mga research corporation

Cadenza Innovation

UN Battery Testing

TP022-10

C18T1-237

ACCREDITED
Testing Laboratory
CERT# 1762.01

MGA Research Corporation - 12790 Main Road - Akron, NY 14001

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TEST REPORT

MGA REPORT NO.:	C18T1-237
TESTS PERFORMED ON:	October 10 - November 12, 2018
TEST DESCRIPTION:	UN Battery Testing
ITEM DESCRIPTION*:	Lithium-Ion Prismatic Cells
PROCEDURE NUMBER:	TP022-10
TEST LABORATORY:	MGA Research Corporation 12790 Main Road Akron, NY 14001
SUBMITTED TO:	Nino Paldan Cadenza Innovation 1 Duracell Drive, Suite A-102 Bethel, CT 06801
REPORT WRITTEN BY:	Mark Waliszewski: Test Technician
DATE:	November 12, 2018
REPORT REVIEWED BY:	Robert Comfort: Test Technician
DATE:	November 12, 2018

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

ACCREDITED
Testing Laboratory
CERT# 1762.01

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C18T1-237

1.0 TEST SUMMARY

Test Conducted and Completion Date:	October 10 - November 12, 2018
Test Conducted For:	Cadenza Innovation
Test Performed By:	Mark Waliszewski Steve Abramowski Rob Comfort James Williams
MGA File Number:	C18T1-237
Test Specification:	UN Battery Testing Per UN Rev. 6, Sections 38.3.4.1 - 38.3.4.5
Test Specimen Data:	Lithium-Ion Prismatic Cells Model: 83Ah S/N's: See Appendix A
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 Cadenza Innovation

2.0 PROGRAM

2.1 T1 ALTITUDE

2.1.1 Test Requirements

In accordance with the recommendations given forth by the Transportation of Dangerous Goods Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.1; Test 1: Altitude Simulation.

2.1.2 Test Procedure

Ten (10) lithium-ion prismatic cells, were at a pressure of less than 11.6 kPa for a minimum of six (6) hours at ambient temperature (20 ± 5 ºC).

2.1.3 Test Results

Ten (10) lithium-ion prismatic cells did not have mass or voltage loss. They did not leak, vent, disassemble, rupture, or catch fire as a result of testing. There was no visible damage. All ten (10) lithium-ion prismatic cells passed the requirements stated in the UN Transportation of Dangerous Goods Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.1; Test 1: Altitude Simulation.

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

2.2 T2 THERMAL

2.2.1 Test Requirements

In accordance with the recommendations given forth by the Transportation of Dangerous Goods Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.2; Test 2: Thermal Test.

2.2.2 Test Procedure

Ten (10) lithium-ion prismatic cells were stored for at least six (6) hours at a temperature of 72 ± 2 ºC, followed by at least six (6) hours at a temperature of -40 ± 2 ºC. The maximum rate of temperature change was thirty (30) minutes. This sequence was repeated ten (10) times. The modules were then stored for twenty-four (24) hours at ambient temperature (20 ± 5 ºC).

2.2.3 Test Results

Ten (10) lithium-ion prismatic cells did not have mass or voltage loss. They did not leak, vent, disassemble, rupture, or catch fire as a result of testing. There was no visible damage. All ten (10) lithium-ion prismatic cells passed the requirements stated in the UN Transportation of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.2; Test 2: Thermal Test. During the testing of both beginning of life units and end of life units, the orange plastic covers warped slightly resulting in the inability to stay properly attached

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

2.3 T3 VIBRATION

2.3.1 Test Requirements

In accordance with the recommendations given forth by the Transportation of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.3; Test 3: Vibration.

2.3.2 Test Procedure

Ten (10) lithium-ion prismatic cells were fastened to an electrodynamic shaker 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 the three mutually perpendicular axes.

The logarithmic frequency sweep was as follows: from 7 Hz, a peak acceleration of g_n 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 g_n occurred (approximately 50 Hz). A peak acceleration of 2 g_n was then maintained until the frequency was increased to 200 Hz.

2.3.3 Test Results

Ten (10) lithium-ion prismatic cells did not have mass or voltage loss. They did not leak, vent, disassemble, rupture, or catch fire as a result of testing. There was no visible damage. All ten (10) lithium-ion prismatic cells passed the requirements stated in the UN Transportation of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.3; Test 3: Vibration.

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

2.4 T4 MECHANICAL SHOCK

2.4.1 Test Requirements

In accordance with the recommendations given forth by the Transportation of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.4; Test 4: Shock.

2.4.2 Test Procedure

Ten (10) lithium-ion prismatic cells were fastened to a drop tower and subjected to a half sine shock with a peak acceleration of 50g and pulse duration of eleven (11) milliseconds. The units under test received three (3) shocks in the positive and negative directions in each of the three (3) orthogonal axes for a total of eighteen (18) shocks.

2.4.3 Test Results

Ten (10) lithium-ion prismatic cells did not have mass or voltage loss. They did not leak, vent, disassemble, rupture, or catch fire as a result of testing. There was no visible damage. All ten (10) lithium-ion prismatic cells passed the requirements stated in the UN Transportation of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.4; Test 4: Shock.

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

2.5 T5 EXTERNAL SHORT CIRCUIT

2.5.1 Test Requirements

In accordance with the recommendations given forth by the Transport of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.5; Test 5: External Short Circuit.

2.5.2 Test Procedure

Ten (10) lithium-ion prismatic cells external case temperatures were stabilized at 57 ± 4 ºC, before being subjected to a short circuit condition with a total external resistance of less than 2 milliohms, measured prior to testing at 1.58 milliohms. After the case temperatures returned to 57 ± 4 ºC, the short circuit continued for an hour. After an additional six (6) hours of observation, the testing was concluded.

2.5.3 Test Results

Ten (10) lithium-ion prismatic cells external case temperatures did not exceed 170 ºC. They did not disassemble, rupture, or catch on fire as a result of testing. There was no visible damage. All ten (10) lithium-ion prismatic cells passed the requirements stated in the UN Transport of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.5; Test 5: External Short Circuit.

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

2.6 T6 Crush

2.6.1 Test Requirements

In accordance with the recommendations given forth by the Transport of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.6; Test 6: Crush.

2.6.2 Test Procedure

Five (5) lithium-ion prismatic cells were crushed between two flat surfaces. Crushing was performed gradually at a speed of approximately 1.5 cm/s at the first point of contact and was continued until one of the following end points was reached:

a) The applied force reached 13 kN ± 0.78 kN.
b) The voltage of the cell dropped by at least 100 mV.
c) The cell was deformed by 50% or more of its original thickness.

2.6.3 Test Results

Five (5) lithium-ion prismatic cells were tested until reaching the aforementioned force limit. All cells experienced minimal deformation, but did not experience significant voltage loss, significant temperature increase, leakage, venting, or flame as a result of this testing.

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

2.7 T8 Forced Discharge

2.7.1 Test Requirements

In accordance with the recommendations given forth by the Transport of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.8; Test 8: Forced Discharge.

2.7.2 Test Procedure

Twenty (20) lithium-ion prismatic cells were forcefully discharged at ambient temperature by connecting them in series with a 12 Volt D.C. power supply at an initial current equal to the maximum discharge current as specified by the manufacturer: 166A. Each cell was forcefully discharged for a time interval (in hours) equal to its rated capacity divided by the initial test current (in Amperes): 0.5 hours.

2.7.3 Test Results

Twenty (20) lithium-ion prismatic cells did not experience disassembly or catch fire as a result of the testing. There was no visible damage. All twenty (20) cells passed the requirements stated in the UN Transport of Dangerous Goods, Manual of Test and Criteria, Sixth Revised Edition, Section 38.3.4.8; Test 8: Forced Discharge.

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	79III	69530878	2/12/2018	2/12/2019	36.01-03
2	Multimeter/DAS	Hioki	LR8400-20	140307931	6/27/2018	6/27/2019	36.13-03
3	Multimeter/DAS	Hioki	LR8400-20	150347151	5/30/2018	5/30/2019	36.13-05
4	Pressure Transducer	Omega	PX409-015V5V	414719	1/22/2018	1/22/2019	23.13-14
5	Vacuum Pump	Gast	2567-V108	113938173	UWCE	N/A	23.01-02
6	Vacuum Chamber	National Appliance Co.	5851	4-82-1711-135	UWCE	N/A	27.18-01
7	Temperature Chamber	Thermotron	F32-CHV-15-15	852716	1/26/2018	1/26/2019	27.02-01
8	Vibration/Shock Controller	Crystal Instruments	Spider-81	1011072	4/25/2018	4/25/2019	24.03-01
9	Vibration/Shock Controller	Crystal Instruments	Spider-80X	2592576	9/26/2018	9/26/2019	24.03-02
10	Electrodynamic Shaker	Unholtz-Dickie	T 208	309	UWCE	N/A	24.04-06
11	Electrodynamic Shaker	Unholtz-Dickie	T1002	264	UWCE	N/A	24.04-04
12	Shunt	Ram Meter	3000A50MV	N/A	6/22/2018	6/22/2019	97.05-02
13	Temperature Chamber	Blue M/Lindburg	MO1440A	U02J-442974-UJ	8/1/2018	N/A	27.06-04
14	Accelerometer	PCB	353A04	2674	3/9/2018	3/9/2019	02.07-13
15	Accelerometer	PCB	352C68	124918	4/5/2018	4/5/2019	02.07-39
16	Scale	Adam Equipment	CBK70A	AE60895	1/26/2018	1/26/2019	56.14-01
17	Battery HiTester	Hioki	3561	130223776	3/9/2018	3/9/2019	36.13-01
18	Power Supply	EMI	50V400A EMHP	84D-8462 (2)	UWCE	N/A	21.26-02
19	Shunt	Empro	HA-500-100	N/A	5/25/2018	5/25/2019	97.01-23

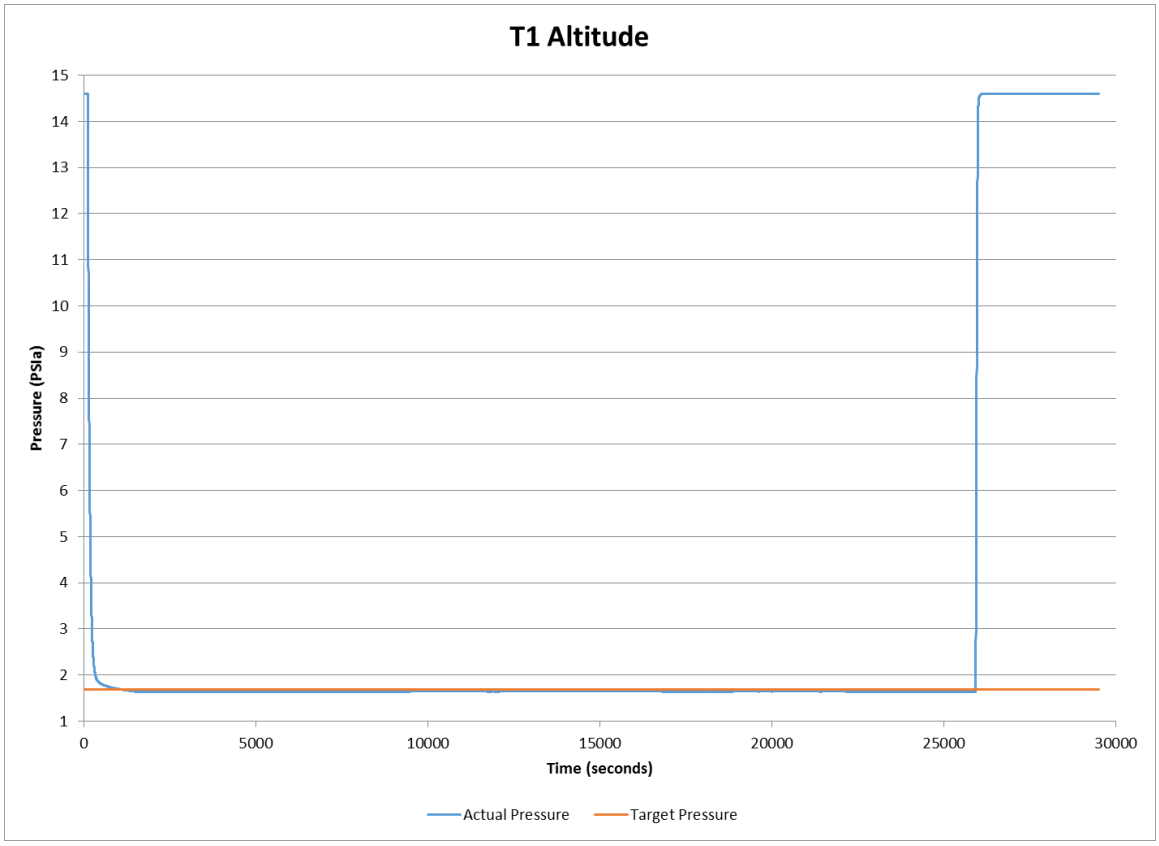
UWCE - Used With Calibrated Equipment

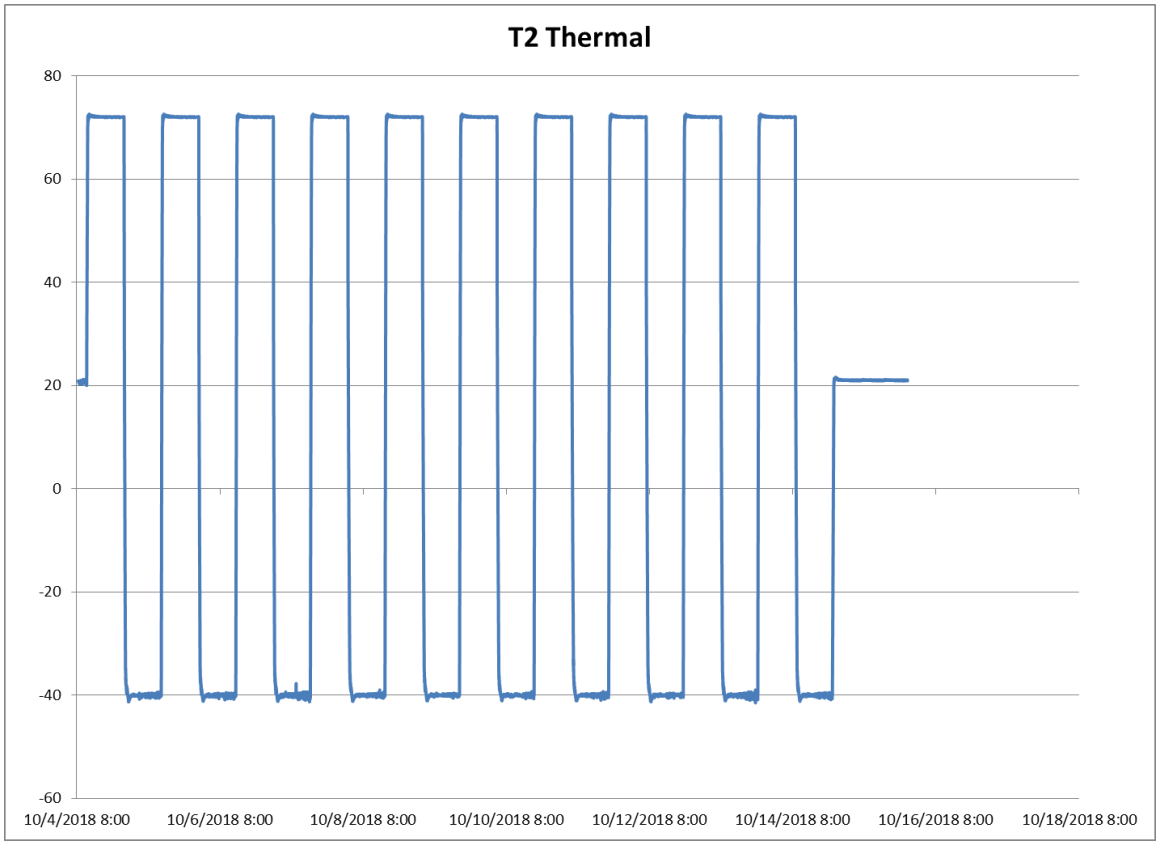
APPENDIX A

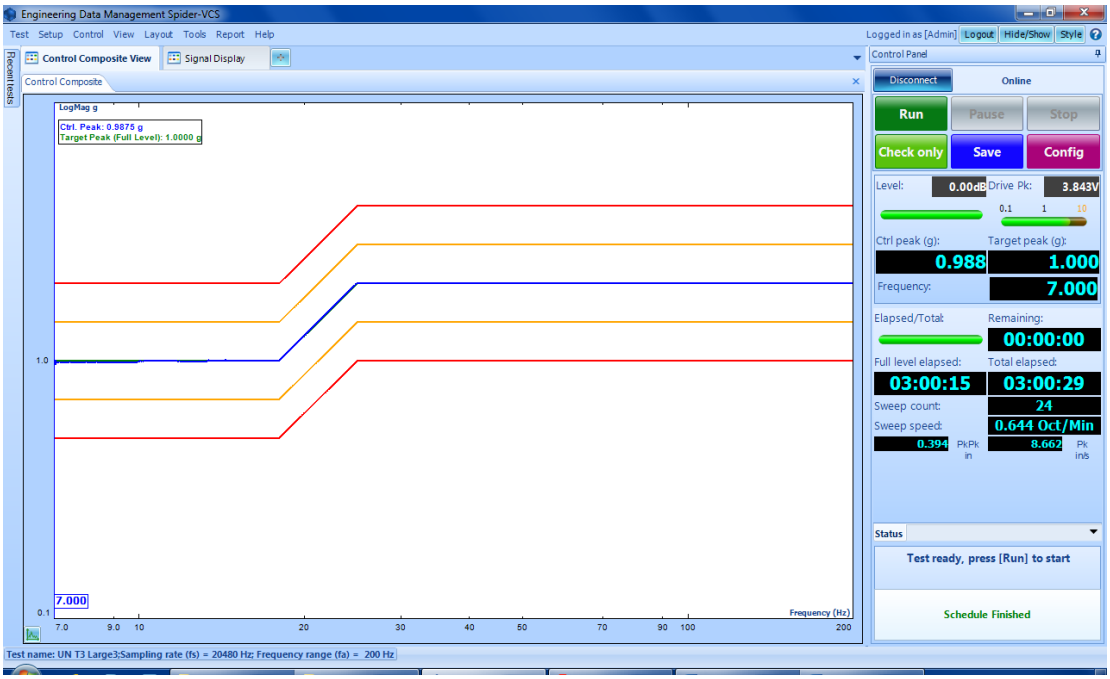
TEST DATA

Mass and Voltage Measurements

	DATE			DATE			DATE			DATE		
	10/3/18	10/3/18		10/4/18	10/16/18		10/22/18	10/24/18		10/29/18	10/30/18	
UN Mass Measurements - grams												
Test:	**T1 – Altitude**			**T2 – Thermal**			**T3 – Vibration**			**T4 - Shock**		
S/N	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**
10003129	2004.000	2004.000	0.00%	2004.000	2003.000	0.05%	2003.000	2003.000	0.00%	2003.000	2003.000	0.00%
10003130	2006.000	2007.000	-0.05%	2007.000	2006.000	0.05%	2006.000	2006.000	0.00%	2006.000	2006.000	0.00%
10003165	1997.000	1998.000	-0.05%	1998.000	1995.000	0.15%	1995.000	1995.000	0.00%	1995.000	1995.000	0.00%
10003166	1998.000	1998.000	0.00%	1998.000	1997.000	0.05%	1997.000	1996.000	0.05%	1996.000	1997.000	-0.05%
10003167	2007.000	2007.000	0.00%	2007.000	2006.000	0.05%	2006.000	2006.000	0.00%	2006.000	2006.000	0.00%
10003168	1983.000	1983.000	0.00%	1983.000	1982.000	0.05%	1982.000	1982.000	0.00%	1982.000	1982.000	0.00%
10003169	2005.000	2006.000	-0.05%	2006.000	2004.000	0.10%	2004.000	2005.000	-0.05%	2005.000	2004.000	0.05%
10003170	1996.000	1996.000	0.00%	1996.000	1995.000	0.05%	1995.000	1995.000	0.00%	1995.000	1996.000	-0.05%
10003171	1991.000	1992.000	-0.05%	1992.000	1991.000	0.05%	1991.000	1991.000	0.00%	1991.000	1990.000	0.05%
10003175	1990.000	1990.000	0.00%	1990.000	1989.000	0.05%	1989.000	1989.000	0.00%	1989.000	1990.000	-0.05%
UN OCV Measurements - Volts												
Test:	**T1 - Altitude**			**T2 - Thermal**			**T3 – Vibration**			**T4 - Shock**		
S/N	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**	**Pre**	**Post**	**Loss**
10003129	4.201	4.197	0.10%	4.197	4.091	2.53%	4.091	4.091	0.00%	4.091	4.092	-0.02%
10003130	4.194	4.190	0.10%	4.190	4.083	2.55%	4.083	4.083	0.00%	4.083	4.084	-0.02%
10003165	4.195	4.190	0.12%	4.190	4.076	2.72%	4.076	4.076	0.00%	4.076	4.077	-0.02%
10003166	4.194	4.189	0.12%	4.189	4.081	2.58%	4.081	4.082	-0.02%	4.082	4.083	-0.02%
10003167	4.194	4.189	0.12%	4.189	4.080	2.60%	4.080	4.079	0.02%	4.079	4.080	-0.02%
10003168	4.203	4.199	0.10%	4.199	4.100	2.36%	4.100	4.093	0.17%	4.093	4.095	-0.05%
10003169	4.201	4.196	0.12%	4.196	4.087	2.60%	4.087	4.087	0.00%	4.087	4.089	-0.05%
10003170	4.194	4.189	0.12%	4.189	4.082	2.55%	4.082	4.082	0.00%	4.082	4.084	-0.05%
10003171	4.200	4.196	0.10%	4.196	4.088	2.57%	4.088	4.088	0.00%	4.088	4.089	-0.02%
10003175	4.200	4.194	0.14%	4.194	4.085	2.60%	4.085	4.085	0.00%	4.085	4.086	-0.02%







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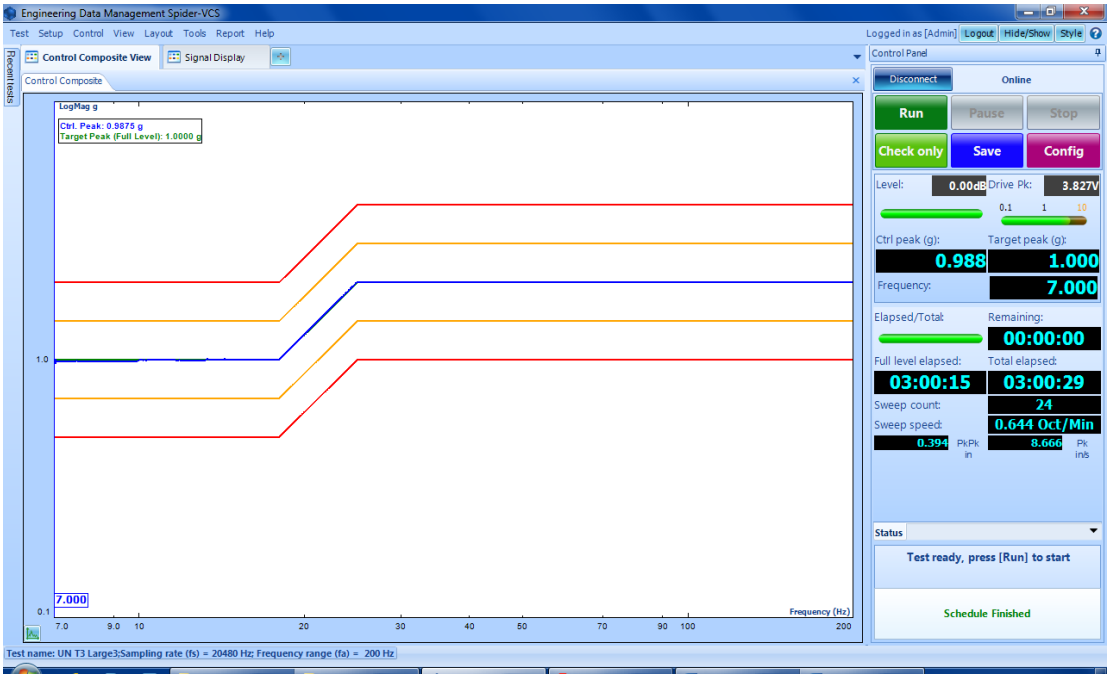

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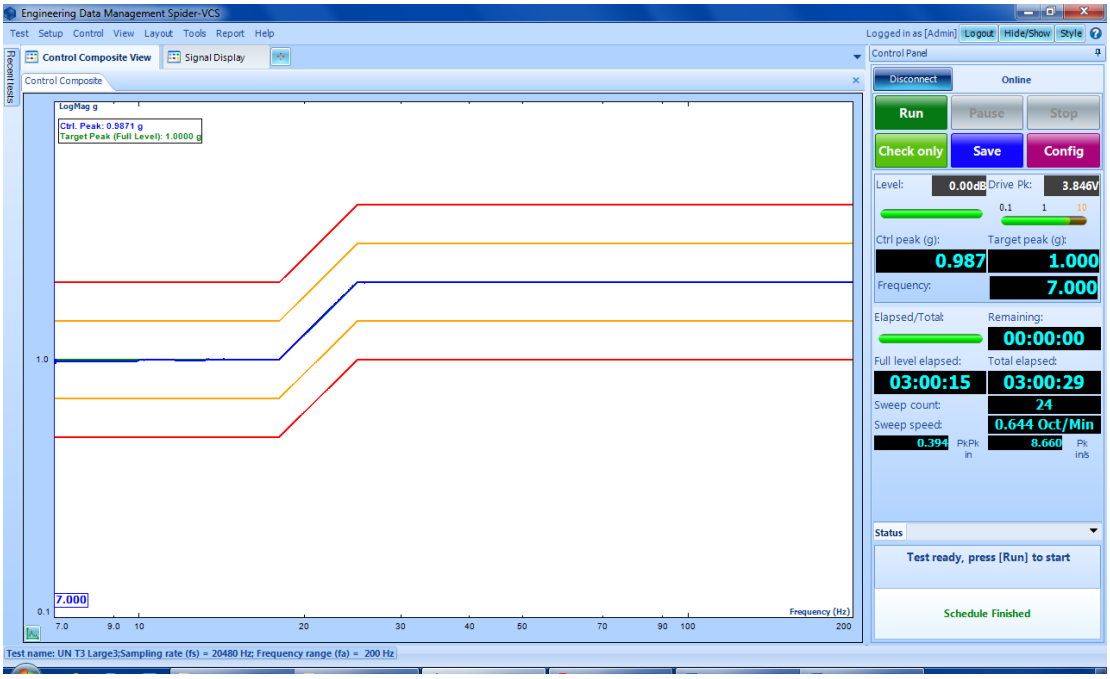

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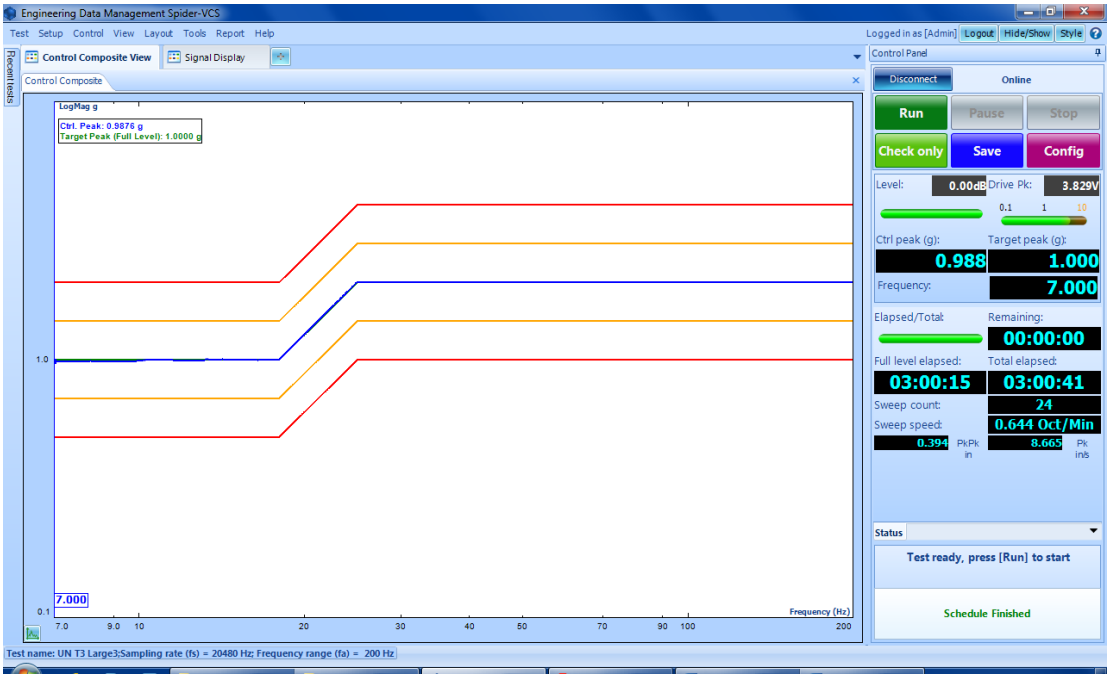

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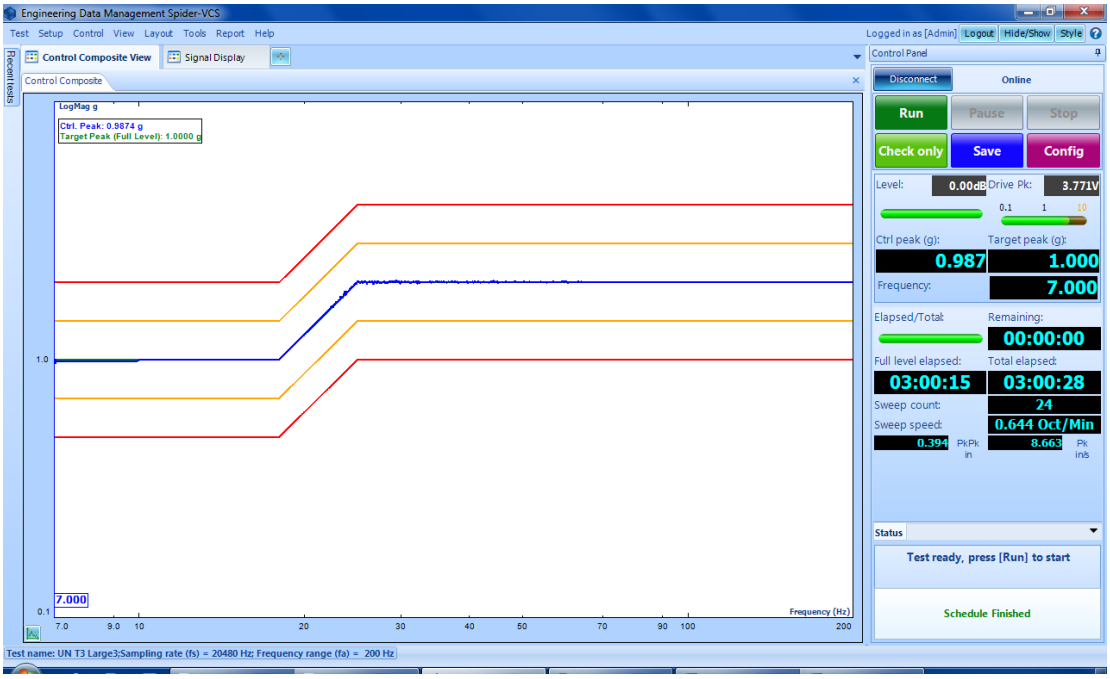

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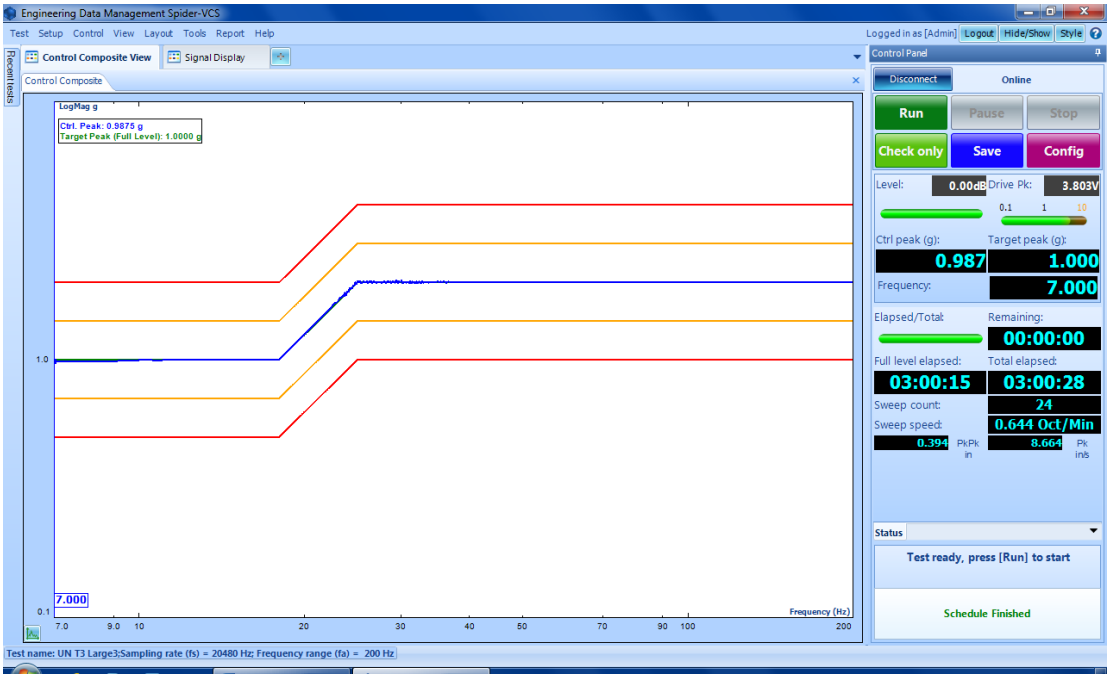

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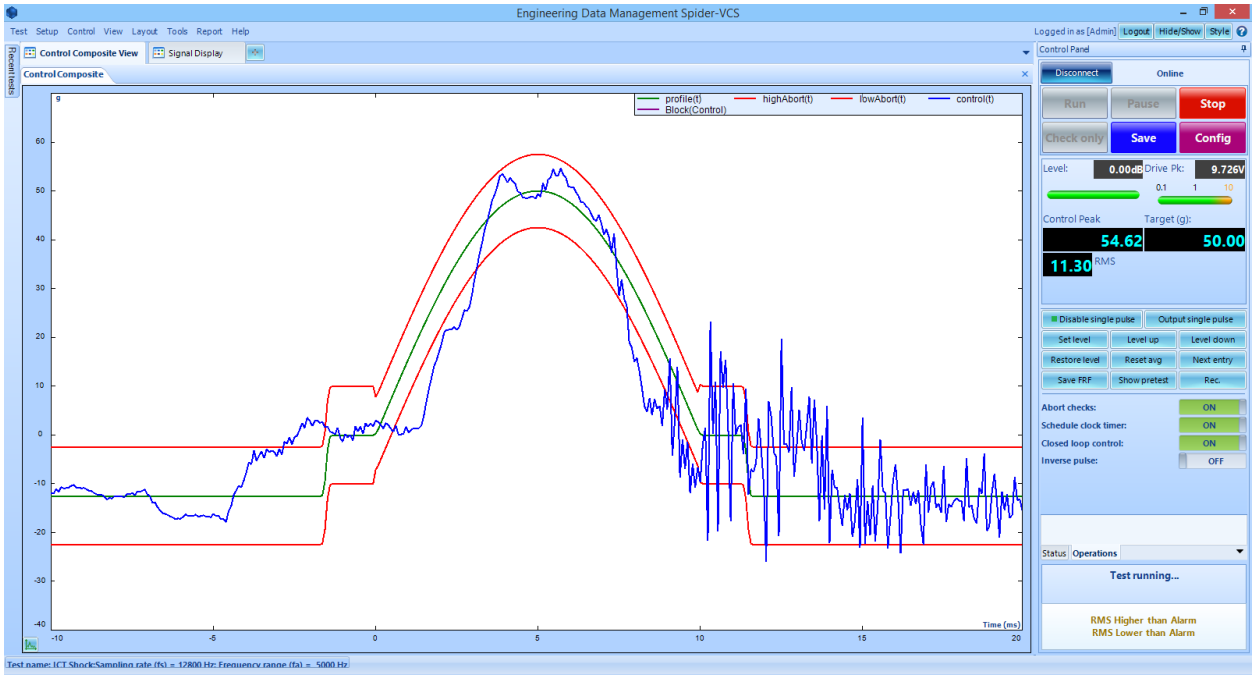

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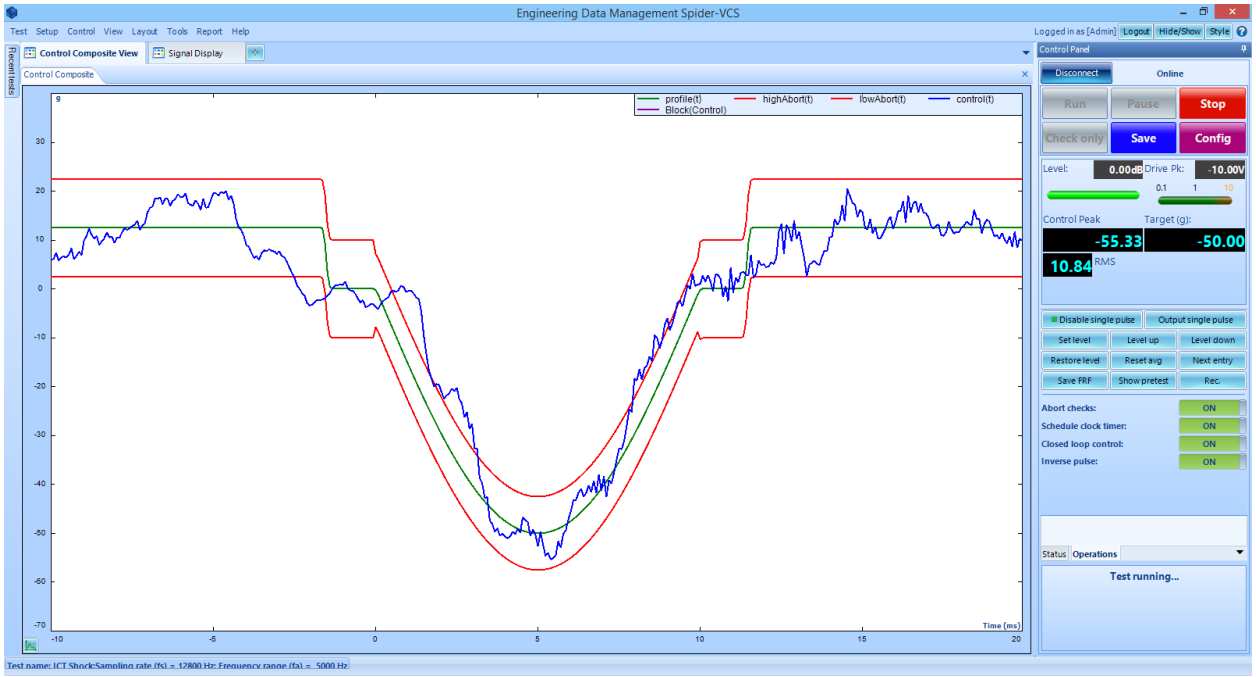

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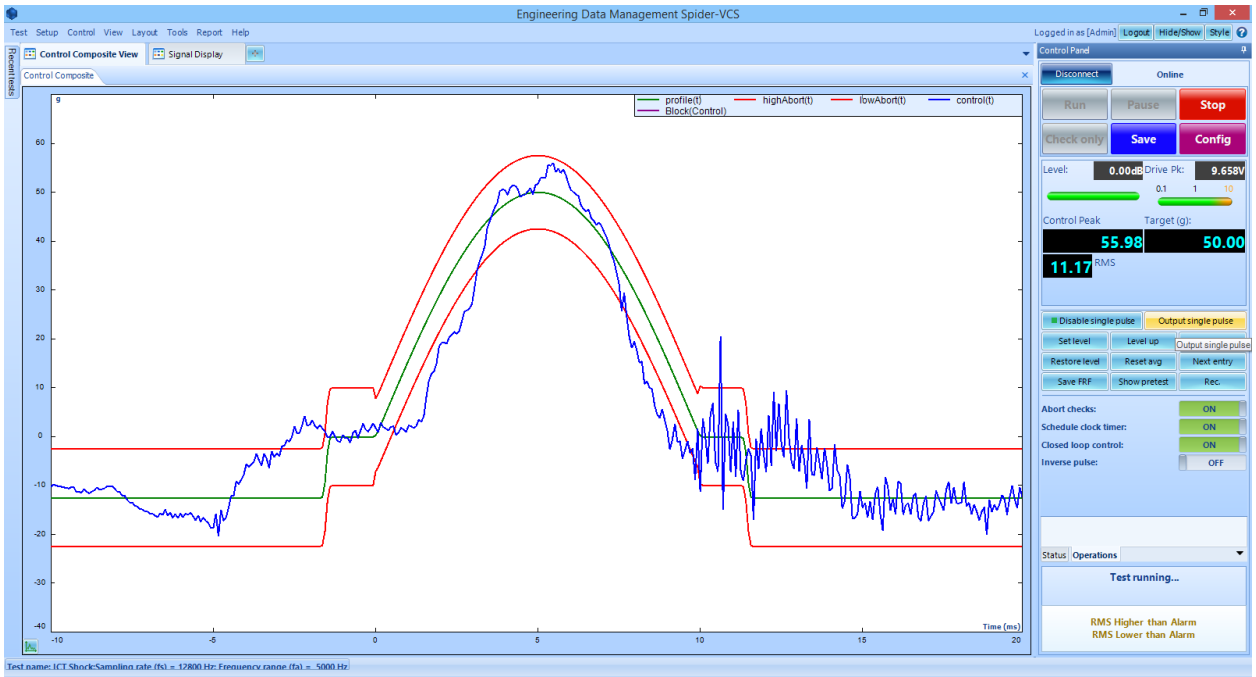
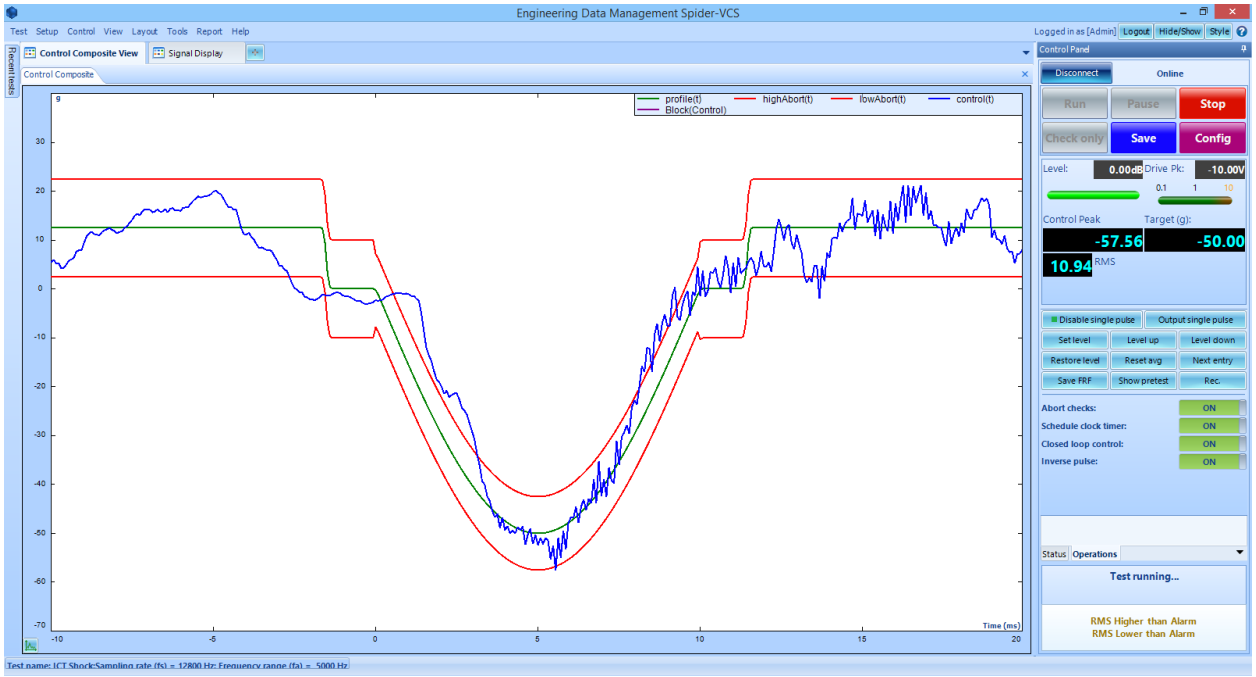


T4 Mechanical Shock (+) Lateral Run 2 Units: 3168, 3169, 3170, 3171, 3175



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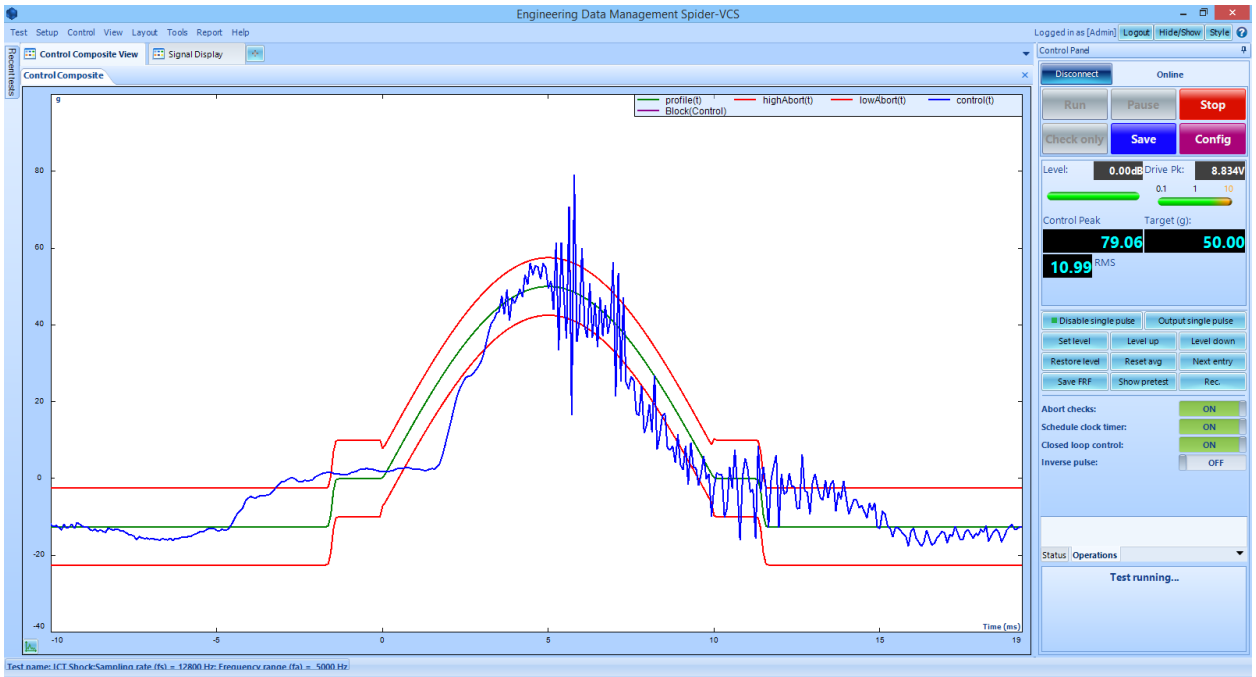

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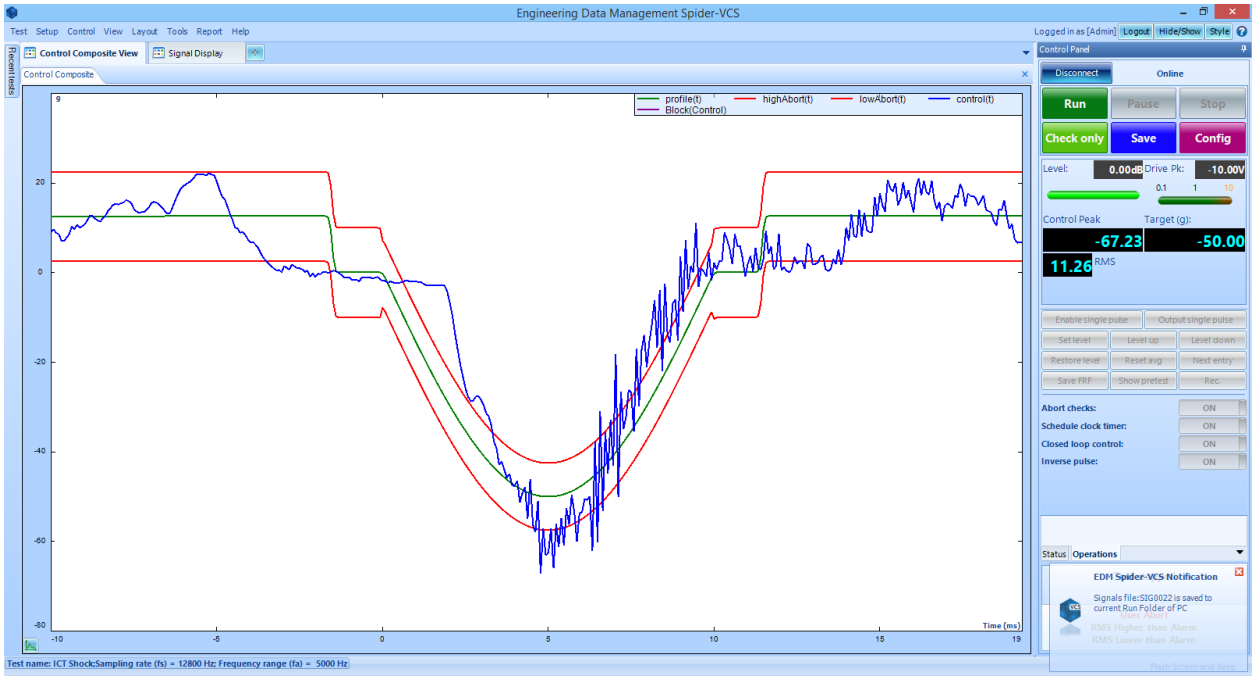

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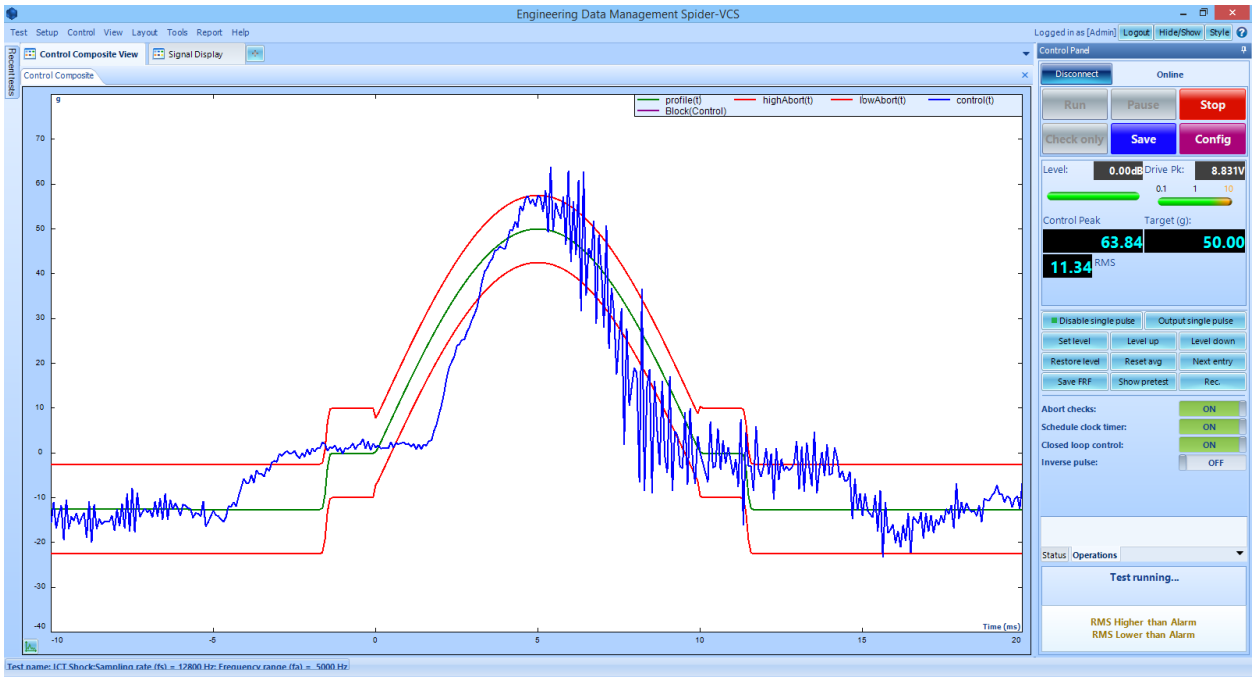

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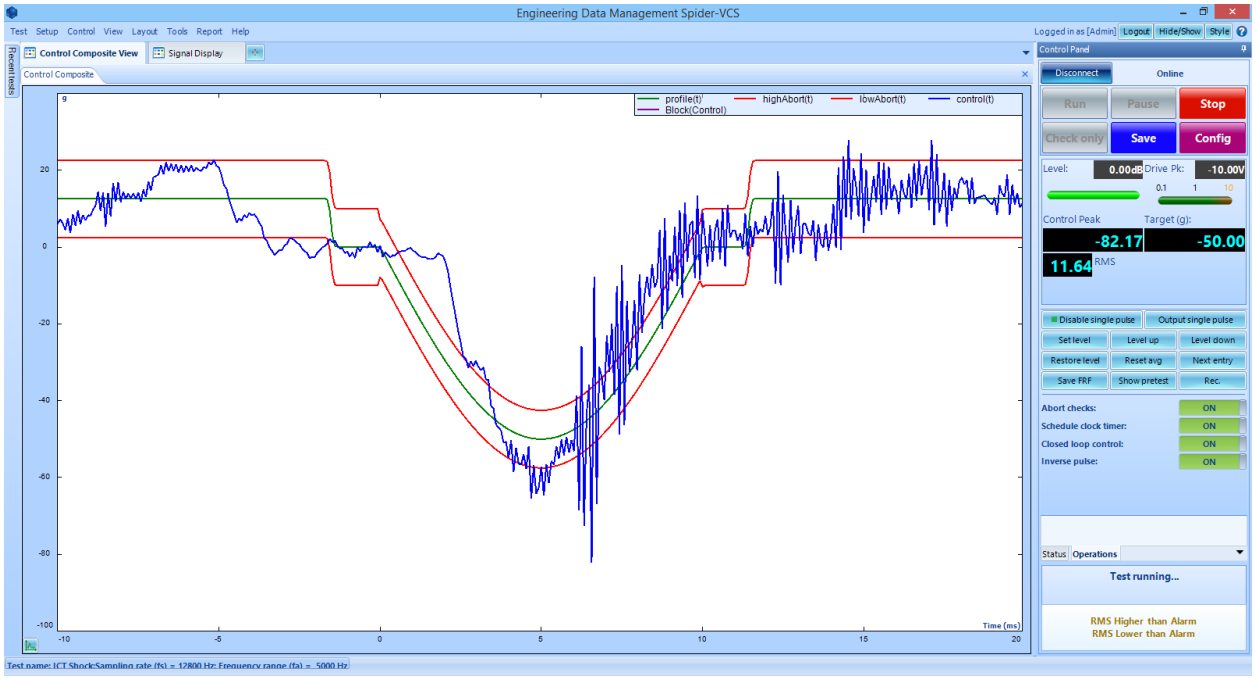
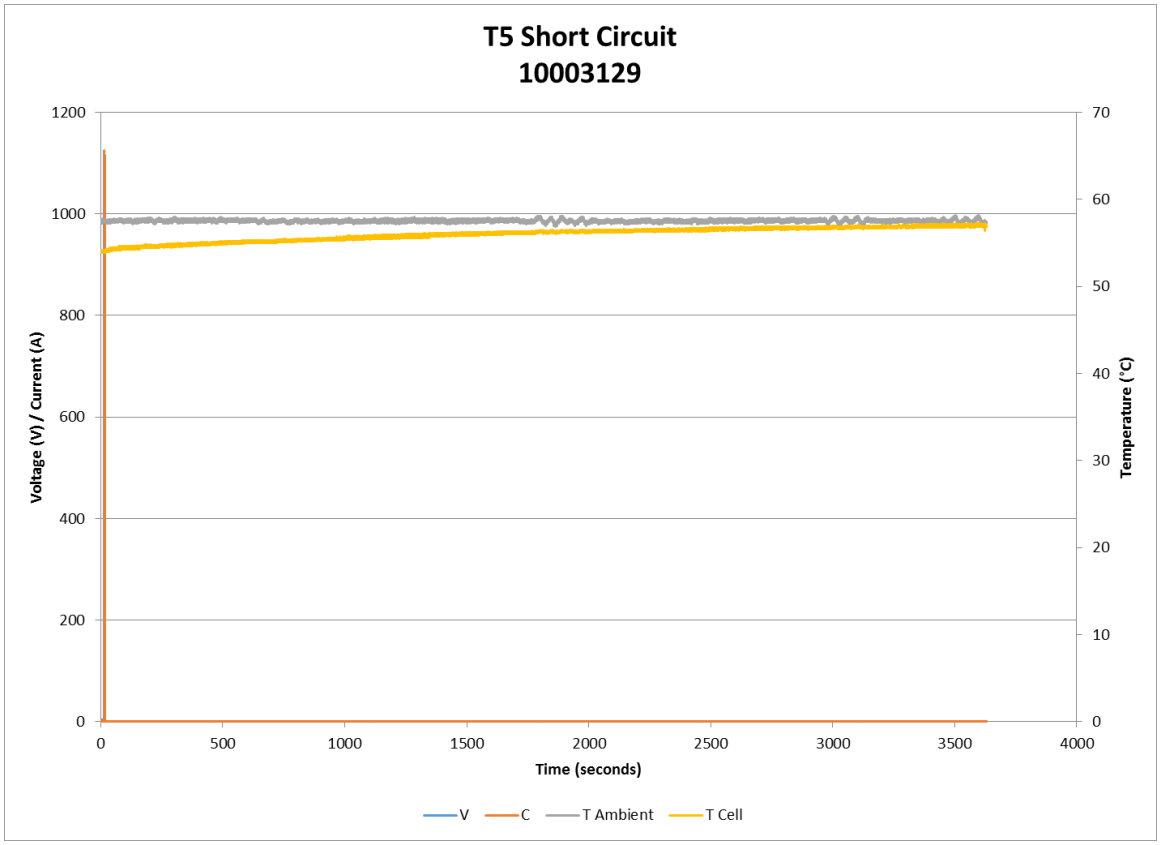
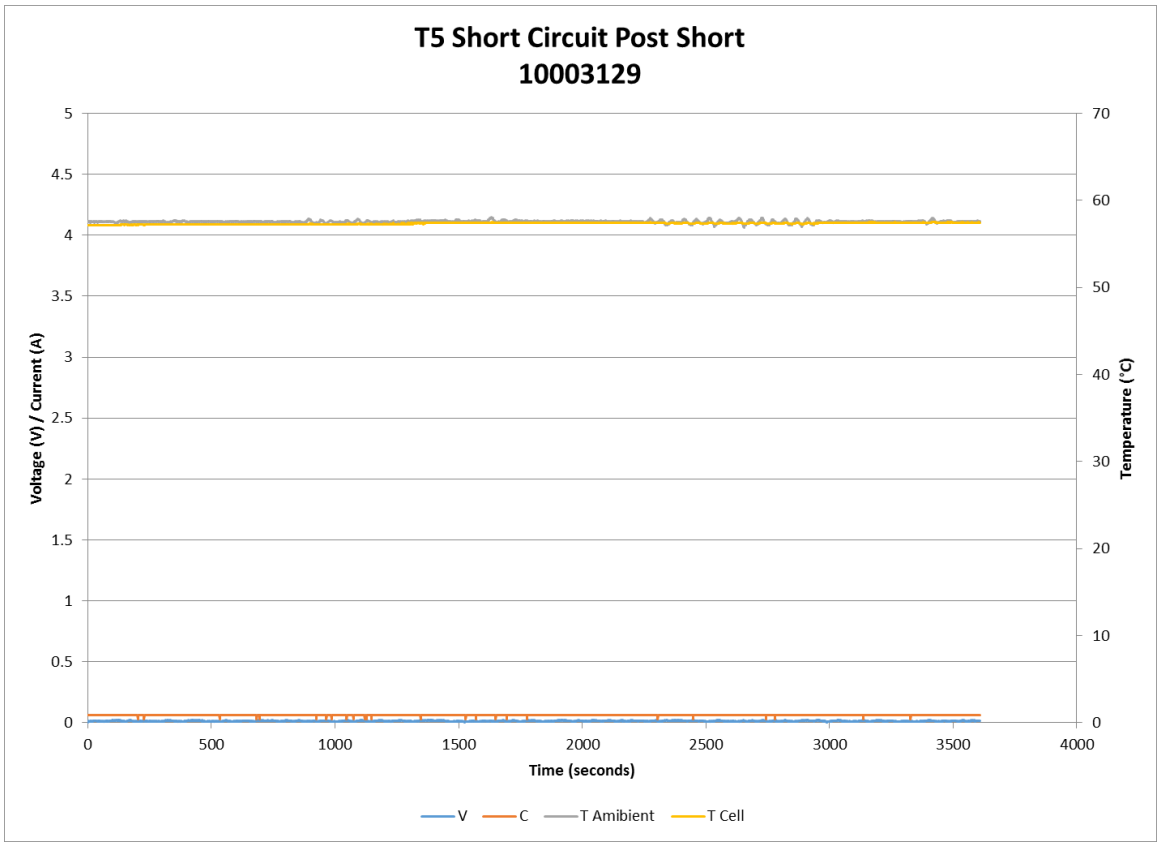


T4 Mechanical Shock (-) Vertical


T5 Short Circuit
10003129
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell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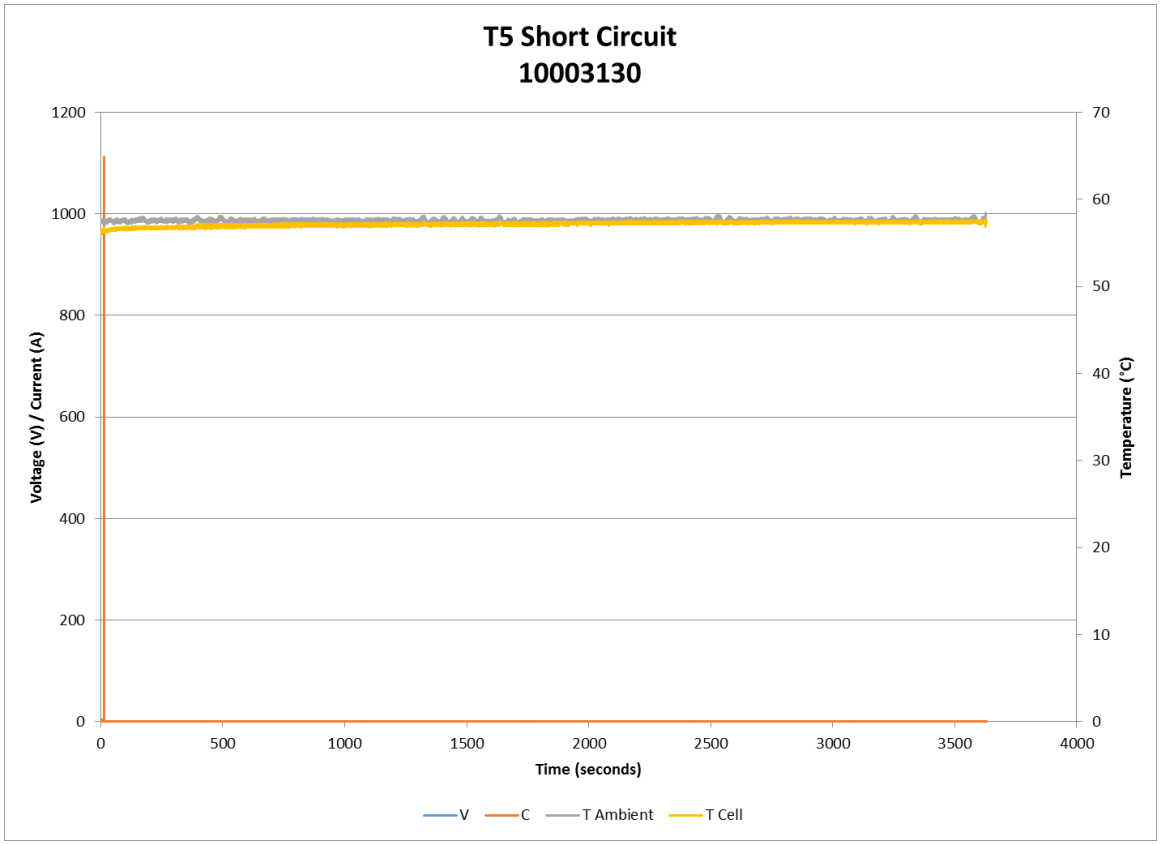
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Amibient
T Cell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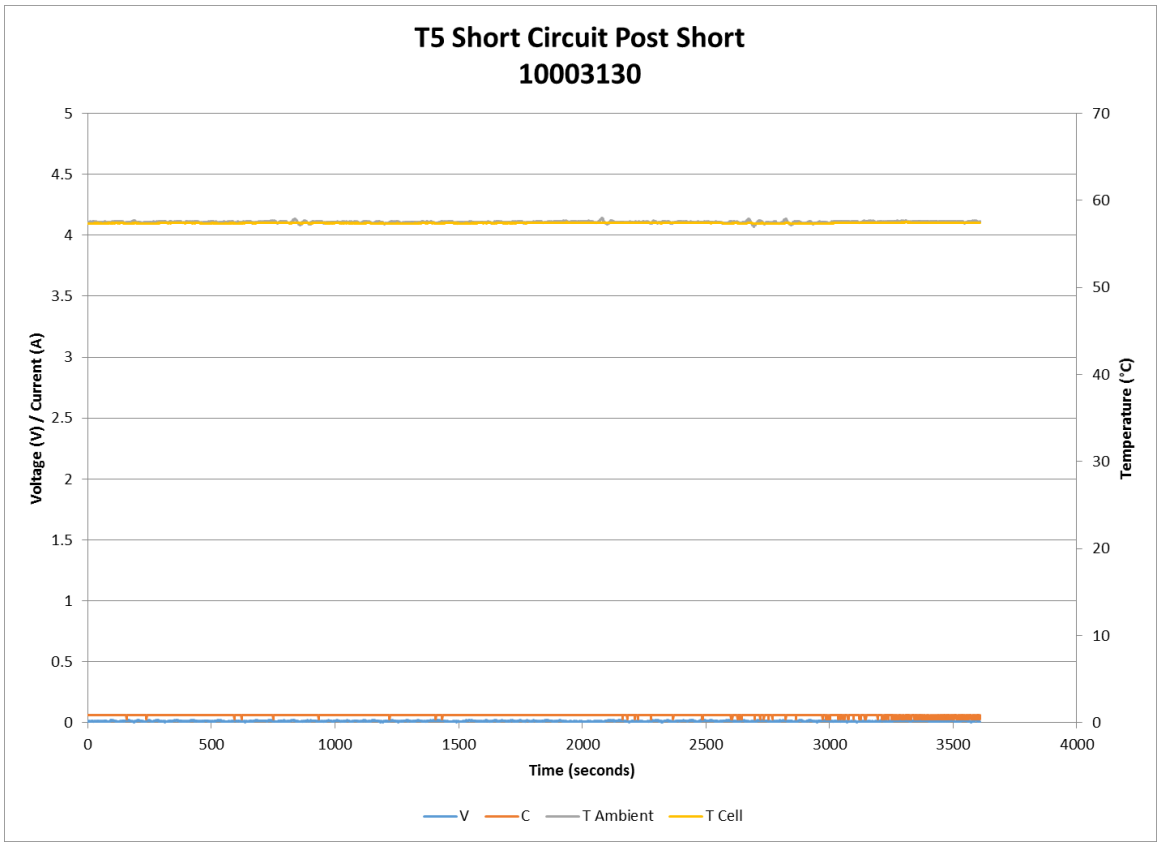
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell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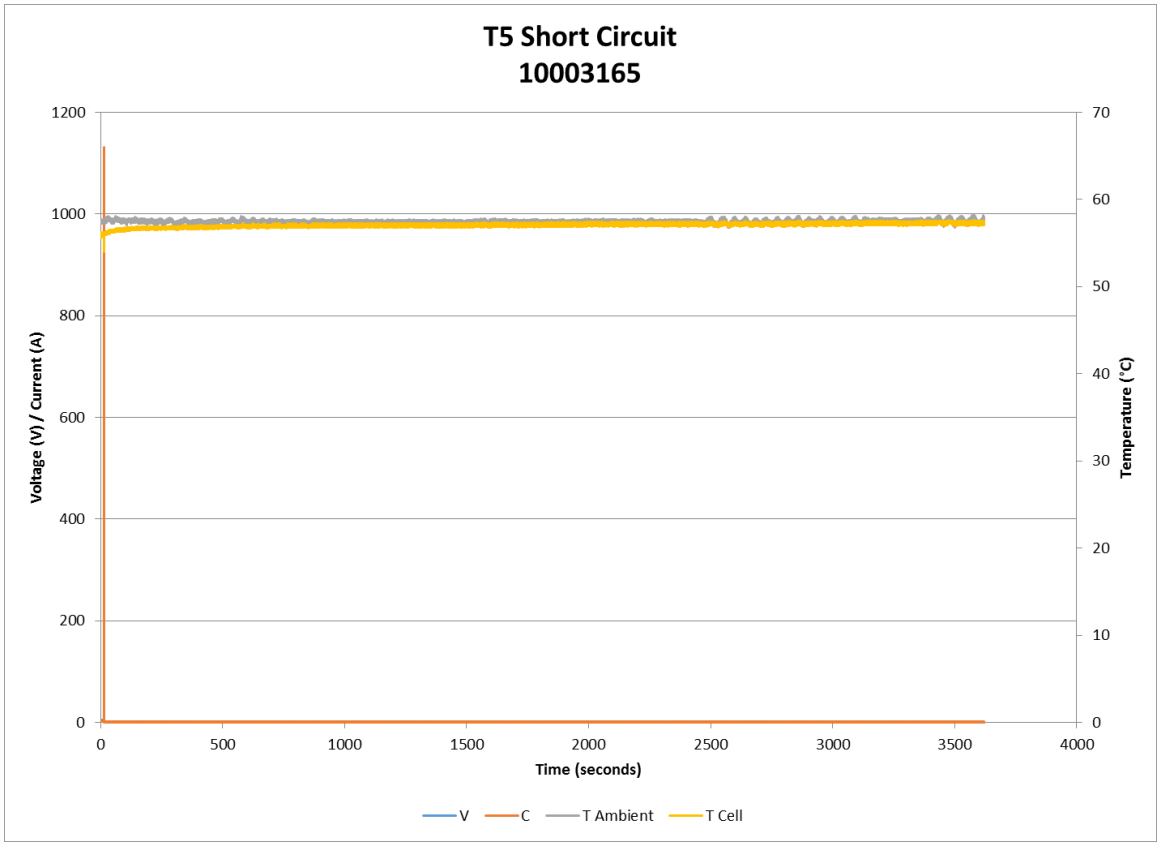
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell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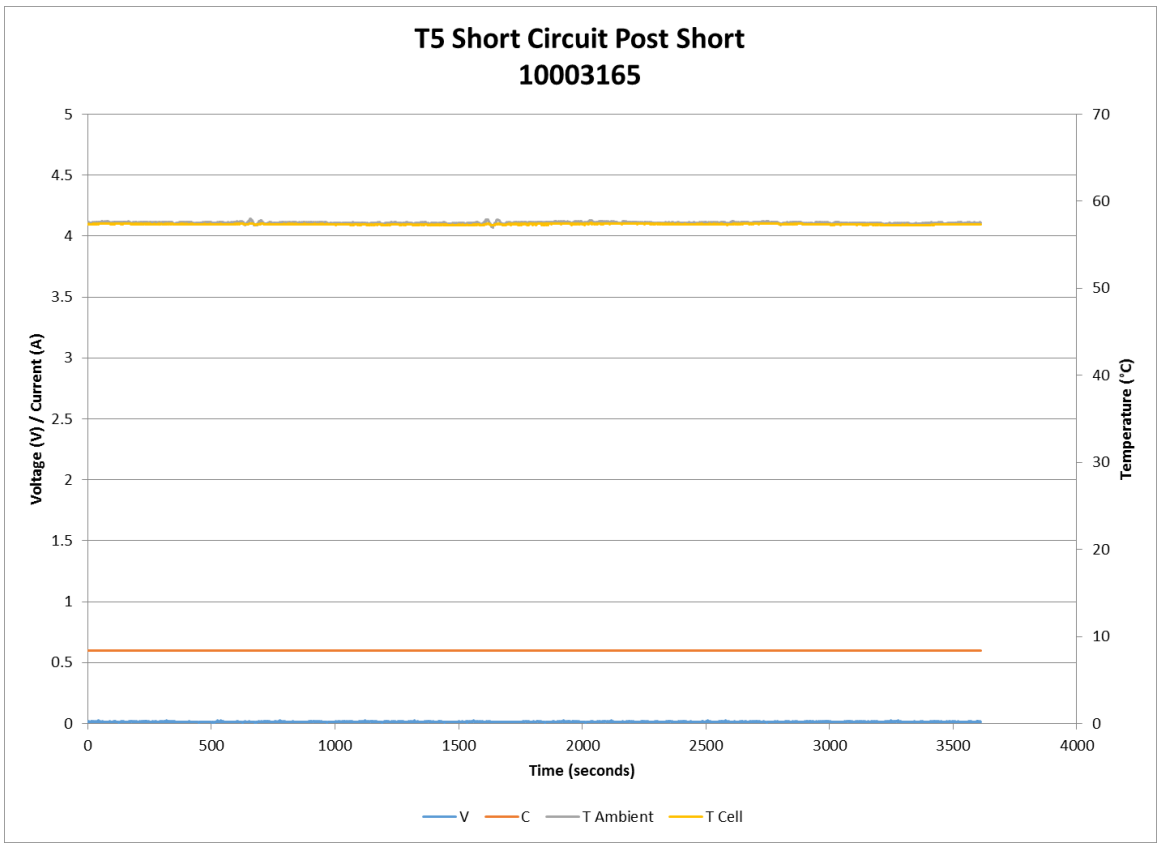
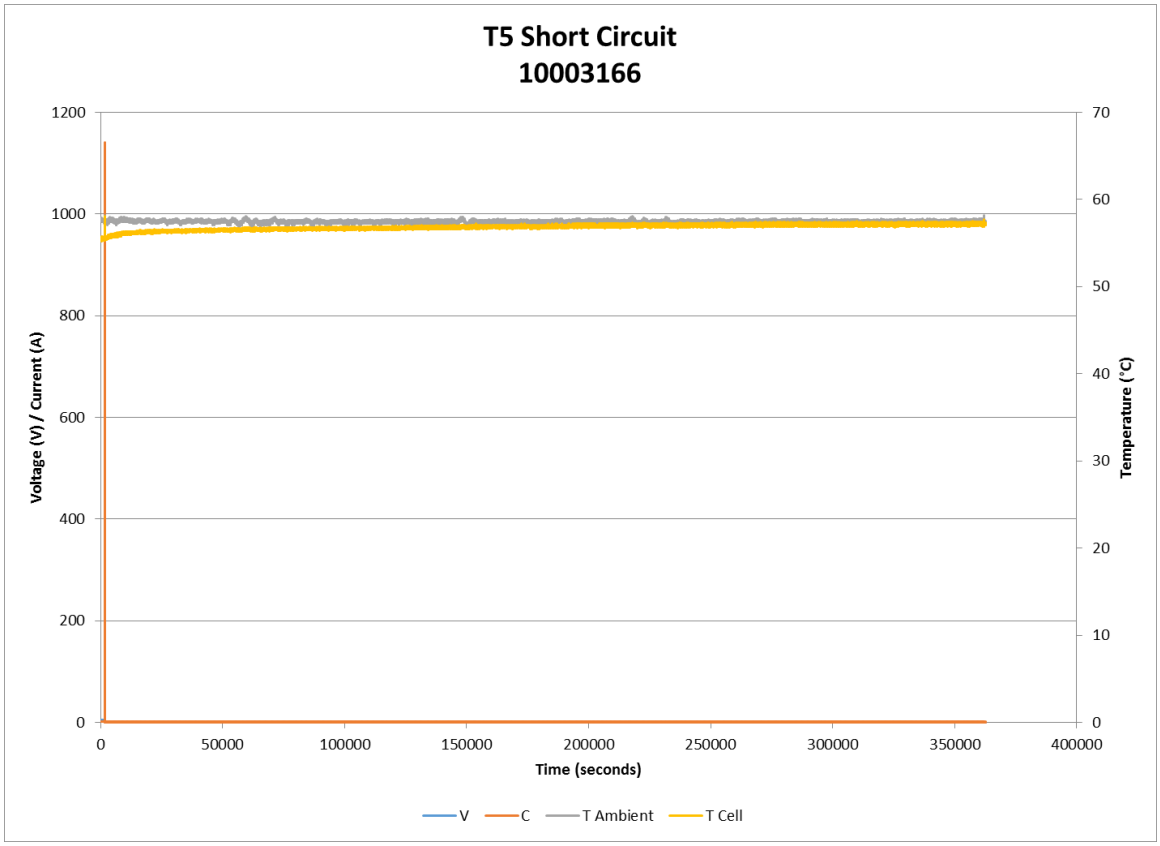
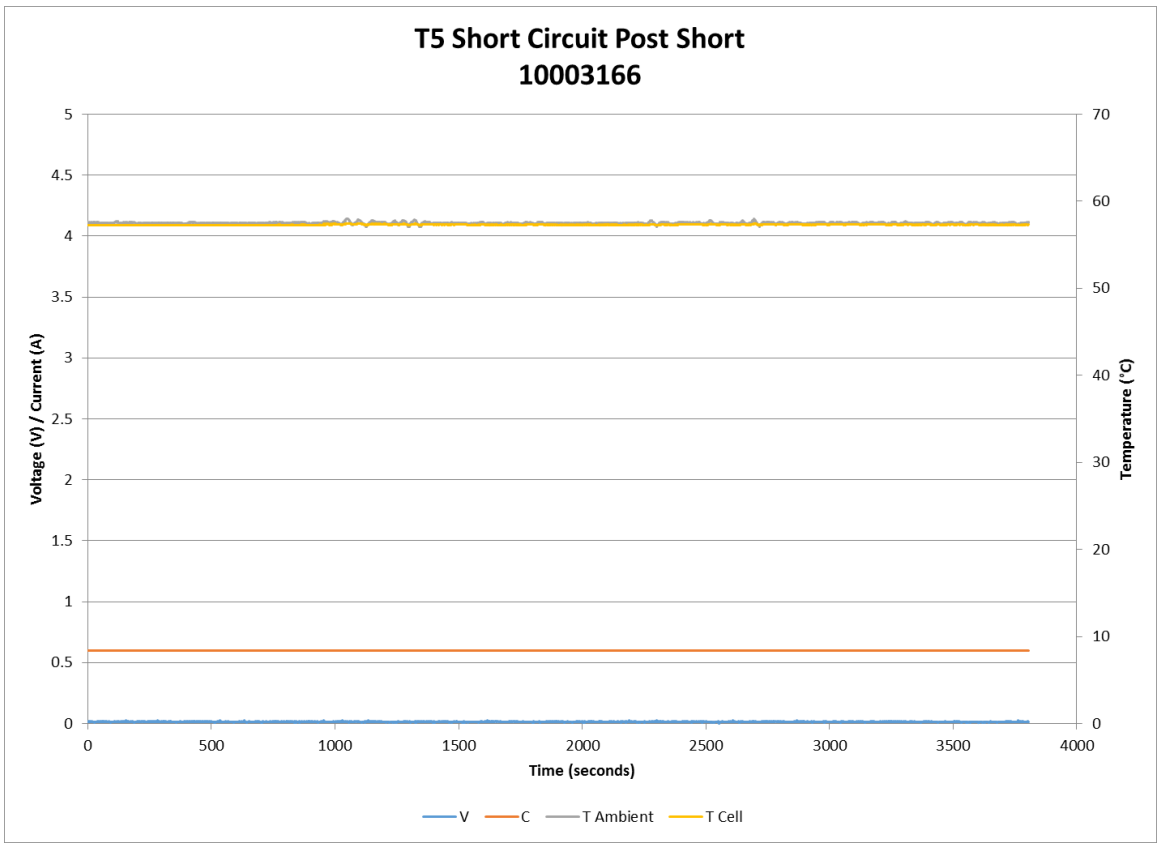
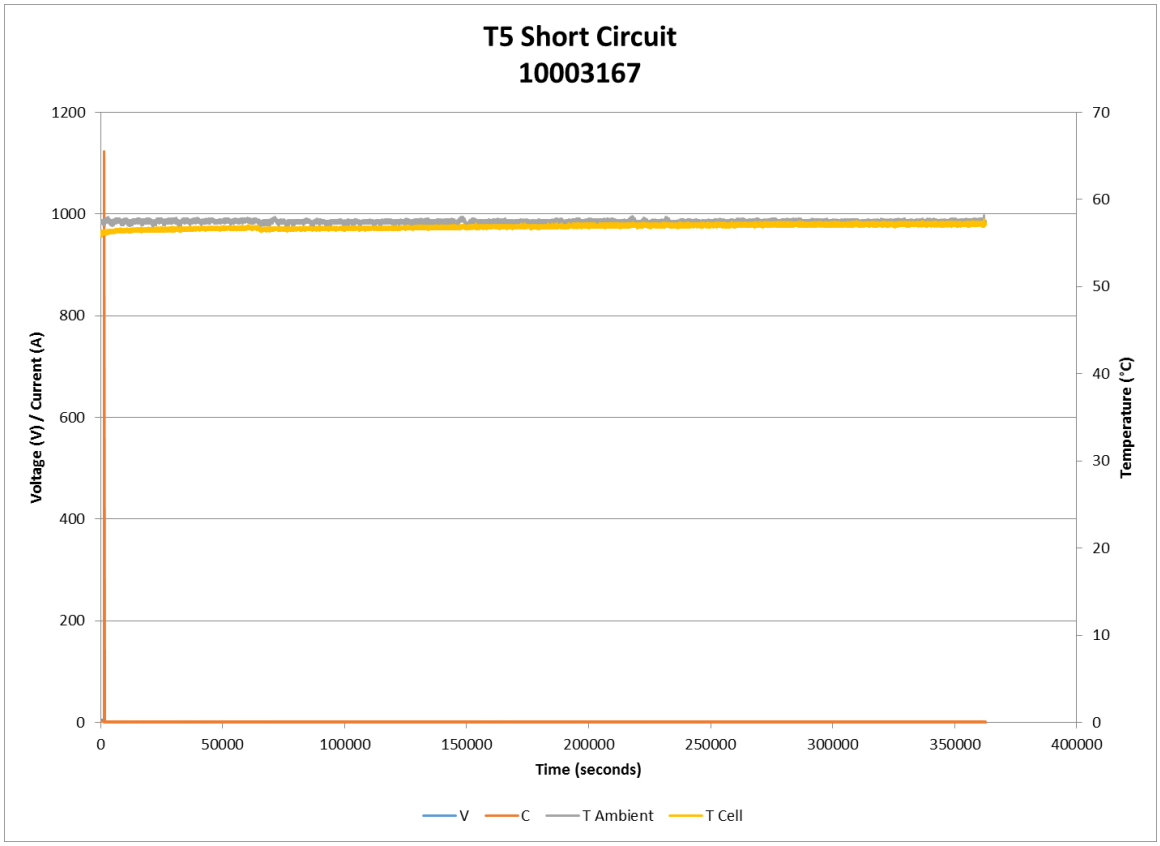
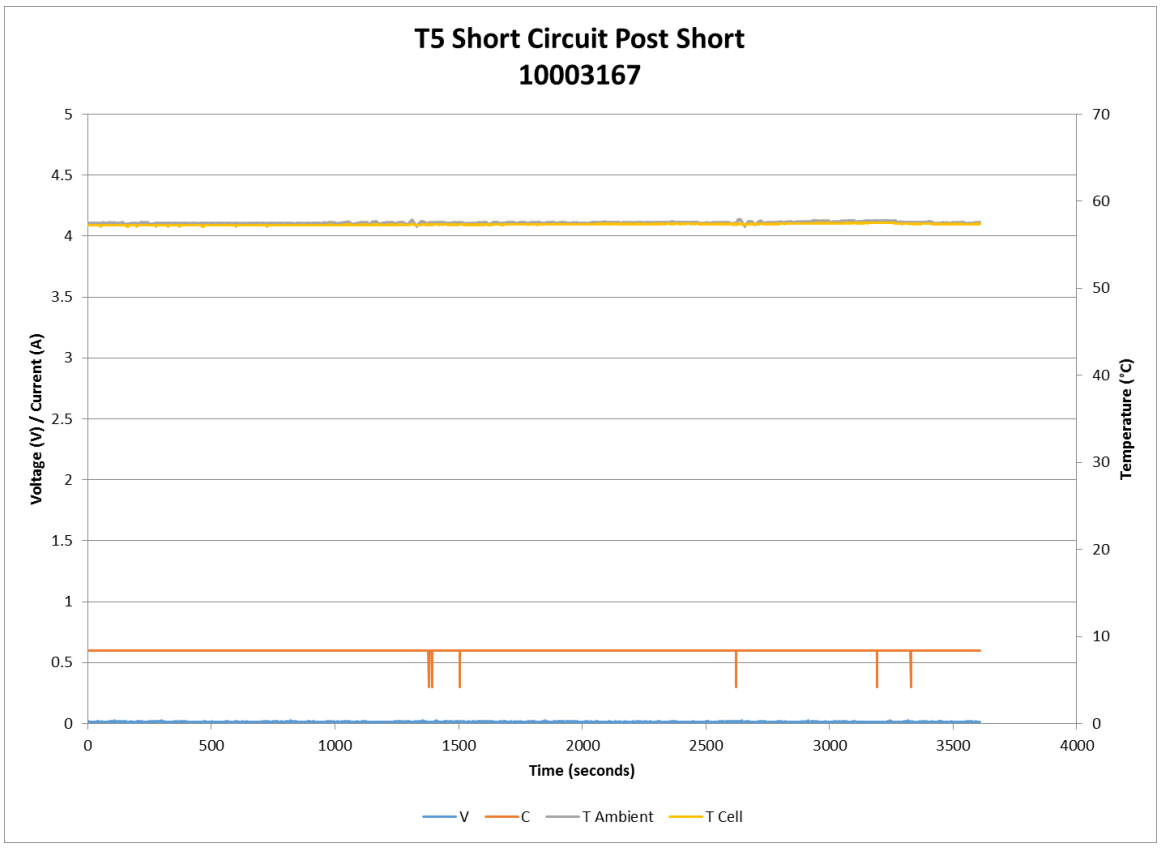
10003165
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

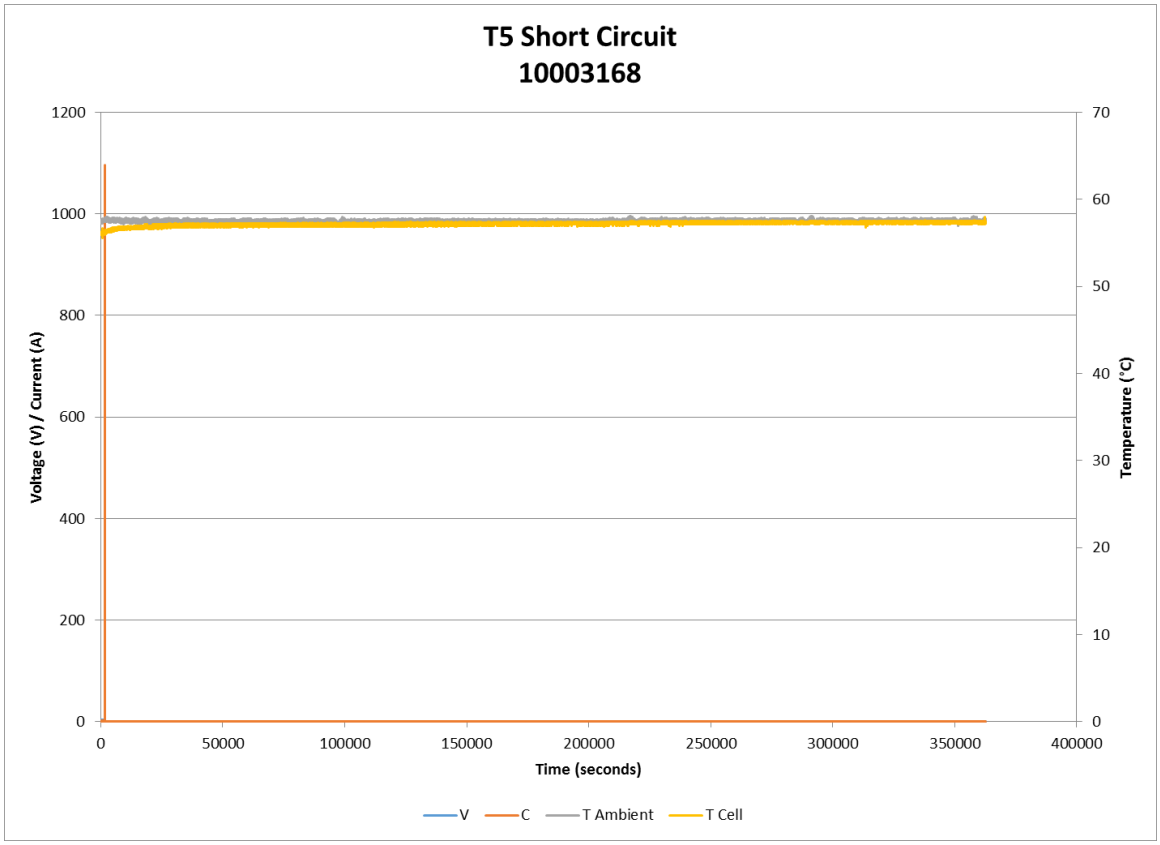

T5 Short Circuit Post Short
10003165
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

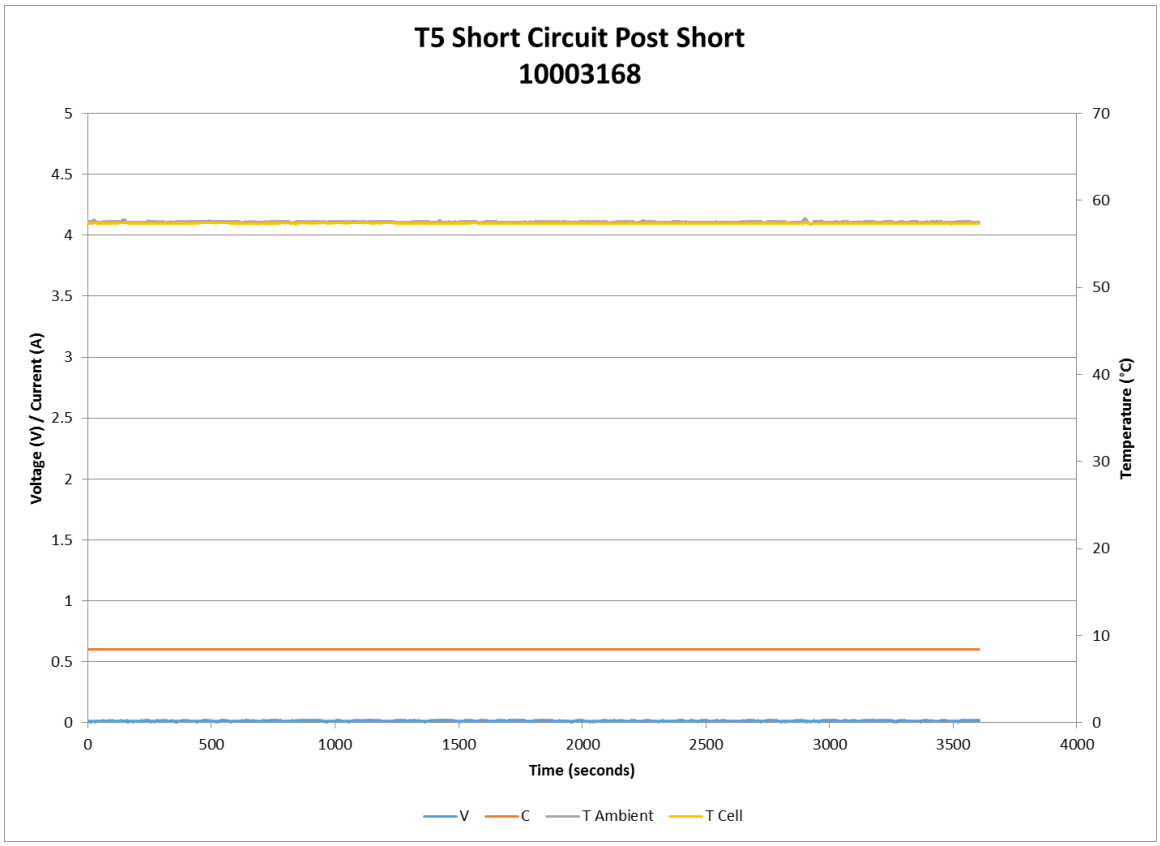

T5 Short Circuit
10003166
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

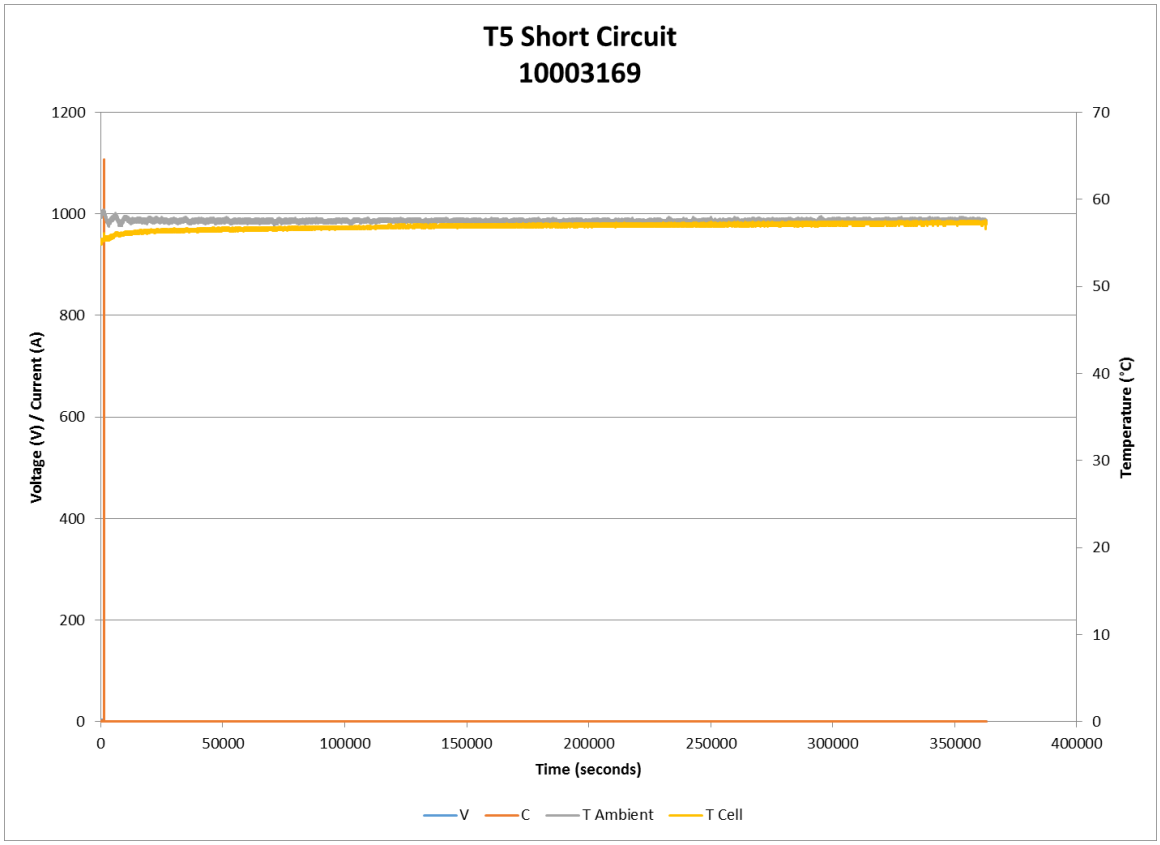

T5 Short Circuit Post Short
10003166
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell


T5 Short Circuit
10003167
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell


T5 Short Circuit Post Short
10003167
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell


T5 Short Circuit
10003168
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell


T5 Short Circuit Post Short
10003168
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell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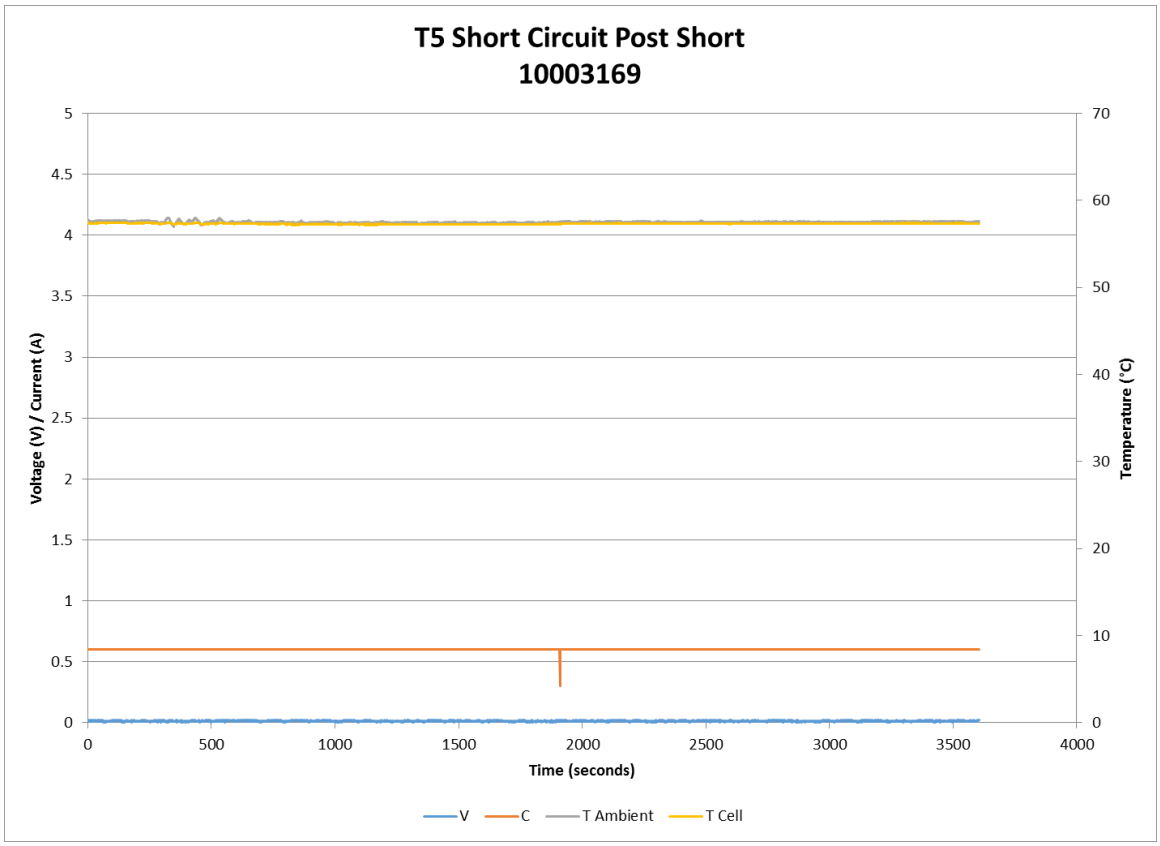
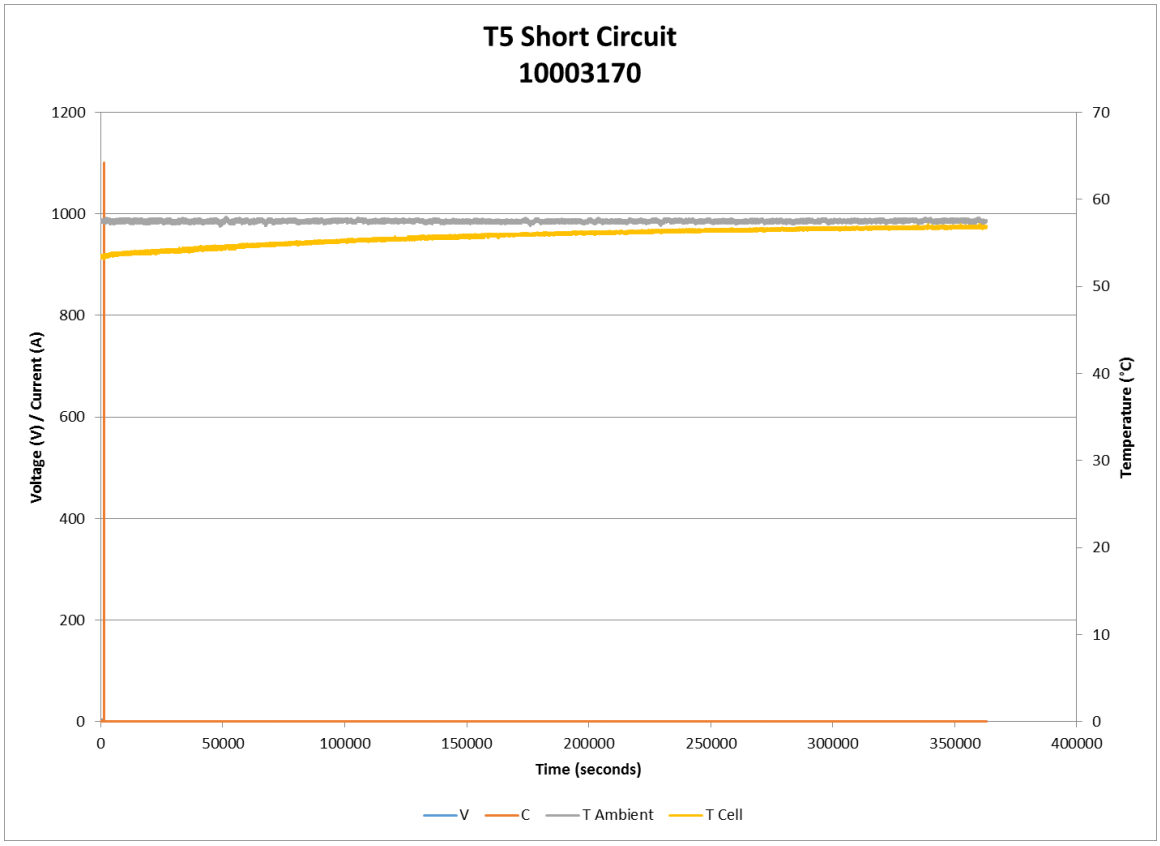
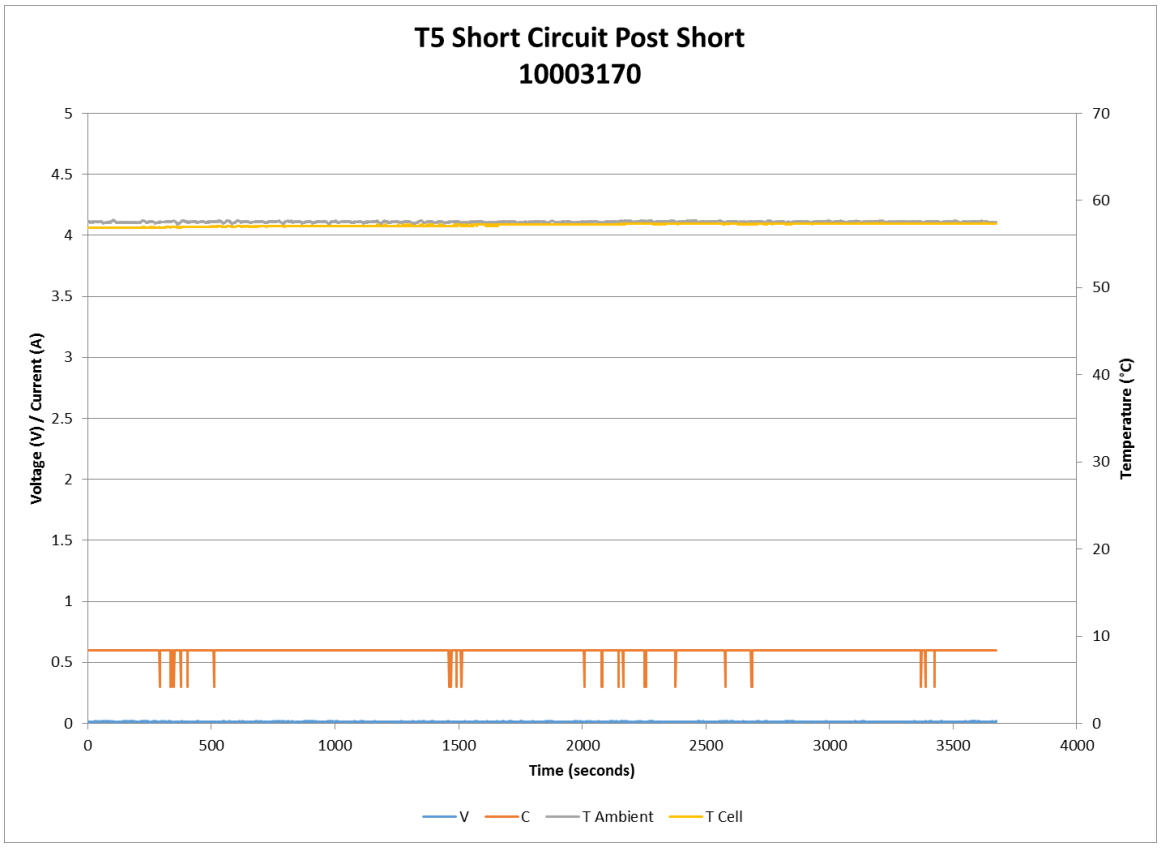
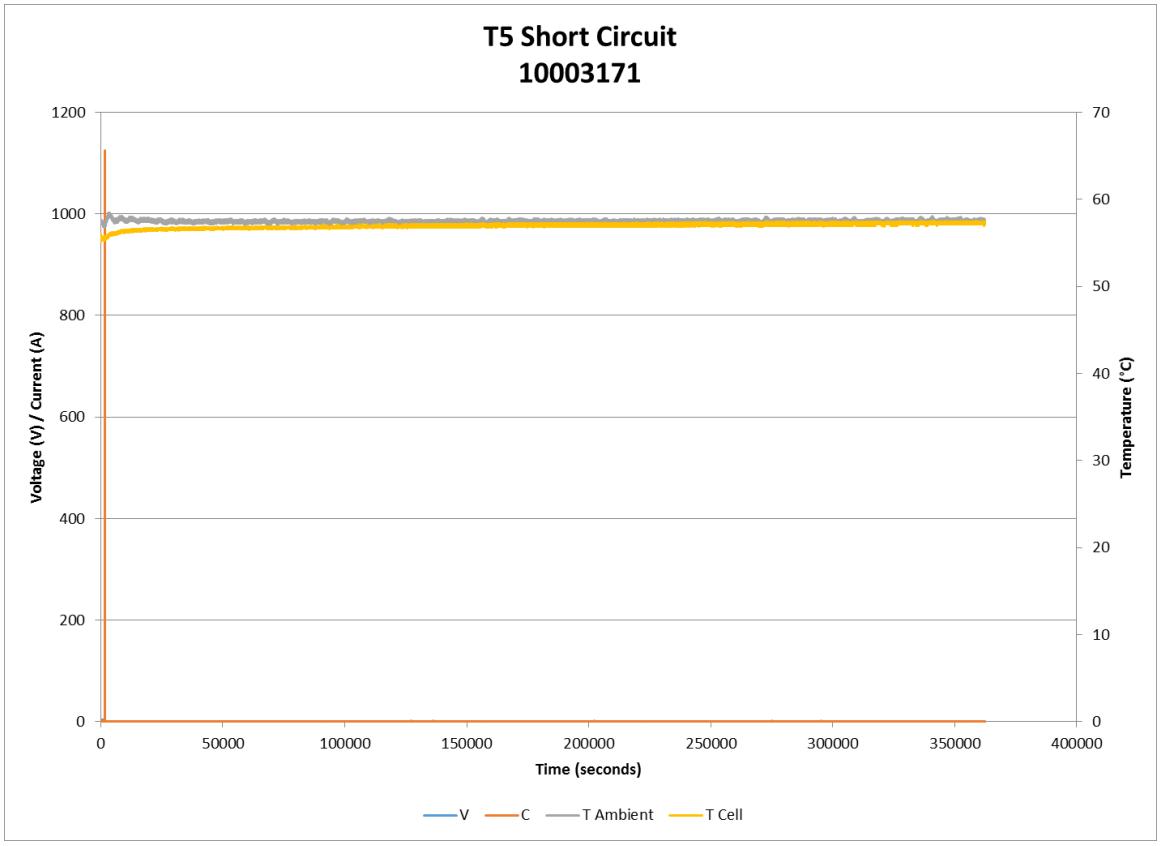
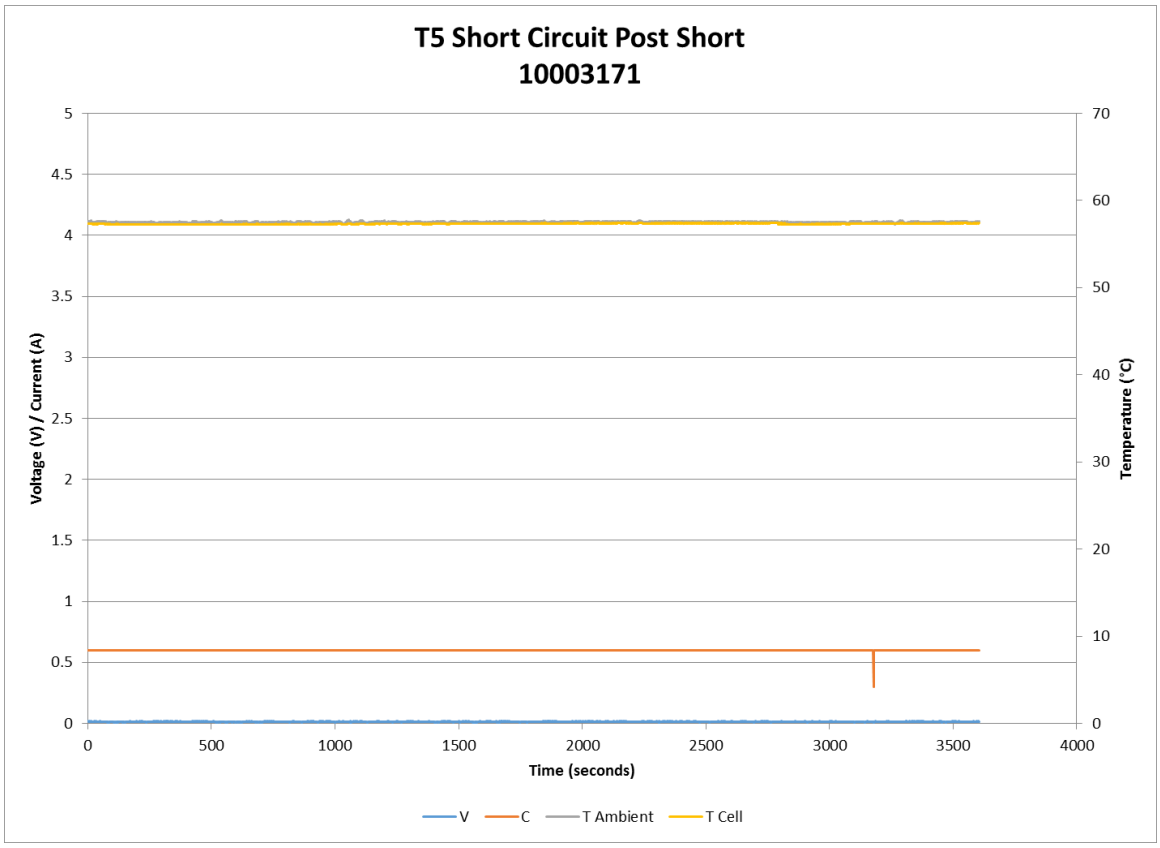
10003169
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

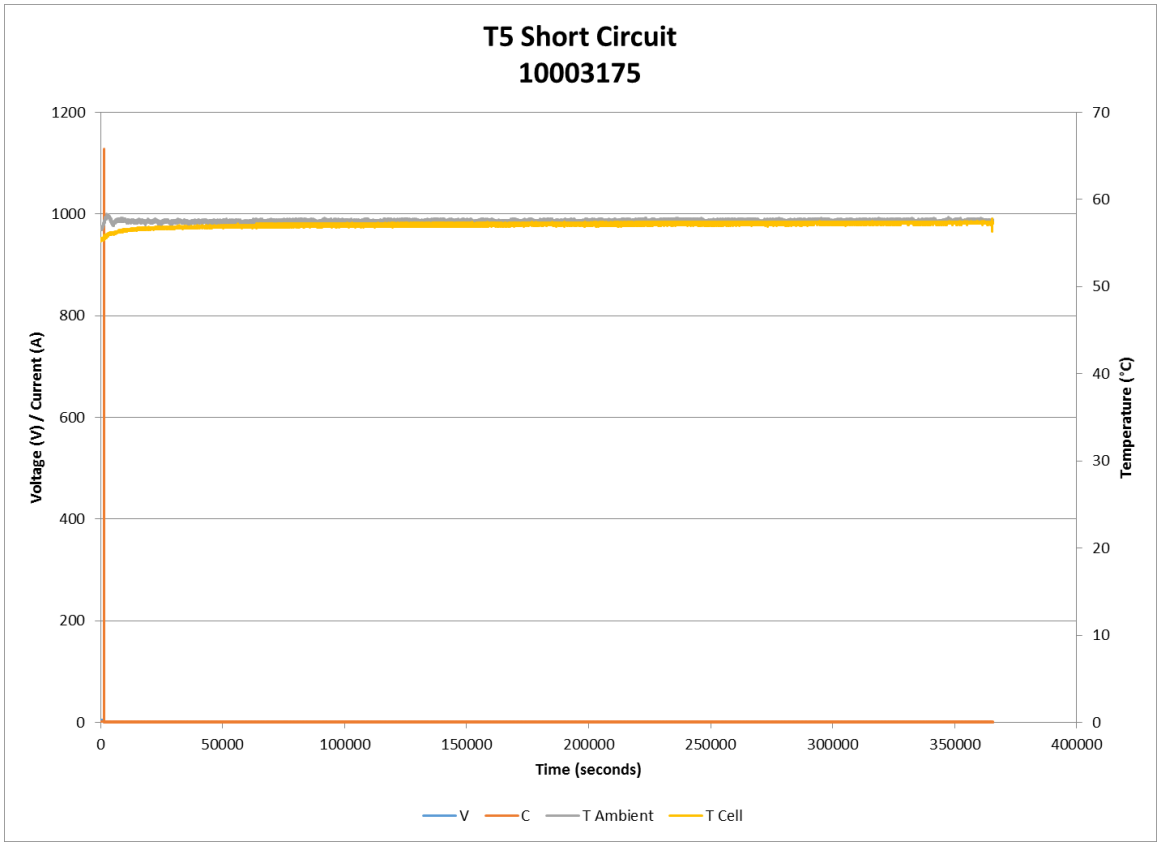

T5 Short Circuit Post Short
10003169
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

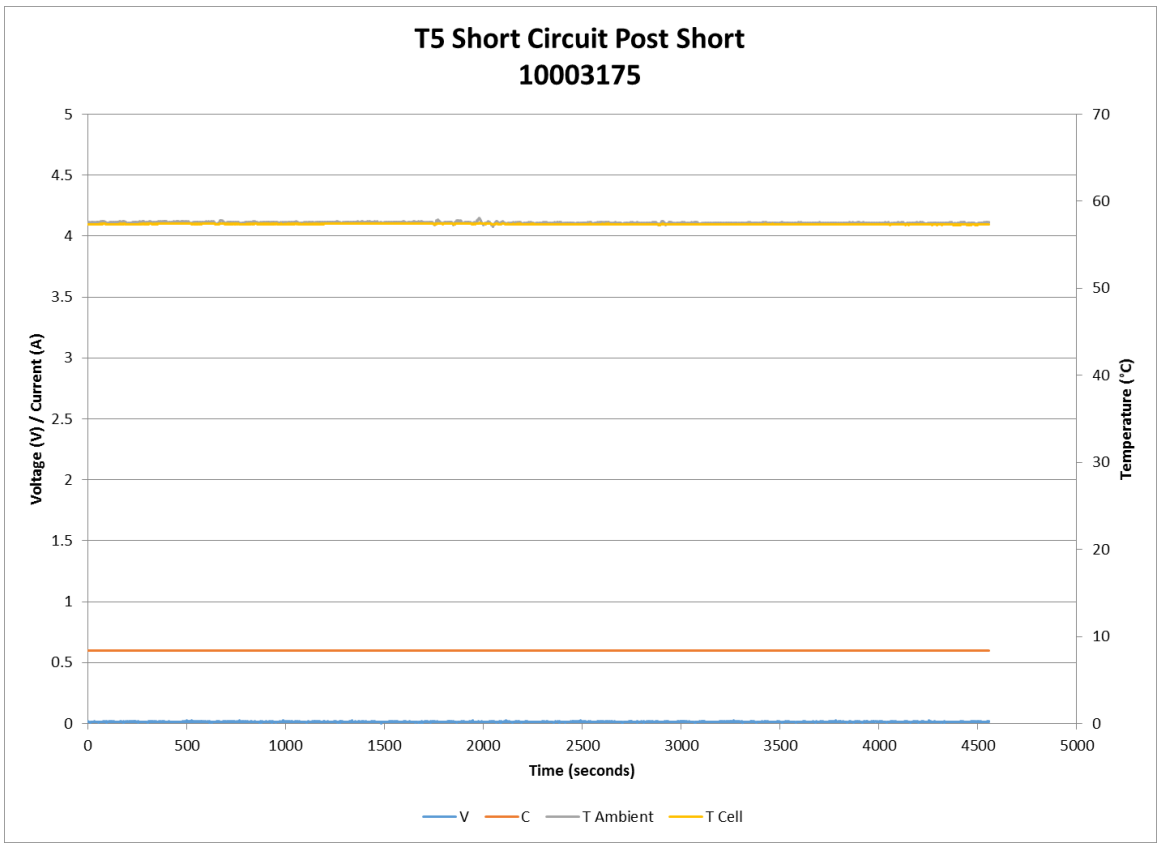

T5 Short Circuit
10003170
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

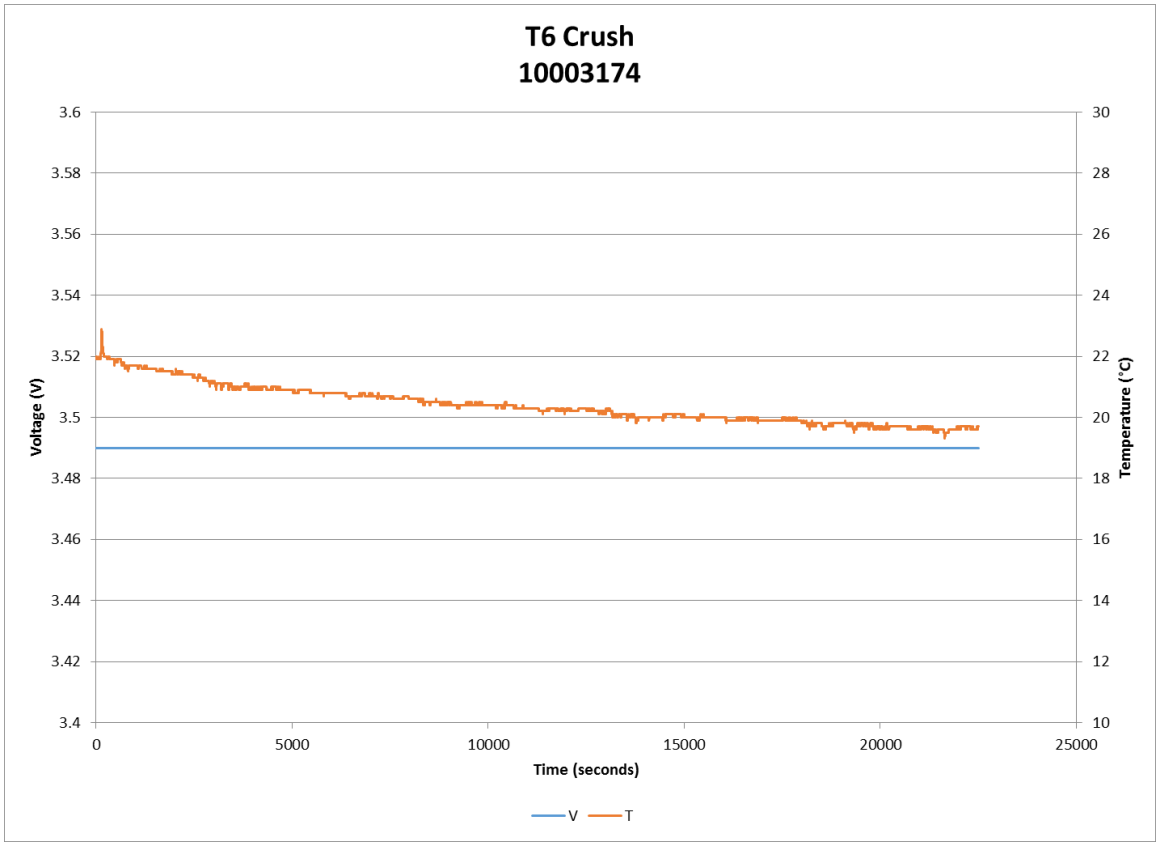

T5 Short Circuit Post Short
10003170
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

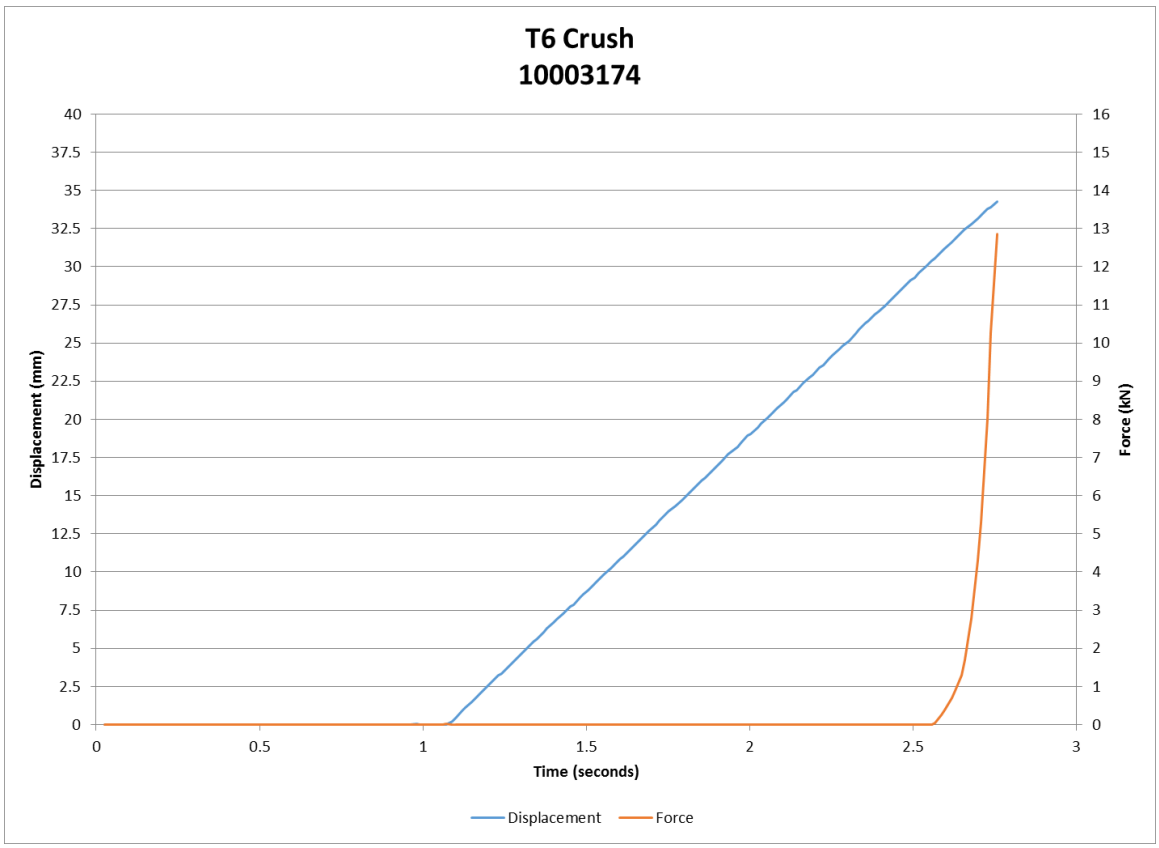

T5 Short Circuit
10003171
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

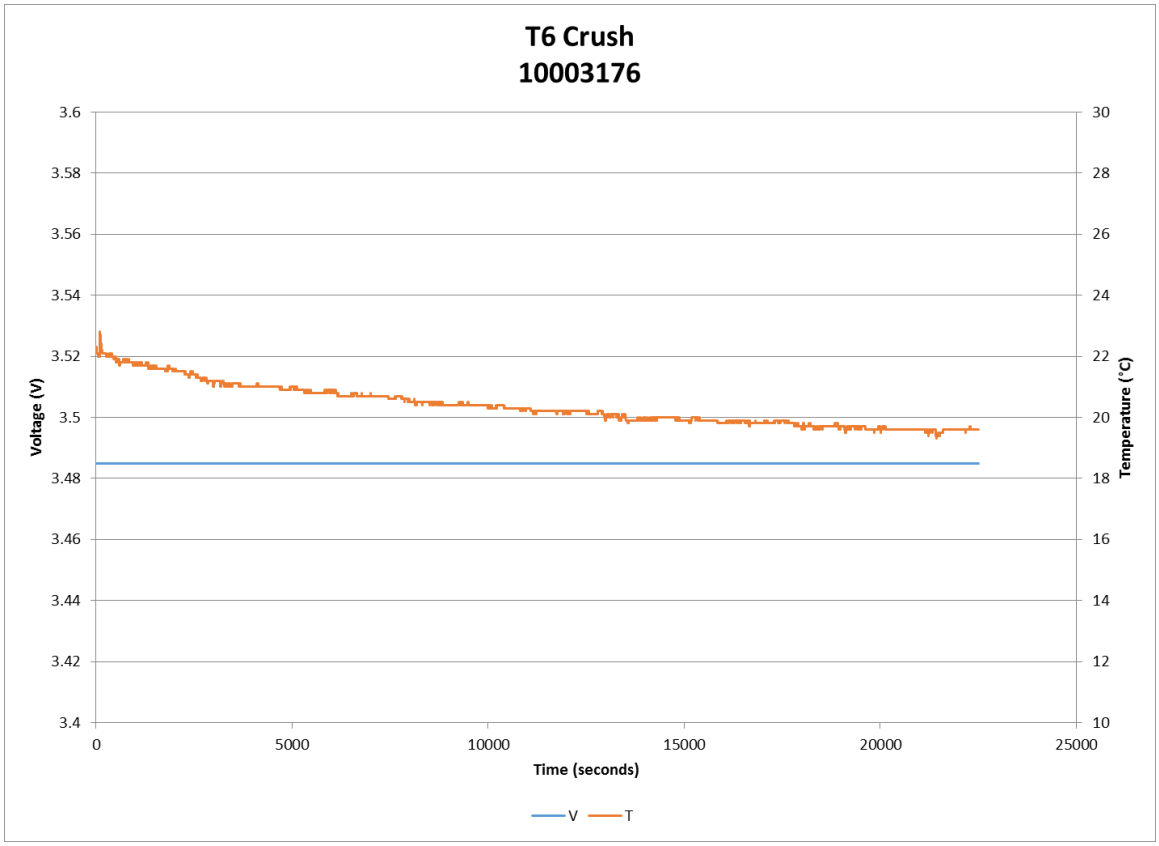

T5 Short Circuit Post Short
10003171
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

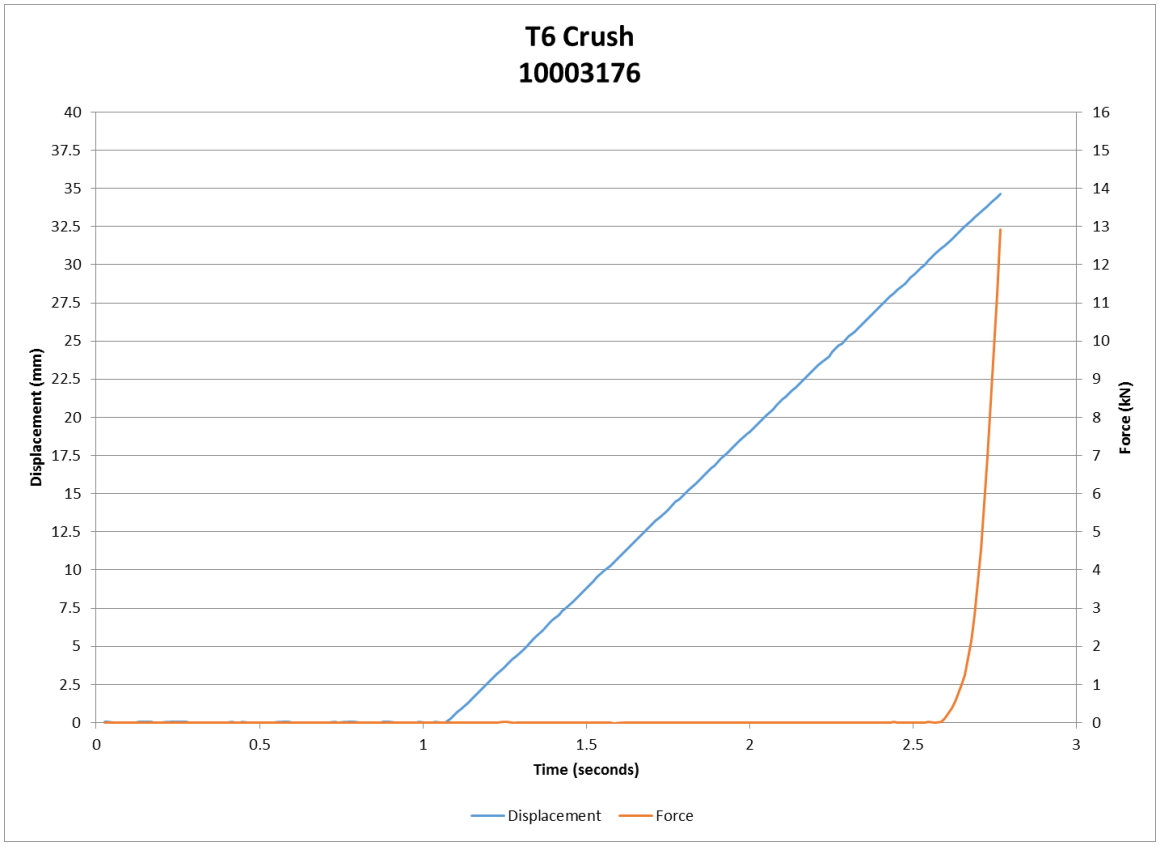

T5 Short Circuit
10003175
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

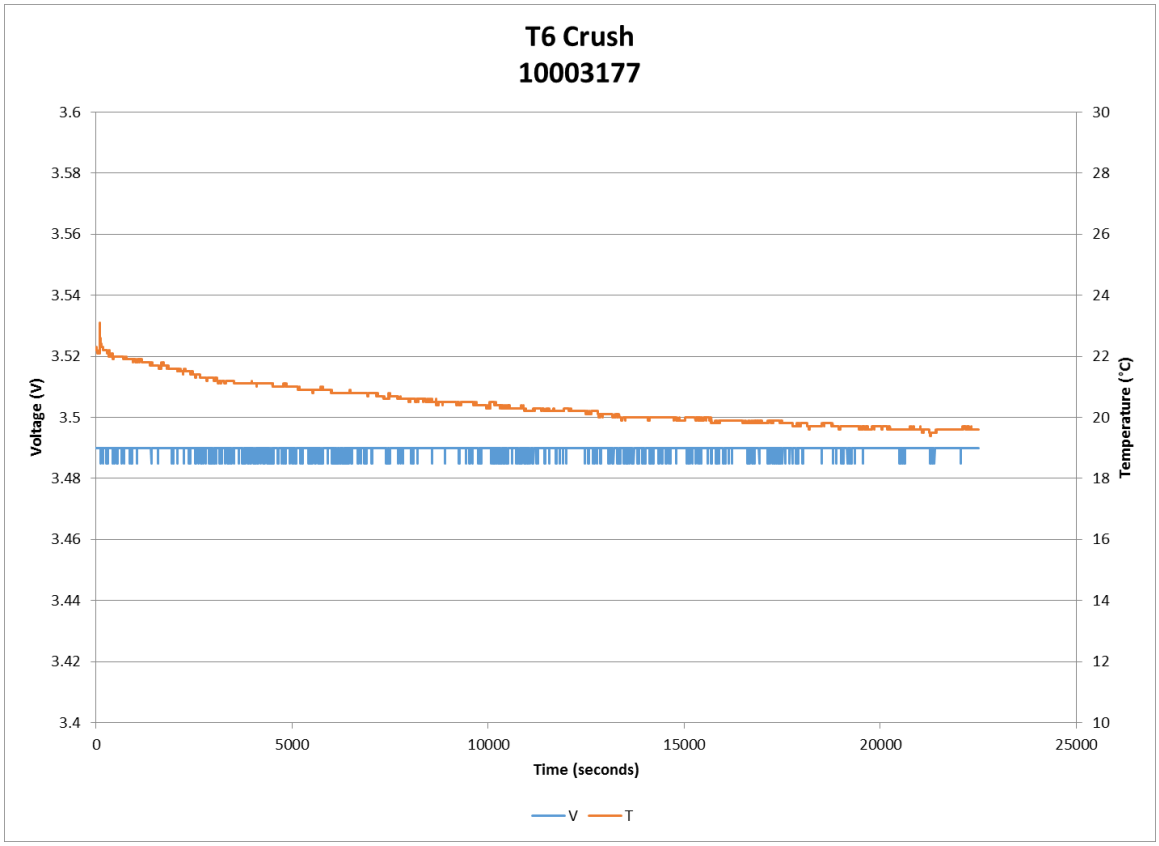

T5 Short Circuit Post Short
10003175
Voltage (V) / Current (A)
Temperature (°C)
Time (seconds)
V
C
T Ambient
T Cell

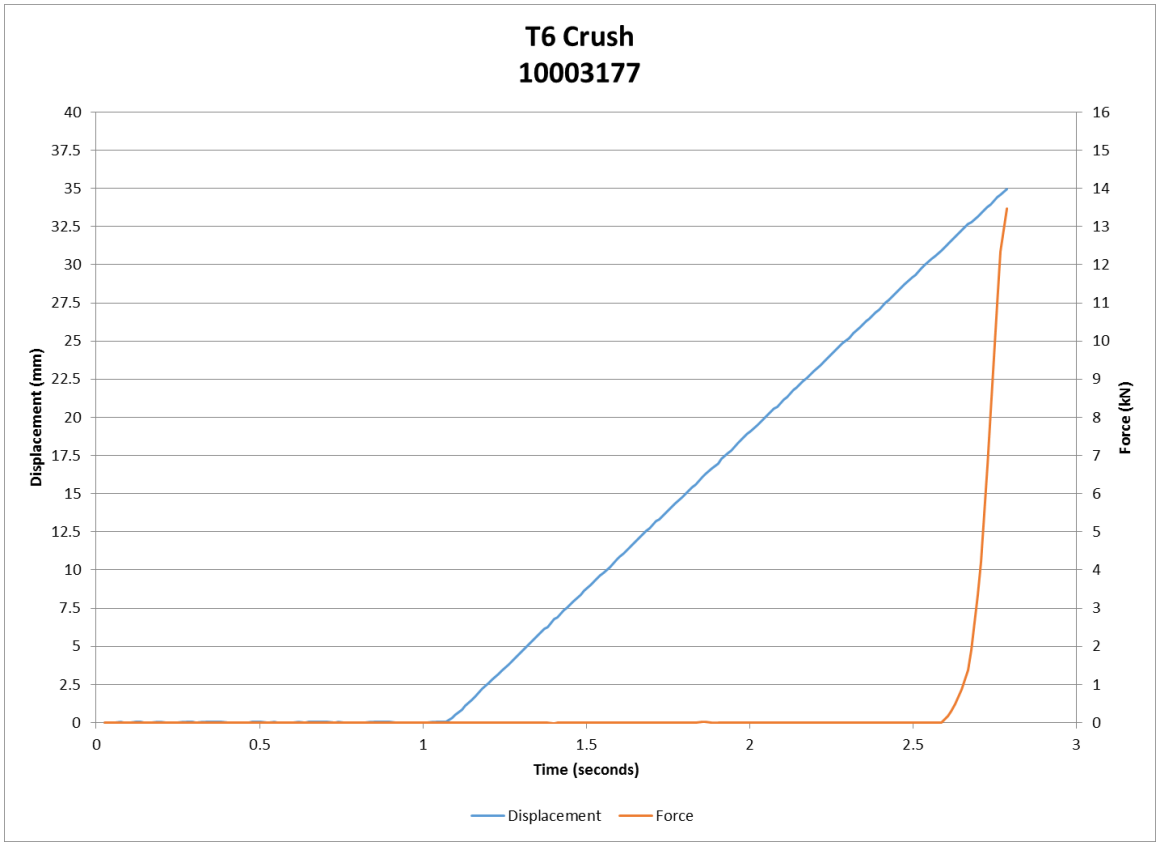

T6 Crush
10003174
Voltage (V)
Temperature (°C)
Time (seconds)
V
T

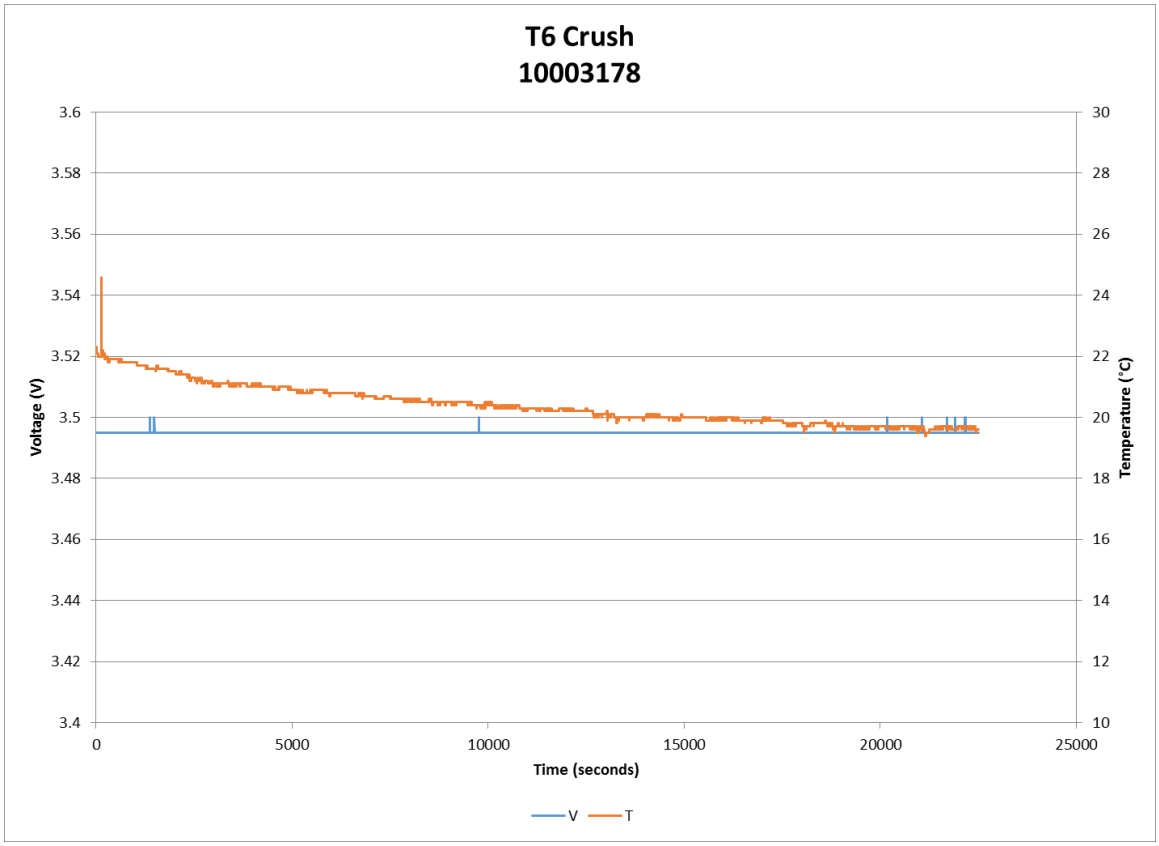

T6 Crush
10003174
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force

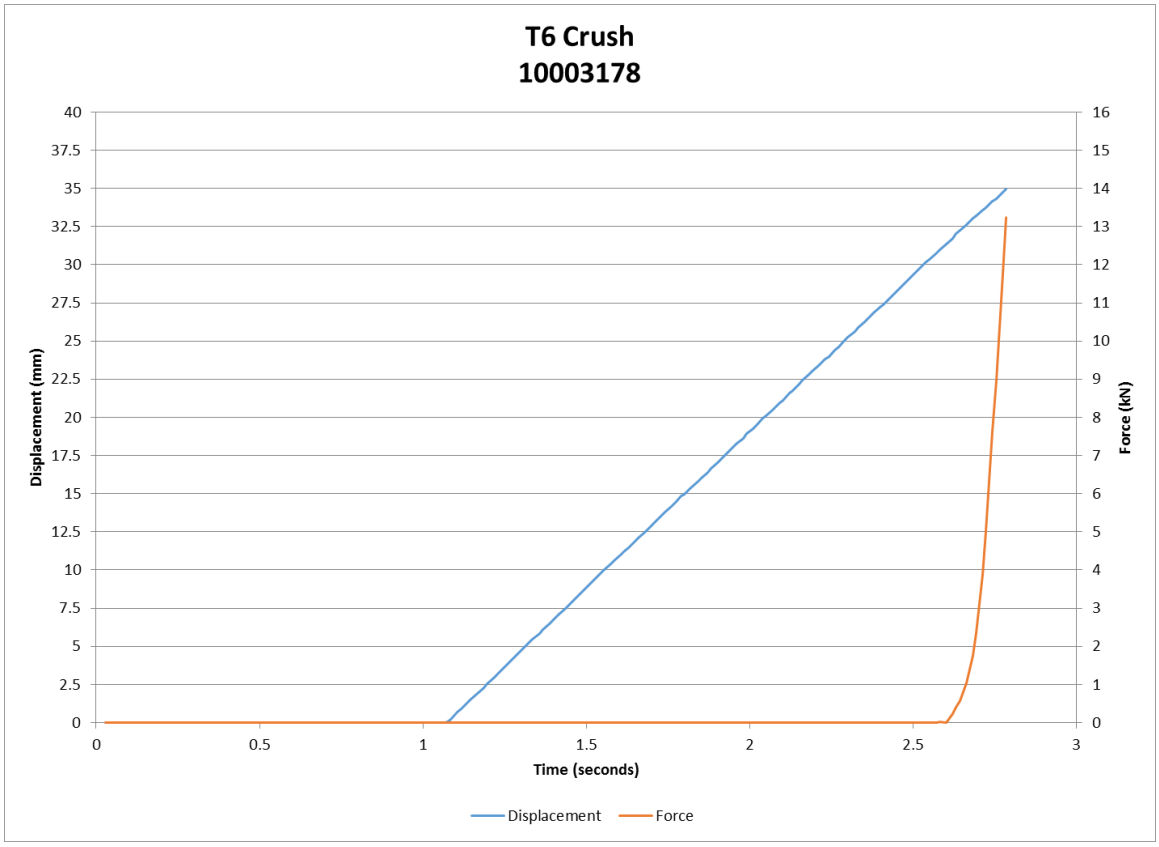

T6 Crush
10003176
Voltage (V)
Temperature (°C)
Time (seconds)
V
T

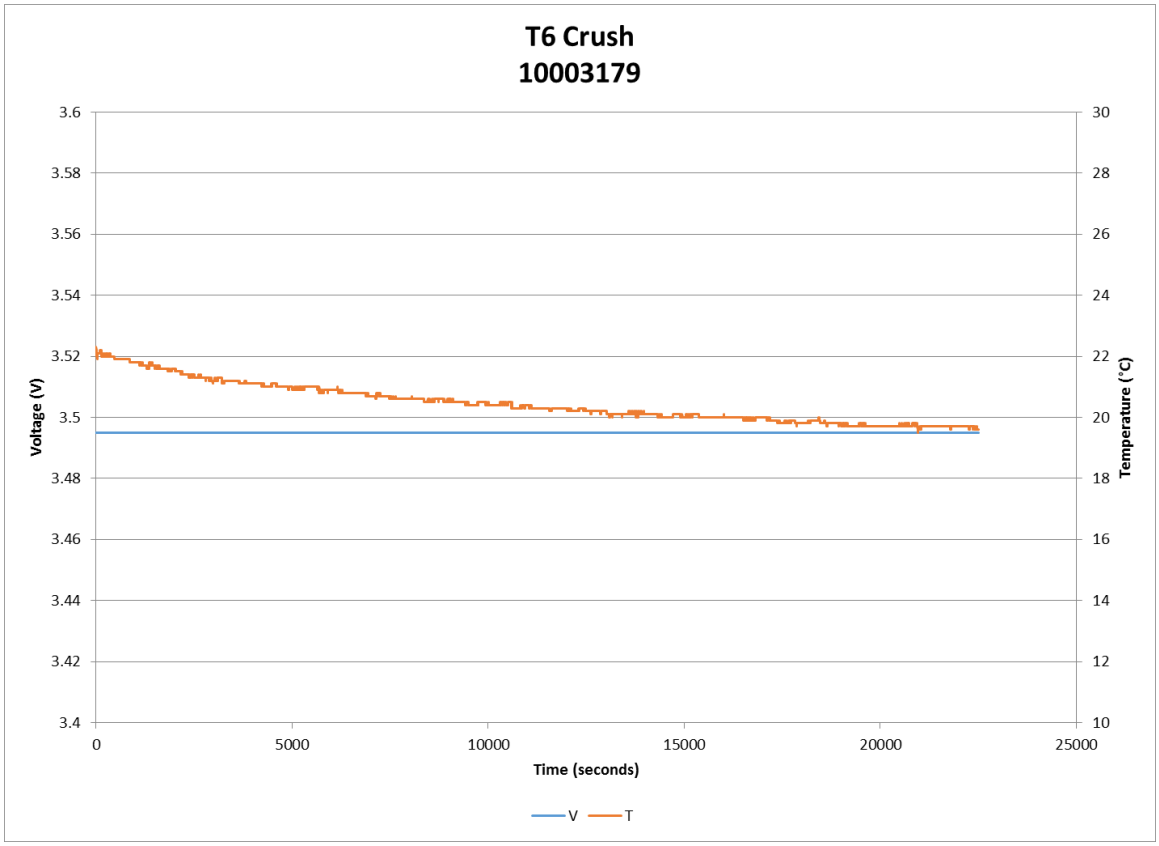

T6 Crush
10003176
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force

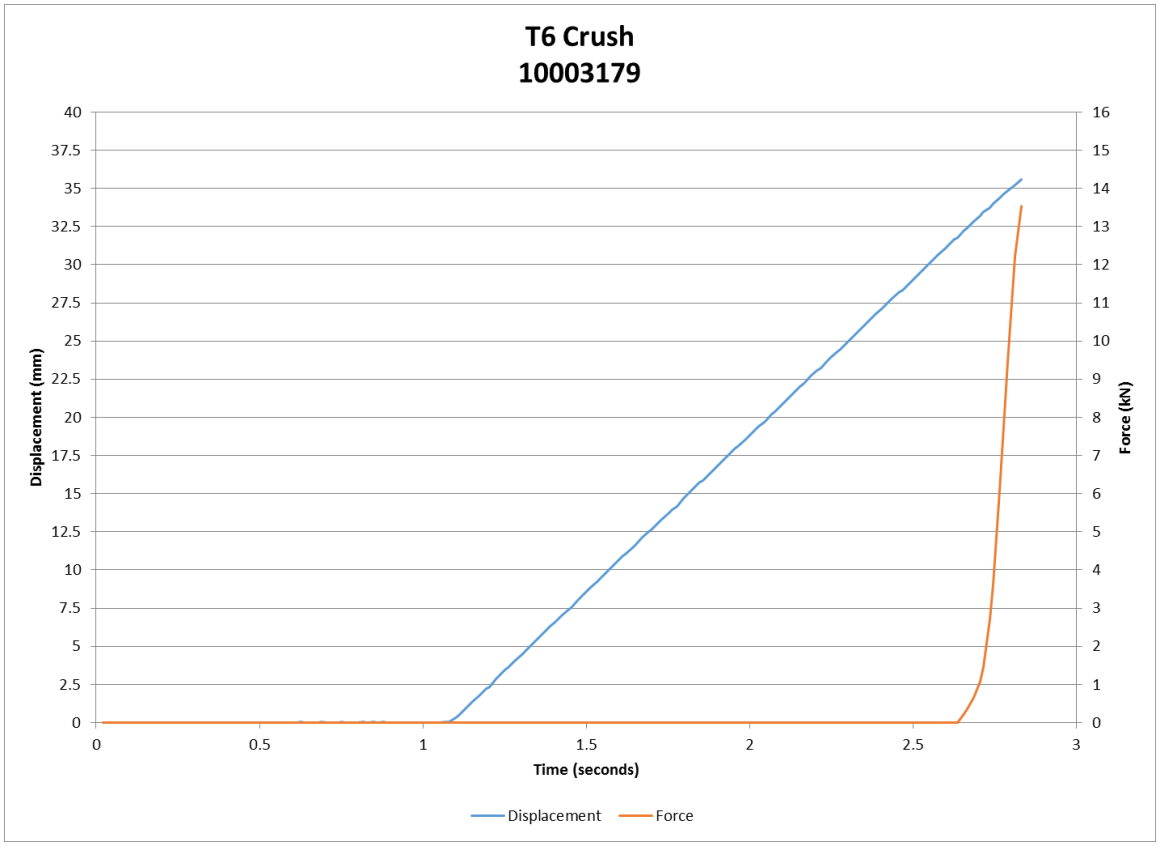

T6 Crush
10003177
Voltage (V)
Temperature (°C)
Time (seconds)
V
T

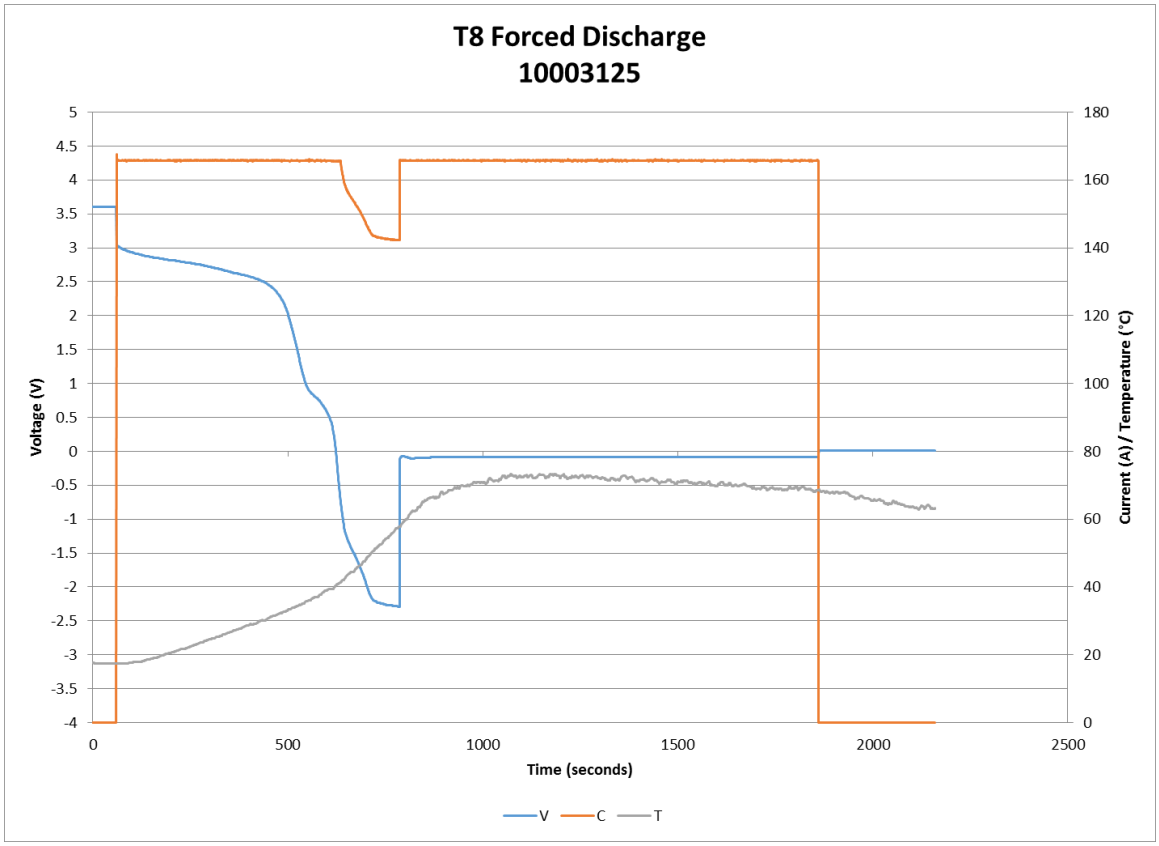

T6 Crush
10003177
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force

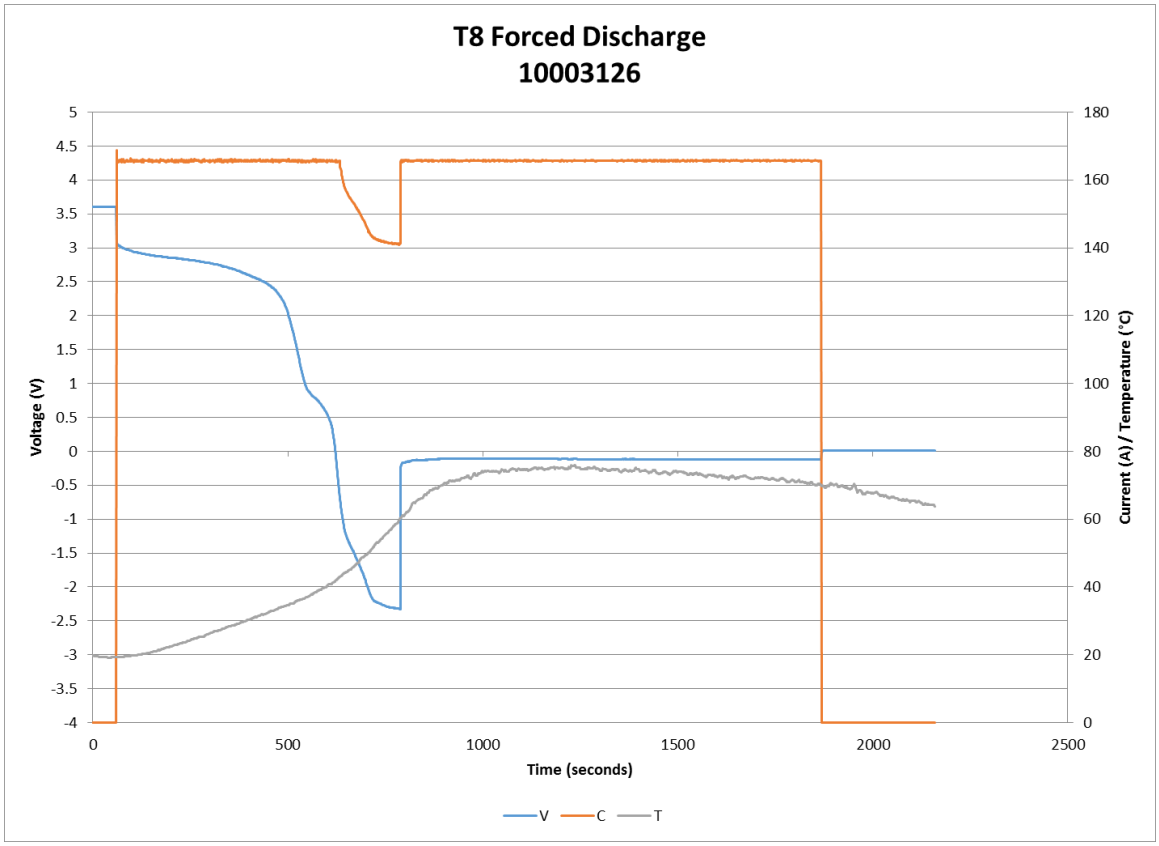

T6 Crush
10003178
Voltage (V)
Temperature (°C)
Time (seconds)
V
T

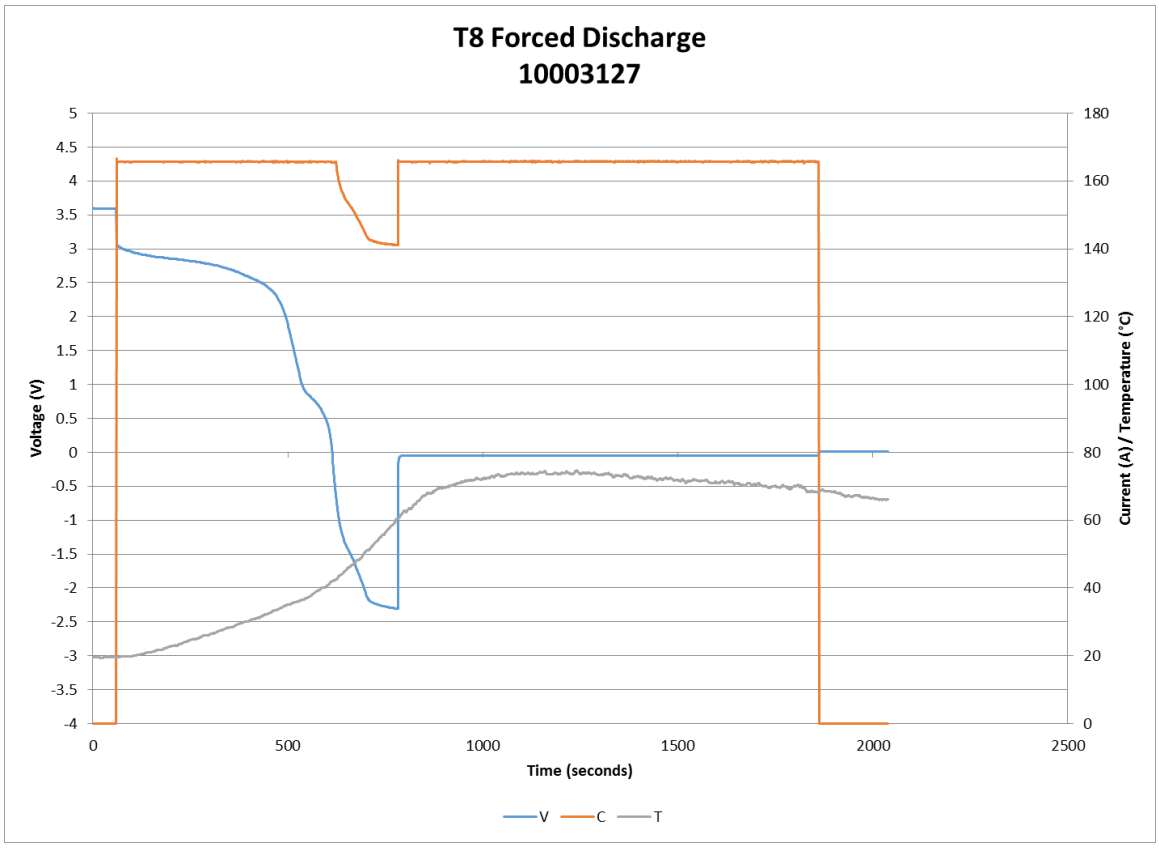

T6 Crush
10003178
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force

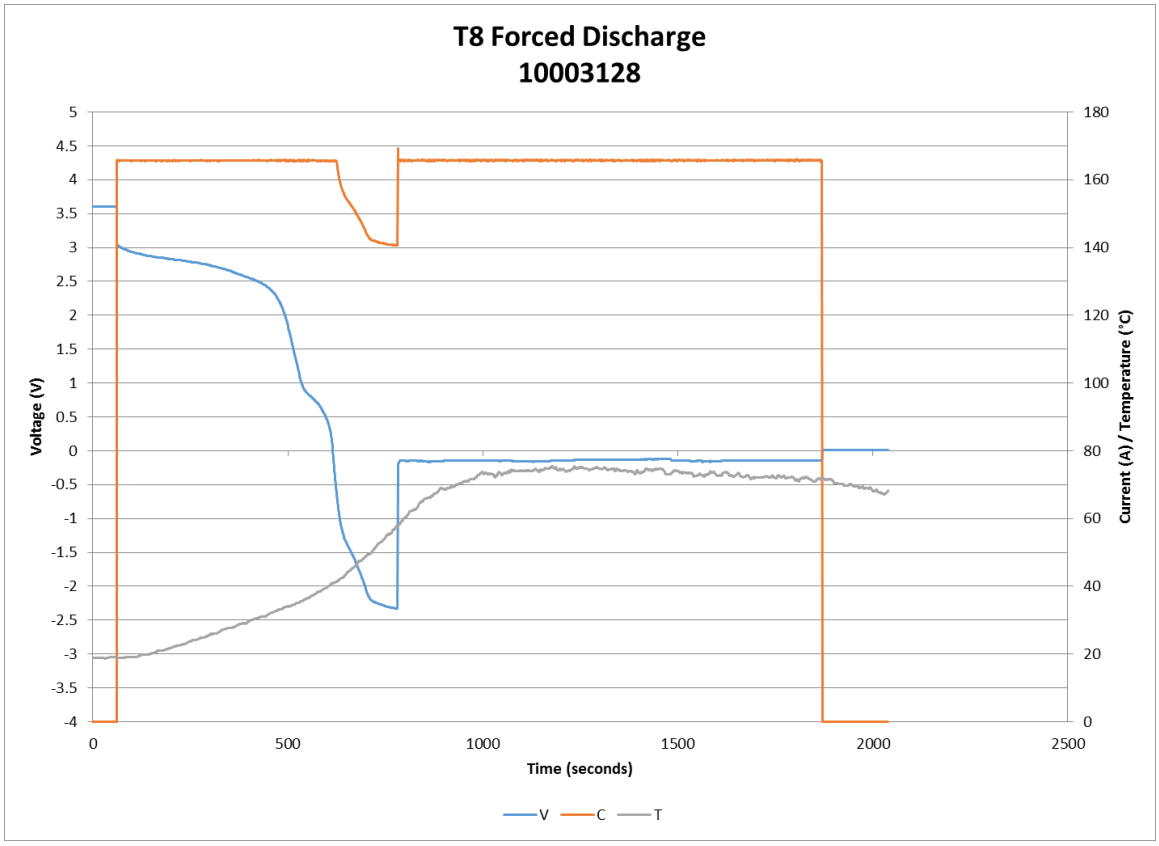

T6 Crush
10003179
Voltage (V)
Temperature (°C)
Time (seconds)
V
T

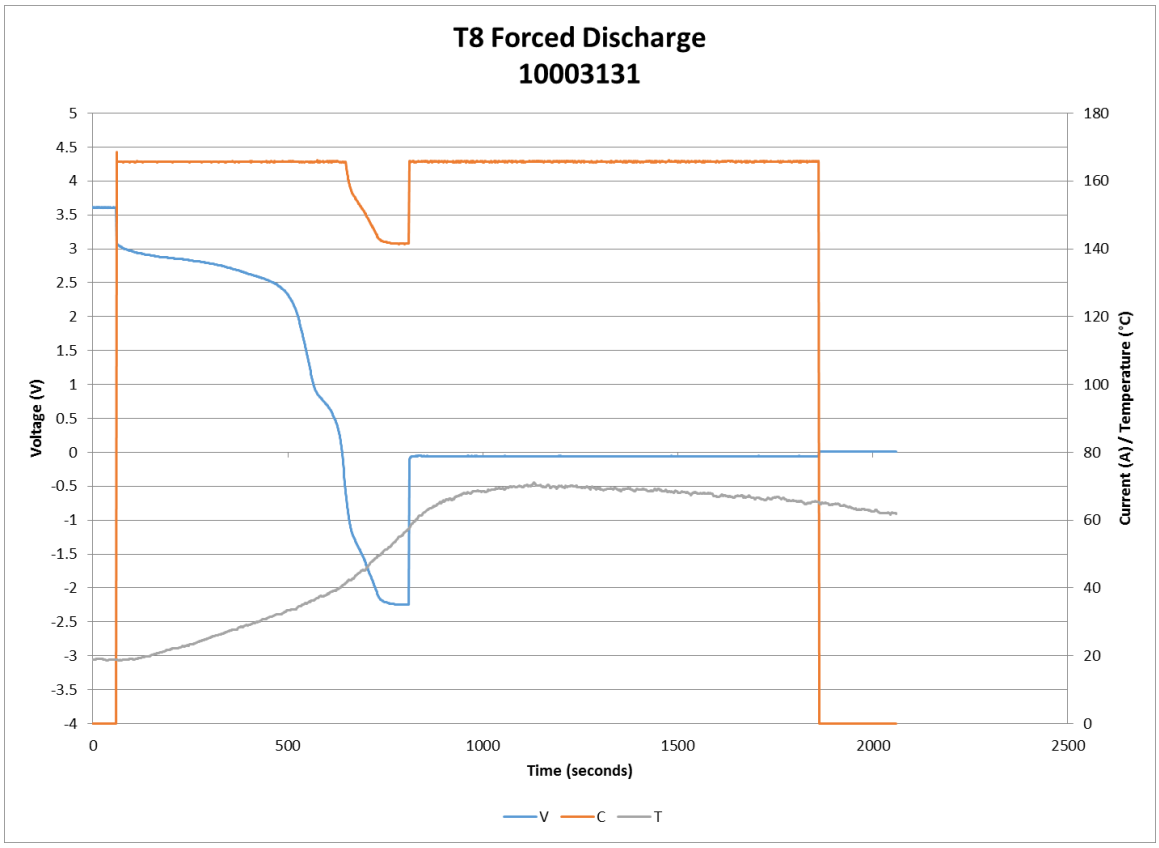

T6 Crush
10003179
Displacement (mm)
Force (kN)
Time (seconds)
Displacement
Force


T8 Forced Discharge
10003125
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003126
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003127
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003128
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T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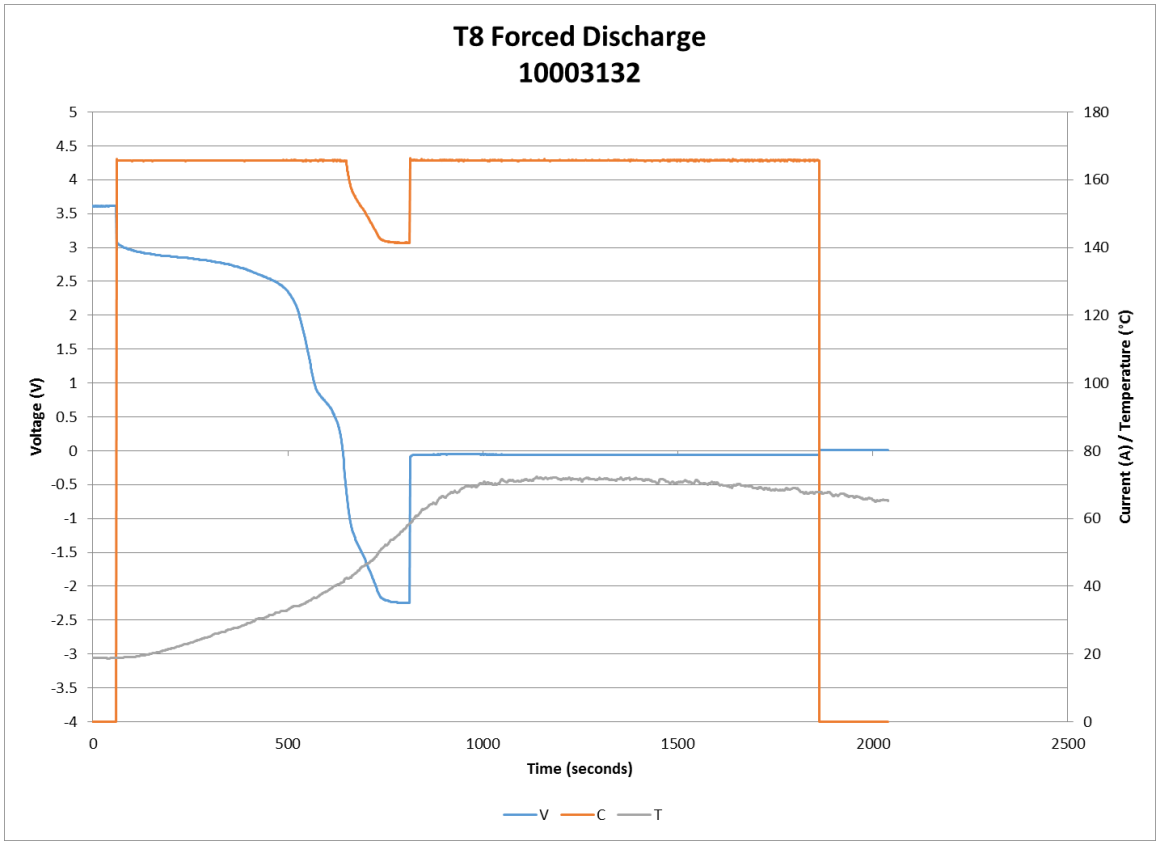
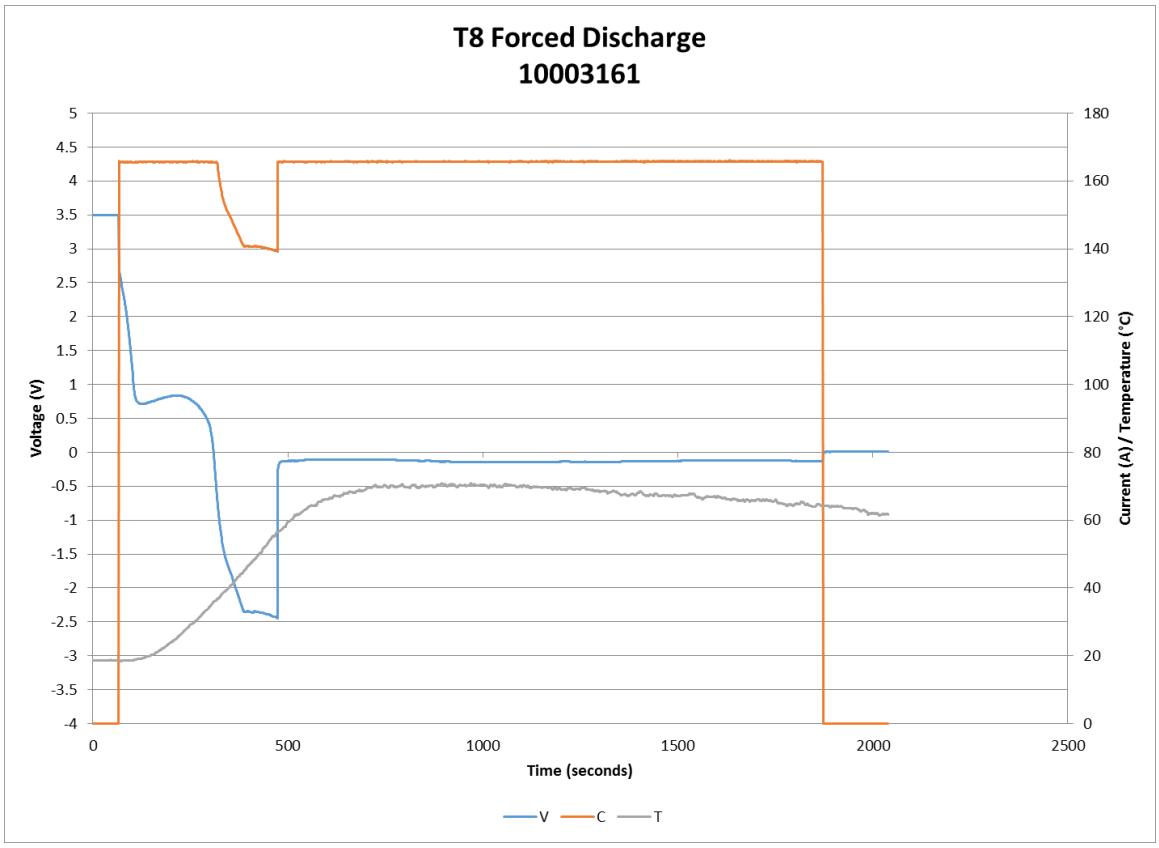
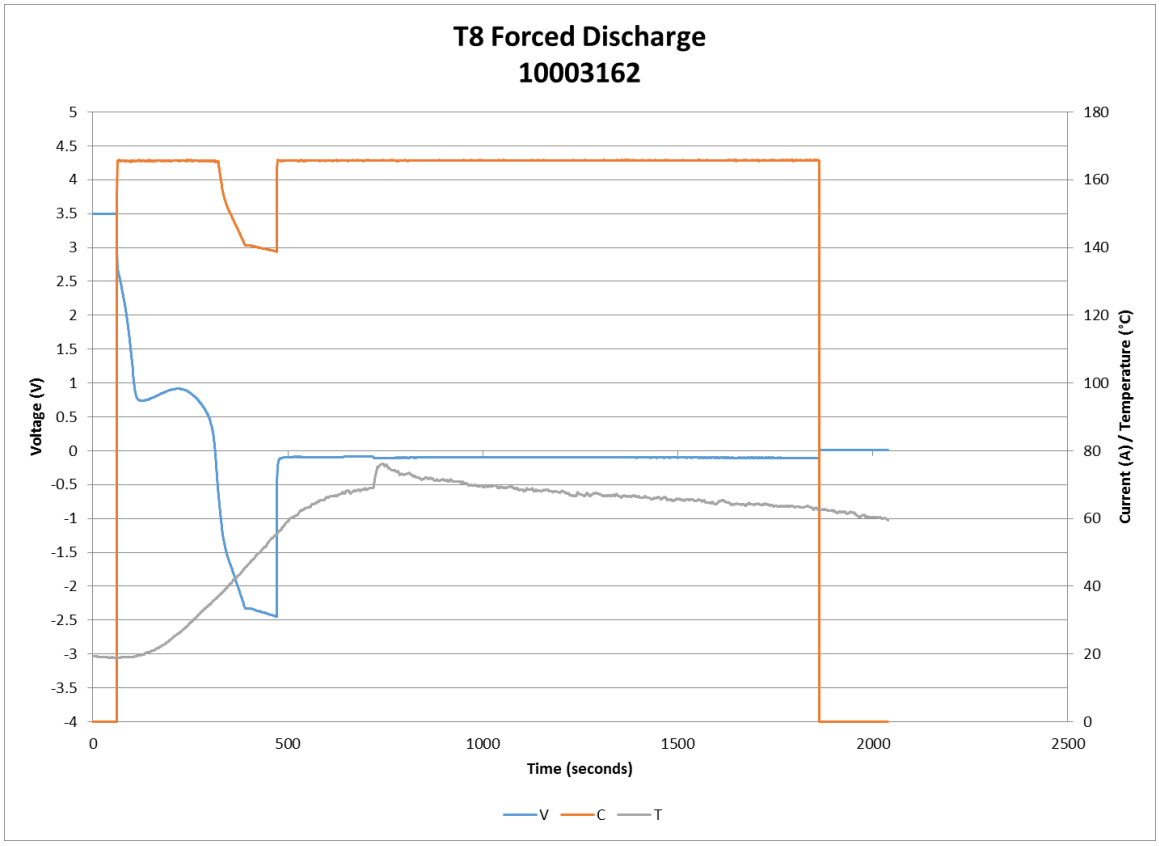
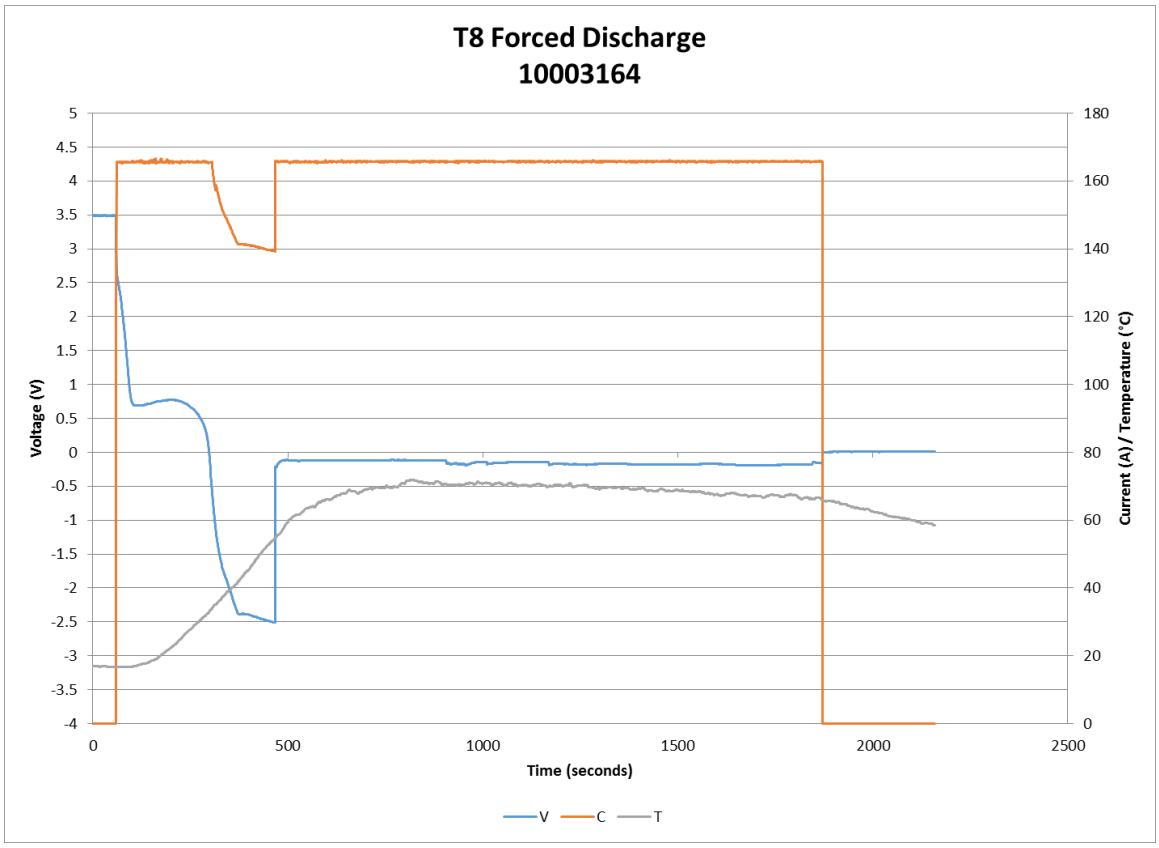
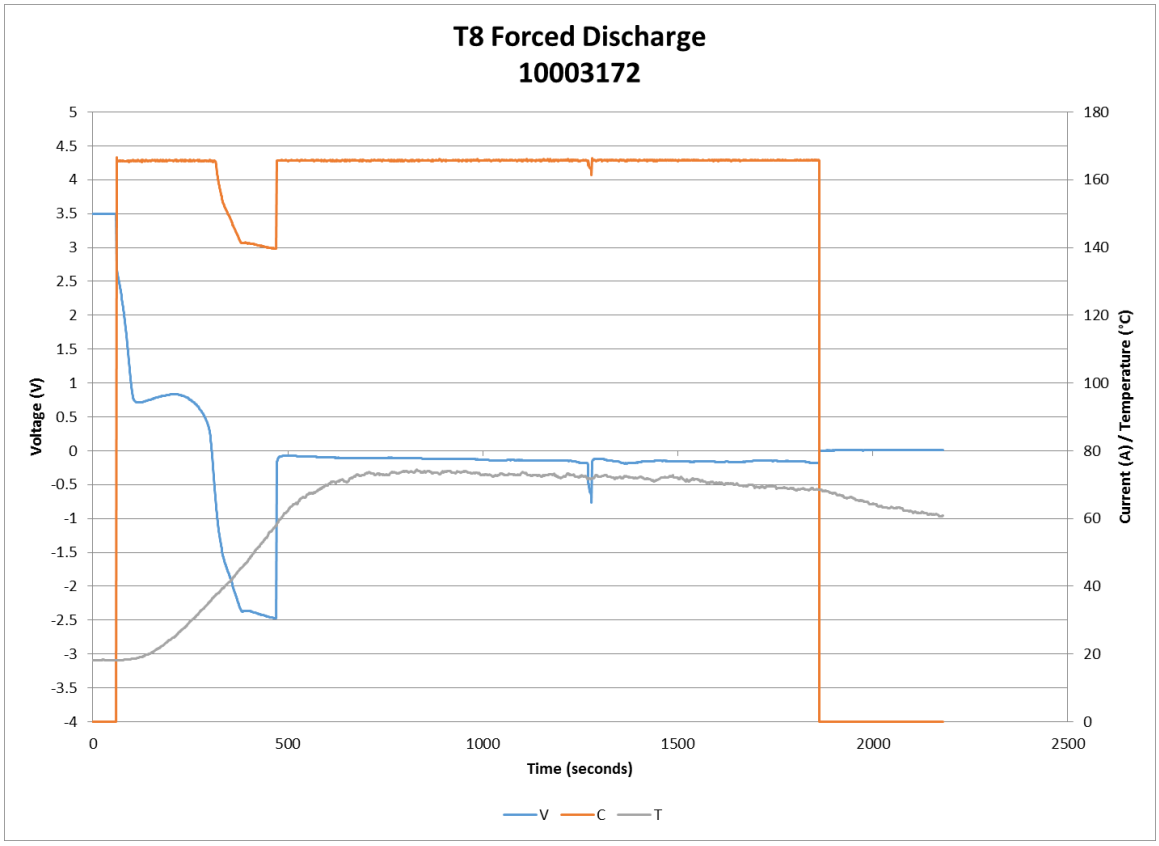
10003131
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

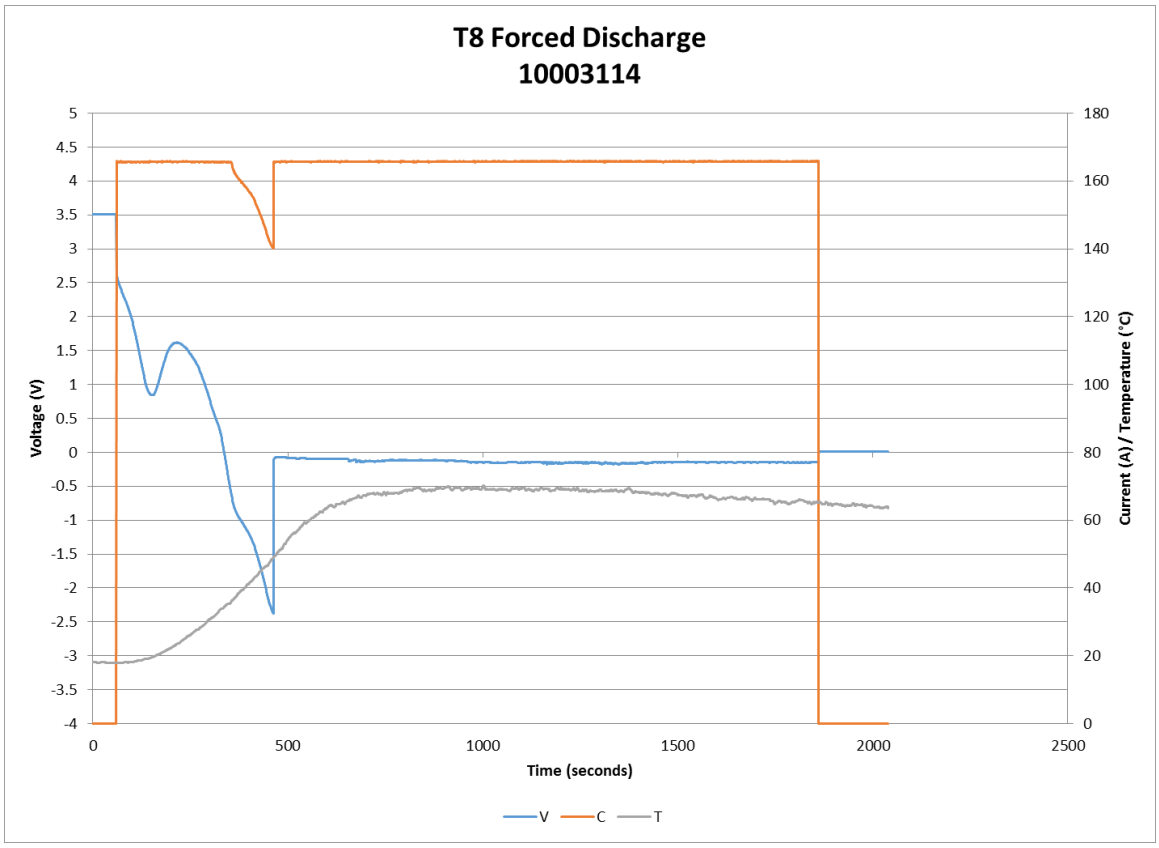

T8 Forced Discharge
10003132
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

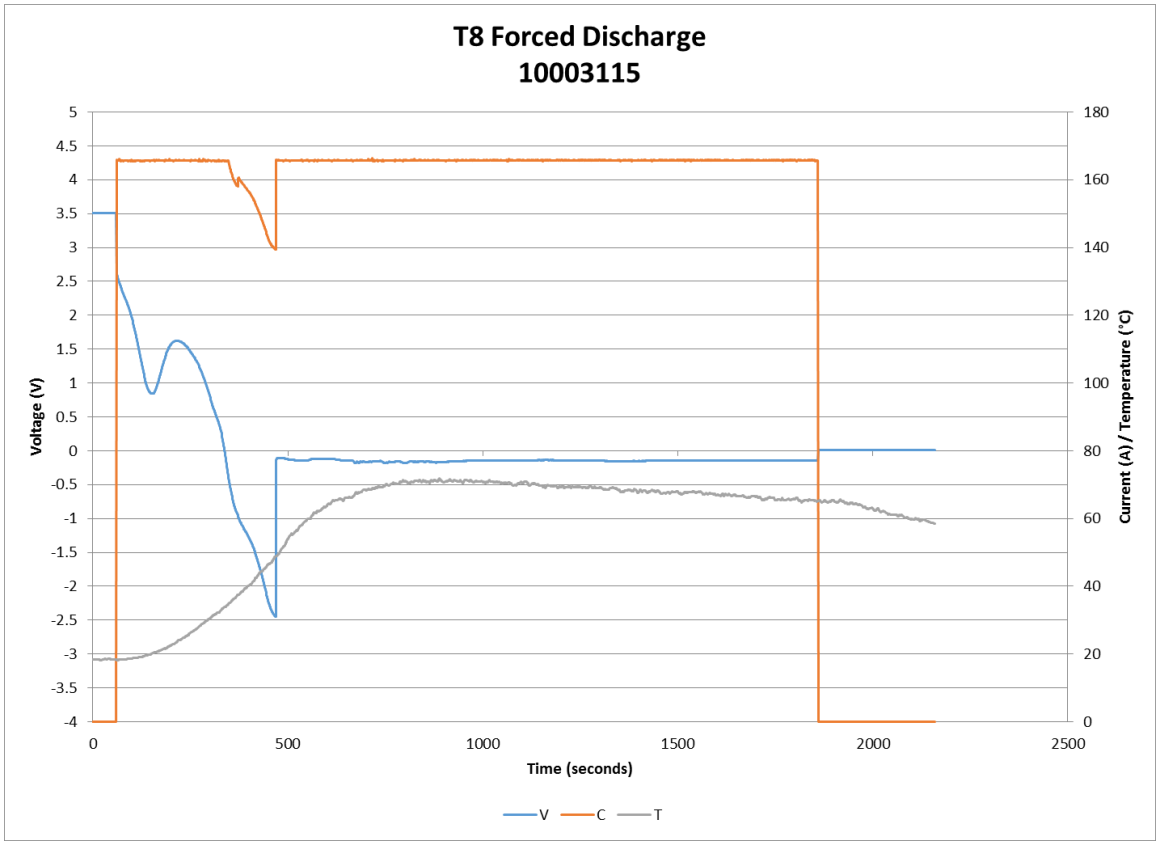

T8 Forced Discharge
10003161
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

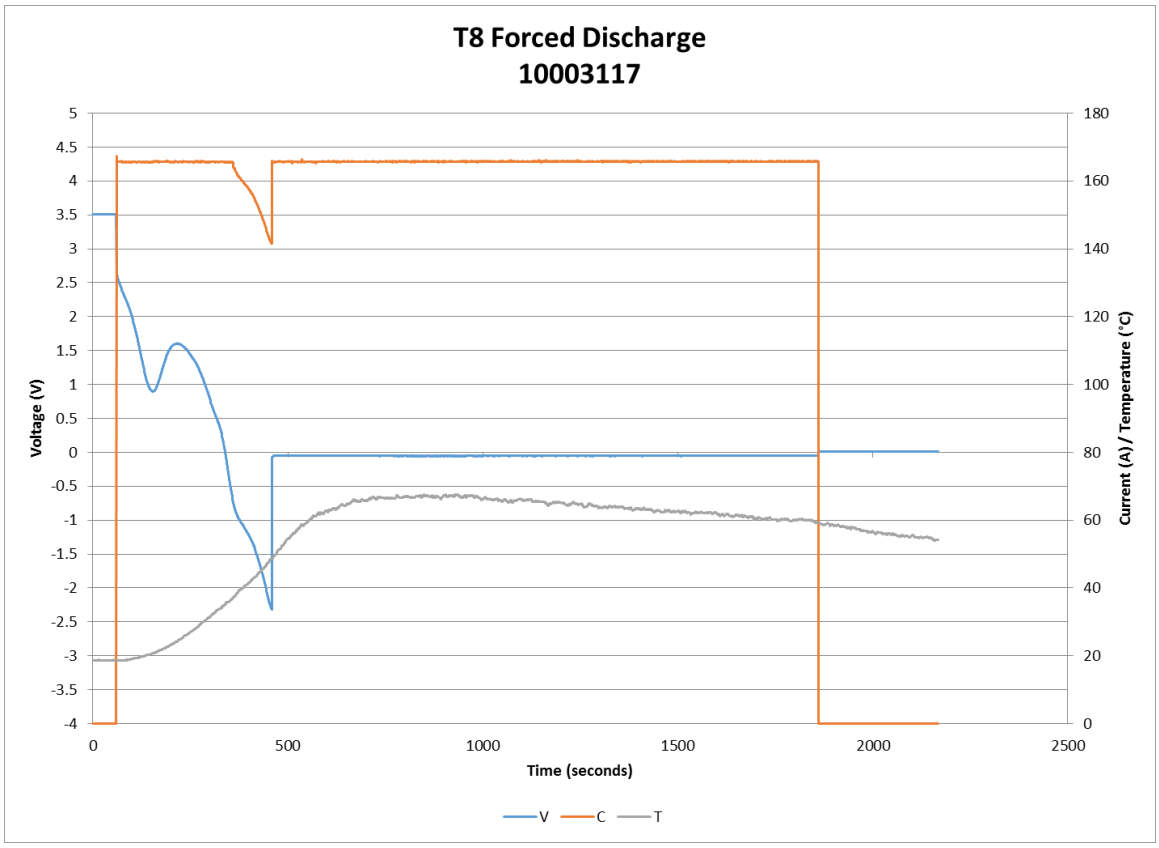

T8 Forced Discharge
10003162
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

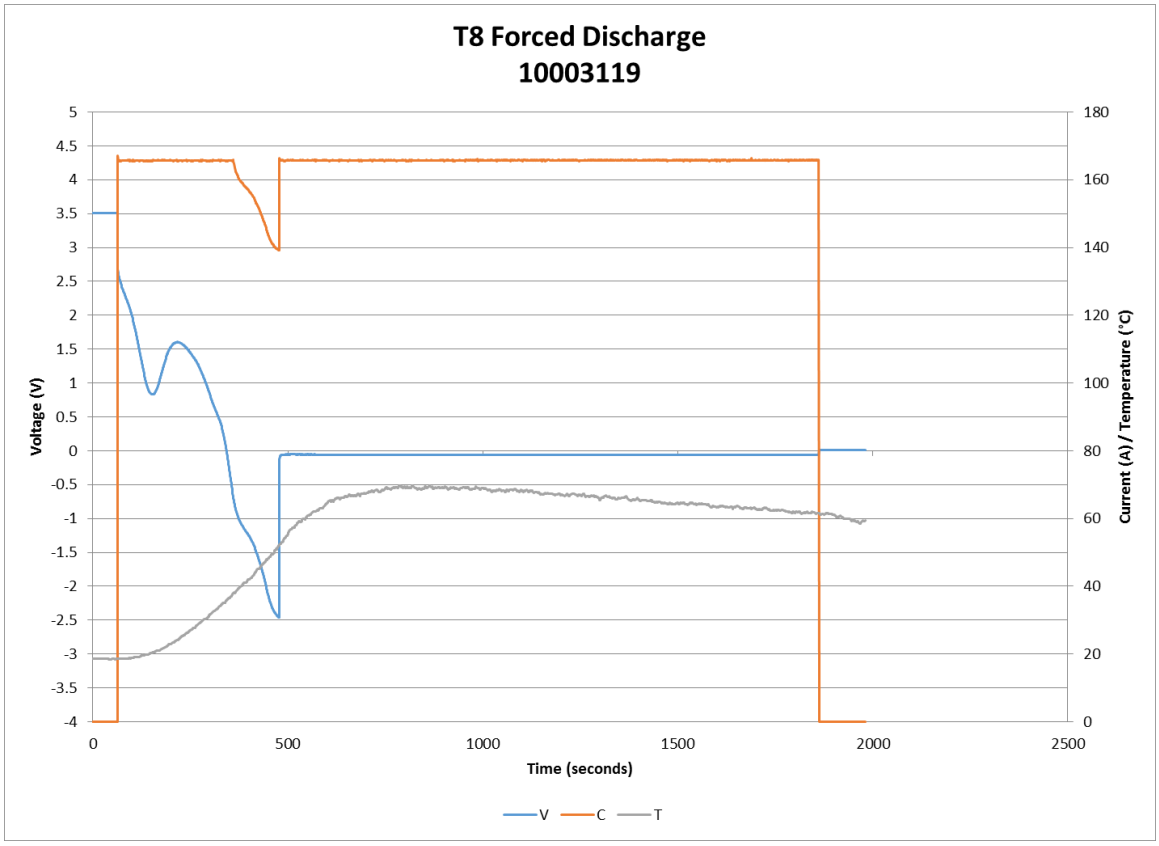

T8 Forced Discharge
10003164
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

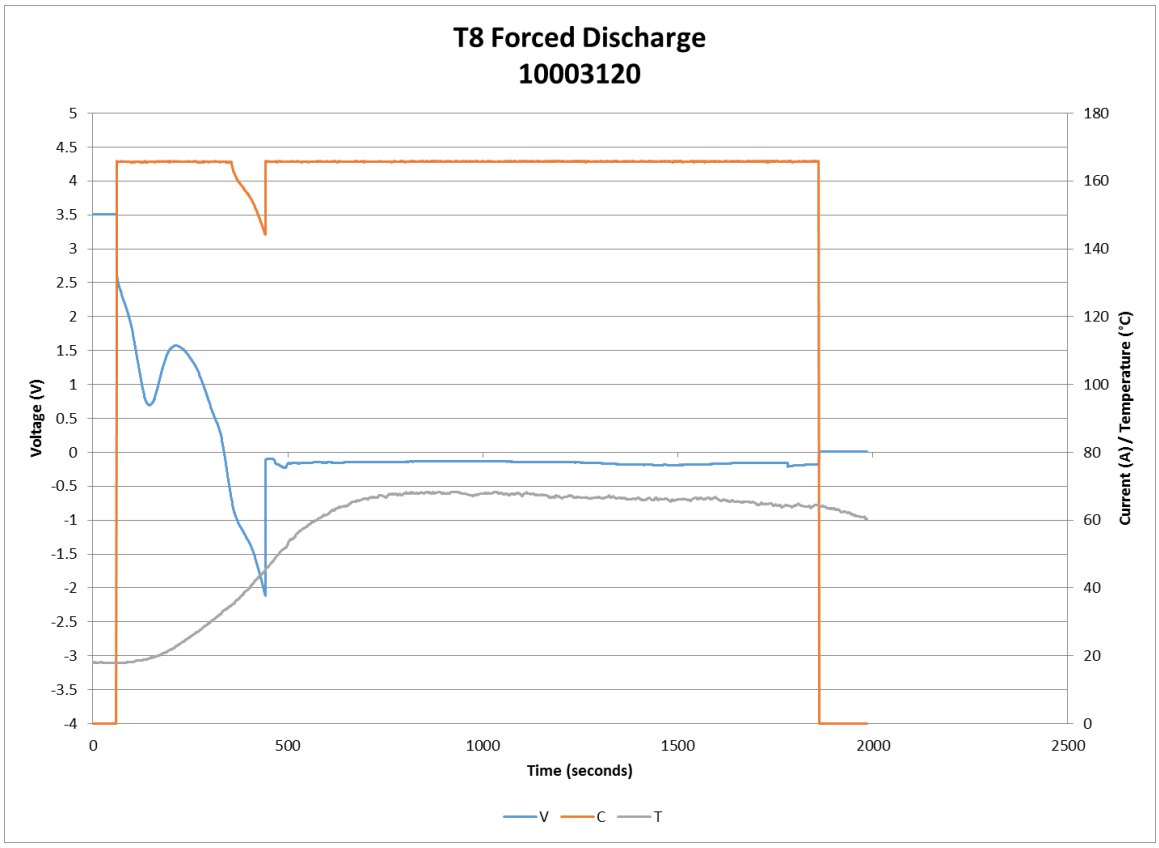

T8 Forced Discharge
10003172
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

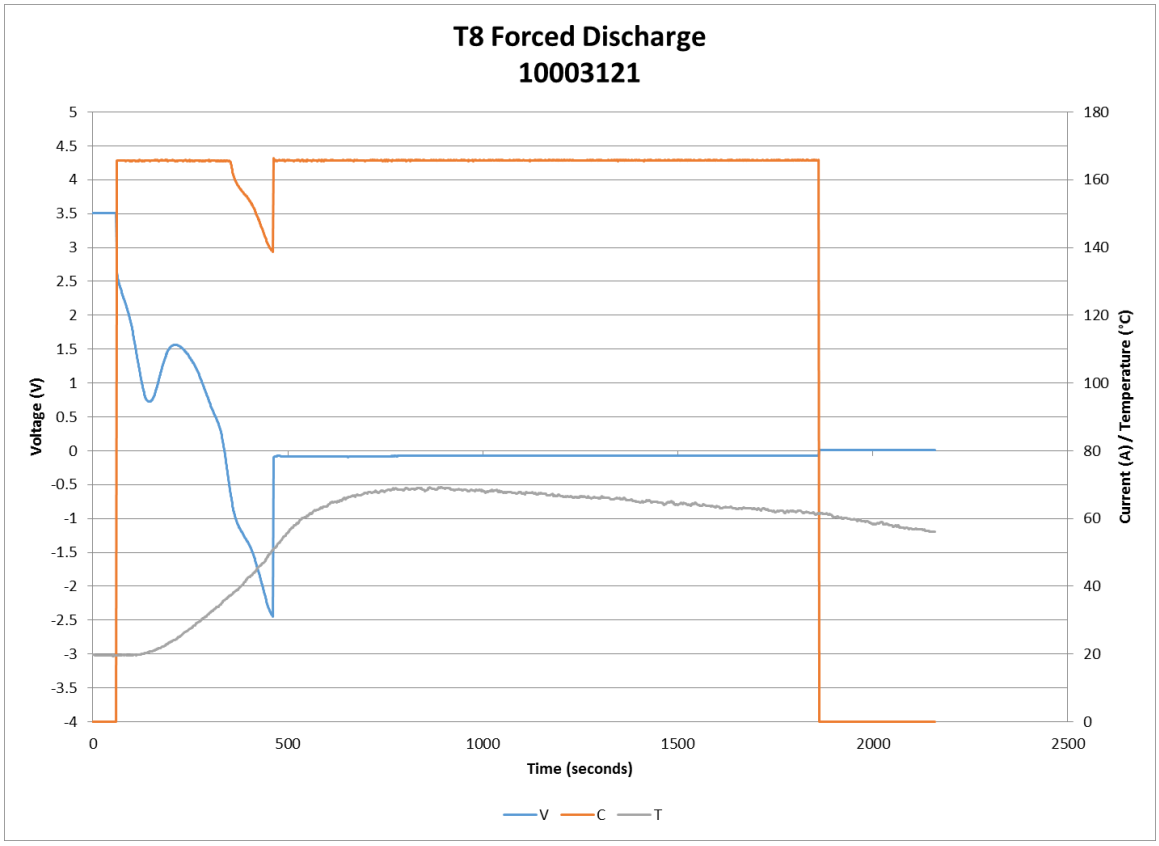

T8 Forced Discharge
10003114
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

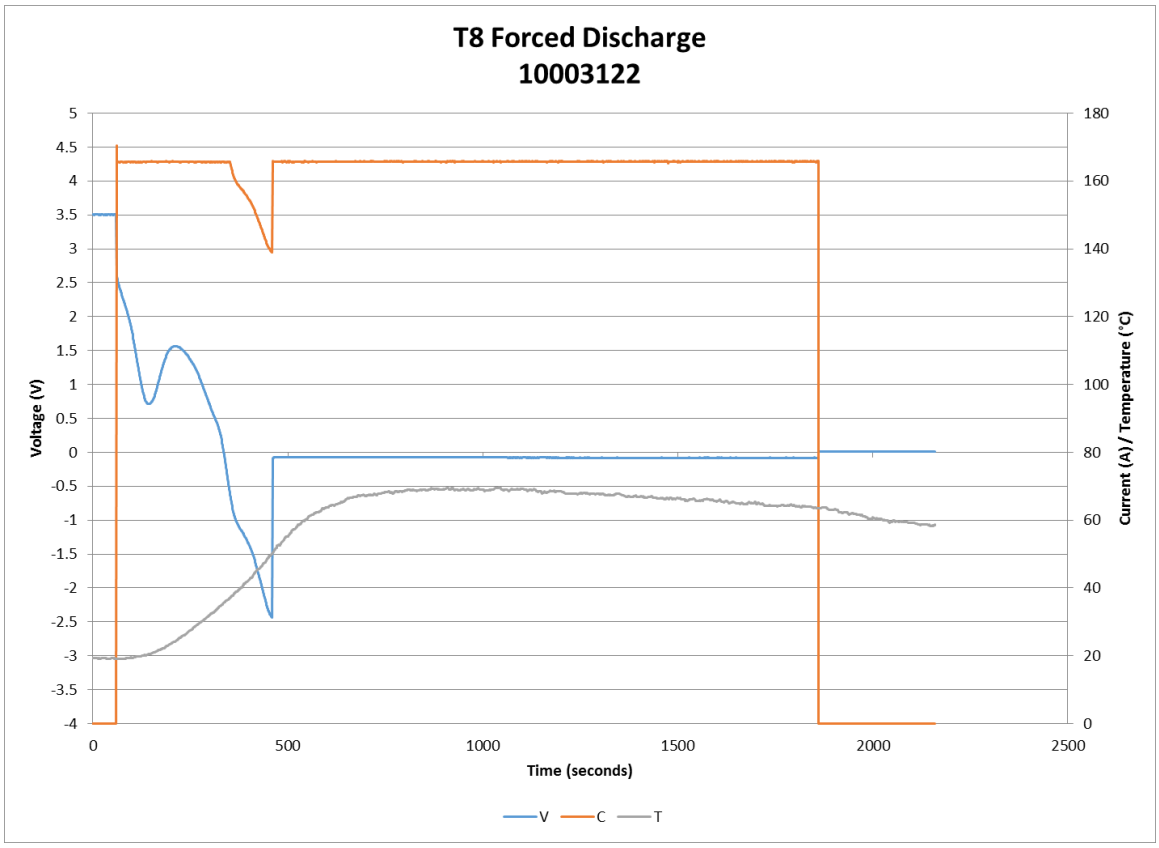

T8 Forced Discharge
10003115
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

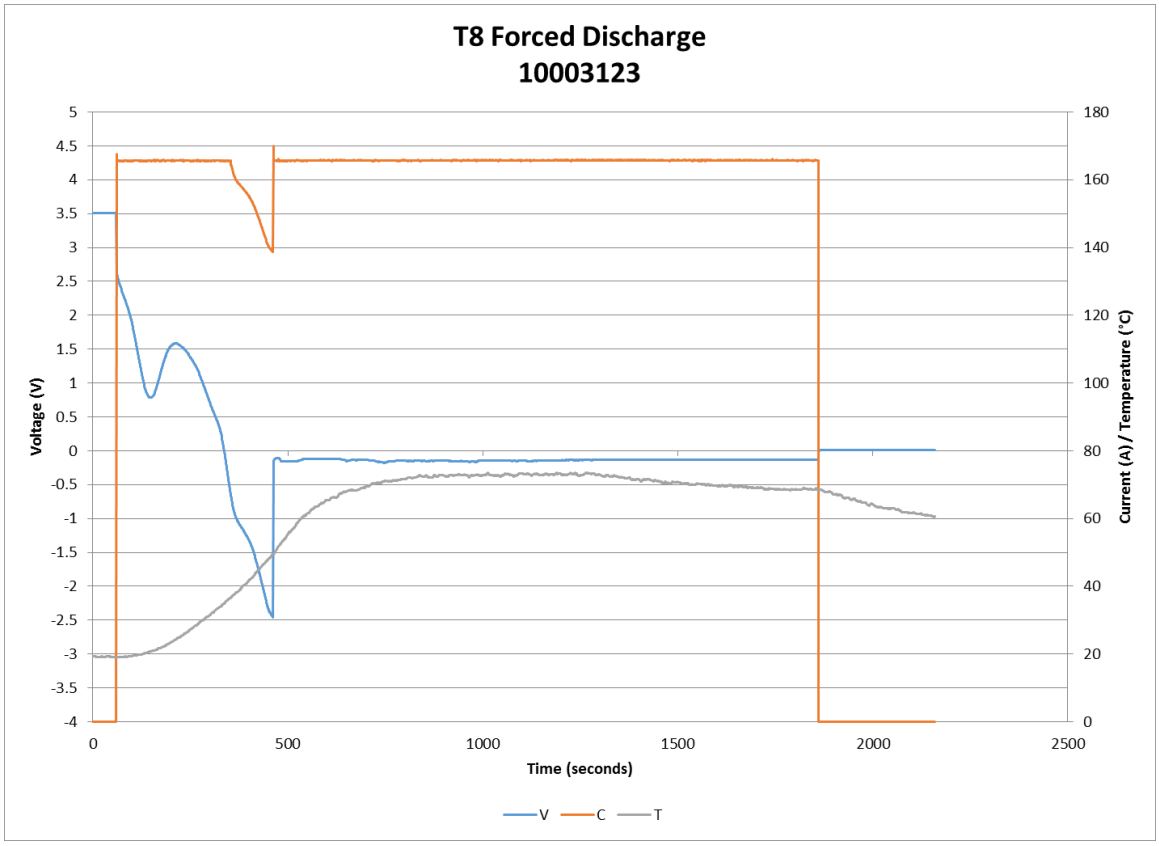

T8 Forced Discharge
10003117
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

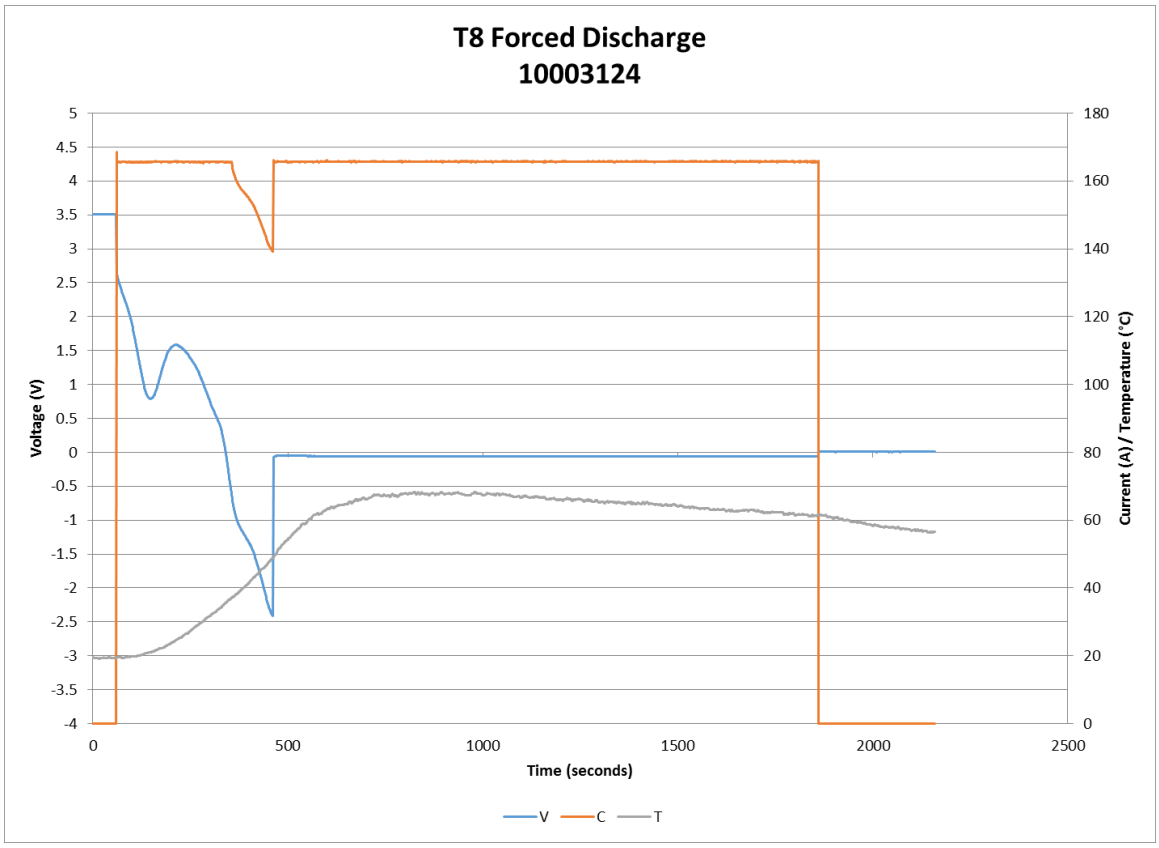

T8 Forced Discharge
10003119
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

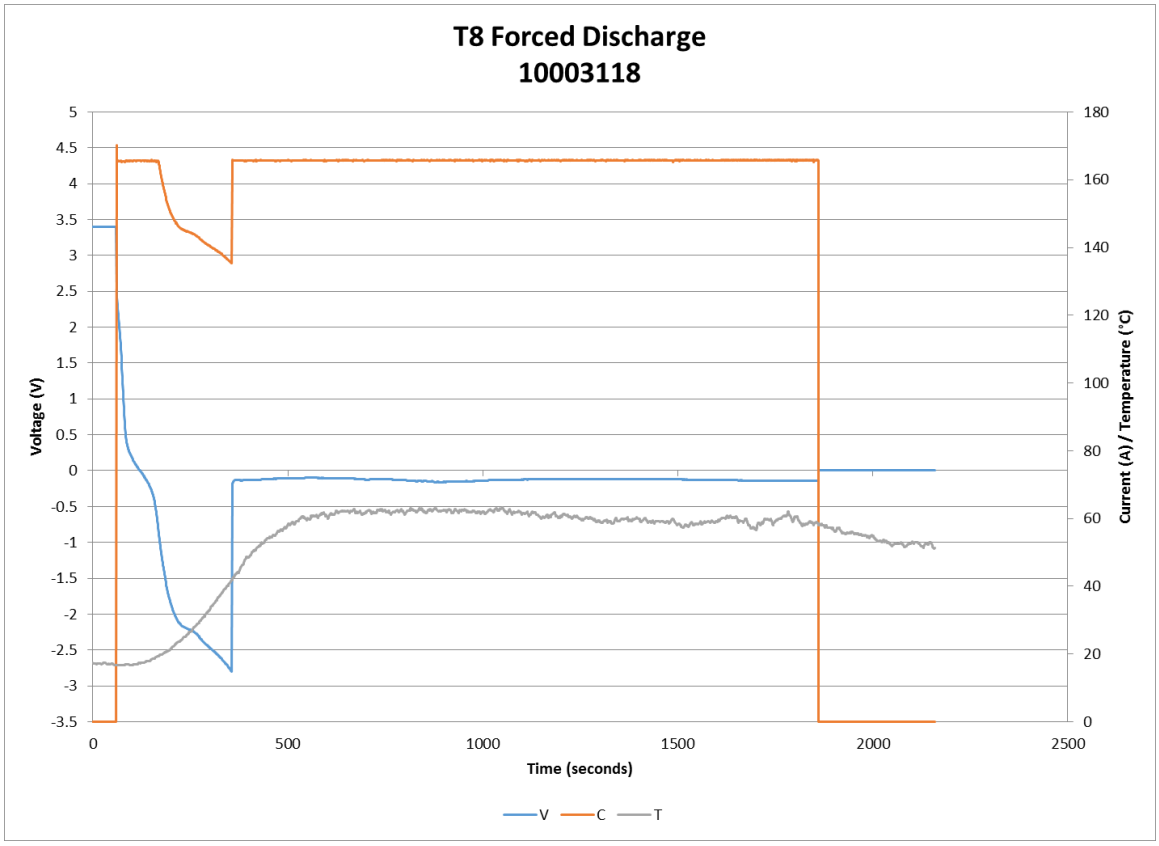

T8 Forced Discharge
10003120
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003121
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003122
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003123
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T


T8 Forced Discharge
10003124
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

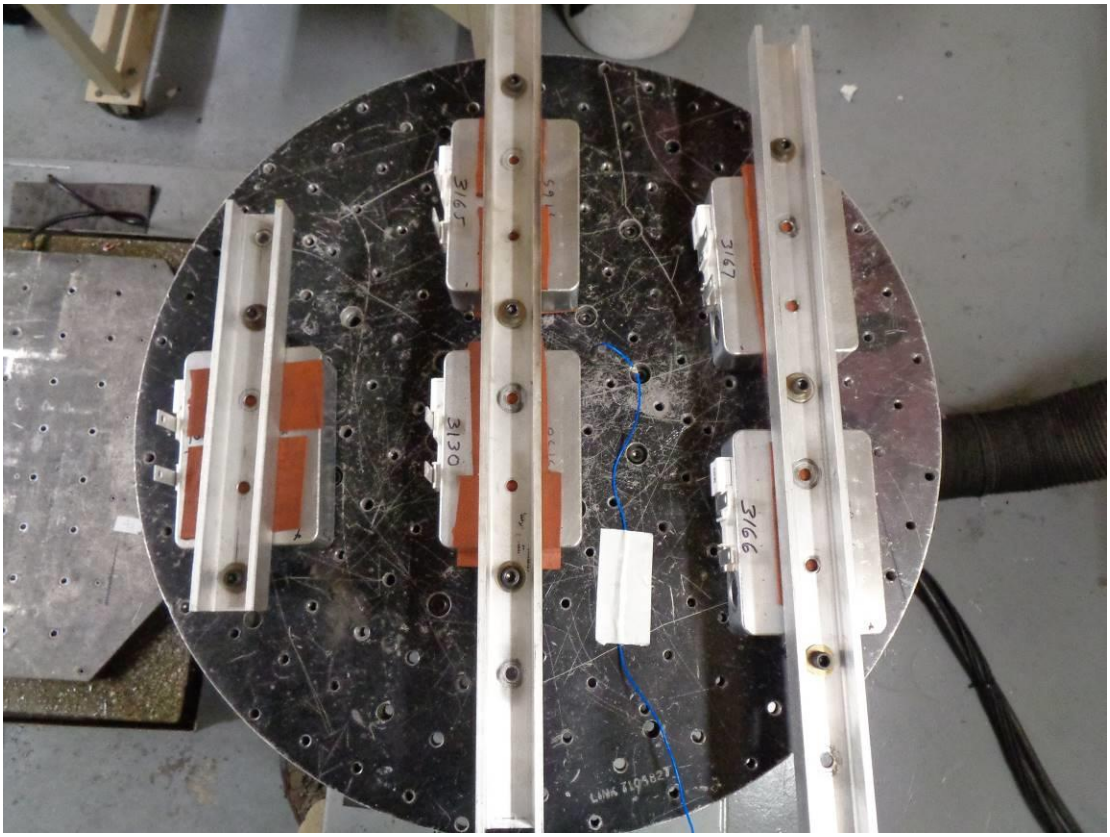

T8 Forced Discharge
10003118
Voltage (V)
Current (A) / Temperature (°C)
Time (seconds)
V
C
T

APPENDIX B

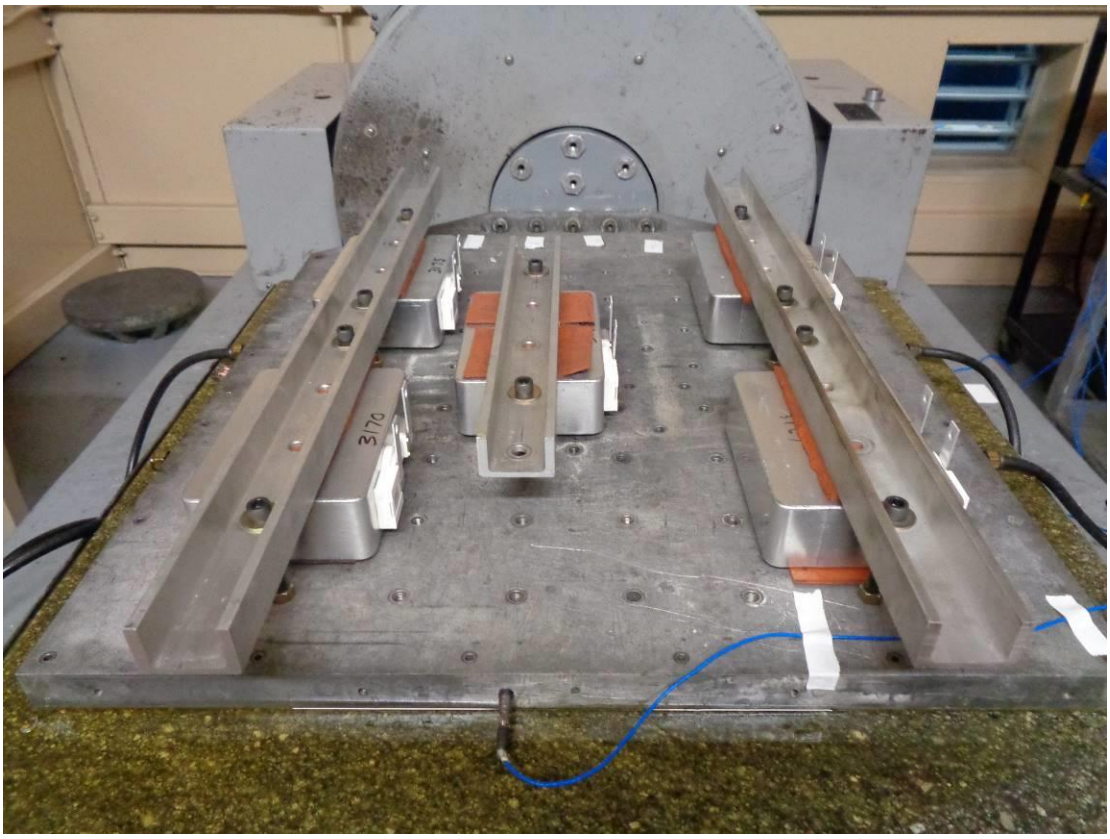
TEST PHOTOGRAPHS

T1 Altitude

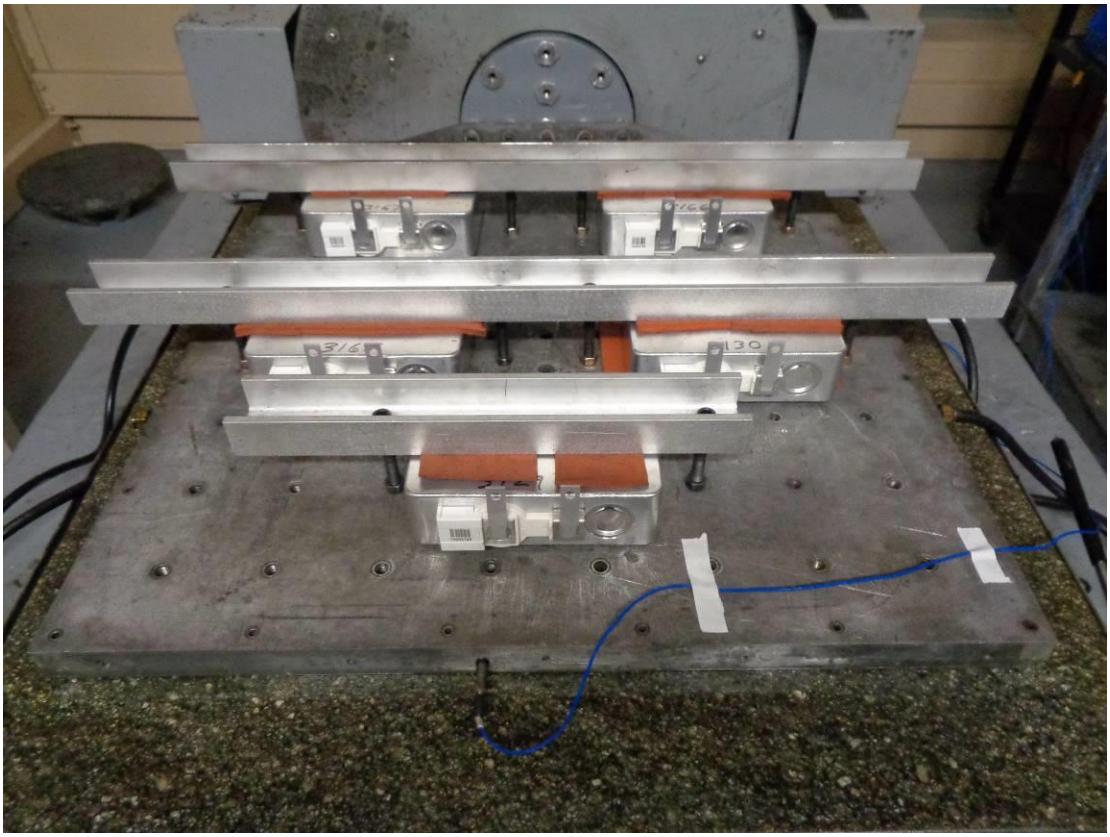
T2 Thermal



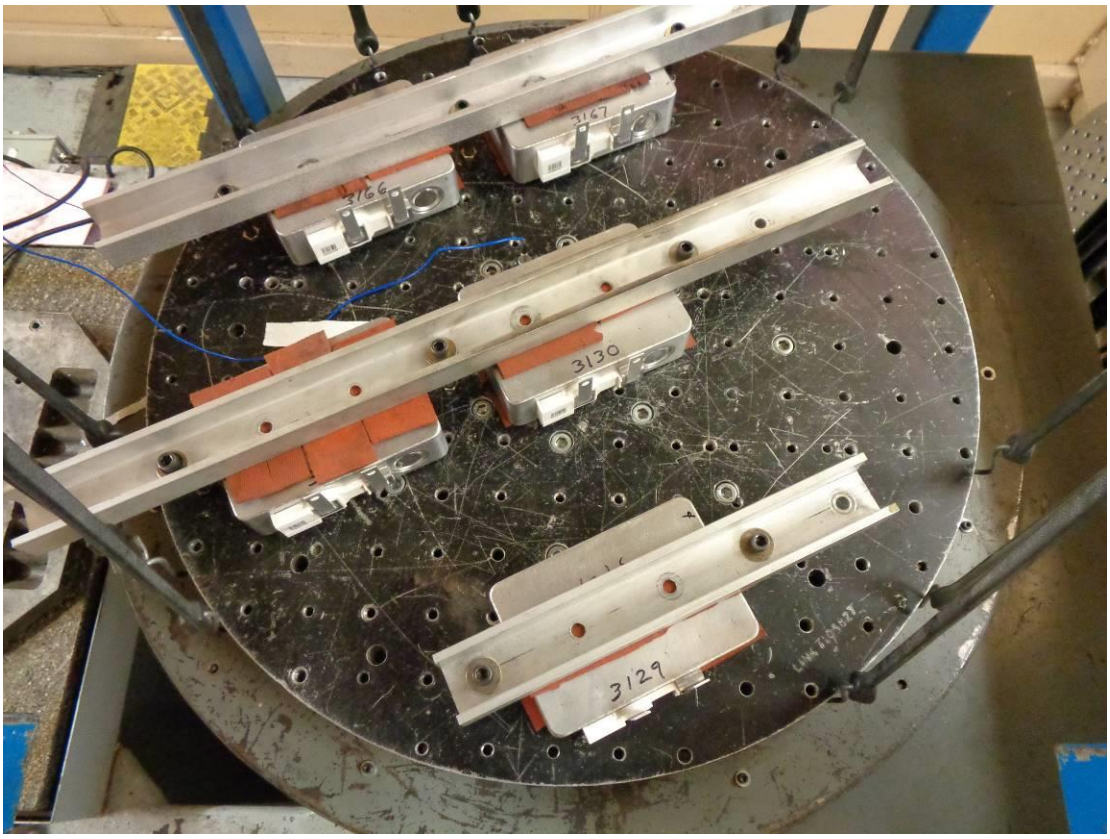
T3 Vibration Lateral



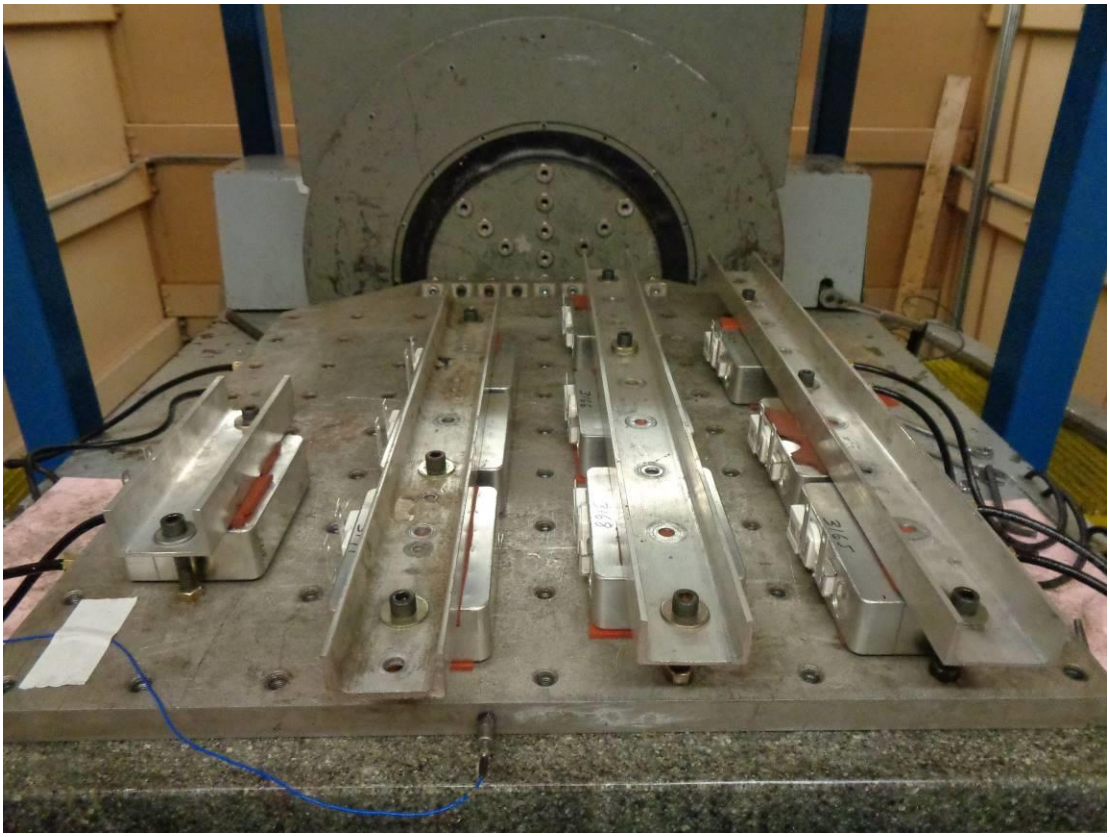
T3 Vibration Longitudinal



T3 Vibration Vertical

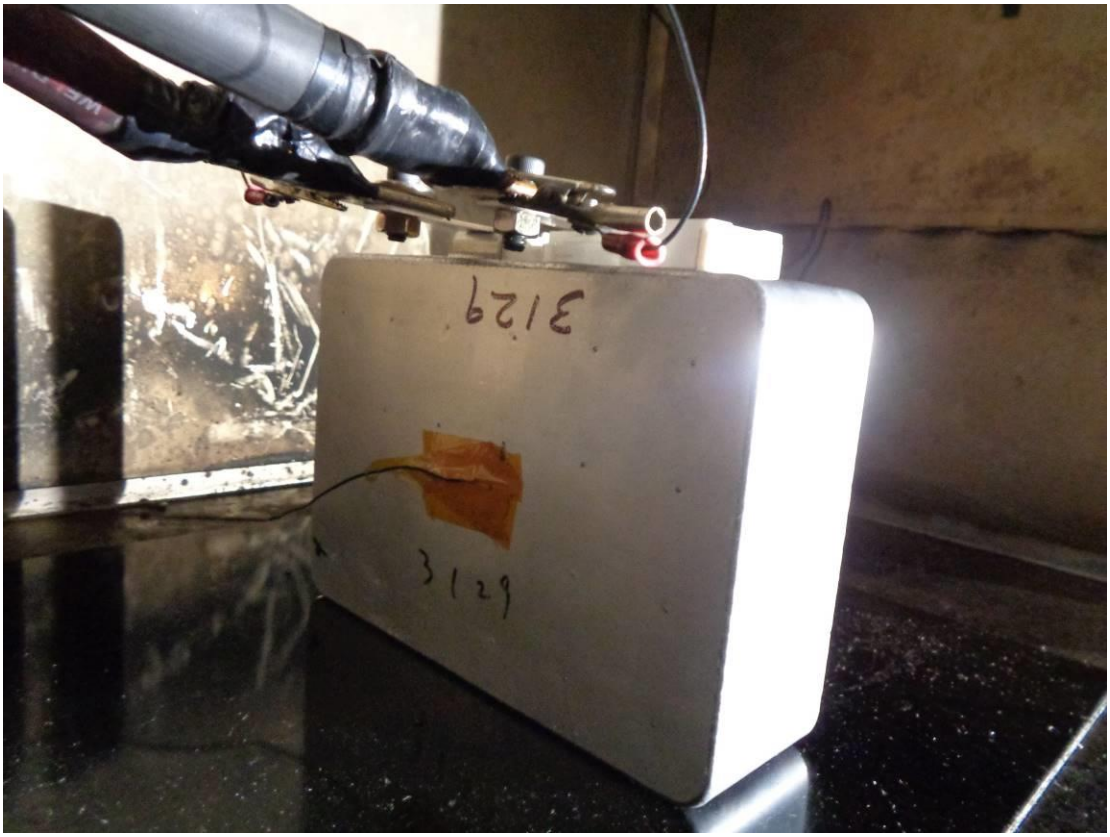


T4 Mechanical Shock Lateral

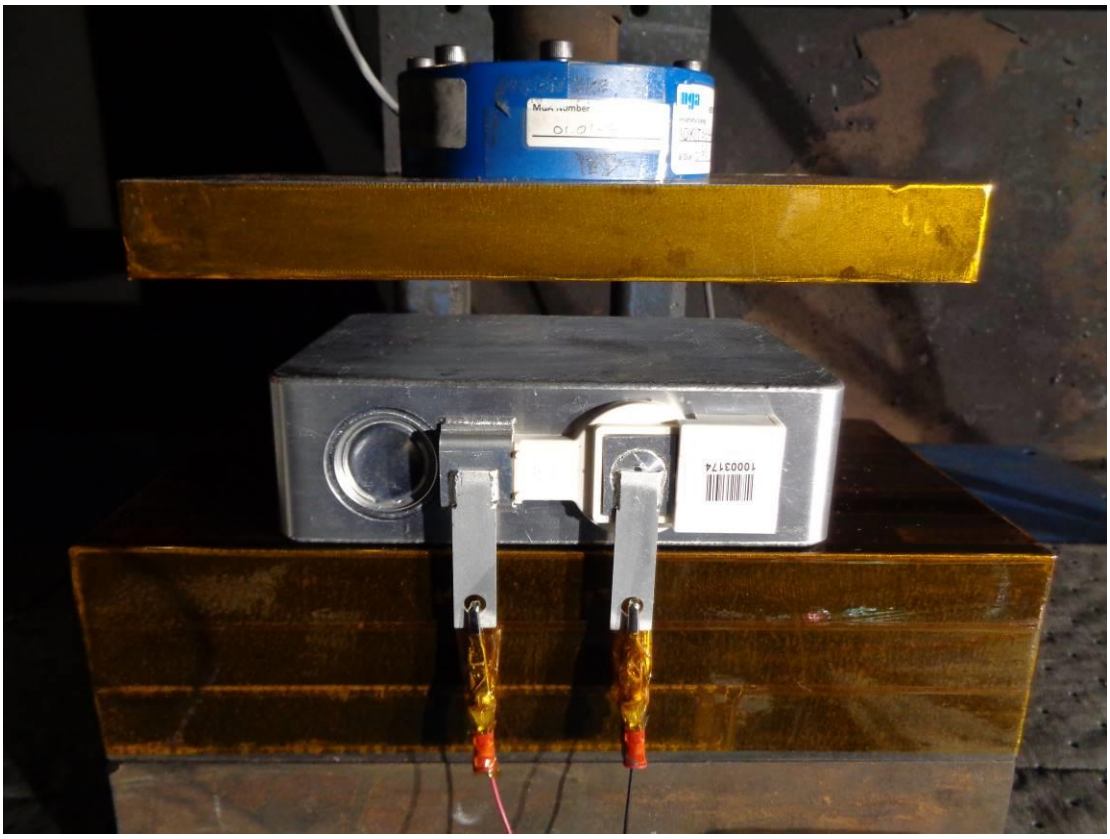


T4 Mechanical Shock Longitudinal

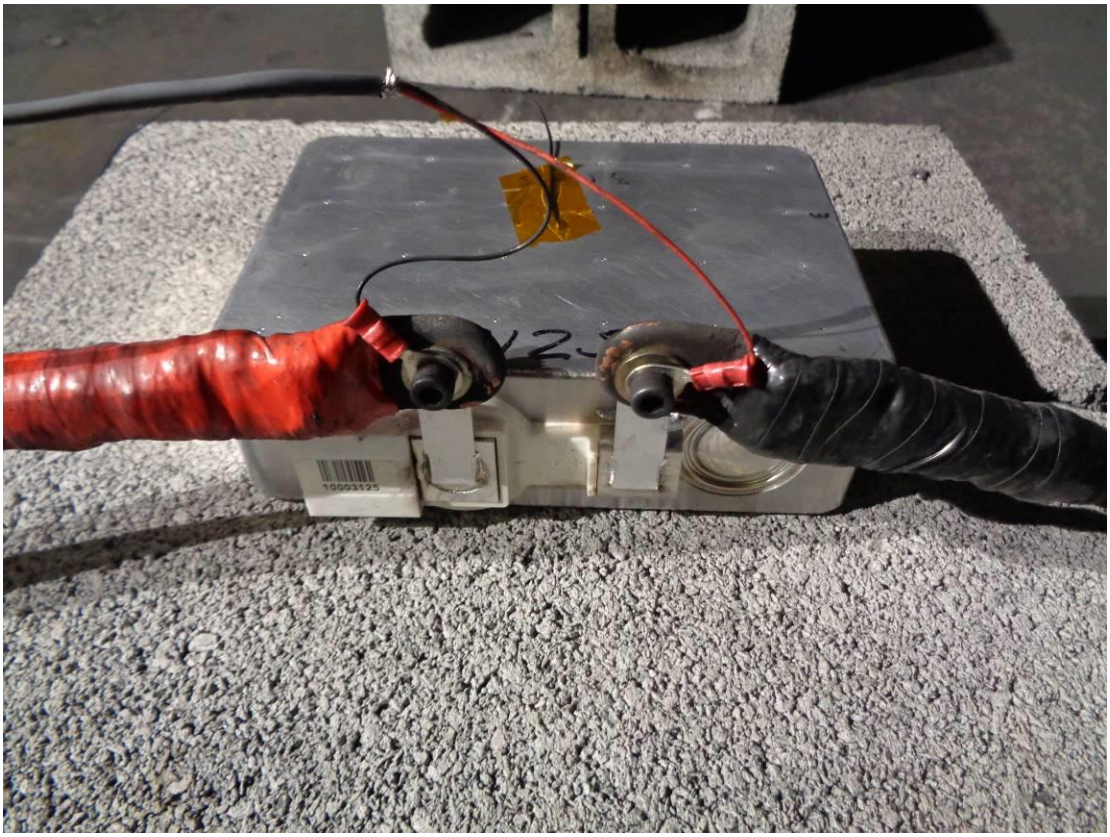
T4 Mechanical Shock Vertical



T5 Short Circuit



T6 Crush



T8 Forced Discharge