



Advanced CFX Cells For Military Applications

**Engineered Power
June 2017**

www.engineeredpower.com

Overview

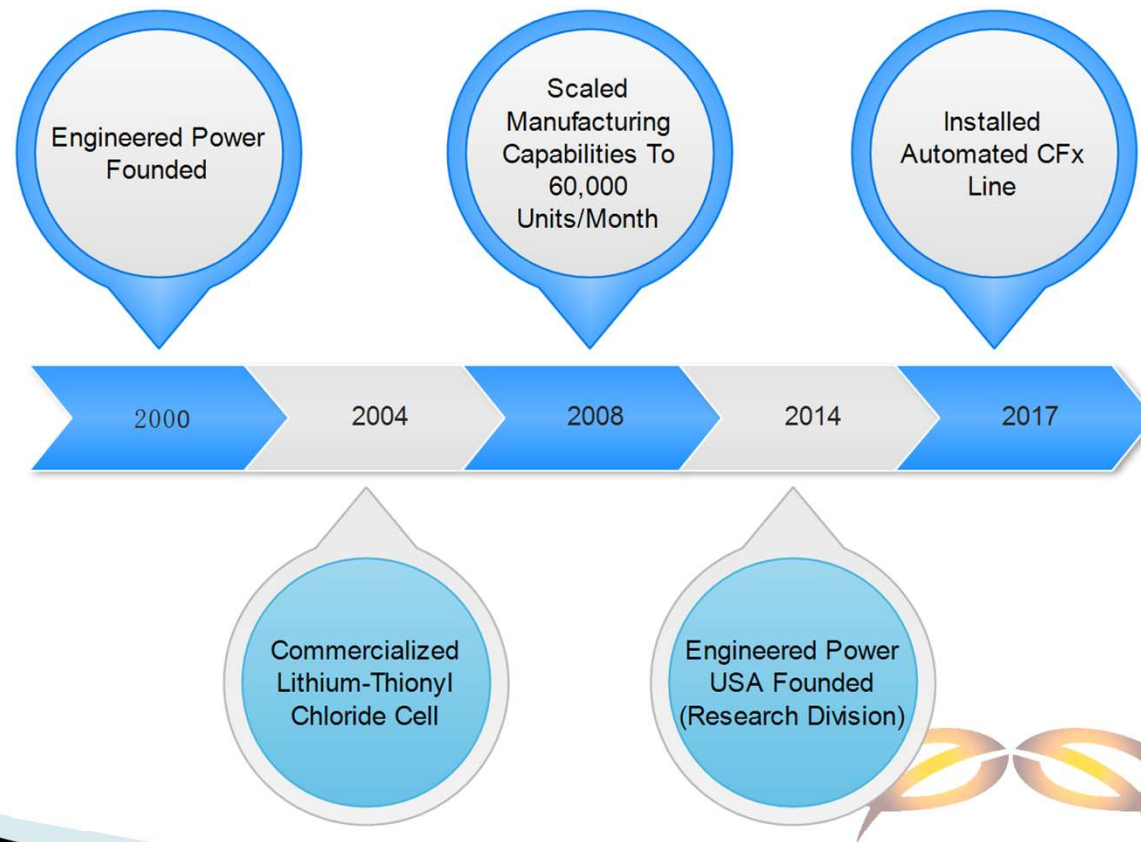
- Company Background
- CFX Electrochemistry
- CFX and Hybrid Cathode Development
- Performance Summary
- Safety Testing



Who we are



- ▶ Engineered Power headquarters is in Calgary, AB, Canada.
- ▶ Over 100 employees and a 40,000 SQF facility.
- ▶ Manufacturer of cylindrical non-rechargeable cells from 1/2AAA to DDD and E.



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Engineered Power Manufacturing Capability

- ▶ Calgary, Alberta
 - AAA to DDD Cylindrical Li Primary Cell Manufacturing
 - Li-Thionyl Cells Different Construction Styles
 - Low rate bobbin style
 - Moderate rate dual anode style
 - High rate spiral style
 - Li-CFx & Li-CFx/MNO₂ spiral styles
 - 80,000 cell/month manufacturing capacity

- ▶ Duarte, California
 - Advanced Li Primary R&D
 - CFx-MNO₂ electrode coating

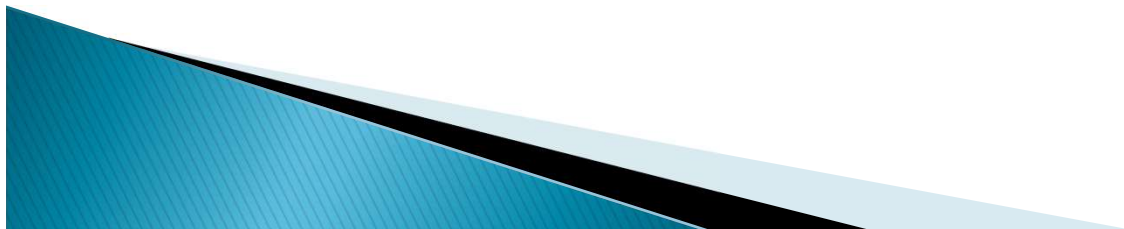


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Product & Facility Pictures



DRY ROOM FACILITY



Product Philosophy

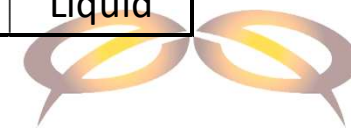
- ▶ Focused on cell design and manufacturing cells for extreme environments.
 - Cells can be customized to perform from -40°C to 225°C .
 - Robust cells can handle shocks of up to 1000G.
 - All cells are manufactured with a glass to metal seal.
 - Primary chemistries including thionyl, CFX and Hybrid MnO_2 .
 - Customized cell designs meet any customer requirements.



CF_x Material Overview














- ▶ **CF_x is an ideal material for many battery applications because it has:**
 - the highest gravitational energy density of any material
 - low self-discharge rate
 - wide temperature range performance
 - high rate capabilities

Cathode	Discharge Potential (V)	Specific Capacity (mAh/g)	Specific Energy (Wh/Kg)	Energy Density (Wh/L)	Cathode Phase
CF _x	2.7-3.0	860	2200	5940	Solid
MnO ₂	2.7-3.1	310	850	4240	Solid
SO ₂	2.7-3.0	420	1150	1650	Liquid
SO ₂ Cl ₂	3.5-3.9	397	1480	2380	Liquid
SOCl ₂	3.3-3.6	480	1580	2590	Liquid



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Battery Comparison

Features	Lithium Carbon Fluoride	Lithium Sulfuryl Chloride	Lithium Thionyl Chloride	Lithium Carbon Fluoride Hybrid
Safety				
High Rate Capability				
Capacity				
Voltage				
Temperature Range				



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DD CFx and Hybrid (CFx & MnO₂) Performance



Established Products

- ▶ **CF_x DD Cell**

Chemistry: 100% CF_x active material

Temperature: -20 to 150° C

A DD cell at 150° C is rated for a capacity of 34Ah

- ▶ **Hybrid CF_x DD**

Chemistry: Hybrid CF_x & MnO₂ Chemistry

Temperature: -30 to 110° C

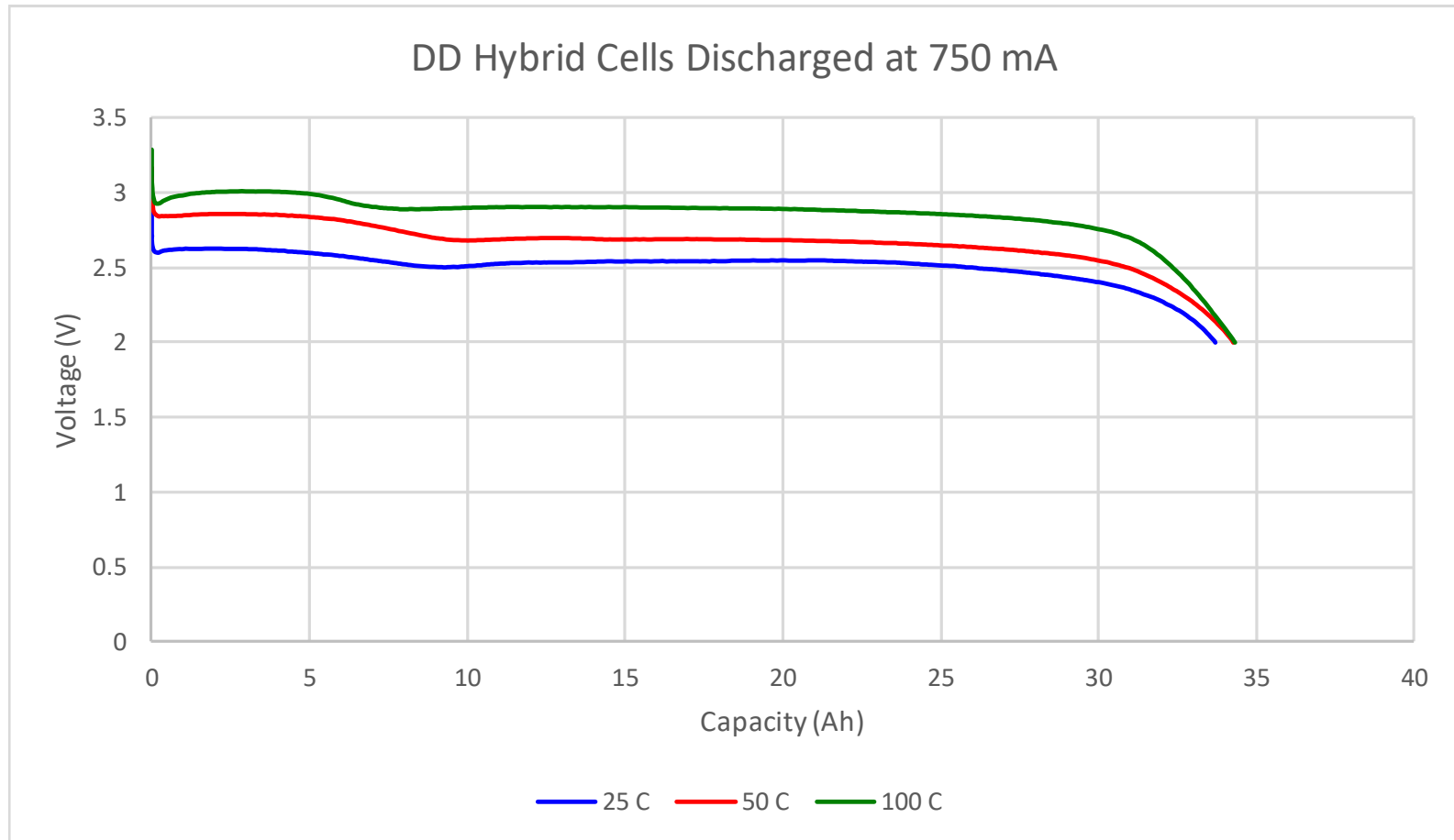
Hybrid chemistry provides cost benefit, high power

A DD cell at 110° C is rated for a capacity of 34Ah



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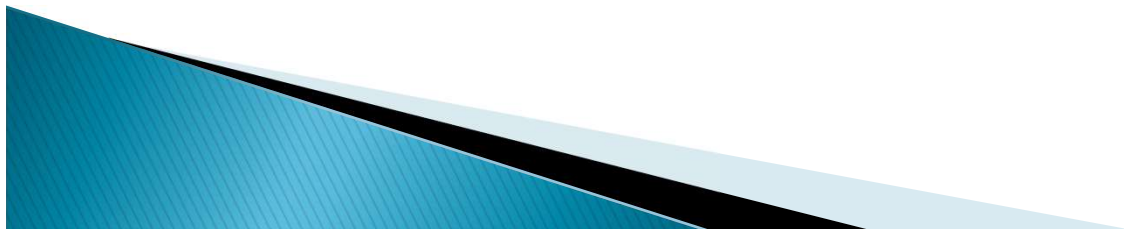
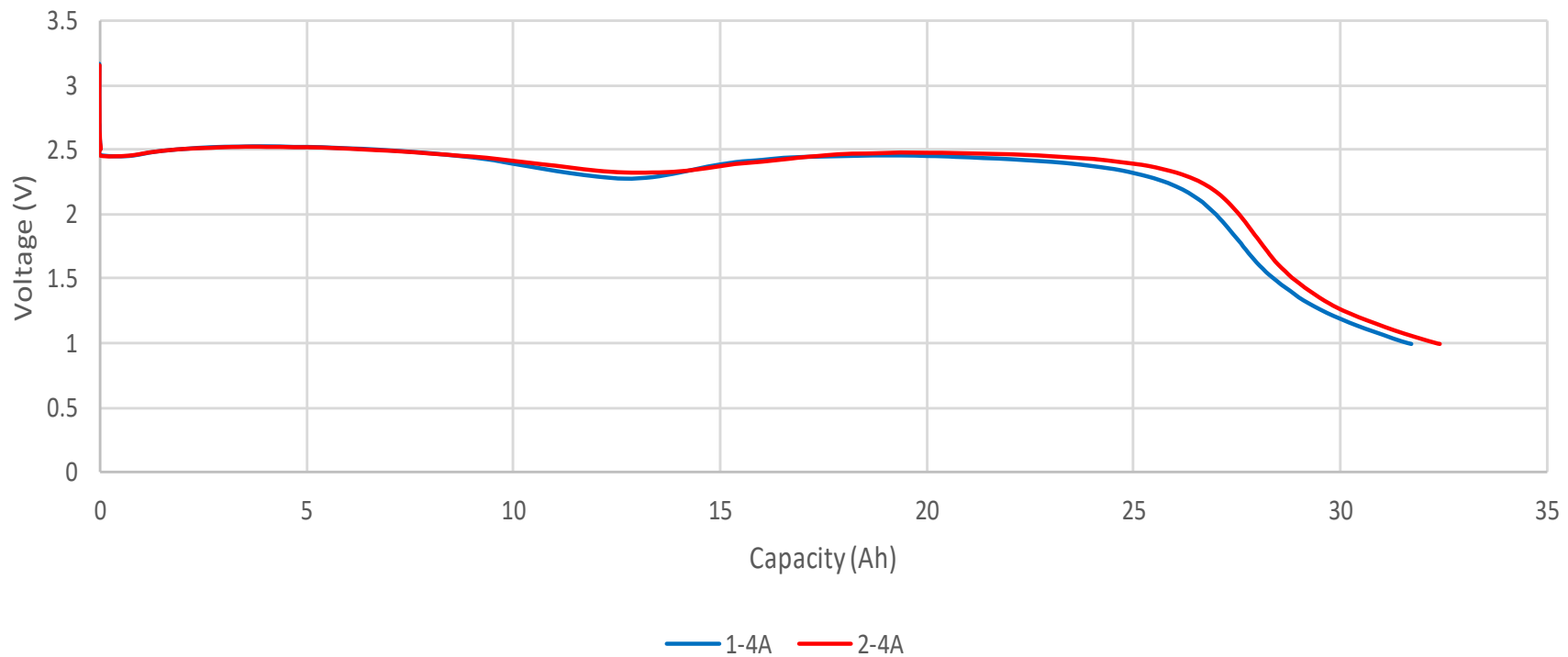
Hybrid DD Cells Tested at Different Temperatures



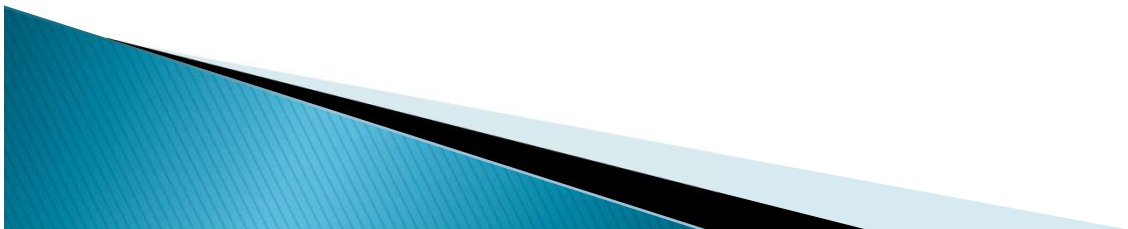
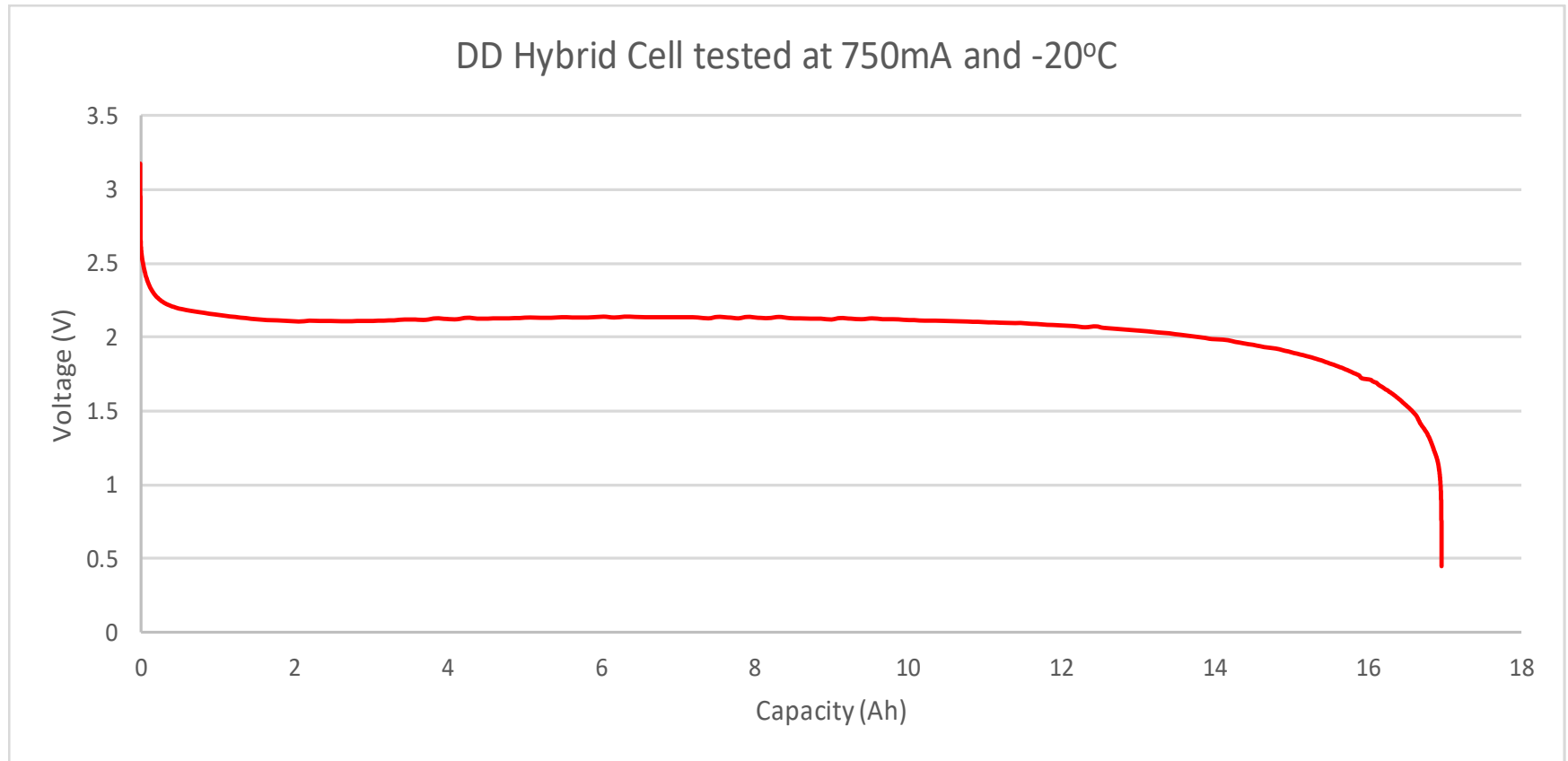
Hybrid DD Tested at 4A



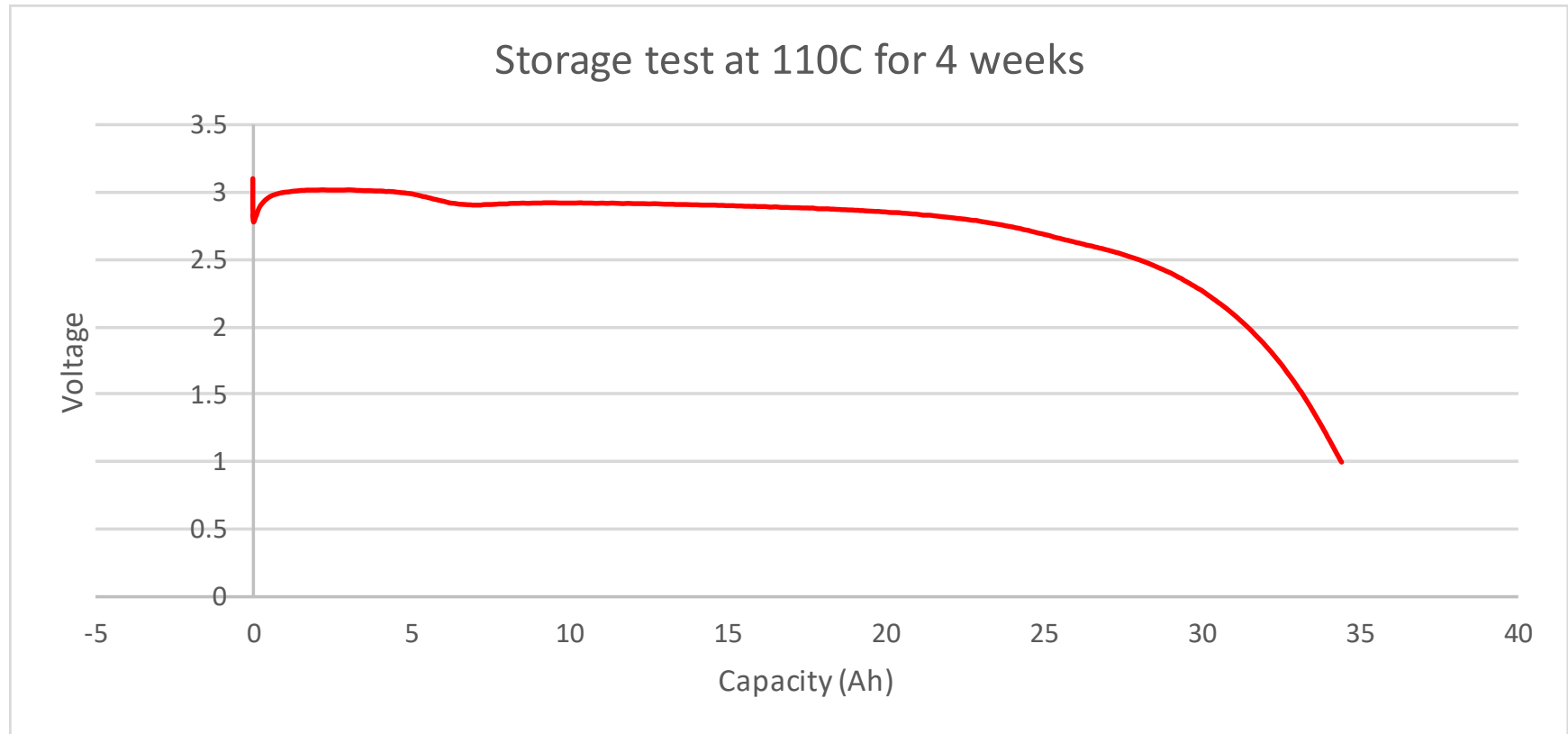
Hybrid DD Cells tested at 4A at 25C



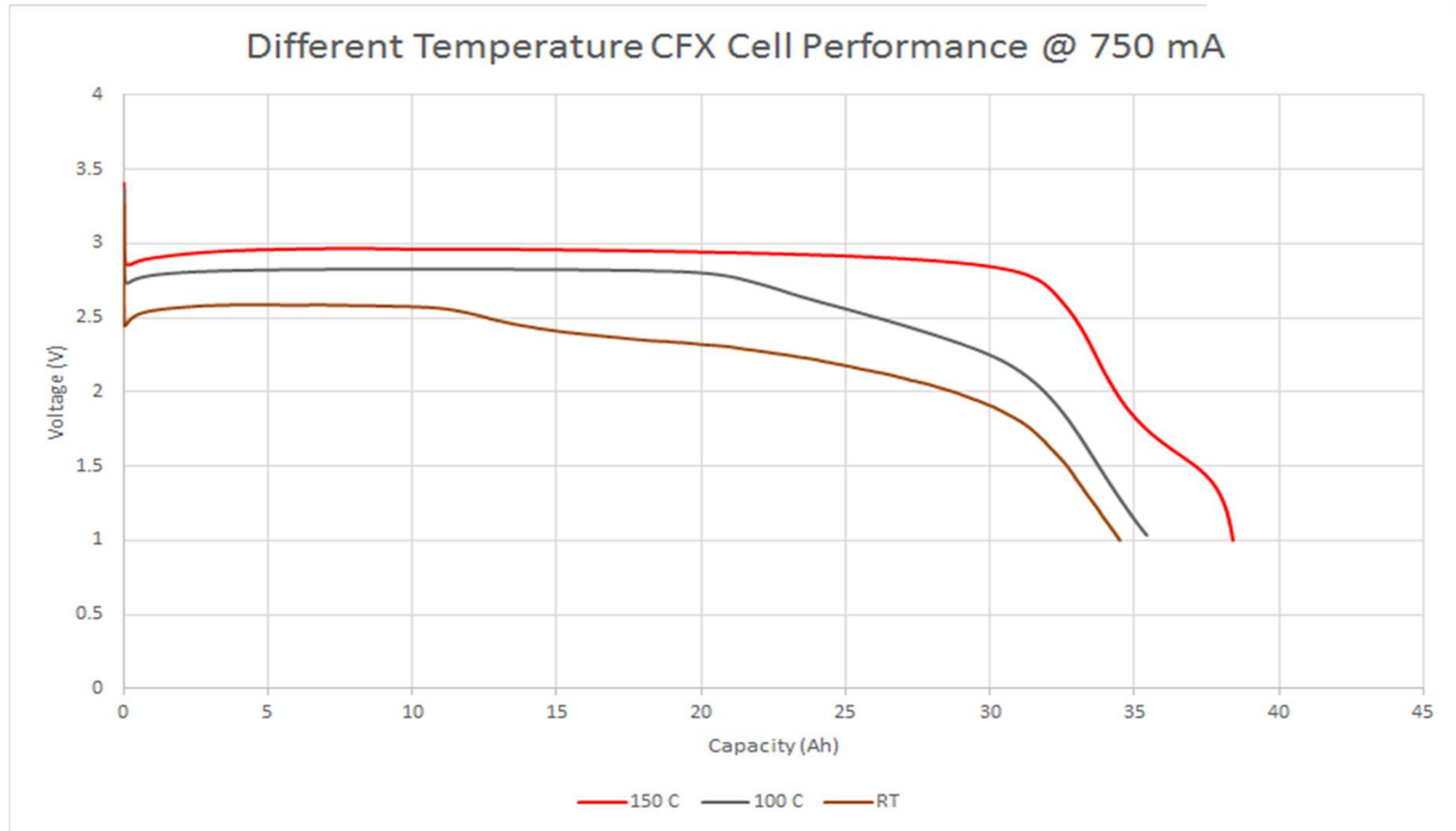
Hybrid DD Tested at -20°C



Hybrid Cell Performance after 110C Storage

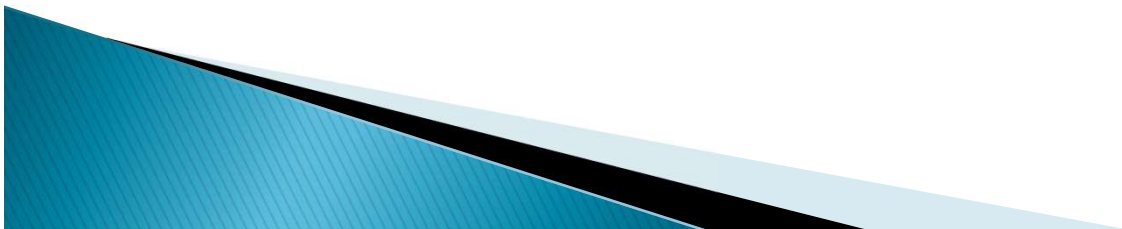
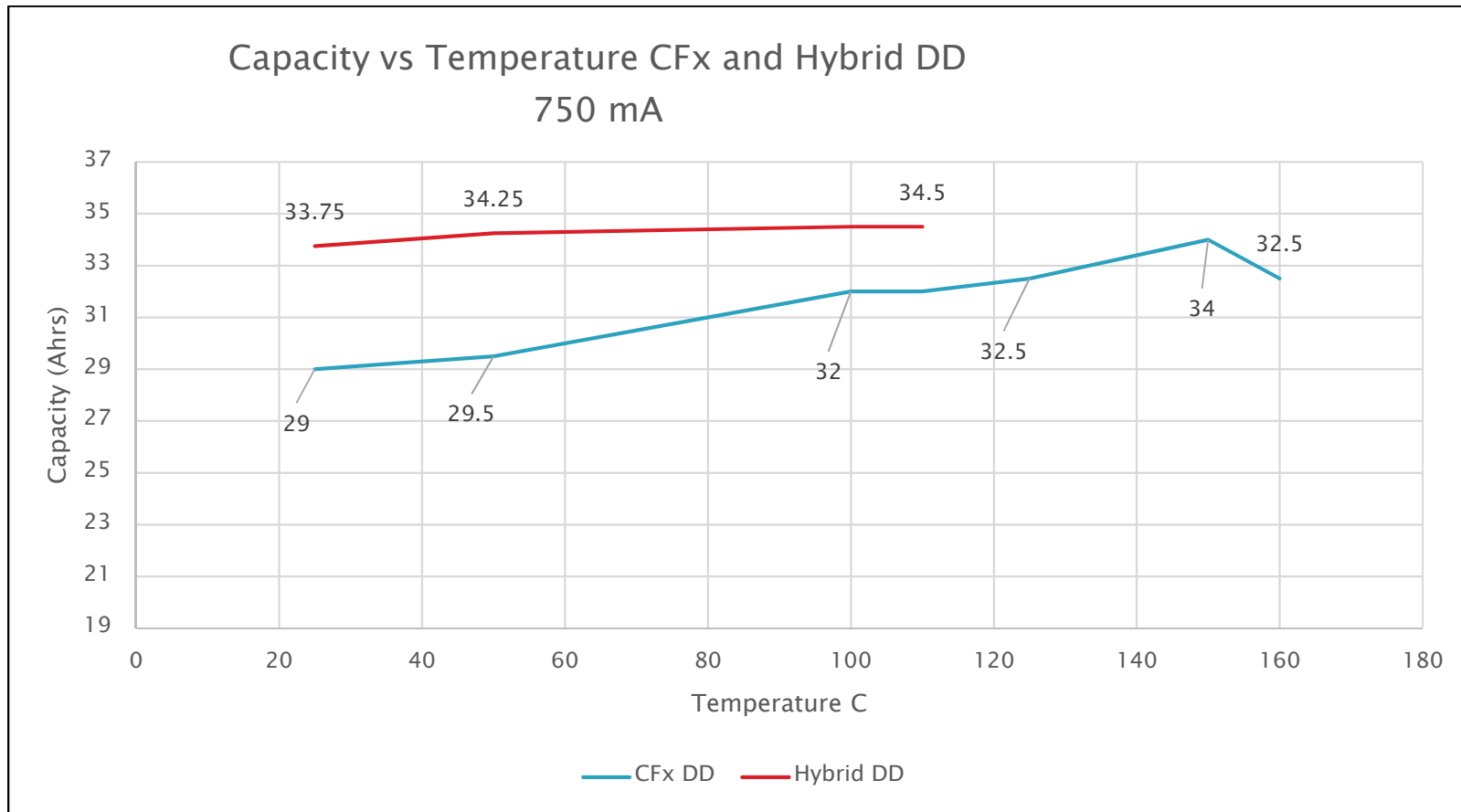


DD CF_x Tested at 750 mA

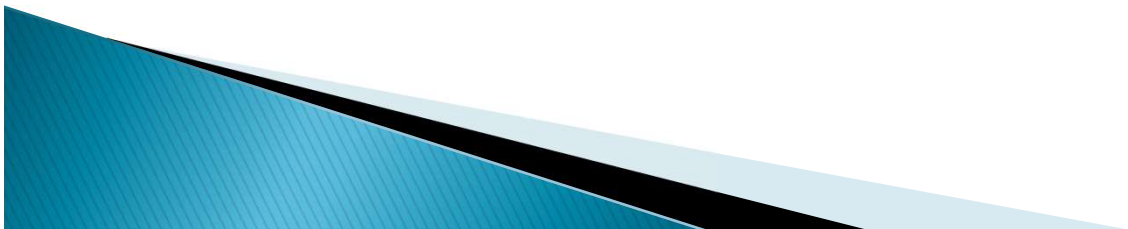
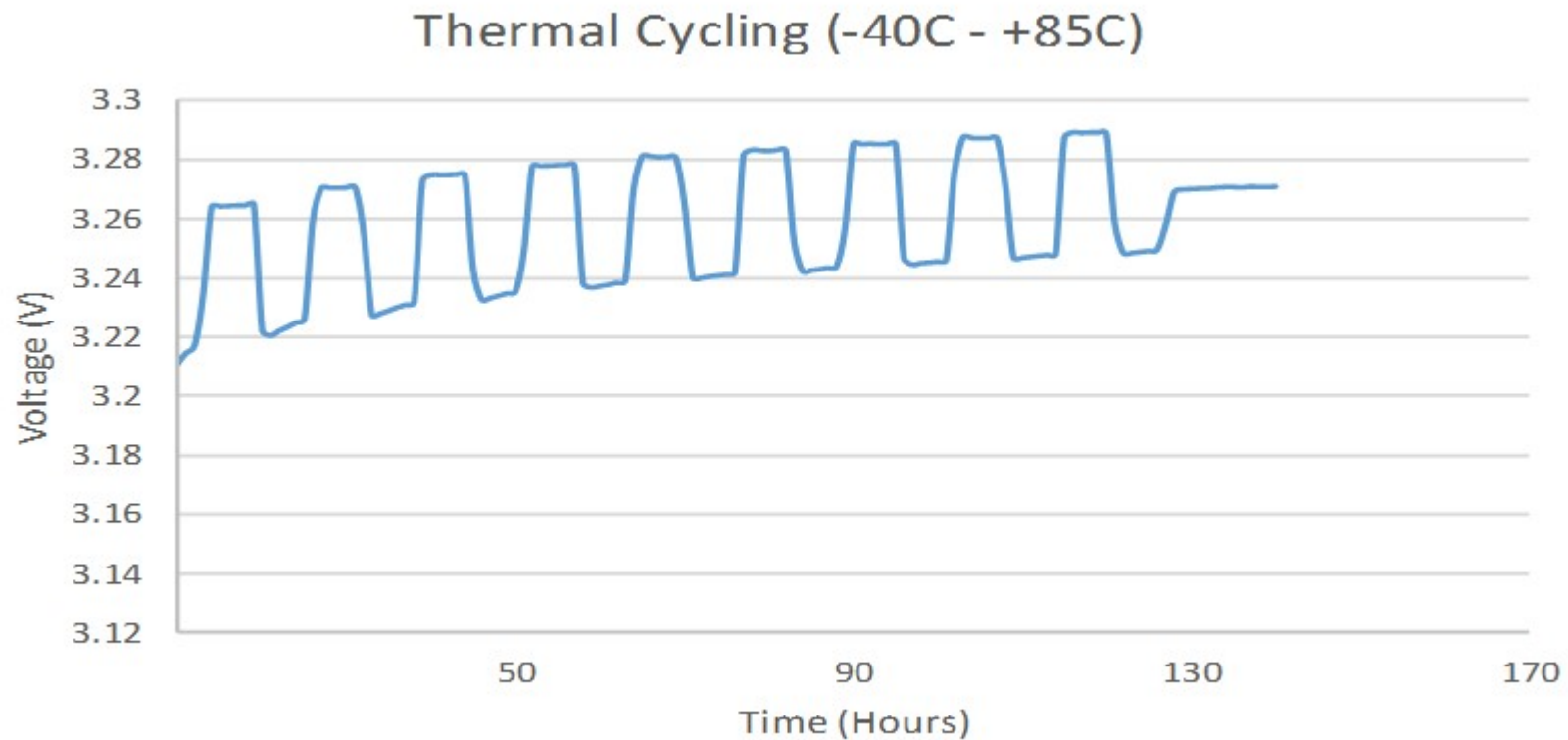


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CF_x and Hybrid DD Capacity



Hybrid Thermal cycling



CF_x and Hybrid DD Specifications

	CF _x DD	Hybrid DD
Open Circuit Voltage	3.3 V	3.3 V
Typical Capacity @ Rated Temp	34 Ah	34 Ah
Energy Density	535 Wh / kg	470 Wh/kg
Operating Temperature	-20 to 150°C	-30 to 110°C
Physical Dimensions	5.0 in (126.2 mm) x 1.25 in (31.8mm)	
Weight	185 g	210 g

High rate capability of up to 5-10A continuous current.

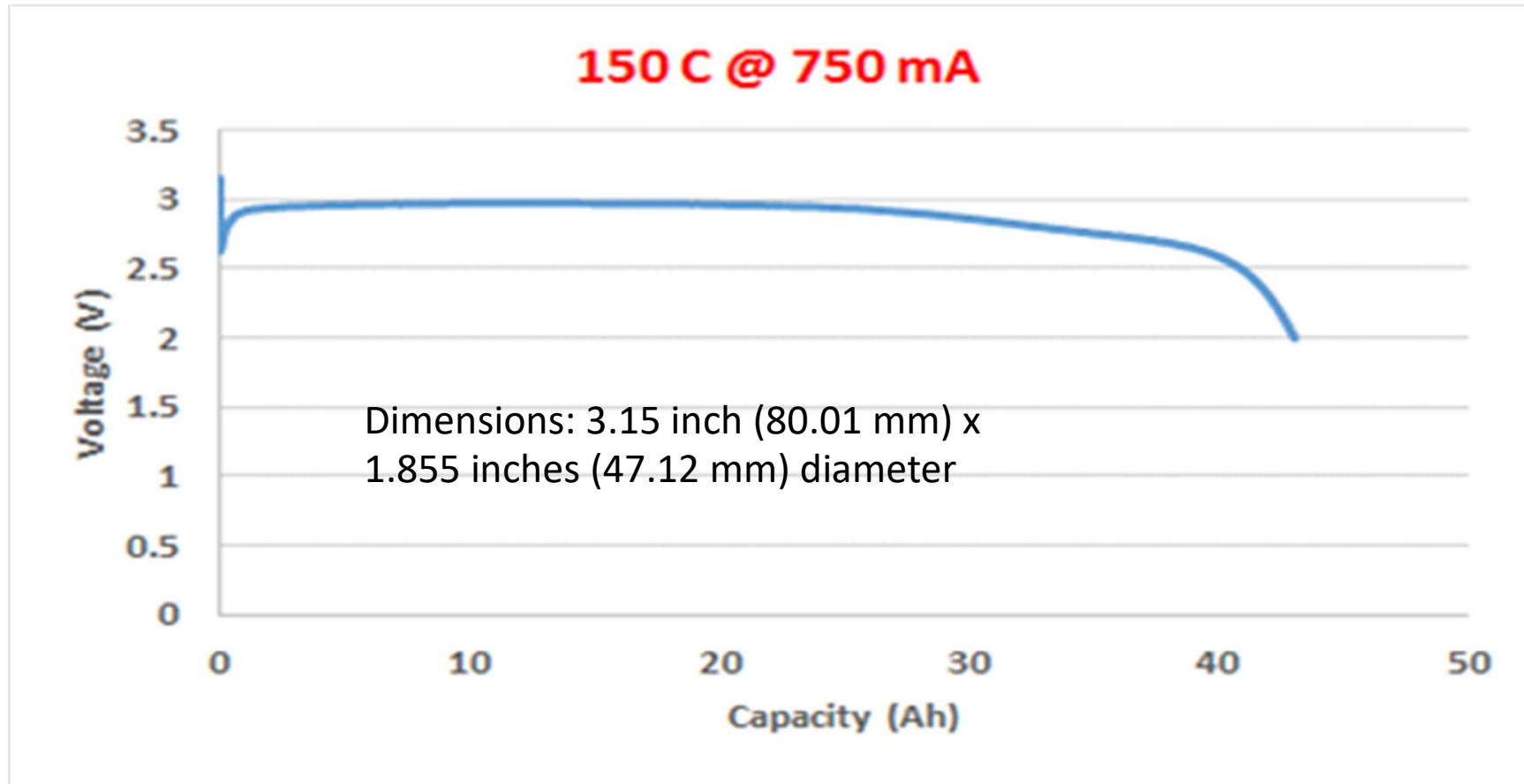


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Prototype CFx cells (D & E)

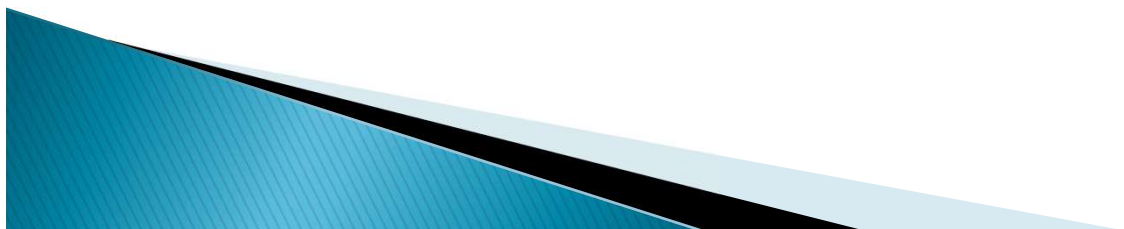
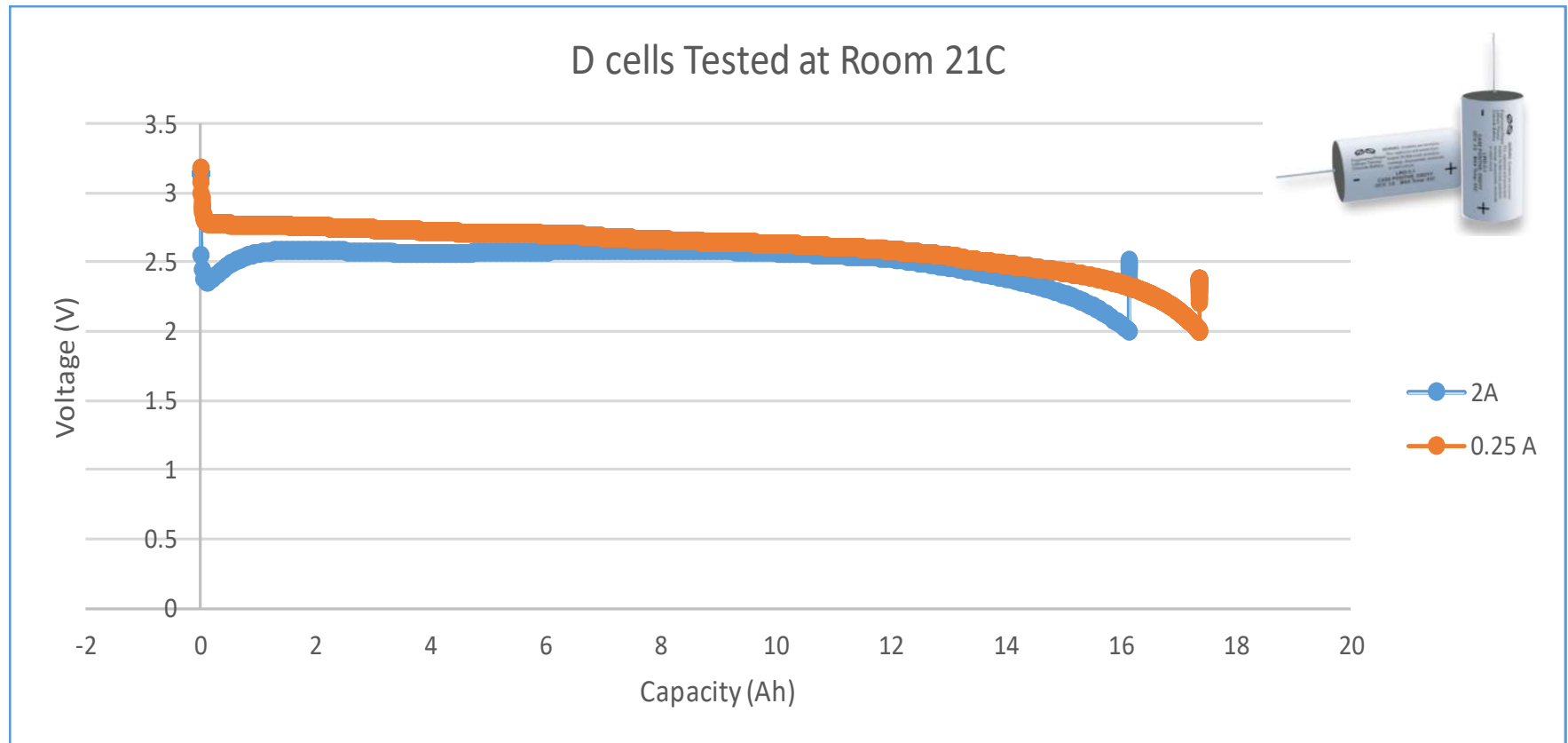


E CFx cell tested at 150C

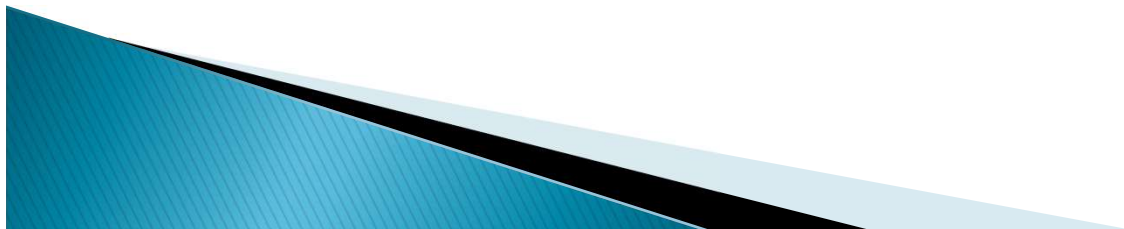
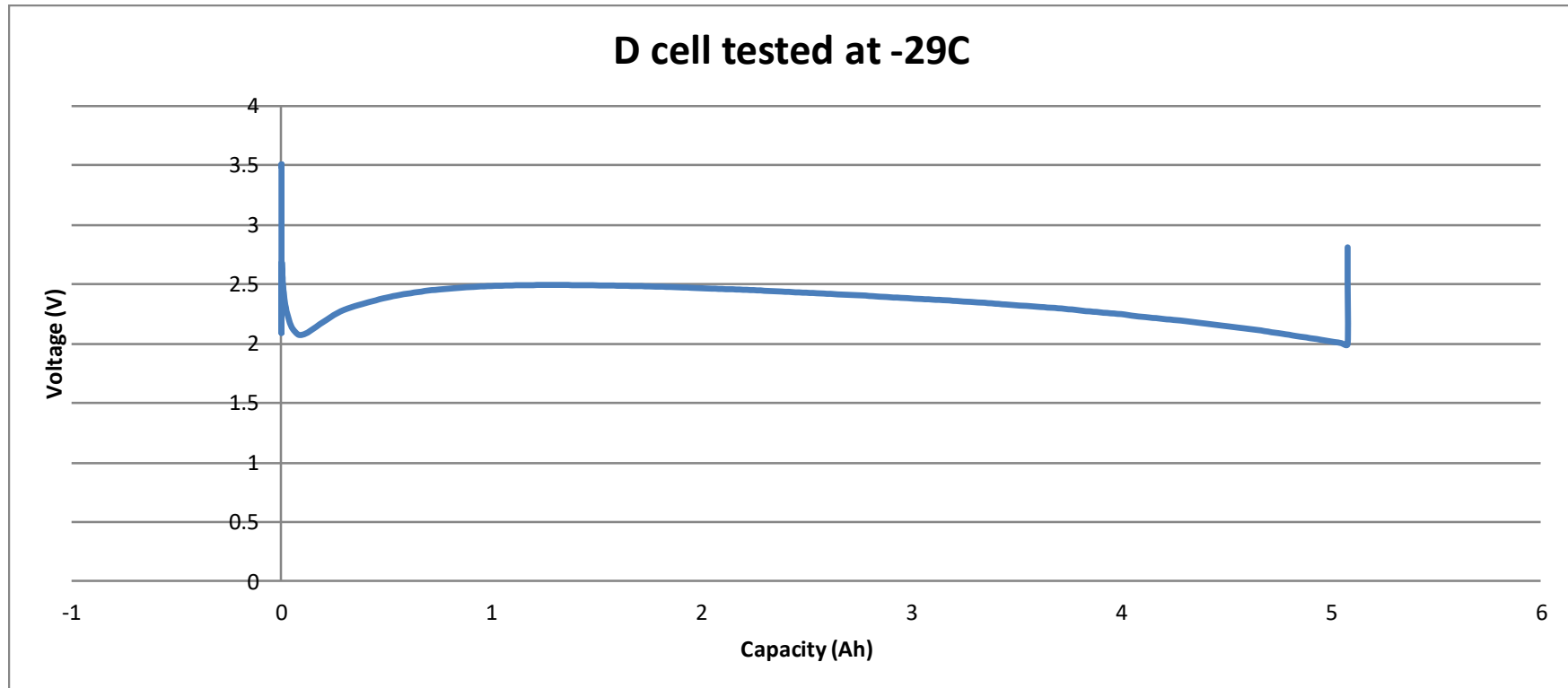


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Hybrid D Tested at Room Temperature



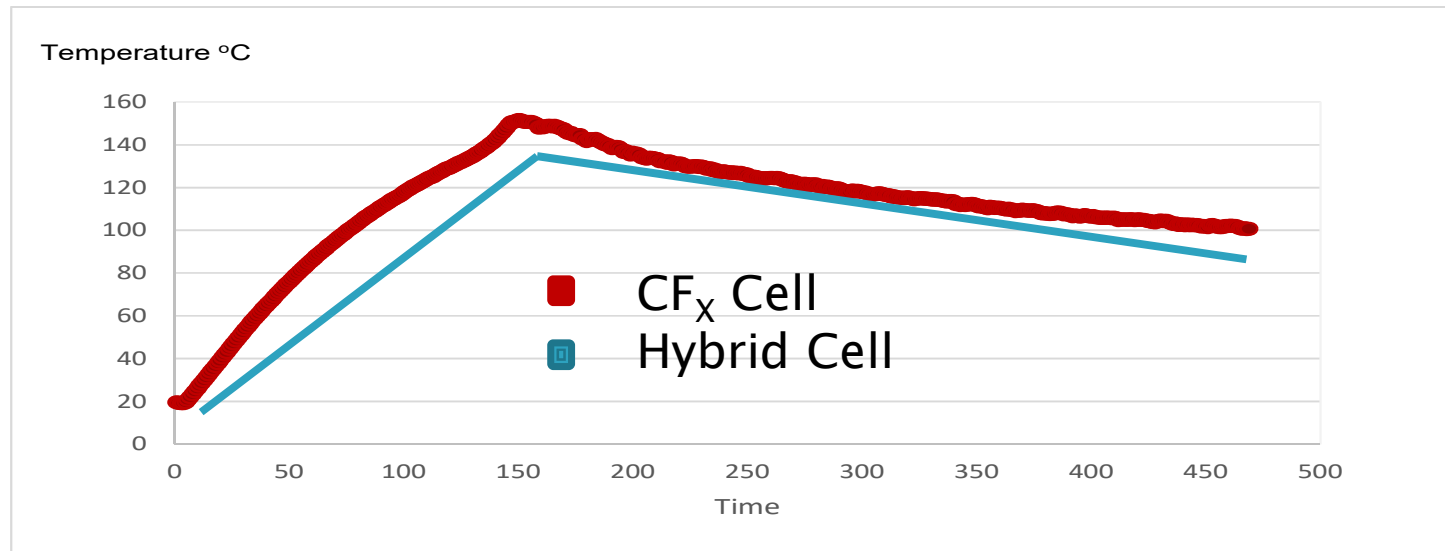
Hybrid D -29°C 2A continuous discharge



DD CFx & Hybrid Safety Testing



Safety – External Short Circuit test



- ▶ Engineered Power simulated a short circuit on the new DD Li-CF_x cell. A short circuit was applied across the (-) and (+) terminals. To pass this test, the cell cannot exceed 170 C, and there can be no external damage or fire of the cell. The Engineered Power DD Li-CF_x and hybrid cells passed this test without the need of an external fuse or circuit.



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Safety – Impact Test – T6

- ▶ This test simulates the crushing of a cell.
- ▶ Pass criteria for this test is the temperature does not exceed +170C & no disassembly or fire within 6 hours of test.
- ▶ Engineered Power passed this test with both CF_x and hybrid cell chemistries.

9.1 KG
Mass

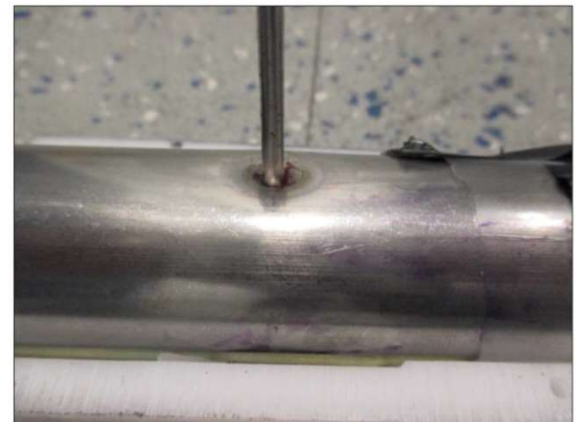
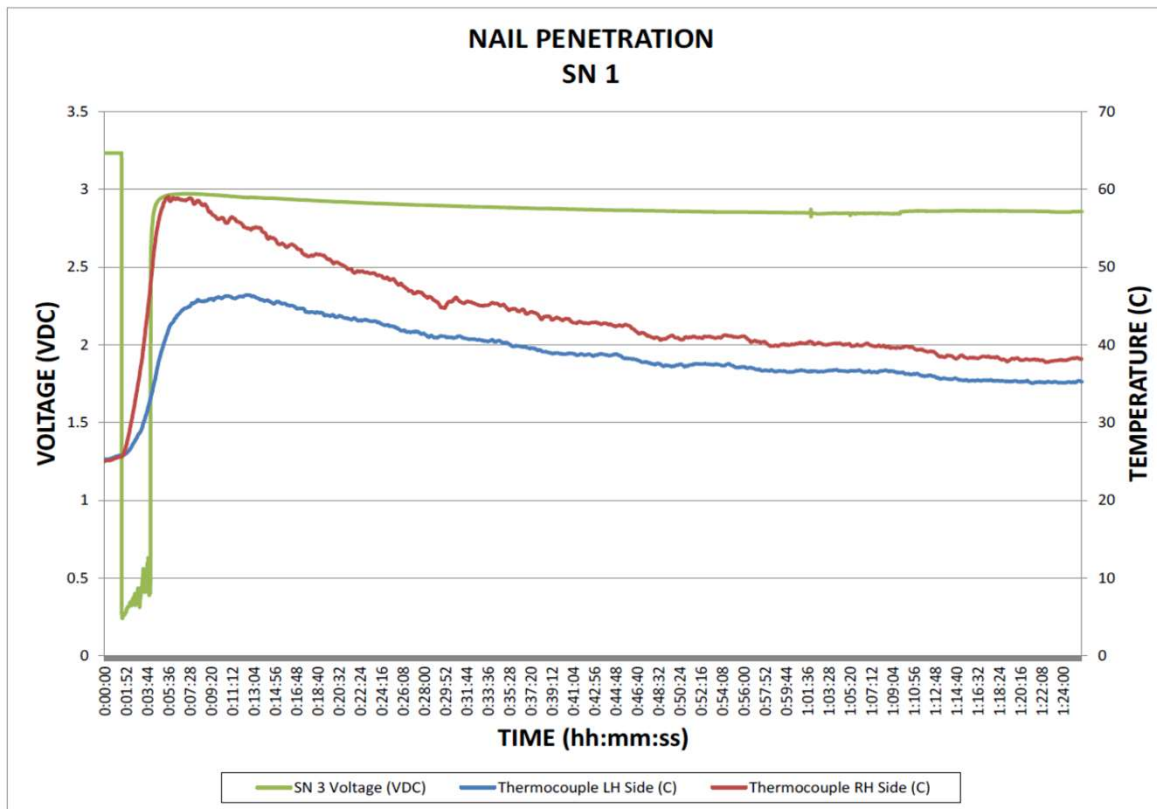
15.8 mm bar

Cell



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Nail Test



Engineered Power DD Cell passed this the nail test penetration with both CF_x and hybrid cell chemistries.



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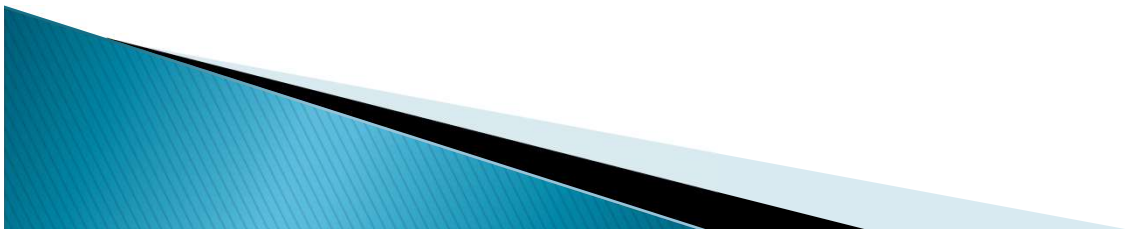
Vibration and Shock Test

▶ Vibration

- **Test 1** : 30–2000Hz sine sweep at 30G, 30min Z-axis (axial) and 30min X/Y-axis (lateral)
- **Test 2**: 5–500Hz random, 20G, 4 hours Z-axis (axial) and 4 hours X/Y-axis (lateral)

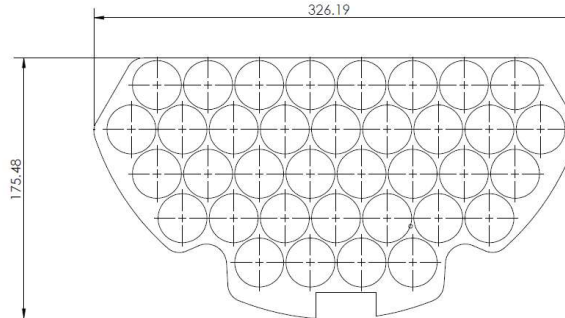
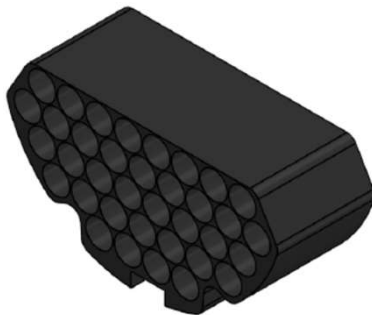
▶ Shock

- 10 shocks in each direction (+axial, –axial, +lateral, –lateral) with total of 40 shocks at 1000G, 0.5msec duration.
- ▶ The DD CF_x and hybrid cells have passed both tests.



Collaboration with Pack Assemblers

- ▶ Engineered Power works with Pack assemblers to incorporate Li-Primary cells
 - Characterize thermal and performance properties
 - Optimize chemistry for end application
 - Modify cell interconnects for efficient pack manufacturing
 - Example: Pipeline Inspection Battery



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Pack Assembler Partners



Next Step

- ▶ CFX & CFX/MN02
 - Working on ATEX, UL and UN certification
 - Analyzing market for AA and D cells
 - Scaling up the manufacturing from 10,000 cells a month to 30,000 DD cells a month.



Questions and Contacts

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