2011 Joint Service Power Expo

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Li-CF_x/MnO_2 Hybrid D-cell with Wide Operating Temperature Range for Military Batteries

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Introduction

Design, Manufacture, Install & Maintain
Power and Communications Systems

- Battery & Energy Products
- Communications Systems

Government, Defense & Commercial Markets

Ultralife Batteries, ABLE
McDowell, RedBlack, AMTI

Headquarters in Newark, NY
Sales & Operations in US, Europe and Asia

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Objective

- **Develop Li-CF_x/MnO_2 Hybrid D-cells into Different Formats of Military Batteries**

Goal:

1) High Capacity
2) High Power
3) Light Weight (High Energy Density)
4) Wide Operating Temperature Range
5) Long Shelf Life
6) Cost Effective
7) Safe (Robust)

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Objective

D-cell in BAxx90 Battery

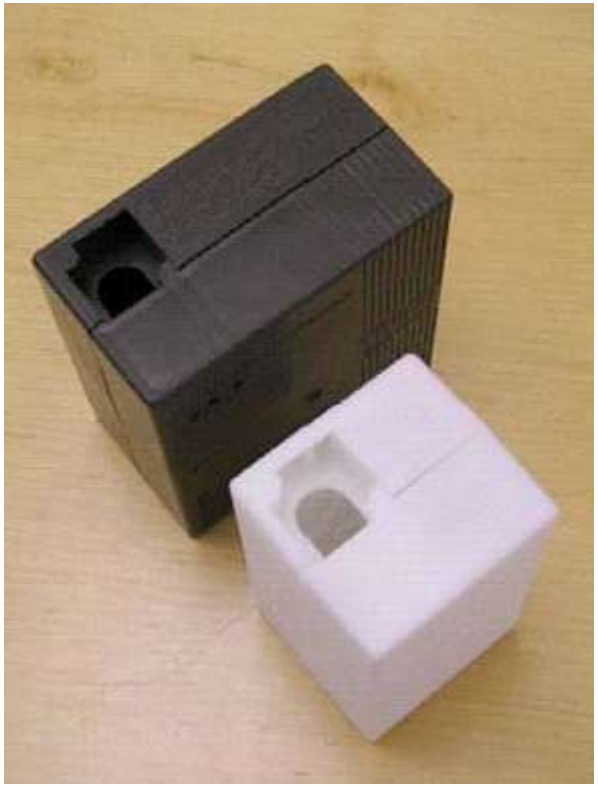
BA5590: 200 Wh, 2.2 lbs, Li-SO_2

BA5390: 300 Wh, 2.9 lbs, Li-MnO_2

Target:

1) 400 Wh, 2.2 lbs in same footprint
2) 200 Wh, 1.1 lbs in half size

<u>400 Wh/kg</u>



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2011 Joint Service Power Expo
Myrtle Beach, SC, May 2-5, 2011

Chemistry Comparison

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Comparison of D-cells with Different Chemistries

Lithium – Cathode Chemistry System	Theoretical specific capacity (mAh/g)	*Safety Concern*	*Specific power (W/kg)*	2A Discharge Capacity (Ah)	*Voltage Delay*	*Cost*
CF_x	864	**Safe**	~15	**15.5; 16.8**	Yes	**Very High**
$SOCl_2$	480	**Yes**	140	**7.0**	Yes	**Medium**
SO_2	418	**Yes**	680	**7.5**	Yes	**Low**
MnO_2	308	**Safe**	300	**10.5, 13**	No	**Low**
CF_x/MnO_2	308~864	**Safe**	15~300	**≥ 15**	No	**Medium**

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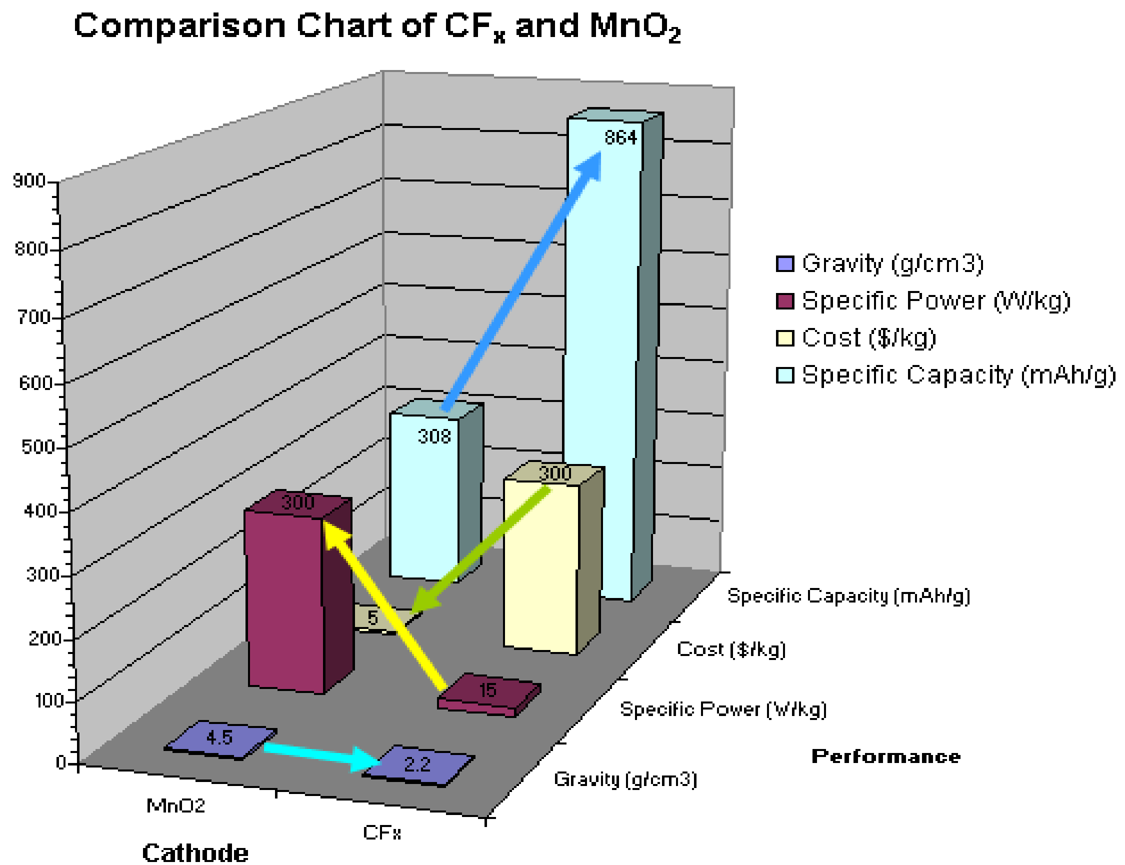
Design of Li-CF_x / MnO_2 Hybrid Chemistry



Hybrid Advantages

Flexibility of cell design
Lower self-discharge rate
Higher energy density

Lower overall thermal signature
Without voltage delay at LT
Relatively low cost

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Design Considerations

1) D-cell (34605)

2) Anode limited design

3) Cathode hybrid structure of CF_x and MnO_2

4) Thermal shutdown separator

5) Common components of UBI existing Li-MnO_2 production D-cell

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Phase I Li-CF_x/MnO_2 Hybrid D-cell

Goal was: Operating T range: -30ºC to +55ºC

1) Different anode

2) Different cathode with hybrid mixture of CF_x and MnO_2

3) All other parts as same as existing Ultralife Li-MnO_2 D-cell
   - Shutdown separator
   - Electrolyte
   - Cell enclosure

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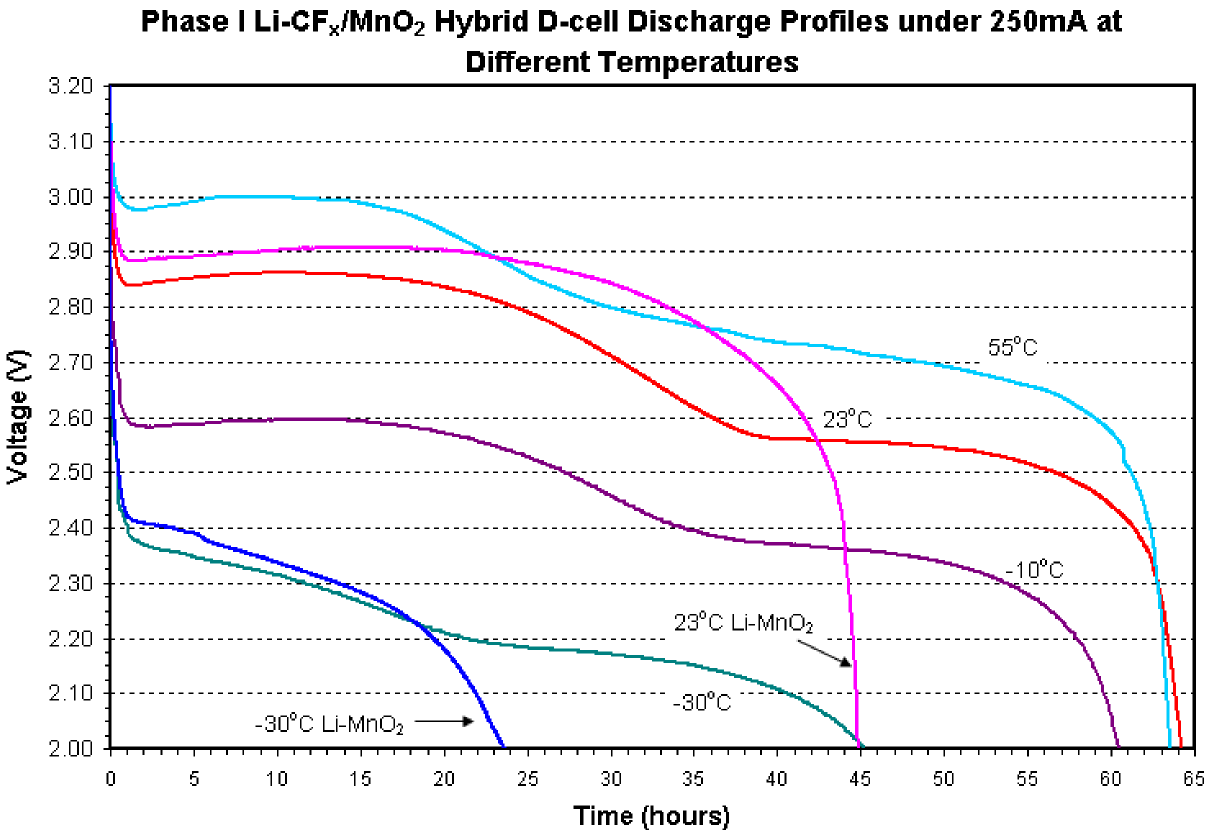
Phase I D-Cell Performance

Phase I Li-CF_x/MnO_2 hybrid D-cell discharge under 250mA constant current at 23°C, 55°C, -10°C and -30°C



Capacity to 2V cutoff

23°C: 16.06 Ah
55°C: 15.89 Ah
-10°C: 15.11 Ah
-30°C: 11.30 Ah

Li-MnO_2:
23°C: 11.20 Ah
-30°C: 5.90 Ah

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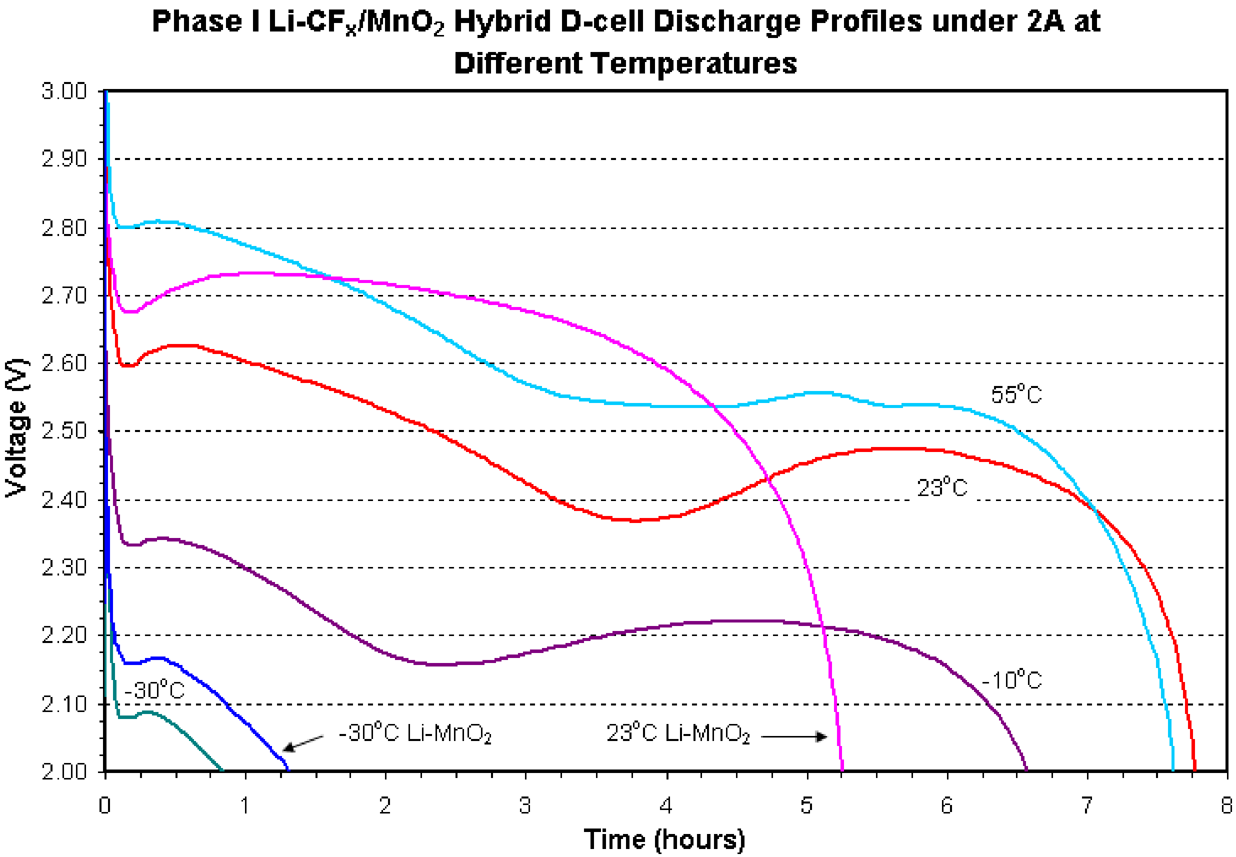
Phase I D-Cell Performance

Phase I Li-CF_x/MnO_2 hybrid D-cell discharge under 2 A constant current at 23ºC, 55ºC, -10ºC and -30ºC



Capacity to 2V cutoff

23ºC: 15.50 Ah
55ºC: 15.20 Ah
-10ºC: 13.23 Ah
-30ºC: 1.85 Ah

Li-MnO_2:
23ºC: 10.51 Ah
-30ºC: 2.63 Ah

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Phase I D-Cell Safety Performance

No	Name	Description	Result
1	UNTR-T1	Altitude	Pass
2	UNTR-T2	Thermal Test	Pass
3	UNTR-T3	Vibration	Pass
4	UNTR-T4	Shock	Pass
5	UNTR-T5	External Short Circuit	Pass
6	UNTR-T6	Impact	Pass
7	UNTR-T8	Forced Discharge	Pass
8	UL	Crush	Pass
9	SAR	Nail Penetration	Pass

Phase II Li-CF_x/MnO_2 Hybrid D-cell

Goal was: Operating T range: -40ºC to +100ºC

Worked on engineering for

1) Anode
2) Cathode using hybrid mixture of CF_x and MnO_2 with different particle size
3) Electrolyte
4) Separator

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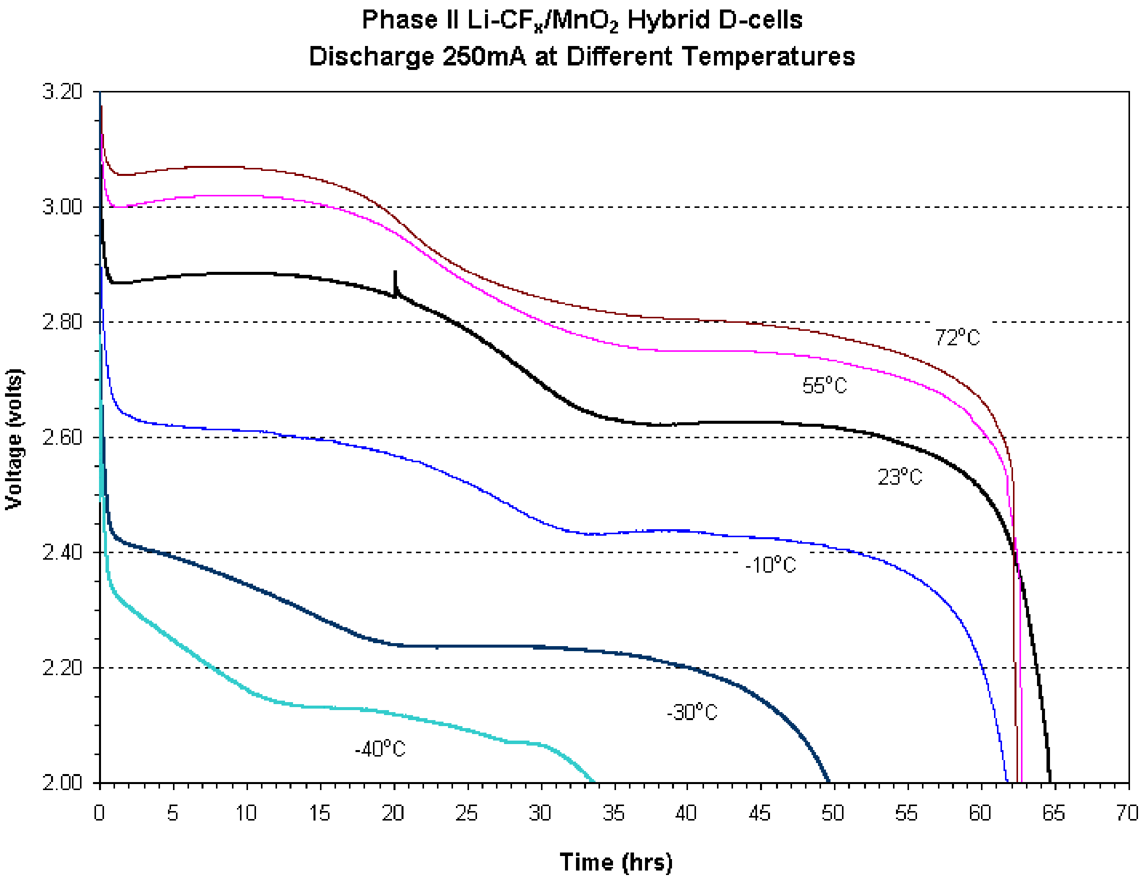
Phase II D-Cell Performance

Phase II Li-CF_x/MnO_2 hybrid D-cell discharge under 250mA constant current at 72°C, 55°C, 23°C, -10°C, -30°C and -40°C



Capacity to 2V cutoff

23°C: 16.05 Ah
55°C: 15.57 Ah
72°C: 15.67 Ah
-10°C: 15.13 Ah
-30°C: 12.16 Ah
-40°C: 8.15 Ah

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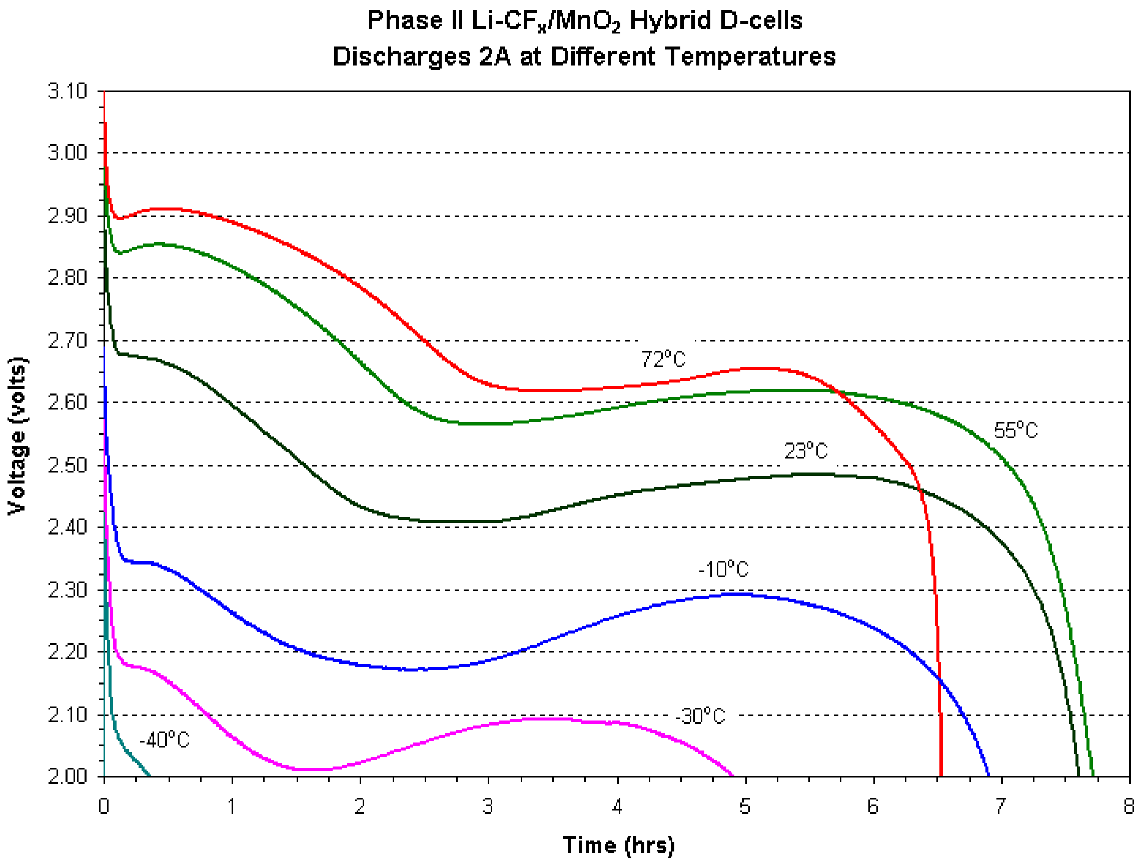
Phase II D-Cell Performance

Phase II Li-CF_x/MnO_2 hybrid D-cell discharge under 2 A constant current at 72^{o}C, 55^{o}C, 23^{o}C, -10^{o}C, -30^{o}C and -40^{o}C



Capacity to 2V cutoff

23^{o}C: 15.13 Ah
55^{o}C: 15.36 Ah
72^{o}C: 12.66 Ah
-10^{o}C: 13.66 Ah
-30^{o}C: 9.80 Ah
-40^{o}C: 0.59 Ah

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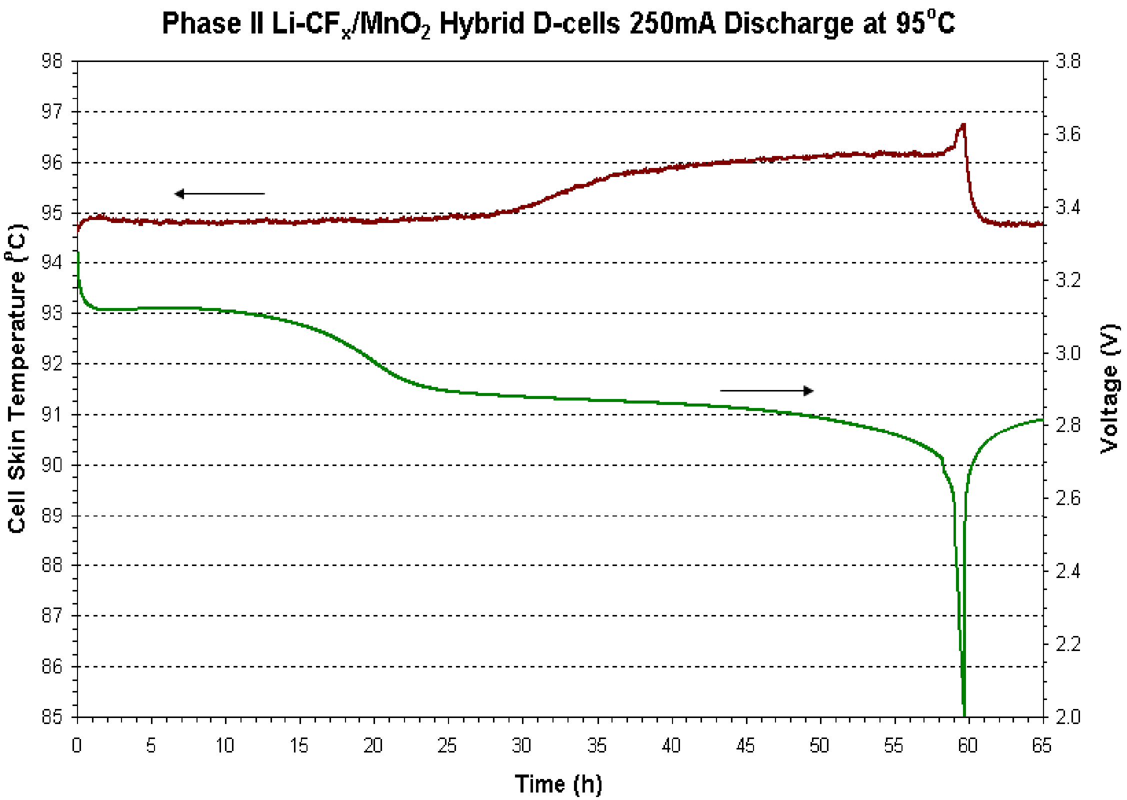
Phase II D-Cell Performance

Phase II Li-CF_x/MnO_2 hybrid D-cell discharge under 250mA constant current at 95^{o}C



2V Cutoff

Capacity: 14.92 Ah
Energy: 43.59 Wh
Max. Skin T: 96.8^{o}C

Phase II D-Cell Safety Performance

No	Name	Description	Result
1	UNTR-T1	Altitude	Pass
2	UNTR-T2	Thermal Test	Pass
3	UNTR-T3	Vibration	Pass
4	UNTR-T4	Shock	Pass
5	UNTR-T5	External Short Circuit	Pass
6	UNTR-T6	Impact	Pass
7	UNTR-T8	Forced Discharge	Pass
8	UL	Crush	Pass
9	SAR	Nail Penetration	Pass

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Acceleration Testing for Shelf Life

Li-CF_x/MnO_2 hybrid D-cells (Phase I) discharge 250 mA after storage 50 days or 100 days at different acceleration temperatures

Equivalent storage terms at 23°C by that at acceleration temperatures	Capacity to 2V cutoff (Ah)	Percentage of capacity remain	Self-discharge rate
100 days at 23°C	15.44	100%	0
5 years at 23°C	15.32	99%	0.4%/year
10 years at 23°C	14.45	94%	0.6%/year
20 years at 23°C	14.15	92%	0.4%/year

Initial Shelf Life Testing

92% of capacity remains

for 20 years by acceleration testing

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Summary

Li-CF_x/MnO_2 Hybrid D-cell

- 15 Ah under 2A constant discharge for both Phase I & Phase II
- Specific energy density increases 47% more than Li-MnO_2 D-cell
- Pass UNTR and other SAR tests for both Phase I & Phase II
- Phase I has operating temperature range from -30^{o}C to 55^{o}C
- Phase II has operating temperature range from -40^{o}C to 72^{o}C
- Initial shelf life tests indicate up to 20 years with 92% capacity remain
- Ready to be used for different formats of military batteries, such as xx47, half size xx90, full size xx90 and large size xx90, some in progress

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Acknowledgement

Li-CF_x/MnO_2 Hybrid D-cell Development Is Also Under
Support of Contract W15P7T-05-D-C002/002
With US Army CERDEC

- Special Thanks to

Mr. Michael Brundage & Mr. Chris Hurley
of US Army RDECOM

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Thank You for Your Attention