



COMBAT SYSTEMS

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Charleston, SC

NDIA
National Defense Industrial Association

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

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Company history RWM Zaugg AG (Switzerland)



1963

*Company founded by S. & R. Zaugg.
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

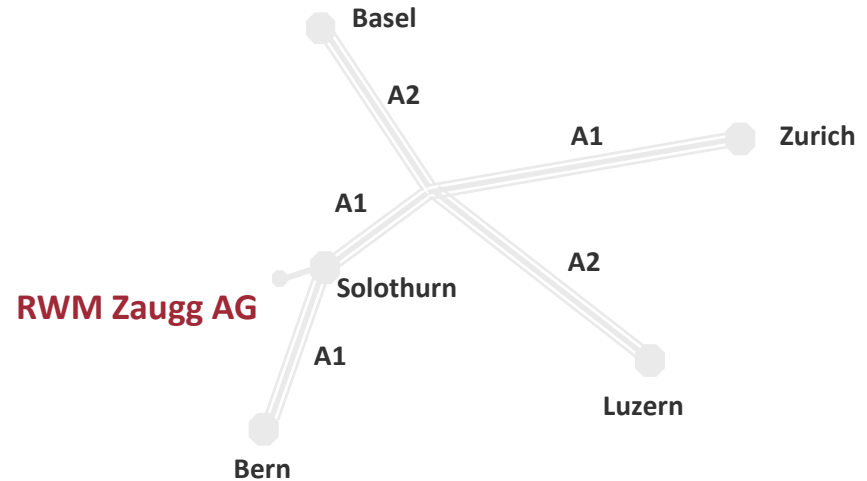
Management buy-out

2007

*Rheinmetall acquires 100% of the company.
New trade name is “RWM Zaugg AG”*



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:

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

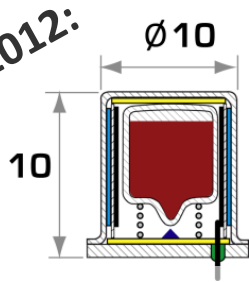
Need for Energy constantly claimed !



S.H. Yoon, 2005



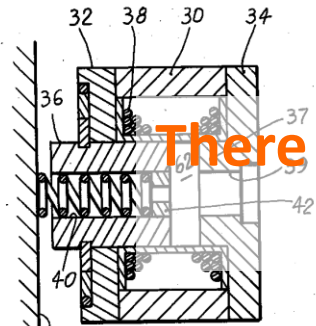
O. Clesca, Fuze Conf. 2012:
20J Battery



이용한 관상력 발전장치 소형화 설계
Generators Using Ring-Shaped Magnet
of Small-Caliber Electronic Fuze
윤석현*
on, Sang-Hyeon

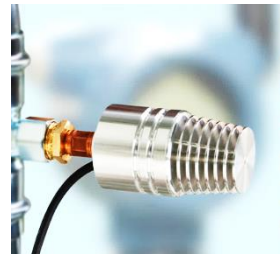
There is a constant need for small Energy Power Systems !

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

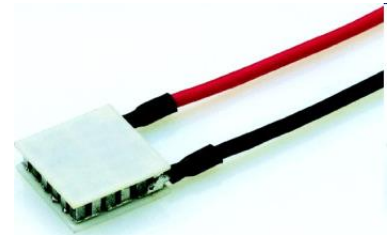


US-Patent

H. Wich, Energy Source Conf. 2014: Alternative Energy source 50-100mJ range



Fuze Conf. 2014:
„Quo Vadis Fuze (Power) ?“



ABSTRACT
...the volume of setback generators based on the conversion of mechanical energy into electrical energy for supply for electronic fuze. In order to prevent the generators from operating accidentally, the setback mechanism of the setback generators is designed to charge a capacitor which is capable of driving electronic circuit of fuze. We performed the simulation results of an electromagnetic analysis tool, Maxwell® that within the charging time of 0.02sec and the critical acceleration for safety is 5.00G. The setback generators with a ring-shaped permanent magnet can be applicable to the small caliber electronic fuze.

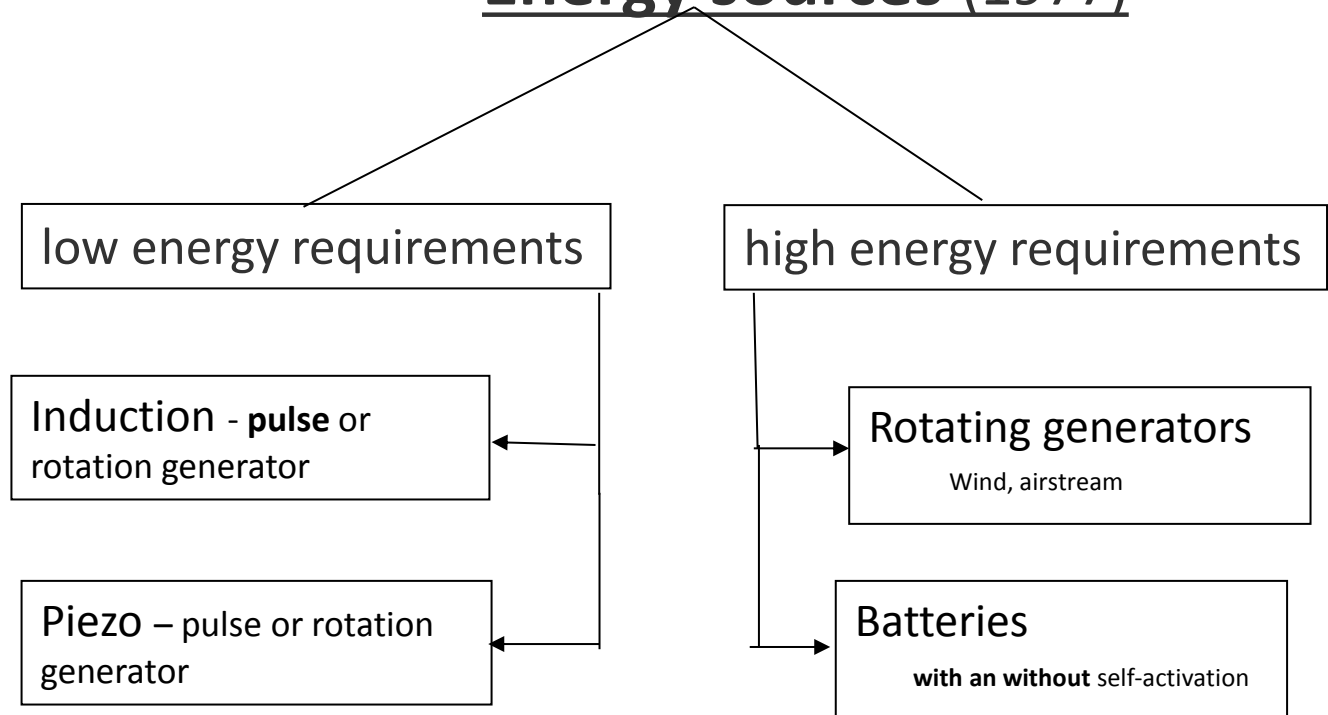
1. 머리말
최근 전자장치의 발달로 인하여 신형의 발전장치 개발이 진행되어 있다. 신형으로 개발할 때의 수 많은 장점을 고려하여, 안전, 소형화, 저전력 소비, 신뢰, 유지보수 용이, 제조공정 단순화 등이 요구되어 있다. 본 논문에서는 이러한 요구사항을 충족시키기 위하여, 관상력 발전장치를 개발하였다. 관상력 발전장치는 관상력 발전장치의 구조를 설명하고, 관상력 발전장치의 작동 원리를 설명한다. 관상력 발전장치의 성능을 평가하고, 관상력 발전장치의 구조를 설명한다. 관상력 발전장치의 구조를 설명한다. 관상력 발전장치의 구조를 설명한다.



A look back in 'history:



Energy sources (1977)



*From: „Handbook on
Weaponry“, Rheinmetall 1977*

(Capacitors Used only for load accumulation)

What is used until today ? Has something changed ?



Reserve Battery

Medium Primary Cell

Setback Generator (electromagnetic)

Piezo Setback Generator

Wind-Generators



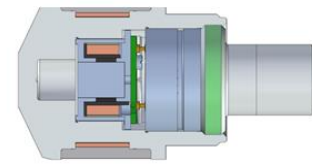
→ No ! All items mentioned in the handbook from 1980 are unchanged ! No new technologies in service.

→ New technologies had been worked in that decades.

A lot of them could not be applied due to the severe environmental requirements of fuzes

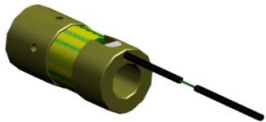
or they are yet not ready for industrialization

A Renaissance for setback generators ?



Technical parameters of setback generators

- Energy density generator: <10mJ
As high as needed by electronics, sensors, ignition; setback 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 relative 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.

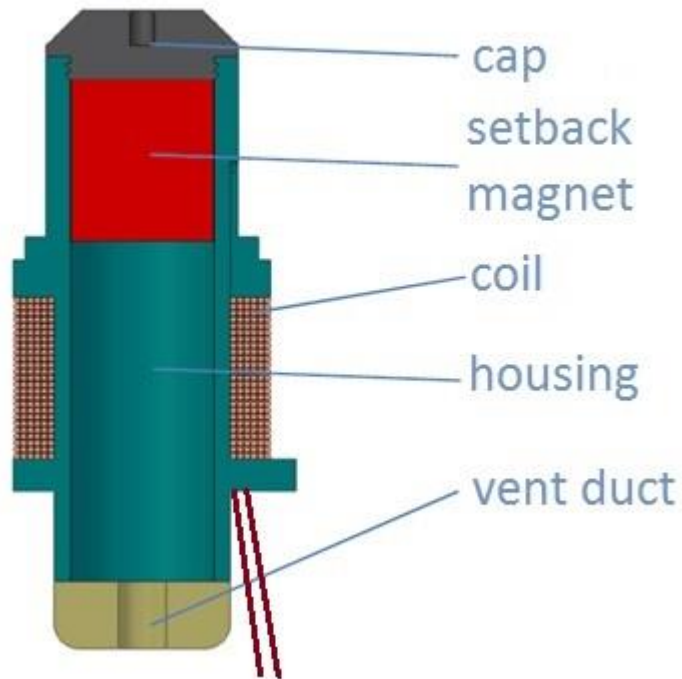


→ **Setback Technology still provides valuable benefits !**

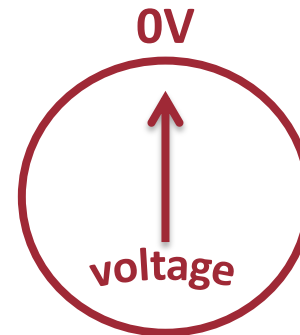


Function principle of a setback generator

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

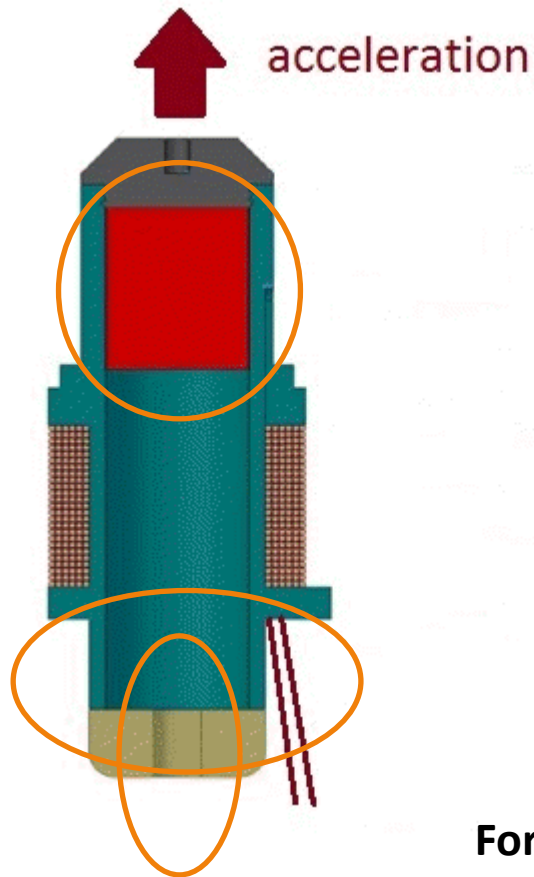


Static state: Setback magnet is hold by magnetic force.





Question: How can the achieve an optimization ?



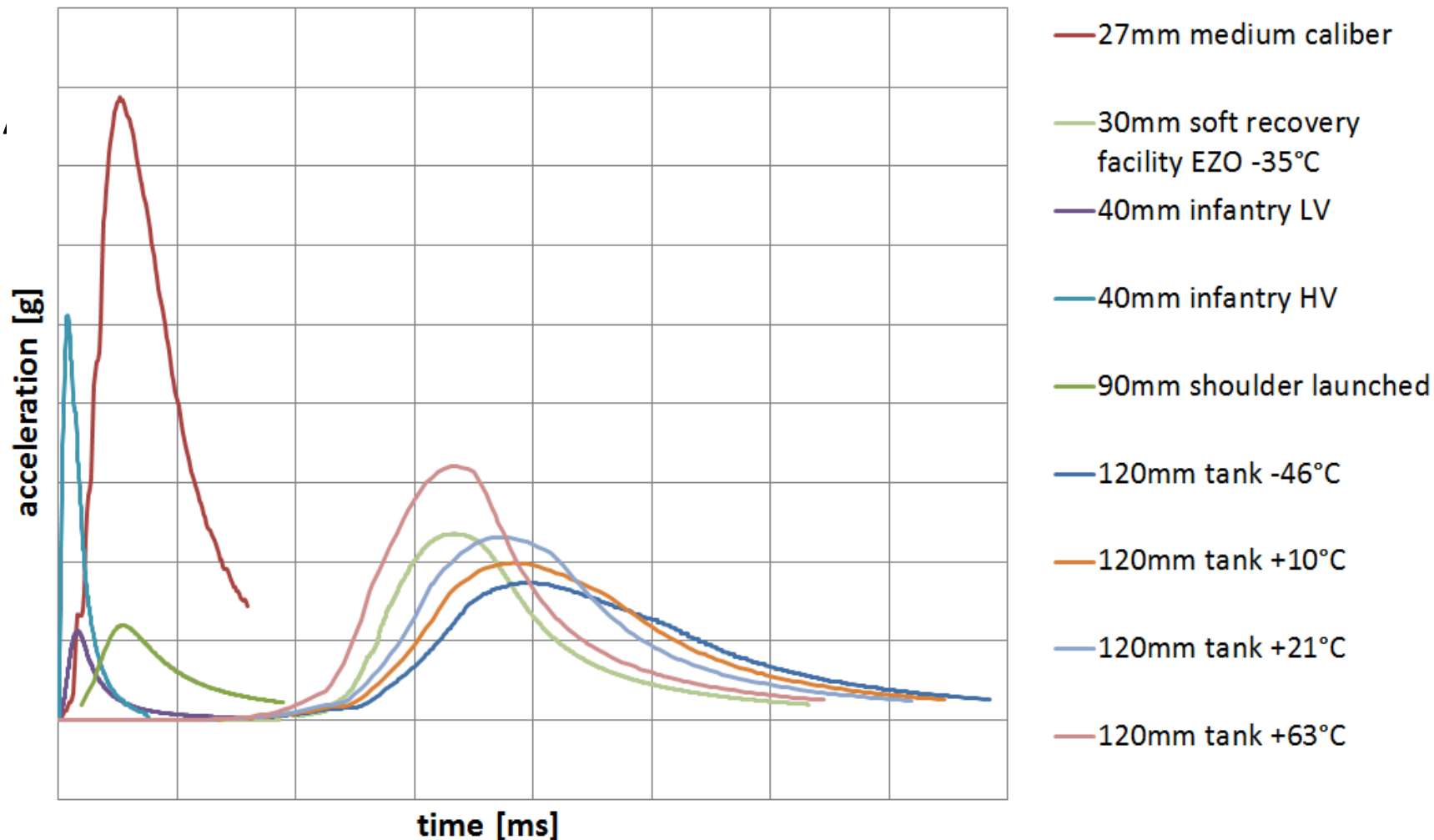
- Travel path of the magnet can be increased! In the example the magnet stops before leaving the coil completely.
- Vent duct in cap to avoid any low pressure area which retards movement of setback magnet. In the example there is only a vent duct at the end.
- Holding mechanism/retention force of setback magnet to be adapted to expected acceleration. In the example the setback magnet is hold 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



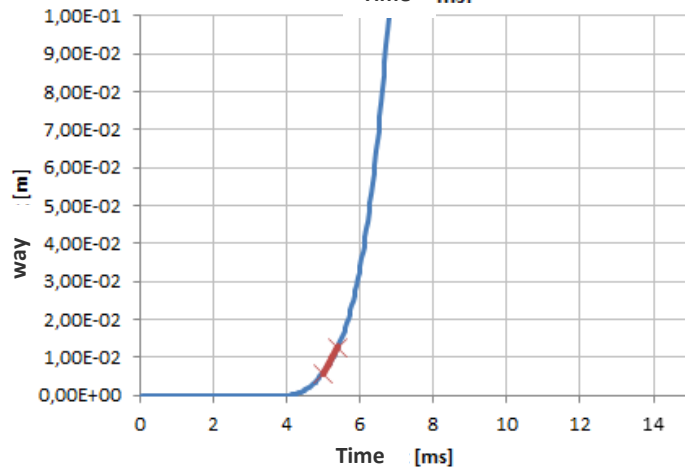
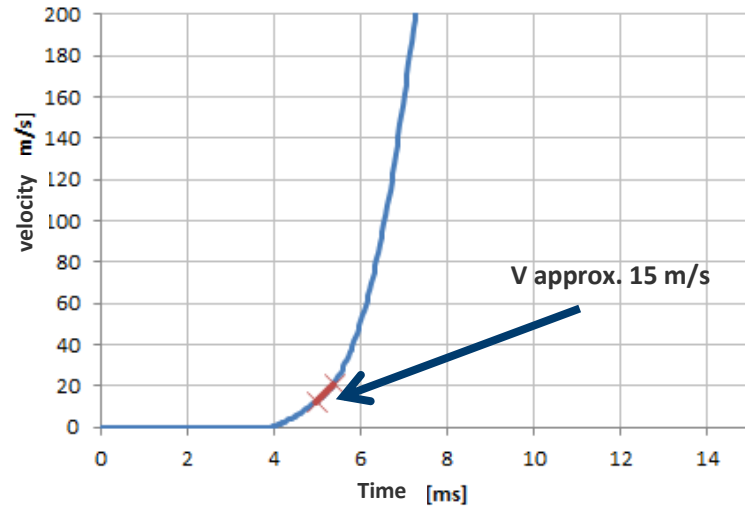
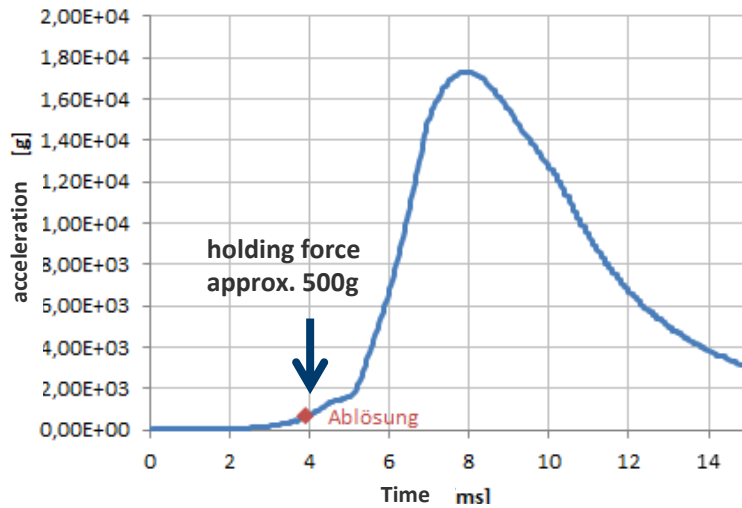
Comparison of different acceleration curves



Example setback generator RTF1147 tank fuze

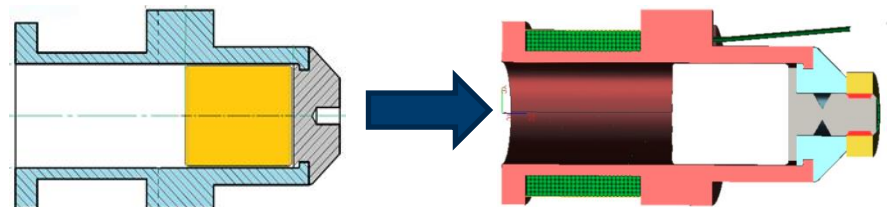


Energy concept: use of a specifically optimized set-back generator



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.

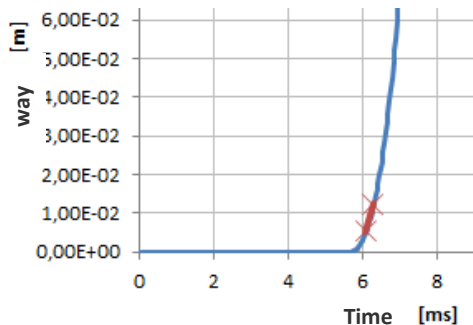
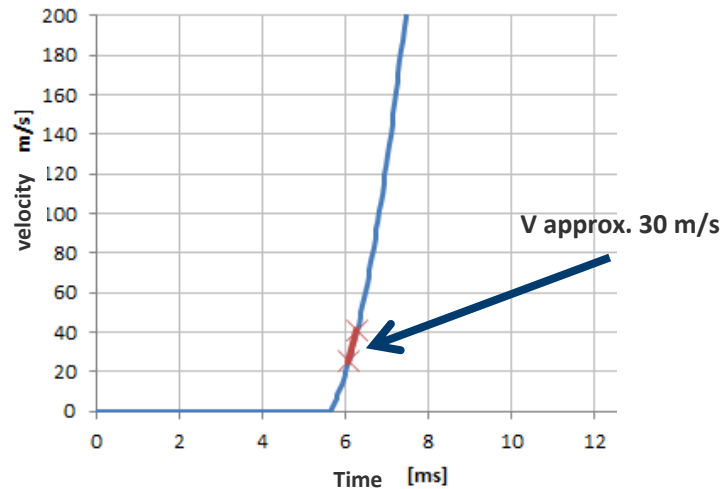
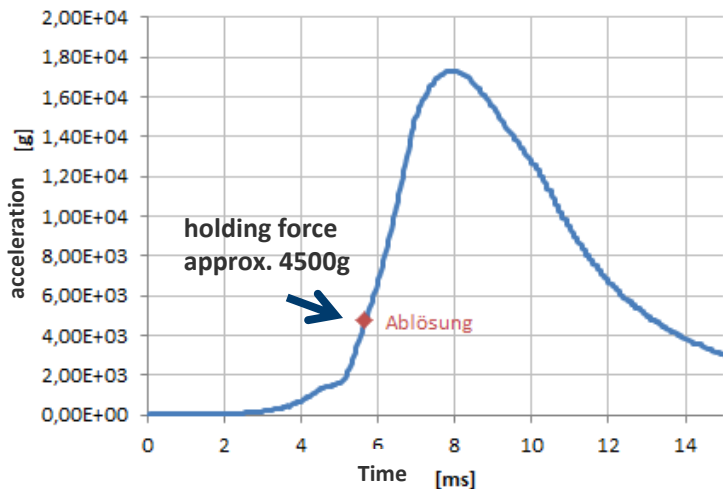
-> Optimization is necessary: Lift of holding force of magnet can bring desired effect



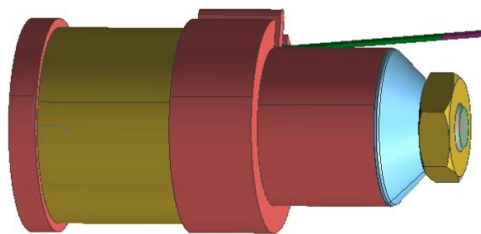
Optimization Setback Generator



- 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



$$U(t) \sim - \frac{d\Phi}{dt} \sim vmag$$



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 !

Konzept Auslegungstool Stossgeneratoren

Voraussetzung: Beschleunigungskurve vorhanden, Daten Spule und Magnet vorhanden

Ziele:

- 1.) Optimierung der Geschwindigkeit des Stossmagneten an der Spule
- 2.) Abschätzung der Spannung an der Spule

Beispiel: Velan Stossgenerator

Kupferlackdraht Qualität	IEC 60317 / Grade 1
Blankdraht \varnothing	0.250 ± 0.004
Aussen \varnothing min.	0.267
Aussen \varnothing max.	0.281
Lacktyp	Polysol 155
Windungen	148 (6 Lagen mit 24-26 Windungen)
Windungs-Richtung	rechts
Lagenisolation	keine
Wicklungsisolation	Isolierband Polyesterfolie 7 X 0.065mm, gelb

Neodym-Supermagnet
Magnetsierungsrichtung: axial (parallel zur Höhe)
Einsatztemperatur: bis 100 °C
Stärke der Magnetsierung: 50M
Art der Beschichtung: Nickel (Ni-Cu-Ni)
Magnet. Flussdichte: 1,4-14,6T

Pos./Menge	Material	Artikelnummer	Menge	Material	Artikelnummer	Menge
1	Magnet NdFeB \varnothing 6x7mm	574245	1	NdFeB Magnet		1.50
	Beschreibung					

Massstab 1:1

1.) Optimierung der Geschwindigkeit

Beschleunigungskurve

Zeit [s] Beschleunigung [m/s²]

Integration

Geschwindigkeitskurve

Zeit [s] Geschwindigkeit [m/s]

Integration

Wegkurve

Zeit [s] Weg [m]

Auslegungstool Stossgenerator

Werte nur in den gelben Feldern ändern!

Haltekraft Magnet: 70 N
Masse Magnet: 0.0015 kg
Lösezeitpunkt: 5.64 ms
Lösebeschleunigung: 4757.050829 g
Lösebeschleunigung: 46656.65667 m/s²
Spulenein-/austritt: Weg [m] Zeit [ms]
Abstand Spulenbeginn - Magnetmitte: 5.40E-03 6.07 25.236 33.245 11.438614
Abstand Spulende - Magnetmitte: 1.24E-02 6.27 41.254

Unten Beschleunigungskurve eingetragene V

Zeit [ms]	Beschleunigung [g]	Integration	Geschwindigkeit [m/s]	Integration	Weg [m]	Zeit [ms]
3.90E-02	5.38E+01					3.90E-02
5.83E-03	2.36E+01		4.00E-03	0	0	5.83E-03
2.74E-02	4.67E+01		1.17E-02	0	0	2.74E-02
6.05E-02	4.67E+01		1.55E-02	0	0	6.05E-02
9.36E-02	4.66E+01		1.54E-02	0	0	9.36E-02
1.27E-01	9.28E+01		2.33E-02	0	0	1.27E-01
1.60E-01	9.28E+01		3.06E-02	0	0	1.60E-01
1.93E-01	9.27E+01		3.06E-02	0	0	1.93E-01
2.26E-01	9.27E+01		3.06E-02	0	0	2.26E-01
2.59E-01	9.26E+01		3.06E-02	0	0	2.59E-01
2.93E-01	9.25E+01		3.15E-02	0	0	2.93E-01
3.26E-01	9.25E+01		3.05E-02	0	0	3.26E-01
3.59E-01	9.24E+01		3.05E-02	0	0	3.59E-01
3.92E-01	9.23E+01		3.05E-02	0	0	3.92E-01
4.25E-01	9.23E+01		3.05E-02	0	0	4.25E-01
4.58E-01	9.22E+01		3.04E-02	0	0	4.58E-01
4.91E-01	9.21E+01		3.04E-02	0	0	4.91E-01
5.25E-01	9.21E+01		3.13E-02	0	0	5.25E-01
5.58E-01	9.20E+01		3.04E-02	0	0	5.58E-01
5.91E-01	9.19E+01		3.03E-02	0	0	5.91E-01
6.24E-01	9.19E+01		3.03E-02	0	0	6.24E-01
6.57E-01	9.18E+01		3.03E-02	0	0	6.57E-01
6.90E-01	9.18E+01		3.03E-02	0	0	6.90E-01
7.24E-01	9.17E+01		3.12E-02	0	0	7.24E-01
7.57E-01	9.16E+01		3.02E-02	0	0	7.57E-01
7.90E-01	9.16E+01		3.02E-02	0	0	7.90E-01
8.23E-01	9.15E+01		3.02E-02	0	0	8.23E-01

2.) Abschätzung der Spannung

Spule:

- Windungszahl n
- Länge l [m]
- Verlustfaktor f (Füllgrad 0,65)

Magnet:

- Magnetische Flussdichte B [Vs/m²]

Geschwindigkeit:

- Optimierte Geschwindigkeit Magnet [m/s]

Induzierte Spannung

$$U = n \cdot l \cdot v \cdot B$$

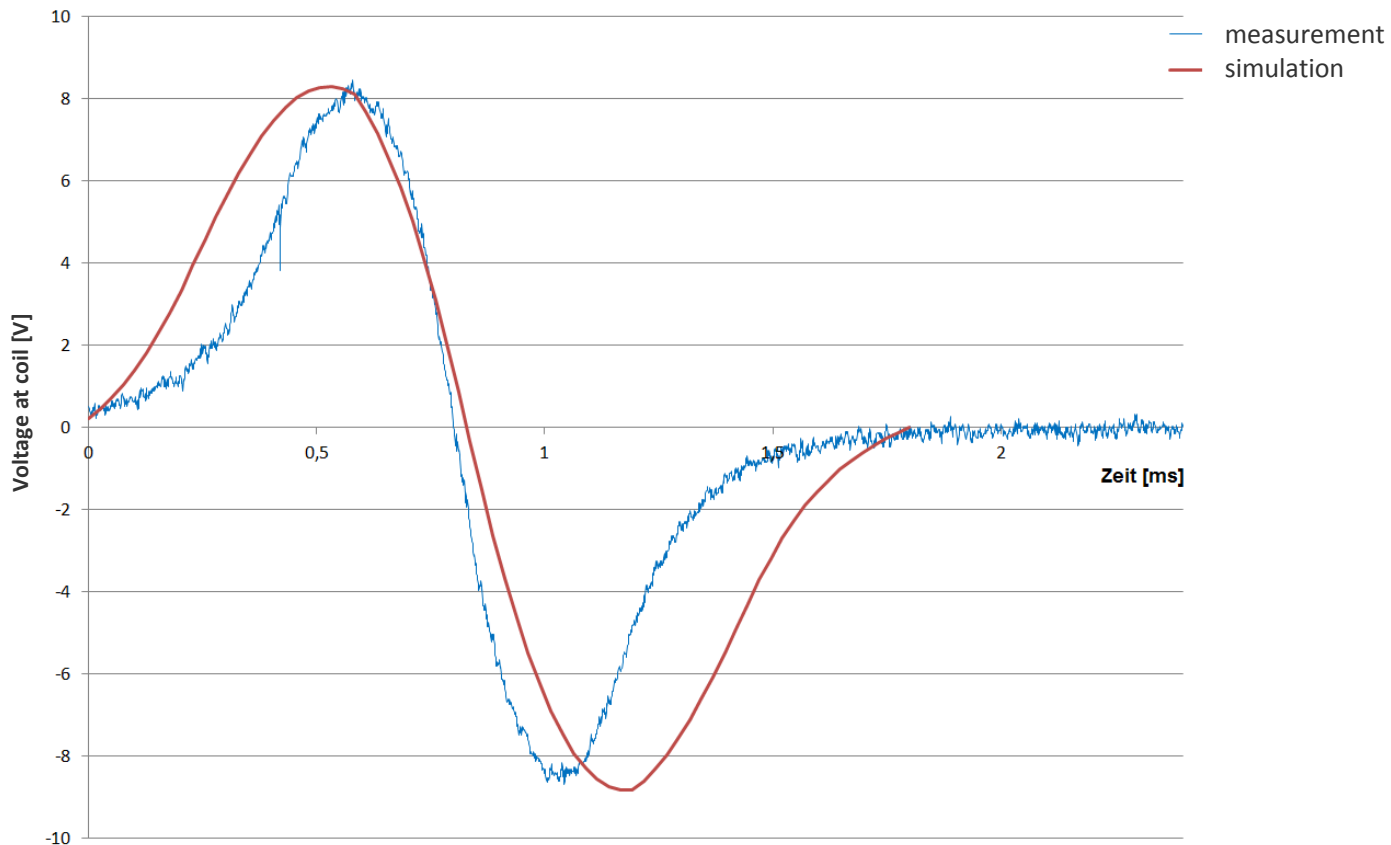
Abschätzung Spannung an der Spule



Measurements & Results

Comparison of measurements and simulation results

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





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

(up to 150% more)

This is remarkable !



Summary

- Choosing 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 a many fuze applications



**Thank you very
much for your
attention !**



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