Design evolution of setback generators – based on the increased demand of energy

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Company history RWM Zaugg AG (Switzerland)

1963
- Location: Derendingen

1972
- Transformation to a Limited Company.
- Trade name is „Zaugg Elektronik AG“

1973
- New location Lohn-Ammannsegg

1995
- Spin-off „Motor control business“
  - Focus on defense business

2000
- Acquisition of the fuze division
  - from EMS-PATVAG AG

2001
- Management buy-out

2007
- Rheinmetall acquires 100% of the company.
- New trade name is “RWM Zaugg AG”
RWM Zaugg AG, CH-4573 Lohn Ammannsegg, Switzerland

We are located in the Heart of Swiss Watchmakers (Swatch / Breitling / Rolex)

- **Year of construction:** 1973
- **Floor space:** 1'340m²
- **Building volume:** 3'954m³
- **Covert area:** 2'000m²
- **Expansion land:** 1'954m²
Portfolio:

- High-g and energy independent fuzes
- Setback Generators
- 40 mm low, medium and high velocity fuzes
- Programmable fuzes
- High-g electronics
- Manufacturing and development competences
Setback Generators for medium and large calibre

- Medium and high-g applications
- For 30-35 mm, 40 mm and 120 mm calibre
- High energy content
- No additional energy source required
**Setback Generators**

### Specifications of Zaugg Set-Back Generators:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>GEN-15.200</th>
<th>GEN-20.200</th>
<th>VELAN.270</th>
<th>RTF 1147</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum voltage [V]:</td>
<td>25</td>
<td>15 / 60</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Temperature range [°C]:</td>
<td>-54 till +71</td>
<td>-46 till +63</td>
<td>-46 till +63</td>
<td>-32 till +63</td>
</tr>
<tr>
<td>Maximum energy [mJ]:</td>
<td>9.4</td>
<td>6.53</td>
<td>7.65</td>
<td>8.7</td>
</tr>
<tr>
<td>Size [mm]:</td>
<td>Ø 15.05 x 8.43 (15.63)</td>
<td>Ø 19.55 (29.8 x 12.05)</td>
<td>Ø 10.9 x 20.8</td>
<td>Ø 11.9 x 26</td>
</tr>
<tr>
<td>Weight [g]:</td>
<td>7.156</td>
<td>15.62</td>
<td>3.38</td>
<td>6.6</td>
</tr>
<tr>
<td>Electrical interface:</td>
<td>Storage capacitor: 30 µF</td>
<td>Storage capacitors: 5.25 µF / 3.3 µF</td>
<td>Storage capacitor: 68 µF</td>
<td>s</td>
</tr>
<tr>
<td>Mechanical interface:</td>
<td>Ø 6.4 mm</td>
<td>Ø 6.4 mm</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Functional parameters:</td>
<td>Requested</td>
<td>≥ 13000 g</td>
<td>≥ 700 g</td>
<td>≥ 13'000 g</td>
</tr>
<tr>
<td>Typical applications</td>
<td>Customer specific</td>
<td>Customer specific</td>
<td>40mm infantry</td>
<td>120m tank</td>
</tr>
</tbody>
</table>
Need for Energy constantly claimed!

There is a constant need for small Energy Power Systems!

There is decreasing energy consumption due to increase of low consuming electronics!


Fuze Conf. 2014: „Quo Vadis Fuze (Power)?“
A look back in ‘history:

Energy sources (1977)

- low energy requirements
  - Induction - pulse or rotation generator
  - Piezo – pulse or rotation generator

- high energy requirements
  - Rotating generators
    - Wind, airstream
  - Batteries
    - with an without self-activation

From: „Handbook on Weaponry“, Rheinmetall 1977

Capsitors

Used only for load accumulation
What is used until today? Has something changed?

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserve Battery</td>
</tr>
<tr>
<td>Medium Primary Cell</td>
</tr>
<tr>
<td>Setback Generator (electromagnetic)</td>
</tr>
<tr>
<td>Piezo Setback Generator</td>
</tr>
<tr>
<td>Wind-Generators</td>
</tr>
</tbody>
</table>

→ No! All items mentioned in the handbook from 1980 are unchanged! No new technologies in service.

→ New technologies had been worked in that decades. A lot of them could not be applied due to the severe environmental requirements of fuzes or they are yet not ready for industrialization.
A Renaissance for setback generators?

Technical parameters of setback generators

- **Energy density**
  - setback generator: <10mJ
  - As high as needed by electronics, sensors, ignition; no system known about 10mJ! Typical: 2-3 mJ

- **Space requirements**
  - As low as possible, disadvantage: High dead volume due to displacement of magnet

- **Activation mechanism**
  - Why? → Stanag: No „stored Energy“ → Activated by setback, advantage: reliable, disadvantage dependent on acceleration curve

- **Duration of supply**
  - Energy should be provided for typical combat distances, disadvantage: energy is supplied by a short pulse → energy storage (capacitor) is needed

- **Hardness against environmental stress (esp. shock)**
  - Can relatively easily be achieved

- **System Safety**
  - System Safety must not be reduced by energy source

- **Maintainability**
  - Not necessary – infinitive lifetime

- **Costs and availability**
  - Definitively no off the shelf product – high IPR level requ.

→ Setback Technology still provides valuable benefits!
Design evolution of setback generators

Function principle of a setback generator

\[ U(t) \sim - \frac{d\Phi}{dt} \sim v_{mag} \]

Static state: Setback magnet is hold by magnetic force.

- cap
- setback magnet
- coil
- housing
- vent duct
Design evolution of setback generators

Question: How can we achieve an optimization?

- Travel path of the magnet can be increased! In the example, the magnet stops before leaving the coil completely.

- Vent duct in cap to avoid any low pressure area which retards movement of setback magnet. In the example, there is only a vent duct at the end.

- Holding mechanism/retention force of setback magnet to be adapted to expected acceleration. In the example, the setback magnet is held by magnetic force.

- Adaptation of the electric circuit for storing an optimized amount of energy in the capacitors.

For these optimization items, methods and tools were developed.
Design evolution of setback generators

Comparison of different acceleration curves

- 27mm medium caliber
- 30mm soft recovery facility EZO -35°C
- 40mm infantry LV
- 40mm infantry HV
- 90mm shoulder launched
- 120mm tank -46°C
- 120mm tank +10°C
- 120mm tank +21°C
- 120mm tank +63°C
Example setback generator RTF1147 tank fuze

Energy concept: use of an specifically optimized set-back generator

With respect to the acceleration, inertia and the rate of time distance equations the voltage achieved from a munition with shown acceleration curves is too low.

-> Optimization is necessary: Lift of holding force of magnet can bring desired effect.
Optimization Setback Generator

- Significant increase of holding force by crash pin (safety bolt)
- Tool for design and calculation of setback generators was created
- Modified setback generator continuously tested in self financed development program with support of EMI and EZO

![Graph showing holding force](chart1.png)

- Holding force approx. 4500g

![Graph showing velocity](chart2.png)

- V approx. 30 m/s

\[
U(t) \sim - \frac{d\Phi}{dt} \sim v_{mag}
\]

Modified setback generator

Modified magnet with holding screw
Development tools for setback generators

Ability to simulate design effects on setback generators enabled quick technology push in actual running activities/projects → easy software tool on Excel basis!
Measurements & Results

Comparision of measurements and simulation results

- small phaser shift can be observed
- amplitudes relate very well
Result

An energy amount between 7-9 mJ were reached and validated under real firing.

(up to 150% more)

This is remarkable!
Summary

- Chosing or adapting any setback generator off-the-shelf only in order to fit the actual fuze design is not sufficient

- In order to obtain an optimized energy output, setback generators must be adapted to the application in relation to
  - acceleration during firing (Input)
  - Voltage Output
  - optimal design

- Tools were created to optimize these parameters with regard to the application

- Setback generators are still a viable power source for many fuze applications
Thank you very much for your attention!
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