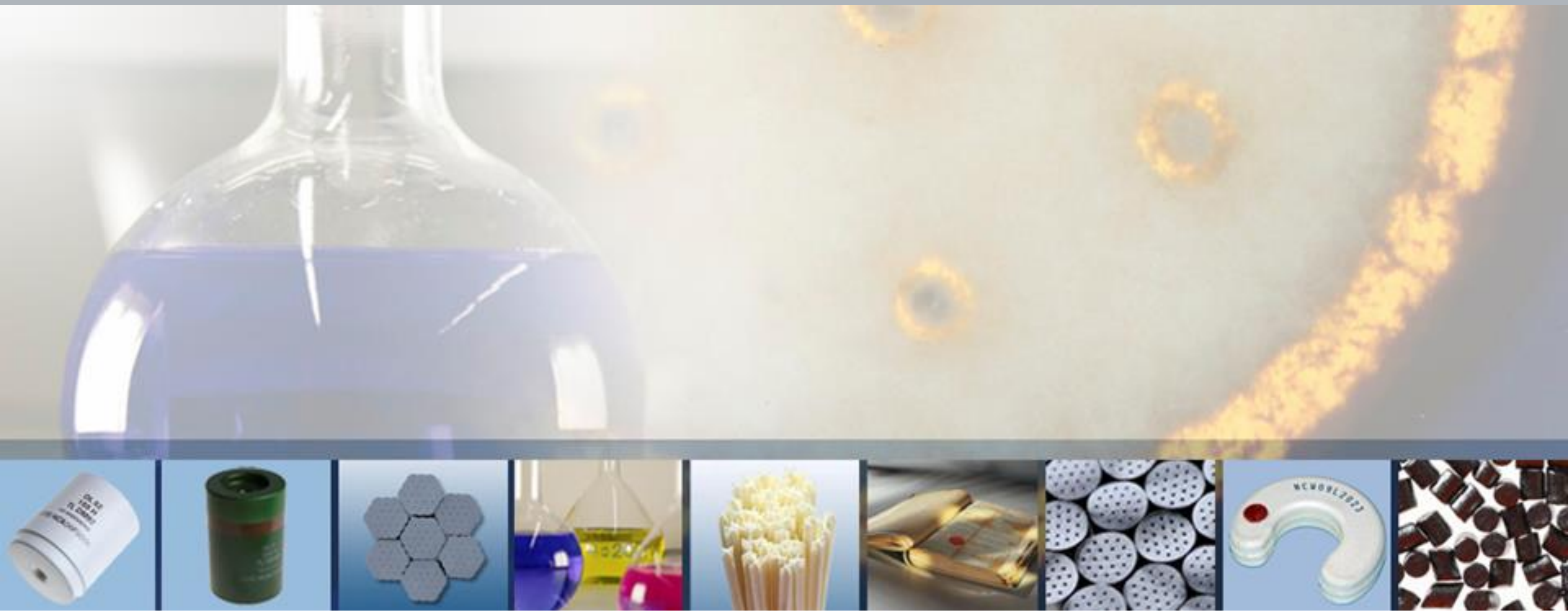

Effects of Long-Term Ageing on Small and Medium Calibre Propellants

Beat Vogelsanger, Ulrich Schädeli, Tiberio Rocci, Beate Pausch

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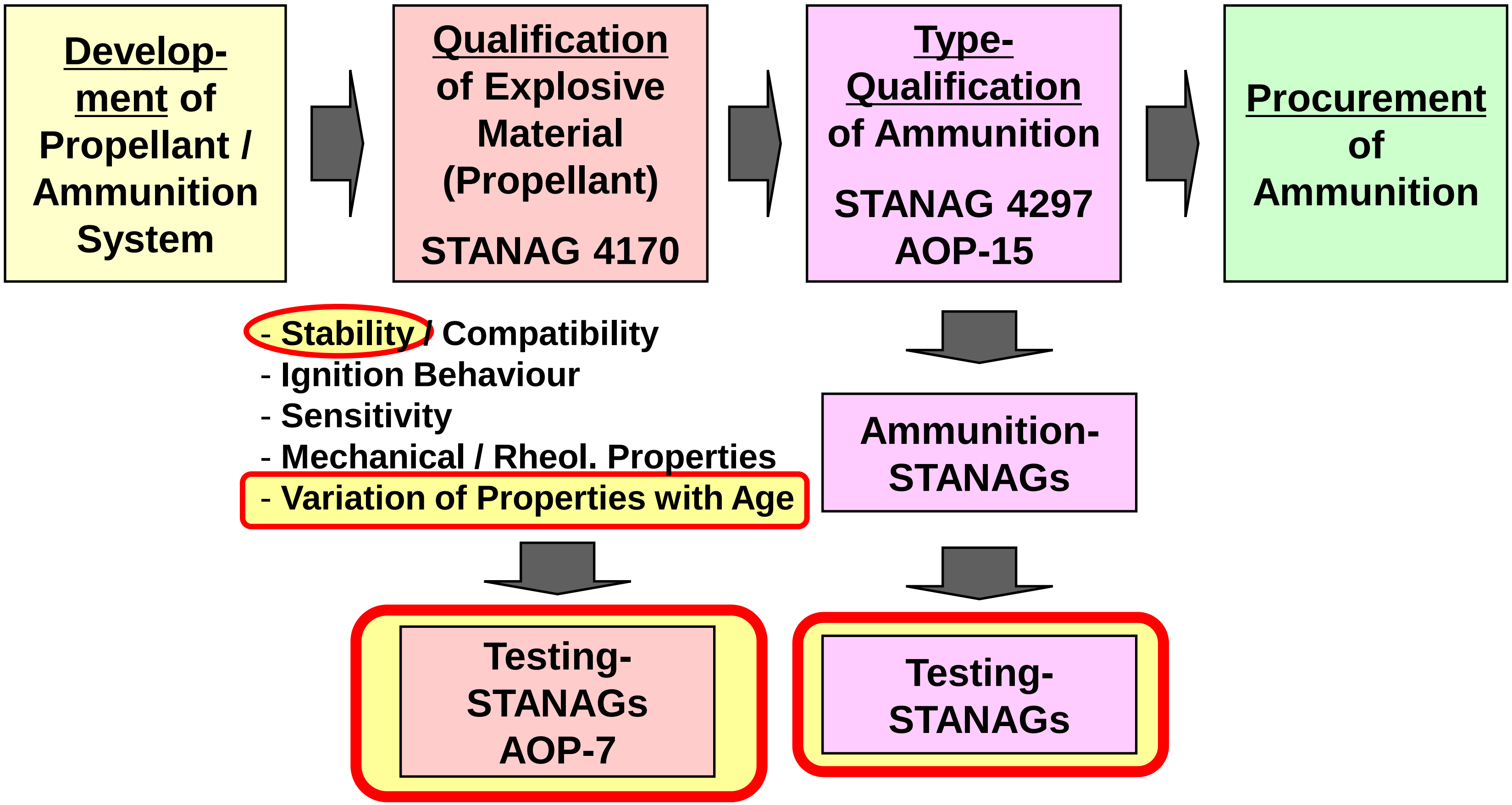
Introduction 1 – NATO Qualification Procedure



- Stability / ageing behaviour is checked during NATO qualification of explosive materials and ammunition

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Introduction 2 – NATO Test Methods

- Chemical Stability
  - STANAG 4620 / AOP-48 Ed. 2 (Stabiliser Depletion)
  - STANAG 4582 (Heat Flow Calorimetry)
    - Typical ageing conditions: 35 days at 70°C
- Ballistic Stability
  - Small Calibre: AEP-97 M-C MOPI (Multi Calibre Manual of Proof and Inspection for NATO 5.56mm, 7.62mm, 9mm and 12.7mm ammunition)
    - Typical ageing conditions: 30 days at 65°C
  - Medium Calibre:
    - Typical ageing conditions not defined in NATO standards
    - Often used: 28 days at 71°C; 30 days at 63°C; …

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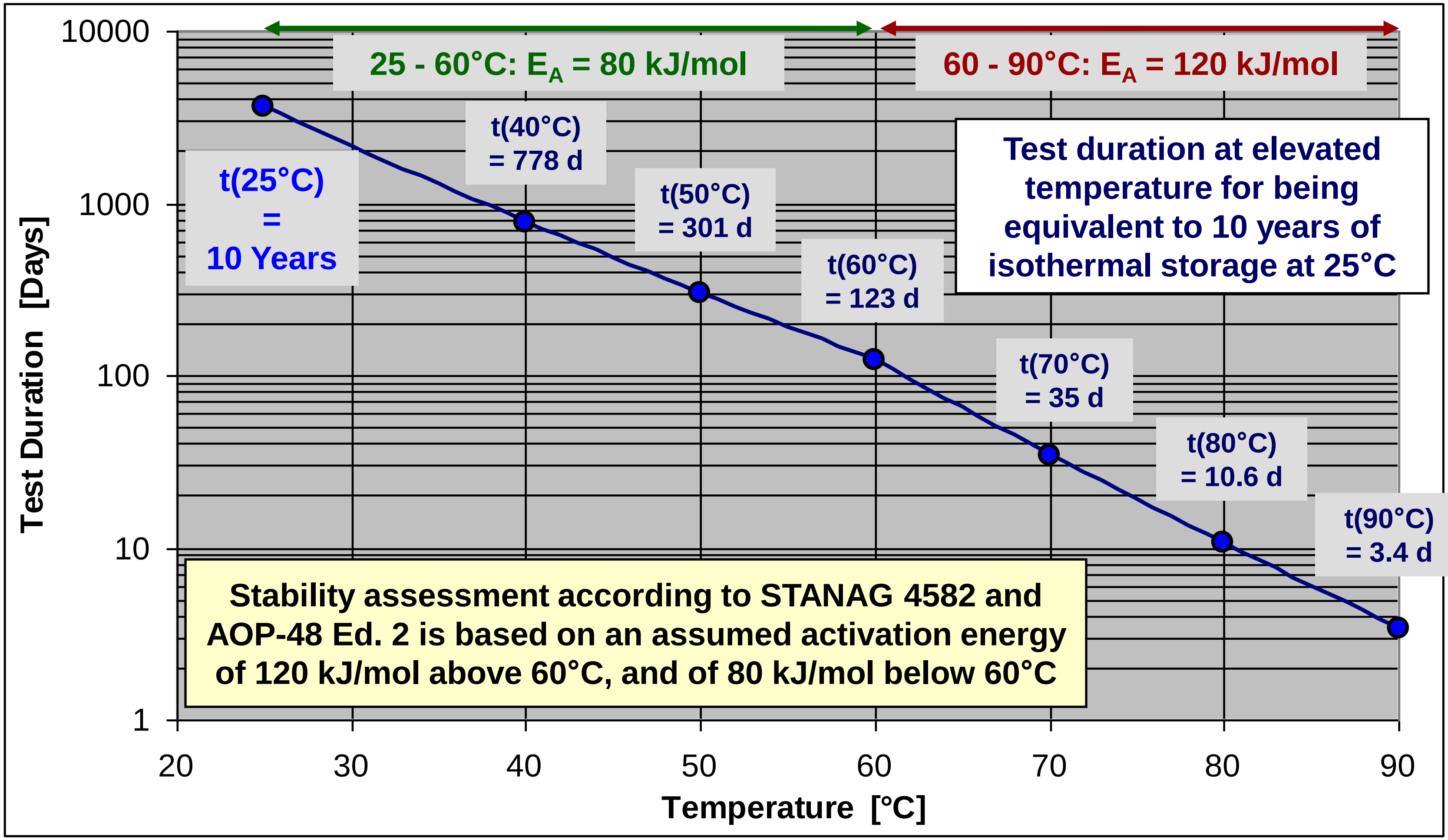
Introduction 3 – Stability STANAG Ageing Sequences



- Each sequence is equivalent to at least 10 years of ageing at 25°C

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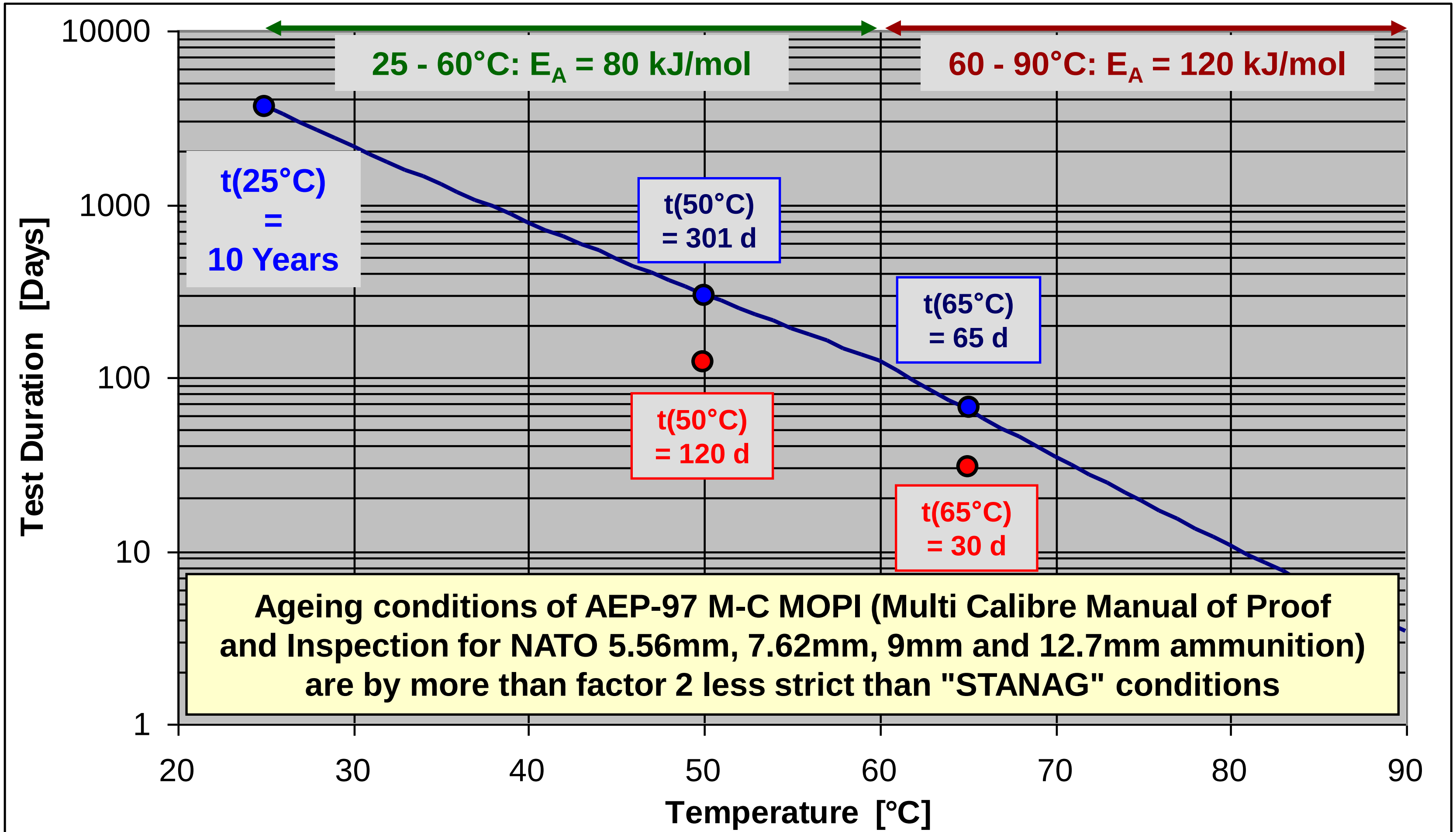
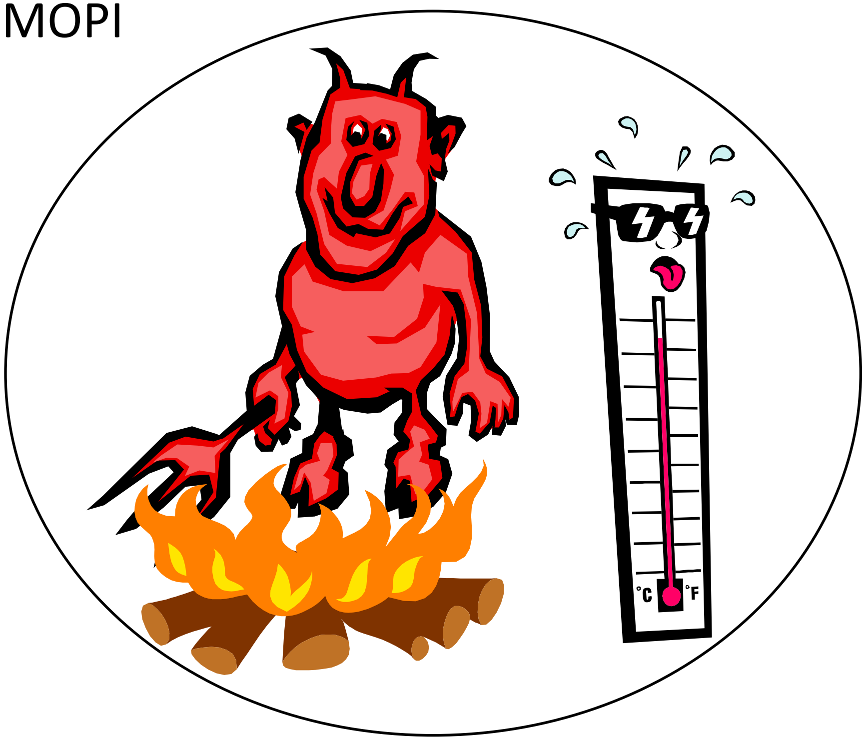
Introduction 4 – AEP-97 / M-C MOPI



- AEP-97 M-C MOPI ageing conditions are equivalent to 4 – 4.6 years at 25°C

Introduction 5 – Effects of Extreme Ageing Conditions

- During NATO qualification of explosive material and ammunition, influence of "moderate" ageing on chemical and interior ballistic properties is checked thoroughly
- But what happens if the ammunition is exposed to ageing conditions that are much more severe than the STANAG or MOPI sequences?
  - Will the deterioration of chemical / ballistic properties be slow and continuously, or appear with an abrupt rise?
  - An abrupt rise in deterioration could result in dangerous situations!



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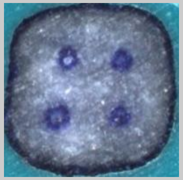
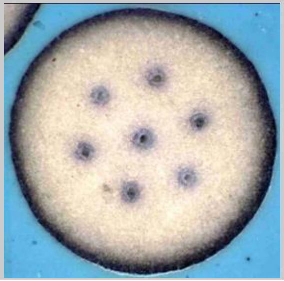
Experimental 1 – Weapon System / Ammunition

- Small Calibre
  - 5.56mm SS109 / GP-90, …
  - 7.62mm Ball
- Medium Calibre
  - 20mm Aircraft Ammunition
  - 30mm LW30 M788

Experimental 2 – Propellants

	Ball Powder	Single Base	EI®	ECL®
Type	'double base'	'single base'	'double base'	'semi nitramine'
Formulation	NC + 15% NG	NC	NC + 5-12% NG	NC + Nitramine
Stability	low	high	intermediate	very high
Performance Potential	baseline	-30 m/s (1p) +0 m/s (4p) +0 m/s (7p)	±0 m/s (1p) +30 m/s (4p) +40 m/s (7p)	+50 m/s (4p) +60 m/s (7p)
Geometry	spheres 	1-perforated  4-perforated (only small cal)  7-perforated (only medium cal) 		

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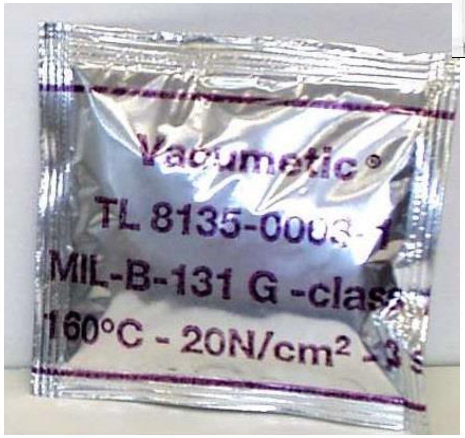
Experimental 3 – Ageing Sequences / Conditions

80°C [Days]	70°C [Weeks]	60°C [Weeks]	Multiple STANAG	≙ at 25°C [Years]
10.6	5	18	1	10
21.2	10	36	2	20
32	15	53	3	30
--	20	--	4	40
--	25	--	5	50
64	30	106	6	60
--	35	--	7	70
--	40	--	8	80
96	45	--	9	90
--	50	--	10	100

- Ageing periods of 1 – 10 times the "STANAG sequence" have been chosen, being equivalent to ageing of at least 10 – 100 years at 25°C

Experimental 4 – Ageing Conditions

- For heat flow calorimetry HFC:
  - 4 mL glass ampoules were fully filled with propellant and sealed by crimping the vial caps



- For assessment of chemical stability (by stabiliser depletion, and nitrocellulose degradation) and change in interior ballistic properties:
  - 30 g of propellant were stored within 3 layers of sealed polymer-coated aluminium bags
- For assessment of interior ballistic properties; at least for some of the propellants, additionally:
  - Ageing was performed in original ammunition / rounds

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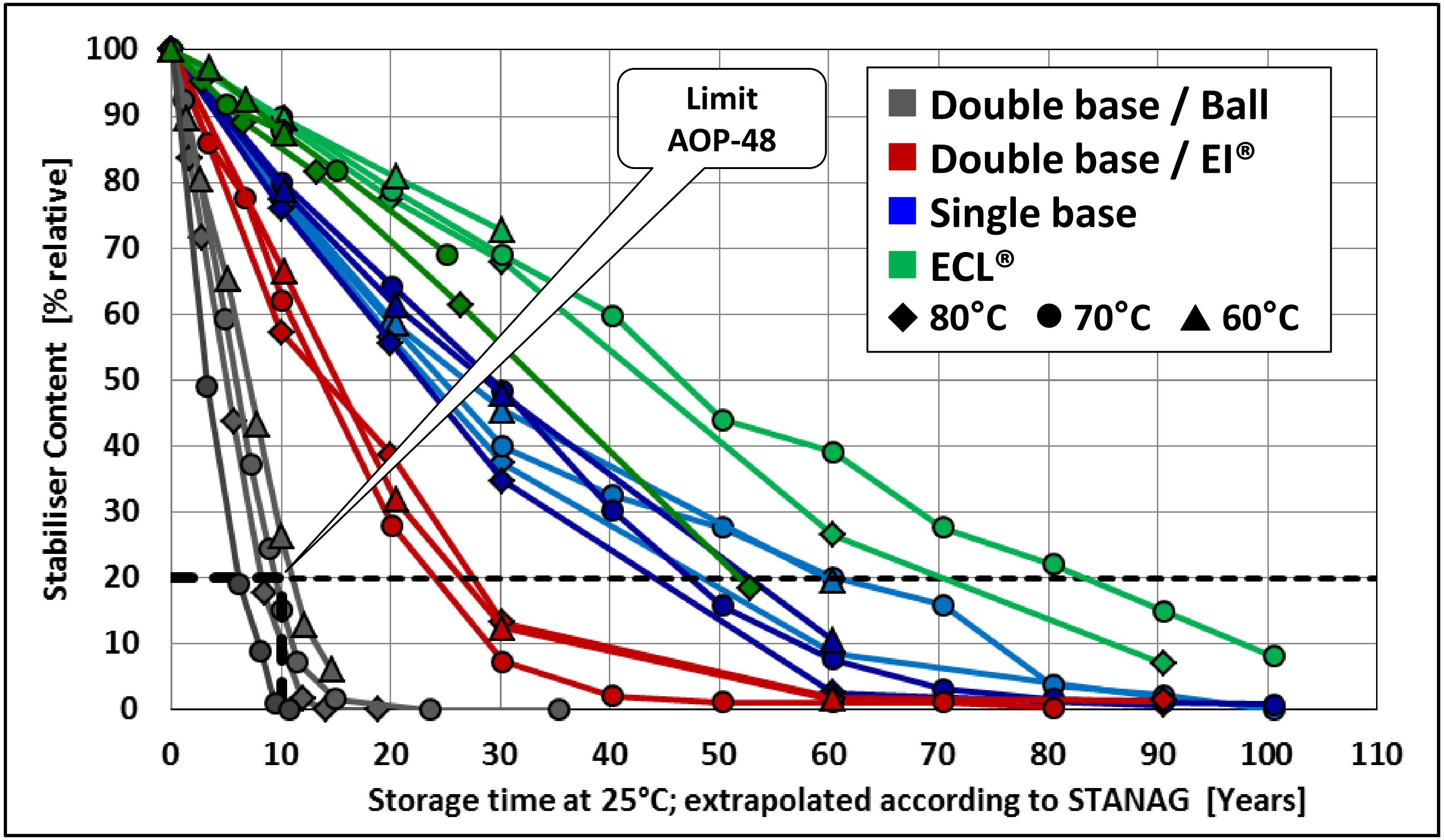
Stabiliser Depletion (all Propellants)



- All tested propellants meet the requirements of AOP-48 Ed. 2
- Single base and ECL® propellants show much slower stabiliser depletion and thus better chemical stability than double base propellants

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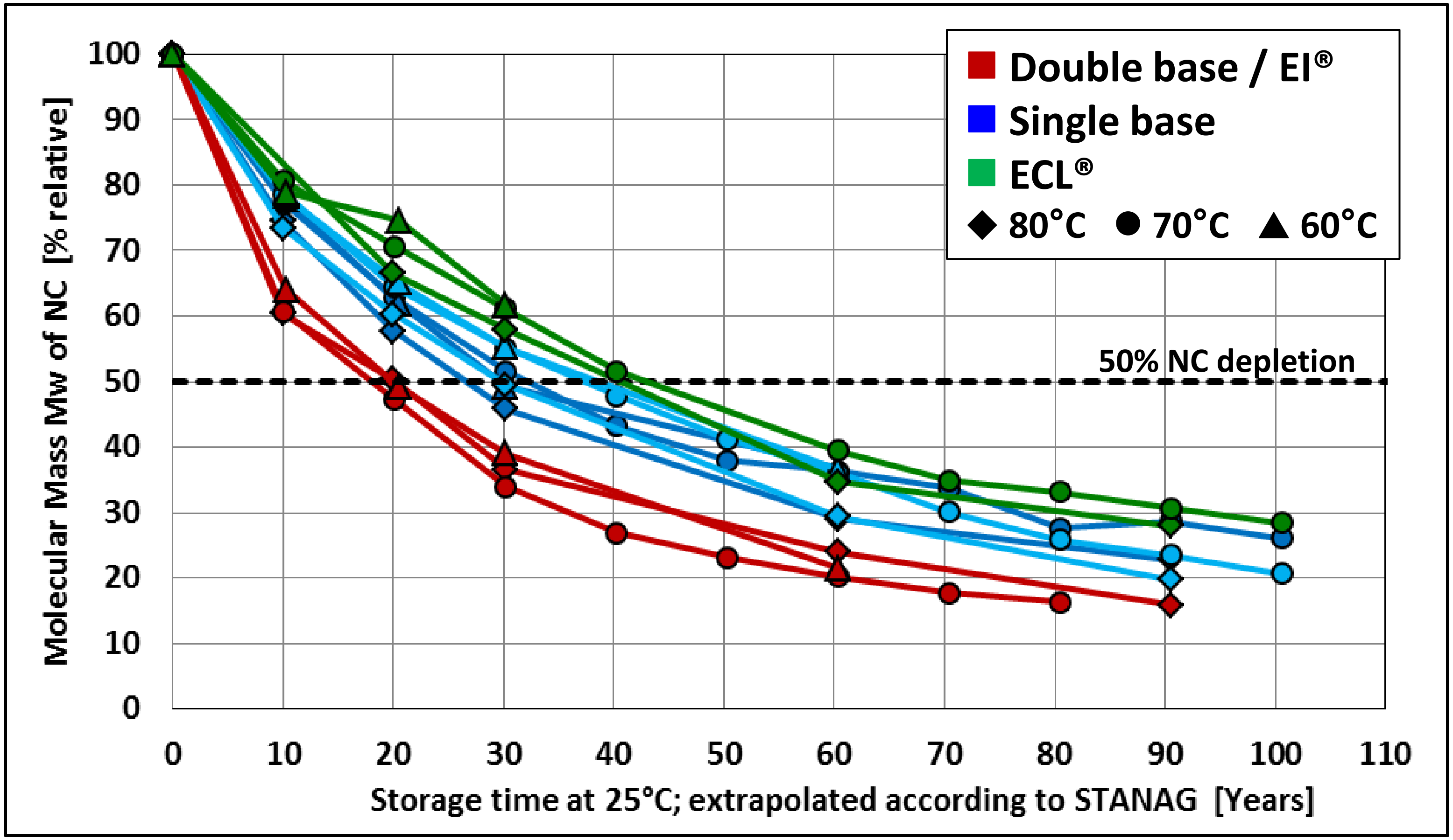
Nitrocellulose Molecular Mass Reduction



- Single base / ECL® propellants show slower relative molecular mass reduction and thus better chemical stability than double base propellants

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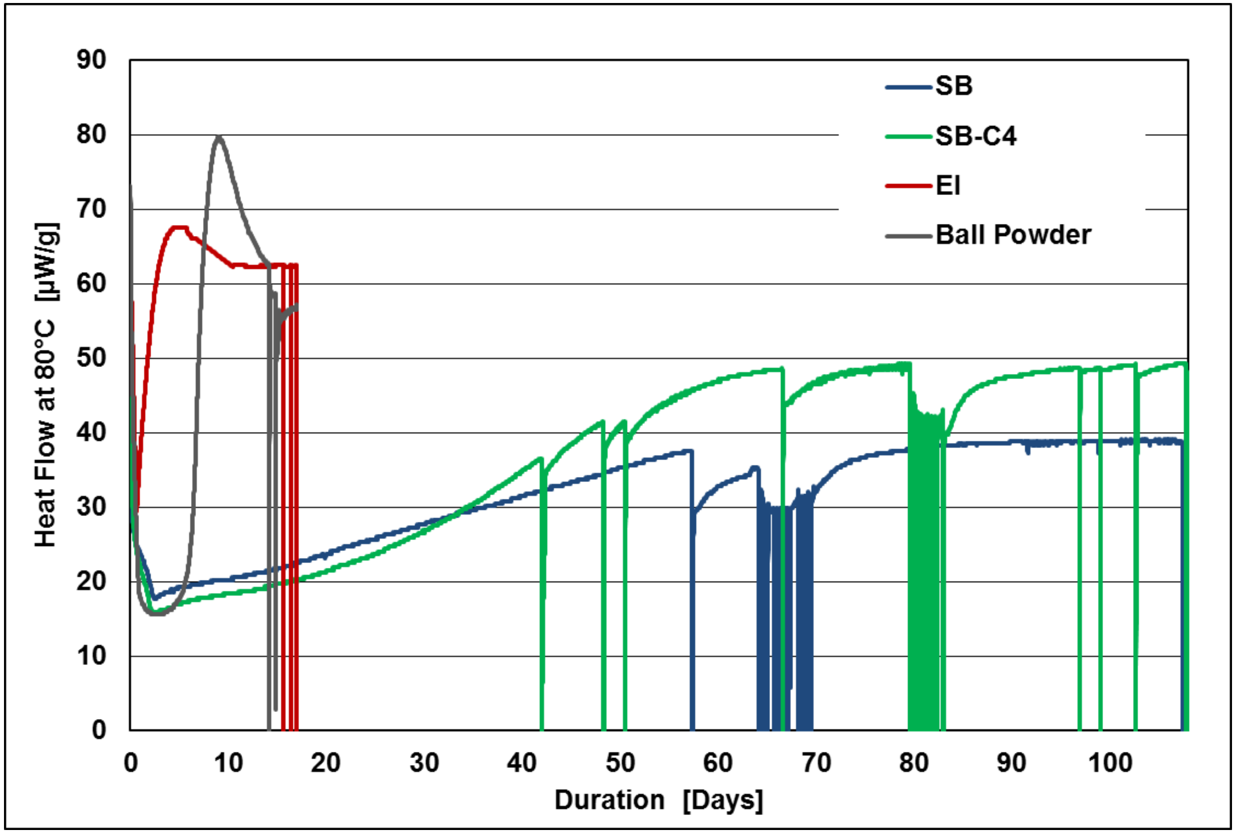
Heat Flow Calorimetry



Breaking of seal of HFC vial due to over-pressure cased by ageing gases during prolonged ageing

- All four tested propellants meet requirements of STANAG 4582
- HFC measurement is deteriorated by overpressure venting after 1 – 4 STANAG durations
- For single base and ECL® propellants, heat flow is much lower and time to overpressure venting of the sample vial is much longer than for double base propellants

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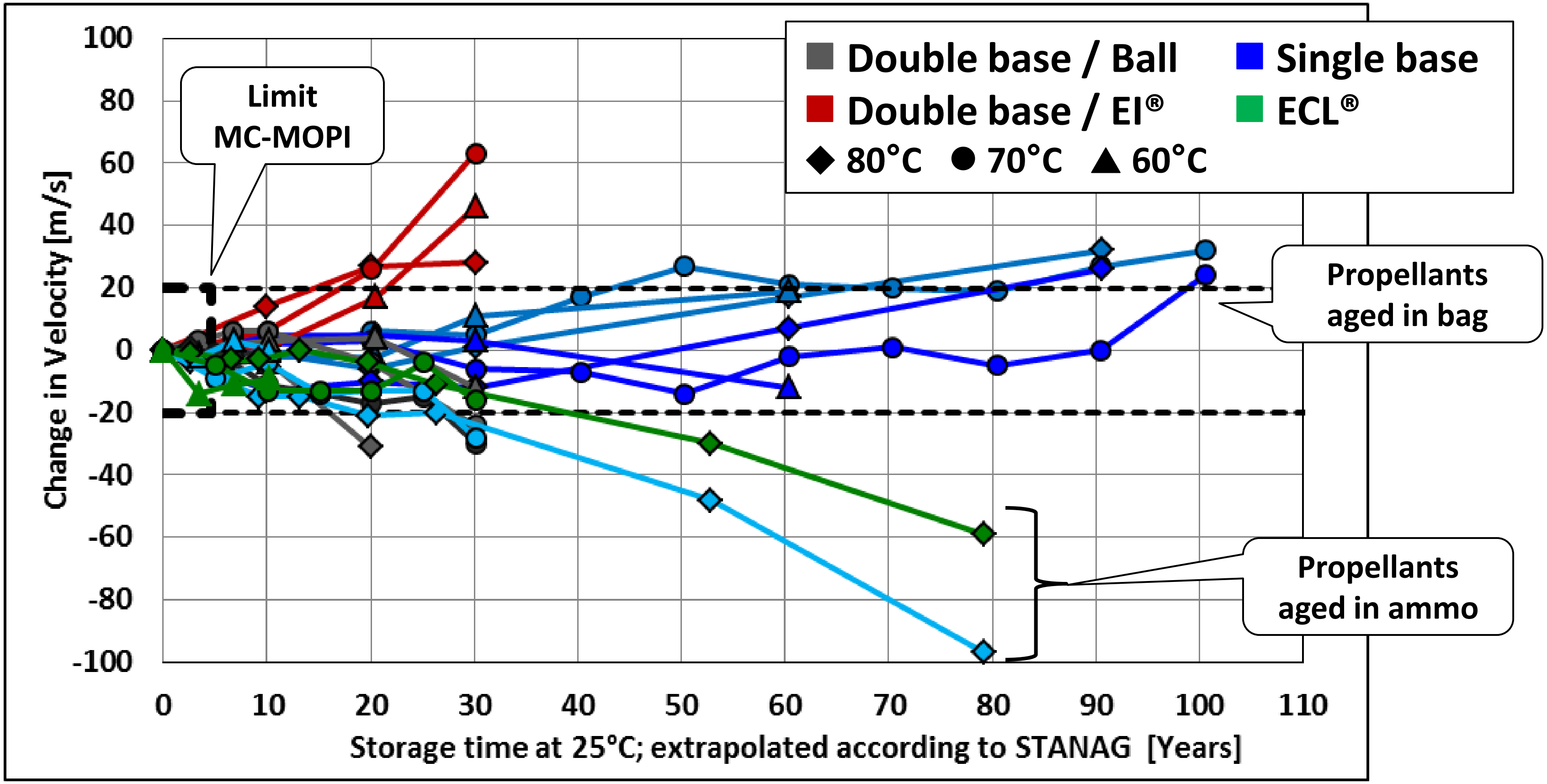
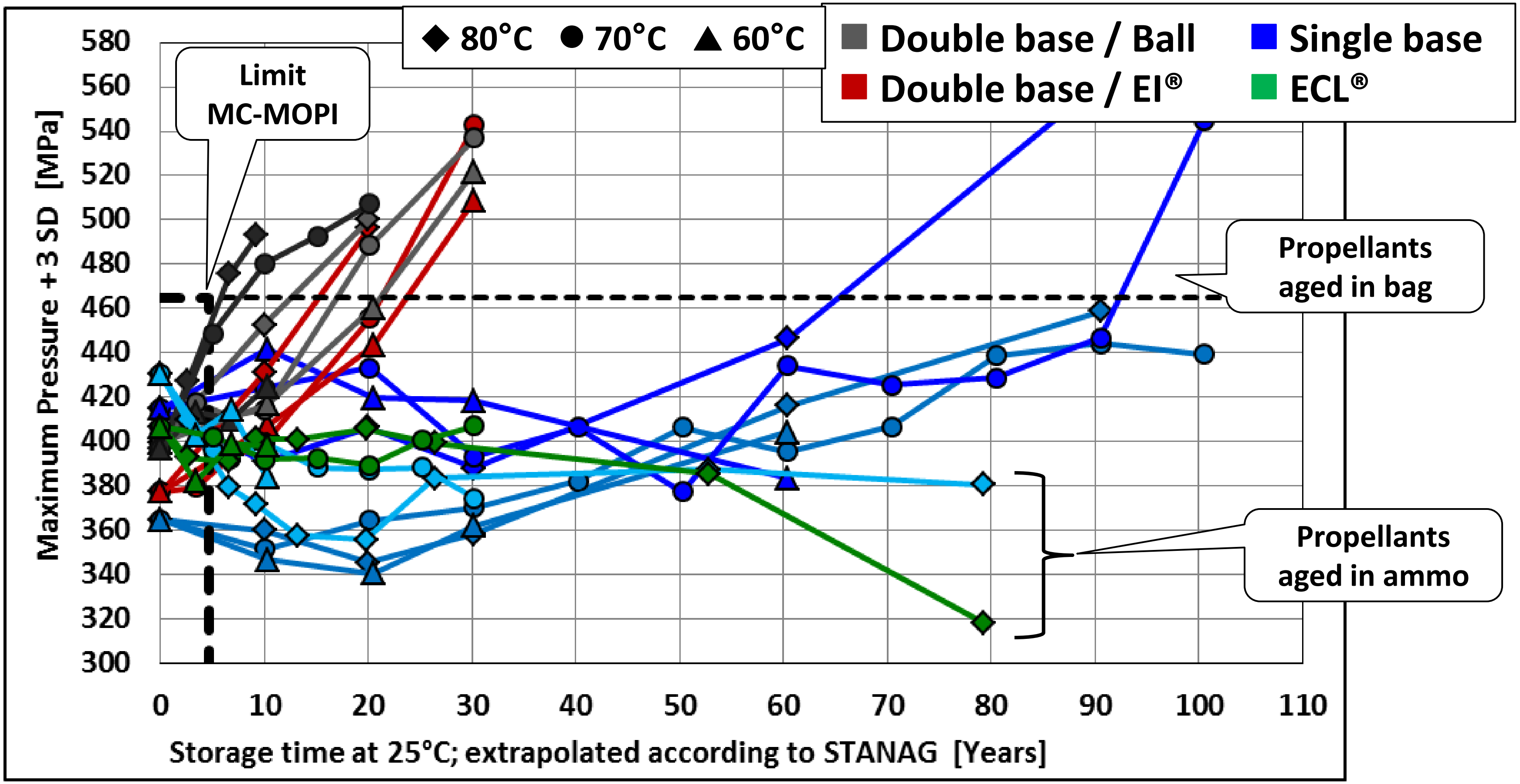
Small Calibre / Muzzle Velocity Change



- All tested propellants meet the requirements of AEP-97 MC-MOPI
- Single base / ECL® show slower change in muzzle velocity than double base
- Ageing of igniter has a significant influence on muzzle velocity change (as seen by the fact that for longer ageing periods, loss of velocity correlates with ignition delay t_2)

Small Calibre / Peak Pressure + 3 SD



- All tested propellants meet the requirements of AEP-97 MC-MOPI
- Double base propellants show an early / dangerous increase in peak pressure
- Single base / ECL® propellants have a much better ballistic stability

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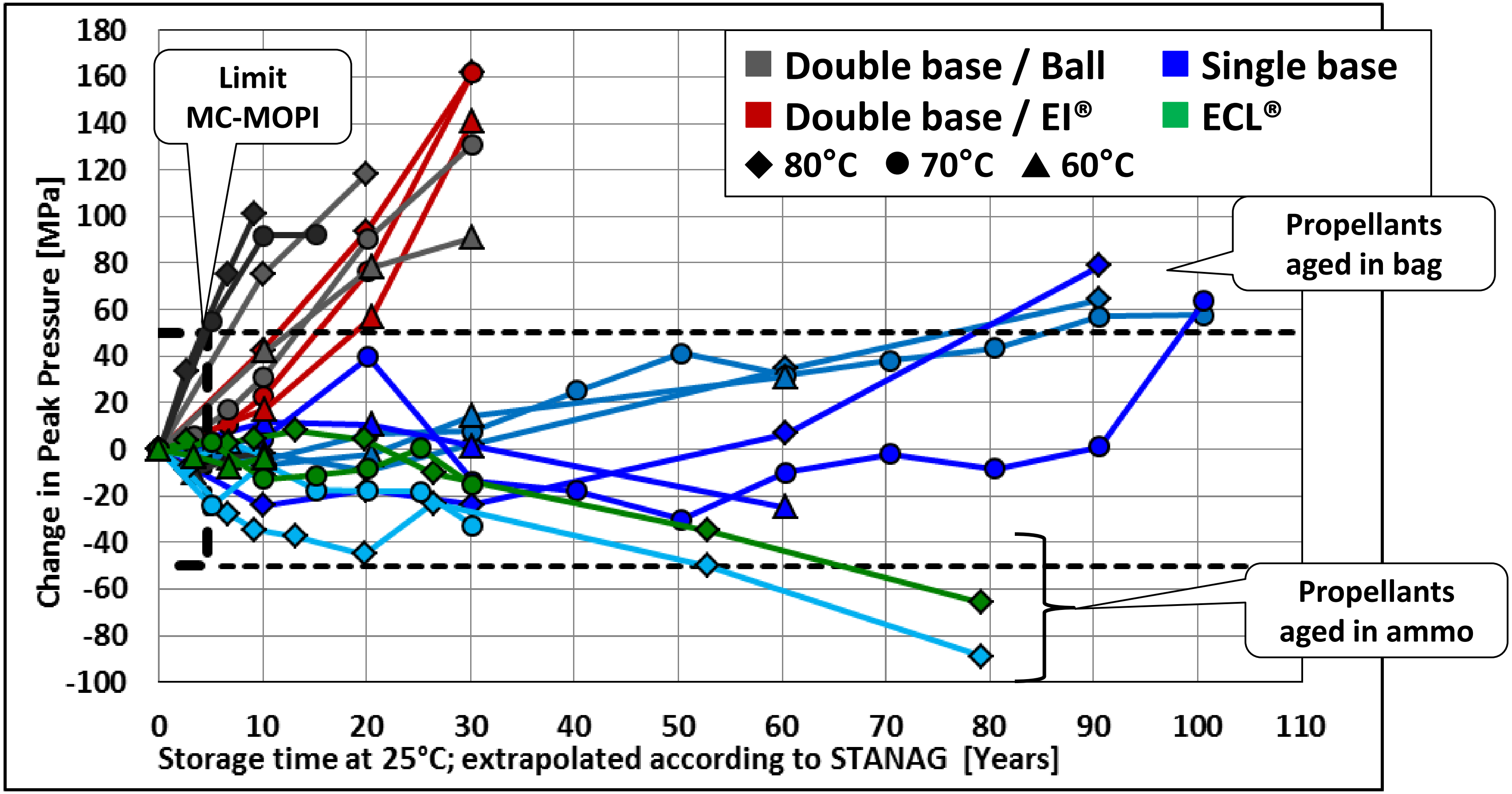
Small Calibre / Peak Pressure Change



- All tested propellants meet the requirements of AEP-97 MC-MOPI
- Single base / ECL® propellants show much slower increase in peak pressure and thus better ballistic stability than double base propellants

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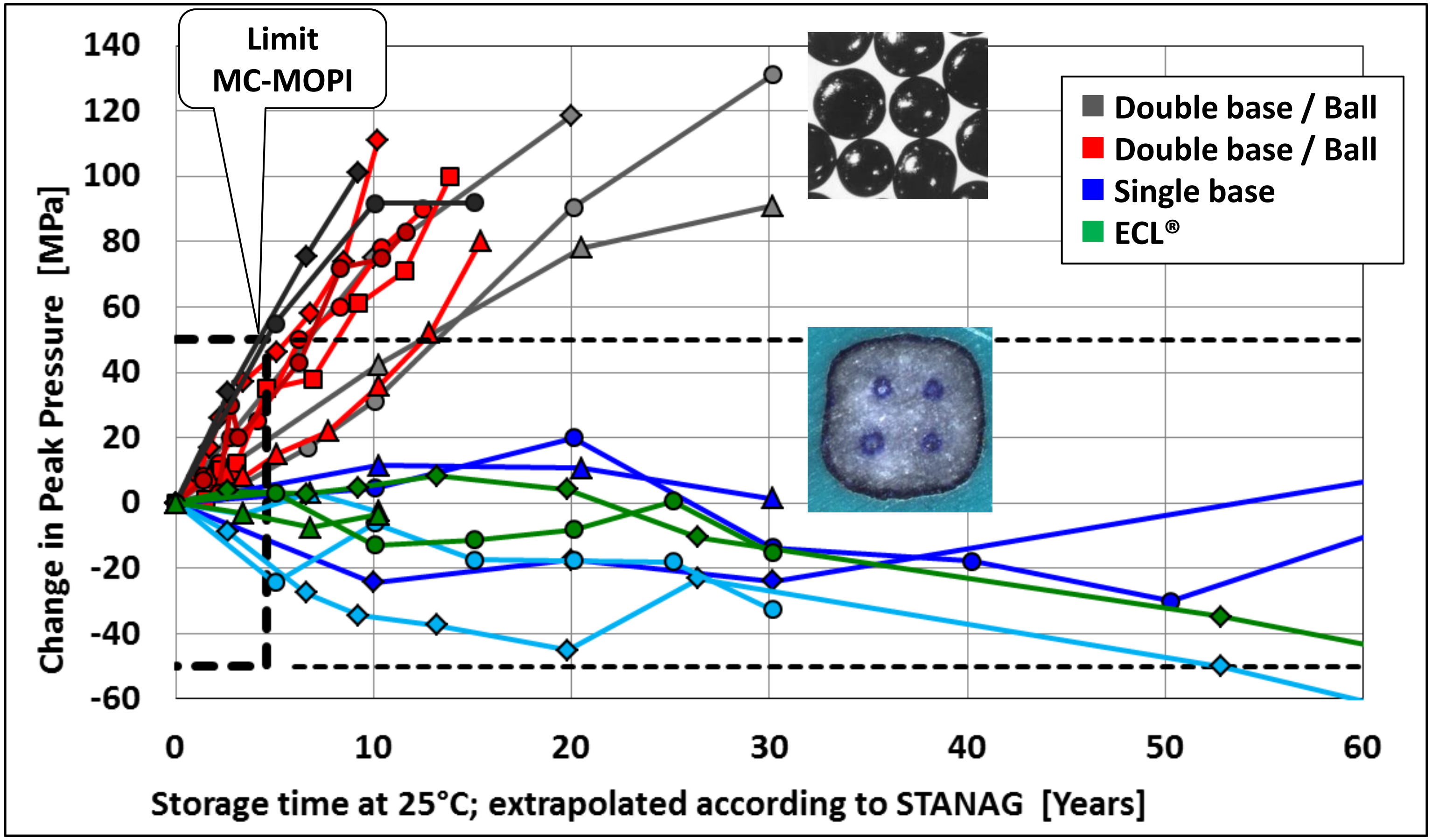
Verification of Results – Peak Pressure Change 5.56mm



Grey / blue / green = own results

Red = Jeunieau, Levebvre, Guillaume, Wilker, Che-valier, Eibl; 35th Internat. Annual Conf. of ICT, 2004

- K5810 UK 80°C
- K5810 UK 70°C
- K5810 UK 65°C
- K5810 UK 60°C
- K5810 GE 70°C

- Results of earlier German / Belgium study confirms obtained results regarding early significant increase in peak pressure of ball powder

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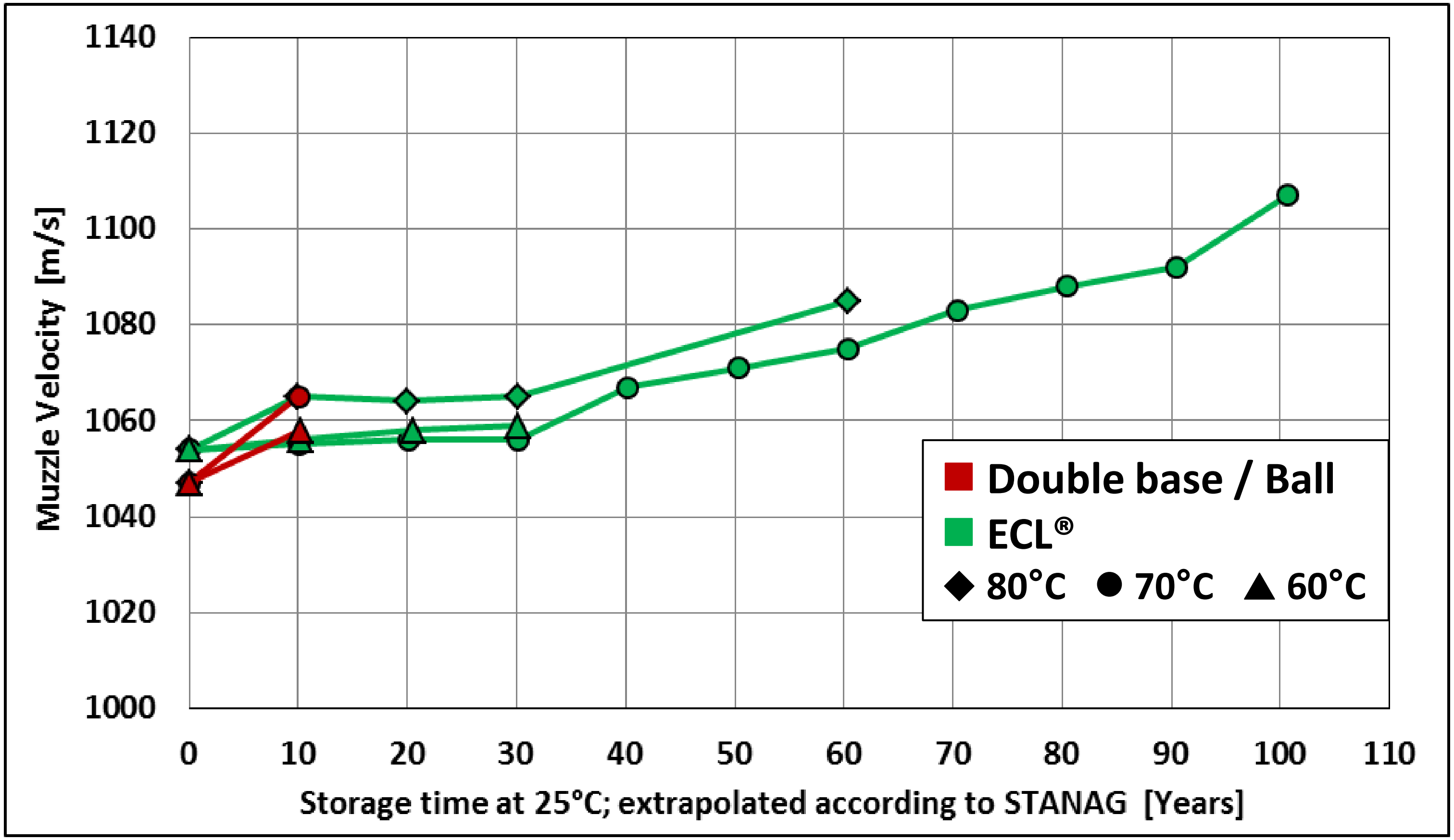
20mm Aircraft Ammunition / Muzzle Velocity



- Ball powder: Moderate change in muzzle velocity after short ageing time
- ECL®: No significant change in muzzle velocity up to 3 STANAG ageing durations, followed by moderate increase when exposed to prolonged extreme ageing

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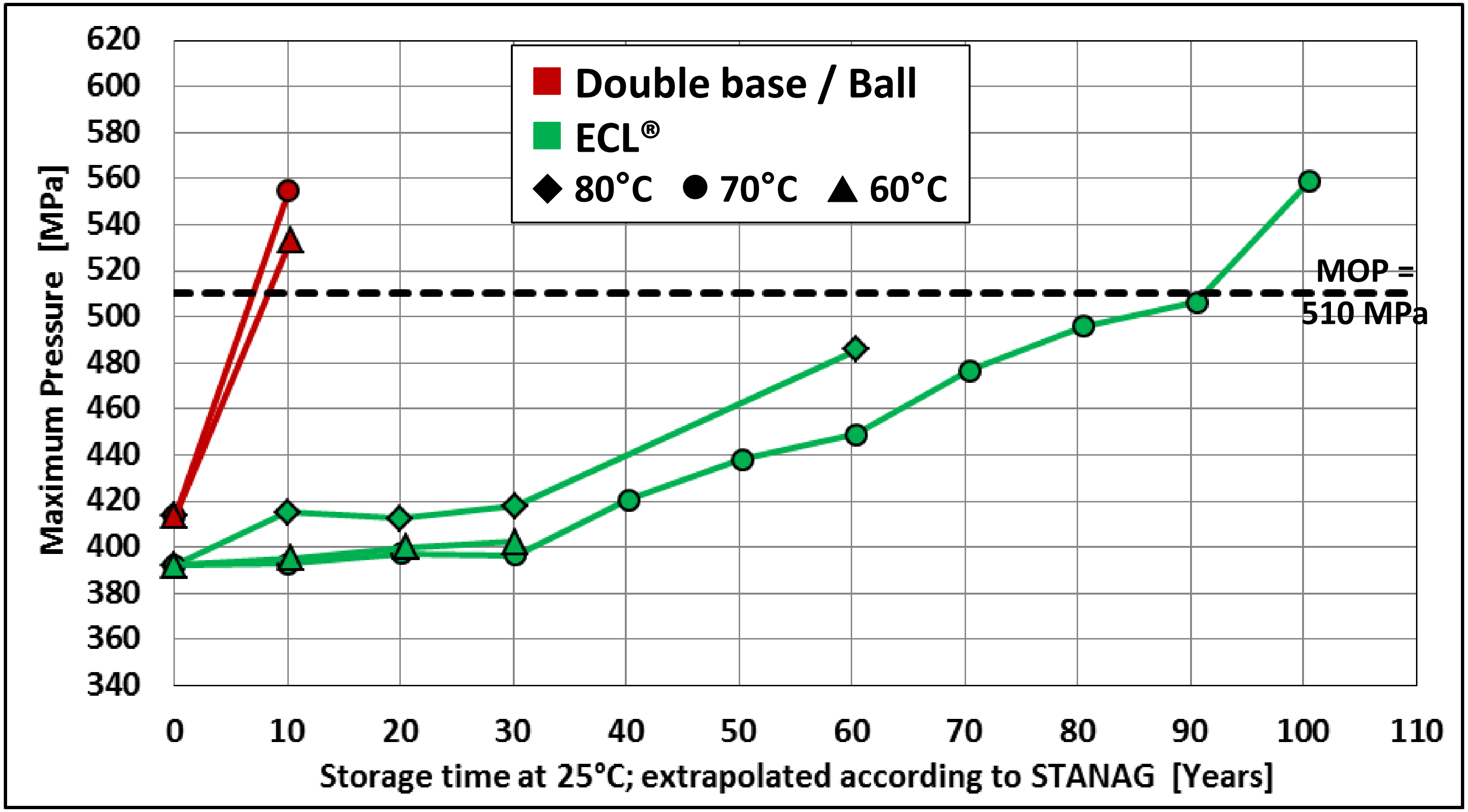
20mm Aircraft Ammunition / Peak Pressure



- Ball powder: Strong increase in peak pressure already after short ageing time
- ECL®: No significant change in peak pressure up to 3 STANAG ageing durations, followed by moderate increase when exposed to prolonged extreme ageing

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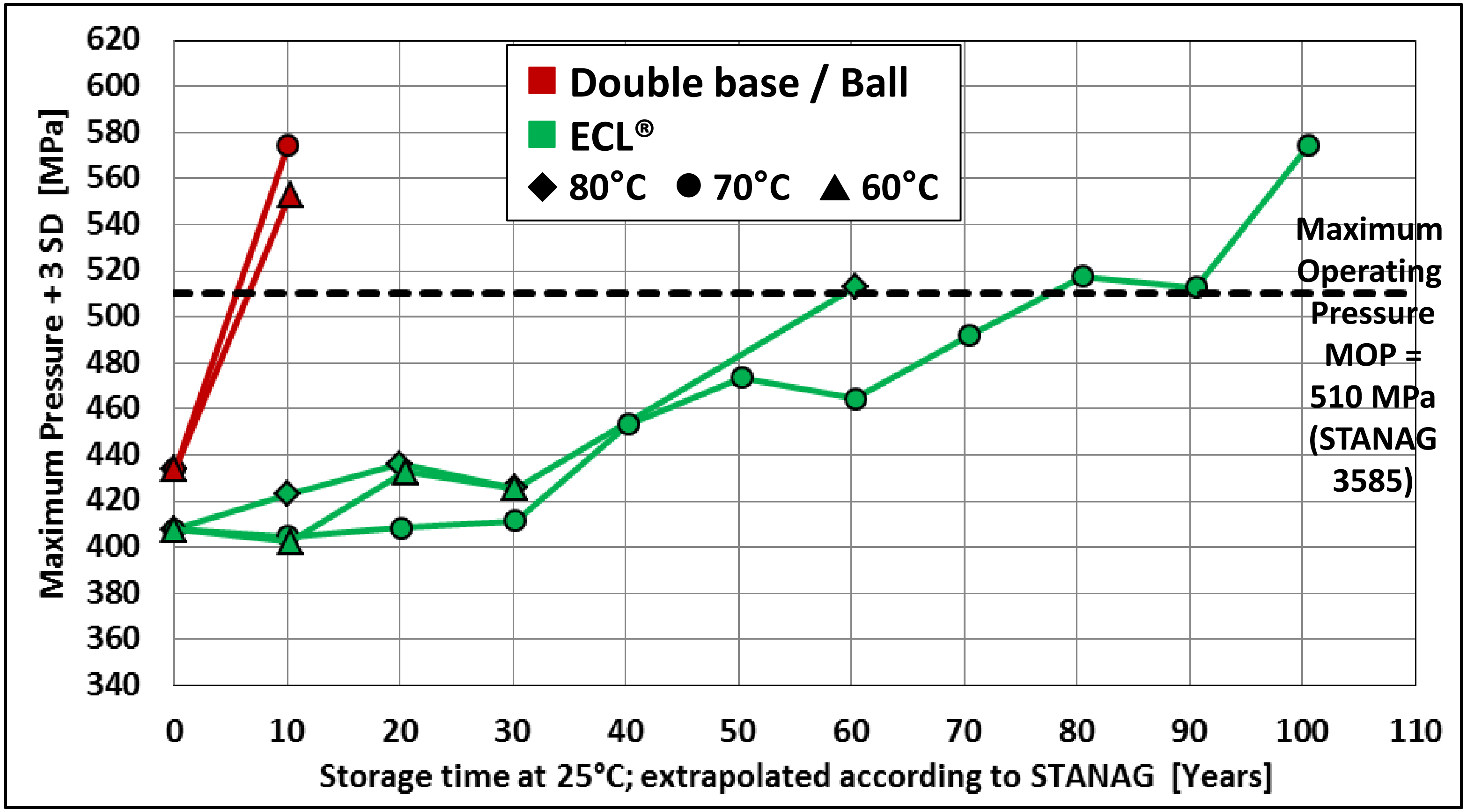
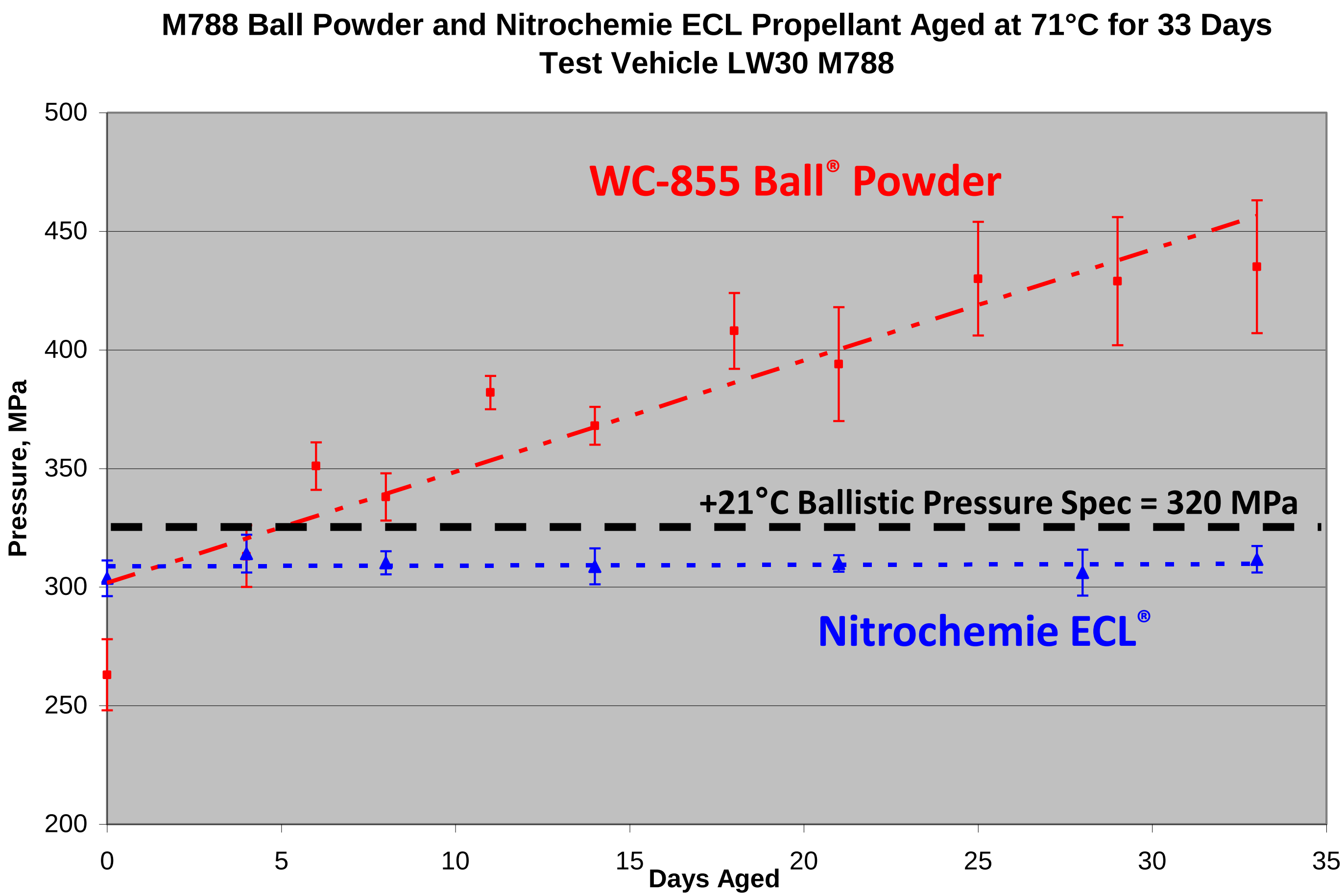
20mm Aircraft Ammunition / Peak Pressure + 3 SD



- Ball powder exceeds the system maximum operating pressure MOP already after <1 STANAG period; ECL® not before 6 – 8 STANAG periods
- ECL® has much better ballistic stability than double base / ball powder

Verification of Results – 30mm x 113 LW 30



Results from Partner:

ATK

Presented by ATK at IMEMTS 2010 in Munich

⇨ WC855 Ball® Powder: Increase of peak pressure by 50% (or 150 MPa)

⇨ ECL® propellant: No change of peak pressure after 33 days at 71°C

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Summary and Conclusions

- Four different propellants types for small and medium calibre ammunition have been subjected to extreme ageing, exceeding the thermal loads applied during qualification by factor 10 (STANAG 4582 / AOP-48) to 20 (AEP-97 M-C MOPI)
- Extreme ageing conditions:
  - Showed only a slow / continuous deterioration of chemical properties
  - But revealed an abrupt rise regarding deterioration of interior ballistics
- Single base and ECL® propellants demonstrated, compared to double base / ball:
  - An increase regarding chemical shelf life by factor 3 (for same stabiliser)
  - An increase regarding ballistic / functional life by factor 4 – 8
- The replacement of double base by new generation of single base or ECL® propellants is therefore advisable if high thermal stability is required

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Thanks very much for your attention !

Financial support by armasuisse (Swiss Defence Procurement Agency; Dr. P. Folly; Project Nr. ARAMIS R-3210/042-73) is gratefully acknowledged !