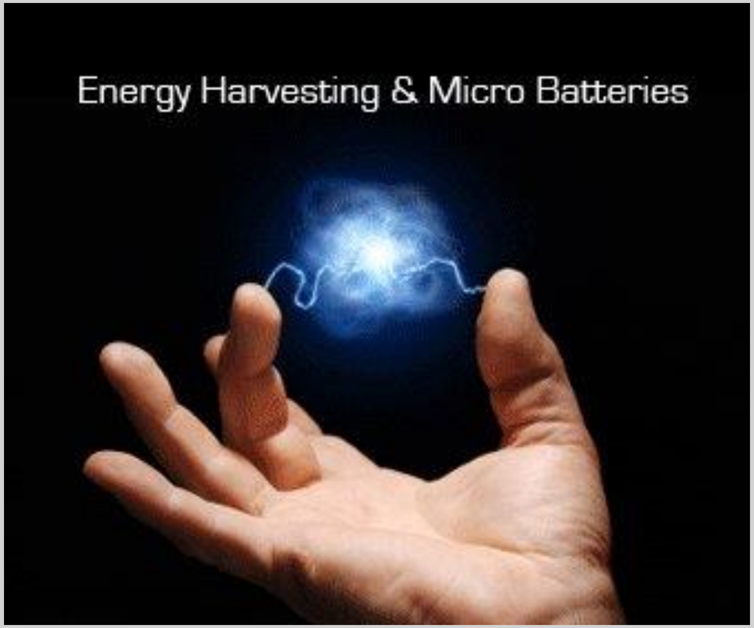
Fuze Power Quo Vadis?

55th Fuze Conference
May 26th, 2011, Salt Lake City, UT

Harald Wich
DIEHL & EAGLE PICHER Batterie-Systeme

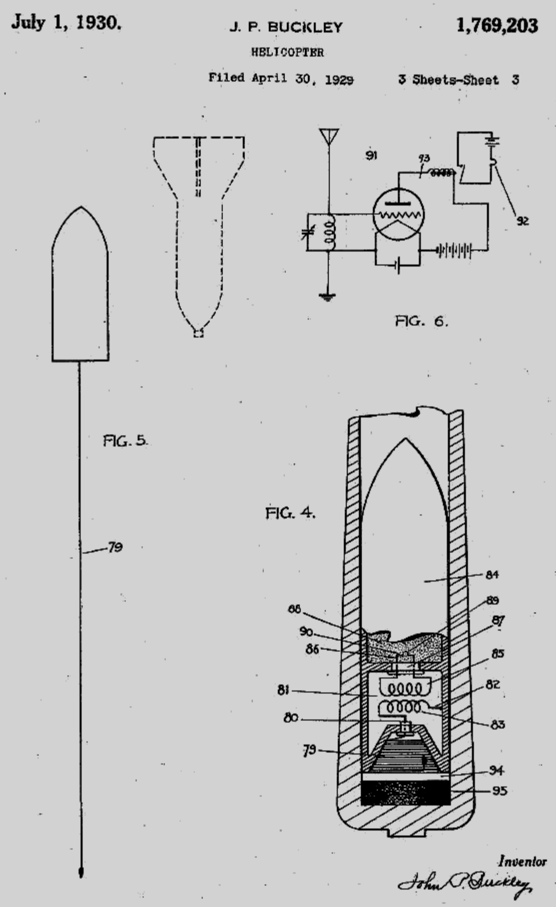
Outline

- History
- Requirements
- Alternative Power Sources
- Liquid Reserve Batteries
- Quo Vadis – Fuze Power ?



Some History

- First time Electric Power required for Proximity Fuzing in the early 1940´s
  - some earlier Patents e.g. US1,769,203 in the 30´s



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DIEHL & EAGLE PICHER
Batterie-Systeme

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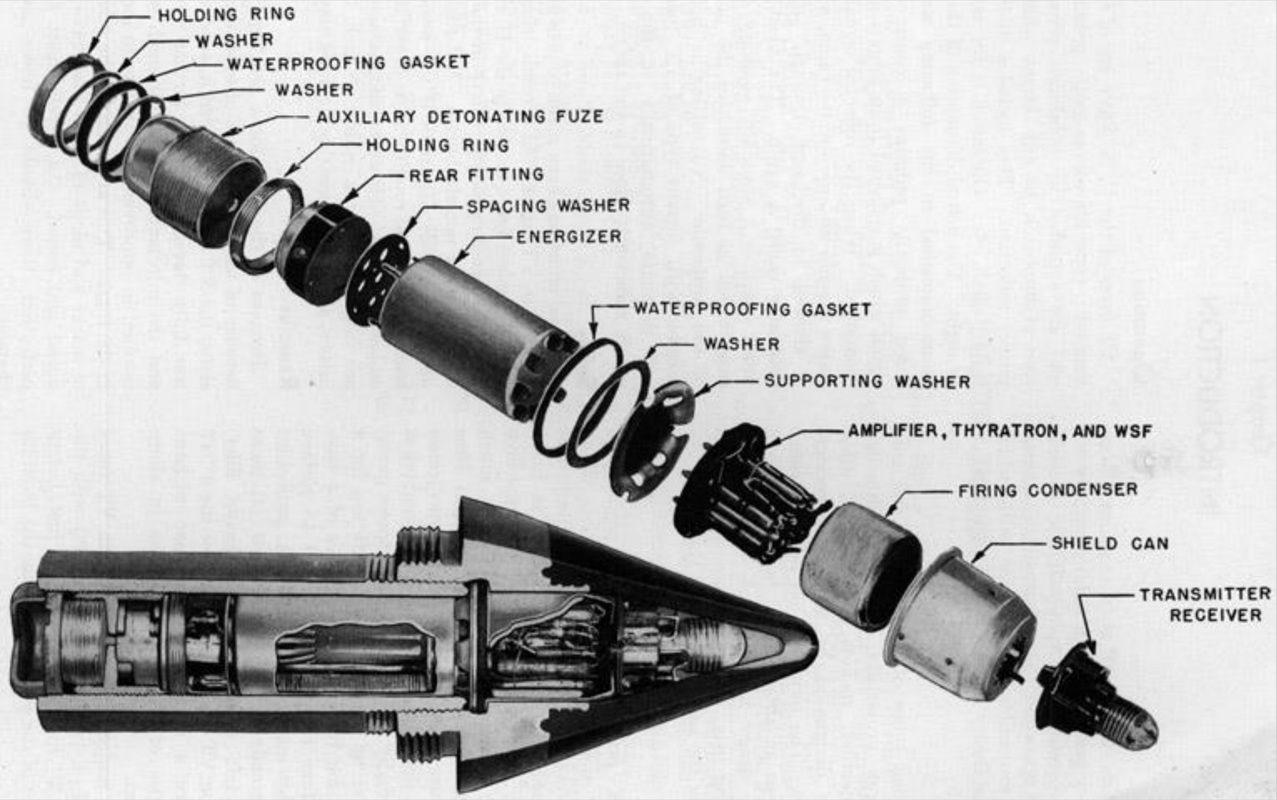

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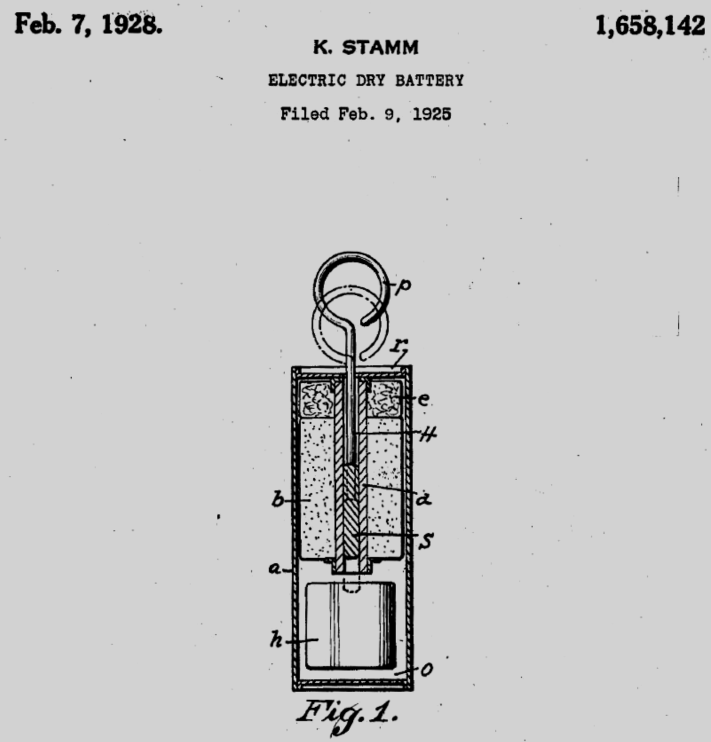

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    ⇨ 70 years of history
- My own experience
  - piezoelectric setback generators

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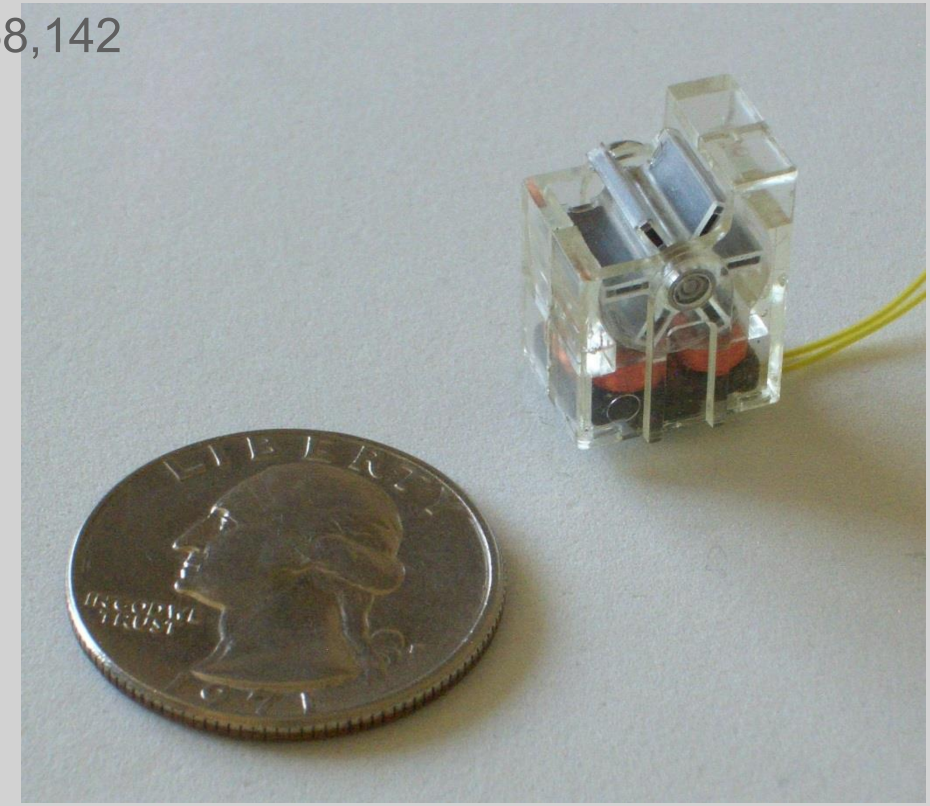

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    - ⇨ 70 years of history
- My own experience
  - piezoelectric setback generators
  - air – driven alternators
  - thermal battery
    - ⇨ dates back 35 years

Requirements general

- Volume (size) and Weight
- Power = Voltage x Current
  - ⇩ ⇩ ↳ µA to 100´s of mA
  - ⇩ ↳ a mere 2 V up to 10´s of V
  - ↳ µW to W
- Lifetime < 10 s to > 600 s
- Energy = $\int_{t=0}^{t_{lt}} V(t) * I(t)\, dt$ µJ up to J
- Rise time ms up to 100´s of ms
- Reliability 99.xxxx%
- Storage Life 10 years +
- Cost nil

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories PD Detonator
  classical artillery
  - 100 µJ M100
  - 5 mJ Silicon Bridge Initiator
  - 50 mJ 1 W/1A
  - 100 mJ LEEFI

⇨ usually a Factor of 3 – 5 (10) in the firing circuit !

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det	
SD	Det + Timer	
		↳ 2 µW e.g. digital watch

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
	↳ 600 µW e.g. RFID-Circuit

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX

➩ some 100 mW´s

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX
CCF	Det + prog. Timer + TX/RX + Control Power
	↳ some W´s

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

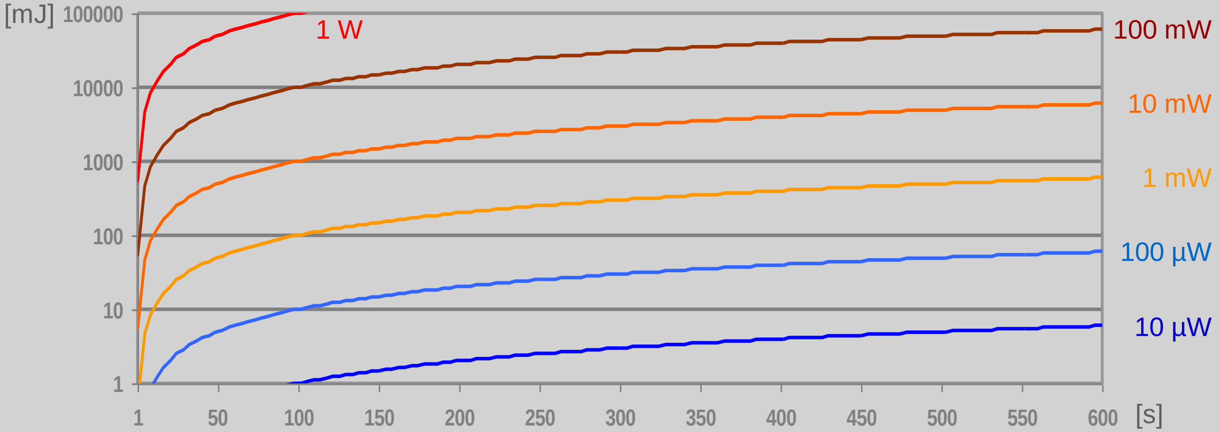
- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX
CCF	Det + prog. Timer + TX/RX + Control Power

- Operating Times

short	≤ 10 – 20 s	direct fire
medium	< 100 s	indirect fire Mortars
long	< 200 s	indirect fire Arty 105/155 mm
x-long	up to 600 s	gliding and/or powered

- Energy



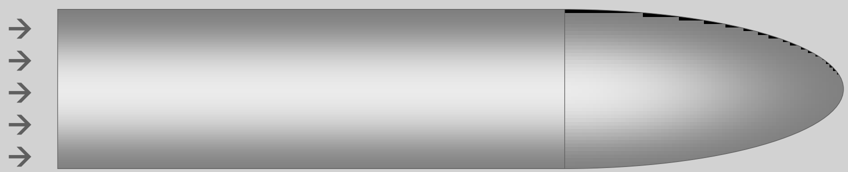
Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

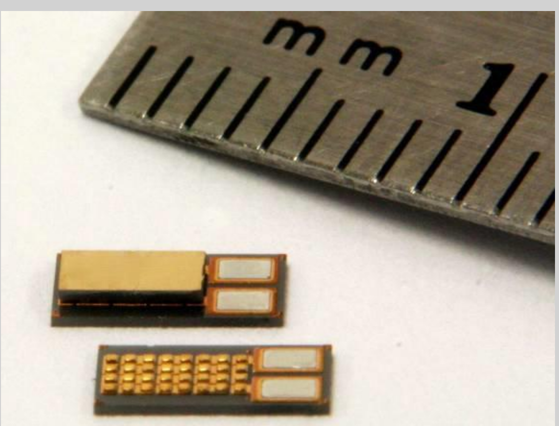
source requires storage device

pressure
temperature



thermoelectric

- access



Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

setback force ← — — — source requires storage device

↳ piezoelectric
electromagnetic

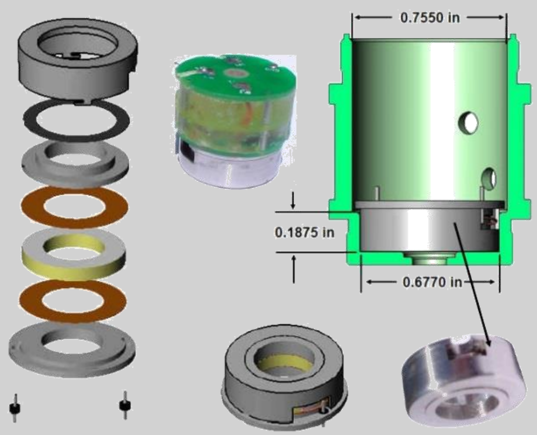
pressure
temperature

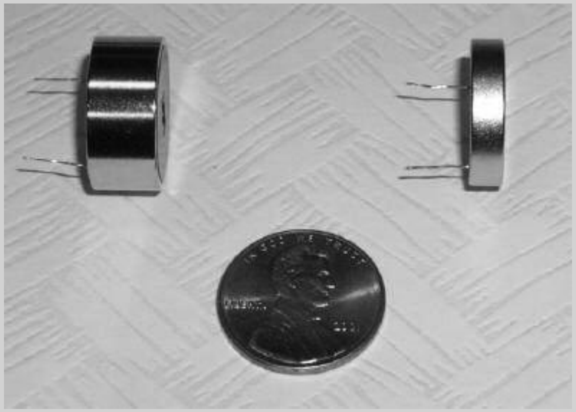
↳ thermoelectric

- access

angular acceleration

↳ electromagnetic





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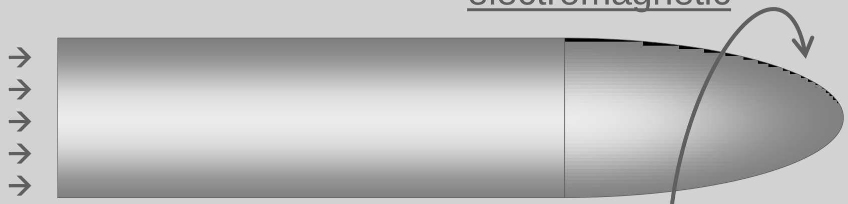


thermoelectric

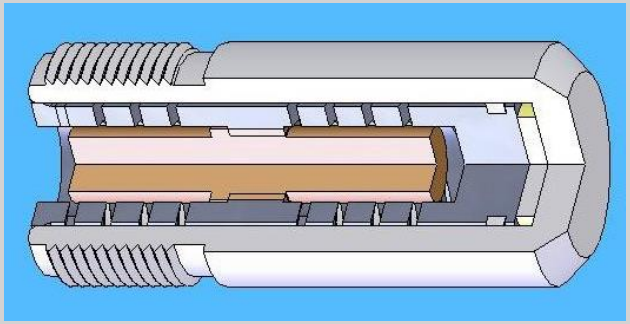
\- access

in-flight vibration

piezoelectric
electromagnetic

angular acceleration

electromagnetic



Alternative Energy Sources

- Where could the energy come from

setback force ← — — — source requires storage device

↳ piezoelectric
electromagnetic

- range of velocity
- air intake

pressure
temperature

↳ thermoelectric

- access

in-flight vibration

↳ piezoelectric
electromagnetic

angular acceleration

↳ electromagnetic

EM air turbine

airstream

↳ aerodynamic heat

↳ thermoelectric
thermo photovoltaic

- rise time
- high speed only

Alternative Energy Sources

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setback force ←
⇘ piezoelectric
electromagnetic

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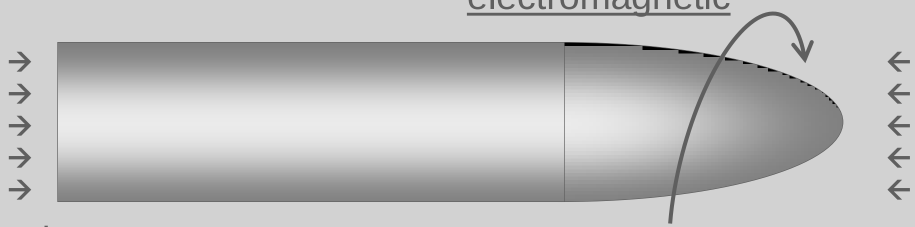


⇗ EM air turbine
air stream
⇘ aerodynamic heat
⇘ thermoelectric
thermo photovoltaic
- rise time
- high speed only

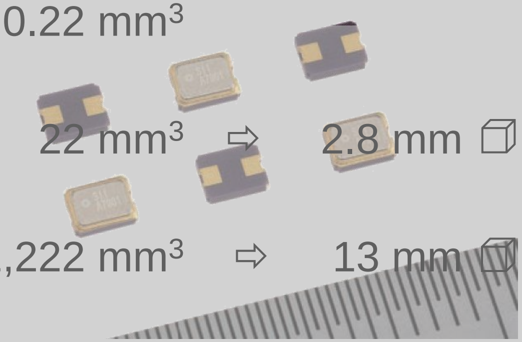
pressure
temperature
⇘ thermoelectric
- access

in-flight vibration
⇘ piezoelectric
electromagnetic

angular acceleration
⇘ electromagnetic

- Capacitive energy storage

storage of	1 mJ	@ 10 V	⇨	20 µF	$0.22\ mm^3$		
		@ 30 V	⇨	2.2 µF			
	100 mJ	@ 10 V	⇨	2000 µF	$22\ mm^3$	⇨	2.8 mm
		@ 30 V	⇨	220 µF			
	10,000 mJ	@ 10 V	⇨	0.2 F	$2{,}222\ mm^3$	⇨	13 mm
		@ 30 V	⇨	0.022 F			



Alternative Energy Sources

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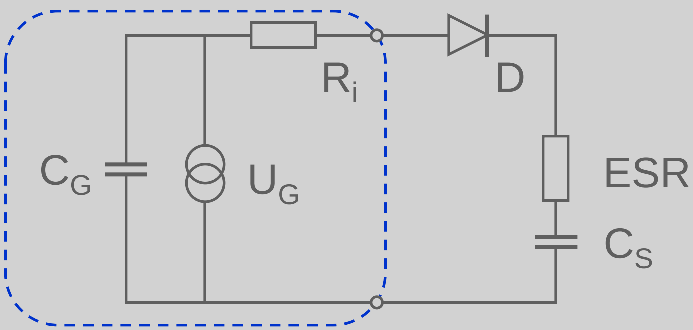
Batterie-Systeme

- Charging and discharging the capacitor

Piezo **G**enerator

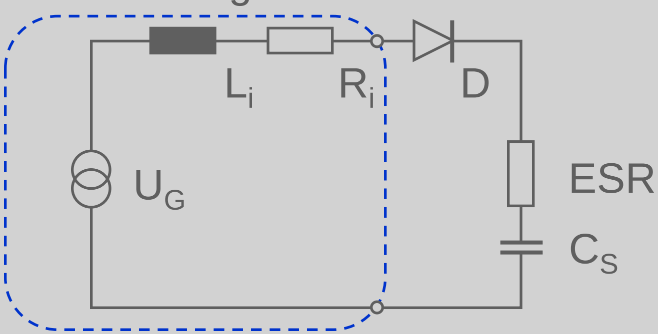


PG-Voltage proportional to pressure (= acceleration)

↳ peak voltage @ peak pressure
ms only ⇨ high currents, matching losses

e.g. storage of 10 mJ	@ 10 V ⇨	200 µF ⇨	1.1 A (2 ms)
	@ 30 V ⇨	22 µF ⇨	0.33 A (2 ms)

Electro**M**agnetic **G**enerator

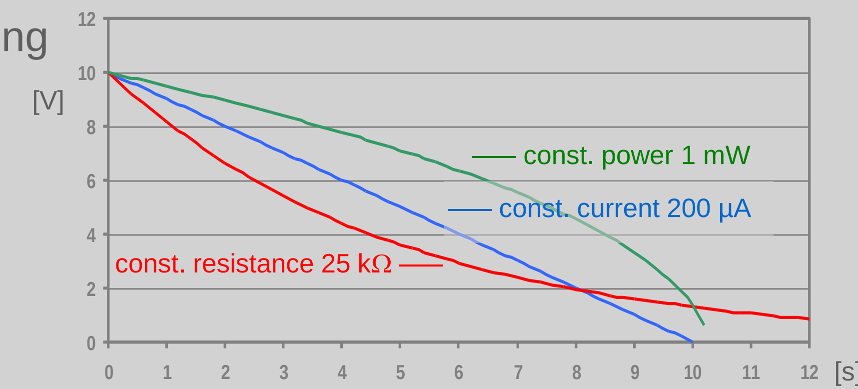


EMG-Voltage proportional to # of turns/inductance

↳ natural frequency $f_r = (2 * \pi * \sqrt{L_i * C_s})^{-1}$

e.g. storage of 10 mJ	@ 10 V ⇨	200 µF ⇨	112 Hz (10 mH)
	@ 30 V ⇨	22 µF ⇨	339 Hz (10 mH)

Discharging



No constant Voltage during discharge!

Alternative Energy Sources

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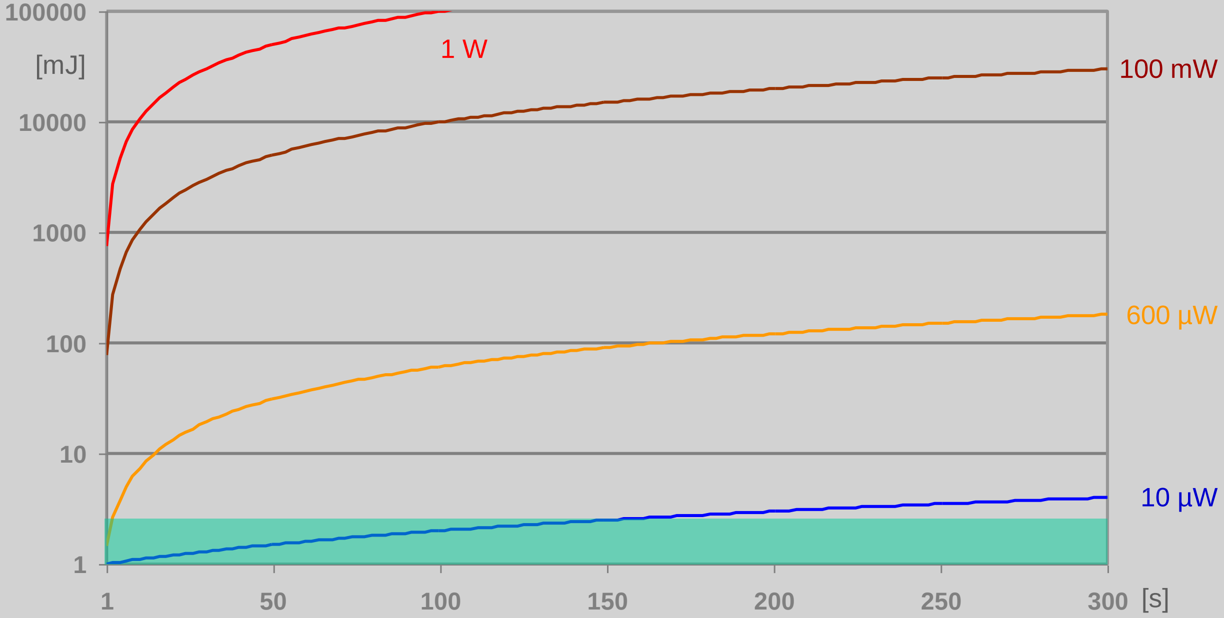
Batterie-Systeme

- Their Energy Output
  some examples



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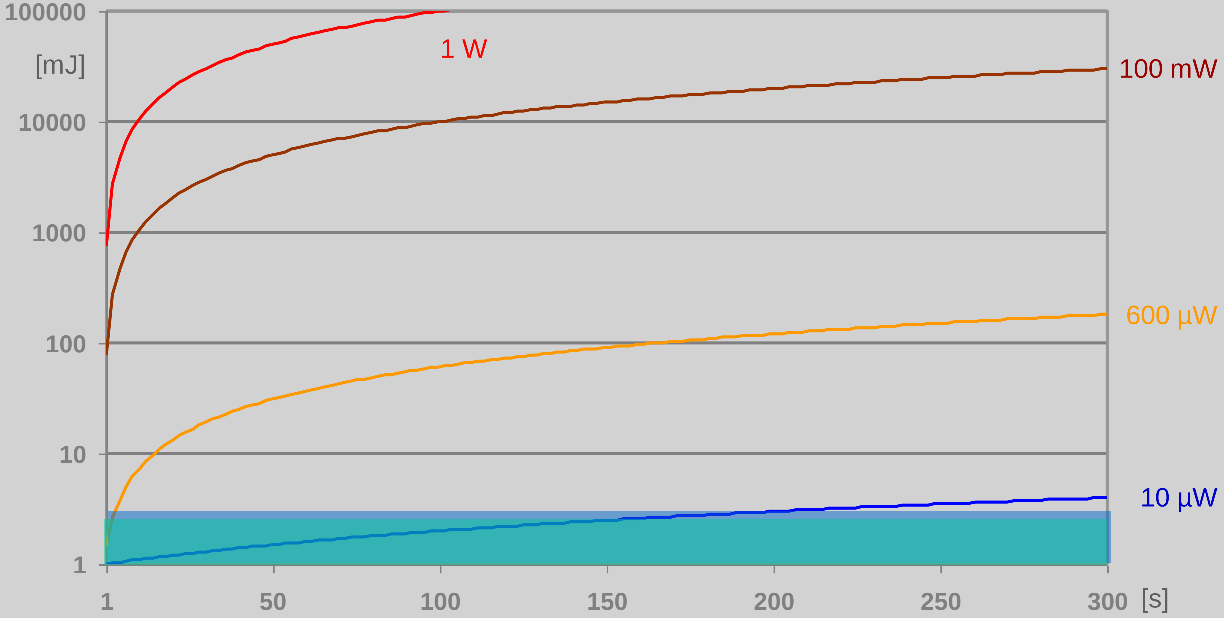

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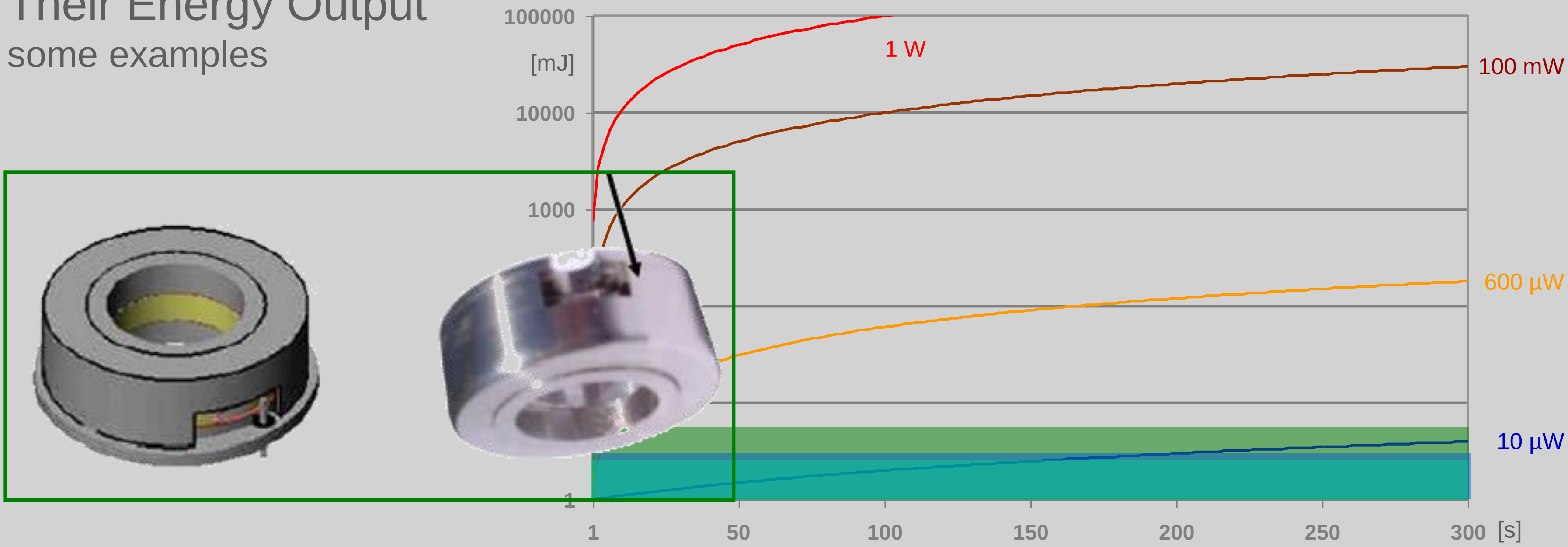

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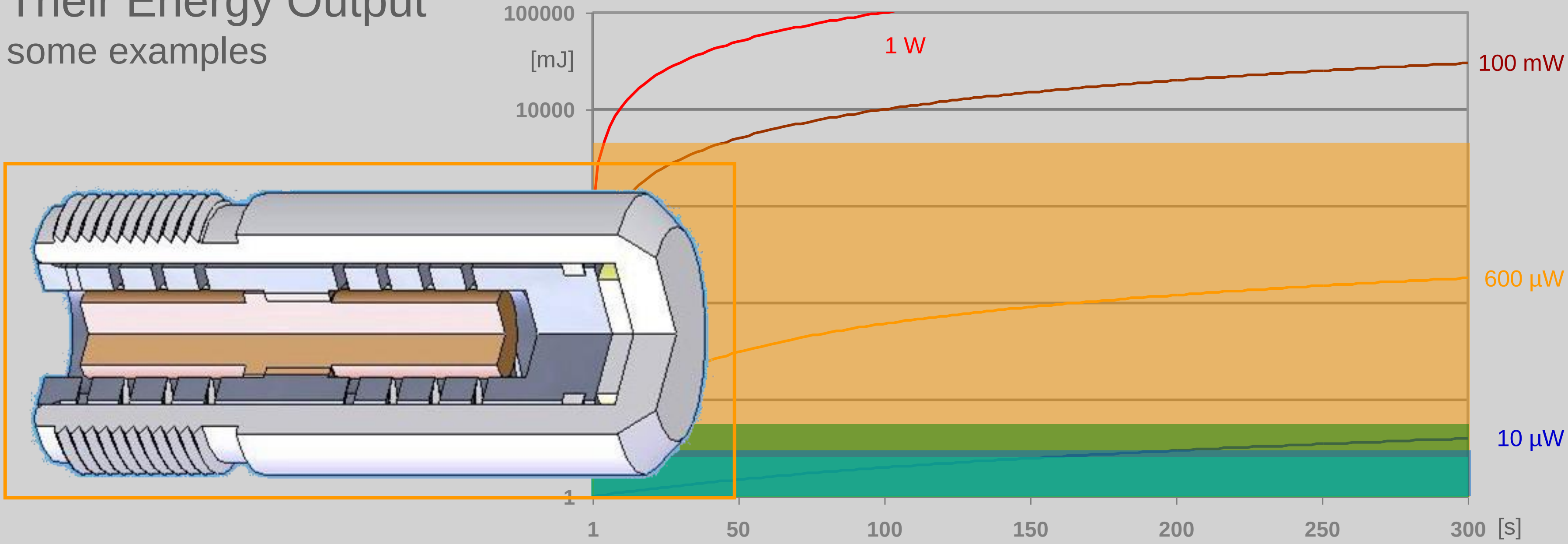

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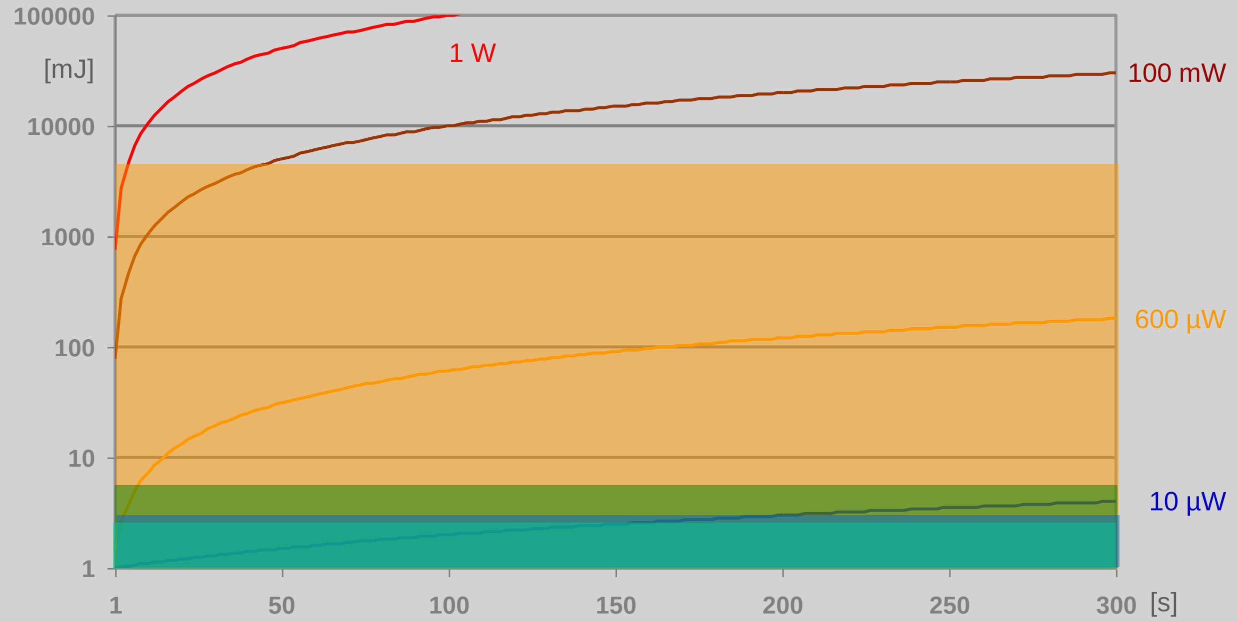


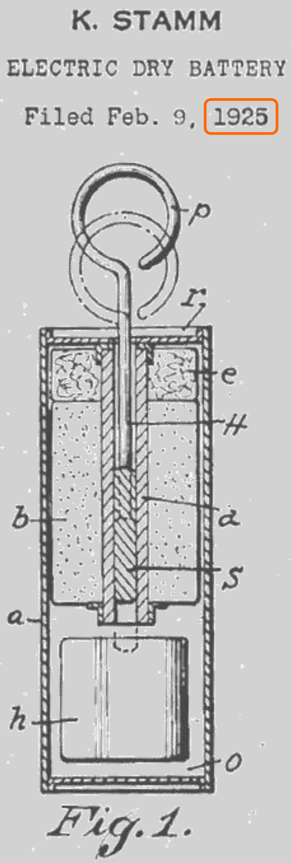
- My Conclusion
  - no significant improvement of energy generated since 35 years

  limited to
  - low energy pyrotechnics
  - short time of flight
  - simple functions

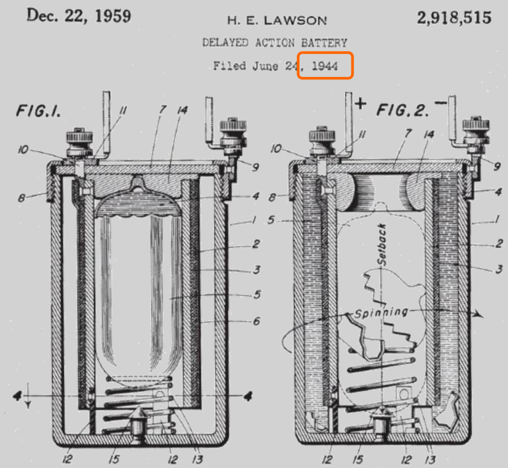
Liquid Reserve Batteries

DIEHL & EAGLE PICHER
Batterie-Systeme

- Legacy



First Reserve Battery



Fuze Battery

Mk53 Fuze

Fuze Battery

MOFA Fuze Battery

Liquid Reserve Battery current

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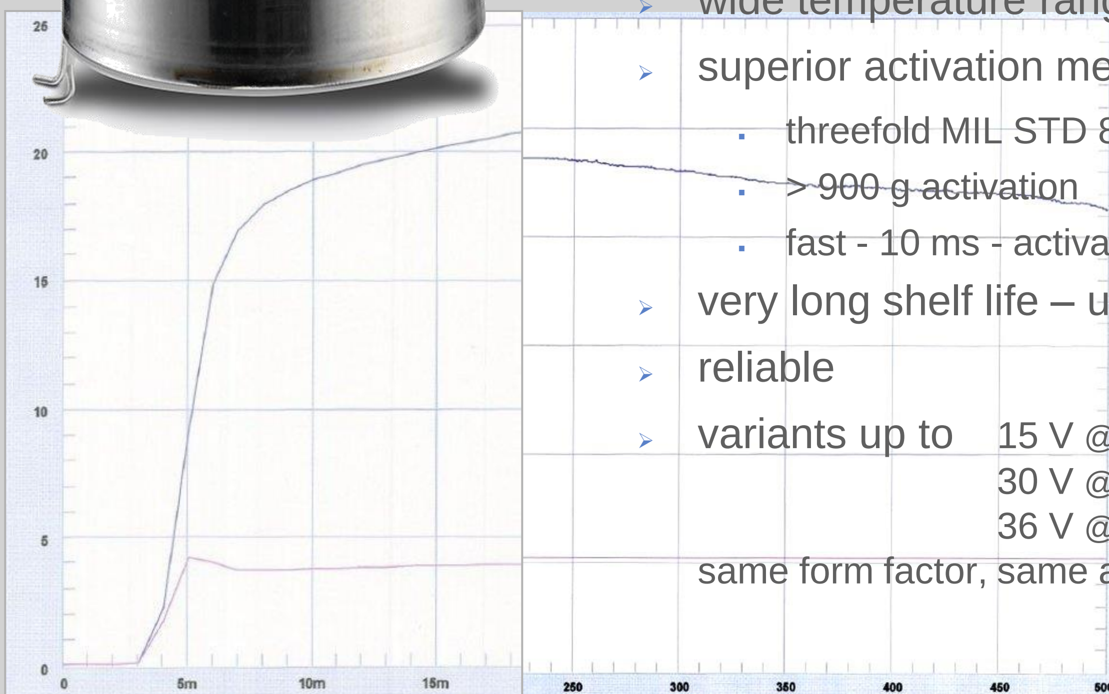
Batterie-Systeme



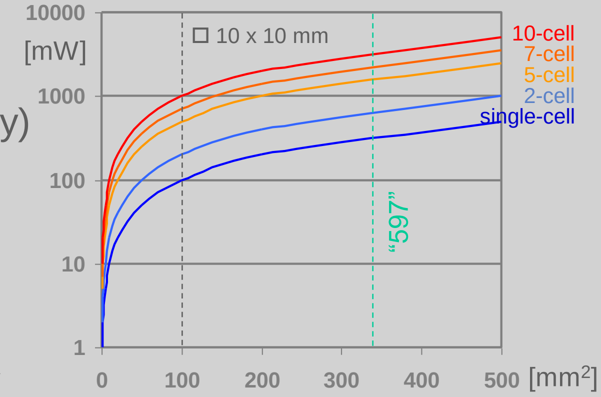
The workhorse (type 597) Lithium Thionyl Chloride

- most common fuze battery in Europe
  (European complement to MOFA-Battery)
- produced in 100 thousand´s
- powerful (0.25 W/cm^2 active cell area)
- wide temperature range -46°C to +63°C
- superior activation mechanism
  - threefold MIL STD 883 1.5 m drop safety
  - > 900 g activation
  - fast - 10 ms - activation under spin environment
- very long shelf life – up to 20 years
- reliable
- variants up to 15 V @ 600 mA
  30 V @ 300 mA
  36 V @ < 100 mA
  same form factor, same activation

Liquid Reserve Battery future

- How big is their Energy-/Power-Density

—— this volume equals **3,000** mJ (Electrochemistry only)



  - what's needed for a complete LRB
    - Electrochemistry
    - Electrolyte separated from Cell Stack

"597"

"762"

    - Activation System

"AM"

"AH/AD"

For low and medium Power a single Cell will be the preferred Solution

Small Liquid Reserve Batteries

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Batterie-Systeme

- Can be very small whilst maintaining their excellent properties
  - superior Power-/Energy-Density
  - long shelf life
  - wide temperature range
  - excellent reliability
  - low cost
- Some recent examples
  - M235

  - M80

  - MRB

  - 40 mm AB

single cell Lithium

multi cell Pb PbO2

Yet a new small Liquid Reserve Battery

DIEHL & EAGLE PICHER
Batterie-Systeme

- For small and medium calibre applications

- 12 mm diameter
- 12 mm high
- single cell Lithium Battery
- 3.0 ÷ 3.6 V closed circuit voltage
- up to 50 mA load current
- setback/spin activation mechanism
  - > 7000 g activation
  - fast - < 5 ms - activation under spin environment
- lifetime > 50 s
- wide temperature range -46°C to +63°C
- very long shelf life – up to 20 years
- reliable
- low cost

Lithium Liquid Reserve Batteries provide superior Energy Density

Thank you for your Attention!

Any Questions, Comments, Objections, …

Diehl & Eagle Picher in a Nutshell

- About the company
  - US/German Joint Venture;
    Shareholders are Eagle Picher Technology, Joplin MO and Diehl BGT Defence, Ueberlingen GE
  - Located in Roethenbach Germany
  - Thermal- and Fuze-Batteries and Battery Packs
  - R&D and Production of the above Batteries
  - Annual Turn Over > 10 mEur

Diehl & Eagle Picher Contact

- How to Contact us
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