

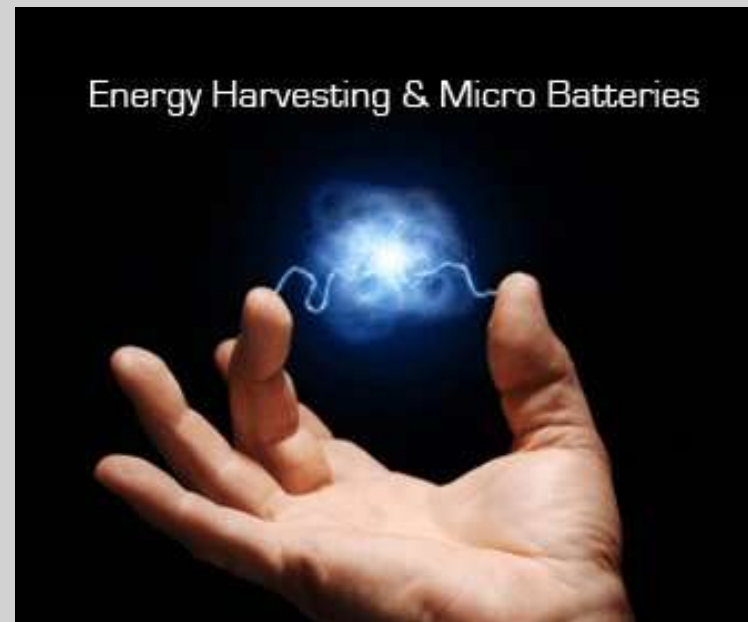
Fuze Power Quo Vadis?



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

Outline

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



Some History

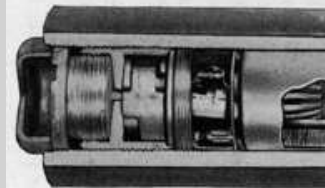
- ◆ First time Electric Power required for Proximity Fuzing in the early 1940's
 - some earlier Patents e.g. US1,769,203 in the 30's
 - Pye Ltd in GB and USNAVY in US – Mk 32 later on Mk 45, Mk 53
 - first "Reserve Type Battery" US1,658,142

⇒ 70 years of history

- ◆ My own experience

- piezoelectric setback generators
- air – driven alternators
- thermal battery

⇒ dates back 35 years



July 1, 1930. J. P. BUCKLEY 1,769,203
HELICOPTER
Filed April 30, 1929 3 Sheets-Sheet 3



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 = $\int_{t=0}^{t_t} V(t) * I(t) dt$ μJ up to J
- ◆ Rise time ms up to 100's of ms
- ◆ Reliability 99.xxxx%
- ◆ Storage Life 10 years +
- ◆ Cost nil

Requirements

◆ Fuze Categories

classical artillery

PD

Detonator

- ⇒ 100 μ J 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

- ◆ Fuze Categories
classical artillery

PD
SD

Det
Det + Timer

↘ 2 μ W e.g. digital watch

Requirements

- ◆ Fuze Categories
classical artillery

PD

Det

SD

Det + Timer

ET

Det + programmable Timer

↳ 600 μ W e.g. RFID-Circuit

Requirements

- ◆ Fuze Categories
classical artillery

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

↙ some 100 mW's

Requirements

- ◆ 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

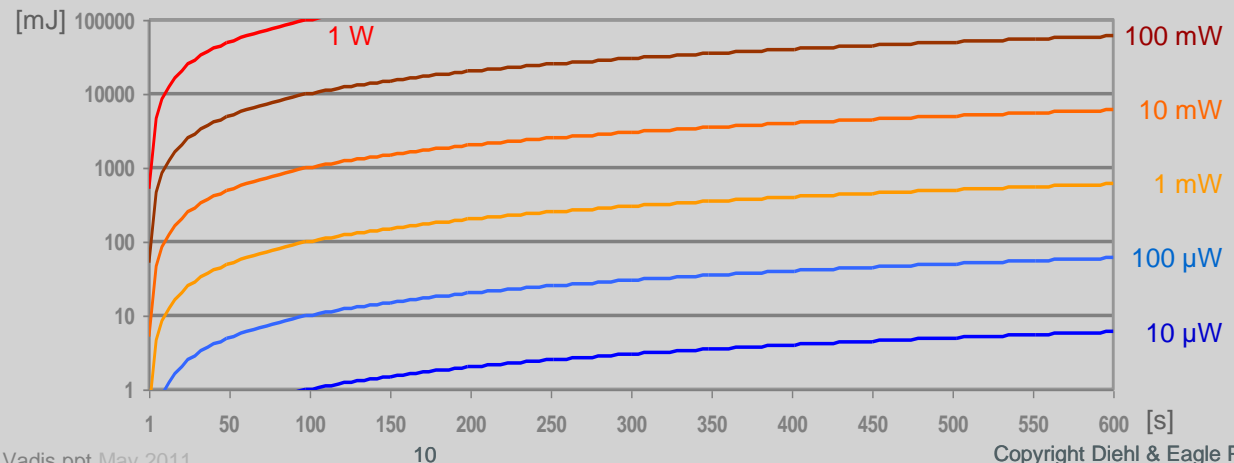
- ◆ Fuze Categories
 - classical artillery

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

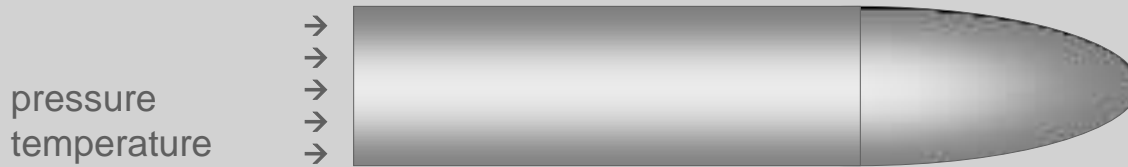
- ◆ Energy



Alternative Energy Sources

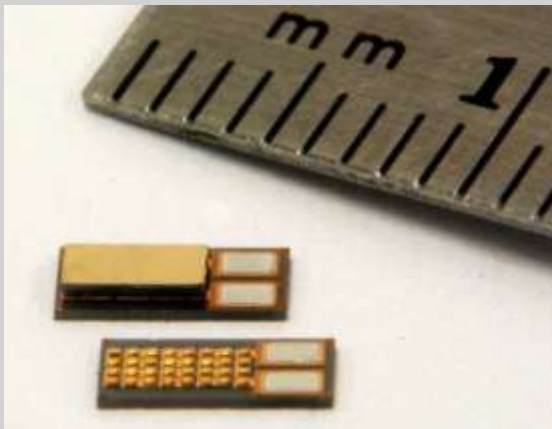
- ◆ Where could the energy come from

==== source requires storage device



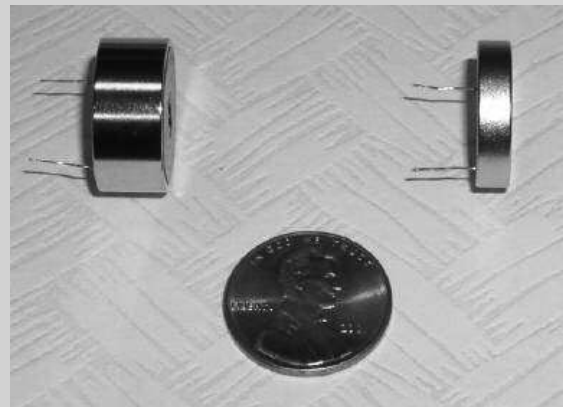
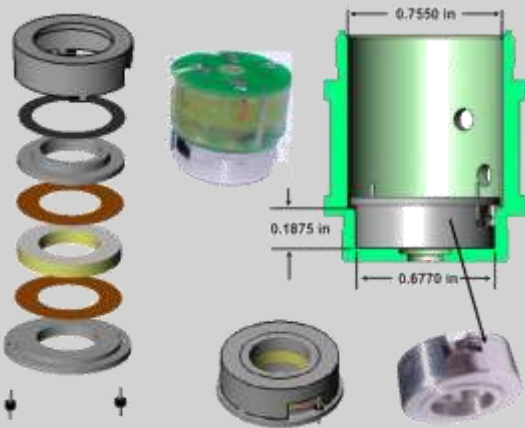
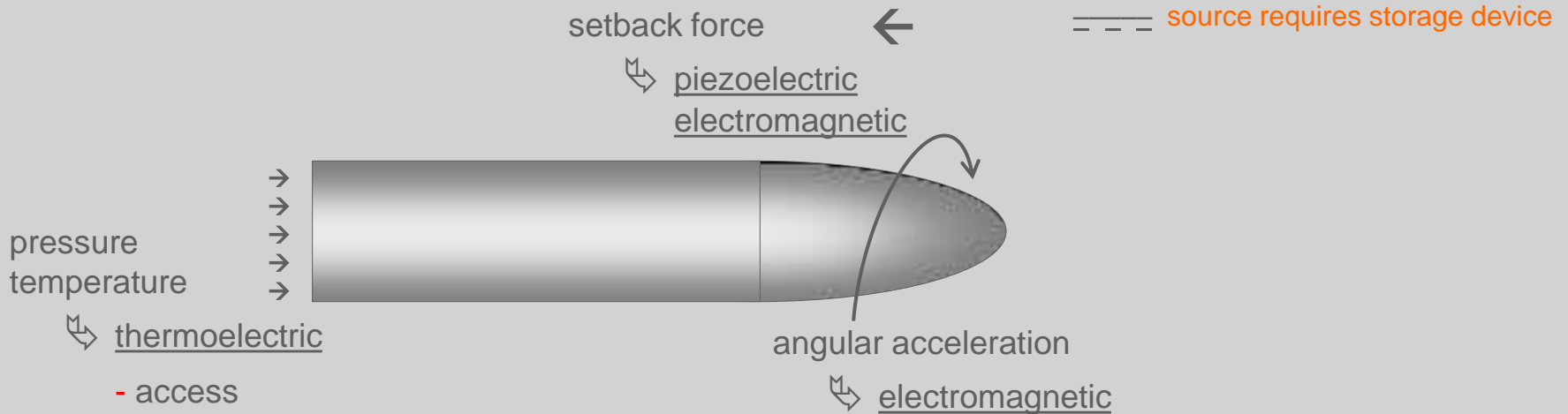
↳ thermoelectric

- access



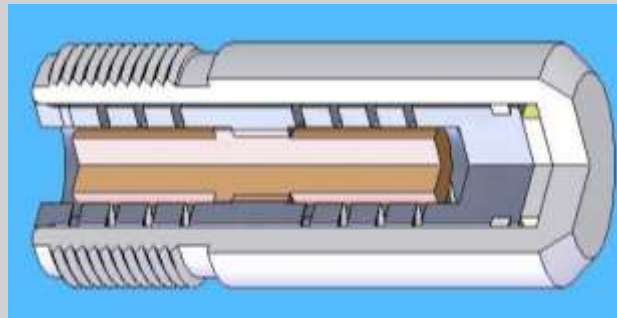
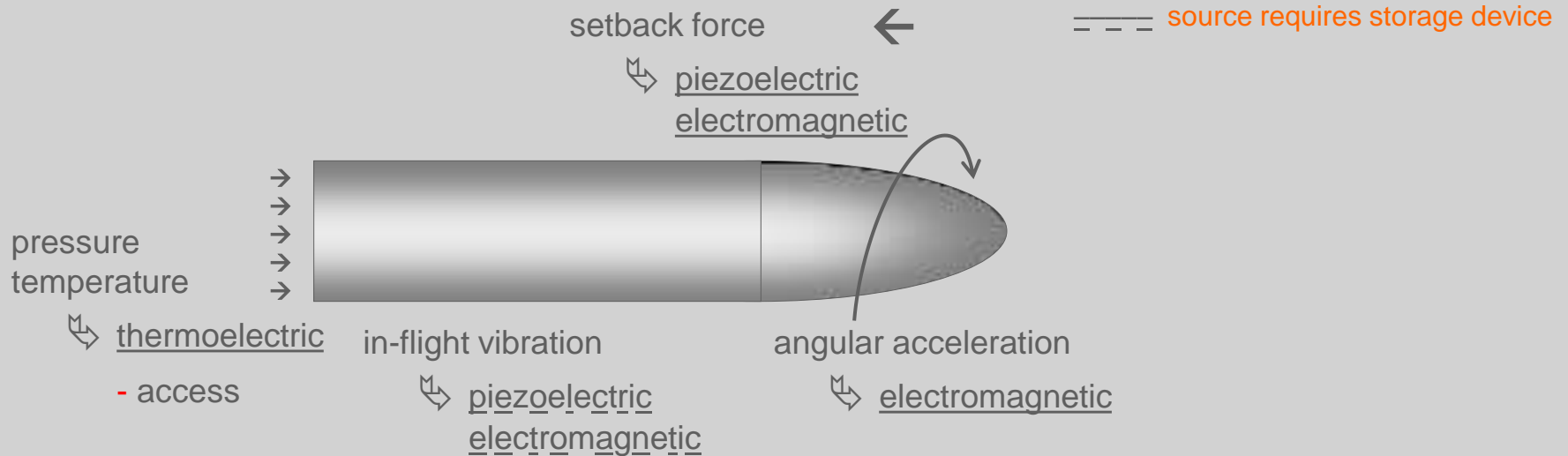
Alternative Energy Sources

- ◆ Where could the energy come from



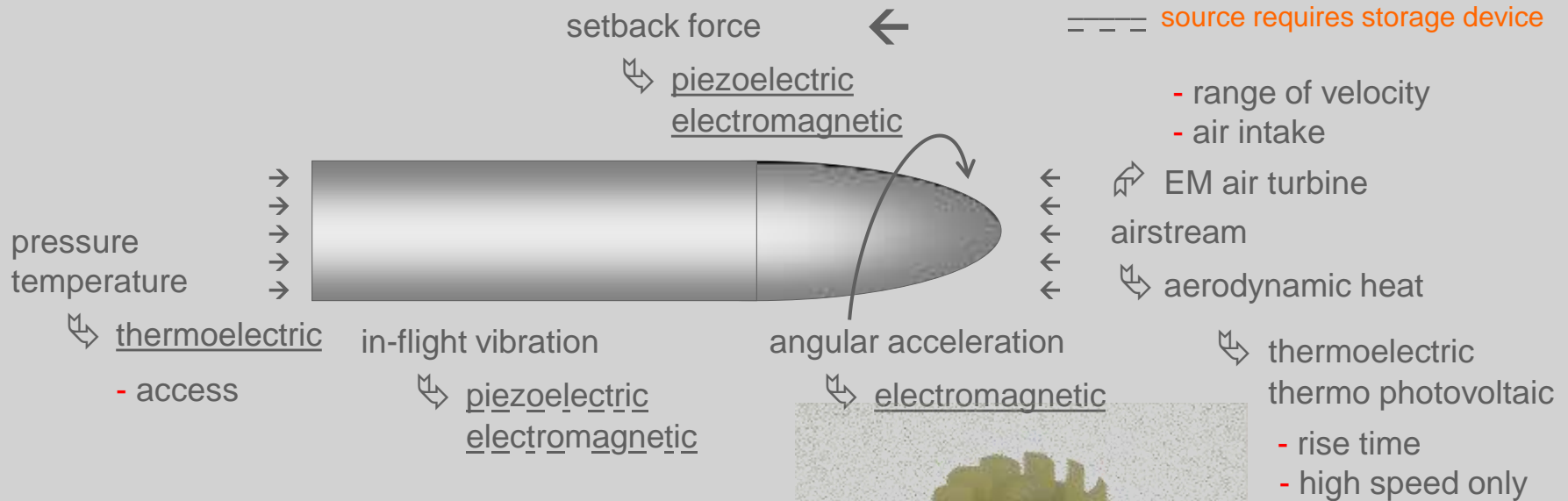
Alternative Energy Sources

- Where could the energy come from



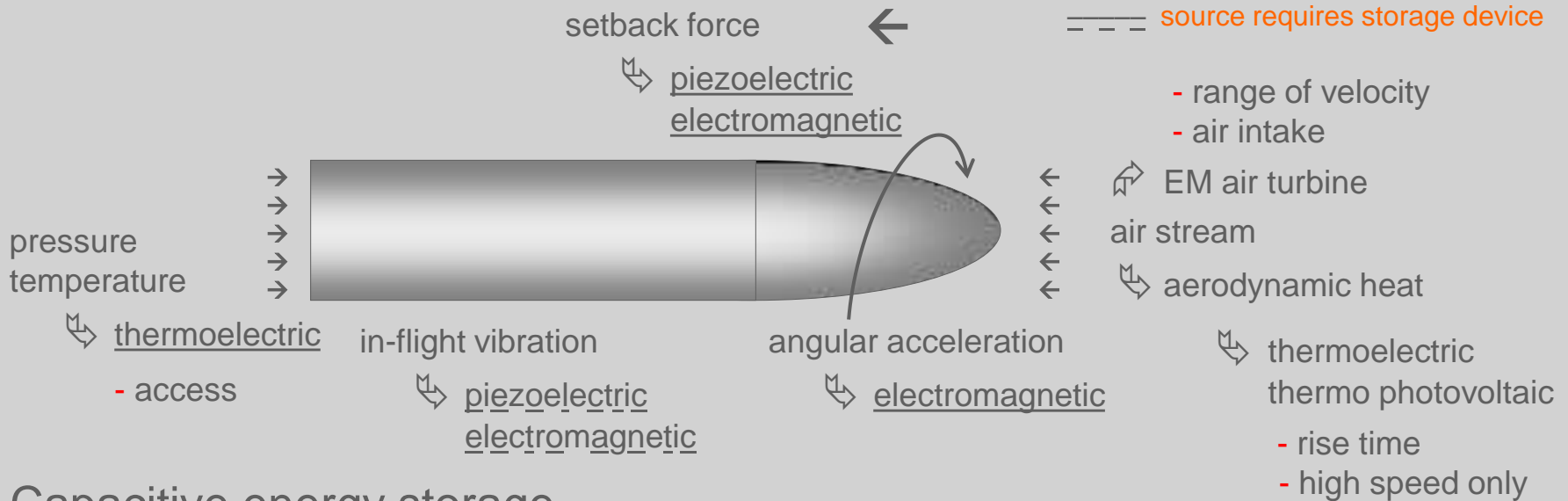
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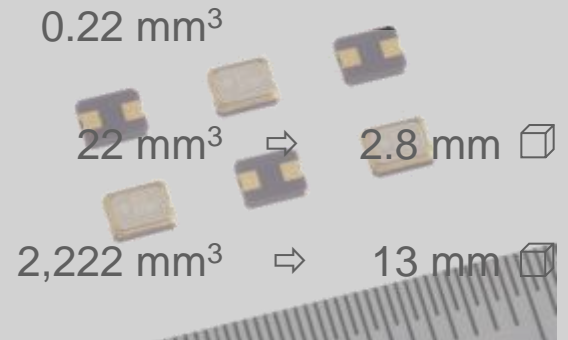
Alternative Energy Sources

◆ Where could the energy come from

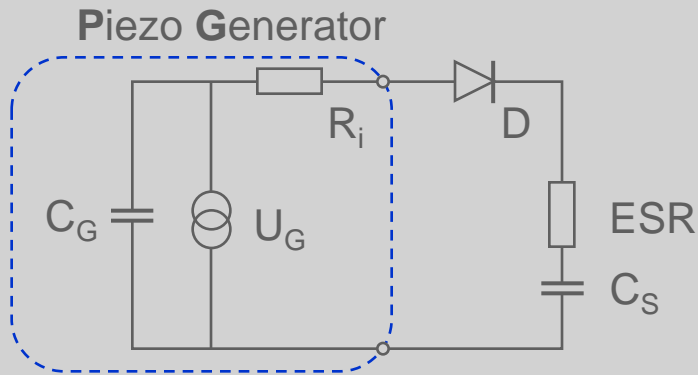


◆ Capacitive energy storage

storage of	1 mJ	@ 10 V ⇔	20 μF
		@ 30 V ⇔	2.2 μF
	100 mJ	@ 10 V ⇔	2000 μF
		@ 30 V ⇔	220 μF
	10,000 mJ	@ 10 V ⇔	0.2 F
		@ 30 V ⇔	0.022 F



◆ Charging and discharging the capacitor



PG-Voltage proportional to pressure (= acceleration)

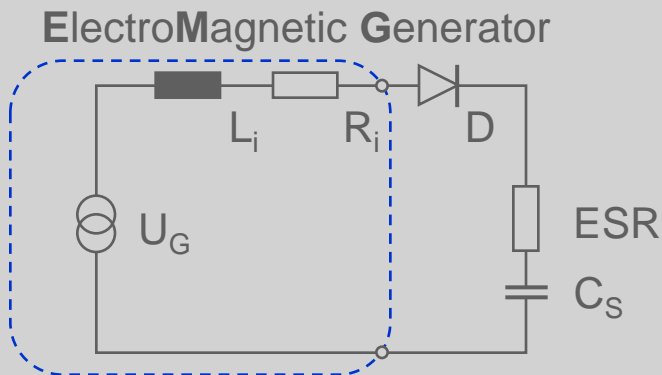
↪ peak voltage @ peak pressure
ms only ⇒ high currents, matching losses

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

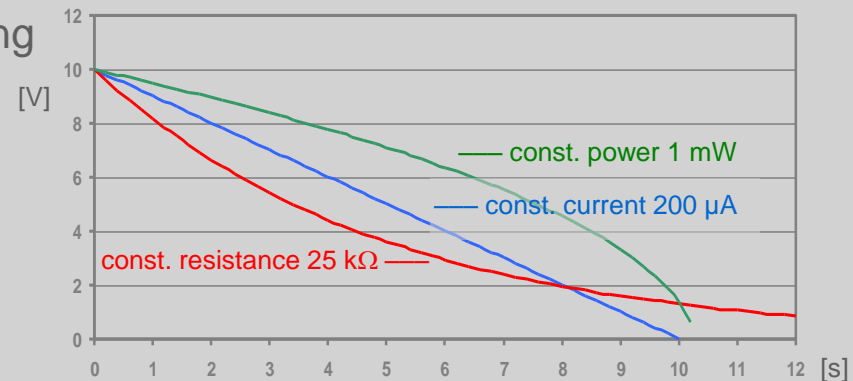
EMG-Voltage proportional to # of turns/inductance

↪ 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)



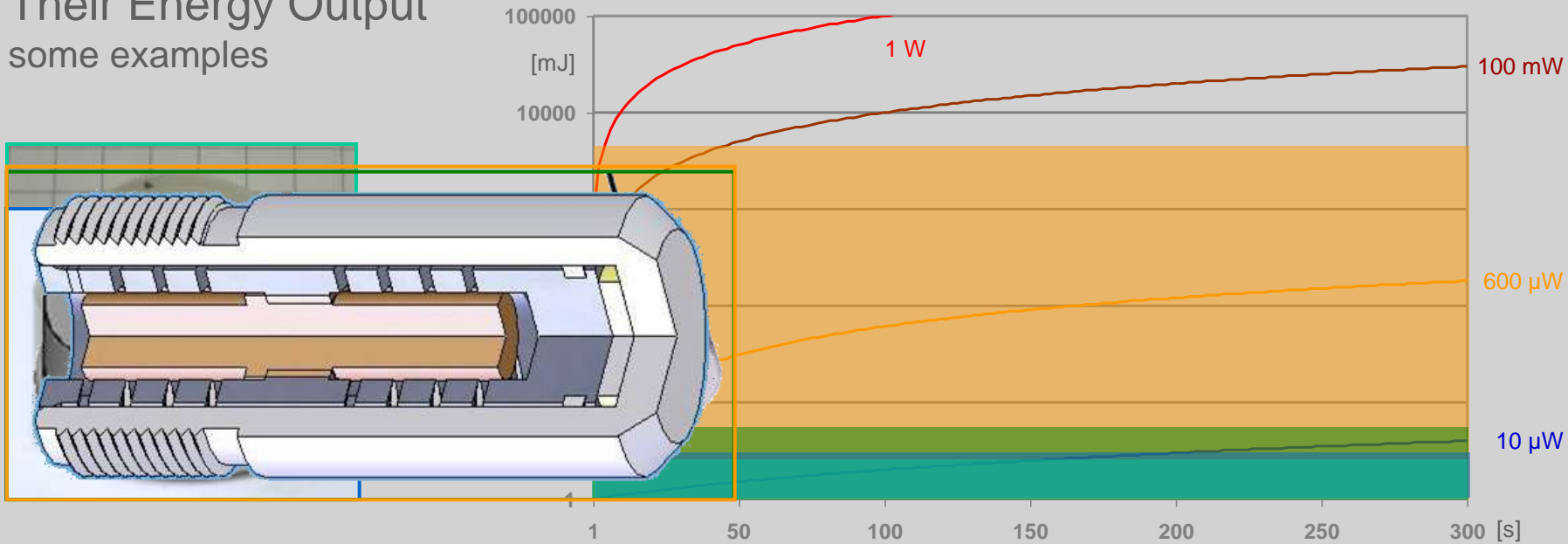
Discharging



No constant Voltage during discharge!

Alternative Energy Sources

- ◆ Their Energy Output
some examples



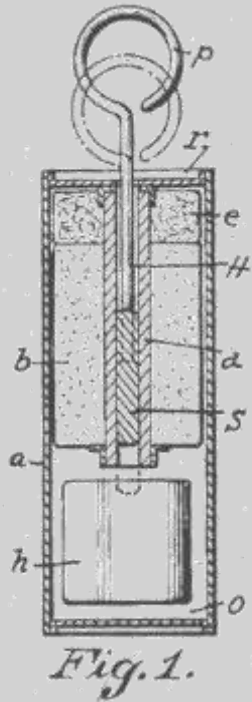
- ◆ My Conclusion

- no significant improvement of energy generated since 35 years
limited to
 - low energy pyrotechnics
 - short time of flight
 - simple functions

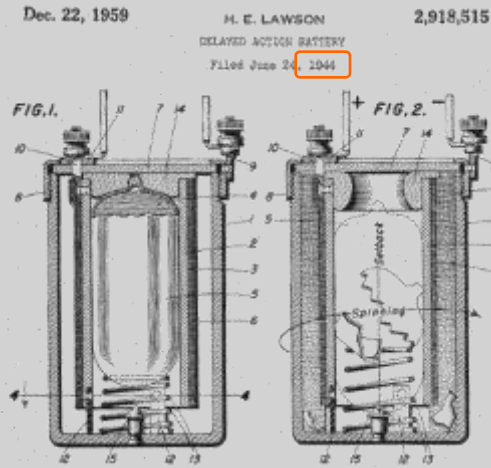
Liquid Reserve Batteries

◆ Legacy

K. STAMM
ELECTRIC DRY BATTERY
Filed Feb. 9, 1925



First Reserve Battery



Fuze Battery



Fuze Battery



MOFA Fuze Battery



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

LONG ENERGIZER
MK 5 MOD 2



Mk53 Fuze

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 $+63^\circ\text{C}$
 - superior activation mechanism
 - threefold MIL STD 883 1.5 m drop safety
 - $> 900 \text{ g}$ 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 @ $< 100 \text{ mA}$
- same form factor, same activation

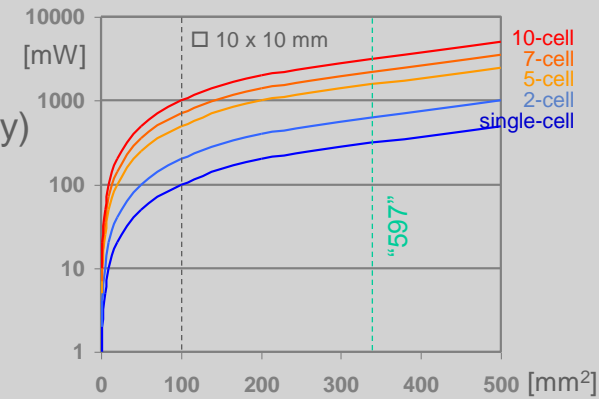


Liquid Reserve Battery future

◆ 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

- ◆ 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

- ◆ 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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