
DIMENSIONS INDICATED ON 0° & 180° PROFILES WERE TAKEN ACROSS THE DAMAGED FLAT SURFACES.

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk — Testing Technician — Date: 12/16/02
L. B. Sheppard — Witness — Date: 12/16/02

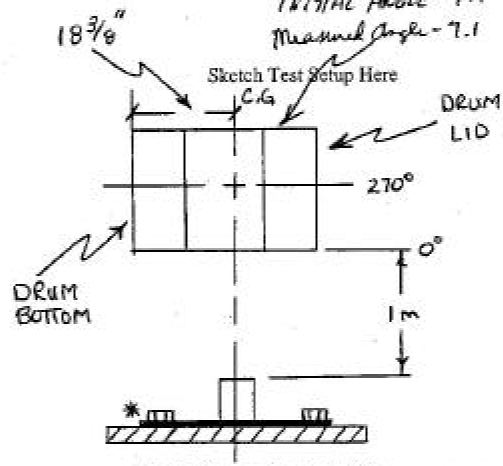
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 7
1 m (40 in) PUNCTURE DROP

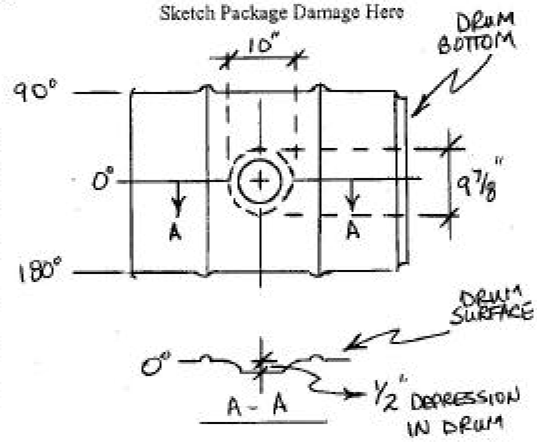
Test Plan:TTG/TP/ES-2100-02, Rev.2 12/7/02
Test Unit TU-3-12/02
Test Location: NTRC, Inside Drop Pad
INITIAL ANGLE - 7.1
Measured Angle - 7.1

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photo and video of the drop.
MBH	Ambient temperature of the test: ___°C, (71 °F) at the time of 1:45P.
MBH	The test drop angle of this unit is 00/7.1° as specified by Figure 4.8. The measured drop angle is 00/7.1. Measuring device: 3U-006-501 Calibration expiration date: 6-03
MBH	The Test Unit has been raised so that the lowest point is 1m above the steel bar. Measuring device: TTG 1m STICK Calibration expiration date: —

Sketch Test Setup Here



Sketch Package Damage Here



Testing Damage Observations:

LOCATION	ORIG DIA.	DRUM DIM. AFTER DROP	DAMAGED AREA
PT. OF IMPACT	22.5"	19 1/4"	≈10" ϕ

Comments: * PUNCH BAR PLATE IS BOLTED DOWN W/ 4 - 1 INCH BOLTS. BOLTS ARE TORQUE TO 200 FT-LB: TORQUE WRENCH K-4804 — CAL. EXP. DATE: 11/26/03

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	1/24/03	L. B. Shappert	1/24/03
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8A
THERMAL TESTING

Test Plan ________
Test Unit TU-3
Test Location AltStom

VERIFIED	TASK
PTS	The Test Unit has been prepared in accordance with the Test Plan. Forms 1A and 2 are complete and the pre-test weights are recorded on Form 3.
PTS	All thermocouples have been installed on the exterior of drum, furnace and test stand in accordance with the Test Plan, Figures ___, ___, ___, ___ and ___.
PTS	All thermocouples have been surveyed to ensure they are working. (Any malfunctions or erratic performance will be addressed in the comments section below.)
PTS	The thermocouple recorder(s) is set to read every 30 seconds.
PTS	*Photographs of the arrangements for the test have been taken.
PTS	The test package has been preheated to over 38 °C (100 °F). Measuring device: Monitoring System Furnace Ch#36 Calibration expiration date: ________
PTS	Furnace has reached the minimum soak point temperature of 800 °C (1475 °F), and has soaked at this temperature for a minimum of 8 hours. The furnace set point temperature has been adjusted to ______ °C (1580 °F) at least one hour prior to each test. Time: 939 am/pm Date: 4-25-03
PTS	The unit has been placed in the furnace, on the support stand, with the damaged area up at: Time: 943 am/pm Date: 4-25-03 Open furnace door time: 65 seconds
PTS	The 31 minute timed test began when 5 out of 6 test unit thermocouples reached the test temperature of 800 °C (1475 °F), as specified in the test plan. Time: 955 am/pm Date: 4-25-03
PTS	Immediately following the timed test (minimum of 30 minutes at 800 °C) the test unit is taken out of the furnace and allowed to cool naturally. 30:07 min Time: 1025 am/pm Date: 4-25-03 Ambient Temperature ______ °C (63° F) 10:25 Plug out
______	The unit stopped outgassing (flames) at ~~10:59~~ 1103; outgassing/burnout lapsed time was 39 min minutes.
PTS	The thermocouple recorder shall be set to record the internal thermocouples at 15 minute intervals for at least 12 hours.

Comments: Original strip chart paper record from furnace controller is included in test records. odor coming from drum indicate foam is burning Also now getting liquid from drum

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature]	______	[signature]	4/25/03
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8D
TEMPERATURE INDICATOR READINGS

Test Plan ________
Test Unit TU-3 - 12/2
Test Location ________

A visual inspection of each temperature indicator on the ES-2100 package consisting of those indicators inside the CV stainless steel shot, outside the CV, and on the ES-2100 drum liner shall be made. The values of the blackouts which occurred shall be recorded below. Dimensions identified under the "Height" column are the dimensions from the bottom of the CV or drum liner to the bottom of the temperature indicators.

RECORD BLACKOUT TEMPERATURES AT THESE LOCATIONS:

ES-2100 TEMPERATURE INDICATOR NUMBER LOCATION CHART

Figure 3.2 – INSIDE OF CV, STEEL SHOT TEMPERATURE @ 12"

12	1 175 °F	2 175 °F

Figure 3.2 – ON THE OUTSIDE OF THE ES-2100 CV

Row/ Height, inches	0°	90°	180°	270°
Bottom	3 175 °F	4 175 °F	5 175 °F	6 175 °F
4.2	7 175 °F	8 175 °F	9 175 °F	10 175 °F
16.8	11 175 °F	12 175 °F	13 225 °F	14 225 °F
Top	15 175 °F	16 225 °F	17 225 °F	18 225 °F

Figure 3.3 – ON THE INSIDE OF THE ES-2100 DRUM INNER LINER

Row/ Height, inches	0°	90°	180°	270°
Bottom	19 200 °F	20 225 °F	21 225 °F	22 225 °F
5	23 225 °F	24 250 °F	25 225 °F	26 250 °F
12.7	27 225 °F	28 250 °F	29 250 °F	30 250 °F
1ST Ledge	31 225 °F	32 250 °F	33 450 °F	34 300 °F
Plug Bottom	35 350 °F	36 500 °F	37 500 °F	38 300 °F

Comments: ________

I certify that the above tasks have been performed and that the observations and comments are correct.

L.B. [signature] 4/30/03 [signature] 4/30/03
Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 13 - **OPERATIONAL LEAK TEST**

Test Plan ES-2100

Test Unit TU-3-12/02

VERIFIED	TASK
______	Post Assembly Leak Test ______ Post Test Leak Test ✓
______	A leak test in accordance with the CALT5 Manufacturer's Instructions Manual was performed on the CV assembly.

Leak Tester Cert. #______ Expiration Date: ______ Leakage Value: ______ ref-cc/sec air

Attach CALT5 Printout Here

See Printout

$$Lr = \frac{V*Ts}{3600*H*Ps}\left(\frac{P1}{T1}-\frac{P1}{T1}\right) ref-cc/\sec$$

$$Lr = \frac{Vcm3*298°K}{3600*\frac{M\min}{60\min}*1atm}\left(\frac{P1atm}{T1°K}-\frac{P2atm}{T2°K}\right) ref-cc/\sec$$

$$Lr = \frac{5.457\ cm3*4.96667}{6\ \min}\left(\frac{\frac{1960.56\ mBar}{1013.25\ mBar/atm}}{(25\ °C+273)°K}-\frac{\frac{1957.66\ mBar}{1013.25\ mBar/atm}}{(25\ °C+273)°K}\right) ref-cc/\sec$$

$$Lr = \frac{5.457\ cm3*4.96667}{6\ \min}\left(\frac{1.9349\ atm}{298\ °K}-\frac{1.9281\ atm}{298\ °K}\right) ref-cc/\sec$$

4.517186365 * .000022819 =

$Lr = 1.0308\times10^{-4}$ ref − cc/sec

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature]	6-24-03	[signature]	6/24/03
Testing Technician	Date	Witness	Date

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

n

System Date THU 07 JUN 1990 15:38:50
CALT No: 0052 Transducer No: 835279
Days since last calibration: ~~521~~ 1-27-03

ORNL
CALT5 - Version U1.43

Pressure Drop
*** LEAKAGE TEST ***

Test Reference No: CI95001
Design/Serial Nos: F313/3043
Comment: Lid Seal
Interspace Volume: 5.457 cc
Settling Time: 5 mins
Test Duration: 6 mins
Temperature: 25°C
Temperature ratio: 1.000
μ ratio: 1.000
Pass Rate (SLR): 1.0E-04 bar cc/sec
Allowable δP : -19 mbar

**** RESULTS ****
Pressure mbar Date/Time

Atmos: 973.89
Start: 1960.56 07 JUN 1990 15:45:27
Final: 1953.66 07 JUN 1990 15:51:27

Leakage Rate: 3.6E-05 bar cc/sec

PASS

Standard conditions:
Temperature: 25°C
Up stream pressure: 1013 mbar
Down stream pressure: 0 mbar

Sig: J Copeland Date: 5-5-03
(Tested by)

Sig: L.B. Shappert Date: 5/5/03
(Supervisor)

Appendix D

Data Sheets for TU-4

TEST FORM 1A
ASSEMBLY OF THE CV

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-4-12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
LBS	CV test unit serial number: 03065
LBS	All containment vessel (CV) components have been visually inspected to ensure they are present and in good condition.
LBS	Temperature indicators have been affixed to the surface of the CV as indicated Figure 3.2 and on Test Form 6D.
LBS	None of the temperature indicators indicate exposure to a temperature in the measured range.
LBS	The container and lid have been clearly marked as " TU- 4".
LBS	A vertical line has been marked on the side of the container and lid with a permanent marker to indicate alignment the two components.
LBS	The CV O-rings and sealing surfaces have been inspected for defects and found acceptable.
LBS	*Refrasil insulation cloth was applied to the inside of the CV.
LBS	** The stainless steel sleeve was inserted after the Refrasil cloth was installed.
LBS	Two (2) temperature labels are in the center of the shot.
LBS	The aluminum sleeve, weighing 24 pounds with the Refrasil, was installed in the CV. Steel shot weighing 101 pounds was installed inside the aluminum sleeve. The shot plus the weight of the sleeve weighs 125 ± 1 pounds. The plastic bag containing the shot has been closed with stranded tape and the bag has been trimmed leaving 1 inche of excess bag.
LBS	The lid has been installed on the container and the previously applied vertical markings align. The washers and bolts have been installed. The initial torque of the bolts was 9 ± 1 ft.-lbs. and applied in the sequence etched on the CV lid. A second torque of the bolts was applied at 18 ± 1 ft.-lbs. A re-torque of 18 ± 1 ft.-lbs. was again applied. All torque as applied was in the sequence etched on the CV lid. Ambient temperature at closure is ____°C (68°F). Torque wrench # 40102X2626 Calibration Expiration Date 12/04/03
MBH 12/7/02	The CV assembly has been leak tested with the Calt#5 per the Manufacturer's Instructions Manual. Leak Tester Cert. #M201288 Expiration Date: 8/18/03 Leakage Value: 8.87 x 10-5 std-cc/sec air
LBS	Mark the top of the CV lid with 0, 90, 180 and 270-degree locations with a permanent marker.
LBS	The CV assembly has been weighed and the weight has been recorded on Form 3.
LBS	Photographs of the assembly have been taken*.

Comments: Photos (1) all marked components (2) CV w/shot loaded; (3) finished CV
* Refrasil is applied to bottom of CV and bottom of CV lid
** Refrasil is applied to exterior of sleeve prior to installing into CV.

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk 12/6/02 LBS [signature] 12/6/02
Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-4 12/02
Test Location NTRC Rm. L-110

VERIFIED	TASK
mbH	The exterior of the drum has been clearly marked "TU-_".
mbH	Record the drum serial number: CB099
mbH	Each urethane foam insert has been clearly marked "TU-4"
mbH	The center-of-gravity markings have been applied to the drum as shown.
mbH	Mark the 0, 90, 180, 270 degree locations on the Drum Lid, Top Plug, and the inner and outside walls of the drum with a permanent marker. The "0" location is the vertical, outside-wall seam of the drum. BJR 12/4/02
mbH	The plastic Leak Check port plug has been removed
	The CV assembly has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
mbH	The Drum Top Plug was weighed and the weight has been recorded on Form 3.
mbH	The Drum Top Plug has been loaded into the drum with the 0 degree rotated and aligned with the 0° degree location on the drum.
mbH	The Drum Lid with no gasket has been installed with the 0 degree mark rotated and aligned with the 0° degree mark on the drum.
N/A	A security seal has been attached to the drum.
mbH	The drum lid washers are placed over the lugs and the drum lid nuts were initially installed and torque to 10 ± 1 ft.-lbs. The nuts were then tightened a second time to a torque of 10 ± 1 ft-lbs. No torque sequence is required to be followed.
	Torque wrench # 40102826 Calibration Expiration Date 12/4/03
mbH	The test package assembly has been weighed and the weight recorded on Form 3.
mbH	Photographs of the assembly have been taken*.

Comments: ____

I certify that the above tasks have been performed and that the observations and comments are correct.

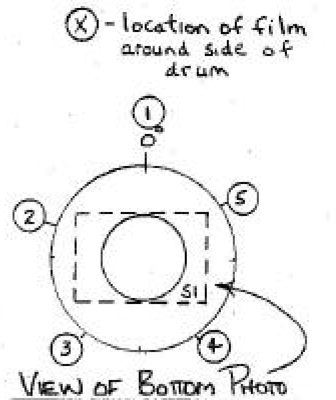
Mark B. Hawk	12/10/02	L.B. Slaugart	12/10/02
Testing Technician	Date	Witness	Date

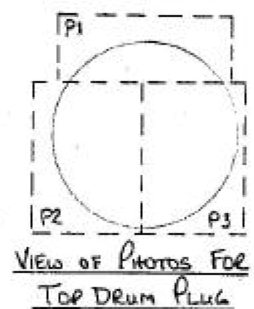
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

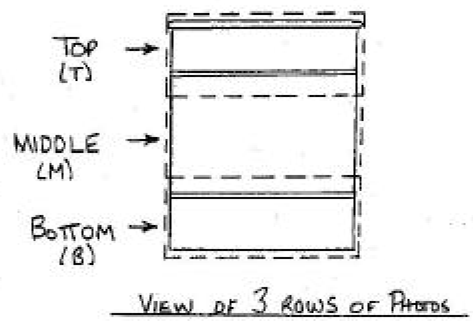
TEST FORM 2A
RADIOGRAPH DRUM LINER

Test Plan TTG/TP/ES-2100, Rev.2
Test Unit TU-4-12/02
Test Location 3017 @ ORNL

VERIFIED	TASK
MBH	The test unit has been clearly marked "TU-___"
MBH	Record the test unit serial number: 03099
MBH	Record the history of the drum, i.e. as built dropped, etc.
	History: New drum – for testing purposes
MBH	Date test unit is radiographed: 12/9/02
MBH	* Still photographs are to be taken as indicated below: Three rows [top (T), middle (M) and bottom(B)] of five pictures per row were taken and numbered T1-T5, M1-M5, and B1 - B5. Three pictures of the Drum Top Plug (P) were taken and numbered P1-P3. One picture of the bottom was taken and numbered S1.







Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk	12/10/02	[signature]	12/10/02
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 3
COMPONENT WEIGHTS

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-4 - 12/02
Test Location NTRC Rm. L-110

PRE-DROP TEST WEIGHTS				POST THERMAL TEST WEIGHTS			
PART NAME	WEIGHT	BY	DATE	PART NAME	WEIGHT	BY	DATE
CV (lid & body)	66 lbs.	LBS	12/6/02				
CV mass (shot)	101 lbs.	LBS	12/6/02				
CV sleeve	24 lbs.	LBS	12/6/02				
CV assembly	191 lbs.	LBS	12/6/02	CV assembly	191 lbs.	LBS	5/5/03
* Drum isolation Foam	13 lbs.	LBS	12/6/02	Drum isolation Foam	13 lbs.	LBS	5/7/03
Drum Top Plug	32 lbs.	MBH	12/10/02	Drum Top Plug	32 lbs.	LBS	5/7/03
Test package Ass'y	451 lbs.	MBH	12/10/02	Test package Ass'y	450 lbs.	LBS	4/29/03

EQUIPMENT

PRE-DROP TEST:

Scale: X522322 Expiration Date: 10/14/03

Accuracy: ± 1 lb.

Scale: ________ Expiration Date: ________

Accuracy: ± ________

POST THERMAL TEST:

Scale: ________ Expiration Date: ________

Accuracy: ± ________

Scale: ________ Expiration Date: ________

Accuracy: ± ________

Comments: * NOTE: TEST PLAN, REV 2 & TEST FORM 3, REV 2 REQUIRE THE DRUM FOAM LID & DRUM FOAM CYLINDER TO BE WEIGHED SEPARATELY. BOTH WERE WEIGHED TOGETHER AND THE CV WAS ASSEMBLED PRIOR TO THE REV. 2a. THE Y-12 PACKAGING ENGINEER HAS WAIVED THE SEPARATE WEIGHING, AS LONG AS EACH COMPONENT IS WEIGHED SEPARATELY AFTER THERMAL TESTING. ATK 12/11/02

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk 12/10/02 — Testing Technician, Date

L.B. Slappert 12/10/02 — Witness, Date

TEST FORM 4 — Test Plan TTG/TP/ES-2100-02 Rev. 1

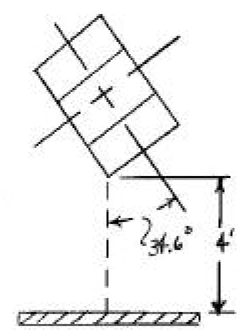
1.2m (4 ft) FREE FALL DROP — Test Unit TU-4-12/02

Test Location NTRC Indoor drop pad Rm L-110

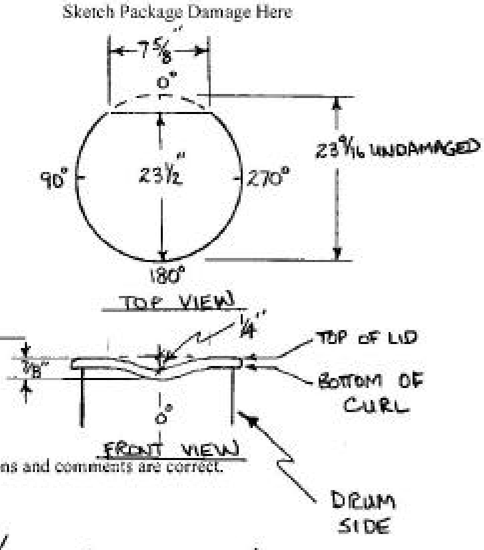
12/11/02

VERIFIED	TASK
mBH	Still and video cameras are setup to take photos and video of the drop
mBH	Photographs of the arrangements for the drop have been taken
mBH	Attitude of the Test Unit shall be 34.6° (computed angle) Tolerance ± 2°
mBH	Measured attitude of the Test Unit 35.5° Level number 311-006-501 Exp. Date 6-03
mBH	The Test Unit has been raised so that the lowest point is 1.2m (4 ft) above an essentially unyielding, horizontal impact surface.
mBH	Measuring device – 4' METAL RULE
mBH	Ambient temperature at the time of the test: °C (69°F)
mBH	The Test Unit was dropped from a minimum of 1.2m (4 ft) onto the drop pad
mBH	Videos* of the drop were made
mBH	Photographs* of the resulting damage were taken

Sketch Drop Setup Here



Sketch Package Damage Here



Testing Damage Observations: DAMAGE TO LID AND DRUM CURL ONLY.

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk — Testing Technician — 12/11/02 — Date

L.B. Sheppard — Witness — 12/11/02 — Date

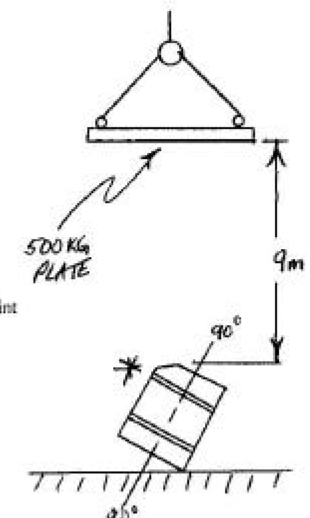
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 6
9m (30 ft) DYNAMIC CRUSH TEST

Test Plan TTG/TP/ES-2100-02 Rev. 1
Test Unit TU-4-12/02
Test Location NTRC Outdoor drop pad

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-drop test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photos and video of the drop
MBH	Photographs of the arrangements for the drop have been taken
MBH	Ambient temperature of the test: ____°C, (43 °F) at the time of 1:55 P.
MBH	The test unit has been placed on an essentially unyielding surface in the orientation shown in Figure 4.7 *
MBH	The angle of the Test Unit is ____° as specified * NOT SPECIFIED The measured drop angle is 31.2. Measuring device: ________________ Calibration expiration date: ________
MBH	The 500 kg (1100 lb) steel plate has been raised so that the lowest point is 30 ½" above the higest point on the Test Unit and the CG of the Crush Plate is centered over the Test Unit CG ±4 in Measuring device: TTG 9 m measurement wire.
MBH	The steel plate was released to fall onto the Test Unit from a Height of at least 9m (30 ft)
MBH	Videos and high speed films* of the drop were made
MBH	Photographs* of the resulting damage were taken

Sketch Test Setup Here



Sketch Package Damage Here

SEE ATTACHED SHEET

Testing Damage Observations: ____________________

Comments: * NOTE: IMPACT POINT IS CHANGED TO DAMAGED CORNER OF LID IN LIEU OF OPPOSITE END. AJU 12/12/02 12:30

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B Hawk	12/12/02	[signature]	12/12/02 1:30 P.M.
Testing Technician	Date	Witness	Date

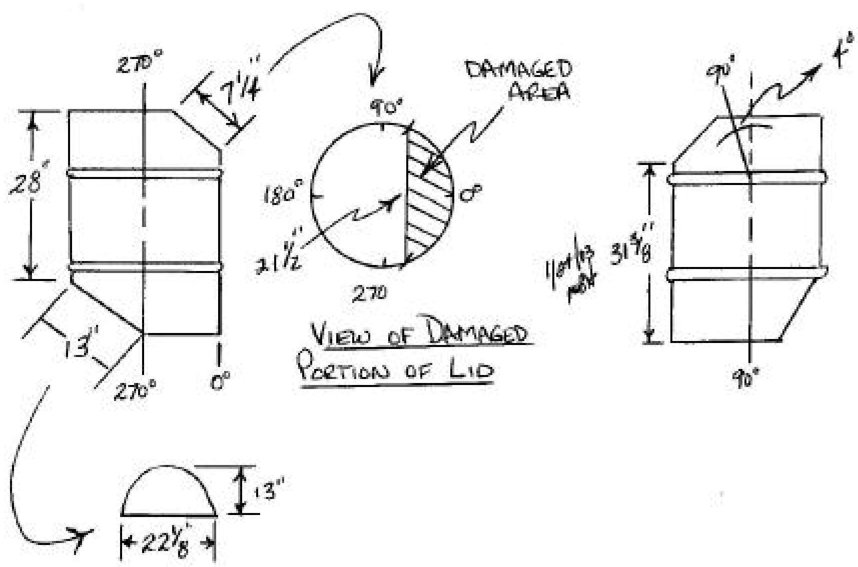
*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

Test Unit TU-4-12/02

TEST FORM 6 (CONTINUED)

SKETCH OF DAMAGE RESULTS

9m (30 ft) CRUSH TEST



VIEW OF DAMAGED FACE BOTTOM CORNER

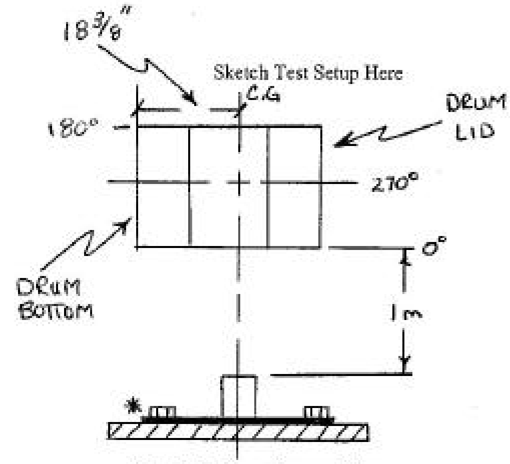
10/17/03

TEST FORM 7
1 m (40 in) PUNCTURE DROP

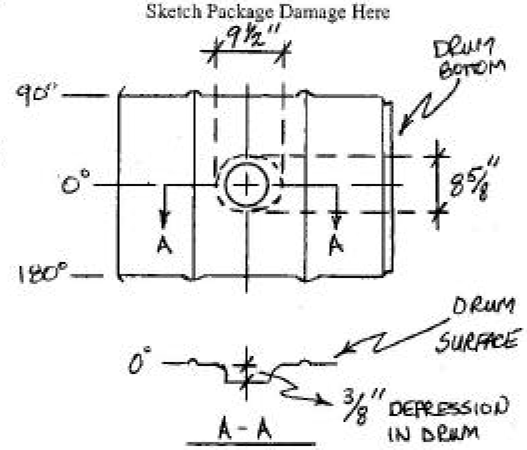
Test Plan:TTG/TP/ES-2100-02, Rev.2
Test Unit TU-4-12/02
Test Location: NTRC, Inside Drop Pad

VERIFIED	TASK
MBH	The Test Unit has been prepared in accordance with the Test Plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
MBH	Still, video and high speed cameras are setup to take photo and video of the drop.
MBH	Ambient temperature of the test: ____°C, (71°F) at the time of 2:35P
MBH	The test drop angle of this unit is 0.0° as specified by Figure 4.8. The measured drop angle is 0.2. Measuring device: 311-006-501 Calibration expiration date: 6-03
MBH	The Test Unit has been raised so that the lowest point is 1m above the steel bar. Measuring device: TTG 1m STICK Calibration expiration date: —

Sketch Test Setup Here



Sketch Package Damage Here



Testing Damage Observations:

LOCATION	DRUM ORIG DIA	DRUM DIM. AFTER DROP	DAMAGED AREA
PT. OF IMPACT	22.5"	21 7/8"	9 1/2" x 8 5/8"

Comments: * PUNCH BAR PLATE IS BOLTED DOWN W/ 4 - 1 INCH BOLTS. BOLTS ARE TORQUE TO 200 FT-LB. TORQUE WRENCH K-4804 — CAL. EXP. DATE: 11/26/03
UPON IMPACT — CAME OUT OF PLUG HOLE

I certify that the above tasks have been performed and that the observations and comments are correct.

Mark B. Hawk	1/26/03	L. B. Shappert	1/26/03
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8A
THERMAL TESTING

Test Plan ________
Test Unit TC-4
Test Location A1940m

VERIFIED	TASK
PTS	The Test Unit has been prepared in accordance with the Test Plan. Forms 1A and 2 are complete and the pre-test weights are recorded on Form 3.
PTS	All thermocouples have been installed on the exterior of drum, furnace and test stand in accordance with the Test Plan, Figures ___, ___, ___, ___ and ___.
PTS	All thermocouples have been surveyed to ensure they are working. (Any malfunctions or erratic performance will be addressed in the comments section below.)
PTS	The thermocouple recorder(s) is set to read every 30 seconds.
PTS	*Photographs of the arrangements for the test have been taken.
PTS	The test package has been preheated to over 38 °C (100 °F). Measuring device: Monitoring system Furnace ch #36 Calibration expiration date: ________
PTS	Furnace has reached the minimum soak point temperature of 800 °C (1475 °F), and has soaked at this temperature for a minimum of 8 hours. The furnace set point temperature has been adjusted to ______ °C (1560 °F) at least one hour prior to each test. Time: 1337 am/pm Date: 4-25-03 1338 door opening
PTS	The unit has been placed in the furnace, on the support stand, with the damaged area up at: Time: 1339 am/pm Date: 4-25-03 Open furnace door time: 65 seconds
PTS	The 31 minute timed test began when 5 out of 6 test unit thermocouples reached the test temperature of 800 °C (1475 °F), as specified in the test plan. Time: 1349 am/pm Date: 4-25-03 30:10 min
PTS	Immediately following the timed test (minimum of 30 minutes at 800 °C) the test unit is taken out of the furnace and allowed to cool naturally. Time: 1419 am/pm Date: 4-25-03 Ambient Temperature ______ °C (69.2 °F)
PTS	The unit stopped outgassing (flames) at __________; outgassing/burnout lapsed time was ________ minutes. 1439 outgassing started 1504 hrs no longer outgassing
PTS	The thermocouple recorder shall be set to record the internal thermocouples at 15 minute intervals for at least 12 hours.

Comments: Original strip chart paper record from furnace controller is included in test records
TC-4 was dropped ~ 4.5 feet immediately outside the furnace.

I certify that the above tasks have been performed and that the observations and comments are correct.

[signature] 4-25-03 [signature] 4/25/03

Testing Technician Date Witness Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 8D
TEMPERATURE INDICATOR READINGS

Test Plan ________
Test Unit TU-4 - 12/2
Test Location ________

A visual inspection of each temperature indicator on the ES-2100 package consisting of those indicators inside the CV stainless steel shot, outside the CV, and on the ES-2100 drum liner shall be made. The values of the blackouts which occurred shall be recorded below. Dimensions identified under the "Height" column are the dimensions from the bottom of the CV or drum liner to the bottom of the temperature indicators.

RECORD BLACKOUT TEMPERATURES AT THESE LOCATIONS:

ES-2100 TEMPERATURE INDICATOR NUMBER LOCATION CHART				
Figure 3.2 – INSIDE OF CV, STEEL SHOT TEMPERATURE @ 12"				
12	1 150 °F		2 150 °F	
Figure 3.2 – ON THE OUTSIDE OF THE ES-2100 CV				
Row/ Height, inches	0°	90°	180°	270°
Bottom	3 175 °F	4 175 °F	5 175 °F	6 176 °F
4.2	7 175 °F	8 175 °F	9 175 °F	10 175 °F
16.8	11 175 °F	12 175 °F	13 175 °F	14 175 °F
Top	15 175 °F	16 175 °F	17 175 °F	18 175 °F
Figure 3.3 – ON THE INSIDE OF THE ES-2100 DRUM INNER LINER				
Row/ Height, inches	0°	90°	180°	270°
Bottom	19 225 °F	20 225 °F	21 225 °F	22 225 °F
5	23 225 °F	24 225 °F	25 225 °F	26 275 °F
12.7	27 225 °F	28 225 °F	29 225 °F	30 225 °F
1ST Ledge	31 350 °F	32 350 °F	33 325 °F	34 300 °F
Plug Bottom	35 375 °F	36 450 °F	37 475 °F	38 450 °F

Comments: Labels Read 4/29/03

I certify that the above tasks have been performed and that the observations and comments are correct.

L.B. [signature] 4/29/03 — RD [signature] 4/29/03

Testing Technician — Date — Witness — Date

*All photographs/movies shall be uniquely identified with Test Unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 13 - **OPERATIONAL LEAK TEST**

Test Plan ES-2100

Test Unit TU-4-12/02

VERIFIED	TASK
______	Post Assembly Leak Test ______ Post Test Leak Test X
______	A leak test in accordance with the CALT5 Manufacturer's Instructions Manual was performed on the CV assembly.
	Leak Tester Cert. # ______ Expiration Date: ______ Leakage Value: ______ ref-cc/sec air

$$Lr = \frac{V * Ts}{3600 * H * Ps}\left(\frac{P1}{T1} - \frac{P1}{T1}\right) ref - cc/\sec$$

Attach CALT5 Printout Here

See printout

$$Lr = \frac{Vcm3 * 298°K}{3600 * \frac{M \min}{60 \min} * 1atm}\left(\frac{P1atm}{T1°K} - \frac{P2atm}{T2°K}\right) ref - cc/\sec$$

$$Lr = \frac{5.181\ cm3 * 4.96667}{6\ \min}\left(\frac{\frac{1938.04 mBar}{1013.25 mBar/atm}}{(25°C + 273)°K} - \frac{\frac{1926.2 mBar}{1013.25 mBar/atm}}{(25°C + 273)°K}\right) ref - cc/\sec$$

$$Lr = \frac{5.181\ cm3 * 4.96667}{6\ \min}\left(\frac{1.9127 atm}{298\ °K} - \frac{1.901\ atm}{298\ °K}\right) ref - cc/\sec$$

4.29872 × .000039262

$Lr = 1.69 \times 10^{-4}\ ref - cc/\sec$

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

RB Mitchell Jr	6-24-03	Mark B Hawk	6/24/03
Testing Technician	Date	Witness	Date

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

n

System Date SAT 02 JUN 1990 11:15:58
CALT No: 0052 Transducer No: 835279
Days since last calibration: ~~516~~ 1-27-03

ORNL
CALT5 - Version V1.43

Pressure Drop
** LEAKAGE TEST **

Test Reference No: CI95001
Design/Serial Nos: F313/3065
Comment: Lid Seal
Interspace Volume: 5.181 cc
Settling Time: 5 mins
Test Duration: 6 mins
Temperature: 25°C
Temperature ratio: 1.000
μ ratio: 1.000
Pass Rate (SLR): 1.0E-04 bar cc/sec
Allowable δP : -19 mbar

*** RESULTS ***
Pressure mbar Date/Time

Atmos: 980.57
Start: 1938.04 02 JUN 1990 11:26:20
Final: 1926.29 02 JUN 1990 11:32:20

Leakage Rate: 6.1E-05 bar cc/sec

PASS

Standard conditions:
Temperature: 25°C
Up stream pressure: 1013 mbar
Down stream pressure: 0 mbar

Sig: [signature] Date: 4-30-03
(Tested by)

Sig: [signature] Date: 4-30-03
(Supervisor)

Appendix E

Additional Photos of TU-1 Tests

Package Preparation

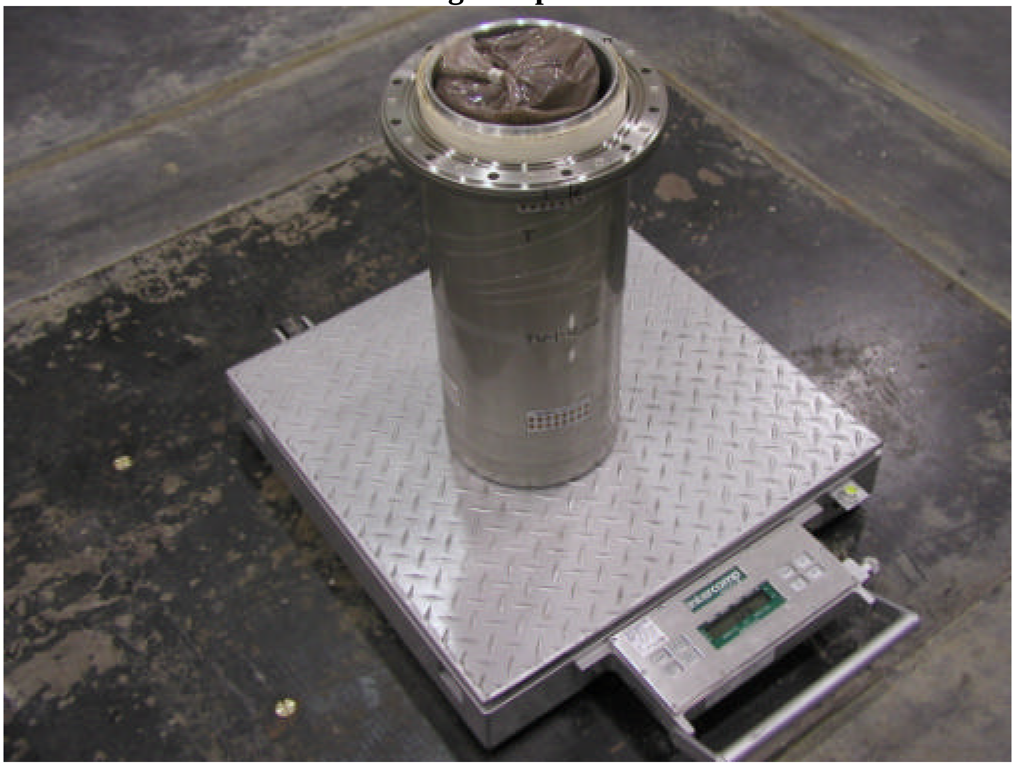


Figure E 1. Weighing CV with aluminum sleeve and steel shot.

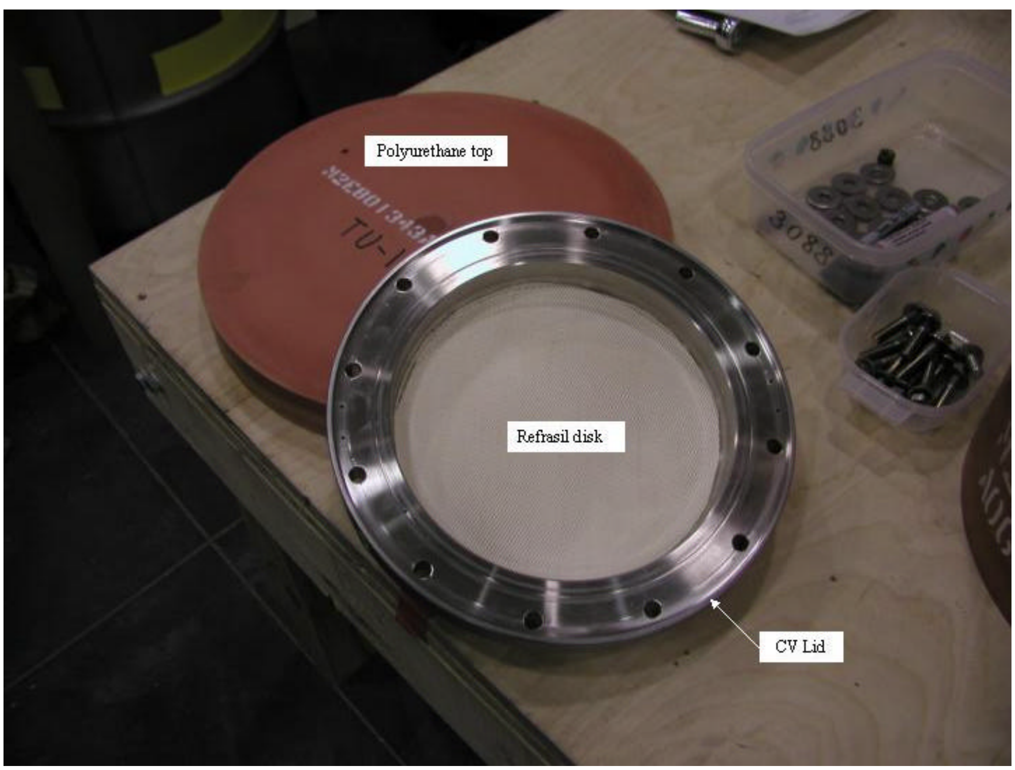


Figure E 2. CV lid with Refrasil disk and Polyurethane top.

Figure E 3. Closed containment vessel (CV) showing temperature labels and leak check port

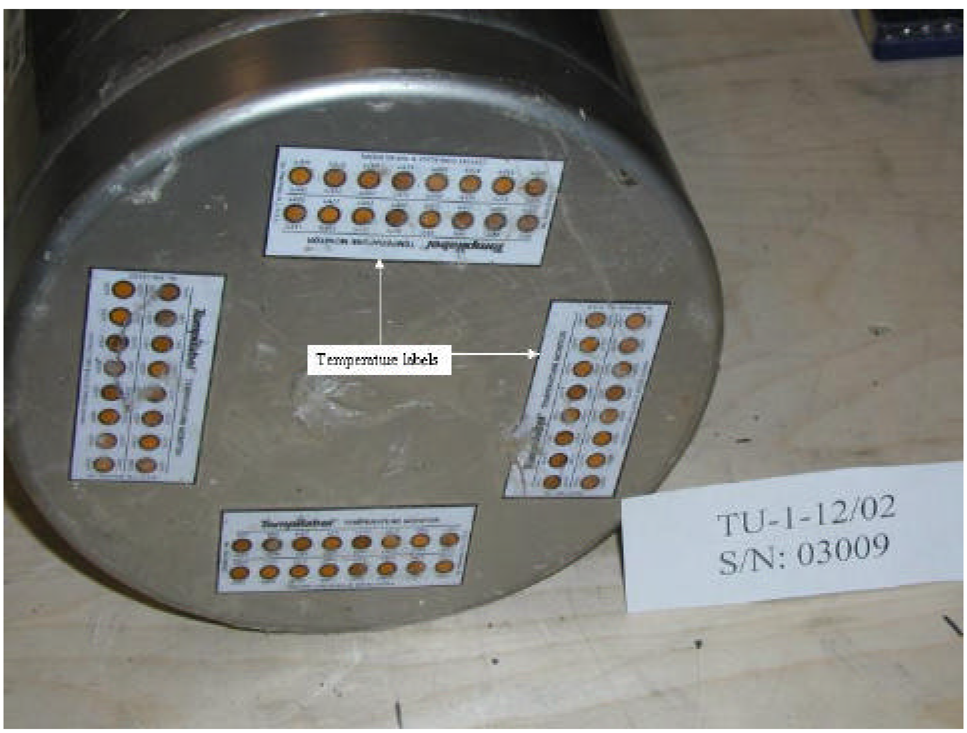


Figure E 4. Temperature labels on the bottom of the CV.

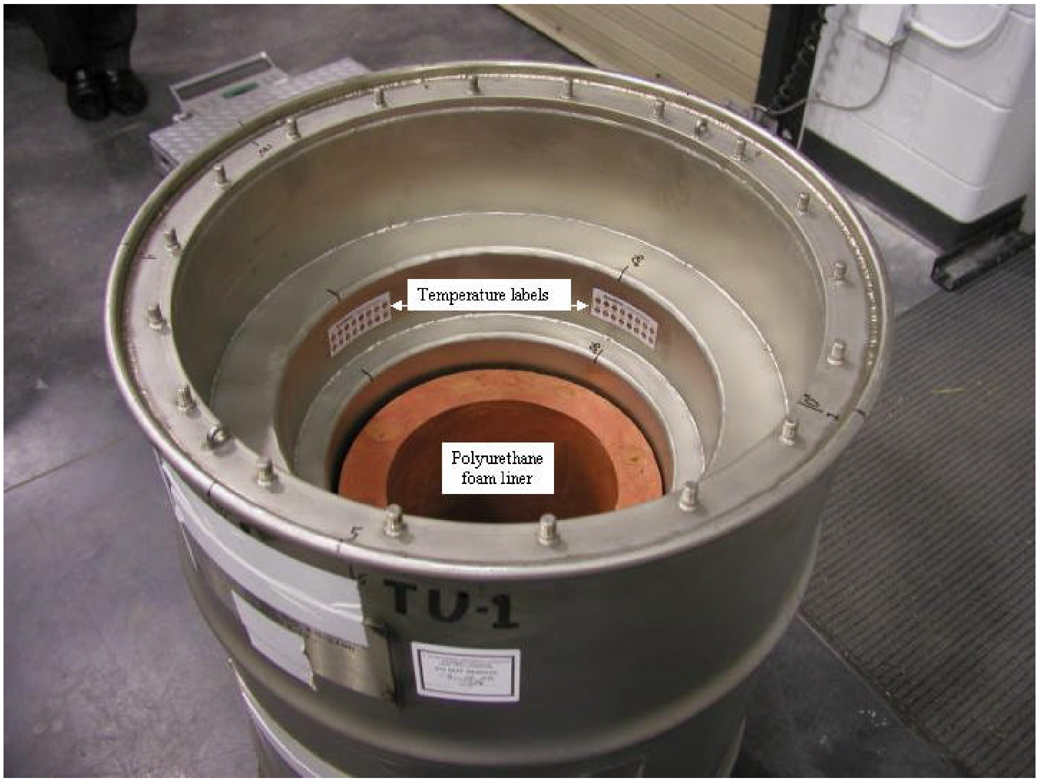


Figure E 5. View of open TU-1 package prior to CV insertion.

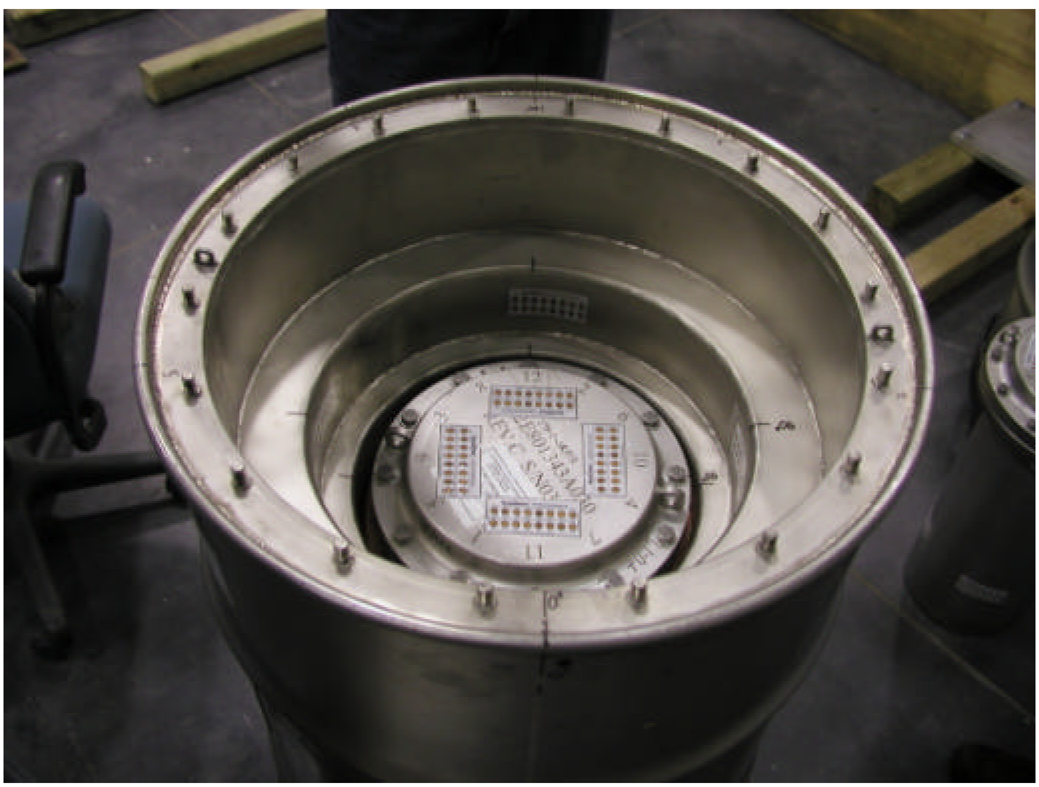


Figure E 6. View of open TU-1 package with CV in place.

Figure E 7. Top view of TU-1 with the top plug in place.

Figure E 8. Torquing the bolts on TU-1 lid.

Normal Condition of Transport (NCT) Tests

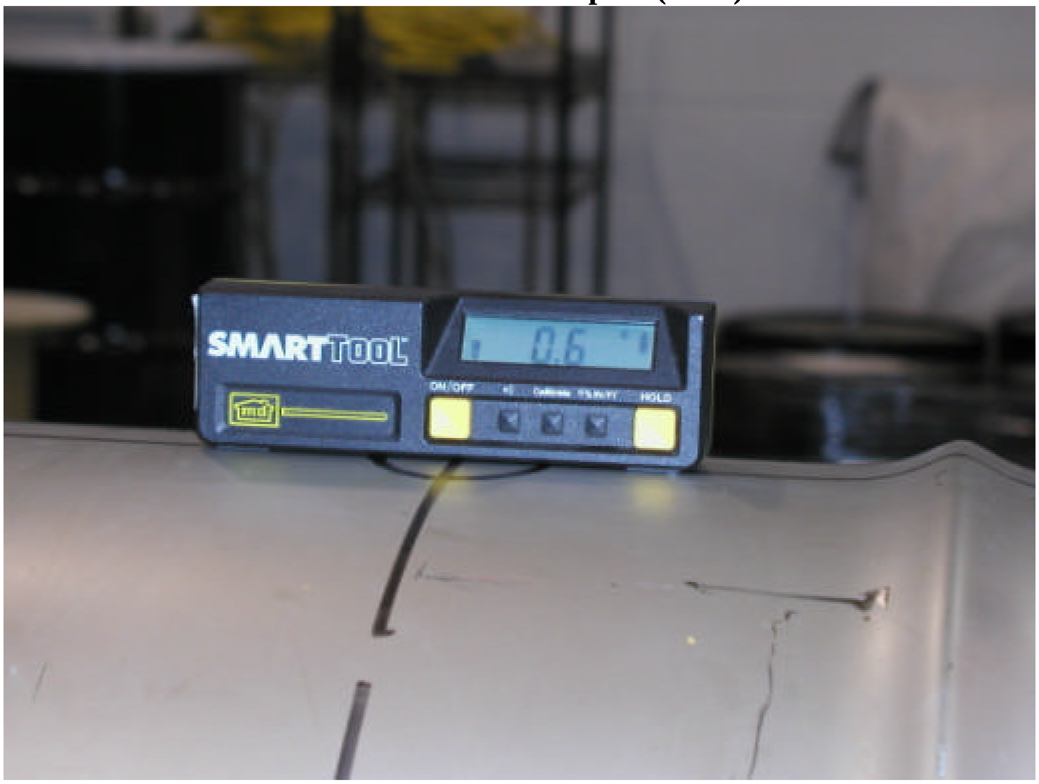


Figure E 9. Measuring how close TU-1 is to horizontal prior to the drop.

Figure E 10. TU-1 package on the drop pad after NCT drop test.

Figure E 11. Top end view of damage to TU-1 on the 0° line – package has been rolled 180°.

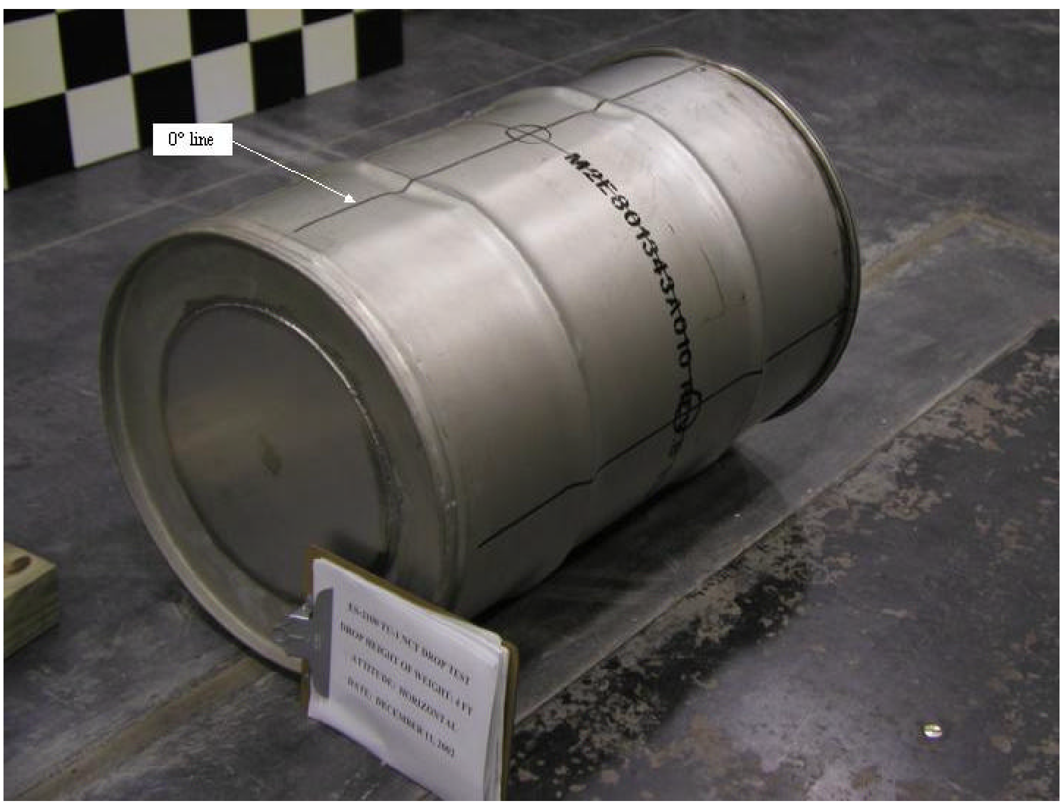


Figure E 12. Bottom end view of damage to TU-1 on the 0° line – package has been rolled 180°.

Hypothetical Accident Condition (HAC) 30-ft Drop Test

Figure E 13. End view of TU-1 lid after the HAC 30-ft drop on the 0° line.

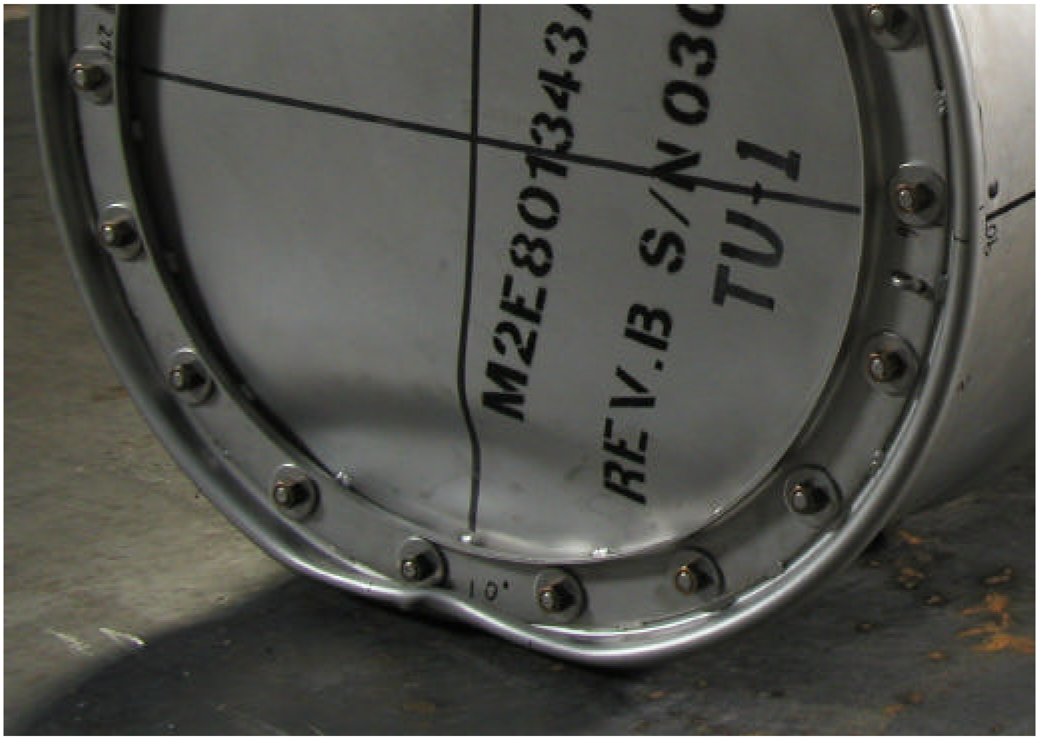


Figure E 14. Close up of damage to the lid area.

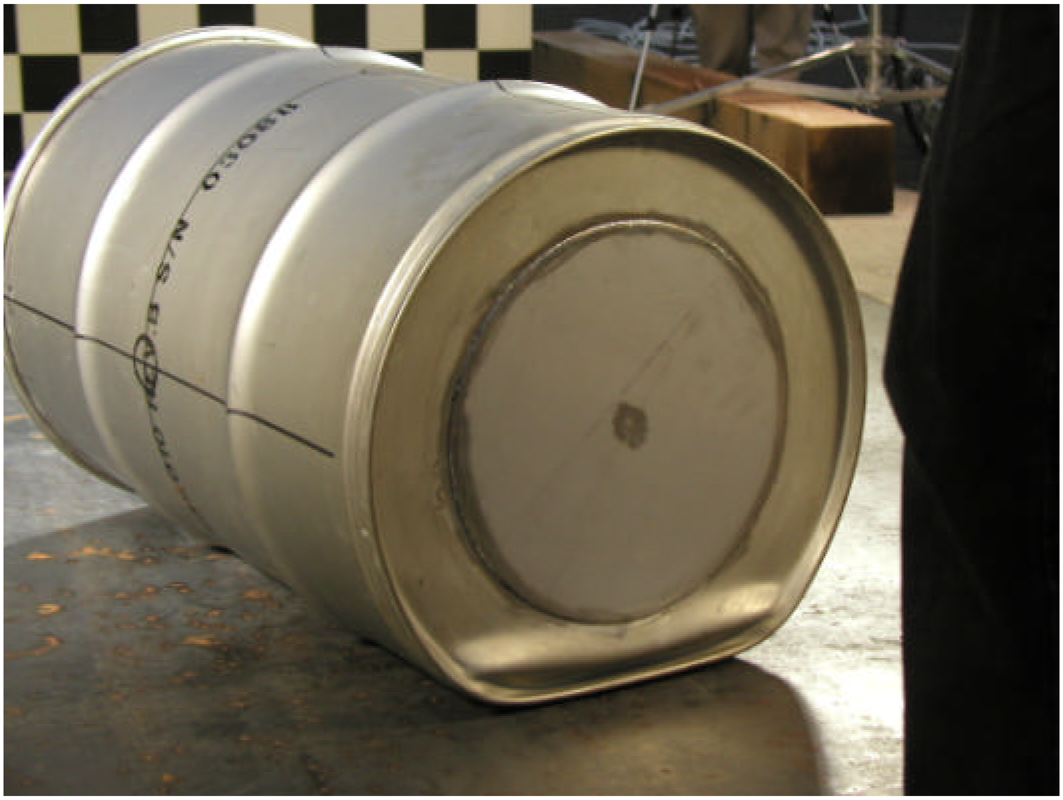


Figure E 15. End view of TU-1 bottom after the HAC 30-ft drop on the 0° line.

Figure E 16. Close-up of damage to the bottom area.

Figure E 17. View of damage along the 0° line from lid end.

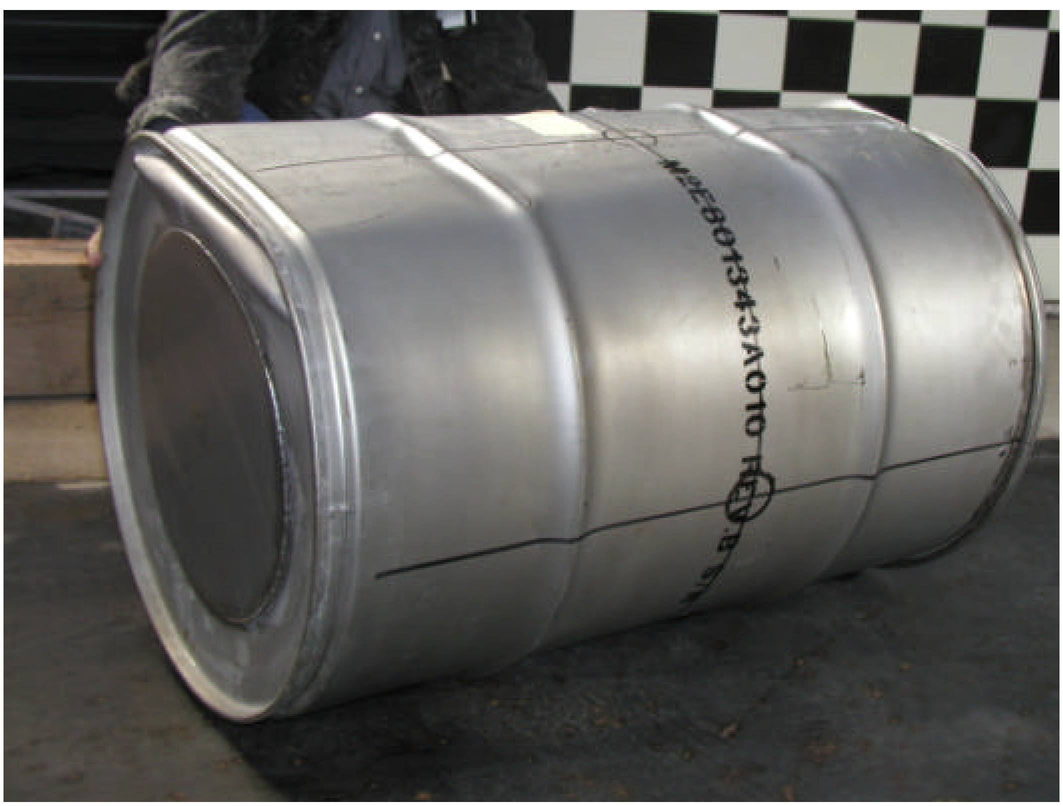


Figure E 18. View of damage on 0° line from bottom end.

Hypothetical Accident Condition (HAC) Crush Test

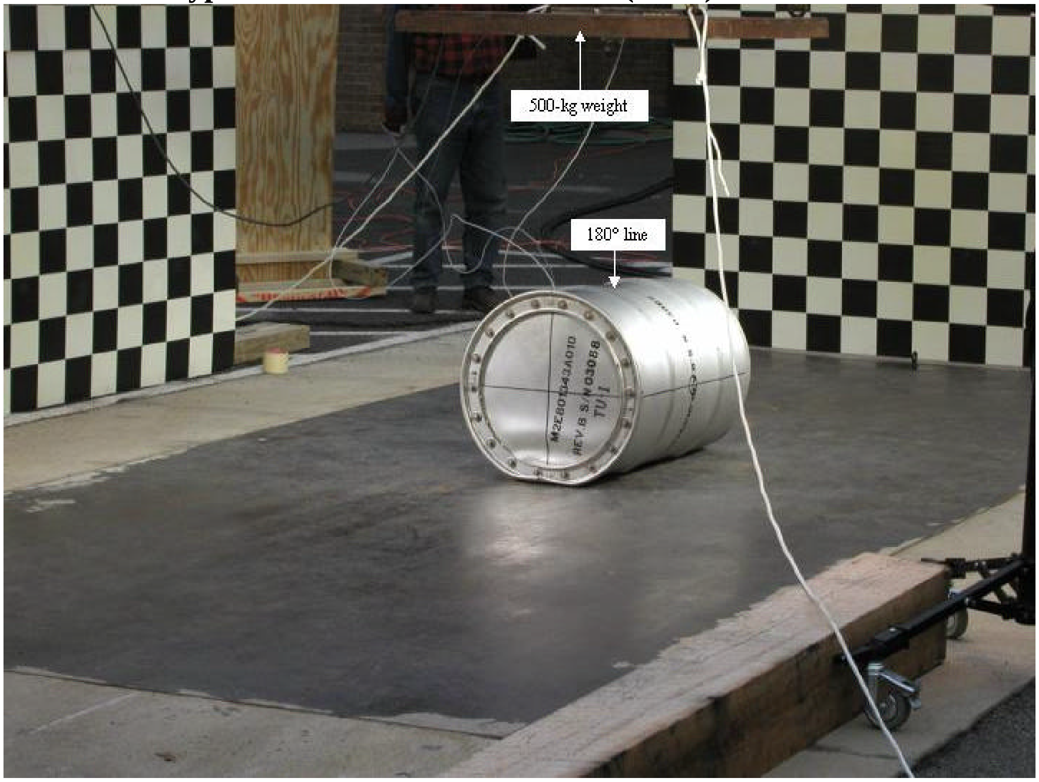


Figure E 19. Set-up for the crush test with TU-1 resting on the already-damaged 0º line.

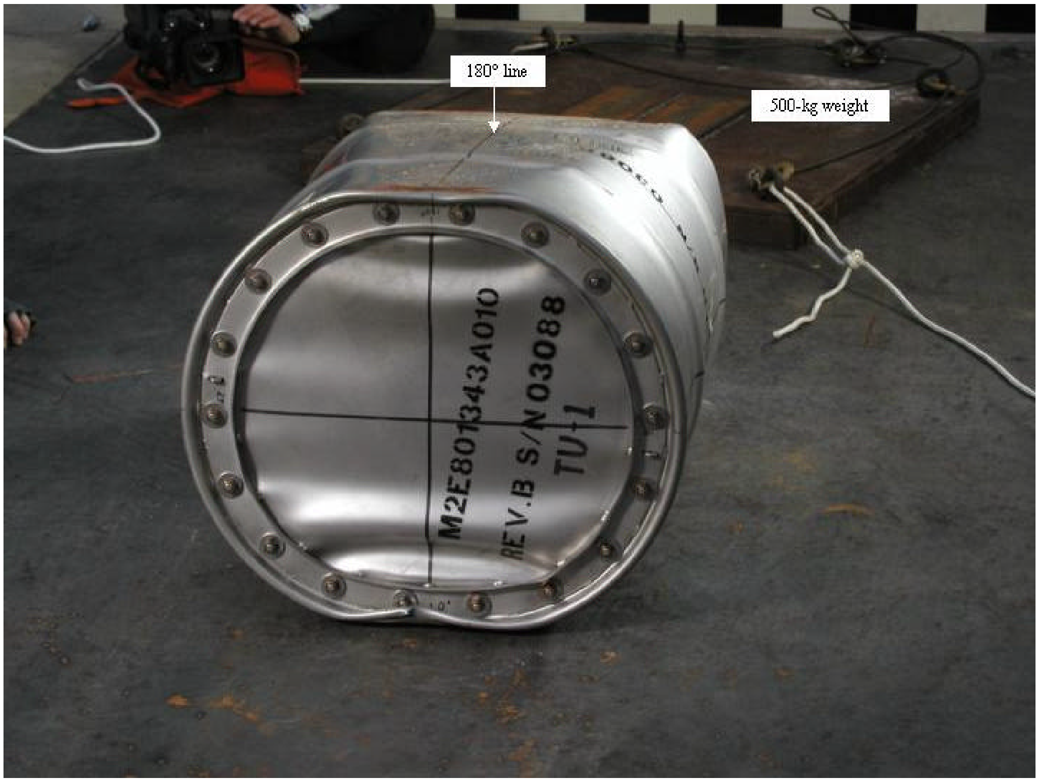


Figure E 20. Results of the crush test on the lid end with 500-kg weight impacting on the 180º line.

Figure E 21. Close up of damage to the lid end on the 180º line from the crush test.

Figure E 22. Close up of damage to the lid end on the 0º line from the crush test.

Figure E 23. Detail of damage to the lid at the 0º line after the crush test.

Figure E 24. Results of the crush test on the bottom end with 500-kg weight impacting on the 180º line.

Figure E 25. Detail of damage to the bottom end of TU-1 in the area identified in Figure E.24.

Hypothetical Accident Condition (HAC) Punch Test

Figure E 26. Measuring the angle of the of the top (180º line) surface relative to the horizontal 0º line.

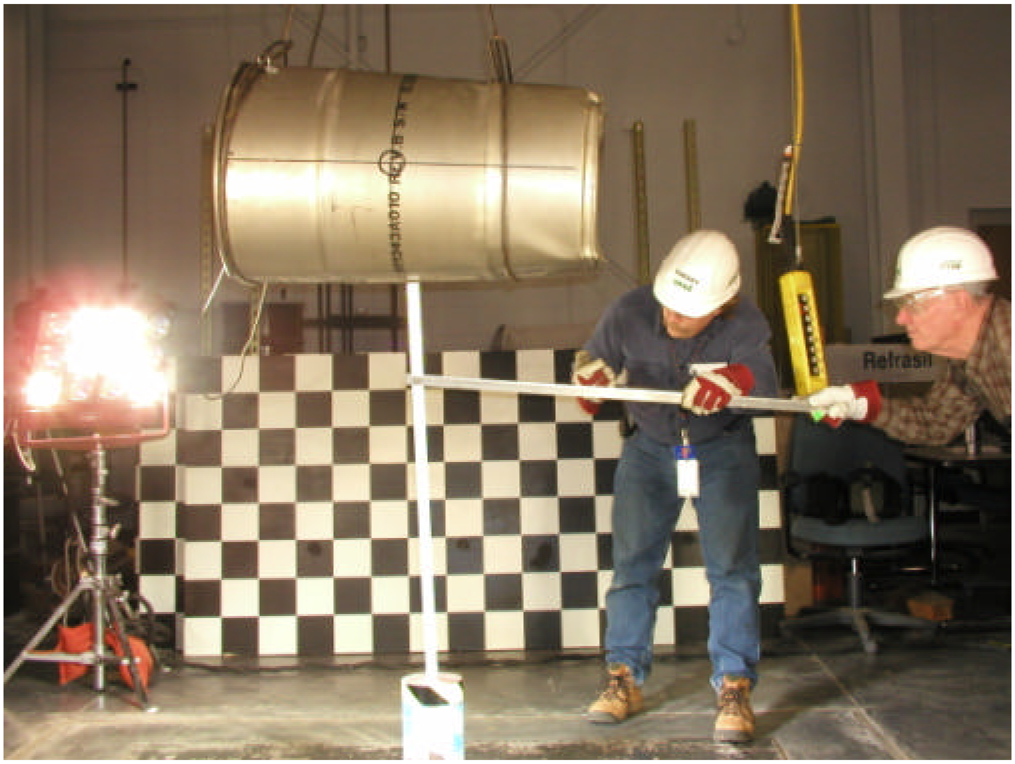


Figure E 27. Measuring the drop height of the TU-1 package above the punch.

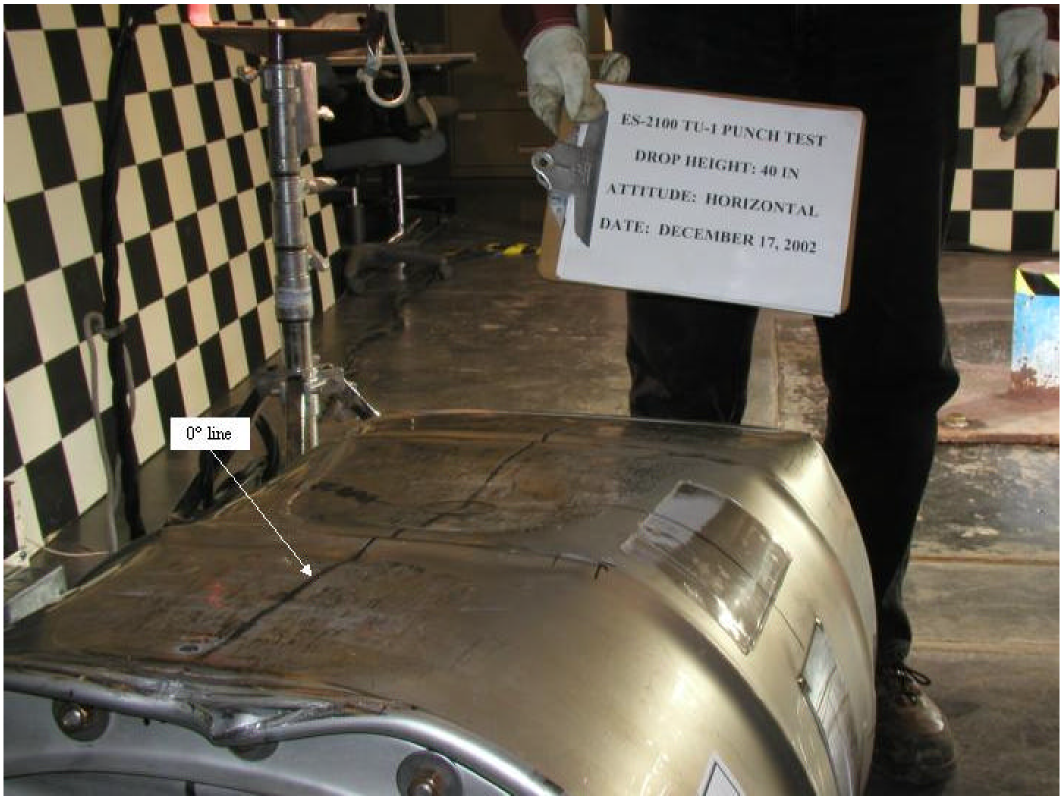


Figure E.28. Damage to TU-1 from the drop onto a punch over the CG on the 0º line.

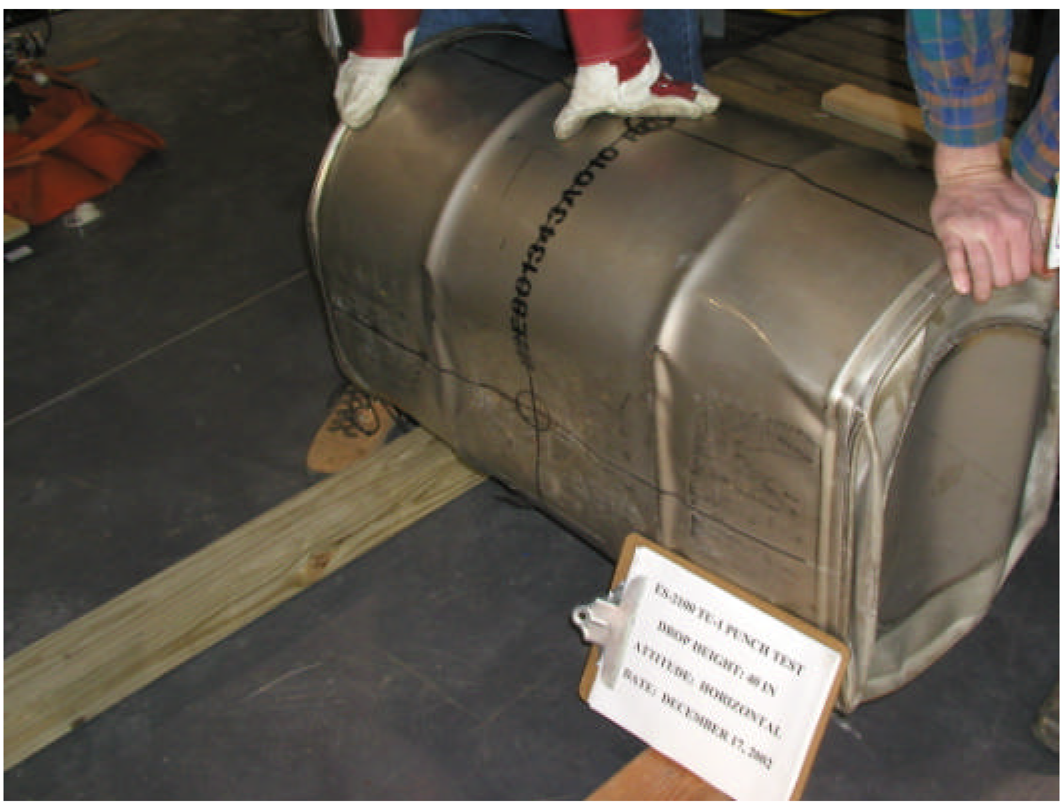


Figure E.29. Side view of the damage from a drop on a punch over the CG on the 0º line.

Figure E.30. Melted foam oozing from the package after Thermal Test.

Appendix F

Additional Photos of TU-2 Tests

Package Preparation

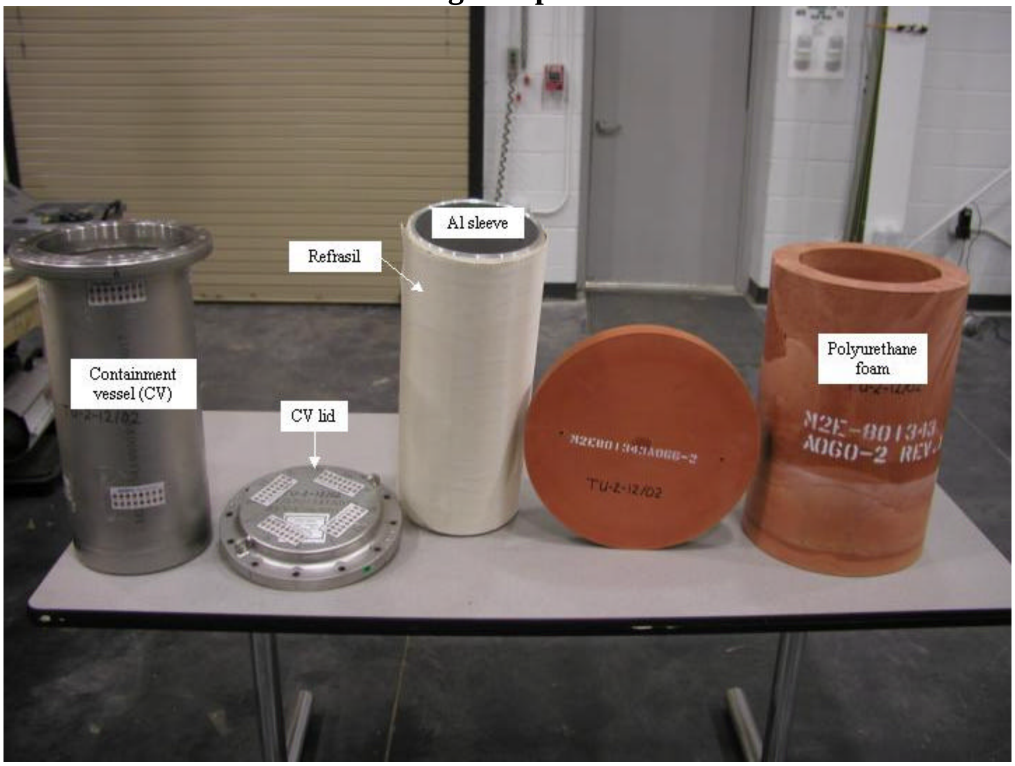


Figure F 1. Contents of TU-2 package.

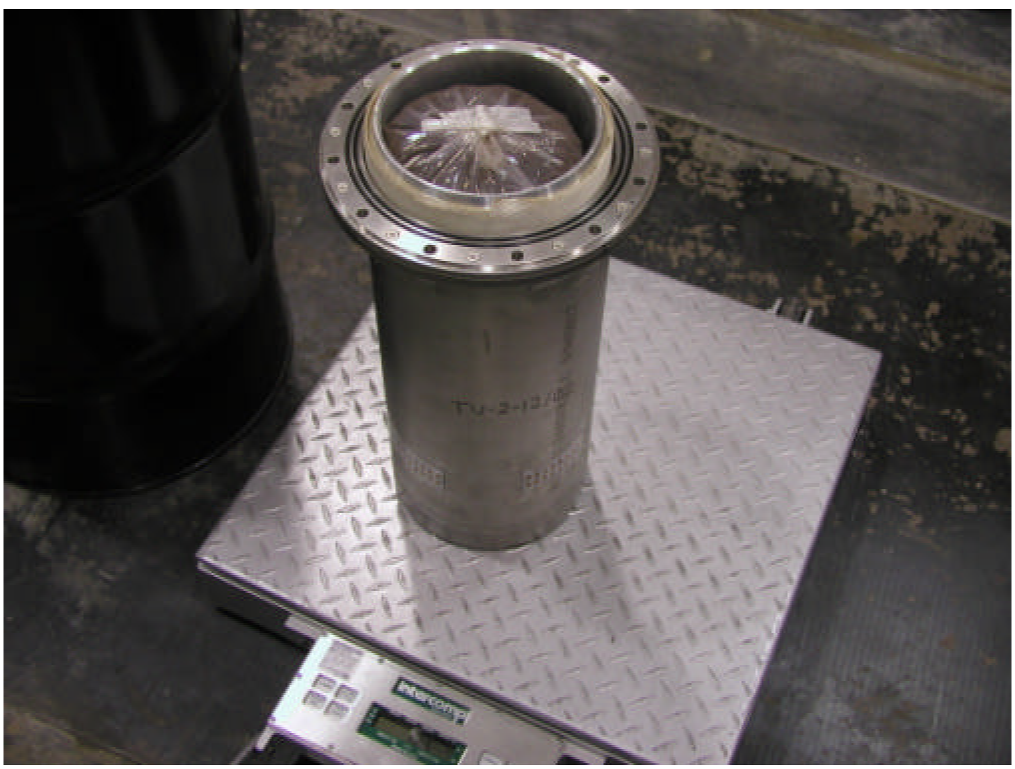


Figure F 2. Weighing the CV, Al sleeve, and surrogate payload (steel shot).

Figure F 3. Sealed CV for TU-2 with temperature labels in place.

Figure F 4. Bottom of CV for TU-2 with temperature labels in place.

Figure F 5. Marking specific locations on the drum.

Figure F 6. Lowering the CV into TU-2.

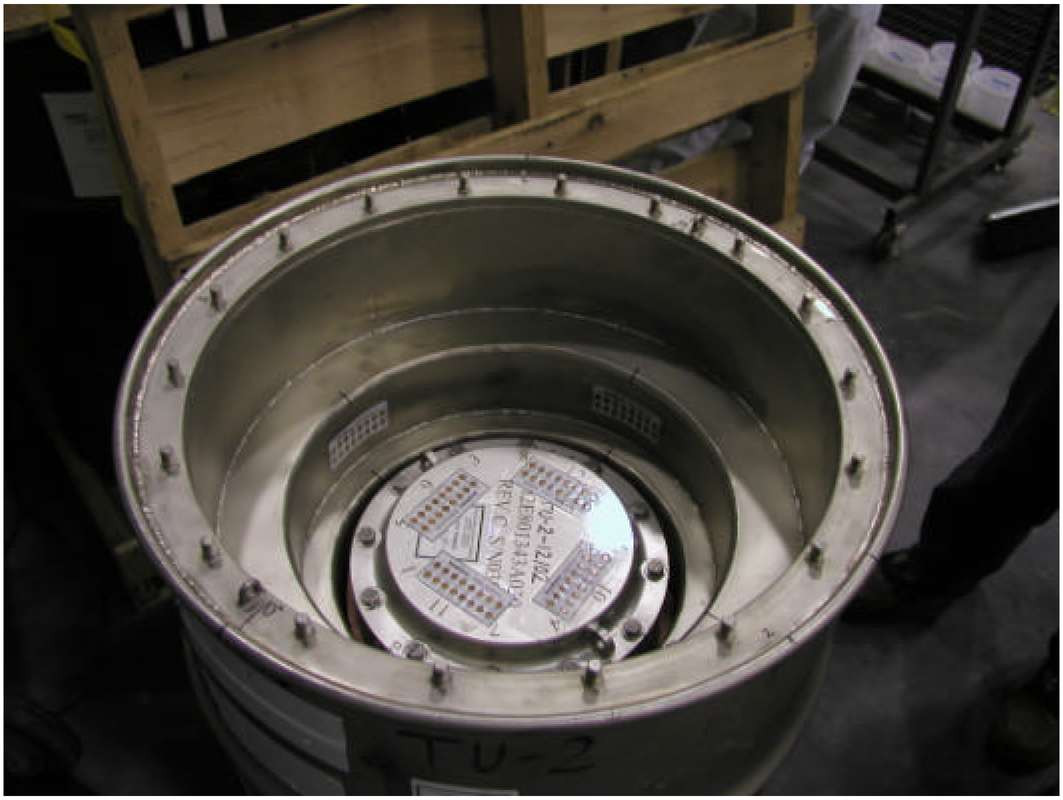


Figure F 7. View of open TU-2 with the CV in place.

Figure F 8. Insertion of the top plug in the TU-2.

Figure F 9. Torquing the bolts on TU-2.

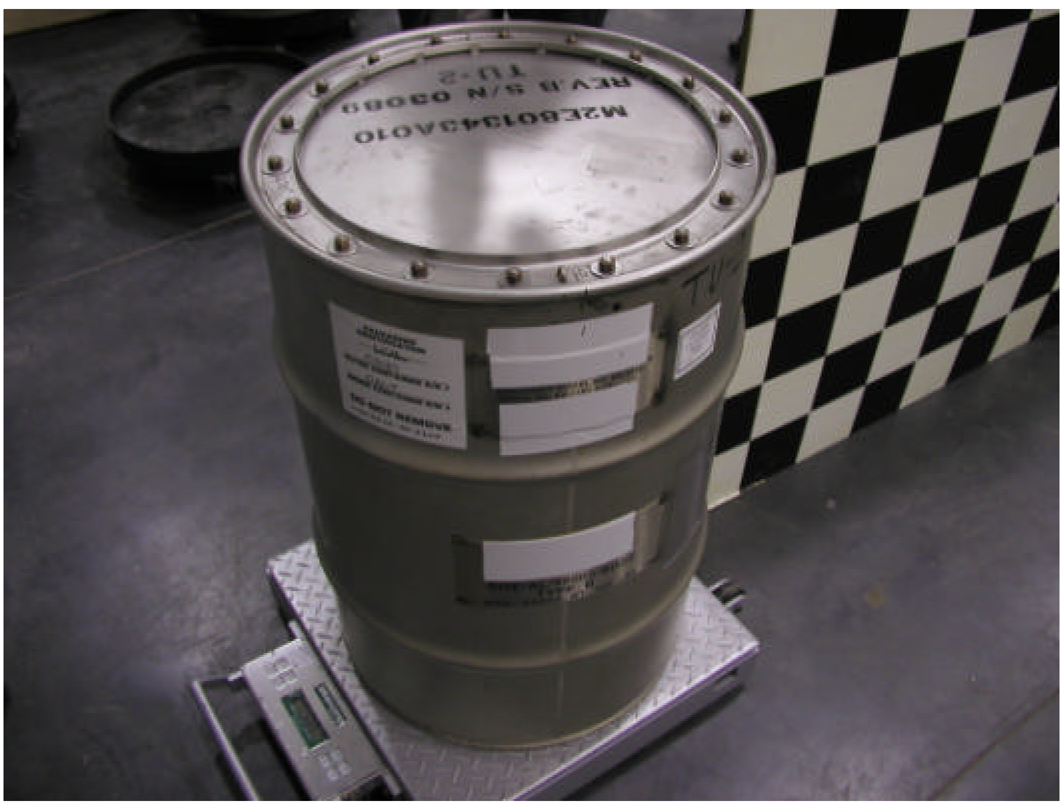


Figure F 10. Weighing the completed TU-2 package.

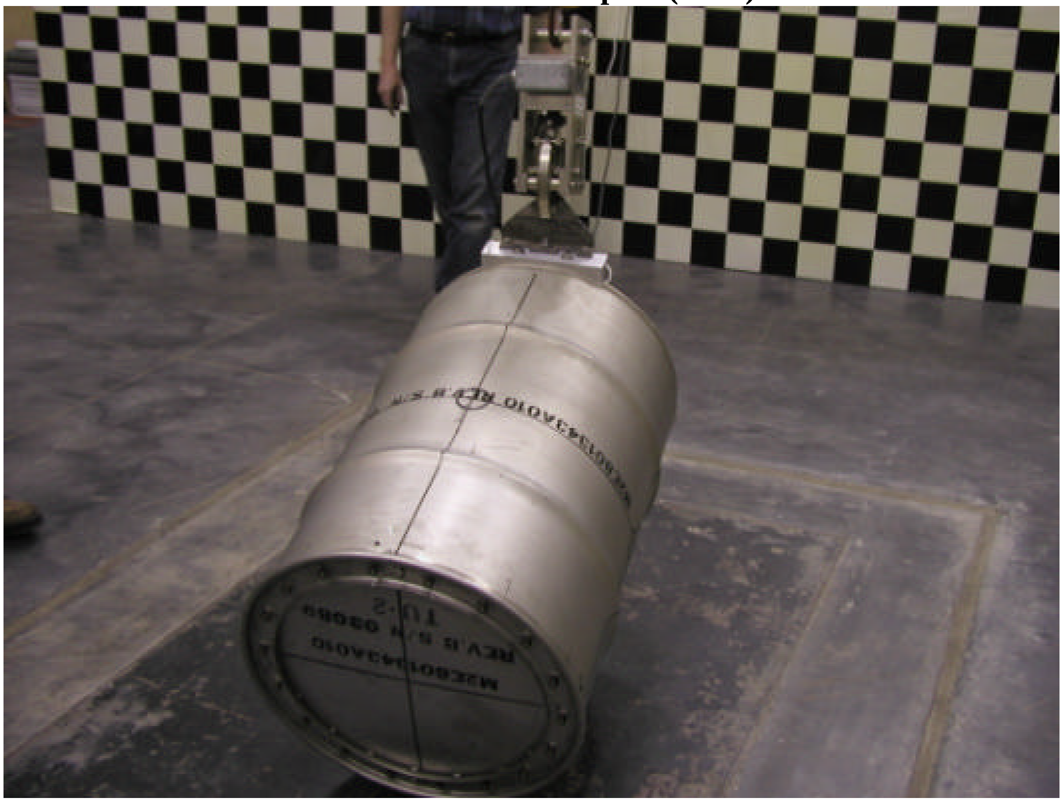


Figure F 11. Preparing TU-2 for a CG-over-corner drop

Figure F 12. Measuring the drop angle on the bottom of TU-2.

Figure F 13. Measuring the drop height of TU-2.

Figure F 14. View of the drop test of TU-2 at the moment of impact.

Figure F 15. Damage to the lid end from the NCT CG-over-corner drop.

Figure F 16. Top view of damage to the lid from the NCT CG-over-corner drop.

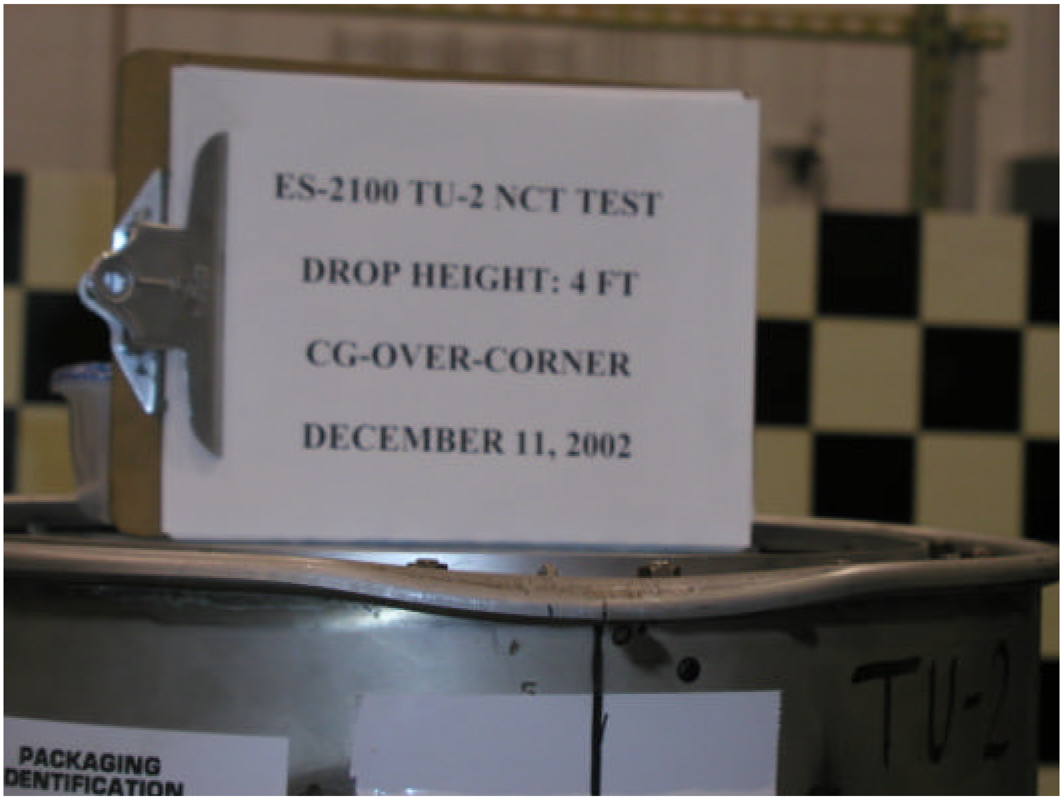


Figure F 17. Close-up of damage to edge of the lid from the CG-over-top-corner drop – front view.

Figure F 18. Close-up of damage to edge of the lid from the CG-over-top-corner drop – side view.

Hypothetical Accident Condition (HAC) 30-ft Drop Test

Figure F 19. Measuring the drop angle on the side of TU-2 prior to drop test.

Figure F 20. Measuring the drop angle on the bottom of TU-2 prior to drop test.

Figure F 21. End view of TU-2 lid after HAC 30-ft drop on the 0º line.

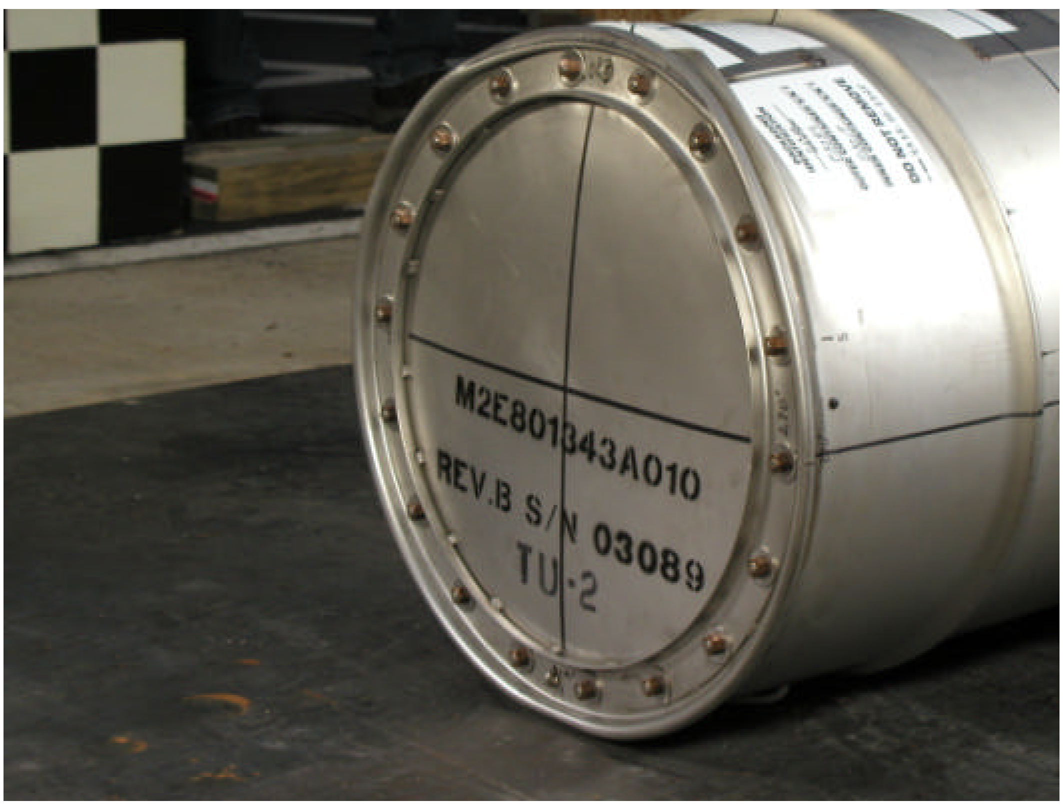


Figure F 22. Close-up of damage to the lid area.

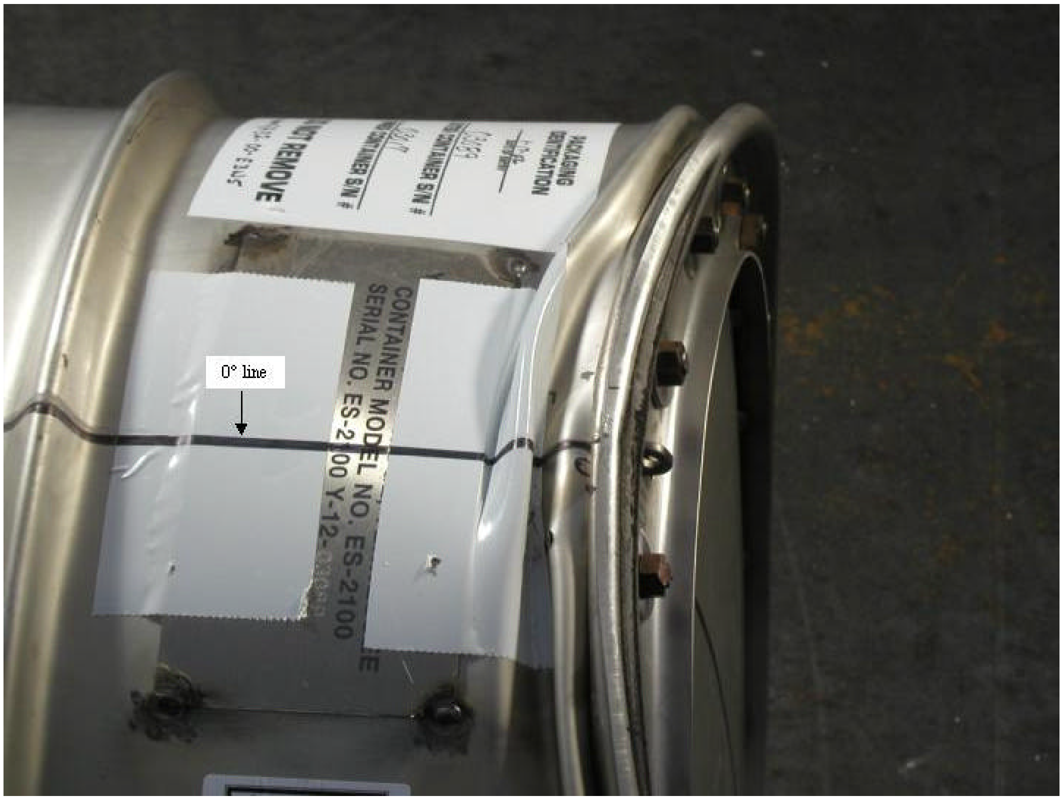


Figure F 23. Close-up of damage to the lid area from the HAC 30-ft drop at the 0º line.

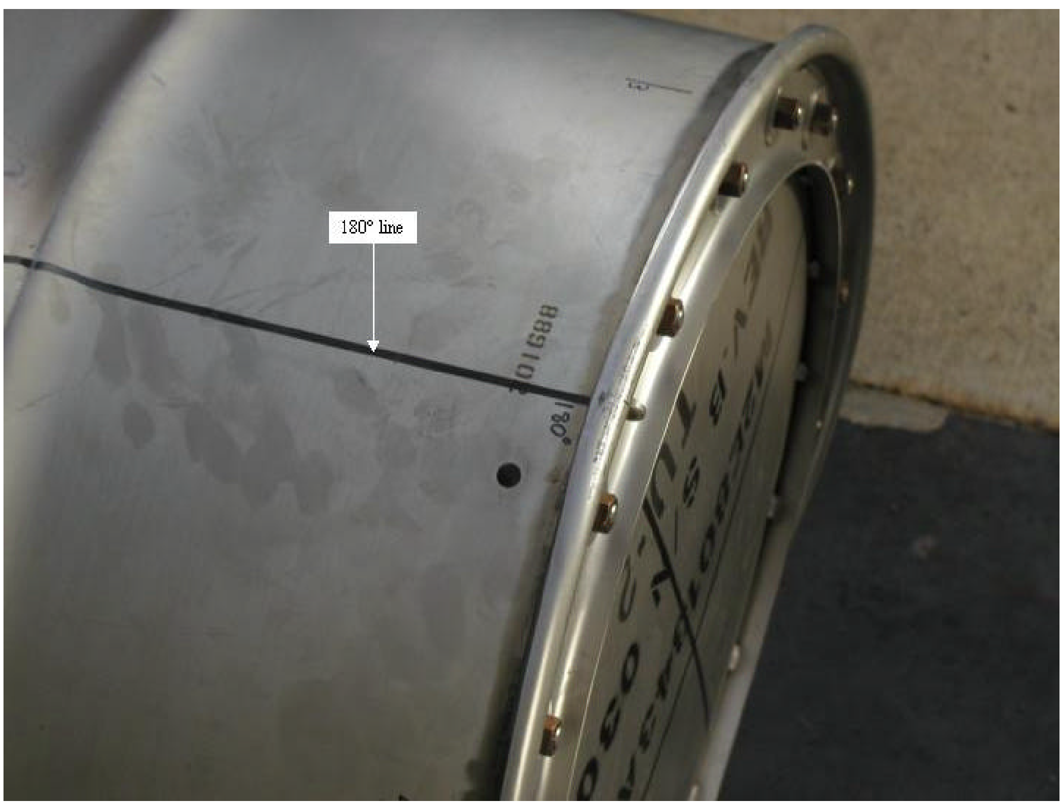


Figure F 24. Close-up of damage to the lid area from the HAC 30-ft drop at the 180º line.

Hypothetical Accident Condition (HAC) Crush Test

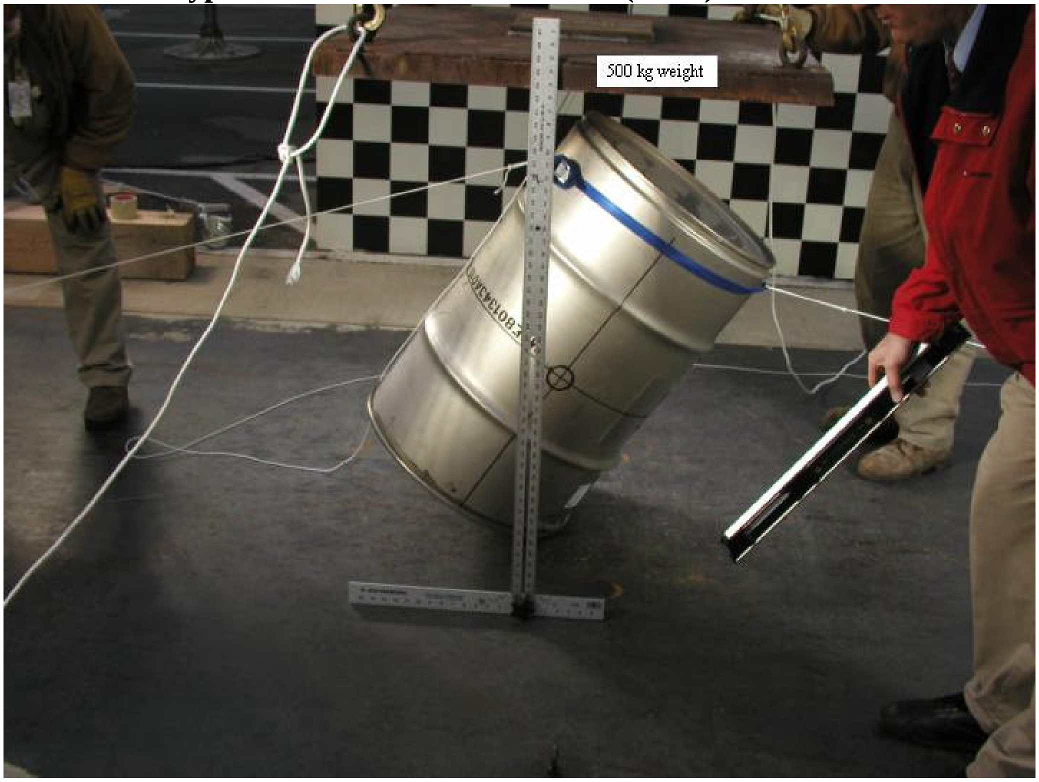


Figure F 25. Set-up for the crush test with TU-2 balanced on edge of lid and held with nylon cords.

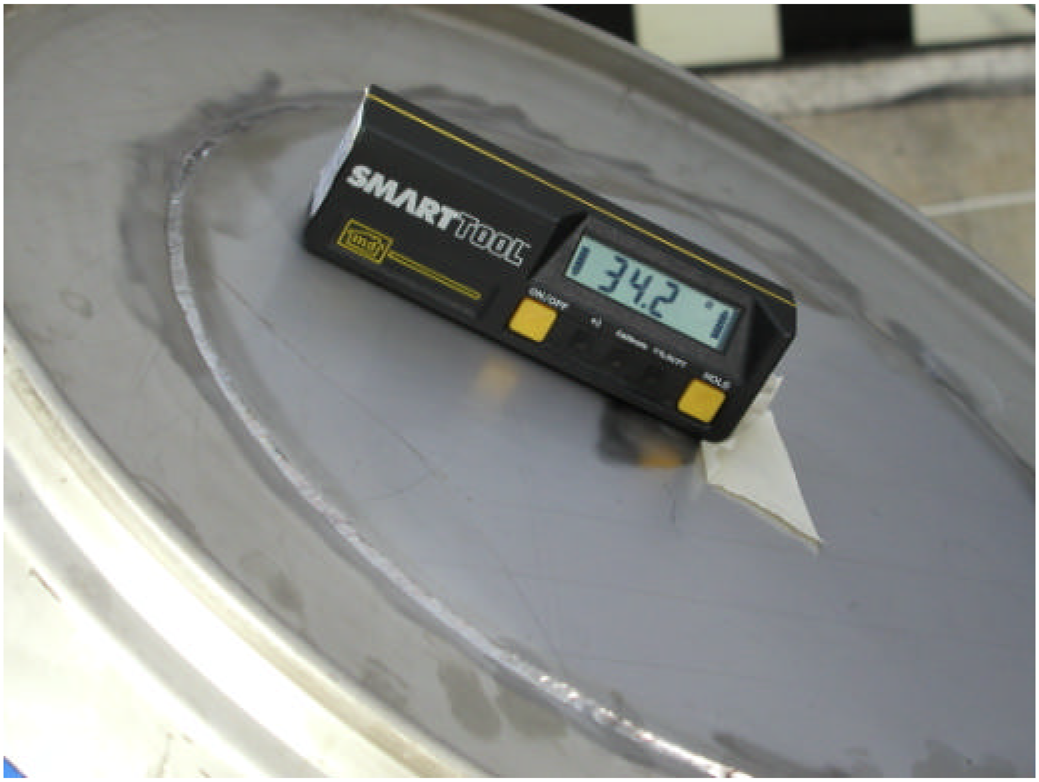


Figure F 26. Measurement of angle of drum bottom prior to drop.

Figure F 27. Aligning the 500 kg weight to the bottom edge of TU-2.

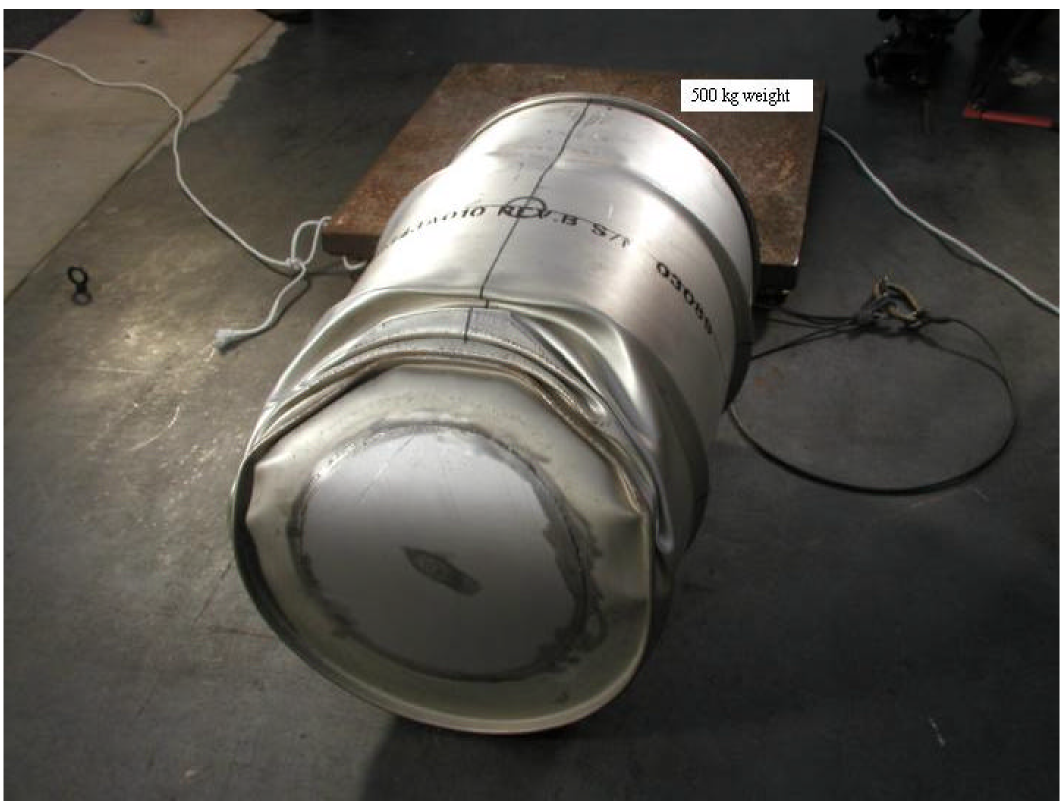


Figure F 28. Damage to the bottom edge of TU-2 after being hit with the 500 kg crush weight.

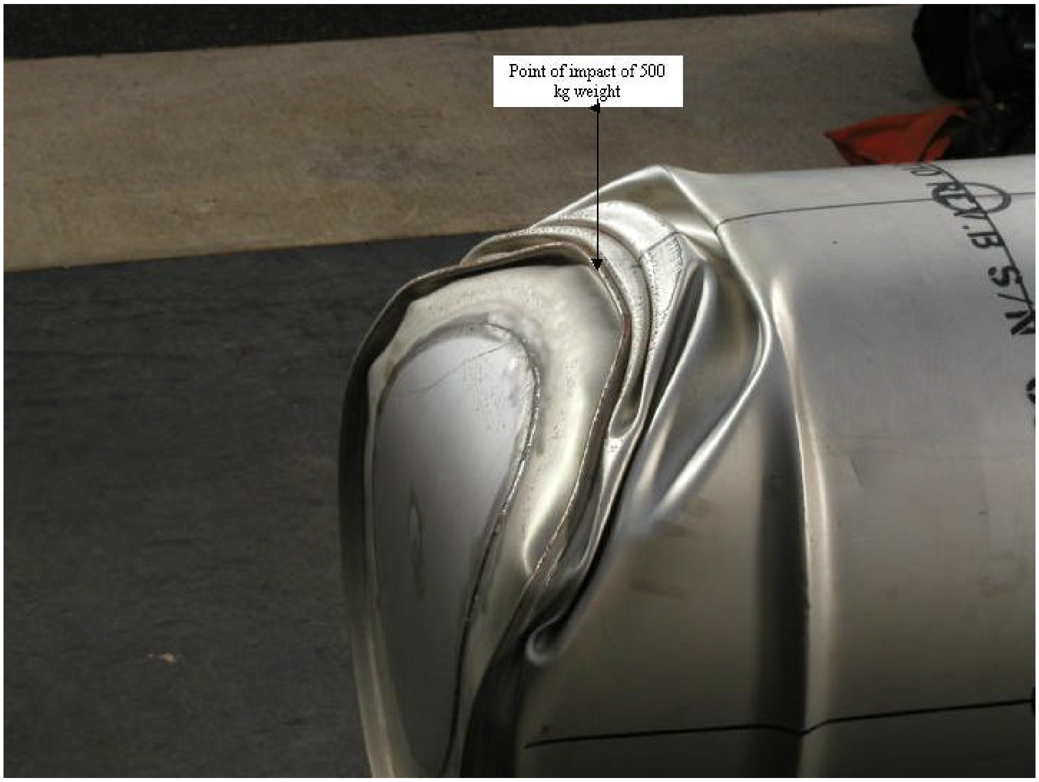


Figure F 29. Close-up of damage to the bottom of TU-2 at point of impact.

Figure F 30. View of TU-2 lid following the HAC crush test.

Figure F 31. Close-up of damage to lid of TU-2 following the crush test.

Hypothetical Accident Condition (HAC) Punch Test

Figure F 32. Removal of the name plate in preparation for the punch test of TU-2.

Figure F 33. Removal of name plate completed.

Figure F 34. Positioning TU-2 over the punch.

Figure F 35. Measuring the height of TU-2 above the punch.

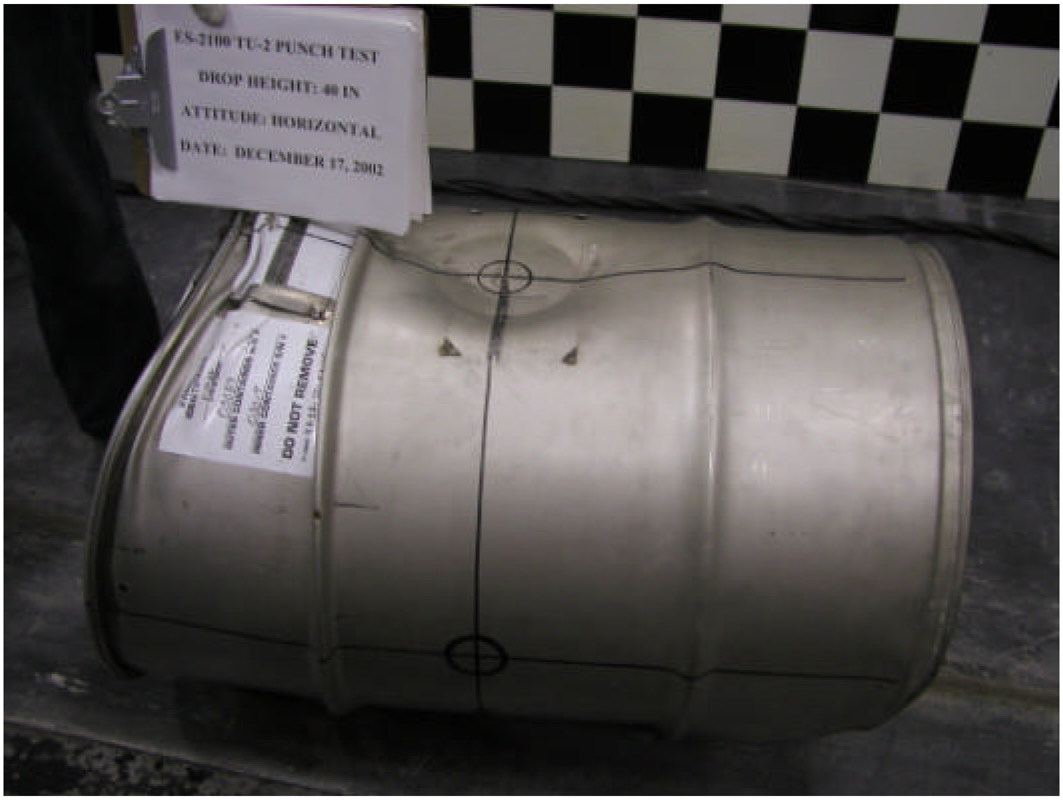


Figure F 36. Damage to TU-2 from the drop onto a punch over the CG on the 0º line.

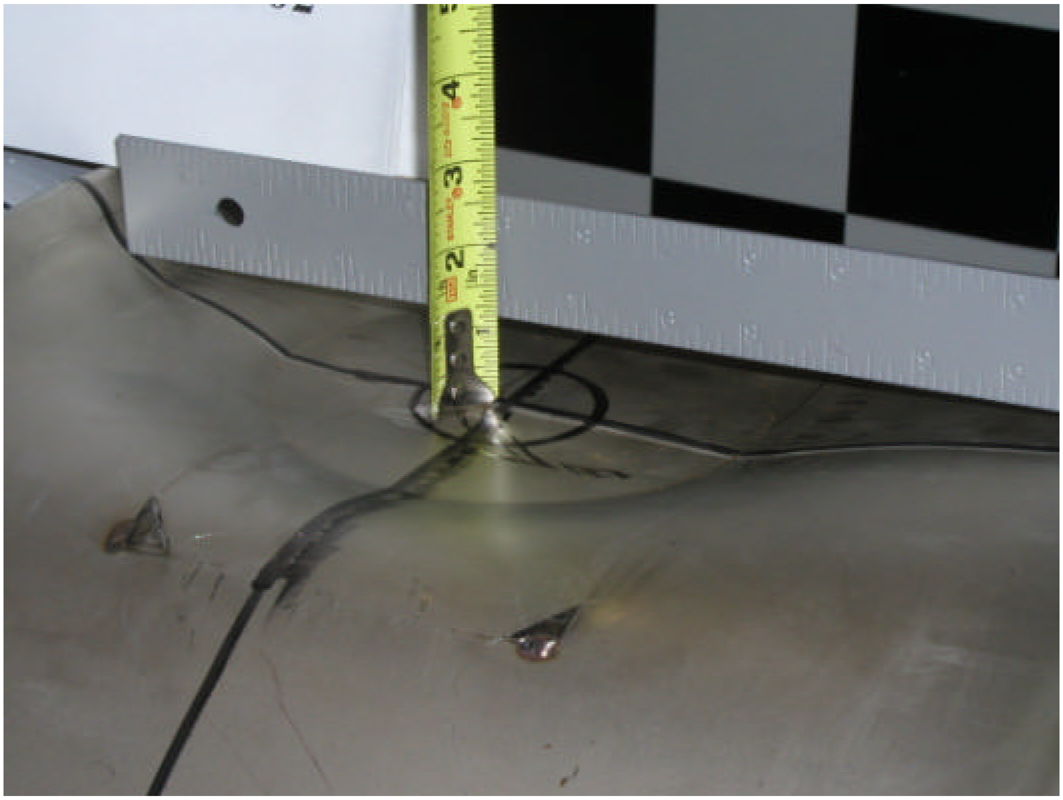


Figure F 37. Measurement of the indentation caused by the punch test.

Figure F 38. Damage to TU-2 from the punch test as viewed from the top end of the package.

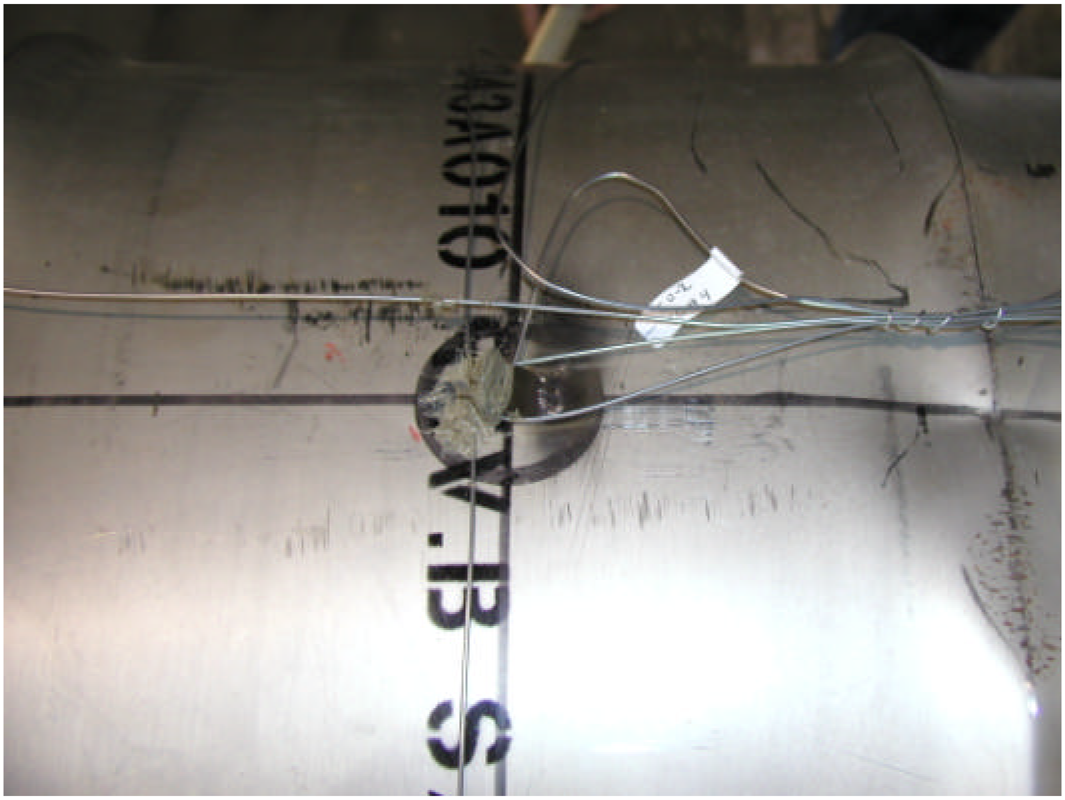


Figure F 39. Thermocouples attached to TU-2 just prior to placing into the Furnace.

Figure F 40. TU-2 during removal from the Furnace.

Figure F 41. Removing TU-2 from the Furnace.

Figure F 42. Removing TU-2 from the Furnace.

Appendix G

Additional Photos of TU-3 Tests

Package Preparation

Figure G 1. Contents of TU-3 package.

Figure G 2. Weighing the CV, Al sleeve, cap, and surrogate payload (steel shot).

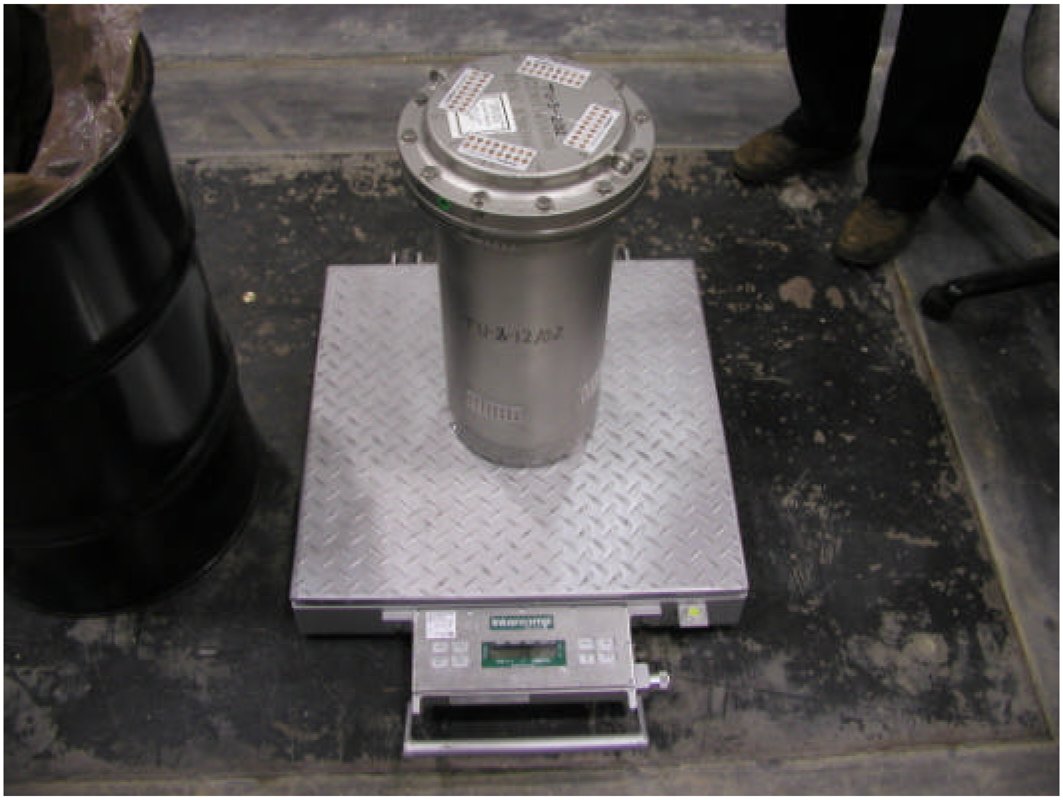


Figure G 3. Sealed CV for TU-3 with temperature labels in place.

Figure G 4. Leak testing the sealed CV.

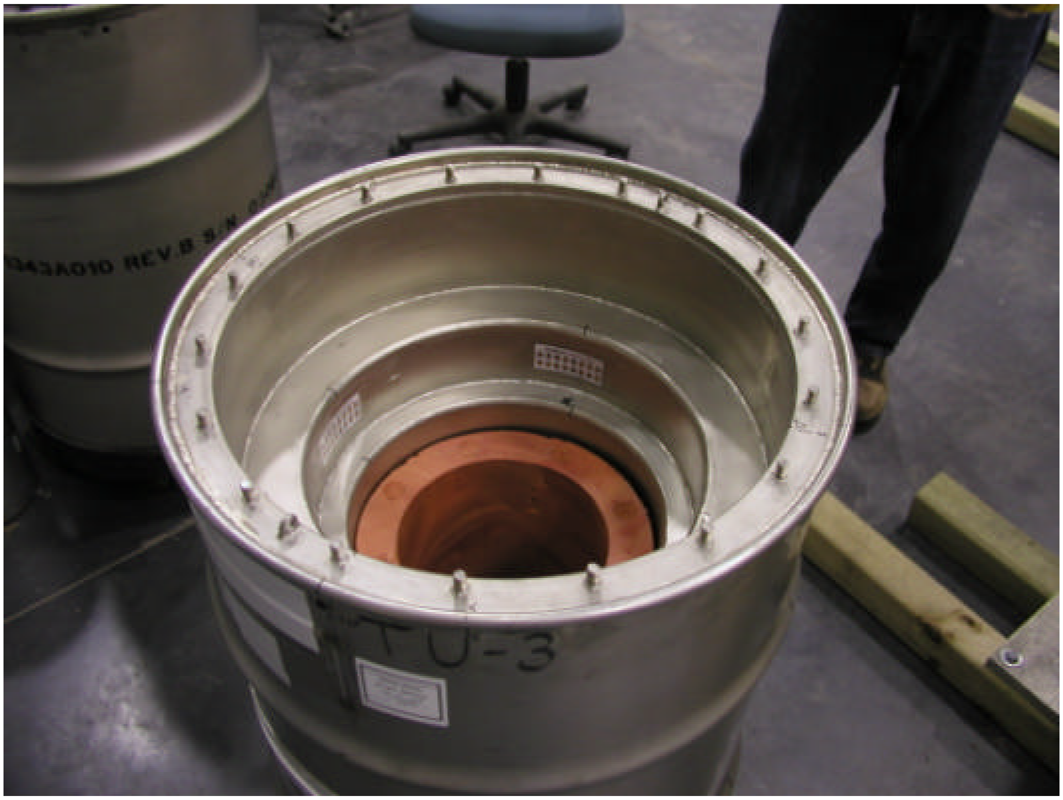


Figure G 5. Preparation of TU-3 to accept the CV.

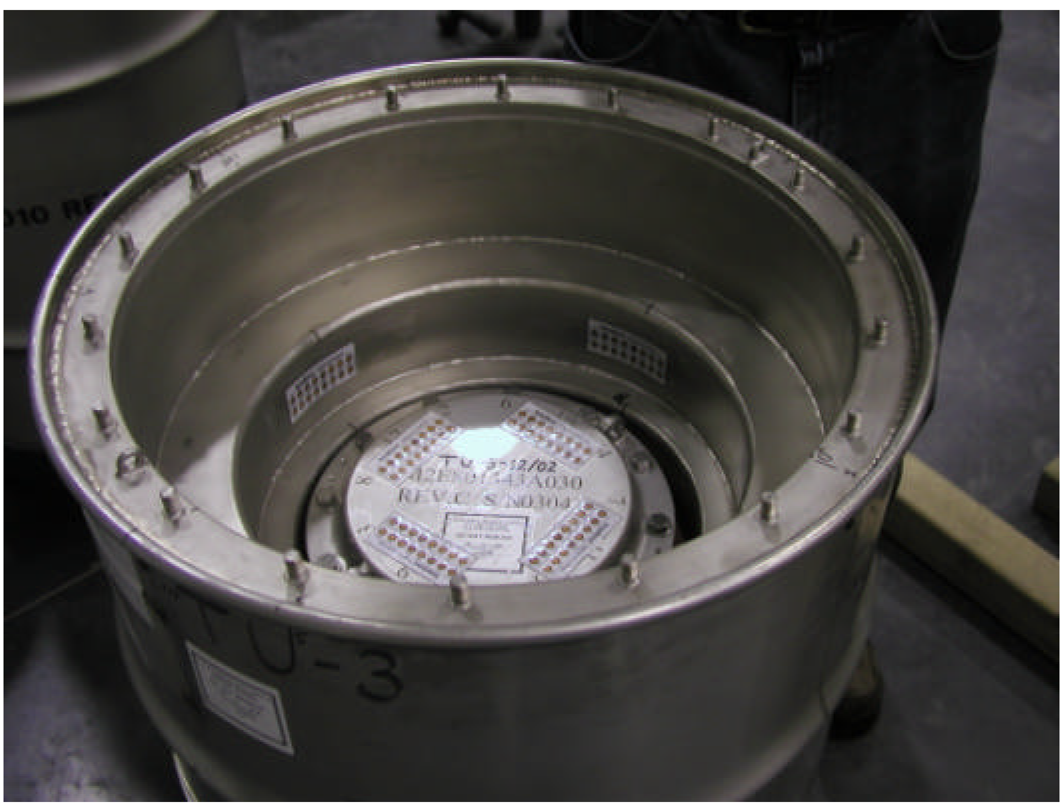


Figure G 6. View of open TU-3 with CV in place.

Figure G 7. Top plug after insertion in the TU-3.

Figure G 8. Weighing the completed TU-3 package.

Normal condition of Transport (NCT) Tests

Figure G 9. Measuring how close TU-3 is to horizontal prior to the drop.

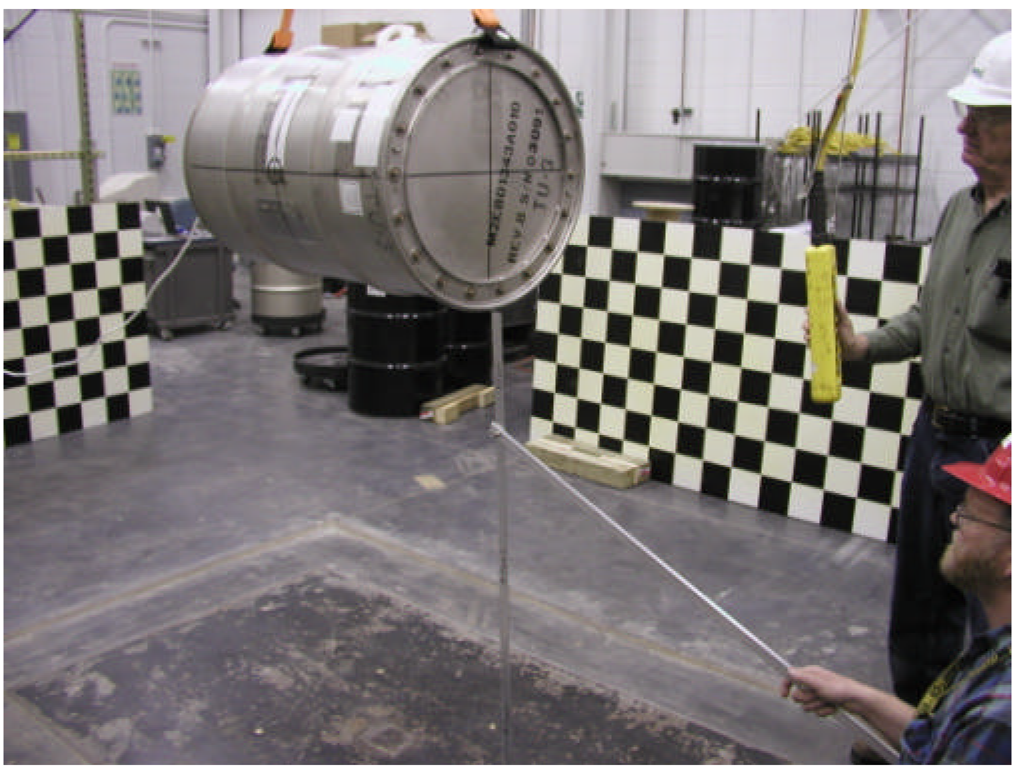


Figure G 10. Measuring the drop height of TU-3.

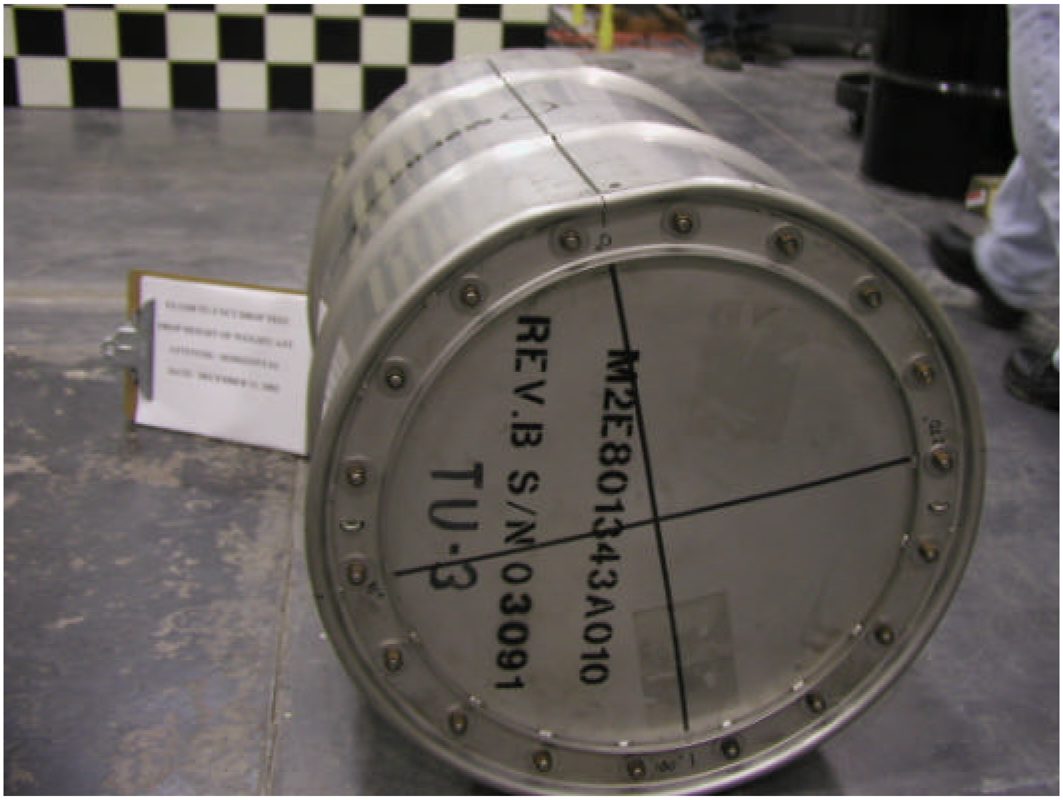


Figure G 11. Top end view of damage to TU-3 on the 0º line – package has been rolled 180º.

Figure G 12. Bottom end view of damage to TU-3 on the 0º line – package has been rolled 180º.

Hypothetical Accident Condition (HAC) Crush Test

Figure G 13. Aligning the center of the 500-kg weight with the center of TU-3 prior to test.

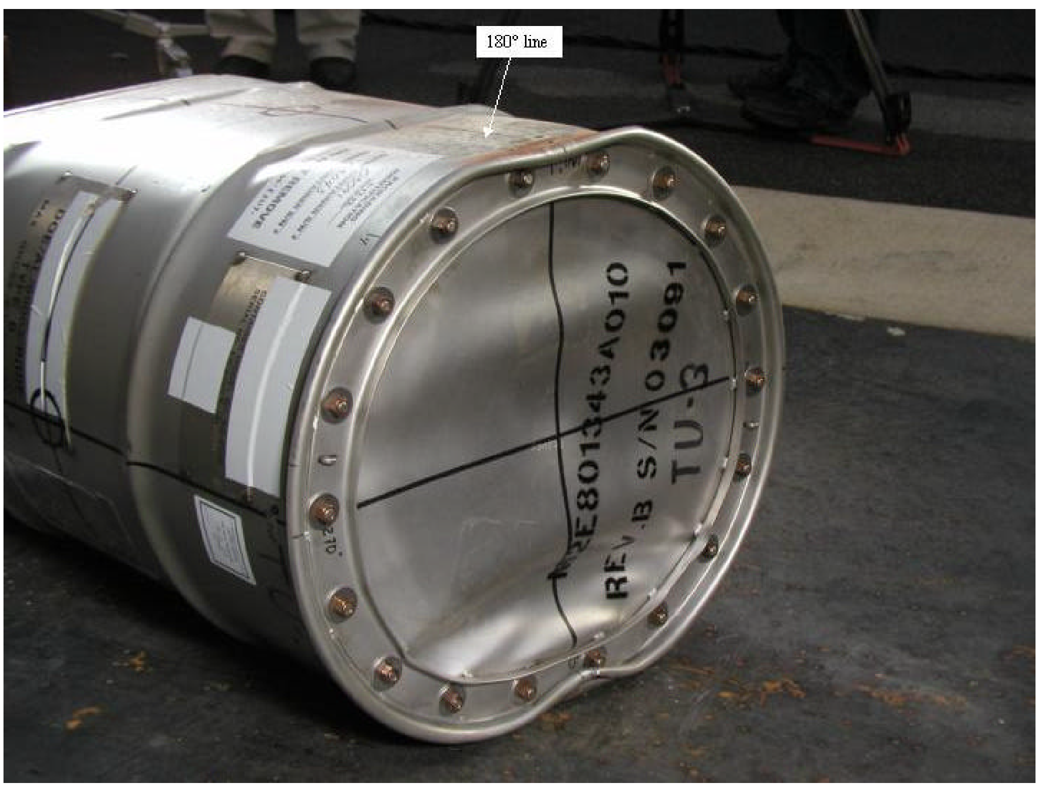


Figure G 14. Results of the crush test on the lid end with the 500-kg weight impacting on the 180° line.

Figure G 15. Close up of damage to the lid end on the 0º line from the crush test.

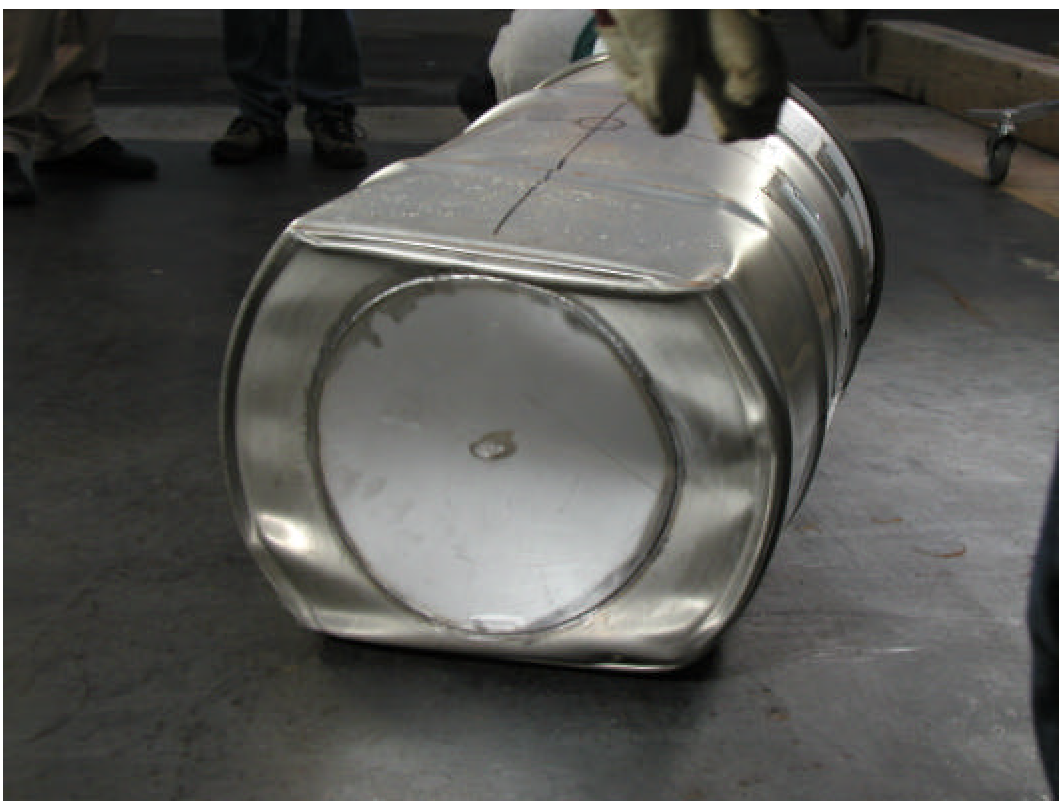


Figure G 16. Damage to the bottom end of TU-3 from the crush test – the 180º line is on top.

Figure G 17. Close up of damage to lid end of TU-3 along the 180º line.

Hypothetical Accident Condition (HAC) Punch Test

Figure G 18. Measuring the drop height of TU-3 prior to dropping on the steel punch.

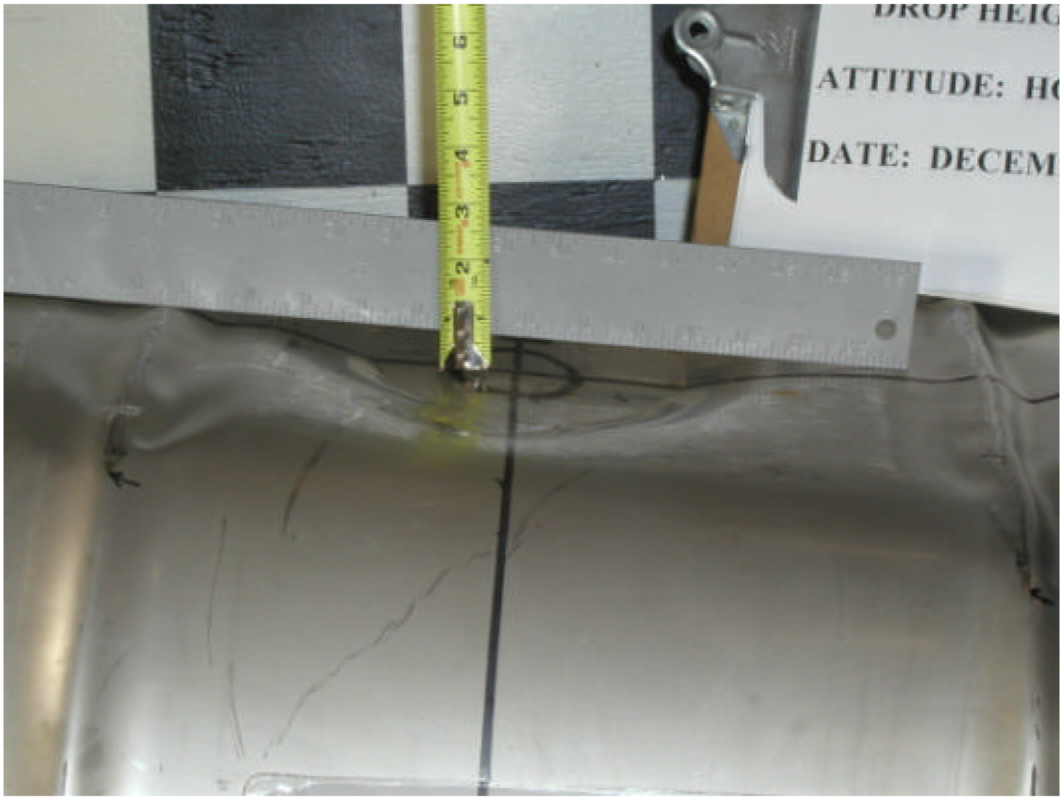


Figure G 19. Measurement of indentation caused by the punch test of TU-3.

Figure G 20. Damage to TU-3 from the drop onto a punch over the CG on the 0º line.

Figure G 21. End of TU-3 Thermocouple attached.

Figure G 22. Furnace Door opened to remove TU-3 from Furnace.

Figure G 23. Removing TU-3 from Furnace.

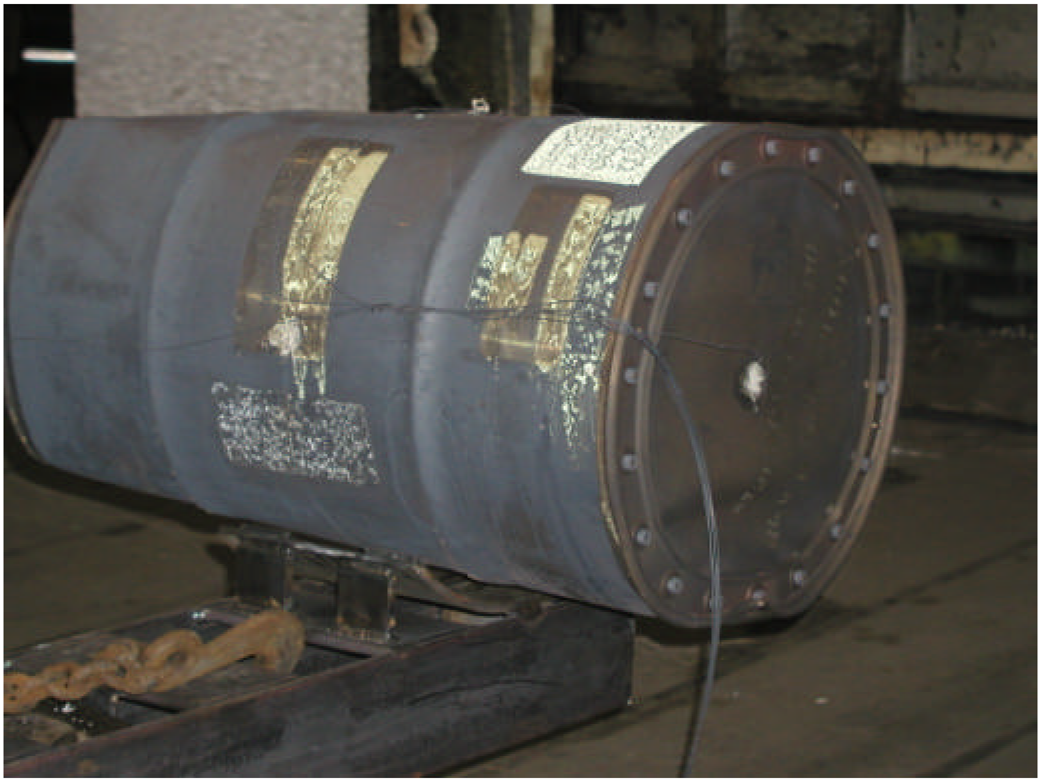


Figure G 24. TU-3 removed from Furnace cooling.

Appendix H

Additional Photos of TU-4 Tests

Package Preparation

Figure H 1. Contents of TU-4 package.

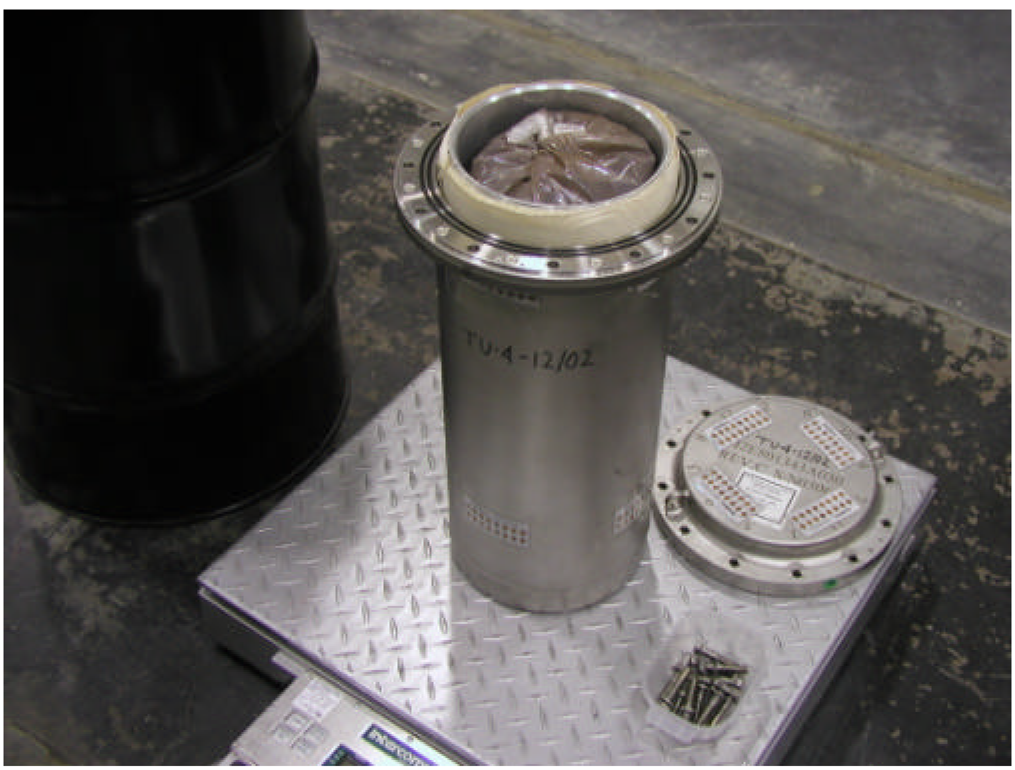


Figure H 2. Weighing the CV, Al sleeve, cap, and surrogate payload (steel shot).

Figure H 3. Sealed CV for TU-4 with temperature labels in pl ace.

Figure H 4. Bottom of CV for TU-4 with temperature labels in place.

Figure H 5. Preparation of TU-4 containing temperature labels and ready to accept the CV.

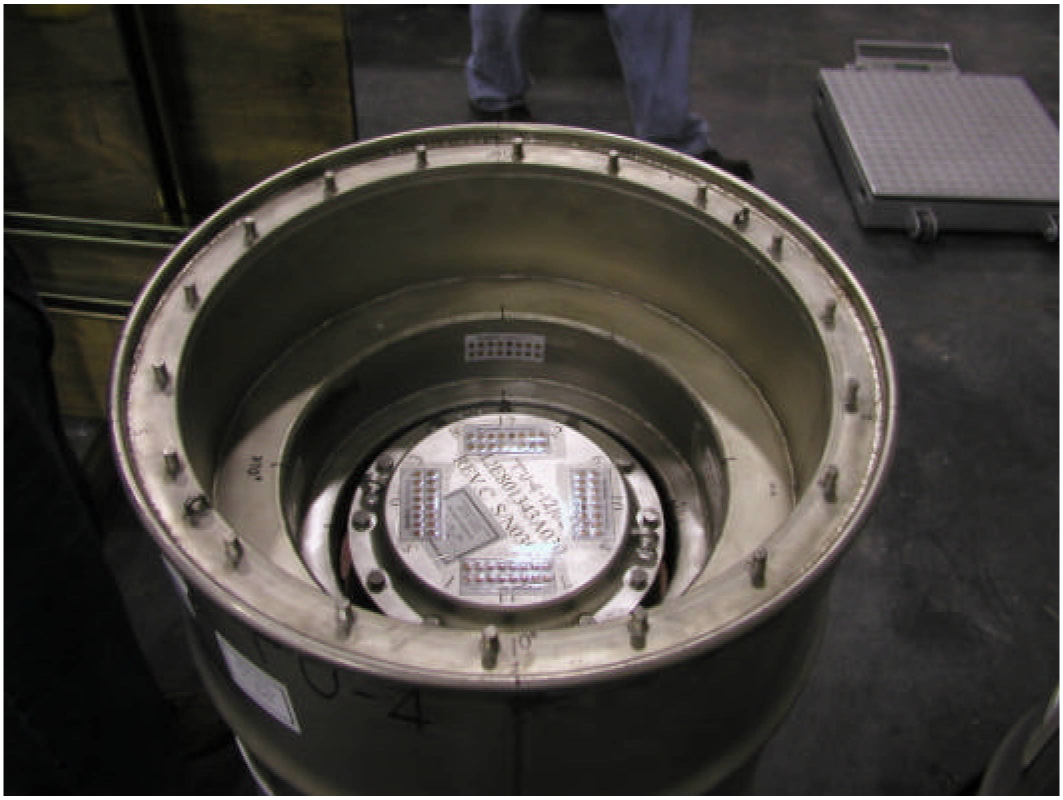


Figure H 6. View of open TU-4 with CV in place.

Figure H 7. View of open TU-4 with polyurethane top in place above the CV.

Figure H 8. View of open TU-4 after top plug has been set in place.

Normal condition of Transport (NCT) Tests

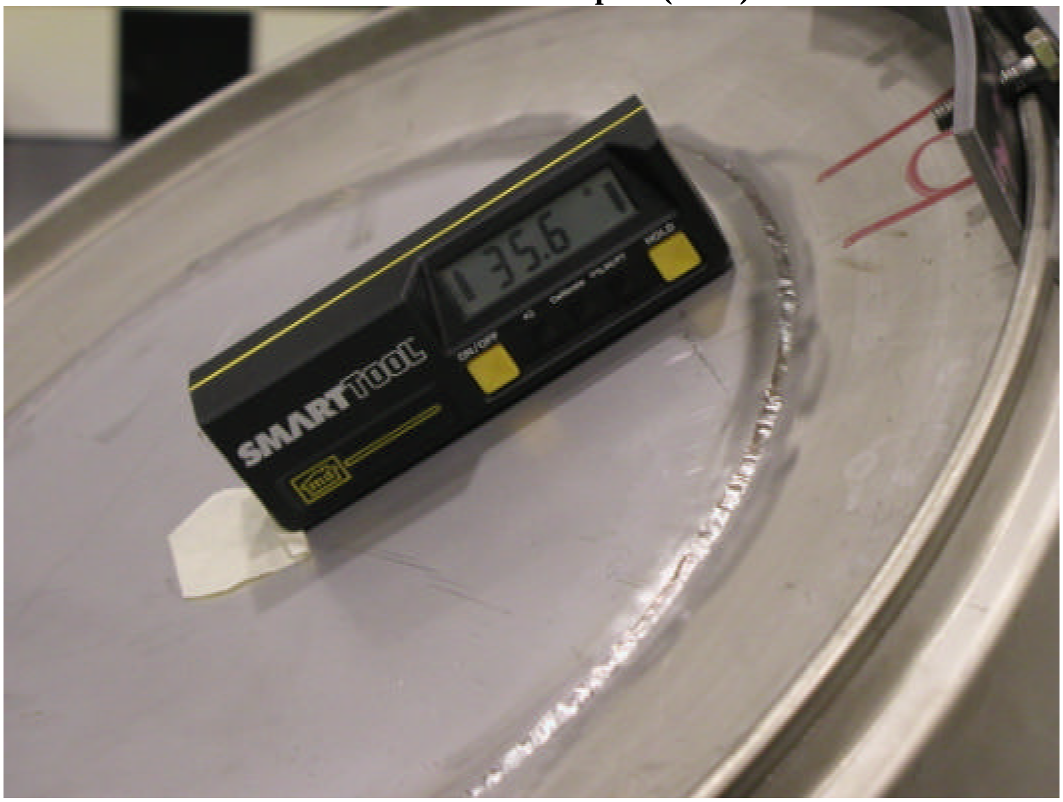


Figure H 9. Measuring the drop angle on the bottom of TU-4.

Figure H 10. Readying TU-4 for the NCT drop test.

Figure H 11. TU-4 suspended just prior to drop.

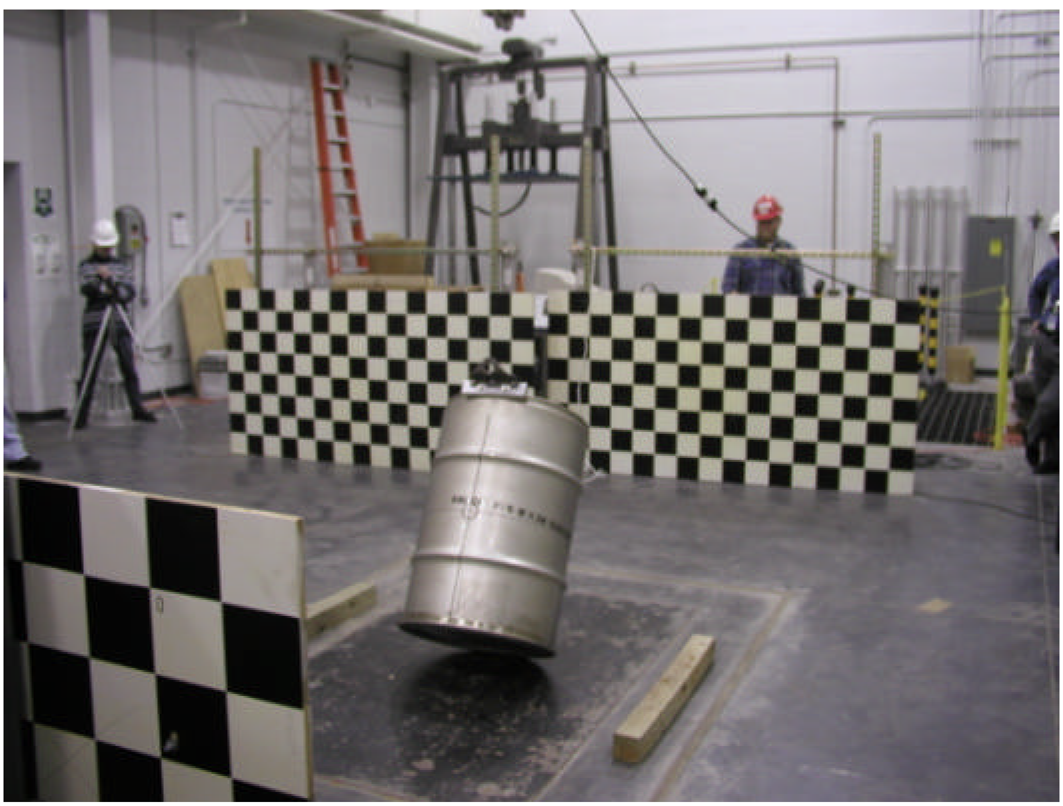


Figure H 12. TU-1 at the moment of impact.

Figure H 13. Damage to lid end from the NCT CG-over-corner drop.

Figure H 14. Top view of damage to the lid from the NCT CG-over-corner drop.

Figure H 15. Close-up of damage of the lid from the CG-over-corner drop – left side view.

Figure H 16. Close-up of damage of the lid from the CG-over-corner drop – right side view.

Hypothetical Accident Condition (HAC) crush test.

Figure H 17. Aligning the 500 kg crush weight above the TU-4 package.

Figure H 18. Close-up aligning the 500 kg crush weight above the TU-4 package.

Figure H 19. Overall setup for the dynamic crush test on TU-4 package.

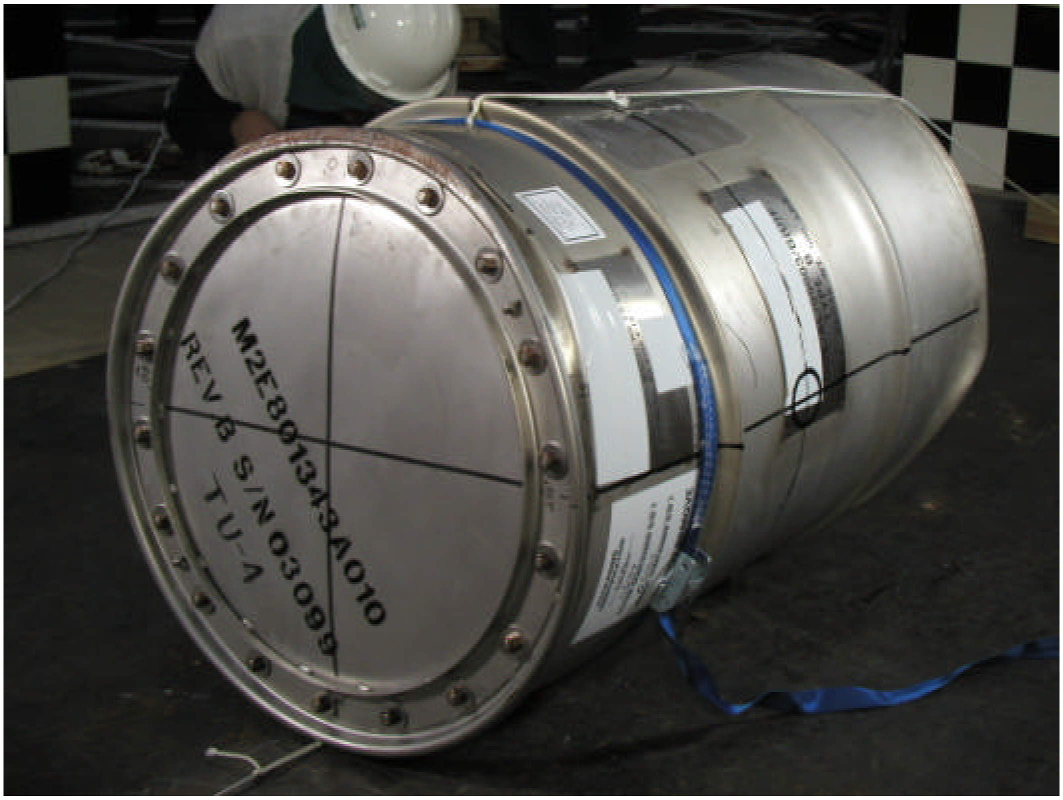


Figure H 20. View of TU-4 lid following the HAC crush test.

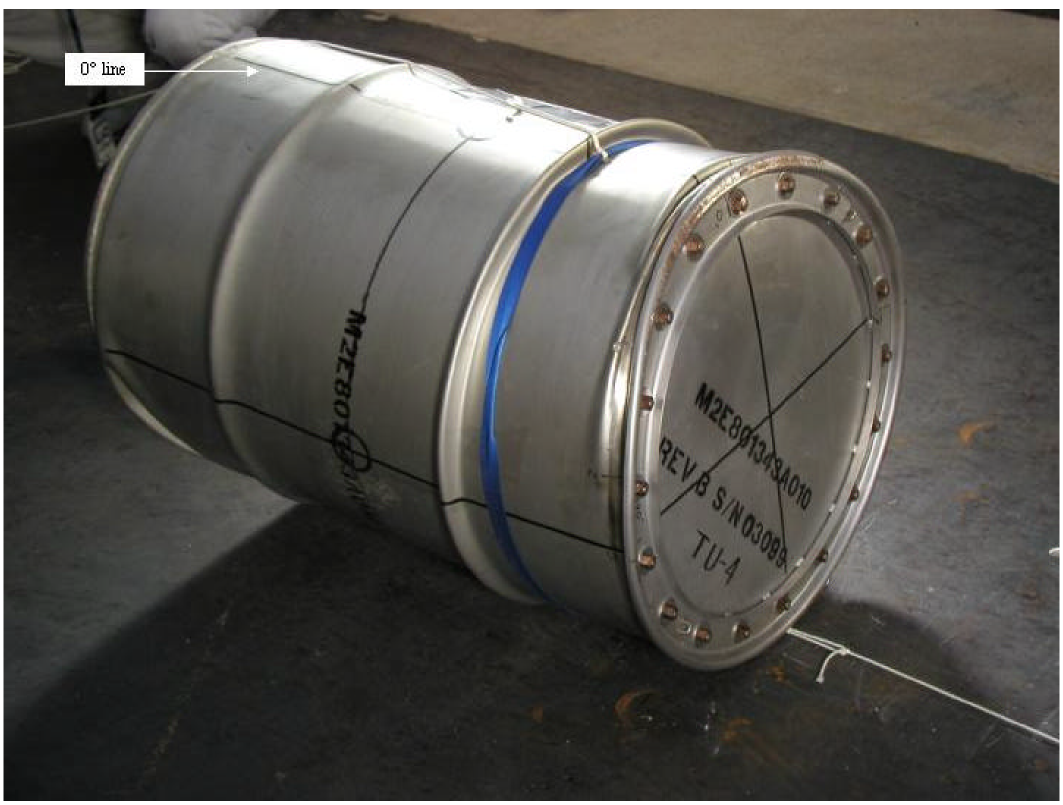


Figure H 21. Side view of TU-4 lid following the HAC crush test.

Figure H 22. Detail of top lid damage at the 0º line.

Figure H 23. View of damage to the bottom of TU-4 from the crush test.

Figure H 24. Close-up of damage to the bottom of TU-4 from the crush test.

Figure H 25. Detail of the damage to the bottom of TU-4 from the crush test.

Hypothetical Accident Condition (HAC) Punch Test

Figure H 26. Alignment of TU-4 package over the punch.

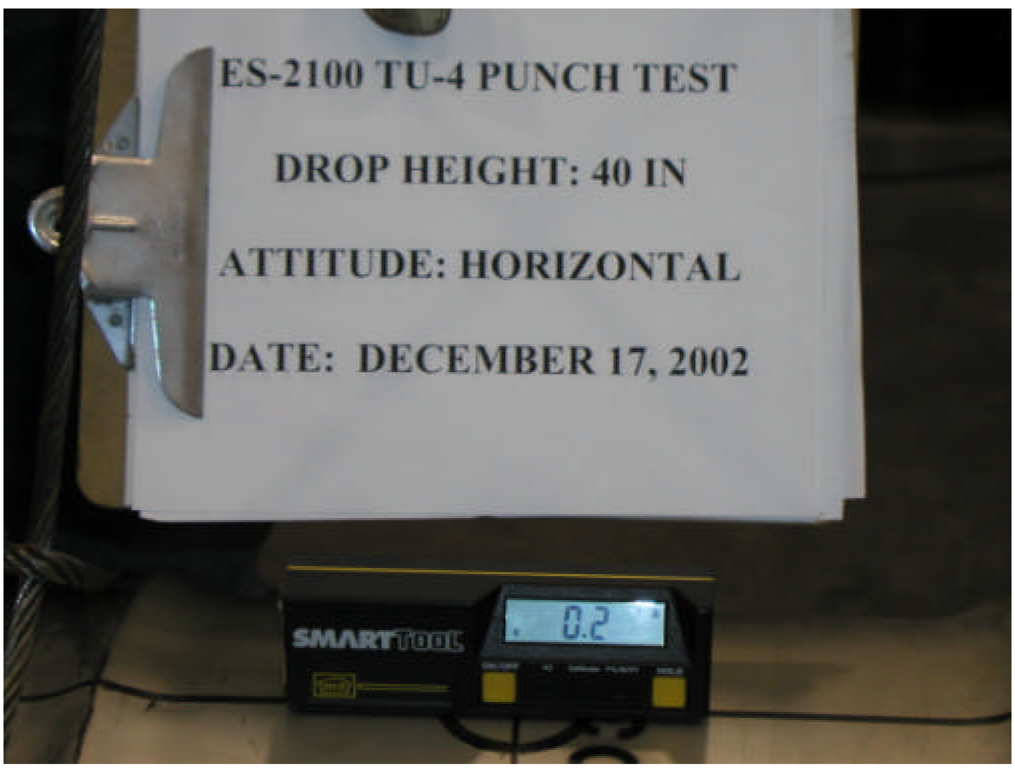


Figure H 27. Measuring how close TU-4 is to horizontal prior to the punch test.

Figure H 28. Measuring the drop height above the punch.

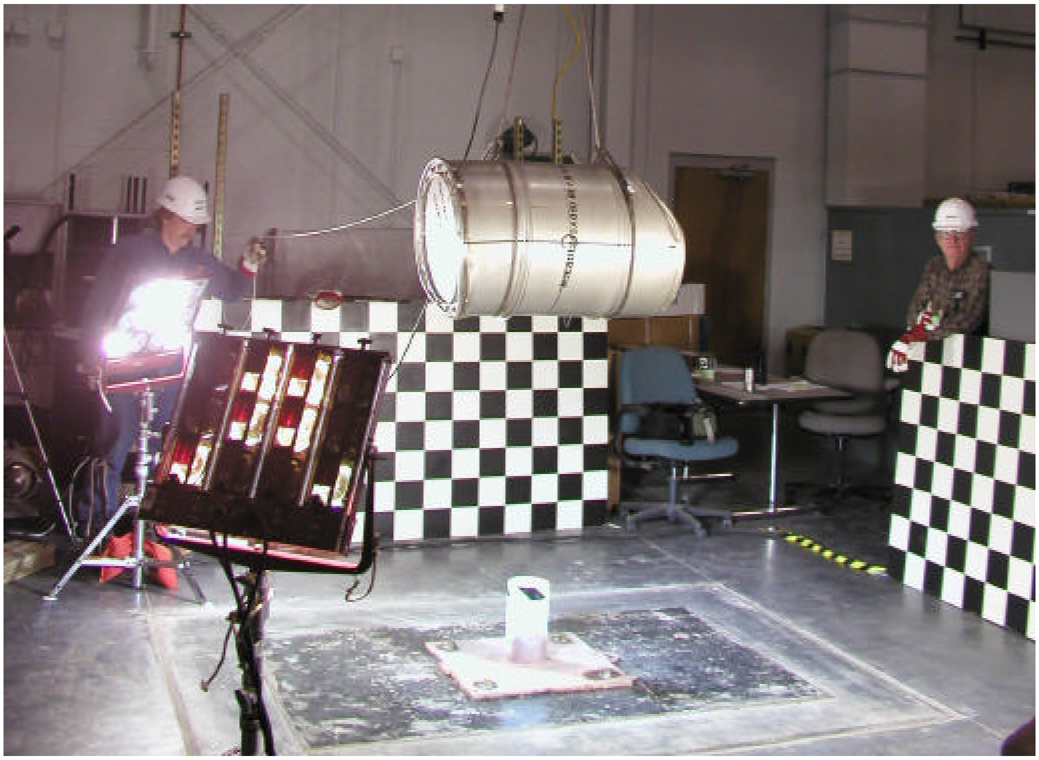


Figure H 29. Ready for the punch test.

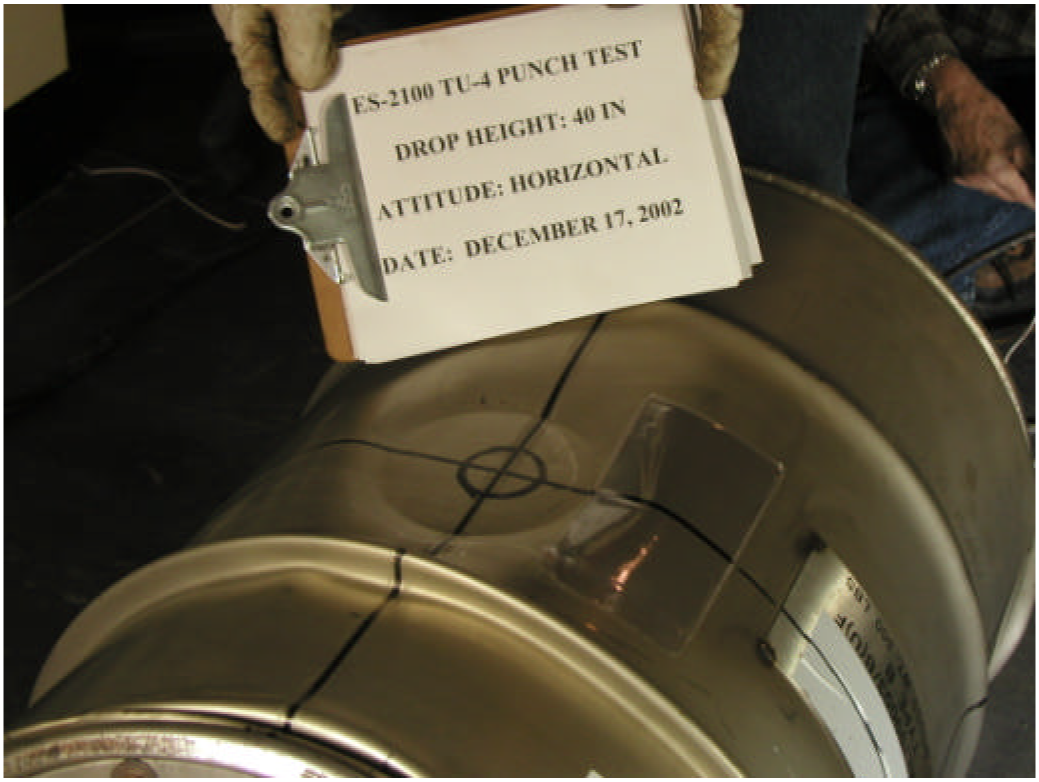


Figure H 30. Damage to TU-4 from the drop onto a punch over the CG on the 0º line.

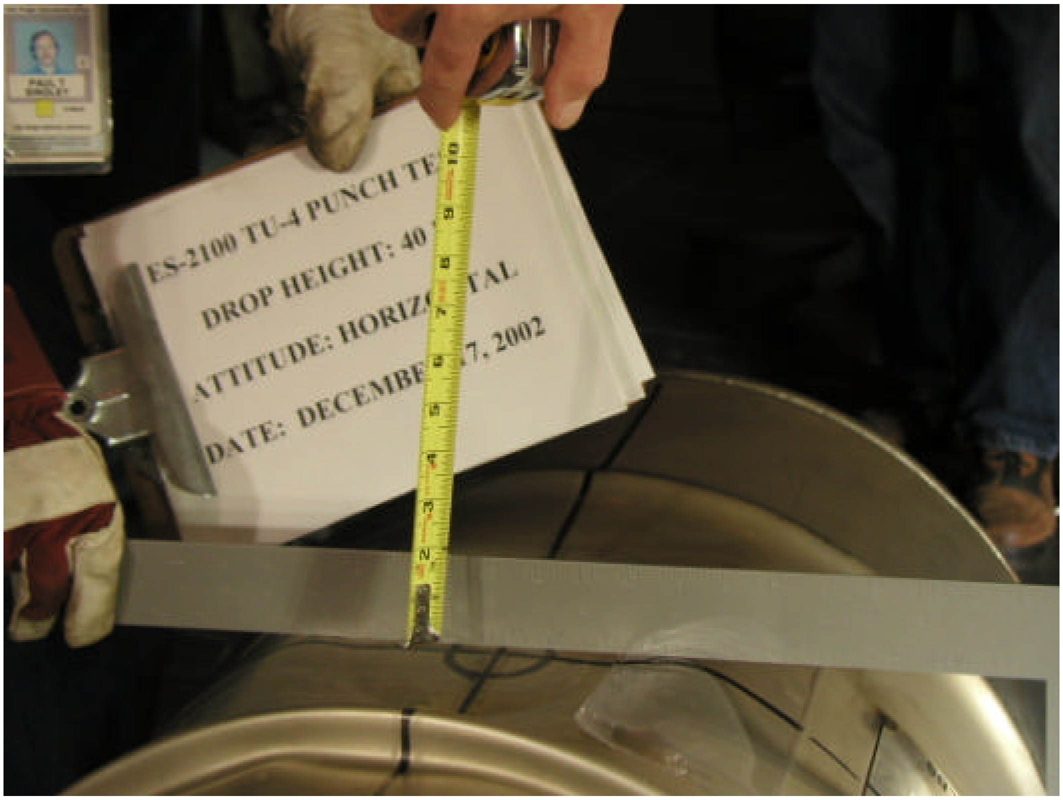


Figure H 31. Measuring the indentation caused by the punch test.

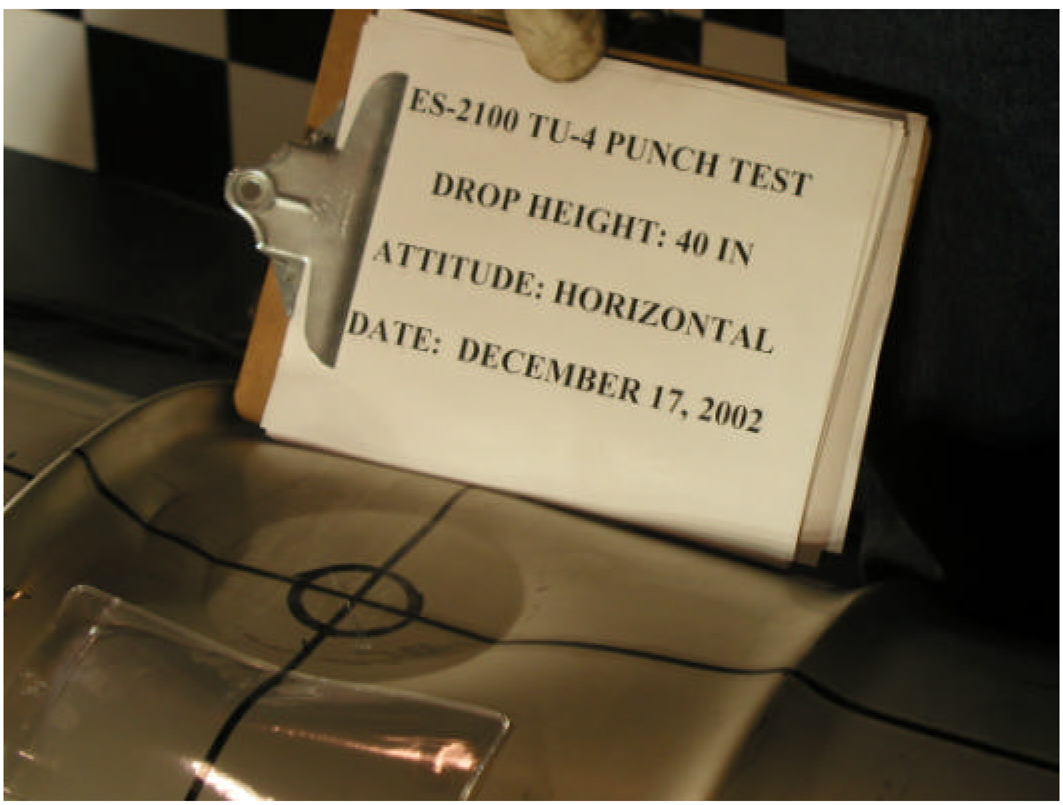


Figure H 32. Close-up of punch damage to TU-4 caused by the punch test.

Figure H 33. Close-up of thermocouple on side of TU-4.

Figure H 34. Close-up of thermocouple on lid of TU-4.

Figure H 35. TU-4 being inserted into the Furnace.

5398

Y-12

OAK RIDGE
Y-12
PLANT

LOCKHEED MARTIN

GAB1296-2

VIBRATION TEST REPORT OF THE ES-2M SHIPPING PACKAGE

September 3, 1997

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Prepared for the
Y-12 Plant Defense Programs
Nuclear Packaging Systems

by
Gerald A. Byington
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U. S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
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VIBRATION TEST REPORT OF THE ES-2M SHIPPING PACKAGE

Prepared for the
Y-12 Plant Defense Programs
Nuclear Packaging Systems

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1. ABSTRACT

This report describes the testing performed and results obtained based on the "Vibration Test Plan of the ES-2M Shipping Package," GAB1296-1[1], and the additional testing found in the "Test Plan of the ES-2LM Shipping Package," GAB0197[2]. These tests were preforined on the ES-2M (medium) shipping package in January and February of 1997. This testing is part of the testing program which demonstrates compliance with the requirements of Title 10, Code of Federal Regulations (CFR), Part 71.71, *Normal Conditions of Transport* (NCT), and Part 71.73, *Hypothetical Accident Conditions* (HAC) for the ES-2M shipping package.

2. INTRODUCTION

Two vibration tests were performed on the 225-kg (495-lb) ES-2M test unit 4 with a mockup payload of two 21.3-kg (47-lb) steel cylinder weights in stainless steel convenience cans. The mockup represents a 16.7-cm (7-in) tall right annular cylinder with an outside diameter of 12.7 cm (5 in) of cast uranium that weighs up to 20 kg (44.1 lb). These tests were designed to verify that the shipping package would function properly and would not vibrate its fasteners loose or damage the containment on the primary containment vessel (PCV) during NCT. The first test was to detect at what frequencies the package received the most damage. The second test was an endurance test meant to simulate the life of the shipping package. The vibrations generated from both tests were such that the Kaolite® 1600[3] impact limiter was cracked. The cracking was first discovered by a tapping on the stainless steel skin with a wrench. The ES-2 drum was then radiographed and it was determined that the Kaolite impact limiter was shattered, though in place, in several places. The effect of the shattered Kaolite impact limiter on the ES-2M shipping package during the HAC was then ascertained. To determine this, test unit 4 was subjected to a 9-m (30-ft) side drop and a 30-minute thermal test. Test unit 4's thermal testing results were then compared to the earlier ES-2M test unit 1.9-m (30-ft) side drop. This comparison was to determine if a PCV temperature increase was generated due to the vibration induced cracking of the Kaolite impact limiter. The package preformed well, with a slight temperature increase on the drum liner and PCV judged to be within the realm of experimental error.

All testing was completed successfully. This test report was combined with other testing to verify compliance of the ES-2M[4] (medium) and the ES-2LM[5] (large, medium) shipping package with 10CFR Part 71.71 and Part 71.73. Reference to this report was included in the joint ES-2M, ES-2LM shipping package Safety Analysis Report for Packaging (SARP).

3. REGULATORY REQUIREMENTS

A package used for the shipment of fissile material must be designed and constructed, its contents be limited, and it must be tested to ensure (1) that there will be no substantial reduction in the effectiveness of the packaging, and (2) that the package will be subcritical in accordance with provisions in 10 CFR §71.55(d), §71.71, §71.55(d)(4), §71.55(e), §71.73, and §71.71(a). As required in §71.71(a), *Normal Conditions of Transport*, "Evaluation of each package design under normal conditions of transport must include a determination of the effect on that design of the conditions and tests specified in this section." This evaluation must include section §71.71(c), "Conditions and test-(5) Vibration normally incident to transport."

4. GENERAL DESCRIPTION OF TESTING

The ES-2M test activities were conducted to ensure compliance with the regulatory requirements. A worst case interpretation of this regulation was made for the ES-2M. This interpretation preformed two vertical vibration tests from 10 to 500 Hertz on the shipping package. The first vibration test was a discrete 0.96G sinusoidal vibration test that stepped the frequency from 10 to 500 Hz. This natural frequency vibration test detected the frequencies that generated the package's worst vibration loads. The second test was a random vibration (colored noise) endurance test. Test unit 4 was monitored inside the drum with a SnapShock-4000[6] G-load recorder on the top of the primary containment vessel (PCV). Test unit 4 was monitored outside the drum with a uniaxial accelerometer on the lid flange and shaker table. The package was disassembled to download SnapShock-4000 data from the top of the PCV lid after each vibration test. During disassembly of the drum, the drum lid loosening torques were recorded. After all vibration testing was completed, the PCV was leak tested and disassembled with the loosening torque recorded. The inside condition of the PCV was documented. The drum and PCV fasteners' loosening torques were compared before and after the test package was vibrated.

The integrity of the Kaolite impact limiter was a concern after the vibration testing. A tap test was used to detect if the vibration testing changed the Kaolite. Further review at the Oak Ridge National Laboratory (ORNL) was conducted. The ES-2M drum was radiographed, and it was determined that the lower half of the Kaolite impact limiter inside the drum was shattered, though in place. The only way to prove the effectiveness of the shattered Kaolite as an insulating impact limiter was to test for HAC. HAC testing consisted of a 9-m (30-ft) side drop, a 1-m (40-in) puncture drop, a 30-minute 800°C (1475°F) thermal test, a PCV leak test, and a PCV 0.9-m (3-ft) water immersion test. To isolate the vibrations' effects on the impact limiter, test unit 4 HAC testing results were compared with other ES-2 test units that endured similar HAC testing.

The results from the testing described above were detailed in this report based on the supporting information. This information was recorded on test forms and in computer data loggers. Videotape, high speed and still cameras were used to record the testing and document all phases of the testing. The test forms were transcribed to the computer forms at the end of this report. The logged computer data was used to generate charts presented in this report. Wyle Laboratories in Huntsville, Alabama performed the vibration testing for the ES-2M and provided a test report[7] of their effort.

5. DESCRIPTION OF TEST UNIT 4

The ES-2M test unit 4, also known as the x-ray unit, was first built to verify the radiography equipment used to inspect each ES-2 drum before and after physical testing. Some parts of this assembly have been marked with both names and others are simply marked "X-ray Unit". However, all parts represent the same container. The test unit 4 (shown in figure 5.1) weighed 225 kg (495 lbs) and was built for the NCT vibration testing and then rebuilt for the HAC drop and thermal testing. The assembly of ES-2M test unit 4 was per drawing M2E801136A056, Rev-A[8], with additional special testing components added for each test. The vibration testing used a SnapShock-4000 peak G-load wireless recording device. The SnapShock-4000 was attached to the top of the ES-2M PCV, and accelerometers were attached to the drum lid and on the shaker table at Wyle Labs. The SnapShock-4000 and accelerometers were removed after the vibration testing was finished. To determine the package's performance during thermal testing, temperature indicating labels (Tempilables)[9] were attached to the outside surface of the PCV (figure 5.2) and to the inside surface of the drum liner (figure 5.3). To display compliance during the HAC testing, six thermocouples were attached to the outside drum surface prior to thermal testing.

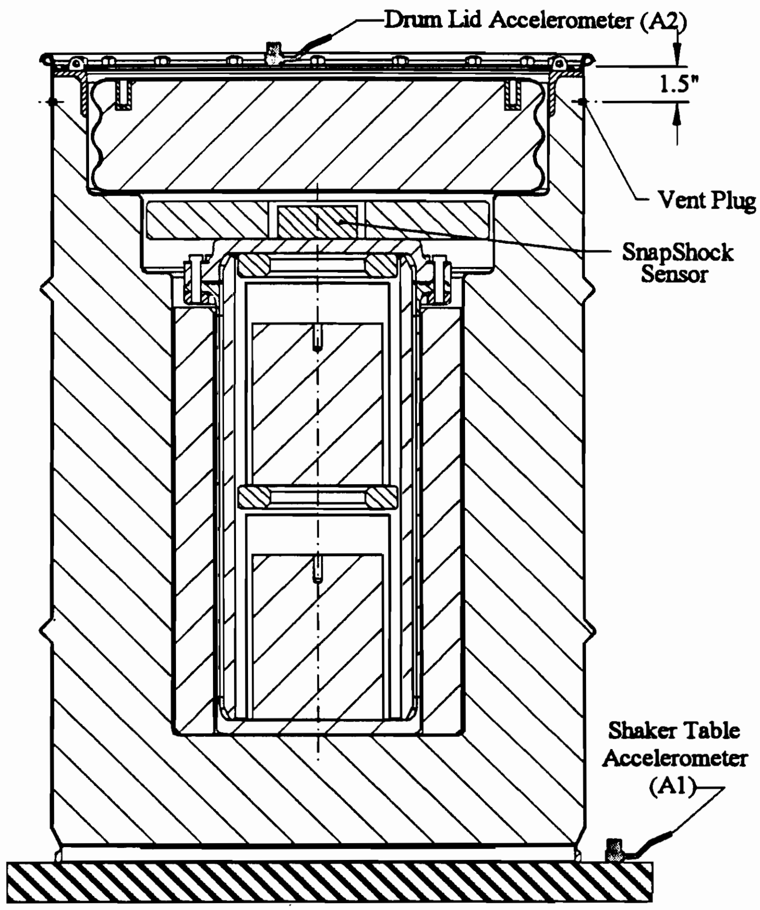
Each 21.3-kg (47-lb) test weight (figure 5.4) was placed in a convenience can as shown in figure 5.5. Figure 5.1 shows the vibration test package, which consisted of two content mockups (figure 5.5) and an aluminum spacer ring (figure 5.6) on top of each mockup, as well as a long aluminum liner (figure 5.6) protecting the PCV (figure 5.2). The stainless steel medium containment vessel, also called the ES-2M PCV (figure 5.2), has two O-rings. The inner O-ring is the containment boundary, and the outer O-ring is use to check the inner O-ring's seal.

The stainless steel PVC also had the SnapShock-4000 attached to the center of the PVC lid by two #6 screws. The PCV and foam inserts (figure 5.7) were placed inside the drum (figure 5.3) under the top plug and drum lid. The foam top insert had a 2×4-in rectangle clearance hole cut for the SnapShock-4000 sensor.

The ES-2 drum was made out of a modified stainless steel military standard 216-liter (57-gallon) drum, commonly called a 55-gallon drum, with an inner liner and a top flange. The void between the drum wall and the inner liner was filled with Kaolite 1600, a fireproof, inorganic, light-weight, cast refractory, thermal insulating, and impact limiting material . The same refractory was cast inside the stainless steel sheet metal shell to make the top plug. This drum was first radiographed in June of 1996 to document the "as manufactured" state with no noticeable cracks. On 1/17/97, the drum was radiographed after both vibration tests were completed. Many cracks were visible, with one large crack that appeared to split the drum horizontally half way up. The lower corners seemed to have been shattered into small pieces like a homogeneous cloud. After drop testing on 1/23/97, additional radiography showed the drum liner had some additional cracking and deflection around the impact locations. However, all radiography sessions showed that, although cracked, the Kaolite 1600 was still in place. Each of these radiography sessions was recorded on videotape for record keeping purposes. Additionally, Test Form 2A was generated to document the findings of the radiography sessions. This form was filled out after the drop testing and before the thermal testing and is included in this test report.

Test forms from the vibration test plan of the ES-2M shipping package and the HAC test plan of the ES-2LM shipping package were recorded during the testing. Some of these test forms had the same number, so a "V" was added to the front number of the vibration test form number. Test Form V1 was used to record the assembly, torquing, and pre-test leak testing of the PCV. Test Form V2 was used to record the assembly, torquing, and labeling of the ES-2M unit 4 shipping package. Test Form V3 was used to record the weight of each component in the ES-2M unit 4 shipping package for both the vibration and HAC testing. Test Form 1 was used to record the assembly, torquing, and leak testing of the PCV before HAC testing. Test Form 2 was used to record the assembly, temperature indicator application, torquing, and center of gravity sticker location of the ES-2M unit 4 shipping package. Test Form 2A was used to record the radiographing of the drum liner after the vibration and drop testing. The other test forms support the testing as detailed in this report.

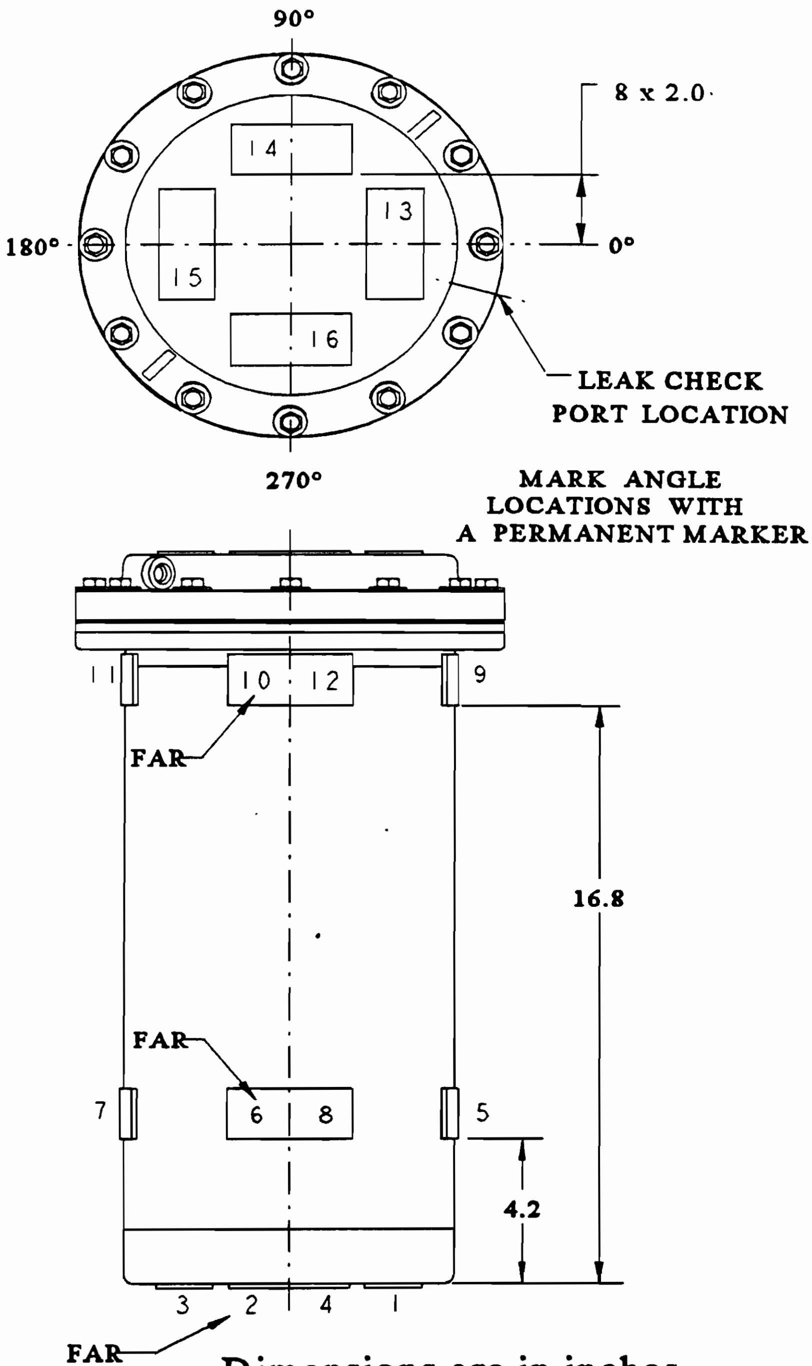
ES-2M Vibration Test Package



Approximate Test Package Weight = 500 lbs

Figure 5.1

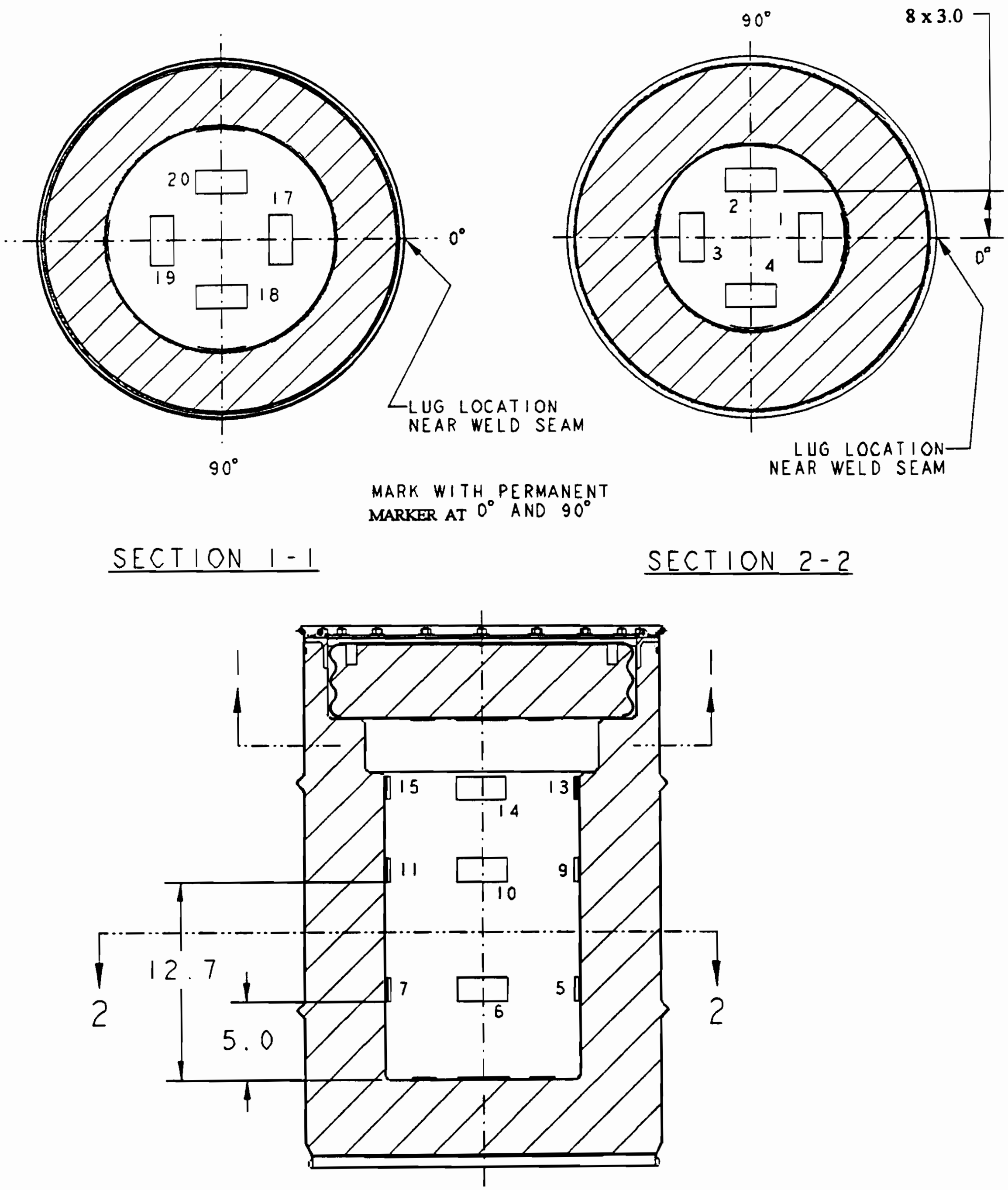
ES-2M, Test Unit 4 PCV
Temperature Indicator Locations



Dimensions are in inches

Figure 5.2

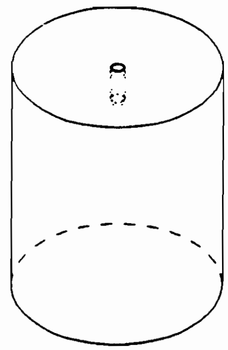
ES-2M, Test Unit 4 Drum Inner Liner Temperature Indicator Locations



Dimensions are in inches

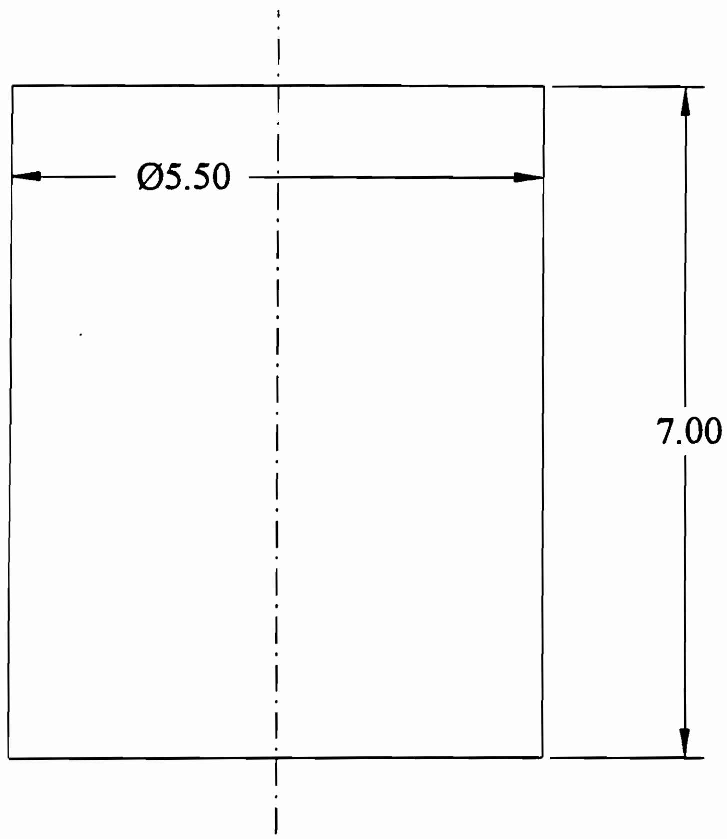
Figure 5.3

Mockup Test Weight



MATERIAL: STEEL

APPROXIMATE WEIGHT: 47.0 lb (21.3 kg)



Dimensions are in inches

Figure 5.4

Test Mockup

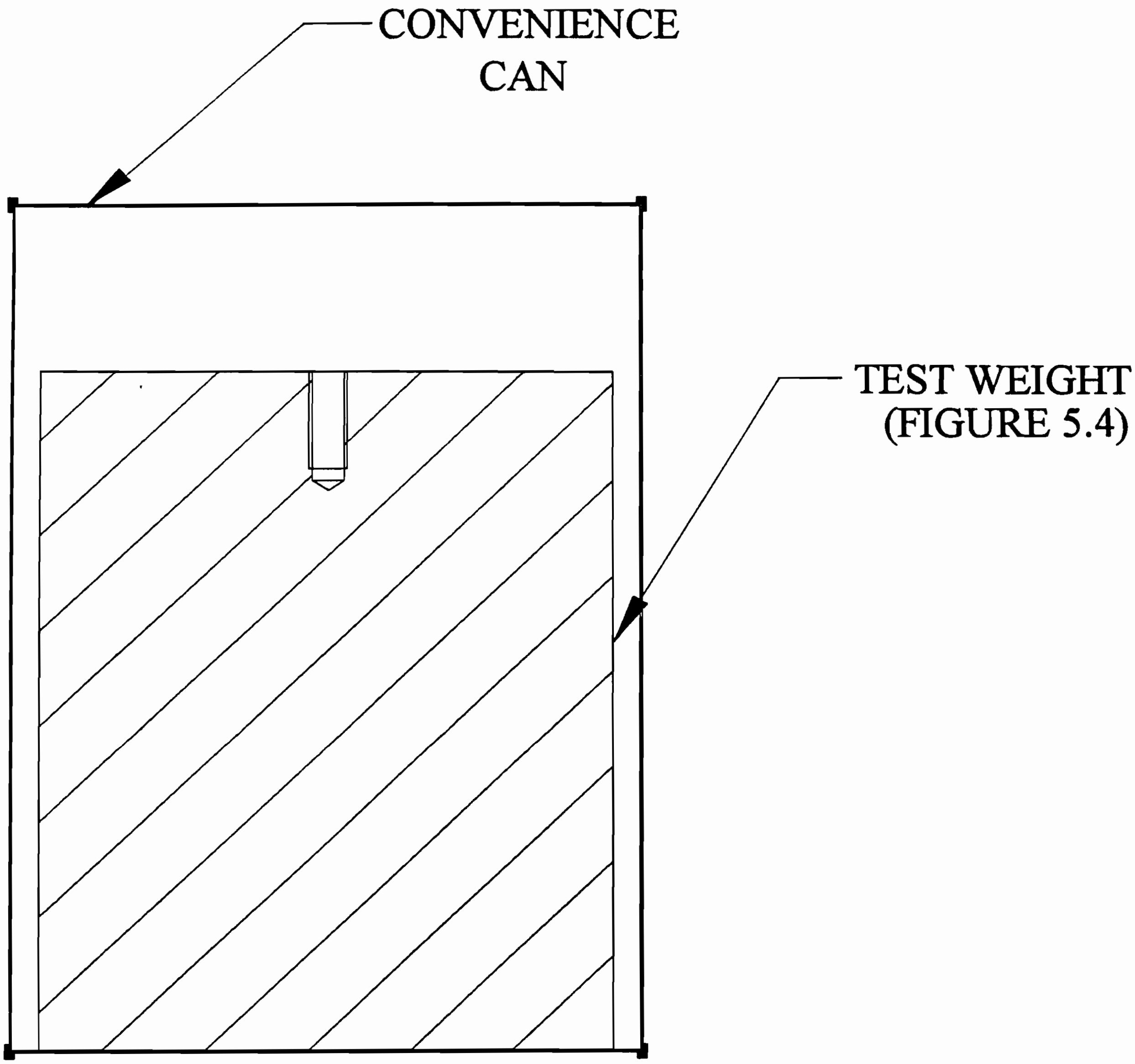
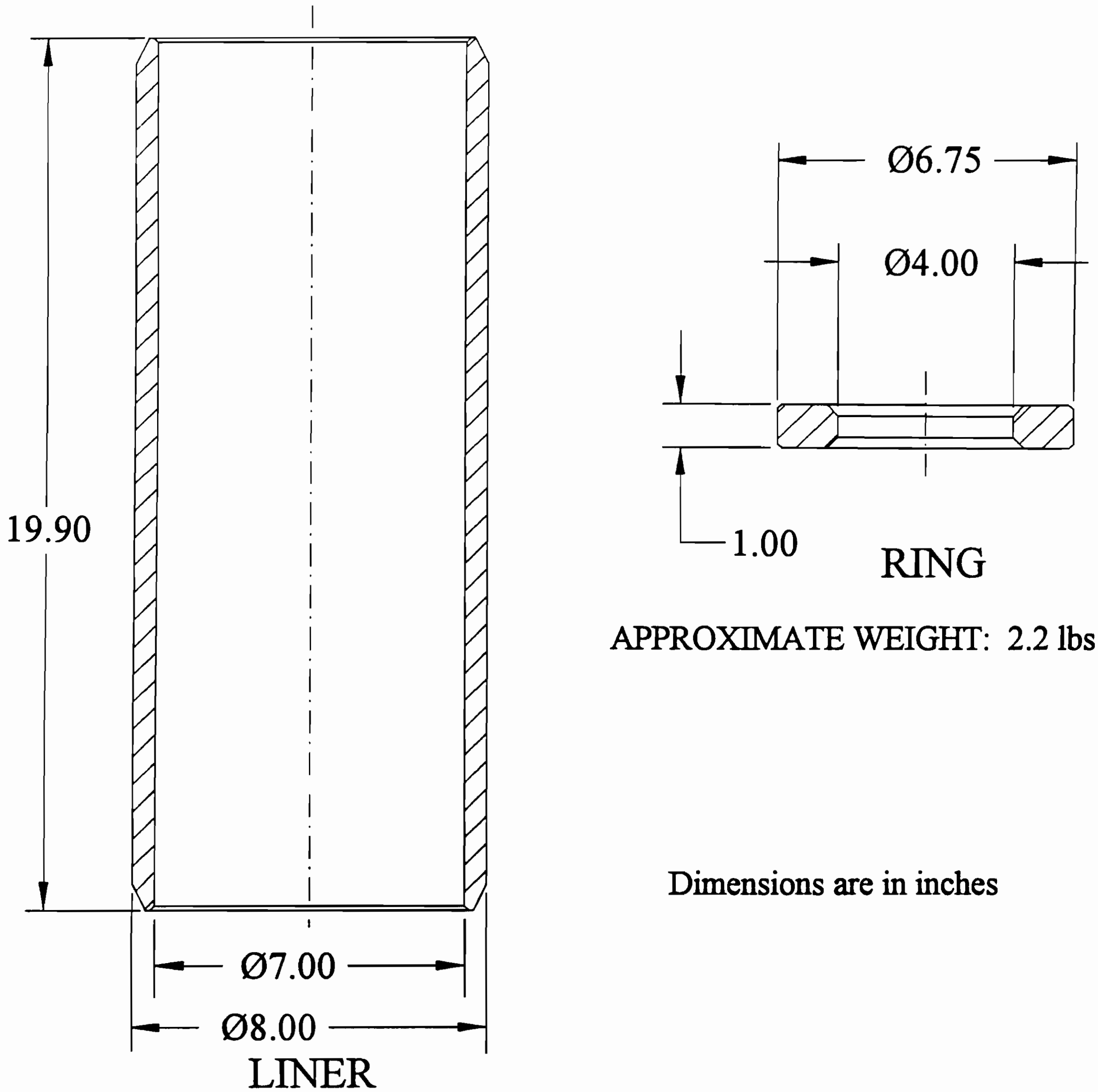


Figure 5.5

ES-2M Aluminum Packing Parts



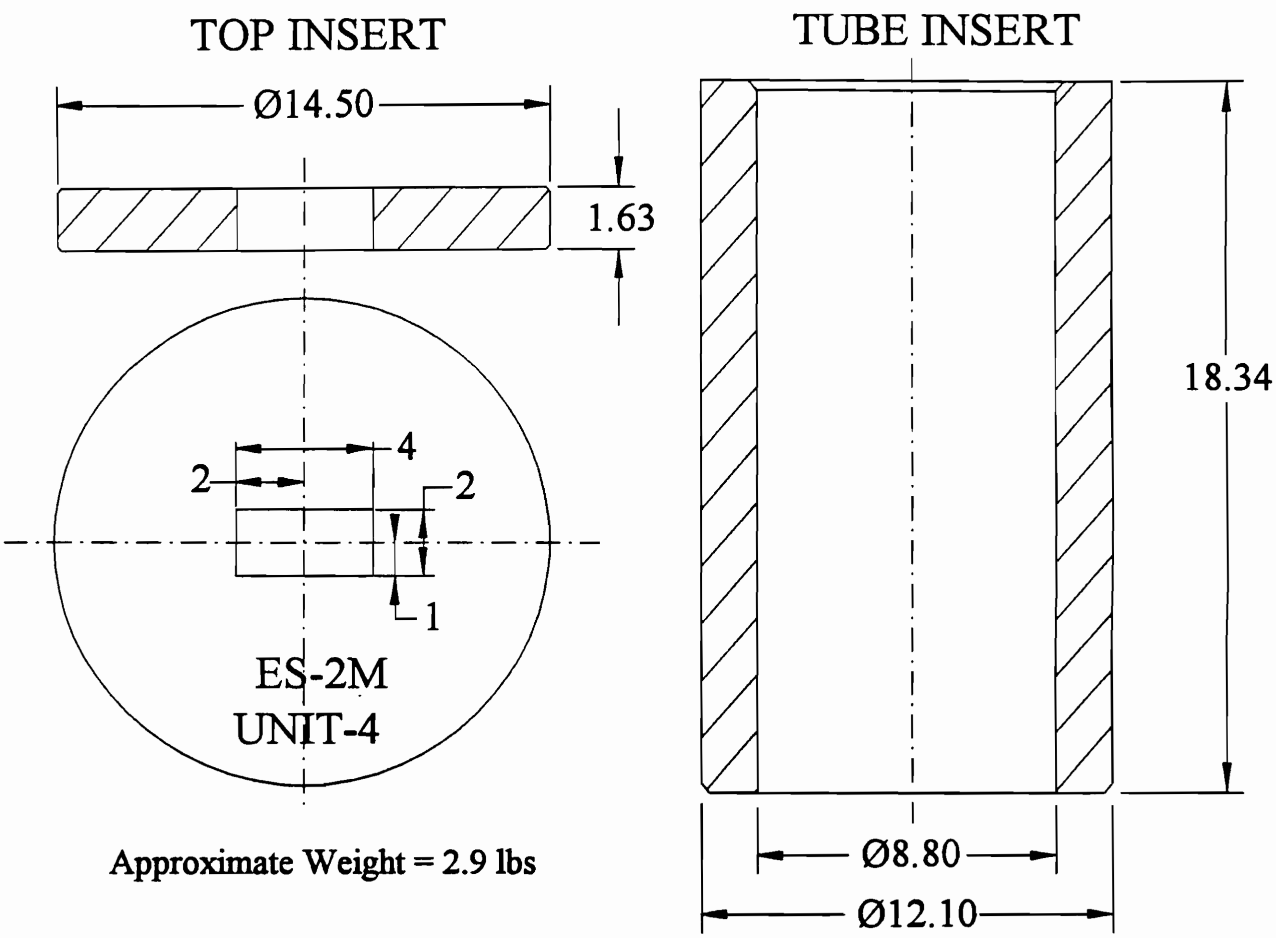
APPROXIMATE WEIGHT: 2.2 lbs

APPROXIMATE WEIGHT: 22.4 lbs

Dimensions are in inches

Figure 5.6

ES-2M Vibration Foam Inserts



Dimensions are in inches

Approximate Weight = 10.9 lbs

Figure 5.7

6. VIBRATION TESTS

These vibration tests ensured compliance with the requirements of Title 10, CFR, Part 71.71, *Normal Conditions of Transport Effects of Vibrations*. A worst case interpretation of this regulation was made for the ES-2M. This interpretation preformed two vertical vibration tests from 10 to 500 Hz on test unit 4. The first vibration test was a natural frequency test that swept the frequencies from 10 to 500 Hz to learn at what frequencies the package received its worst vibration loads. The second test was a random vibration endurance test that lasted for about 42 hours. The random vibrations for the test were defined by DOE's Safe Secure Trailer (SST) Transport Vibration Envelope[10] vertical axis Power Spectral Density (PSD), as shown in figure 6.1. A line defined by "PSD=0.0132/FREQ" went through the SST PSD maximum peak values to define the normal conditions of transport. The power spectrum generated by the NCT random vibration line was an overall rms level of 0.2276G(rms). Since this random vibration was to be an endurance test, the tested power spectrum levels were multiplied by 4.17 times (6.2 decibels). The tested power spectrum was "PSD=0.23/FREQ". This PSD line generated an overall rms level of 0.95G.

The 6.2 dB random vibration power increase over the SST power spectrum compares with MIL-STD-810D, *Transportation Vibration for a Category 1 Common Carrier Environment*, using the method 514.3 testing with an overall rms level of 1.04G(rms). MIL-STD-810D specifies a test time duration of 60 minutes for each 1000 miles traveled in a common carrier. Using this mileage rate as an estimate, the ES-2M went through a fully loaded simulated 42,000-mile road test on a common carrier. The random vibration test should generate comparable damage to the ES-2M as generated by 42 fully loaded 1,000-mile trips on a common carrier.

Each of the vertical vibration test setups was the same as shown in figures 5.1 and 6.2. Test unit 4 was clamped to the shaker table by two 1-inch threaded rods. Each threaded rod was connected to a 1×5-inch aluminum bar over a wooden 2×4 that spanned over a plywood square placed on top of the drum, as shown in figure 6.2. One accelerometer (A1) was on the input base of the shaker table, one accelerometer (A2) was on the drum flange lid, and a ±10G SnapShock-4000 peak G-load data recorder was on the top center of the PCV's lid. The SnapShock-4000 sensitivity was set by a 320Hz noise filter for each test. The SnapShock-4000 recorded the G-load all of the time, but only saved either data from the peak positive or negative G-load at the end of each recording period. The maximum number of records in the SnapShock-4000 is 4086. The recording period can be set over a wide range of time. For the ES-2 testing, two settings were used: 33.6 seconds for the natural frequency test, and 2.24 minutes the random vibration endurance test. The SnapShock-4000 collected vibration data that included the date, time, and the peak G-load for each programmed time span. Wyle Laboratories recorded the test date, time, frequency, and G-load of the input to the test unit 4 mounted on a shaker table. Overall, the following information was gathered: date, time, input PSD at the shaker table, reaction PSD at the drum lid, the frequency, and the reaction peak G-load at the PCV's lid.

The testing generated many accelerations greater than 13Gs up or down on the vertical axis, thus overloading the SnapShock-4000 G limit. The SnapShock-4000 accuracy is uncertain once the G-load recorded is overloaded. The SnapShock-4000 data was downloaded to a personal computer (PC) by its infrared data link after each test was completed. The SnapShock-4000 peak G-load data recorder on the PCV lid of test unit 4 was used to record the peak G-load during both vibration tests. The SnapShock-4000 was reset before and after each test. To reset the SnapShock-4000, the drum lid was opened and the fastener breakaway torques were recorded on Test Form V6, the SnapShock-4000 data was downloaded to the PC. After the data was verified, the SnapShock-4000 was reset and started and the test package was reassembled.

SST Transport Vibration Envelopes[9]

Max SST PSD - - - - - - Tested PSD ——-·-·-·- MIL-STD-810D ———— Method 514.3

Overall rms Level: 0.2276 G Overall rms Level: 0.95 G Overall rms Level: 1.04 G

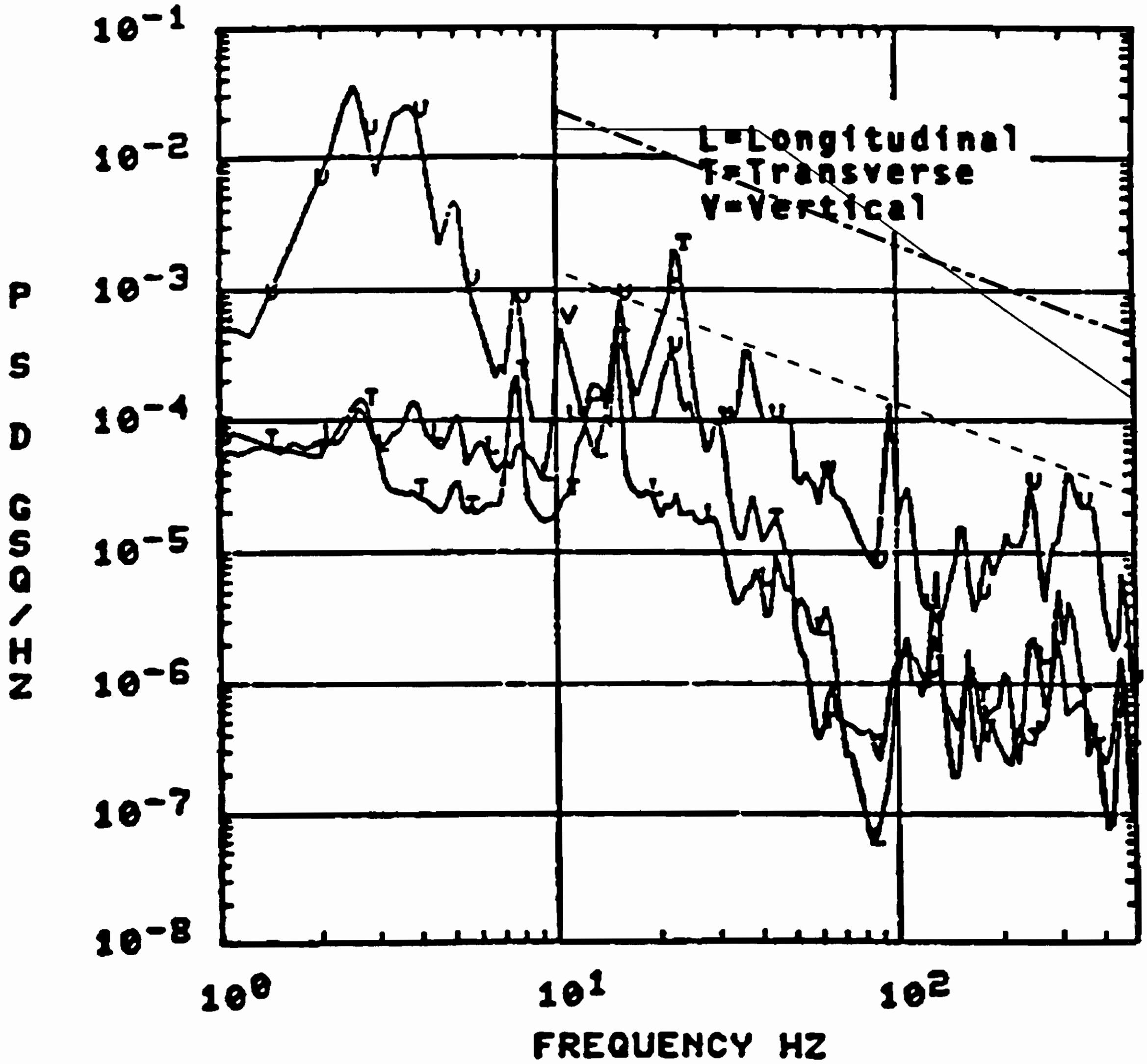


Figure 6.1

Vertical Vibration Setup

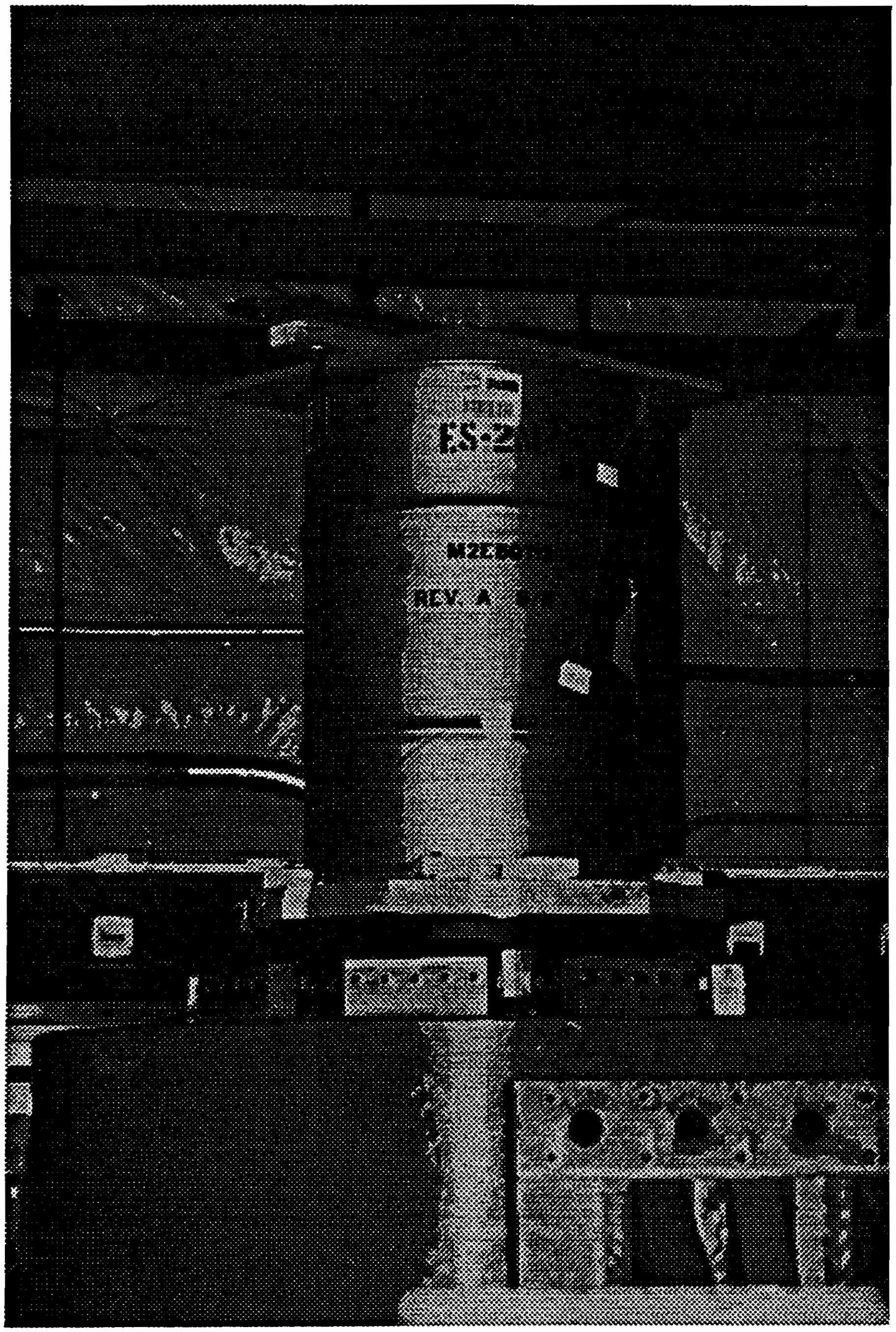


Figure 6.2

6.1 NATURAL FREQUENCY VIBRATION TEST

The natural frequency test recorded on Test Form V5A was about 4 hours long. This test identified which frequencies generated the highest vertical vibration impact loads on the ES-2M. Accelerometers A1 and A2, with the SnapShock-4000, recorded data while the test package was held at each discrete frequency for about 34 seconds and then stepped to the next frequency. Each frequency (from 10 to 500Hz) received sinusoidal acceleration of 0.96Gs. The frequency step size was 1Hz from 10 to 250Hz. At 250Hz, the frequency step size was increased to 2 Hz as the frequency scanning continued to 500Hz. The 0.96G sinusoidal acceleration was selected based on the power spectrum density root-mean-square (rms) acceleration to be received during the random vibration testing of 0.95Grms. An average of the positive and negative peak accelerations was plotted to show this data. Accelerometers A1 (at the shaker table) and A2 (on the drum flange lid) were plotted in figure 6.3. The A1 shaker table accelerometer shows an average acceleration of 1.06Gs through most of the frequencies. Accelerometer A2 on the drum flange lid showed a maximum average acceleration peak of 3.12Gs at 124Hz and 3.92Gs at 140Hz.

As shown in figure 6.4, the absolute value of PCV lid measured SnapShock-4000 G acceleration data were also plotted with the data modified based on inverting the 320Hz noise filter. After 200Hz, the signal to noise ratio was too high so that only noise was being amplified. Above 200Hz, the plotted, increased G-loads are not correct. The largest PCV lid accelerations occurred from 10Hz to 28Hz at a level of about 13Gs. From 28Hz to 42Hz, the acceleration level dropped to about 4Gs and stayed almost constant through 70Hz. From 70Hz through 90Hz, the acceleration level fell to about 1.8Gs then stayed almost constant to 140Hz. From 140Hz through 190 Hz, the acceleration level fell to about 0.8Gs, where it remained. This clearly shows that the lower the frequency, the more acceleration force to which the PCV is subjected.

Natural Frequency Testing:
Average Shaker Table and Drum Lid Peak Accelerations

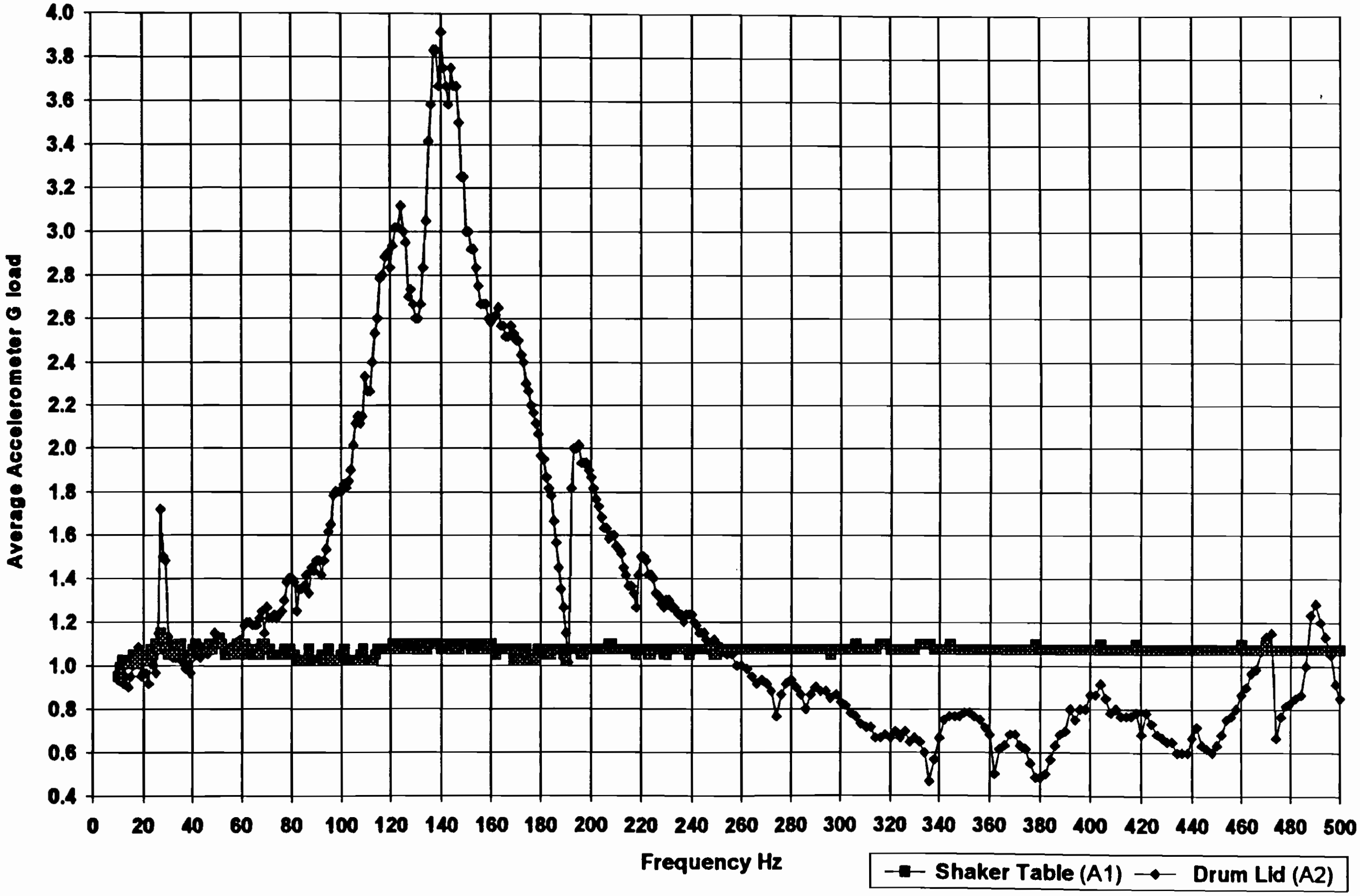


Figure 6.3

Natural Frequency Testing: PCV Lid Peak Accelerations

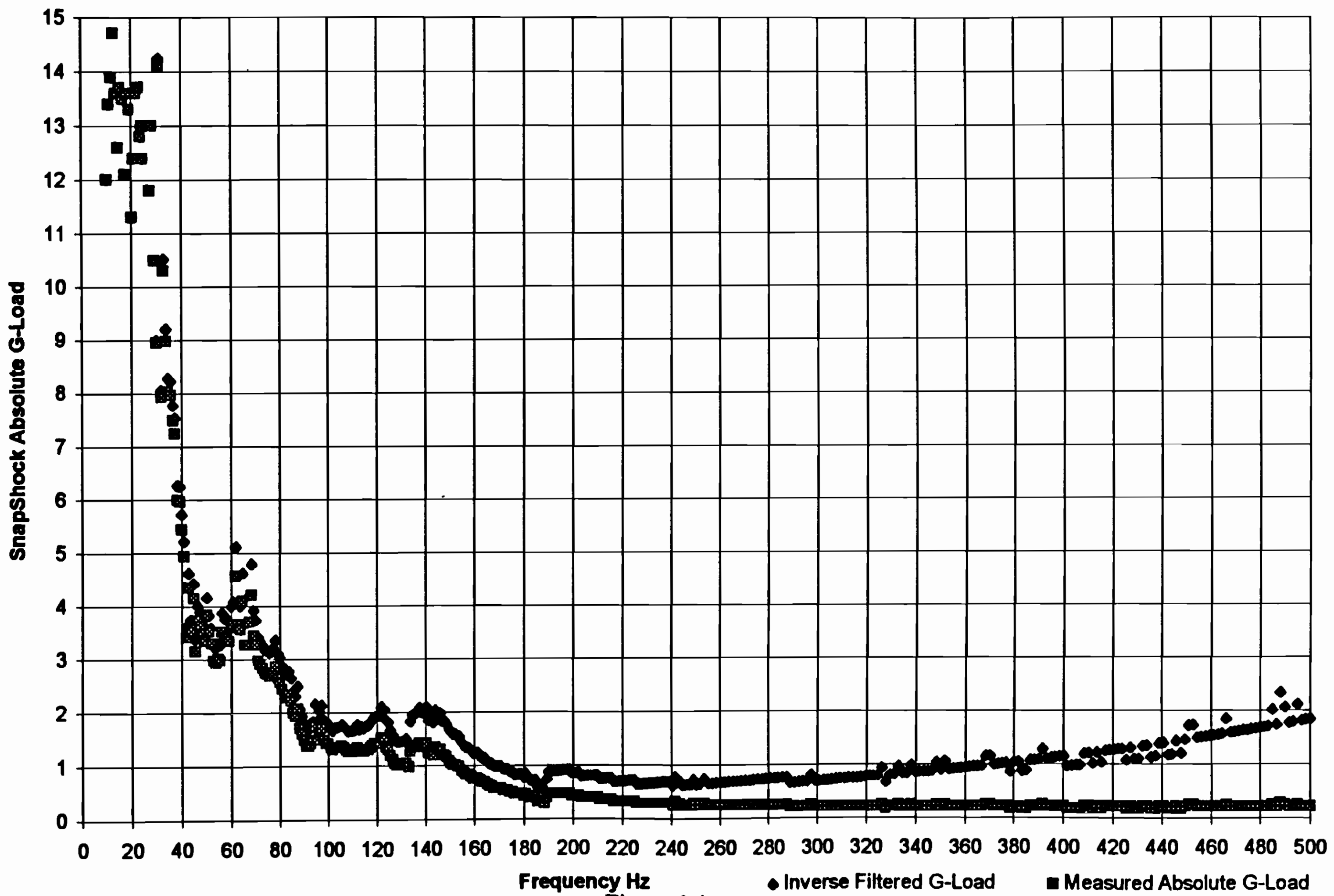


Figure 6.4

6.2 RANDOM VIBRATION TEST

The second test was a random vibration endurance test recorded on Test Form V5B that lasted for about 42 hours. Using MIL-STD-810D as a guideline, this random vibration test simulated the damage to the ES-2M that would be generated by 42 fully loaded 1,000-mile trips on a common carrier. The force levels were multiplied more than 4.17 times (6.2dB increase) from the maximum peak values obtained by the power spectral density (PSD) plot for the SST transport vibration envelope in the vertical axis, as shown in figure 6.1. The random vibration test applied all frequencies from 10 to 500Hz at different force magnitudes continuously for the 42-hour duration of the test. The vibration setup was checked at the beginning, in the middle, after an unscheduled stop, and at the end of the test. In the middle of the night a power surge brought the shaker table off-line for about one hour. The random vibration endurance test was restarted from that point, with the extra time added to the test. Each vibration setup check generated a plot of both accelerometers, A1 and A2. These plots showed little change throughout the test. A sample PSD plot taken at the end of the test is shown for accelerometer A1 recorded at the shaker table in figure 6.5, and accelerometer A2 recorded at the drum's lid in figure 6.6.

All frequencies were applied continuously during the random vibration endurance test. Therefore, the high G-loads seen at the lower frequencies of the natural frequency vibration test were continuously present. The SnapShock-4000 data recorder (with a $\pm$10G range) started recording the G-loads for the random vibration test on the PCV at approximately $\pm$15Gs every 2.24 minutes. The positive peak channel slowly fell to 11.1Gs where the SnapShock-4000 failed at a false positive value of 11.1Gs. The SnapShock-4000 still recorded the negative peak values up to 20Gs, with most of the readings near -13Gs (see figure 6.7). The sound generated from the random vibration endurance test was consistent with the sound generated during the low frequencies of the natural frequency vibration test. Sections of both tests were recorded on videotape.

6.3 POST-VIBRATION TESTING DISASSEMBLY

After the vibration tests were completed, the package was disassembled with the drum loosening torques recorded on Test Form V6. Cameras were used to take still pictures, and videotape was used to record the physical condition of the package during disassembly. The temperature inside the drum for test unit 4 was about 95°F, while the testing room was about 55°F. A brass pipe plug that was in the leak check port vibrated loose. The loose plug bounced around the PCV flange, making circles on top of the foam tube insert. The threads on the brass plug were worn off by the vibrations. The brass plug is not part of the package's containment system. It was used to preserve cleanliness of the screw threads and the leak test port during testing. The ES-2 drum was tapped with a wrench to determine soundness of the Kaolite impact limiter after the vibration testing. The tap test found that the tapping sound at the bottom of the liner directly below the PCV was dull. The dull sound suggested that the impact limiter was cracked and/or not in contact with the inner liner at that location. At ORNL the ES-2 drum was radiographed, and it was found the Kaolite 1600 in the lower drum had shattered, but was still in place. The real time radiography on 1/17/97 also included the ES-2LM test units 5, 6, 7, and 8. These were documented on a videotape and digital pictures to become part of the official test record.

The PCV O-ring was leak tested to a value of 9.0×10^{-6} std-cc/sec in air as recorded on Test Form V6. PCV disassembly fastener breakaway torques were recorded on Test Form V6. The lid was removed and pictures of the PCV contents were made. The inside of the PCV's lid showed a wear pattern indicating that it was only hit by the aluminum liner on its outer edge. The welds inside the bottom weldment of the PCV have a small weld seam buildup on them. This weld seam buildup at the bottom head and top flange ground a ring into the aluminum liner. The aluminum grinding generated fine dust inside the PCV. The dust pattern inside the PCV lid indicated that the mockup weights did not appear to have hit the PCV lid. The upper end of the top stainless steel convenience can was not damaged. All other stainless steel convenience can ends with a mockup weights on them were destroyed by the mockup weights pounding on them. Still pictures and videotape were used to record the physical condition of the stainless steel can ends that had been damaged.

Vertical Axis Vibration Shaker Table Input Accelerometer (A1)

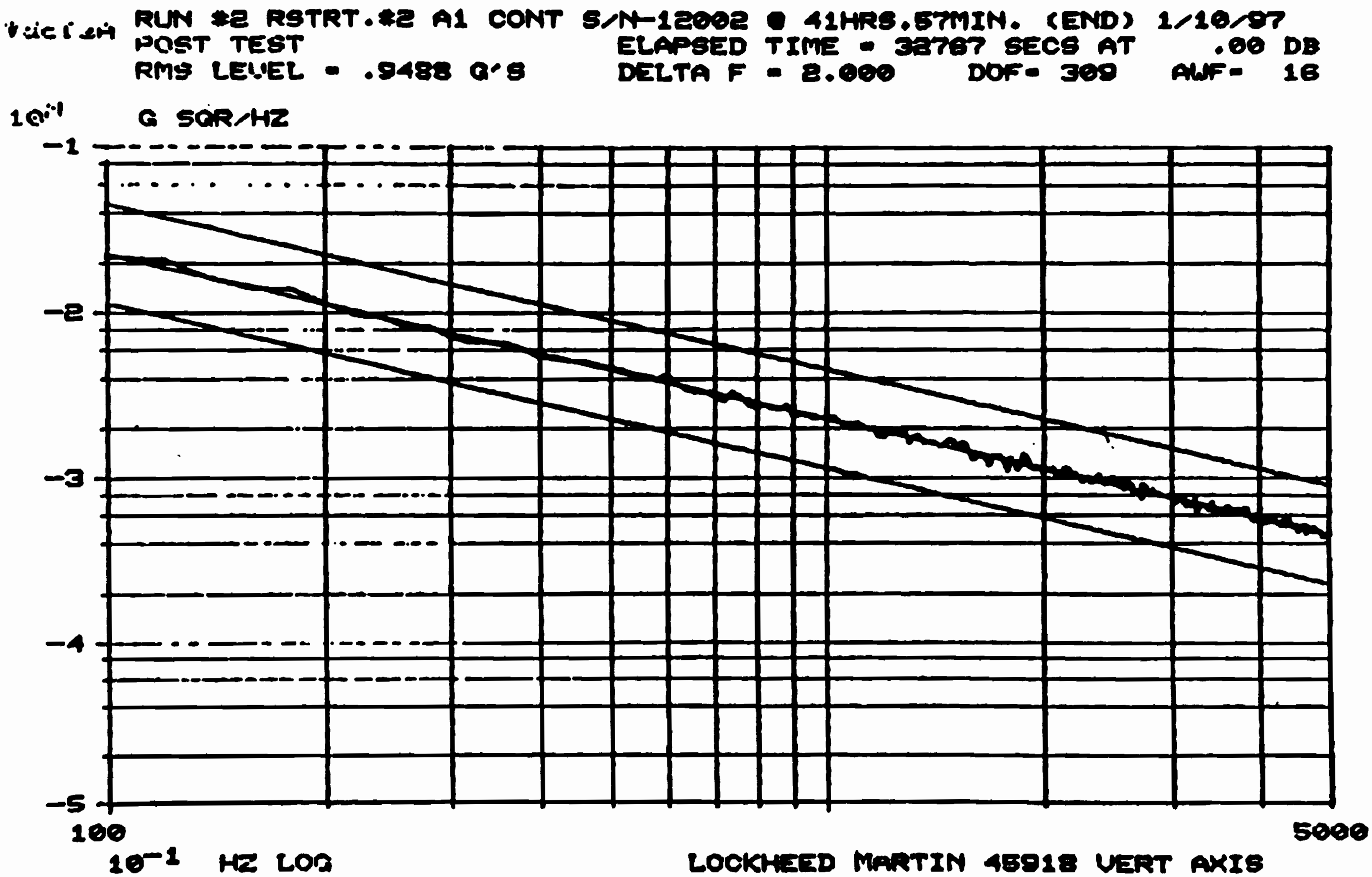


Figure 6.5

Random Vibration at the Drum Lid Accelerometer (A2)

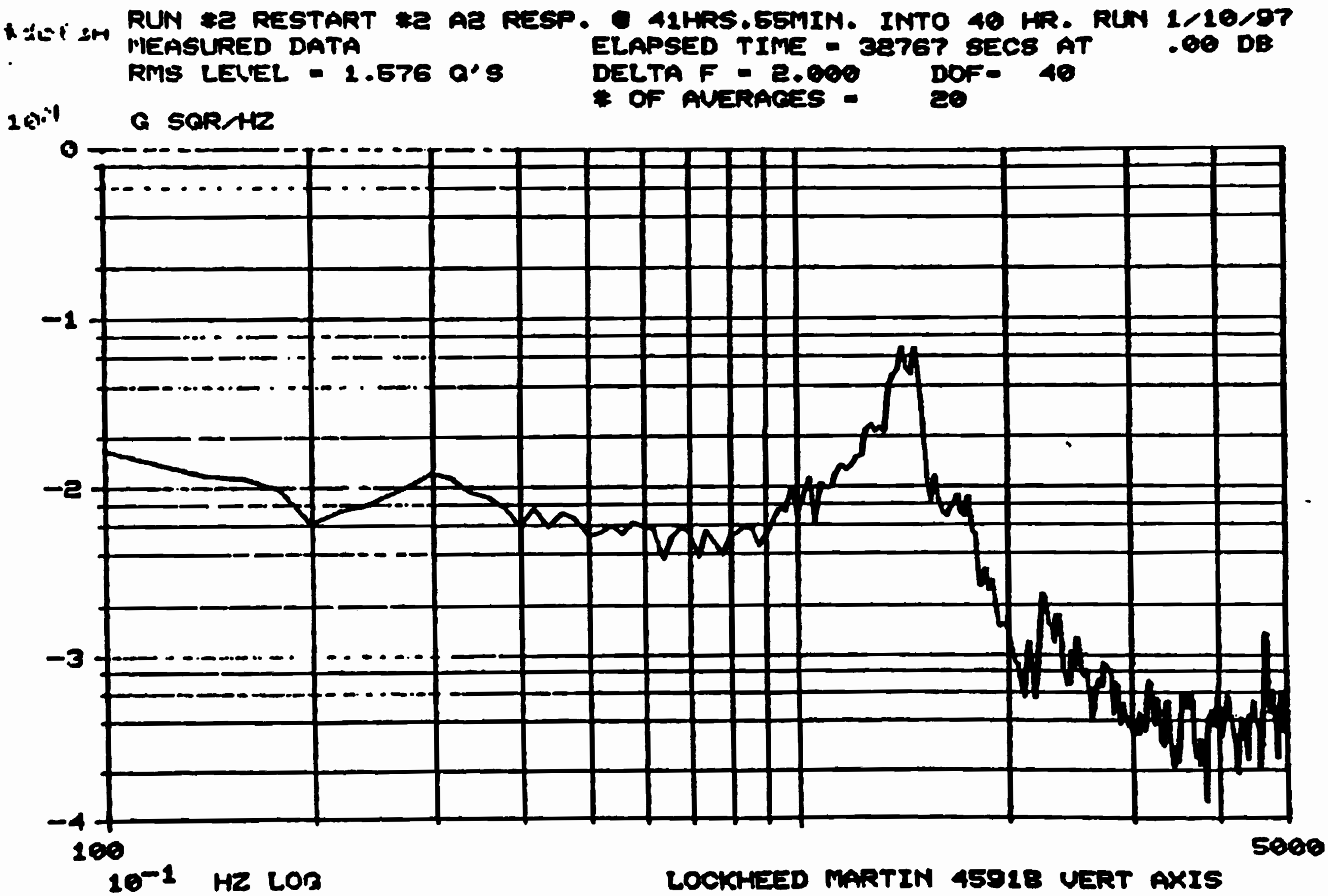


Figure 6.6

Random Vibration Testing: PCV Peak Accelerations

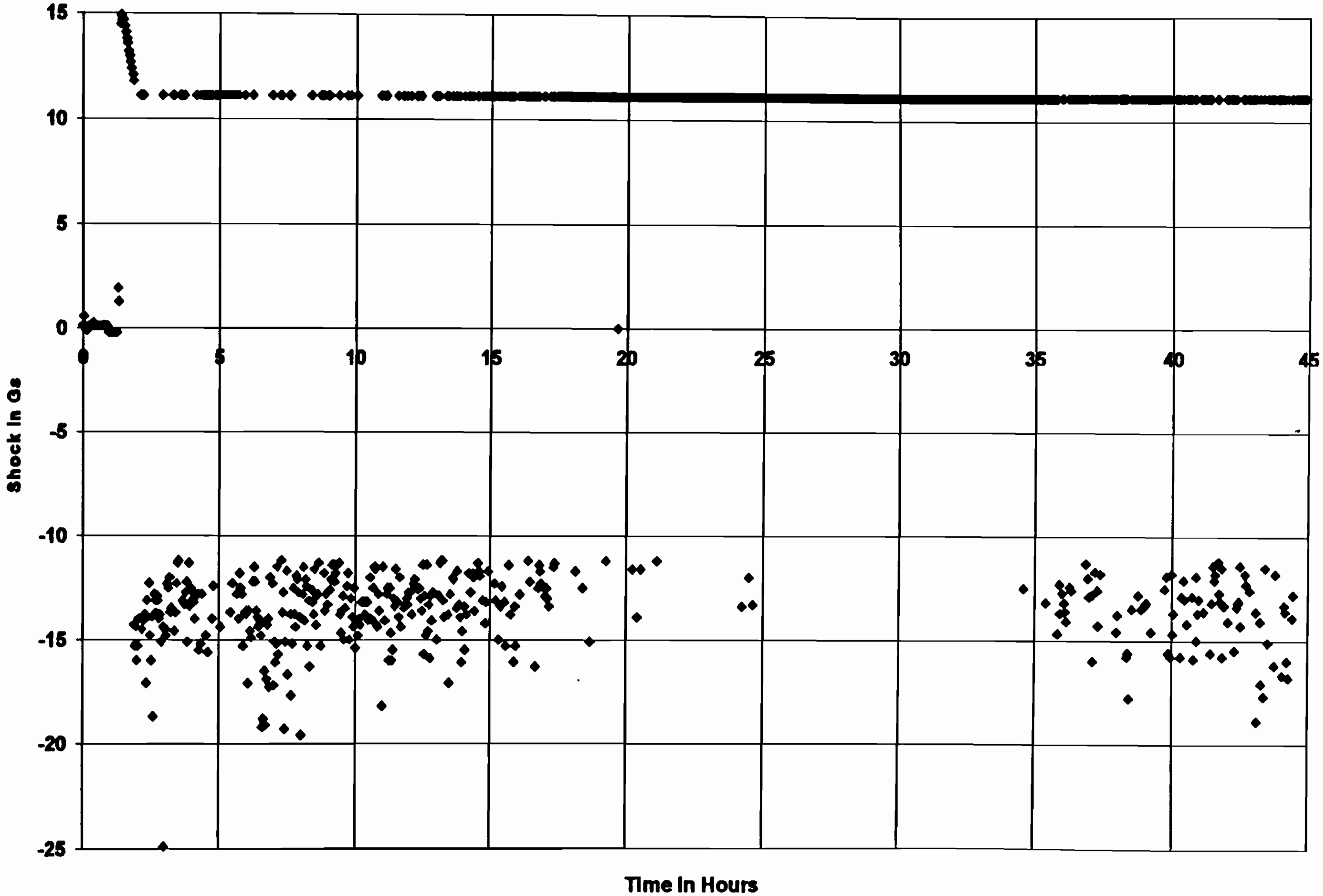


Figure 6.7

6.4 VIBRATION TESTING BREAKAWAY TORQUE COMPARISON

During assembly, a breakaway torque history table was generated on Test Form V4 when the drum lid fasteners were torqued to 120±10 in-lb (10±1 ft-lb) and removed three times. The average assembly history breakaway torque values for the 18 fasteners were 82.2, 88.1, and 87.8 in-lb. The average post-vibration breakaway torque values (recorded on Test Form V6) after shipping to the testing lab, the natural frequency testing, and the random vibration endurance testing were 84.2, 83.3, and 85.6 in-lb, respectively. The average post-vibration testing drum lid fastener breakaway torques were between the maximum and minimum breakaway torque values generated during the average assembly breakaway torque history preparation. Therefore, the vibrations did not affect the drum lid fasteners' breakaway torque.

During assembly, a breakaway torque history table was generated on Test Form V4 when the PCV fasteners were torqued to 215±10 in-lb (18±1ft-lb) and removed three times. The average assembly history breakaway torque values for the 12 fasteners were 182.9, 173.3, and 167.5 in-lb. The average of the post-vibration PCV fastener breakaway torques (recorded on Test Form V6) was 167.9 in-lb. The post-vibration testing PCV fasteners' average breakaway torque was between the maximum and minimum breakaway torque values generated during the average assembly breakaway torque history preparation. Therefore, the vibrations did not affect the PCV fasteners' breakaway torque.

7. HAC TESTING

After the vibration testing was completed, the ES-2M test unit 4 was tested to 10 CFR 71.73, HAC, from January through March of 1997, with ES-2LM test units 5, 6, and 7. Test Forms 1 and 2 were taken from the HAC ES-2M test plan[11] used in July of 1996. Test Forms 2A, 4, 5, 6A, 6C, 6D, and 7A were taken from HAC ES-2LM test plan[2]. The assembled weight recorded on Test Form V3 was 224.5 kg (495.0 lb). Test Form V3 was also used to record the package's 4.1-kg (9-lb) loss of weight due to the thermal testing at Lindberg Heat Treat in Solon, Ohio. Test unit 4 had the SnapShock-4000 removed from the PCV lid and new O-rings installed in preparation for drop and thermal testing. The PCV O-ring seal was leak tested to a value of 1.8×10^{-5} std-cc/sec in air, as recorded on Test Form 1. The PCV and the drum shown in figures 5.2 and 5.3 had the temperature labels installed. The post-vibration ES-2M test unit 4 was subjected to a 9-m (30-ft) side orientation free drop, a 1-m (40-in) puncture free drop, a 30-minute 800°C (1475°F) thermal test, and an 8-hour 0.9-m (3-ft) water immersion HAC testing.

7.1 HAC IMPACT TESTING

All drop tests were conducted on an essentially unyielding drop test pad located at ORNL's 2000 Area. The drop test pad is constructed from a 10.2-cm (4-in) thick steel plate on top of a 0.9-m (3-ft) diameter reinforced concrete column that reaches down to bedrock. The procedure followed for the 9-m (30-ft) side drop free fall test was recorded on Test Form 4. Puncture drop test for ES-2M test unit 4 was conducted at the same drop area with a 15-cm (6-in) diameter steel bar welded to the drop pad plate. The steel punch bar was at least 20 cm (8 in) long, and the top edge radius was smaller than 0.6 cm (0.25 in). The top of the punch bar was placed horizontal. The 1-m (40-in) free fall puncture test was recorded on Test Form 5.

Unit 4 was first dropped on its side at a measured angle of 0.2° from a distance of 9 m (30 ft) onto a flat, essentially unyielding surface (Figure 7.1). The impact of test unit 4's side drop was absorbed with almost no bounce as compared with other ES-2 side orientation drop tests. The drum's side was deformed along its axis, generating a flattened trapezoidal impact section of 21.6 cm (8.5 in) at the top and 26.7 cm (10.5 in) at the bottom of the drum. The drum lid did not lose any fasteners. A wrinkle formed on the drum lid, but no welds were ripped on the nut plate reinforcing ring. The lid was still firmly attached to the drum, with no visible separation or rips (see Test Form 4 for a sketch of the damage from this drop). The test unit was puncture tested in a position for which maximum damage was expected (Figure 7.2). The selected location was the center of gravity over the solid steel punch bar, with the damaged side receiving the puncture impact. The puncture drop was at a measured angle of 0.5° and at a distance of 1 m (40 in) onto the upper end of the solid steel punch bar. The impact of the punch's center was 42.5 cm (16.75 in) from the lid. The indentation generated an average surface depth of 0.97 cm (0.38 in). See Test Form 5 for a sketch of the damage from this drop.

After the impact testing, the package was radiographed to determine the extent of the damage caused by the impact testing. The results of this inspection were recorded on Test Form 2A. Each crack found during the radiography and described on Test Form 2A was a three dimensional curving shape. The real time radiography on 1/23/97 also included the ES-2LM test units 5, 6, 7, and 8. These were documented on a videotape and digital pictures to become part of the official test record.

ES-2M Unit 4
9-m (30-ft) Free Fall Side Drop

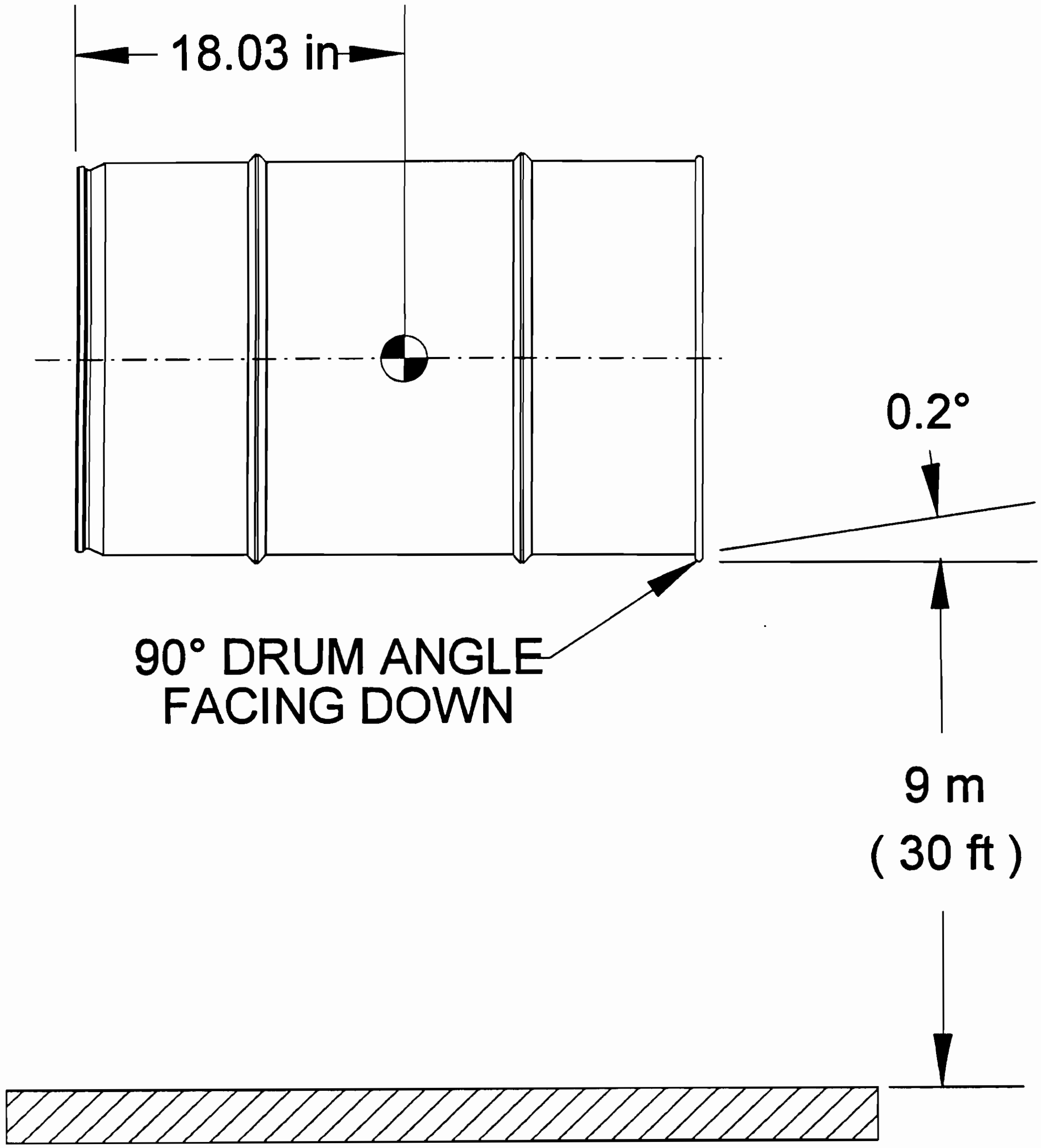


Figure 7.1

ES-2M Units 4
1-m (40-in) Puncture Drop

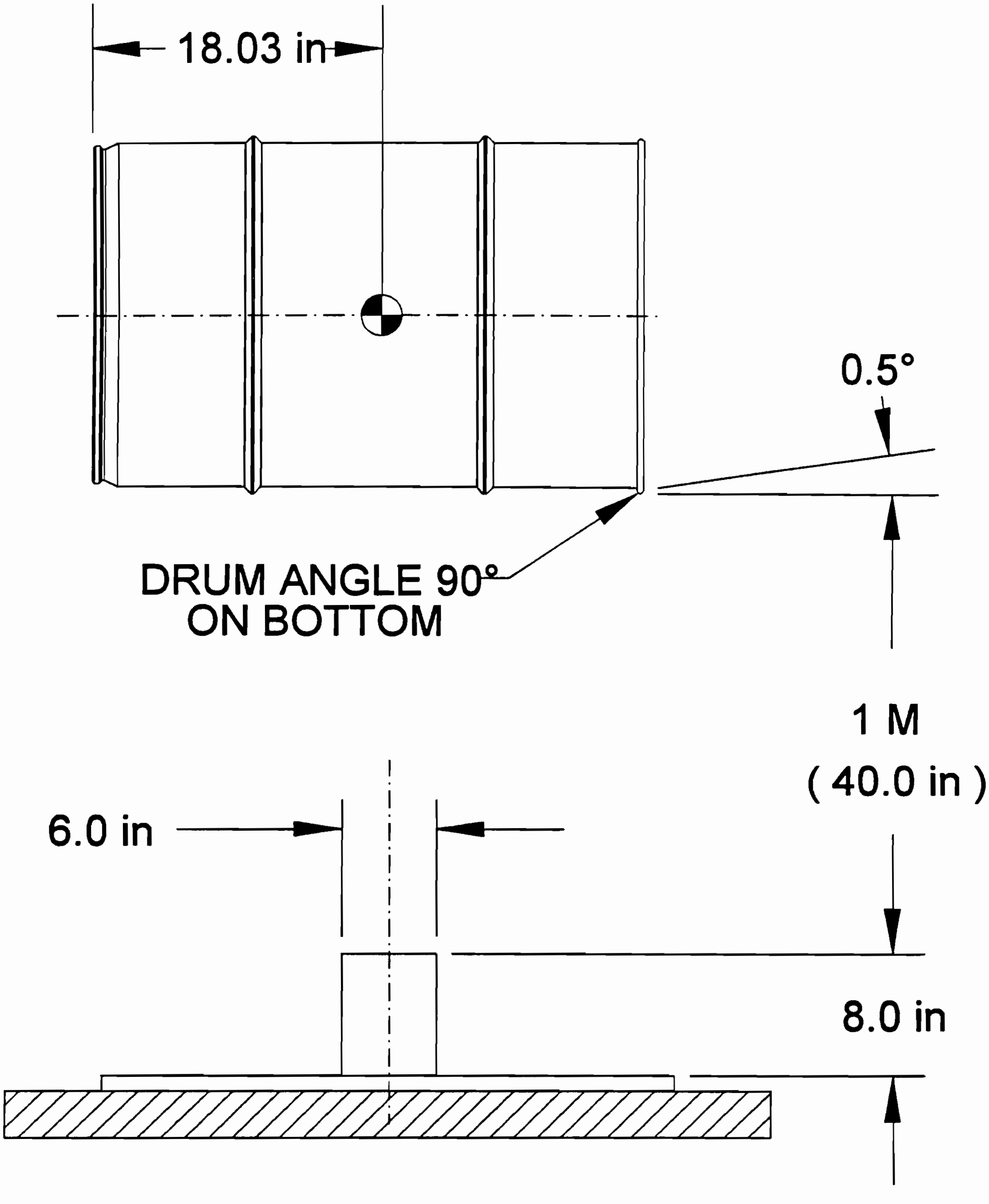


Figure 7.2

7.2 THERMAL TESTING

Thermal testing of ES-2M test unit 4 was conducted at the same time that ES-2LM thermal testing was performed. The description below includes furnace setup, package setup, and the HAC thermal testing.

7.2.1 FURNACE SETUP

The thermal testing was conducted at Lindberg Heat Treat in Solon, Ohio, using furnace #639 with the package on support stands (piers) as shown in figure 7.3. A trial thermal test was conducted on a mockup package before testing test unit 4. This trial thermal test was to characterize the time and temperatures required for the furnace to recover the lost heat from the package's thermal load generated by the door opening and loading the package. A total of 26 thermocouples was installed in the furnace as shown in Figures 7.4, 7.5, and 7.6. The test package support stand (shown in Figures 7.3 and 7.6) had two thermocouples attached. The approximate location of test unit 4 in the furnace during testing is shown in Figure 7.3.

The support stand was attached to the furnace floor before heating. Before heating the furnace, Lindberg's employees practiced loading and unloading a test package in the cold furnace to assure that the furnace door would not remain open more than 90 seconds during loading. Thermal test data was recorded on Test Form 6A for each test unit. This data shows that the amount of time the door was open during loading was 45 seconds.

The furnace temperature controller's accuracy is ±2.8°C (±5°F). Temperature data was recorded from the furnace's control as thermocouple 26F. The average temperature of the 26 furnace thermocouples in furnace #639 was about 14.5°C (26°F) higher than the furnace controller's set temperature. The temperature range of the 26 furnace thermocouples during the thermal test was ±22.2°C (±40°F) from the average furnace temperature. A minimum of 8 hours before the beginning of all thermal testing, the furnace was turned on with a set-point temperature of 871°C (1600°F). At least one hour before the beginning of each individual thermal test, the furnace set-point was adjusted to 871°C (1600°F). The furnace control temperature strip chart or data recorder ran continuously for at least an hour before and during each thermal test.

7.2.2 PACKAGE SETUP

Each test unit was preheated to over 38°C (100°F) by placing ES-2M unit 4, along with ES-2LM units 5, 6, and 7 in a 6-ft cube heated environmental chamber. The environmental chamber is a welded steel frame with fiberglass insulation panels. The environmental chamber was heated by a torpedo type kerosene space heater controlled by a mechanical bulb thermostat with a control range of 100°F to 200°F. It was heated from the bottom with four floor register vents located around the perimeter and an eight-inch manual damped center venting stove pipe.

The packages were preheated for more than five days before the thermal testing began. The preheat thermocouple temperature data for the test units was measured on the top center of two drums and recorded on a Fluke data logger (figure 7.7). A computer thermal analysis[12] of the predicted temperatures was plotted with the measured data from figure 7.7 as shown in figure 7.8. Figure 7.8 shows that the predicted temperature of the top center external drum skin temperature is about 5°F higher than the measured temperature at 120 hours. This preheat temperature prediction accuracy was deemed acceptable based on previous experience with the ES-2M unit 3 preheat[3]. This thermal analysis was also able to predict the preheated temperatures of the ES-2LM PCV shown in figure 7.9. The thermal analysis showed that at 126 hours (49 hours @ 150°F and 77 hours @ 115°F) that the temperature of the ES-2LM drum top center and the PCV temperatures were within 0.5°F of each other. Using this logic, the PCV for the ES-2LM and the ES-2M test unit 4 was estimated to have been about 110°F when it was thermally tested. The approximate preheat time for test unit 4 was 49 hours at 150°F and was held at 115°F for an additional 94 hours.

After preheating, test unit 4 was removed from the preheat environmental chamber. During this handling water was observed pouring out of the drum lid around the lid security seal lug. The water most likely got into the drum when drop testing in the rain on 1-22-97. Most of the water was poured out during the package before the thermal test. Because the package was not opened and wiped dry, some water adhered to the internal surfaces of the package. After draining the package, test unit 4 was weighed with scales at Lindberg Heat Treat in Solan, Ohio to detect the pre-thermal test weight as recorded on Test Form V3. The final package preparation included welding on six external thermocouples (1P through 6P) placed per figure 7.10 and verification of the thermocouples' operability. To eliminate any radiant viewing factors between the thermocouple tips and the furnace walls, the tips and attachment tip plates were covered with a ceramic coating[13].

Furnace Container Support Pier Locations

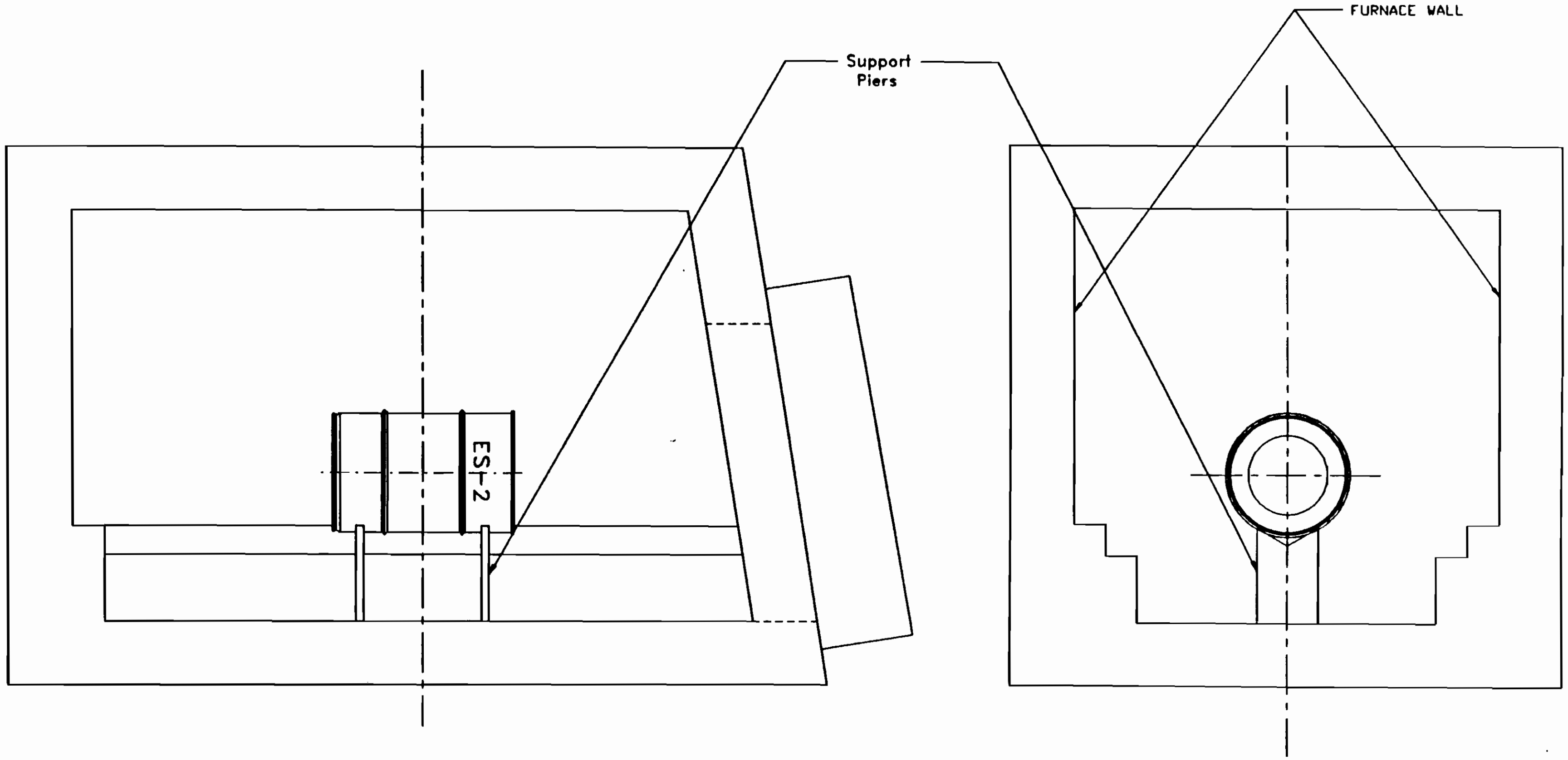


Figure 7.3

Furnace Side Wall Thermocouple Locations

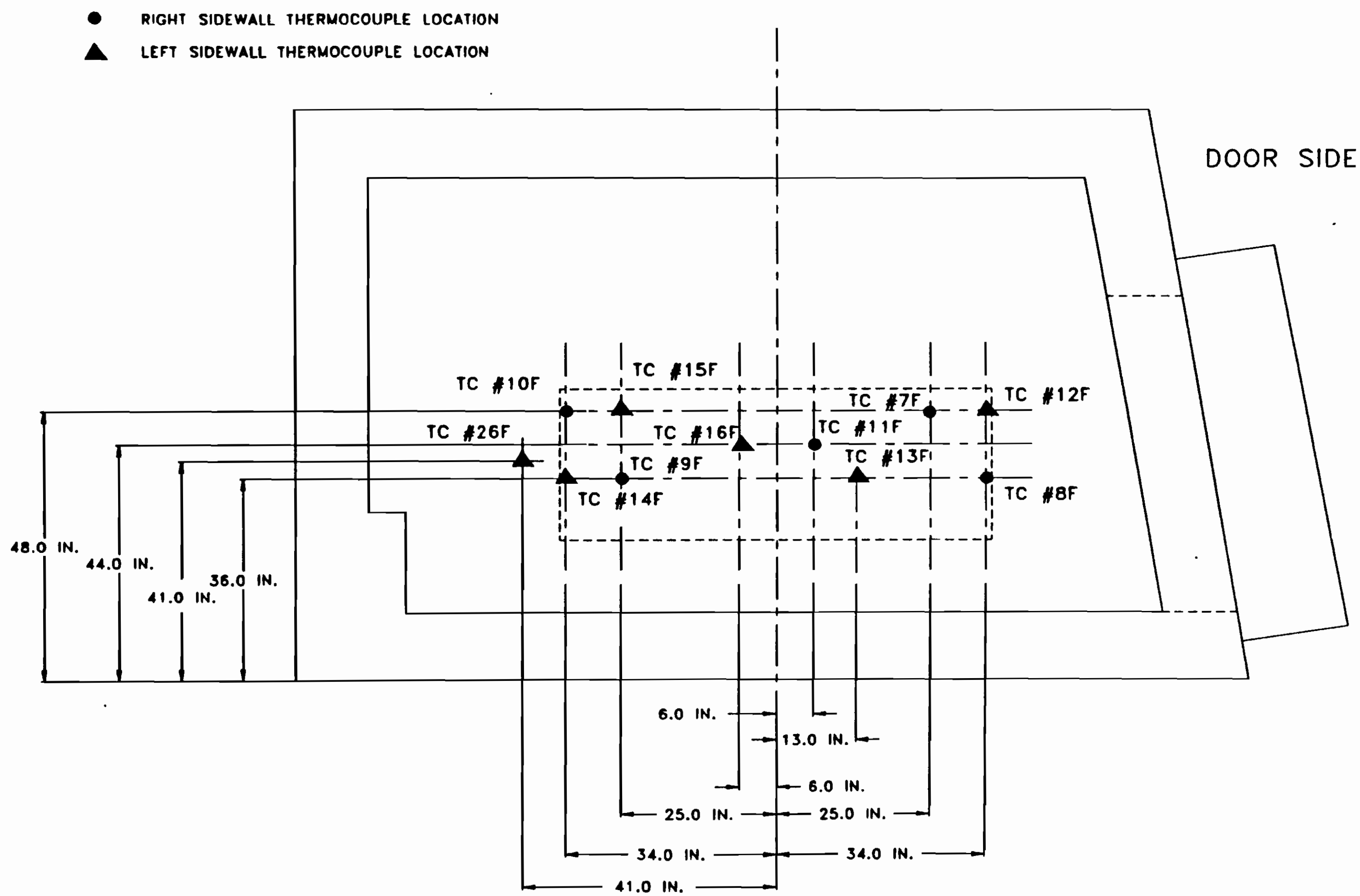


Figure 7.4

Furnace Floor and Roof Thermocouple Locations

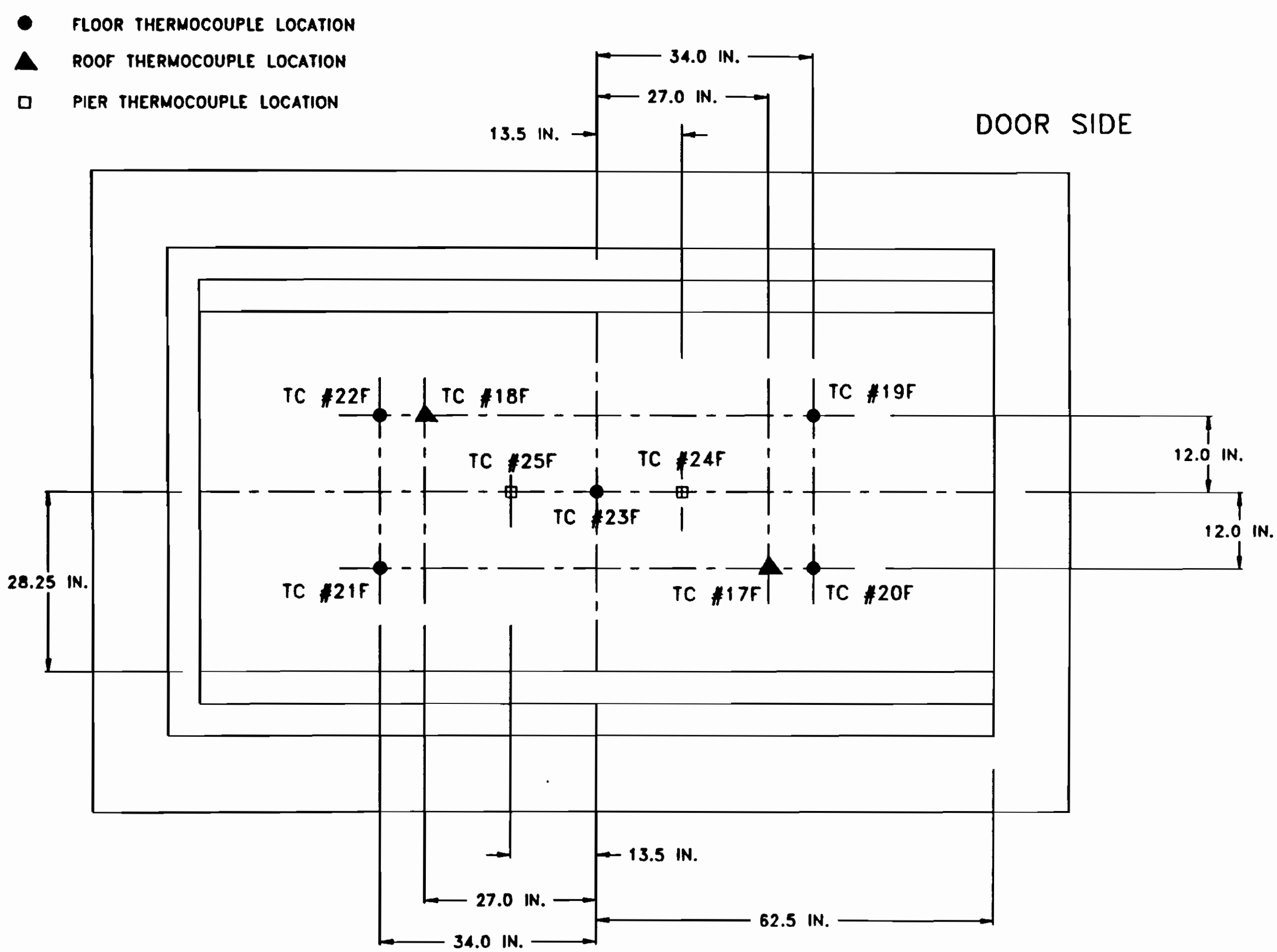


Figure 7.5

Furnace Door and Back Wall Thermocouple Locations

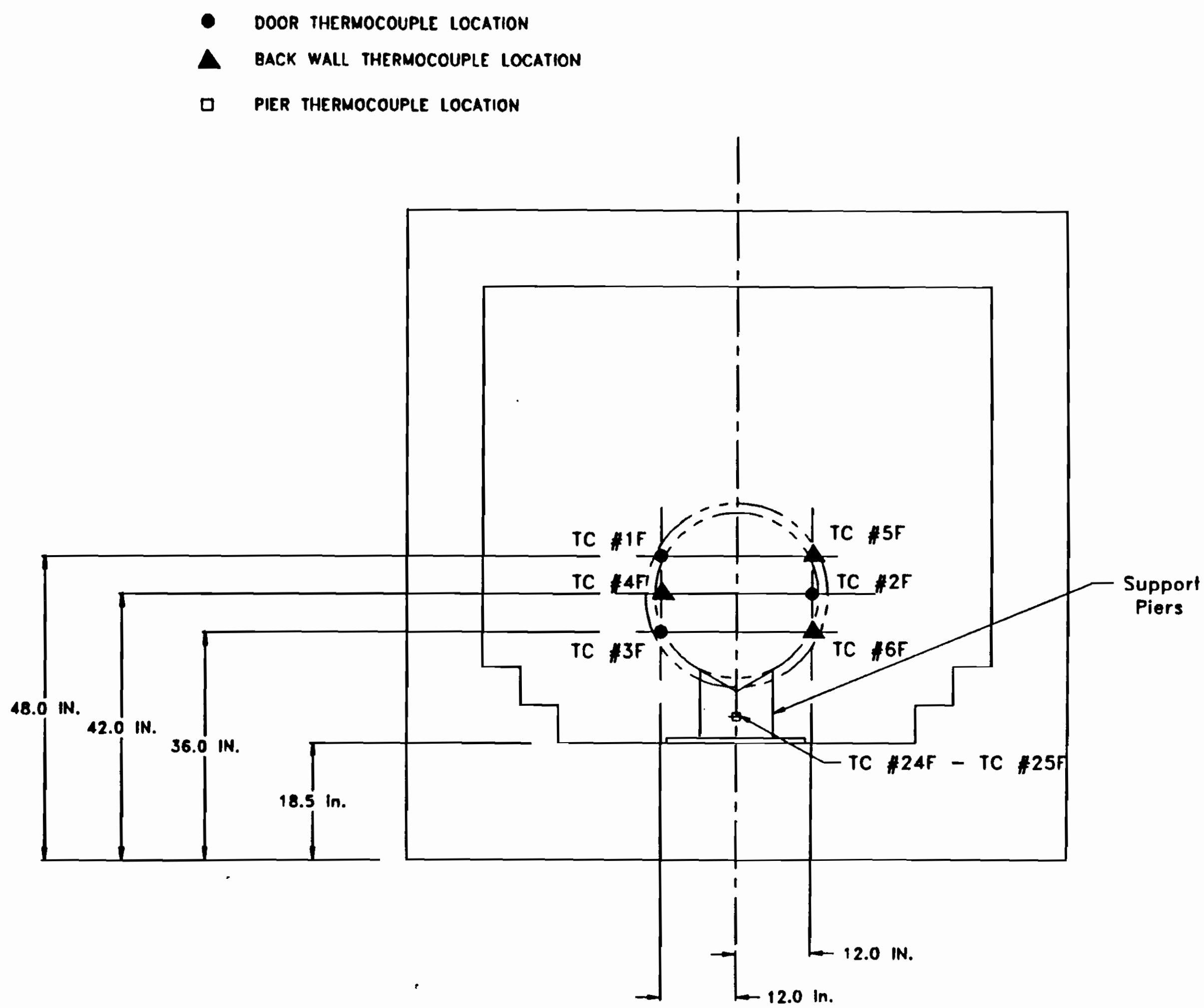


Figure 7.6

Measured External Drum Temperatures for ES-2M and ES-2LM Preheat

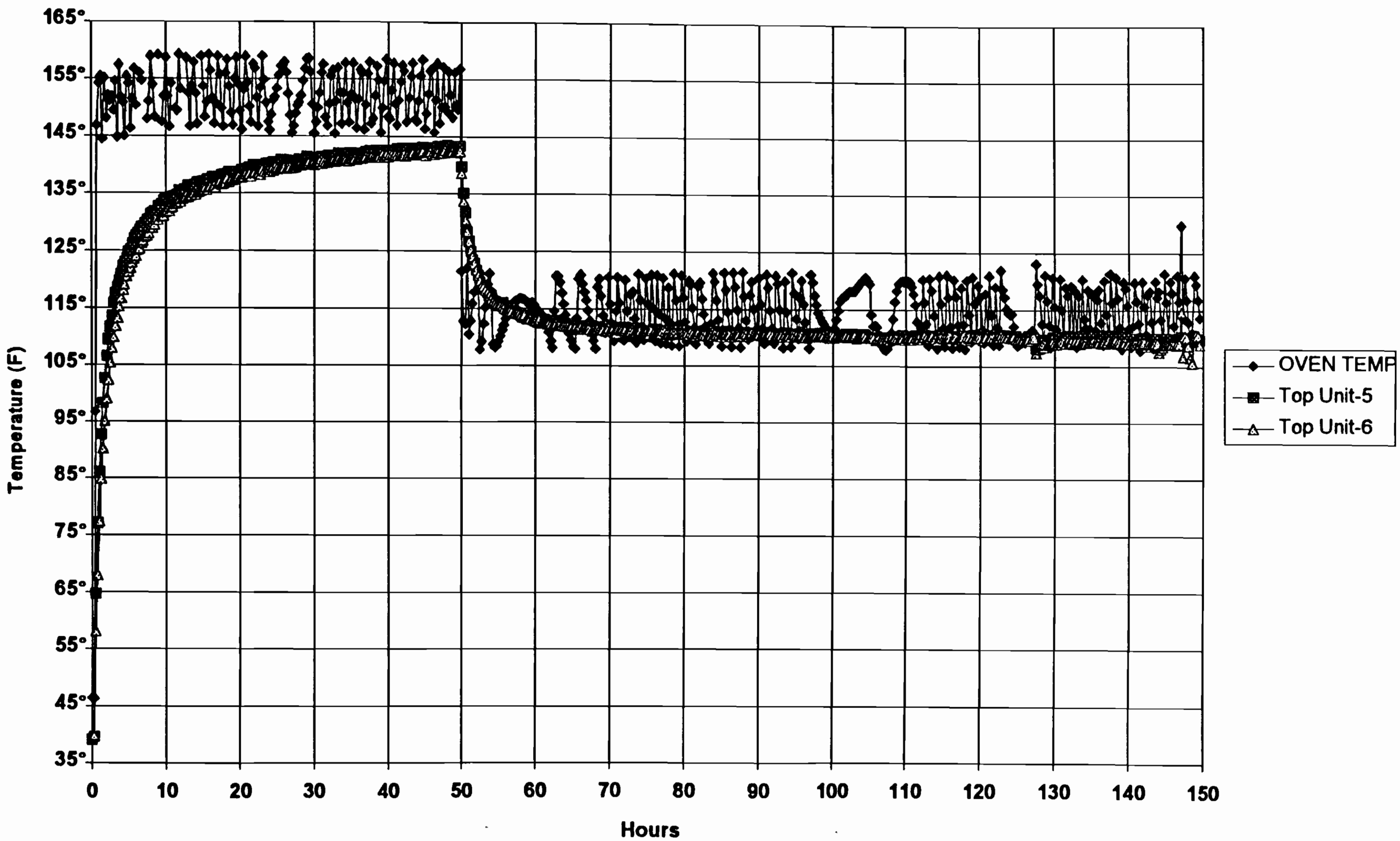


Figure 7.7

Analytical External Drum Temperatures for ES-2M and ES-2LM Preheat

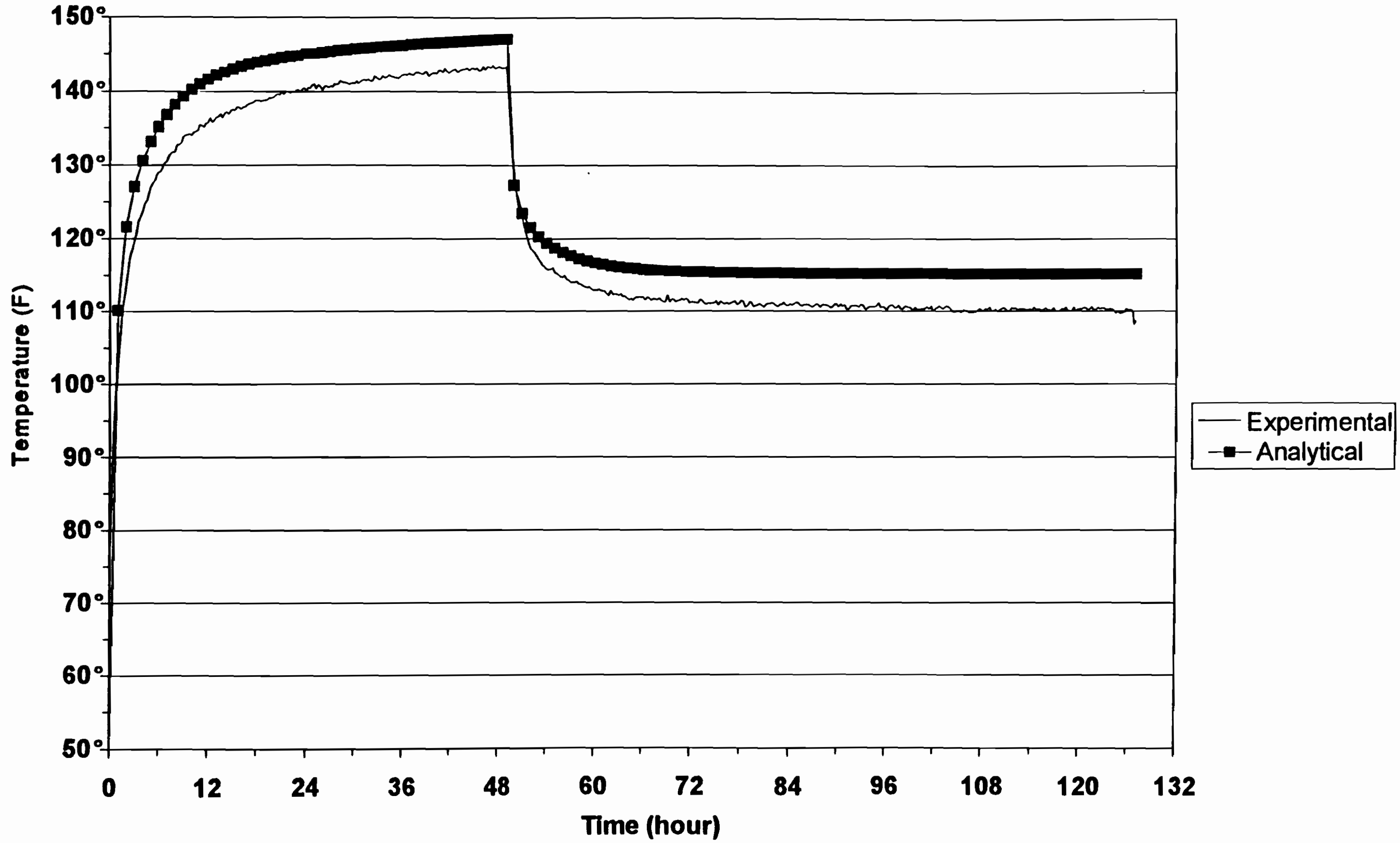


Figure 7.8

Analytical Prediction of PCV O-Ring Temperatures for ES-2LM Preheat

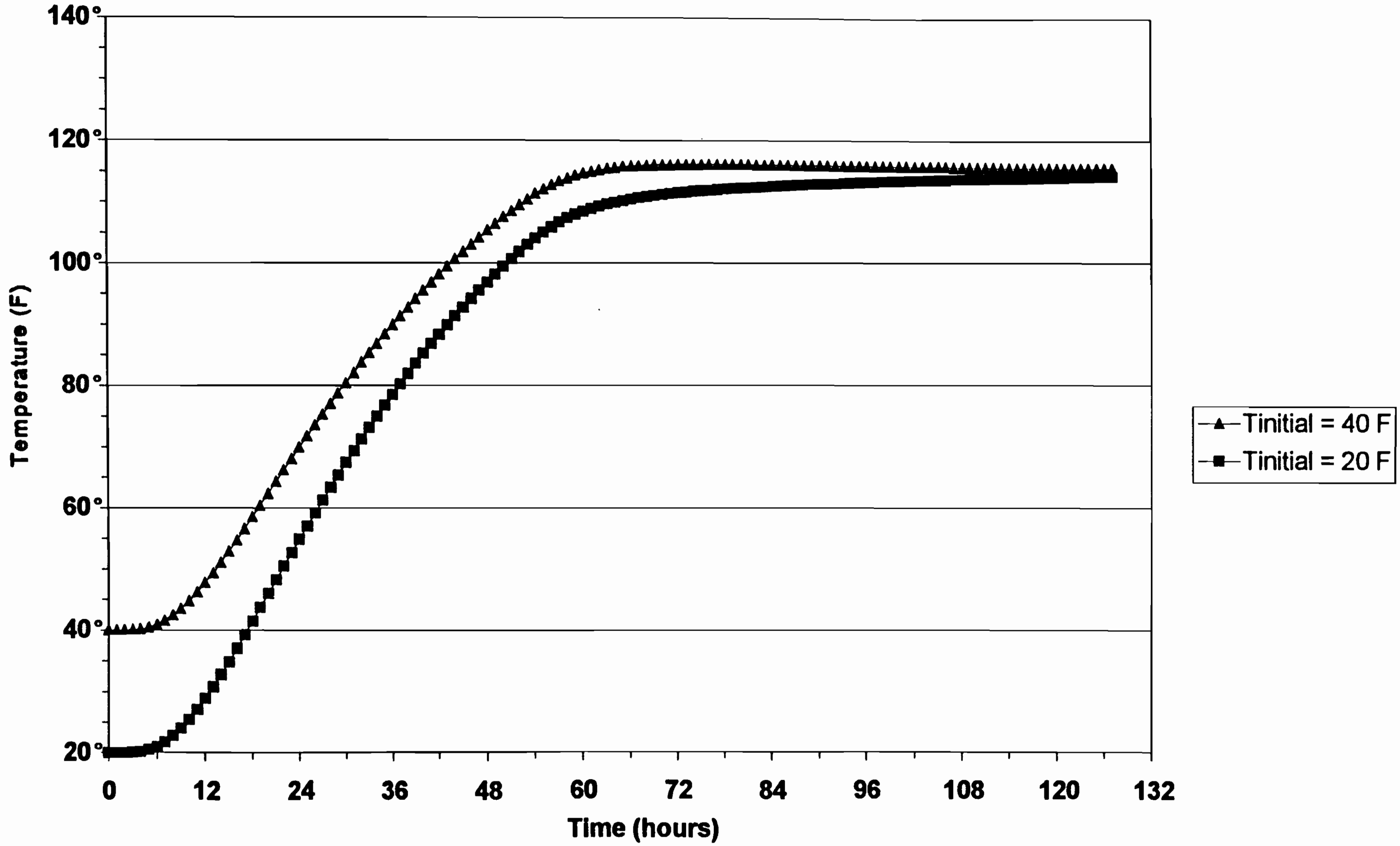


Figure 7.9

ES-2M Unit 4:
Outer Drum Thermocouple Locations

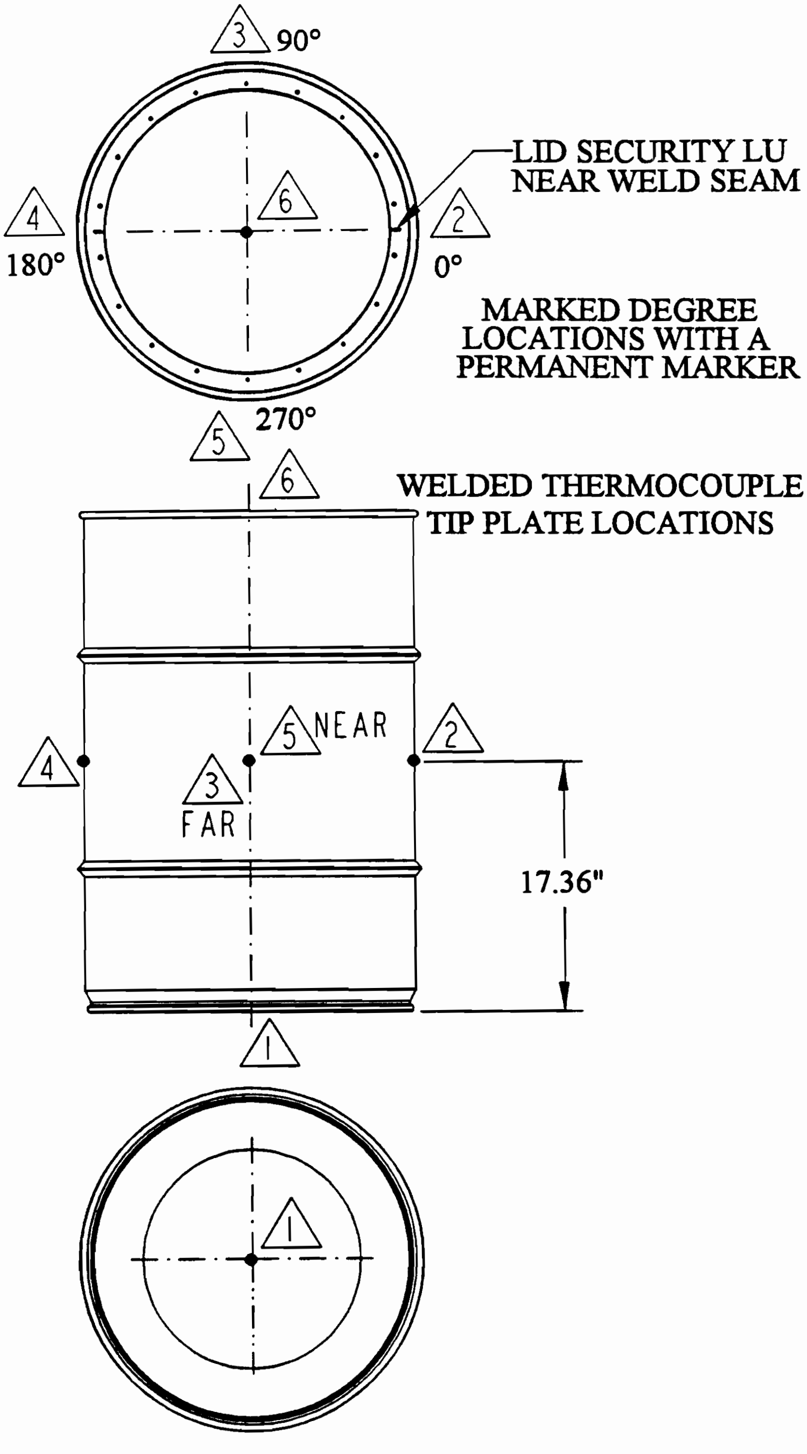


Figure 7.10

7.2.3 HAC THERMAL TESTING

Thermal testing data was recorded on Test Form 6A for test unit 4. At least one hour before the beginning of testing, the furnace set-point was adjusted to 871°C (1600°F). Test unit 4 was loaded into the furnace after all functioning thermocouple temperatures in the furnace walls and support stand were reading 800°C (1475°F) or higher. Test unit 4 was placed in the preheated furnace on the support stand positioned with the long axis horizontal. As shown in figure 7.3, the package lid was toward the furnace door, and the damaged side (or 90° as marked on the test unit, see figure 7.10) of the package was facing upward.

During the testing of test unit 4, the thermocouple temperature data recorder was set to record every 30 seconds. The 26 furnace thermocouples (1F to 26F) temperatures are plotted in figure 7.11. This package took approximately 11.3 minutes to get 5 of the 6 external thermocouples (1P to 6P) more than 800°C (1475°F), which was test time zero. Figure 7.12 shows the outer drum thermocouple temperatures. A close-up thermocouple temperature plot in figure 7.13 shows that the temperature at 6P, the drum lid top thermocouple began to fall at 1350°F. This phenomenon was observed in every thermal testing of the ES-2 and was probably due to air and water held in the cast refractory of the top plug. The top plug has a vent hole on the top center plate. As the drum heated up the plug burned away and the hot air, water vapor, and steam was vented below the drum lid at the thermocouple location. This vented gas cooled the P6 thermocouple for almost 14 minutes during the testing. Once time zero was obtained, the furnace set temperature was adjusted to keep the external package thermocouple temperatures above 1475°F. These furnace adjustments ranged from a low of 849°C (1560°F) to a high of 877°C (1610°F) and are recorded on Test Form 6A. The temperature effect of the furnace adjustments on test unit 4 can also be seen in figures 7.11 and 7.13. The package was exposed to the radiation environment for 31 minutes after time zero, for a total time in the furnace of 42.3 minutes.

The external drum thermocouples were disconnected shortly after the package was removed from the furnace. The test unit was allowed to cool for more than 20 minutes in front of the furnace before it was moved to a cooling rack. At both locations the test unit was not exposed to artificial cooling. Since the inorganic thermal insulating and impact limiting material is fireproof, the thermal testing caused no combustion of packaging materials. No visible damage was generated due to the thermal testing. As documented on Test Form V3, the package lost 9 pounds of weight due to the thermal testing. The weight loss was determined to be due to water in the cast refractory, which was vaporized during thermal testing, and this was consistent with all other ES-2 thermal testing.

ES-2LM Unit 4: Furnace Temperatures

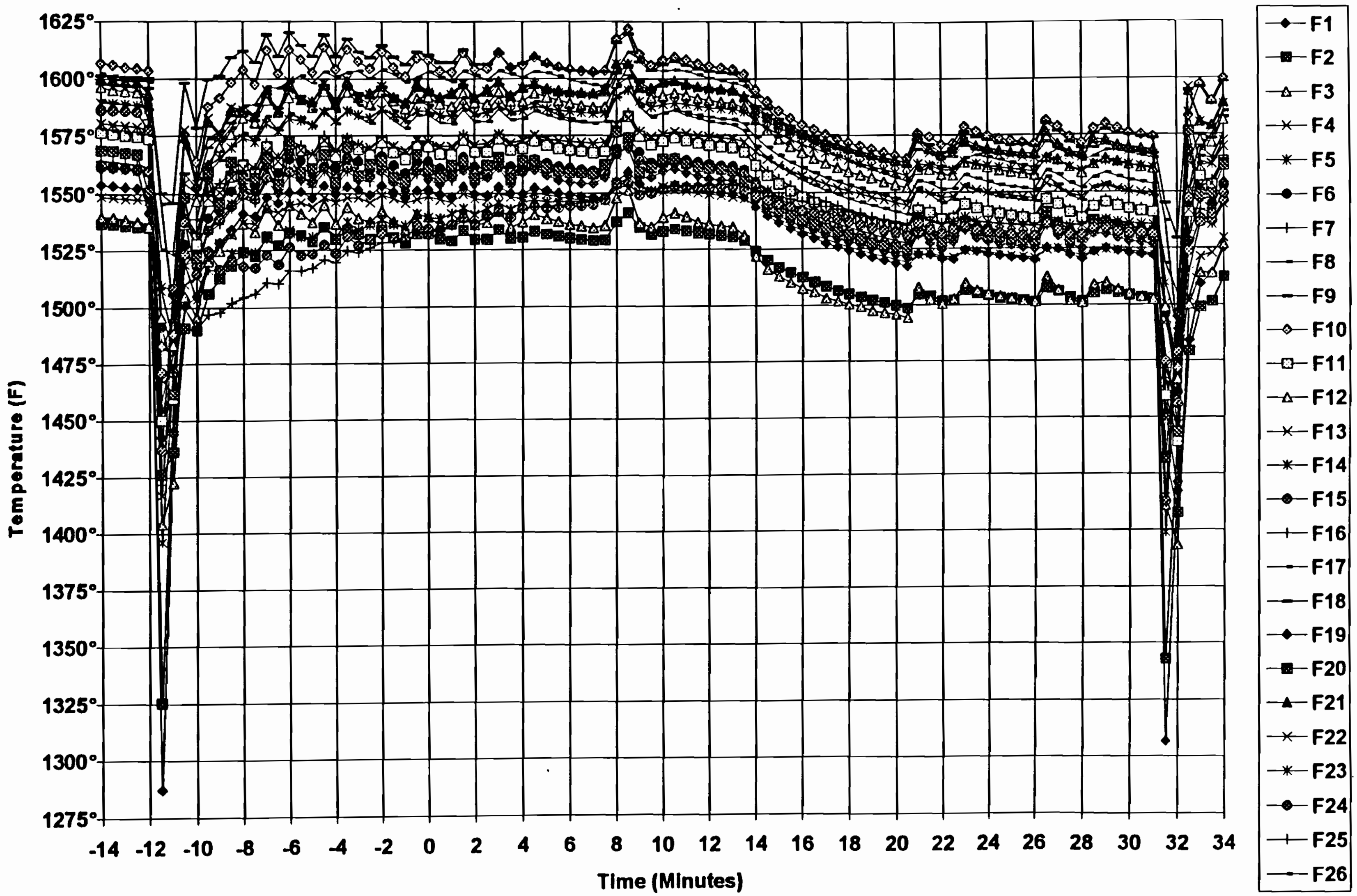


Figure 7.11

ES-2LM Unit 4: Outer Drum Temperatures

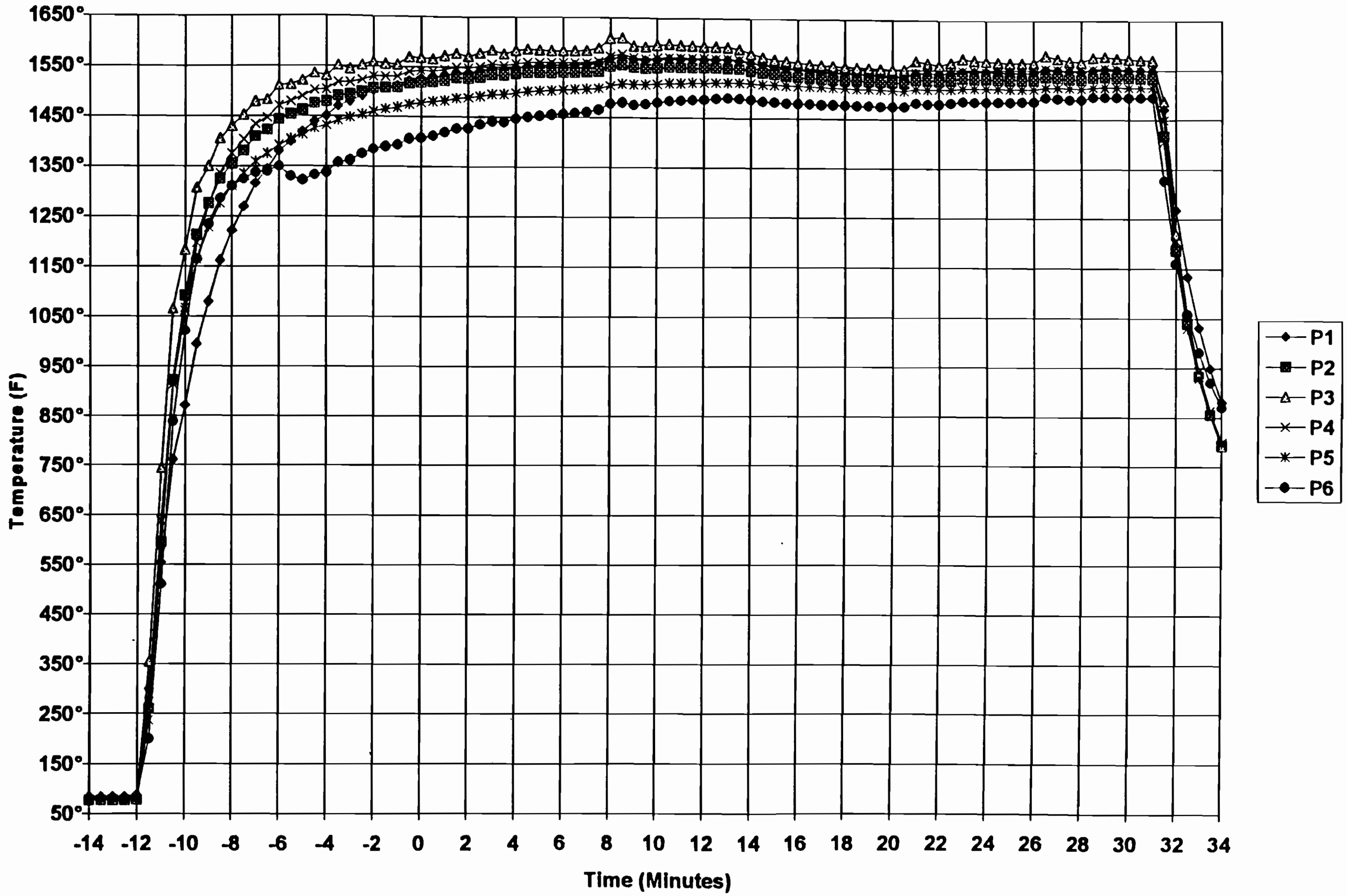


Figure 7.12

ES-2LM Unit 4: Outer Drum Close-Up

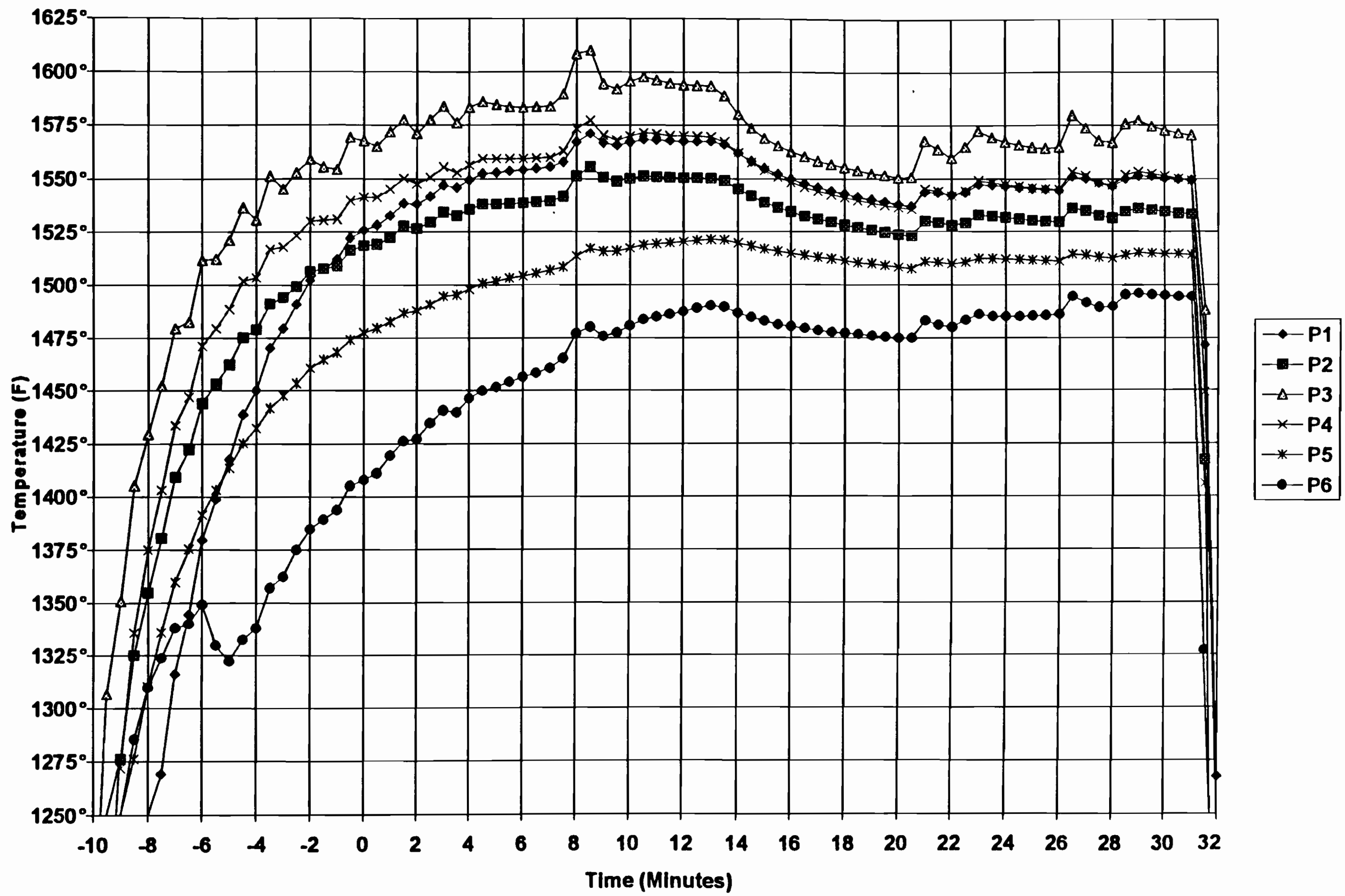


Figure 7.13

7.3 POST-THERMAL HAC TESTING

After cooling over night, test unit 4 was disassembled and inspected. Testing damage was recorded on test forms and with photographs and videotape. The post-thermal weight of the test unit was recorded on Test Form V3. Test unit 4 was visually inspected, and the condition of the package and any observations were recorded.

The drum lid was removed with some difficulty. The drum lid's rolled edge was pushed against the nut and stud number 10 at the impact location of 90°. Since a wrench could not remove this nut, it was cut off with a power grinder. The rest of the nuts were removed with their breakaway torques ranging from 70 to 175 in-lbs. A pry bar was used to disengage the drum's false wire and the lid's rolled edge. Once the lid was off, most of the top plug's paint markings were observed to have been removed by steam. As discussed in section 7.2.3, some steam was generated when the cast refractory in the top plug was heated. The ES-2M history has shown that the top plug's vent hole on the top center plate vents about 0.5-kg (1.25-lb) of water as steam.

The visible damage to the top plug and drum liner was due to being bent out of shape from the drop testing. The top plug had to be pried out of the drum. As shown in the photographs and drawings, (available on request) these parts had imprints of the PCV hitting the drum liner. No visible weld rips or holes were observed on the drum liner or the PCV from the drop testing. The parts had no tar deposits, smoke, or heat damage.

The maximum blackout Tempilable temperatures for test unit 4 were recorded on Test Form 6D. The Tempilable temperatures for the drum liner ranged from 200°F to 225°F, and on the PCV outside surfaces the maximum temperatures ranged from 150°F to 175°F. No Tempilables were placed inside the PCV due to the vibration damage to the test mockups packaging material. The temperature labels from Test Form 6D for the ES-2M test unit 1 and ES-2LM test unit 5 are shown below in section 8 for comparison. Both unit 1 and unit 5 had been drop tested in a similar orientation (side drop). Thus, comparisons between these units and unit 4 (vibrated then side dropped) are valid.

The PCV from test unit 4 underwent leak and immersion testing that was recorded on Test Form 7A. The PCV O-rings was successfully leak tested to a value of 1.6×10^{-5}std-cc/sec in air. The PCV was immersed under a head of water of at least 0.9 m (3 ft), (actual measurement of 64.5 inches) for not less than eight hours (actual measurement of 8 hours and 3 minutes) and in a horizontal position on the immersion fixture. After the PCV was dried with paper towels, it was opened. The PCV screw removal torques were recorded on Test Form 7A and ranged from 125 in-lb to 180 in-lb with an average of 153.3 in-lb. All holes were still aligned, and each screw went back into place without binding. No evidence of water leaking into the PCV past the O-ring seal was observed, as no water was found inside the containment vessel. All of the parts went back into the package for return shipment to storage after drum studs numbered 1 and 17 were also cut off to get the lid back on the drum.

8. HAC TESTING RESULTS AND COMPARISONS

An array of maximum temperature blackout labels was used to determine information about the performance of the ES-2 packaging system. The temperature labels used for thermal testing were in 25°F increments from 125°F to 500°F. Each of the test packages in this comparison received the same HAC testing, including the 9-m (30-ft) side drop free fall test. The temperature labels from the ES-2M test unit 1 and ES-2LM test unit 5 were compared with the vibration test unit 4. The comparison tables shown below are for each test unit's drum liner and PCV.

Some temperature labels' arrays were in slightly different locations for each test unit, but the readings are comparable. For ES-2LM-5, the 1" ledge temperature label readings were next to the large containment vessel's flange, where the insulation is about 3 inches thick. All other temperature label readings on the drum liner were located where the insulation is about 5 inches thick. The average 5-inch insulation drum liner maximum blackout temperatures for test unit 1 (208°F), test unit 4 (220°F), and test unit 5 (223°F) show small differences. These small temperature differences are assumed to be within the tolerances of the testing.

The PCVs also had some temperature label arrays with differing locations. ES-2M test unit 1 had the temperature label arrays placed inside the PCV, while labels for ES-2M test unit 4 and ES-2LM test unit 5 were placed outside the PCV. Other thermal differences were attributed to the ES-2M and the ES-2LM having different packing arrangements and mockup loads during testing. The average PCV maximum blackout temperatures for test unit 1 (150°F), test unit 4 (183°F), and test unit 5 (167°F) show small differences. While test unit 4 did have a higher average temperature at the PCV, this is not necessarily indicative of decreased performance due to vibration testing. Units 1 and 4 were of similar configuration, but the temperature indicating labels on unit 1 were inside the PCV, while those on unit 4 were outside the PCV, which would explain the higher average temperatures found on unit 4. Units 4 and 5 were of dissimilar configuration, as unit 5 was an ES-2LM unit which contains an additional containment vessel outside of the PCV. The effect of heat abatement due to the extra containment vessel would be substantial, thus explaining the higher temperatures found on unit 4.

Table 8.1 Drum Liner Blackout Temperature Indicator Readings in °F

Drum Angle Locations		0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°
Row Height from Bottom		0.0" (Bottom)				5.0"				12.7"				1" Ledge				23.2" (Plug Bottom)			
Test Unit	TempLable #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ES-2M-1	Side Drop	200	200	200	N/A	225	200	200	200	200	200	200	200	225	200	175	225	225	225	225	225
ES-2M-4	Virb/SideDrop	N/A	N/A	N/A	N/A	225	225	225	225	200	250	200	225	225	N/A	225	200	200	225	225	225
ES-2LM-5	Side Drop	N/A	225	225	225	225	225	225	225	200	225	225	225	300	N/A	300	225	225	225	225	225

Temperature Indicators Locations are slightly different for each Test Unit, Data Taken from Test Form 6D

Table 8.2 PCV Blackout Temperature Indicator Readings in °F

Drum Angle Locations		0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°
Row Height from Bottom		0.0" (Bottom)				4.0"				10.5"				17.0"				21.44" (Lid Bottom)			
Test Unit	TempLable #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ES-2M-1	Side Drop	N/A	N/A	N/A	N/A	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Test Unit	TempLable #	1	2	3	4	5	6	7	8					9	10	11	12	13	14	15	16
ES-2M-4	Virb/SideDrop	N/A	N/A	N/A	N/A	175	175	175	175					175	175	175	175	200	200	200	200
ES-2LM-5	Side Drop	N/A	N/A	N/A	N/A	150	175	175	175					175	150	150	150	175	175	175	175

Temperature Indicators Locations are slightly different for each Test Unit, Data Taken from Test Form 6D

9. TESTING SUMMARY AND CONCLUSIONS

The vibration testing was a demanding test that simulated the transportation of a fully loaded ES-2M over the road for approximately 42,000 miles on a common carrier. Without any padding, the testing destroyed the package's convenience cans and shattered the drum's Kaolite impact limiter (though shattered, the Kaolite did remain in place), but it did not shake loose any fasteners. The drum's shattered Kaolite impact limiter worked well as an impact limiter, with no drum lid fasteners breaking loose and almost no bounce from the 9-m (30-ft) side drop. The drum's confinement design pinned the lid and top plug into the drum, making it difficult to remove the containment vessel.

The cast refractory Kaolite impact limiter performed well as the drum's thermal insulator. The blackout temperature indicator tables have shown that the vibration damage in the Kaolite did not substantially reduce the thermal protection to the PCV. The maximum PCV lid blackout temperatures on test unit 4 was 200°F, which is well below the maximum O-ring operation temperature of 300°F for 1000 hr[14].

After being subjected to two strenuous "normal" condition vibration tests, the ES-2M test unit 4 passed all phases of HAC testing. It is concluded that the testing performance of the ES-2M shipping package has met the requirements of Title 10, CFR 71.71(c)(5).

10. SUPPORTING INFORMATION

Test unit 4 was reassembled and shipped to Y-12 for storage as a record of the test. The test data that supports the testing documentation shall be maintained as part of the master file, *Vibration Test Report of the ES-2M Shipping Package*, GAB1296-2. This test data shall be maintained as long as the package certification is active.

10.1 PHYSICAL TEST FORMS

The data to substantiate the discussions above for the four test units was hand recorded on individual sets of the appropriate test forms. Test forms V1 through V6 were taken from the Vibration ES-2M test plan[1]. Test forms 1 and 2 were taken from the HAC ES-2M test plan[10] used in July of 1996. Test forms 2A, 4, 5, 6A, 6C, 6D, and 7A were taken from the HAC ES-2LM test plan[2]. This data was transcribed to the blank spaces on these forms as required, with the originals filed with the master file for these tests. When the information was not available, the blank lines on the forms were filled with "N/A." An example of this occurs where the forms ask for tool or instrument certification information and the device described was not used in the test or the information was not available. The completed and signed test forms were included in the master file, *Vibration Test Report of the ES-2M Shipping Package*, GAB1296-2.

10.2 TEST PHOTOGRAPHS AND MOTION PICTURES

Many color photographs, videotapes, and high speed motion pictures of the tests were made according to the *Vibration Test Plan of the ES-2LM Shipping Package*, GAB0196-1. These photographs, videos, and pictures are available on request. Additional records, such as charts, certifications, drawings, and computer data files etc., were filed with the master file of *Vibration Test Report of the ES-2M Shipping Package*, GAB1296-2.

11. REFERENCES

1. Byington, G. A., *Vibration Test Plan of the ES-2M Shipping Package*, Lockheed Martin Energy Systems, Inc., GAB1296-1, 12-06-96.

2. Byington, G. A., *Test Plan of the ES-2LM Shipping Package*, Lockheed Martin Energy Systems, Inc., GAB0197.

3. Koalite® 1600 is a registered trademark of Thermal Ceramics. Thermal Ceramics, P.O. Box 923, Augusta, Georgia 30903-0923

4. Byington, G. A., *Test Report of the ES-2M Shipping Package*, Lockheed Martin Energy Systems, Inc., GAB0796-2.

5. Byington, G. A., *Certification Test Report of the ES-2LM Shipping Package*, Lockheed Martin Energy Systems, Inc., GAB0297.

6. SnapShock-4000, Instrumented Sensor Technology, 4704 Moore Street, Okemos, MI 48864-1722, (517)349-8487

7. Wakefield, J., *Vibration Testing of an ES-2 Shipping Container*, Wyle Laboratories, Huntsville, Alabama 35807, Report No. 45918-01, P.O. No. 84YLFP22, February 21, 1997

8. The Drawings used to build the ES-2M Drop Test Assembly (M2E801136A056 Rev-A) are;
M2E801136A010 Rev-B Drum Assembly
M2E801136A030 Rev-B Medium Container Assembly
M2E801136A051 Rev-A ES-2M Shipping Foam Packing Parts
M2E801136A055 Rev-A ES-2M Shipping Test Weight
M2E801136A057 Rev-A ES-2M Al Liner and Ring

9. Tempilable, Temperature Monitor (from 125 °*F* to 500 °*F*), No. 16B-125/52, So. Plainfield, N.J.

10. C.F.Magnuson, "Manufacture-to-Stockpile Sequence," SAND83-0480, Figure 3.30, *SST Transport Vibration Envelope.*

11. Byington, G. A., *Test Plan and Procedure for Certification Testing of the ES-2M Shipping Package*, Lockheed Martin Energy Systems, Inc., GAB0796-1, July 29, 1996.

12. Anderson, J. C., *Miscellaneous Thermal Analyses of the ES-2 Shipping Package*, DAC-EA-801208-A005, X-10 Plant, Oak Ridge, Tennessee, May 1997.

13. ITC 213 Ceramic Coating for Metals, International Technical Ceramics Inc., Ponte Verdra Florida 32082

14. "Parker O-ring Handbook (GL-9/92)", Parker Seal Group, O-ring Division, 2360 Palumbo Drive, Lexington, KY 40512, Figure A3-6 Seal Life at Temperature

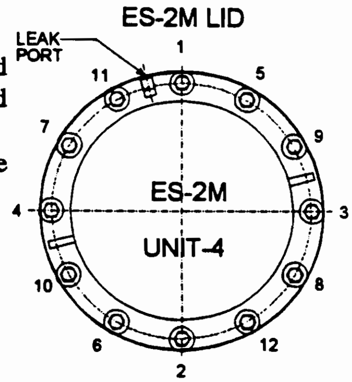
APPENDIX A

NCT VIBRATION TEST FORMS

TEST FORM V1
ASSEMBLY OF THE PCV/SCV

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: 9201-1, Y-12

VERIFIED	TASK
✔	The container serial numbers: PCV/~~SCV~~ 12000
✔	All containment vessel (PCV/~~SCV~~) components have been dimensionally verified to comply with drawing specifications.
N/A	Temperature indicators have been affixed to the interior surface of the PCV/~~SCV~~ as shown in the attached figure. (No temperature indicators are required on prototype for normal conditions testing.)
N/A	None of the temperature indicators indicate exposure to a temperature in the measured range.
✔	The containers, lids, mockup, and inserts have been clearly marked as "ES-2M, Unit -4."
✔	The PCV/~~SCV~~ O-rings, O-ring glands, and sealing surfaces have been inspected for defects and found acceptable.
✔	Foam inserts and mockup have been weighed and weights have been recorded on form 3.
✔	The Alum. inserts and mockups have been inserted into the PCV, the lid installed with the leak port aligned as close to the PCV weld seam as possible, mark the lid alignment with a permanent marker. Torque the screws to 216 ± 12 in-lb (18 ± 1 ft-lb) in the sequence shown at right. Ambient temperature at closure ____°C (70 °F). Torque wrench # M101993 Expiration Date 12-97
✔	The PCV assembly has been leak tested to one of the following procedures (____) OO-R-031 (F) or (✔) NPS-R-001. Leak Tester Cert. # 34 Expiration Date See Comments Leakage Value 1.6×10^{-5} std-cc/sec air
N/A	The SCV assembly has been leak tested to one of the following procedures (____) OO-R-031 (F) or (___) NPS-R-001. Leak Tester Cert. # ________ Expiration Date ________ Leakage Value ________ std-cc/sec air
✔	The PCV/~~SCV~~ assembly has been weighed and the weight has been recorded on Form 3.
N/A	Thermocouples have been attached to the exterior surface of the PCV/~~SCV~~ if this unit is to obtain time-temperature data. These thermocouples have been surveyed to ensure they are working, which has been noted on Form 6B.
✔	* Photographs of the assembly have been taken.



Comments: 1) The PCV had no weld seam.
2) The Calt-5 No. 34 with transducer No. 1393/000 was last tested 50 days ago on 10-23-96.

I certify that the above tasks have been performed and that the observations and comments are correct.

Stephen McTeer	12-12-96	G. A. Byington	12-12-96
Testing Technician	Date	Witness	Date

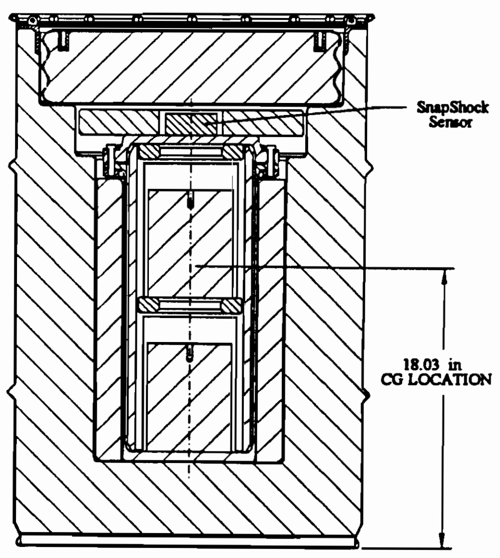
*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V2
ASSEMBLY OF TEST PACKAGE

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Location: 9201-1, Y-12

VERIFIED	TASK
✔	The drum has been clearly marked "ES-2M, Unit -4."
✔	Record the drum serial number: 12002
N/A	The center of gravity targets have been applied to the drum as shown.
✔	Each insulation insert has been clearly marked "ES-2M, Unit -4."
✔	The insulation inserts were weighed together and the weight has been recorded on Form 3.
✔	The lower and middle insulation inserts have been loaded into the drum.
✔	The PCV/~~SCV~~ assembly has been loaded into the drum, with the seams aligned.
✔	The top insulation inserts have been loaded into the drum.
N/A	The gap between the top insulation inserts and the top of the drum is ________.
✔	The drum lid with NO GASKET has been installed, mark the lid alignment with a permanent marker.
✔	The drum lid nuts were installed and torqued to 120 ± 12 in-lb, following the sequence shown on TEST FORM V4.
	Torque wrench # M101993 Expiration Date 12-97
N/A	A security seal has been attached to the drum.
✔	The test package assembly has been weighed and the weight recorded on Form 3.
✔	* Photographs of the assembly have been taken.

CENTER OF GRAVITY MARKING



Comments: ES-2M Unit -4 is also Known as the "X-Ray Unit". The X-Ray Unit was used to test the radiographing of the drum liner.

I certify that the above tasks have been performed and that the observations and comments are correct.

Stephen McTeer	12-12-96	G. A. Byington	12-12-96
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V3
COMPONENT WEIGHTS

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: 9201-1, Y-12

PRE-TEST WEIGHTS

PART NAME	WEIGHT	BY	DATE	PART NAME	WEIGHT	BY	DATE
Upper Assem. Mockup	47.0 lb	SMM	12-10-96				
Lower Assem. Mockup	47.0 lb	SMM	12-10-96				
ES-2M Alum. inserts	27.0 lb	SMM	12-10-96				
ES-2M assembly	187.5 lb	SMM	12-12-96				
~~SCV~~ inserts	NA lb	NA					
~~SCV~~ assembly	NA lb	NA		WEIGHT's at			
Drum insulation Foam	15.1 lb	SMM	12-10-96				
Drum Top Plug	45.0 lb	SMM	12-10-96	Test Unit Before Thermal	499.5 lb	SMM	2-4-97
Test Unit Ass'y @Y-12	495.0 lb	SMM	12-10-96	Test Unit After Thermal	490.5 lb	SMM	2-5-97

EQUIPMENT

PRE-TEST:				POST-THERMAL TEST:			
Scale #	M-80562	Expiration date	*	Scale #		Expiration date	
	Accuracy ±				Accuracy ±	0.5 *lb*	
Scale #	M-80254	Expiration date	10-97	Scale #		Expiration date	
	Accuracy ±				Accuracy ±		

Comments: *The scale certification and number was updated during the assembly process. All components were weighed on the same scales.

I certify that the above tasks have been performed and that the observations and comments are correct.

Stephen McTeer	12-12-96	G. A. Byington	2-5-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V4
FASTENER TORQUE HISTORY

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: 9201-1, Y-12

VERIFIED — TASK

✓ The drum lid nuts shall be installed and torqued to 10 ± 1 ft-lb, then removed. Make sure each fastener is replaced in it's original location. Repeat this process three times recording the breakaway torque for each nut on the table below. The Drum lid shall be removed with the nuts loosened in the sequence shown below.

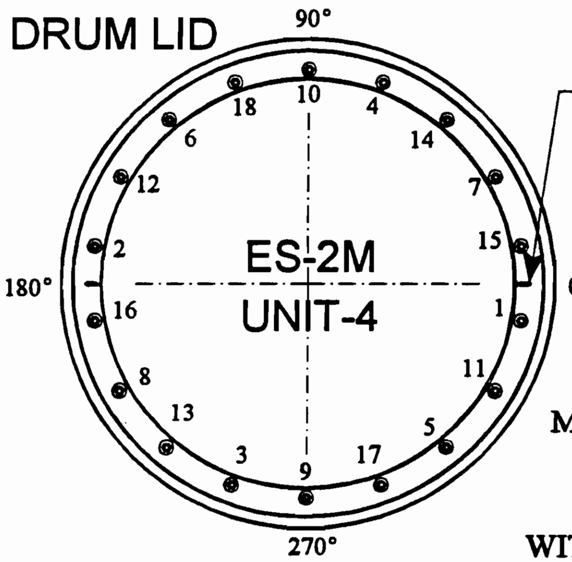
Record breakaway torque for each nut in **in-lb** or ~~ft-lb~~(circle one), Torque wrench # M-101993 Expiration Date 12-97

DATE	TIME	SCREW #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave
12/12	11:00	First	80	80	80	80	80	100	70	75	80	80	75	85	85	85	90	85	80	90	82.22
12/12	11:10	Second	80	80	75	80	90	80	75	85	90	90	80	90	90	90	100	100	100	110	88.06
12/12	13:00	Third	80	80	60	80	90	90	80	80	90	90	80	90	90	110	100	100	90	100	87.78

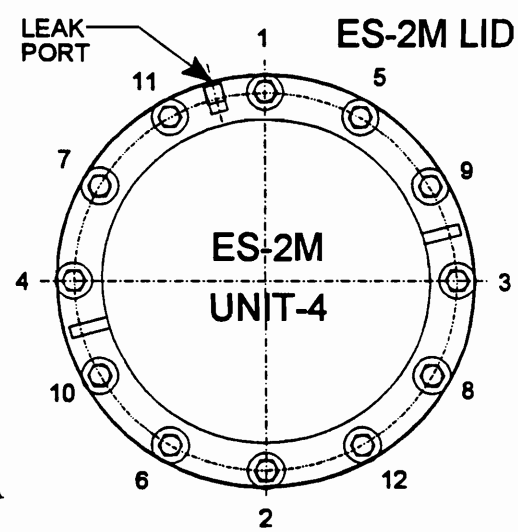
✓ The PCV lid screws shall be installed and torqued to 18 ± 1 ft-lb, then removed. Make sure each fastener is replaced in it's original location. Repeat this process three times recording the breakaway torque for each screws on the table below. The PCV lid shall be removed with the screws loosened in the sequence shown below.

Record breakaway torque for each screws in **in-lb** or ~~ft-lb~~(circle one), Torque wrench # M-101993 Expiration Date 12-97

DATE	TIME	SCREW #	1	2	3	4	5	6	7	8	9	10	11	12	Ave
12/11	13:00	First	200	190	190	180	120	180	180	180	195	200	200	180	182.9
12/11	13:10	Second	170	170	175	165	160	180	160	170	190	185	185	170	173.3
12/11	13:20	Third	160	170	170	180	160	170	170	170	165	165	165	165	167.5



MARK FASTENER NUM
AND LOCATION ON
LID AND FASTENER
WITH A PERMANENT MA



Observations: ____________________

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date
Stephen McTeer	*12-12-96*	*G. A. Byington*	*12-12-96*

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V5A
NATURAL FREQUENCY VIBRATION TESTING

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: Wyle Labs Huntsville, Al

VERIFIED	TASK
✔	Before the testing the Drum lid was removed with the nuts loosened in the sequence shown on Test Form V4, record this data in the table on Test Form V6 in the Post-Ship row.
✔	To verify the data generated by the SnapShock-2000 G-load sensor during the Test Unit's transport to test location, download the data to a PC. Document the, PATH \ FILENAME.EXT of the data file, the total time data was generated, and the data collection time span (Bin Size).

Path \ Filename.Ext C:\SNAP\Y12_2WYL.TXT File Size 287286 File Date & Time 01/06/97 08:49:54 pm
Unit: 0594 Print Threshold is 0.000000 to 0.000000 Filter: 320.000 Hz Rate: 2.24 Minutes Bin Total: 4085
Total time: 6.5 Days START DATE & TIME: 12-12-96 09:07:41 END DATE & TIME: 12-18-96 17:27:57

✔	Before the vibration testing set the SnapShock-2000 G-load sensor Bin Size to 33.6 seconds.
✔	Verify the data collection time span (Bin Size) of the SnapShock-2000 G-load sensor is properly set and the SnapShock-2000 G-load sensor was SWITCHED ON.
✔	Reassemble the drum and torque the drum lid nuts to 10 ± 1 ft-lb, follow the sequence shown on Test FormV4. Torque wrench # M101993 Expiration Date 1-97
✔	Start the natural frequency vibration testing, Sweeping the frequency from 10 to 500 Hz at a G-Load for each frequency of 0.96 G's Dwelling on each frequency for 34 seconds and the Start time 2:52:54 GAB time.
✔	After testing remove the Drum lid with the nuts loosened in the sequence shown on Test Form V4, record this data in the table on Test Form V6 in the Post-NF row.
✔	After testing download the SnapShock-2000 G-load sensor data to a PC. Document the, path\Filename.ext of the data file, the start time data was generated, and the total time data was generated.

Path \ Filename.Ext C:\SNAP\WYLENF.TXT File Size 174758 File Date & Time 01/08/97 10:34:28 am
Unit: 0594 Print Threshold is 0.000000 to 0.000000 Filter: 320.000 Hz Rate: 33.6 Seconds Bin Total: 2482
Total time: 23.13 Hours START DATE & TIME: 01-07-97 21:10:49 END DATE & TIME: 01-08-97 20:18:53

✔ * Photographs and videotaping have been taken of the vibration testing and setup.

Observations: The Test Plan had the wrong Random Frequency Test had the wrong G-load, the true G-load was about 0.96 Grms. The Natural Frequency Vibration Test sine wave input G-load was changed to +0.96 G's.

The SnapShock shock recorder Unit #594 lost it's calibration string. We called IST Co. and got the information faxed to us to recelebrate the SnapShock.

The PC time was set 12 hours off at 8:20am on 1/8/97. Since the PC time for this file was 12 hours off the true start time on 01/07/97 was 09:10:49am and the true end time on 01/08/97 was 8:18:53am.

My watch and PC time was 0:02:40 slower then the Wyle's tape time.

Wyle change the Frequency by hand every 34 seconds or so? GAB recorded Frequency vs time during the test for charting.

At 05:18:11pm @ 250 Hz the delta for the frequency was changed to 2 Hz from 1 Hz.

I certify that the above tasks have been performed and that the observations and comments are correct.

G. A. Byington	1-8-97	M. R. Feldman	1-8-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V5B
ENDURANCE VIBRATION TESTING

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: Wyle Labs Huntsville, Al

VERIFIED	TASK
✔	Before the vibration testing set the SnapShock-2000 G-load sensor Bin Size to 2.24 minutes.
✔	Verify the data collection time span (Bin Size) of the SnapShock-2000 G-load sensor is properly set and the SnapShock-2000 G-load sensor was **SWITCHED ON**.
✔	Reassemble the drum and torque the drum lid nuts to 10 ± 1 ft-lb, following the sequence shown on Test Form 4. Torque wrench # M-101993 Expiration Date 1-97
✔	Start the 40 hour endurance vibration testing of random frequencies from 10 to 500 Hz. Use an overall rms acceleration G-Load of 0.96 grms over all of the frequencies. Record the Start date and time 1/8/97 10:46:06am the stop time 1/10/97 7:37:51am and the testing duration 41:58 hr:min.
✔	After testing remove the Drum lid with the nuts loosened in the sequence shown on Test Form V4, record this data in the table on Test Form V6 in the Post-EV row.
✔	After testing download the SnapShock-2000 G-load sensor data to a PC. Document the, path\Filename.ext of the data file, the start time data was generated, and the total time data was generated.

Path \ Filename.Ext C:\SNAP\WYLEEVT1.TXT File Size 82712 File Date & Time 01/10/97 07:57:40 am
Unit: 0593 Print Threshold is 0.000000 to 0.000000 Filter: 320.000 Hz Rate: 2.24 Minutes Bin Total: 1203
Total time: 44.87 Hours START DATE & TIME: 01-08-97 10:46:06 END DATE & TIME: 01-10-97 07:37:51

✔ * Photographs and videotaping have been taken of the vibration testing setup.

Observations: The Root Mean Square(rms) G load was calculated using a straight line between two points on the PSD plot. These points were (0.023 PSD, 10 Hz) and (0.00046 PSD, 500 Hz). This line created an overall rms level of about 0.96Grms.

Analogue accelerometer plots of the Shaker table base and Drum Lid Flange were taken several time during the test.

The Shaker table went off line during the testing and was restarted with no problems. The test ran about 41 hours and 58 minutes during this time the package sounded like a Harly Davidson Motorcycle as recorded on videotape.

Once the package was removed form the shaker table and opened the following observations were made.

The inside of Test Unit-4 was warm approximately 95°F, while the room was at 55°F.

The leak check brass plug came loose and made circles around the inside liner on top of the foam tube insert which polished off the plug's threads.

A tap test was preformed with a wrench on the inner liner and the outer drum. A dull damped sound was heard only at the bottom of the inner liner. The SnapShock seemed to have failed. The G-loads ranged from +11 to +15 and -11 to -25 with most around +/-13G's. The SnapShock was designed to have a +/- 10 G range. The positive channel read only 11.1 G's after 2 hours into the testing. The negative channel still appeared to be operational.

I certify that the above tasks have been performed and that the observations and comments are correct.

G. A. Byington	*1-10-97*	*M. R. Feldman*	*1-10-97*
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM V6
POST-VIBRATION PACKAGE DISASSEMBLY

Test Plan GAB1296-1
Test Unit ES-2M Unit-4
Test Location: Wyle Labs Huntsville, Al

VERIFIED — TASK

✔ Following the vibration test the Drum lid was opened and examined to determine if any damage had occurred. The Drum lid was removed with the nuts loosened in the sequence shown on TEST FORM V4. Note the security seal Lug near the drum weld seam as reference point for nut numbering on TEST FORM V4.

Record breakaway torque for each nut in **in-lb** or ~~ft-lb~~ (circle one), Torque wrench # M-101993 Expiration Date 1-97

DATE	TIME	SCREW #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave
1/7/97	8:25	Post-Ship	65	80	90	75	90	60	80	65	90	95	80	90	90	95	85	90	95	100	84.17
1/8/97	8:10	Post-NF	80	90	80	85	90	70	80	70	90	80	80	85	85	85	90	90	80	90	83.33
1/10/97	7:30	Post-EV	80	80	75	90	85	75	85	75	85	90	85	90	80	90	90	100	90	95	85.56

✔ The post-vibration inspection and data recording remove the PCV assembly from the package and leak test to one of the following procedures (____) OO-R-031 (F) or (✔) NPS-R-001.

Leak Tester Certification # M-201287 Expiration Date N/A* Leakage Value 9.0×10^{-6} std-cc/sec air
* Leak tester was just refurbished at the factory on 10/23/96.

✔ Following the vibration test, the PCV assembly was opened and examined to determine if any damage had occurred. The PCV lid were removed with the screws loosened in the sequence shown on TEST FORM V4. Note Leak Port as reference point for screw numbering on TEST FORM V4.

Record breakaway torque for each screws in **in-lb** or ~~ft-lb~~ (circle one), Torque wrench # M-101993 Expiration Date 1-97

DATE	TIME	SCREW #	1	2	3	4	5	6	7	8	9	10	11	12	Ave
1/10/97	8:56	POST	170	165	170	160	170	180	160	170	170	175	165	160	167.9

✔ Photographs have been taken of the opened PCV to show the amount of damage.

Observations: Inside the PCV there were no bags or padding. The Aluminum rings and spacers bounced around and created much noise, heat and dust. The SST convenience cans were worn opened. The bottom of each can and the top of the bottom can was worn off. No wear was seen on the inside bottom of the Lid. The outer diameter of the Aluminum Sleeve was ground by the inside upper and lower end welds, cutting a groove around the sleeve. The bottom of the PCV showed a small amount of wear but seemed to be inside the tolerance specification.

I certify that the above tasks have been performed and that the observations and comments are correct.

G. A. Byington	1-10-97	M. R. Feldman	1-10-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

APPENDIX B

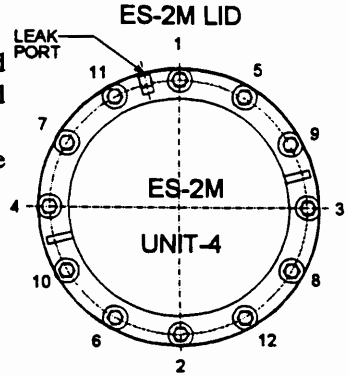
HAC TEST FORMS

TEST FORM 1
ASSEMBLY OF THE PCV/SCV

Test Plan GAB0796-1
Test Unit ES-2M Unit-4
Test Location: 9201-1, Y-12

VERIFIED	TASK
✔	The container serial numbers: PCV/~~SCV~~ 12000
✔	All containment vessel (PCV/~~SCV~~) components have been dimensionally verified to comply with drawing specifications.
1-17-97	Temperature indicators have been affixed to the interior surface of the PCV/~~SCV~~ as shown in the attached figure. (No temperature indicators are required on prototype for normal conditions testing.)
1-17-97	None of the temperature indicators indicate exposure to a temperature in the measured range.
1-17-97	The containers, lids, mockup, and inserts have been clearly marked as "ES-2M, Unit -4."
1-17-97	The PCV/~~SCV~~ O-rings, O-ring glands, and sealing surfaces have been inspected for defects and found acceptable.
N/A*	Foam inserts and mockup have been weighed and weights have been recorded on form 3.
1-17-97	The Alum. inserts and mockups have been inserted into the PCV, the lid installed with the leak port aligned as close to the PCV weld seam as possible, mark the lid alignment with a permanent marker. Torque the screws to 216 ± 12 in-lb (18 ± 1 ft-lb) in the sequence shown at right. Ambient temperature at closure ____°C (70 °F). Torque wrench # M101993 Expiration Date 1-97
1-17-97	The PCV assembly has been leak tested to one of the following procedures (____) OO-R-031 (F) or (✔) NPS-R-001. Leak Tester Cert. # 34 Expiration Date See Comments Leakage Value 1.8×10^{-5} std-cc/sec air
N/A	The SCV assembly has been leak tested to one of the following procedures (___) OO-R-031 (F) or (___) NPS-R-001. Leak Tester Cert. # ________ Expiration Date ________ Leakage Value ________ std-cc/sec air
N/A	The PCV/~~SCV~~ assembly has been weighed and the weight has been recorded on Form 3.
N/A	Thermocouples have been attached to the exterior surface of the PCV/~~SCV~~ if this unit is to obtain time-temperature data. These thermocouples have been surveyed to ensure they are working, which has been noted on Form 6B.
✔	Photographs of the assembly have been taken.

ES-2M LID



Comments: 1) The PCV had no weld seam.

2) The Calt-5 No. 34 with transducer No. 1393/000 was last tested 86 days ago on 10-23-96.

* The weight did not change during the vibration testing.

I certify that the above tasks have been performed and that the observations and comments are correct.

Stephen McTeer	1-17-97	G. A. Byington	1-17-97
Testing Technician	Date	Witness	Date

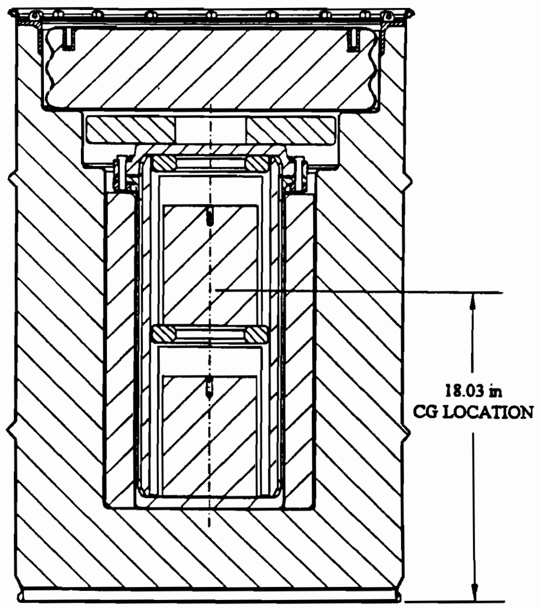
*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan GAB0796-1
Test Unit ES-2M Unit-4
Location: 9201-1, Y-12

VERIFIED	TASK
1-17-97	The drum has been clearly marked "ES-2M, Unit -4."
1-17-97	Record the drum serial number: 12002
1-22-97	The center of gravity targets have been applied to the drum as shown.
1-17-97	Each insulation insert has been clearly marked "ES-2M, Unit -4."
N/A*	The insulation inserts were weighed together and the weight has been recorded on Form 3.
✓	The lower and middle insulation inserts have been loaded into the drum.
✓	The PCV/~~SCV~~ assembly has been loaded into the drum, with the seams aligned.
✓	The top insulation inserts have been loaded into the drum.
N/A	The gap between the top insulation inserts and the top of the drum is ________.
✓	The drum lid with NO GASKET has been installed, mark the lid alignment with a permanent marker.
✓	The drum lid nuts were installed and torqued to 120 ± 12 in-lb, following the sequence shown on TEST FORM 4.
	Torque wrench # M101993 Expiration Date 1-97
N/A	A security seal has been attached to the drum.
N/A*	The test package assembly has been weighed and the weight recorded on Form 3.
✓	Photographs of the assembly have been taken.

CENTER OF GRAVITY MARKING



Comments: ES-2M Unit -4 is also Known as the "X-Ray Unit". The X-Ray Unit was used to test the radiographing of the drum liner.

* The weight did not change during the vibration testing.

I certify that the above tasks have been performed and that the observations and comments are correct.

Stephen McTeer	1-17-97	G. A. Byington	1-17-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

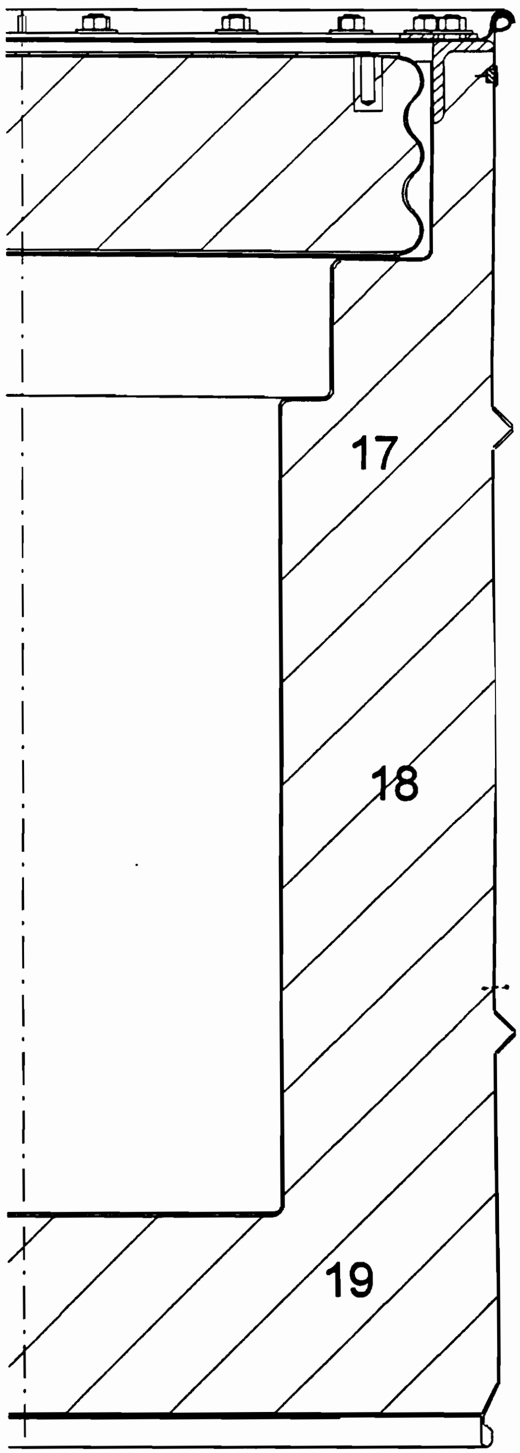
TEST FORM 2A
RADIOGRAPH OF DRUM LINER

Test Plan GAB0197
Test Unit ES-2M Unit-4
Location ORNL Waste Management Bldg. 7824

VERIFIED	TASK
✔	Record the drum name "ES-2M, Unit 4."
✔	Record the drum serial number: 12002
✔	Record the history of the drum, ie. as built, dropped, etc. History VIBRATION, 30 FOOT SIDE DROP at 90° on the drum lid.
✔	Record the start date and time of the radiograph. Start Date 1/23/97 Start Time 1:09pm
✔	* Videotape the Drum Liner rotating with the drum serial number and the drum name on the videotape.
✔	* View the Drum Liner and record any observation on the sketch to the right and with a digital photograph. Check the locations numbered on the sketch.

Digital Photograph Number	Approximate Drum Angle Location	Reference Picture Location With Videotape Time
17	90°	13:28
18	135°	13:29
19	90°	13:36

SKETCH OBSERVATIONS



Comments: The Top Corner Koalite looks OK.
The PCV flanged dented the liner like ES-2M Test Unit-1. Photo #17 shows the damage.
Photo #18 shows a horizontal crack half way up the drum. This damage was found on 01/17/97 on the Post Vibration and Pre-Drop Inspection. The punch seemed to increase the damage at the crack. Photo #18. The outer drum was dimpled below the punch area.
Also on 01/17/97 many homogeneous cloud like cracks were noted below the liner and too the corners. Some minor cracking was found in the bottom center of the liner. Small crack found in the corner Photo #19.

I certify that the above tasks have been performed and that the observations and comments are correct.

Sherry E. Williams	1-23-97	M. R. Feldman	1-23-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

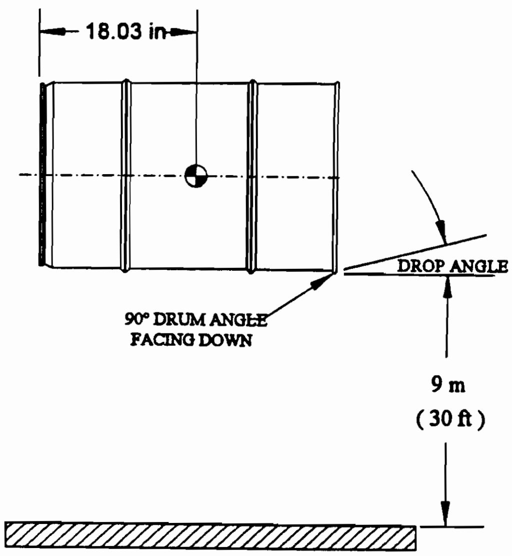
TEST FORM 4
9-m (30-ft) FREE FALL DROP

Test Plan GAB0197
Test Unit ES-2M Unit-4
Test Location: ORNL Test Site

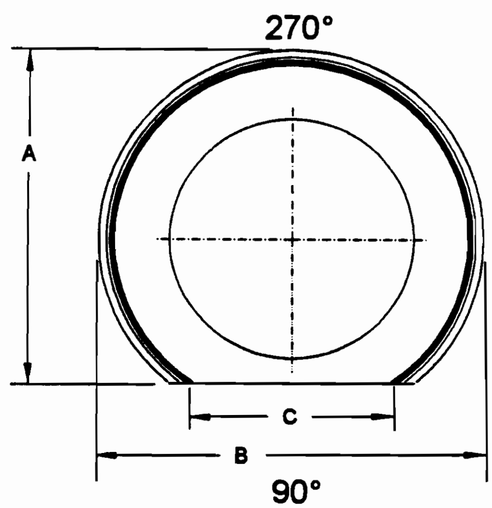
VERIFIED	TASK
1-22-97	The Test Unit has been prepared in accordance with the test plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
1-22-97	Still, video, and high-speed movie cameras are set up to take photographs/movies* of the drop testing.
1-22-97	Photographs* of the arrangements for the drop have been taken.
1-22-97	Ambient temperature of the test: ____ °C (57 °F) at the time of 10:00 am .
1-22-97	The Test Drop Angle of this unit is 0.0 ° as defined by figure to the right . The Measured Drop Angle is 0.2 °. Measuring device ProSmart Level Exp. Date N/A
1-22-97	The Test Unit has been raised so that the lowest point is 30 ft above an essentially unyielding, horizontal impact surface. Measuring device # N/A Exp. Date N/A
1-22-97	The Test Unit was dropped from a minimum of 9 *m* (30 *ft*) oriented as shown at right onto an essentially unyielding, horizontal impact surface.
1-22-97	Video/high speed movies* of the drop were made.
1-22-97	*Photographs of the damage resulting from the drop have been taken.

Testing Damage Observations: Small amount of Kaolite dust was observed coming out of the bottom of the drum around the skip welds.
No nuts or washers were lost.

PRE-DROP TEST UNIT ORIENTATION
(Indicate tolerance on orientation)



Looking at Bottom of the Drum



Comments: A Large flattened trapezoidal area, 10.5" across bottom and 8" across at the top.

	Before		After		
	A	B	A	B	C
Top	23.62	23.62	22.87	23.62	8.5
Bot	N/A	N/A	N/A	N/A	10.5

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	1-22-97	G. A. Byington	1-22-97
Testing Technician	Date	Witness	Date

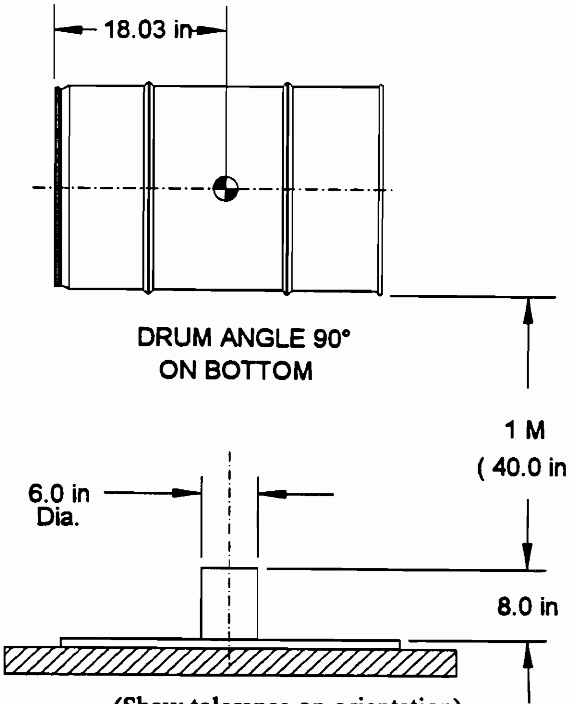
*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 5
1-m (40-in) PUNCTURE DROP

Test Plan GAB0197
Test Unit ES-2M Unit-4
Test Location: ORNL Test Site

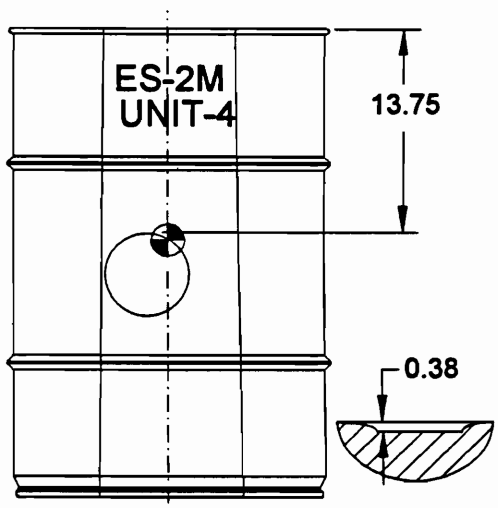
VERIFIED	TASK
1-22-97	The Test Unit has been prepared in accordance with the test plan. Forms 1 and 2 are complete and the pre-test weights are recorded on Form 3.
1-22-97	Still, video, and high-speed movie cameras are set up to take photographs/movies* of the drop testing.
1-22-97	Photographs* of the arrangements for the drop have been taken.
1-22-97	The steel puncture bar is no greater than 15 cm (6 in) in diameter and no less than 20 cm (8 in) long, with the corners having a radius of no more than 6 mm (0.25 in), and resting on an essentially unyielding, horizontal impact surface.
1-22-97	Ambient temperature at the time 2:05 pm of the test: ____ °C (50 °F).
1-22-97	The Test Drop Angle of this unit is 0.0 ° as defined by figure at the right. The Measured Drop Angle is 0.5 °. Measuring device ProSmart Level Exp. Date N/A
1-22-97	The Test Unit has been raised so that the lowest point is 1 *m* or (40 in) above the steel puncture bar. Measuring device # AMSE-1000 Exp. Date N/A
1-22-97	The Test Unit was dropped from a minimum of 1 *m* (40 in) onto the steel bar.
1-22-97	Video/high speed movies* of the drop were made.
N/A	Photographs* of the damage resulting from the drop have been taken.

PRE-DROP TEST UNIT ORIENTATION



(Show tolerance on orientation)

MAIN PUNCTURE LOCATION



Testing Damage Observations: ______________________

Comments: ______________________

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	1-22-97	G. A. Byington	1-22-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 6A
THERMAL TESTING

Test Plan GAB0197
Test Unit ES-2M Unit-4
Test Location: Lindberg Heat Treat, Solan, OH

VERIFIED	TASK
2-4-97	The test plan calls for NA thermocouples attached to the Test Unit primary containment vessel (or inner container if only one), NA thermocouples attached to the Test Unit secondary containment vessel, 6 thermocouples attached to the Test Unit drum, 26 thermocouples in the furnace, and 2 furnace thermocouples attached to the test stand.
2-4-97**	The test package has been preheated to over 38 °*C* (100 °*F*).
2-4-97	The test package weight has been recorded on Test Form 3 and thermocouples have been attached to the Test Unit as shown in Figure 4.5.
2-4-97	Thermocouples and test stand have been installed in the furnace as shown in Figures 7.3, 7.4, 7.5, and 4.6.
2-4-97	Photographs* of the arrangements for the test have been taken.
2-4-97	All thermocouples have been surveyed to ensure they are working. (Any malfunctions or erratic performance will be addressed in the comments section below.)
2-4-97	Furnace has reached the minimum soak point temperature of 800 °*C* (1475 °*F*), and has soaked at this temperature for a minimum of 8 hours. The furnace set point temperature has been adjusted to ______ °*C* (1600 °*F*) at least one hour prior to each test. Date 2-3-97 Time 6:45 pm
2-4-97	The thermocouple recorder(s) is (are) set to read every 30 seconds.
2-4-97	The unit has been placed in the furnace, on the support stand, with the damaged area up at: Date 2-4-97 Time 10:42:30 am Open furnace door time: 45 sec.
✔	The 31 minute timed test began when 5 out of 6 Test Unit thermocouples reached the test temperature of 800 °*C* (1475 °*F*) as specified in the test plan. Date 2-4-97 Time 10:53:45 am
✔	Immediately following the timed test (a minimum of 30 minutes at 800 °*C*) the Test Unit is taken out of the furnace and allowed to cool naturally. Date 2-4-97 Time 11:24:45 pm Ambient Temperature ______ °*C* (56.2 °*F*)
✔	The unit stopped outgassing (flames) at 11:24:45 pm; outgassing/burnout lapsed time was 0.
NA	The thermocouple recorder shall be set to record the internal thermocouples at 15 minute intervals for at least 12 hours.

Comments: Furnace started at 1600°F, was Raised to 1610°F at 11:01, Lowered to 1600°F at 11:02, Lowered to 1560°F at 11:07, Raised to 1565°F at 11:12.

** The package was drained of water that was inside the drum due to the rain during drop testing.

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	2-4-97	M. R. Feldman	2-4-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 6C
POST-THERMAL TESTING INSPECTION

Test Plan GAB0197
Test Unit ES-2M Unit-4
Test Location: Lindberg Heat Treat, Solan, OH

VERIFIED	TASK
2-5-97	Following the thermal test and after cooling, the test package was weighed, and the weight recorded on Form 3.
2-5-97	The drum, lid, nuts, and studs have been visually examined to determine the extent of the testing damage. Observations: After the thermal testing the Outer Drum and fastening Nuts had scale on them. The removal torque for the Drum Lid Nuts ranged from 70 to 175 in-lbs. Had to cut off Stud #10 at the impact location.
2-5-97	The camera(s) are set up to take photographs* and videotape of the damage due to testing.
2-5-97	Open the Test Unit and record the damage generated by removing the drum lid. Observations: Lid came off relatively easy, a pry bar was required.
2-5-97	The Top Plug Assembly has been removed and visually inspected to determine the extent of impact and thermal damage. Record the temperature indicator blackout reading on Test Form 6D. Observations: Some of the Top Plug paint markings were steamed off. A pry bar was required to remove the Top Plug with some difficulty. The Top Plug was stuck along the 90°-270° line. # 2 Stud was bent over during the Top Plug removal.
N/A	The SCV assembly has been removed and visually examined for damage. Record the temperature indicator blackout readings on Test Form 6D. Observations: Not in the ES-2M
N/A	The SCV assembly has been weighed and the weight recorded on Form 3.
N/A	Use Test Form 7B for the SCV post thermal leak check, immersion, and disassembly.
2-6-97	The PCV assembly has been removed and visually examined for damage. Record the temperature indicator blackout readings on Test Form 6D. Observations: No visible damage.
N/A	The PCV assembly has been weighed and the weight recorded on Form 3.
2-6-97	Use Test Form 7A for the PCV post thermal leak check, immersion, and disassembly.
2-7-97	Open the polyethylene bag containing the oxide mockup stainless steel shot. Record the temperature indicator blackout readings on Test Form 6D.
2-7-97	All loose parts shall be placed in separate polyethylene bags, marked " ES-2M , Unit 4 ," taped closed, and prepared for storage with the test package.
2-7-97	Mark and reassemble the test package for shipment.
2-7-97	*Photographs of the damage resulting from the testing have been taken.

Comments: Water was inside the drum due to rain during drop testing. Some droplets of water were still inside the liner after the thermal test. Had to cut-off studs 10,17, & 1 to put the lid back on the drum for shipment to Oak Ridge. See attached page for the torque required to remove the drum lid nuts. Individual parts were not weighed due to differences between the scales.

The Top Plug was taped to the top of the drum for return shipment.

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	2-7-97	G. A. Byington	2-7-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 6D
TEMPERATURE INDICATOR READINGS

Test Plan GAB0197
Test Unit ES-2M Unit-4
Test Location: Lindberg Heat Treat, Solan, OH

A visual inspection of each temperature indicator on the ES-2M package consisting of; the outside the PCV, and the ES-2 drum liner shall record the values of the blackouts which occurred below:

RECORD BLACKOUT TEMPERATURES AT THESE LOCATIONS:

ES-2M TEMPERATURE INDICATOR NUMBER LOCATION CHART				
ON THE INSIDE THE PCV, STAINLESS STEEL SHOT TEMP. @ 12"				
12	1 NA °F		2 NA °F	
(Figure 5.2) ON OUTSIDE OF THE ES-2M CONTAINER PCV				
Row Height	0°	90°	180°	270°
Bottom	1 NA °F	2 NA °F	3 NA °F	4 NA °F
4.2	5 175 °F	6 175 °F	7 175 °F	8 175 °F
16.8	9 175 °F	10 175 °F	11 175 °F	12 175 °F
Top	13 200 °F	14 200 °F	15 200 °F	16 200 °F
ON INSIDE OF THE ES-2L CONTAINER SCV				
Row Height	0°	90°	180°	270°
Bottom	1 NA °F	2 NA °F	3 NA °F	4 NA °F
4.0	5 NA °F	6 NA °F	7 NA °F	8 NA °F
10.5	9 NA °F	10 NA °F	11 NA °F	12 NA °F
17.0	13 NA °F	14 NA °F	15 NA °F	16 NA °F
Top	17 NA °F	18 NA °F	19 NA °F	20 NA °F
(Figure 5.3) ON THE INSIDE OF THE ES-2 DRUM INNER LINER				
Row Height	0°	90°	180°	270°
Bottom	1 NA °F	2 NA °F	3 NA °F	4 NA °F
5	5 225 °F	6 225 °F	7 225 °F	8 225 °F
12.7	9 200 °F	10 250 °F	11 200 °F	12 225 °F
1 Ledge	13 225 °F	14 NA °F	15 225 °F	16 200 °F
Plug Bottom	17 200 °F	18 225 °F	19 225 °F	20 225 °F

Comments: Unit-4 was the vibration Unit which did not have the SCV. Temp labels were not applied to the bottom of the PCV. The 1 Ledge Temp labels were applied below the ledge facing the PCV's flange
The Temp labels were not applied to the internal weights due to vibration damage.
NA means that the temperature reading was not available or damaged.

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	2-7-97	G. A. Byington	2-7-97
Testing Technician	Date	Witness	Date

*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

TEST FORM 7A
0.9-m (3-ft) IMMERSION TEST
AND PCV DISASSEMBLY

Test Plan GAB0197
Test Unit ES-2M Unit-4
Location: Lindberg Heat Treat, Solan, OH

VERIFIED TASK

2-6-97 The post-thermal inspection and data recording remove the PCV assembly from the package and leak test to one of the following procedures (___) OO-R-031 (F) or (✔) NPS-R-001.

Leak Tester Certification # 34 Expiration Date NA Leakage Value 1.6×10^{-5} std-cc/sec air

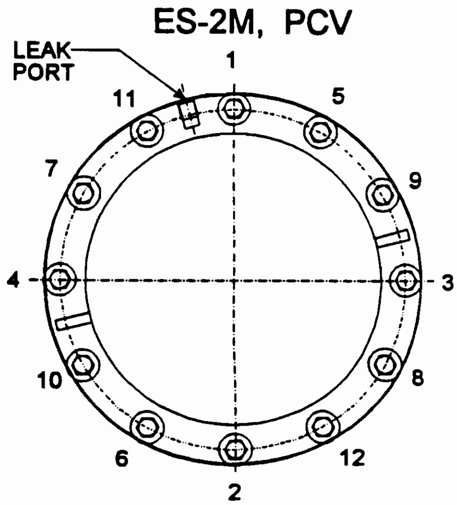
2-6-97 Following the leak test, the PCV assembly was taken to the water tank located (H_2O Quench tank in front of furnace #638) where it was immersed under a head of water of at least 0.9 *m* (3 *ft* or 1.3 *psig*) to highest point of PCV assembly for a period not less than 8 hours.

Measured water depth 64.5 inches

Measured water Temperature 57.8 °F

Date In 2-6-97 Time In 12:42 pm

Date Out 2-6-97 Time Out 8:45 pm



2-7-97 Following the immersion test, the PCV assembly was opened and examined to determine if any damage had occurred. The PCV lid was removed with the screws loosened in the sequence shown to the right.

Record breakaway torque for each screws in *in-lb* or ~~*ft-lb*~~, Torque wrench # M101993
Expiration Date 1-28-98

1	2	3	4	5	6	7	8	9	10	11	12
150	140	125	165	150	160	140	180	140	150	175	165
								Average Loosening Torque			153.333

2-7-97 Photographs* have been taken of the opened PCV to show the amount of water inleakage.

✔ Return to Test Form 6C.

Observations: The PCV was dried as much as possible prior to unscrewing the fasteners and removing the lid. When the lid was removed some excess water was between the flanges. Outside of the O-ring grooves. No water was observed inside the PCV.

I certify that the above tasks have been performed and that the observations and comments are correct.

S. M. McTeer	2-7-97	G. A. Byington	2-7-97
Testing Technician	Date	Witness	Date

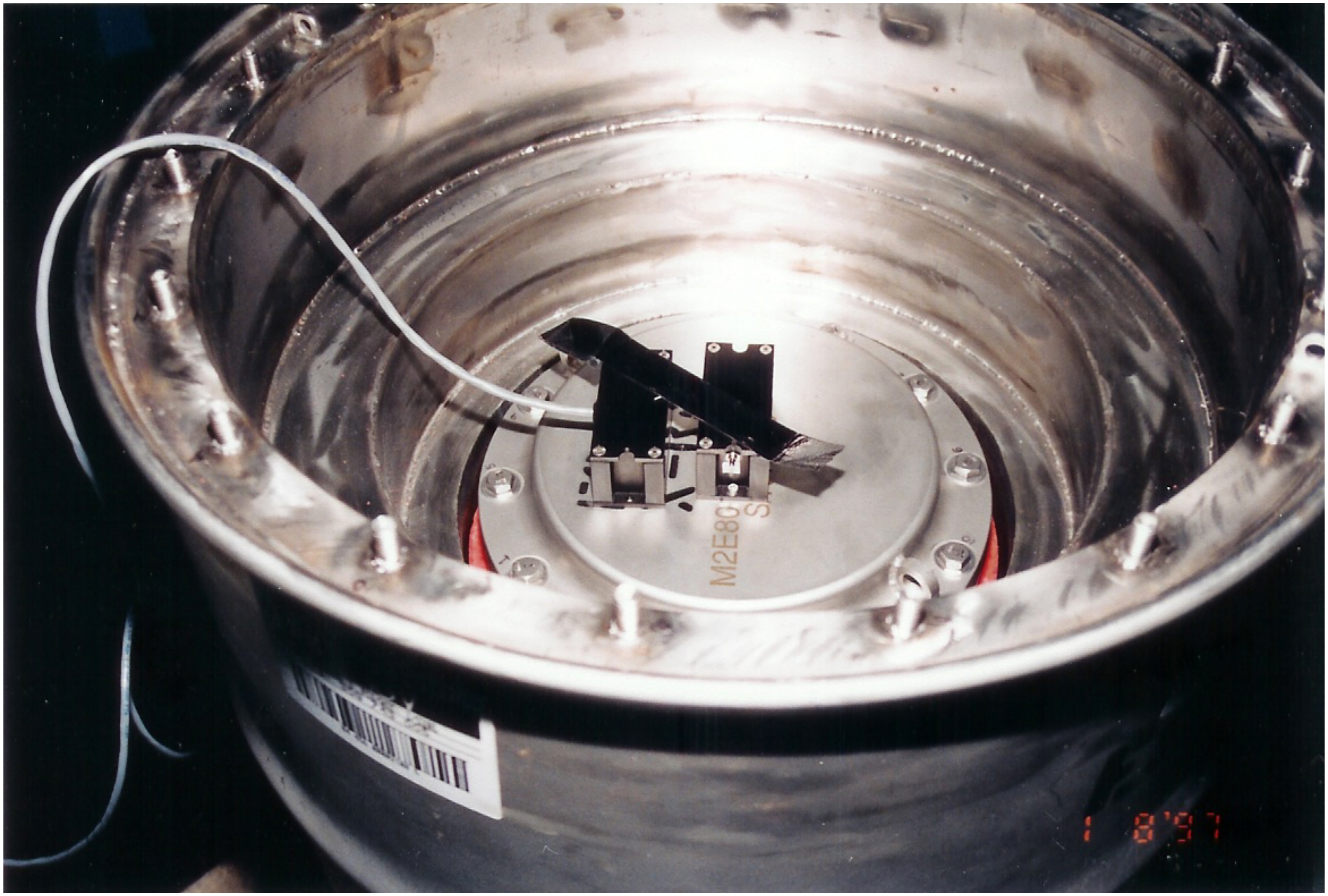
*All photographs/movies shall be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed.

ES-2M Vibration Testing 1/10/97

Containment Vessel with vibration G-load recorder on CV Lid

ES-2M Vibration Testing 1/10/97

Turning on the vibration recorder before the testing

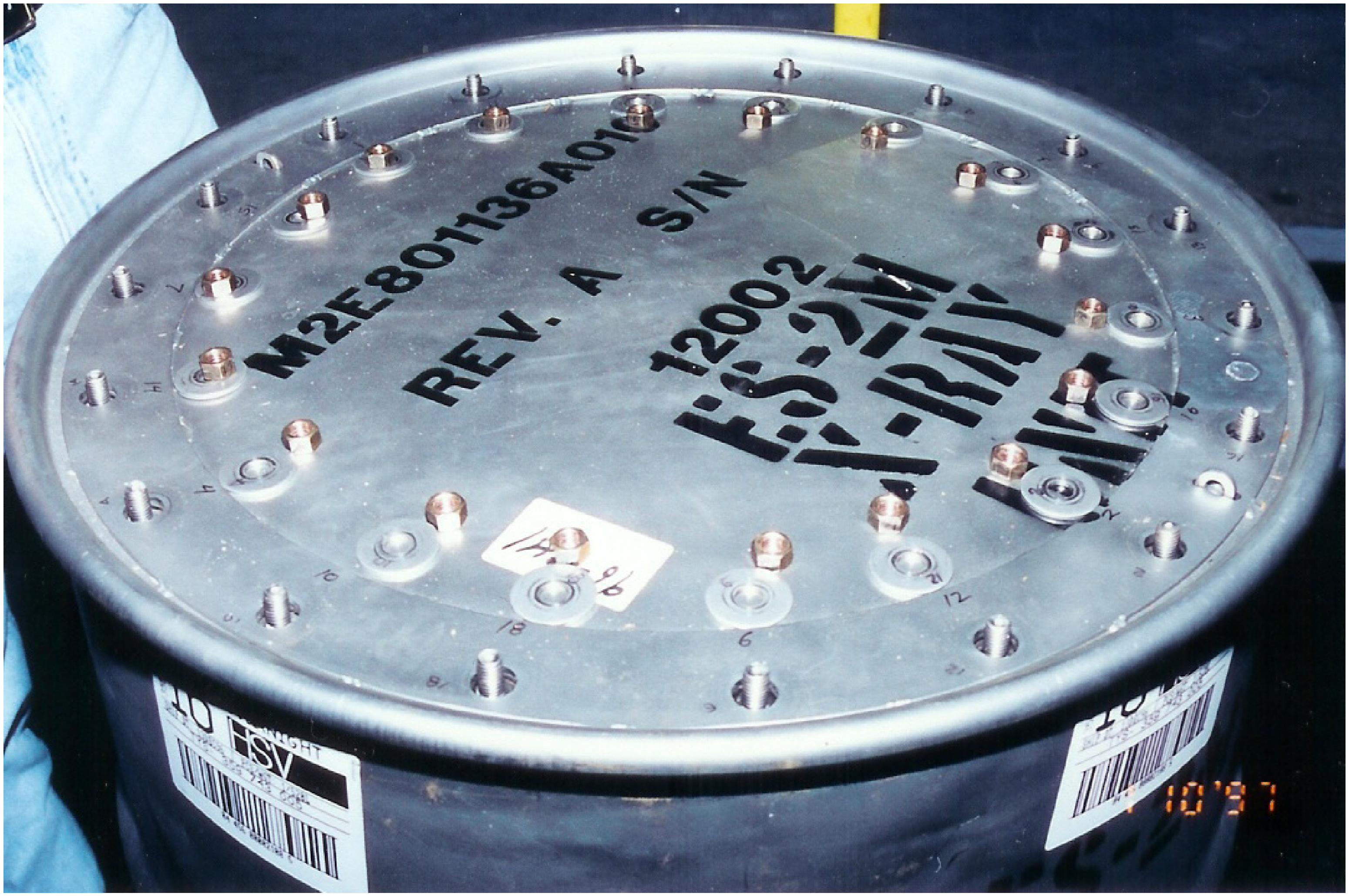


ES-2M Vibration Testing 1/10/97

ES-2M on the Vibration Table during testing

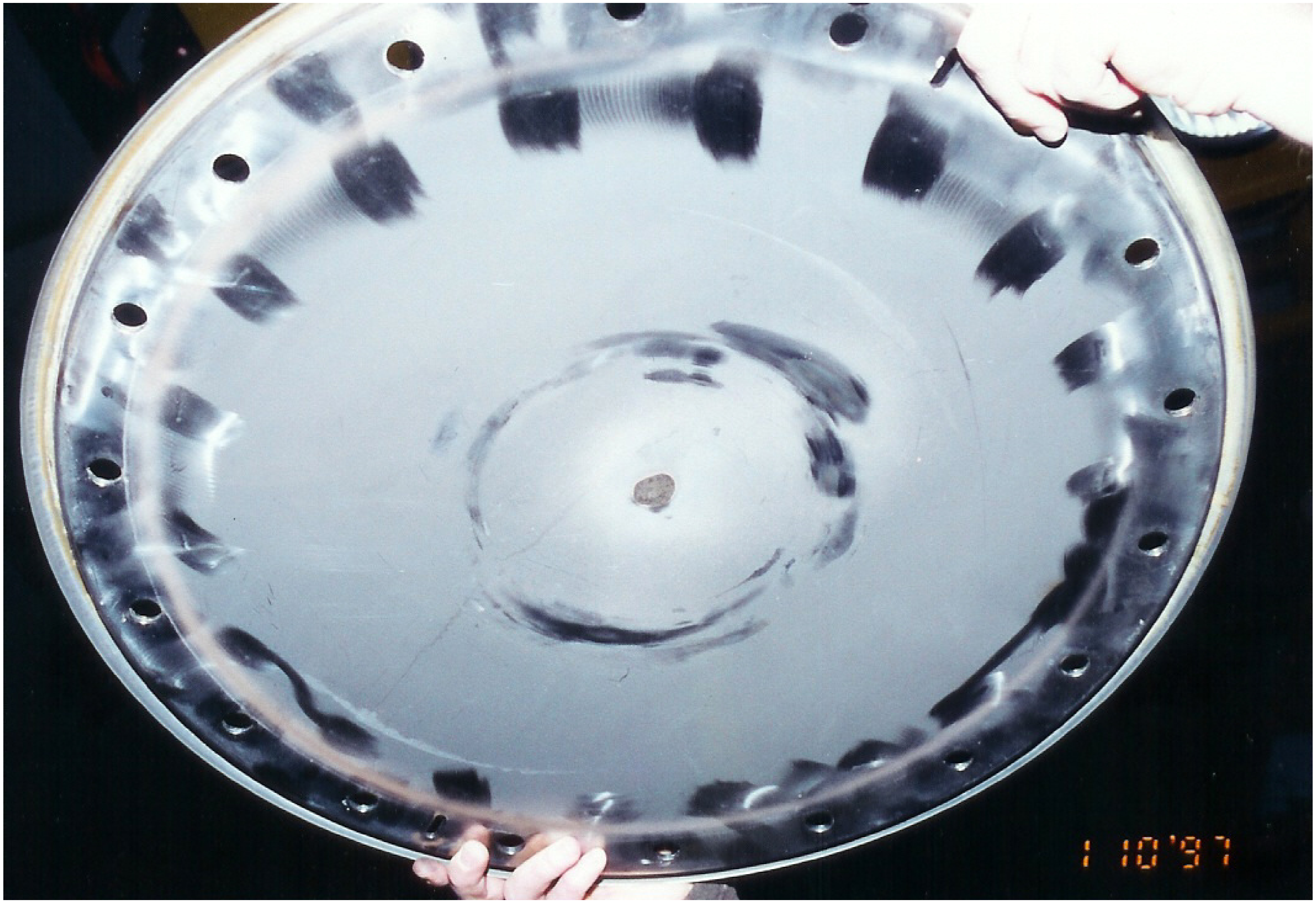
ES-2M Vibration Testing 1/10/97

Removing the Drum Lid after testing



ES-2M Vibration Testing 1/10/97

Metal Dust under the Drum Lid after 44 hours of testing



ES-2M Vibration Testing 1/10/97

Top Plug after vibration testing show metal dust and some wear spots

ES-2M Vibration Testing 1/10/97

Top Plug after vibration testing show metal dust and some wear spots

ES-2M Vibration Testing 1/10/97

Top Plug after vibration testing show metal dust and some wear spots

ES-2M Vibration Testing 1/10/97

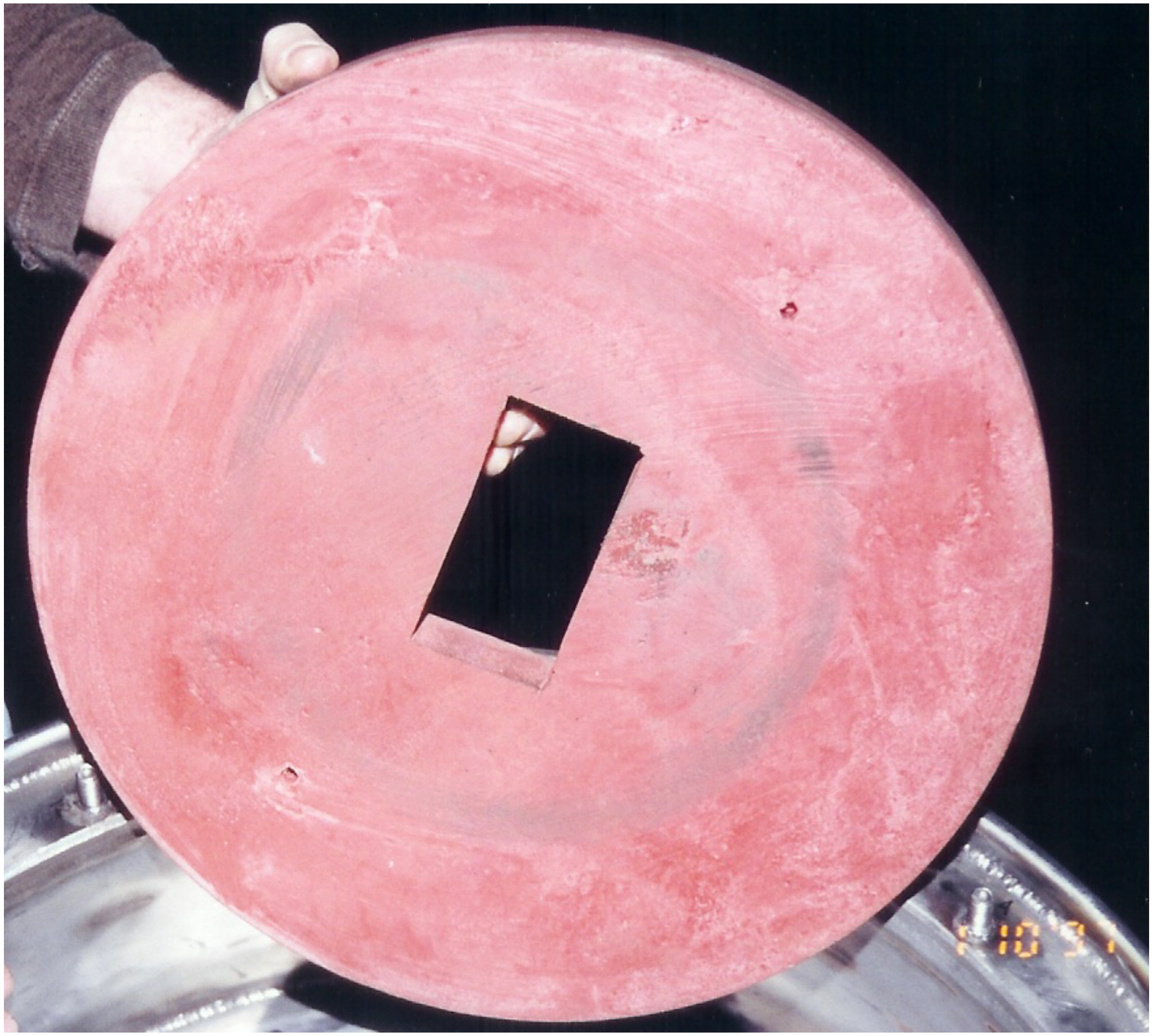
Bottom of the Top Plug showing metal to metal wear after testing

ES-2M Vibration Testing 1/10/97

Top Foam after testing

ES-2M Vibration Testing 1/10/97

Bottom of Top Foam after testing

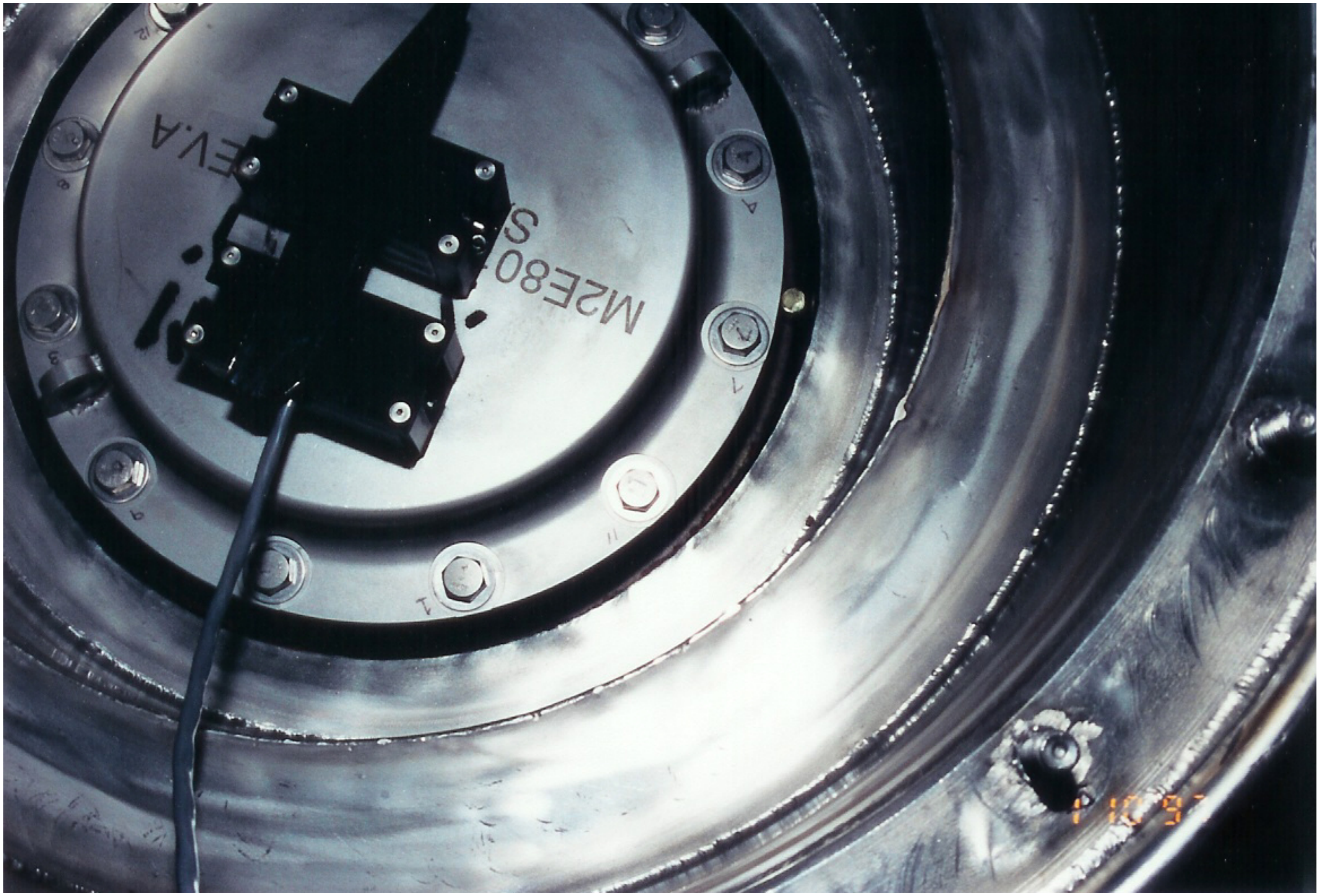


ES-2M Vibration Testing 1/10/97

Containment Vessel after testing

ES-2M Vibration Testing 1/10/97

After testing the Leak Check port plug is loose and vibrated off its threads



ES-2M Vibration Testing 1/10/97

Removing the Containment Vessel after testing

ES-2M Vibration Testing 1/10/97

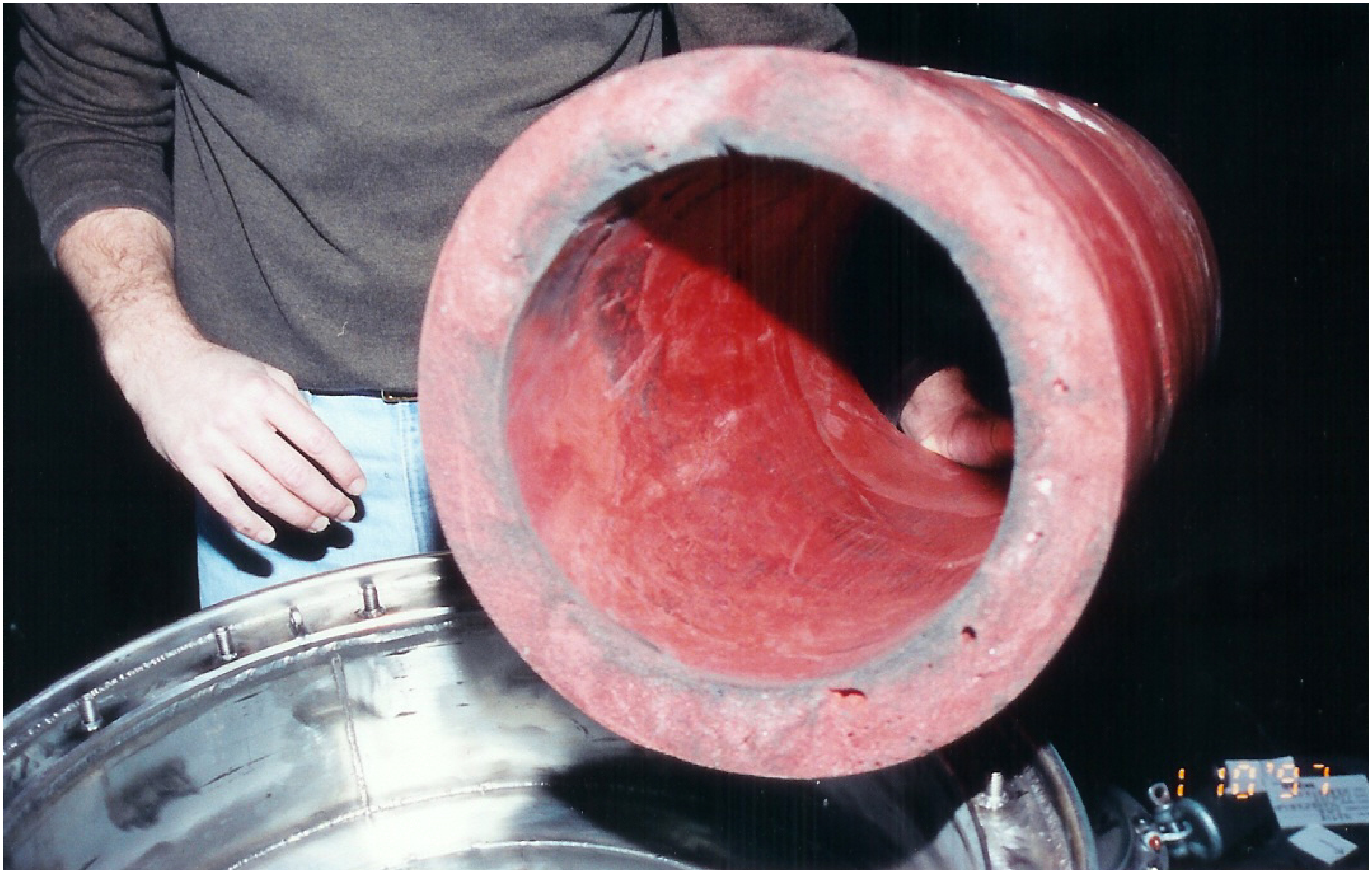
Removing the Containment Vessel after testing

ES-2M Vibration Testing 1/10/97

Inner Liner and Foam Tube after testing

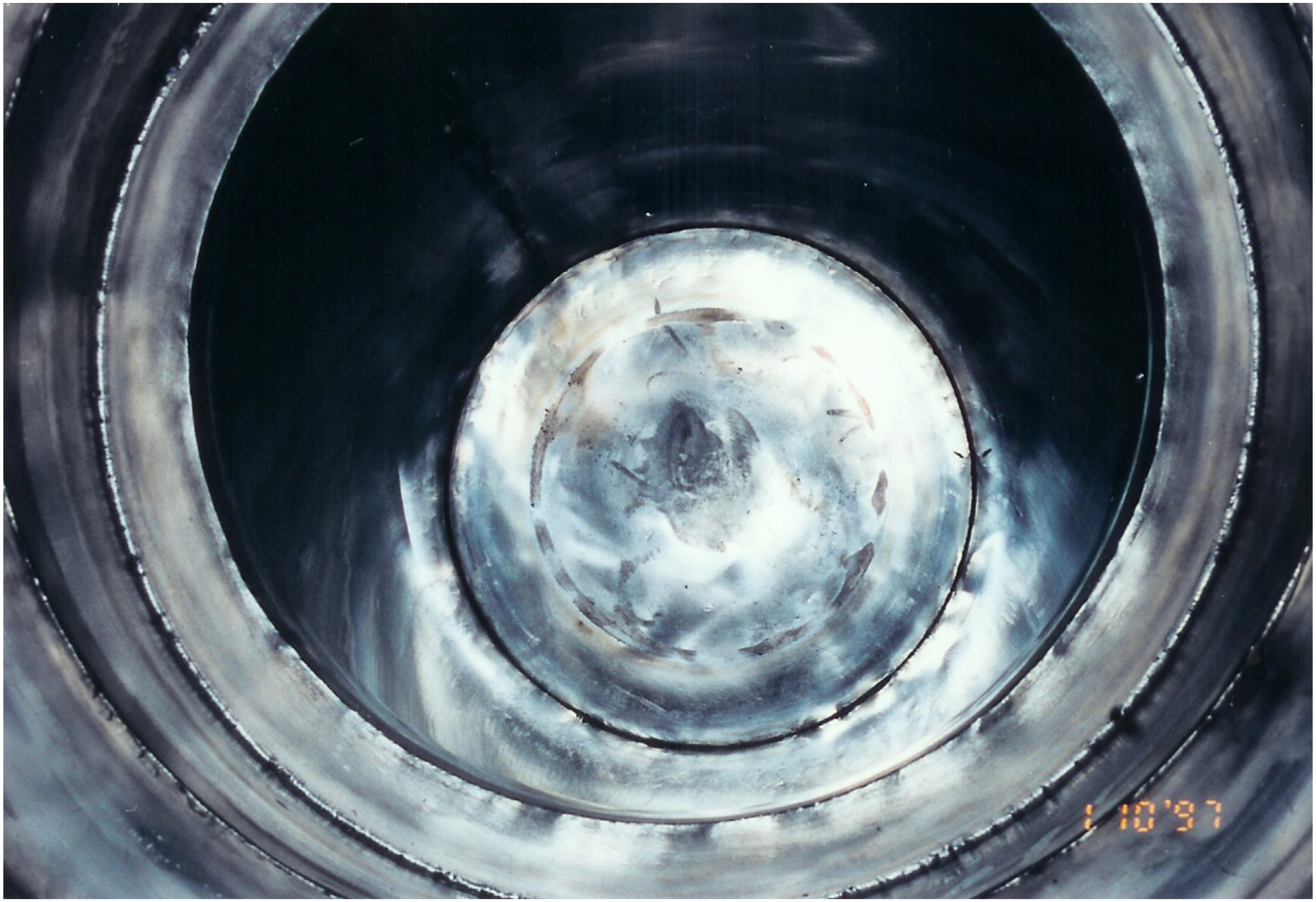
ES-2M Vibration Testing 1/10/97

Bottom of Foam Tube after testing



ES-2M Vibration Testing 1/10/97

Inner Liner after testing showing some metal wear at the bottom



ES-2M Vibration Testing 1/10/97

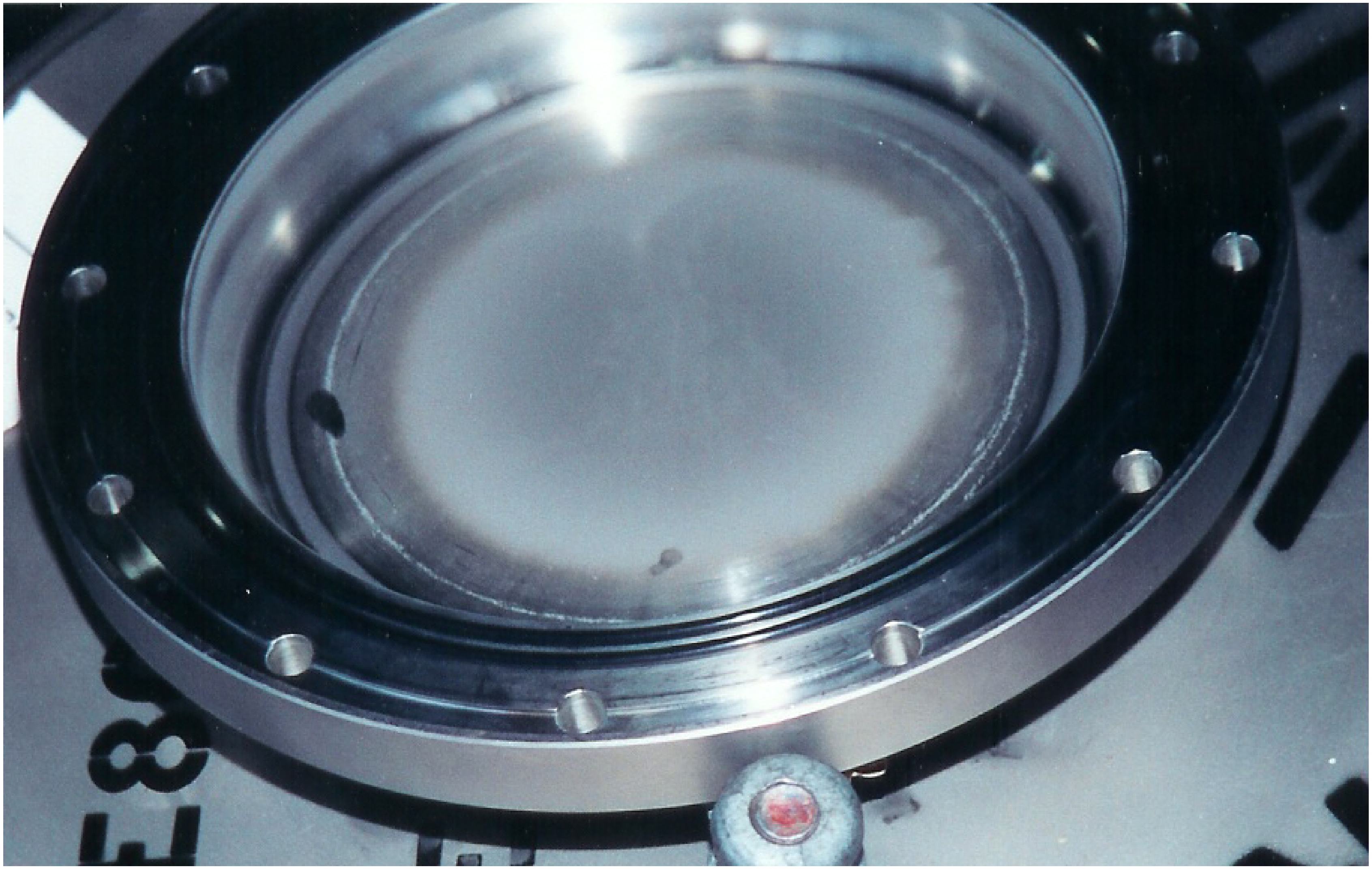
Leak Testing the CV after testing

ES-2M Vibration Testing 1/10/97

After testing shows where the Aluminum tube bounced into the bottom of CV Lid

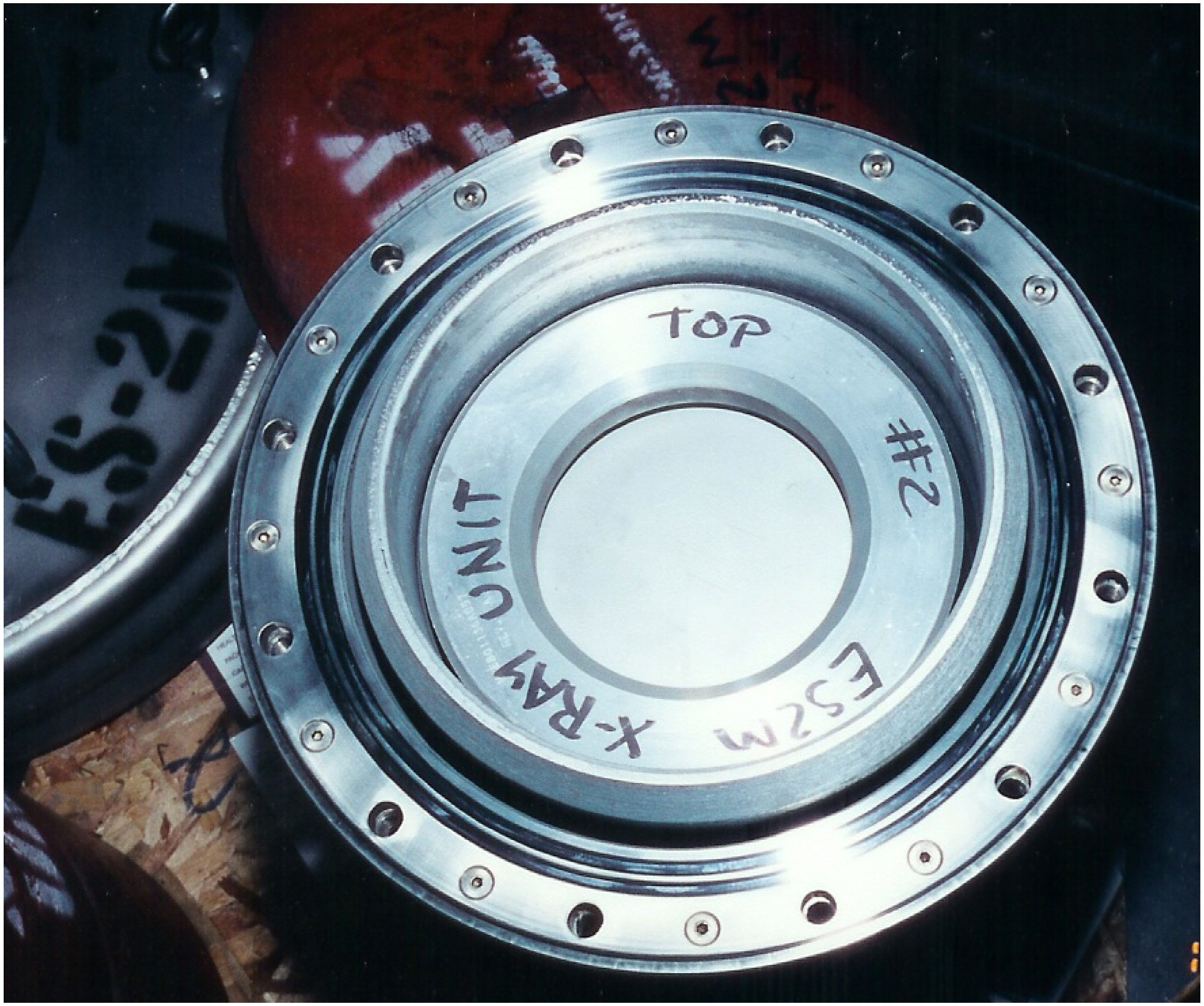
ES-2M Vibration Testing 1/10/97

After testing shows only where the Aluminum tube bounced into the bottom of CV Lid



ES-2M Vibration Testing 1/10/97

Opened CV after testing



ES-2M Vibration Testing 1/10/97

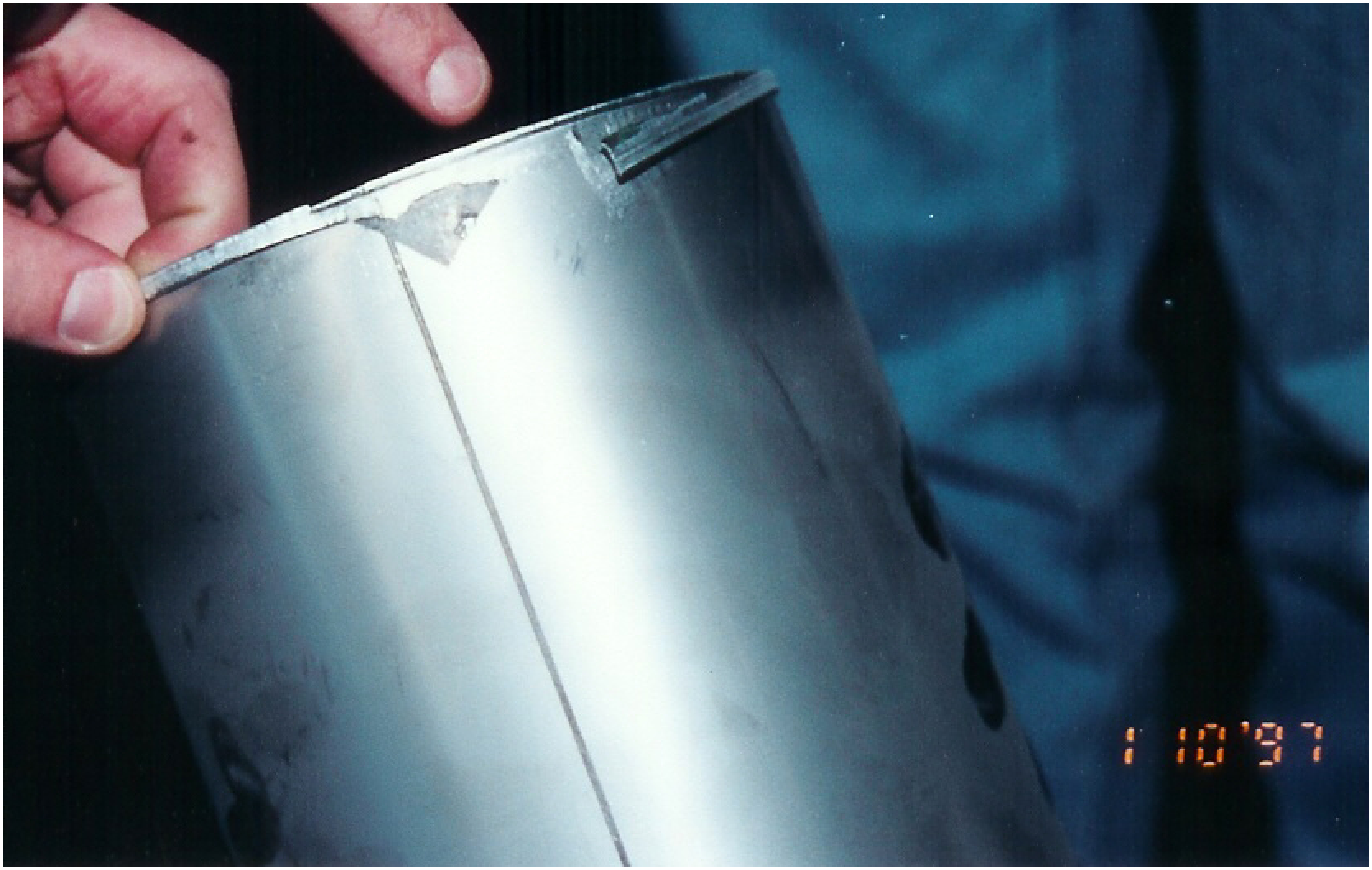
Top Aluminum spacer removed after testing

ES-2M Vibration Testing 1/10/97

Top can removed without the bottom head after testing

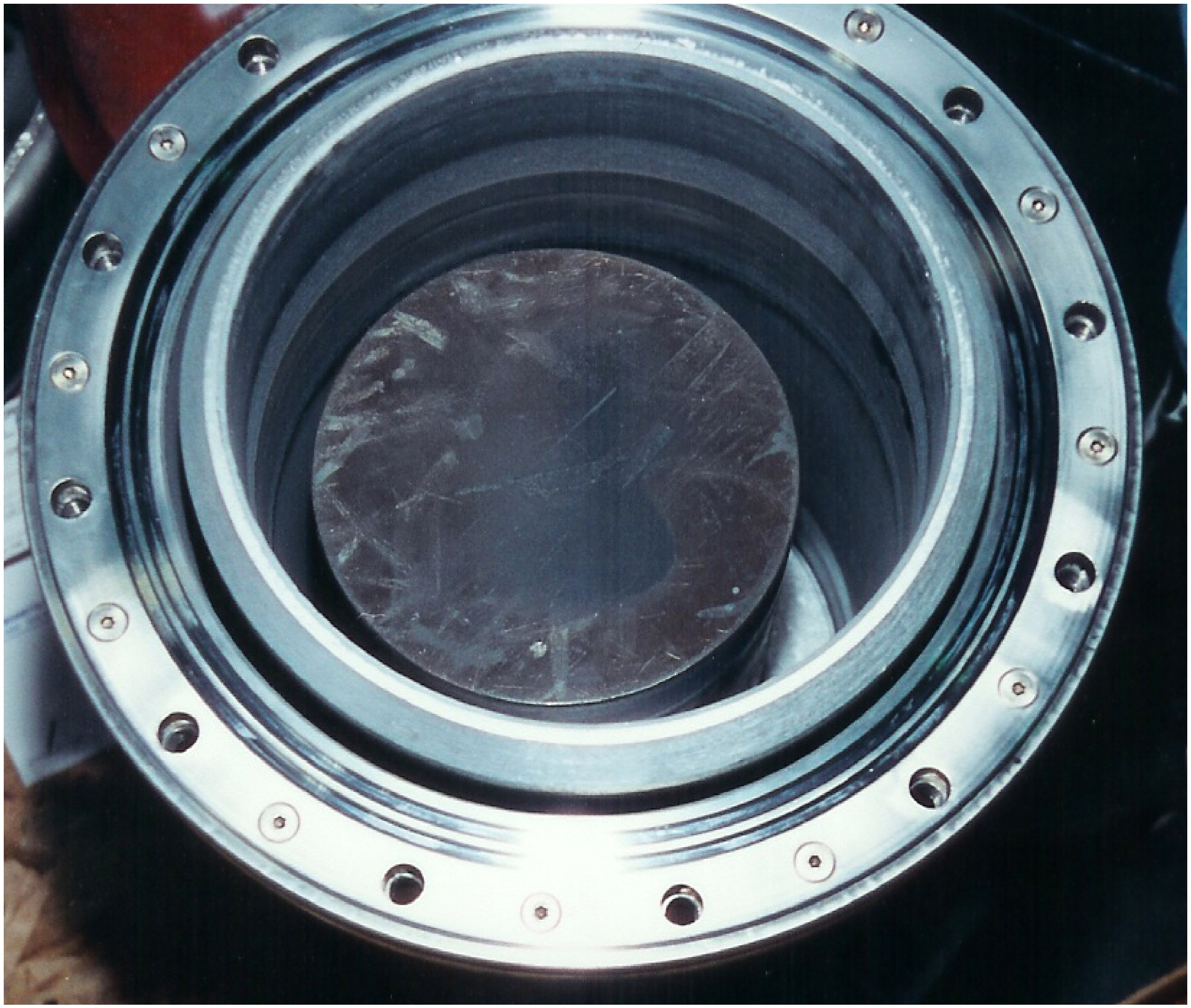
ES-2M Vibration Testing 1/10/97

Top can damage to bottom head crimp after testing



ES-2M Vibration Testing 1/10/97

Top test weight after testing



ES-2M Vibration Testing 1/10/97

Aluminum tube removed after testing

ES-2M Vibration Testing 1/10/97

Aluminum tube removed after testing

ES-2M Vibration Testing 1/10/97

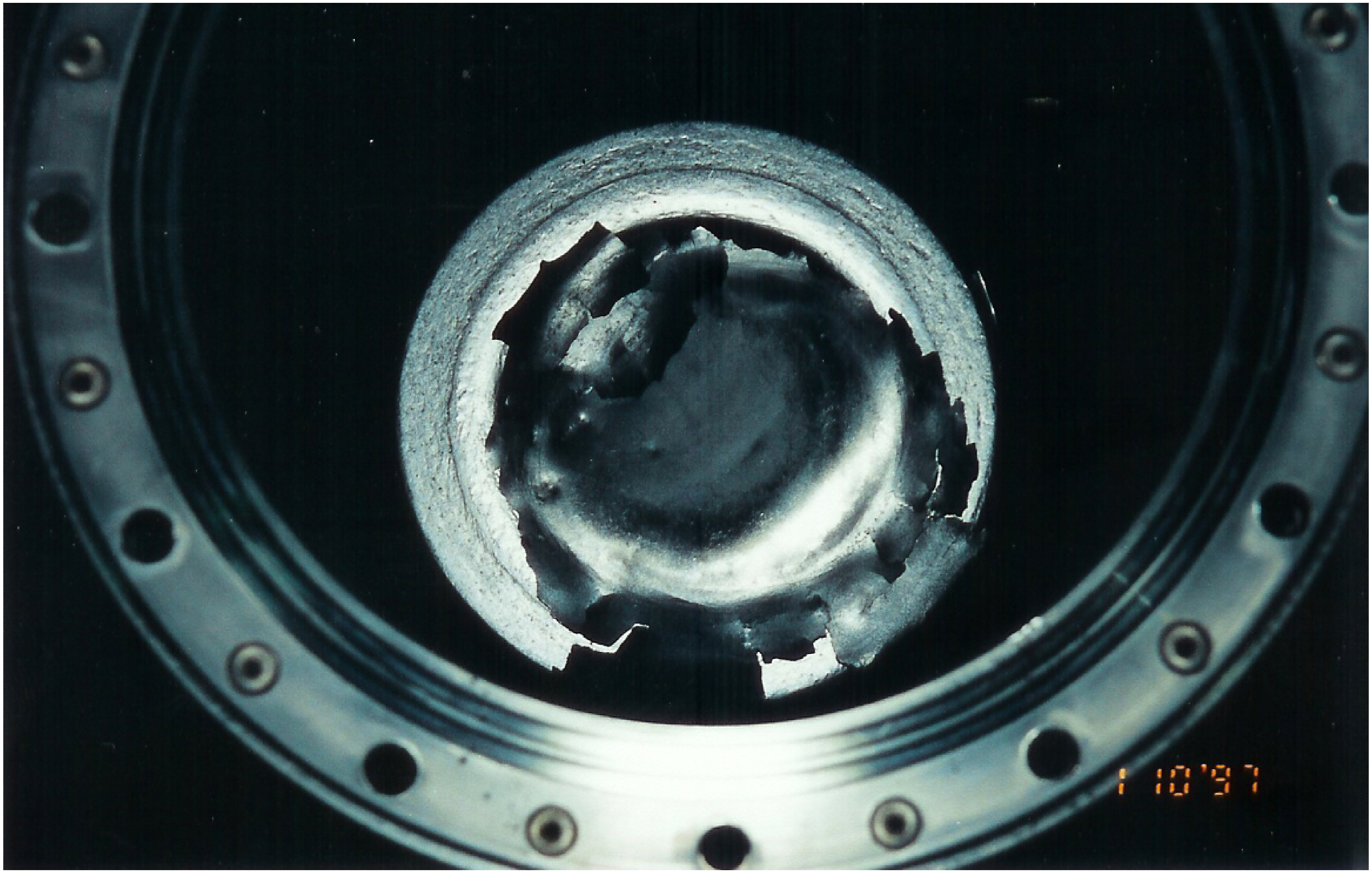
Top test weight after testing

ES-2M Vibration Testing 1/10/97

Top test weight after testing

ES-2M Vibration Testing 1/10/97

Bottom of top can after testing



ES-2M Vibration Testing 1/10/97

Bottom of Top Can after testing

ES-2M Vibration Testing 1/10/97

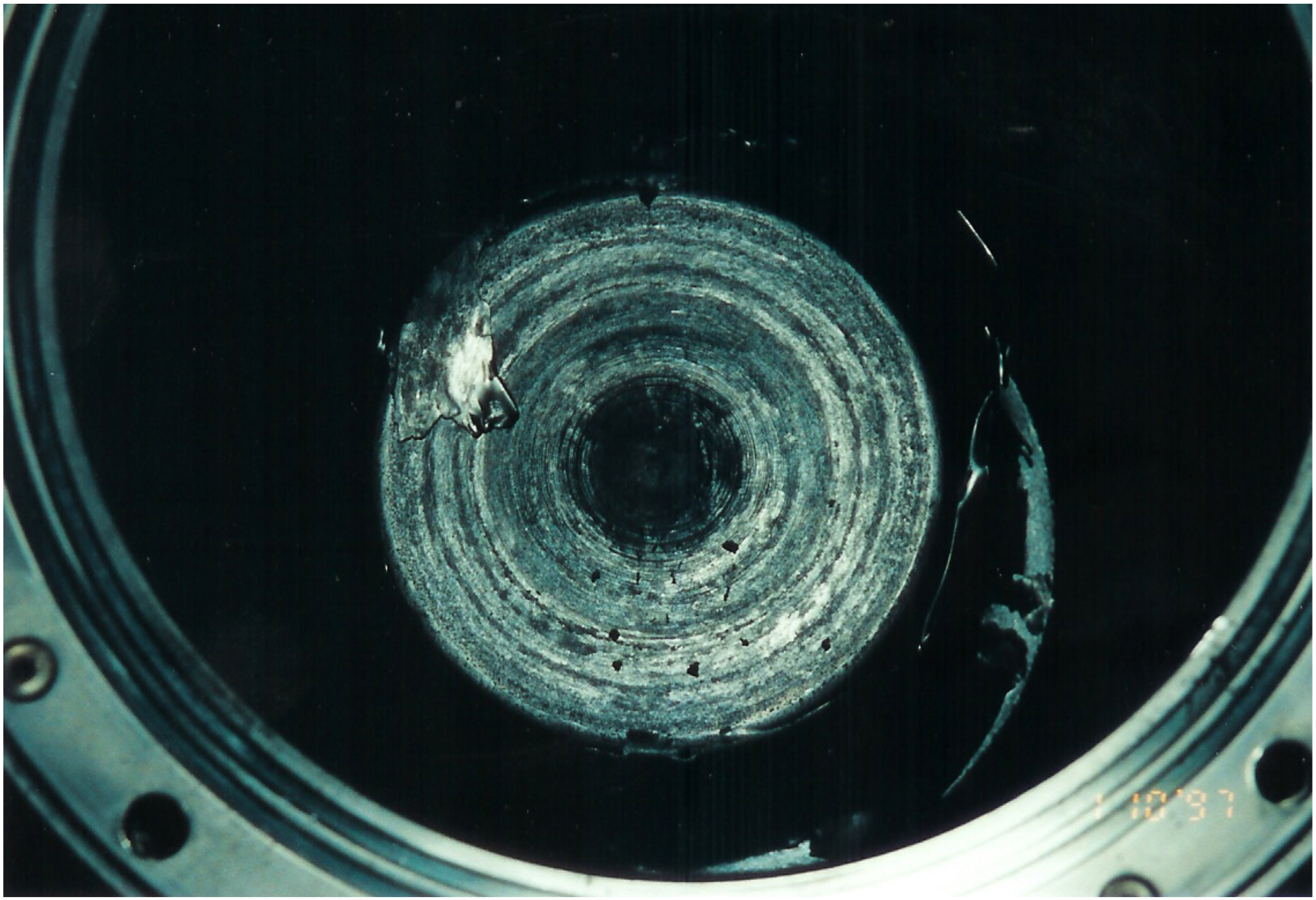
Middle Aluminum Spacer after testing

ES-2M Vibration Testing 1/10/97

Top of Bottom Can after testing

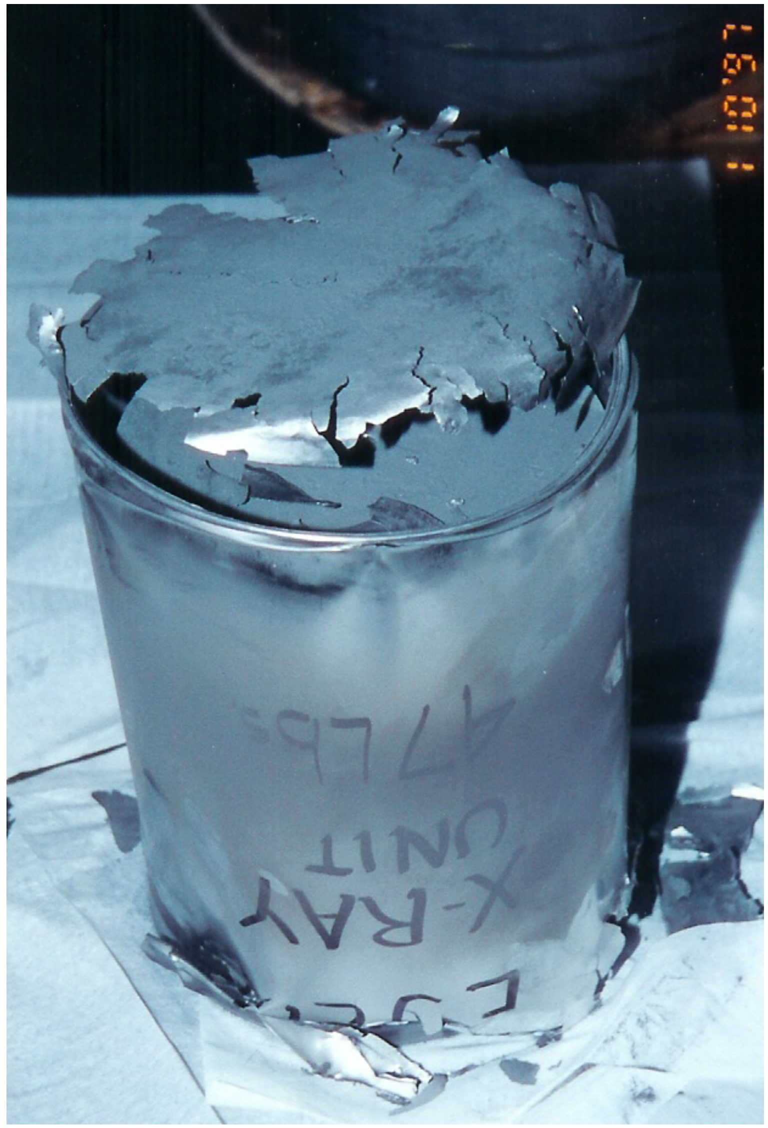
ES-2M Vibration Testing 1/10/97

Top of bottom test weight after testing



ES-2M Vibration Testing 1/10/97

Bottom test weight after testing



ES-2M Vibration Testing 1/10/97

Bottom test weight after testing

This photo shows the top plug of one of the tested DPP-2 packages. Due to the damage from the CG over corner drop and crush test, the top plug had to cut out of the package in order to extract the containment vessel. This photo shows that even after undergoing the full suite of drop, crush and thermal tests, the Kaolite in the plug, although it is cracked and broken, remains in solid form and within the plug liner.