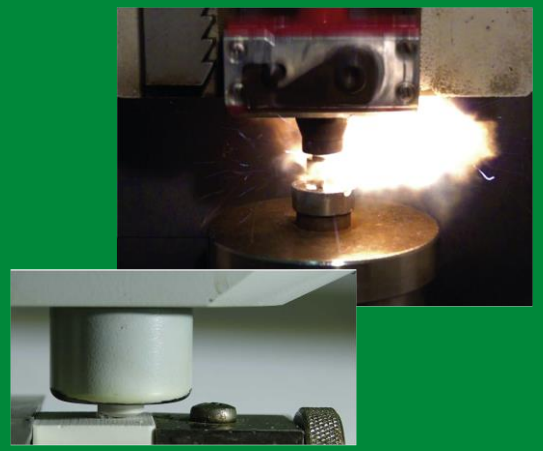
LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

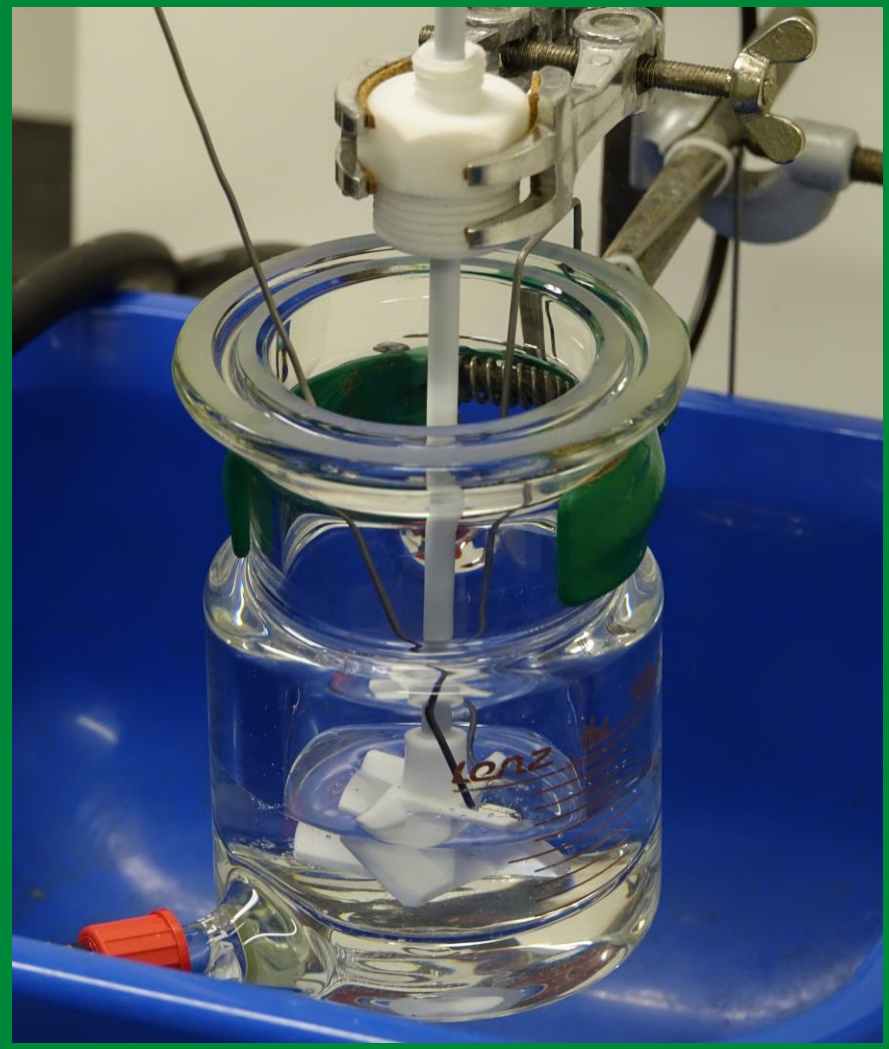
BIAZZI

AUSTIN POWDER

EMTO GmbH
ENERGETIC MATERIALS TECHNOLOGY

Impact and Friction Sensitivities of PETN During Manufacture





Tobias Lenz, M.Sc.

Research Group of
Prof. Dr. Thomas M. Klapötke

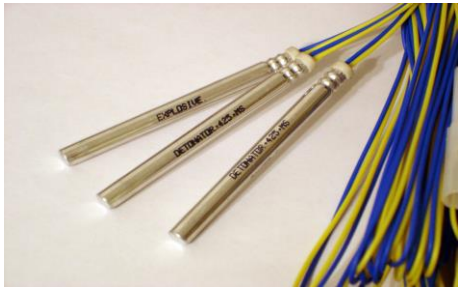
LMU, Munich, Germany

23.06.2022

Pentaerythritol Tetranitrate

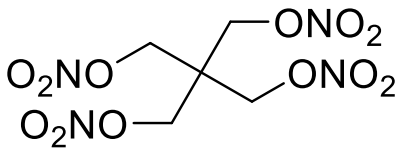
- Large scale PETN manufacturing since 1930's
- Moderately to very sensitive
- PETN-related accidents still happen

https://www.austinpowder.com



Application:

- Booster charge (Pentolite)
- Detonator (main charge)
- Detonating cord (multifunctional)



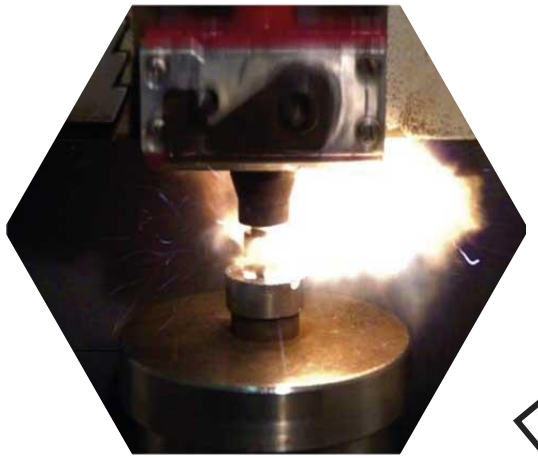
PETN

https://www.sse-schweiz.com

[1] a) T. M. Klapötke, *Chemistry of High-Energy Materials, 6th Ed.,* **2022**; b) R. M. J. Köhler, A. Homburg, *Explosivstoffe, Vol. 10*, WILEY-VCH Verlag GmbH, Weinheim, **2008**; c) E. Berlow, R. H. Barth, J. E. Snow, *The Pentaerythritols*, Reinhold Publishing Corporation, New York, **1958**.

Motivation

Better understanding of the sensitivities



Cleaning

Handling

Transport

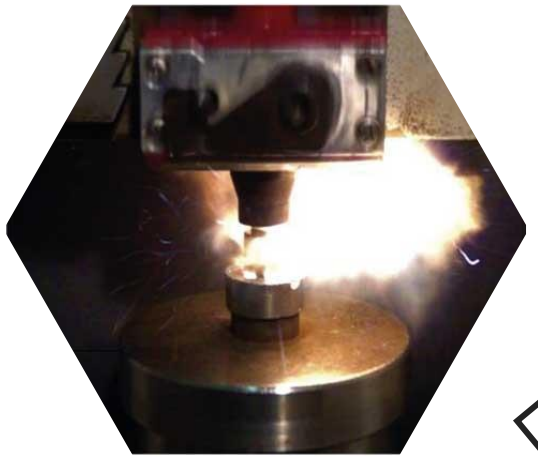
Safer Process

Plant Design

Personal Equipment

Motivation

Better understanding of the sensitivities



Handling

Transport

Cleaning

Safer Process

Plant Design

Personal Equipment

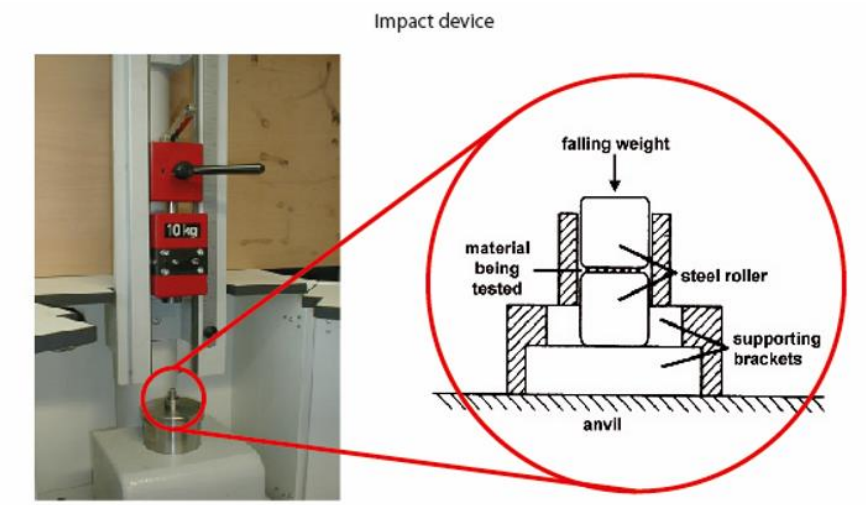
Lack of reliable sensitivity data during production[1]

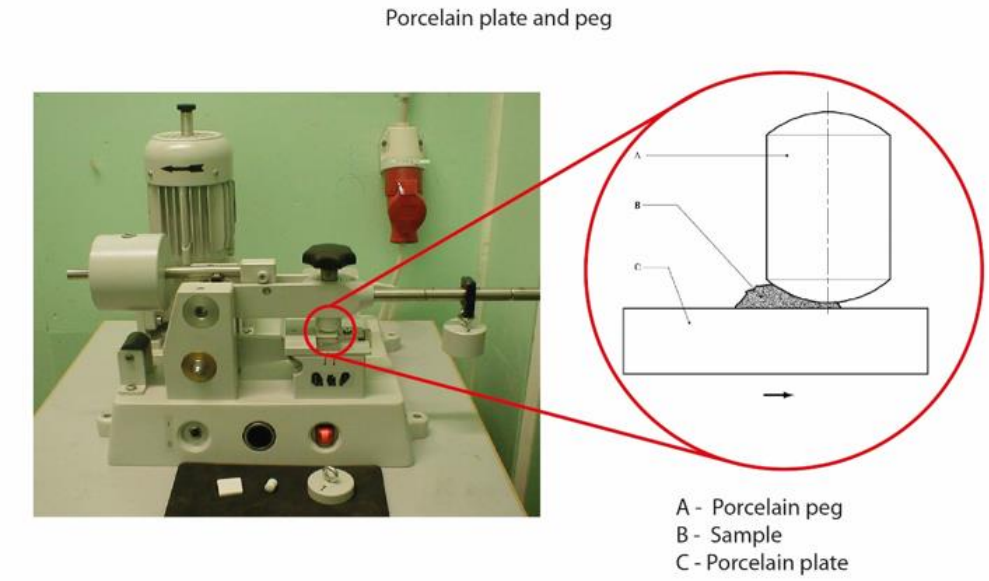
➢ Risk of accident or damage

[1] a) S. Boisvert, R. Deshais, ICI Explosives Canada, Quebec, **1992**; b) R. S. Gow, *Vol. 46*, ICI Research Brochure No. 46, Research Department, Nobel Division, Stevenson, **1955**.

Mechanical sensitivities

BAM Impact and Friction Sensitivity

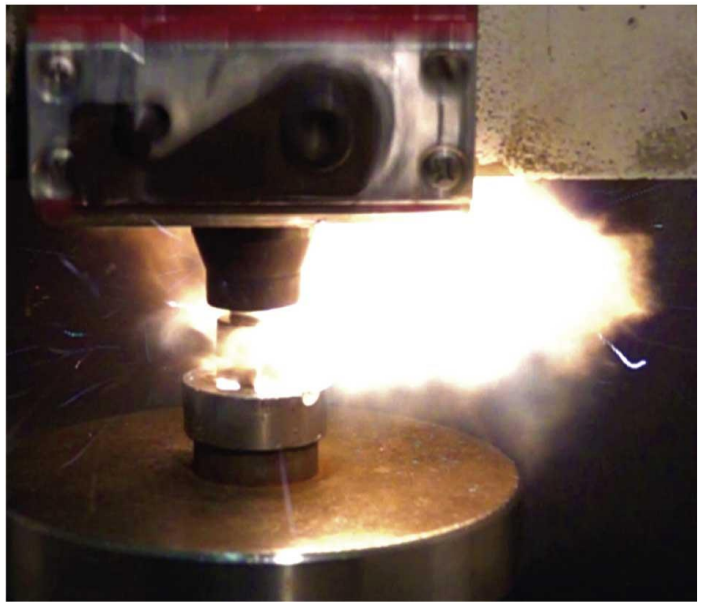


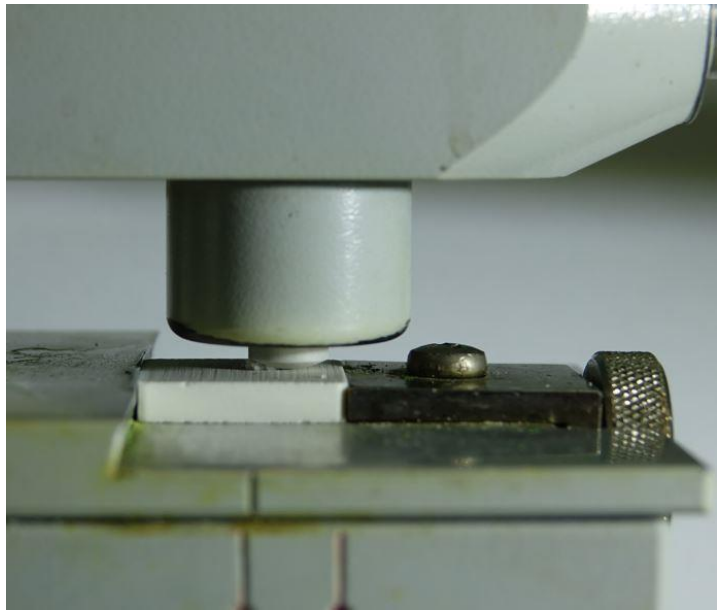


[1] U.N., Transport of dangerous goods; New York and Geneva, **2015**.

Mechanical sensitivities

BAM Impact and Friction Sensitivity

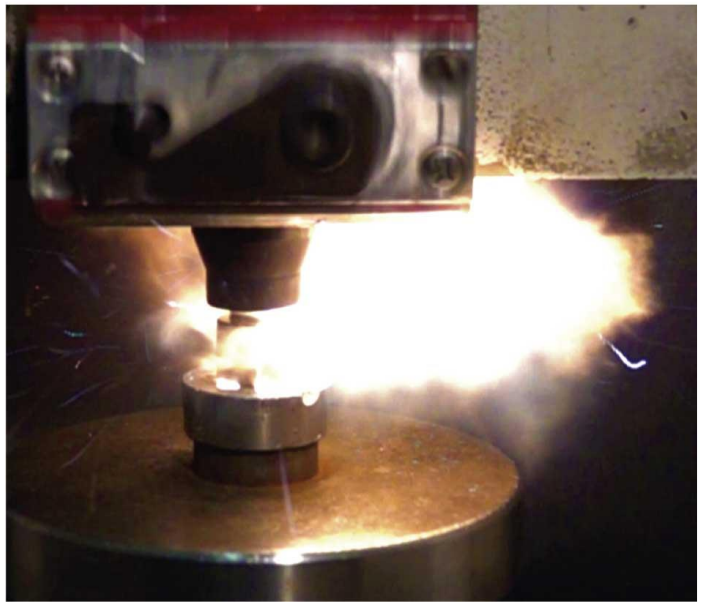


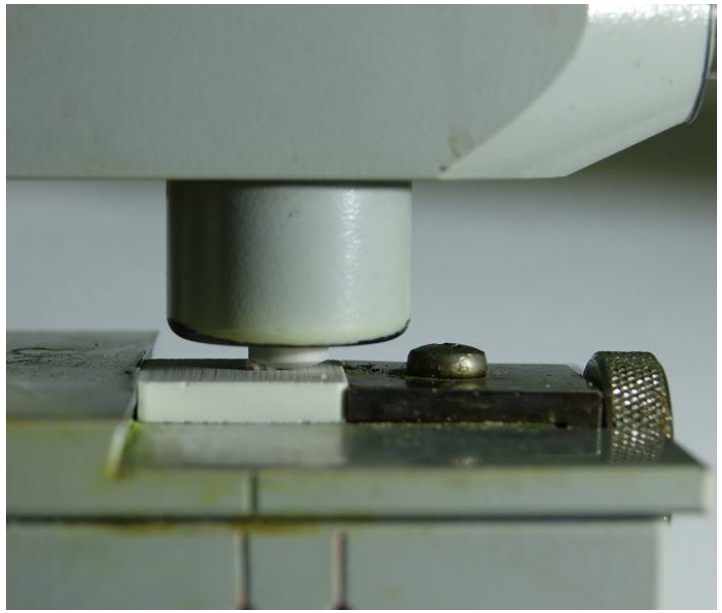


[1] U.N., Transport of dangerous goods; New York and Geneva, **2015**.

Mechanical sensitivities

BAM Impact and Friction Sensitivity



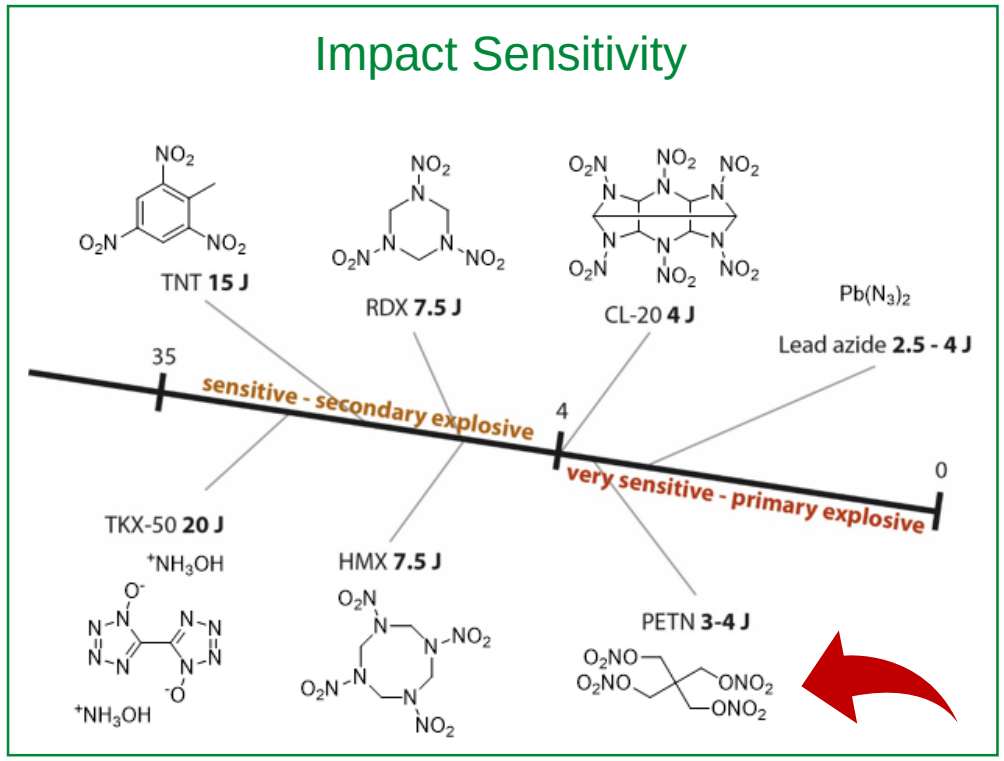


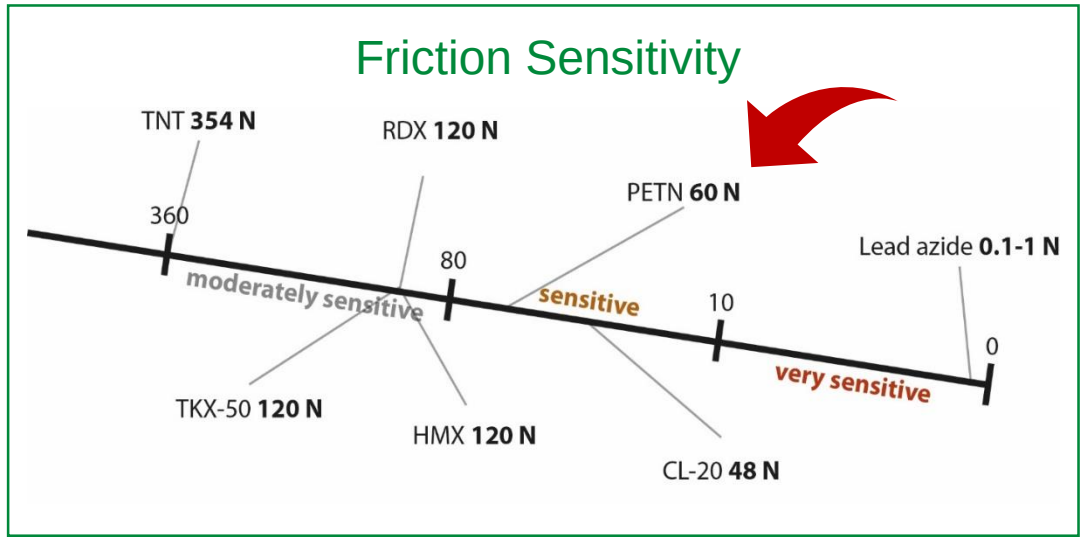
- One out of six method for lower detonation limit
- Comparison with literature values is difficult
  - Often lack of standardization, poor documentation

[1] U.N., Transport of dangerous goods; New York and Geneva, **2015**.

Mechanical sensitivities

Understanding sensitivity through comparison

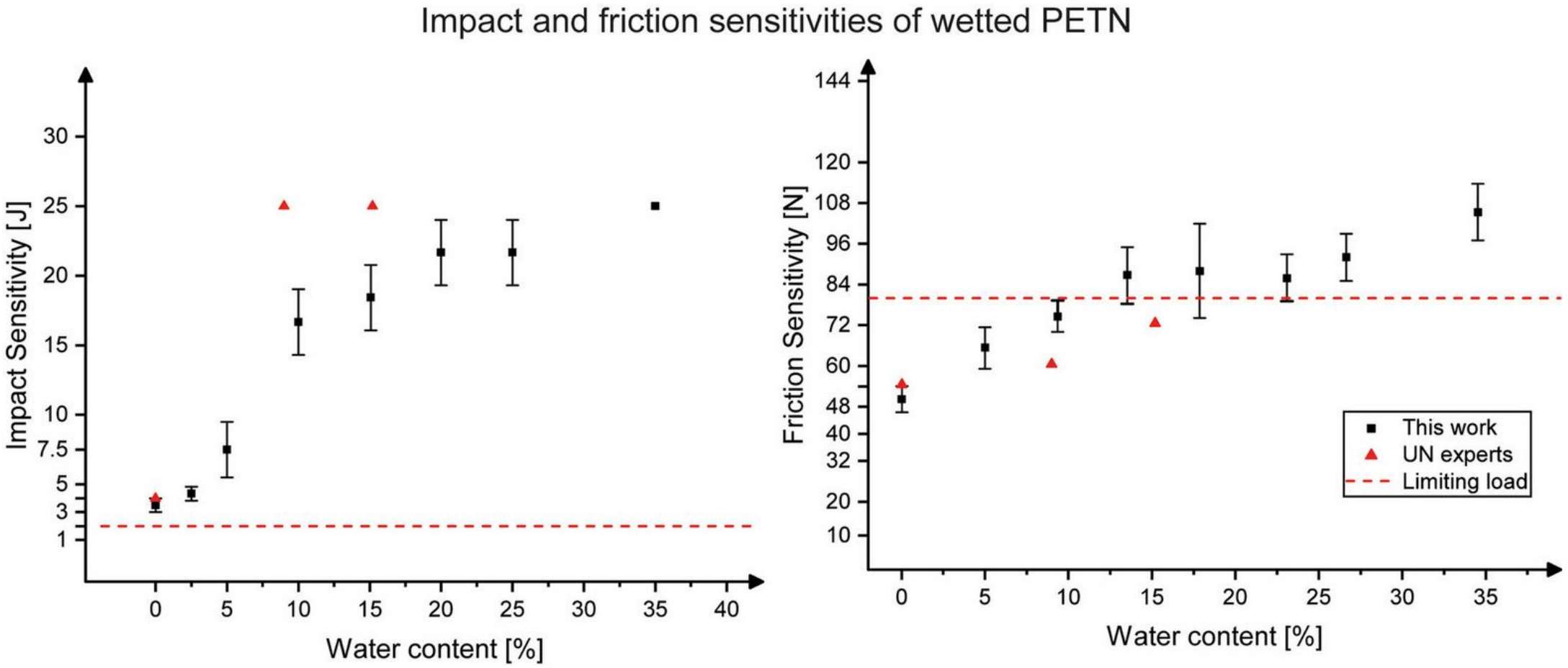




[1] J. Köhler, D. R. Meyer, D. I. A. Homburg, Explosivstoffe, 10. Ed., **2008**; [2] T. M. Klapötke, Energetic Materials Encyclopedia, *2nd Ed.*, **2021**.

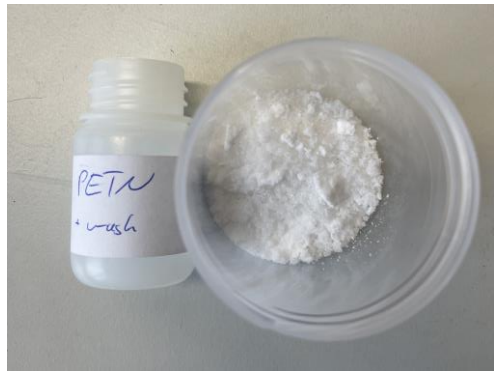
Something to compare

Pure PETN



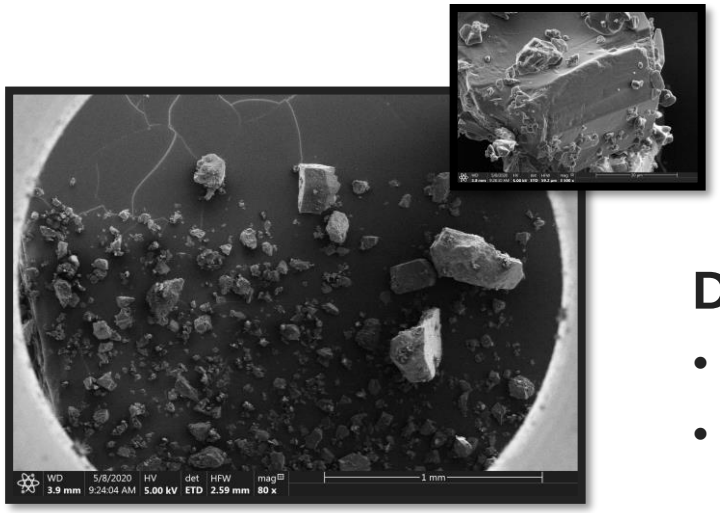
[1] T. M. Klapötke, G. Lemarchand, T. Lenz, M. Mühlemann, J. Stierstorfer, R. Weber, *Prop., Explos., Pyrotech.* **2022**, *47*, e202200150;
[UN experts] a) UN/SCETDG/47/INF.8 **2015**, b) UN/SCETDG/49/INF.9 **2016**, c) U.N., Transport of dangerous goods; New York and Geneva, **2015**.

Something to compare



Industrial Samples – SSE

- Washed and spent acid wet sample
- ~1.3% DIPE in PE
- Specific nitration conditions



Detonating Cord

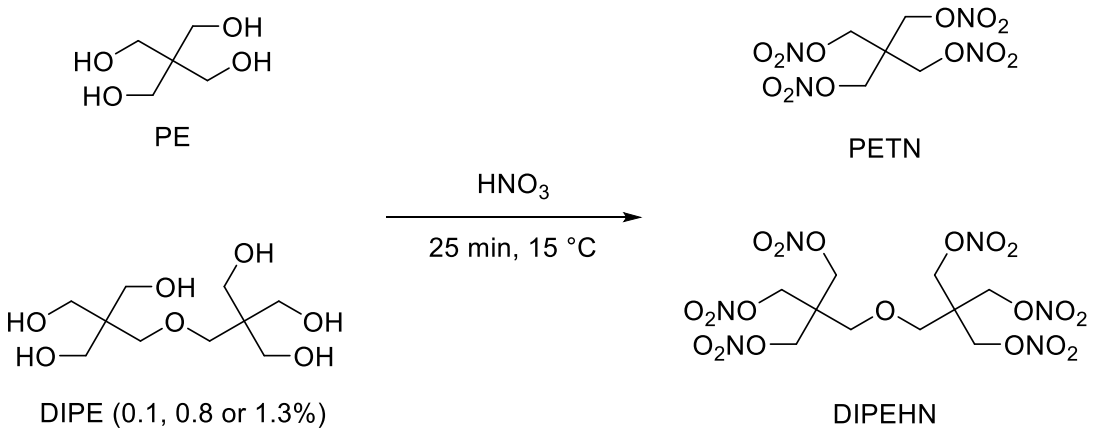
- IS: 3 ± 0 J
- FS: 56 ± 3 N

https://www.sse-schweiz.com

[1] T. M. Klapötke, G. Lemarchand, T. Lenz, M. Mühlemann, J. Stierstorfer, R. Weber, *Prop., Explos., Pyrotech.* **2022**, *47*, e202200150;
[UN experts] a) UN/SCETDG/47/INF.8 b) UN/SCETDG/49/INF.9.

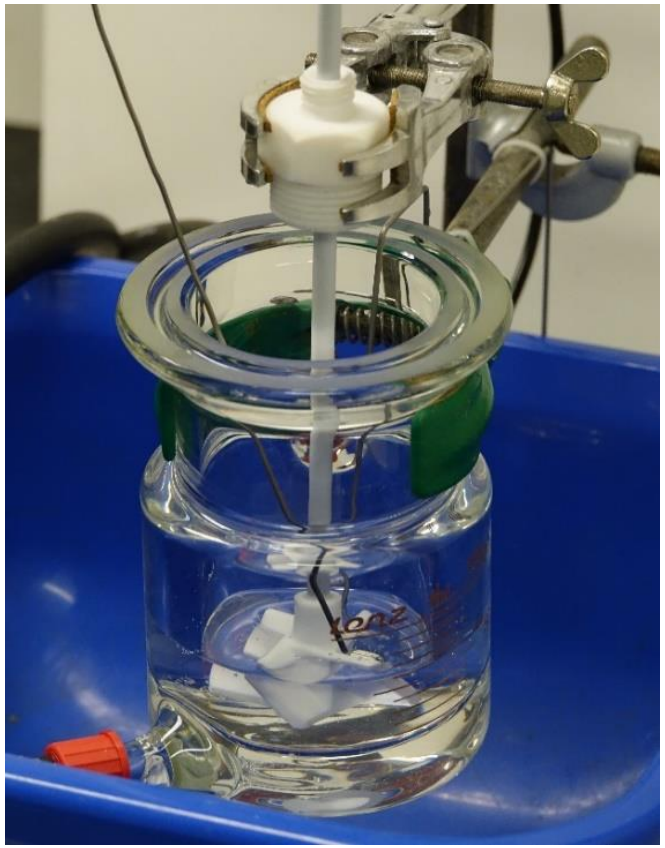
Synthesis

Nitration



LMU synthesis:

- → 30 g scale (50 mL HNO_3, 15 g PE)[2]
- → 0.1 to 1.3% DIPE in PE



Reactor 50 mL

[1] I. Rodger, J. D. Mcirvine, *Can J Chem Eng.* **1963**, *41*, 87-90. (Spent Acid stability)
[2] Recreated BIAZZI continuous process

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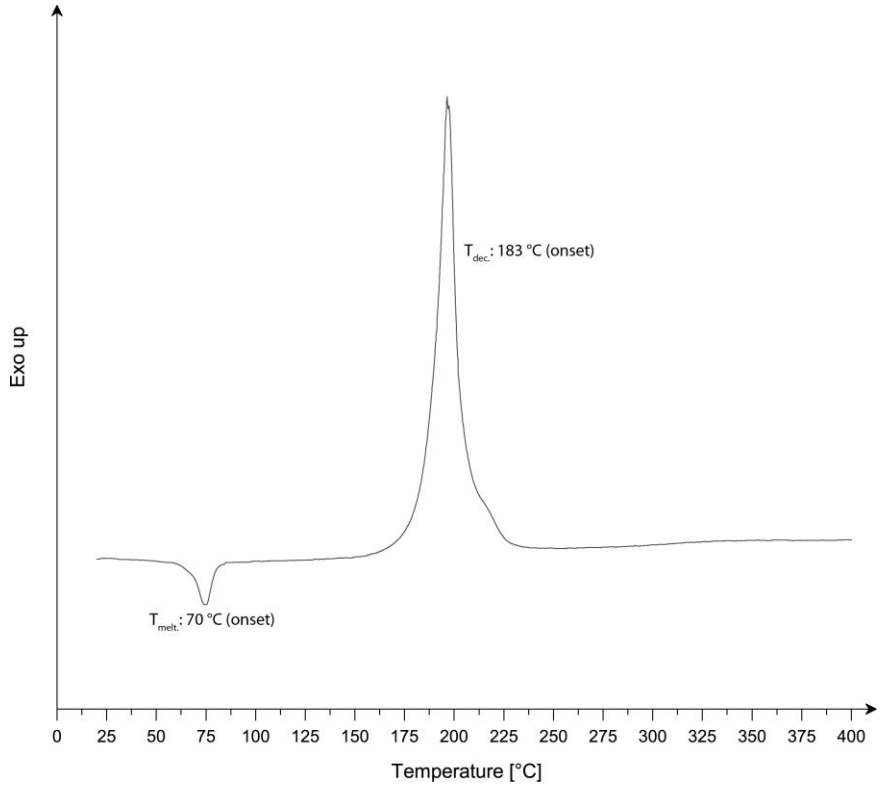
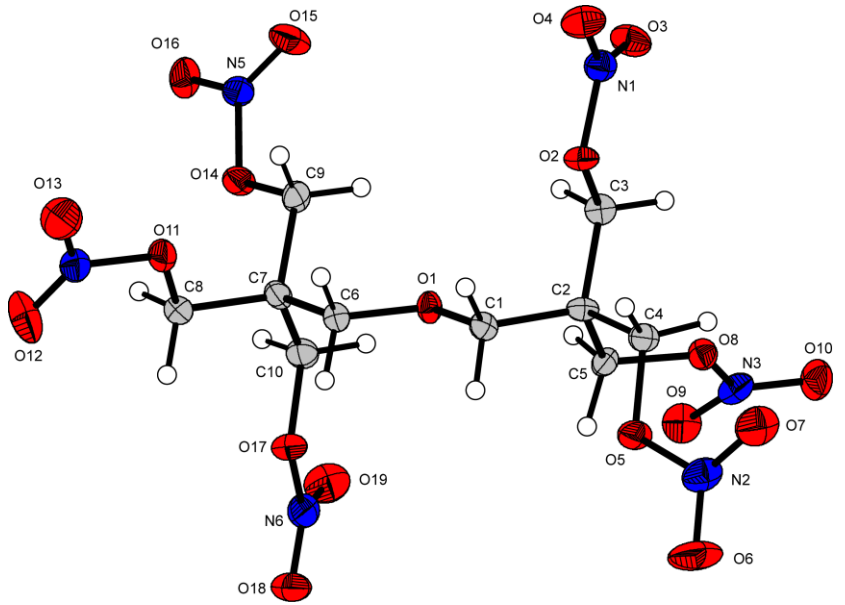
Synthesis

Properties of PETN and DIPEHN



DTA-Plot of DIPEHN

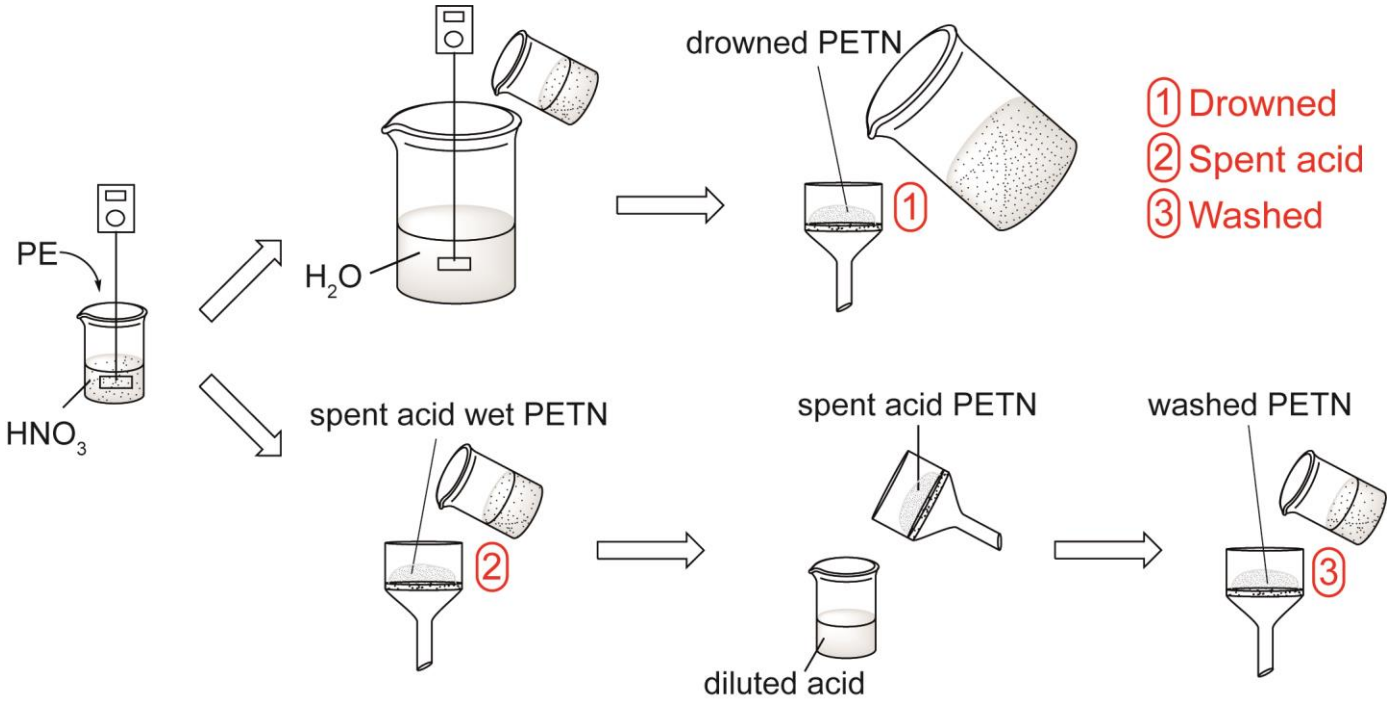
Crystal structure of DIPEHN

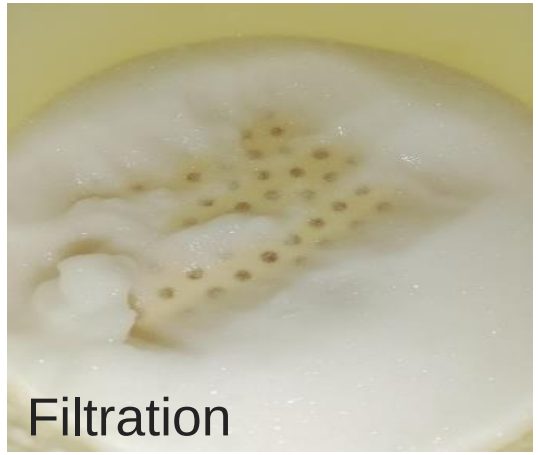


	DIPEHN	PETN
Formula	$C_{10}H_{16}N_6O_{19}$	$C_5H_8N_4O_{12}$
T_{melt} / T_{dec}	70 / 183	141 / 180
Density [g cm^{-3}]	1.644	1.778
p_{C-J} [GPa]	25.9	30.84
D [m s^{-1}]	7758	8429
IS [J]	3.0	3.0 - 4.0
FS [N]	144 - 192	54

Synthesis

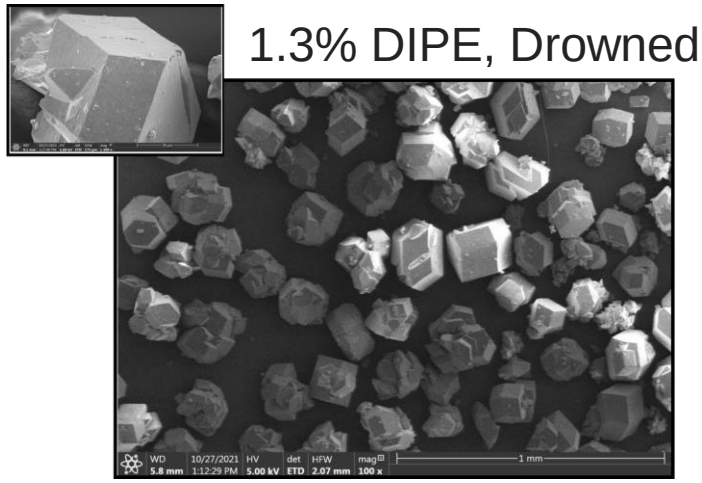
Synthesis of three industry like grades of PETN



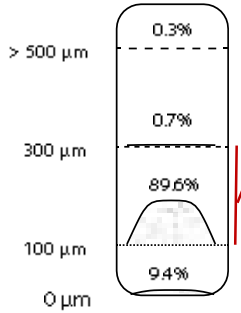


[1] Recreated BIAZZI continuous process or SSE batch process

Morphology and particle size



1.3% DIPE, Drowned

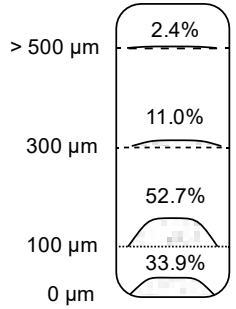


Main Fraction

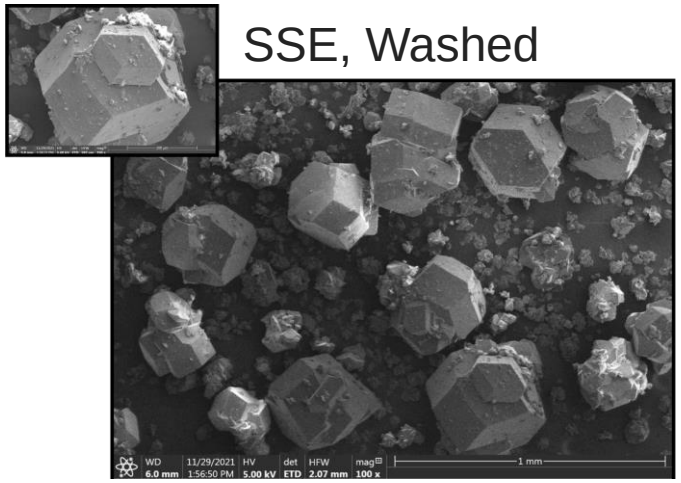
➔Comparable particle sizes and morphology for all LMU samples

➔Larger particles for SSE samples

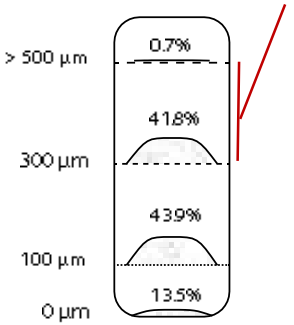
Detonating Cord



Smaller Particles



SSE, Washed



Larger Particles

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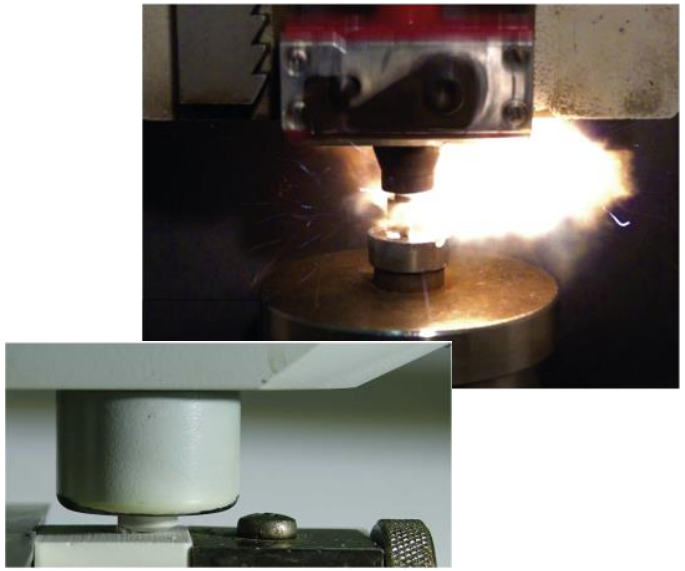
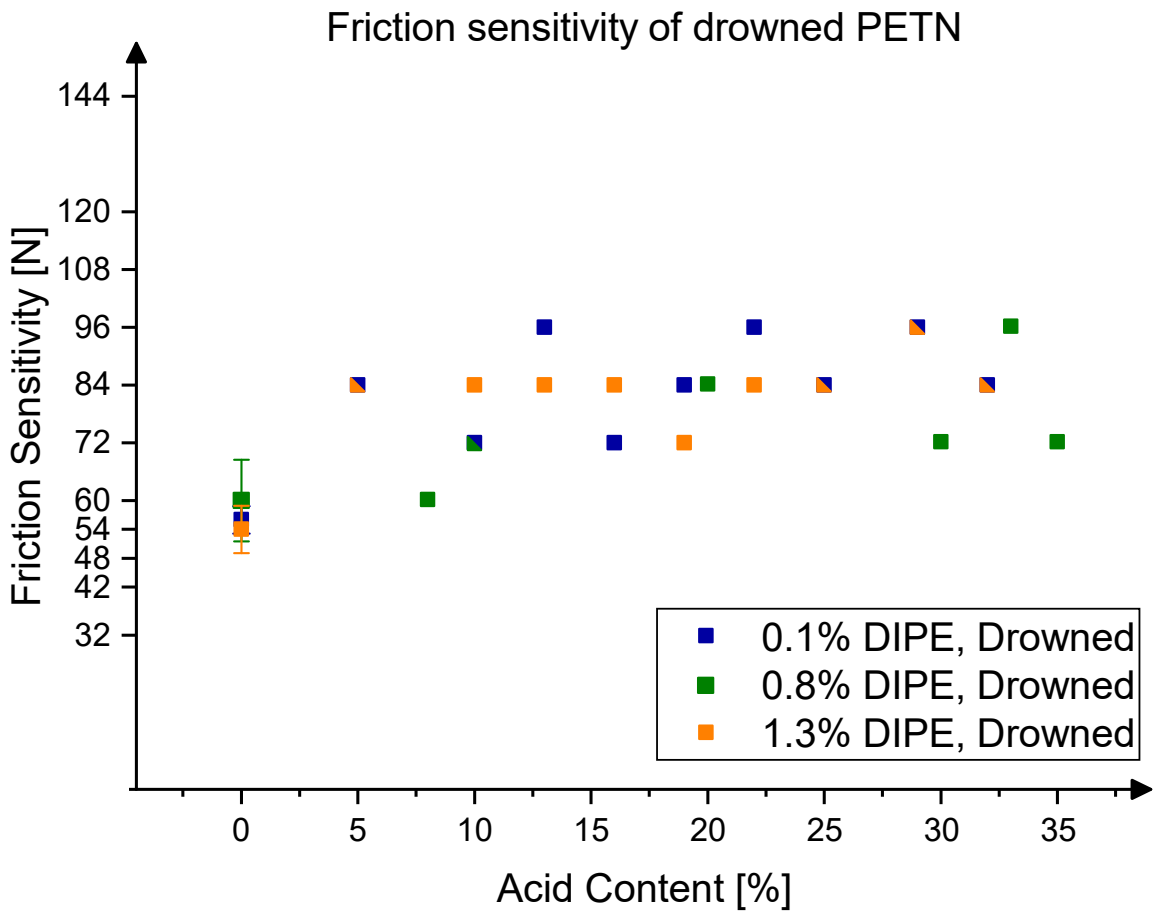
Impact and Friction Sensitivities of PETN During Manufacture

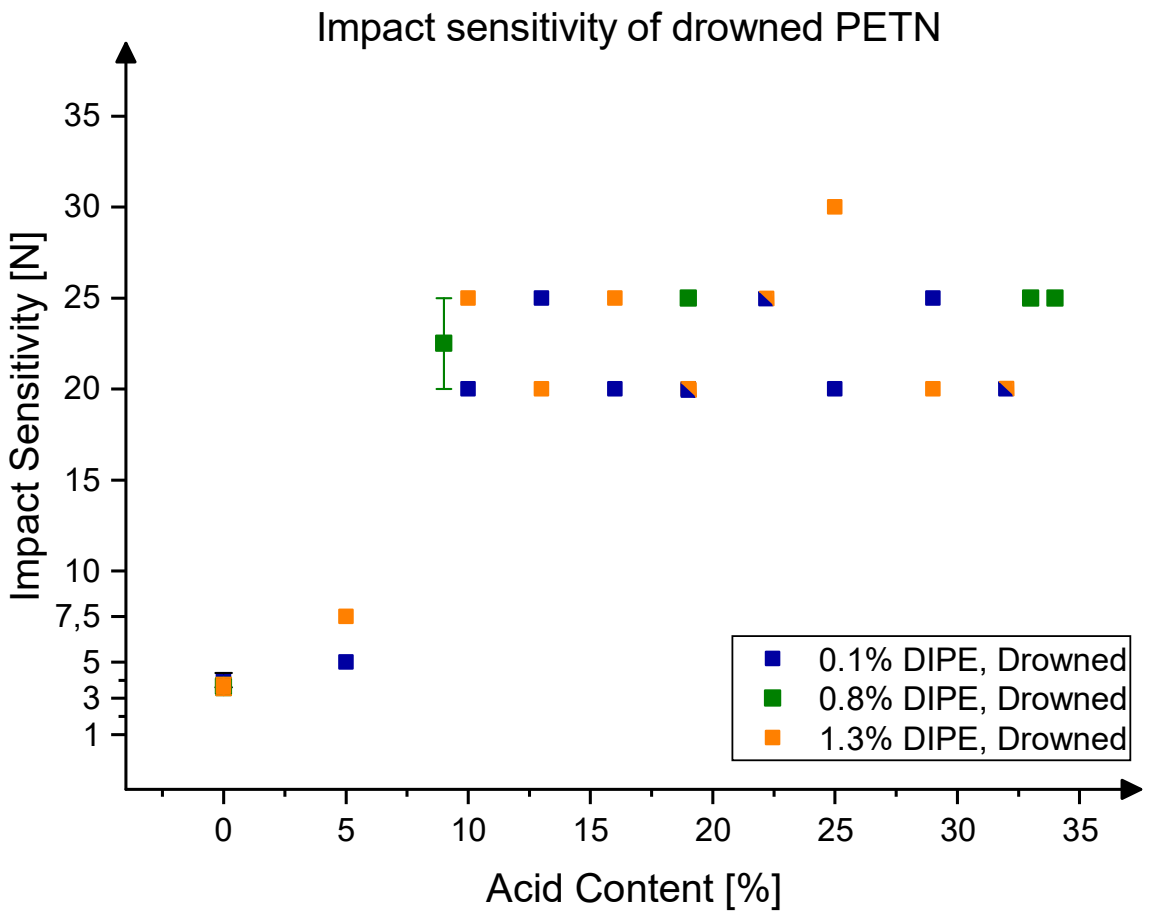
-

Results

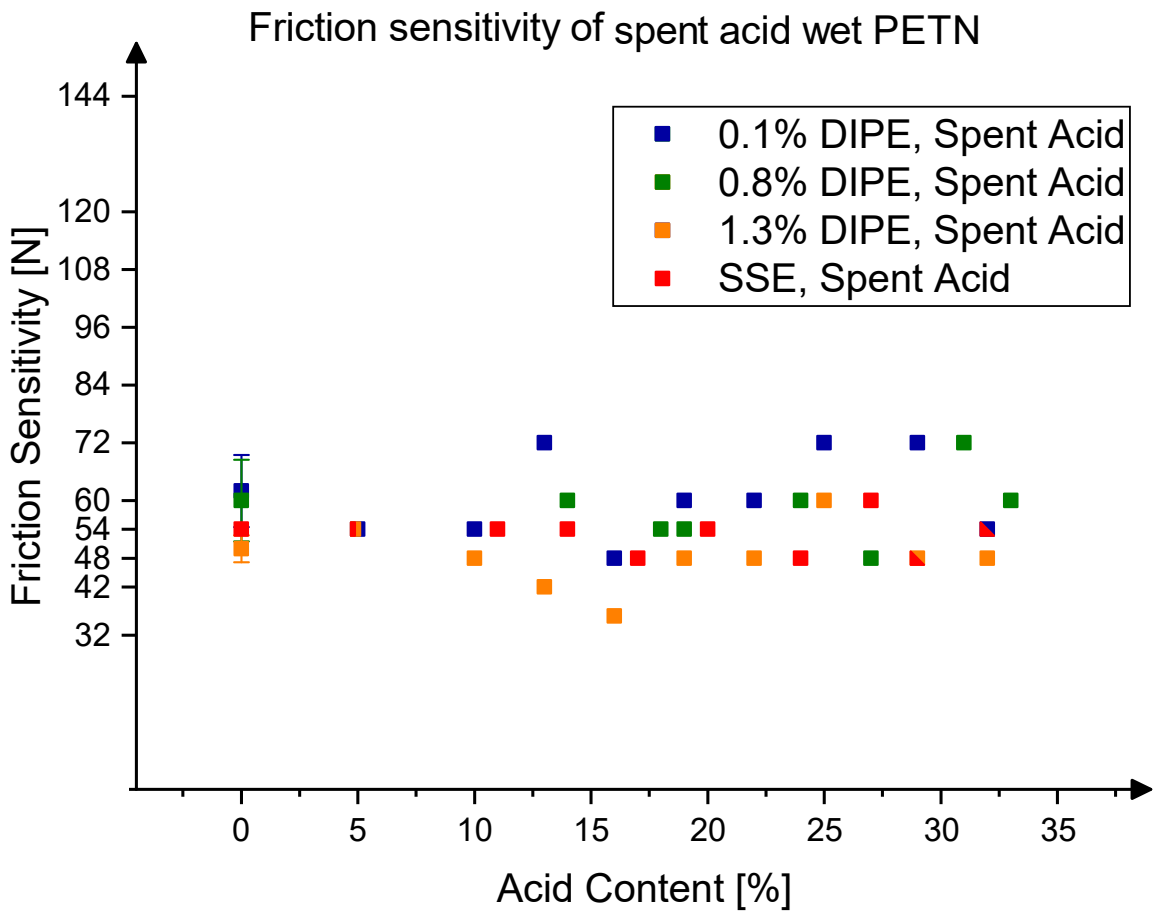


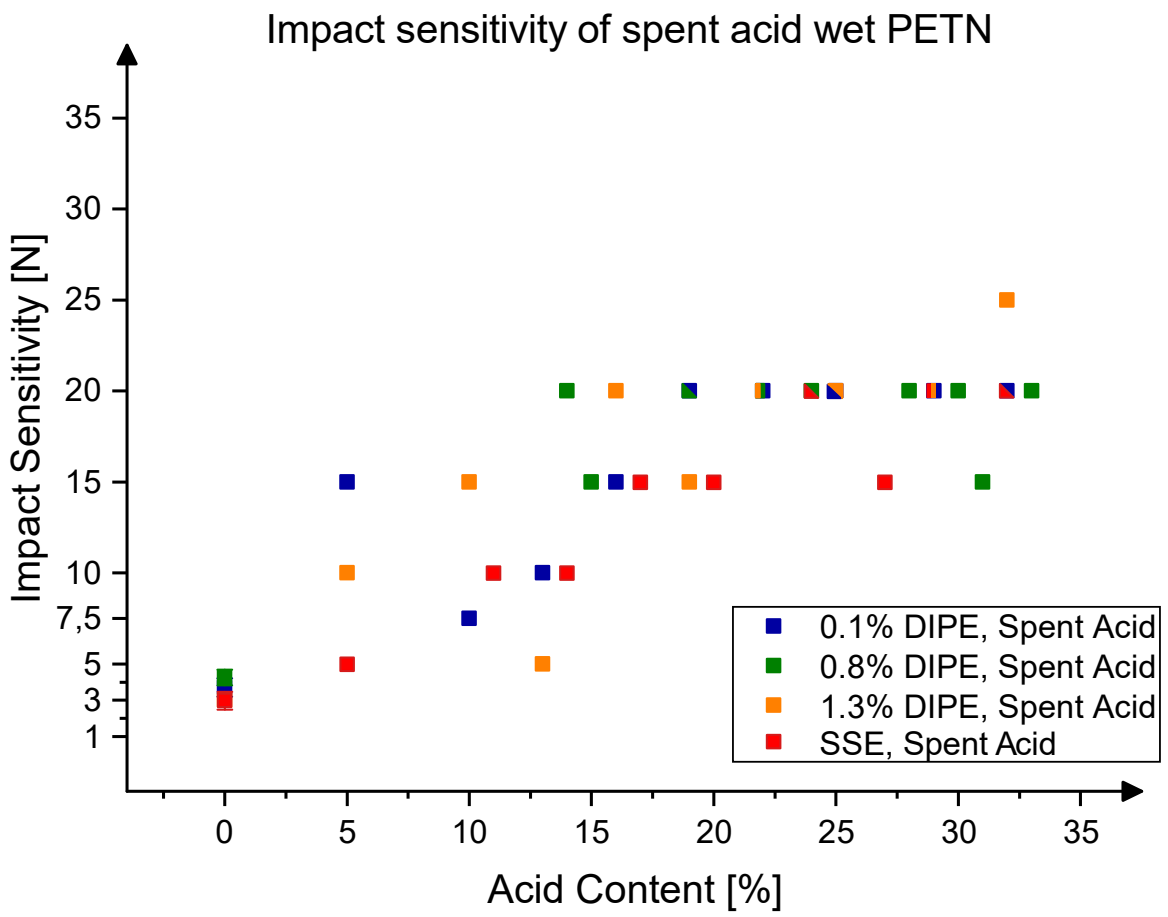
Sensitivity of drowned PETN



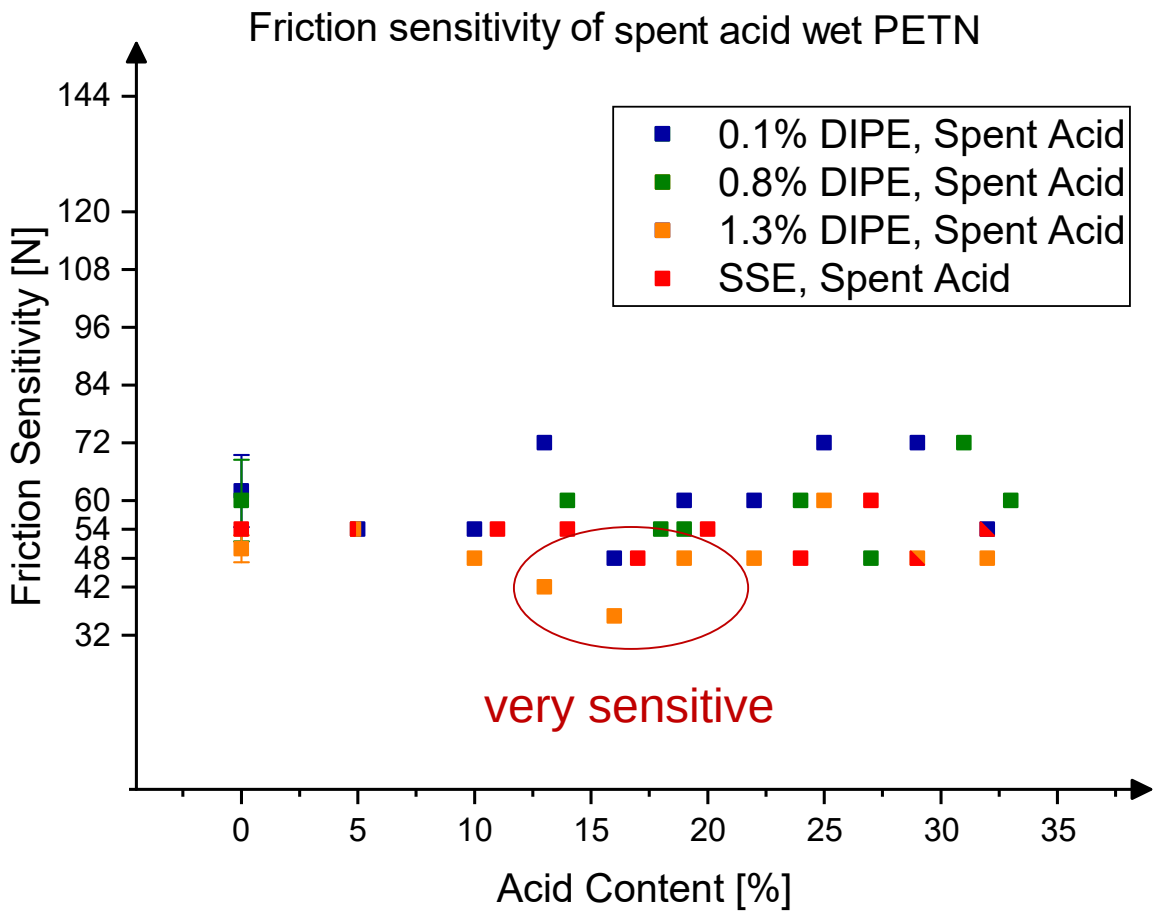


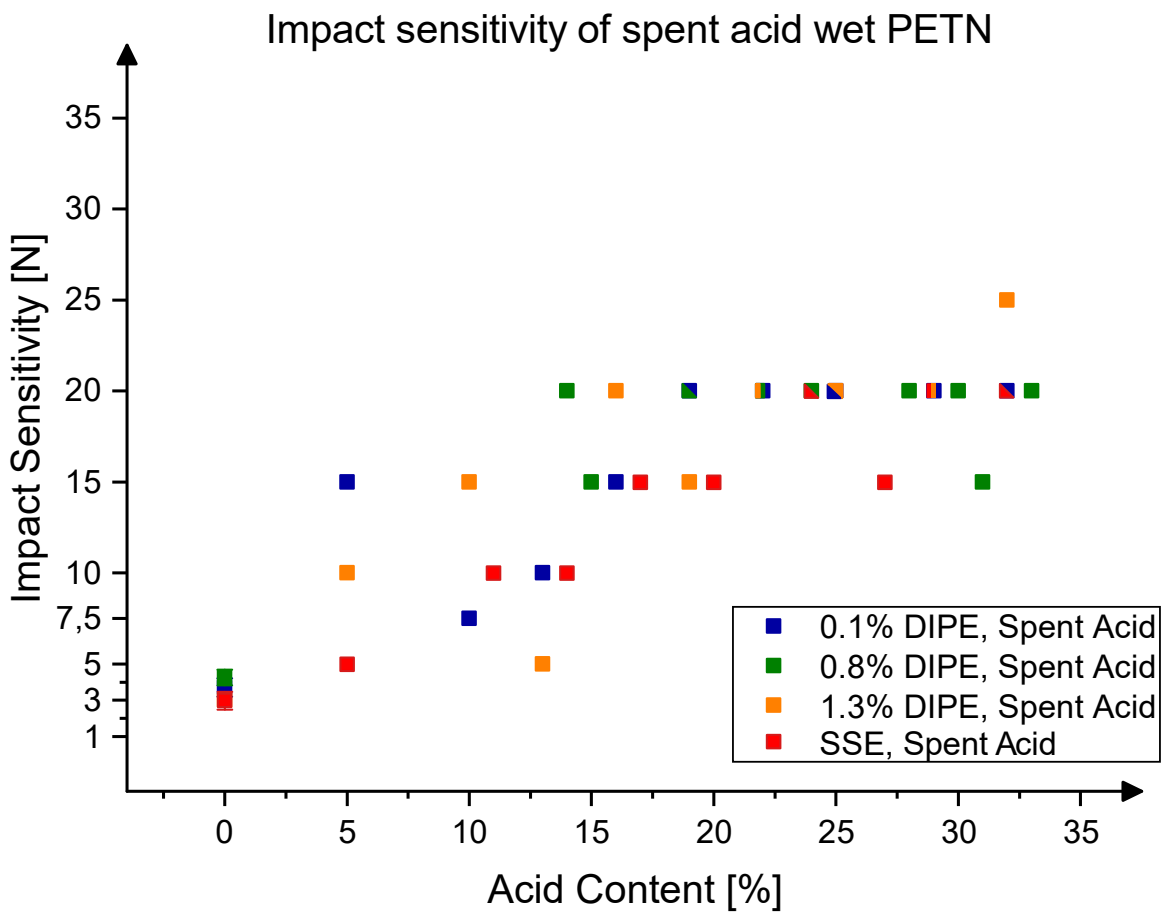
Sensitivity of spent acid wet PETN



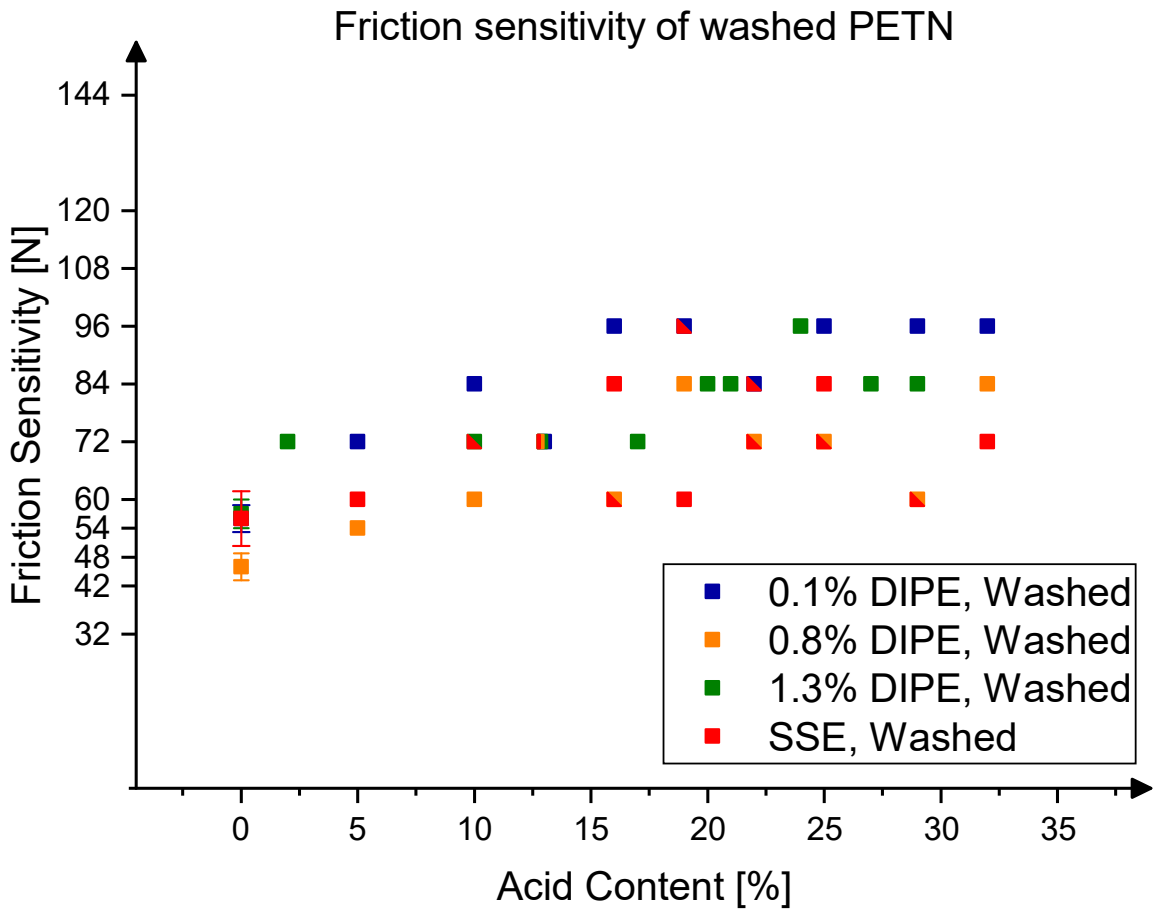


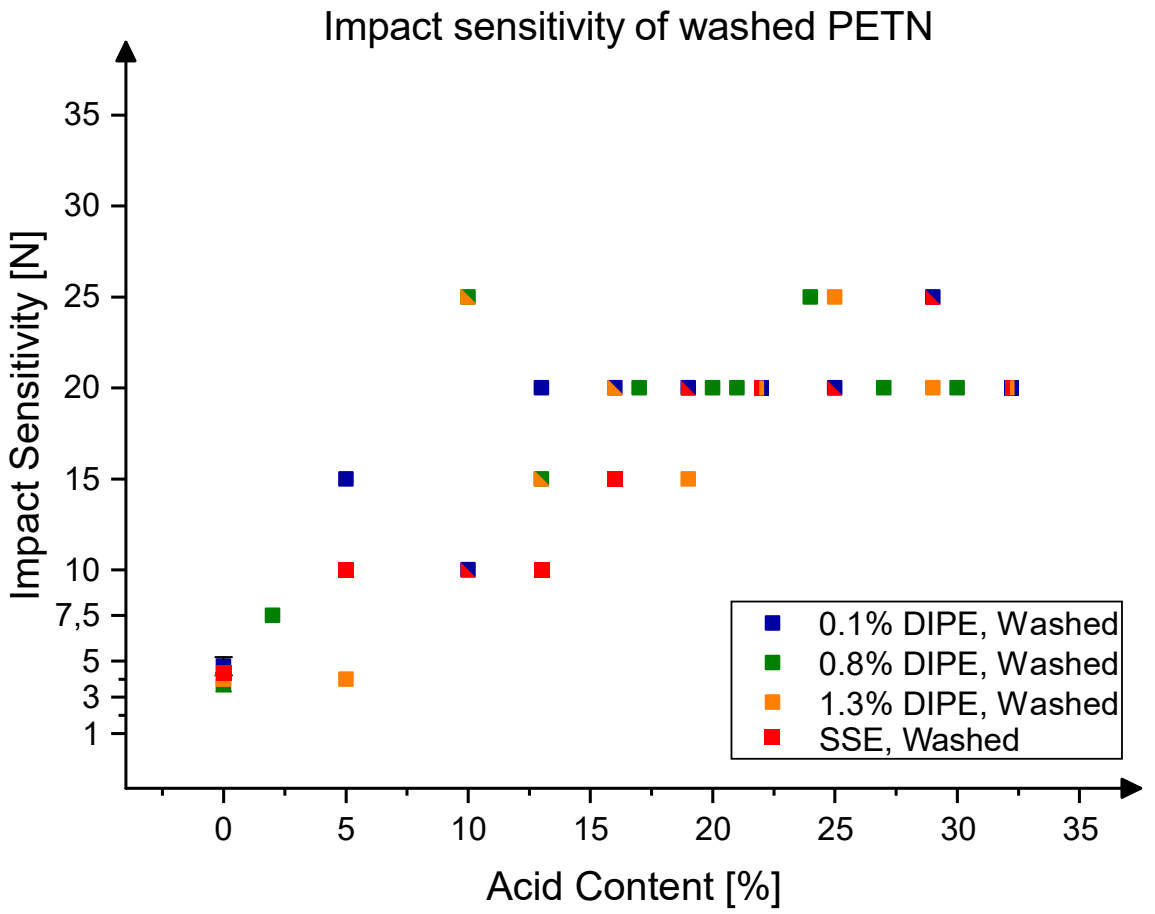
Sensitivity of spent acid wet PETN





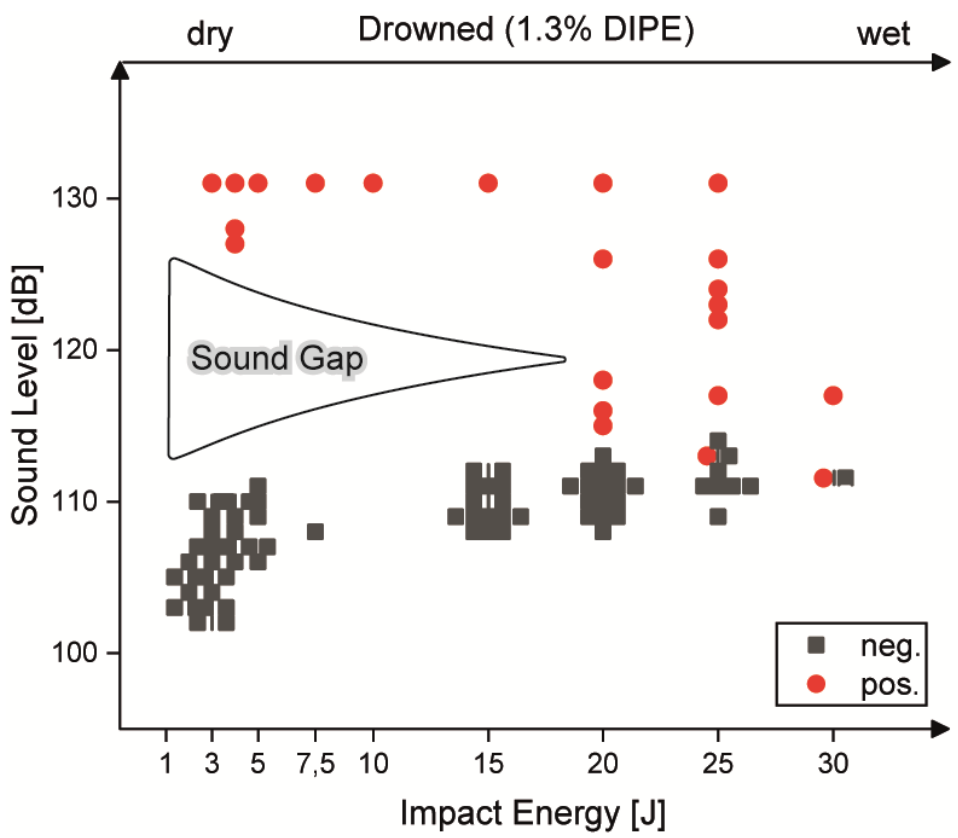
Sensitivity of washed PETN

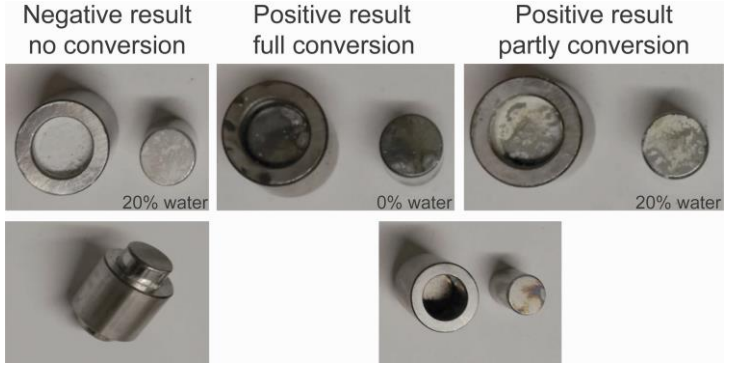




Sensitivity of PETN – Sound Level

Measurement of sound level during impact tests

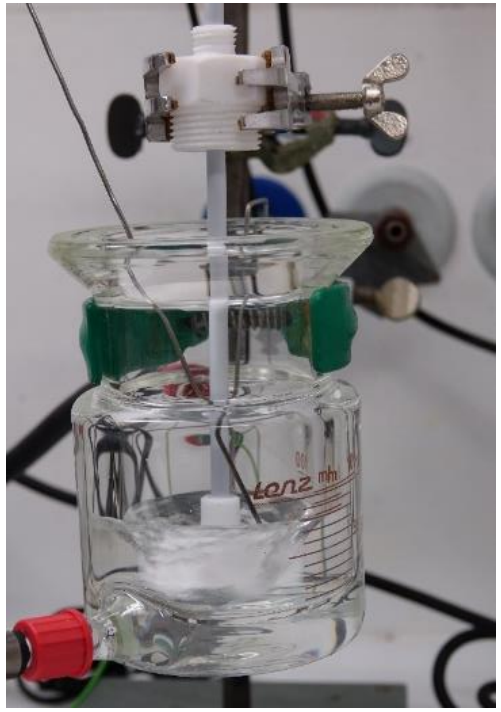




Impact sleeves of water-wet PETN

- → Often quieter positive results for wet samples
- → Reduced explosion propagation by acidic water (empirically observed)

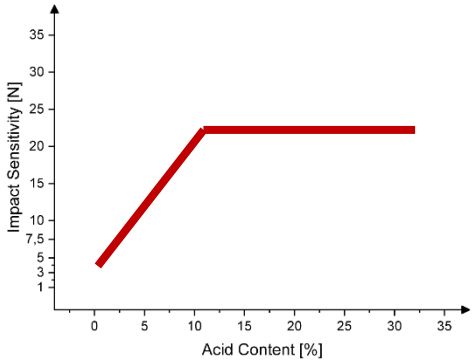
Conclusion



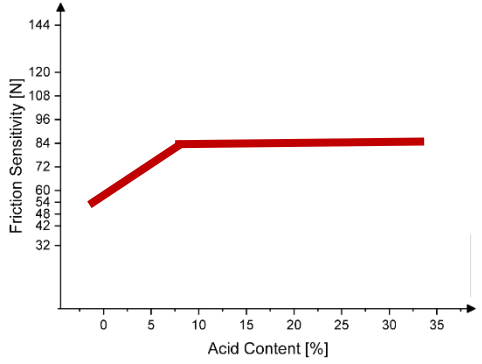
Risk assessment of PETN manufacture:

- Minor influence of DIPE content (0.1-1.3%)
- Washed and drowned as sensitive as recry. PETN
- Most sensitive: spent acid wet PETN

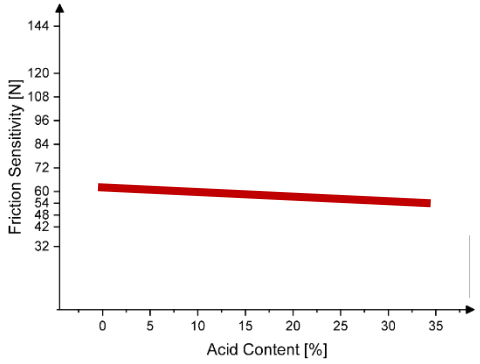
Impact Sensitivities



Friction Sensitivity Washed/Drowned



Friction Sensitivity Spent Acid



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- Dr. J. Stierstorfer

- Dr. M. Mühlemann
- G. Lemarchand

- Ralf Weber

- Fabian Venetz

Thank you for your attention!