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
Requirements general

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

- Fuze Categories
  - PD
  - Detonator
    - 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

- **Fuze Categories**
  - PD (classical artillery)
  - SD (Det + Timer)

- **Power Consumption**
  - 2 µW (e.g. digital watch)
## Requirements

- **Fuze Categories**
  - **PD** Det
  - **SD** Det + Timer
  - **ET** Det + programmable Timer

### Classical artillery

- **600 µW** e.g. RFID-Circuit
Requirements

- Fuze Categories

  classical artillery

<table>
<thead>
<tr>
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<th>PD</th>
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⇒ 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**
  - 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 $\leq 10 \text{–} 20 \text{s}$ direct fire
  - medium $< 100 \text{ s}$ indirect fire Mortars
  - long $< 200 \text{ s}$ indirect fire Arty 105/155 mm
  - x-long up to 600 s gliding and/or powered

- **Energy**

![Energy Graph](image)
Alternative Energy Sources

- Where could the energy come from

- Pressure
- Temperature

- Thermoelectric
  - Access
Alternative Energy Sources

- Where could the energy come from

- pressure
- temperature
- setback force
  - piezoelectric
  - electromagnetic
- thermoelectric
  - access
- angular acceleration
  - electromagnetic

Source requires storage device
Alternative Energy Sources

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temperature

  ↩️ thermoelectric
  - access

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  ↩️ setback force

  ↩️ angular acceleration

  ↩️ in-flight vibration

  ↩️ electromagnetic

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- electromagnetc

source requires storage device
- range of velocity
- air intake
- EM air turbine
- airstream
- aerodynamic heat
- thermoelectric
- thermo photovoltaic
- rise time
- high speed only

setback force
Alternative Energy Sources

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- Capacitive energy storage

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<tr>
<th>Storage of</th>
<th>@ 10 V</th>
<th>@ 30 V</th>
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<tr>
<td>1 mJ</td>
<td>20 μF</td>
<td>2.2 μF</td>
</tr>
<tr>
<td>100 mJ</td>
<td>2000 μF</td>
<td>220 μF</td>
</tr>
<tr>
<td>10,000 mJ</td>
<td>0.2 F</td>
<td>0.022 F</td>
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Values in mm³:
- 0.22 mm³
- 22 mm³
- 222 mm³
- 0.2 µF
- 0.022 µF
- 2.8 mm
- 13 mm
Alternative Energy Sources

- Charging and discharging the capacitor

**Piezo Generator**

- 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)

**ElectroMagnetic Generator**

- EMG-Voltage proportional to # of turns/inductance
  - natural frequency $f_r = \left(2 \pi \sqrt{L_i C_s}\right)^{-1}$
- 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**

  - First Reserve Battery
  - Fuze Battery
  - MOFA Fuze Battery
  - Mk53 Fuze
Liquid Reserve Battery  current

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/cm² 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
  - Activation System

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
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

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