

„Lead is Dead“

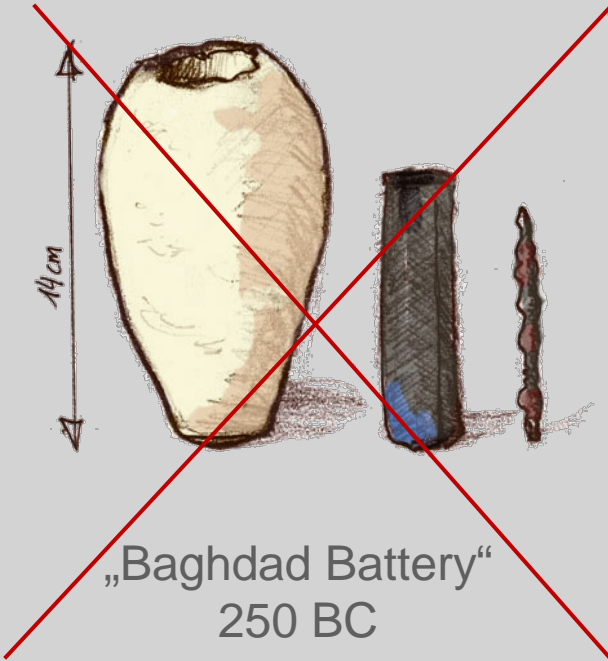


58<sup>th</sup> Annual Fuze Conference  
July 9<sup>th</sup>, 2015  
Harald Wich  
Diehl & Eagle Picher GmbH

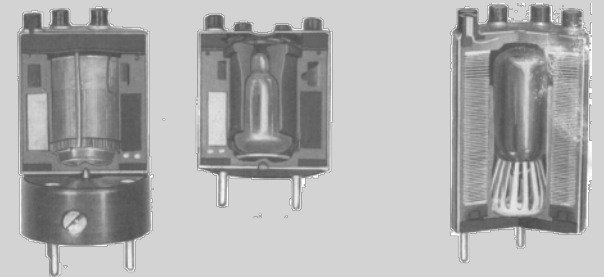
# Overview

- ◆ History
- ◆ From Lead to Lithium
- ◆ MK44
- ◆ PS115
- ◆ Others
- ◆ Opinions
- ◆ Conclusions

# History



„Voltaic Pile“  
1800 AD



SHORT ENERGIZER MK 4 MOD 2  
(LEFT HALF SECTION PLUGGED INTO  
SPIN BREAKER MK 1 MOD 0)

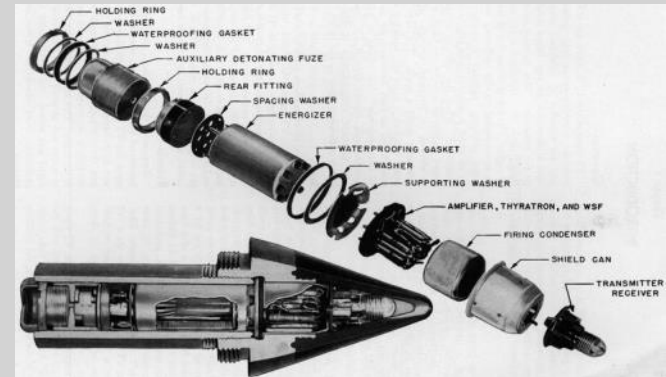
LONG ENERGIZER  
MK 5 MOD 2

Lead Reserve Battery

WW2 Prox Fuze (VT-Fuze)



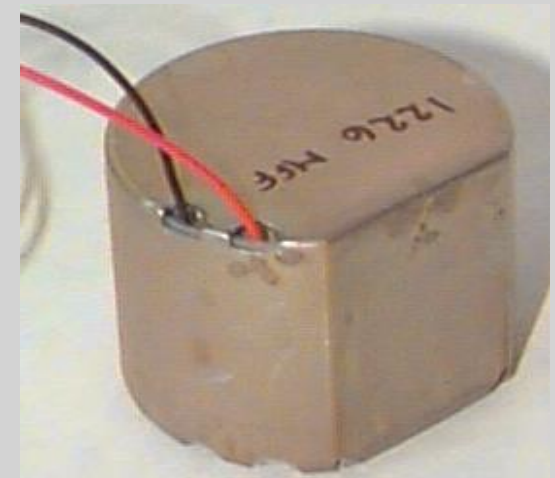
Mk53



# From Lead to Lithium

- ◆ Lead Batteries were good for about 50+ years (despite some weaknesses)
- ◆ invention/development of the Lithium Battery started ca 1912
  - first commercial lithium primaries sold in 1970s
- ◆ US started MK44 (lead) replacement programme (2004 NDIA Fuze Conference, Eugene Marquis)

1996



# Why Change from Lead to Lithium?

- ◆ poor low temperature performance
- ◆ growing environmental concern (not a big issue in 1996, but ...)  
(2004 NDIA Fuze Conference, Paul F. Schisselbauer)
- ◆ MK44 Lead-Chemistry Battery non-producible within the US  
(2001 NDIA Fuze Conference, Michael A. Till; 2004 NDIA Fuze Conference, Paul F. Schisselbauer)
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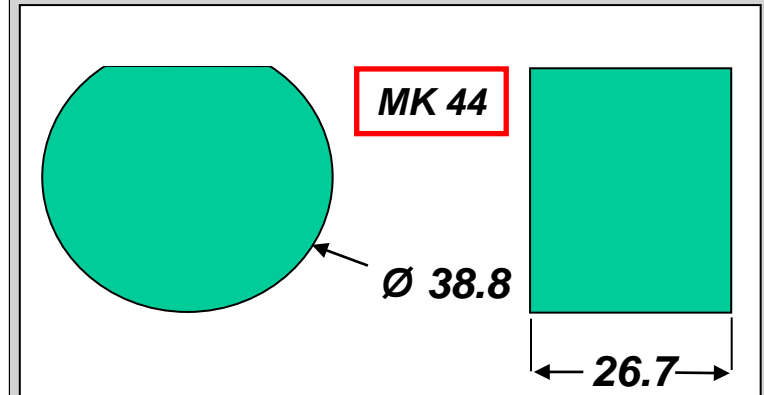
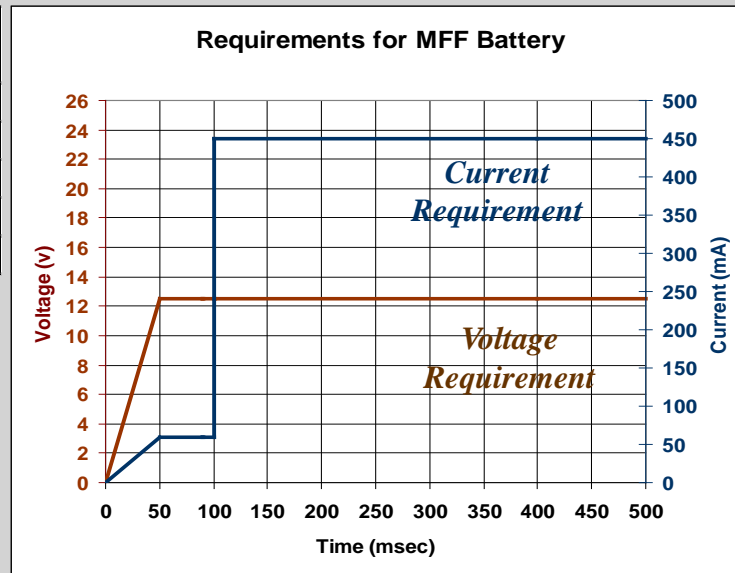
“Lead is Dead”

(2005 NDIA Fuze Conference, Eugene Marquis)

# The Way from Lead to Lithium

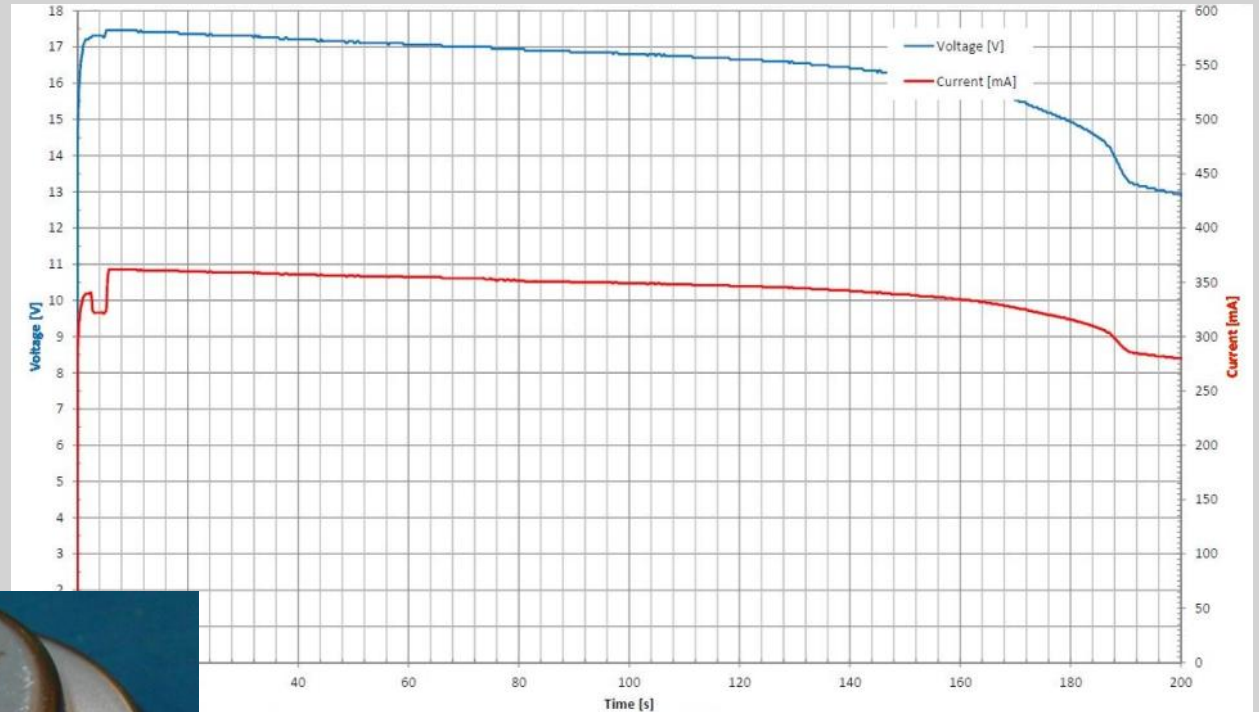
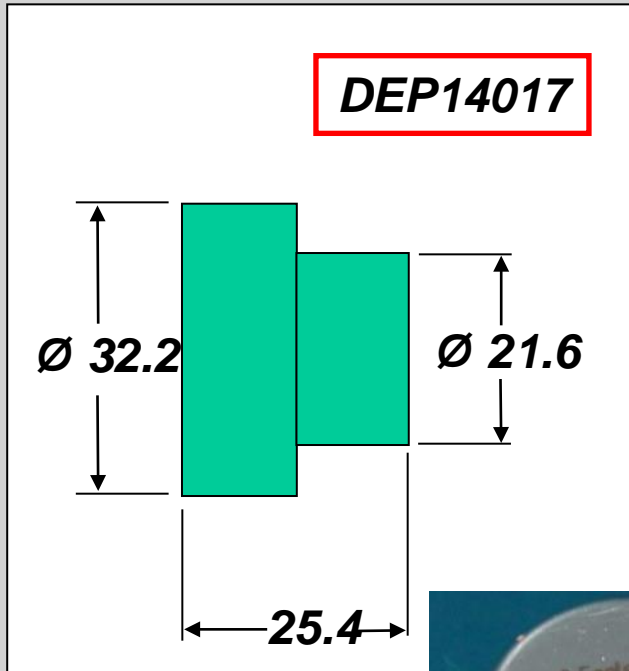
- various attempts to upgrade MOFA-Battery
  - more cells, high-rate electrolyte,
  - to fulfil MK44 requirements within envelop

Time (msec)	Voltage (v)	Current (mA)
0	0	0
50	12.5	60
99.9	12.5	60
100	12.5	450
140 sec	12.5	450



- „After several years and several million dollars, still not sufficiently successful“  
 (2008 NDIA Fuze Conference, Jeff Swank)

# Our DEP14017 as MK44 Replacement



RT; 56R//50 mA; 9000 1/min



- ◆ D&EP's DEP14017 successfully introduced into US MK419

First lot (5.400) delivered in 2013

**NAVSEA Fuze Housing And Battery Assembly** **ENGAGEMENT SYSTEMS**

**IMPROVEMENTS FOR MOD 1**

- Performance:** Improved battery
- Cycle Time:** Integrated fuze housing
- Yield:** Reduced steps increases yield
- Cost:** Reduced chip size Integrate PWBs

MOD-1	
<ul style="list-style-type: none"> <li>✓ Integrated into one part</li> <li>✓ Simplified assembly</li> </ul>	
<ul style="list-style-type: none"> <li>✓ Lithium-SOCL2 reserve battery</li> <li>✓ Standard sockets</li> <li>✓ Simple assembly done outside of fuze</li> <li>✓ Eliminated shimming</li> <li>✓ Miniaturized components</li> <li>✓ Firing cap re-sized for M100</li> </ul>	

**Fuze & Battery Assembly Design Updates Simplify Assembly And Reduces Cost**

Distribution Statement A - Approved for Public Release; Distribution is unlimited


**Battery** **ENGAGEMENT SYSTEMS**

- MOD0 MK44 Lead Acid Reserve Energizer is obsolete
- Previous MFF studies identified and tested a replacement battery:


**Lithium-SOCL2 Reserve Battery**

**IMPROVEMENTS FOR MOD 1**

- Performance:** Improved rise time
- Cycle Time:** N/A
- Yield:** N/A
- Cost:** Battery cost reduced



MOD 0: ME44 Lead Acid Reserve Energizer



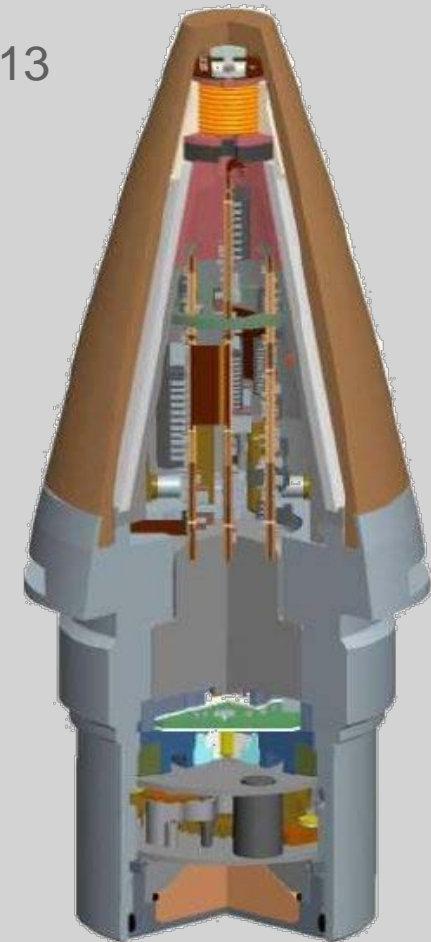
MOD-1 Lithium-SOCL2 Reserve Battery

**PIP Design Results**

✓ Batteries Procured
✓ Simplified Assembly
✓ Battery Tests Verify Battery Exceeds Goal
✓ Battery Tests Verify Rise Time Exceeds Threshold
✓ Simulation & Lab Tests Verify Functionality

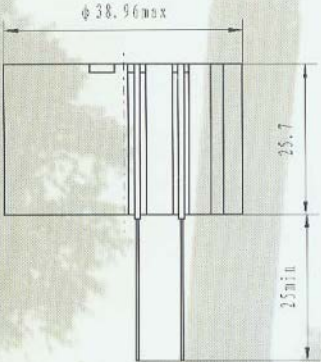
**Battery Characteristics Exceed Fuze Requirements and Reduces Cost**

Distribution Statement A - Approved for Public Release; Distribution is unlimited





# Our next Step



**Battery:**  
**Model MD-115**


Battery of MD-115( equivalent to US PS-115 Battery) is a stocksolution Type plumbous acid battery used for electrical proximity fuze.

**Applicable Range:** all kinds of electrical fuze for middle and large caliber high explosive shell used for 105mm howitzer, 122mm howitzer, 130mm cannon, 152mm cannon, 155mm howitzer, 175mm gun, 8 inch howitzer and 4.2 inch mortar.

It works under double environmental forces:  
Backlash acceleration: 1100g-25000g;  
rotational speed: 2700-21600 resolve/min.

**Performance Feature:** Nominal Voltage: 30v.  
Average Energy: >6000MAS.  
Activation Time: T ≤ 1S (U ≥ 23V),  
Max Voltage: ≤ 36V  
Voltage noise: ≤ 200mv

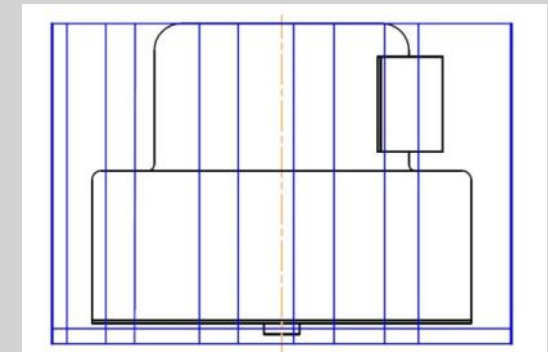
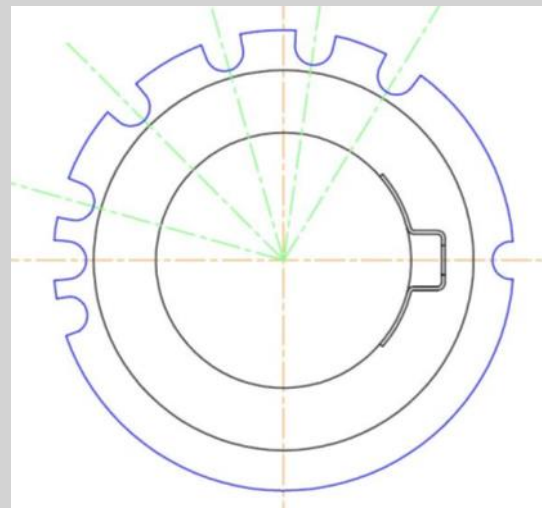
**Working Temperature:** -40→+60°C.  
**Storage Life:** 15 years.  
**Dimensions:** Outer Diameter ≤ 38.96mm  
height ≤ 25.7mm  
**Battery Mass:** 78±3g



- ♦ Height [mm]
- ♦ Diameter [mm]
- ♦ Weight [g]
- ♦ Voltage max [V]
- ♦ Voltage min [V] \*
- ♦ Current [mA] peak \*
- ♦ Capacity/Lifetime [mAs/s]
- ♦ Activation Time [s] @ 23 V
- ♦ Acceleration [g´ s]
- ♦ Spin [rpm]
- ♦ Temperature [°C]
- ♦ Environment

\* Customer defined

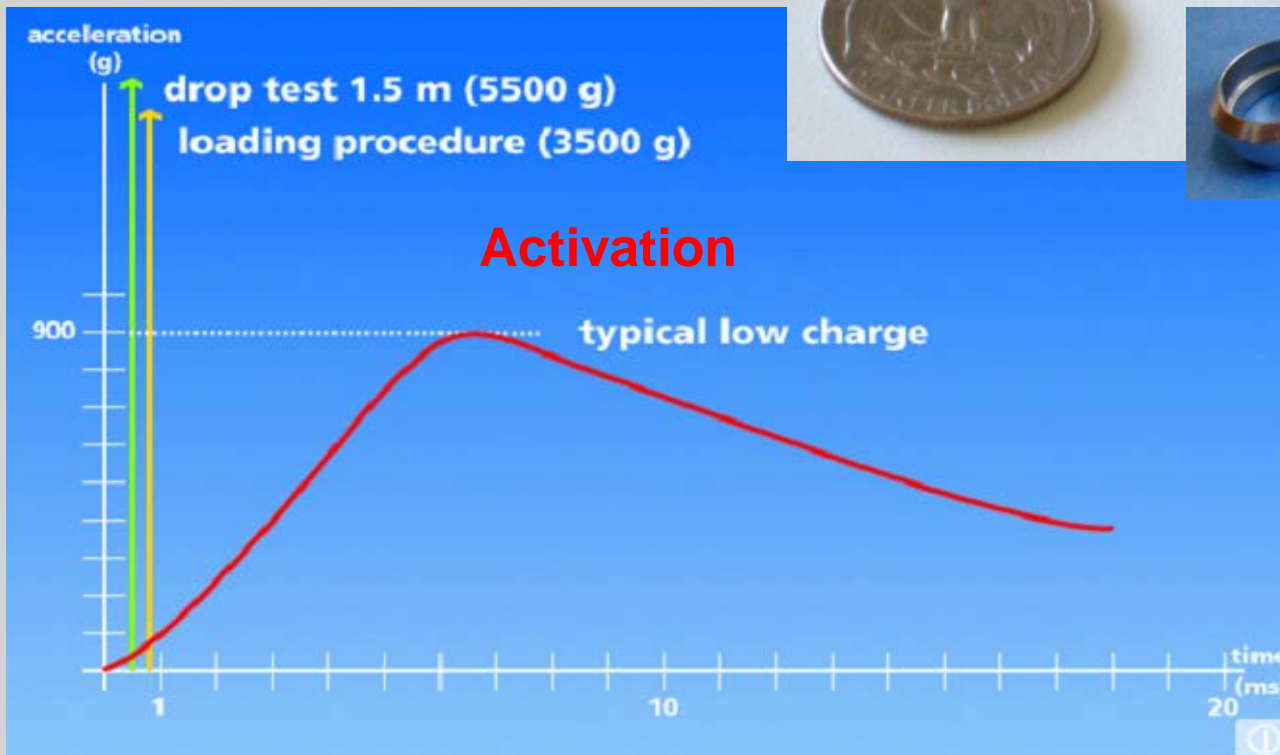
	PS-115	DEP14012
Height [mm]	< 25.7	<b>25.33</b>
Diameter [mm]	< 38.96	<b>32.17</b>
Weight [g]	< 78	<b>40</b>
Voltage max [V]	< 36	<b>28.8</b>
Voltage min [V] *	> 20	<b>20</b>
Current [mA] peak *	250	<b>250</b>
Capacity/Lifetime [mAs/s]	6,000/200	<b>60,000/200</b>
Activation Time [s] @ 23 V	< 1	<b>0.1</b>
Acceleration [g´ s]	> 1100	<b>1000</b>
Spin [rpm]	> 2,700	<b>2,700</b>
Temperature [°C]	-40 - +60	<b>-46 - +63</b>
Environment		<b>MIL-STD 883B</b>



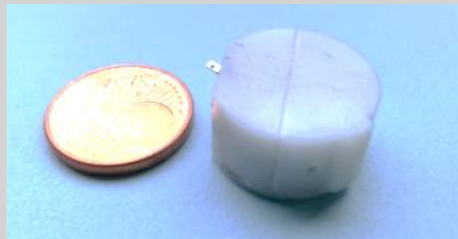
# The DEP 14012 Activation

- ◆ unique activation device

no activation

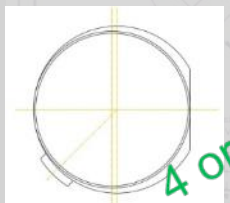


# Some More Examples of Lead Batteries

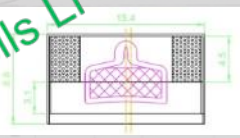


PX-20

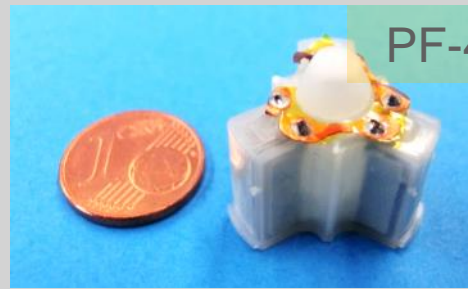
Activation time	Battery will get activate /generate voltage when subjected to specified Acceleration & Spin. Maximum 200 msec for 14V under 15 mA load. 18Volts at Ambient temp under 15mA load.
Nominal Voltage level	Just after the activation time along all the specified duration the battery voltage with a current of 15mA, shall not be less than 14 volts [-40°C] not higher than 25v (+60°C)
Nominal Current level	15mA under 1K Ω load
Operating Time	Operating Time from Activation till Voltage drops below 14V shall be not less than 15 sec
Operating Temperature	-40°C to +60°C



4 or 5 - cells Li



	PX-20	DEP14203
• Voltage max [V]	< 18	✓
• Voltage min [V]	> 14	✓
• Current [mA]	15	✓
• Activation Time [s] @ 14 V	< 0.2	0.01
• Acceleration [g's]	> 25,000	✓
• Spin [rpm]	> 40,000	✓
• Temperature [°C]	-40 - +60	-46 - +63

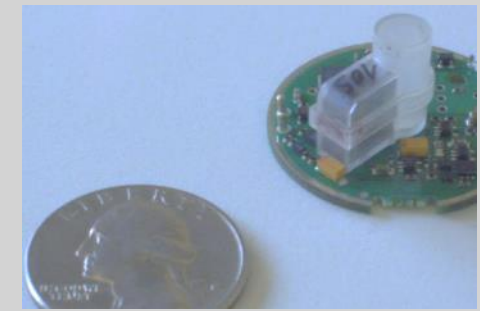


PF-40

diameter d = 22 mm  
height h = 14/19.5 mm

11 - cells Li

	PF-40	DEP14204
• Voltage min [V]	> 39	✓
• Current [mA]	10	✓
• Temperature [°C]	-31 - +60	-46 - +63



MRB



Fabricated MRB  
10 - cells Li

	MRB	DEP14204
• Voltage min [V]	> 30	✓
• Current [mA]	10	✓
• Activation Time [s] @ 14 V < 0.05		0.01
• Temperature [°C]	-32 - +60	-46 - +63
• Environment	MIL-STD 331B	✓

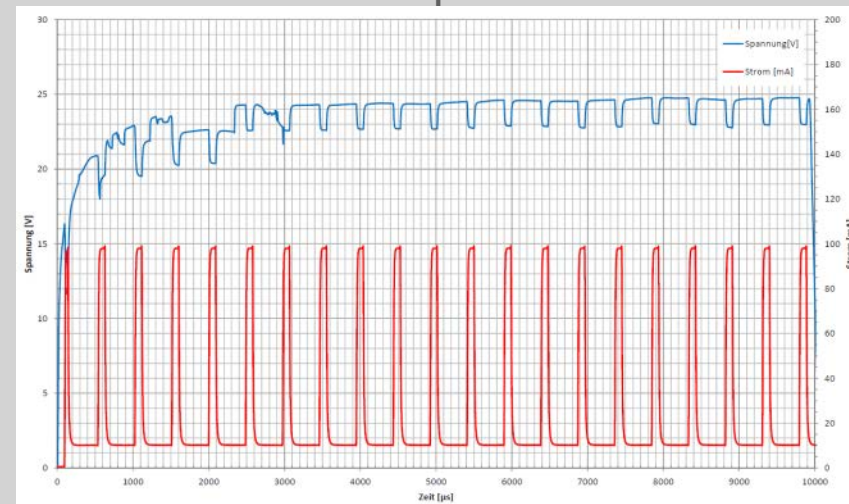
Sang-Hee Yoon \*, Joong-Tak Son, Jong-Soo Oh  
Journal of Power Sources 162 (2006) 1421-1430

# Obsolete Opinions about Lithium Reserve Batteries

- ◆ widely heard quotations:
  - Lead has a higher energy density (capacity) per volume. \*
  - Lead is more powerful per area cell surface. \*\*
  - Lead is faster. \*\*\*
- ◆ the truth for lithium:
  - High cell voltage usually results in high energy density up to 100 mJ/mm<sup>3</sup>
  - Proper cell design and electrolyte results in high power more than 200 mW/cm<sup>2</sup>
  - Proper cell- and flow-design results in fast activation two examples

- ◆◆ Diehl/Eagle Picher Conclusion
- Meets Fit, Form, & Function of MK44
    - Limited mechanical repackaging of fuze
    - **Rise time same as MK44**
  - Need to test 5x2 battery
    - To determine if Mission Life Requirement would be met ◆◆

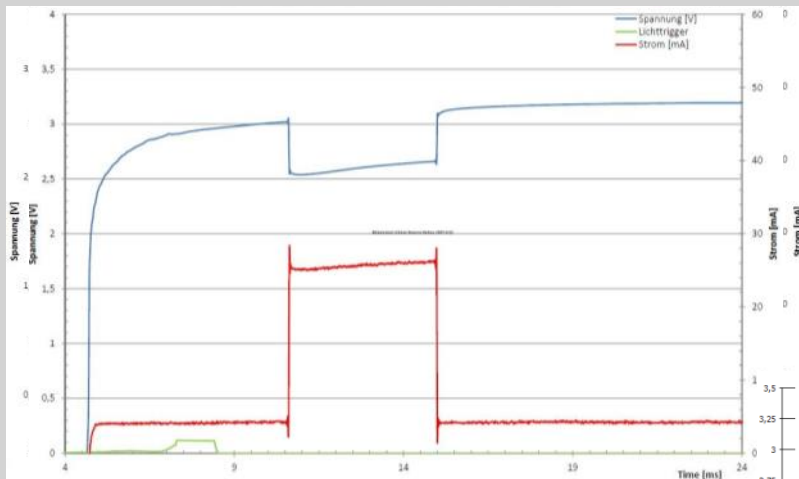
DEP 1400x  
at RT



\* no source  
\*\* 2008 NDIA Fuze Conference, Jeff Swank  
\*\*\* 2002, 2004, 2005 NDIA Fuze Conference, Till, Marquis Sang-Hee Yoon \*, Joong-Tak Son, Jong-Soo Oh  
Journal of Power Sources 162 (2006) 1421–1430

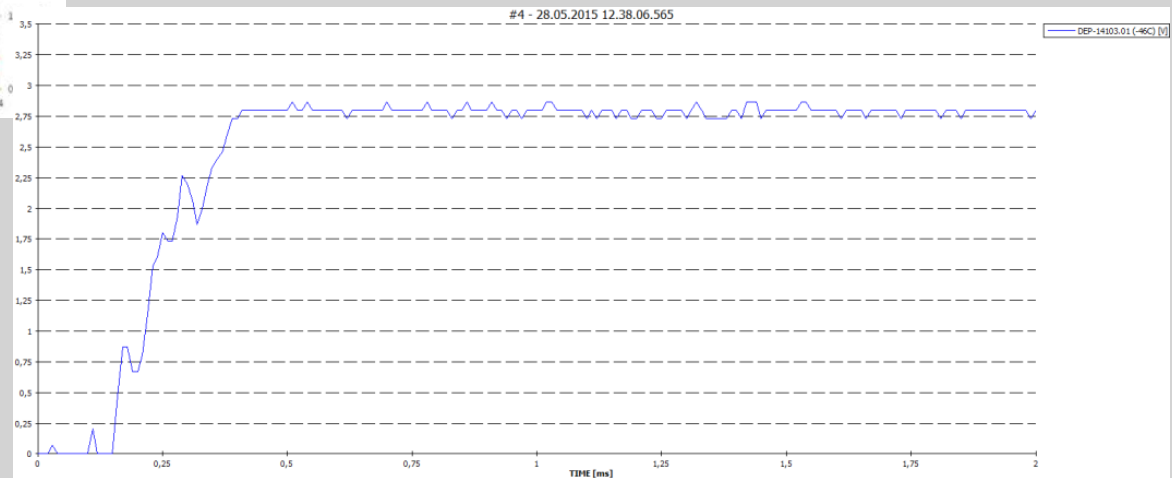
# Obsolete Opinions about Lithium Reserve Batteries

- ◆ more on lithium rise time



DEP 14103  
at -46°C

DEP 14103  
at -46°C



**Lithium Reserve Batteries activate quickly if properly designed!**

# Conclusion

- ◆ Lead Batteries can be substituted by a Lithium plug-in-replacement in most cases. In some applications a cylindrical Li-battery is the more favourable solution
  - long shelf live due to
    - glass ampoule
    - tightness
  - superior low temperature performance
  - high energy/power density
  - fast rise-time



Thank you for your attention!

Questions?

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