



# LGChem M36T Performance and Life Testing for Satellite Applications

Jeffrey R. Belt Ph.D.

11/15/2022

*EPS Proprietary:*

*THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION  
AND, EXCEPT WITH WRITTEN PERMISSION OF ELECTRIC  
POWER SYSTEMS, SUCH INFORMATION SHALL NOT BE  
PRODUCED IN WHOLE OR IN PART, PUBLISHED OR  
DISCLOSED, OR USED FOR ANY OTHER PURPOSE.*

# Outline

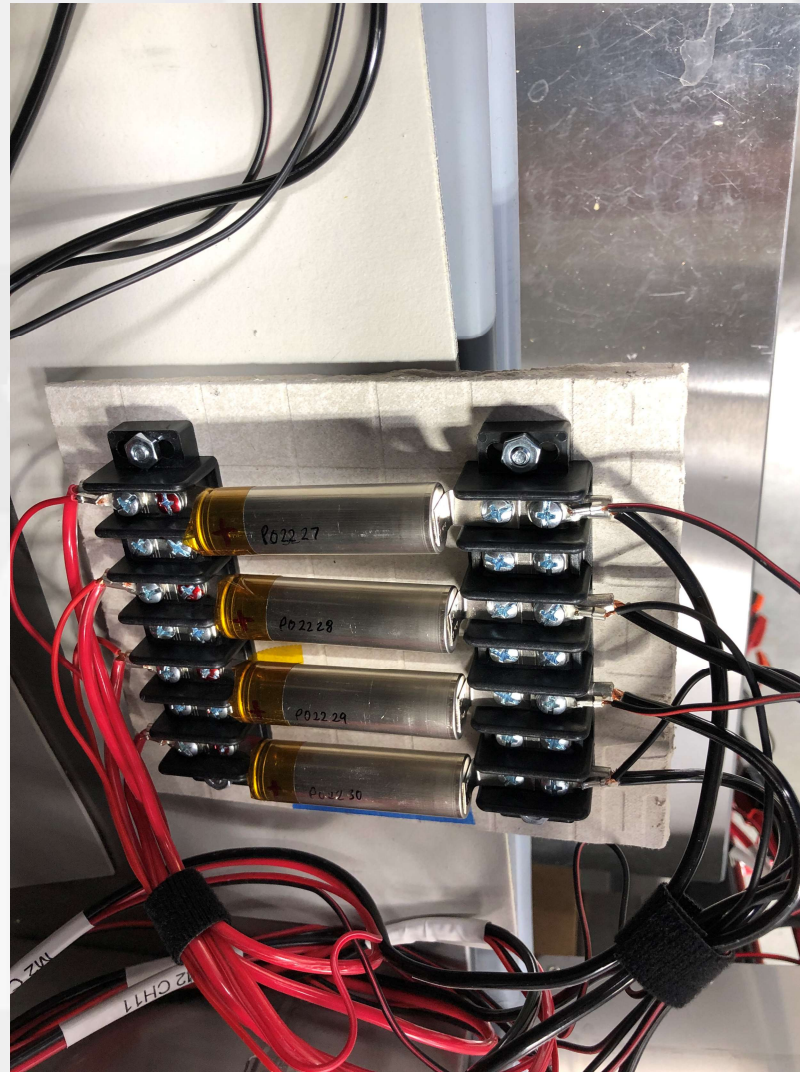
- **Cell Setup**
- **Performance Tests Results**
  - HPPC
  - Discharge Rate
  - Charge Rate
  - OCV
- **Life Test Results**
- **Thermal Runaway Results**



11/18/2022

# Cell test setup

- LG Chem M36T



# Characterization Testing

---

11/18/2022

4

# Hybrid Pulse Power Characterization Test

∴ HPPC Data sheet, charts to follow. This shows OCV, discharge resistance, power capability at 10% DOD increments

HPPC Results file created by:		Project1						
Input File:		P02221002 - 035.csv						
Comment:		P022 LGChem 3.3Ah M36 Cell 22 (RPT 0)						
Processing Date/Time:		1/4/2022 12:17:08 PM						
10% DOD	Max V	Min V	Idis Final	PPL	% DODppl	Scaling Fa	Energy	Capacity
0.340004	4.2	2.5	6.999313		0	0	11.48229	3.269882
DOD	OCV	Rdis	Pdis	WHdis	Rdis2s	Pdis2s	Rdis12s	Pdis12s
0	4.187457							
10	4.081941	0.039743	99.51128	1.338871717	0.035074	112.7588		
20	4.001907	0.039935	94.02292	2.651108503	0.034376	109.2264		
30	3.906767	0.039248	89.60773	3.929749727	0.034053	103.2785		
40	3.798733	0.037733	86.04765	5.174499989	0.033144	97.9602		
50	3.69604	0.038119	78.44206	6.380934238	0.033144	90.21432		
60	3.628748	0.038271	73.73351	7.556801319	0.033355	84.60076		
70	3.553979	0.039346	66.96856	8.706263542	0.034118	77.23006		
80	3.446479	0.044065	53.6974	9.825931549	0.036839	64.23034		
90	3.247578	0.082658	22.6107	10.88732624	0.059363	31.48309		
DOD	OCV (inter	Rregen	Pregen	WHregen	Rregen Du	Pregen Du	Vreginit	
10.57088	4.077372	0.039834	12.92945	1.414289951	0.039834	12.92945	4.067903	
20.57076	3.996477	0.039657	21.55459	2.724767208	0.039657	21.55459	3.97818	
30.57076	3.900601	0.038435	32.71713	4.001445293	0.038435	32.71713	3.88159	
40.57076	3.792872	0.037144	46.03483	5.244177341	0.037144	46.03483	3.780499	
50.57076	3.6922	0.037345	57.11015	6.448878765	0.037345	57.11015	3.677958	
60.57076	3.62448	0.037526	64.41369	7.623133183	0.037526	64.41369	3.610361	
70.57076	3.547843	0.038561	71.03128	8.771131516	0.038561	71.03128	3.533684	
80.57076	3.435127	0.04073	78.87181	9.888783455	0.04073	78.87181	3.423972	
90.57076	3.239256	0.057133	70.62624	10.94507217	0.057133	70.62624	3.180972	



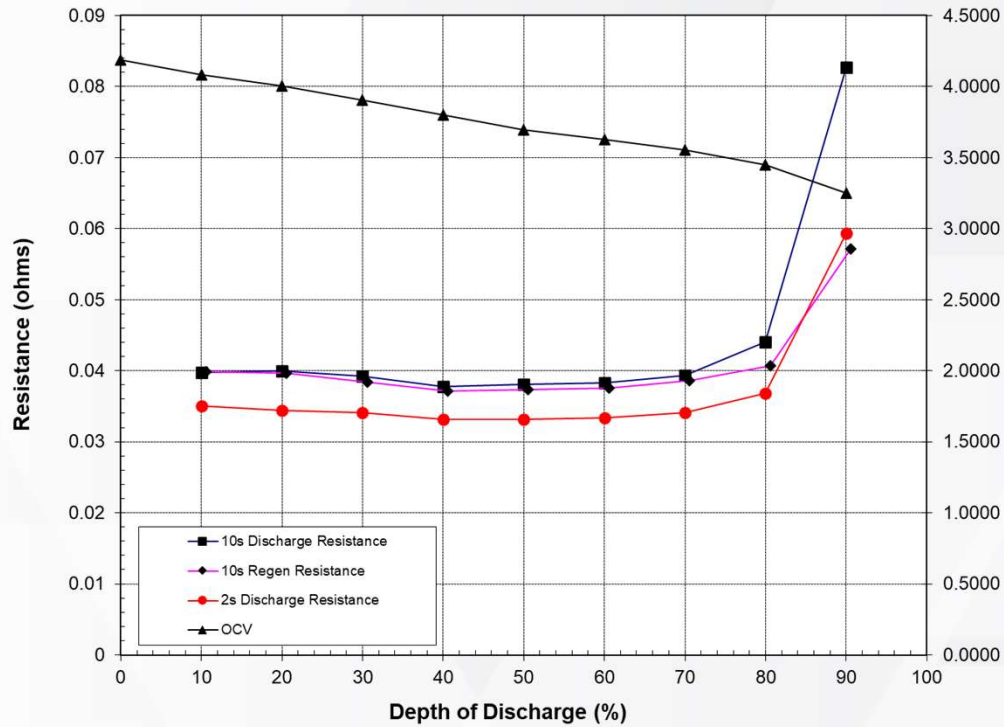
11/18/2022

# Hybrid Pulse Power Characterization Test

Pulse Resistance and Open Circuit Voltage Measured by HPPC Test (test P02221002 - 035.csv)

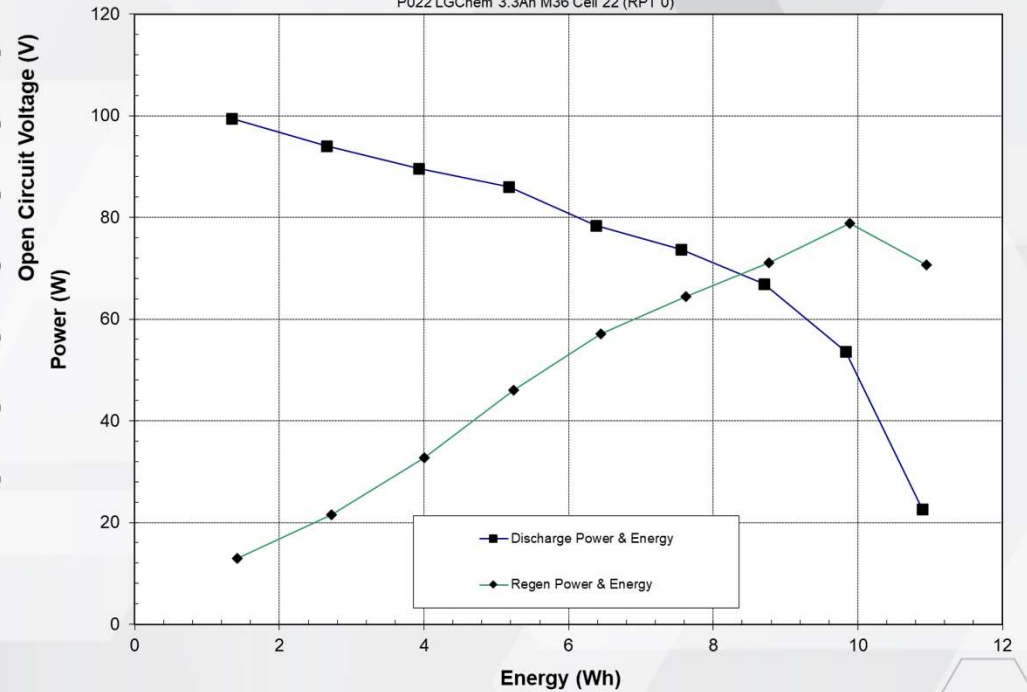
P022 LGChem 3.3Ah M36 Cell 22 (RPT 0)

∴ Resistance & OCV Chart  
Power and Energy Chart



Pulse Power Capability vs Net Energy Removed (HPPC Test) (test P02221002 - 035.csv)

P022 LGChem 3.3Ah M36 Cell 22 (RPT 0)



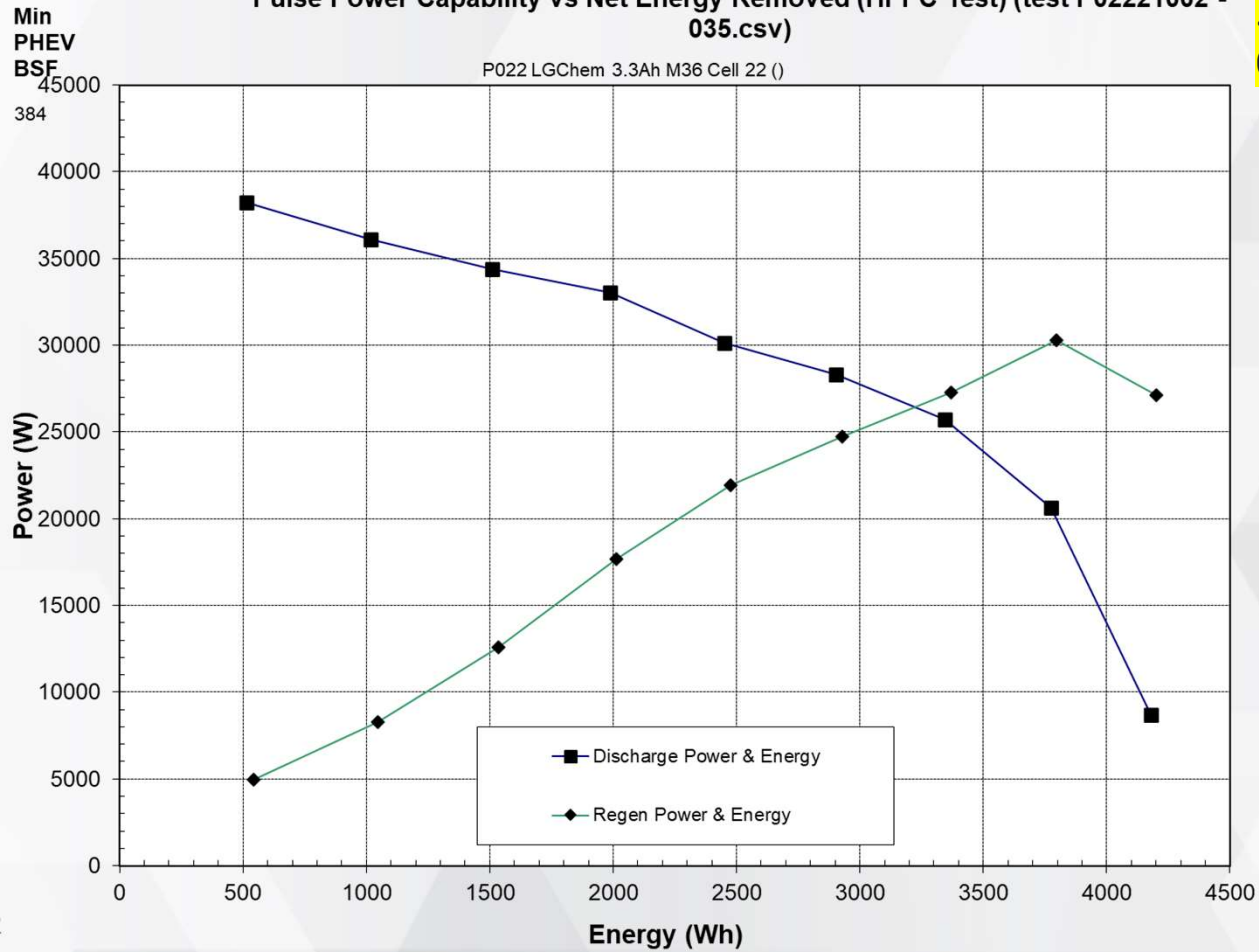
11/18/2022



# Scaled-Hybrid Pulse Power Characterization

Pulse Power Capability vs Net Energy Removed (HPPC Test) (test P0221002 - 035.csv)

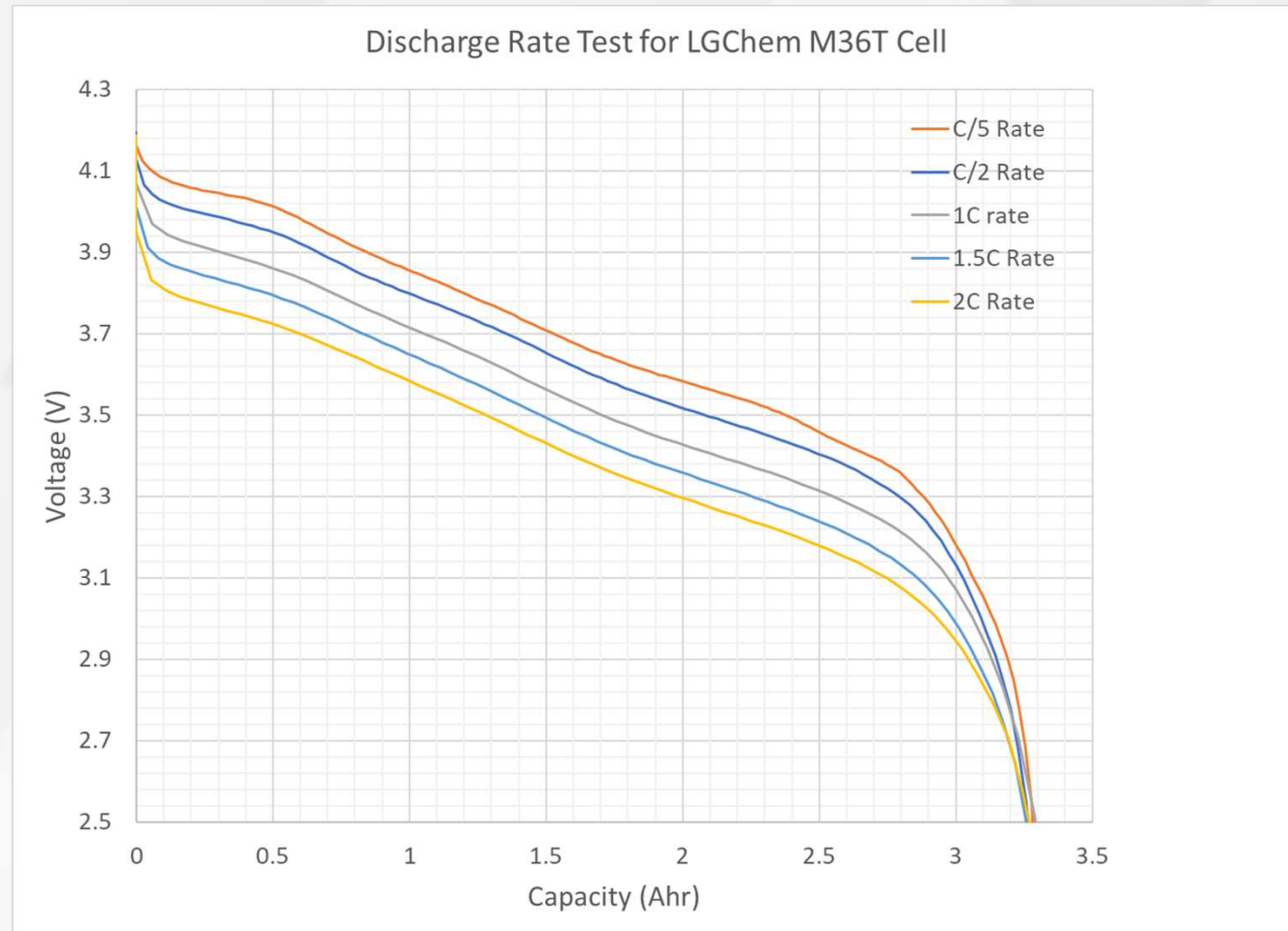
∴ Scaled Power and Energy Chart



11/18/2022

# Discharge Rate Test

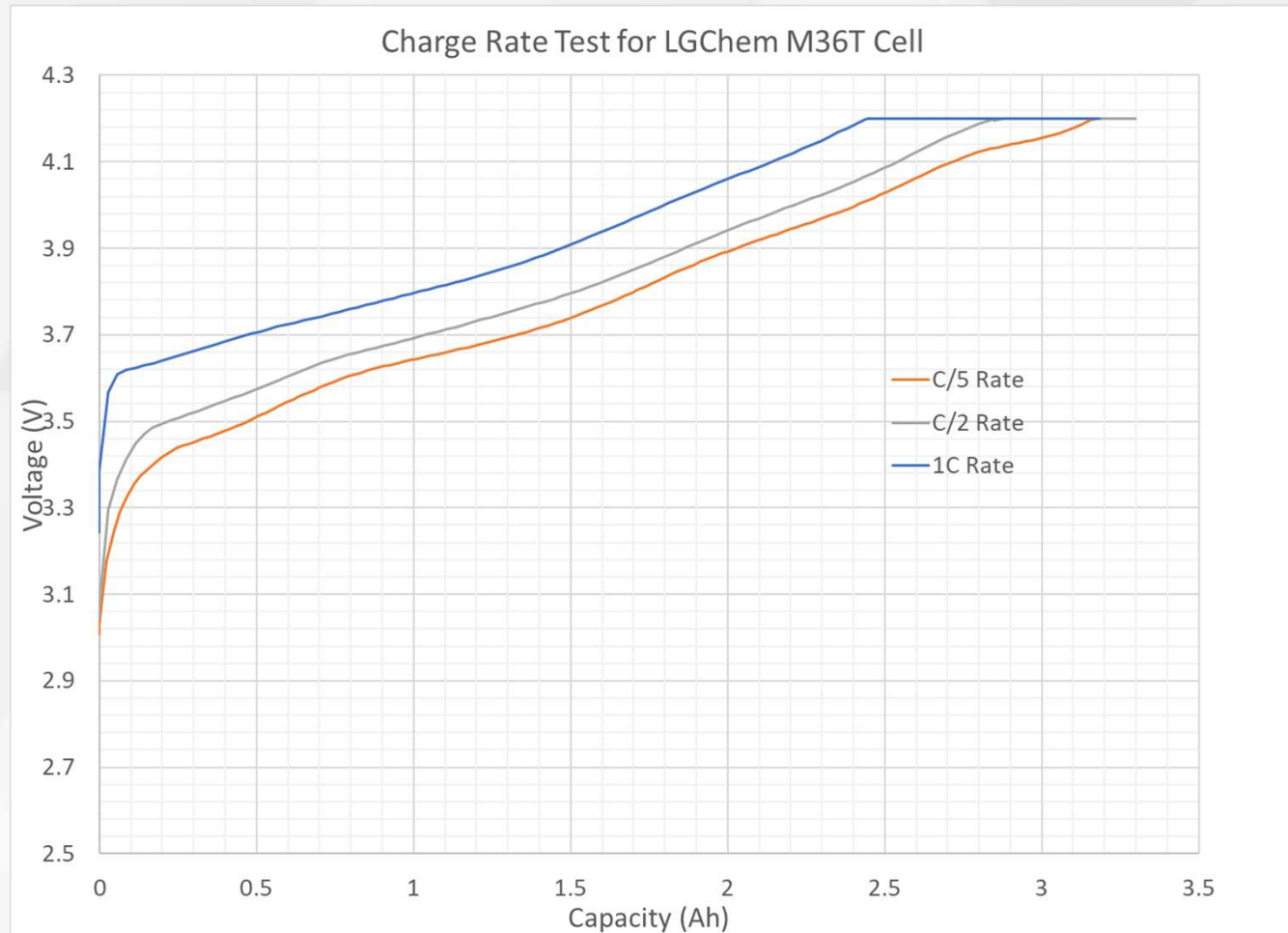
∴ Increasing C-rate shows increasing levels of overpotential (loss) for discharge





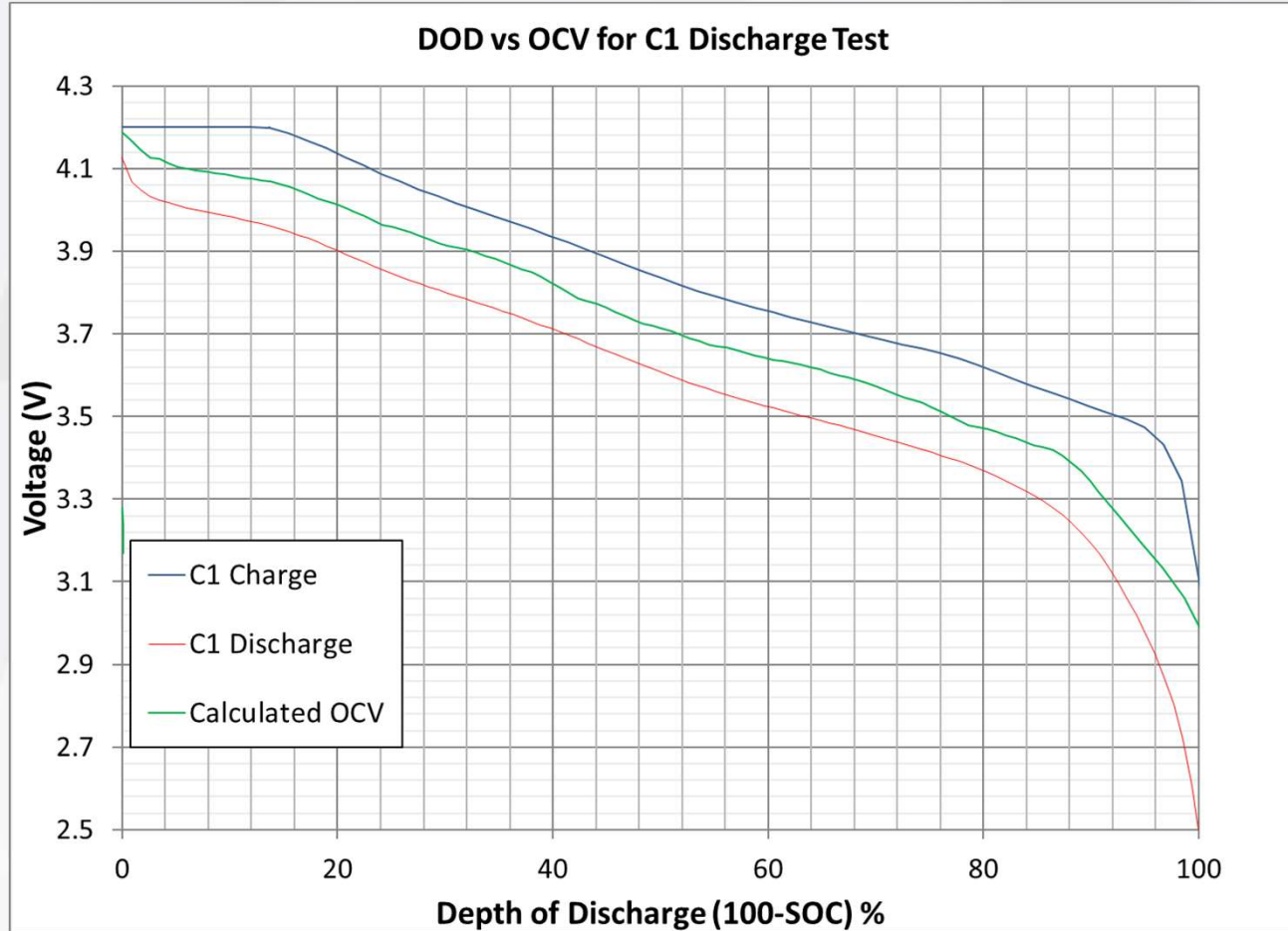
# Charge Rate Test

∴ Increasing C-rate shows increasing levels of overpotential (loss) for charge



# Open Circuit Voltage Test

∴ Shows equilibrium voltage (open circuit) as a function of state of charge



# Life Testing

---

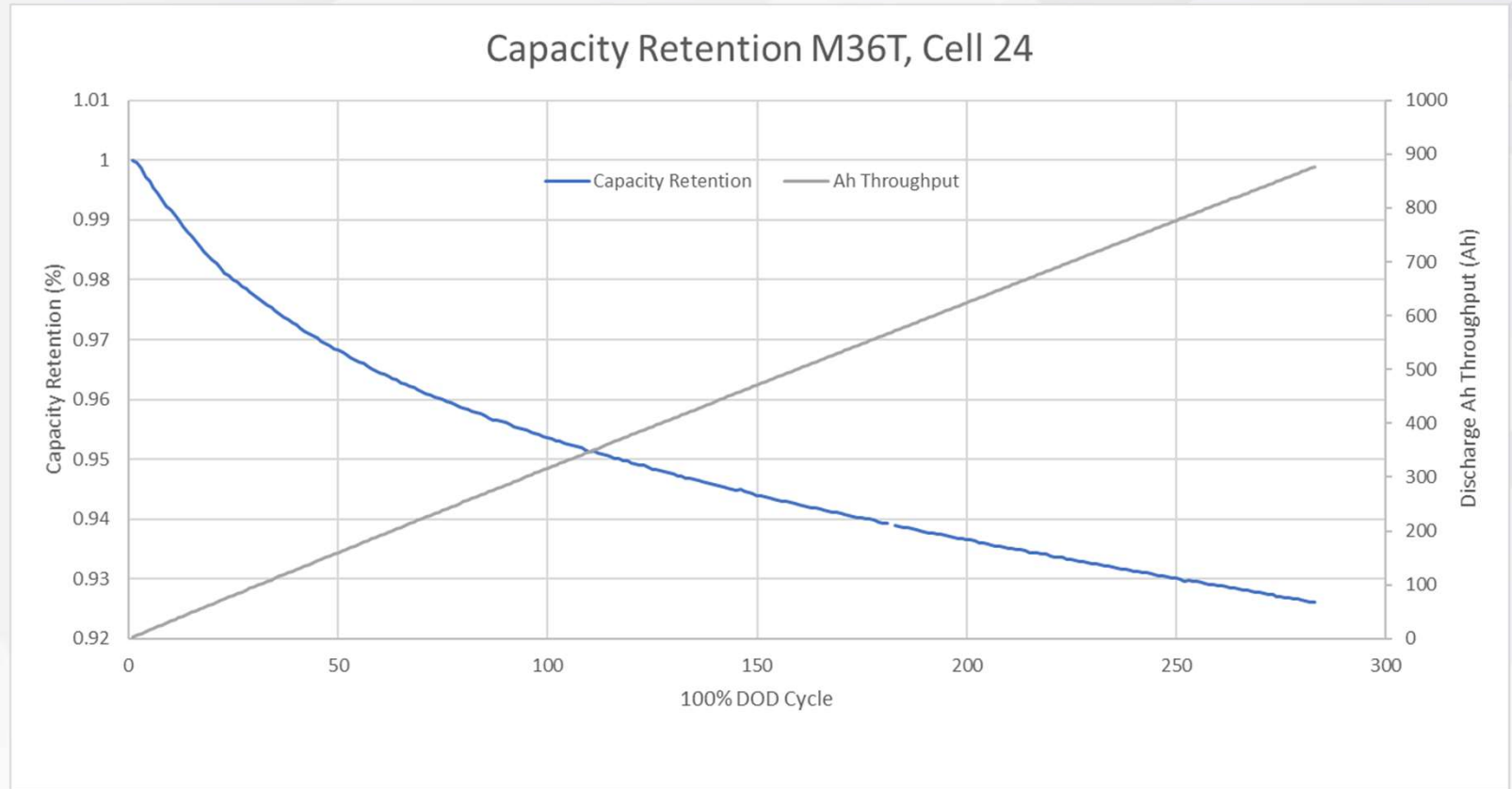
11/18/2022

11

# 100% DOD, 1C/0.5C Cycle Life @25°C

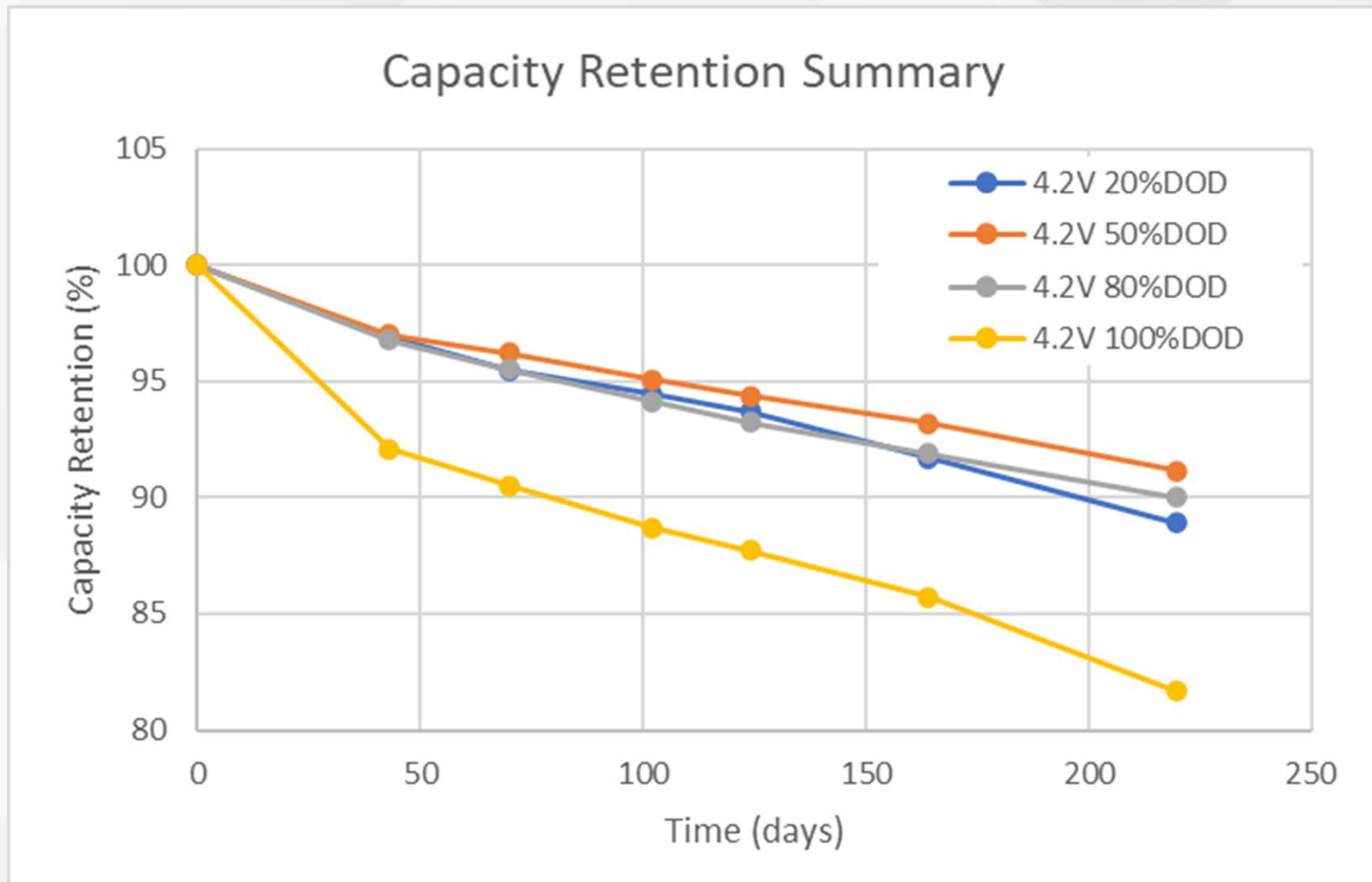
∴ Capacity Retention after 100 cycle is 95.4%

At 80% (SOH/Capacity Retention) cycle life is 1516 cycles at 25°C



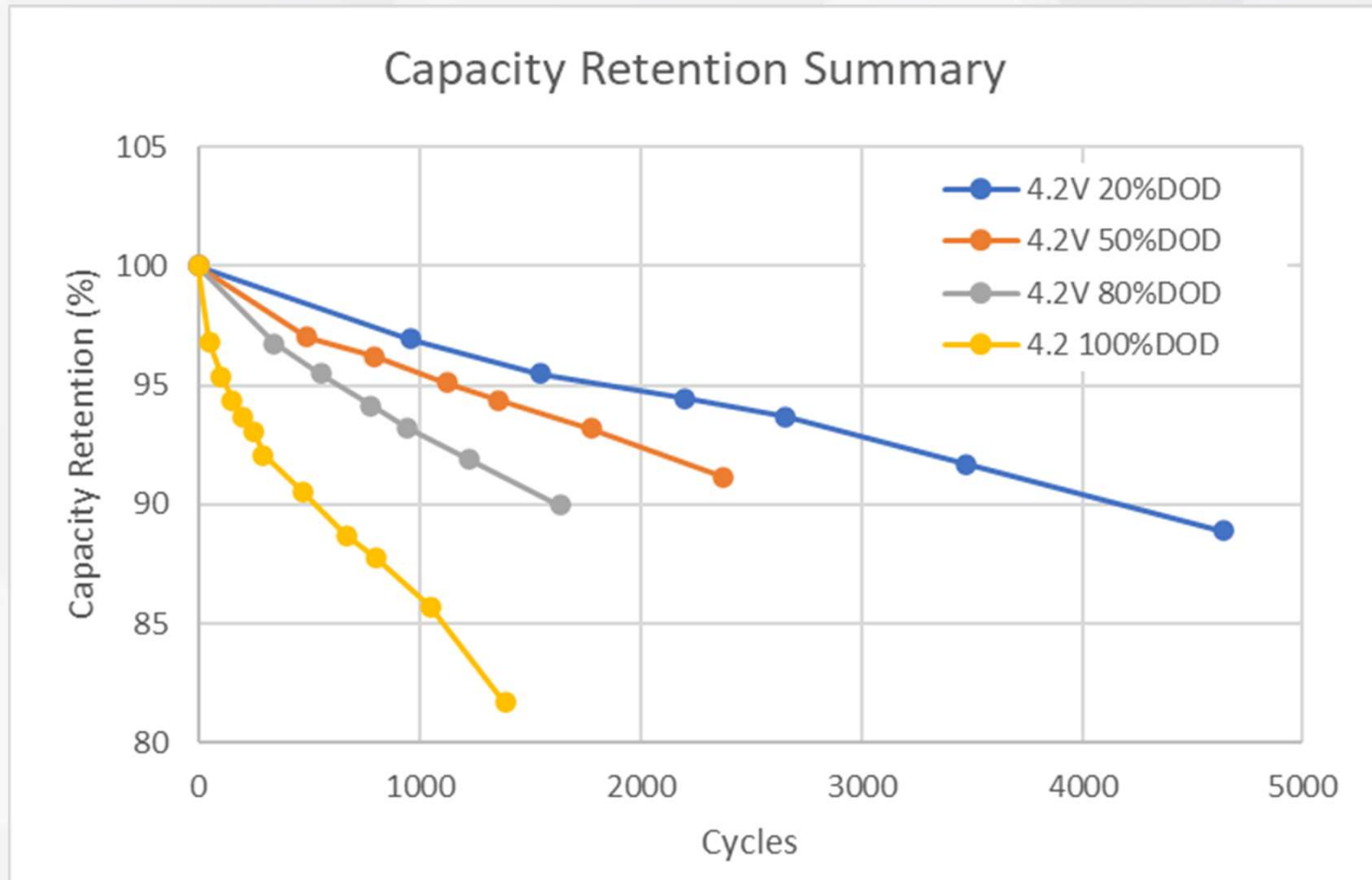
# Cycle Life: Capacity versus time @25°C

∴ 1C discharge,  
0.5C charge



# 1C/0.5C Cycle Life: Capacity versus cycles @25°C

∴ 1C discharge,  
0.5C charge



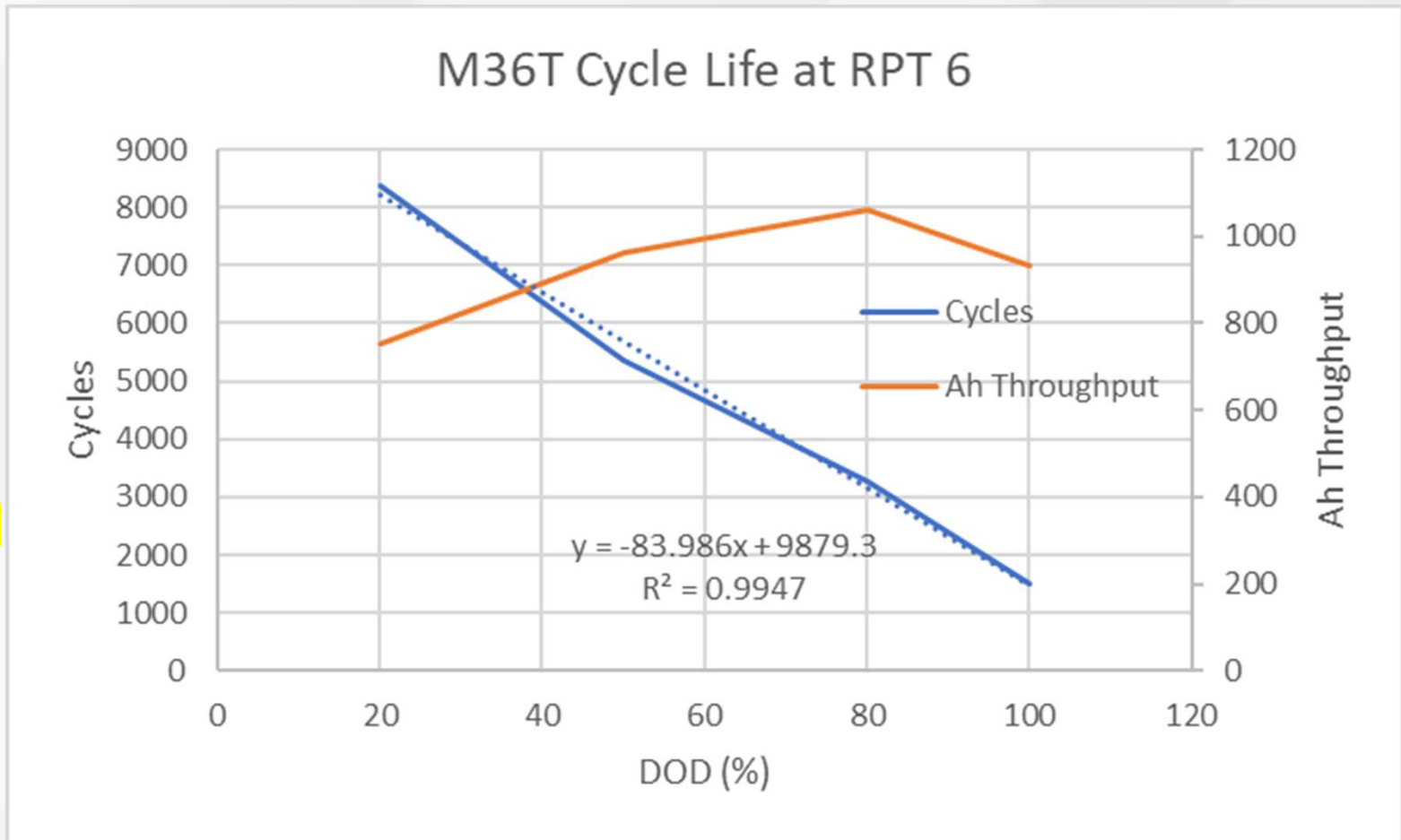


# Cycle Life as a function of Depth of Discharge @25°C

∴ Cycle Life increases with decreasing DOD

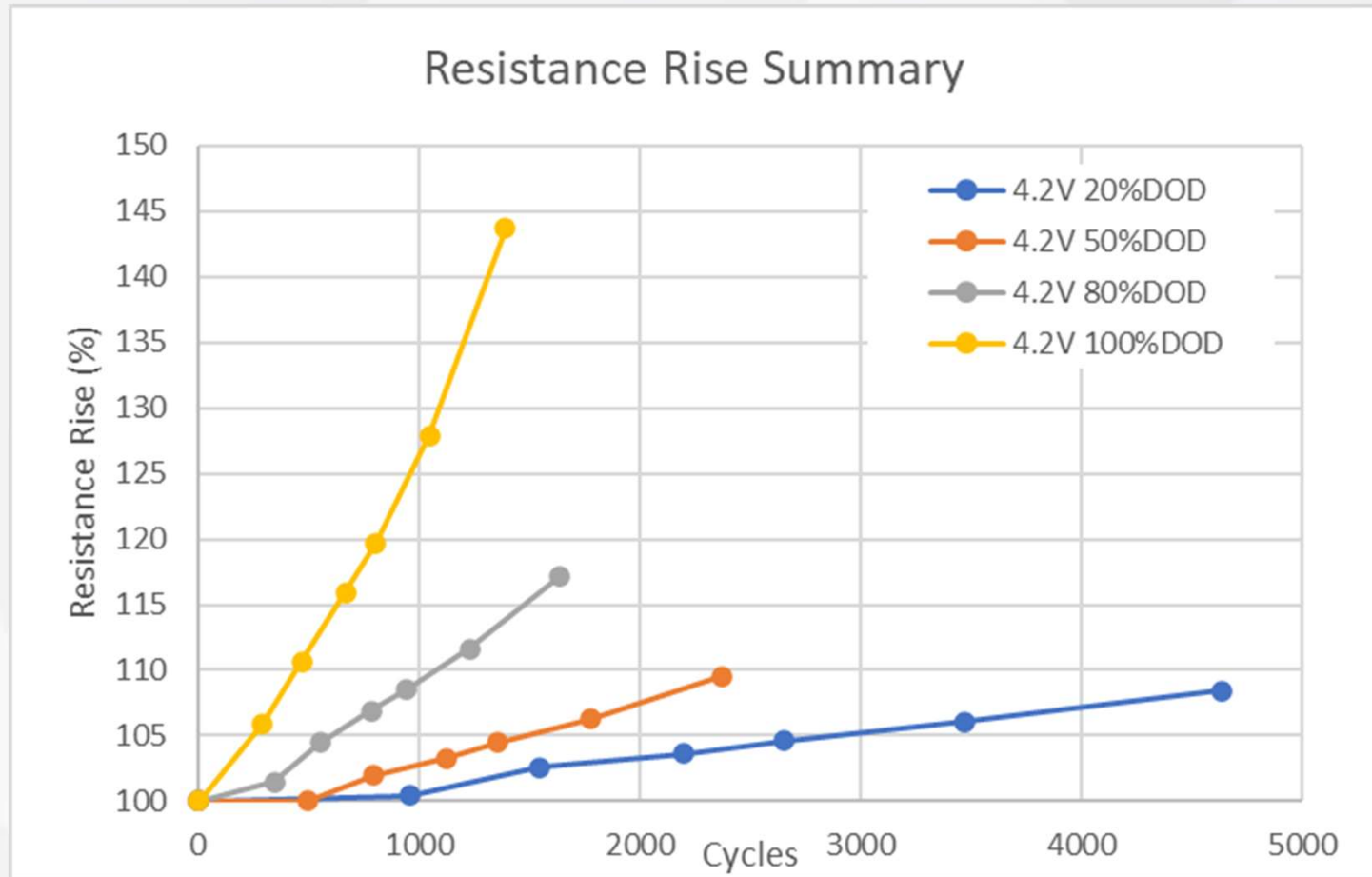
∴ Ah Throughput increases with increasing DOD

$$\text{DOD\%} = 83.986 * (\text{Cycles}) + 9879.3$$

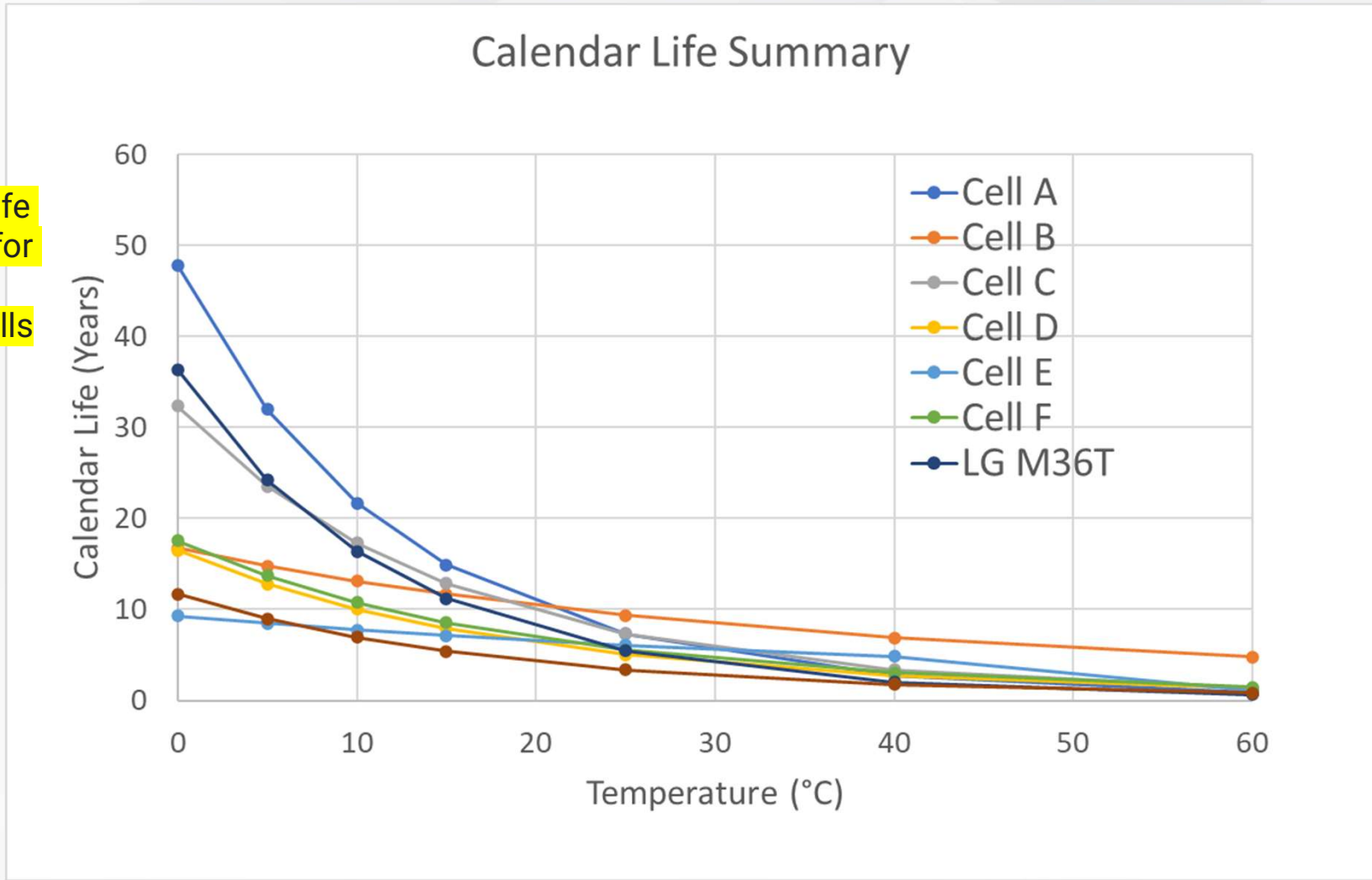


# 100% DOD, 1C/0.5C Cycle Life: Resistance @25°C

∴ Resistance rise is highest at 100% DOD

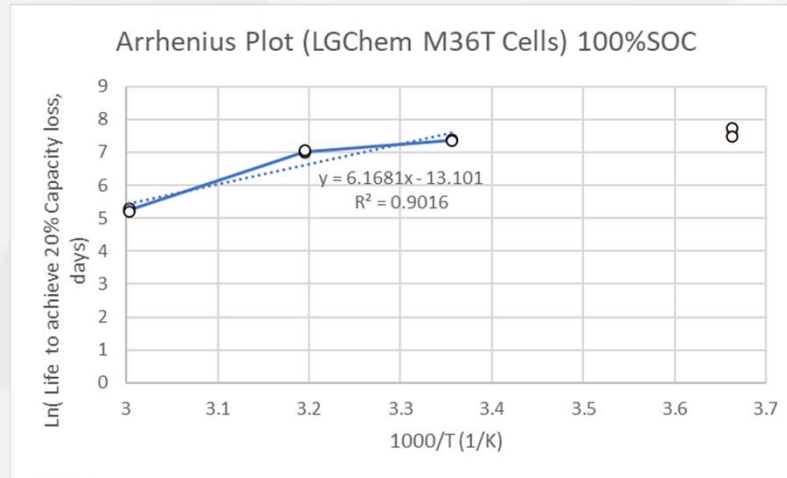


∴ Calendar Life Estimations for multiple cylindrical cells

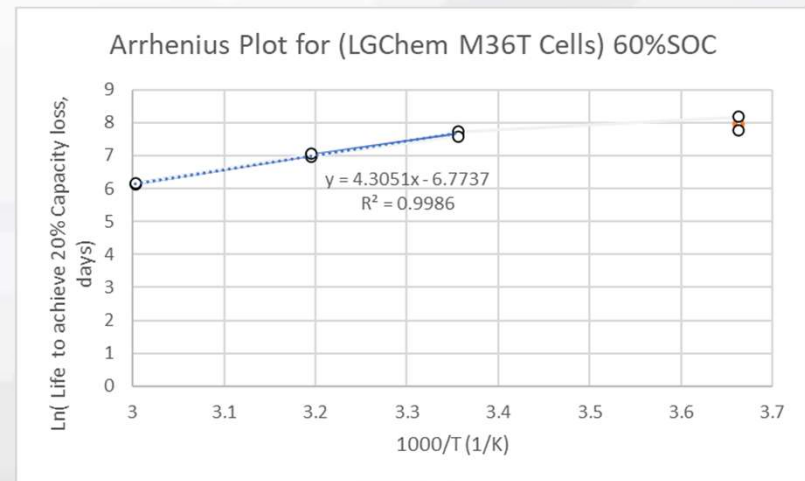


# Calendar Life Estimations, 219days

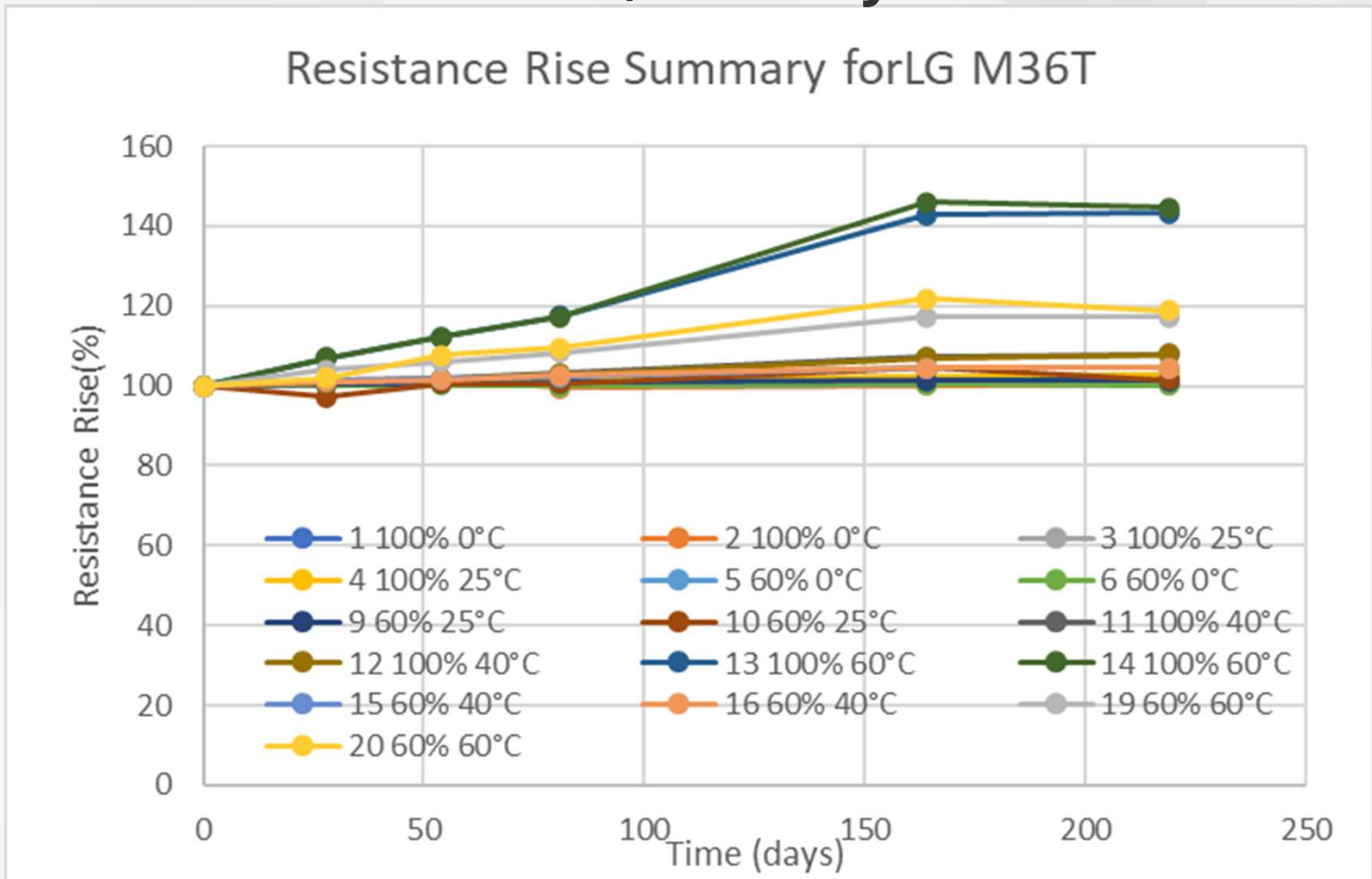
M36T 100% SOC Life	
Temp	Cal Life (Yrs)
0	36.34
5	24.20
10	16.35
15	11.20
25	5.46
40	2.02
60	0.62



M36T 60% SOC Life	
Temp	Cal Life (Yrs)
0	22.11
5	16.65
10	12.66
15	9.72
25	5.89
40	2.95
60	1.29



# Calendar Life Estimations, 219days



11/18/2022

# Thermal Runaway

Alexander Sorensen

11/18/2022

20



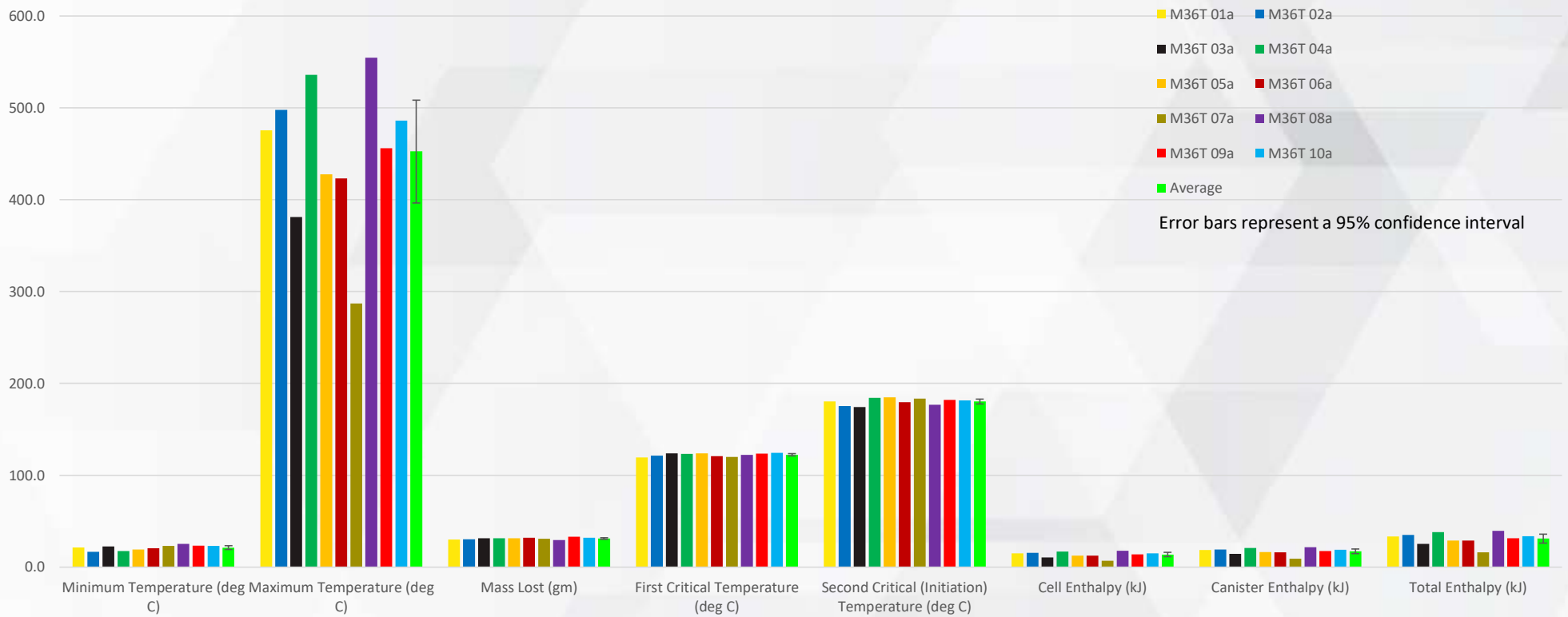
# M36T Thermal Runaway Results

Test	Minimum Temperature (deg C)	Maximum Temperature (deg C)	Mass Lost (gm)	First Critical Temperature (deg C)	Second Critical (Initiation) Temperature (deg C)	Cell Enthalpy (kJ)	Canister Enthalpy (kJ)	Total Enthalpy (kJ)
M36T 01a	21.4	475.4	30.1	119.3	180.3	14.9	18.6	33.5
M36T 02a	16.6	497.8	30.4	121.4	175.4	15.6	19.3	35.0
M36T 03a	22.6	381.1	31.5	123.8	174.3	10.7	14.5	25.2
M36T 04a	17.5	535.9	31.4	123.3	184.4	17.1	20.9	38.0
M36T 05a	19.2	427.6	31.4	123.7	184.8	12.6	16.4	28.9
M36T 06a	20.5	423.2	32.1	120.9	179.5	12.6	16.3	28.8
M36T 07a	23.1	287.1	30.9	120.0	183.5	7.0	9.3	16.2
M36T 08a	25.3	554.4	29.5	122.2	176.7	17.9	21.6	39.5
M36T 09a	23.2	456.1	33.1	123.5	182.1	13.8	17.6	31.4
M36T 10a	23.2	486.1	32.1	124.3	181.6	15.0	18.8	33.8
<b>Average</b>	<b>21.3</b>	<b>452.5</b>	<b>31.2</b>	<b>122.2</b>	<b>180.2</b>	<b>13.7</b>	<b>17.3</b>	<b>31.0</b>
st. dev	2.8	78.2	1.1	1.8	3.7	3.2	3.6	6.8
<b>95% Confidence Interval</b>	<b>2.0</b>	<b>55.9</b>	<b>0.8</b>	<b>1.3</b>	<b>2.7</b>	<b>2.3</b>	<b>2.5</b>	<b>4.8</b>



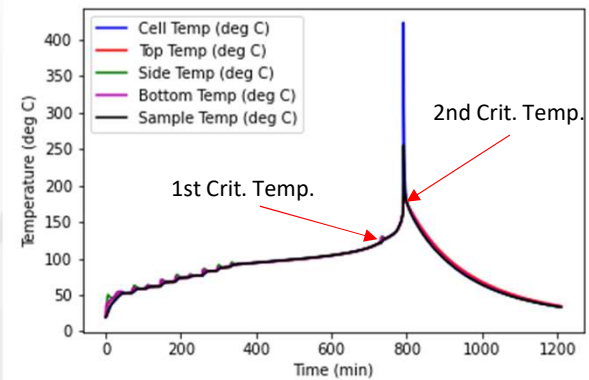
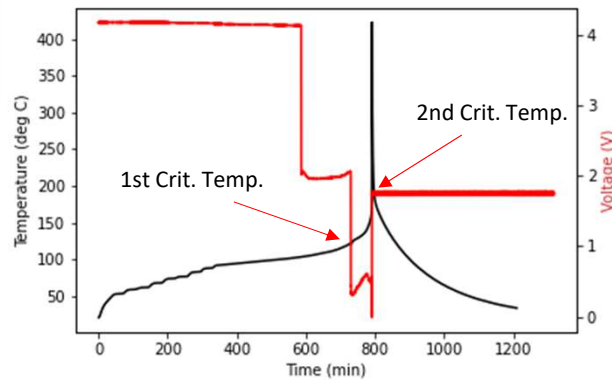
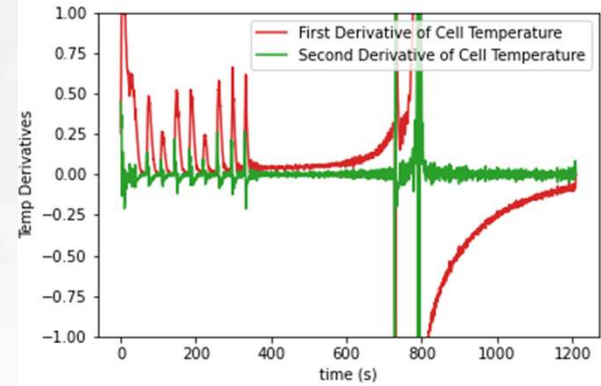
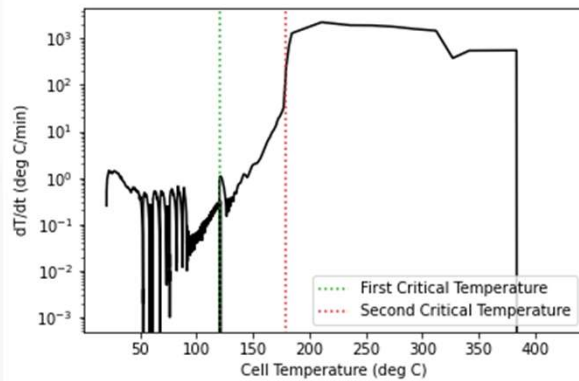
11/18/2022

# M36T Thermal Runaway Results Continued



11/18/2022

# M36T Thermal Runaway Results Continued



# Questions?

---

11/18/2022

24