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ARCIMOTO
UN38.3 TRANSPORTATION TESTING

SCOPE OF WORK
Model Name: Battery-Module Assembly
Part number: 002128

REPORT NUMBER
103619246DET-001

ISSUE DATE	**[REVISED DATE]**
29-October-2018	[NA]

PAGES
35

DOCUMENT CONTROL NUMBER
RT-L-AMER-DET-003

Attn: Mr. Gerrit Hurenkamp
Arcimoto, Inc.
2034 West 2nd Ave
Eugene, OR 97402
Phone: (559) 321-1694
E-mail Address: gerrith@arcimoto.com

DATE RECEIVED: 08/30/2018
DATE TESTED: 09/25/2018 through 10/22/2018

WORK REQUESTED / APPLICABLE DOCUMENTS:

Per the client's request and in accordance with UN 38.3 6th Edition and our quotation number 00893903, dated 06/20/2018; perform Battery Testing as described below:

- T1 – Altitude Simulation
- T2 – Thermal Test
- T3 – Vibration
- T4 – Shock

DESCRIPTION OF TEST SAMPLES:

SAMPLE DESCRIPTION: Four (4) Lithium-Ion Battery-Module Assemblies

MANUFACTURER: Arcimoto

PART NUMBER: 002128

RATINGS: 51.8V, 183.4Ah, 9500Wh

SPECIFICATION SECTIONS T1 through T4:
Four (4) Lithium-Ion Battery-Module Assemblies, sample numbers:

1 Cycle
- SN 1
- SN 2

25 cycles
- SN 3
- SN 4

Condition of Test Sample: Production

Testing Performed at:
Intertek
45000 Helm Street, Suite 150
Plymouth Twp., MI 48170

Photographs of Sample	
	
BATTERY PACK - FRONT	BATTERY PACK - BACK

RESULT SUMMARY: The tested samples met the test requirements. See below breakout for tests performed.

Specification Section	Test Description	Results
T1	Altitude Simulation	Pass
T2	Thermal Test	Pass
T3	Vibration	Pass
T4	Shock	Pass

Lucas Salinas	Nick Diamond
Engineer	Sr. Associate Engineer
October 29, 2018	
Report No.: 103619246DET-001	

EQUIPMENT LIST:

Asset #	Description	Manufacturer	Model	Serial#	Last Cal	Next Cal Due
160468	MULTIMETER	FLUKE	12	68151007	12/7/2017	12/7/2018
169029	SCALE	AEADAM	GFK 330aH	AE82650	7/9/2018	7/9/2019
162596	LXI DATA ACQUISITION / SWITCH UNIT	AGILENT	34972A	MY49008371	3/22/2018	3/22/2019
161279	ALTITUDE CABINET	ENTELA	N/A	N/A	VBU	VBU
161279.1	PRESSURE TRANSDUCER	FAIRCHILD	TA870212A	366027	12/1/2017	12/1/2018
373-207.1	ENVIRONMENTAL CHAMBER	ENVIROTRONICS	ENVIROTRONICS WPH1000-2-30-WC-	09158856	8/27/2018	8/27/2019
373-207P	Environmental Chamber	ENVIROTRONICS	WPH1000-2-30-WC-RUM	09158856	VBU	VBU
372-090	LXI DATA ACQUISITION / SWITCH UNIT	AGILENT	34972A	MY49003180	12/8/2017	12/8/2018
376-056	ACCELEROMETER	PCB	353B15	LW197020	8/10/2018	8/10/2019
376-041	SIGNAL PROCESSOR	VIBRATION RESEARCH	VR9500	951C711D	6/8/2018	6/8/2019
160122	VIBRATION SHAKER	UNHOLTZ-DICKIE	# 560	290	REF ONLY	REF ONLY
160112	VIBRATION AMP	UNHOLTZ-DICKIE	TA-117SA-560	1987	VBU	VBU
375-042	SIGNAL PROCESSOR	VIBRATION RESEARCH	VR9500	951394BE	2/2/2018	2/2/2019
161197	SHOCK MACHINE (asset for controller is 375-042)	AVCO	SM-220 MP	HP-0011	VBU	VBU
372-210	DIGITAL MULTIMETER	FLUKE	77 IV	38990065	9/12/2018	9/12/2019
376-009	ACCELEROMETER	PCB	350B03	46081	10/19/2017	10/19/2018
376-008	ACCELEROMETER	PCB	350B03	46080	11/22/2017	11/22/2018

**VBU = "Verified Before Use"*

SECTION 1

T1 – ALTITUDE SIMULATION

Date Received: 08/30/2018
Date(s) Tested: 09/25/2018 through 09/26/2018

Description of Samples:
Four (4) Lithium-Ion Battery-Module Assemblies, sample numbers:

1 Cycle
- SN 1
- SN 2

25 Cycles
- SN 3
- SN 4

Purpose:
This test simulates air transport under low-pressure conditions.

Test Procedure:
Prior to testing the voltage and mass were measured on each sample. The samples were then placed into an altitude cabinet, stored at a pressure of 11.6 kPa or less for six (6) hours at ambient temperature. After testing, the voltage and mass were measured on each sample.

Acceptance Criteria:
Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

T1 – ALTITUDE SIMULATION (cont'd)

Results:

The test samples conformed to the acceptance criteria; there was no mass loss, no leakage, no venting, no disassembly, no rupture, no fire and the open circuit voltage of each test sample after testing was not less than 90% of its voltage immediately prior to this procedure.

T1 - Altitude Simulation								
Sample No.	Pre Conditioning Cycles	Voltage Pre Test (VDC)	Voltage Post Test (VDC)	% Change (Not Greater Than 10%)	Weight Pre Test (Grams)	Weight Post Test (Grams)	% Change (Not Greater Than 0.1%)	Meets requirement
1	1	58.0	57.9	0.172	53806	53808	-0.004	Pass
2	1	58.0	57.9	0.172	53988	53990	-0.004	Pass
3	25	58.0	58.0	0.000	53858	53858	0.000	Pass
4	25	58.1	58.0	0.172	53848	53848	0.000	Pass

Appendix:

Appendix A – Photographs

Appendix B – Altitude Simulation Graph

Disposition of Test Samples:

At the completion of testing, the samples continued to T2 – Thermal Test.

SECTION 2

T2 – THERMAL TEST

Date Received: 08/30/2018
Date(s) Tested: 09/26/2018 through 10/08/2018

Description of Samples:
Four (4) Lithium-Ion Battery-Module Assemblies, sample numbers:

1 Cycle
- SN 1
- SN 2

25 Cycles
- SN 3
- SN 4

Purpose:
This test assesses cell and battery seal integrity and internal electrical connections. The test is conducted using rapid and extreme temperature changes.

Test Procedure:
Prior to testing the voltage and mass were measured on each sample. The samples were placed into an environmental chamber and stored for twelve (12) hours at 72°C ± 2°C, followed by storage of equal time at a temperature of -40°C ± 2°C. The maximum time interval between test temperature extremes was 30 minutes. This procedure was repeated 10 times, after which all samples were stored for 24 hours at ambient temperature. After testing the voltage and mass were measured on each sample.

Acceptance Criteria:
Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

T2 – THERMAL TEST (cont'd)

Results:
The test samples conformed to the acceptance criteria; there was no mass loss, no leakage, no venting, no disassembly, no rupture, no fire and the open circuit voltage of each test sample after testing was not less than 90% of its voltage immediately prior to this procedure.

T2 - Thermal Test								
Sample No.	Pre Conditioning Cycles	Voltage Pre Test (VDC)	Voltage Post Test (VDC)	% Change (Not Greater Than 10%)	Weight Pre Test (Grams)	Weight Post Test (Grams)	% Change (Not Greater Than 0.1%)	Meets requirement
1	1	57.9	57.5	0.691	53808	53792	0.030	Pass
2	1	57.9	57.5	0.691	53990	53976	0.026	Pass
3	25	58.0	57.6	0.690	53858	53848	0.019	Pass
4	25	58.0	57.6	0.690	53848	53836	0.022	Pass

There is no recorded data for the first temperature cycle as the Agilent was not set up until the 2nd day of the test. The plan was to use Chamber Monitoring, but it was deemed too inconsistent, so the Agilent was added.

There is also no recorded data for the 9th and 10th cycles as the Agilent did not correctly record the 4th data pull. Only most recent 25000 lines of data were able to be recovered, so roughly 2.5 days of data were lost.

Appendix:
Appendix A – Photographs
Appendix C – Thermal Test Graph

Disposition of Test Samples:
At the completion of testing, the samples continued to T3 – Vibration.

SECTION 3

T3 – VIBRATION

Date Received: 08/30/2018
Date(s) Tested: 10/08/2018 through 10/15/2018

Description of Samples:
Four (4) Lithium-Ion Battery-Module Assemblies, sample numbers:

1 Cycle
- SN 1
- SN 2

25 Cycles
- SN 3
- SN 4

Purpose:
This test simulates vibration during transport.

Test Procedure:
Prior to testing the voltage and mass were measured on each sample. The samples were firmly secured to the platform of the vibration machine without distorting the packs in such a manner as to faithfully transmit the vibration. The test samples were subjected to sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle was repeated 12 times for a total of three (3) hours for each of the three (3) mutually perpendicular mounting positions of the sample. One of the directions of vibration must be perpendicular to the terminal face.

The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1g is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8mm (1.6mm total excursion) and the frequency increased until a peak acceleration of 2g occurs (approximately 25 Hz). A peak acceleration of 2g is then maintained until the frequency is increased to 200 Hz. After testing the voltage and mass were measured on each sample.

Acceptance Criteria:
Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

T3 – VIBRATION (cont'd)

Results:

The test samples conformed to the acceptance criteria; there was no leakage, no venting, no disassembly, no rupture and no fire and the open circuit voltage of each test cell or battery after testing was not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

T3 - Vibration								
Sample No.	Pre Conditioning Cycles	Voltage Pre Test (VDC)	Voltage Post Test (VDC)	% Change (Not Greater Than 10%)	Weight Pre Test (Grams)	Weight Post Test (Grams)	% Change (Not Greater Than 0.1%)	Meets requirement
1	1	57.5	57.400	0.174	53792	53800.000	-0.015	Pass
2	1	57.5	57.400	0.174	53976	53982.000	-0.011	Pass
3	25	57.6	57.600	0.000	53848	53854.000	-0.011	Pass
4	25	57.6	57.600	0.000	53836	53844.000	-0.015	Pass

Appendices:

Appendix A – Photographs
Appendix D – Vibration Plots

Disposition of Test Samples:

At the completion of testing, the samples continued to T4 – Shock.

SECTION 4

T4 – SHOCK

Date Received: 08/30/2018
Date(s) Tested: 10/19/2018 through 10/22/2018

Description of Samples:
Four (4) Lithium-Ion Battery-Module Assemblies, sample numbers:

1 Cycle
- SN 1
- SN 2

25 Cycles
- SN 3
- SN 4

Purpose:
This test simulates possible impacts during transport.

Test Procedure:
Prior to testing the voltage and mass were measured on each sample. The samples were secured to the testing machine by means of a rigid mount with support on all mounting surfaces of each test battery. Each sample was subjected to a half-sine shock of peak acceleration depending on the mass of the battery. The pulse duration shall be eleven (11) milliseconds. Table 1 provides the formulas below are provided to calculate the appropriate minimum peak accelerations.

Battery	Minimum peak acceleration	Pulse duration
Small batteries	150 g_n or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{100850}{mass*}\right)}$ whichever is smaller	6 ms
Large batteries	50 g_n or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{30000}{mass*}\right)}$ whichever is smaller	11 ms

* Mass is expressed in kilograms.

Table 1: T4 – Shock Peak Acceleration Formula

The peak acceleration for these large battery packs is 23.6g.

Each sample was subjected to three (3) shocks in the positive direction followed by three (3) shocks in the negative direction of the three mutually perpendicular mounting positions. After testing the voltage and mass were measured on each sample.

T4 – SHOCK (cont'd)

Acceptance Criteria:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Results:

The test samples conformed to the acceptance criteria; there was no leakage, no venting, no disassembly, no rupture and no fire and the open circuit voltage of each test cell or battery after testing was not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

T4 - Shock								
Sample No.	Pre Conditioning Cycles	Voltage Pre Test (VDC)	Voltage Post Test (VDC)	% Change (Not Greater Than 10%)	Weight Pre Test (Grams)	Weight Post Test (Grams)	% Change (Not Greater Than 0.1%)	Meets requirement
1	1	57.400	57.480	-0.139	53800.000	53802.000	-0.004	Pass
2	1	57.400	57.480	-0.139	53982.000	53982.000	0.000	Pass
3	25	57.600	57.640	-0.069	53854.000	53854.000	0.000	Pass
4	25	57.600	57.610	-0.017	53844.000	53842.000	0.004	Pass

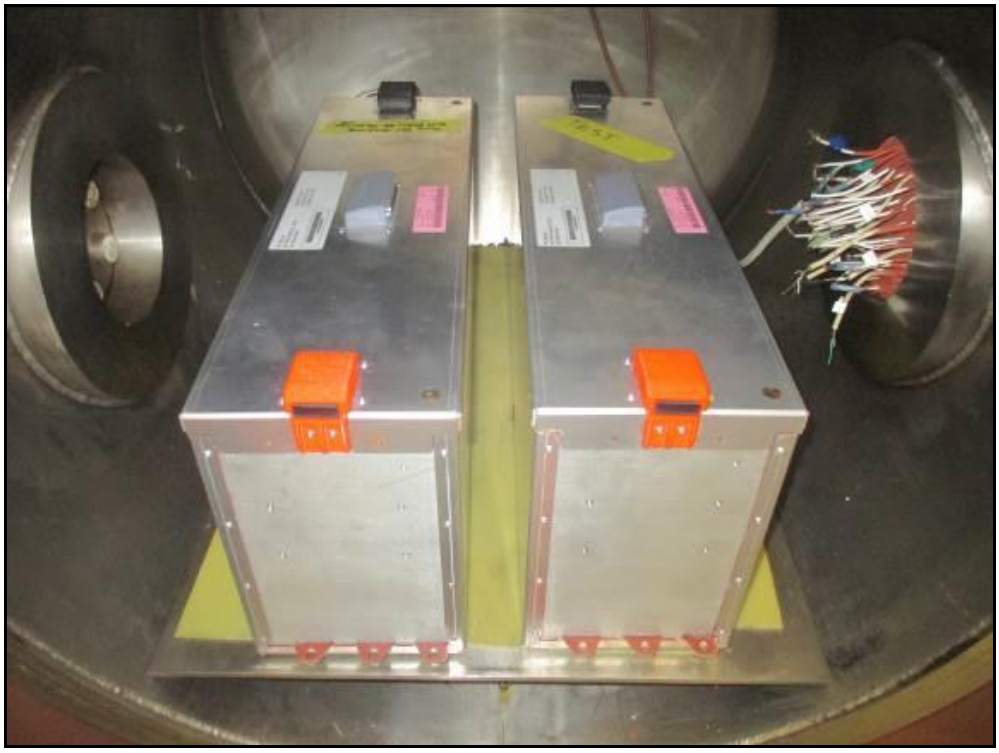
Appendices:

Appendix A – Photographs
Appendix E – Shock Plots

Disposition of Test Samples:

At the completion of testing, the samples were returned to the client.

APPENDIX A – PHOTOGRAPHS
T1 – Altitude Simulation

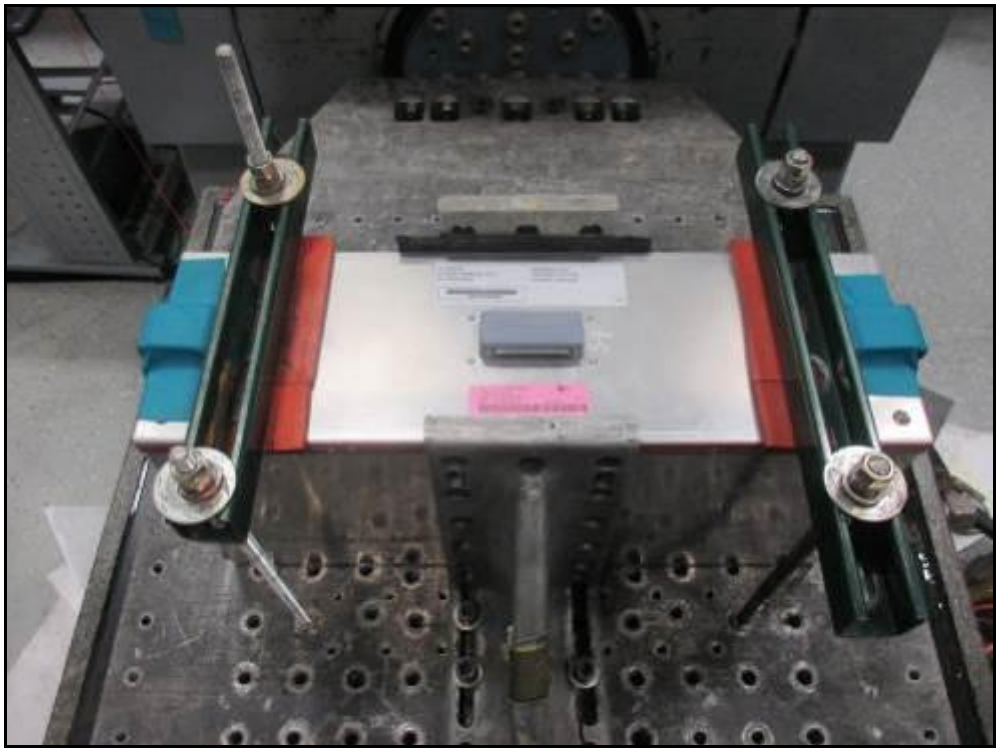


Photograph 1: Altitude Simulation Setup

APPENDIX A – PHOTOGRAPHS (cont'd)
T2 – Thermal Test

Photograph 2: Thermal Test Setup

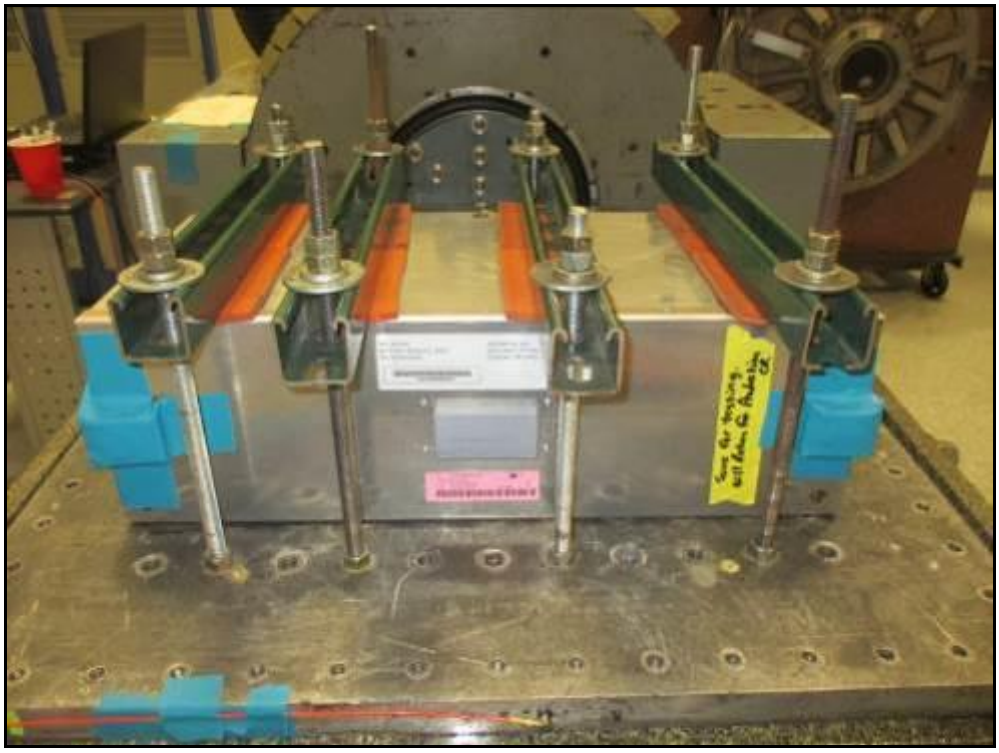
APPENDIX A – PHOTOGRAPHS (cont'd)
T3 – Vibration



Photograph 3: Vibration Test Setup – Fore/Aft Direction

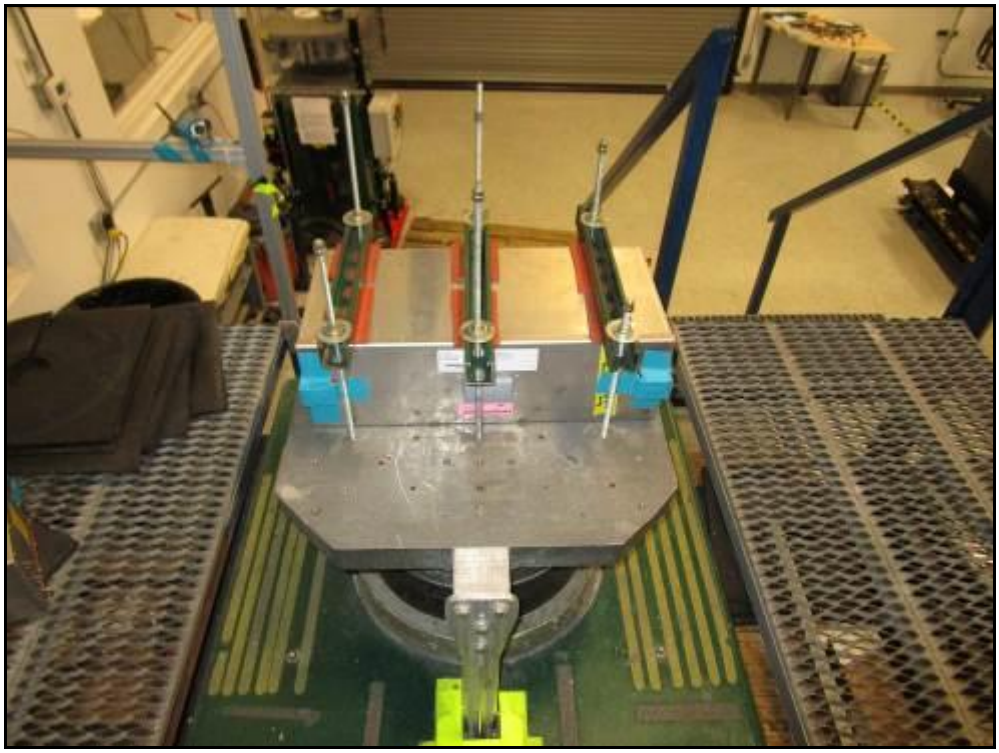
Photograph 4: Vibration Test Setup – Lateral Direction

APPENDIX A – PHOTOGRAPHS (cont'd)
T3 – Vibration

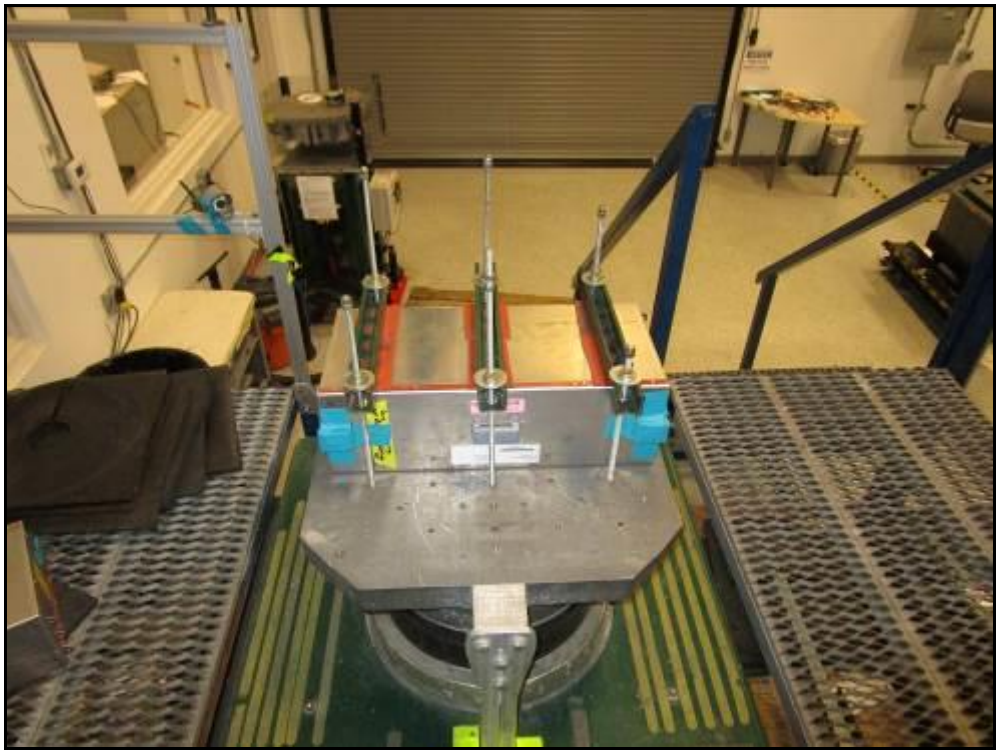


Photograph 5: Vibration Test Setup – Vertical Direction

APPENDIX A – PHOTOGRAPHS (cont'd)
T4 – Shock

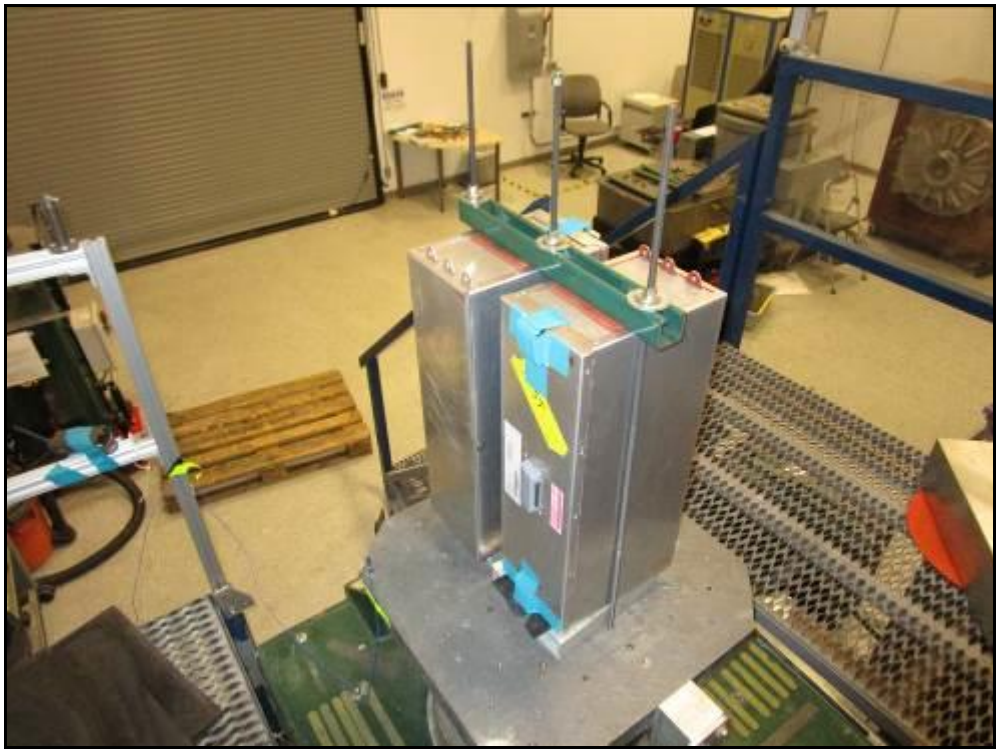


Photograph 6: Shock Test Setup –Fore/Aft, Positive Direction

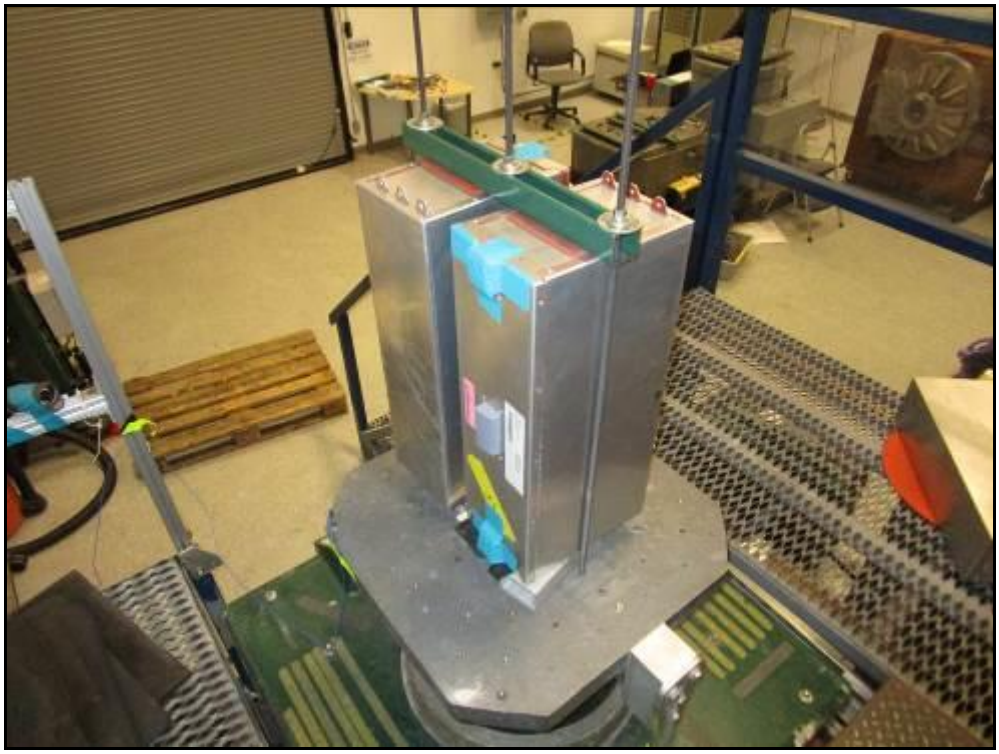


Photograph 7: Shock Test Setup – Fore/Aft, Negative Direction

APPENDIX A – PHOTOGRAPHS (cont'd)
T4 – Shock

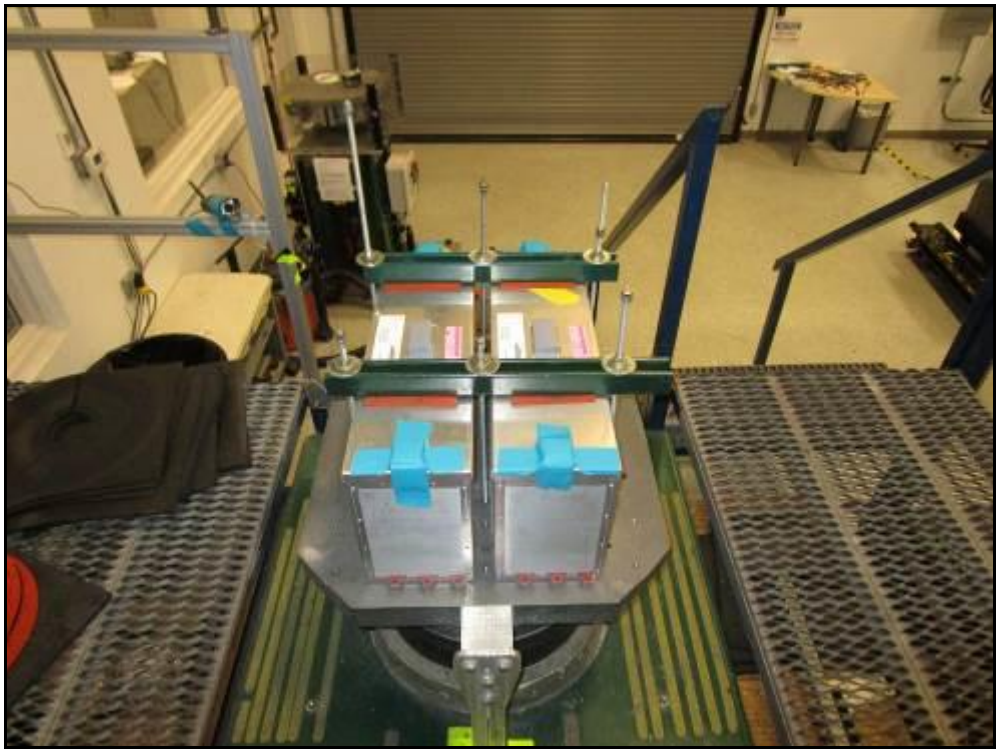


Photograph 8: Shock Test Setup – Lateral, Positive Direction

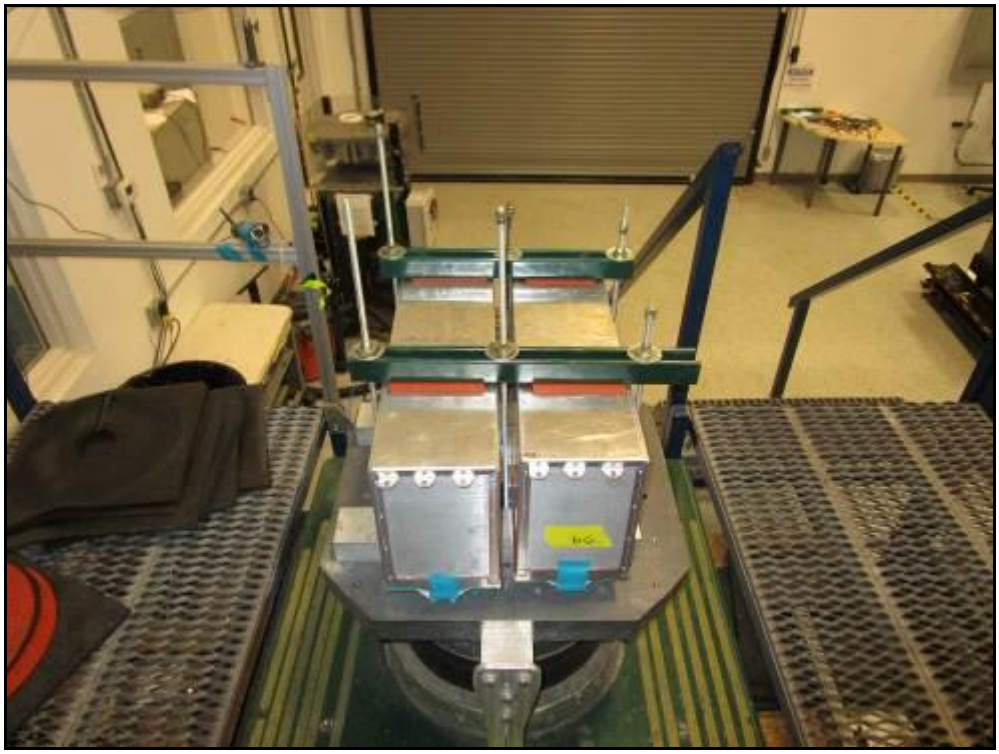


Photograph 9: Shock Test Setup – Lateral, Negative Direction

APPENDIX A – PHOTOGRAPHS (cont'd)
T4 – Shock



Photograph 10: Shock Test Setup – Vertical, Positive Direction



Photograph 11: Shock Test Setup – Vertical, Negative Direction

APPENDIX B
T1 – Altitude Simulation Graph

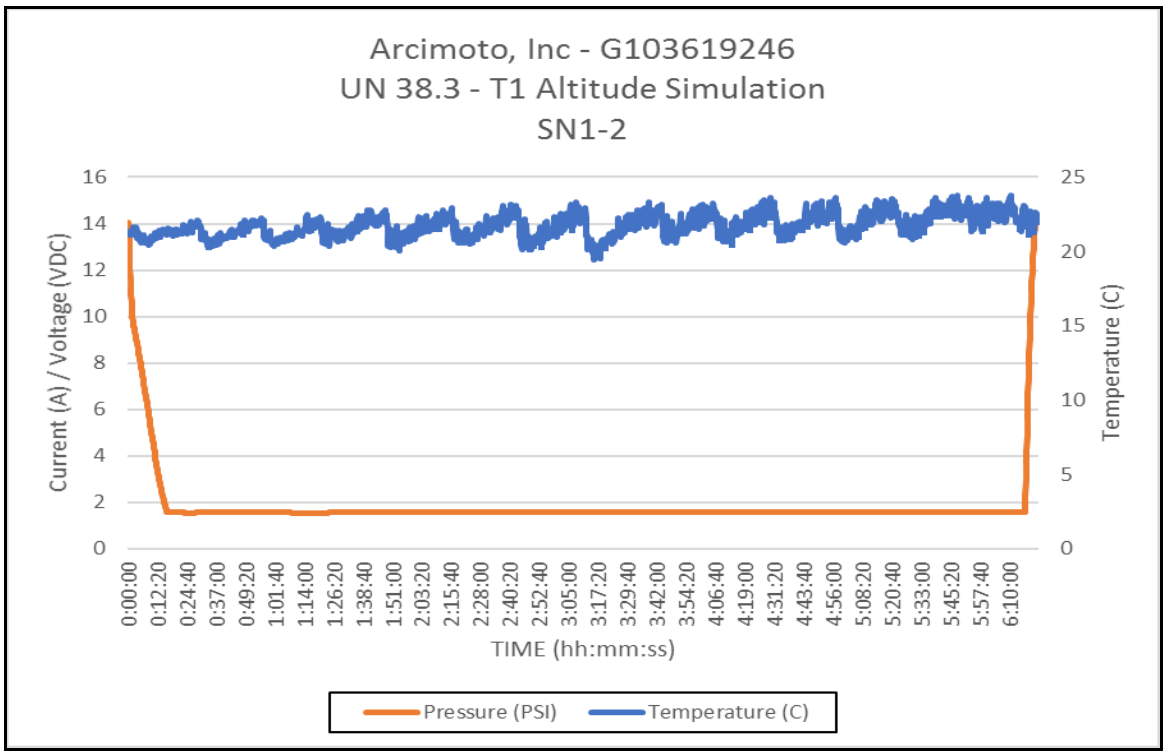


Figure 1: Altitude Simulation Graph; SN1-2

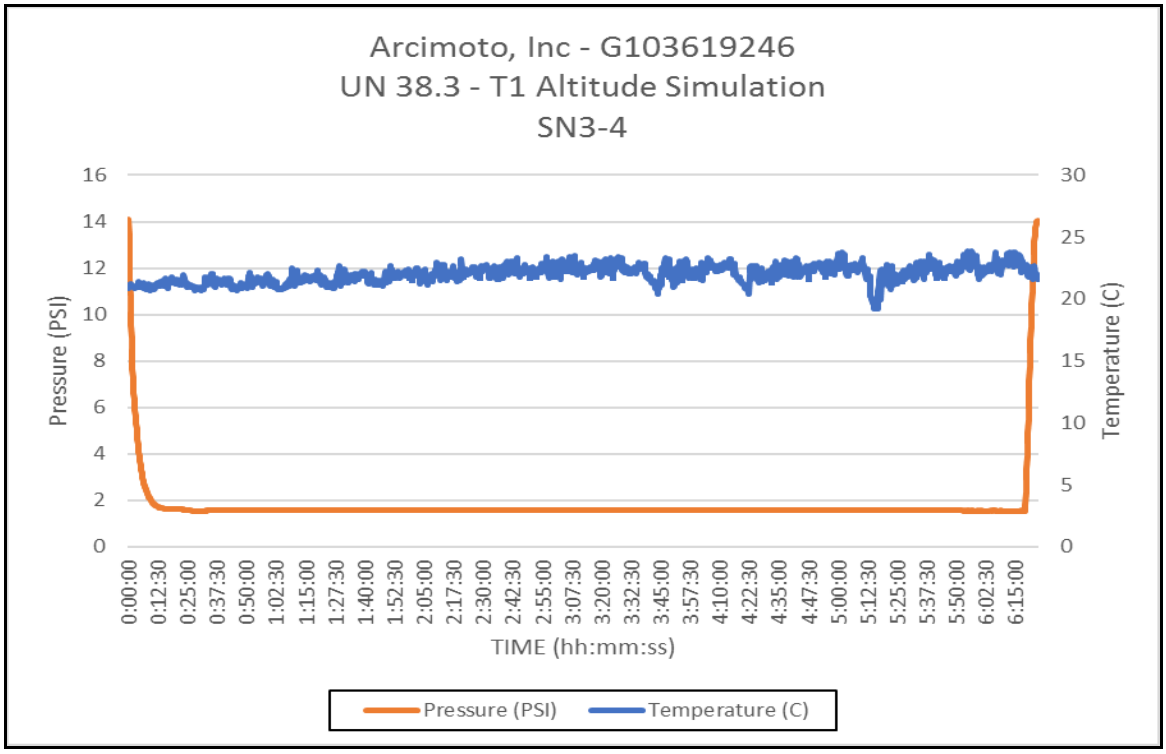


Figure 2: Altitude Simulation Graph; SN3-4

APPENDIX C
T2 – Thermal Test Graph

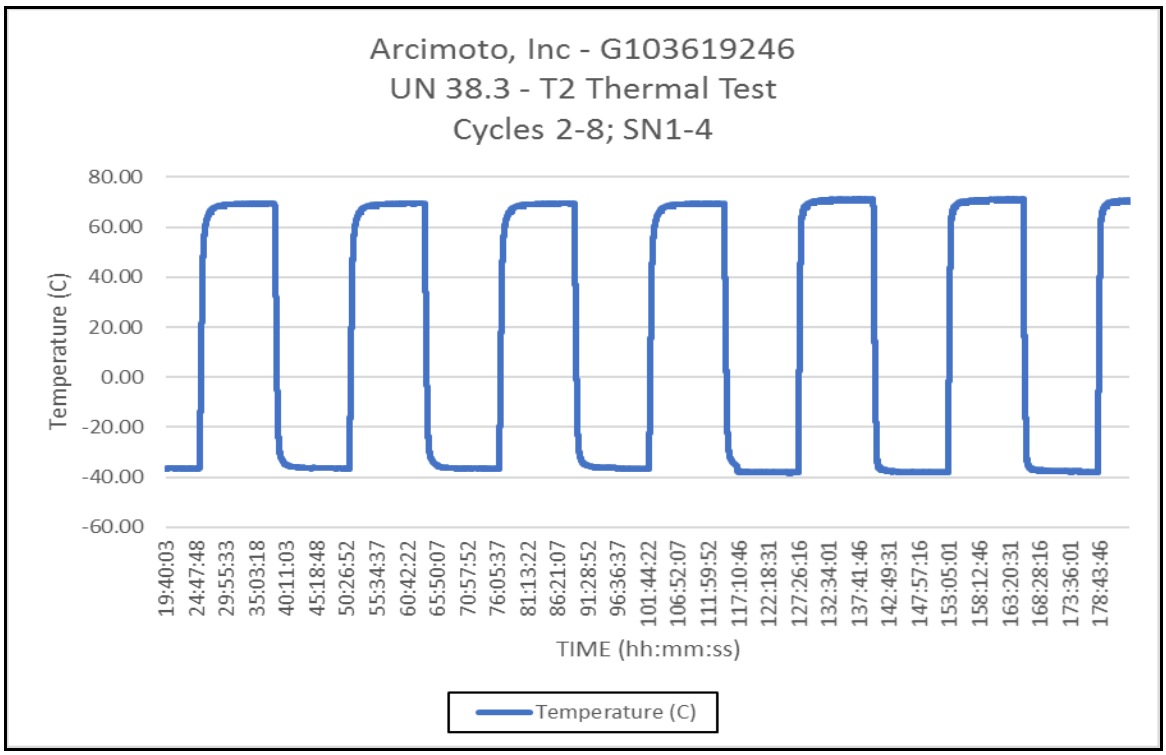


Figure 3: Thermal Test Graph, Cycles 2-8; SN1-4

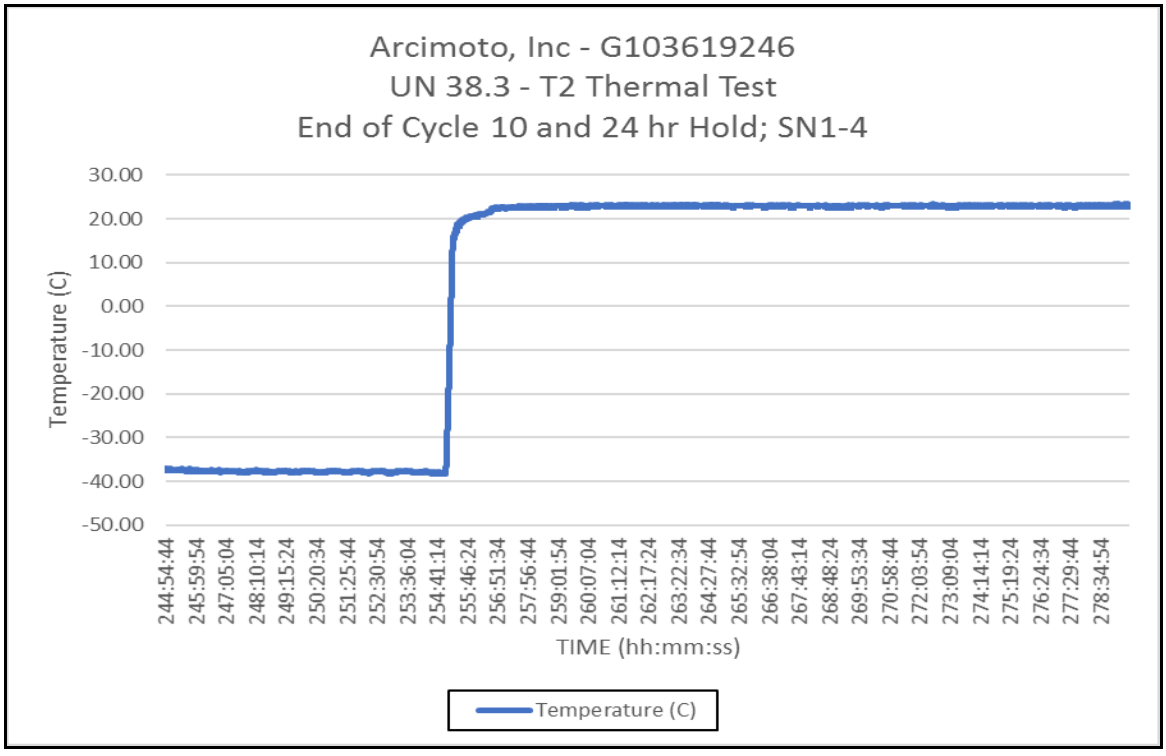


Figure 4: Thermal Test Graph, End of Cycle 10 and 24 hr Hold; SN1-4

APPENDIX D
T3 – Vibration Plots

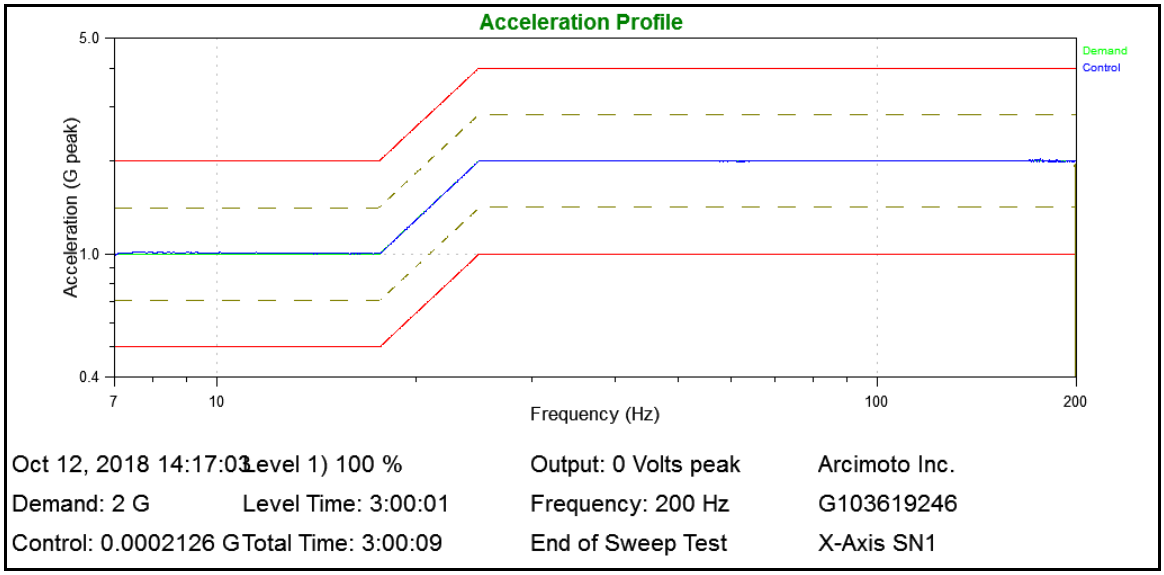


Figure 5: Vibration Plot – Fore/Aft Direction; SN1

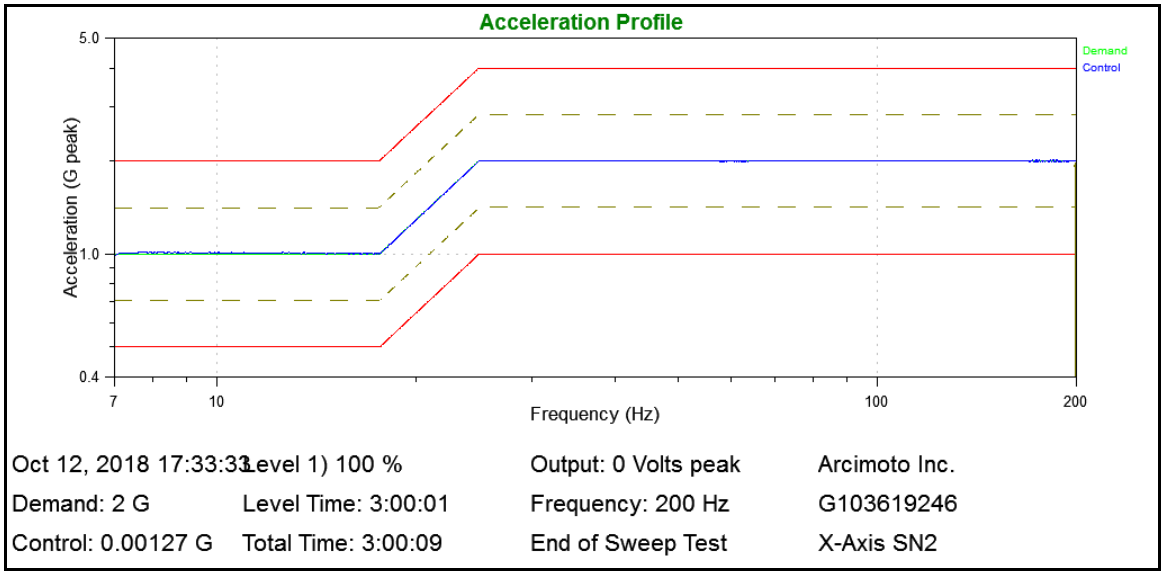


Figure 6: Vibration Plot – Fore/Aft Direction; SN2

APPENDIX D
T3 – Vibration Plots (cont'd)

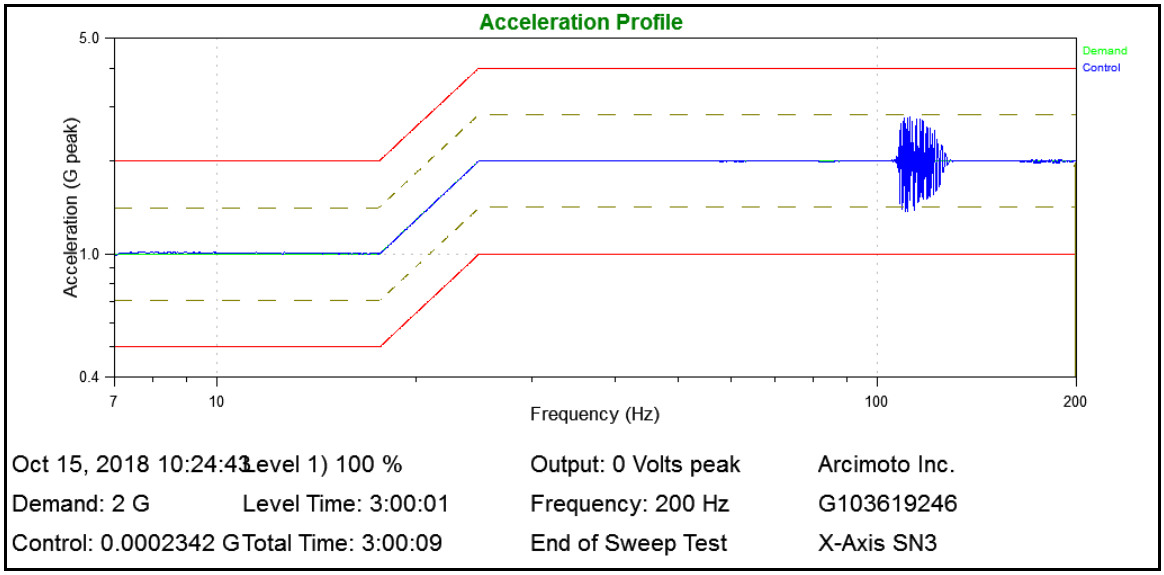


Figure 7: Vibration Plot – Fore/Aft Direction; SN3

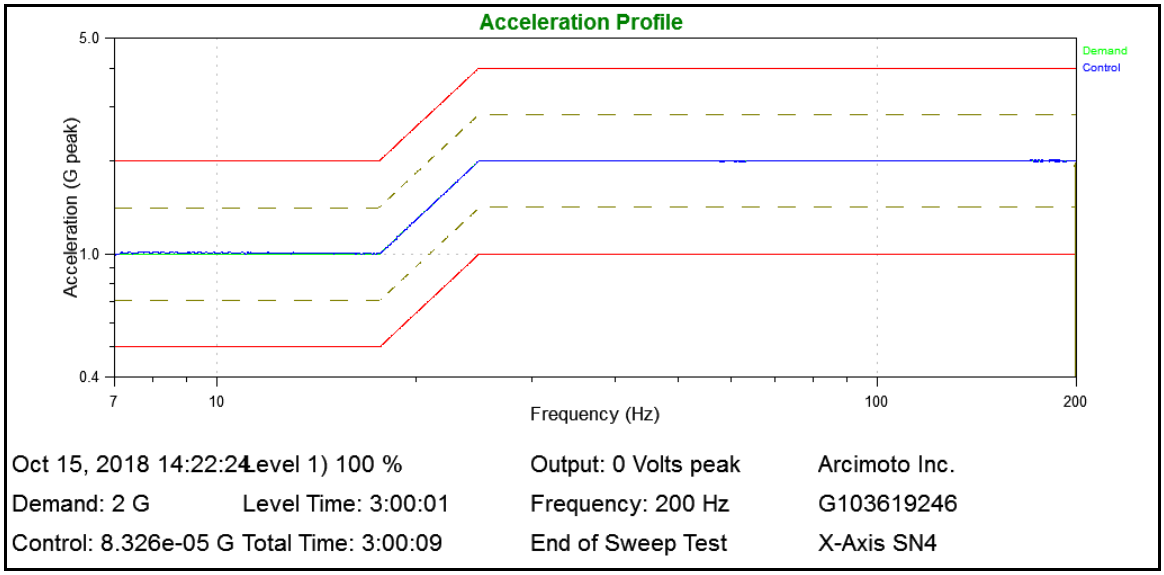


Figure 8: Vibration Plot – Fore/Aft Direction; SN4

APPENDIX D
T3 – Vibration Plots (cont'd)

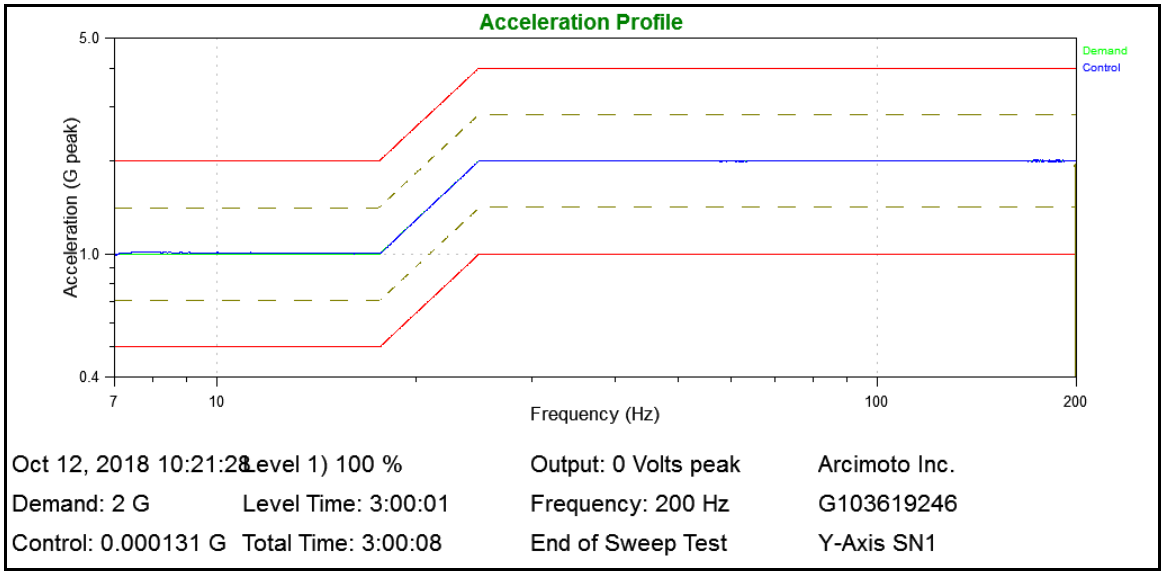


Figure 9: Vibration Plot – Lateral Direction; SN1

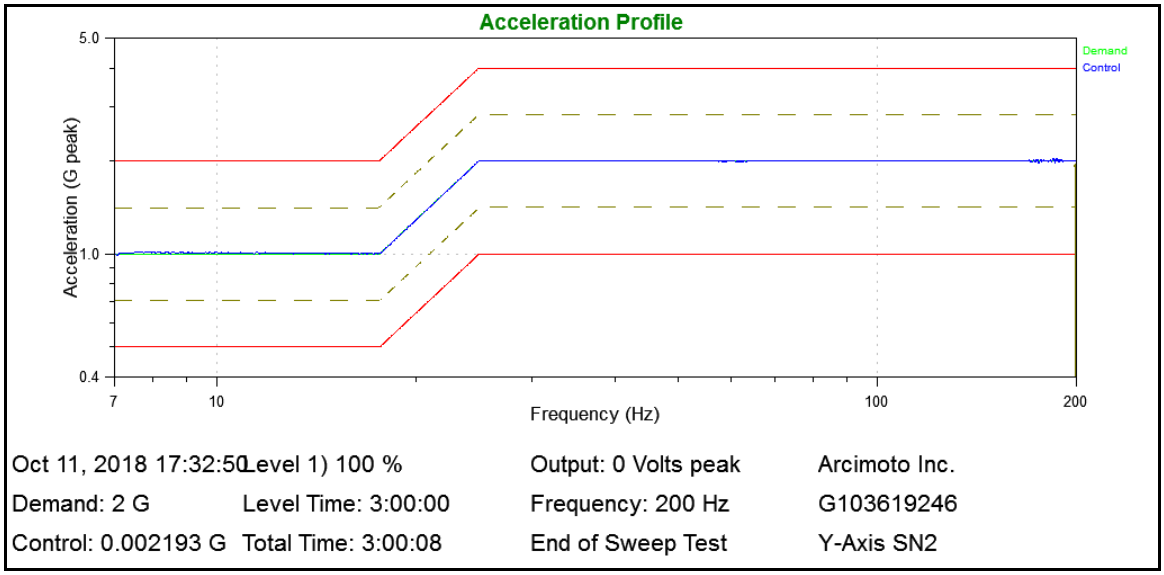


Figure 10: Vibration Plot – Lateral Direction; SN2

APPENDIX D
T3 – Vibration Plots (cont'd)

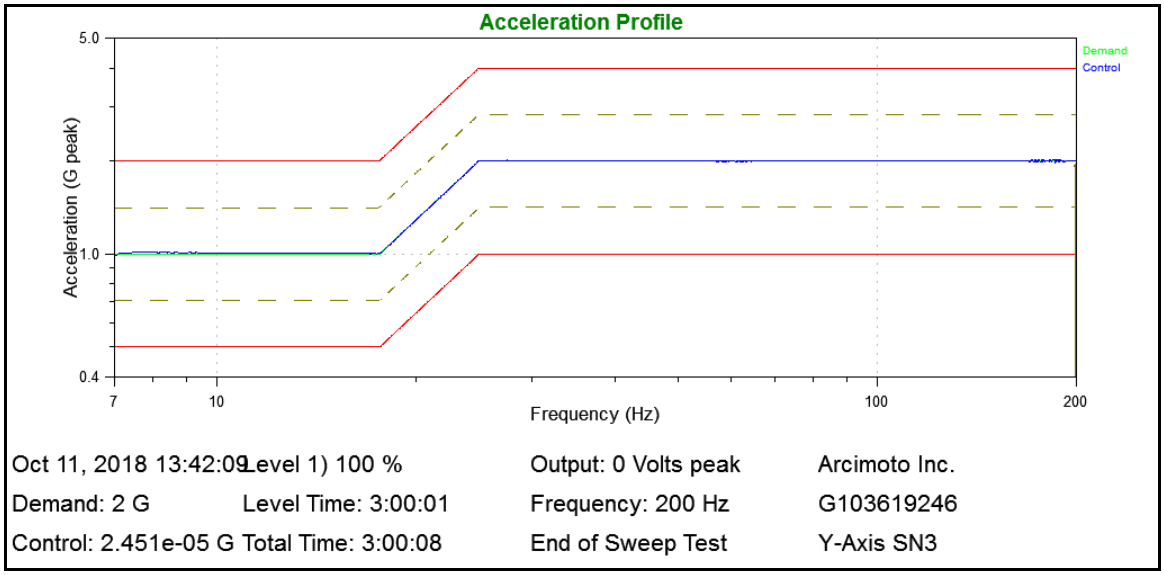


Figure 11: Vibration Plot – Lateral Direction; SN3

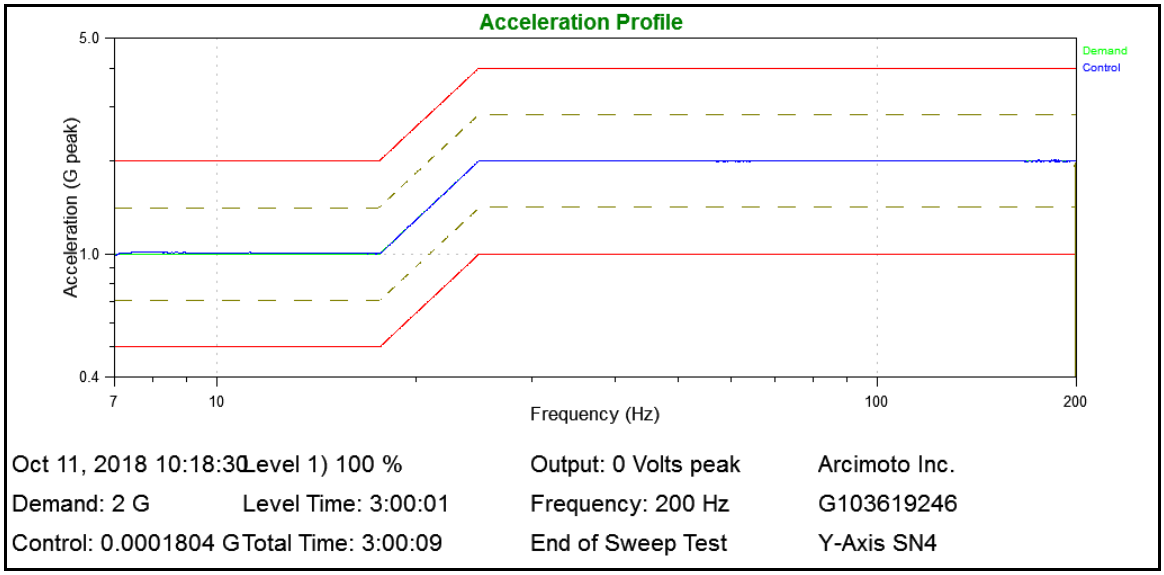


Figure 12: Vibration Plot – Lateral Direction; SN4

APPENDIX D
T3 – Vibration Plots (cont'd)

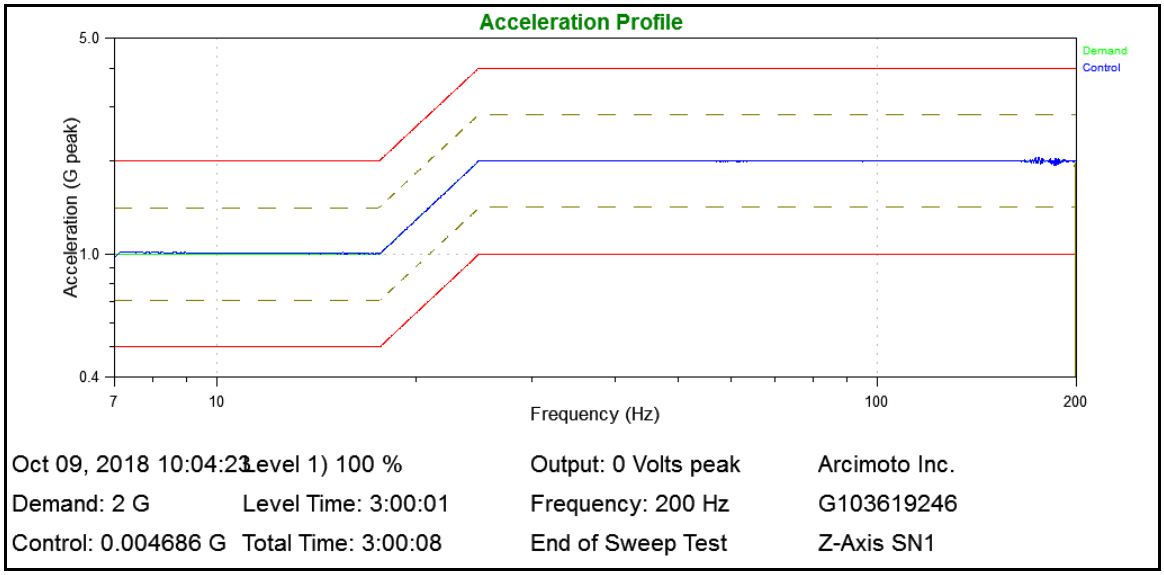


Figure 13: Vibration Plot – Vertical Direction; SN1

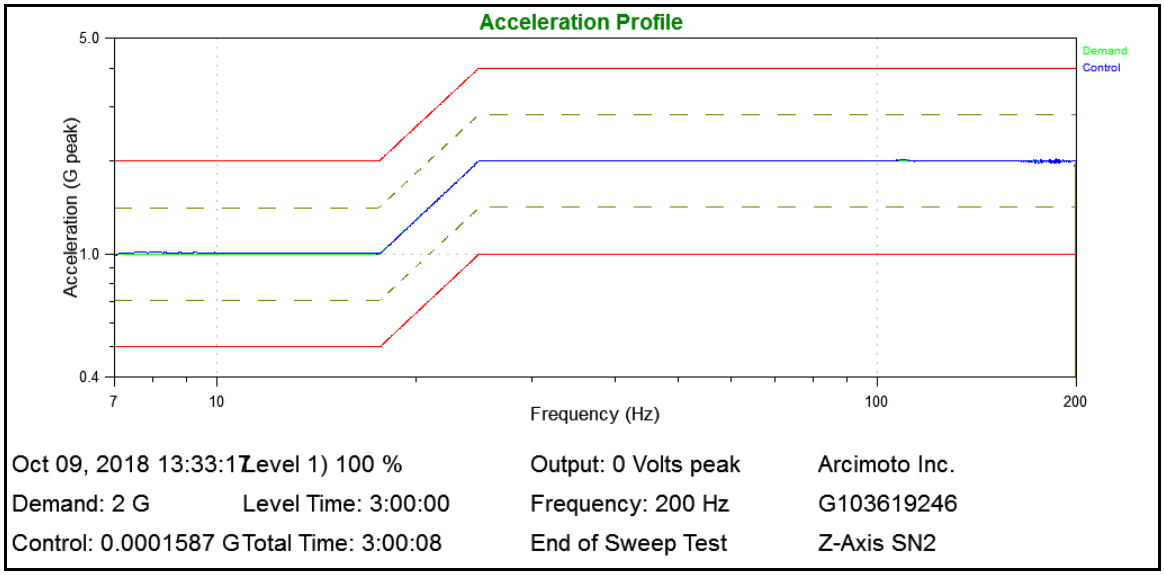


Figure 14: Vibration Plot – Vertical Direction; SN2

APPENDIX D
T3 – Vibration Plots (cont'd)

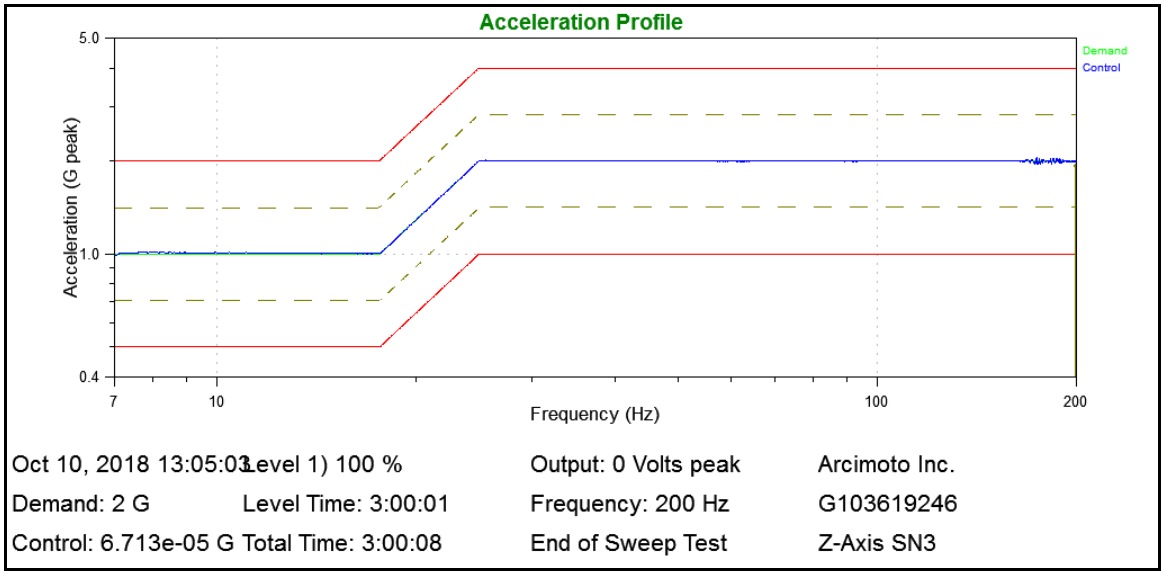


Figure 15: Vibration Plot – Vertical Direction; SN3

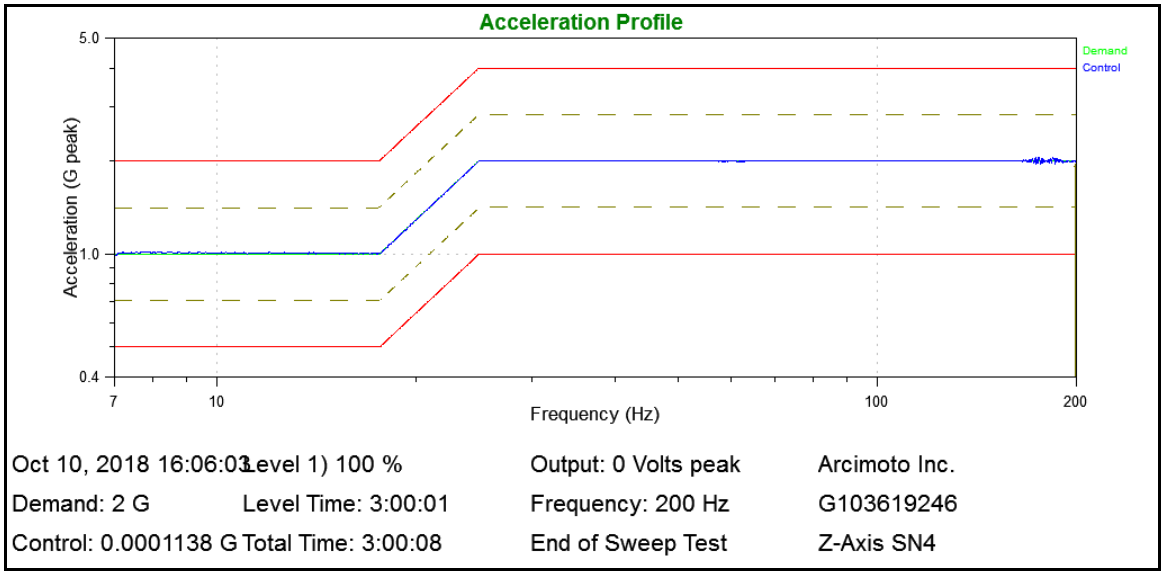


Figure 16: Vibration Plot – Vertical Direction; SN4

APPENDIX E
T4 – Shock Plots

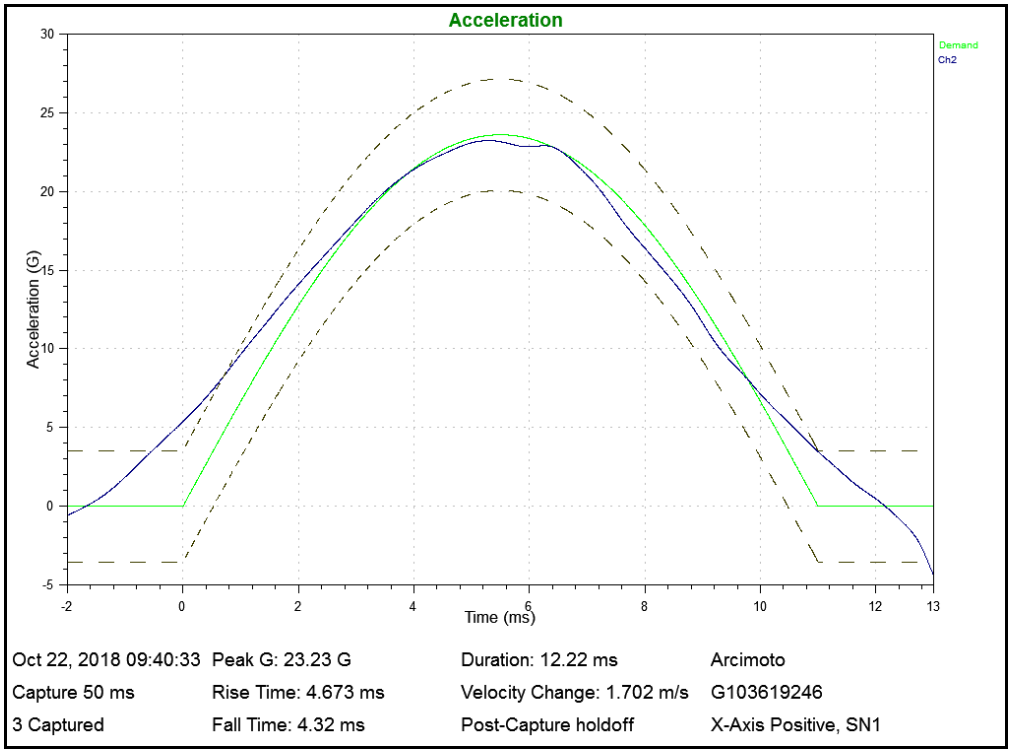


Figure 17: Shock Plot –Fore/Aft, Positive Direction; SN1

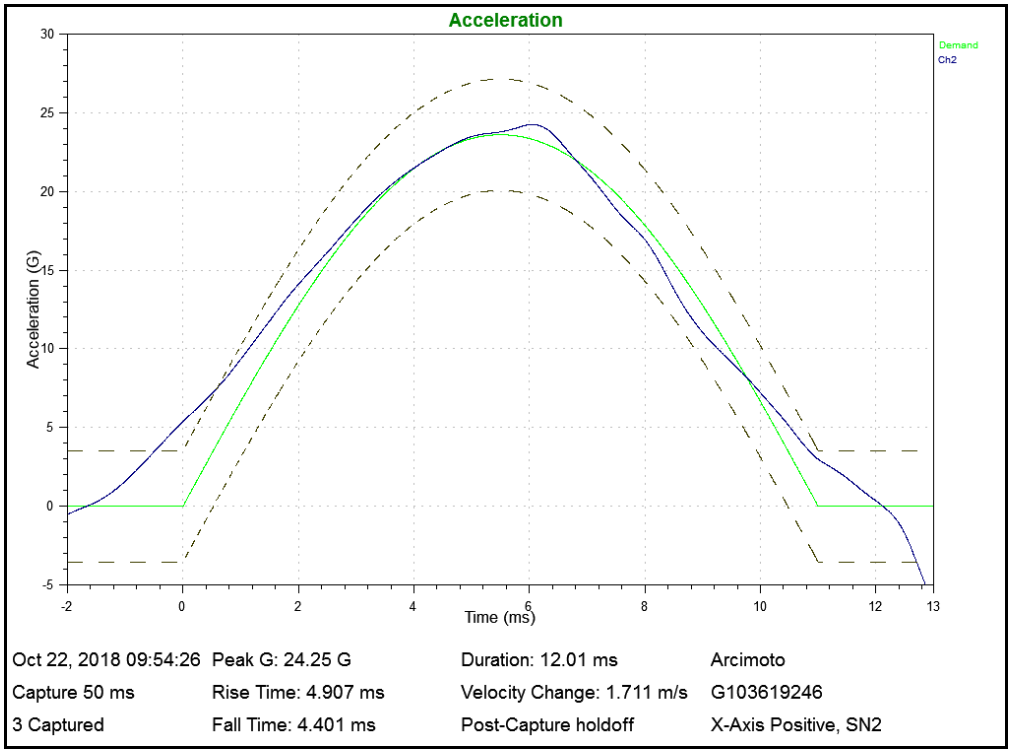


Figure 18: Shock Plot –Fore/Aft, Positive Direction; SN2

APPENDIX E
T4 – Shock Plots (cont'd)

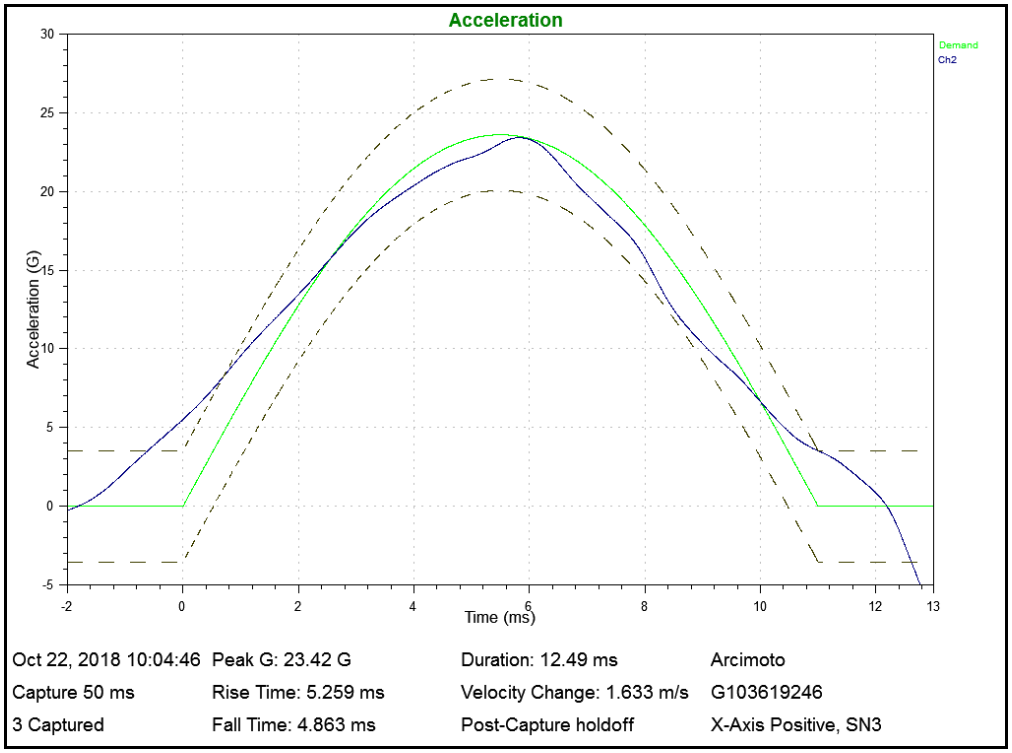


Figure 19: Shock Plot –Fore/Aft, Positive Direction; SN3

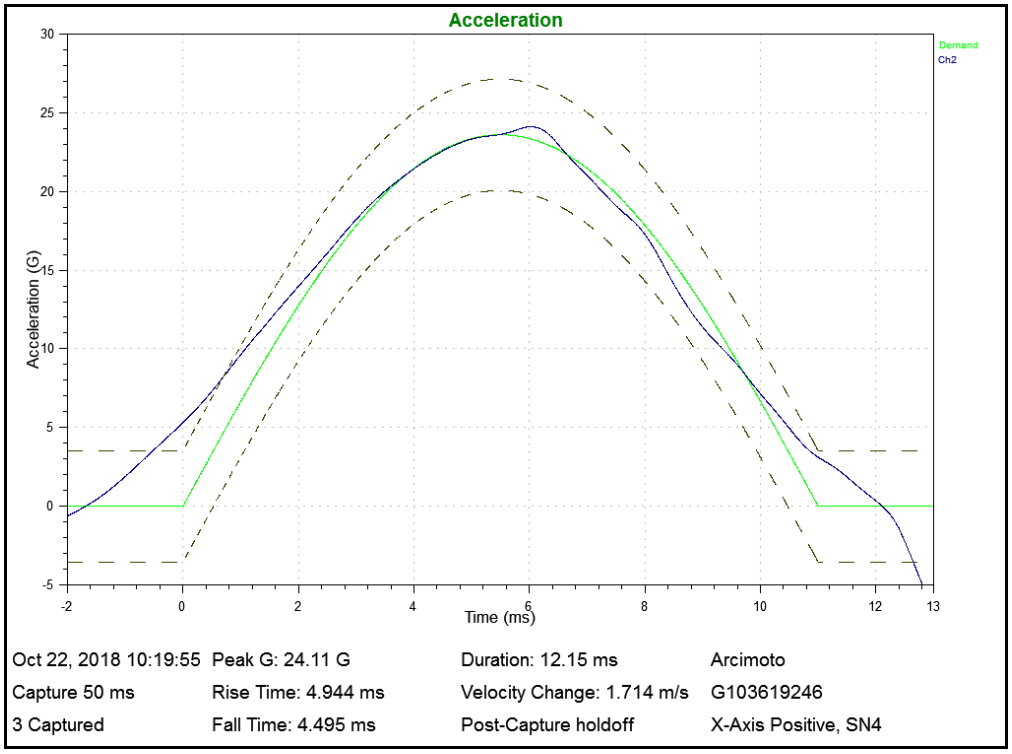


Figure 20: Shock Plot –Fore/Aft, Positive Direction; SN4

APPENDIX E
T4 – Shock Plots (cont'd)

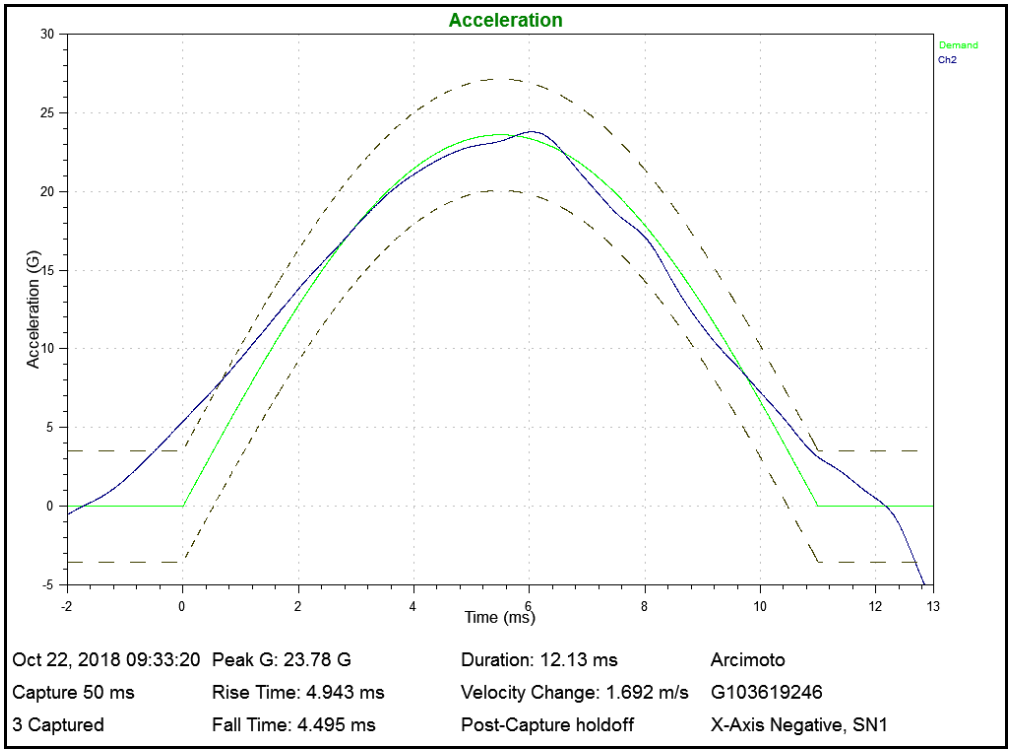


Figure 21: Shock Plot –Fore/Aft, Negative Direction; SN1

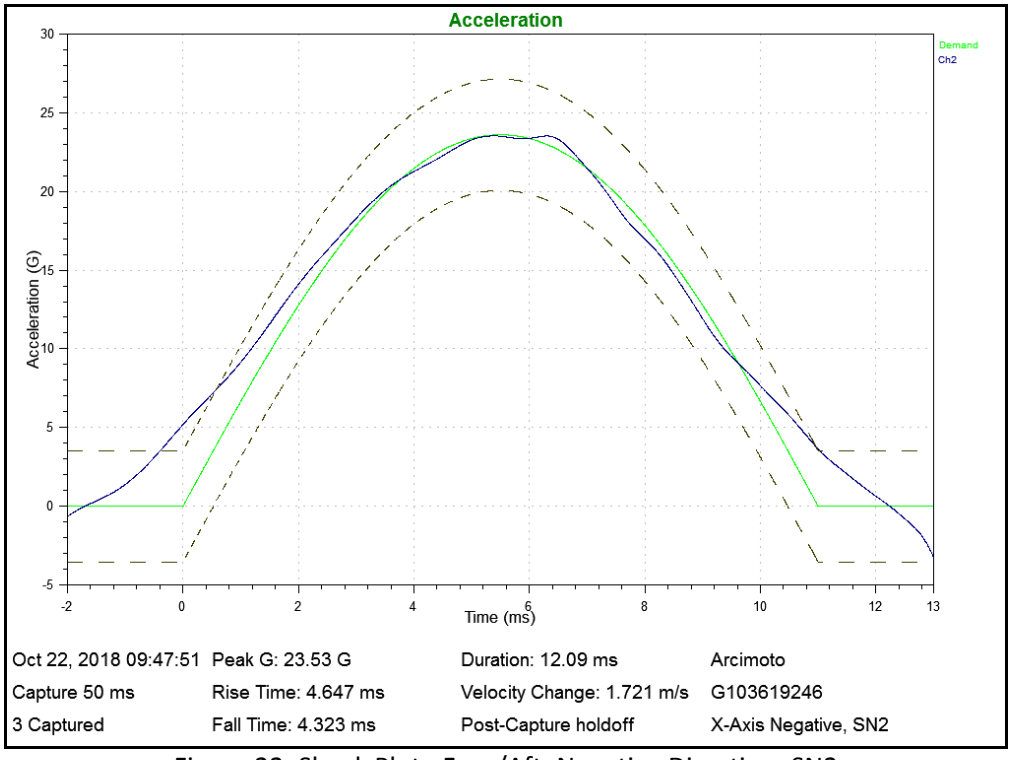


Figure 22: Shock Plot –Fore/Aft, Negative Direction; SN2

APPENDIX E
T4 – Shock Plots (cont'd)

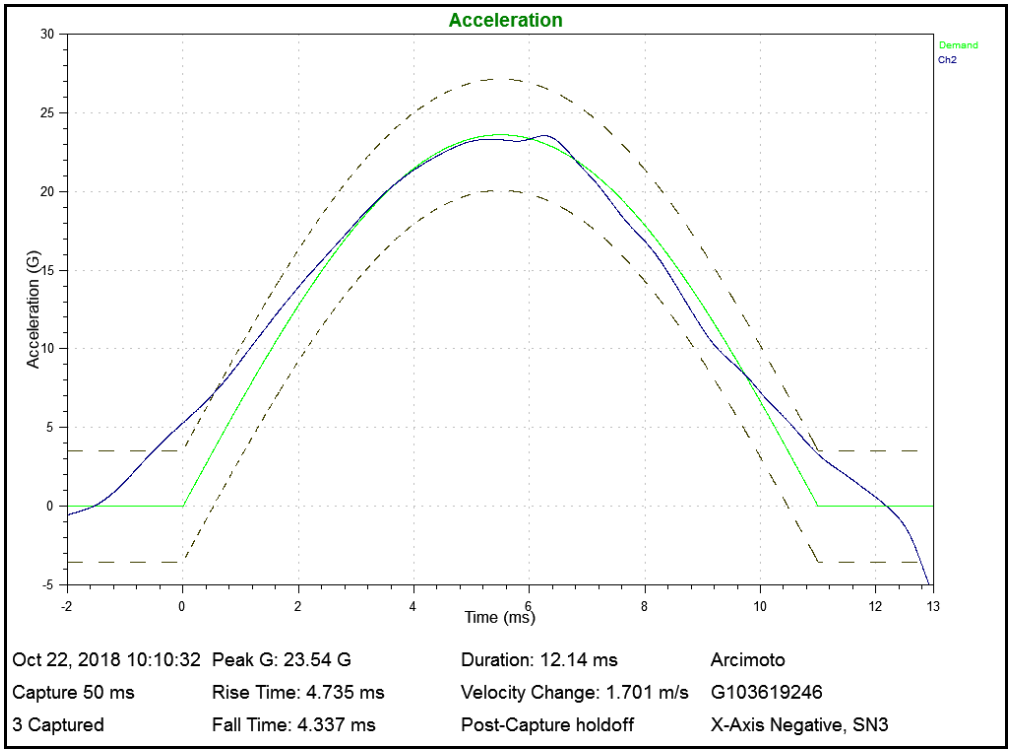


Figure 23: Shock Plot –Fore/Aft, Negative Direction; SN3

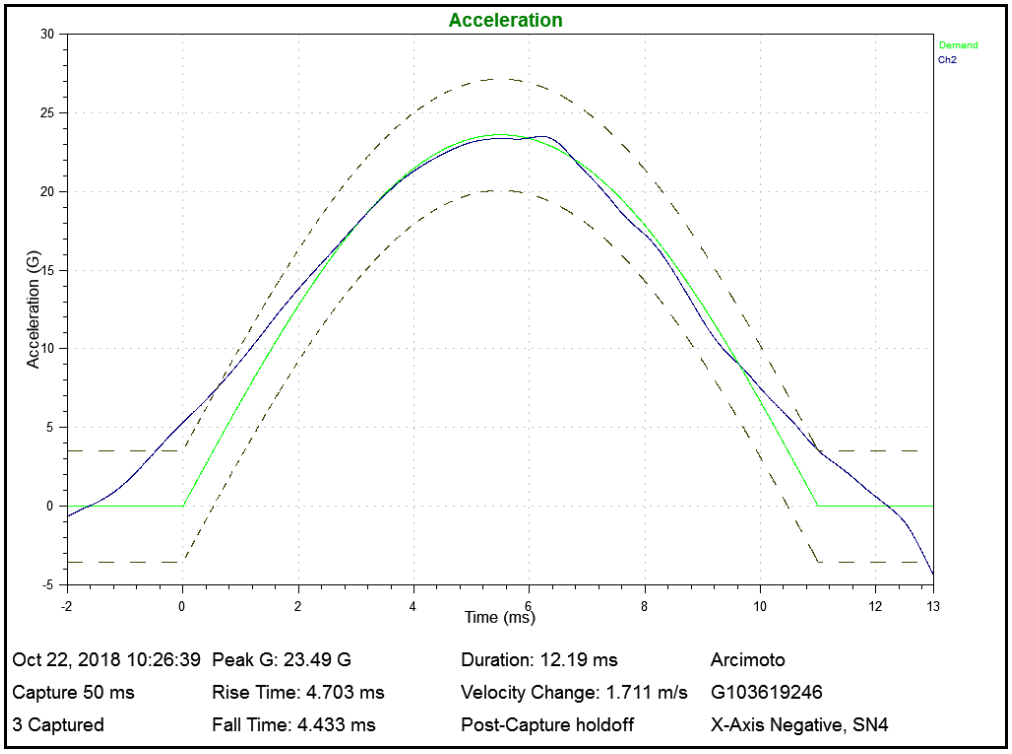


Figure 24: Shock Plot –Fore/Aft, Negative Direction; SN4

APPENDIX E
T4 – Shock Plots (cont'd)

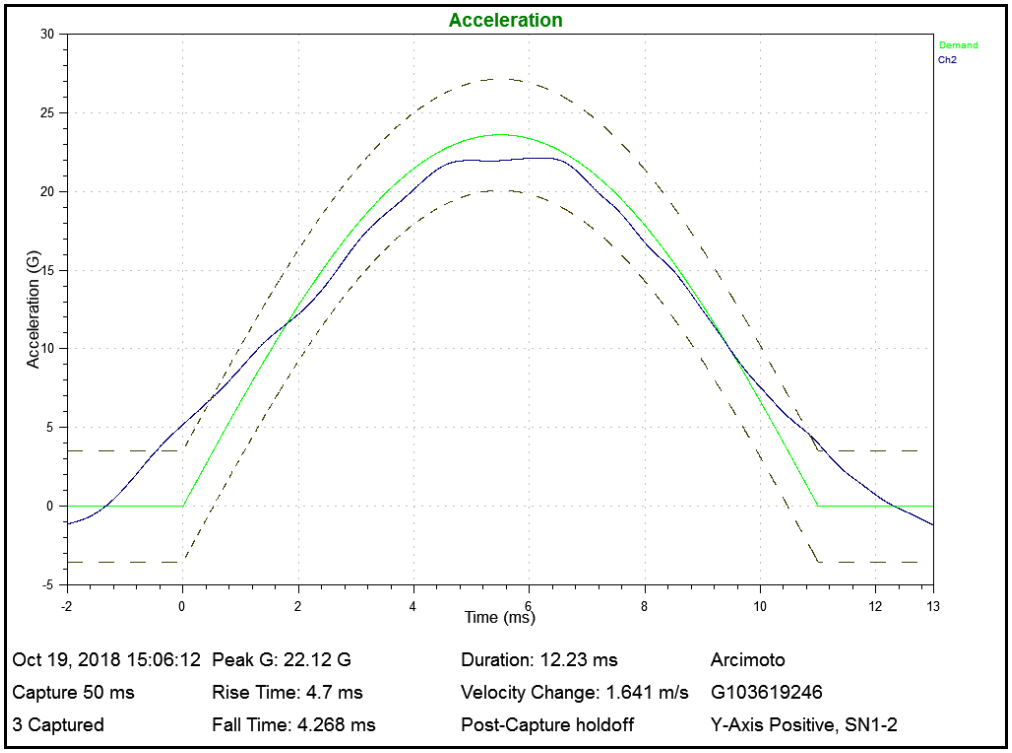


Figure 25: Shock Plot – Lateral, Positive Direction; SN1-2

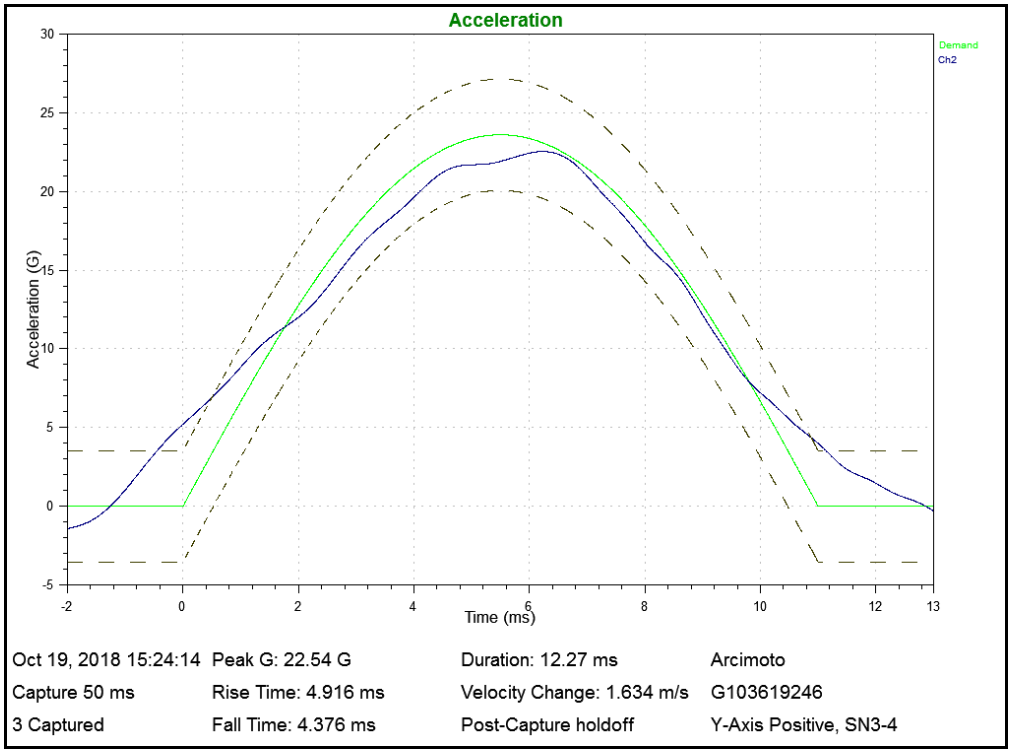


Figure 26: Shock Plot – Lateral, Positive Direction; SN3-4

APPENDIX E
T4 – Shock Plots (cont'd)

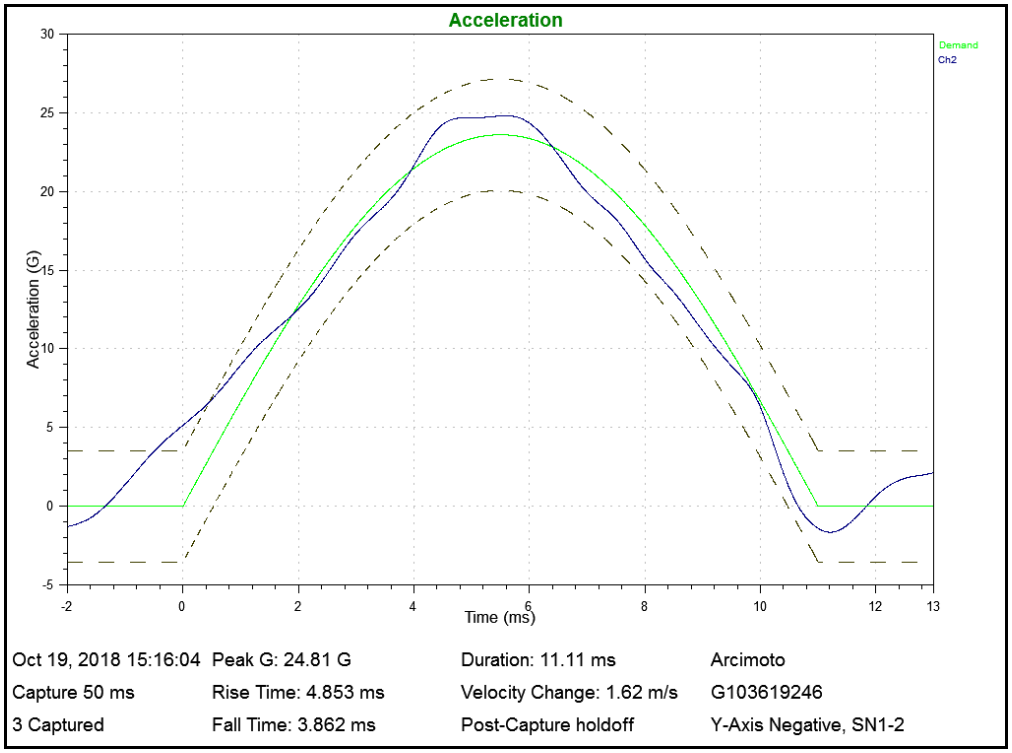


Figure 27: Shock Plot – Lateral, Negative Direction; SN1-2

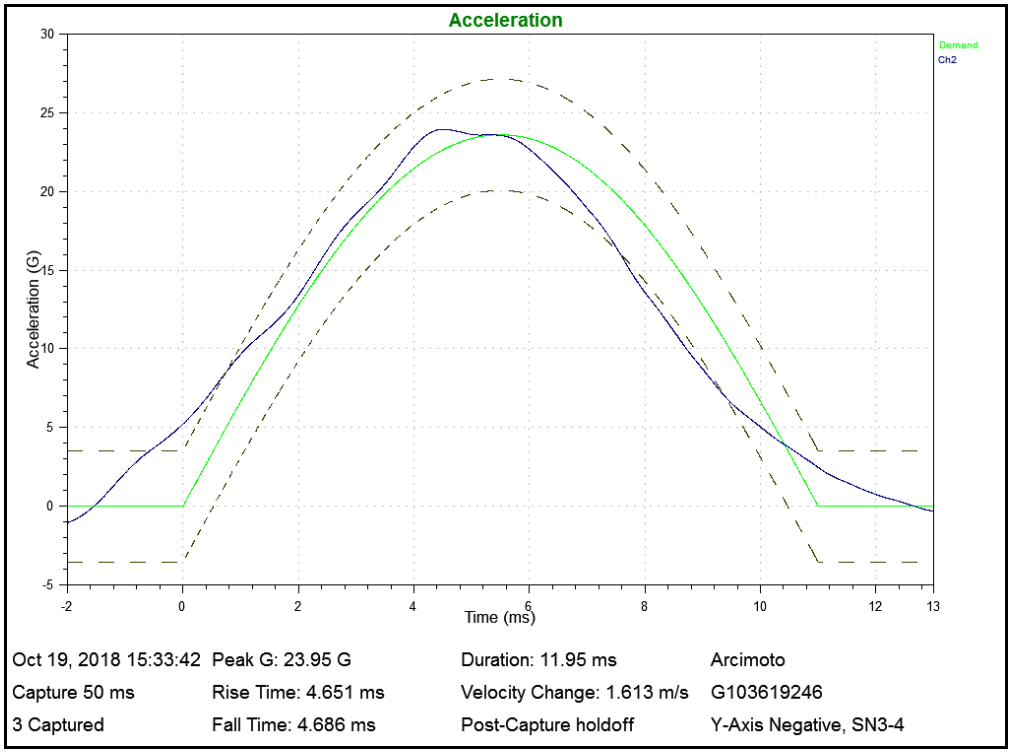


Figure 28: Shock Plot – Lateral, Negative Direction; SN3-4

APPENDIX E
T4 – Shock Plots (cont'd)

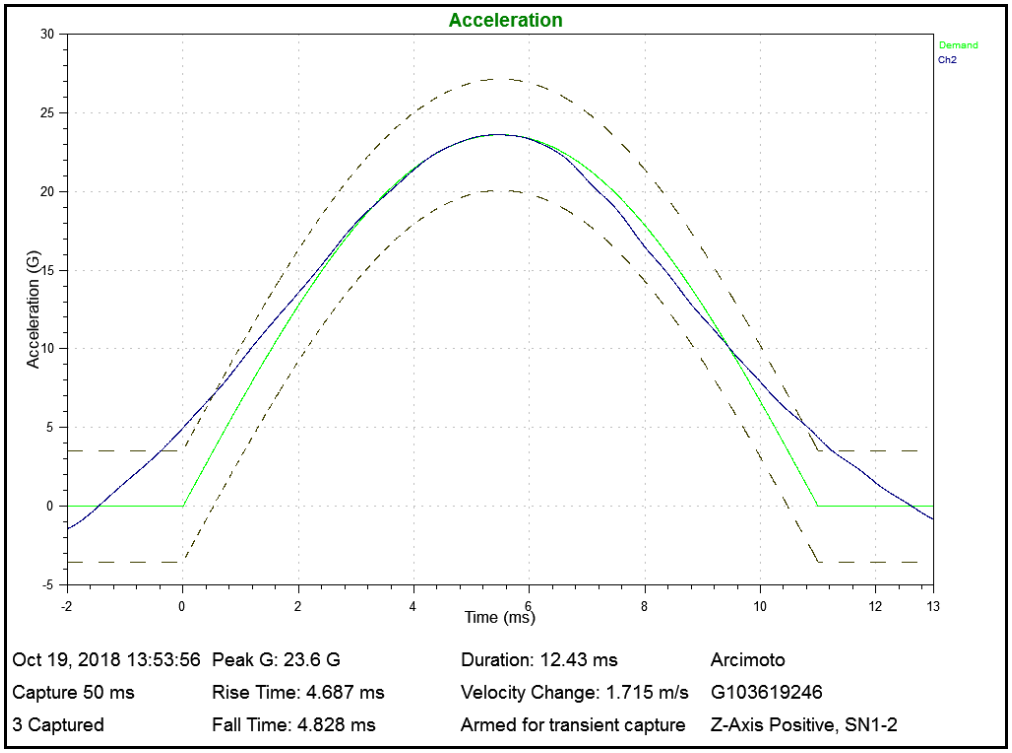


Figure 29: Shock Plot – Vertical, Positive Direction; SN1-2

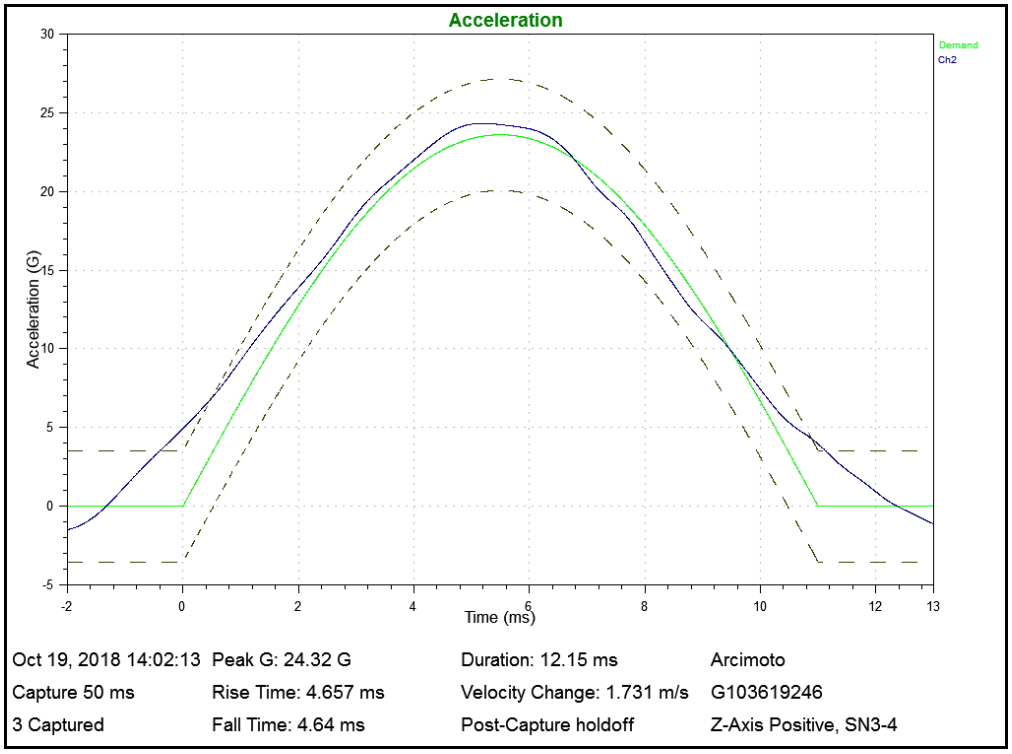


Figure 30: Shock Plot – Vertical, Positive Direction; SN3-4

APPENDIX E
T4 – Shock Plots (cont'd)

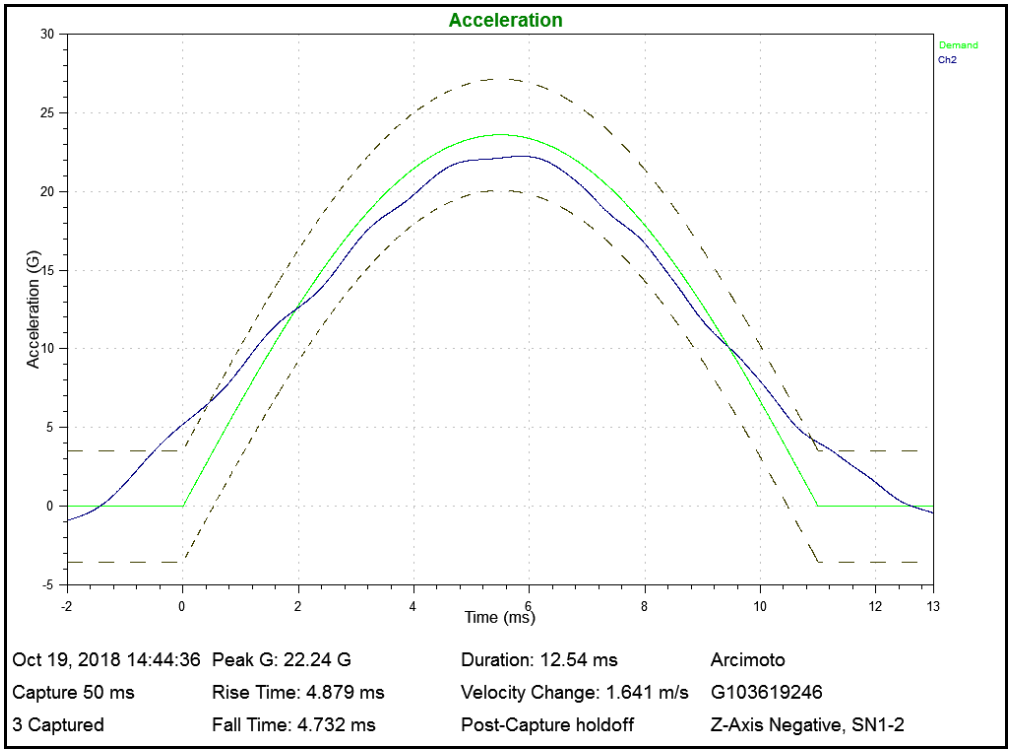


Figure 31: Shock Plot – Vertical, Negative Direction; SN1-2

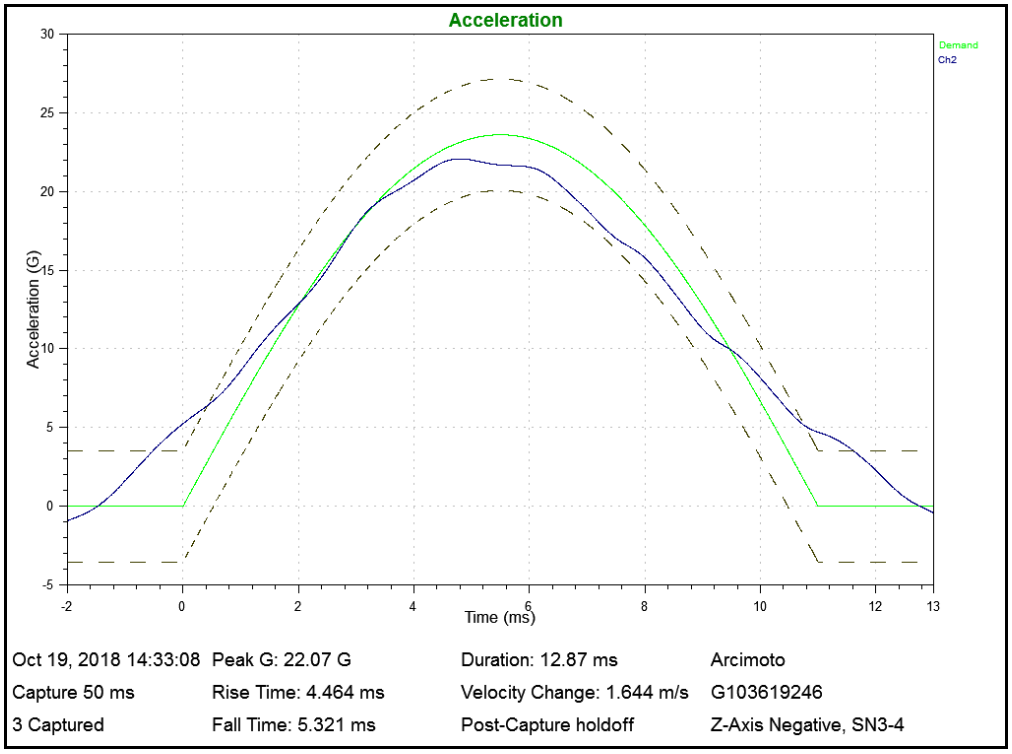


Figure 32: Shock Plot – Vertical, Negative Direction; SN3-4