Small, high specific Energy Power Sources for Medium Caliber Fuzes

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Overview

- Terminology
- Fuze Power Requirements
- How much is this
- Specific Densities
- What’s around
- Conclusion and Future Work
Terminology

- Voltage
- Wh
- Power
- Ws
- Current
- W
- Coulomb
- C-Rate
- Joule
- OCV
- Capacity
- 5 C
- mAh
- Impedance
- C/5
- Energy
- As
Terminology

- The Electric Circuit

- Voltage [V] x Current [A] = Power [W]
- Current [A] x Time [s] = Capacity [As, Ah]
- \( \frac{1}{\text{Discharge Time [h]}} = \text{C-Rate} \)
What is needed for a Fuze

- Power/Energy Requirement depends on
  - Complexity of Fuze
    - Igniter Circuit
    - Functions
    - Speed
  - Component Selection
  - Design
  - Flight Time

Hear more in # 16521
What is needed for a Fuze

- Legacy Large Caliber Fuzes
What is needed for a Fuze

- New Medium Caliber Fuzes

![Graph showing the relationship between Voltage (U) and Power (P) with various energy levels.]
How much is that

- A few comparisons
Specific Densities

- Why is that so important to you?
  - Power Sources are characterized by capacity
    - Per weight
    - Per volume
  - Fuzes are usually restricted by volume
Specific Densities

- **Energy vs Power**
  - **Beta Batt**
    - Energy: 40 J / mm³ → very high
    - Power: 125 nW / mm³ → very low
  - **ELDC**
    - Energy: 4 mJ / mm³ → low
    - Power: 125 mW / mm³ → high

*Example: LTC-Primary Battery*
Specific Densities

- C-Rate
  - Tesla Roadster 56 kWh (≈ 200 MJ), max Power 215 kW → 4 C
  - Fuze Battery Large Cal (e.g. 500 J) 200 s (≈ 1/20 h) → 20 C
    Medium Cal (e.g. 5 J) 20 s (≈ 1/200 h) → 200 C!

⇒ If the Battery can manage only 4 C (like a Tesla Roadster)
   it needs 50 times the Capacity the Fuze requires!
What’s around

- Legacy

„Baghdad Batterie“
250 BC

„Patent K. STAMM“
1925

„Duracell AR-13D“
1971
What’s around

- Capacitors
  - Power Density
  - Energy Density; $- \frac{J}{mm^3}$
  - How to charge

- Set-Back Generators; Piezo; Electromagnetic
  - Power Density
  - Energy Density; $< 10 \ \mu J/mm^3$
  - Short Pulse only
What’s around

- Fuze Batteries miniaturized

**DEP-14103**
- 3 J; 3 \( \text{mJ/mm}^3 \)
- 50 mW
- Ø 11 mm; h 11 mm

**DEP-14104**
- 10 J; 7 \( \text{mJ/mm}^3 \)
- 75 mW
- Ø 10/11 mm; h 10/13 mm

**DEP-14202**
- 100 J; 50 \( \text{mJ/mm}^3 \)
- 500 mW
- Ø 10/20 mm; h 3/11 mm
What’s around

- A novel solution

  - Converter + Heat Source → Thermo Electric Generator

  ▶ in barrel heating
  ▶ aerodynamic heating
  ▶ pyrolants (fuel)

$$\eta_{\text{Max}} = \frac{T_{\text{hot}} - T_{\text{cold}}}{T_{\text{hot}}} \cdot \frac{\sqrt{1 + Z_M \cdot \bar{T}} - 1}{\sqrt{1 + Z_M \cdot \bar{T}} + \frac{T_{\text{cold}}}{T_{\text{hot}}}}$$

$$E = \int_{0}^{\infty} P(t)$$
What’s around

- **TEPS**
  - High Energy Density Fuel $4 \text{ J/mm}^3$
  - High burning Temperature
  - Independent of operating Temperature ($\Delta \vartheta$-principle)
What’s around

- **TEPS**
  - Max Power at Start
  - Longer Power than Set-Back
    - Easy charge of
    - Small capacitor
  - High Energy Density
  - Independent of Spin

![Graph showing voltage and energy over time for different heat pellets.](image-url)
What’s around

• TEPS

DEP-15001

100 mJ; 100 μJ/mm³
100 mW
Ø 12.6 mm; h 12.5 mm

DEP-15030

200 mJ; 120 μJ/mm³
200 mW
Ø 17 mm; h 12.5 mm

DEP-15060

2000 mJ; 650 μJ/mm³
1000 mW
Ø 23.6 mm; h 12.5 mm

• Easy to scale Voltage, Energy, Life-Time, Size
Conclusion and Future Work

- Two new Product Lines of small Fuze Power Supplies
- Meet all known Requirements
- Significant increased Energy Density
- Excellent Power Density
- Spinning and Non-Spinning

Future work
- Manufacturability
- Live-Firing
- Qualification
Thank you for your attention!

Questions?
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