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ARCIMOTO INC.
UN38.3 TRANSPORTATION TESTING

SCOPE OF WORK
Model Number: 006008

REPORT NUMBER
104913789DET-001

ISSUE DATE

14-April-2022

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

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DATE RECEIVED: 02/03/2022
DATE TESTED: 02/25/2022 through 04/08/2022

WORK REQUESTED / APPLICABLE DOCUMENTS:

Per the client's request and in accordance with UN Manual of Test and Criteria, Sixth revised edition, Amendment 1; "Recommendations on the Transport of Dangerous Goods," Section 38.3 "Lithium metal and lithium ion batteries" and our quotation number Qu-01200061, dated 11/15/2021; perform Battery Testing as described below:

- T1 – Altitude Simulation
- T2 – Thermal Test
- T3 – Vibration
- T4 – Shock
- T5 – External Short Circuit

DESCRIPTION OF TEST SAMPLES:

SAMPLE DESCRIPTION: Four (4) 006008 Lithium-ion Battery Packs

MANUFACTURER: Arcimoto Inc.

MODEL NUMBER: 006008

RATINGS: 50.96V 192Ah

SPECIFICATION SECTIONS T1 through T5:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- 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
T5	External Short Circuit	Pass

Patrick Weil	Nick Diamond
Battery Engineer	Sr. Associate Engineer
April 14, 2022	
Report No.: 104913789DET-001	

EQUIPMENT LIST:

Asset #	Description	Manufacturer	Model	Serial#	Last Cal	Next Cal Due
372-211	DIGITAL MULTIMETER	FLUKE	77 IV	38990370	10/17/2021	10/17/2022
169029	SCALE	AEADAM	GFK 330aH	AE82650	5/14/2021	5/14/2022
373-135	DATA ACQ/SWITCH UNIT	KEYSIGHT	34972A	MY49021271	1/20/2022	1/20/2023
376-019	DC POWER SUPPLY	MASTECH	HY3030E	388405	VBU	VBU
161279.1	PRESSURE TRANSDUCER	FAIRCHILD	TA870212A	366027	1/20/2022	1/20/2023
161279	ALTITUDE CABINET	ENTELA	N/A	N/A	VBU	VBU
373-165P	ENVIRONMENTAL CHAMBER	THERMOTRON	SE-1000-10-10	46381	4/9/2021	4/9/2022
161-332	TRUE RMS MULTIMETER	FLUKE	114	11740686	8/19/2021	8/19/2022
160112	VIBRATION AMP	UNHOLTZ-DICKIE	TA-117SA-560	1987	VBU	VBU
160122	VIBRATION SHAKER	UNHOLTZ-DICKIE	# 560	290	REF ONLY	REF ONLY
376-041	SIGNAL PROCESSOR	VIBRATION RESEARCH	VR9500	951C711D	6/25/2021	6/25/2022
376-055	ACCELEROMETER	PCB	353B15	LW197019	8/5/2021	8/5/2022
375-478	Accelerometer	PCB	J35B15	241933	10/19/2021	10/19/2022
375-226	SIGNAL PROCESSOR	VIBRATION RESEARCH	VR9500	951C3F2E	9/15/2021	9/15/2022
375-298	11,000 lb Shaker	ETS SOLUTIONS	M544A/GT900M	SH1506182-2	REF ONLY	REF ONLY
375-298.1	Electrodynamic Shaker - 11KLBF	ETS SOLUTIONS	MPA712/M544A/GT900M	SH1506182-2	REF	REF
375-458	ACCELEROMETER	PCB	353B15	LW231469	8/26/2021	8/26/2022
376-152	RESISTANCE METER	HIOKI	RM3548	160833497	1/24/2022	1/24/2023
161-335.1	CONTROLLER/CHAMBER	WATLOW	F4	N/A/1009000089	11/22/2021	11/22/2022
372-089	DATA ACQ/SWITCH UNIT	AGILENT	34972A	MY49003232	5/11/2021	5/11/2022
161310	DATA ACQ/SWITCH UNIT	AGILENT	34972A	MY49002644	1/20/2022	1/20/2023
376-086	BATTERY HITESTER	HIOKI	3554	150520162	3/30/2022	3/30/2023
376-032	Switching Power Supply	TEKPOWER	TP3010E	119486	VBU	VBU
162187.1	CONTROLLER/CHAMBER	WATLOW	F4	018909/01046092	12/13/2021	12/13/2022
162187P	ENVIRONMENTAL CHAMBER	ENVIROTRONICS	SSH32c-ac	01046092	VBU	VBU

**VBU = "Verified Before Use"*

SECTION 1

T1 – ALTITUDE SIMULATION

Date Received: 02/03/2022
Date(s) Tested: 02/25/2022 through 02/28/2022

Description of Samples:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- 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								
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	25	58.85	58.80	0.08	53144	53144	0.00	Pass
2	25	58.78	58.74	0.07	53180	53180	0.00	Pass
3	1	58.86	58.74	0.20	53184	53182	0.00	Pass
4	1	58.68	58.68	0.00	53236	53234	0.00	Pass

Appendix:

Appendix A – Photograph
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: 02/03/2022
Date(s) Tested: 03/08/2022 through 03/21/2022

Description of Samples:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- 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								
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	25	58.80	58.28	0.88	53144	53154	-0.02	Pass
2	25	58.74	58.21	0.90	53180	53174	0.01	Pass
3	1	58.74	58.00	1.26	53182	53192	-0.02	Pass
4	1	58.68	57.96	1.23	53234	53244	-0.02	Pass

Appendix:

Appendix A – Photograph
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: 02/03/2022
Date(s) Tested: 03/21/2022 through 03/23/2022

Description of Samples:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- 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	25	58.28	58.33	-0.09	53154	53150	0.01	Pass
2	25	58.21	58.26	-0.09	53174	53184	-0.02	Pass
3	1	58.00	58.05	-0.09	53192	53188	0.01	Pass
4	1	57.96	58.01	-0.09	53244	53238	0.01	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: 02/03/2022
Date(s) Tested: 03/24/2022

Description of Samples:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- 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 23.75g.

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	25	58.33	58.33	0.00	53150	53150	0.00	Pass
2	25	58.26	58.26	0.00	53184	53186	0.00	Pass
3	1	58.05	58.05	0.00	53188	53190	0.00	Pass
4	1	58.01	58.01	0.00	53238	53240	0.00	Pass

Appendices:
Appendix A – Photographs
Appendix E – Shock Plots

Disposition of Test Samples:
At the completion of testing, the samples continued to T5 – External Short Circuit.

SECTION 5

T5 – EXTERNAL SHORT CIRCUIT

Date Received: 02/03/2022
Date(s) Tested: 04/04/2022 through 04/08/2022

Description of Samples:
Four (4) 006008 Lithium-ion Battery Packs, sample numbers:

25 Cycles, 100% SOC
- SN 1
- SN 2

1 Cycle, 100% SOC
- SN 3
- SN 4

Purpose:
This test simulates an external short circuit.

Test Procedure:
The battery to be tested shall be heated for a period of time necessary to reach a homogenous stabilized temperature of 57°C ± 4°C, measured on the external case. This period of time depends on the size and design of the battery and should be assessed and documented. If this assessment is not feasible, the exposure time shall be at least twelve (12) hours for large batteries. Then the samples shall be subjected to a short circuit condition with a total external resistance of less than 0.1 Ohm at 57°C ± 4°C. This short circuit condition continued for one (1) hour after the sample's external case temperature returned to 57°C ± 4°C. The samples were observed for a further six (6) hours for the test to be concluded.

Actual pre-test measured resistance:
SN 1 = 0.2mΩ
SN 2 = 0.2mΩ
SN 3 = 0.3mΩ
SN 4 = 0.3mΩ

Acceptance Criteria:
Batteries meet this requirement if their external temperature does not exceed 170°C and there is no disassembly, no rupture and no fire within six hours of this test.

T5 – EXTERNAL SHORT CIRCUIT (cont'd)

Results:

Client provided test fixture containing two copper bars, a steel extender for the positive terminal, and 5 contactors in parallel. Sample voltage and temperature were monitored during test, but current was not able to be recorded. The test fixture was activated by powering the contactors with 24V 2.5A. Multiple contactors welded shut during each test and were replaced according to the document "Procedure To Replace a Shorted Contactor in The Battery Module Shorting Bar" provided by the client. Resistance was measured before each test.

Samples were exposed to a temperature of 57°C ± 4°C for 12 hours before being transferred to a non-temperature-controlled bunker for testing. As a result, the external case temperature at the start of test was less than 53°C, but the internal temperatures did not have sufficient time to cool down. The test samples conformed to the acceptance criteria; at the completion of testing the batteries' external temperature did not exceed 170°C and there was no disassembly, no rupture or fire within six hours of this test.

Appendices:

Appendix A – Photograph
Appendix F – External Short Circuit Graphs

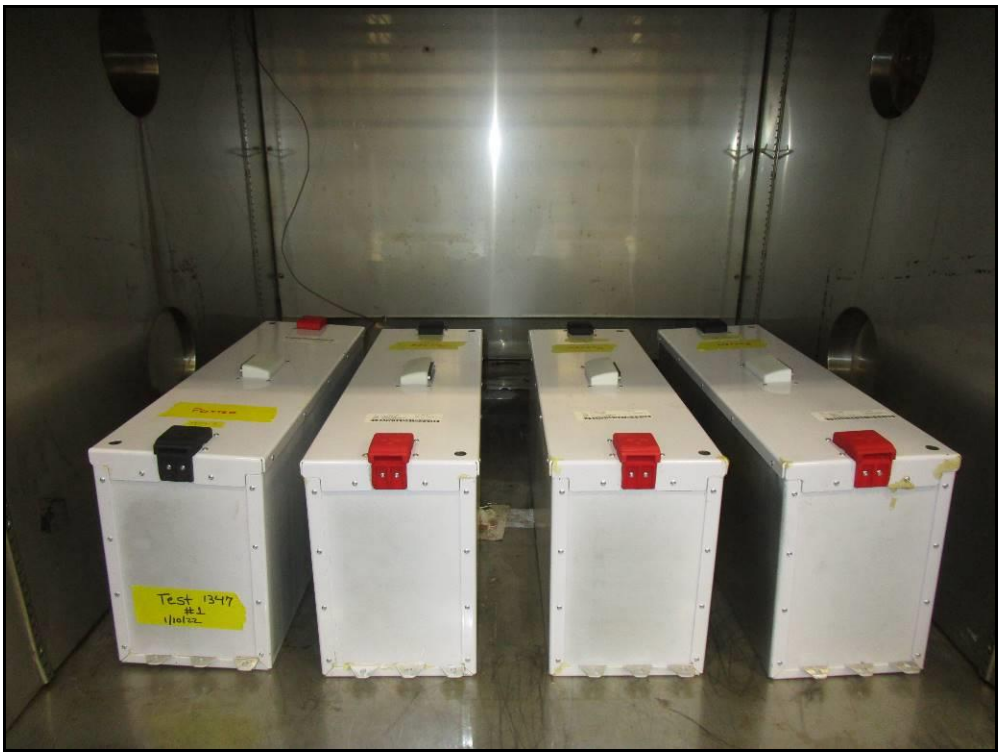
Disposition of Test Samples:

At the completion of testing, the samples were recycled.

APPENDIX A – PHOTOGRAPHS
T1 – Altitude Simulation

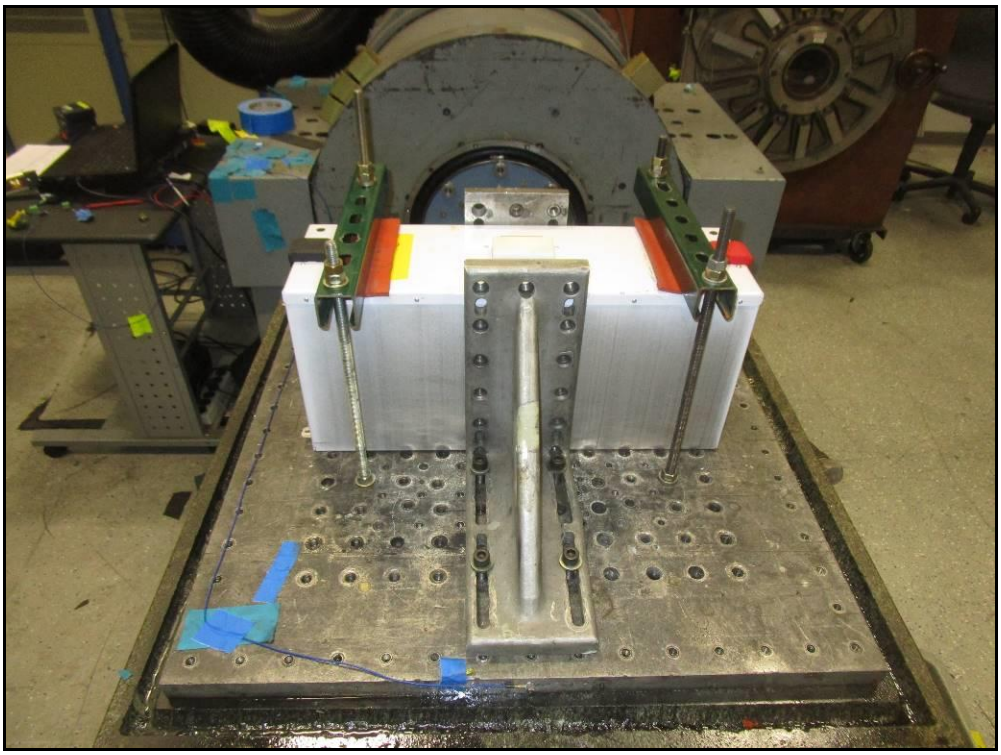
Photograph 1: Altitude Simulation Setup

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



Photograph 2: Thermal Test Setup

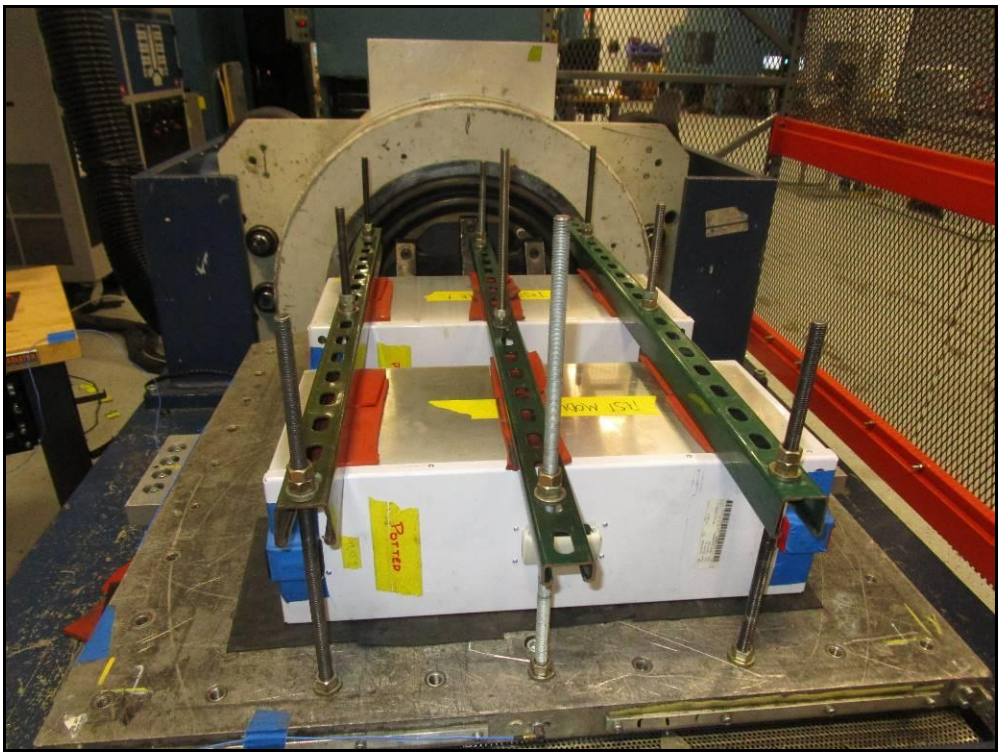
APPENDIX A – PHOTOGRAPHS (cont'd)
T3 – Vibration



Photograph 3: Vibration Test Setup – Fore/Aft Direction

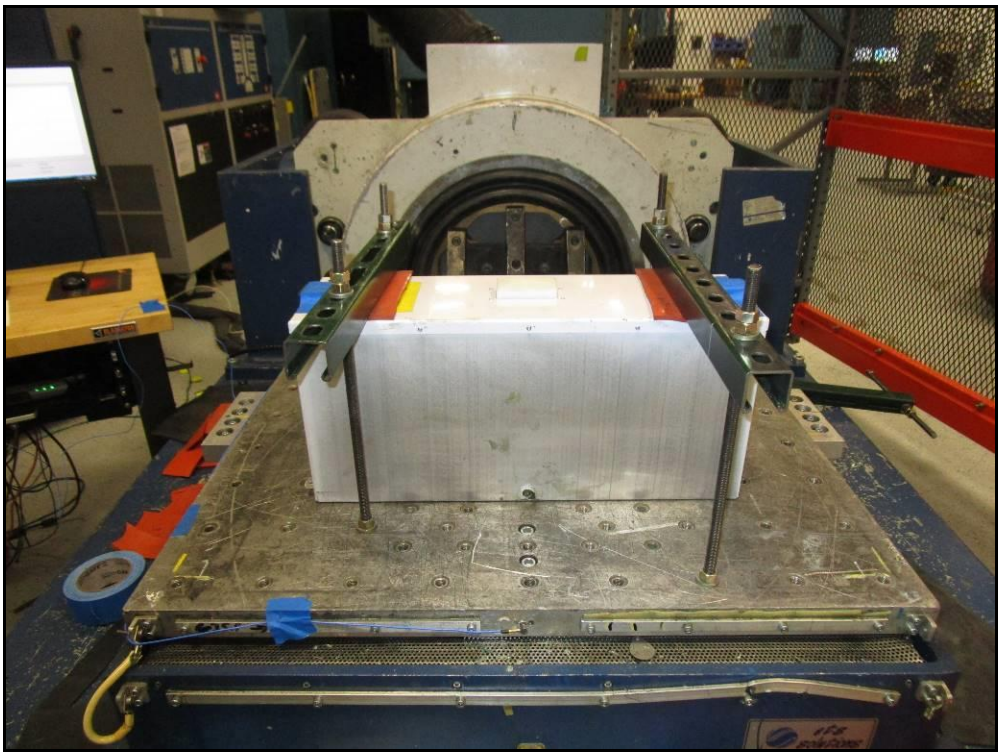
Photograph 4: Vibration Test Setup – Lateral Direction

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

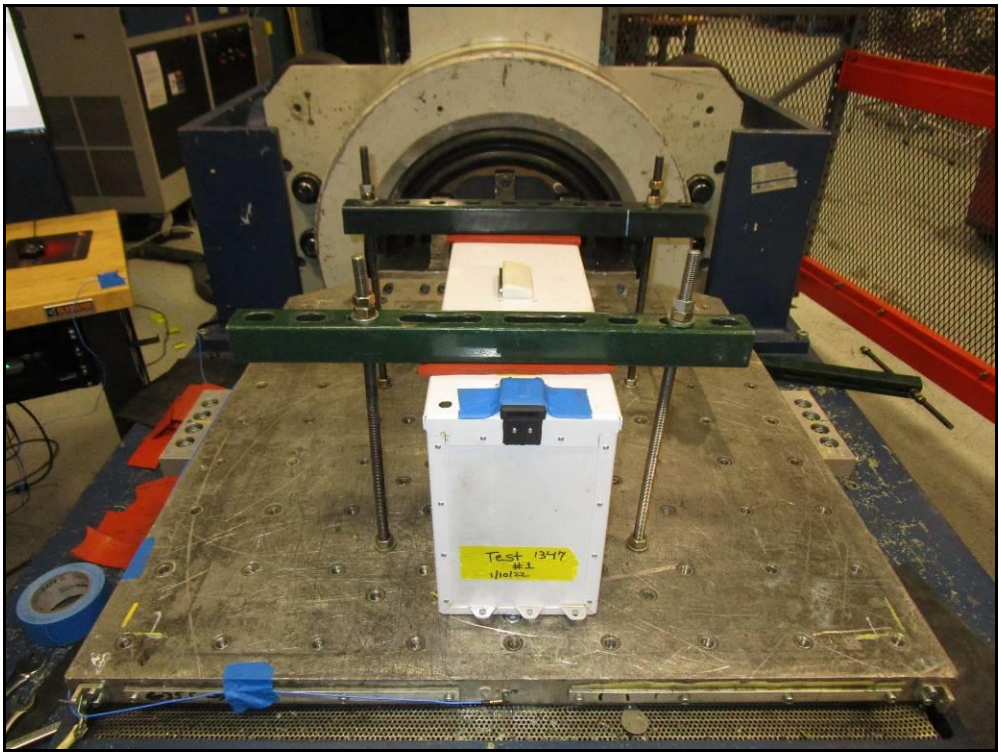


Photograph 5: Vibration Test Setup – Vertical Direction

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

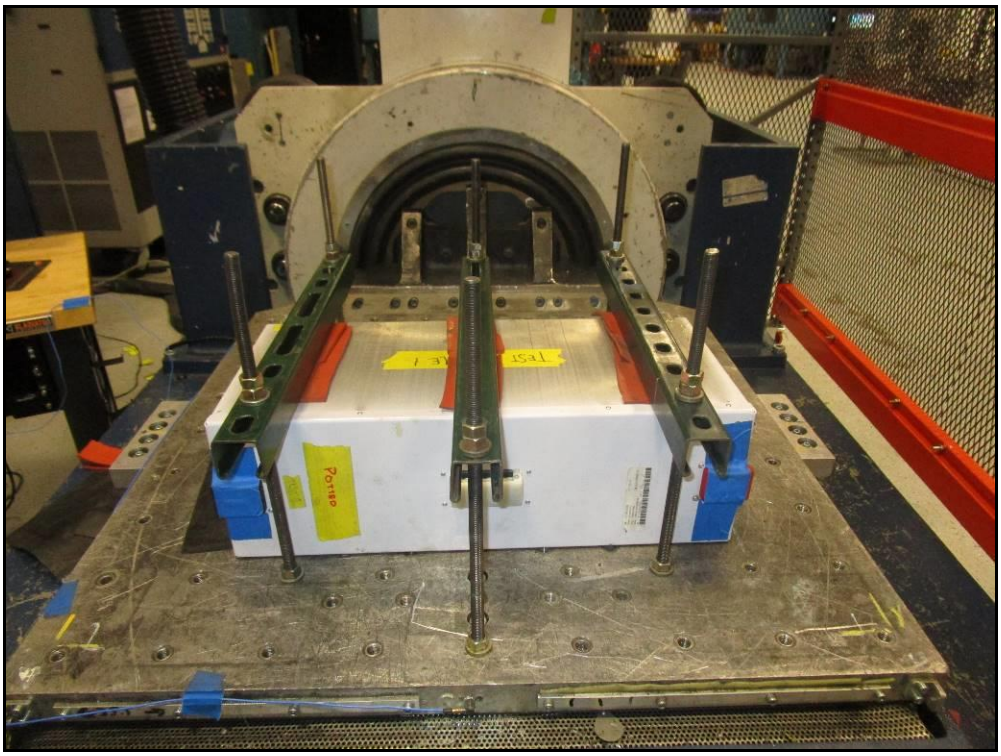


Photograph 6: Shock Test Setup –Fore/Aft, Positive and Negative Direction



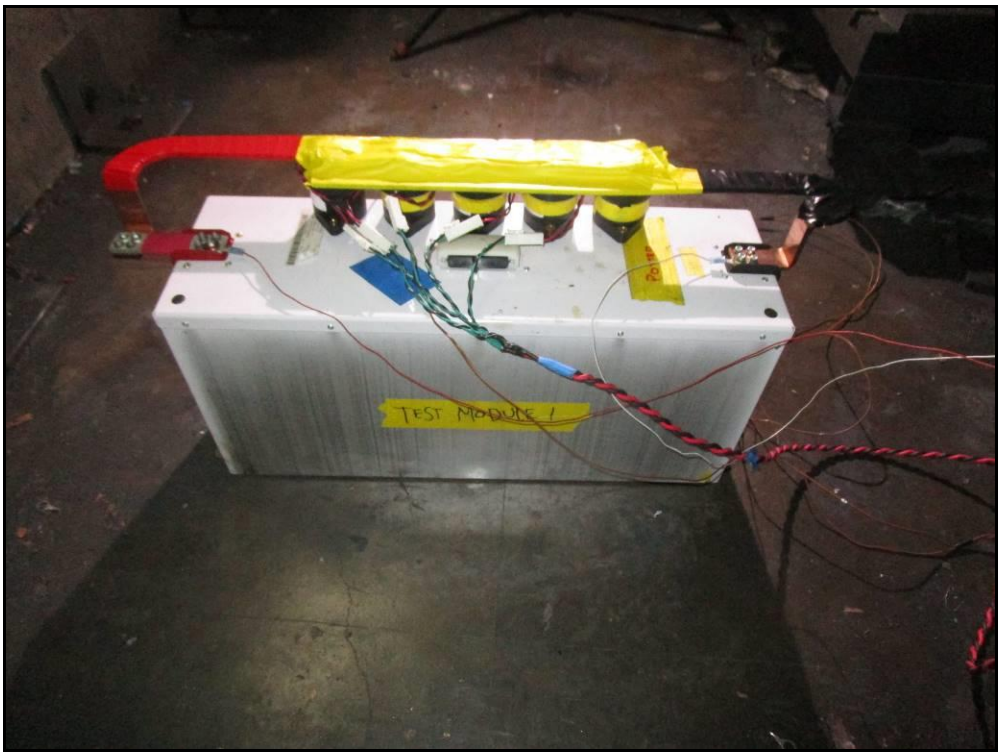
Photograph 7: Shock Test Setup – Lateral, Positive and Negative Direction

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

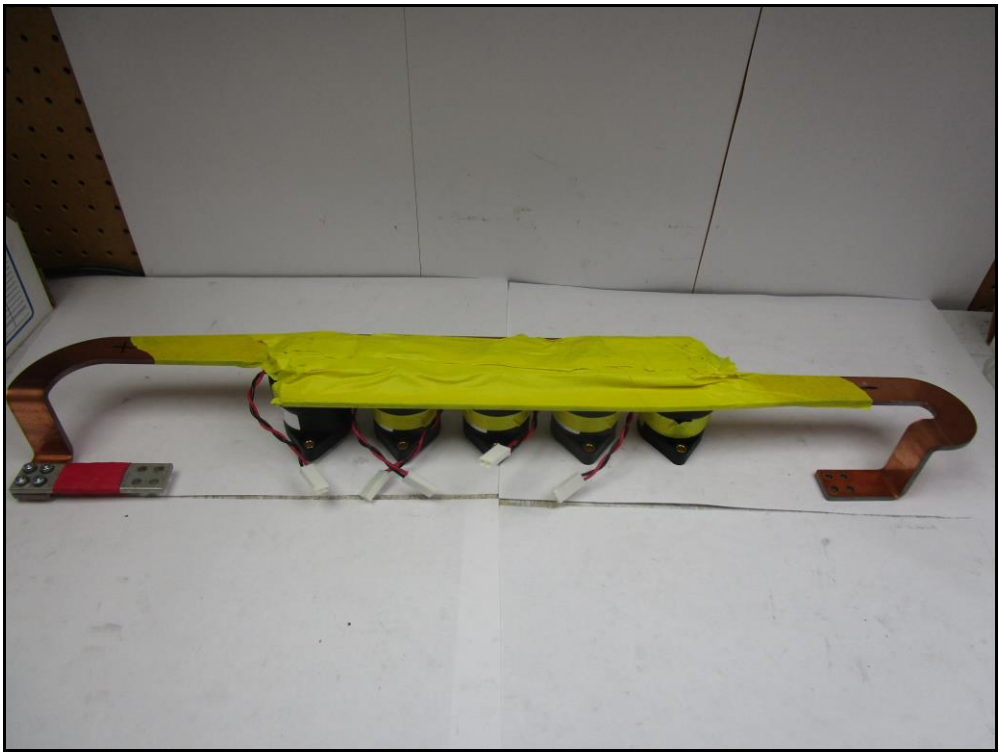


Photograph 8: Shock Test Setup – Vertical, Positive and Negative Direction

APPENDIX A – PHOTOGRAPHS (cont'd)
T5 – External Short Circuit



Photograph 9: External Short Circuit Test Setup



Photograph 10: Client Provided Shorting Bar

APPENDIX B
T1 – Altitude Simulation Graph

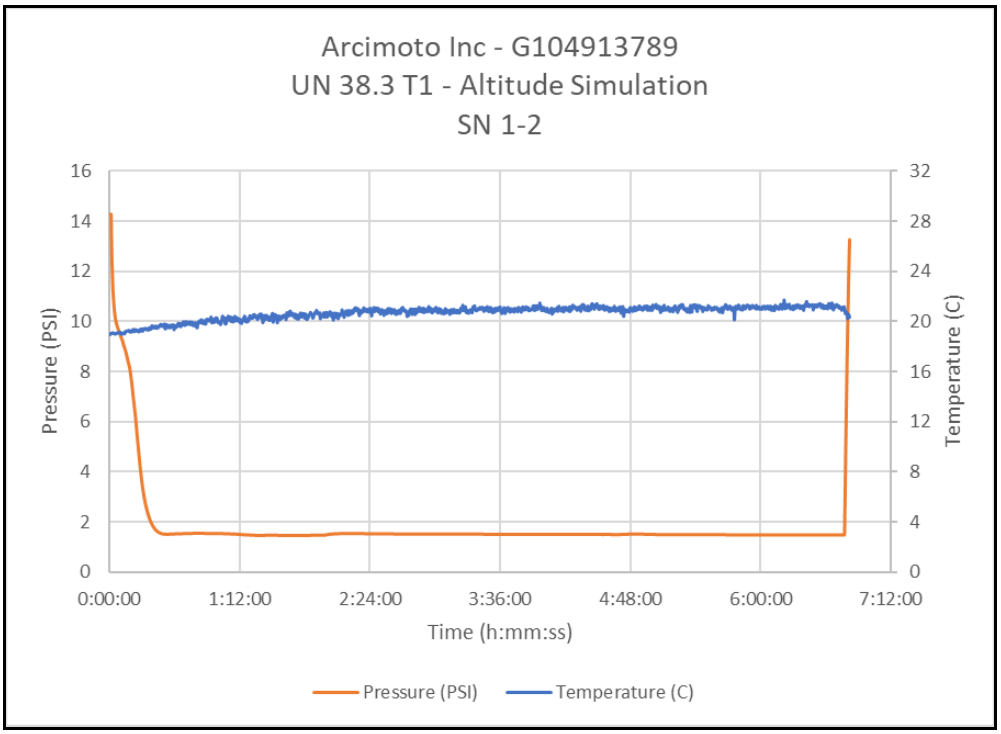


Figure 1: Altitude Simulation Graph; SN1-2

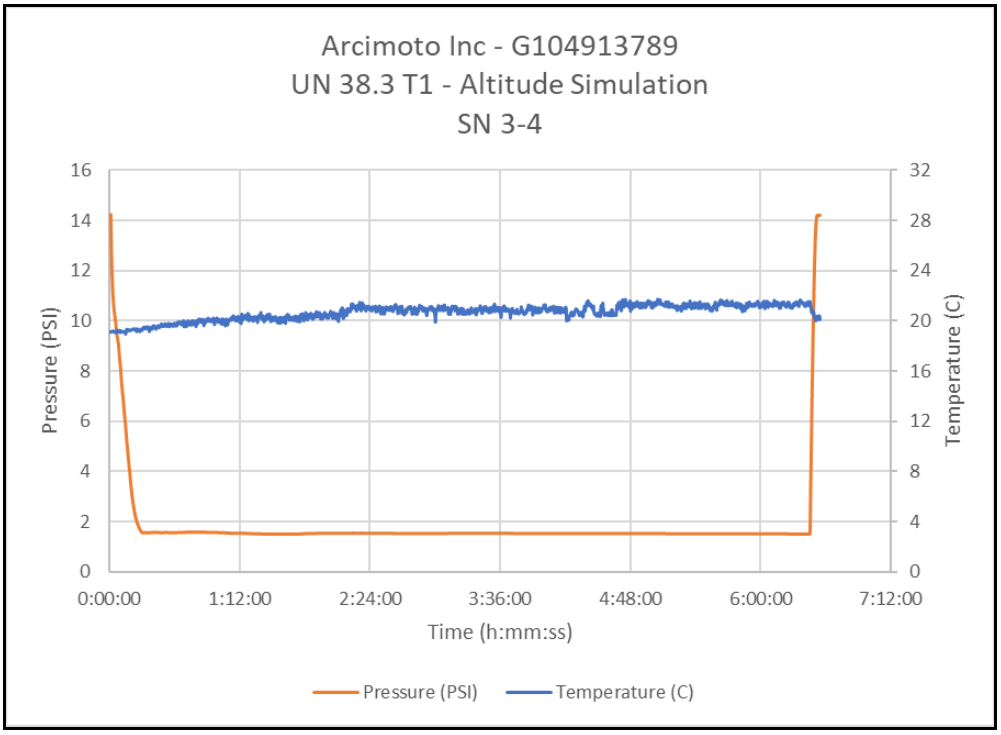


Figure 2: Altitude Simulation Graph; SN3-4

APPENDIX C
T2 – Thermal Test Graph

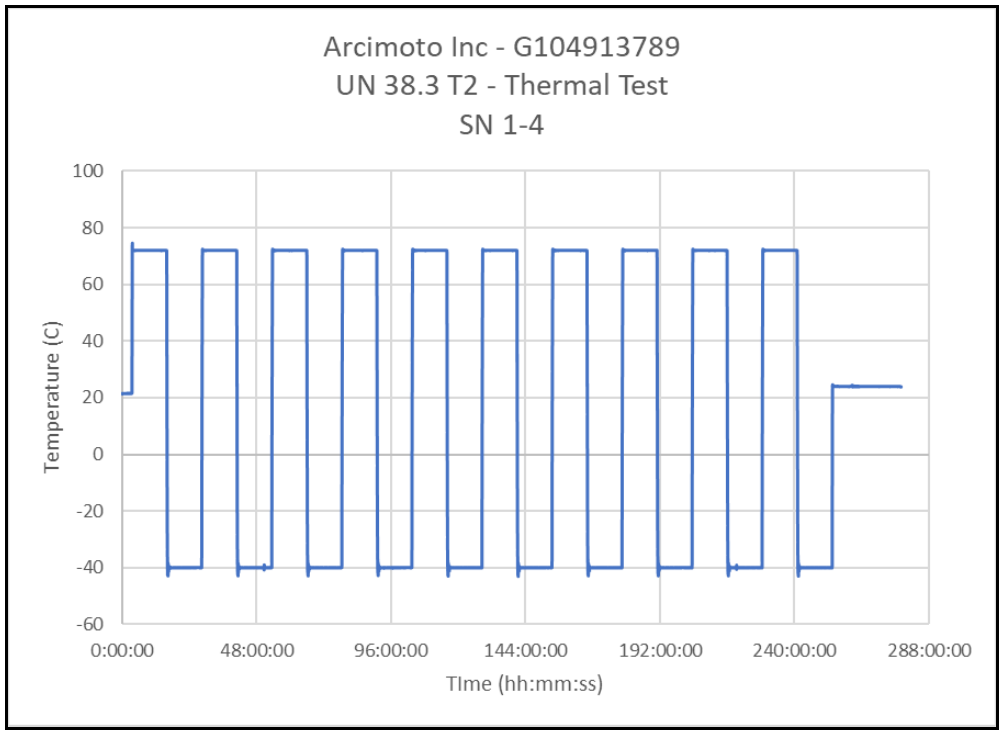


Figure 3: Thermal Test Graph

APPENDIX D
T3 – Vibration Plots

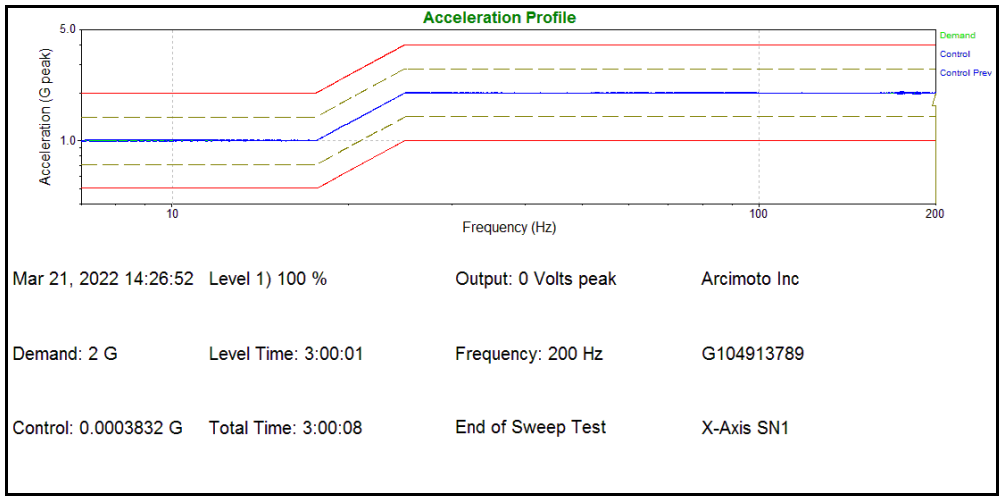


Figure 4: Vibration Plot – Fore/Aft Direction; SN1

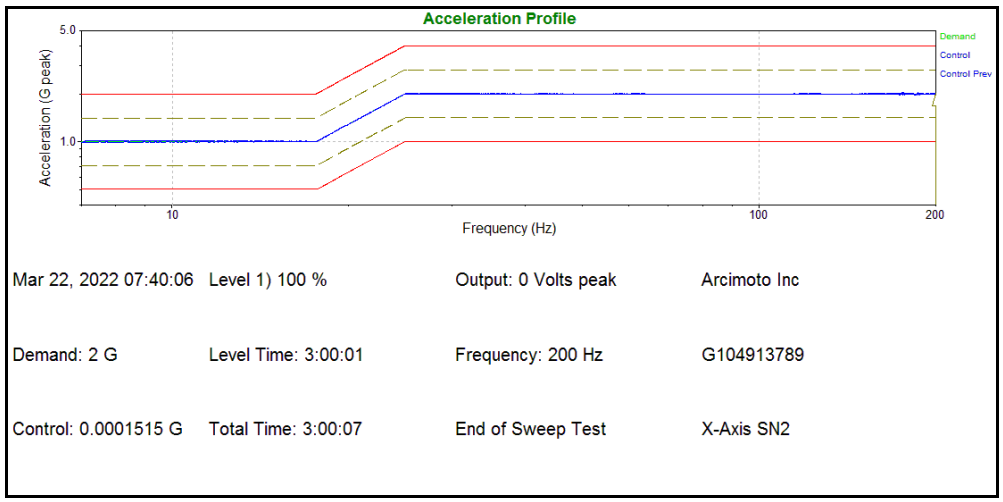


Figure 5: Vibration Plot – Fore/Aft Direction; SN2

APPENDIX D
T3 – Vibration Plots (cont'd)

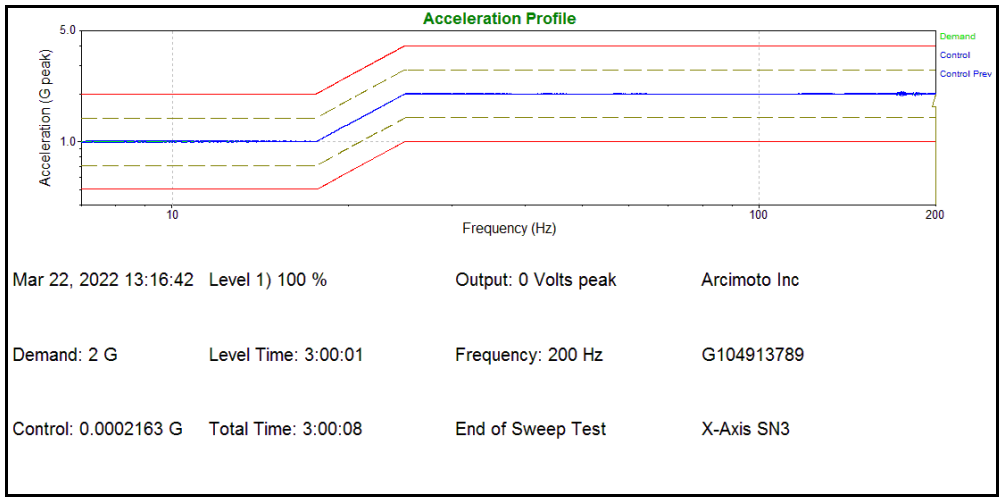


Figure 6: Vibration Plot – Fore/Aft Direction; SN3

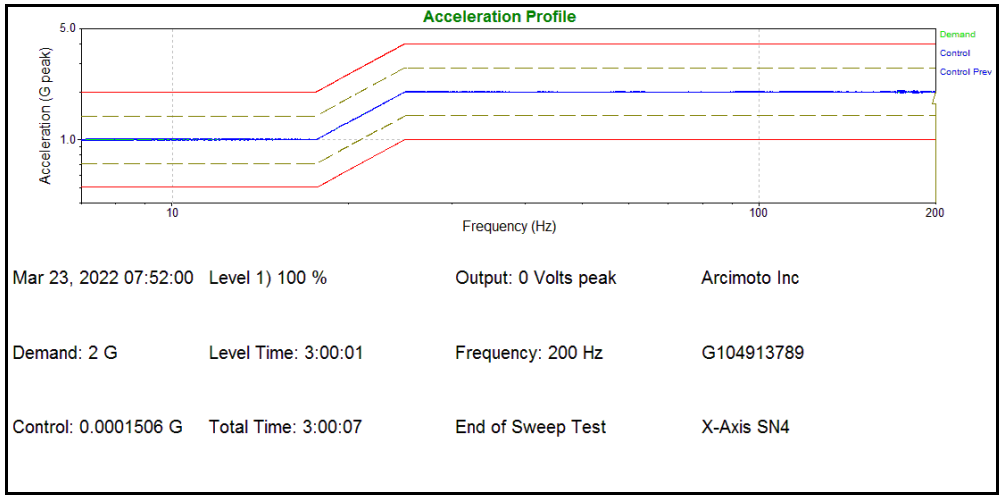


Figure 7: Vibration Plot – Fore/Aft Direction; SN4

APPENDIX D
T3 – Vibration Plots (cont'd)

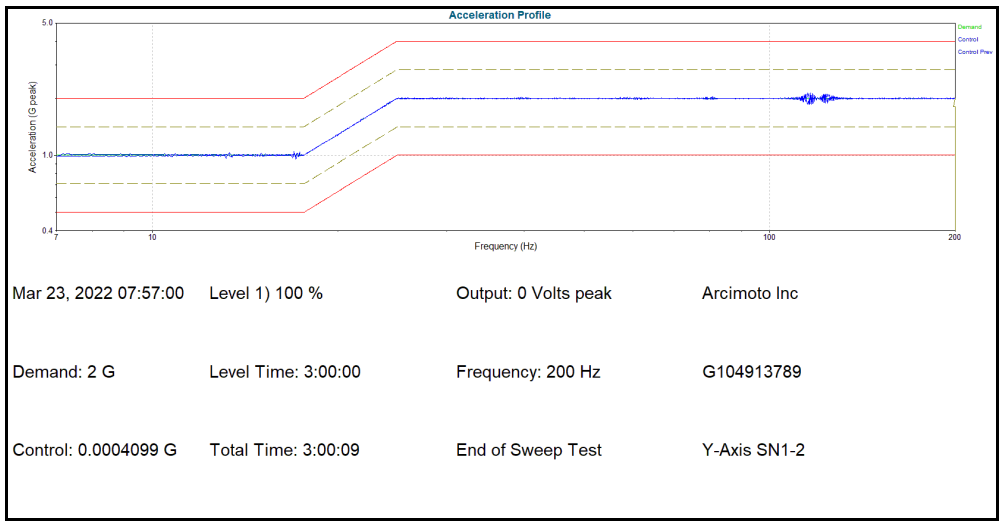


Figure 8: Vibration Plot – Lateral Direction; SN1-2

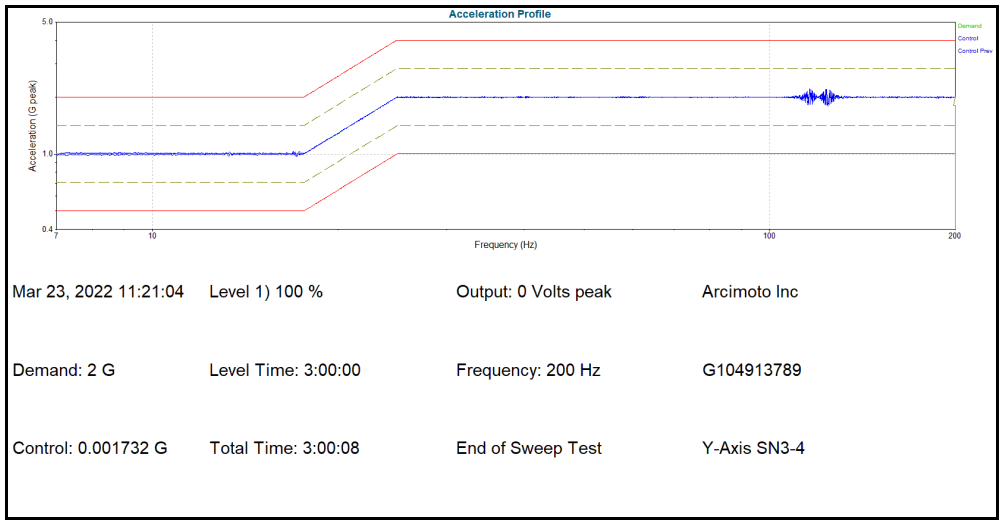


Figure 9: Vibration Plot – Lateral Direction; SN3-4

APPENDIX D
T3 – Vibration Plots (cont'd)

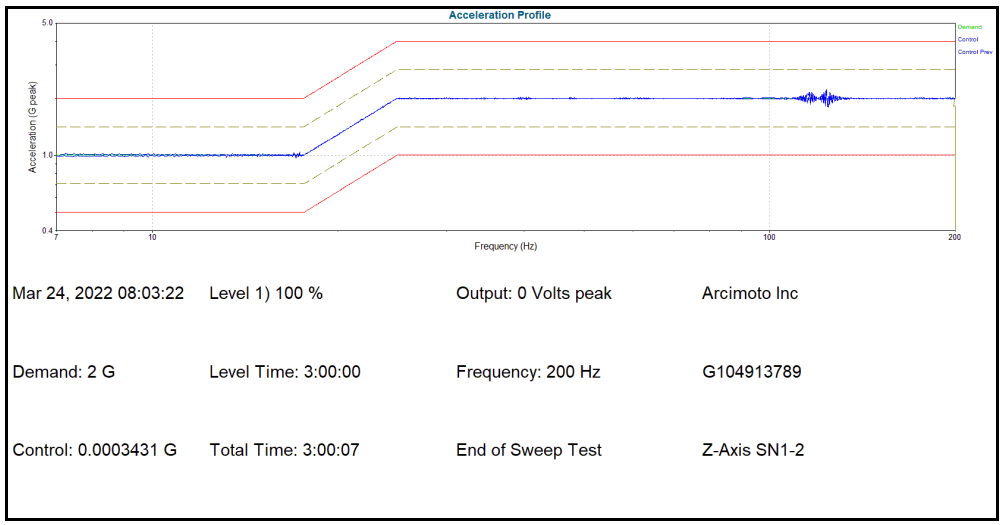


Figure 10: Vibration Plot – Vertical Direction; SN1-2

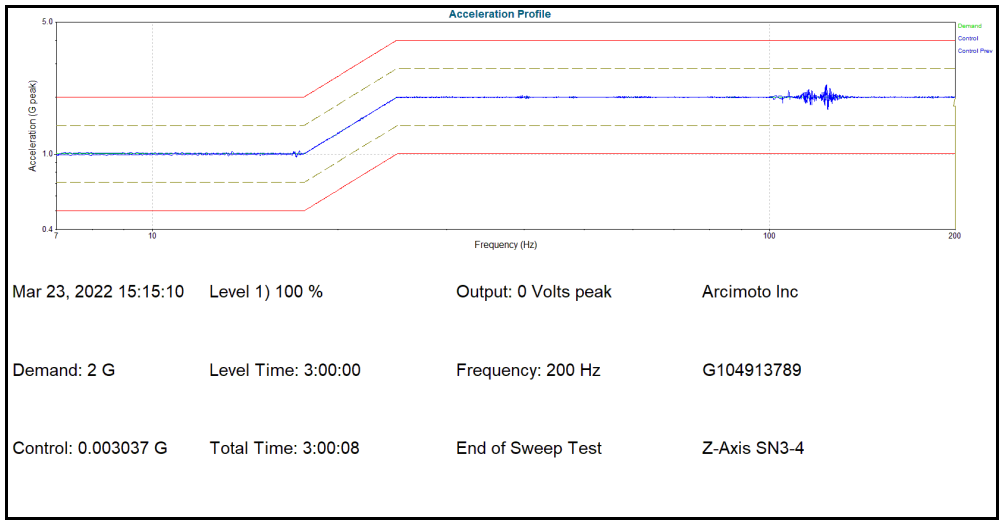


Figure 11: Vibration Plot – Vertical Direction; SN3-4

APPENDIX E
T4 – Shock Plots

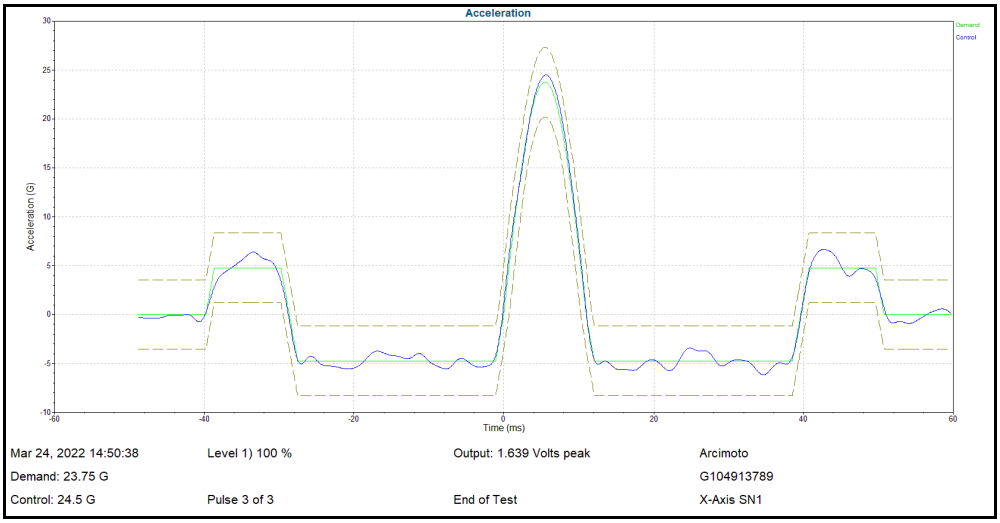


Figure 12: Shock Plot –Fore/Aft, Positive Direction; SN1

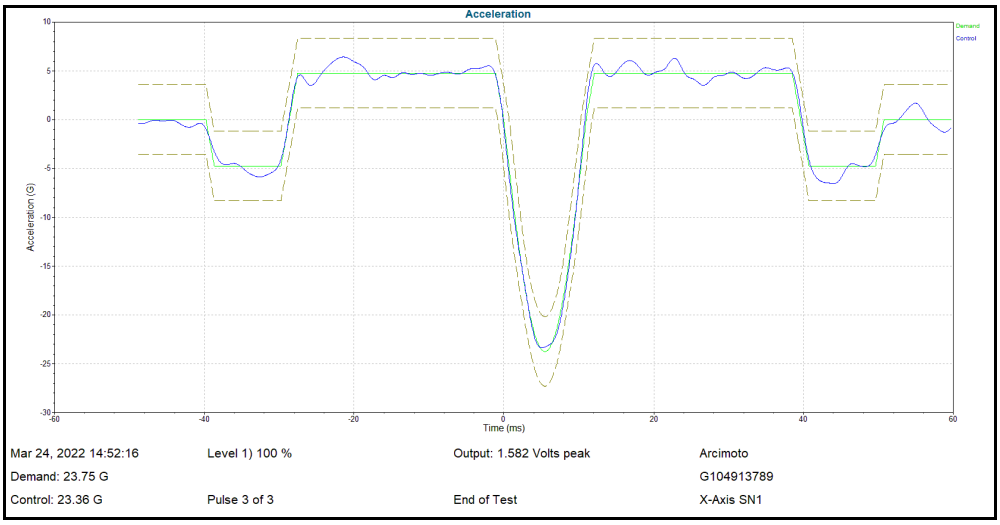


Figure 13: Shock Plot –Fore/Aft, Negative Direction; SN1

APPENDIX E
T4 – Shock Plots (cont'd)

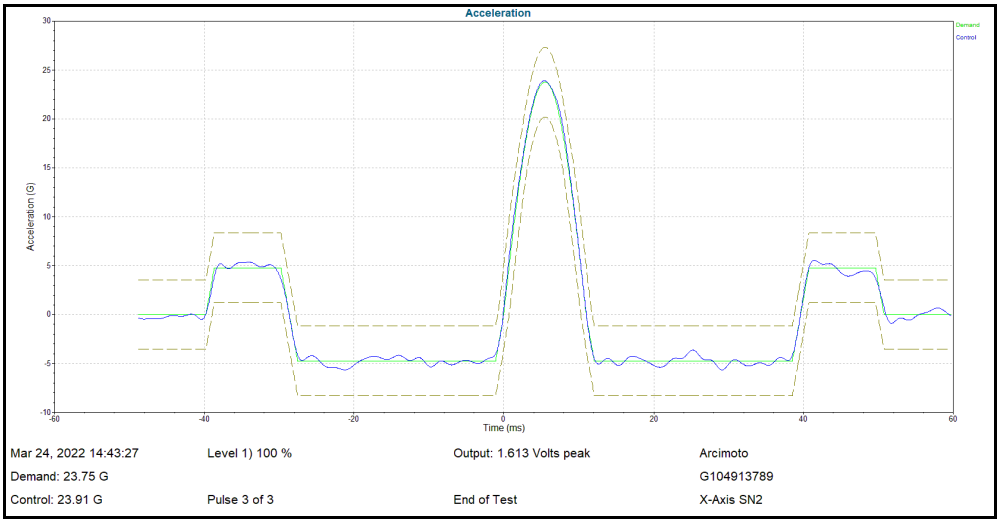


Figure 14: Shock Plot –Fore/Aft, Positive Direction; SN2

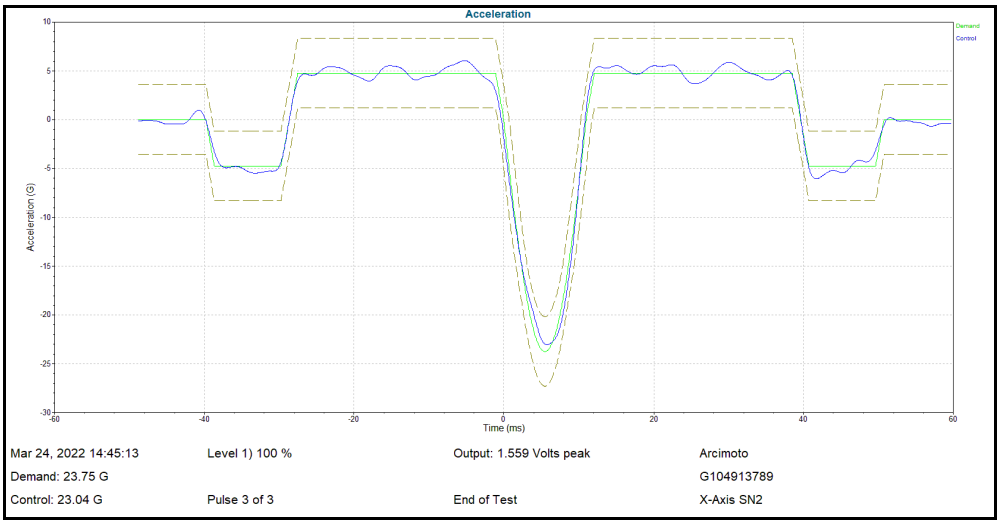


Figure 15: Shock Plot –Fore/Aft, Negative Direction; SN2

APPENDIX E
T4 – Shock Plots (cont'd)

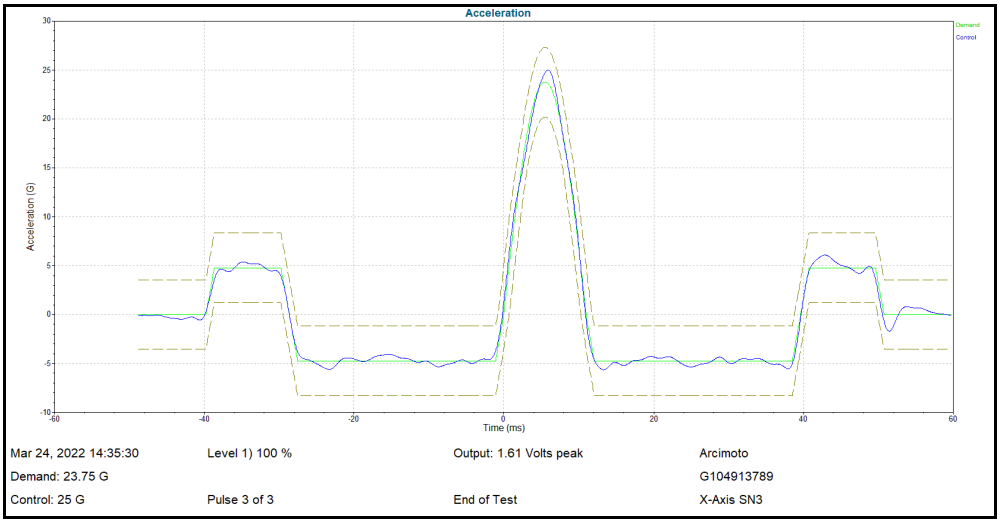


Figure 16: Shock Plot –Fore/Aft, Positive Direction; SN3

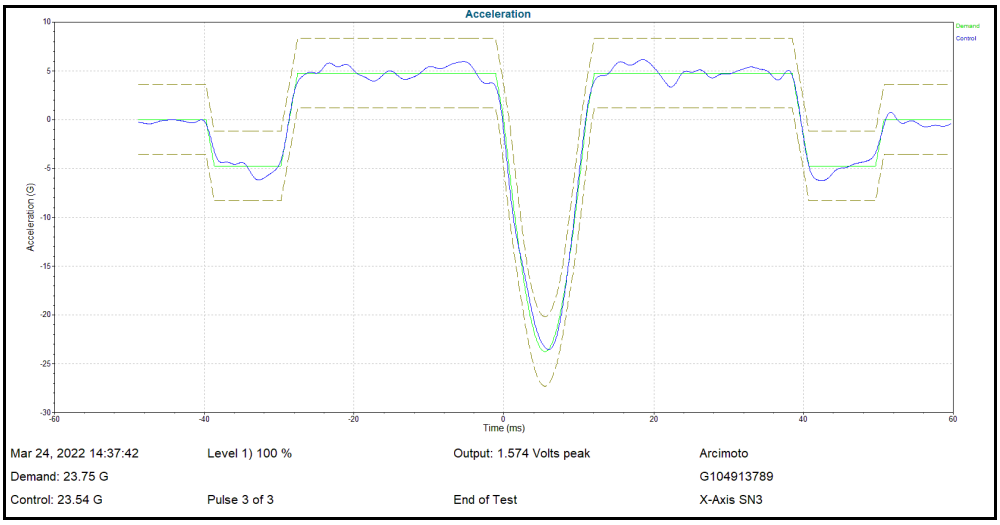


Figure 17: Shock Plot –Fore/Aft, Negative Direction; SN3

APPENDIX E
T4 – Shock Plots (cont'd)

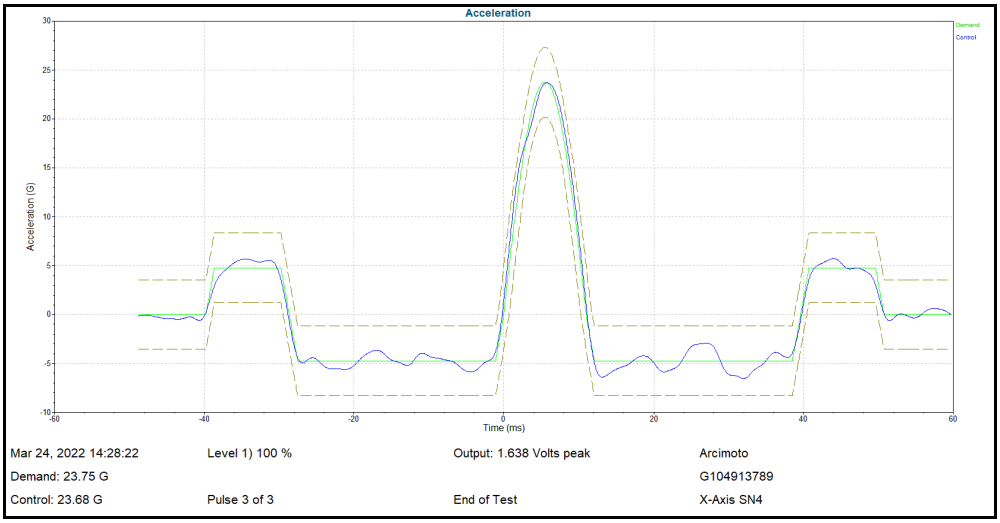


Figure 18: Shock Plot –Fore/Aft, Positive Direction; SN4

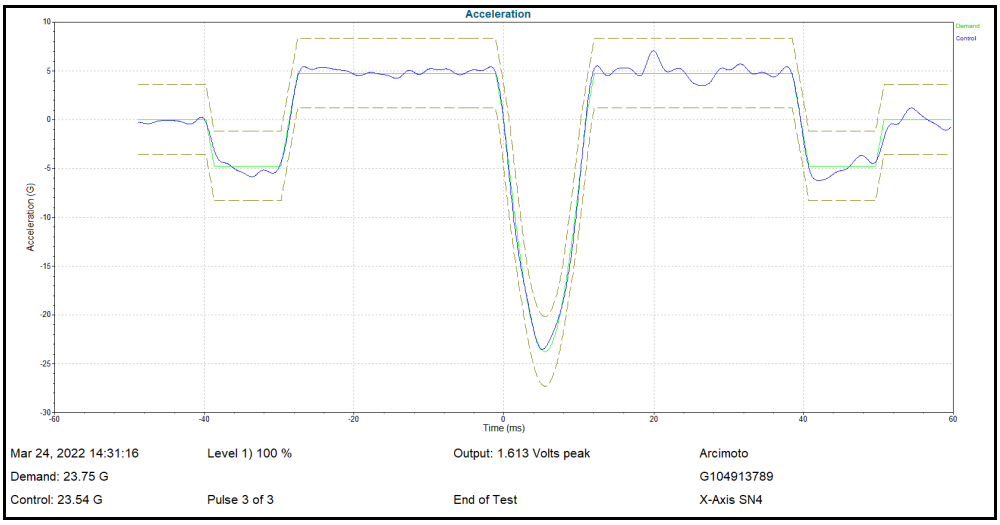


Figure 19: Shock Plot –Fore/Aft, Negative Direction; SN4

APPENDIX E
T4 – Shock Plots (cont'd)

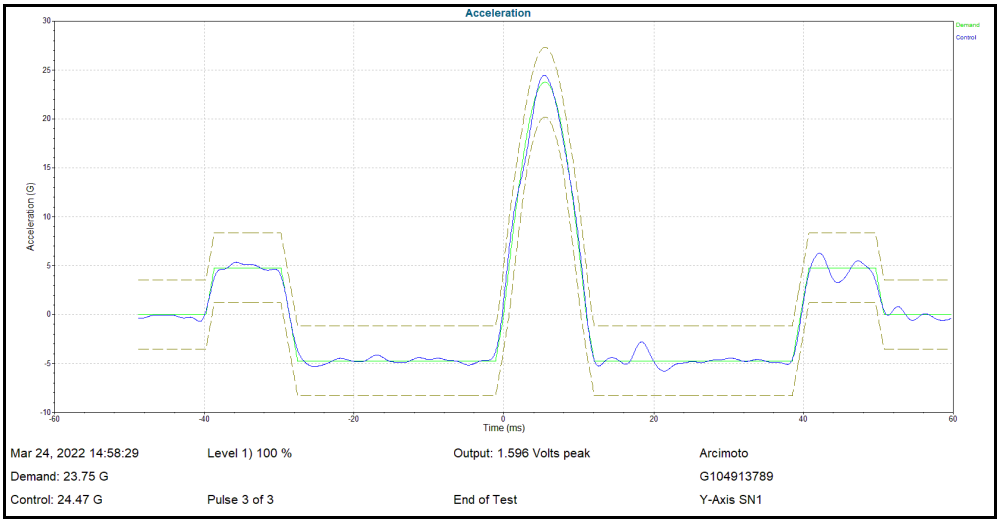


Figure 20: Shock Plot – Lateral, Positive Direction; SN1

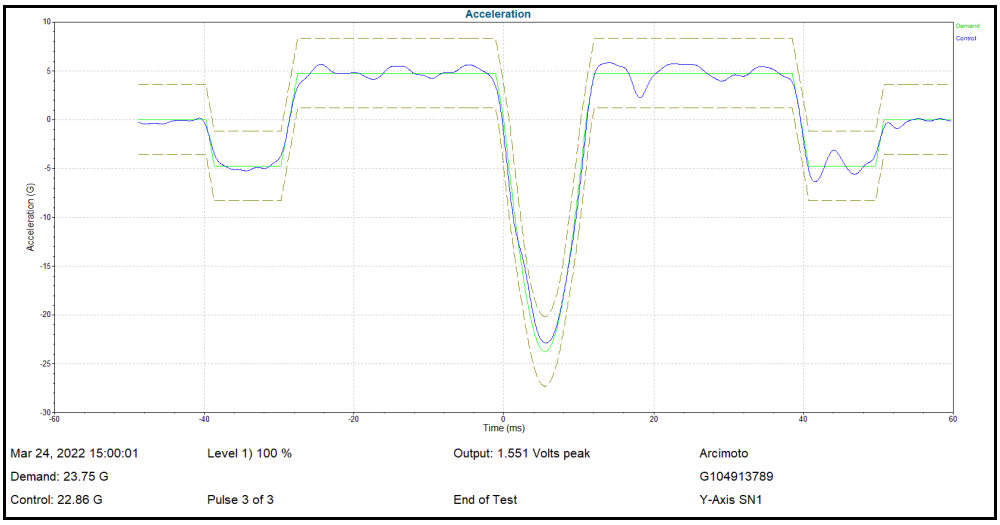


Figure 21: Shock Plot – Lateral, Negative Direction; SN1

APPENDIX E
T4 – Shock Plots (cont'd)

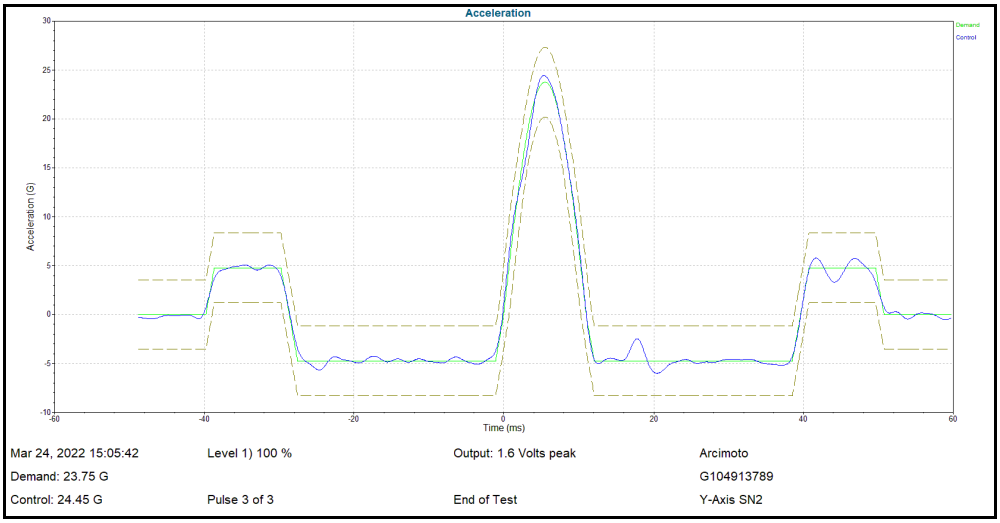


Figure 22: Shock Plot – Lateral, Positive Direction; SN2

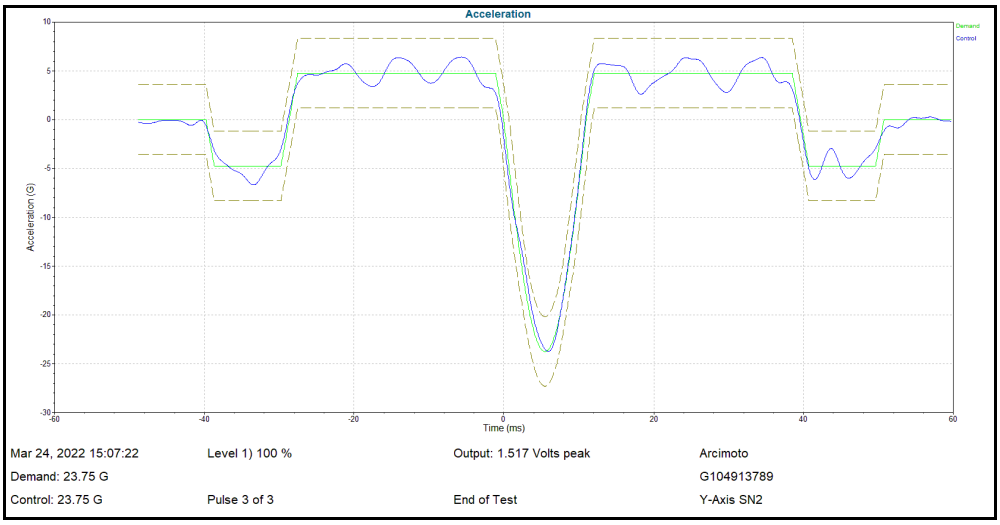


Figure 23: Shock Plot – Lateral, Negative Direction; SN2

APPENDIX E
T4 – Shock Plots (cont'd)

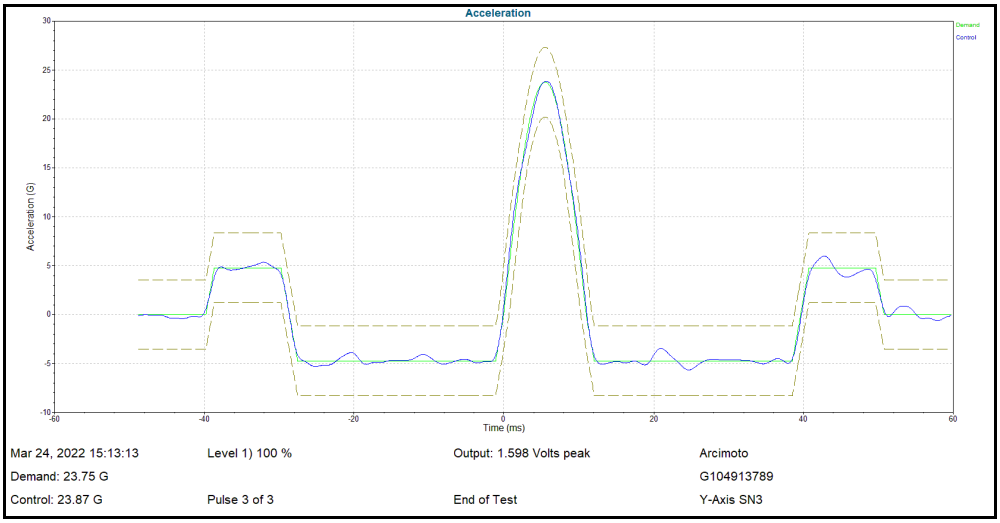


Figure 24: Shock Plot – Lateral, Positive Direction; SN3

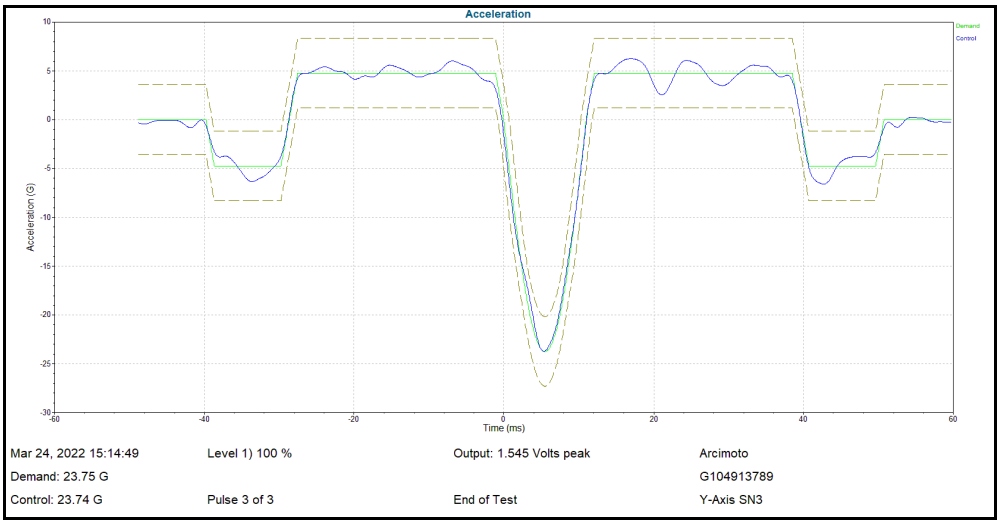


Figure 25: Shock Plot – Lateral, Negative Direction; SN3

APPENDIX E
T4 – Shock Plots (cont'd)

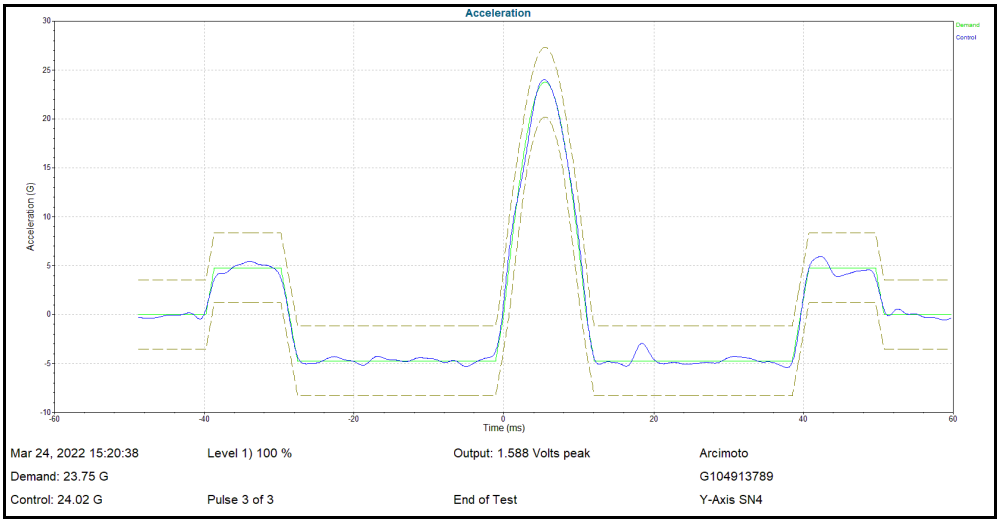


Figure 26: Shock Plot – Lateral, Positive Direction; SN4

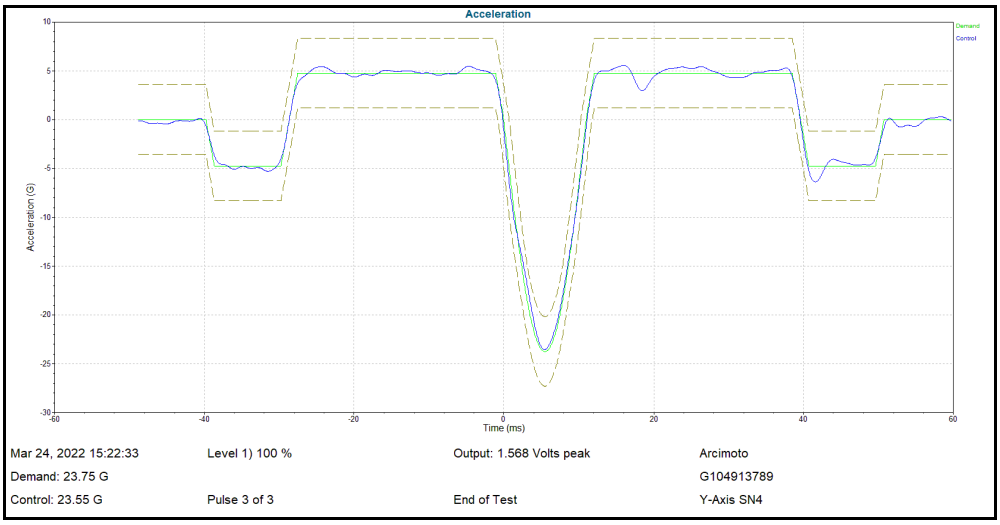


Figure 27: Shock Plot – Lateral, Negative Direction; SN4

APPENDIX E
T4 – Shock Plots (cont'd)

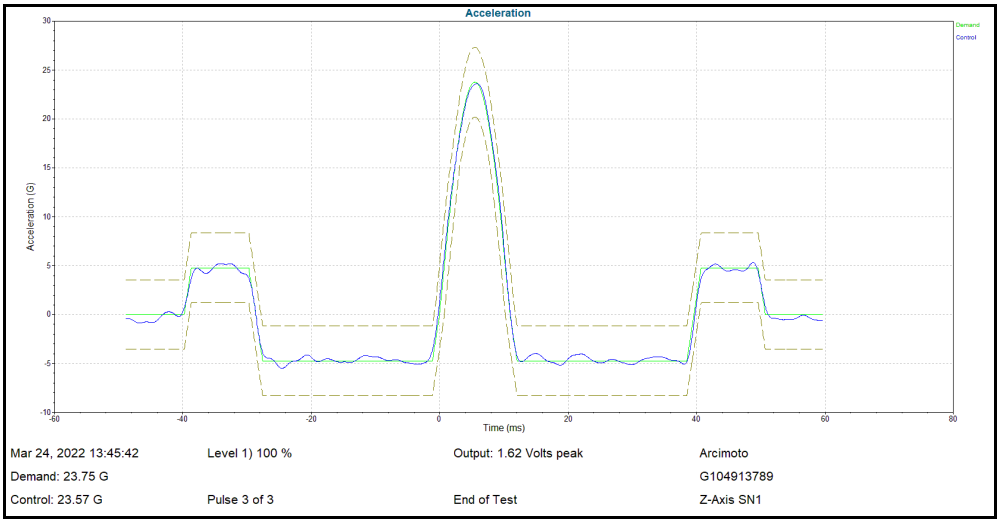


Figure 28: Shock Plot – Vertical, Positive Direction; SN1

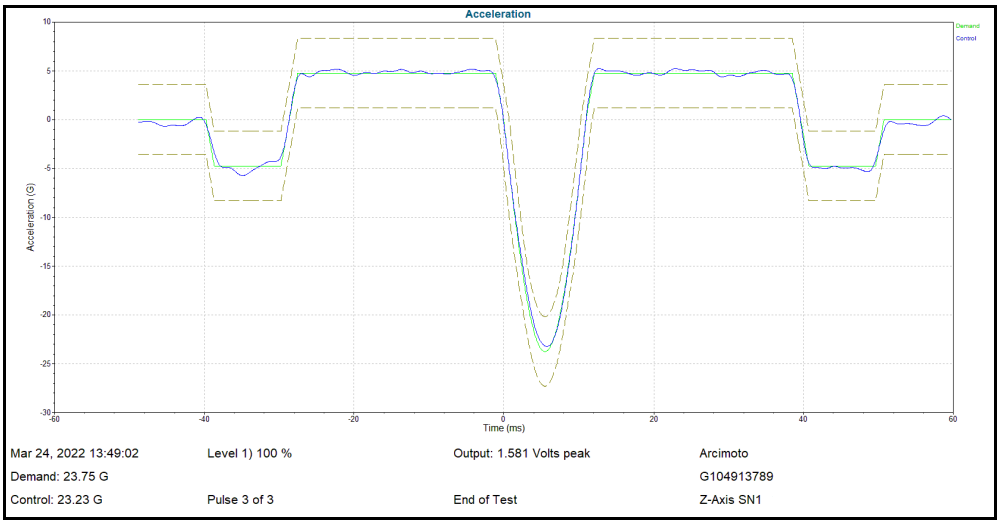


Figure 29: Shock Plot – Vertical, Negative Direction; SN1

APPENDIX E
T4 – Shock Plots (cont'd)

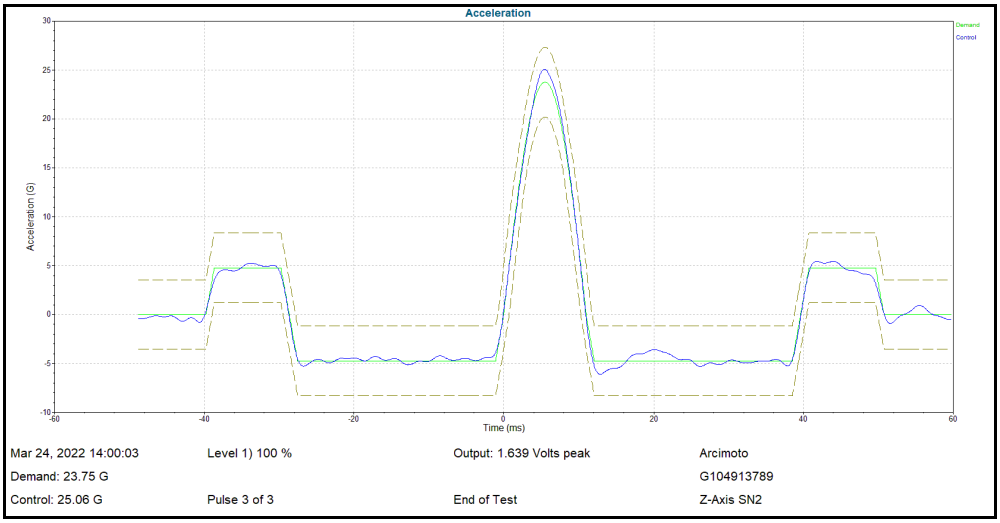


Figure 30: Shock Plot – Vertical, Positive Direction; SN2

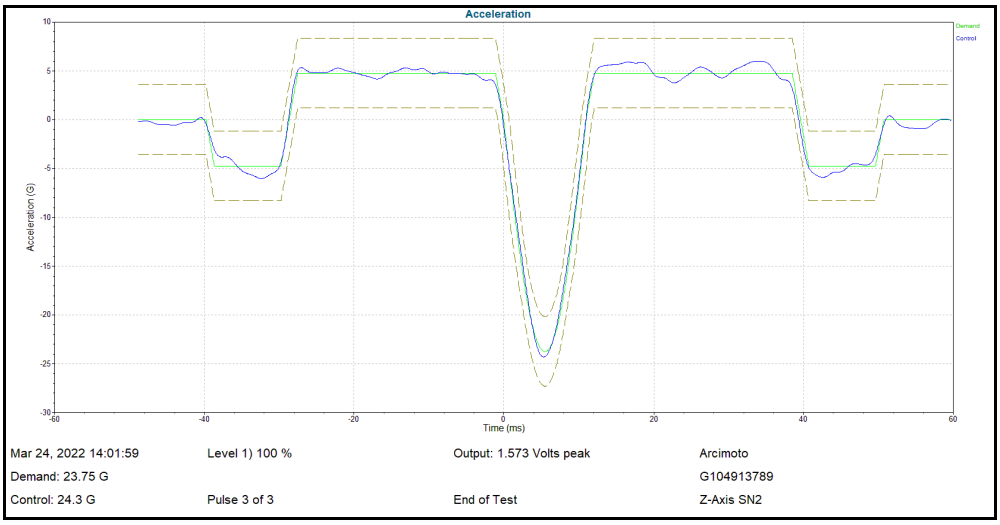


Figure 31: Shock Plot – Vertical, Negative Direction; SN2

APPENDIX E
T4 – Shock Plots (cont'd)

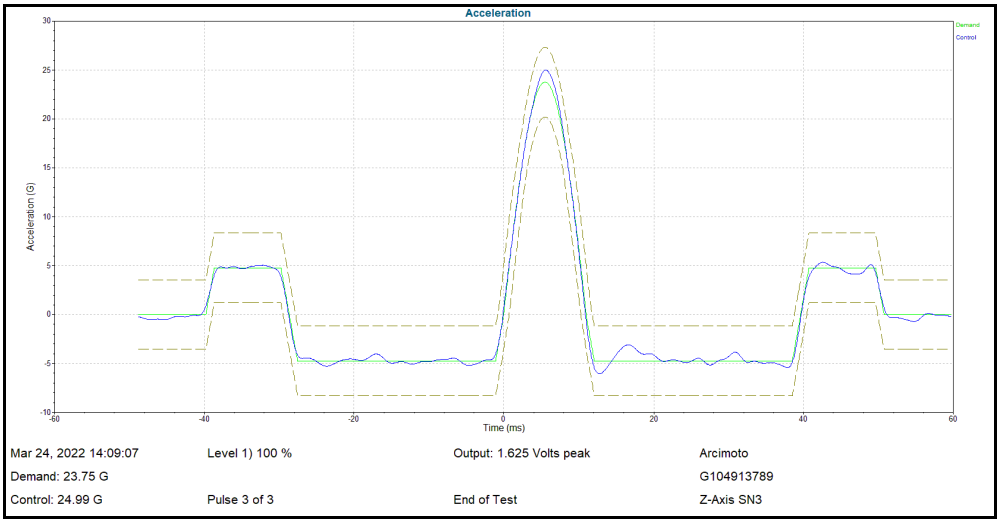


Figure 32: Shock Plot – Vertical, Positive Direction; SN3

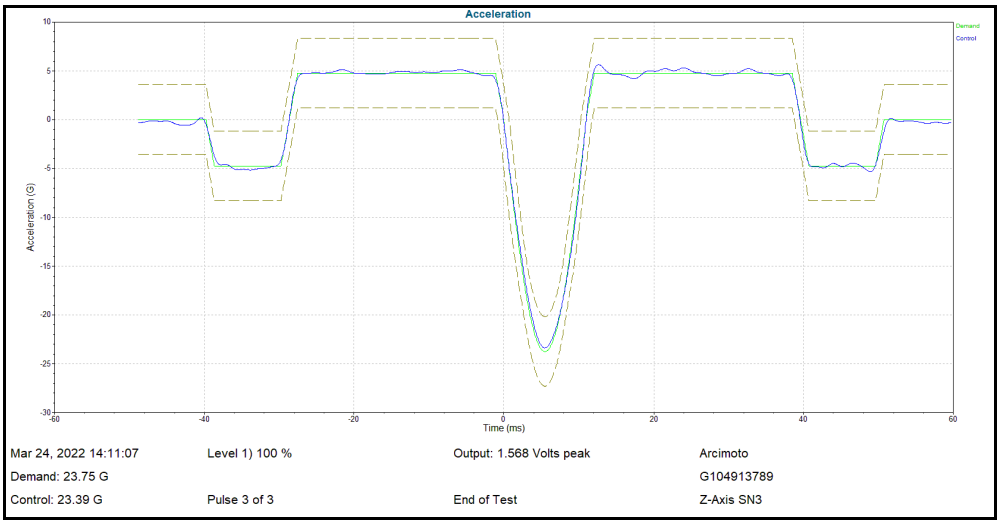


Figure 33: Shock Plot – Vertical, Negative Direction; SN3

APPENDIX E
T4 – Shock Plots (cont'd)

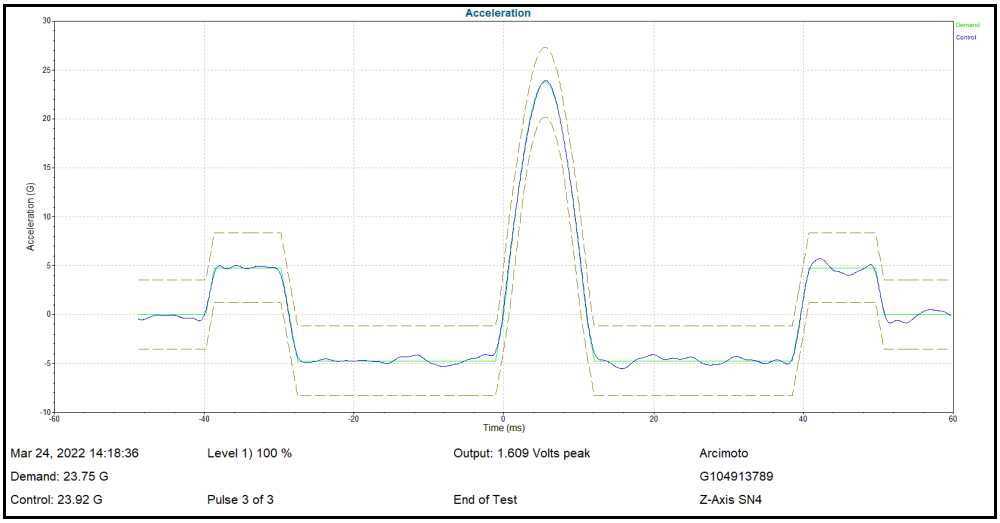


Figure 34: Shock Plot – Vertical, Positive Direction; SN4

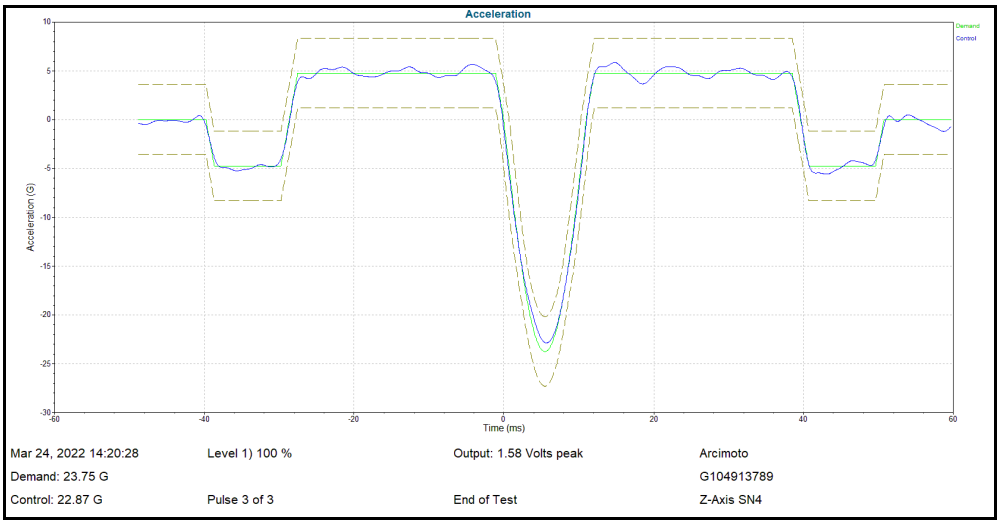


Figure 35: Shock Plot – Vertical, Negative Direction; SN4

APPENDIX F
T5 – External Short Circuit Graphs

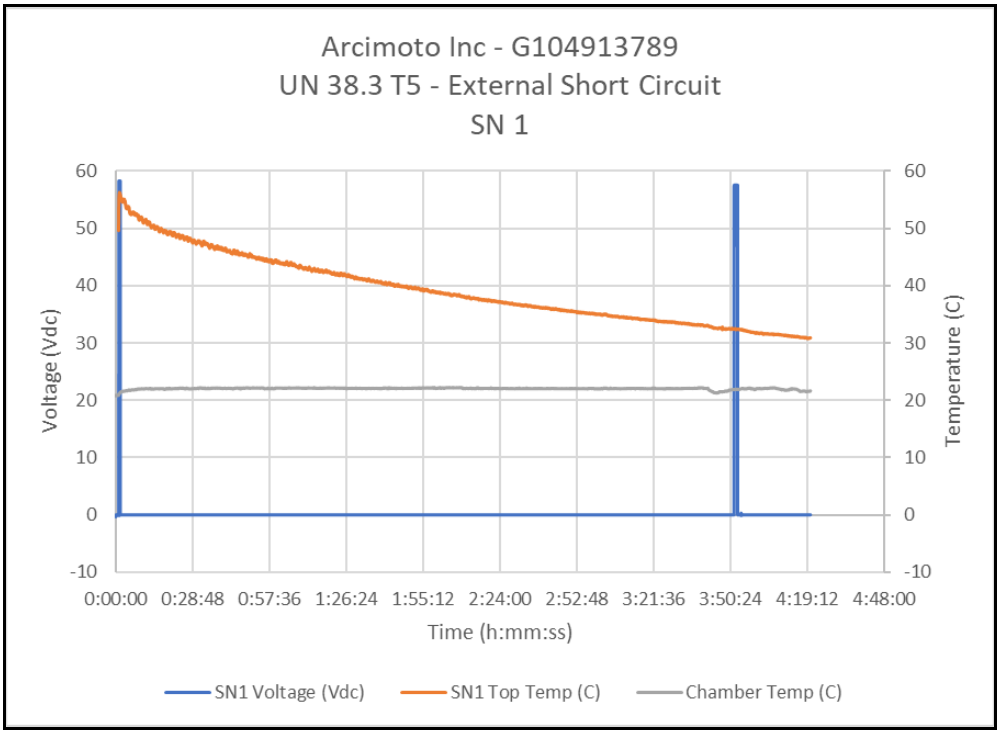


Figure 36: External Short Circuit Graph – Voltage / Temperature vs. Time; SN1

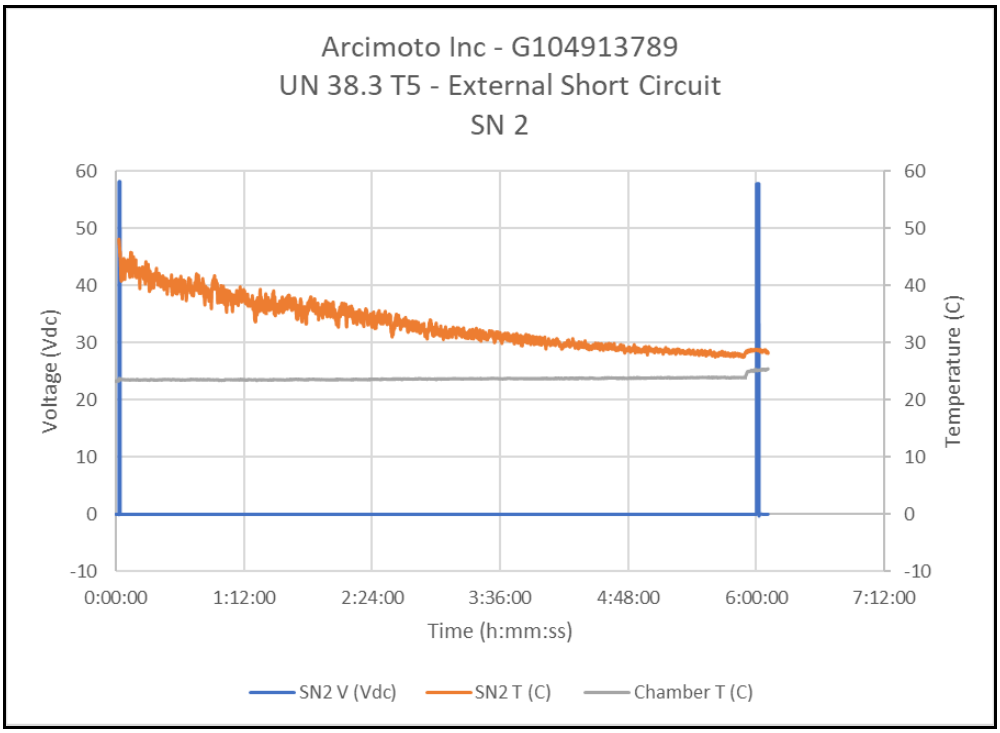


Figure 37: External Short Circuit Graph – Voltage / Temperature vs. Time; SN2

APPENDIX F
T5 – External Short Circuit Graphs (cont'd)

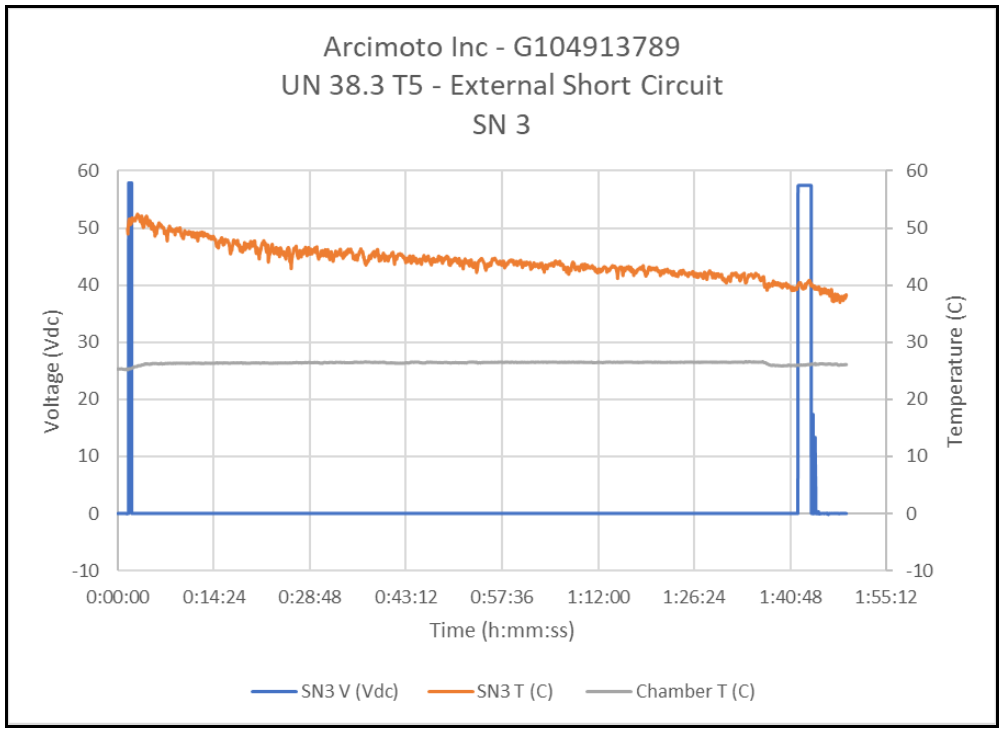


Figure 38: External Short Circuit Graph – Voltage / Temperature vs. Time; SN3

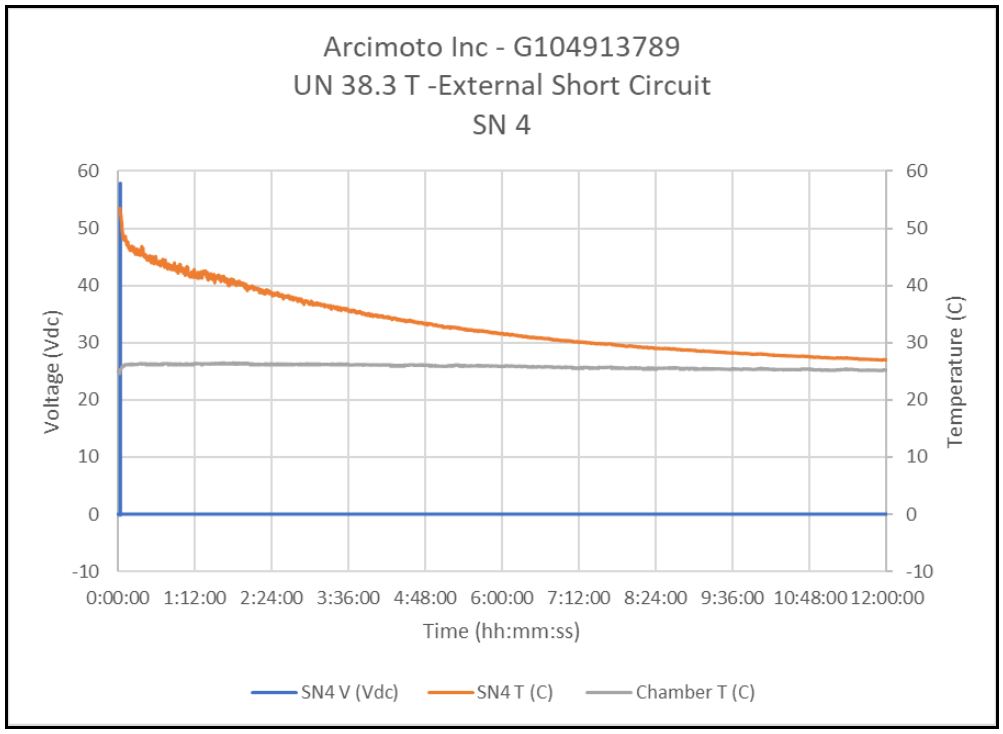


Figure 39: External Short Circuit Graph – Voltage / Temperature vs. Time; SN4