DIEHL & EAGLE PICHER
Batterie-Systeme

Small, high specific Energy Power Sources for Medium Caliber Fuzes

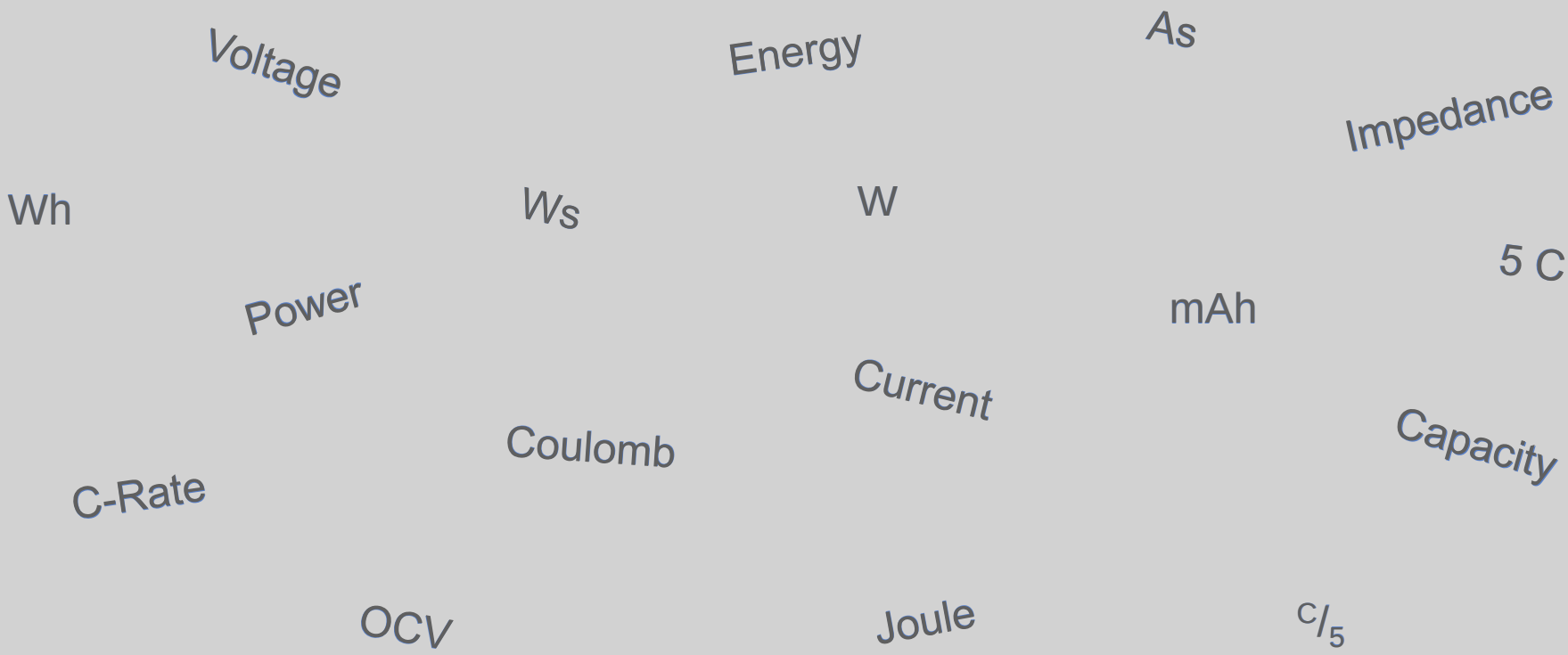
57th Annual Fuze Conference
July 30th, 2014
Harald Wich
Diehl & Eagle Picher GmbH

Overview

DIEHL & EAGLE PICHER
Batterie-Systeme

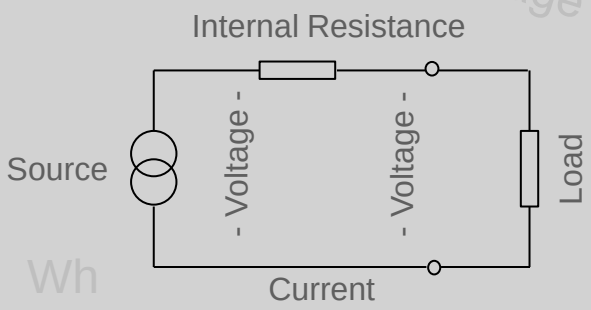
- Terminology
- Fuze Power Requirements
- How much is this
- Specific Densities
- What’s around
- Conclusion and Future Work

Terminology



Terminology

- The Electric Circuit



- Voltage [V] x Current [A] = Power [W]
- Power [W] x Time [s] = Energy [Ws = J]

+ Current [A] x Time [s] = Capacity [As, Ah]

+ $\frac{\text{Power [W]}}{\text{Energy [Wh]}}$ or $\frac{1}{\text{Discharge Time [h]}}$ = C-Rate

What is needed for a Fuze

DIEHL & EAGLE PICHER
Batterie-Systeme

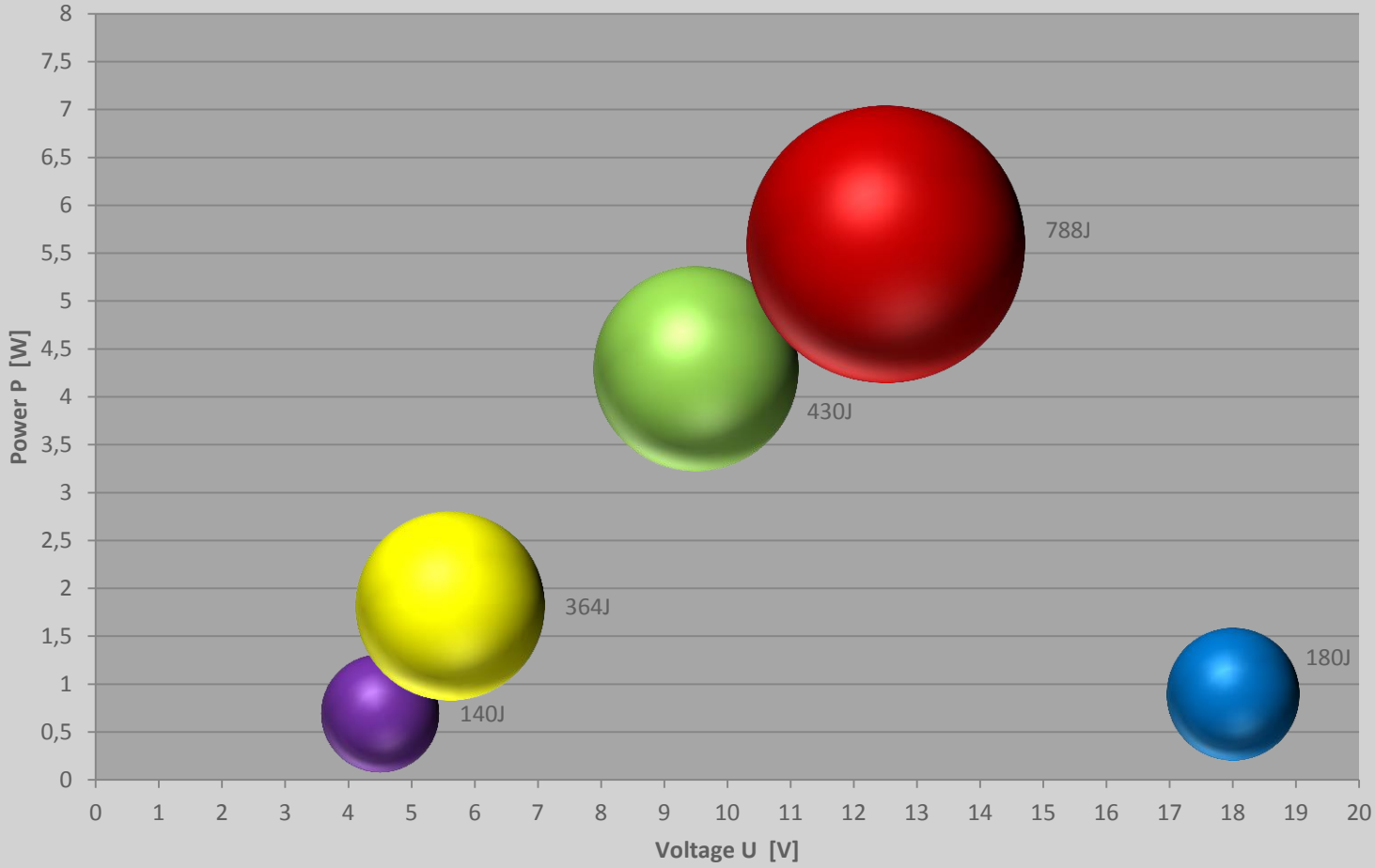
- Power/Energy Requirement depends on
  - Complexity of Fuze
    - Igniter Circuit
    - Functions
    - Speed
    -
    -
  - Component Selection
  - Design
  - Flight Time

Hear more in # 16521

What is needed for a Fuze

DIEHL & EAGLE PICHER
Batterie-Systeme

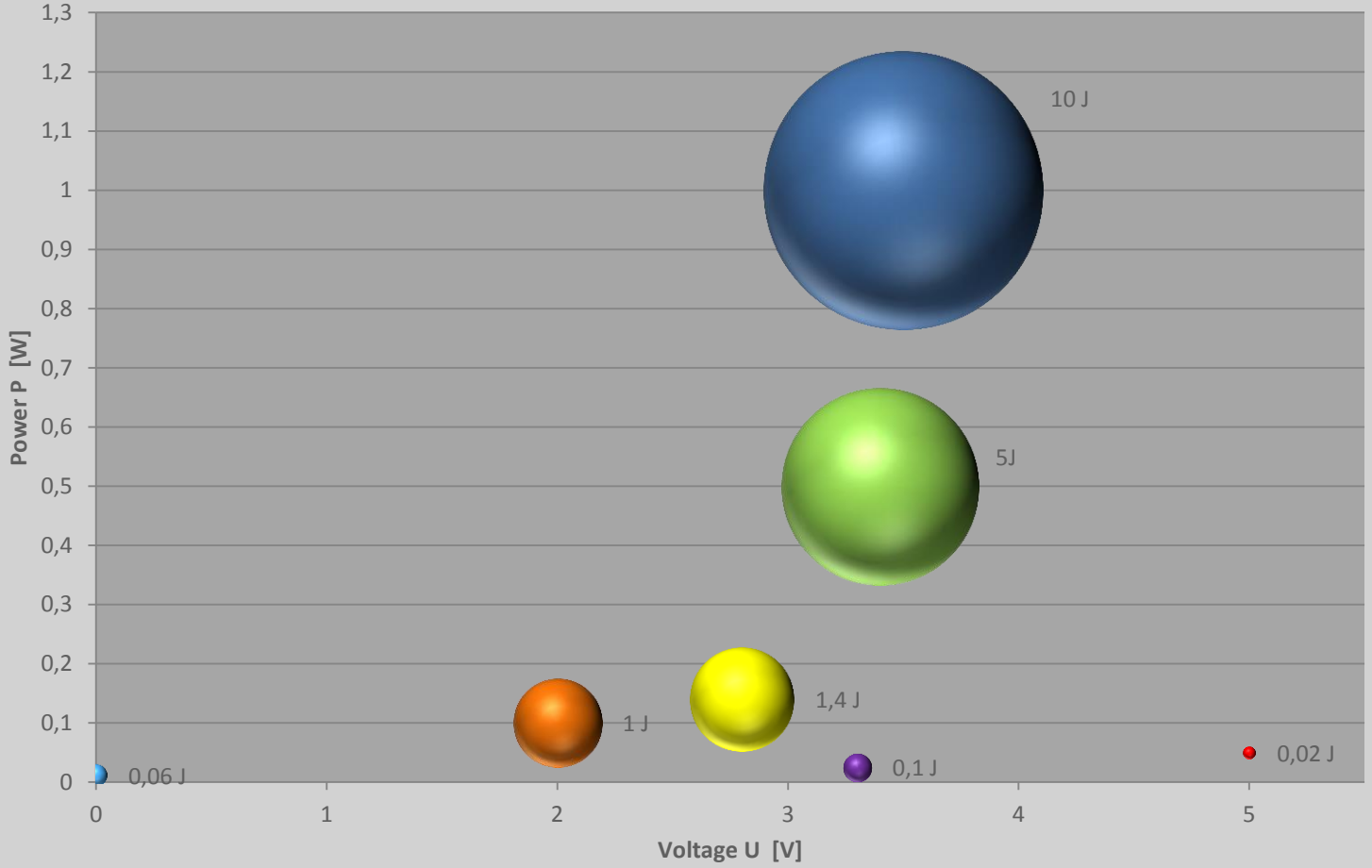
- Legacy Large Caliber Fuzes



What is needed for a Fuze

DIEHL & EAGLE PICHER
Batterie-Systeme

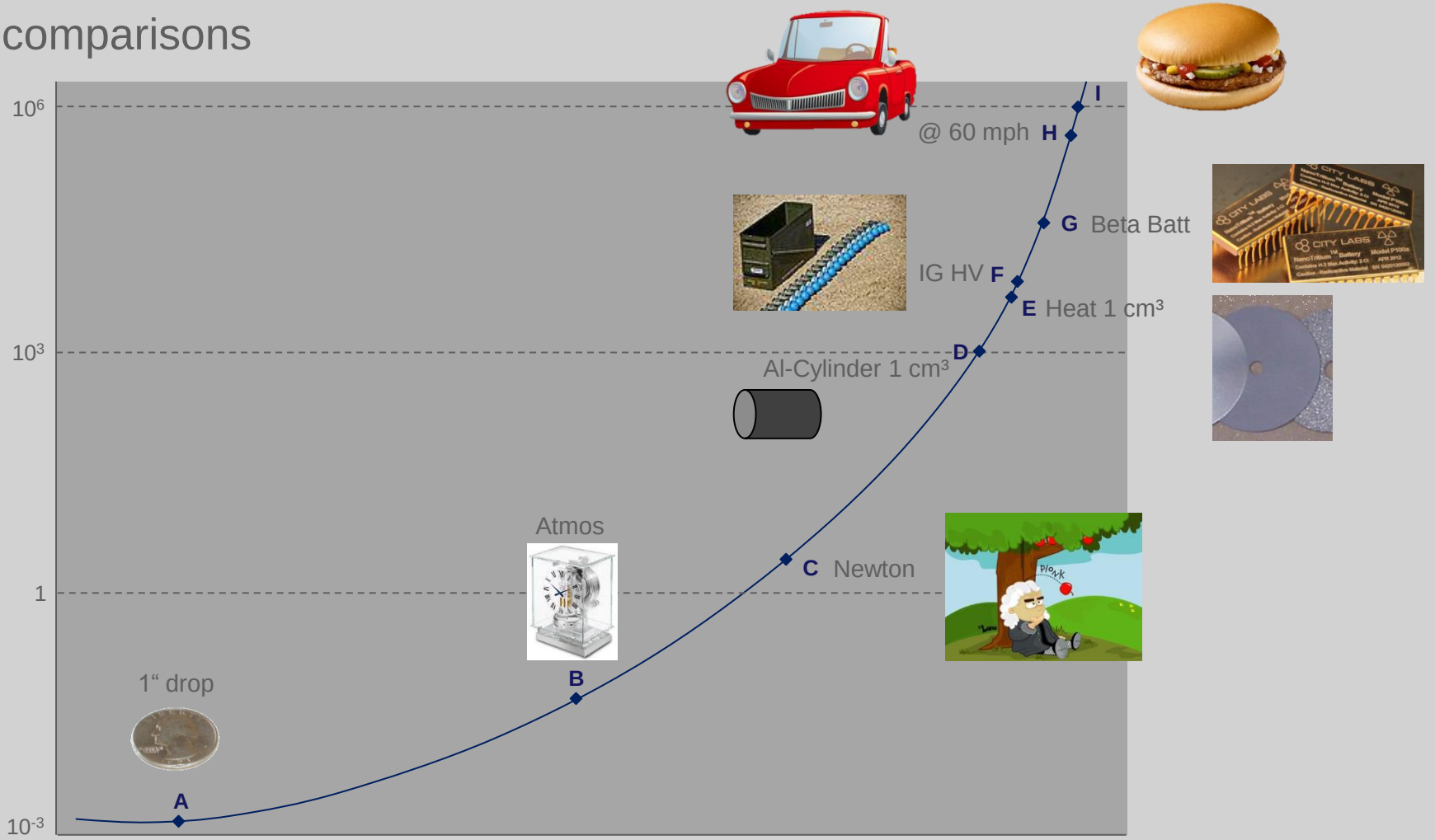
- New Medium Caliber Fuzes



How much is that

DIEHL & EAGLE PICHER
Batterie-Systeme

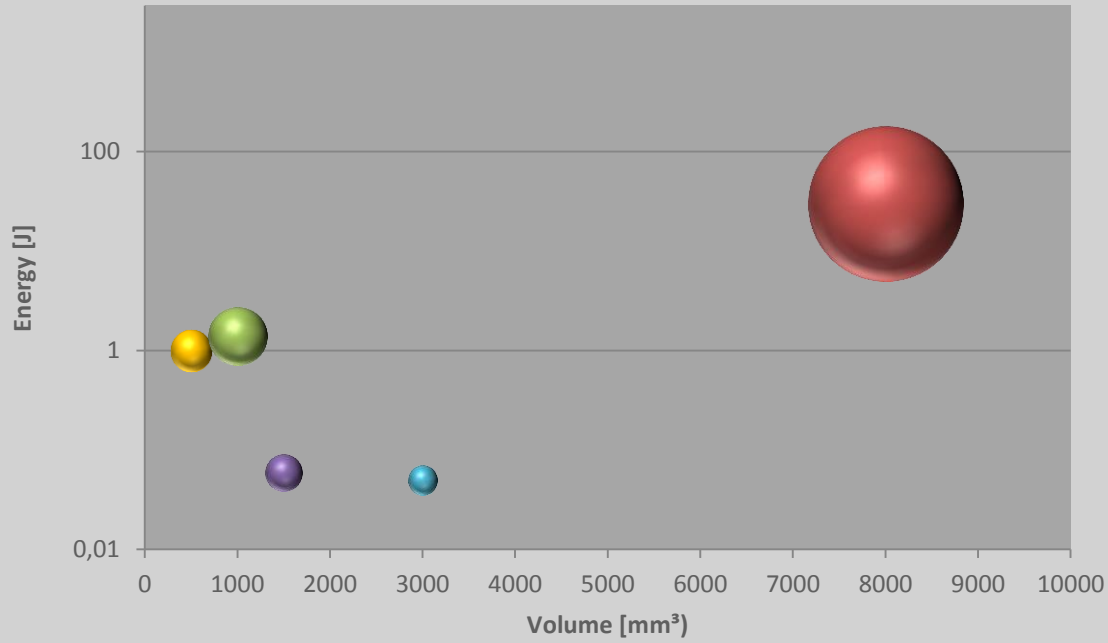
- A few comparisons



Specific Densities

DIEHL & EAGLE PICHER
Batterie-Systeme

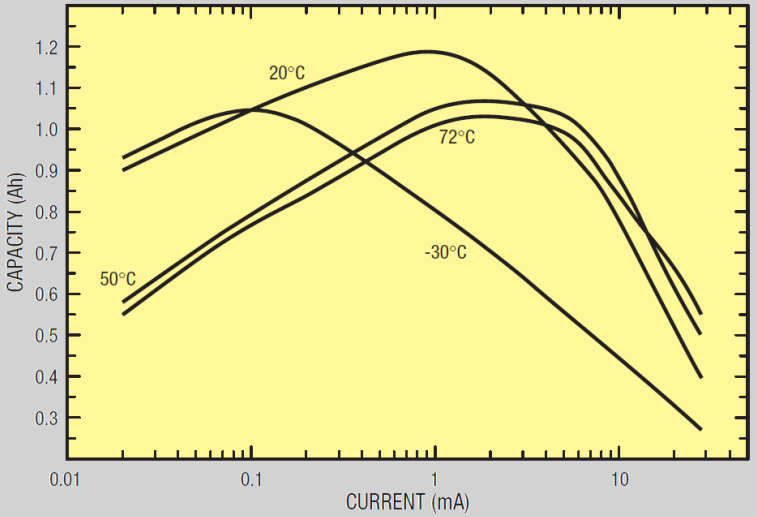
- Why is that so important to you?
  - Power Sources are characterized by capacity
    - Per weight
    - Per volume
  - Fuzes are usually restricted by volume



Specific Densities

DIEHL & EAGLE PICHER
Batterie-Systeme

- 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

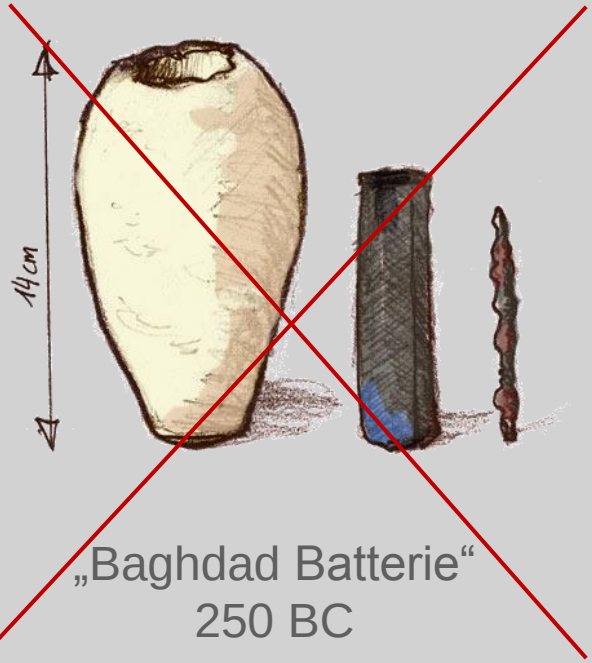
DIEHL & EAGLE PICHER
Batterie-Systeme

- 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** !

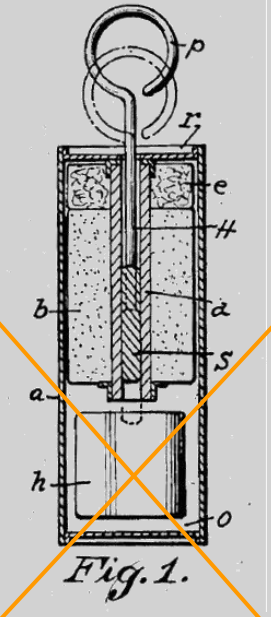
⇨ If the Battery can manage only 4 C (like a Tesla Roadster)
it needs 50 times the Capacity the Fuze requires !

What's around

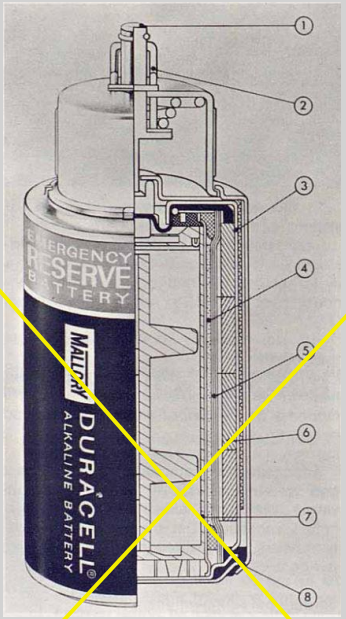
- Legacy



„Baghdad Batterie“
250 BC



„Patent K. STAMM“
1925



„Duracell AR-13D“
1971

What's around

DIEHL & EAGLE PICHER
Batterie-Systeme

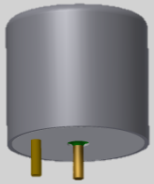
- Capacitors
  - \+ Power Density
  - – Energy Density; - $^{J}/_{mm^3}$
  - – How to charge
- Set-Back Generators; Piezo; Electromagnetic
  - \+ Power Density
  - – Energy Density; < 10 $^{\mu J}/_{mm^3}$
  - – Short Pulse only

What’s around

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Batteries miniaturized

DEP-14103



3 J; 3 $^{mJ}/_{mm^3}$

50 mW

Ø 11 mm; h 11 mm

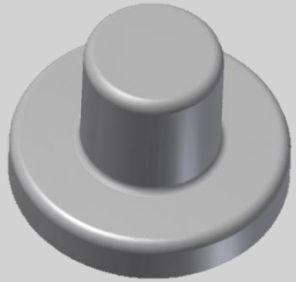
DEP-14104

10 J; 7 $^{mJ}/_{mm^3}$

75 mW

Ø 10/11 mm; h 10/13 mm

DEP-14202



100 J; 50 $^{mJ}/_{mm^3}$

500 mW

Ø 10/20 mm; h 3/11 mm

What's around

DIEHL & EAGLE PICHER
Batterie-Systeme

- A novel solution
  - Converter + Heat Source → in barrel heating / aerodynamic heating / pyrolants (fuel)
    ↓
    Thermo **E**lectric **G**enerator

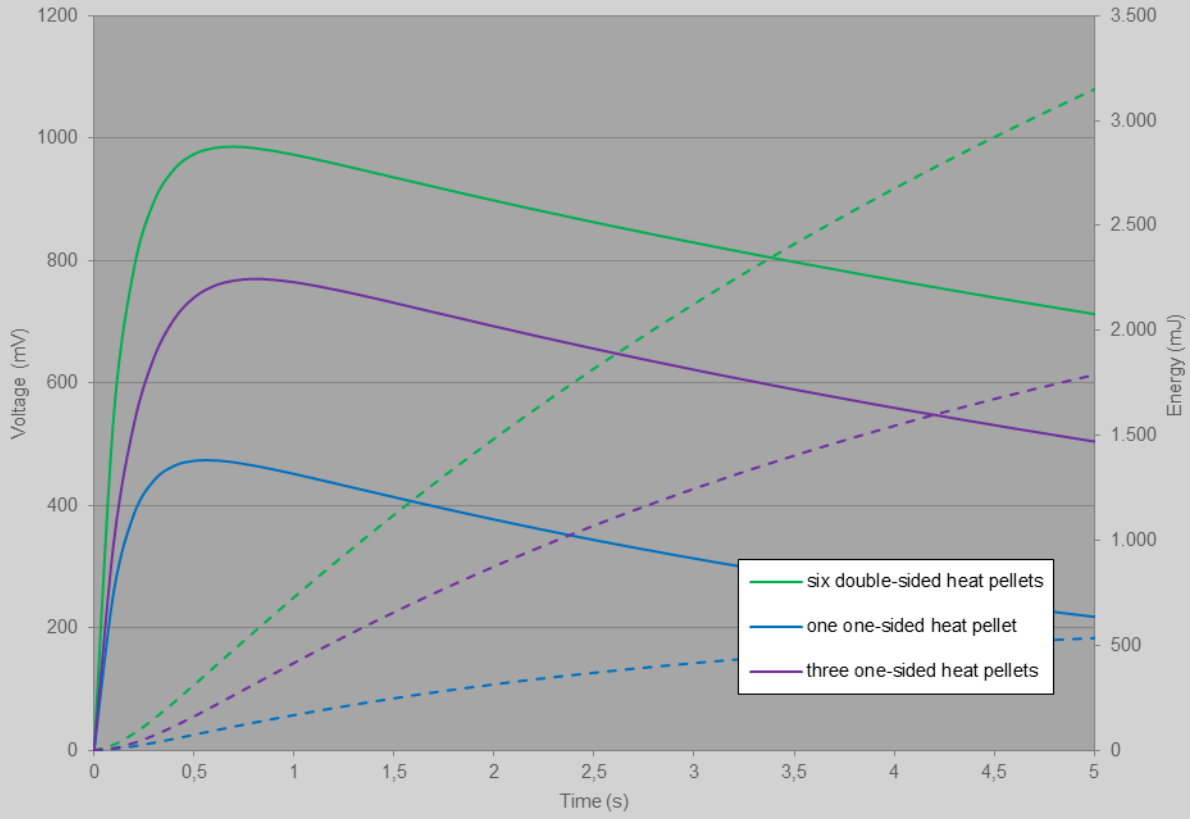
$$\eta_{Max} = \frac{T_{hot} - T_{cold}}{T_{hot}} \cdot \frac{\sqrt{1 + Z_M \cdot \overline{\overline{T}}} - 1}{\sqrt{1 + Z_M \cdot \overline{\overline{T}}} + \frac{T_{cold}}{T_{hot}}}$$

$$E = \int_{\circ}^{\infty} P\,(t)$$

What's around

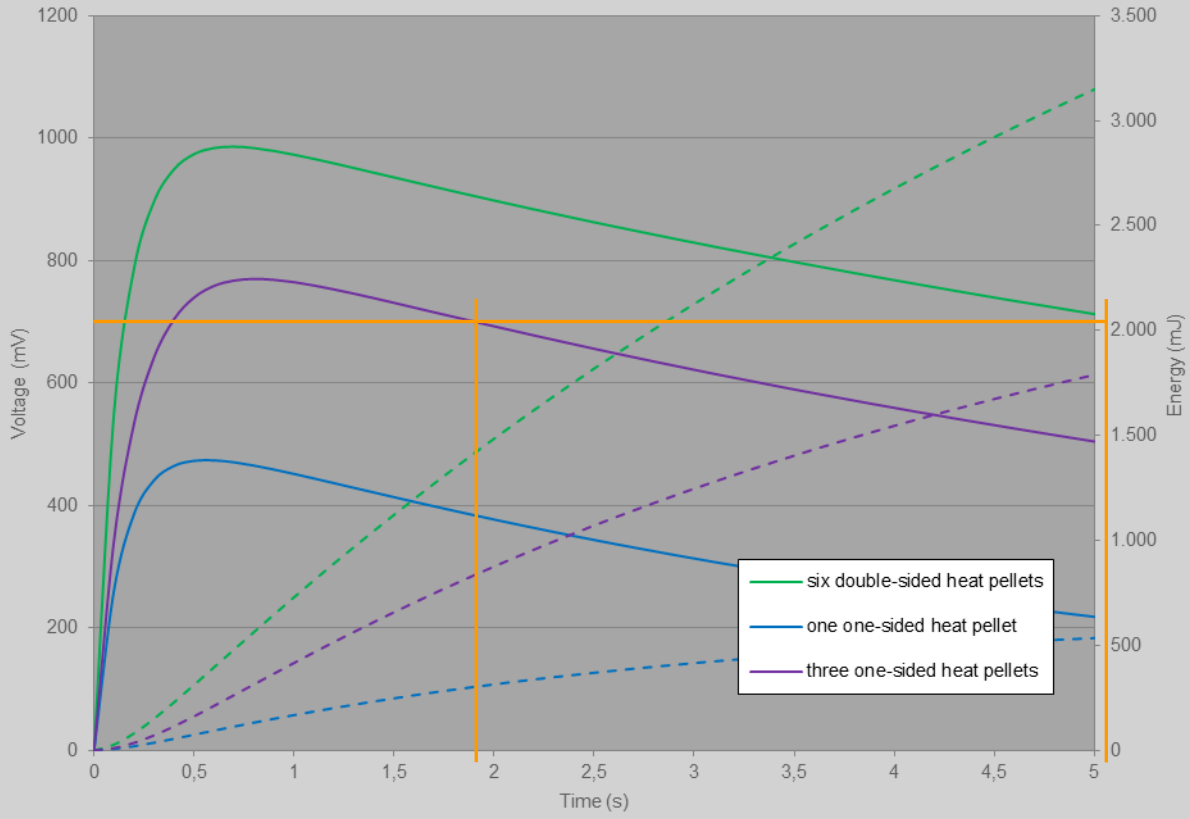
DIEHL & EAGLE PICHER
Batterie-Systeme

- TEPS
  - High Energy Density Fuel 4 $^{J}/_{mm^3}$
  - 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



What's around

DIEHL & EAGLE PICHER
Batterie-Systeme

- TEPS

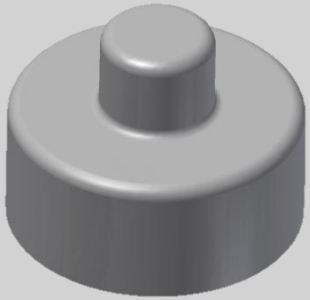
DEP-15001

100 mJ; 100 $^{\mu J}/_{mm^3}$

100 mW

Ø 12.6 mm; h 12.5 mm

DEP-15030

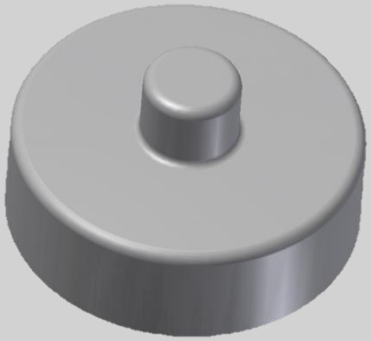


200 mJ; 120 $^{\mu J}/_{mm^3}$

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

DIEHL & EAGLE PICHER
Batterie-Systeme

- 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

DIEHL & EAGLE PICHER
Batterie-Systeme

Thank you for your attention!

Questions?

Diehl & Eagle Picher Contact

DIEHL & EAGLE PICHER
Batterie-Systeme

- How to Contact us
  - Presenter — Harald Wich
  - Mail — Diehl & Eagle Picher GmbH
Fischbachstrasse 20
90552 Roethenbach a d Pegnitz
Germany
  - Phone — +49-911-957-2073
  - Fax — +49-911-957-2485
  - Email — harald.wich@diehl-eagle-picher.com
  - Web — www.battery.de