Li/CFx Batteries
The Renaissance

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Li-CFx – The First Commercial Lithium Cells in the Market

Main application:
Lures for large fishing fleets

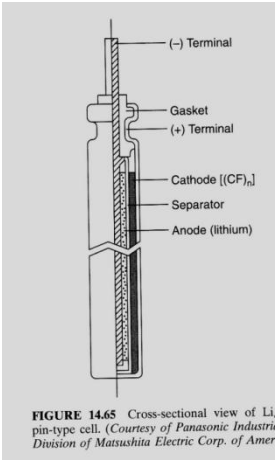


FIGURE 14.65 Cross-sectional view of Li pin-type cell. (*Courtesy of Panasonic Industri Division of Matsushita Electric Corp. of Amer*

The first Lithium Cell commercially developed in the 1970's by National (Panasonic)

Why Li-CFx

Cathode Material	Theoretical Capacity (Ah/Kg)	(Ah/L)	Operating Voltage (V)	Energy Density (Wh/Kg)	(Wh/L)
CF_x	864	2330	2.6	2203	5942
SO_2	418	600	2.8	1150	1650
MnO_2	308	1540	2.8	847	4235

Highest theoretical energy density -
(current cells in the market practically use only ~30% of the theoretical values in comparison to ~47.8% in MnO2)

Manu.	Chemistry	P.N	Wh/Kg	% from Theoretical
EP	CFx	LC3355 (AL)	660	29.9%
Saft	SO2	G62/1	317	27.5%
FDK	MnO2	CR6/L	405	47.8%

Lithium Carbon Monoflouoride (Li/CFx)

1. 3.7 - 3.2V Open circuit voltage.
2. High energy density especially per weight (max 1063 Wh/Kg).
3. Low to medium discharge rates.
4. Good flatness of discharge voltage.
5. -40/+130°C operating temperature range.
6. Low self discharge (<2% per year).
7. Good safety and reliability.
8. - Cylindrical, prismatic and coin shapes
   - Bobbin and spiral internal construction
   - Commercial, Industrial, Military and Medical markets.

Li-CFx Limitations

- High Heat during High Current discharge.
- Lower nominal voltage in compare to Li-Mno2.
- Low to medium power capabilities.
- Severe voltage delays at low temperatures.
- High material cost – only 5 makers world wide.

2009 Li-CFx World Market Share

- Li-CFx is considered to be ~9% of the world's primary battery market (revenue breakdown by chemistry).

- Market share by revenue:
  - Panasonic ~ 57%
  - Spectrum Brands ~ 26%
  - Greatbatch Medical ~ 3%
  - Eagle-Picher ~ 3%
  - QinetiQ ~ 3%
  - Quallion ~ 2.5%
  - All others ~ 1.5%

* Based on market research.

Panasonic
ideas for life

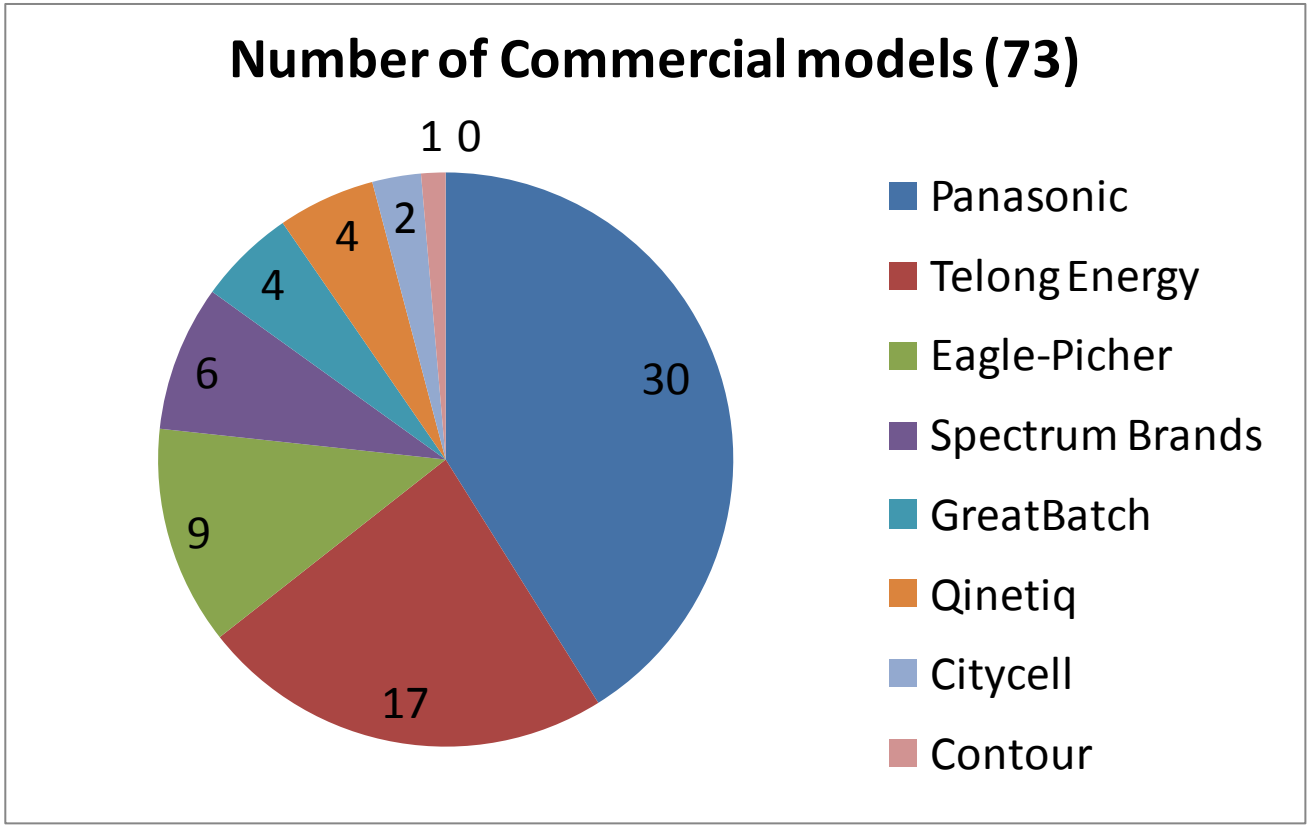
Spectrum BRANDS

Greatbatch Medical

EaglePicher

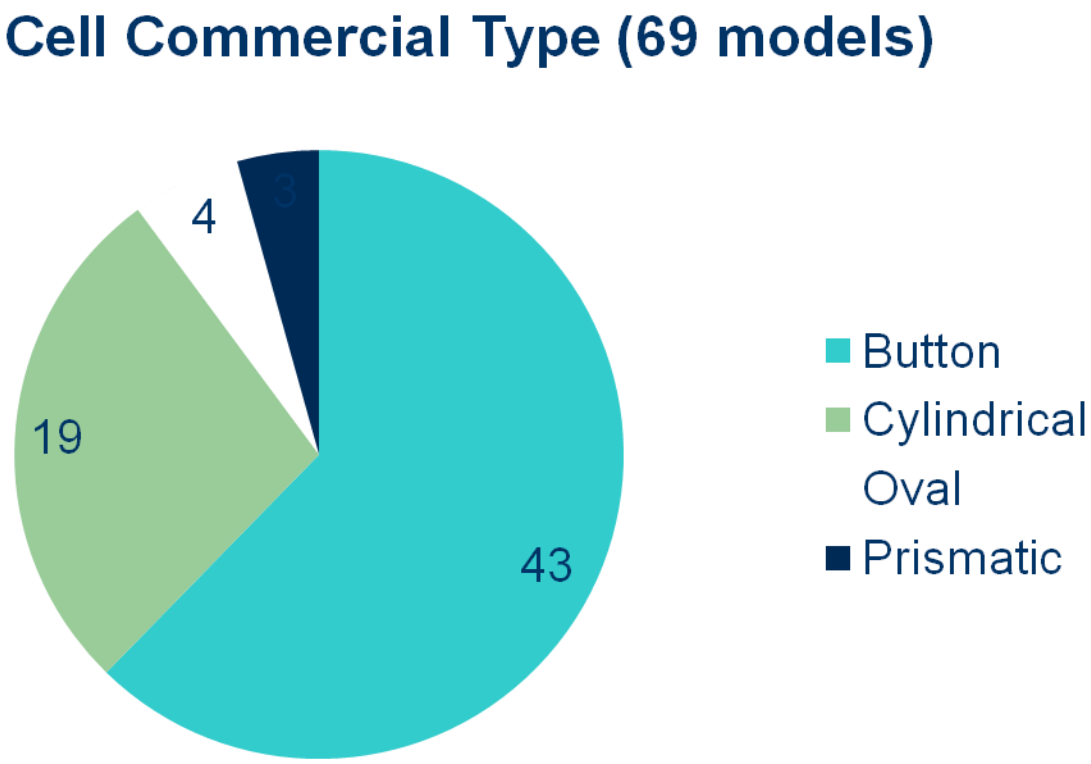
QUALLION
Powering Life.

Market by Number of Commercial Models (2010)



Panasonic is leading the market.

Market by Cell Commercial Type



The market is dominated by Button cells.

Primary Lithium Spiral Cells Comparison

	Li/MnO_2	Li/SO_2	$Li/SOCl_2$	Li/CFx (F1) *	Li/CFx-MnO2 hybrid **
(Wh/kg)	150-330	150-315	220-560	260- 780	784
(Wh/l)	300-710	230 - 530	700 - 1041	440- 1478	1039
Power Capability (W/kg)	250-400	100-230	100-210	50-80 (Only one EP model with 233)	165
Temperature Range (°C)	-20 to 60	-55 to 70	-55 to 150	-20 to 130	-40 to 90
Typical Shelf Life (Years)	5-10	10	15-20	15	10
Cost/Delivered Energy	Moderate	Low	Moderate	High	Moderate - High

** Saft, Ultralife, EP, Contour

* Lithium Carbon Monofluoride, Eagle-Picher, Quallion, Spectrum Brands, Contour

BR –vs- CR Comparison Table

Item		BR	CR
Negative Material		Lithium (Li)	Lithium (Li)
Positive Material		Poly-Carbonmonofluoride (CF)n	Manganese Dioxide (MnO_2)
Storage Temperature over 60°C		Good (up to +85°C)	Not recommended
Operating Temperature:	Cylindrical Type	-40°C~+85°C	-40°C~+70°C
	Coin Type	-30°C~+80°C	-30°C~+60°C
	High Temperature Coin Type	-40°C~+125°C	-
	Pin Type	-30°C~+80°C	-
Current Handling Capability		Good	Excellent
Discharge Voltage Characteristics		Stable to end of battery life	Gradually decreases
Discharge Current Characteristics		Better for Low Drain	Better for High Drain
Typical applications		Real Time Clock, Memory B/U	Pulse Discharge, RFID, Keyless Entry, Flashes

BR is better for high temperatures

Li-CFx Next Generation Military Batteries

- U.S. Army is pushing to increase Primary D-Size cells energy density for extended missions.

- New programs established for primary cells/batteries development: Li-CFx, Li-CFx-Mno2. Saft, Ultralife, Eagle-Picher, Spectrum Brands, Quallion and Contour)

- Li-CFx military batteries are expected to be the leading battery technology for the military market within 3-10 years.

Model	Chemistry	D-Size Cell Capacity
BA5590	Li-So2	Max 9.2Ah
BA5390	Li- Mno2	Max 13Ah
No Number	Li-Cfx	Max 17Ah

BA-5590 and 1/2BA-5590

Li-CFx/Mno2 Mix Blend Cells

- Li-CFx provides higher capacity than LiMnO2 or $LiSO_2$ but the raw materials are expensive and considered a low/moderate power system.

- A blend of CFx and MnO2 cathodes provides slightly less capacity but:
  - Less expensive material cost.
  - Higher operating voltage.
  - Improved rate capabilities.
  - Improved heat management.
  - Improved voltage delay.
  - Improved cold temp. performance.

Primary Lithium D-Size Spiral Cells For Military Applications

	Li/SO_2 Saft LO26SXC	Li/MnO_2 Ultralife U10026	$Li/SOCl_2$ Saft LSH20	Li/SO_2Cl_2 Greatbatch 3B0035	L i/CFx (F1) ** Eagle-Picher LC3355	Li/CFx-MnO2 * Saft LH-33550
Capacity (AH)	9.2	13	15	15	16	15.1
Capacity on 2A discharge	7.5	10.5	7	10	15.5	15
Nominal Voltage (V)	2.8 (0.5A)	3 (0.25A)	3.3 (0.015A)	3.4 (0.5A)	2.6 (2A)	2.5 (2A)
Weight Energy Density 2A (Wh/kg)	253	250	210	280	639	355
Volume Energy Density 2A (Wh/l)	389	545	403	538	1000	961
Power Capability 2A (W/kg)	67.5	47	56	56	82.5	47.6
Weight (Grams)	80	113	100	100	80 (63 for Al)	~105
Temperature Range (°C)	-60 to 71	-40 to 72	-60 to 85	-20 to 93	-40 to 90	-30 to 90

* Also developed by Ultralife, EP, Contour, ** Eagle Picher Presentation / Lithium Mobile 2010

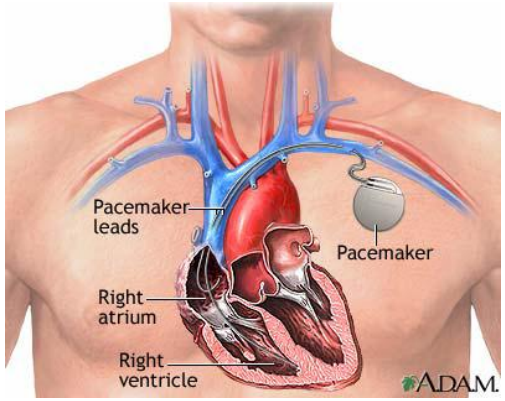
Li-CFx Cells for Medical Applications

- Mainly manufactured by Greatbatch, Eagle Picher and Quallion.
- Characterized by a relatively flat voltage discharge profile, low internal resistance and low weight making them useful in drug-infusion pumps, neurostimulators and some pacemakers.

Greatbatch Medical Li-CFx 2570 Cell

EP 2.3ah Medical Li-CFx Cell

Prototype ICD cell

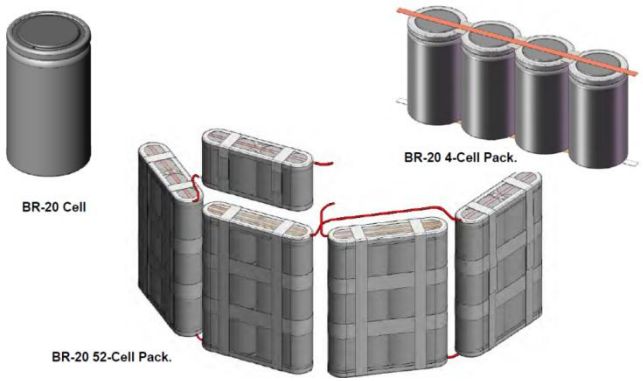


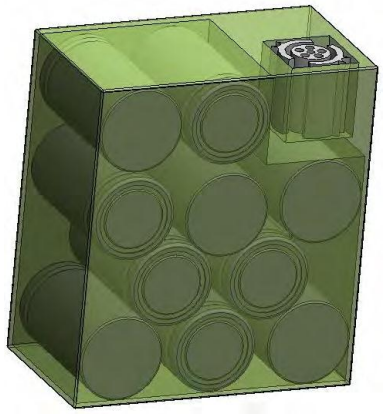
Panasonic

- The biggest player on the Li-CFx cells market.
- Manufactures Pin, Button and Cylindrical cells mainly for the commercial markets.
- Applications like: Calculators, Cameras, Cordless, Translators, Watches and Memory Backup.

Spectrum Brands

- The second player on the commercial Button market.
- 28-year producer of Li-CFx coin cells.
- Developing high rate AA, 5/4D, Tall D, Pouch and D-Size Li-CFx cells.
- Reduced material weight by replacing all heavy components (end cup, PTC, washer/vent, grommet).
- Built BA-5590 lighter and with a higher capacity battery than the standard batteries in use.





Telong Energy Technology

- Li-CFx cell maker from China.
- Full line of Button cells for the commercial market.

Chengdu Jianzhong Lithium Battery

- The only cylindrical Li-CFx cell maker from China.
- 2 products 2/3A and D Size.
- Lower capacities than compatible American made cells.

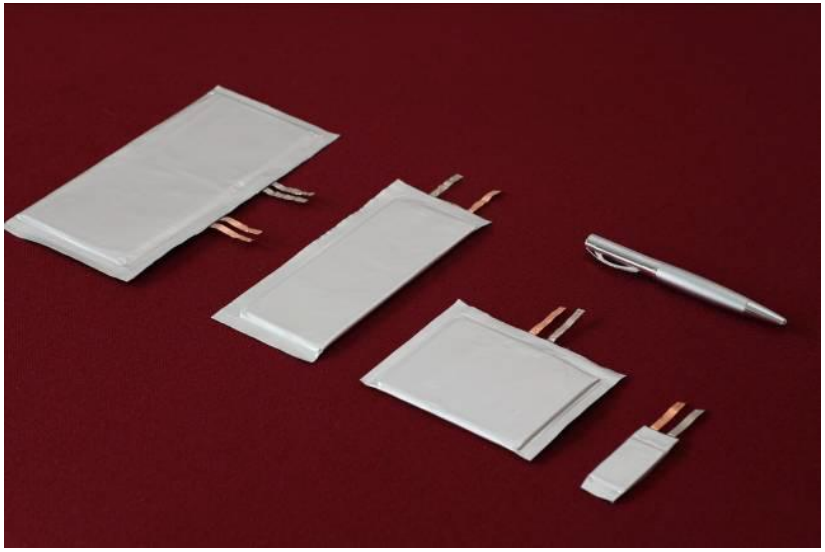
Li/CFx

GB	IEC	Max.dimension(mm)	Weight (g)	Nominal voltage (V)	Cut off voltage (V)	Capacity (Ah)	Max.operating current (mA)	Pulse current (mA)	Operating temperature(℃)
BR17335	2/3A	17.0×33.5	14	3.0	2.5	1.9	200	500	-30~+75
BR34615	D	34.0×61.5	95	3.0	2.0	14.0	500	2000	-30~+75

http://www.china-li-battery.com/producta_5/

QinetiQ Li-CFx Pouch Cells

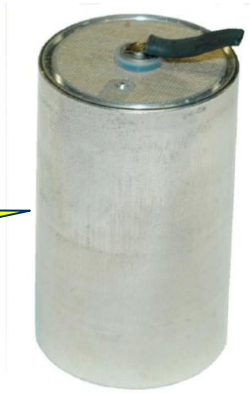
- The only manufacturer to make Pouch cells (4 sizes).
- The prismatic geometry allows for more efficient packing into rectangular battery packs and thermal cooling compared with cylindrical cells.
- Different cell sizes with capacities between 1Ah to 45Ah and energy density of up to 650 Wh/Kg.
- 17Ah cells used for the UK Army BA5590 military battery.



Eagle-Picher Li-CFx D-Size Aluminum Can Cells

- 17 Ah D-Size cell developed.
- First to employ an aluminum can.
- 17 grams less than stainless steel can (63 instead of 80 grams).
- Aluminum case increases energy density by 100 Wh/kg on cell level.
- Rivet seal replaces a more conventional Glass to Metal seal.

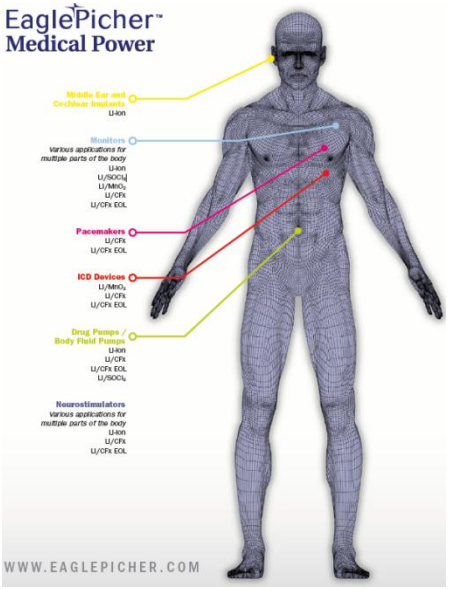
Aluminum can is an important development



D cell with Al Hardware
(63 grams)

Eagle-Picher Li-CFx for Medical Applications

- Capacities up to 10Ah.
- Cylindrical, Prismatic or D-Shaped.
- Bobbin, Elliptical Wound or Stacked Plate.
- New cells with End-of-Life Indicator.



Contour Energy Systems

- **Li-CFx developer with proprietary Fluorinetic™ technology which improves performance versus traditional Li-CFx.**

- **Main advantages are up to 20-30% more capacity, up to 2x discharge power capabilities, wider operating temperature ranges (up to 220 °C) and low to moderate cost.**

- **Coin, Pouch and Cylindrical cells are under development for the commercial, medical, industrial, automotive and military markets.**

New commercial cells (10/2010)

Contour ENERGY SYSTEMS

Contour Energy BR2032

Contour BR2032 Cells

	Capacity mAh	Max constant discharge current (Ma)	Discharge operating temperatures (°C)
Contour	265	10	-30 to 80
Spectrum Brands	195	5	-40 to 85
Panasonic	190	5	-30 to 80
Telong	180	3	0 to 130
Panasonic CR2032	240	5	-30 to 80

Contour BR2032 are the best coin cells in the market

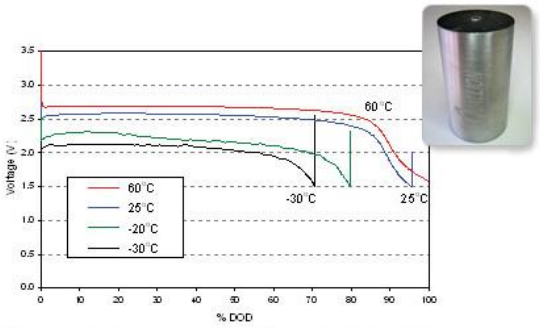
Contour™ ENERGY SYSTEMS

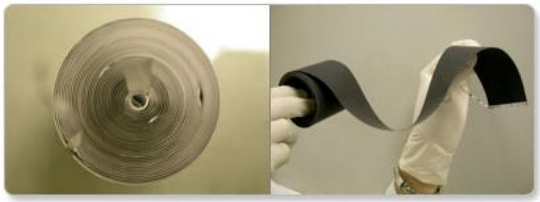
Contour Energy BR2032

Quallion

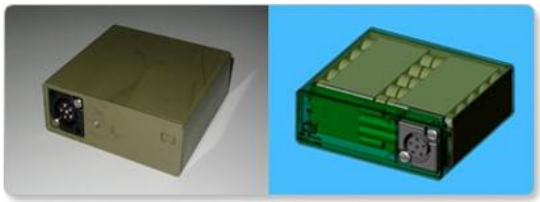
- Developing Li-CFx cells for the medical, aerospace and military markets.
- 15Ah D-Size cells with maximum current discharge up to 3A.
- Further development needed.

Second generation half-BA-5590 pack using Li/CFx chemistry





The jellyroll inside of a D-cell case. There are more than 30 winds present inside the D-cell case.
13b. The flexible thin-film coated CFx electrode used inside the D-cell.



Tracer Technologies

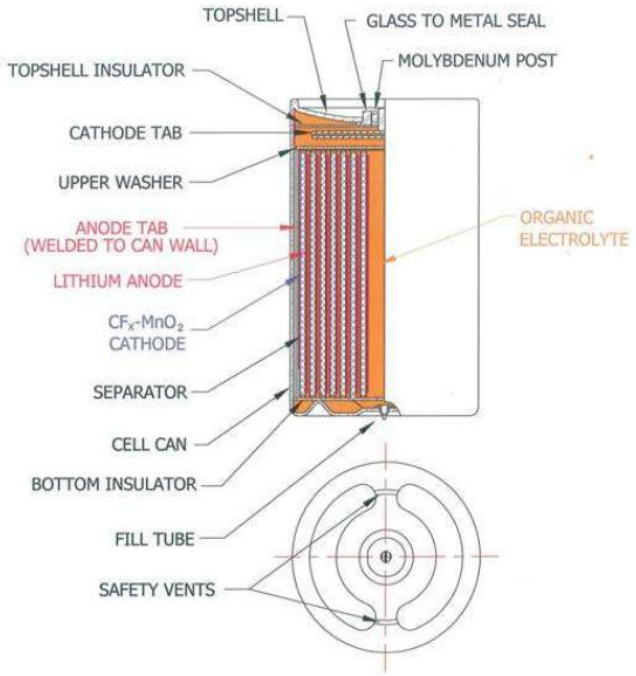
- **Lithium battery maker, Boston, U.S.**
- **Manufactures Li-CFx cells for the oil exploration market (High Operating Temperature Cells).**
- **No public information about the cells or the manufacturing capabilities.**

TRACER Technologies, Inc.

www.tracer-eco.com

Saft

- As a part of a program done with the U.S. army, Saft developed a hybrid cathode Li-MnO2:CFx D- size cell (LH-33550).
- 14.5 Ah capacity in 2A rate.
- -30 to 90 °C operating temperature range.
- Further development is needed.

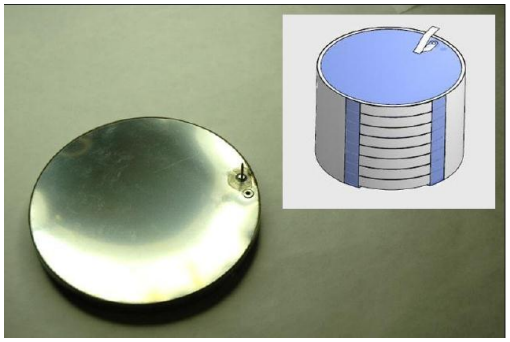


Ultralife

- As part of a program completed with the U.S. Army Li/MnO2– CFx hybrid chemistry has been developed.
- Higher energy density than Li-MnO2 > 47%.
- Higher power density than Li-CFx.
- No voltage delay on LT.
- Relative low cost compared to Li-CFx.
- D-size cell capacity of ~ 15Ah under 2A achieved.

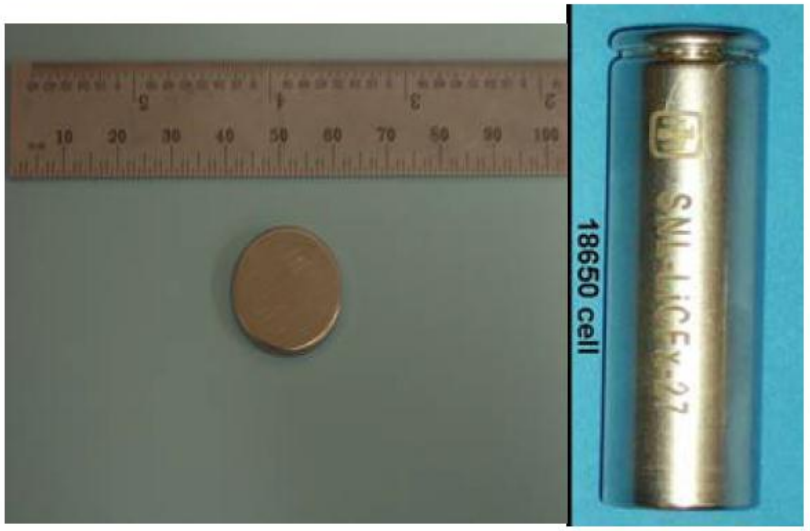
MaxPower, Inc.

- As part of NAVAIR programs design and build Li/CFx batteries that improve the performance of current batteries in use.
- 14.4Ah cell with 94mm diameter & 64.5 mm highest.
- Battery with 485 Wh/l & 270 Wh/Kg.
- Longer work time.
- -40 to 70 °C temperature operation range.



Li-CFx Development at Sandia

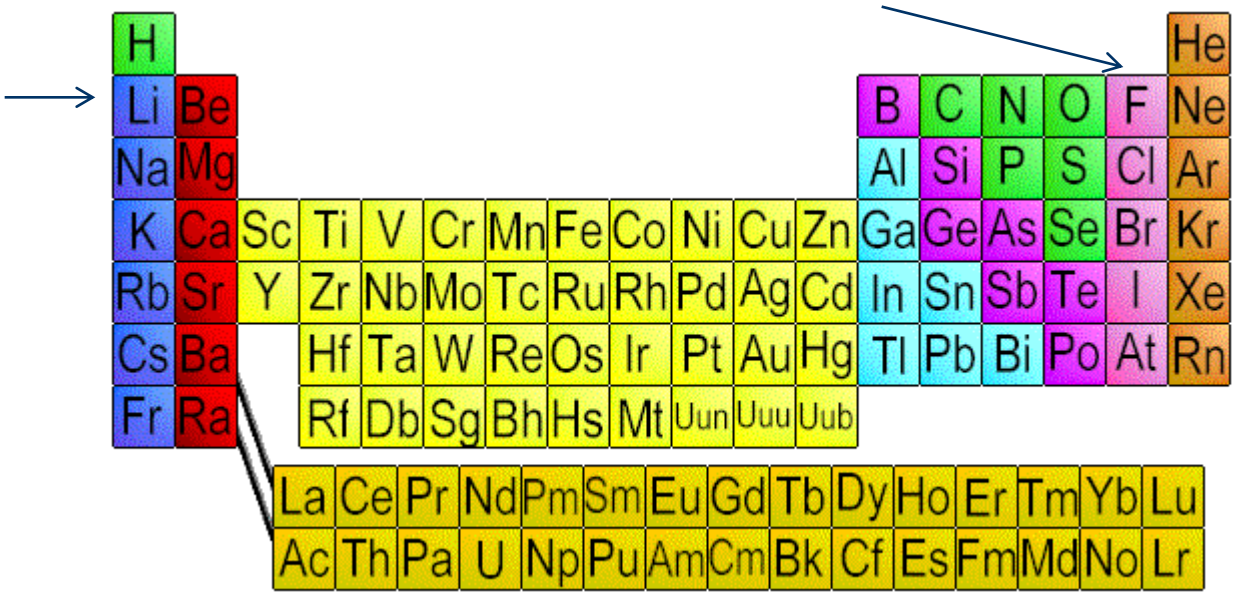
Development of
Li-CFx 2016 coin and
18650 primary cells at
Sandia National Lab



Type	Capacity (Ah)	Weight (gr)	Energy Density (wh/kg)
18650	3.6	28	347

Fluoride Based Rechargeable Batteries

The highest energy density theoretically possible



$\frac{1}{2} F_2 + Li = LiF$

$E_0 = 5.915$ V

6112 Wh/Kg Theoretical reaction

Divided by 2 for packaging and divided by 2 for rechargeable to get ~ 1500 Wh/Kg versus best rechargeable battery today 250-300Wh/Kg

Fluoride Based Rechargeable Batteries

Researchers at Karlsruhe Institute of Technology (KIT) believe they have developed a new rechargeable concept.

- **Fluoride shuttle – transfer of fluoride anions between electrodes.**
- **Enhance the storage capacity (X10 than LI-Ion) and also improve safety.**
- **Can be done without lithium metal – lithium metal free batteries with a fluoride containing electrolyte, metal anode and metal fluoride cathode.**

Karlsruhe Institute of Technology

- **Low discharge voltage compare to Lithium Ion system.**

Summary

- The Li-CFx and Li-CFx/Mno2 batteries market is expected to grow due to technology advantages and manufacturing cost reduction.
- Its higher energy density and low self-discharge characteristics make Li-CFx important to the military and other markets.
- Aluminum can developed by EP is an important development for weight reduction.
- Contour Energy is developing promising advances in Li-CFx technology with superior performance.
- QinetiQ has succeeded in developing promising pouch cells for military applications.

Thank You for Your Attention

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1. **Public web sources.**
2. **Shmuel De-Leon Battery/Energy Sources DataBase ® (Includes 29000 cell PDF data sheets) http://www.sdle.co.il/Default.asp?sType=0&PageId=45580**