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# Unfavourable Trade-Off: High Temperature Explosives vs Performance Sacrifice

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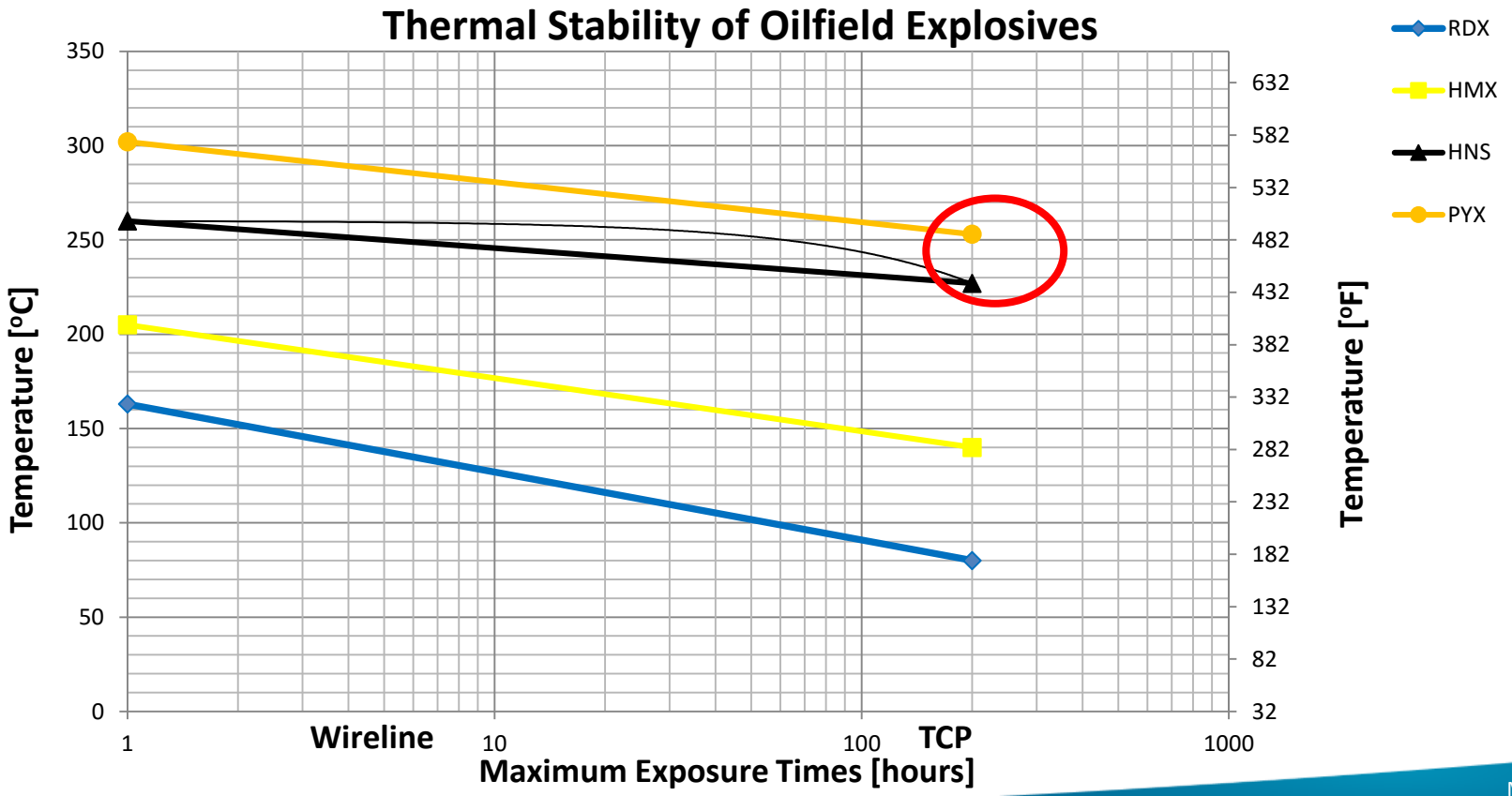
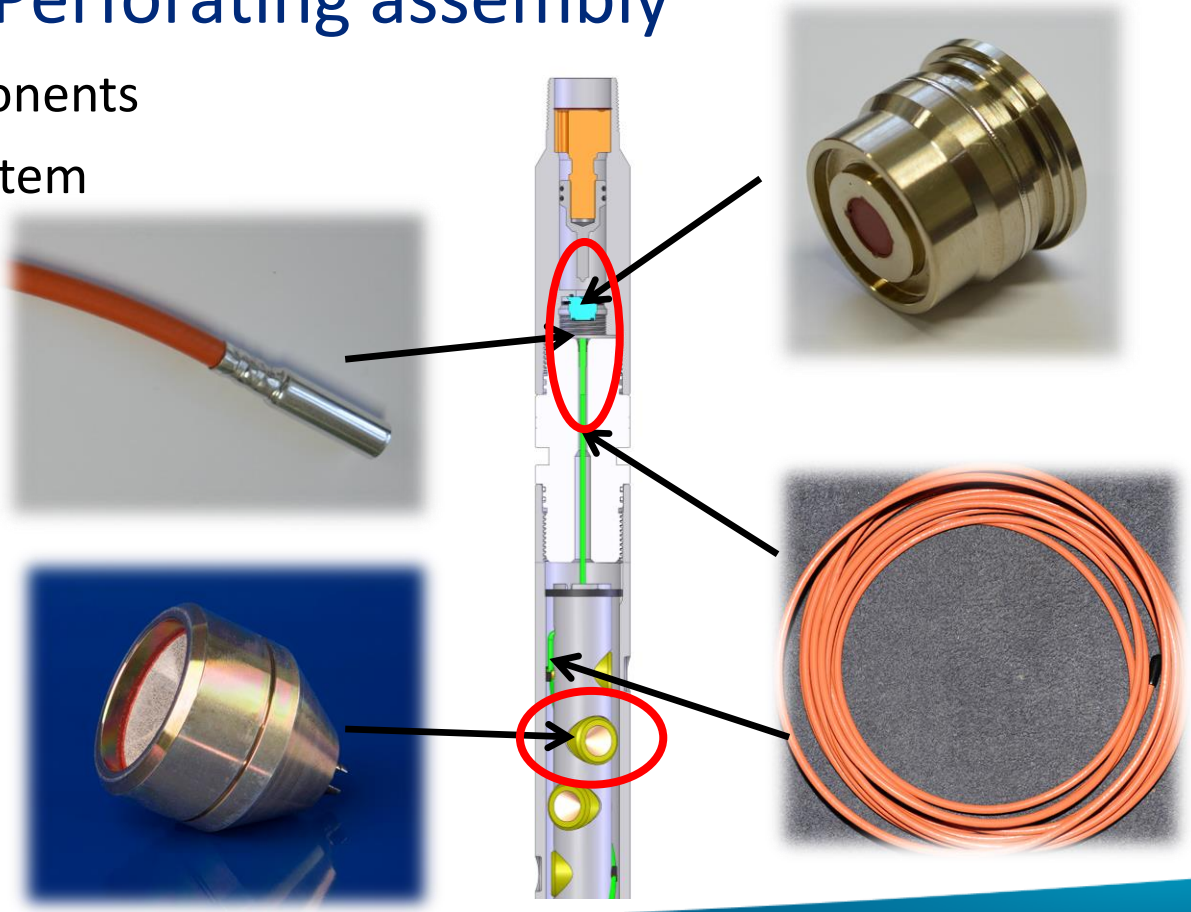
AUTHORS: J. Loehken; L. McNelis, F. Montenegro, J. Müller, A. Gomez, S. Steingass; DynaEnergetics

# Introduction & Background:



# Ballistics in Perforating assembly

- Explosive Components in a TCP Gun System



# Criteria For Ballistics

Factors in a harsh
high temperature environment:

- Safety
- System reliability not just component reliability
- Performance

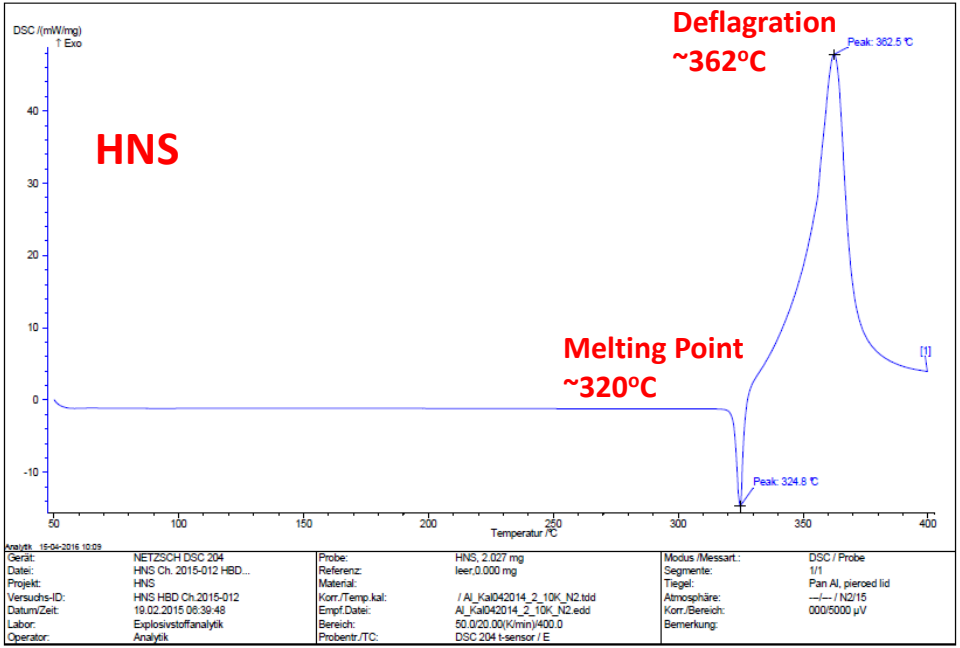
➢ Test Initiation-System
Initiator-Booster-Detonating Cord

➢ Test Performance of shaped charges after/during temperature exposure

# High Temperature Initiation Components

- DSC (Differential Scanning Calometry) Analysis for HNS:
- Current Percussion Initiators are limited by both the primary Ex. ($PbN_6$) and the main base load HNS to approx. 300°C.

➢ Alternatives to $PbN_6$ & HNS with a higher thermal stability and equivalent ballistic output




Lab Analysis courtesy of Dynitec GmbH

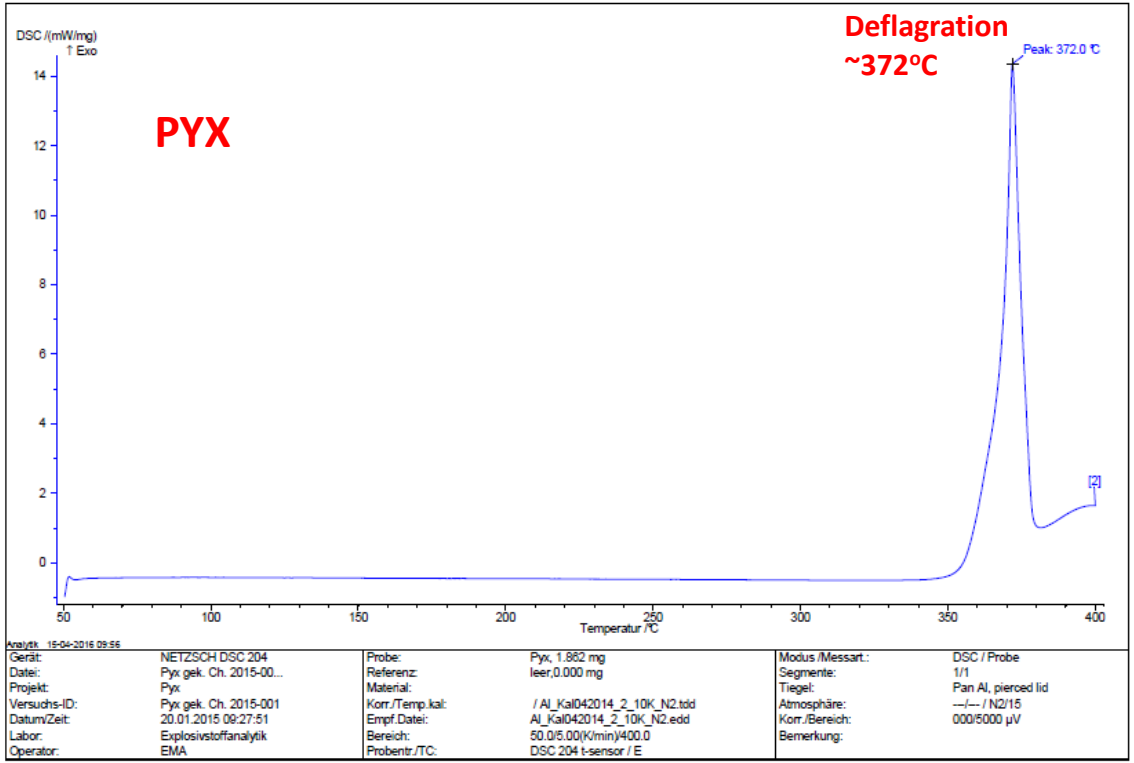
# High Temperature Initiation Components

- DSC Analysis for PYX: higher thermal stability

➢ PYX Bi-Directional Booster

➢ PYX Detonating Cord

➢ PYX based PI using a $PbN_6$ alternative appears to have a potential for higher thermal stabilility

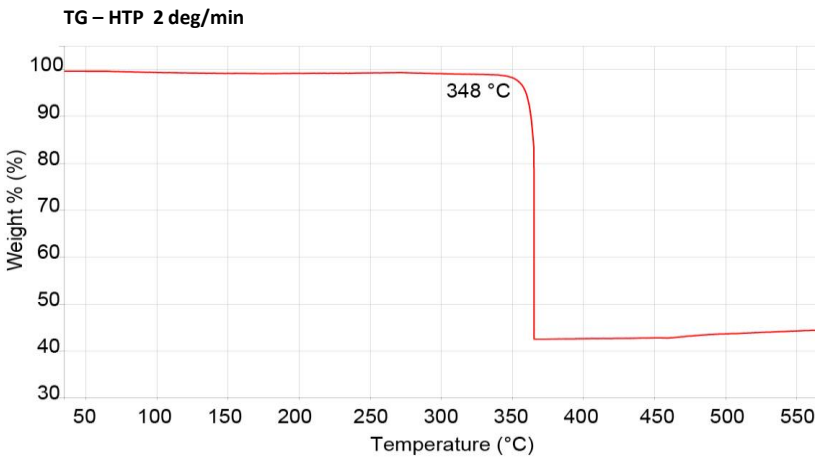


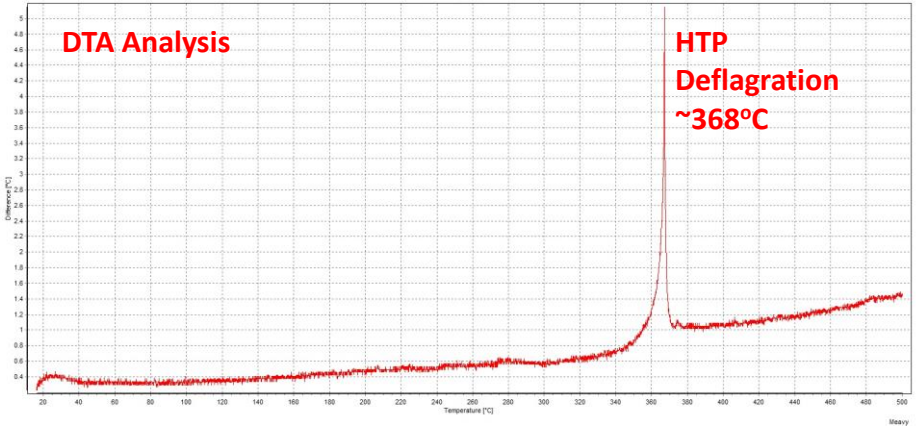

Lab Analysis courtesy of Dynitec GmbH

# High Temperature Initiation Components

- New High-Temp-Primary (HTP), free of $PbN_6$ ,with higher thermal stability (approx. 350°C)

➢ Percussion Initiator with HTP and PYX Base Load



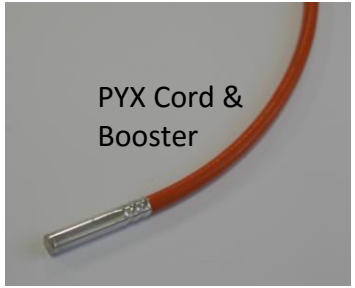




Lab Analysis courtesy of Dynitec GmbH

# Initiating System Testing

- HTP-PYX Percussion Initiator → PYX Bi-Directional Booster → PYX Detonating Cord
- Expected loss of approx. 3-5% VoD during exposure
- PI function and high-order transfer to exposed booster & detonating cord confirmed with Pb witness plate

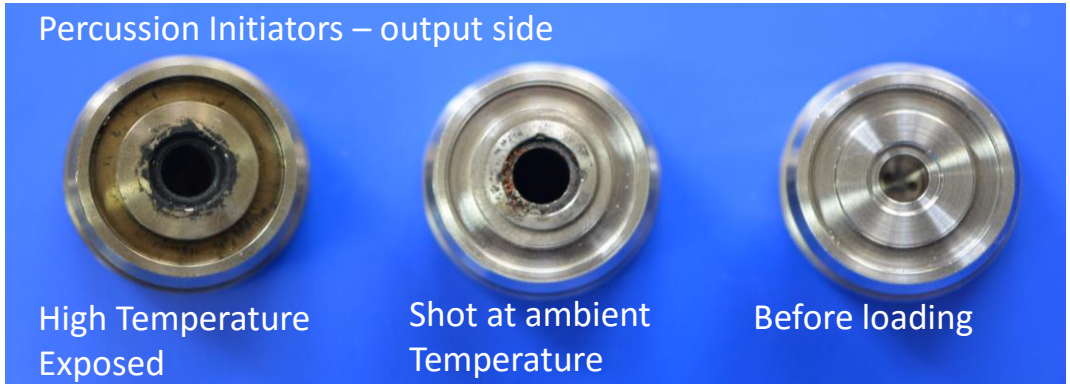
| PYX cord Exposure | VoD (m/Sec) | % Reduction |
|---|---|---|
| Ambient | 6340 | 0% |
| 290°C/ 2hrs | 6125 | 3,40% |
| 250°C/100hrs | 5934 | 6,40% |
| 250°C/200hrs | 5890 | 7,1% |



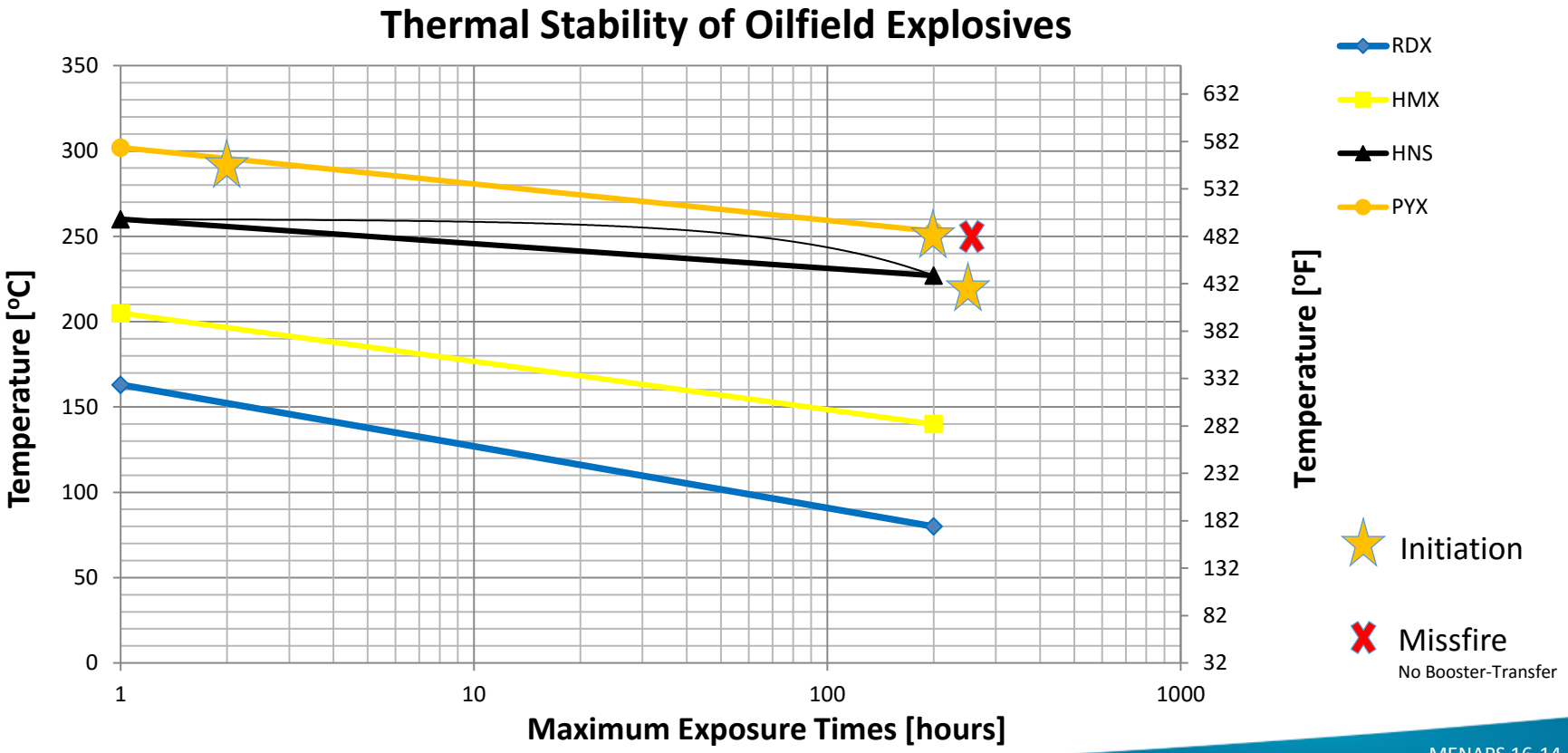
# Initiating System Test Results

- Sets of Percussion Initiators, Boosters and Cord were tested during & after exposure to temperature
- Changes in explosive output of PI can be observed in output bore-diameter
- HTP stable up to 250°C/250hrs, PYX loses performance

| Exposure Conditions | Average Output Bore Diameter (") | Result |
|---|---|---|
| None | 0.2 | Unused Status |
| None/Ambient | 0.252 | High Order Transfer |
| 290°C/2hrs | 0.248 | High Order Transfer |
| 220°C/250hrs | 0.239 | High Order Transfer |
| 250°C/100hrs | 0.244 | High Order Transfer |
| 250°C/200hrs | 0.230 | High Order Transfer |
| 250°C/250hrs | 0.21 | PI Fired – No Transfer to Booster |



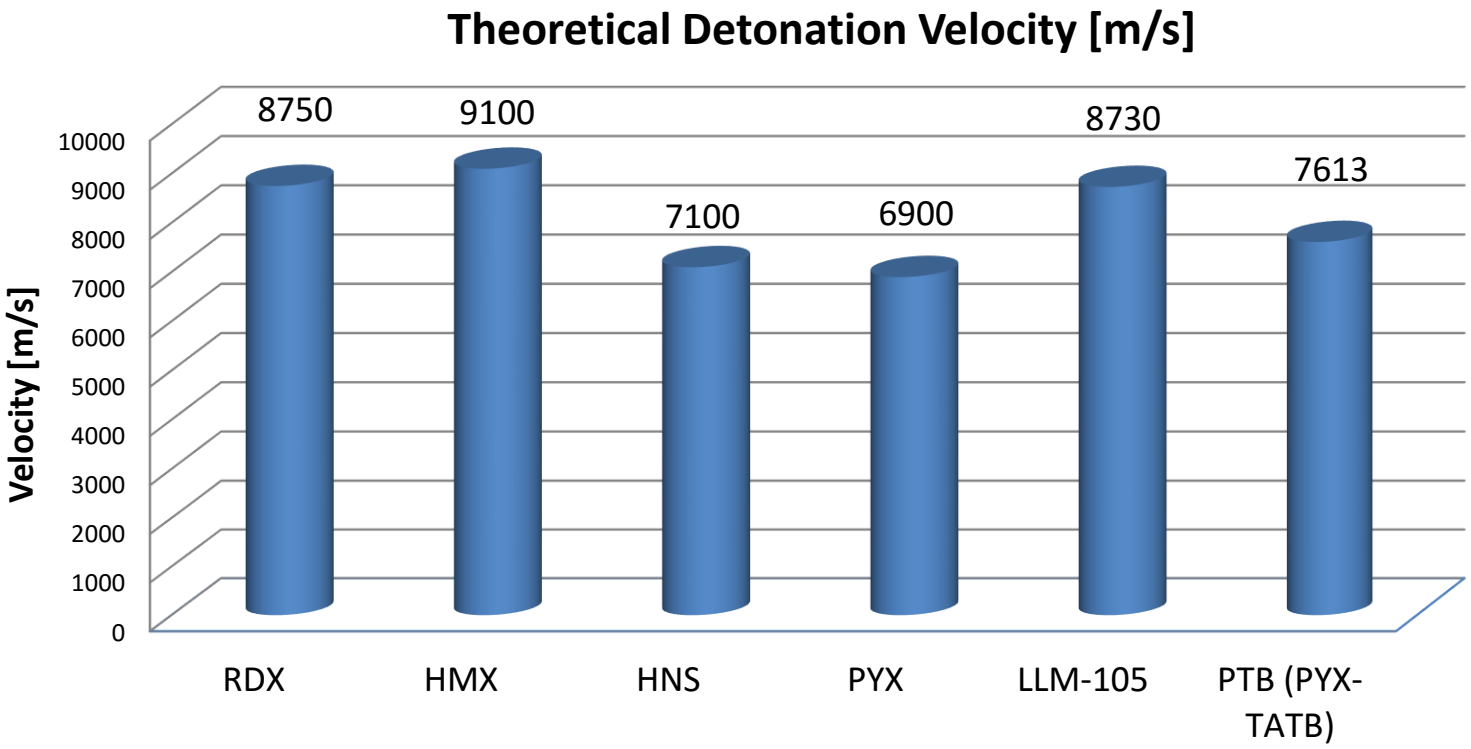
# Confirmation of Thermal Stability Data Points



# Properties of Oilfield Explosives – Shaped Charges:

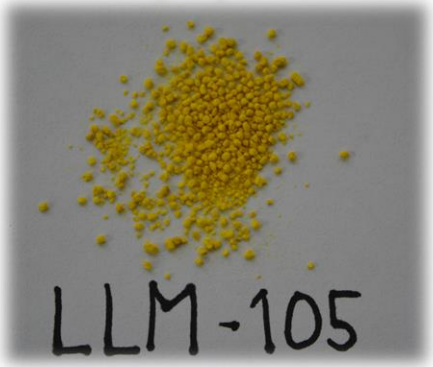
| Explosive Name | Acronym | Thermal Deflagration / Decomposition Point (°C) | Max Density (g/cm$^{-3}$) | Theoretical VoD (m/s) |
|---|---|---|---|---|
| Hexogene | RDX | 230 | 1,82 | 8750 |
| Octogene | HMX | 287 | 1,96 | 9100 |
| Hexanitrostibane | HNS | 320(melting) 360(deflagration) | 1,74 | 7100 |
| Pycrlaminodinitropyridin | PYX | 373 | 1,75 | 6900 |
| Diamino-3,5-Dinitropyrazine-1-Oxide | LLM-105 | 352 | 1,83 | 8730 |
| 1,3,5-triamino-2,4,6-tinitrobenzene | PTB (PYX-TATB) | 355 | 1,79 | 7613 |

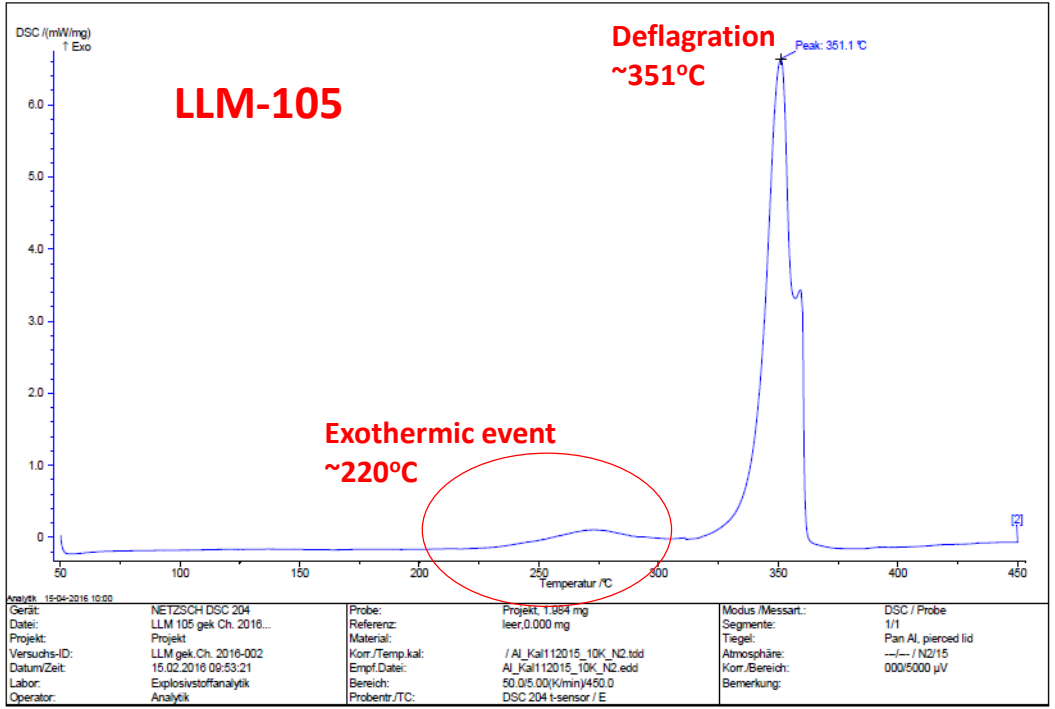
# Properties of Oilfield Explosives – Shaped Charges:



# Analysis of LLM-105

- DSC & TG Analysis:
- Exothermic event at approx. 220°C
- Thermal instability also published in literature



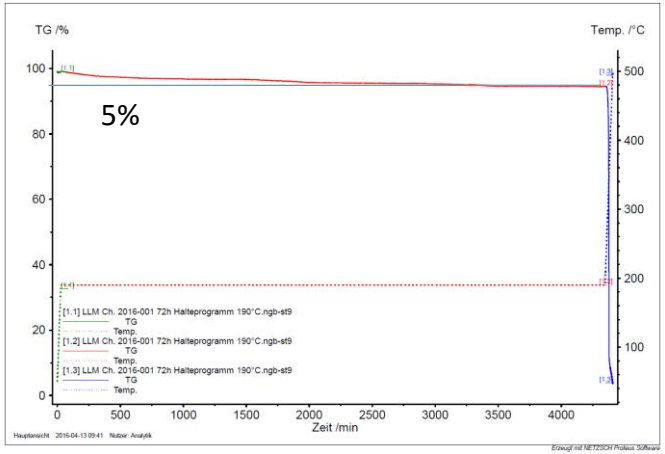



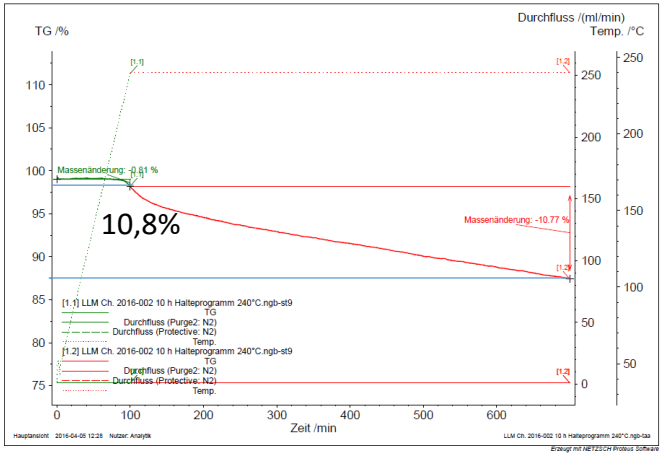
# Analysis of LLM-105

- TG (Thermogravimetric) Analysis:

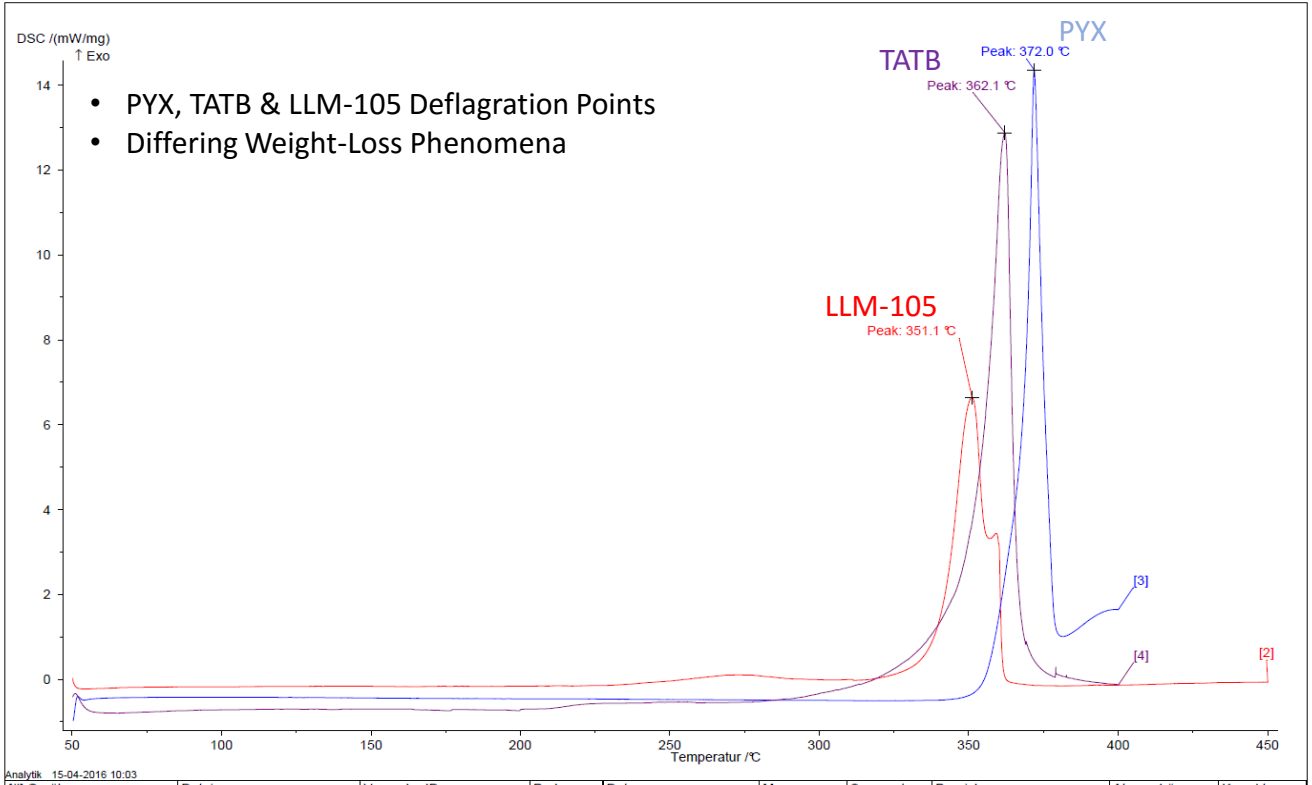
| LLM-105 | Exposure Conditions | TG Weight Loss |
|---|---|---|
| | 190°C / 72hrs | 5% |
| | 220°C / 24hrs | 7,40% |
| | 240°C / 10hrs | 10,80% |
| | 280°C / 15hrs | 93% |

- Constant weight less/outgassing at high temperatures
- Small weight loss <1% during ramp-up to 240°C
- Not stable for high temperature applications



# High Temperature DSC Comparison

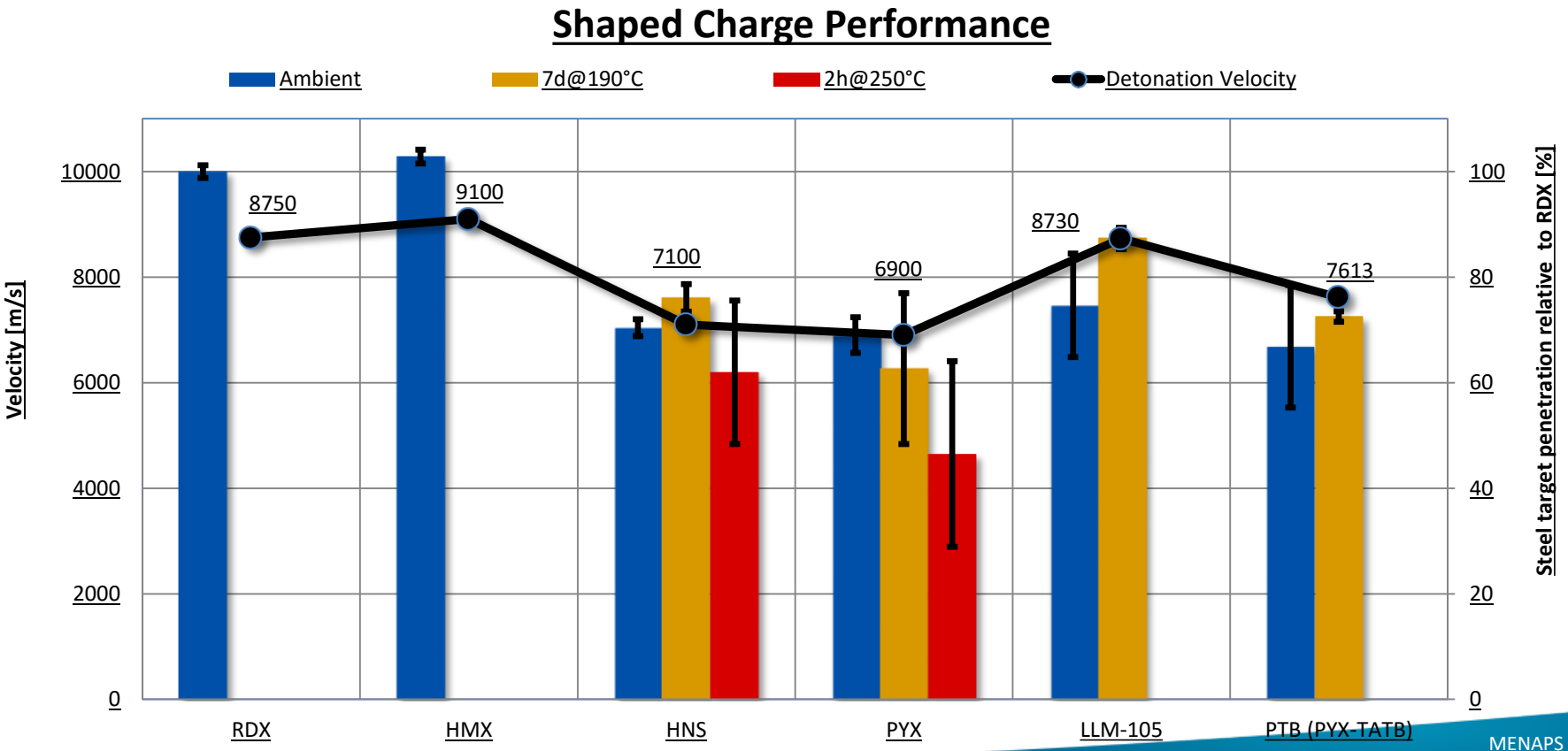



- PYX, TATB & LLM-105 Deflagration Points
- Differing Weight-Loss Phenomena

Analytik 15-04-2016 10:03

| [#] Gerät | Datei | Versuchs-ID | Probe | Datum | Masse | Segment | Bereich | Atmosphäre | Korrektur |
|---|---|---|---|---|---|---|---|---|---|
| [2] NETZSCH DSC 204 | LLM 105 gek Ch. 2016... | LLM gek.Ch. 2016-002 | Projekt | 15.02.2016 09:53:21 | 1.984 mg | 1/1 | 50.0/5.00(K/min)/450.0 | ---/--- / N2/15 | 000 |
| [3] NETZSCH DSC 204 | Pyx gek. Ch. 2015-00... | Pyx gek. Ch. 2015-001 | Pyx | 20.01.2015 09:27:51 | 1.862 mg | 1/1 | 50.0/5.00(K/min)/400.0 | ---/--- / N2/15 | 000 |
| [4] NETZSCH DSC 204 | TATB Ch. 2016-001 10... | TATB Ch. 2016-001 | TATB | 08.04.2016 12:03:59 | 2.076 mg | 1/1 | 50.0/10.00(K/min)/400.0 | ---/--- / N2/15 | 000 |

# Performance at Ambient & High Temp Conditions



# Summary

- Certain critical function points on the Thermal Stability Graph were confirmed for system functionality with PYX and HTP  Percussion Initiator.
- Booster & Detonating Cord performance was confirmed during & after exposure
- Significant Performance Degradation of shaped charges after exposure to high temperatures (250$^{o}$C).
- Potential application for LLM-105 lies above RDX & HMX but below HNS & PYX. Vacuum stability tests indicates that an application up to 190°C/long term exposure may be possible.  LLM-105 exhibits large outgassing >220°C.
- Possibly a potential application for the alternative PTB material after further refinement of the synthesis process.

# References


- T.D.Tran, P.F. Pagoria, D.M.Hoffman, J.L Cutting, R.S.Lee, R.L.Simpson: „Characterization of 2,6-Diamino-3,5-Dinitropyrazine-1-Oxide (LLM-105) as an Insensitive High Explosive Material“-2002.

- P.F. Pagoria, A.R. Mitchell, R.D.Schmidt, R.L.Simpson, F. Garcia, J.W.Forbes, R.W.Swansiger, D.M.Hoffman: „Synthesis, Scale-Up and Chracterization of 2,6-Diamino-3,5-Dinitropyrazine -1-Oxide (LLM-105)“-1998.

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- T.M.Klapötke: „Chemie der hochenergetischen Materialien“-2009

# QUESTIONS?
# THANK YOU!