Aquion Energy

Abuse Testing

TP002-02, TP007-08, TP016-10, TP018-11, TP020-09, TP027-05, TP030-02, TP031-03, TP032-06, TP033-04

C14T1-010

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websites: www.technicalserviceslab.com and www.mgaresearch.com

TEST REPORT

MGA REPORT NO.:	C14T1-010
TESTS PERFORMED ON:	December 5, 2013 - March 3, 2014
TEST DESCRIPTION:	Abuse Testing
ITEM DESCRIPTION*:	Salt Water Batteries
PROCEDURE NUMBER:	TP002-02, TP007-08, TP016-10, TP018-11, TP020-09, TP027-05, TP030-02, TP031-03, TP032-06, TP033-04

TEST LABORATORY:

MGA Research Corporation
Technical Services Laboratory
12790 Main Road
Akron, NY 14001

SUBMITTED TO:

Cyril Truchot
Aquion Energy
32 39th Street
Pittsburgh, PA, 15201

REPORT WRITTEN BY:

Steve Keller: Test Technician

DATE: March 3, 2014

REPORT REVIEWED BY:

Steve Abramowski: Deputy Quality Manager

DATE: March 3, 2014

*The results presented in this report relate only to the specified test items.

ACCREDITED
Testing Laboratory
CERT# 1762.01

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C14T1-010

1.0 TEST SUMMARY

Test Conducted and Completion Date:	December 5, 2013 - March 3, 2014
Test Conducted For:	Aquion Energy
Test Performed By:	Jeremy LeGasse Michael Greiner Steve Abramowski Steve Keller
MGA File Number:	C14T1-010
Test Specification:	Abuse Testing Per UL 1973, UN 38.3, SAE J1455, SAE J2464, and customer specifications
Test Specimen Data:	Salt Water Batteries Model 402-0000004 S/N's: 111311060066, 111311060048, 111311060013, 111311060047, 111311060014, 111311060037, 111311060023, 111311060050, 111311060008, S111311070003, S111311150001, S111311070006, S111311070008, S111311140004
Condition of Test Specimen upon Receipt:	Good
Condition of Test Specimen upon Completion:	Tested
Disposition of Test Items:	Upon completion of testing, test items were returned to Aquion Energy

2.0 PROGRAM

2.1 DROP IMPACT

2.1.1 Test Requirements

UL 1973 - 28

2.1.2 Test Procedure

A battery stack was held at a height of 10cm then dropped onto a concrete surface in the vertical position.

2.1.3 Test Results

There was minor damage on the bottom-left corner of stack. There was no loss of voltage during the test. It did not leak, vent, disassemble, rupture or catch fire as a result of the testing.

See Appendix A for test data results.
See Appendix B for test photographs.

2.2 VIBRATION

2.2.1 Test Requirements

UN 38.3 Test T3

2.2.2 Test Procedure

A battery stack were fastened to a shaker head and subjected to a sinusoidal sweep between 7 Hz and 200 Hz and back to 7 Hz, traversed in fifteen (15) minutes. This cycle was repeated twelve (12) times for a total of three (3) hours in each of three (3) mutually perpendicular axes.

The logarithmic frequency sweep was as follows: from 7 Hz, a peak acceleration of 1 gn was maintained until 18 Hz was reached. The amplitude was maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 2 gn occured (approximately 50 Hz). A peak acceleration of 2 gn was then maintained until the frequency was increased to 200 Hz.

2.2.3 Test Results

The battery stack did not have voltage loss. It did not leak, vent, disassemble, rupture or catch fire as a result of the testing. There was no visible damage.

See Appendix A for test data results.
See Appendix B for test photographs.

2.3 ALTITUDE

2.3.1 Test Requirements

UN 38.3 Test T1

2.3.2 Test Procedure

A cell and a battery stack were stored at a pressure of less than 11.6 kPa for a minimum of six (6) hours at ambient temperature (20 ± 5 ºC).

2.3.3 Test Results

The battery stack had no visual damage, loss of voltage, or events observed.
The cell had minor voltage loss but no visual damage or events observed.

See Appendix A for test data results.
See Appendix B for test photographs.

2.4 SALT FOG

2.4.1 Test Requirements

UL 1973 - 35

2.4.2 Test Procedure

Two cells were subjected to three 2 hour sprays separated by 20-22 hour humidity soaks in a salt atmosphere in accordance to Rev C of MIL-STD-810.

2.4.3 Test Results

Minor voltage loss was observed in both cells. Some swelling of the cells was observed.

See Appendix A for test data results.
See Appendix B for test photographs.

2.5 SAND/DUST (Non A2LA Certified)

2.5.1 Test Requirements

SAE J1455 Sec. 4.7

2.5.2 Test Procedure

See document attached to the end of the report.

2.5.3 Test Results

See document attached to the end of the report.

2.6 SHOCK

2.6.1 Test Requirements

UN 38.3 Test T4

2.6.2 Test Procedure

A battery stack was fastened to a drop tower and subjected to a half sine shock with a peak acceleration of 50 g and pulse duration of eleven (11) milliseconds. The battery received three (3) shocks in the positive and negative directions in each of three (3) orthogonal axes for a total of eighteen (18) shocks.

2.6.3 Test Results

The battery stack did not have voltage loss. It did not leak, vent, disassemble, rupture or catch fire as a result of the testing. There was no visible damage.

See Appendix A for test data results.
See Appendix B for test photographs.

2.7 NAIL PENETRATION

2.7.1 Test Requirements

SAE J2464 Sec. 4.3.3

2.7.2 Test Procedure

A battery stack and a cell, tested separately, were penetrated by a 20mm diameter steel nail at a rate of 80 mm/sec. The battery stack was to be penetrated vertically through the top three cells. The cell was to be penetrated completely through its side.

2.7.3 Test Results

During penetration, the nail bent inside the battery stack and protruded from the side of the third cell. Both the battery stack and the nail experienced slight leaking and significant voltage loss as a result of the penetration.

See Appendix A for test data results.
See Appendix B for test photographs.

2.8 CRUSH

2.8.1 Test Requirements

UL 1973 - 25

2.8.2 Test Procedure

Three battery stacks, one per each orthogonal axis, were set between two flat platens of a hydraulic-controlled crush system. The unit, while not being exposed to a charge or load, was subjected to crushing at a rate of 1 mm/sec until applied force reached a force limit of 100 ± 6kN.

2.8.3 Test Results

The maximum force limit was reached on all three battery stacks. No visual damage, loss of voltage, or events were observed.

See Appendix A for test data results.
See Appendix B for test photographs.

2.9 ROLL-OVER

2.9.1 Test Requirements

SAE J2464 Sec. 4.3.4

2.9.2 Test Procedure

A battery stack and two cells were subjected to a full rotation at a rate of 15 seconds per 90 degrees. At each 90 degree interval, the units were held for one hour.

2.9.3 Test Results

The cells had minor voltage loss. Slight leaking was observed from the stack. No visual damage, loss of voltage, or events were observed.

See Appendix A for test data results.
See Appendix B for test photographs.

2.10 IMMERSION

2.10.1 Test Requirements

UL 1973 - 34

2.10.2 Test Procedure

Two cells, tested separately, were immersed in water for a period of 30 minutes.

2.10.3 Test Results

The cells had minor voltage loss. No visual damage, loss of voltage, or events were observed.

See Appendix A for test data results.
See Appendix B for test photographs.

2.11 THERMAL CYCLING

2.11.1 Test Requirements

UL 1973 - 33

2.11.2 Test Procedure

A cell and a battery stack were placed in a test chamber and subjected to the cycles below.
- Chamber temperature was raised to 75 ±2°C (167 ±3.6°F) within 30 min and maintained for 6 hours.
- Chamber temperature was reduced to 20 ±2°C (68 ±3.6°F) within 30 min and maintained for 2 hours.
- Chamber temperature was reduced to -40 ±2°C (-40 ±3.6°F) within 30 min and maintained for 6 hours.
- Chamber temperature was raised to 20 ±2°C (68 ±3.6°F) within 30 min.
- Sequence was repeated for a further 9 cycles.
- At the conclusion of the cycling, the samples remained at room temperature, 25 ±5°C (77 ±9°F) for 24 hours.

2.11.3 Test Results

The cell had minor voltage loss. No visual damage, loss of voltage, or events were observed in the battery stack.

See Appendix A for test data results.
See Appendix B for test photographs.

2.12 OVERCHARGE

2.12.1 Test Requirements

UL 1973 - 13

2.12.2 Test Procedure

A fully discharged cell was subjected to an overcharge to at least 110% of the maximum specified charging voltage.

2.12.3 Test Results

No visual damage or events were observed.

See Appendix A for test data results.
See Appendix B for test photographs.

3.0 TEST EQUIPMENT LIST

Item	Description	Manufacturer	Model No.	Serial No.	Cal Date	Date Due	MGA Ref
1	Multimeter	Fluke	26III	75860523	2/17/14	2/17/15	36.01-02
2	Rotisserie System	MGA	N/A	N/A	UWCE	N/A	56.34-01
3	Vacuum Chamber	MGA	Box Style	N/A	UWCE	N/A	56.20-03
4	Vacuum Pump	Dayton	2567-V108	587	UWCE	N/A	23.01-01
5	Scale	Pennsylvania	7300	97-243690	2/19/13Δ	2/19/14Δ	56.15-01
6	Salt Chamber	Industrial Filter & Pump Mfg. Co.	411.1ACD	S-6325	2/20/13Δ	2/20/14Δ	27.08-01
7	Pressure Gauge	US Gauge	60 PSI	300	4/10/13	4/10/14	23.04-07
8	Multimeter	Fluke	79III	69540818	2/3/14	2/3/15	36.01-03
9	Thermal Vacuum Chamber	National Appliance Co.	5851	4-82-1711-135	UWCE	N/A	27.18-01
10	Pressure Transducer	Omega	PX219-30V45G5V	78288	8/23/13	8/23/14	23.13-02
11	Multimeter	Fluke	26III	75860525	4/5/13	4/5/14	36.01-04
12	Humidity Chamber	Ransco	16535	136023/9-04353	4/17/13	4/17/14	70.05-01
13	Temperature Chamber	Thermotron	F32-CHV-15-15	852716	2/19/13Δ	2/19/14Δ	27.02-01
14	DAS	Keithley	2700	0958442	6/17/13	6/17/14	36.08-05
15	Power Supply	Sorensen	DC520-50EMI	0609A0141Z	UWCE	N/A	21.23-03
16	Shunt	Empro	HA-25-50	N/A	7/11/13	7/11/14	97.01-21

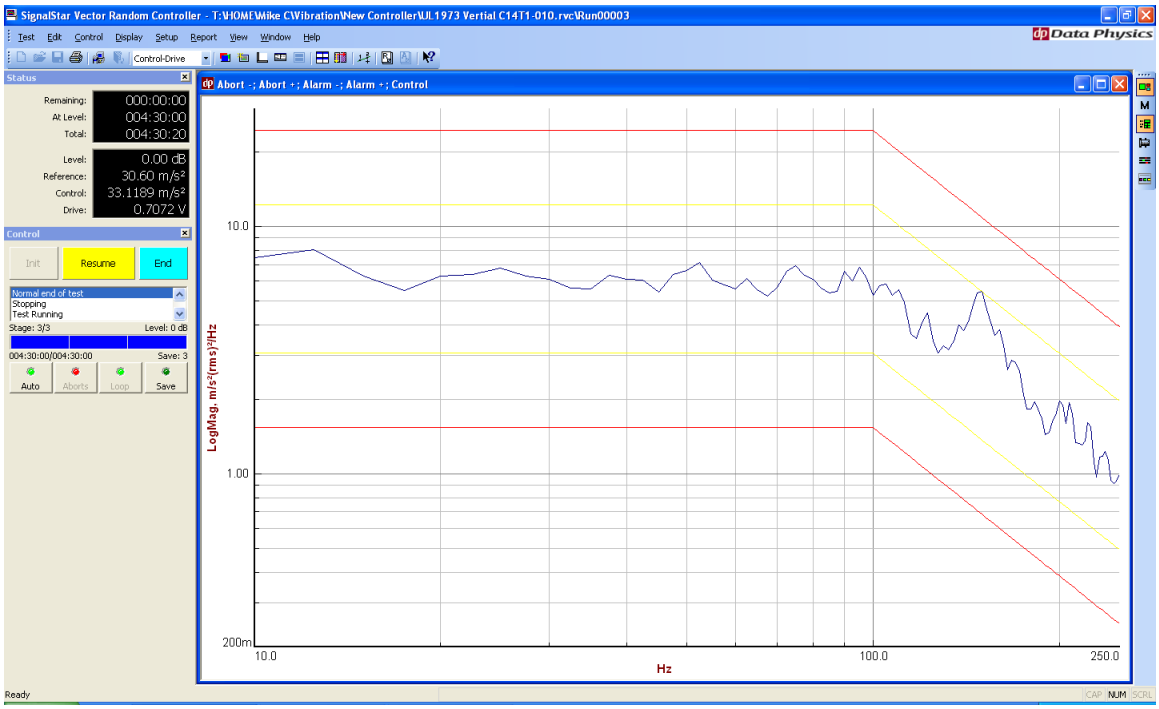
17	LVDT	MTS System Corporation	GHT0060UD60 1V0	90345074	2/18/14	2/18/15	03.08-03
18	Load Cell	Interface	1210ACK-5K	444597A	11/19/13	11/19/14	01.01-53
19	LVDT	MTS System Corporation	GHT0300UD60 1V0	90346699	2/19/14	2/19/15	03.08-02
20	LVDT	MTS System Corporation	GHT0300UD60 1V0	90346705	2/19/14	2/19/15	03.08-01
21	Vibration Controller	Data Physics	DP720/DP780	3060	2/20/13Δ	2/20/14Δ	24.02-05
22	Accelerometer	PCB	352C68	19493	5/24/13	5/24/14	02.07-36
23	Vibration System	Unholtz-Dickie	T1002	264	UWCE	N/A	24.04-04
24	Load Cell	Interface	1232AF-100K	332317A	2/28/13Δ	2/28/14Δ	01.01-08
25	Load Cell	Interface	1232AF-100K	136156A	3/19/13	3/19/14	01.01-37

UWCE - Used With Calibrated Equipment

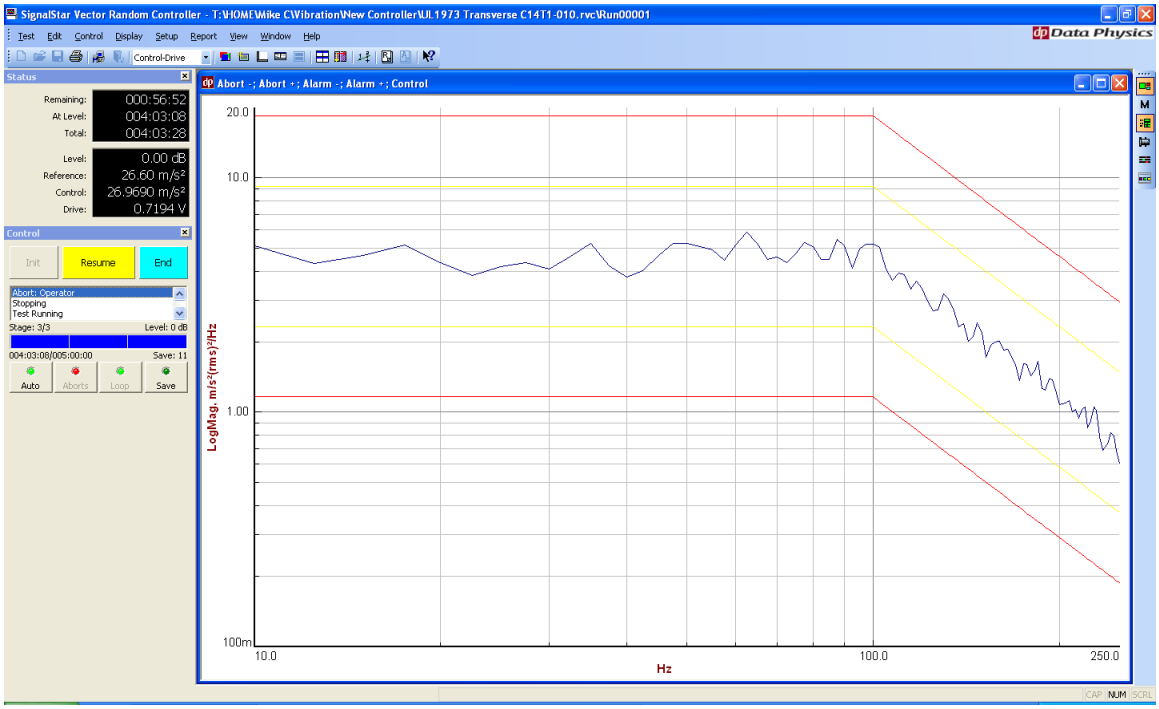
Δ - Calibration dates are reflective of when equipment was used for testing

APPENDIX A

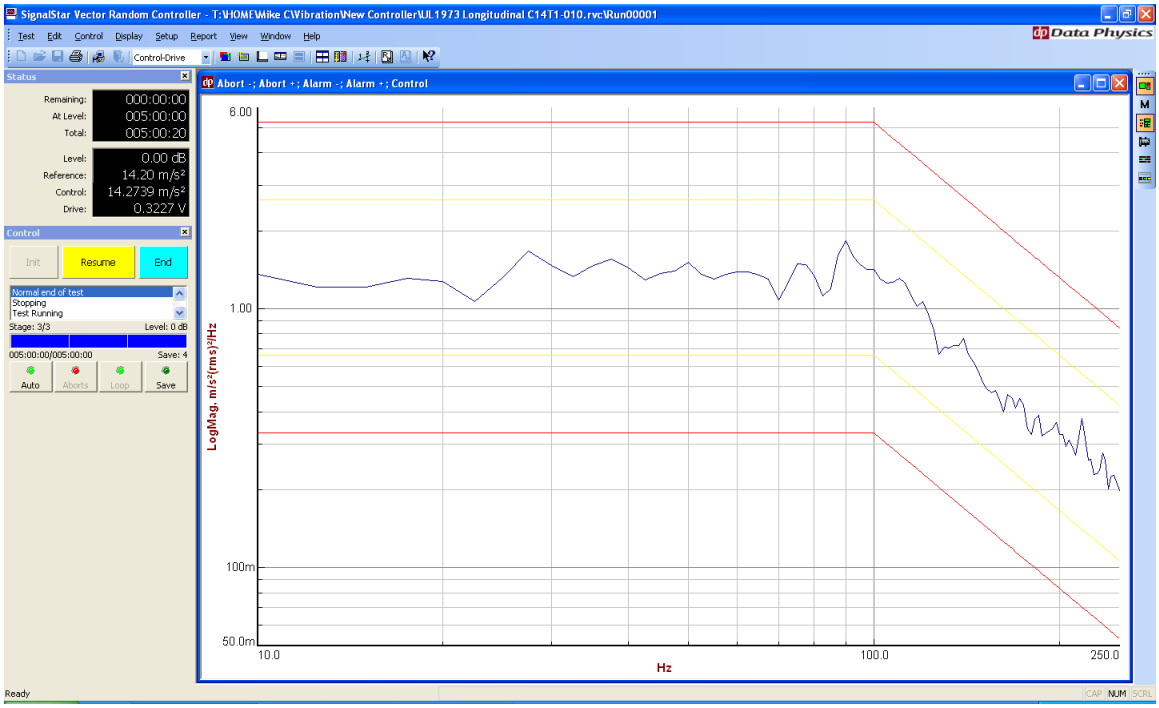
TEST DATA



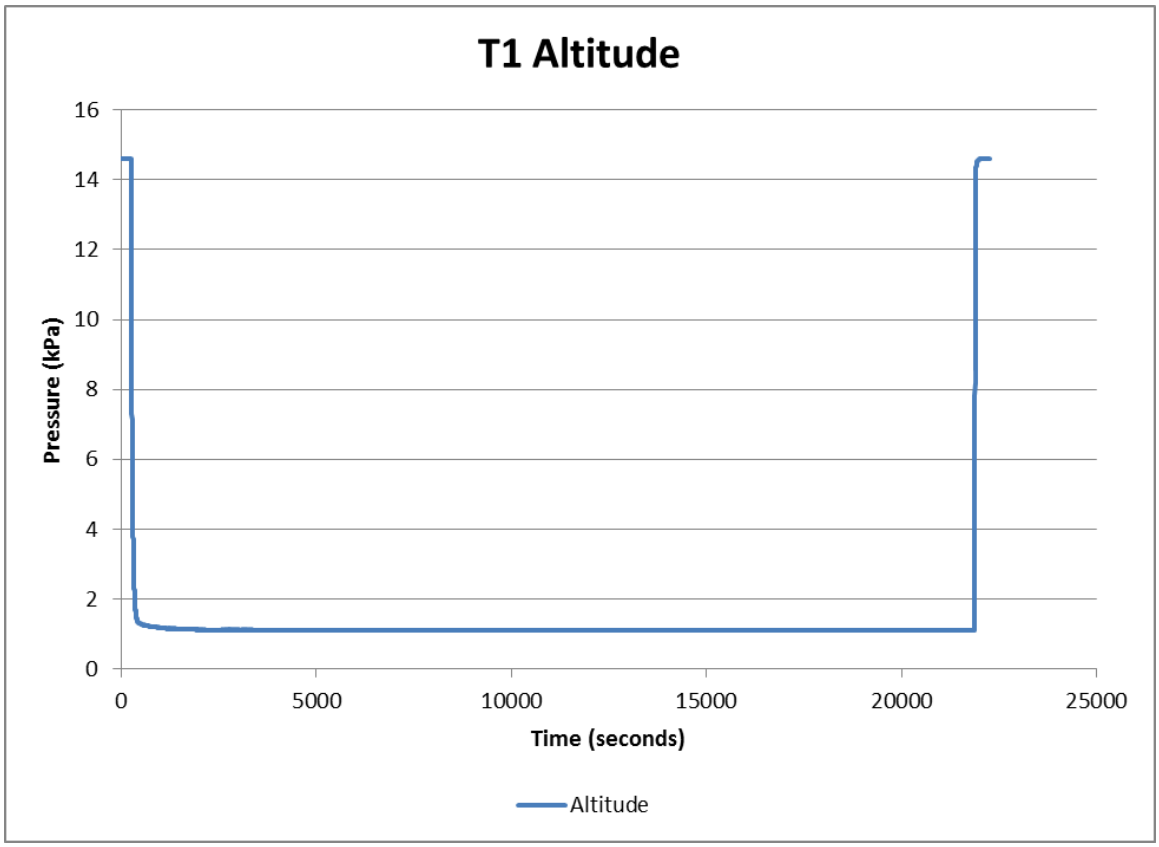
Vibration – X Axis

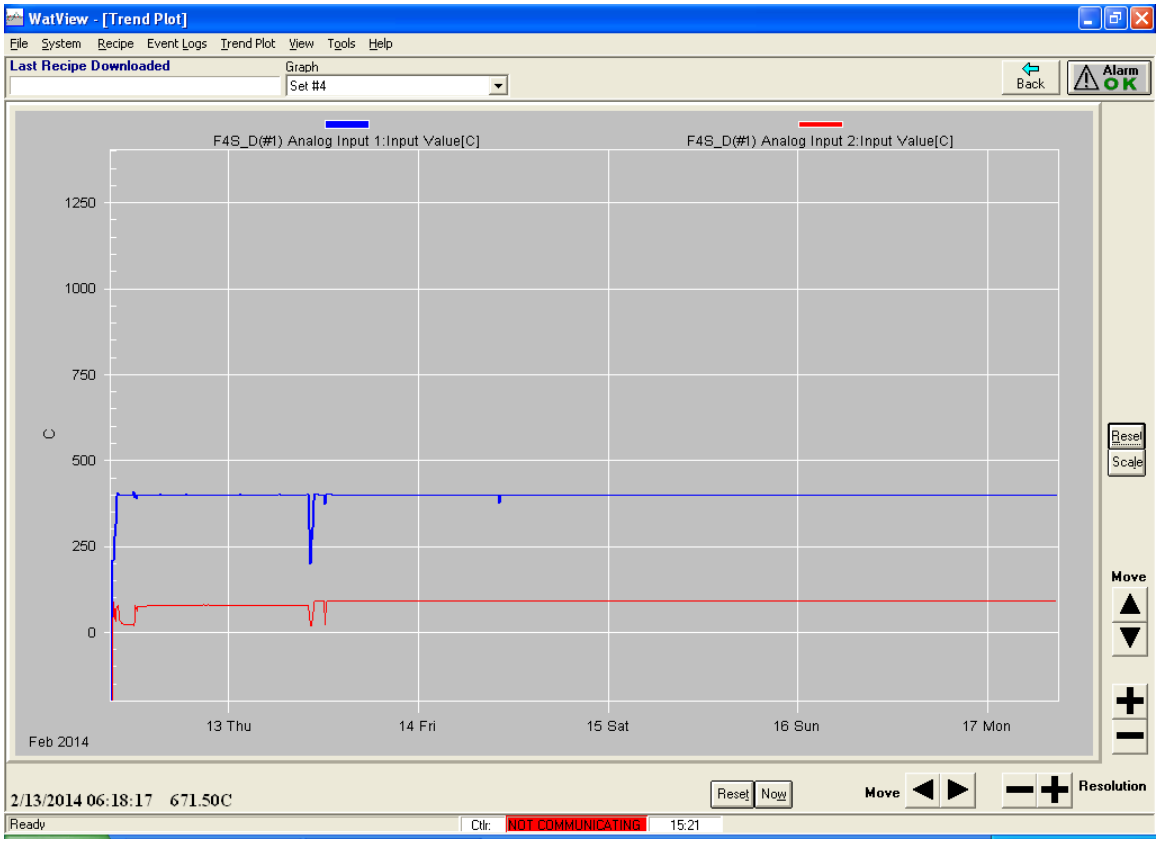


Vibration – Y Axis

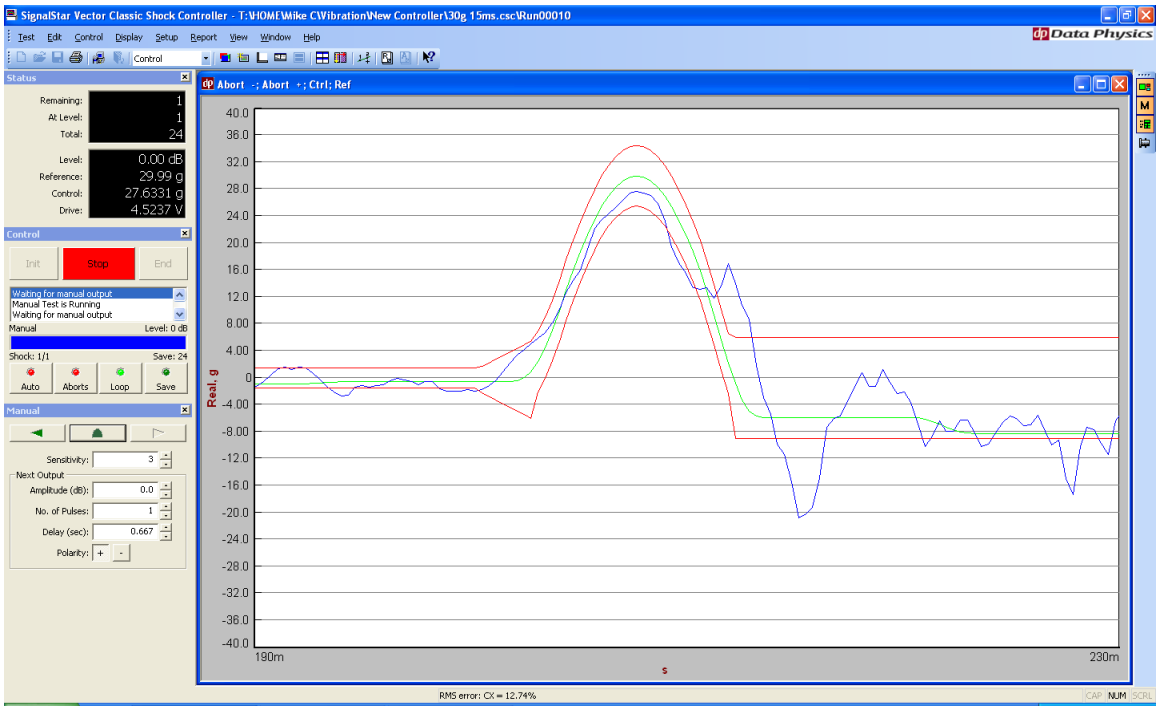


Vibration – Z Axis

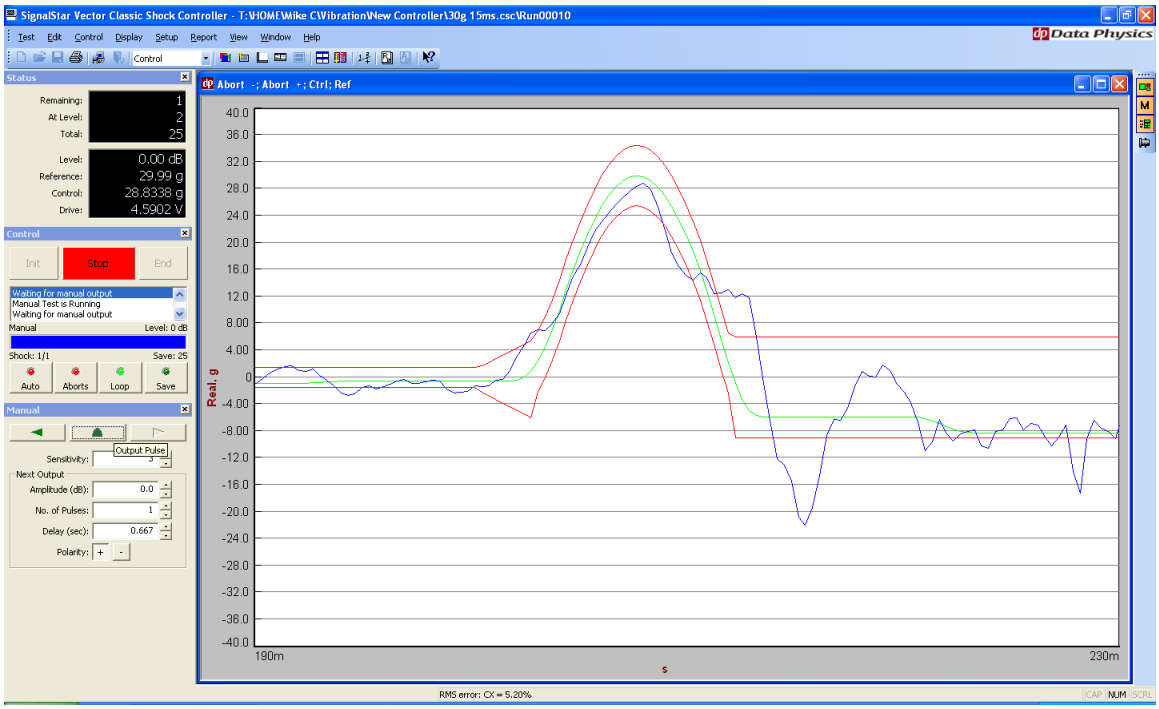




Salt Fog & Humidity Cell Test



Shock – (+) X Axis (1)



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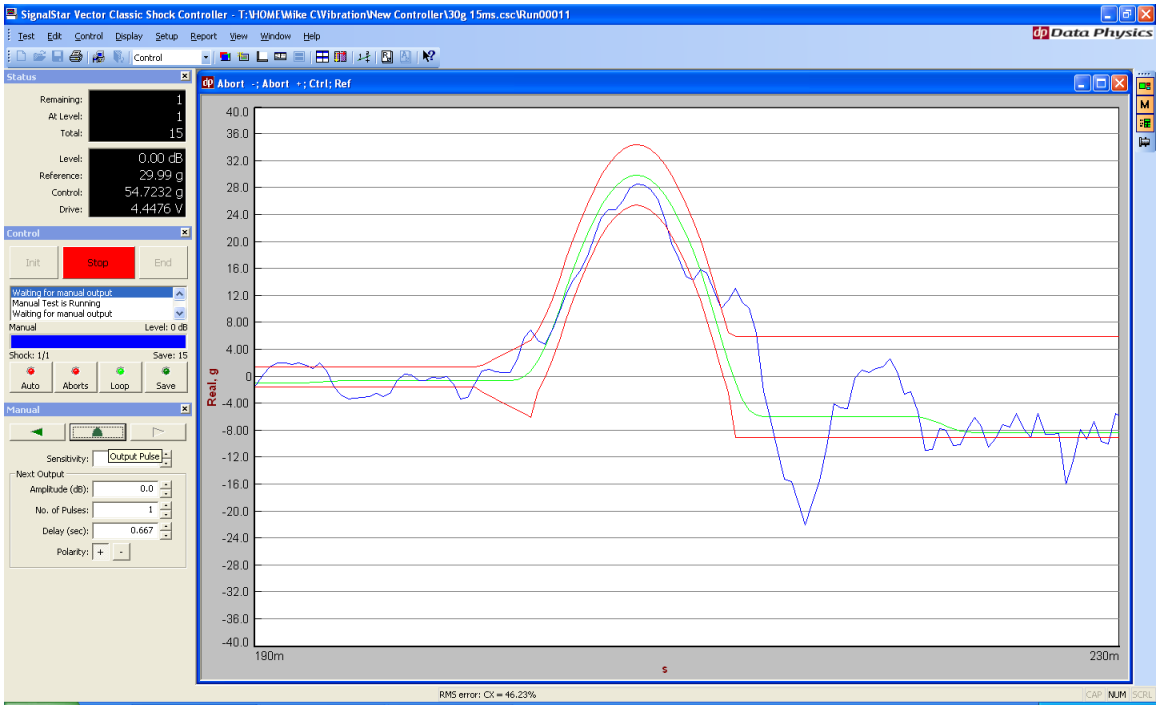

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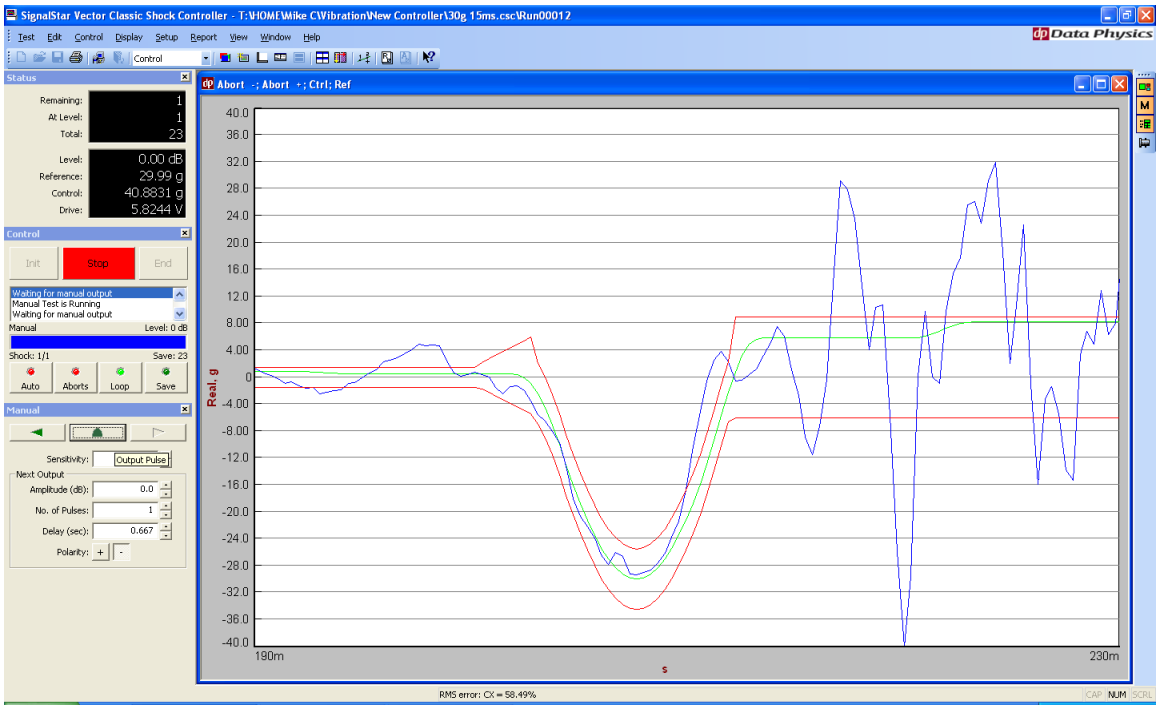

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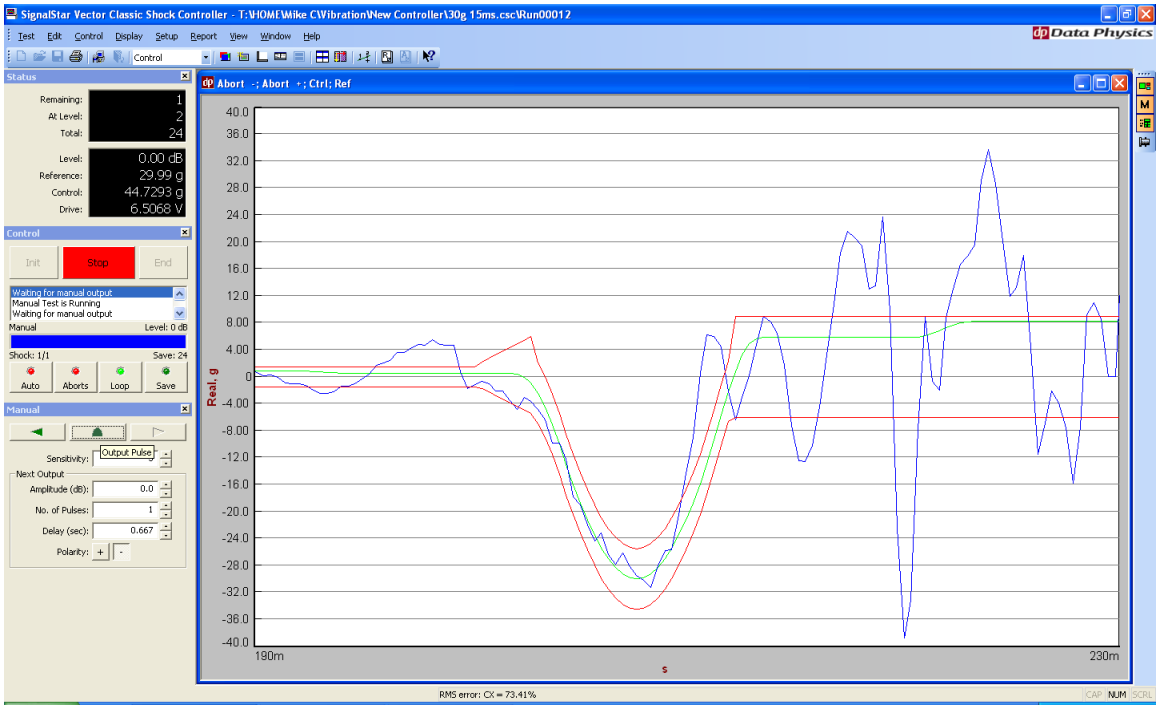

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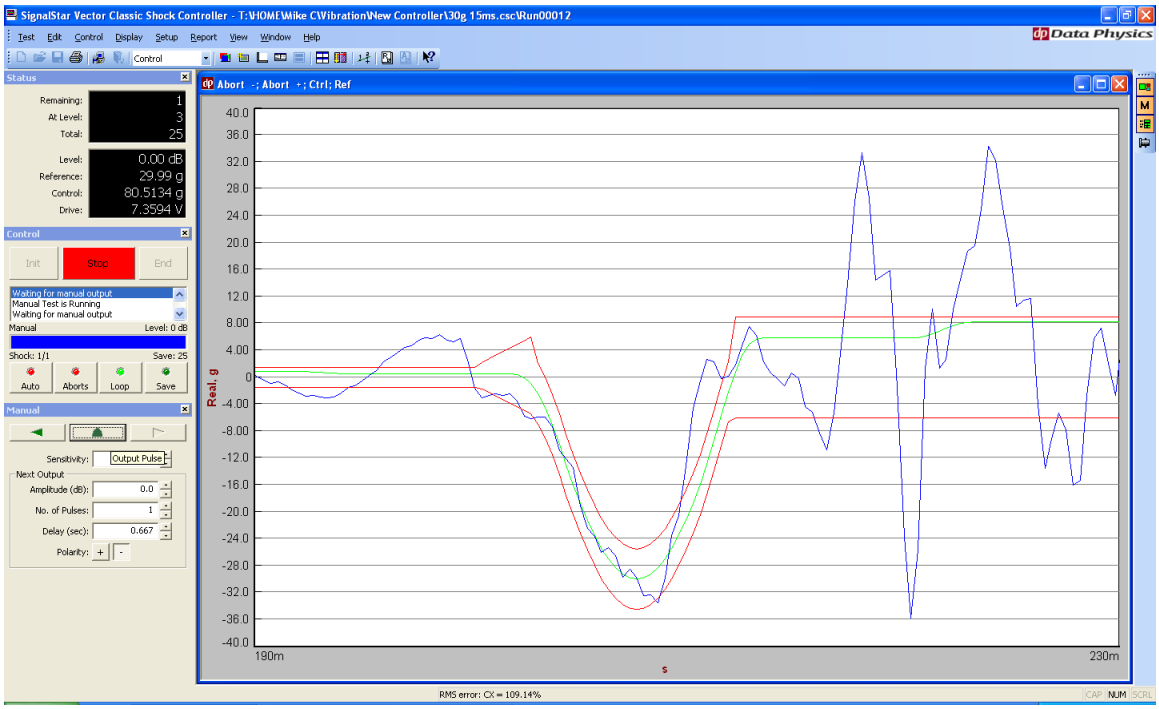

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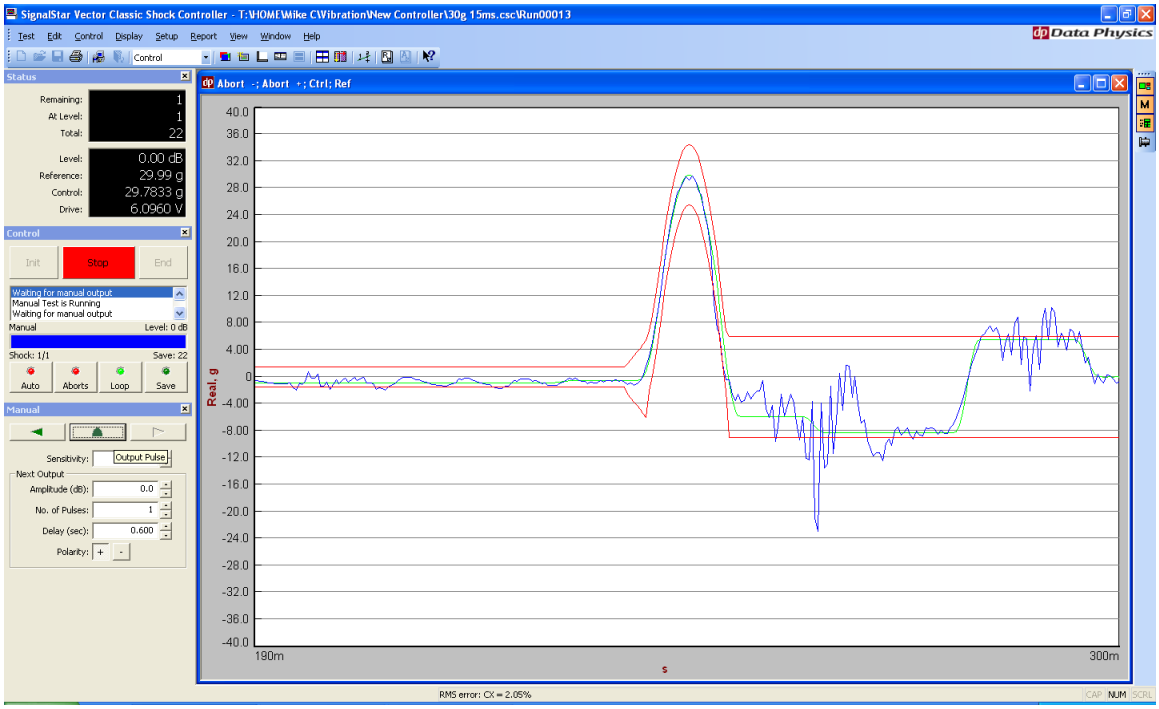

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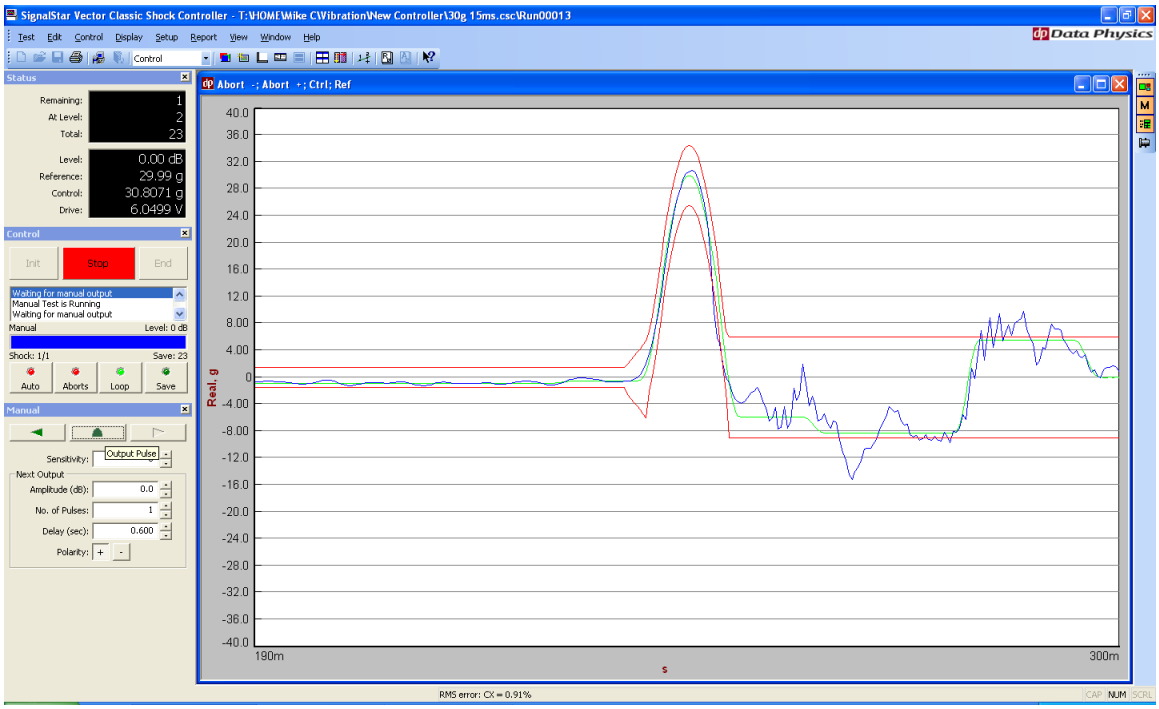

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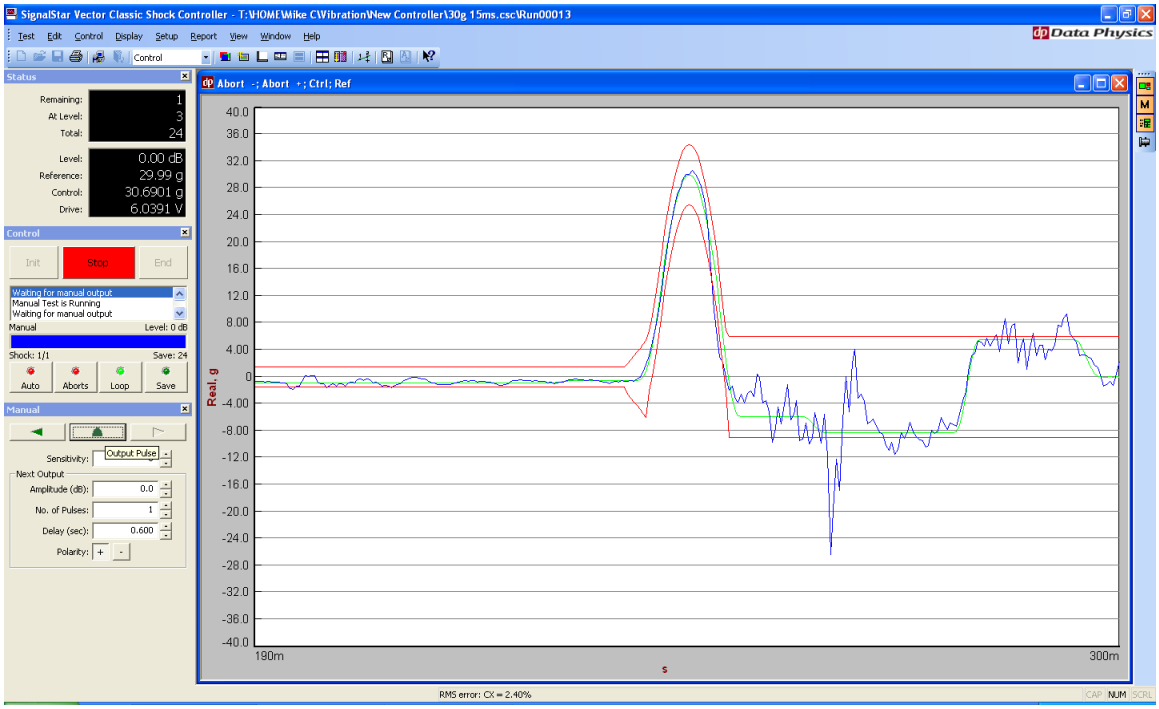

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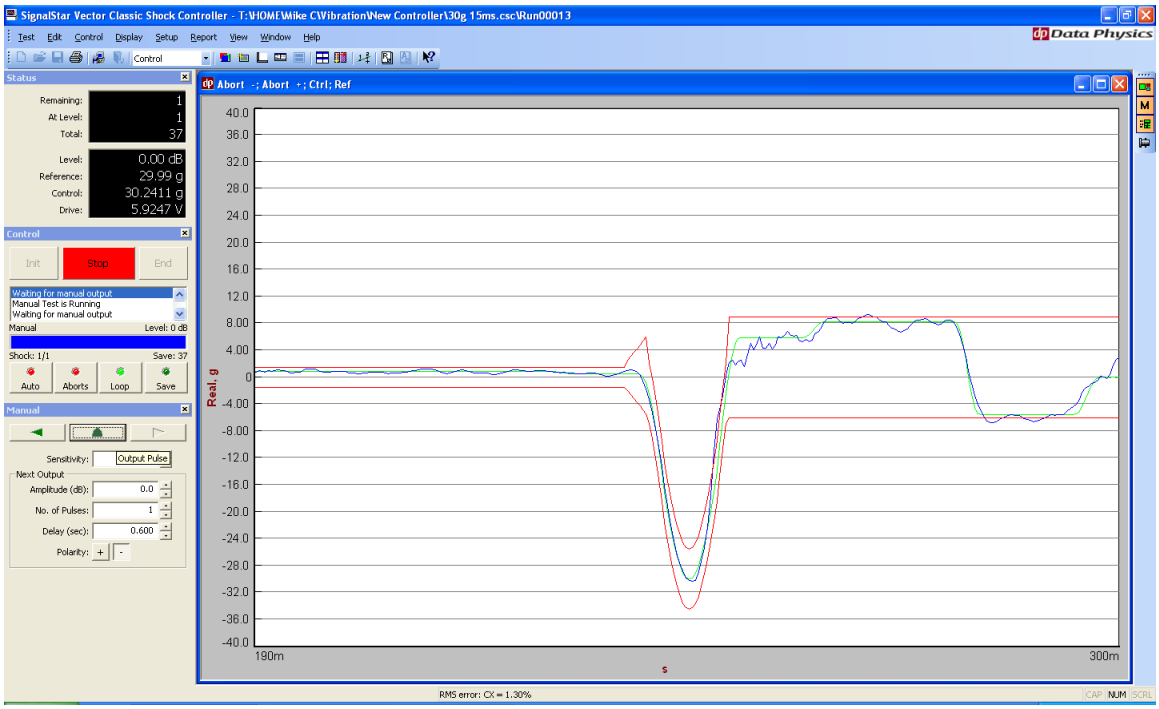

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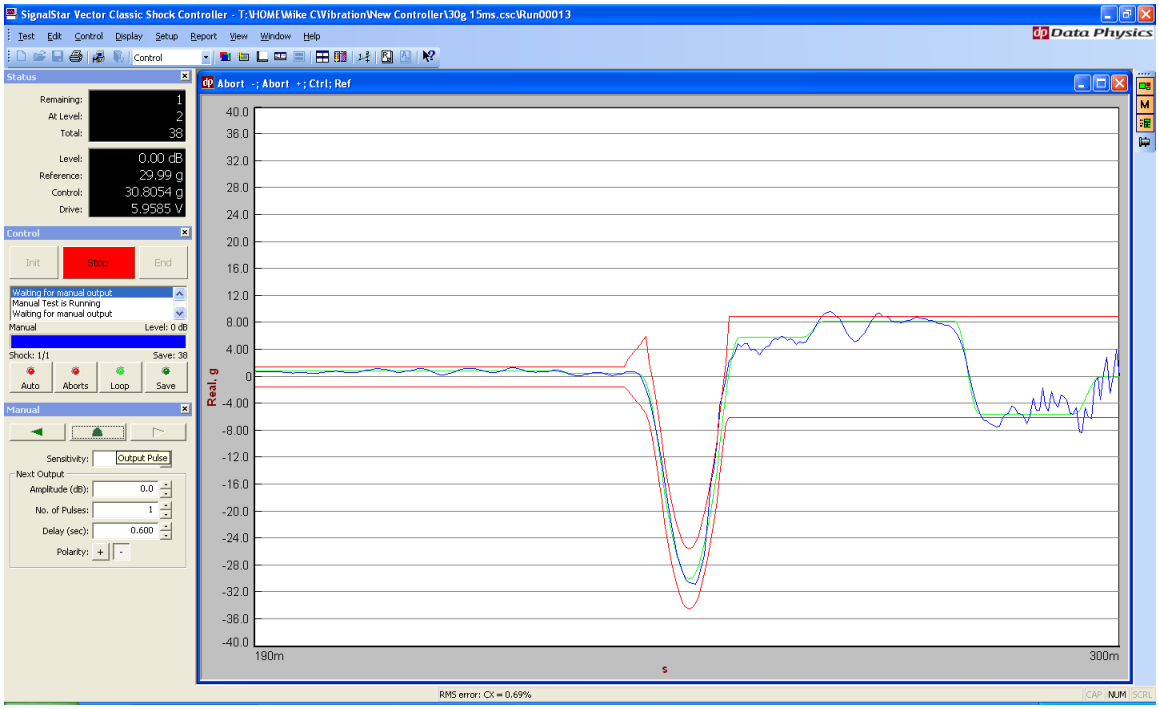

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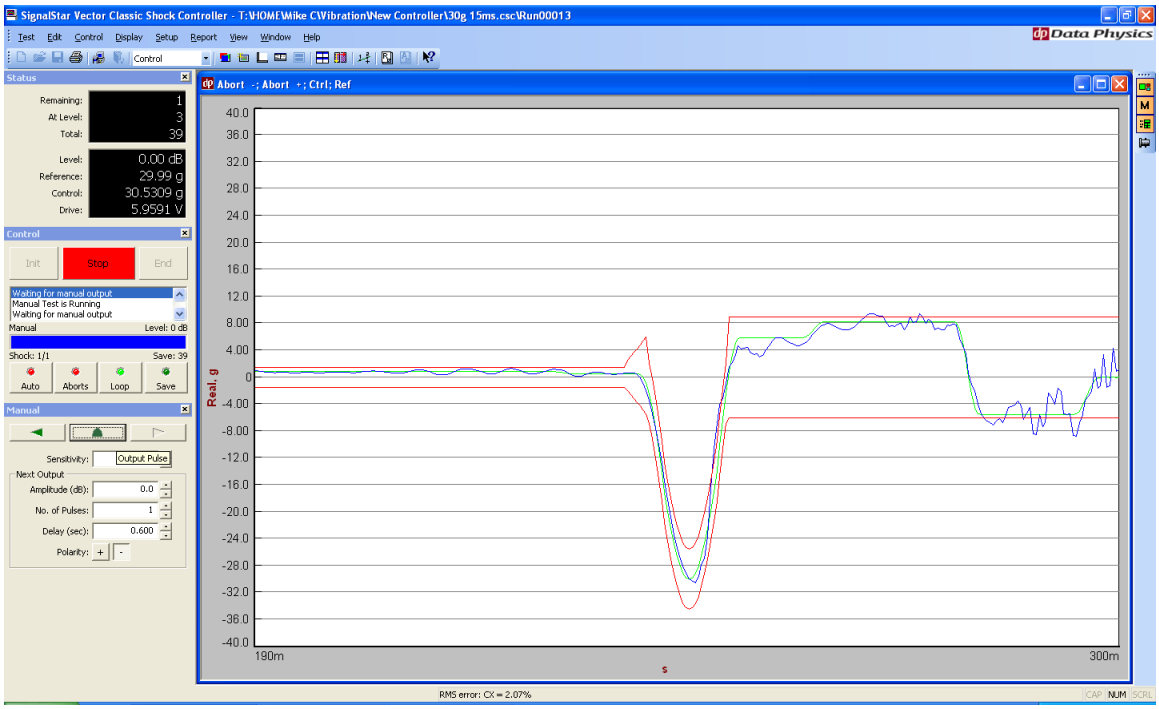

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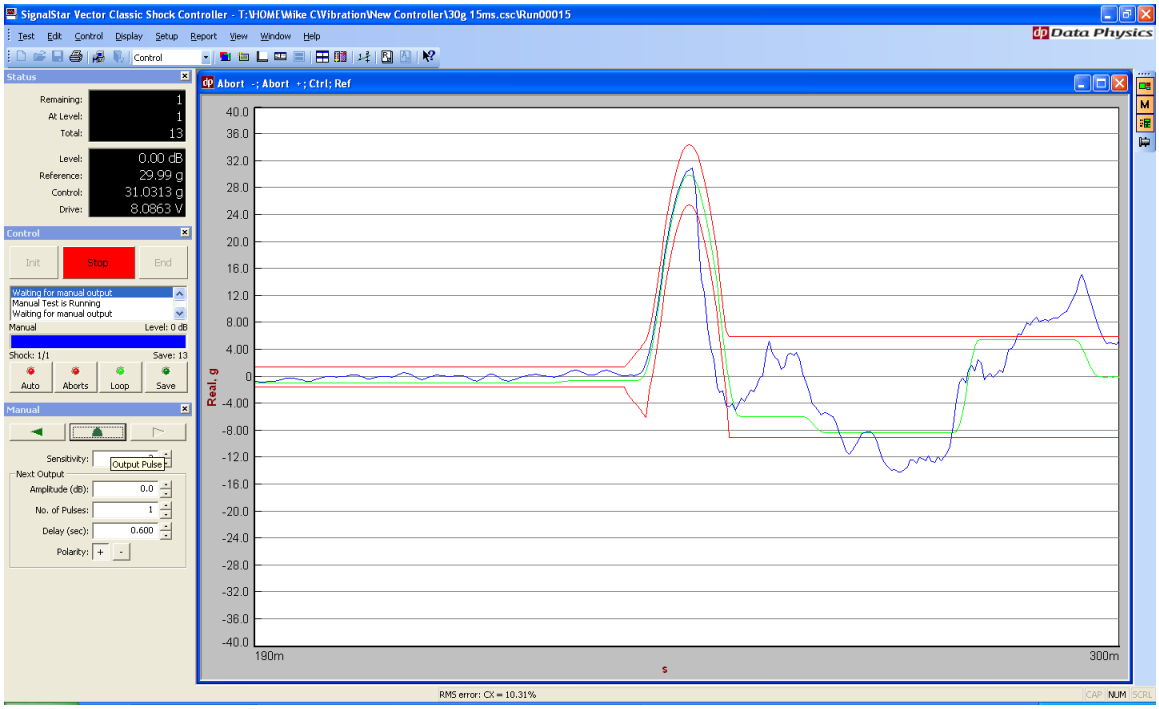

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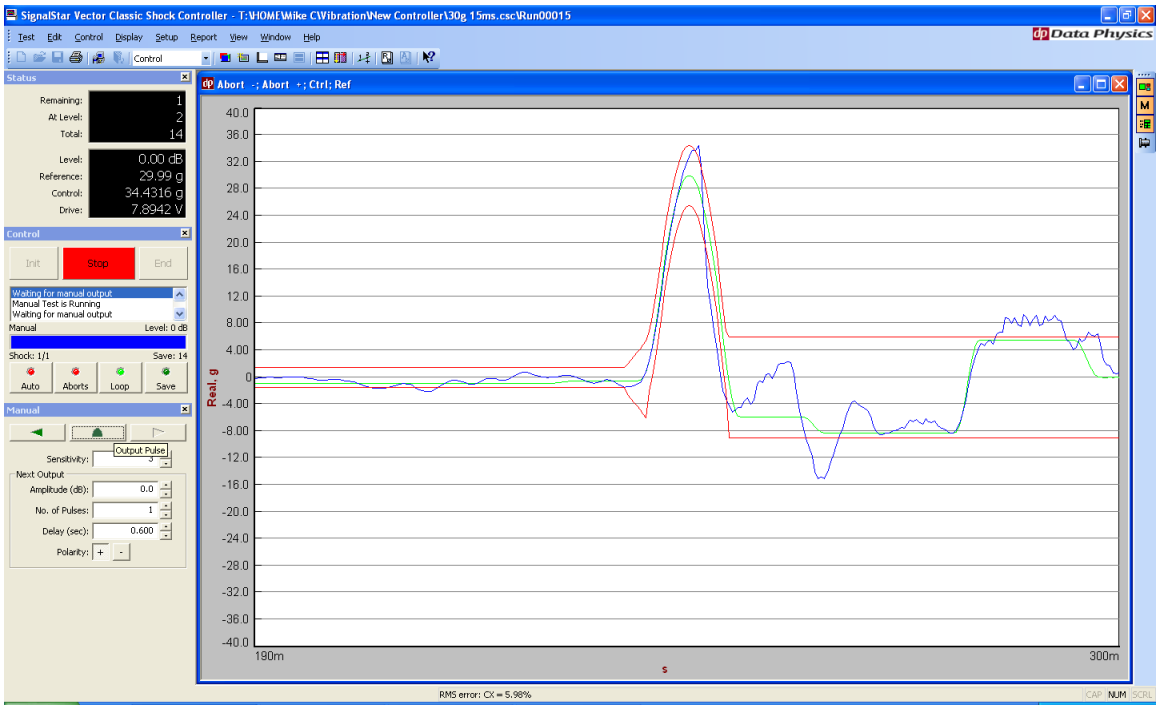

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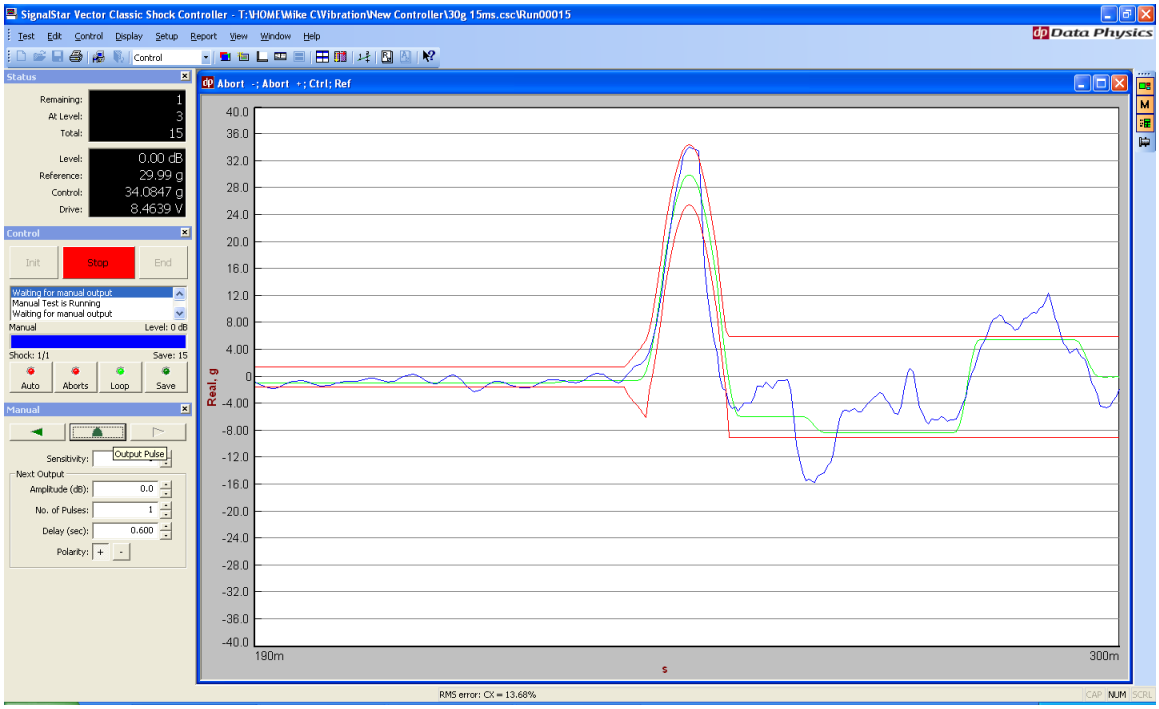

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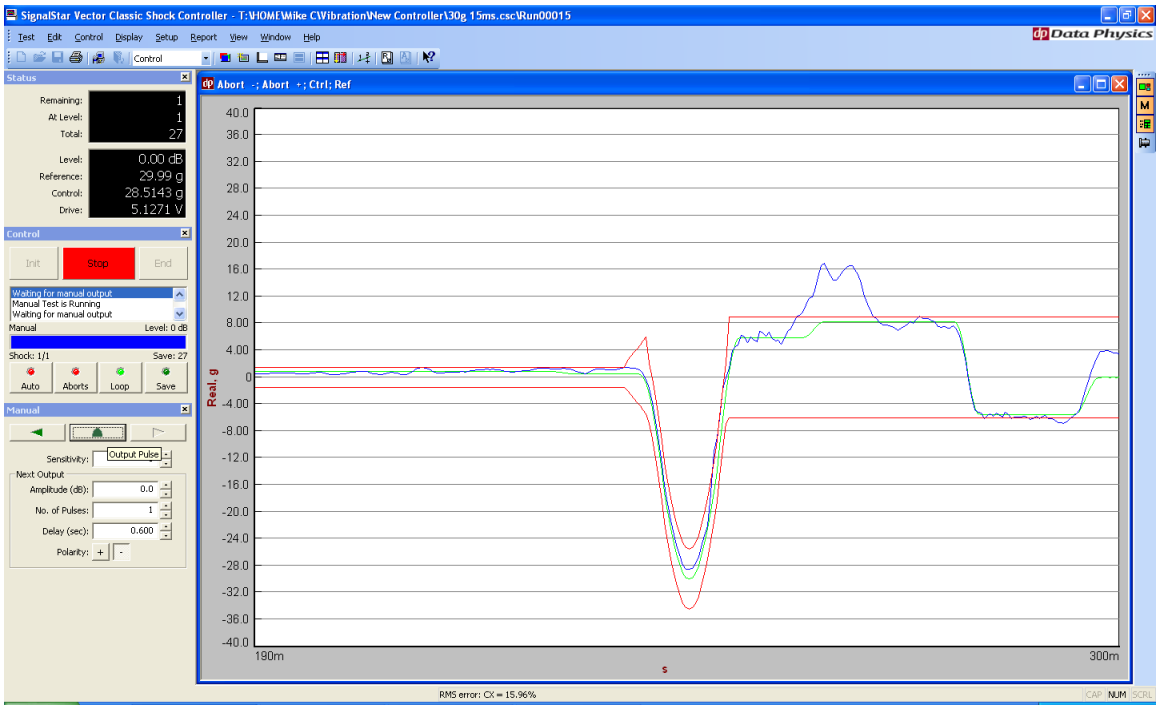

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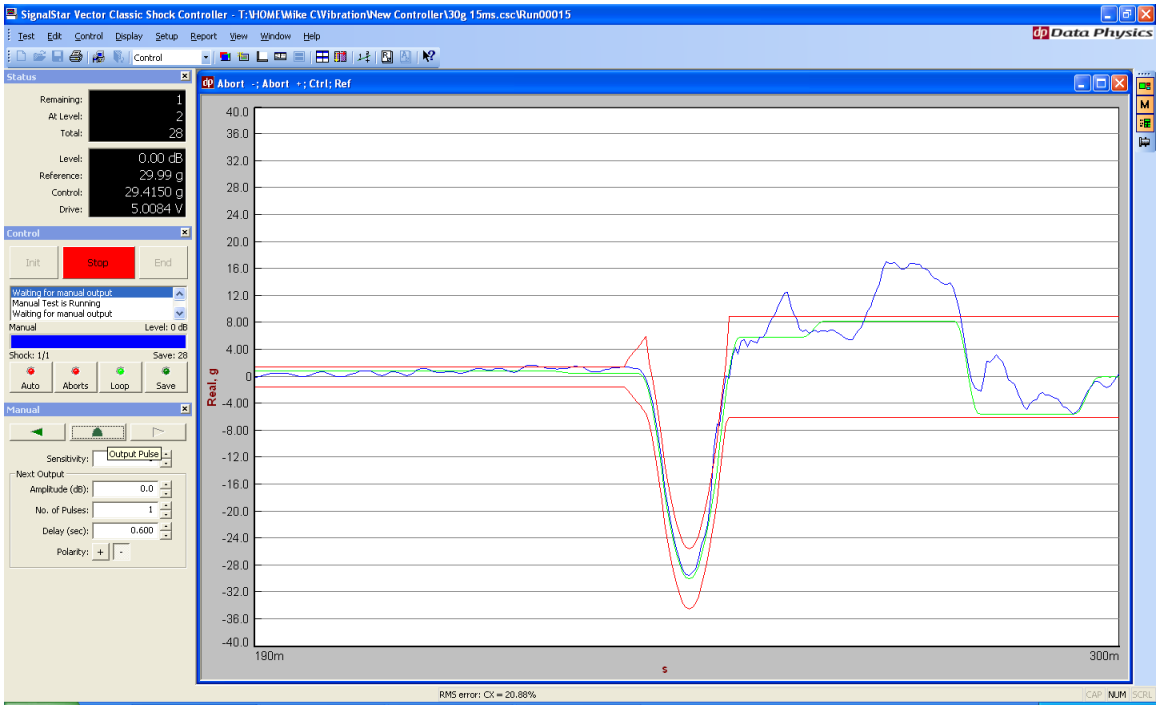

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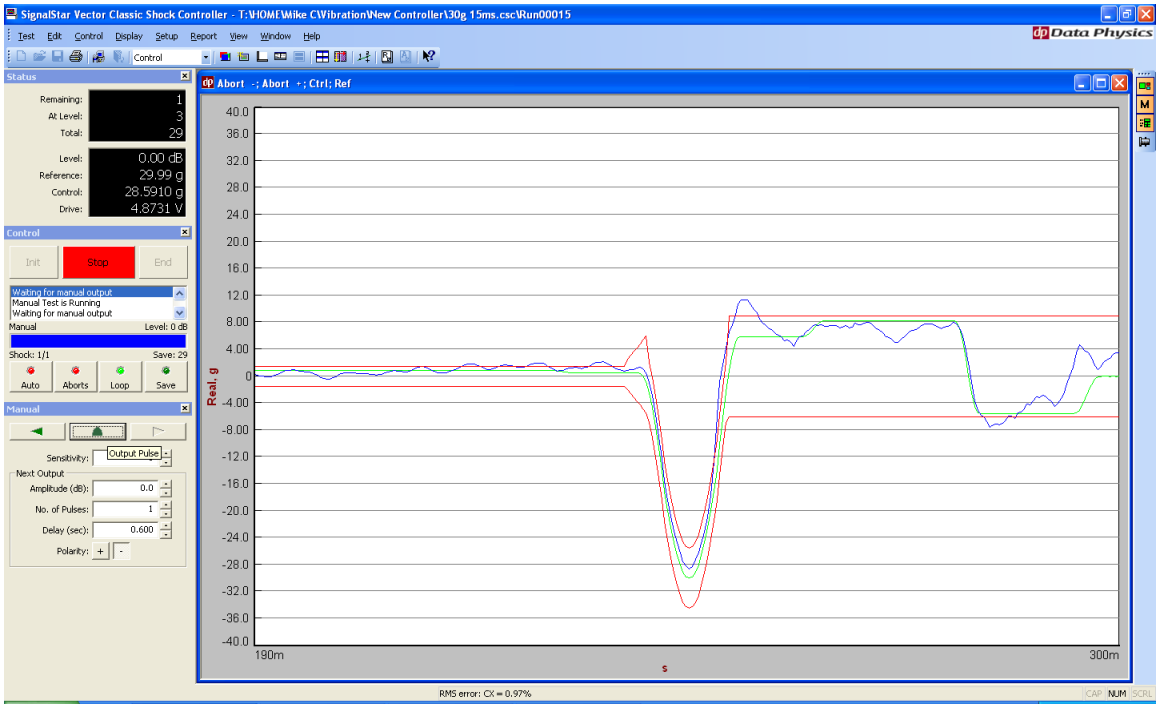

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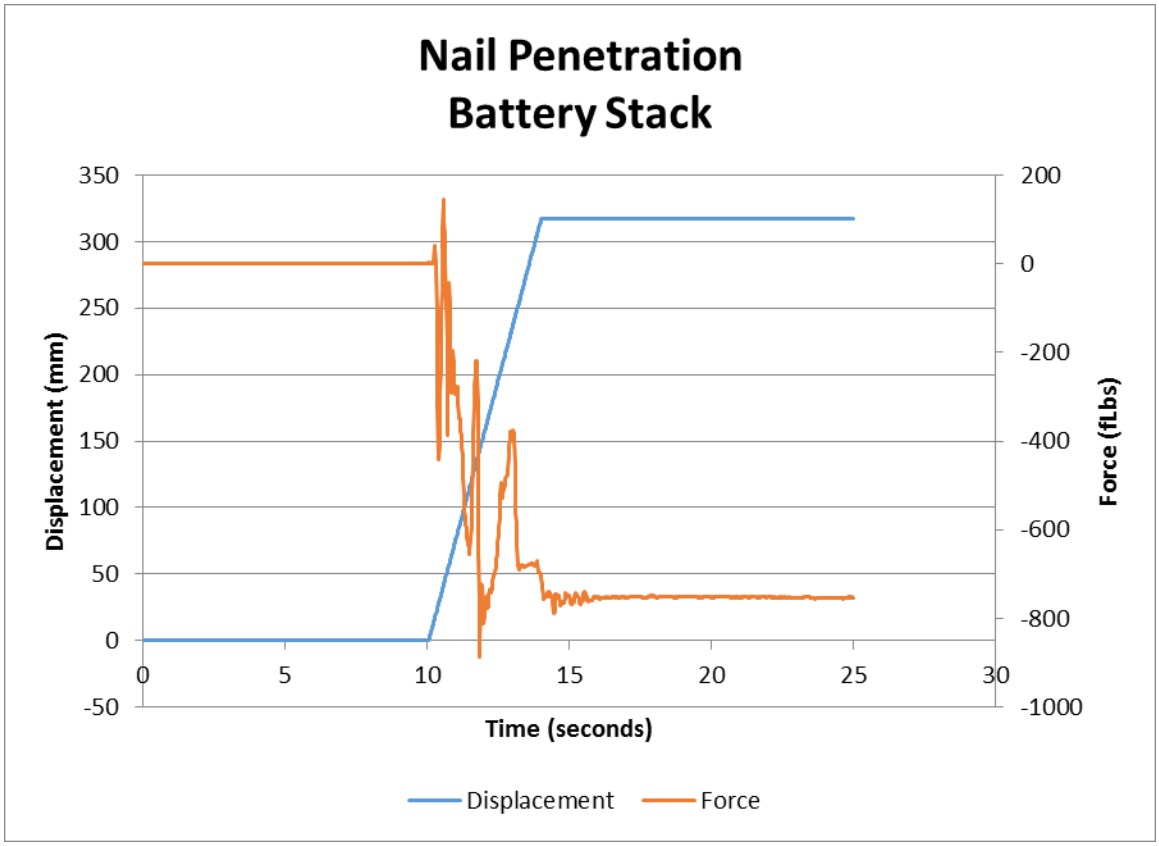
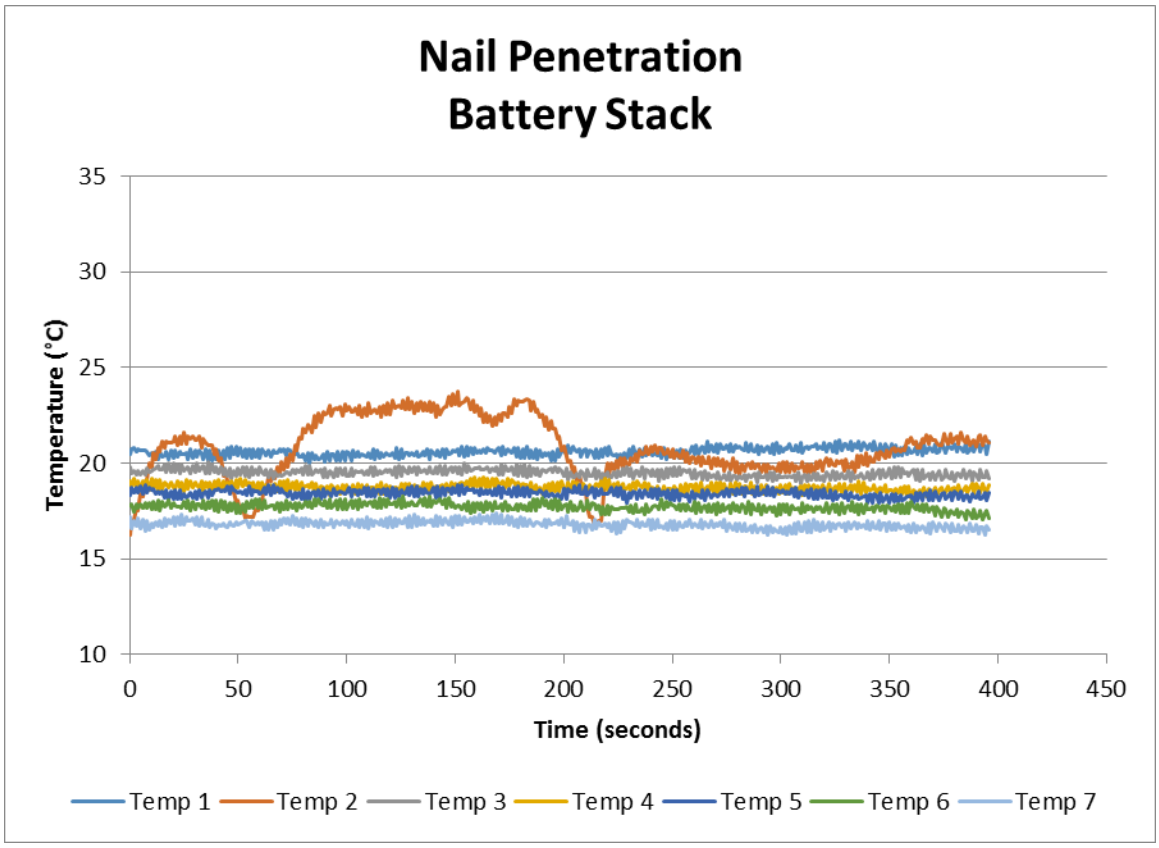
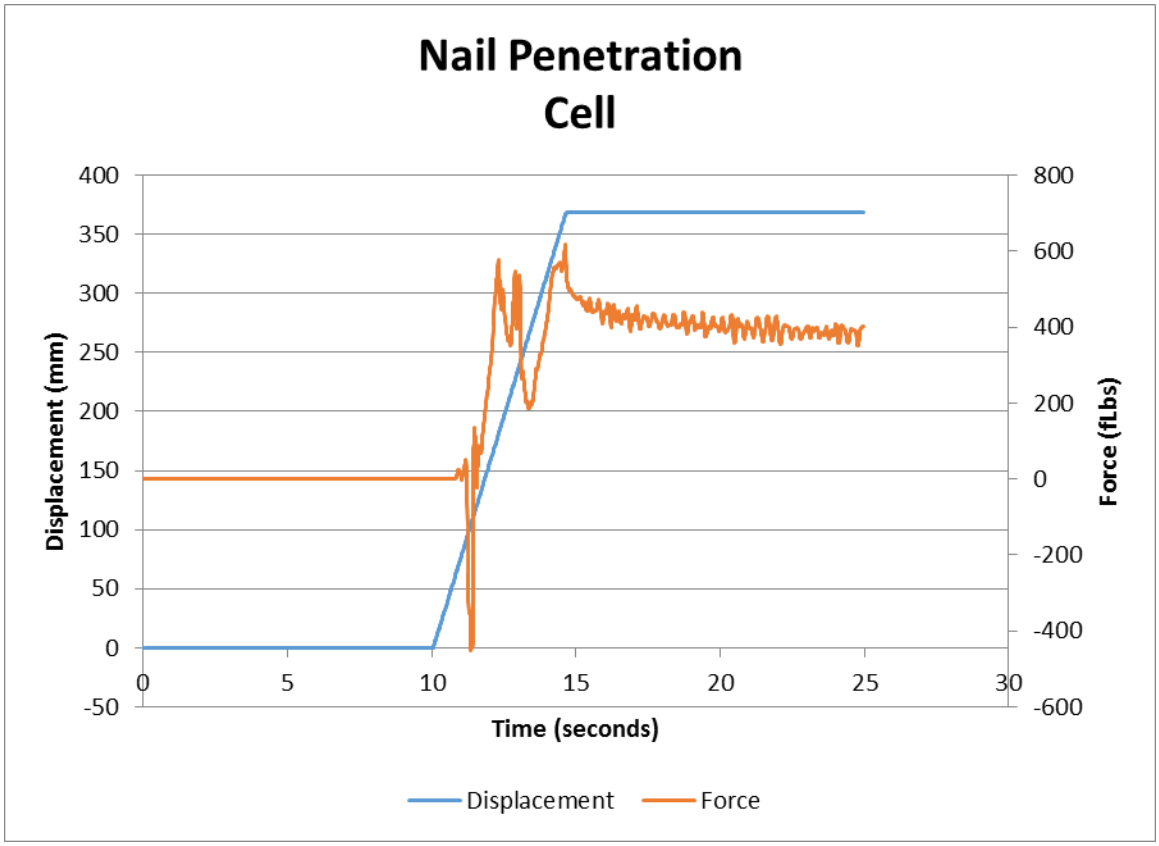



Nail Penetration
Battery Stack
Temperature (°C)
35
30
25
20
15
10
0
50
100
150
200
250
300
350
400
450
Time (seconds)
Temp 1
Temp 2
Temp 3
Temp 4
Temp 5
Temp 6
Temp 7


Nail Penetration
Cell
Displacement (mm)
400
350
300
250
200
150
100
50
0
-50
0
5
10
15
20
25
30
Time (seconds)
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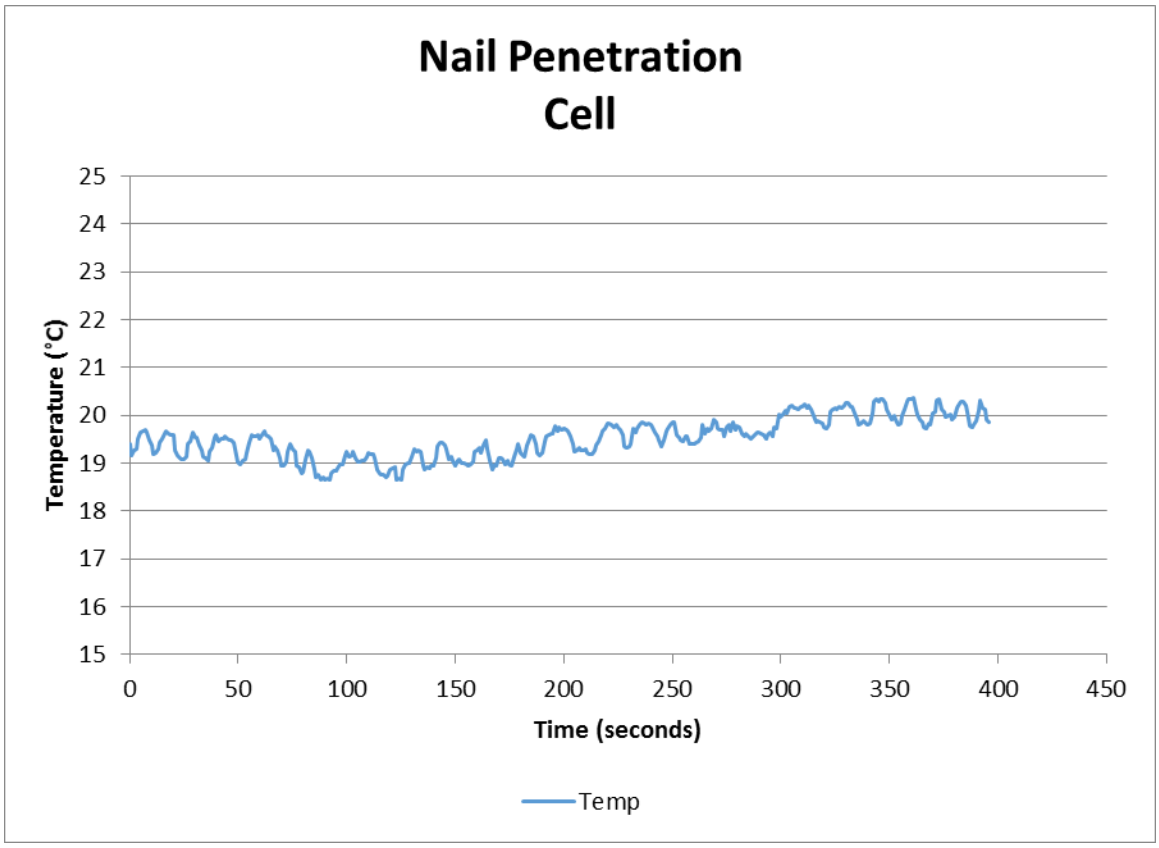
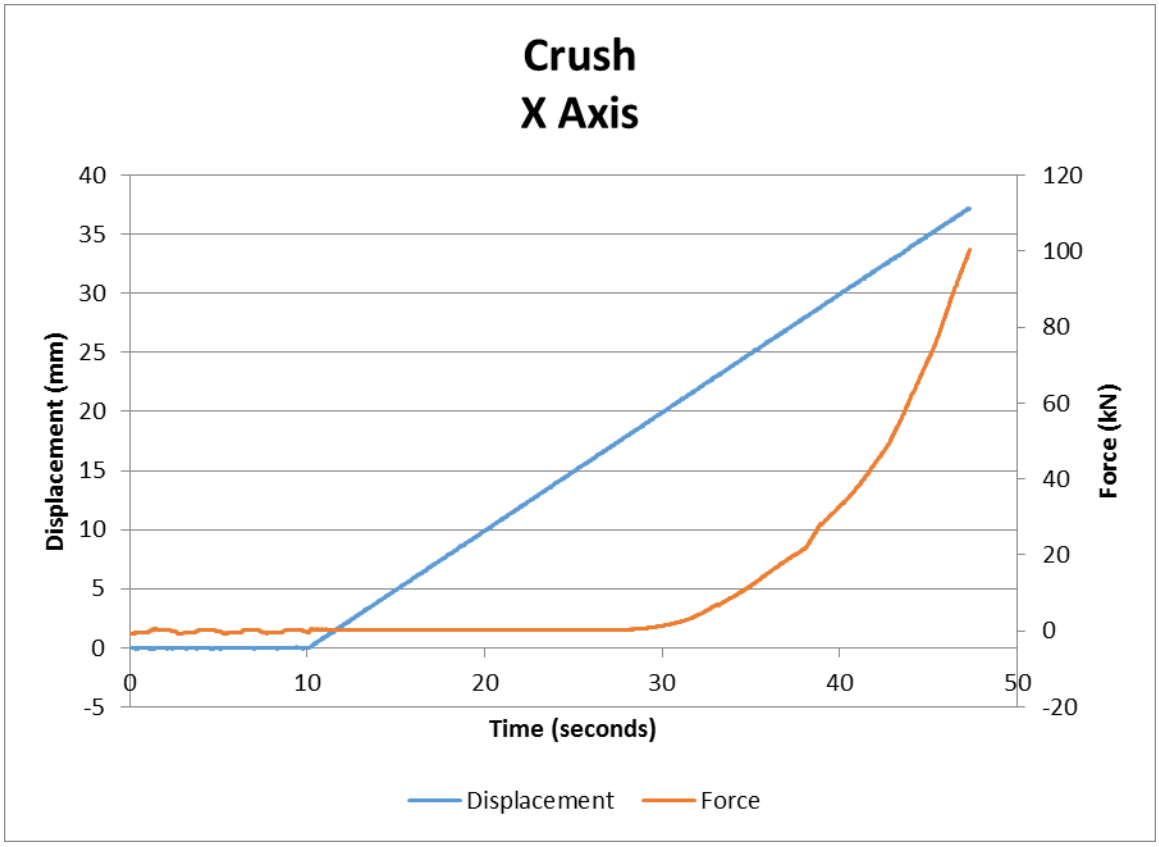
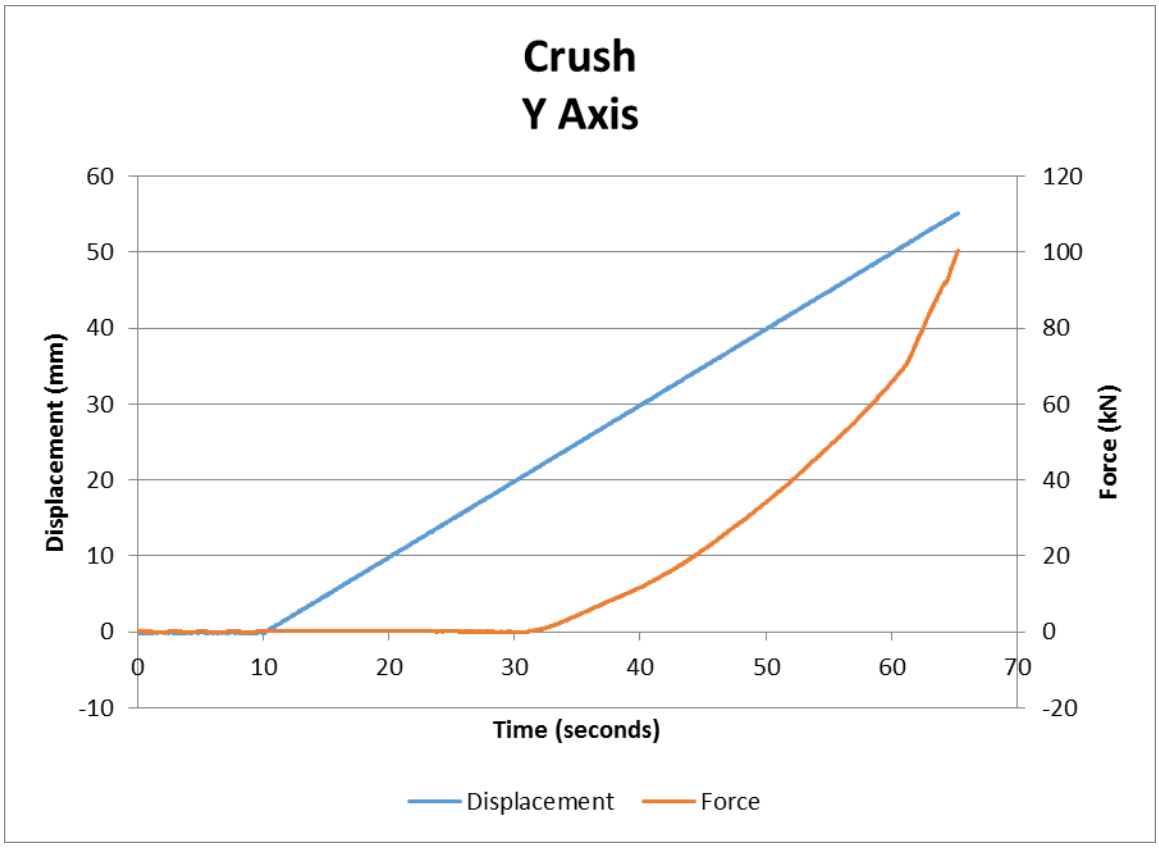
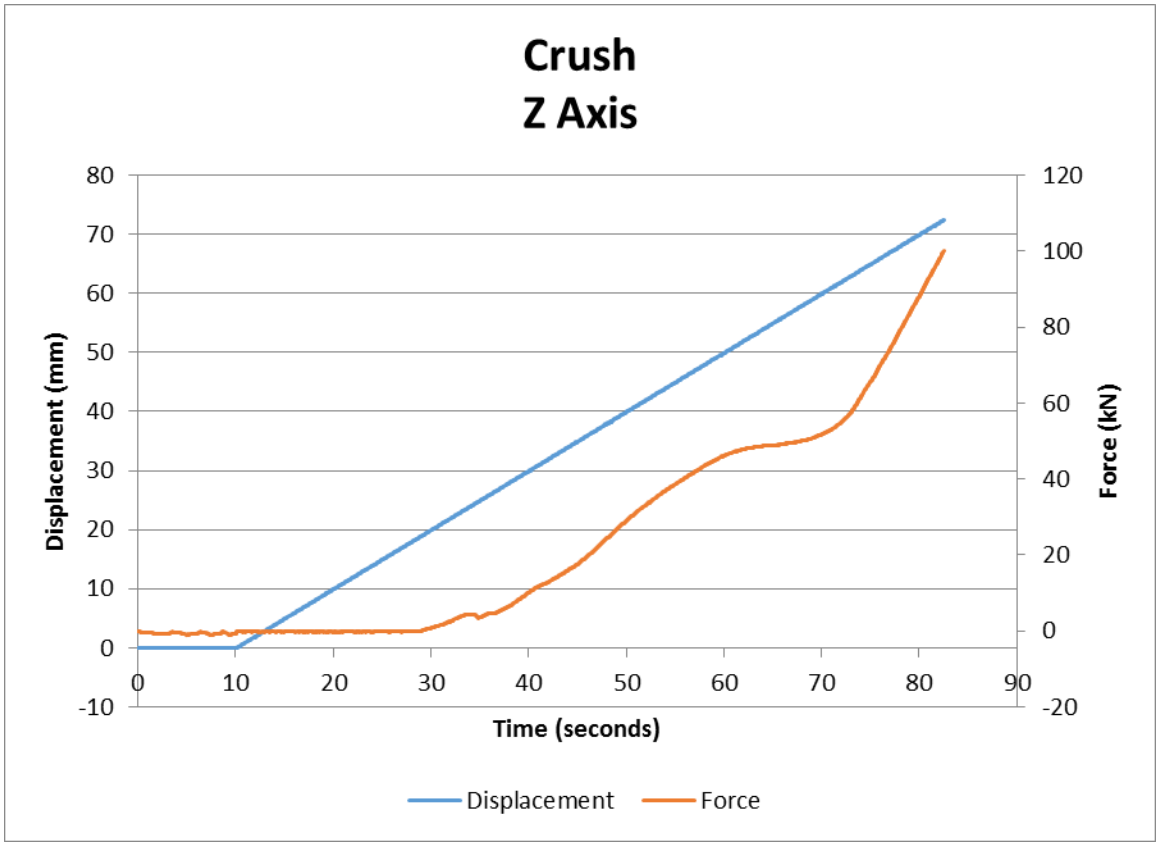
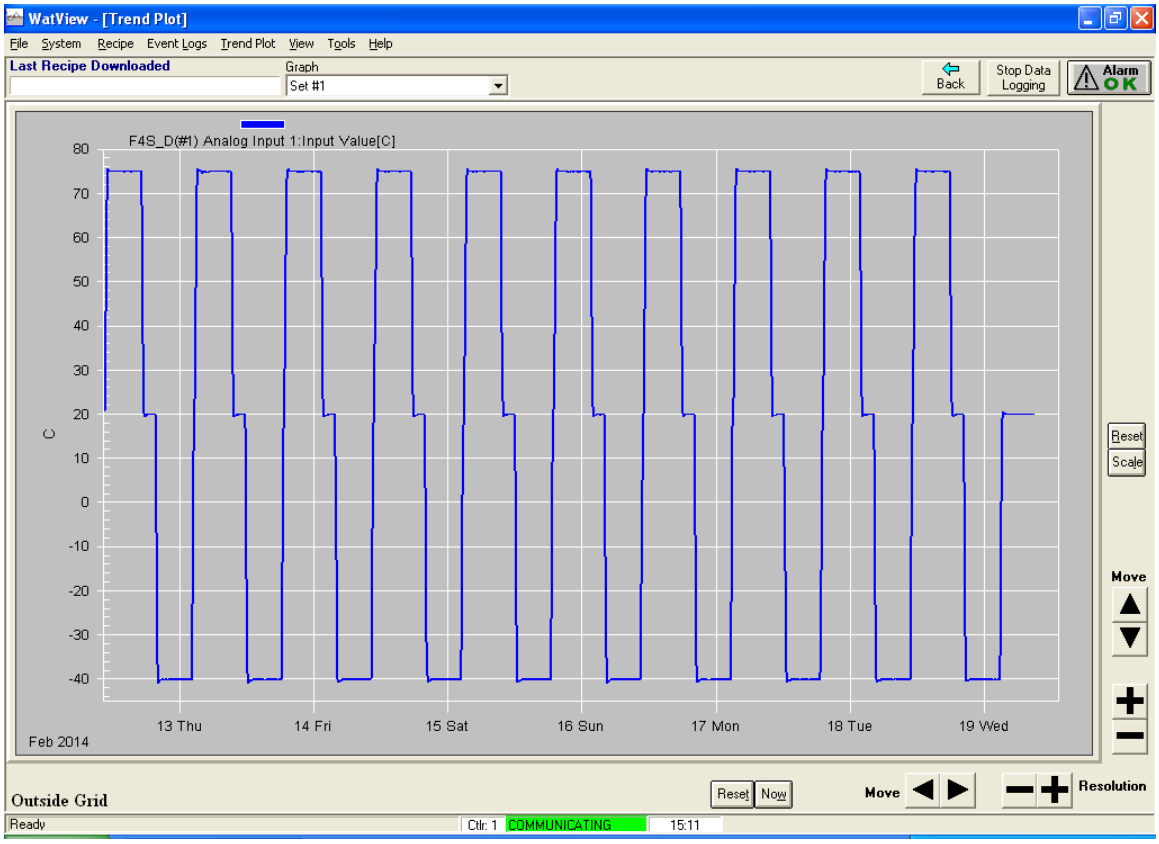
600
400
200
0
-200
-400
-600
Force (fLbs)
Displacement
Force


Nail Penetration Cell
Temperature (°C)
25
24
23
22
21
20
19
18
17
16
15
0
50
100
150
200
250
300
350
400
450
Time (seconds)
Temp

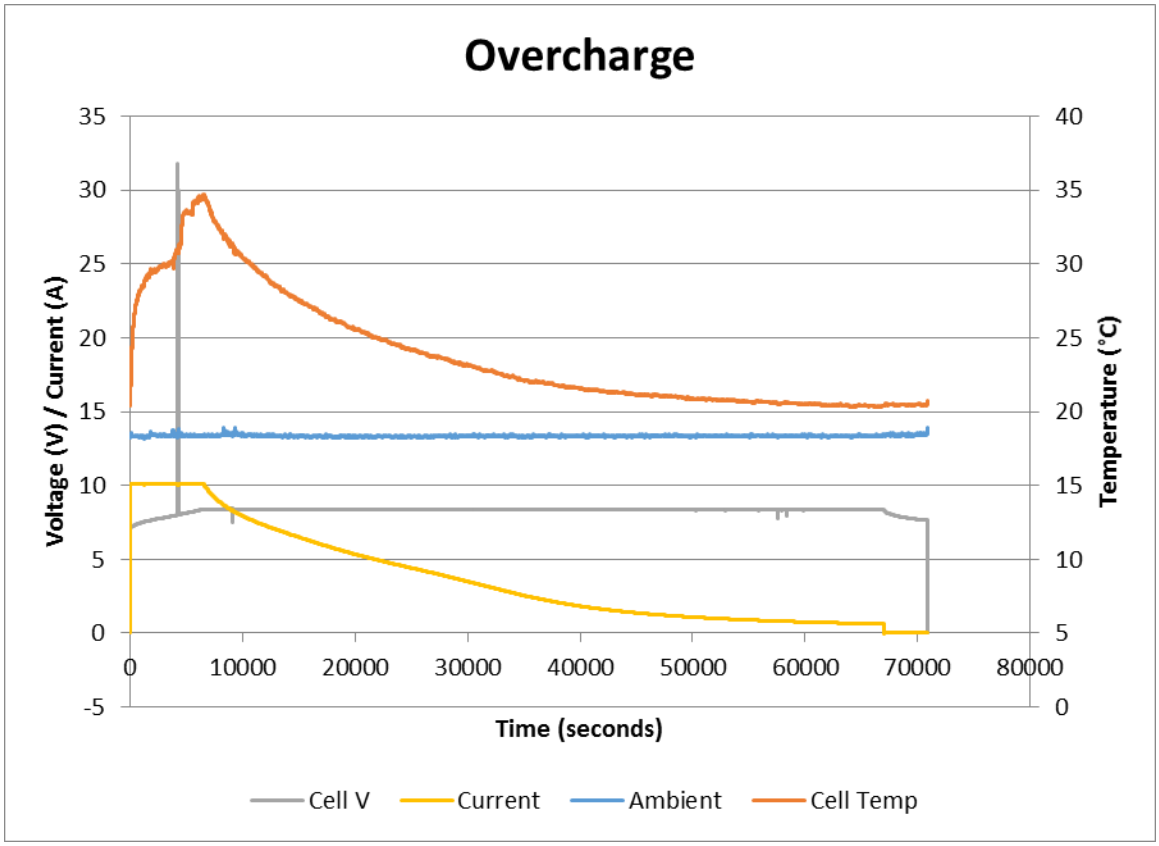

Crush X Axis
Displacement (mm)
40
35
30
25
20
15
10
5
0
-5
0
10
20
30
40
50
Time (seconds)
120
100
80
60
40
20
0
-20
Force (kN)
Displacement
Force


Crush
Y Axis
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force


Crush
Z Axis
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force



Thermal Cycling

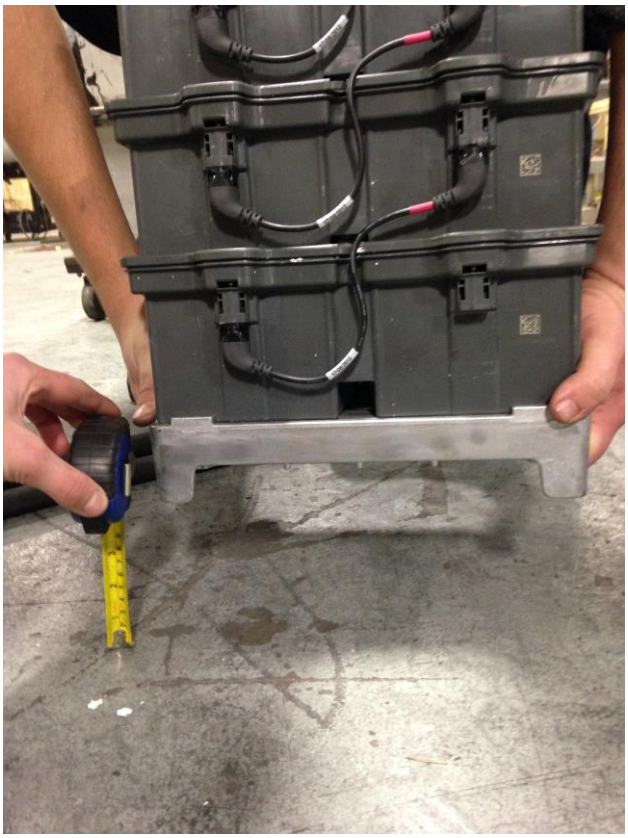


Test Data Summary

Test Type	Pre Voltage	Post Voltage
Drop Impact	48.6	48.6
Vibration	48.5	48.5
Altitude	48.6	48.6
Altitude Cell	7.00	6.81
Salt Fog Cell 1	6.56	6.39
Salt Fog Cell 2	6.96	6.72
Shock	48.5	48.5
Nail Penetration	47.8	39.8
Nail Penetration Cell	6.69	3.42
Crush 1	48.3	48.3
Crush 2	48.4	48.4
Crush 3	48.4	48.4
Roll-over	44.8	44.8
Roll-over Cell 1	7.06	6.82
Roll-over Cell 2	6.90	6.57
Immersion Cell 1	6.80	6.79
Immersion Cell 2	6.63	6.53
Thermal Cell	6.61	6.31

APPENDIX B

TEST PHOTOGRAPHS



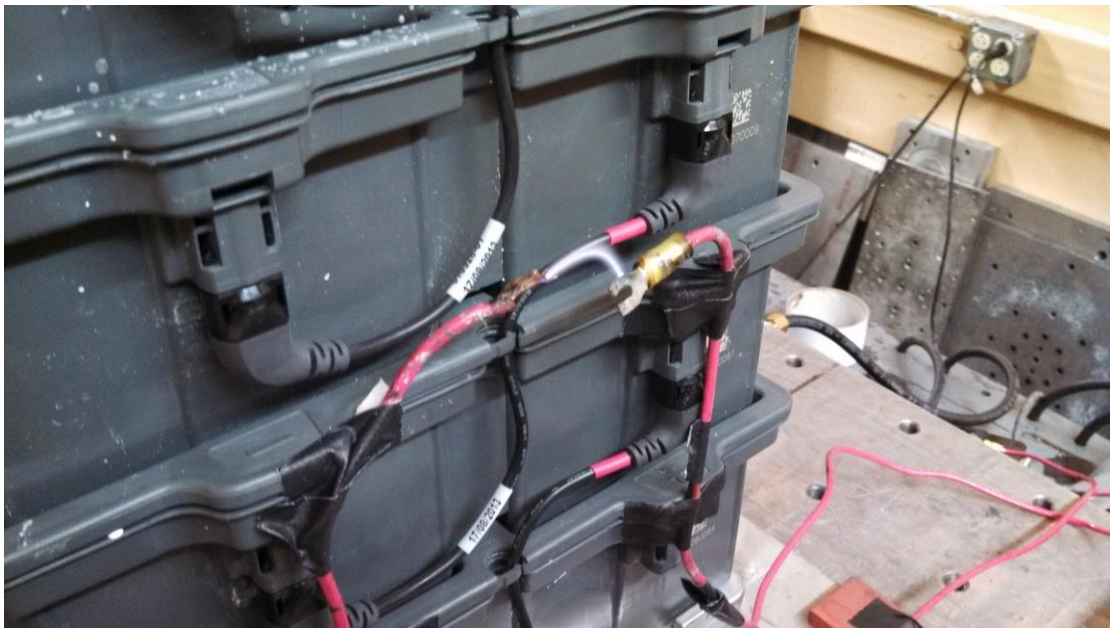
Drop – Pre-Test

Drop – Post-Test

Vibration - X Axis

Vibration - Y Axis

Vibration -Z Axis



Vibration – Post-Test (Spark)

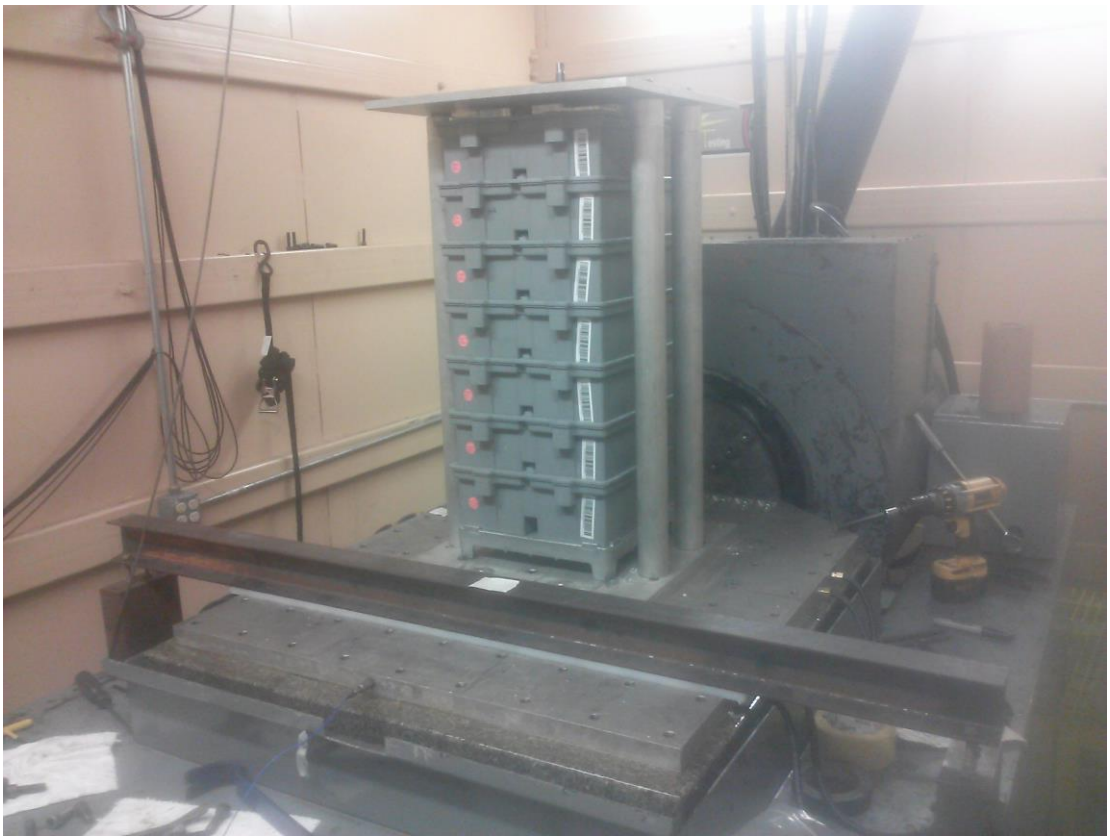
Altitude (Battery Stack)

Altitude (Cell)

Salt Fog – Pre-Test

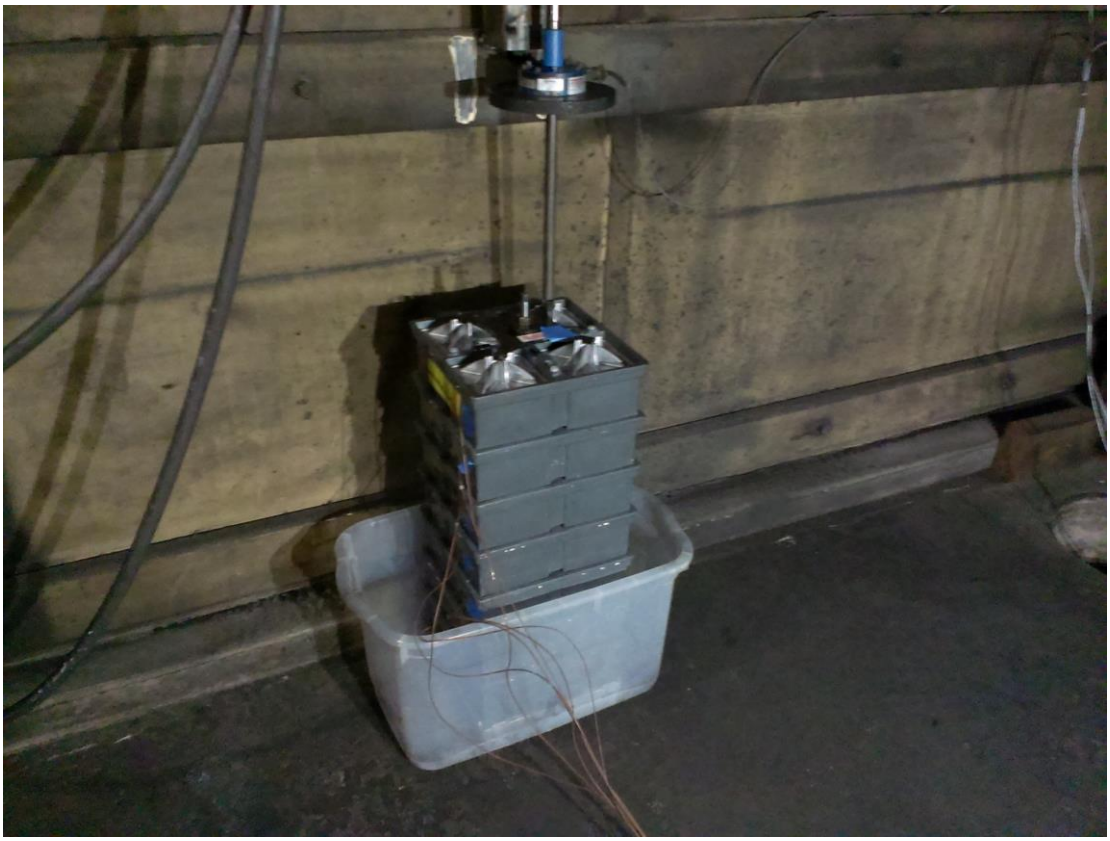
Salt Fog - Post-Test

Shock - X Axis



Shock - Y Axis

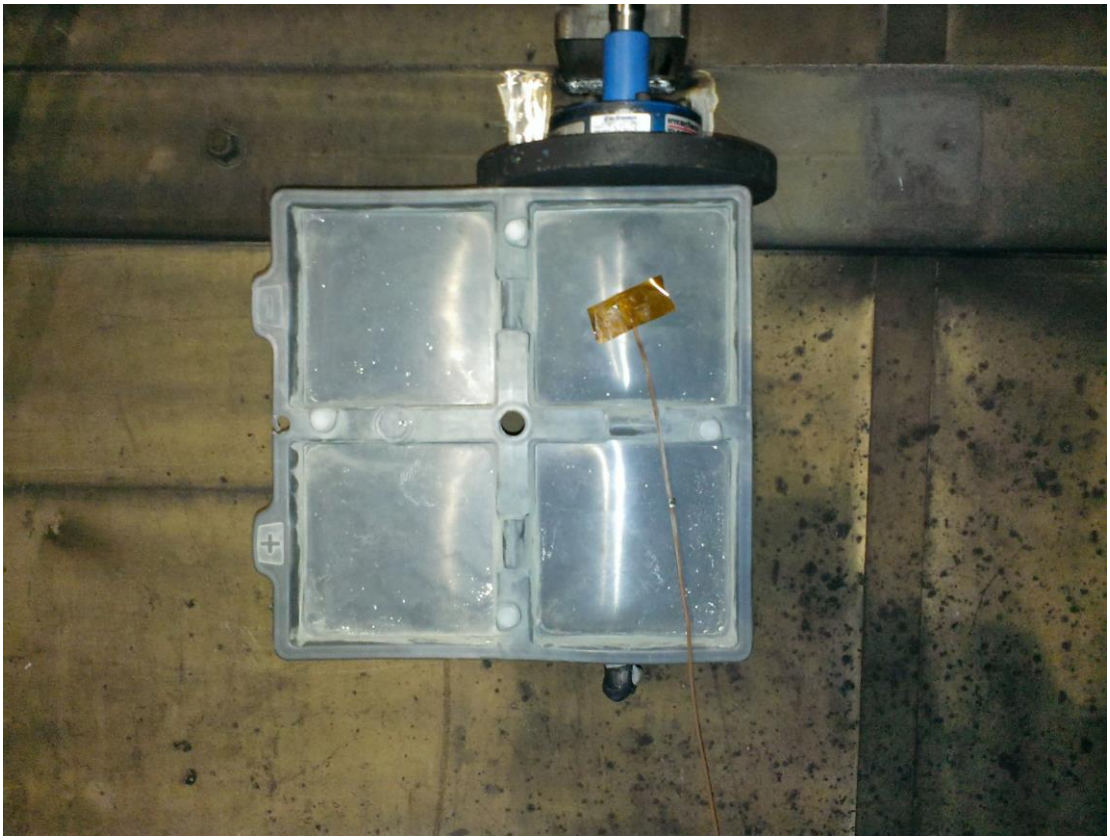
Shock - Z Axis



Nail Penetration – Pre-Test (Battery Stack)

Nail Penetration – Post-Test (Battery Stack)

Nail Penetration – Pre-Test (Cell)



Nail Penetration – Post-Test (Cell)

Crush - X Axis Pre-Test

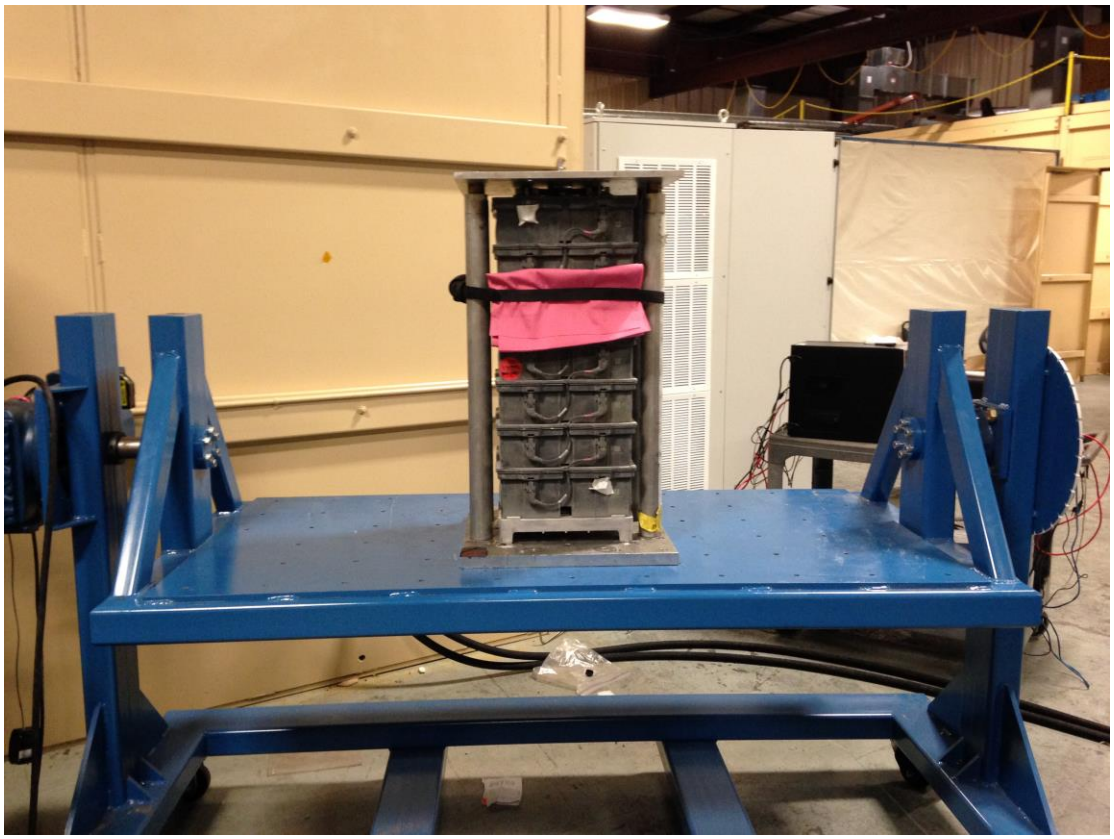
Crush - X Axis Post-Test

Crush - Y Axis Pre-Test

Crush - Y Axis Post-Test

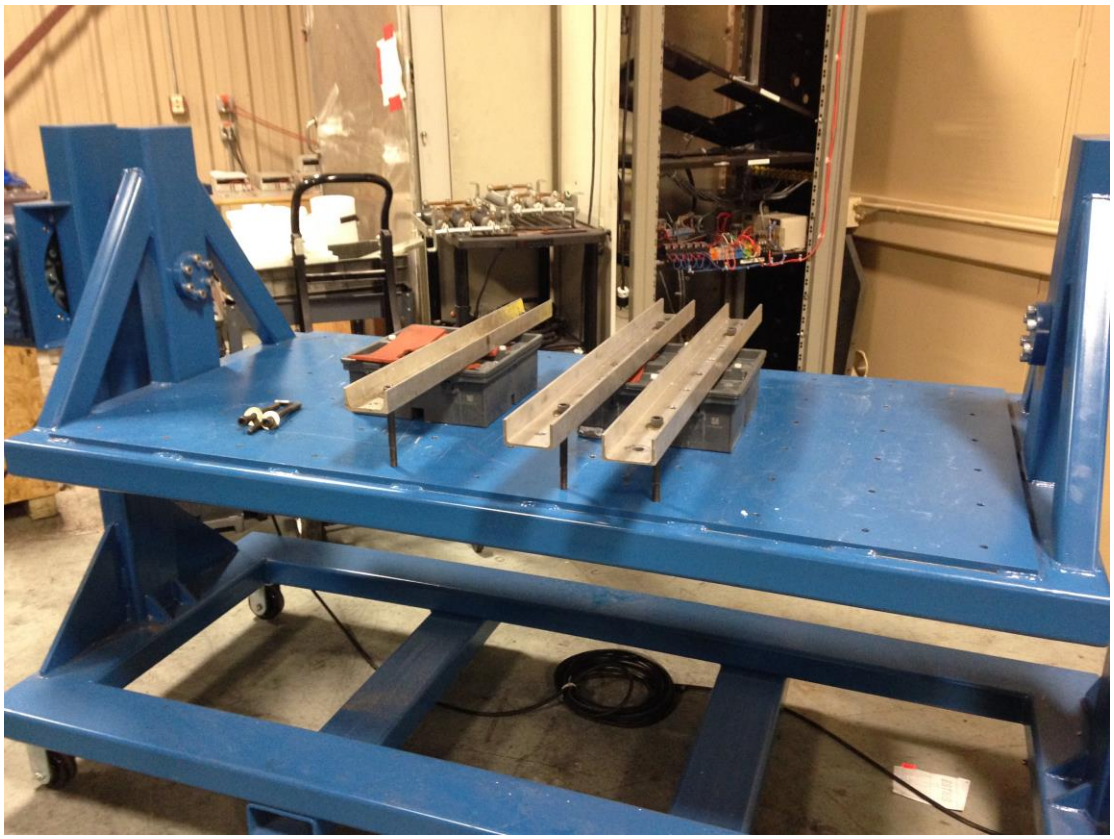
Crush - Z Axis Pre-Test

Crush - Z Axis Post-Test

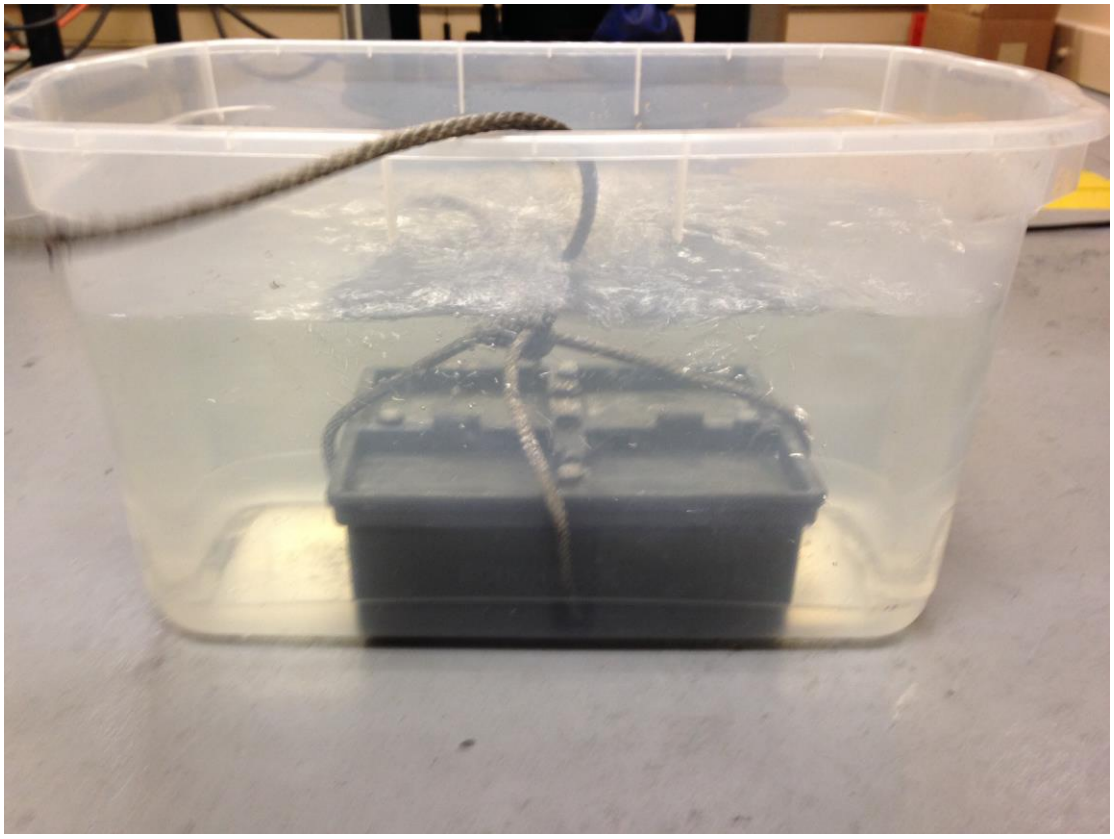


Roll-over (Battery Stack)

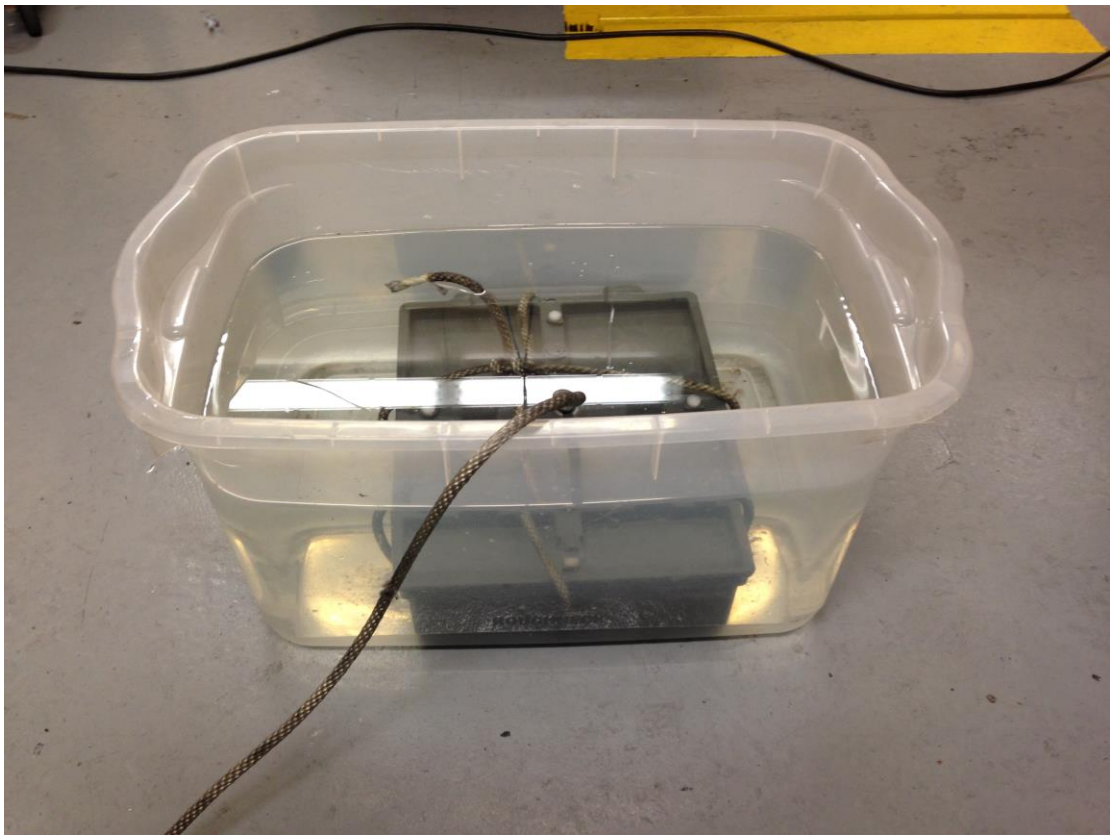
Roll-over – Post-Test (Battery Stack Leak)



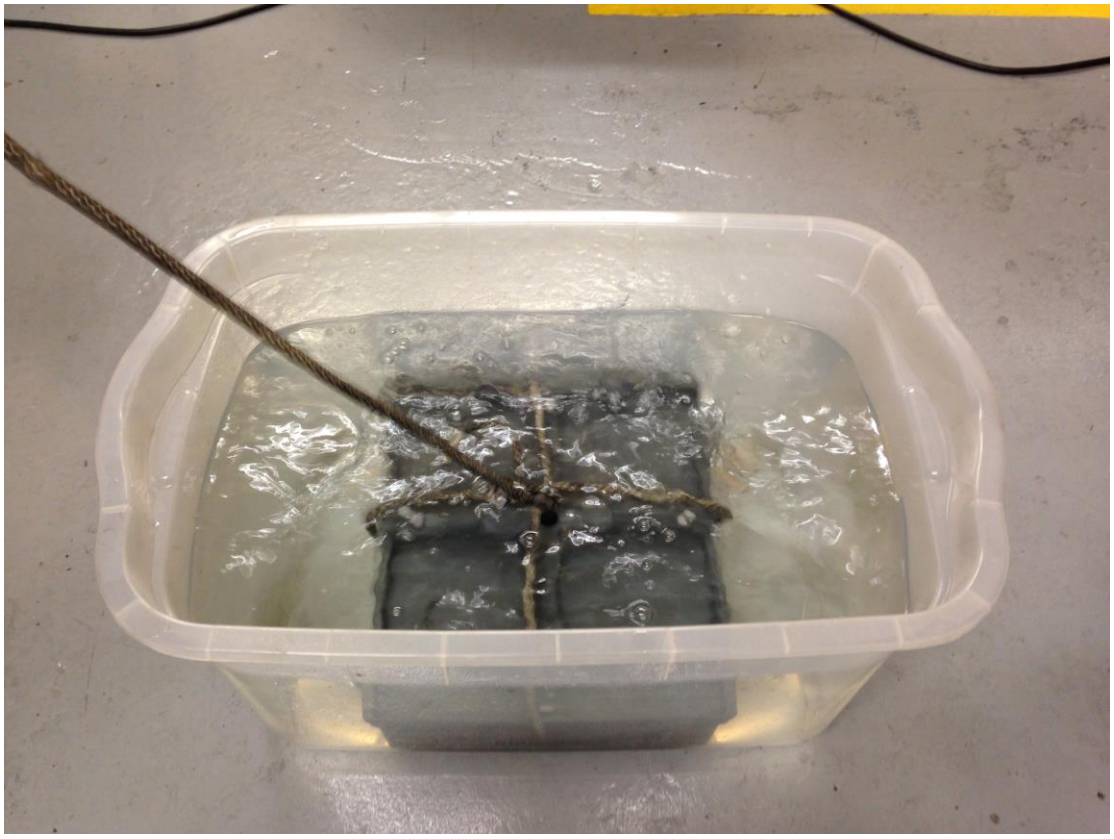
Roll-over (Cells)



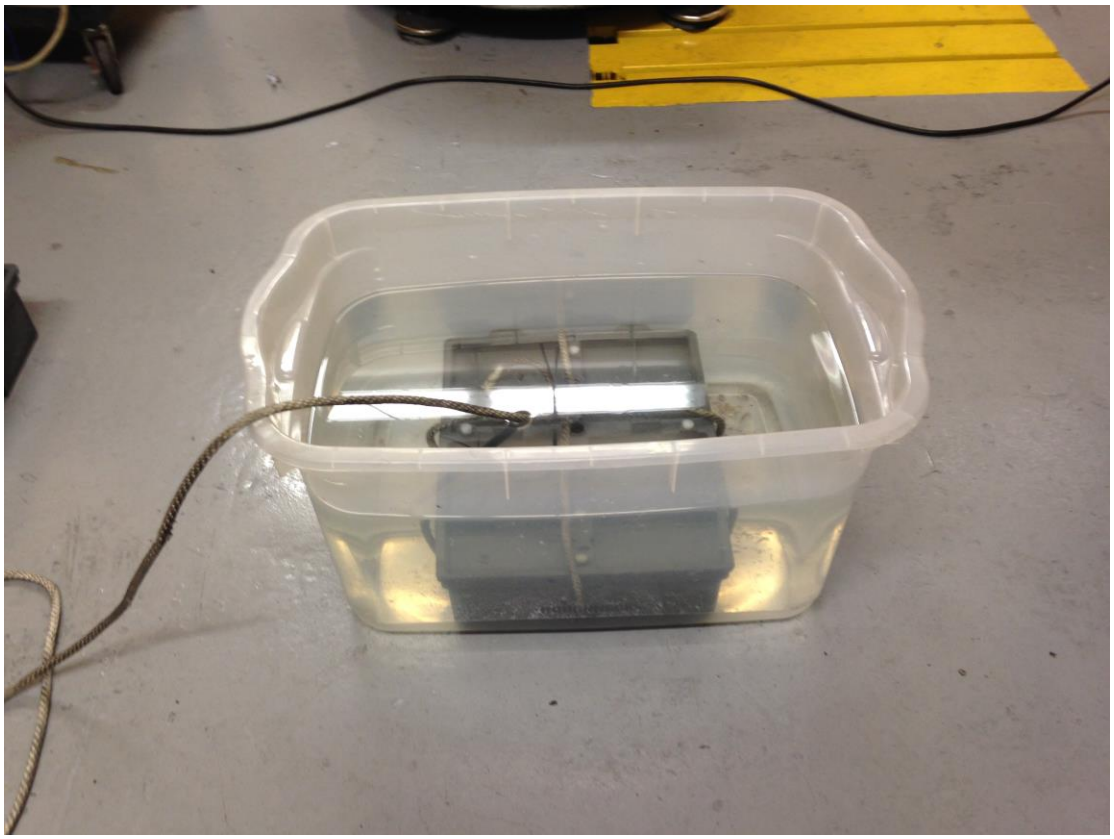
Immersion – Start of Test (First Cell)



Immersion – Post-Test (First Cell)



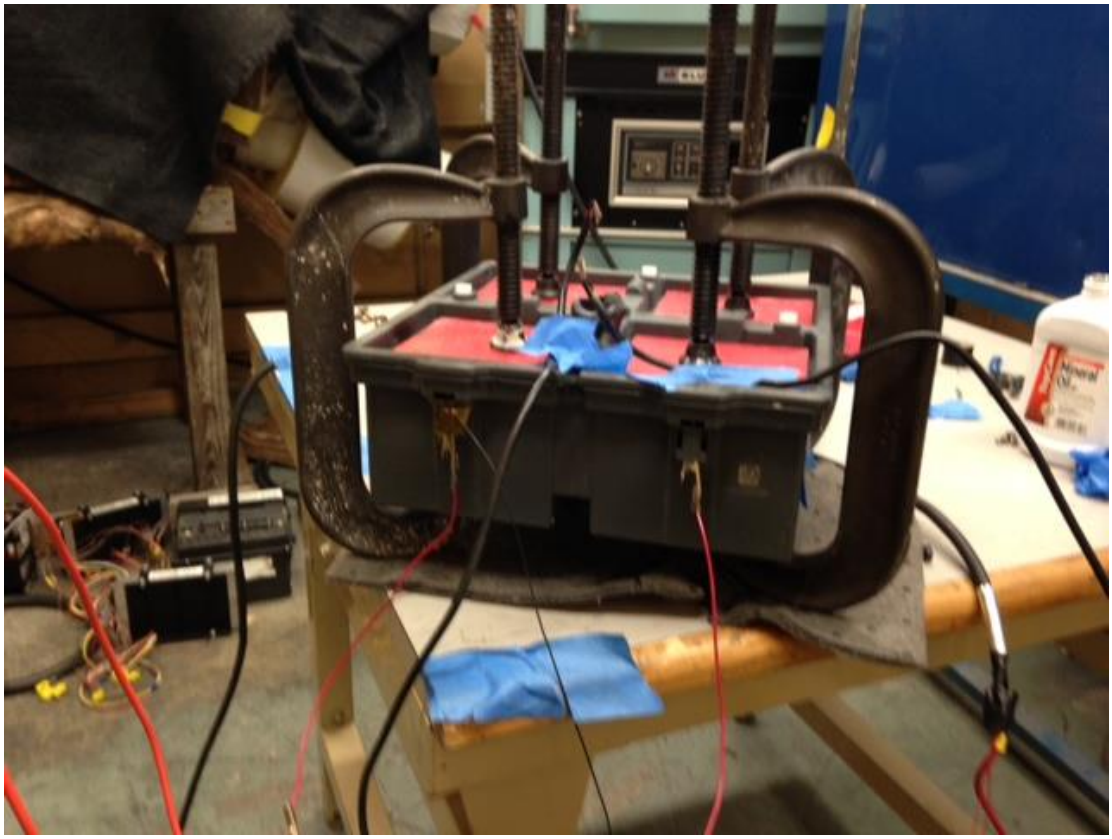
Immersion – Start of Test (Second Cell)



Immersion – Post-Test (Second Cell)

Thermal Cycling (Battery Stack)

Thermal Cycling (Cell)



Overcharge

DAYTON T. BROWN INC.
Founded 1950

ENGINEERING AND TEST DIVISION
1175 CHURCH STREET, BOHEMIA, LONG ISLAND, NEW YORK 11716 (631) 589-6300

TEST REPORT NO.: 413722-01-04-R13-1314

DAYTON T. BROWN, INC. JOB NO.: 413722-01-000

CUSTOMER: MGA RESEARCH CORPORATION
12790 MAIN ROAD
AKRON, NY 14001

SUBJECT: DUST TESTING PERFORMED ON ONE BATTERY

PURCHASE ORDER NO.: T13-011

ATTENTION: MR. JEREMY LEGASSE

THIS REPORT CONTAINS: TWO PAGES AND ONE ENCLOSURE

PREPARED BY	J. VIOLA
TEST ADMINISTRATOR	R. CALDERERO
DEPARTMENT SUPERVISOR	T. ZIMOULIS
DATE	10 JANUARY 2014

THE DATA CONTAINED IN THIS REPORT WAS OBTAINED BY TESTING IN COMPLIANCE WITH THE APPLICABLE TEST SPECIFICATION AS NOTED

TABLE OF CONTENTS

1.0 ABSTRACT

This test report details the results of the dust testing performed on one Battery, under reference (a) to the requirements of reference (c).

Results of the test are detailed in the following text.

The test item was nonoperating during testing.

Test data pertinent to this program will remain on file at Dayton T. Brown, Inc. for 90 days.

The test results recorded in this report relate only to those items tested.

This test report shall not be reproduced, except in full, without the written approval of Dayton T. Brown, Inc.

2.0 REFERENCES

(a) Customer Purchase Order No.: T13-011

(b) Dayton T. Brown, Inc. Job No.: 413722-01-000

(c) Test Specification: SAE J1455, Revised AUG94

3.0 ADMINISTRATIVE INFORMATION

Customer	MGA Research Corporation 12790 Main Road Akron, NY 14001
Test Item Description	Battery
Quantity Received	One
Serial No.	DTB #1 (As assigned by Dayton T. Brown, Inc.)
Date Received	13 December 2013
Dates Tested	18 and 19 December 2013
Date Shipped	19 December 2013

4.0 TEST PROGRAM OUTLINE

Test	Test Item Description	Results
Dust	Battery, Serial No. DTB #1	See test results in Enclosure 1.

Enclosure 1

Dust Test and Results

TEST REQUIREMENT

The dust test shall be conducted in accordance with reference (c).

TEST RESULTS

A pretest visual inspection of the test item revealed no anomalies.

All testing was performed in accordance with the referenced specification.

Refer to the following page of this enclosure for the test data.

The test item completed all phases of testing.

A post-test visual inspection revealed a thin layer of dust on the exterior surface area of the test item.

DAYTON T. BROWN INC.
Founded 1950

DUST TEST DATA SHEET

JOB No.: 413722-01-000 **DATE** 18 Dec 13

TIME	Chamber Ambient (°F)	Dust Cycling (Y or N)	Hours Into Test	Remarks	TECH.
1540	74.4	Y	0	Start	SM
1640	74.8	Y	1		VD
1740	74.9	Y	2		VD
1840	75.3	Y	3		VD
1940	75.6	Y	4		VD
2040	75.1	Y	5	END SOAK - SECURE OFF	VD

COMMENTS

ENGINEER Ralph Calderon

Test equipment utilized for the program reported herein was within its assigned interval of calibration.
Details are on file at Dayton T. Brown, Inc. and will be made available upon request.

Job Sub: **413722-01** **TEST: DUST**

ITEM	MANUFACTURER	MODEL	DTB NO.	ACCURACY	CAL DUE DATE
RECORDER, CHART TRULINE	HONEYWELL	DR4500	12-21	TYPE T ± 0.7°F; RH ± 0.2% RH	04/13/2014
CONTROLLER, ENVIRONMENTAL SYSTEM	JC SYSTEMS	600	25-59	RTD ± 1.08°F, RH ± 1% RH	04/13/2014
SCALE, DIGITAL 8200 GRAMS	ACCULAB	ATL-8201-1	38-56	± 0.3 GRAMS	01/19/2014

Photo 1 – File No. RC13-0691
Dust test setup

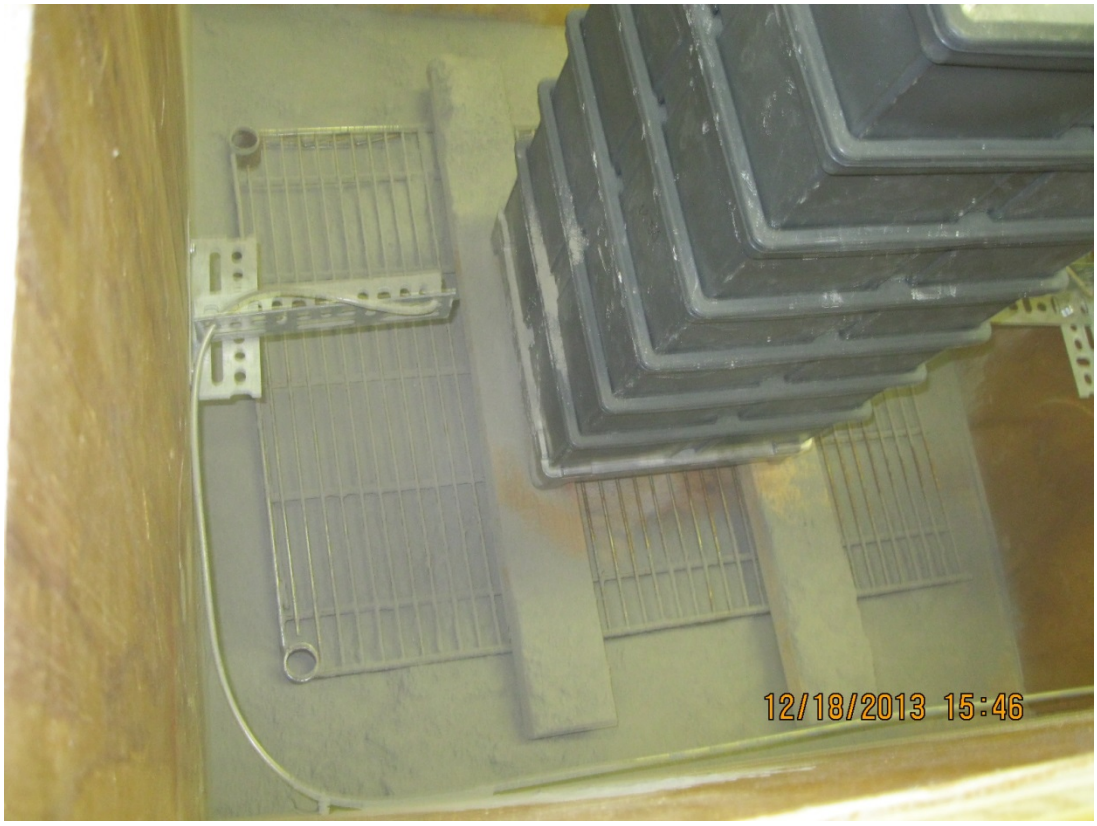


Photo 2 – File No. RC13-0692
Dust test setup during dust testing