Advanced NiMH Power Battery for High Rate Applications

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Who is G4 Synergetics?

Charge

G4 Manufactures Ultra High Power, Rechargeable Advanced NiMH Batteries

Discharge

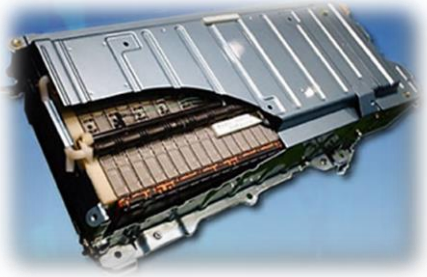
Company Overview

- Long history of nickel battery development
  - General Electric
  - Energizer
  - Gates
- Team consists of battery veterans with over 150 years experience
- Based in United States (Alachua, FL)

Land: 103 acres
Facility: ~40,000 sq. ft.

Why did G4 select Ni-MH?

Proven battery technology for high power applications



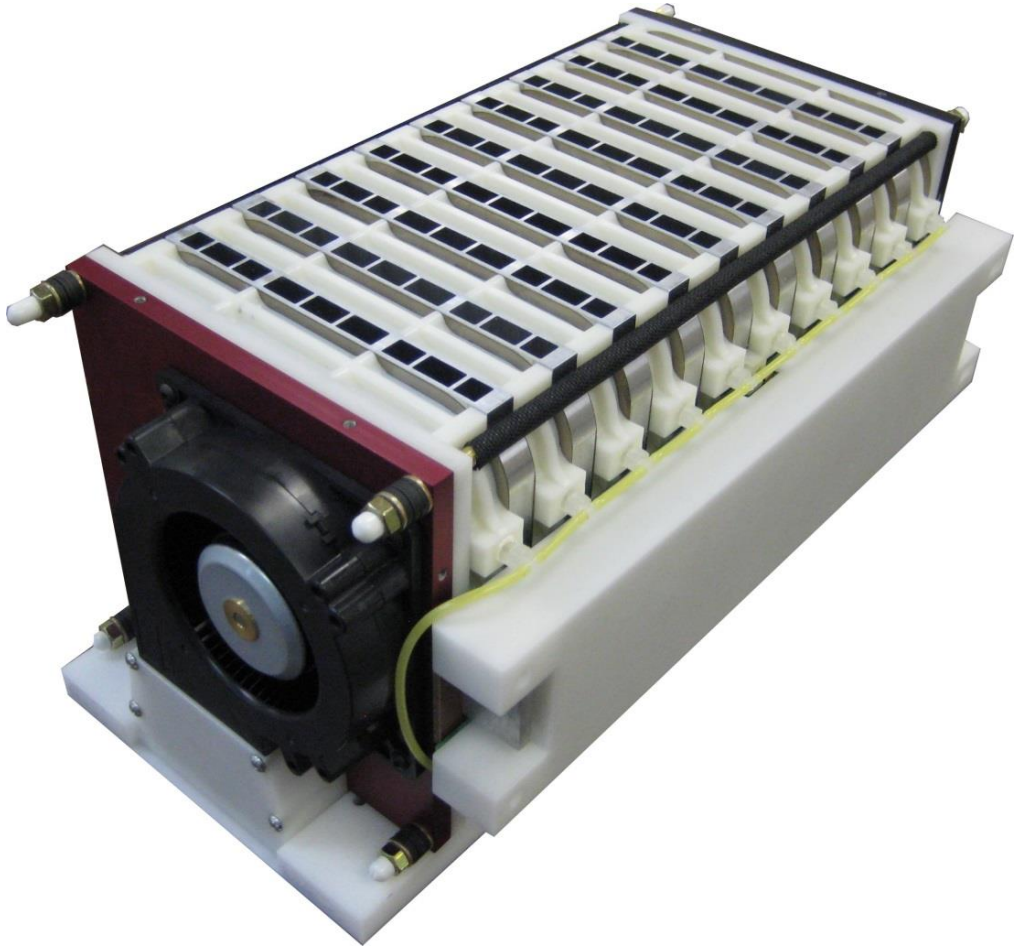
- The HV battery, battery control module are covered for **8 years/100,000 miles.**

Source (April 2014): www.toyota.com

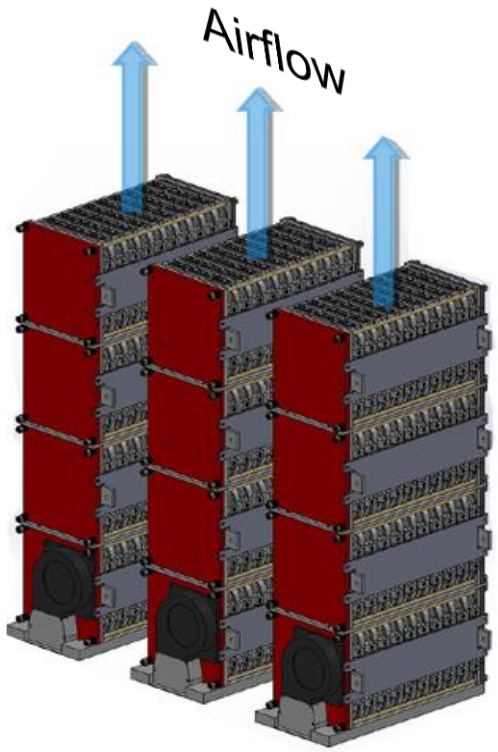
Commercially Proven Chemistry for Safe and Long Cycle Life Performance

What is unique about the G4 design?

Stacked Configuration w/BMS



45Ah, 12V Module



What does this battery architecture actually achieve?

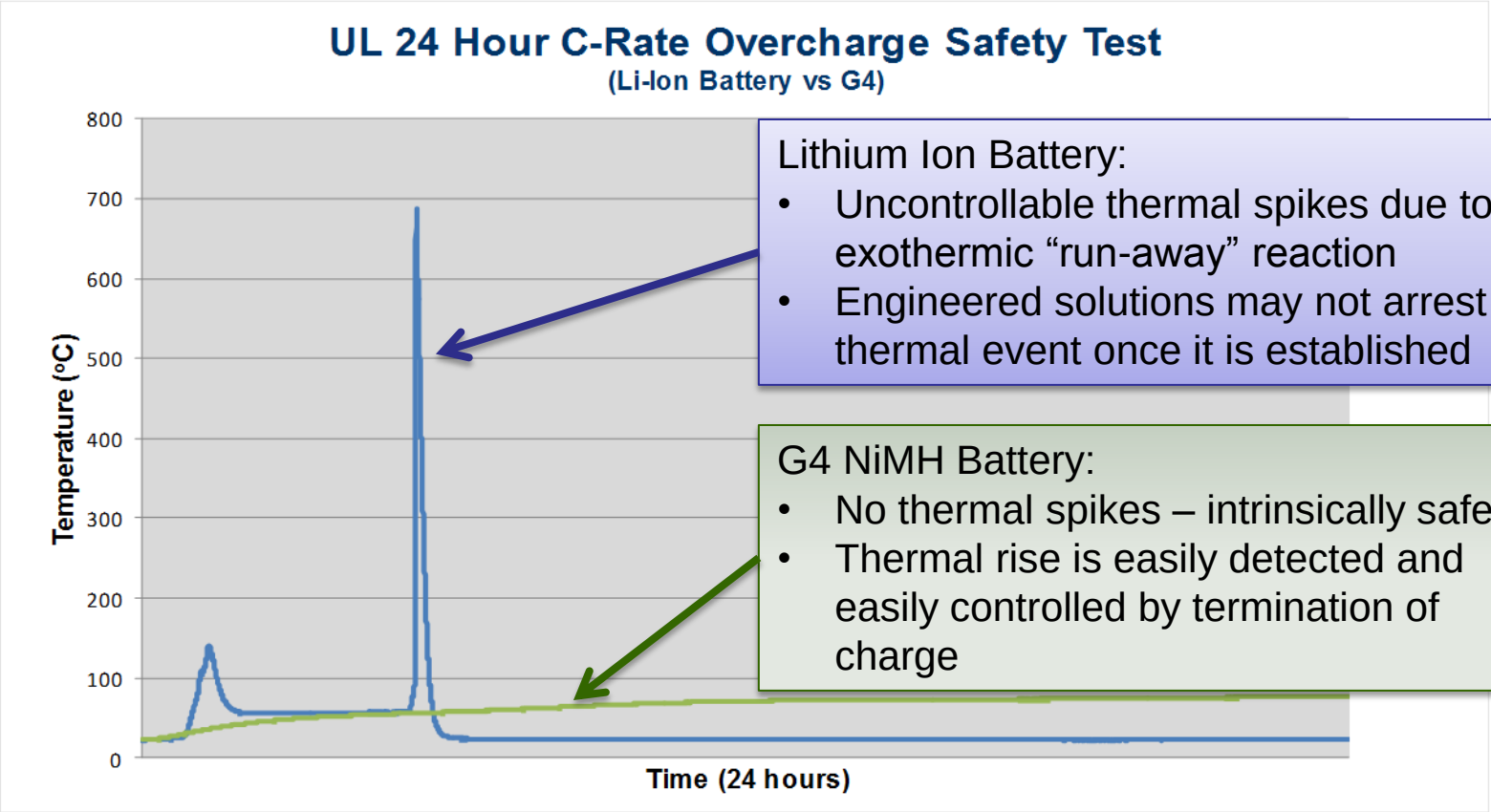
Chemistry	Lead Acid	Standard Lithium Ion	EDLC (Super-capacitor)	LTO Lithium Ion	NiMH
Positive Electrode	$PbO_2/PbSO_4$	LCO, LMO, LFP, NMC	Activated Carbon	LCO, LMO, LFP, NMC	NiOOH
Negative Electrode	$Pb/PbSO_4$	Graphite	Activated Carbon	LTO	Metal hydride
Cost at system level			>$8,00 kWH (comp chg/dc <90s)		er kWH
Strengths:	Low cost solution	High volume production and decreasing system cost	Can be charged and discharged very quickly	Can be charged quickly	High power Long life
Weaknesses:	Cannot be charged quickly. Low gravimetric energy density	If charged faster than C/2.5 lithium plating can occur and safety/cycle life is compromised	Low ener density a cost		

- **High energy**
- **Low cost**
- **Slow charge**

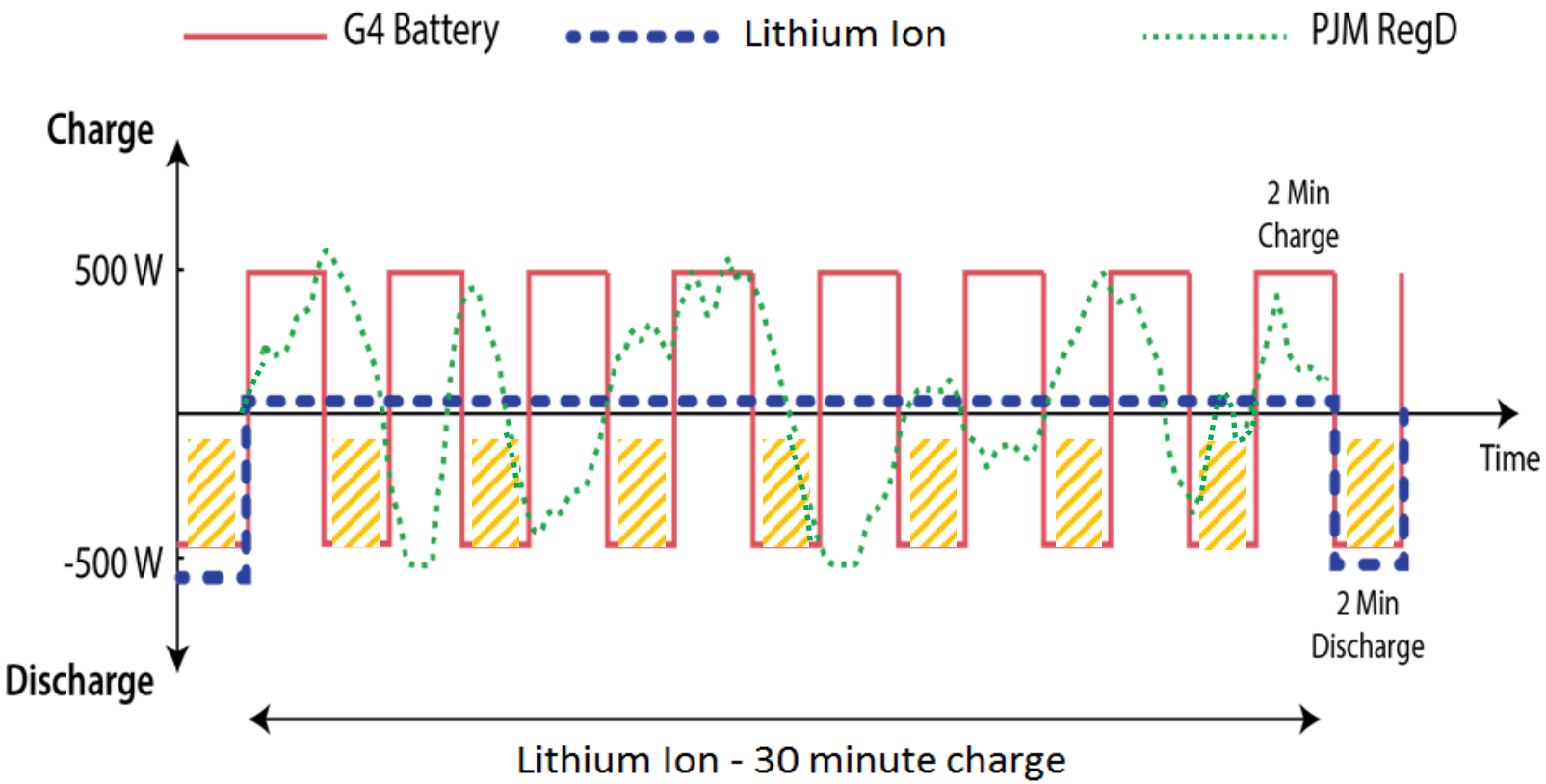
- **High power**

- **Moderate energy**
- **Reasonable cost**

G4 Unique Safety Features

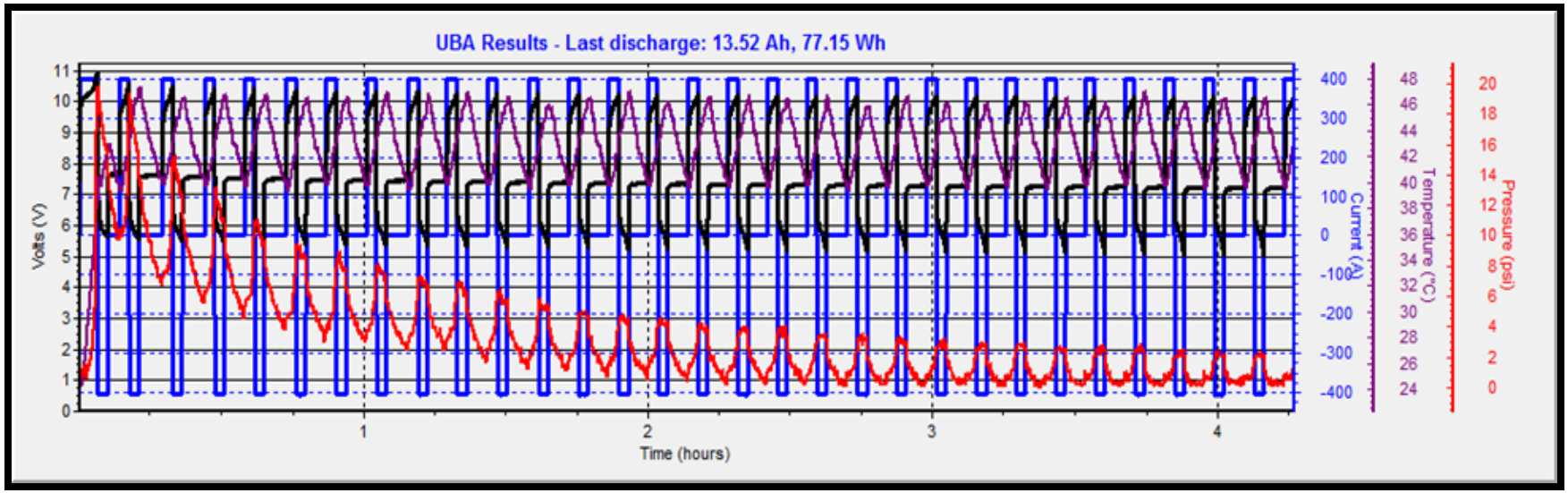


2-Cell Li-Ion battery had a violent event after ~6 Hours, G4 architecture allowed continuous, safe venting



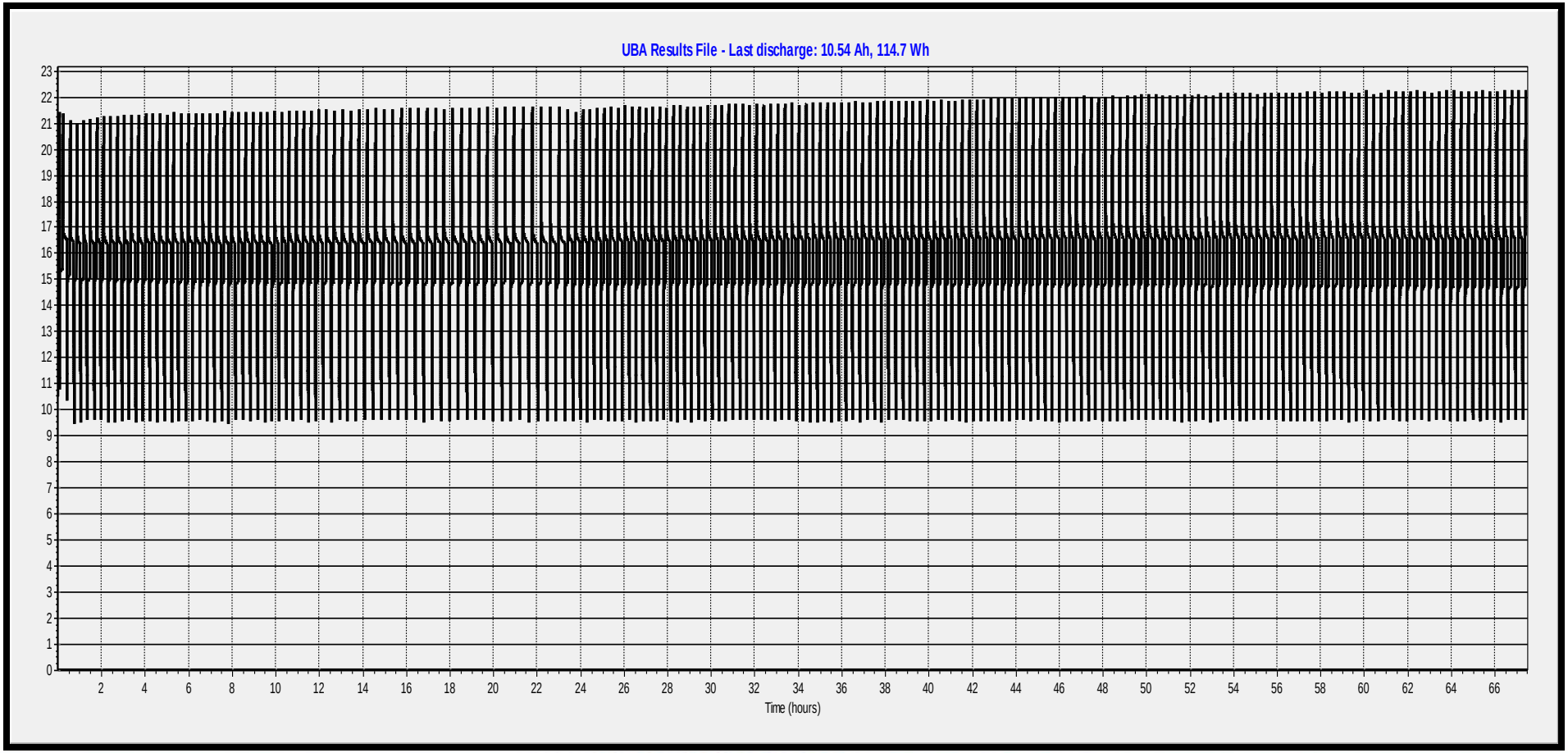
In this model, G4 delivers ~7 times more energy than competitive Lithium-Ion polymer batteries (LPB) at nearly the same discharge power

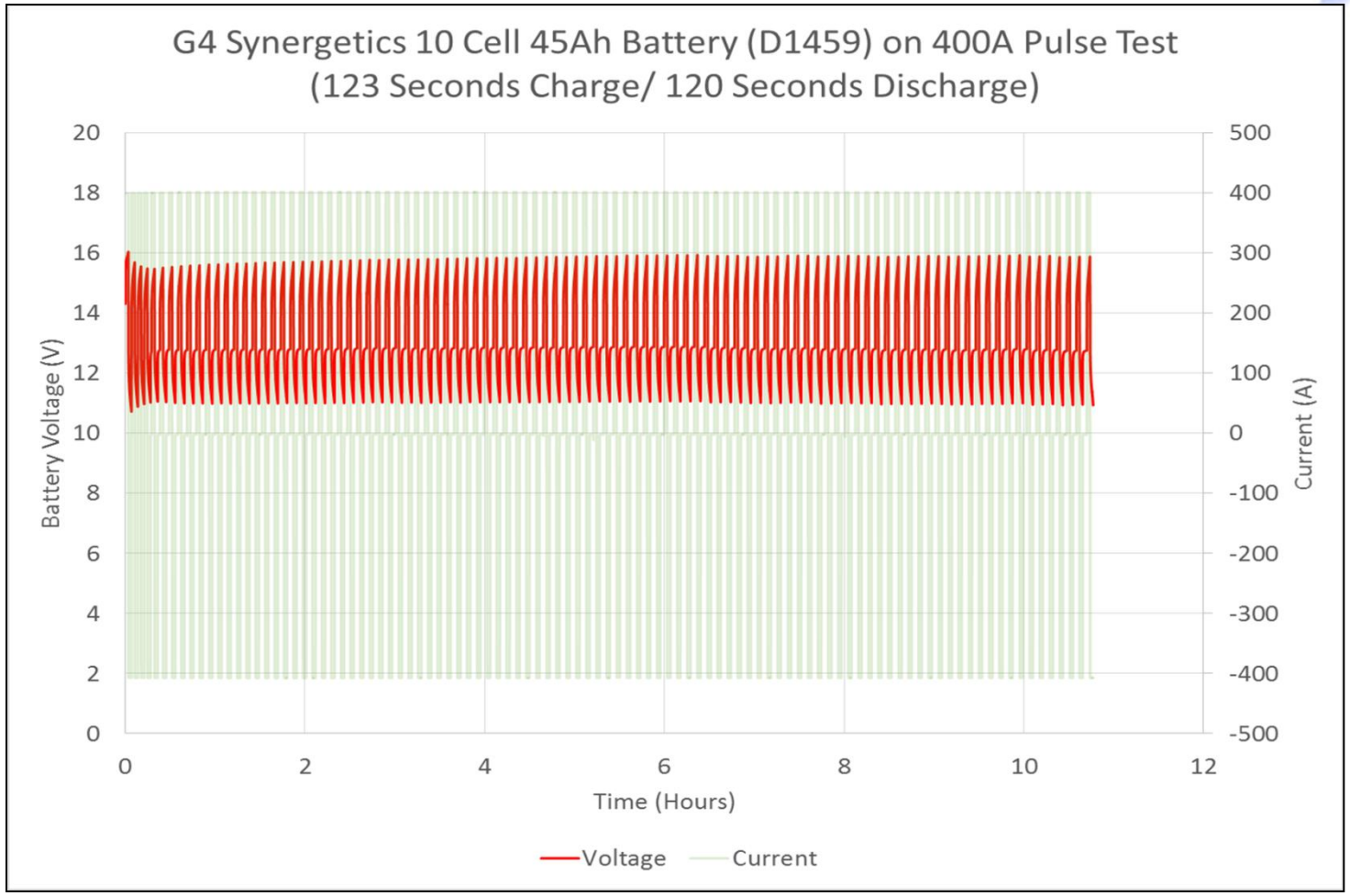
D1301: High Rate, 6-Cell, 25Ah, Battery @ 400A, 30 Cycles Test (fans on)



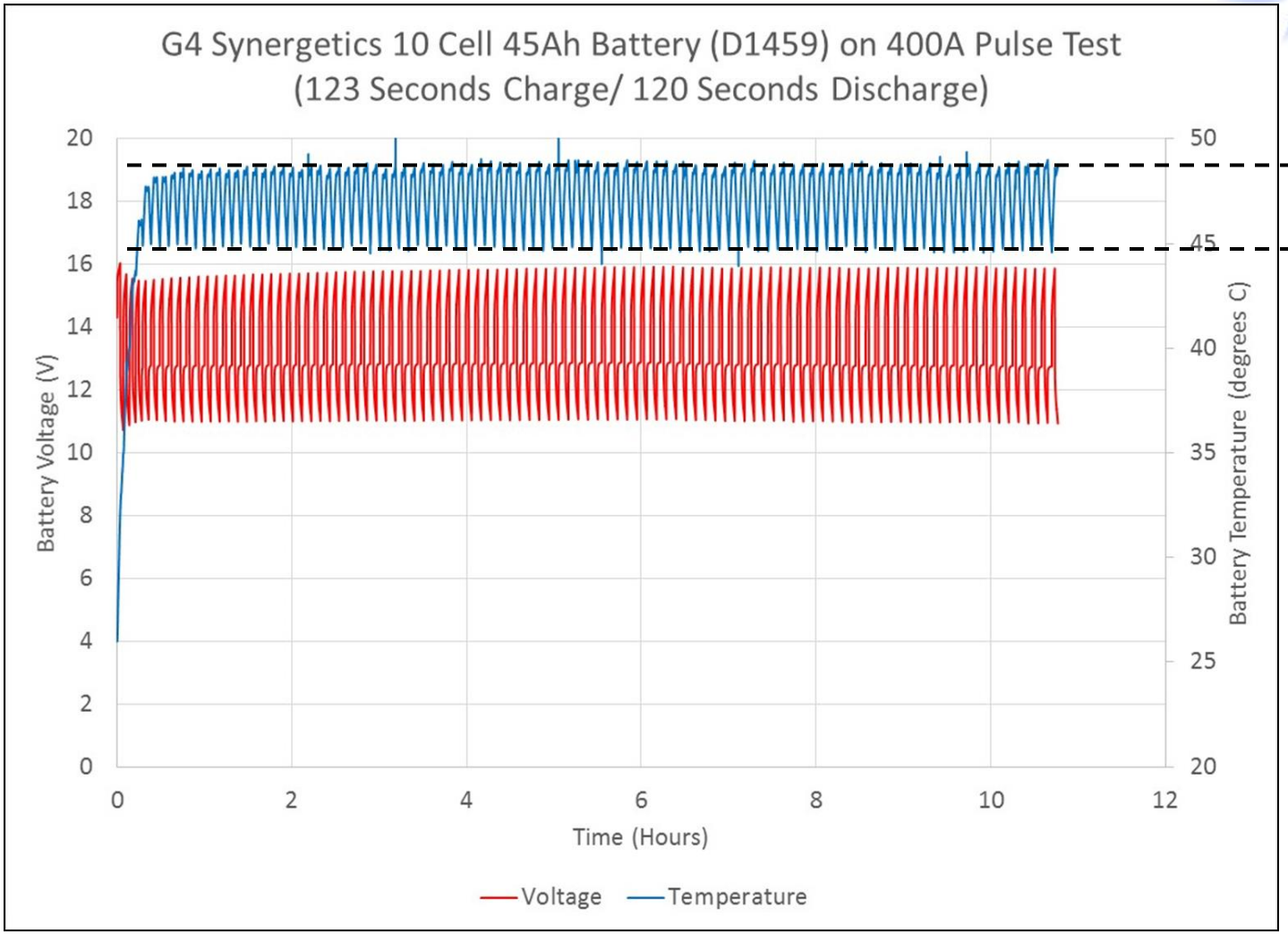
2 min pulses at 400 Amps, 5 minute dwell period between pulses

D1251:12-cell G4 Battery:400A,2 Minute Test (Fans on) for 200 Cycles

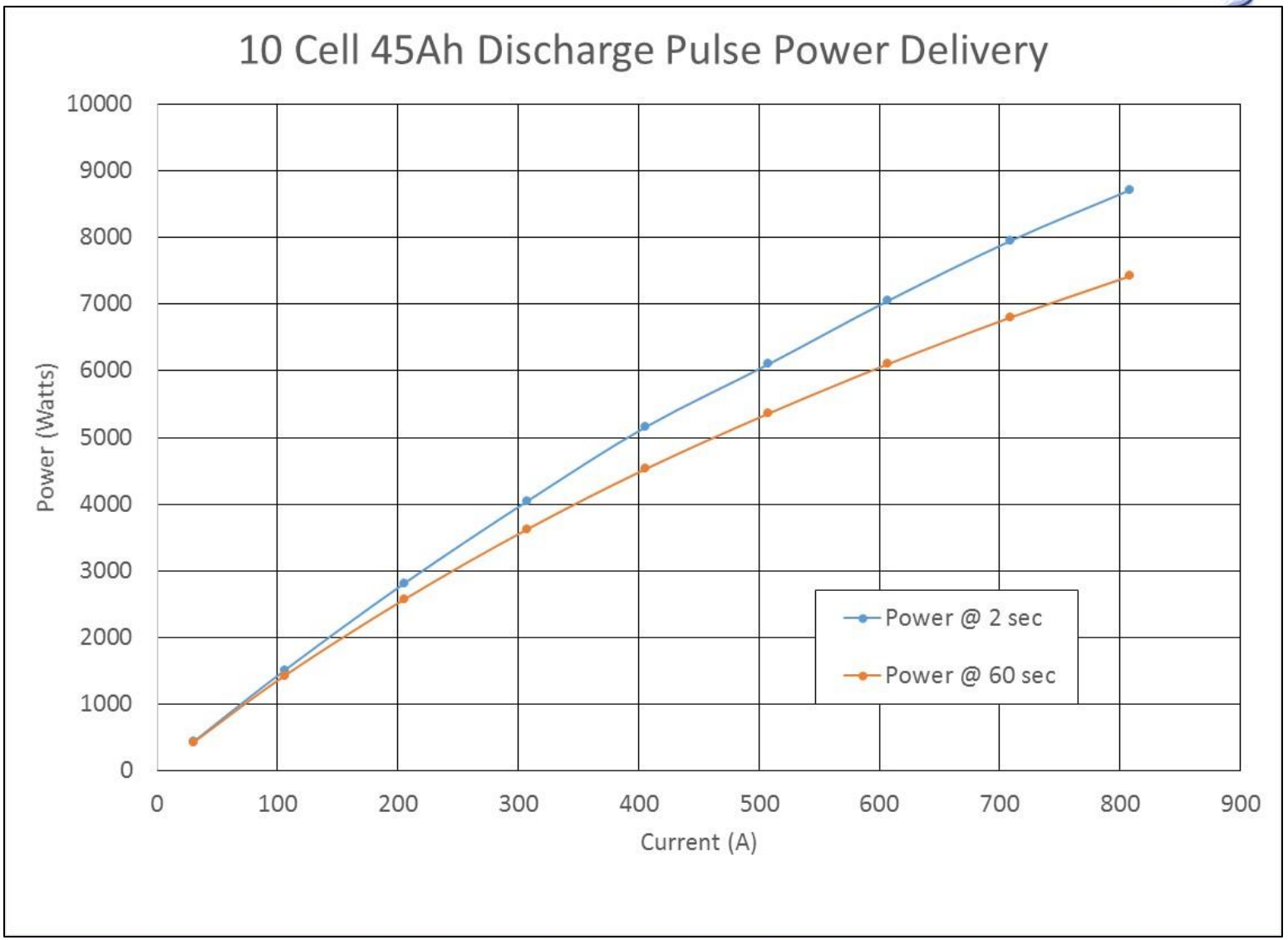


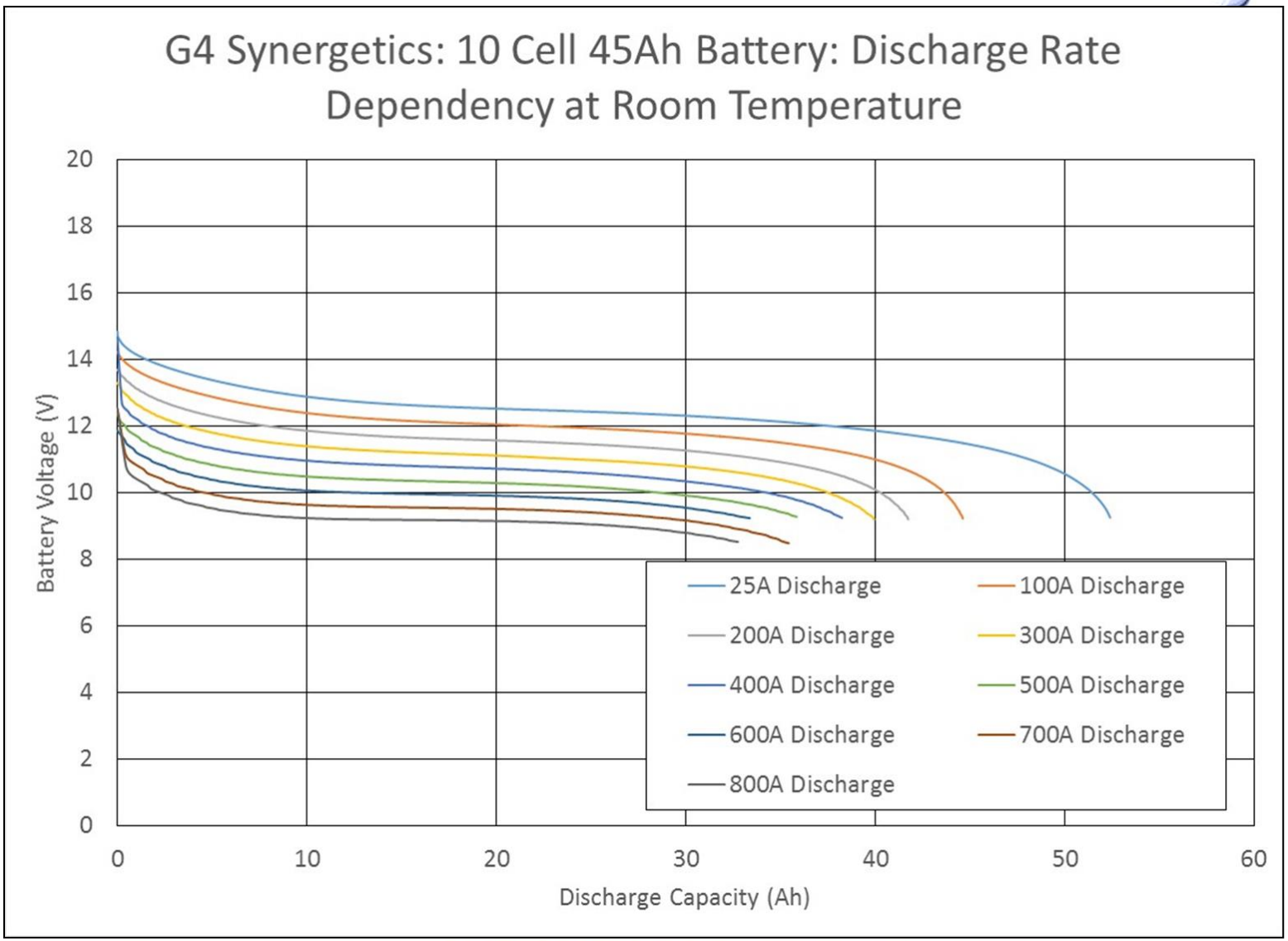


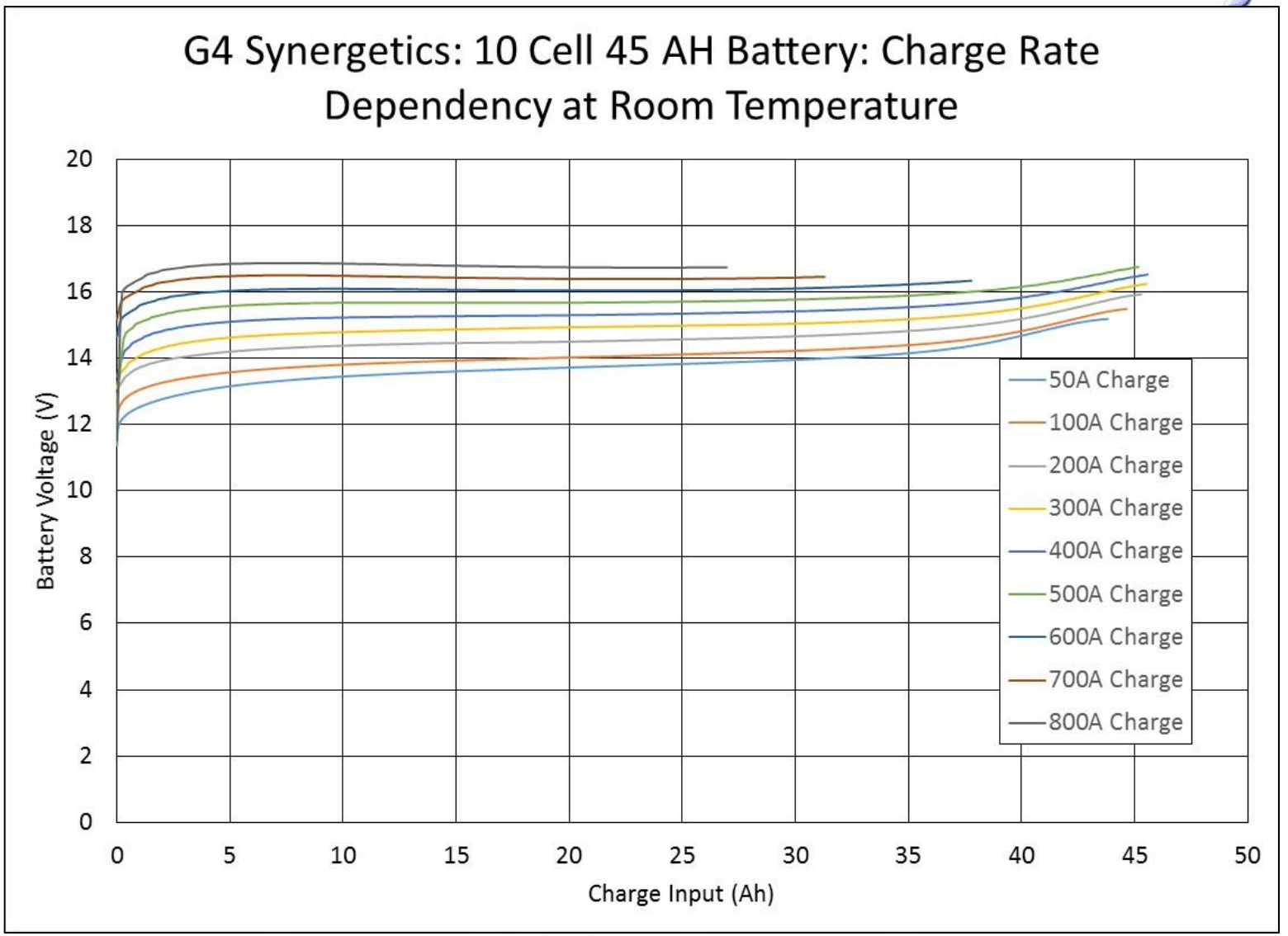
~2 minutes dwell period v. 5 minutes in 25Ah design



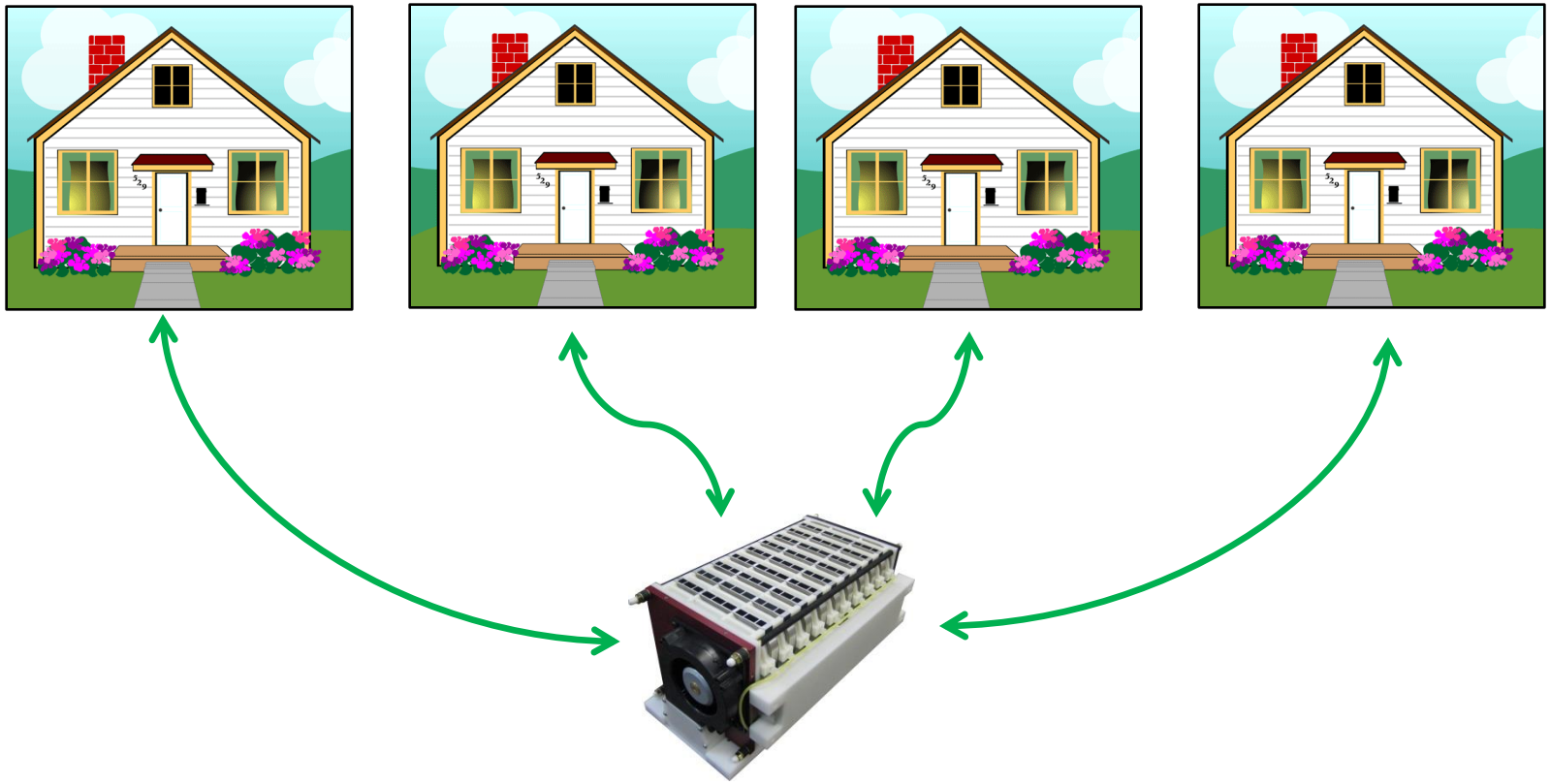
Battery cooled to 45°C between discharge/charge


10 Cell 45Ah Discharge Pulse Power Delivery
Power (Watts)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
900
Current (A)
Power @ 2 sec
Power @ 60 sec

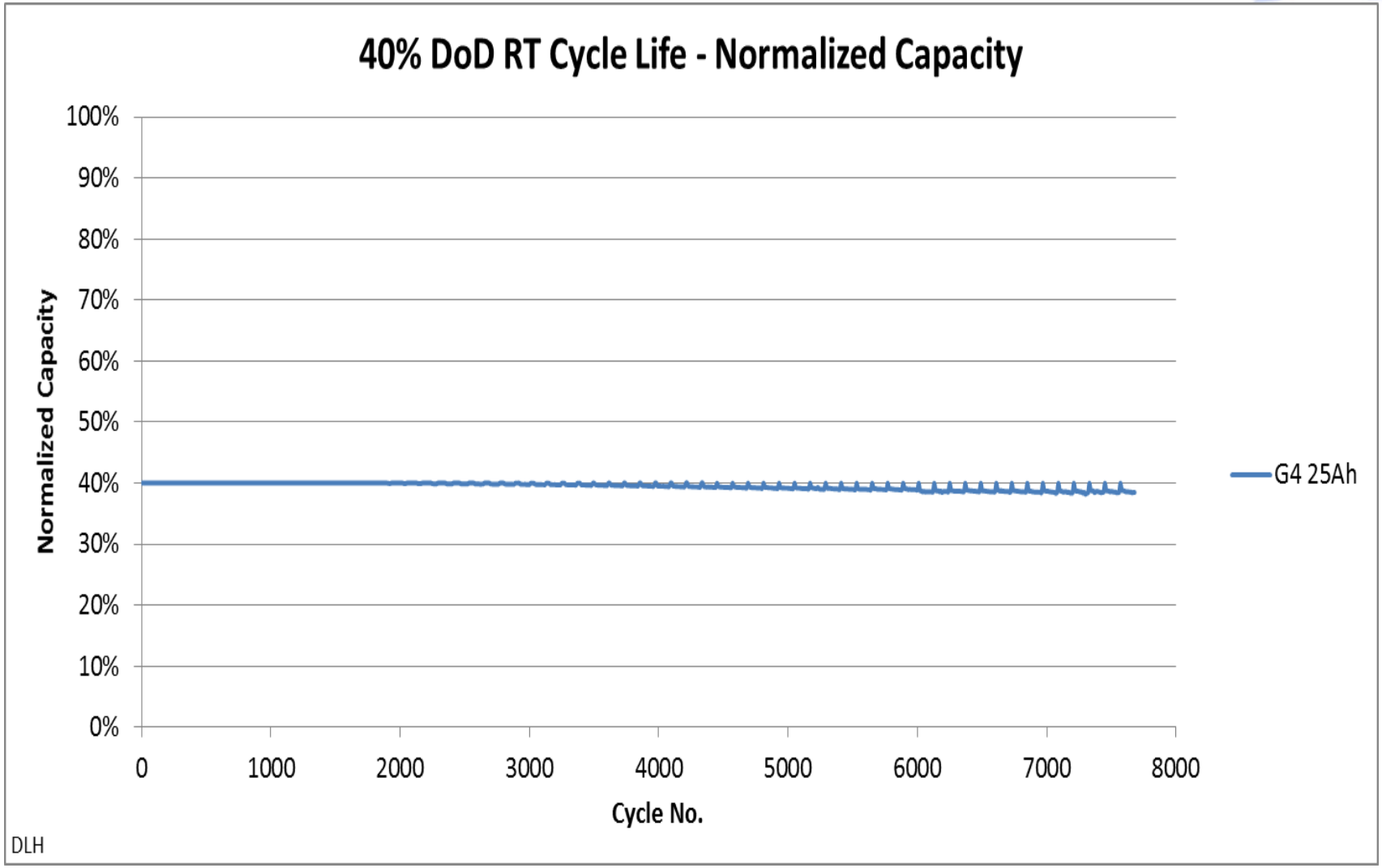

G4 Synergetics: 10 Cell 45Ah Battery: Discharge Rate Dependency at Room Temperature
Battery Voltage (V)
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
Discharge Capacity (Ah)
25A Discharge
100A Discharge
200A Discharge
300A Discharge
400A Discharge
500A Discharge
600A Discharge
700A Discharge
800A Discharge

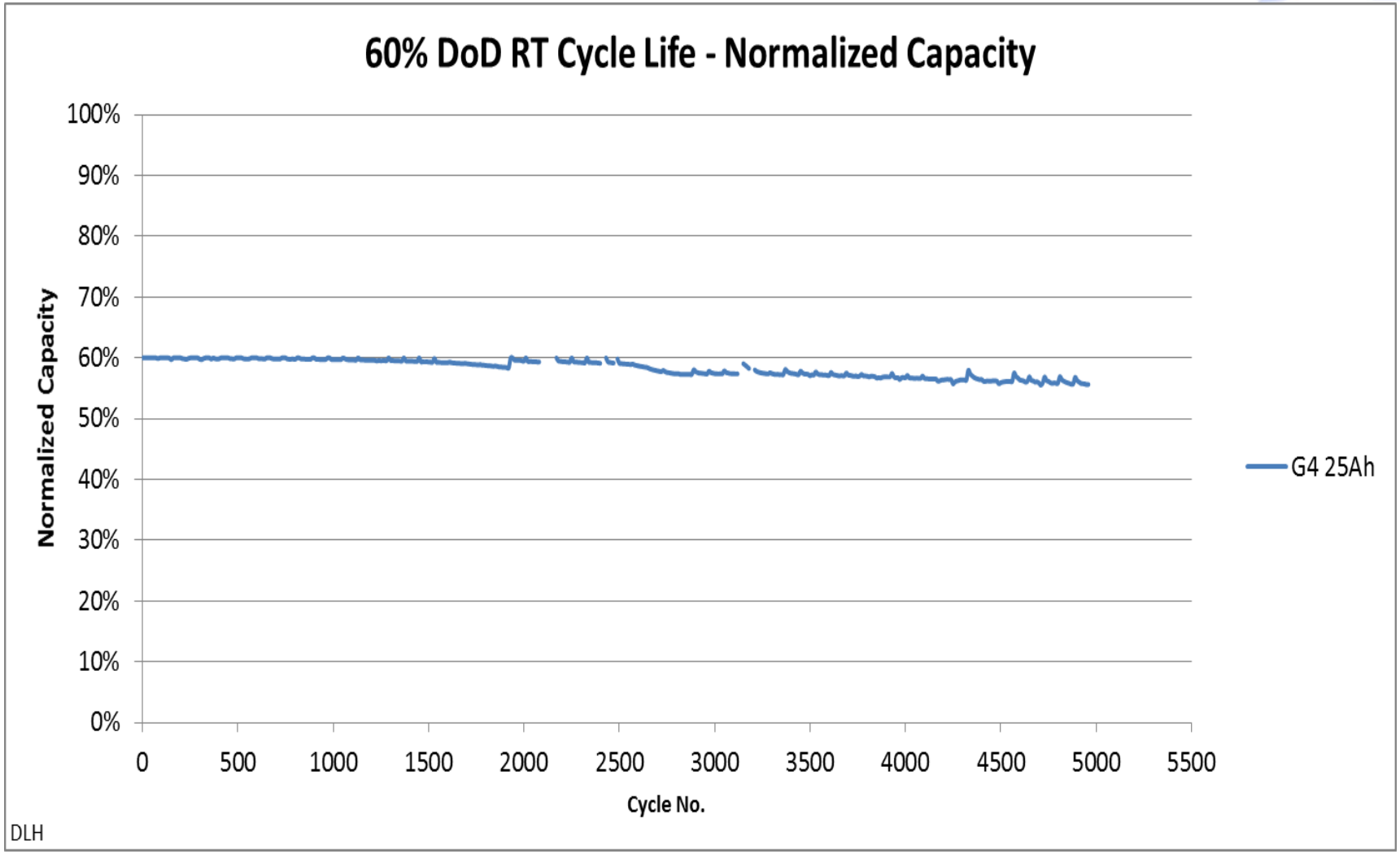

G4 Synergetics: 10 Cell 45 AH Battery: Charge Rate Dependency at Room Temperature
Battery Voltage (V)
Charge Input (Ah)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
40
45
50
50A Charge
100A Charge
200A Charge
300A Charge
400A Charge
500A Charge
600A Charge
700A Charge
800A Charge

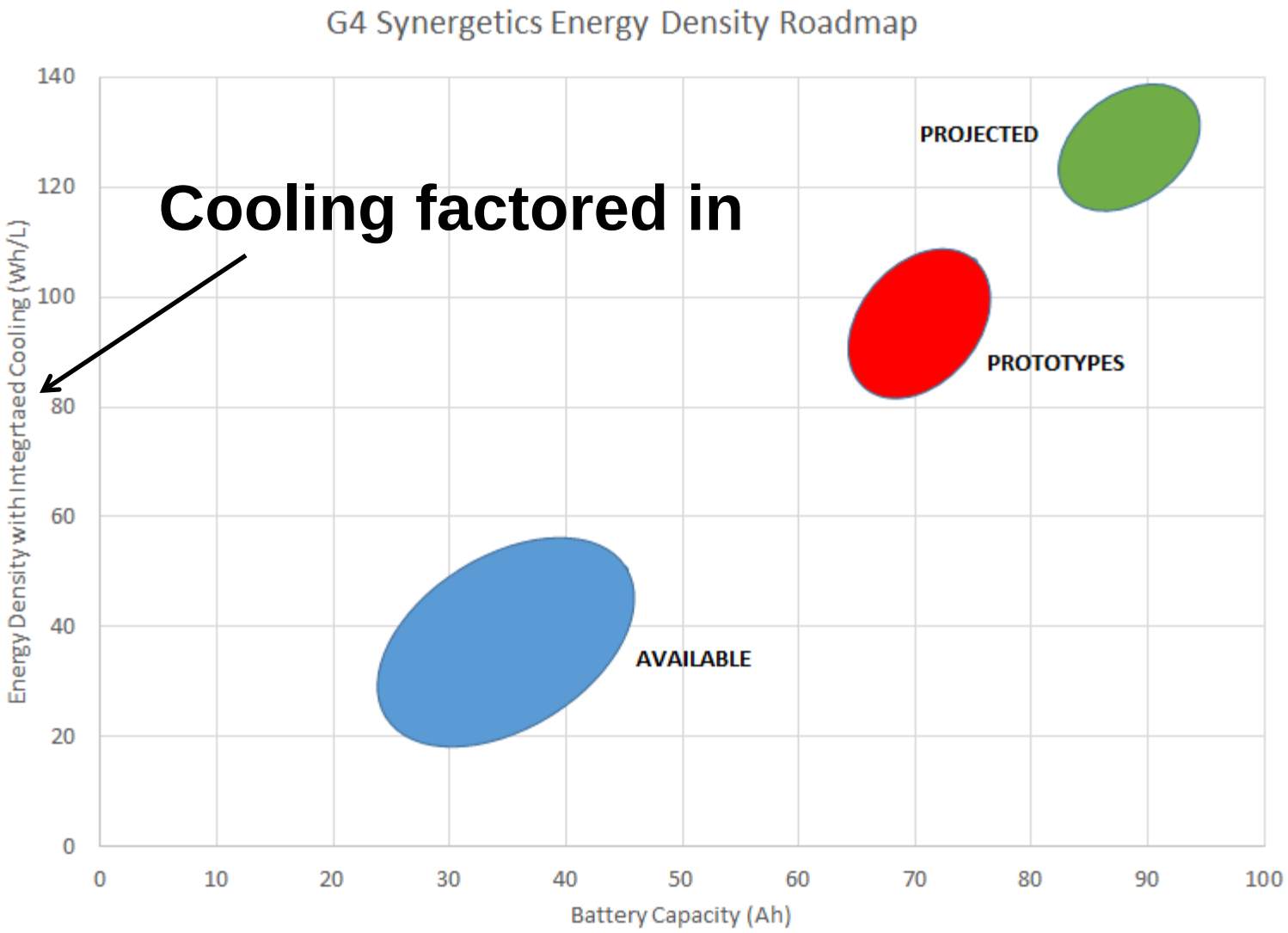
How much current is 800A?



45Ah, 12V Module


40% DoD RT Cycle Life - Normalized Capacity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Normalized Capacity
0
1000
2000
3000
4000
5000
6000
7000
8000
Cycle No.
G4 25Ah
DLH


60% DoD RT Cycle Life - Normalized Capacity
Normalized Capacity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Cycle No.
G4 25Ah
DLH


G4 Synergetics Energy Density Roadmap
Cooling factored in
PROJECTED
PROTOTYPES
AVAILABLE
Energy Density with Integrtaed Cooling (Wh/L)
Battery Capacity (Ah)
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80
90
100

So What? You made us snooze with all this data!

The Real Question is: "What can the G4 battery do for the warfighter?

Military Investigations:

1. Pulsed power weapons and applications - in evaluation stage at UTA
2. Rapid recharge capability at high rates could re-deploy assets in rapid fashion
3. For FOB/facilities, smoothing/firming of intermittent energy sources (PV, wind), power/voltage stability
4. Potential to circumvent stringent and costly testing criteria – DOT “friendly”
5. Strategic applications that G4 is not privy to

The University of Texas at Arlington's Pulsed Power and Energy Laboratory - **David Alan Wetz Jr., Ph.D**

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