ECL® Propellant Demonstration

Consolidation of 105 mm Artillery M67/M200 into Single Charge System

Benefits for the Warfigther

Kelly Moran (ATK)

Nguyen Tran (ARDEC)

Dominik Antenen, Peter Zoss, Kurt Ryf (Nitrochemie)

NDIA Conference

44th Annual Gun & Missile System Conference

Kansas City, 8th April 2009

Main Goals of Improvement Program

- Replace current charge system M67 (7 zones) and M200 (standalone long range)
- Create compact charge system with 5 – 6 zones with sufficient overlap capacity
- Facilitate handling for operation, improve reliability and shelf live for operation in complex terrain under extreme loads
- Optimize life cycle cost

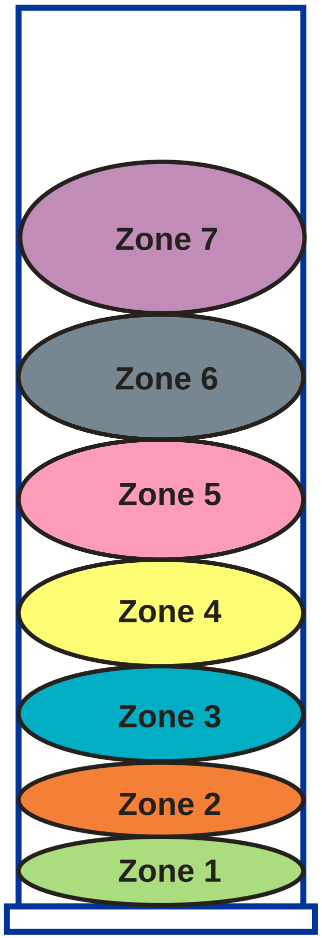
Current Situation – M67 and M200

Gun
- M119A2

Propellant
- M1 (DNT, DBP, DPA)

Range
- 11,5 km

M 67



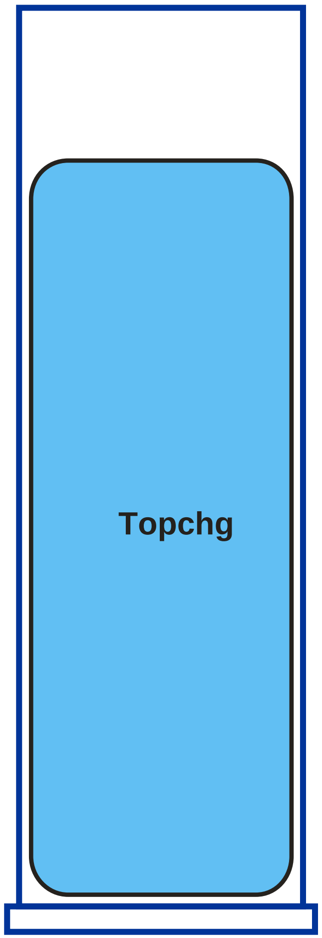
Goal

Logistic advantage

Higher stow capacity

Lower overall cost

M 200



Gun
- M119A2

Propellant
- M30 (NG, NQN)

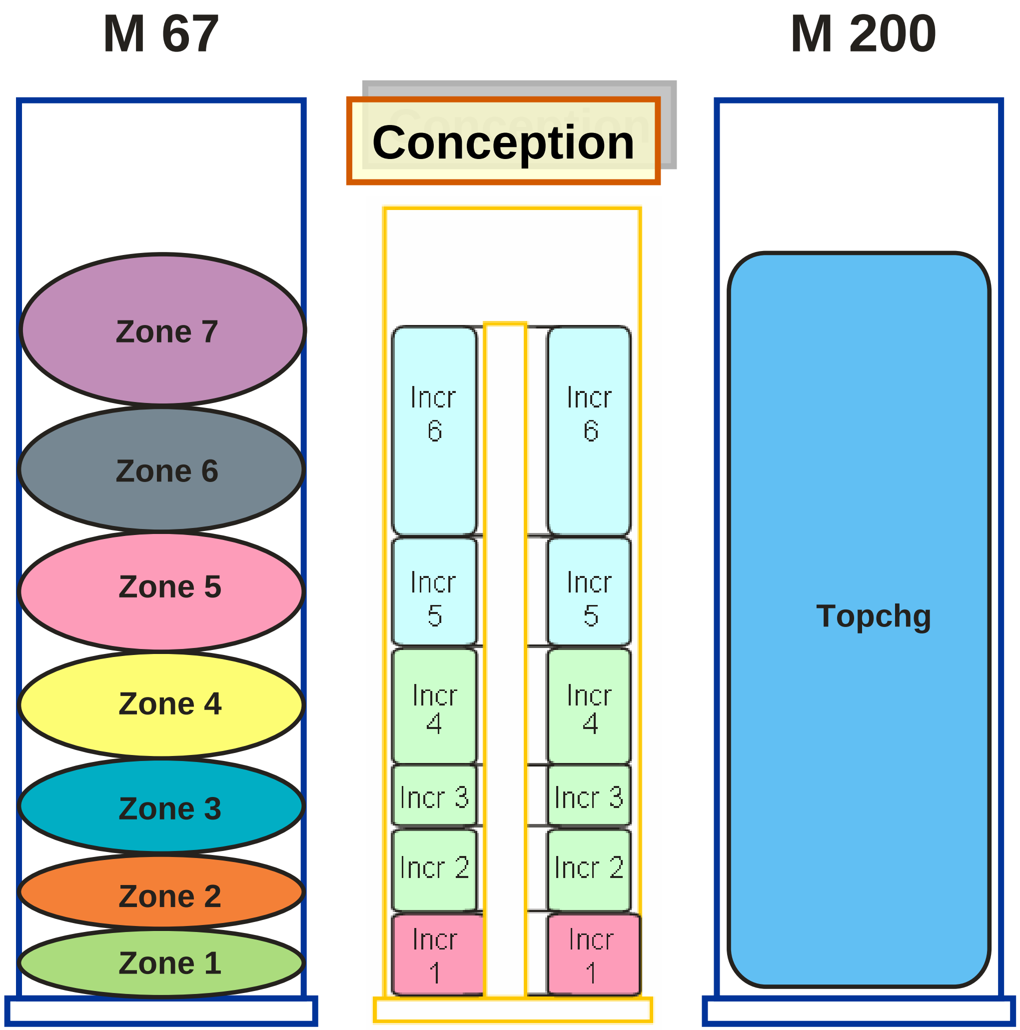
Range
- 14 km

Single Charge System with 6 Zones

Gun
- M119A2

Propellant
- M1 (DNT, DBP, DPA)

Range
- 11,5 km



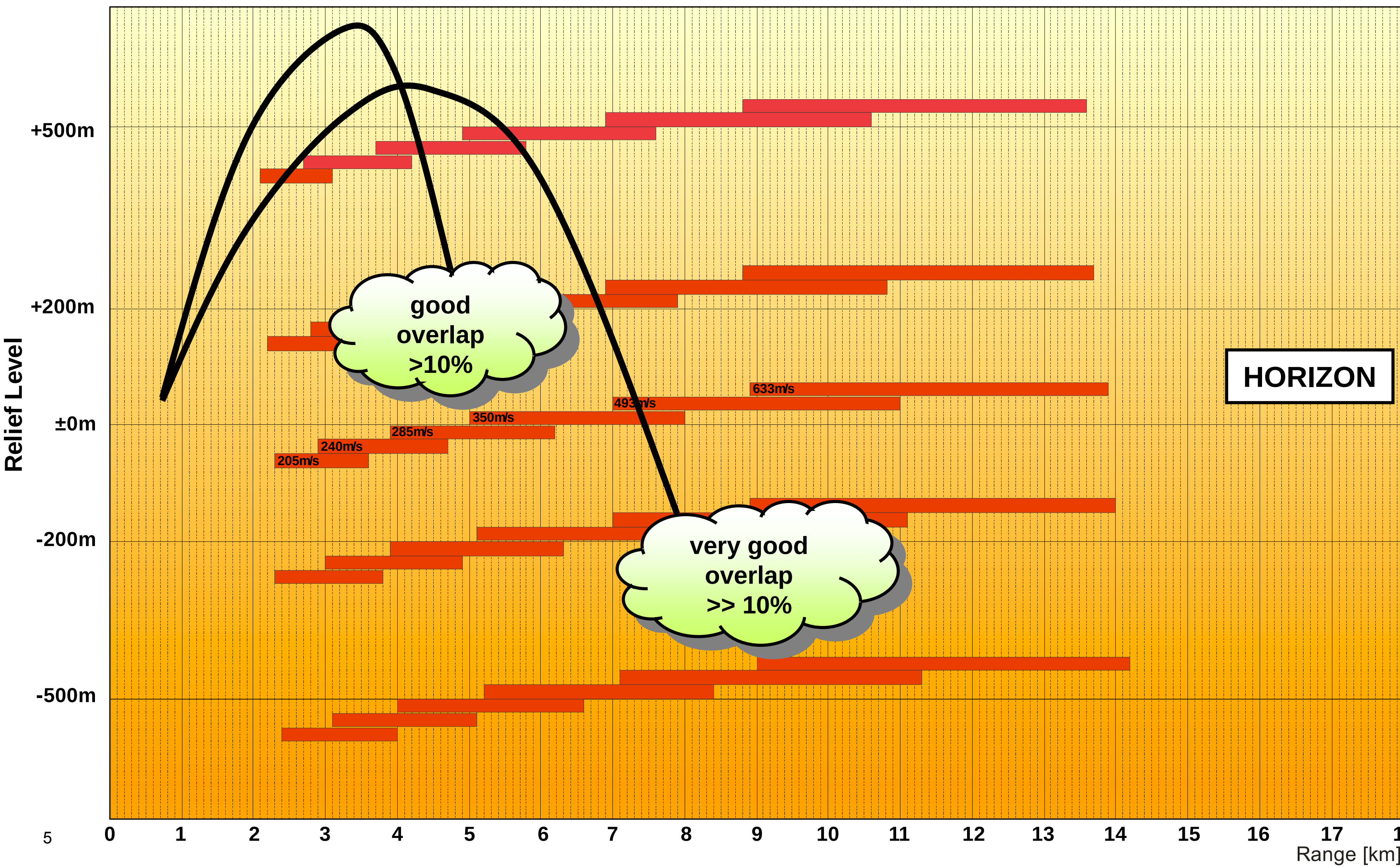
Gun
- M119A2

Propellant
- M30 (NG, NQN)

Range
- 14 km

Nitrochemie's Proposed 6 Zone Design Solution

General overlap situation in complex Terrain



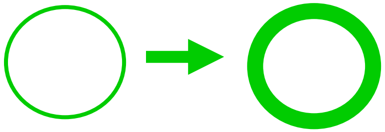
ECL® - Advanced Charge System Concept

General Benefits over *NG containing Propellants*

Chemical Compatibility
- → bag materials
- → igniter materials
- → varnishes

No Migration of NG
- → safety
- → igniter
- → bags, containers

Shelf Life and IM Properties
= essential for freedom missions!



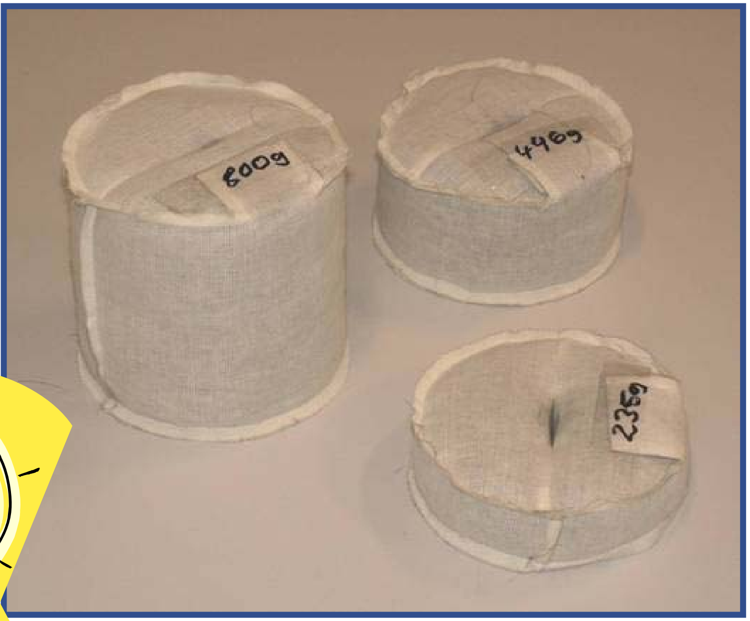
Improved IM Properties
- → external mechanical impacts
- → cook-off resistance

No Diffusion of Deterrents
- → consistency in ballistic performance
- → no detoriation of accuracy

Improvement of Charge Compactness

ATK
RHEINMETALL NITROCHEMIE

Donut Bags Improve Loading and Handling of Propellant Charges



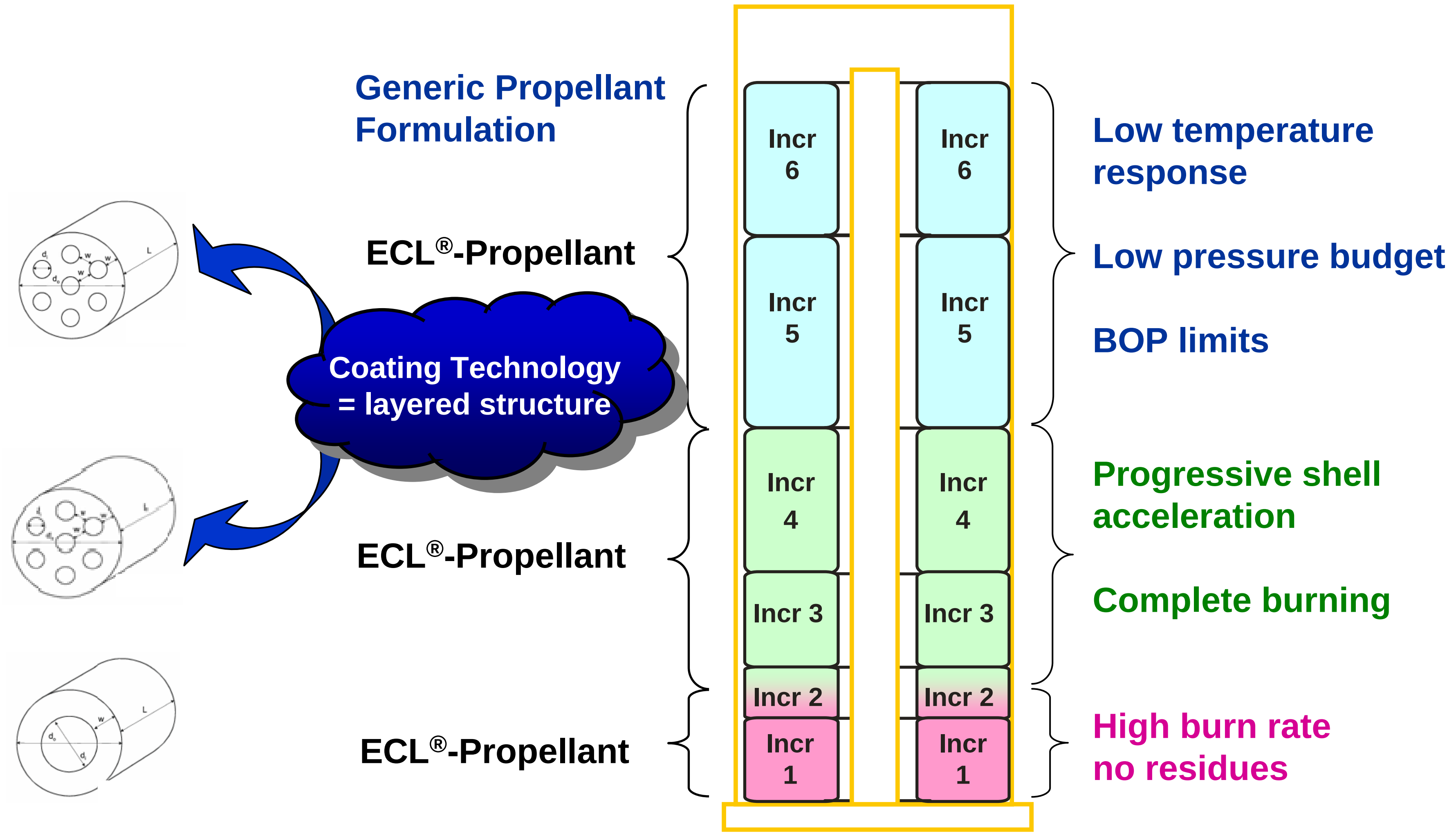
Current bag design (M67 and M200)

➡ **poor loading capacity of M67**

Proposed design for single integrated charge system (XM350) includes donut-style bags of 3 different sizes providing:

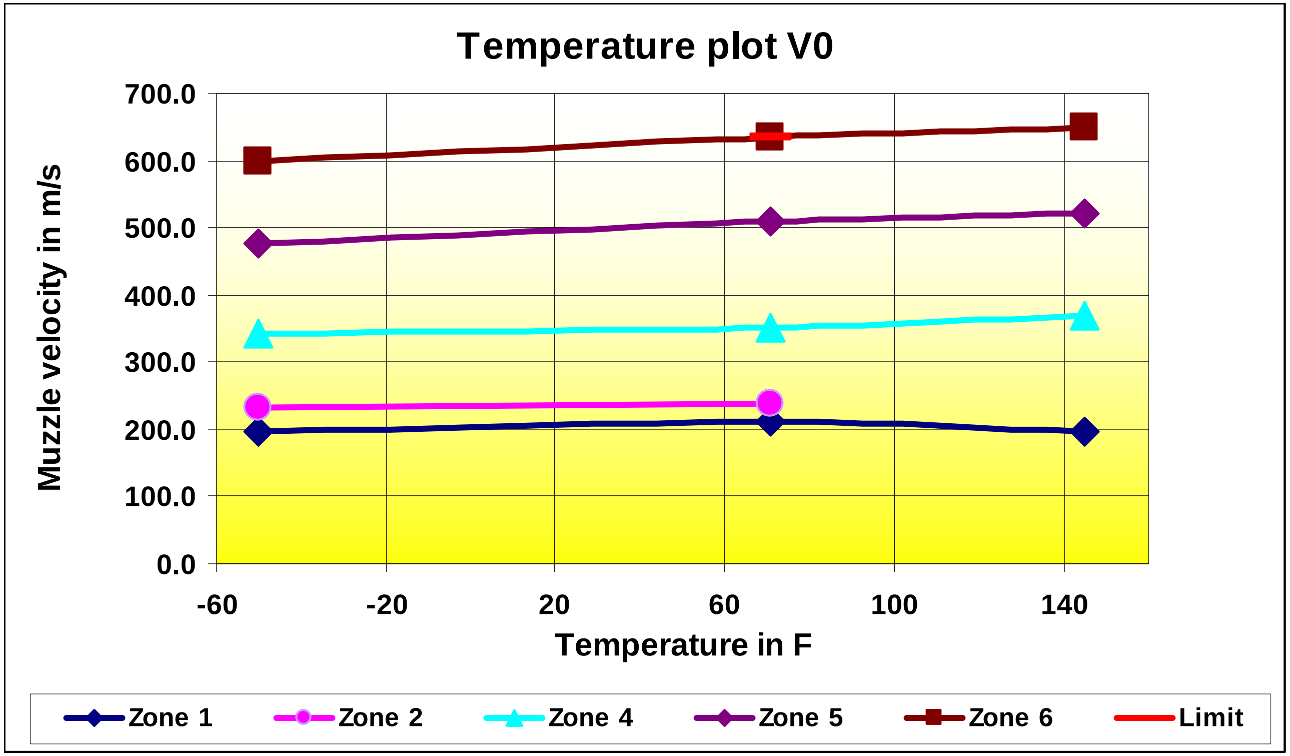
- ***optimal loading capacity!***
- ***easy handling for troops***

Tailored ECL® Propellant Design for 6 Zone Concept



Demonstration Firing (Yuma June 2008)

Results of Velocity Measurements



Goals @ 70F

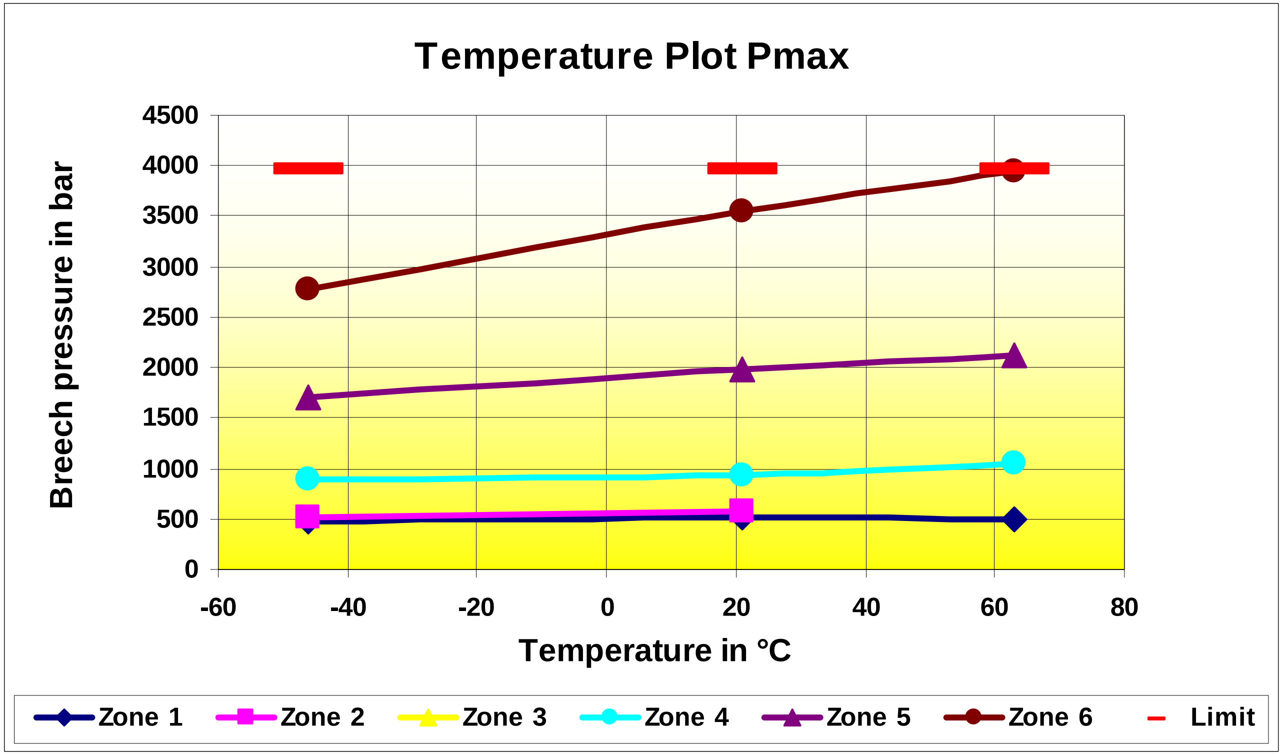
Zone 1	**199m/s**
Zone 2	**238m/s**
Zone 3	**285m/s**
Zone 4	**350m/s**
Zone 5	**501m/s**
Zone 6	**652m/s**
Zone 6 nominal (MIL)	**633m/s**

Achieved: **634.5m/s @ Zone 6 and +21°C**
Not fired: **Intermediate Zone 3**

Velocities close to targeted ranges

Demonstration Firing (Yuma June 2008)

Results of Pressure Measurements (Piezo)



Pressure limit

57500psi

3965bar

Pressure requirements achievable by correction of propellant design (known and reliable measures)

Pressure at hot close to permissible limit!

- **Correction of temperature response for high zone!**
- **Modelling of propellant design (coating parameters)**
- **Optimization of pressure budget (headroom in charge weight)**

Demonstration Firing (Yuma June 2008)

ATK
RHEINMETALL NITROCHEMIE

Summary and Conclusions

- **6 Zone conception with propellant design based on same generic formulation (3 different grain types of ECL®)**
- **Required and targeted velocities for individual charge increments fulfilled**
  → Range and overlap requirements
- **Pressure budget for highest zone at hot (145°F) close to operational pressure limit**
  → Temperature response of higher charge zones to optimize (adaptation of burn rate profile)
- **Consistent pressure – time curves (no signs of pressure waves = safe for firing at any condition)**
- **Headroom for propellant charge for optimization of pressure budget**

Final Requirement achievable with slight modifications!

Two Major Influences on Barrel Wear

- Barrel wear due to Thermal Erosion
- Barrel wear due to Chemical Erosion

Theoretical Assessments to Barrel Erosion

Comparison ECL Charge Design vs fielded Design (results from YPG firing test June 2008)

M67 Zone 7

M1 propellant (flame temperature 2575K)

- **Velocity 503.3m/s**
- **Pressure 39275psi**

M200 (stand alone charge)

M30 propellant (flame temperature 3070K)

- **Velocity 651.5m/s**
- **Pressure 46081psi**

ECL (Zones 5 and 6)

ECL propellant (flame temperature 2850K)

- **Velocity zone 5 509.6m/s**
- **Velocity zone 6 634.5m/s**
- **Pressure zone 5 28698psi**
- **Pressure zone 6 50812psi**

Calculation of Erosion (thermo-mechanical approach)

$$\text{Erosion} \sim (m_c)^{1.5} \cdot (T_{ex})^{7} \cdot (v_0)^{1.4} \cdot (p_{max})^{5}$$

Semi-empirical formula based on experience and measured values

m_c	=	Charge Mass
Tex	=	Flame Temperature
v_0	=	Muzzle Velocity
p_{max}	=	Peak Pressure

Barrel erosion has been measured through life assessment and proof in tank and artillery guns.

Measurements in plain steel barrels with mechanical measurement and thin layer method (activated steel).

Theoretical Assessments to Barrel Erosion

Barrel Life Estimation Assessments (Different comparisons)

$$\text{Erosion} \sim (m_c)^{1.5} \cdot (T_{ex})^{7} \cdot (v_0)^{1.4} \cdot (p_{max})^{5}$$

Semi-empirical formula shows the main drivers for barrel erosion are flame temperature and pressure level

M200 vs ECL zone 6
Theoretical; only flame temperature changes — **- 41% less erosion**

M200 vs ECL zone 6
Practical; ECL not optimized; YPG results — **- 7% less erosion**

M67 zone 7 vs ECL zone 5
Practical; ECL not optimized; YPG results — **- 62% less erosion**

M200 still slightly more erosive compared to ECL® Zone 6!

M67 Zone 7 significantly more erosive compared to ECL® Zone 5!

Calculation of erosion (thermo-chemical approach: Lawton)

Erosion = A exp (Tmax / Bo)

Theoretical approach with respecting gas composition

- **A:** Propellant erosion coefficient (depends on propellant gas composition)
- **Bo:** Hardness coefficient (105 for typical gun steel)
- **T_{max}:** Maximum bore temperature during firing (assumption 80% of flame temperature)

- $A = \exp(0.23f(CO_2) + 0.27f(CO) + 0.28f(H_2O) + 0.74f(H_2) + 0.16f(N_2) + 1.55f(R) - 31.36)$

- **f:** The volume fraction of each species in percent
- **f(R):** Represents the dissociated products

Hydrogen as main cause for erosion (steel attack)

Theoretical Assessments to Barrel Erosion

Conclusions

- **Thermal Erosion and Chemical Erosion have different aspects which have to be observed separately!**
- **Erosion calculated by thermo-mechanical approach shows good-natured behaviour of ECL propellant!**
- **Erosion compared to M67 charge (M1 propellant) expected to be significantly lower (pressure difference)**
- **Erosion compared to M30 (stand alone charge) at least comparable or slightly better for ECL propellant (lower flame temperature)!**
- **The thermo-chemical approach by Lawton results in comparable erosion due to comparable Hydrogen contents (for same pressure)!**

Modelling of Propellant Design

Methodology for Simulation of Ballistic Data

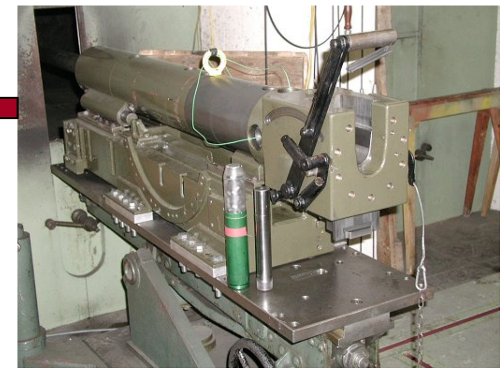
Thermodynamic Data
- Code

Burn Rate Date
- Closed vessel
- Pressure-time history

Simulation of closed vessel
- Burn Rate Coefficient
- Coating Effects

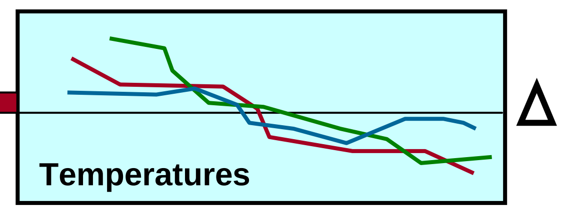
IB - Code
- System data
- Prediction of ballistic performance data

Gun Simulation
- 38mm firing tests



Data Analysis
- Gun system → simulation

Result
- Correlation factors for V / P



Correlation
- Model Adaptation

Reliable prediction
- ***Propellant design modelling***

Follow-on Work

Adaptation of Propellant Design

Analysis of firing results (2009)

Reproduction in larger quantities

US Qualification ?

Acknowledgments

- **ARDEC for supporting ECL technology for this program**
- **Nguyen Tran from ARDEC for leading this project**
- **Peter Zoss and Kurt Ryf from Nitrochemie as co-workers from Nitrochemie**
- **Kelly Moran, Duncan Langlois and Steven Ritchie from ATK as our strategic partner**

Point of contact: kurt.ryf@nitrochemie.com

THANKS!