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

- The Electric Circuit

- Voltage [V] x Current [A] = Power [W]
- Current [A] x Time [s] = Capacity [As, Ah]
- \[ \frac{\text{Power [W]}}{\text{Energy [Wh]}} \text{ or } \frac{1}{\text{Discharge Time [h]}} = \text{C-Rate} \]
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
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: $J/\text{mm}^3$
    - How to charge
- Set-Back Generators; Piezo; Electromagnetic
  - Power Density
    - Energy Density: $< 10 \mu J/\text{mm}^3$
    - Short Pulse only
What’s around

- Fuze Batteries miniaturized

**DEP-14103**
- 3 J; 3 mJ/ mm³
- 50 mW
- Ø 11 mm; h 11 mm

**DEP-14104**
- 10 J; 7 mJ/ mm³
- 75 mW
- Ø 10/11 mm; h 10/13 mm

**DEP-14202**
- 100 J; 50 mJ/ mm³
- 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 ($\Delta \varphi$-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
What’s around

- **TEPS**

**DEP-15001**

- 100 mJ; 100 $\mu$J/mm$^3$
- 100 mW
- Ø 12.6 mm; h 12.5 mm

**DEP-15030**

- 200 mJ; 120 $\mu$J/mm$^3$
- 200 mW
- Ø 17 mm; h 12.5 mm

**DEP-15060**

- 2000 mJ; 650 $\mu$J/mm$^3$
- 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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