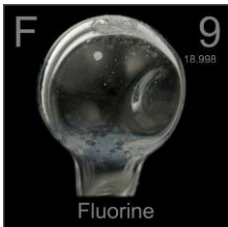


Shmuel De-Leon
Energy Ltd

Li/CFx Batteries The Renaissance

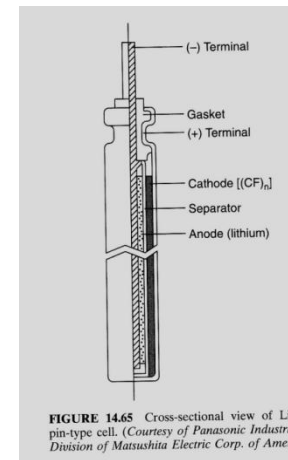
8/6/2011

Shmuel De-Leon
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Li-CFx - Historic Point

The first Lithium Cell
commercially
developed in 1970's



Lithium Carbon Monofluoride (Li/CF_x)

1. 3.7 - 3.2V Open circuit voltage.
2. High energy density especially per weight.
3. Bobbin, spiral, coin and cylindrical shapes.
4. Low to medium discharge rates.
5. -40/+130°C operating temperature range.
6. Low self discharge.
7. Commercial, Industrial, Military and Medical markets.



Li-CFx Limitations

- Severe voltage delays at low temperatures.
- High Heat during High Current discharge.
- Low to medium power capabilities.
- High cathode material cost.



Why Li-CFx

Cathode Material	Theoretical Capacity		Operating Voltage (V)	Energy Density	
	(Ah/Kg)	(Ah/L)		(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 practically use only 10% of the theoretical value and there is a wide place for development).
- Flat discharge curve.
- Extreme operating temperature range.
- Very low self discharge (<2% a year).
- Thermal stability.
- Reliability.
- Safety.



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 ~ 50%

Greatbatch Medical ~ 20%

Spectrum Brands ~ 20%

Eagle-Picher ~ 3%

QinetiQ ~ 3%

Quallion ~ 2.5%

All others ~ 1.5%

* Based on market research.

Panasonic
ideas for life

 Greatbatch
Medical

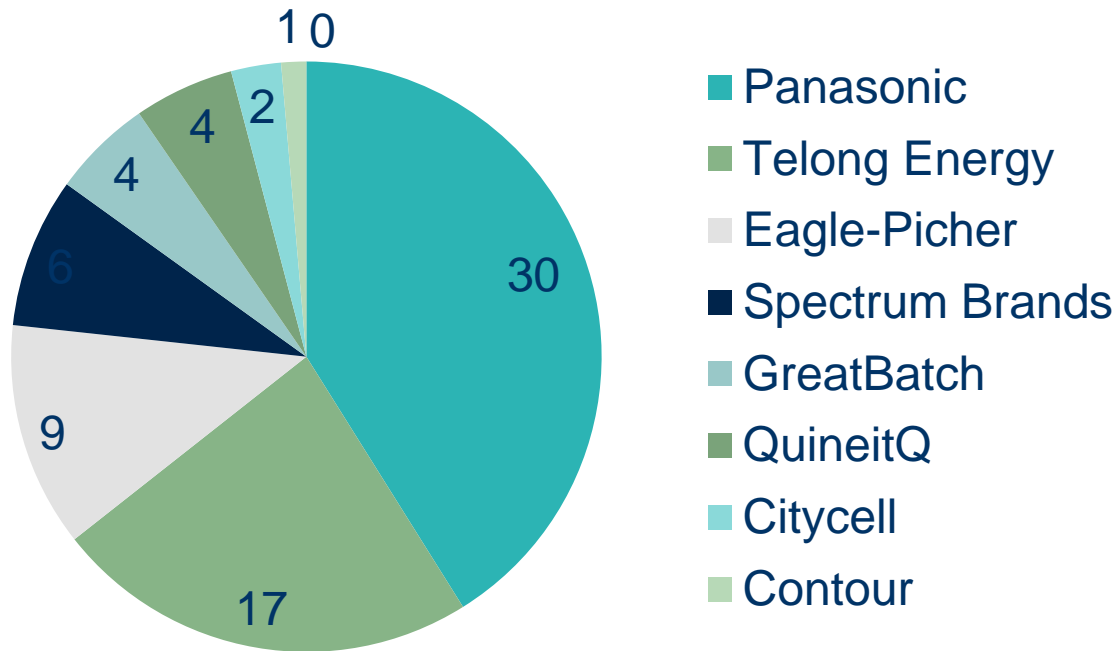
 **Spectrum**
BRANDS

 EaglePicher

 **QUALLION**
Powering Life.

Market by Number of Commercial Models

Number of Commercial models (73)



.Panasonic is leading the market

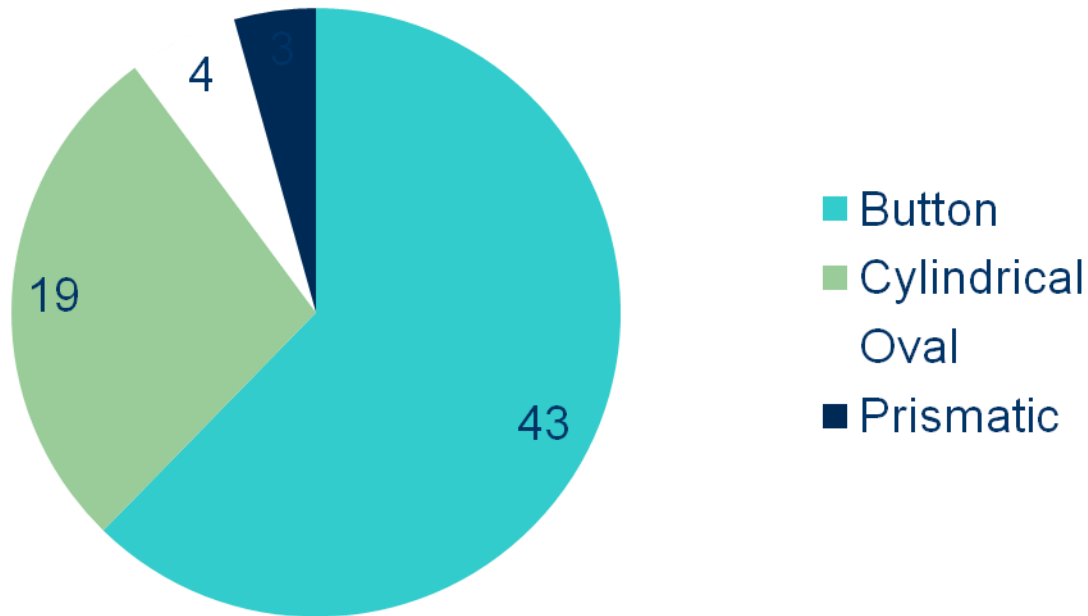
Panasonic
ideas for life

TELONG 天龙王能源科技有限公司
Telong Energy Technology (Shenzhen) Co., Ltd



Market by Cell Commercial Type

Cell Commercial Type (69 models)



.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-MnO ₂ hybrid **
Weight Energy Density (Wh/kg)	150-330	150-315	220-560	260- 780	784
Volume Energy Density (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

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

Li-CFx Next Generation Cells for Military Applications

- **U.S. Army is pushing to increase Primary D-Size cells energy density for extended missions.**
- **When Li-So₂ D size cell for BA5590 provides 9.2Ah and Li-Mno₂ for BA5390 provides 13Ah, Li-CFx can provide 18-16.5 Ah.**
- **New programs established for primary battery development:**
 - a. Li-CFx cells.**
 - b. Li-CFx-Mno₂ cells.**
-

Li-CFx Next Generation Cells for Military Applications

- **Li-CFx provides higher capacity than LiMnO_2 or LiSO_2 but the raw materials are expensive and considered a low/moderate power system.**
- **A blend of CFx and MnO_2 cathodes provides slightly less capacity but less expensive material cost and higher operating voltage.**

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 ₂ Cl ₂ Greatbatch 3B0035	Li/CFx (F1) ** Eagle-Picher LC3355	Li/CFx-MnO ₂ * 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, ** Eagle Picher Presentation / Lithium Mobile 2010

Li-CFx Military Battery Market Forecast

- **6 battery companies developing Li-CFx cells for the military market: Saft, Ultralife, Eagle-Picher, Spectrum Brands, Quallion and Contour.**
- **BA-5590 is the most popular military battery and is expected to be the first one to use Li-CFx D-Size cells.**
- **Li-CFx military batteries are expected to be the leading battery technology for the military market within 3-10 years.**

BA-5590



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



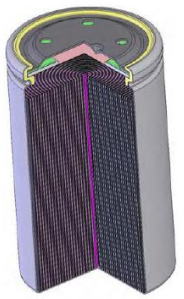
Prototype ICD cell

Panasonic

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



Spectrum Brands



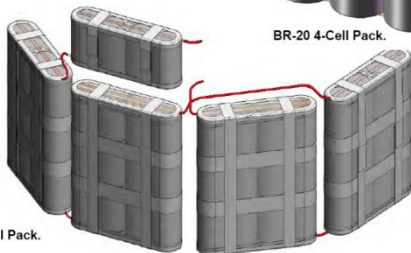
- The second player on the button commercial market.
- 28-year producer of Li-CFx coin cells.
- Developing high rate AA, 5/4D, Tall D, Pouch and D-Size Li-CFx cells.
- Reduce Material Weight by replacing all heavy components (end cup, PTC, washer/vent, grommet).
- Built BA-5590 Lighter and with higher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



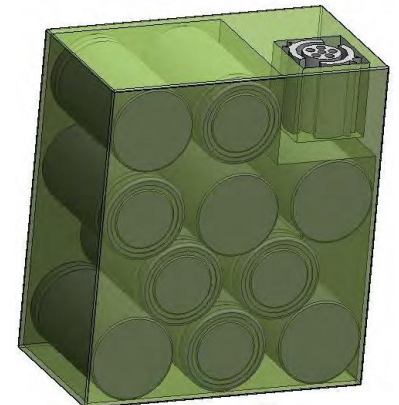
BR-20 Cell



BR-20 4-Cell Pack.



BR-20 52-Cell Pack.



Telong Energy Technology

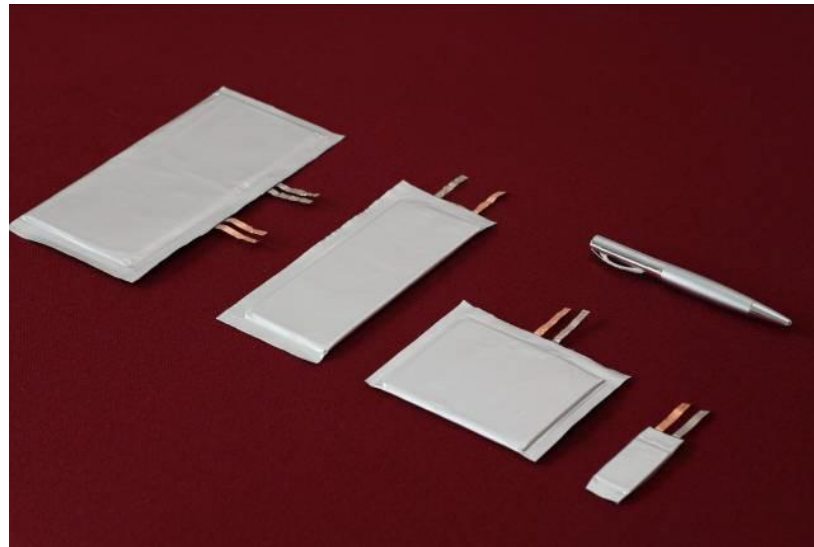
- Li-CFx cell maker from China.
- Full line of Button cells for the commercial market.



www.sztlg.com

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.

Aluminum can is an important development



D cell with Al Hardware
(63 grams)

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 cells in the market

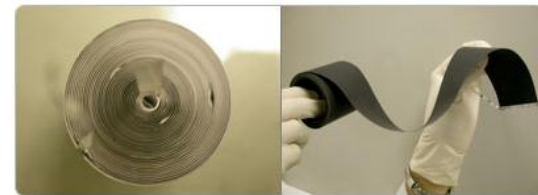
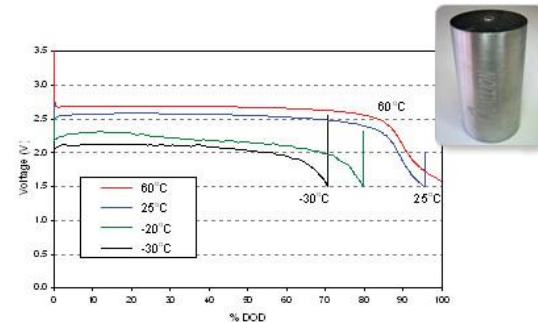


Contour Energy BR2032

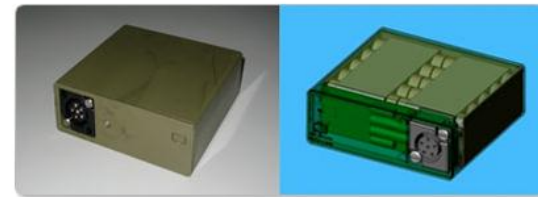


Quallion

- 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.



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 information about the cells or the manufacturing capabilities.



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).
- 15.1 Ah capacity.
- -30 to 90 operating temperature range.
- Further development is needed.



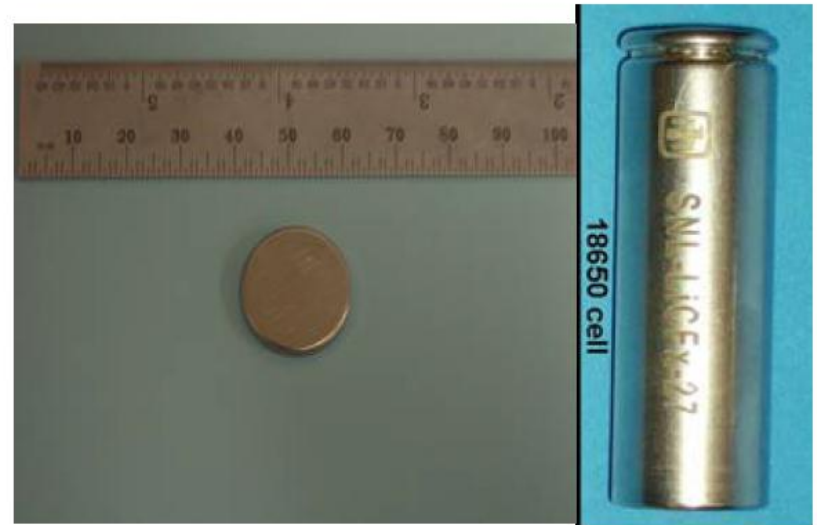
Ultralife

- 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.
- Higher power density than Li-CFx.
- No voltage delay on LT.
- Relative low cost compared to Li-CFx.
- D-size cell capacity of ~ 17Ah achieved on the Lab.



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

Summary

- **The Li-CFx 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.**
- **Most battery makers manufacture the traditional Poly-Mono carbonate technology.**
- **Contour Energy is developing promising advances in Li-CFx technology with superior performance.**
- **QinetiQ succeed to develop a promising pouch cells for military applications.**

Thank You for Your Attention

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Information for presentation obtained by:

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&PagelD=45580>

Market Commercial Cells

Company Name	Part #	Model #	Cell Shape	Common Size	Max Capacity (AH)
Eagle Picher Technologies	10AH		Prismatic	Non common	10.00
Electrochem	2282	2282	Oval	Non common	1.69
Electrochem	2570	2570	Oval	Non common	0.94
Eagle Picher Technologies	2AH		Prismatic	Non common	2.00
Eagle Picher Technologies	3.5AH		Prismatic	Non common	3.50
Electrochem	9086	9086	Oval	Non common	2.50
Electrochem	9424	9424	Oval	Non common	1.30
Panasonic	BR-1/2AA	BR	Cylindrical	1/2AA	1.00
Panasonic	BR-1/2AAH	BR	Cylindrical	1/2AA	1.00
Telong Energy Technology Co	BR1025	BR	Button	1025	0.02
Panasonic	BR1216	BR	Button	1216	0.03
Telong Energy Technology Co	BR1216	BR	Button	1216	0.02
Panasonic	BR1220	BR	Button	1220	0.04
Telong Energy Technology Co	BR1220	BR	Button	1220	0.04
Panasonic	BR1225	BR	Button	1225	0.05
Energizer	BR1225	BR	Button	1225	0.05
Spectrum brands Inc	BR1225	BR	Button	1225	0.04
Telong Energy Technology Co	BR1225	BR	Button	1225	0.04
Panasonic	BR1225A	BR	Button	1225	0.05
Telong Energy Technology Co	BR1616	BR	Button	1616	0.04
Panasonic	BR1616	BR	Button	1616	0.05
Telong Energy Technology Co	BR1620	BR	Button	1620	0.06
Telong Energy Technology Co	BR1632	BR	Button	1632	0.10
Spectrum brands Inc	BR1632	BR	Button	1632	0.13
Panasonic	BR1632	BR	Button	1632	0.12
Panasonic	BR1632A	BR	Button	1632	0.12
Panasonic	BR-2/3A	BR	Cylindrical	2/3A	1.20
Panasonic	BR-2/3AG	BR	Cylindrical	2/3A	1.45
Panasonic	BR-2/3AH	BR	Cylindrical	2/3A	1.35
Spectrum brands Inc	BR2016	BR	Button	2016	0.07
Panasonic	BR2016	BR	Button	2016	0.08
Telong Energy Technology Co	BR2016	BR	Button	2016	0.06
Panasonic	BR2020	BR	Button	2020	0.10
Telong Energy Technology Co	BR2025	BR	Button	2025	0.13
Spectrum brands Inc	BR2032	BR	Button	2032	0.20

Market Commercial Cells

Company Name	Part #	Model #	Cell Shape	Common Size	Max Capacity (AH)
Panasonic	BR2032	BR	Button	2032	0.19
Contour energy systems	BR2032	BR	Button	2032	0.27
Telong Energy Technology Co	BR2032	BR	Button	2032	0.18
Telong Energy Technology Co	BR2050	BR	Button	2050	0.25
Panasonic	BR2320	BR	Button	2320	0.11
Spectrum brands Inc	BR2325	BR	Button	2325	0.18
Panasonic	BR2325	BR	Button	2325	0.17
Telong Energy Technology Co	BR2330	BR	Button	2330	0.22
Panasonic	BR2330	BR	Button	2330	0.26
Panasonic	BR2330A	BR	Button	2330	0.26
Spectrum brands Inc	BR2335	BR	Button	2335	0.30
Telong Energy Technology Co	BR2354	BR	Button	2354	0.42
Telong Energy Technology Co	BR2430	BR	Button	2430	0.23
Telong Energy Technology Co	BR2450	BR	Button	2450	0.45
Panasonic	BR2450A	BR	Button	2450	0.60
Panasonic	BR2477A	BR	Button	2477	1.00
Panasonic	BR2477A	BR	Button	2477	1.00
Telong Energy Technology Co	BR2477H	BR	Button	2477	0.80
Panasonic	BR3032	BR	Button	3032	0.50
Panasonic	BR425	BR	Cylindrical	425	0.03
Citycell Battery Company Limited	BR425	BR	Cylindrical	425	0.03
Panasonic	BR435	BR	Cylindrical	435	0.05
Citycell Battery Company Limited	BR435	BR	Cylindrical	435	0.05
Telong Energy Technology Co	BR621	BR	Button	621	0.01
Panasonic	BR-A	BR	Cylindrical	A	1.80
Panasonic	BR-AG	BR	Cylindrical	A	2.20
Panasonic	BR-AH	BR	Cylindrical	A	2.00
Panasonic	BR-C	BR	Cylindrical	C	5.00
Eagle Picher Technologies	LC-3155 (SS)	LC	Cylindrical	Non common	13.50
Eagle Picher Technologies	LC-3355 (AL) - bare cell	LC	Cylindrical	D	16.50
Eagle Picher Technologies	LC-3355 (SS)	LC	Cylindrical	D	16.00
Eagle Picher Technologies	LC-3355 (SS) - bare cell	LC	Cylindrical	D	16.50
Eagle Picher Technologies	LC-34118 (SS)	LC	Cylindrical	DD	33.50

Market Commercial Cells

Company Name	Part #	Model #	Cell Shape	Common Size	Max Capacity (AH)
Eagle Picher Technologies	LCF112	LCF	Cylindrical	Non common	39.40

<http://www.sdle.co.il/Default.asp?sType=0&PageId=45580>

Shmuel De-Leon Battery DataBase