Characterisation of aged Polymer Bonded eXplosives - Development of STANAG 4666

IMEMTS – 2007 (Miami - Florida)

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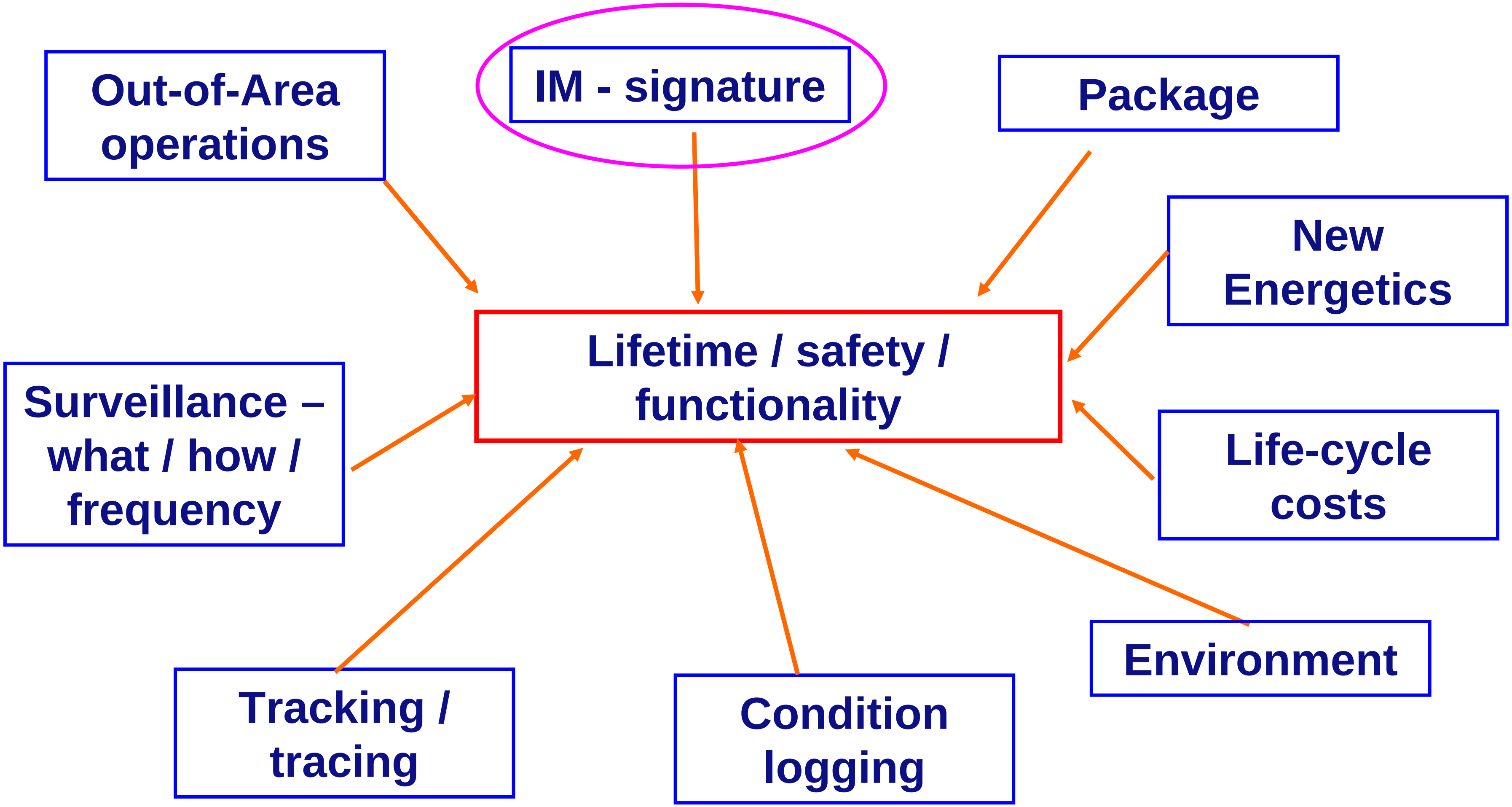
Senior Scientist Lifetime Studies

Overview

1. Introduction Lifetime
2. History of STANAG
3. Workshop in Finland (2005)
4. Reference documents - Techniques
5. Aim of STANAG
6. What is changing, making material critical
7. Conclusion
8. Acknowledgement

Lifetime


Out-of-Area operations
IM - signature
Package
New Energetics
Lifetime / safety / functionality
Surveillance – what / how / frequency
Life-cycle costs
Tracking / tracing
Condition logging
Environment

Insensitive Munitions

- RNLA had not yet insensitive munitions
- TNO advised RNLA on adequate protection

Anti tank weapon at the back of jeep in Afghanistan: 1 bullet on AT-4 could be fatal

Transport conditions - example

Current-future activities for SG1

- **In 2003 a survey of the member nations was conducted to determine which standards are needed**
- **Those high on the list include;**
  - **Standardization of surveillance activities**
  - **Update of ingredients specifications and methods**
  - **<u>Standard to cover "Ageing of PBXs"</u>**

History of STANAG 4666

- **MSIAC workshop – May 2005**

- **Start for AC-326-SG 1 – CNG to set up a new document;**

  The aim of this agreement is to standardize accelerated ageing and testing protocol by which aged samples of PBX's, cast-cured compositions using 'inert' or 'energetic' binders can be assessed and compared.

- **Title STANAG 4666 :**
  Explosives: Explosives, assessment of ageing of Polymer Bonded Explosives (PBX's) cast cured compositions using inert or energetic binders

- **Custodian nation : The Netherlands - TNO**

Areas to cover by the working group in Finland

- What other specifications do people use to look at ageing of PBXs
- What is the aim/goal of this STANAG
- Can the STANAG help to fill gaps in STANAG 4170
- What is the scope of materials covered by this STANAG, e.g. for cast-cured inert binder PBXs only, pressed, etc
- Is only an update of STANAG 4581 required?
- Can/should sentencing criteria be suggested/included
- Is the STANAG to be designed to help find the critical ageing mechanisms of the PBX (e.g. a decision tree) or is this assumed prior to application?

NAVSEA 8020.C

- **Spells out mandatory requirements to qualify new energetic materials for USA usage**

- **Accelerated ageing is an essential part of the qualification process**
- **Conditions of ageing;**
  - **60^{o}C, 1, 2, 4, 6, 8 months, sealed containers**
  - **70^{o}C: 1, 2, 4, 6 months, sealed containers**
  - **25^{o}C, 30% RH - until final (type qualification)**

Compositions based on polyester binders are aged under controlled 30% RH

NAVSEA 8020.C

Requirements to meet qualification include:

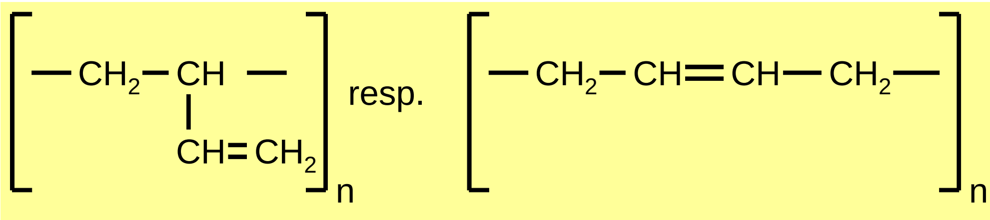
- **No substantial change in:**
  - **Ignition temperature (DTA)**
  - **Impact sensitivity**
  - **Friction sensitivity**
  - **Shock sensitivity**
  - **Stabiliser/antioxidant level (% change)**

- **>20% change in mechanical properties may require further tests**

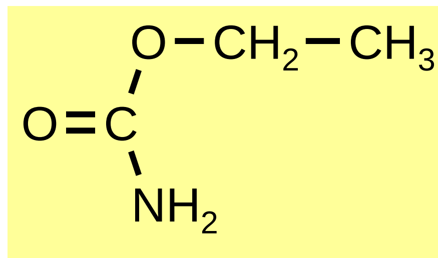
- **Safe(shelf) life at 25^{o}C – minimum 20% stabiliser remaining at 20 years**

- **Safe use(service) life - <20% change in post-cure properties, no substantial change in shock sensitivity, no fissures after 30 days at 60^{o}C in x-ray fissure test**

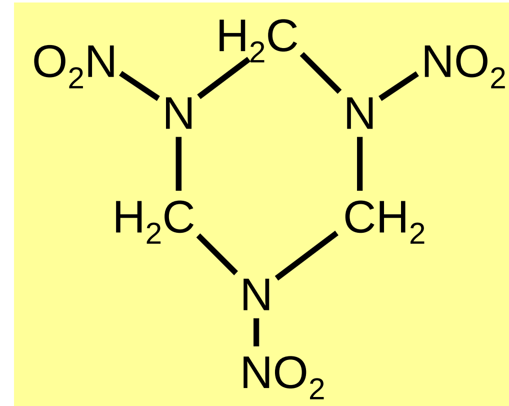
PBX – energetic materials /// binders



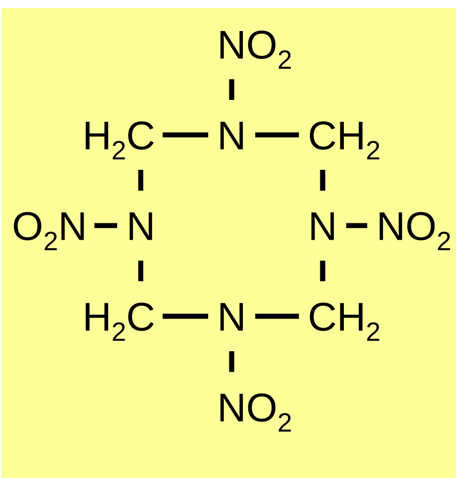
HTPB



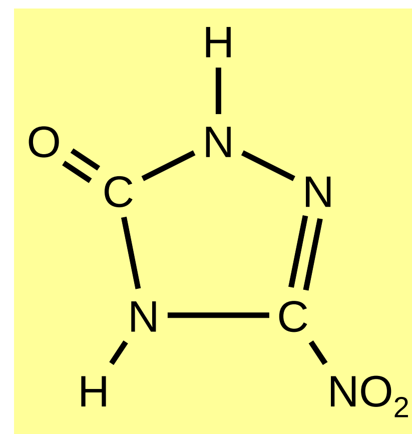
Poly-Urethane



RDX



HMX



NTO

CAST PBX

- **80 – 90 % solid load**
- **10 – 20 % binder**
- **Binders : HTPB , GAP, PolyNimmo, PolyGlyn, HTPE (future ?)**
- **Energetic Material**
  - **RDX, HMX, RS-RDX, AP, Al, AN, TATB, NTO, DOA, DOS, IPD, TMETN, BDNPA/F, TEGDN**
  - **FOX-7, CL-20, AND, GAP-azide**

What is leading to IM properties *vs* Ageing ?

- **Mechanical properties**
- **Friability**
- **Sensitivity**
- **Burning / detonation process**
- **One or two (or even more) IM compositions in a article**
- **Influence of humidity on one component or all**
- **Taking into account all stabilizers ?**

First line of test methods

- Molecular weight (diffusion processes / hardening) [GPC]
- Detonation velocity
- Porosity (ultrasound sufficient enough ?)
- Flyer impact
- Focusing on energetic part or binder ?
- What is maximum ageing temperature
- Ignitability – separate or ignition train

STANAG 4581 - Contents

- Accelerated ageing conditions
  - Bulk block sample
  - “Sealed” condition
  - Only one temperature – 60^{o}C, 3/6 months
- How to prepare test samples from aged ‘bulk’ material
- Chemical analysis methods
  - Sol content
  - Cross link density
  - HPLC analysis of antioxidant content
  - GC analysis of plasticiser content
- Mechanical tests
  - Uniaxial tensile test (STANAG 4506)
  - Dynamic Mechanical analysis (DMA) (STANAG 4540)
  - Shore Hardness (ASTM D2240-00)
- Refers to many other STANAGS for actual testing methods

Tests methods

Possible new methods in STANAG 4666 edition 1

- **Tests for filler-binder interface**
- **Dilatometry (pressure)**
- **Microscopy (SEM, optical, FTIR imaging)**
- **TMA (expansion)**
- **Friability (critical dp/dt, critical velocity, number of repeats/velocities….)**
- **Small scale sensitivity tests – one company uses ESD as key screening method**
- **Hardness techniques – shore hardness, DMA, others?**
- **Shock sensitivity**

Proposed test methods in draft STANAG 4666

CHEMICAL TESTS

- **1A Measurement of the soluble fraction**
- **1B Measurement of crosslink density**
- **1C Measurement of antioxidant content (HPLC)**
- **1D Measurement of plasticizer content**

MECHANICAL TESTS

- **2A Uniaxial tensile test**
- **2B Dynamic mechanical analysis**
- **2C Measurement of Shore A hardness**
- **2D Thermal Mechanical Analyses**

Cont'd

THERMAL TESTS

- **3A** **Differential Scanning Calorimetry**
- **3B** **Thermogravimetry**
- **3C** **Pressure Vacuum Stability Test**
- **3D** **Heat Flow Calorimetry (HFC)**

OTHER TESTS

- **4A** **Scaning Electron Microscopy**
- **4B** **Shock Sensitivity**
- **4C** **Friability Test**
- **4D** **FTIR spectroscopy**

Examples for new techniques

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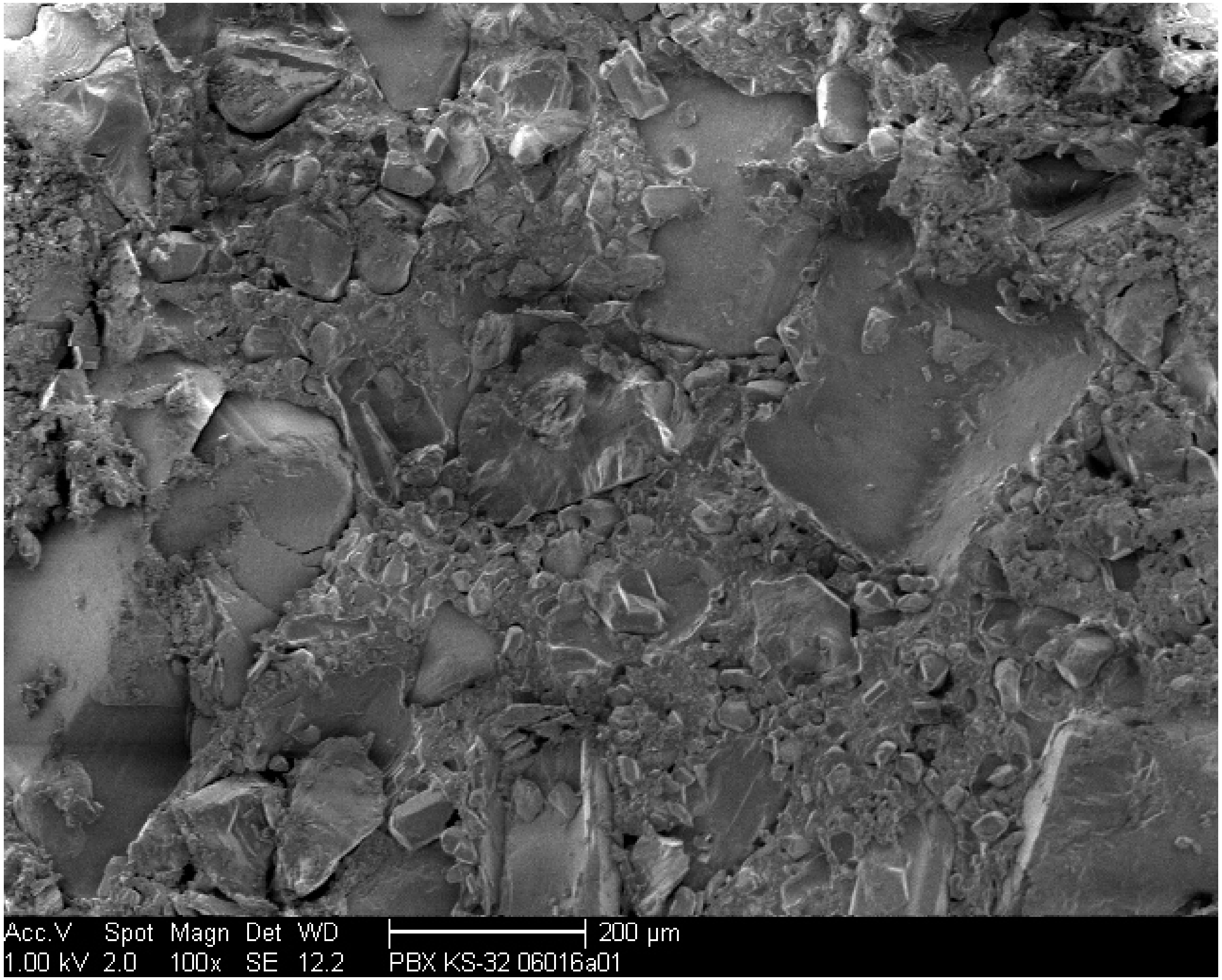
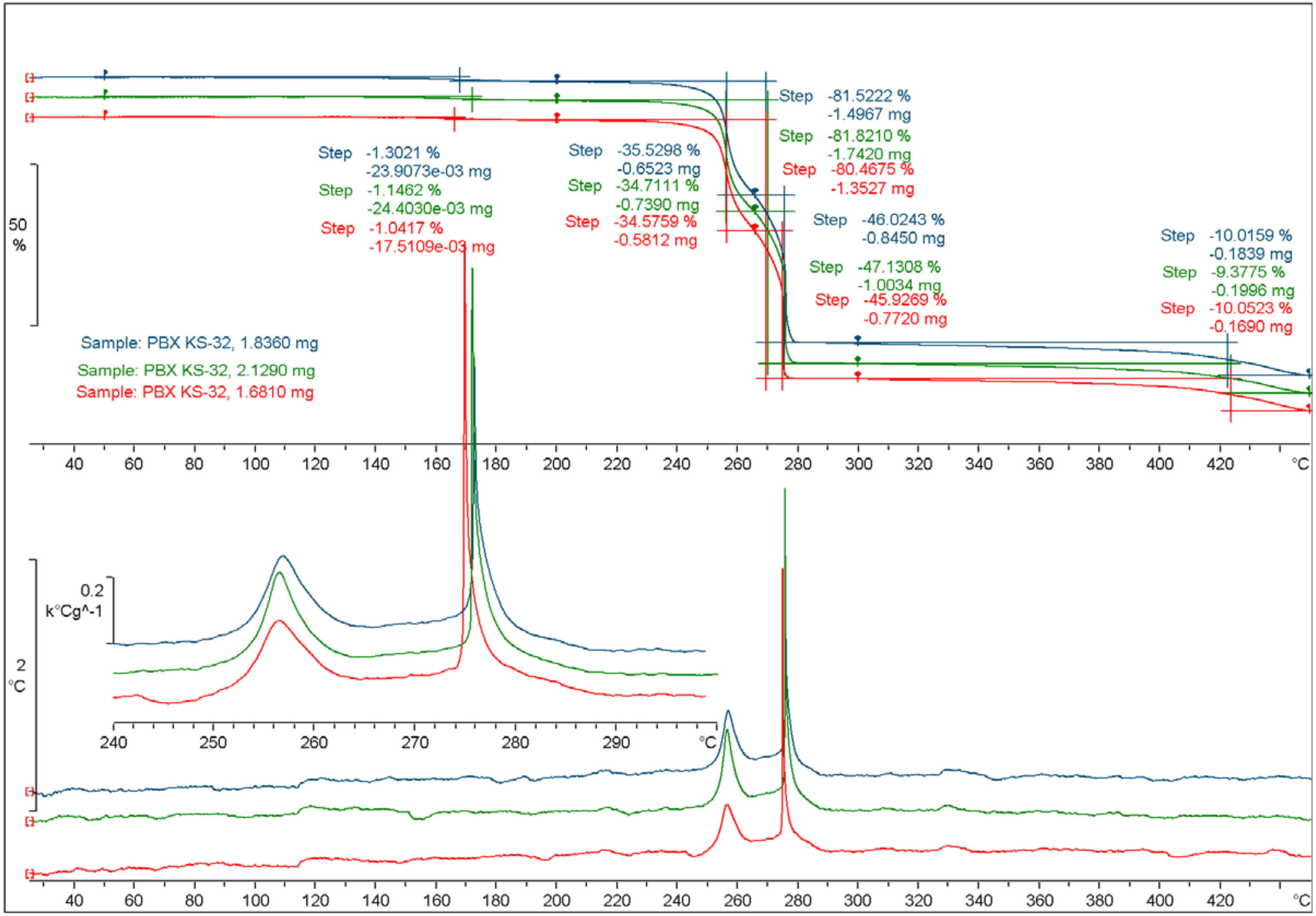
SEM

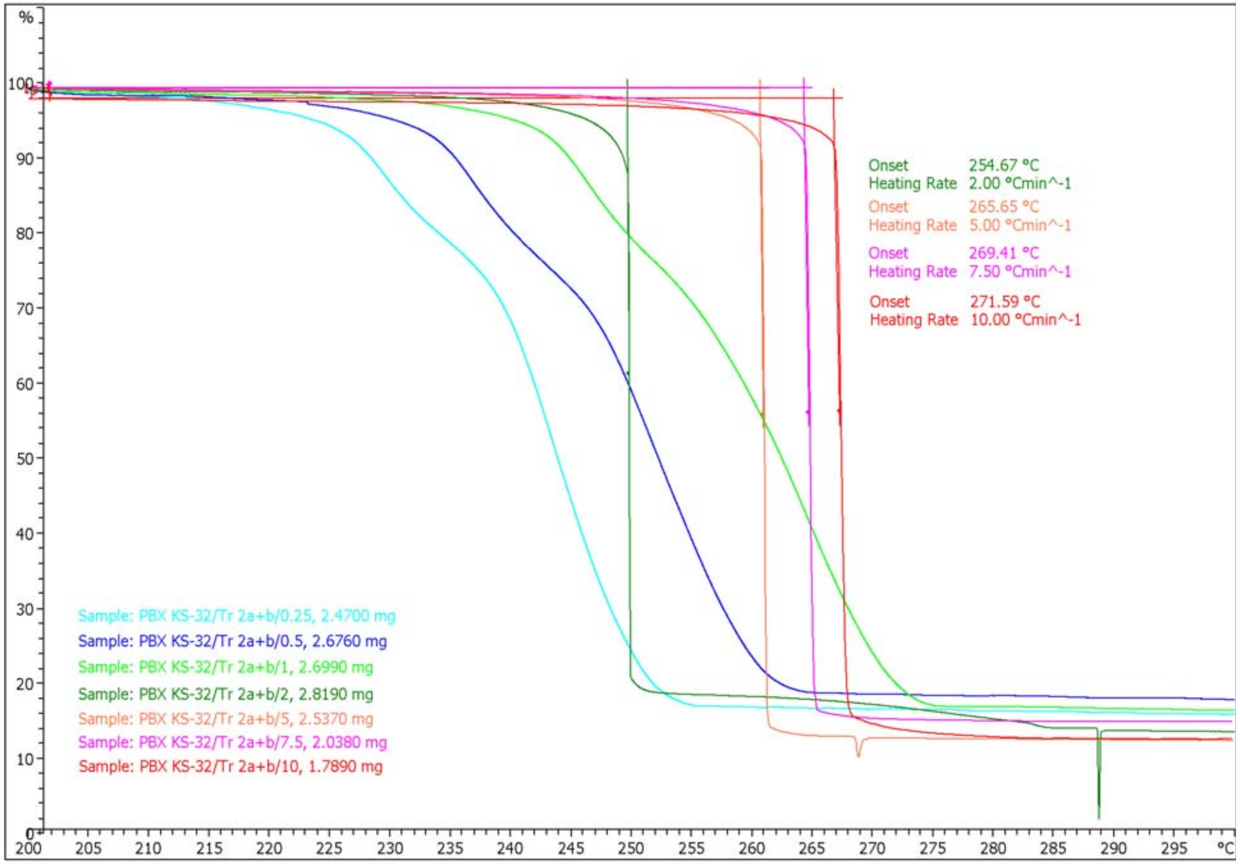

Acc.V Spot Magn Det WD
1.00 kV 2.0 100x SE 12.2
200 µm
PBX KS-32 06016a01

Thermal analysis (TG-SDTA)

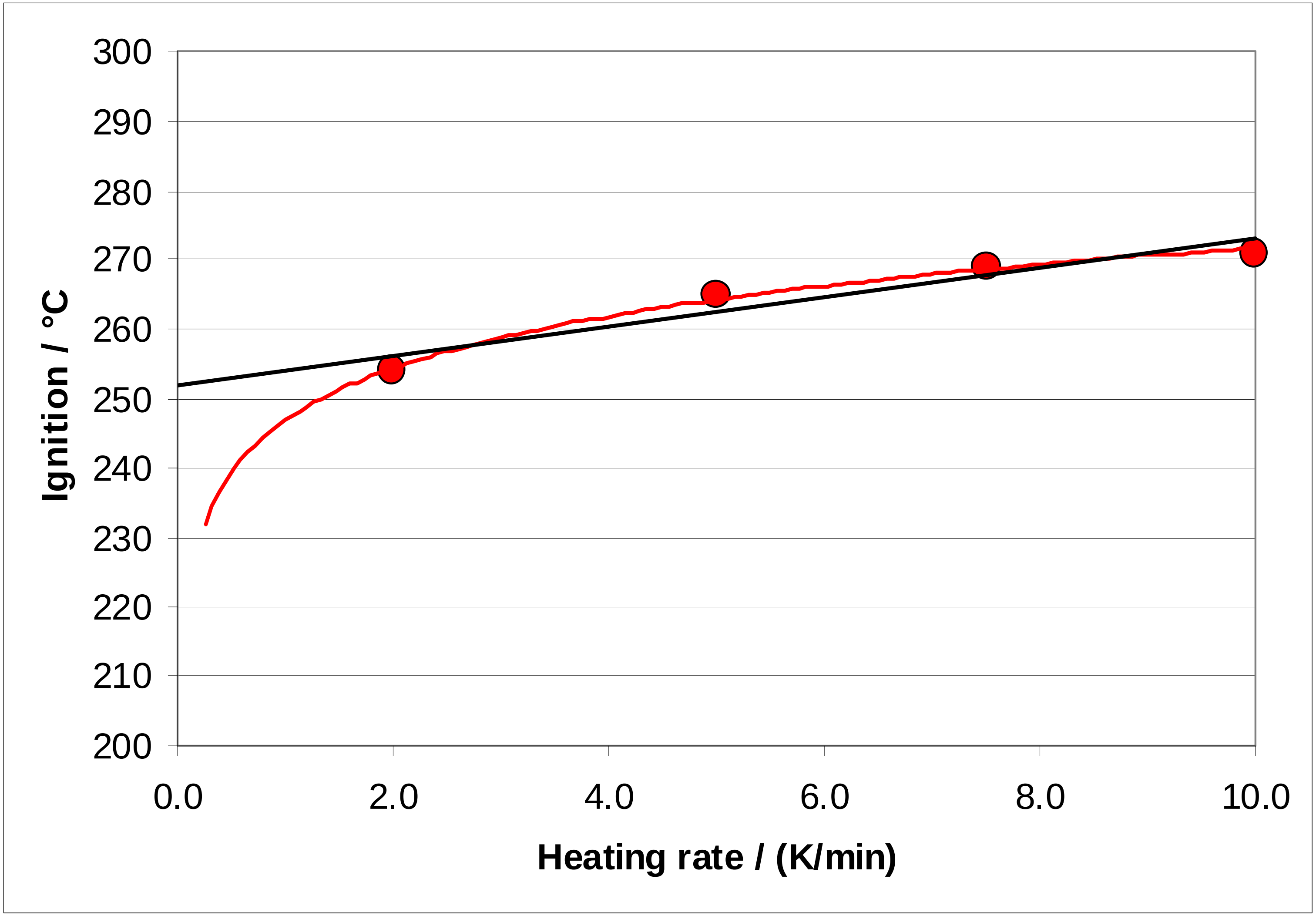


Kinetics

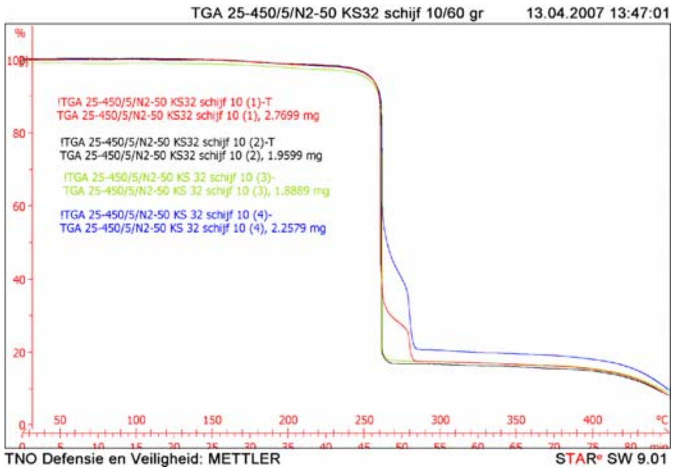
- The applied heating rates are: 0.25 K/min; 0.5 K/min; 1 K/min; 2 K/min; 5 K/min; 7.5 K/min; en 10 K/min

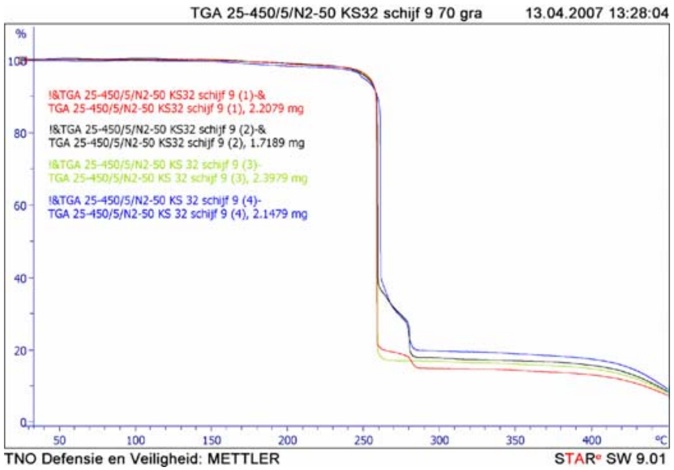


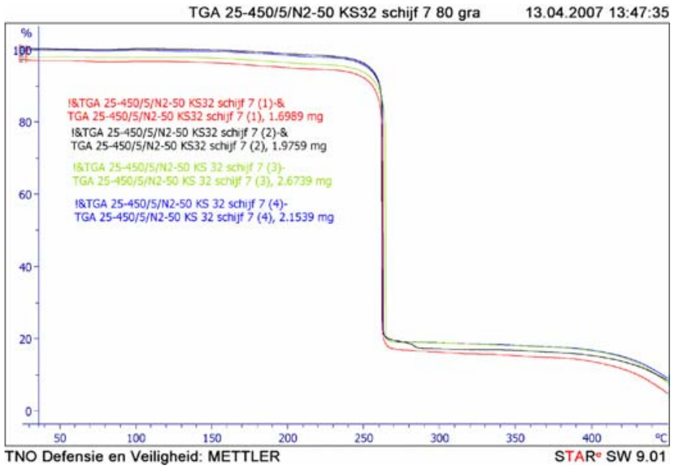
Ignition temperature



Aged at 60 / 70 / 80 C







Decomposition profile is changing as function of ageing temperature

Discussion / Conclusion

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Discussion / conclusion

- Proposed test methods has to be evaluated
- Additional tests are advisable to be performed on different compositions by participating countries
- First edition of STANAG will be set-up and forwarded to the SG-1 members

Acknowledgement

- Dutch Ministry of Defence for supporting the TNO-activities inside the NATO community

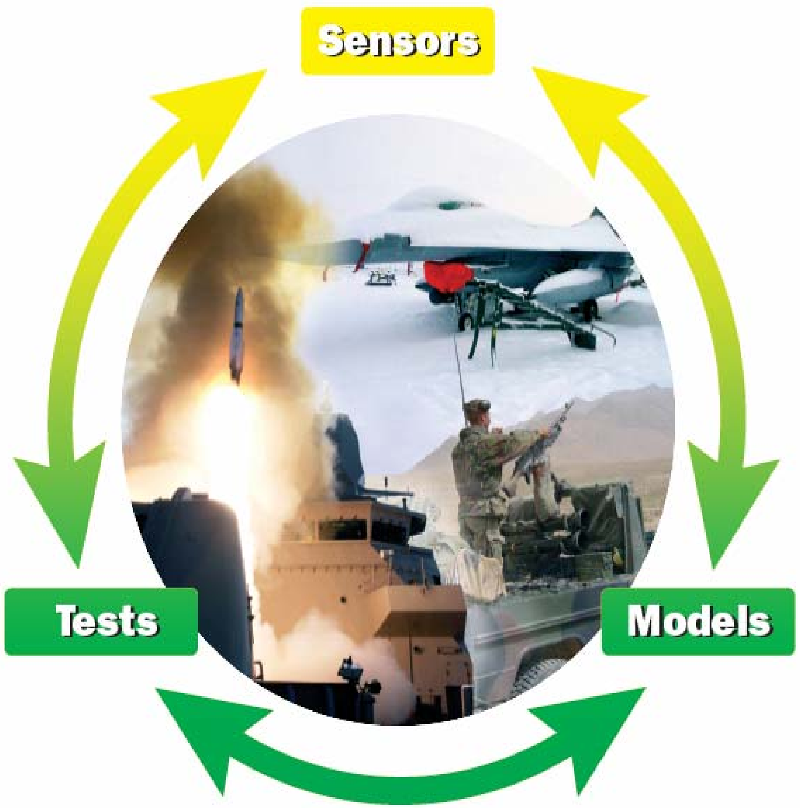
- Co-authors:

  - TNO Richard Bouma (member of AC-326-SG-1)

- Custodiangroup, AC326-SG-1 on life assessment

- Audience for listening

Center of Expertise for Lifetime Studies



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