DEFENCE R&D DÉFENSE

Exudation Problems and Solutions with the GIM Melt-Cast Explosive

M. Brassard

DRDC Valcartier

Acknowledgments

Co-authors
- P. Brousseau
- G. Ampleman
- S. Thiboutot
- S. Brochu
- S. Trudel
- P. Béland
- T. Gamache

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Summary

- Background on our RIGHTTRAC project
- Presentation of the exudation problem
- Solution identified
- Conclusions

RIGHTTRAC Concept

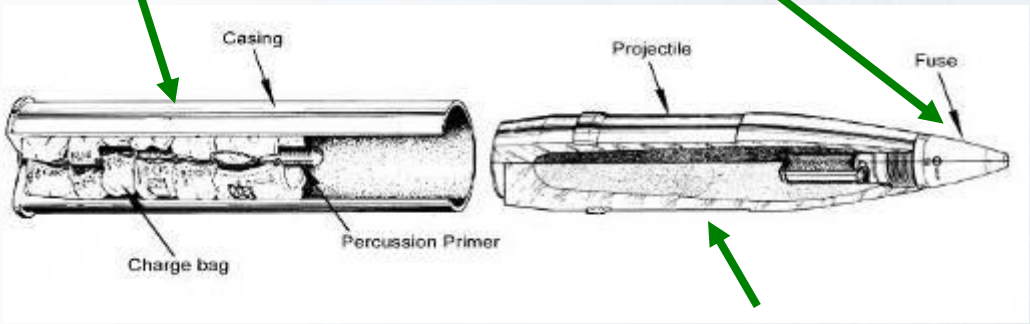
- Test vehicle : 105-mm M1 artillery round
  - Scalable to other weapons

Avoid using toxic and carcinogenic ingredients in gun propellants

Decrease the production of UXOs

Green/IM propellant

More reliable fuzing system with self-destruct mechanism



Green/IM explosive

Avoid RDX

Background – Avoid RDX

Water solubility (mg/L)	
RDX	HMX
42	5.0

EPA Lifetime Health Advisory for Drinking Water (μg/L)	
RDX	HMX
2	400

- HMX is less soluble than RDX
- HMX is less toxic than RDX
- Factor of 1000 better for the environment!
- Other energetic solids could also be appropriate but at this point in time, HMX is our best bet!

http://www.clu-in.org/char/technologies/exp.cfm
http://www.epa.gov/waterscience/criteria/drinking/dwstandards.pdf

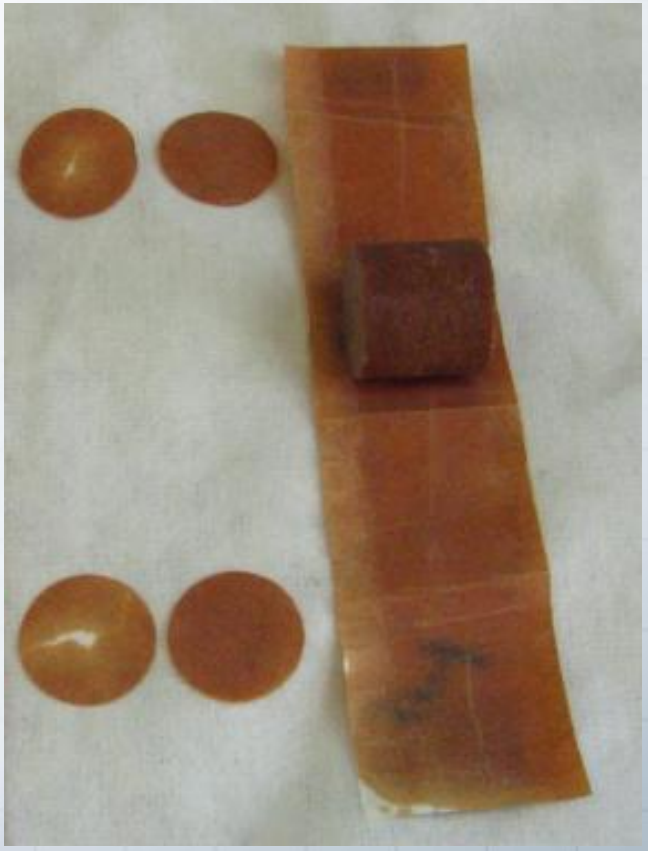
RIGHTTRAC – Explosives

- Main explosive charge
  - Option 1. Green/IM Explosive (GIM)
    - Mix of melt-cast explosives with an Energetic Thermoplastic Elastomer (ETPE) patented by DRDC Valcartier
      - TNT/HMX/ETPE
    - Conventional melt-cast apparatus can be used without modifications
    - Recyclable products for remilitarization

  - Option 2. Polymer-Bonded Explosive (HMX-based
    - HMX/HTPB/DOA
    - High mechanical strength, good explosive properties, excellent chemical stability, insensitivity

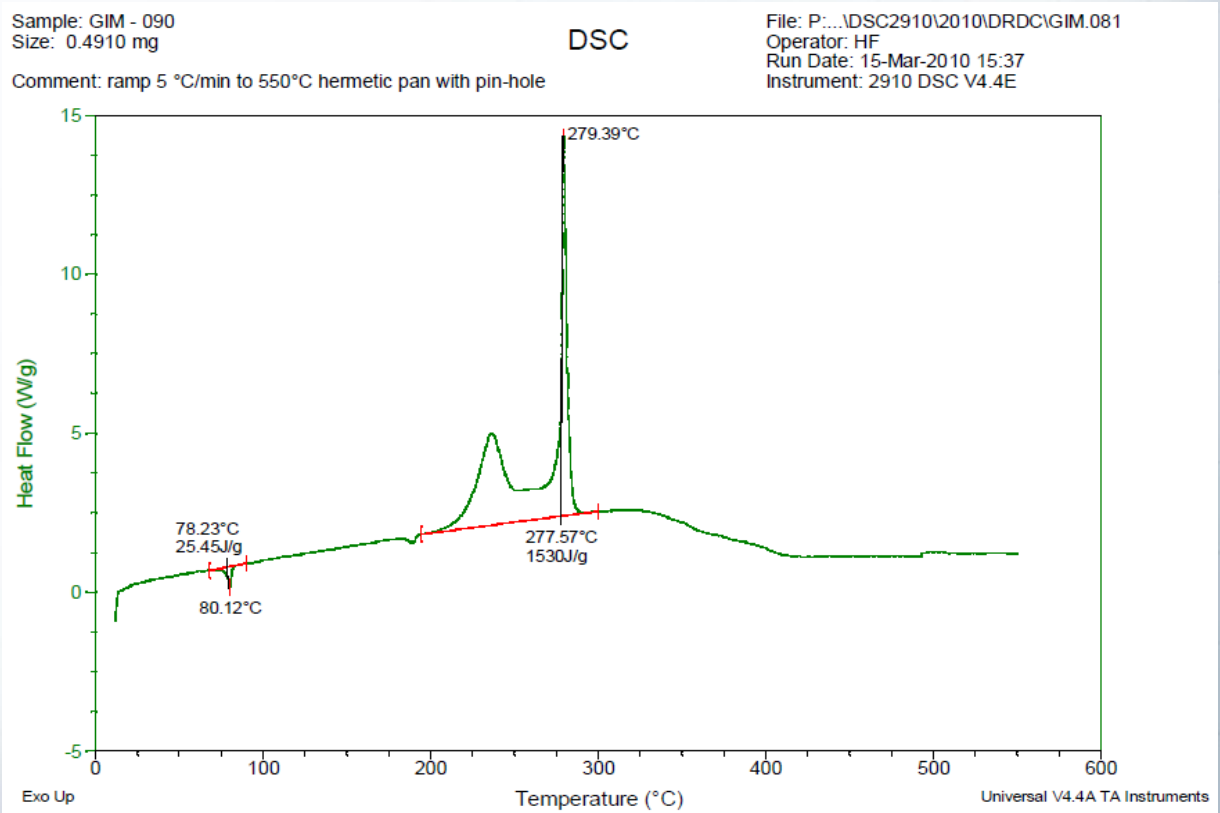
GIM Explosive

- The melt-cast explosive was selected
- A number of AOP-7 tests were performed
- Significant problems were detected with the exudation test at 70 ºC for 320 hours
  - Large amounts of liquids lost
    - > 3% original mass
  - Composition of the liquid exudate
    - TNT 46 %
    - ETPE 52.8 %
    - HMX 1.2 %



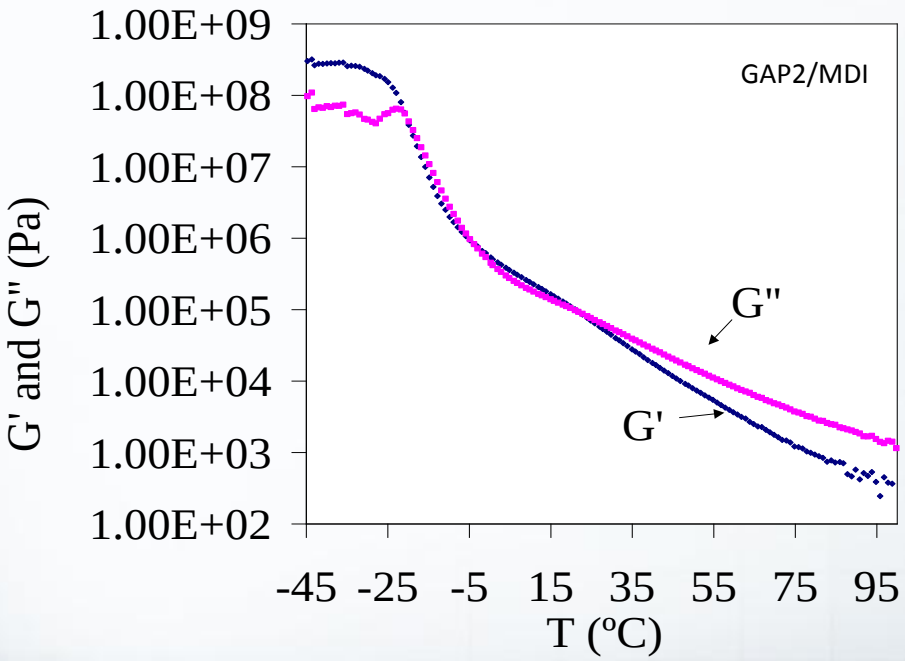
Exudation of the GIM

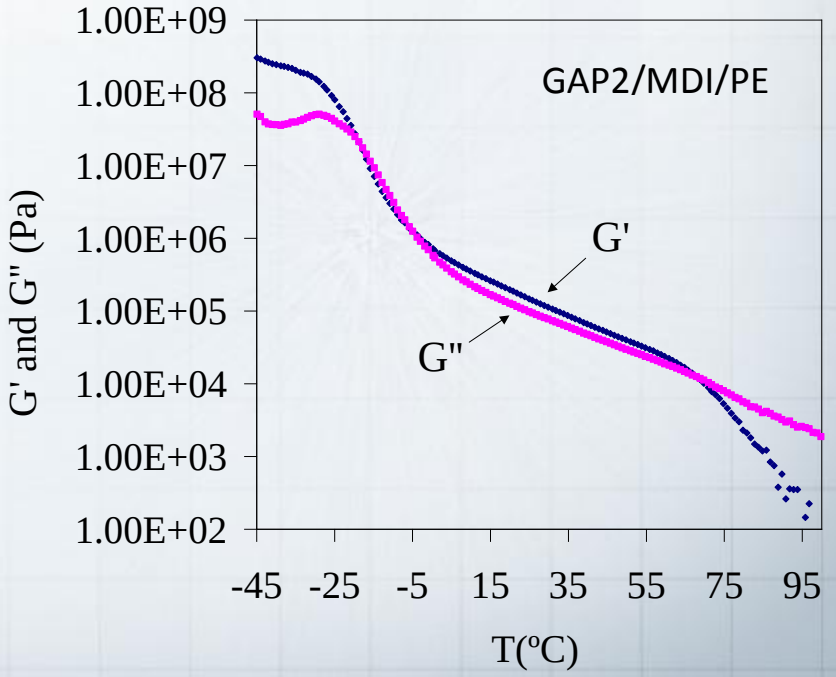
- Why?
  - Is the polymer lowering the melting point of the mix below 70 ºC?
    - No
      - The structure is intact at 70 ºC
      - The DSC does not tell that story (onset may be a few degrees lower)



Exudation of the GIM

- Why
  - Is the polymer melting?
    - No
      - We have dynamic mechanical data to prove it
      - The polymer softens but does not melt at such temperatures
      - We tested with stiffer polymers and still had exudation





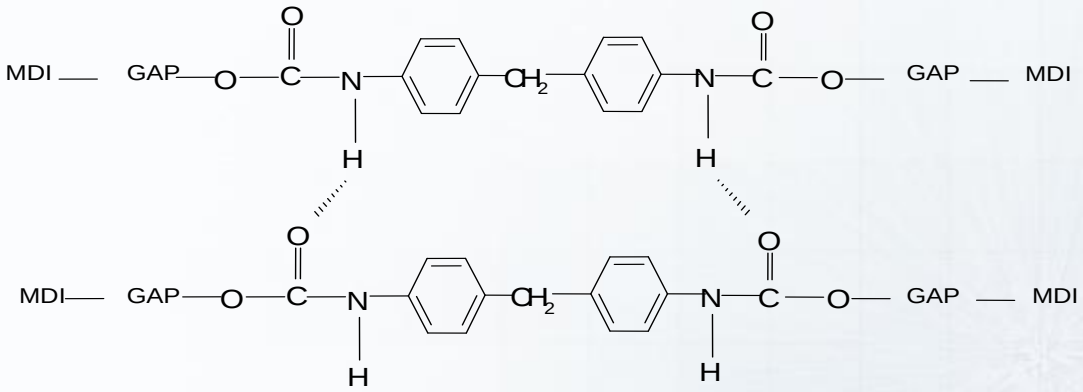
Exudation of the GIM

- Why?
  - The polymer is polydispersed. Are the very short chains leaving?
    - Yes, but not some large ones as well.
      - The molecular weight may be influencing

ETPE in the GIM	Mn	Mw
3M-01 (original)	13000	34100
3M-01 (in the exudate)	10500	26400

Exudation of the GIM

- We decided to look at the polymer characteristics
  - Molecular weight
    - It is a linear polymer formed by reacting GAP diol with MDI
      - Forms hydrogen bonds between chains



    - Our lot of ETPE was made by 3M in the USA according to our specs
      - We may have gone a little conservative on the NCO/OH ratio
        - » Keep the polymer linear and not crosslinked

Exudation Test

- We made our own exudation test
  - To represent a 105-mm shell, open
  - Quicker to set and assess
  - Visual impact as well (see the liquid come out if any)
  - Simple cylinders (31-mm diam x 254-mm long)
  - Open in a container
  - 320 hours at 70 ºC

- We ran tests with different versions of the ETPE

Exudation of the GIM

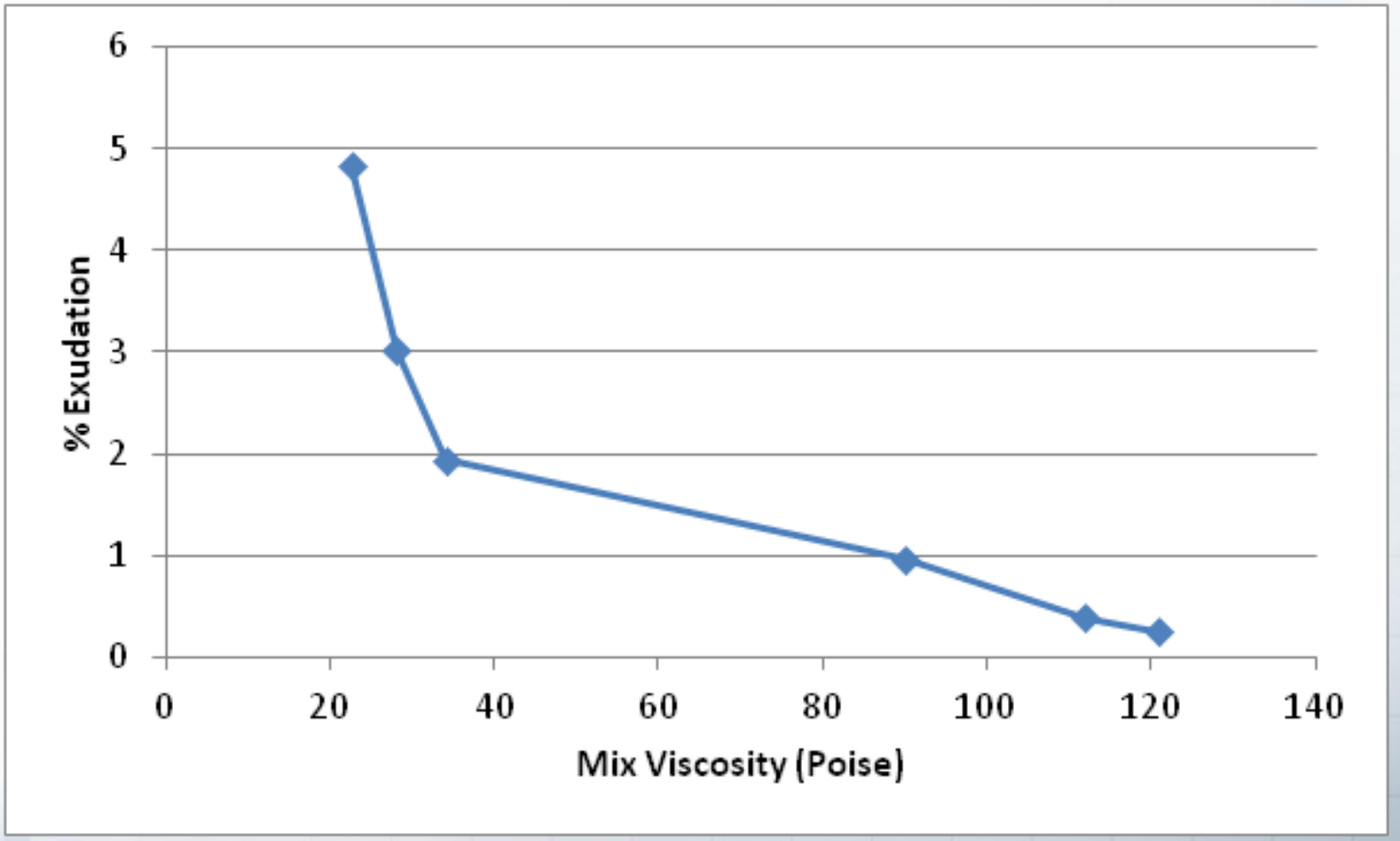
- We found that the molecular weight of the polymer strongly affected the exudation
  - The highest molecular weights gave the lowest exudation results

ETPE	Mn	Mw	% Exudation
3M-01	13000	34100	4.84
DRDC 2008-04	14600	39400	3.02
DRDC 2000-1	18400	60900	1.94
DRDC 0.950	*	*	0.97
DRDC 0.955	*	*	0.39
DRDC 0.960	*	*	0.25
Octol (no ETPE)	-	-	0.32

* Not measurable by GPC. Some crosslinking

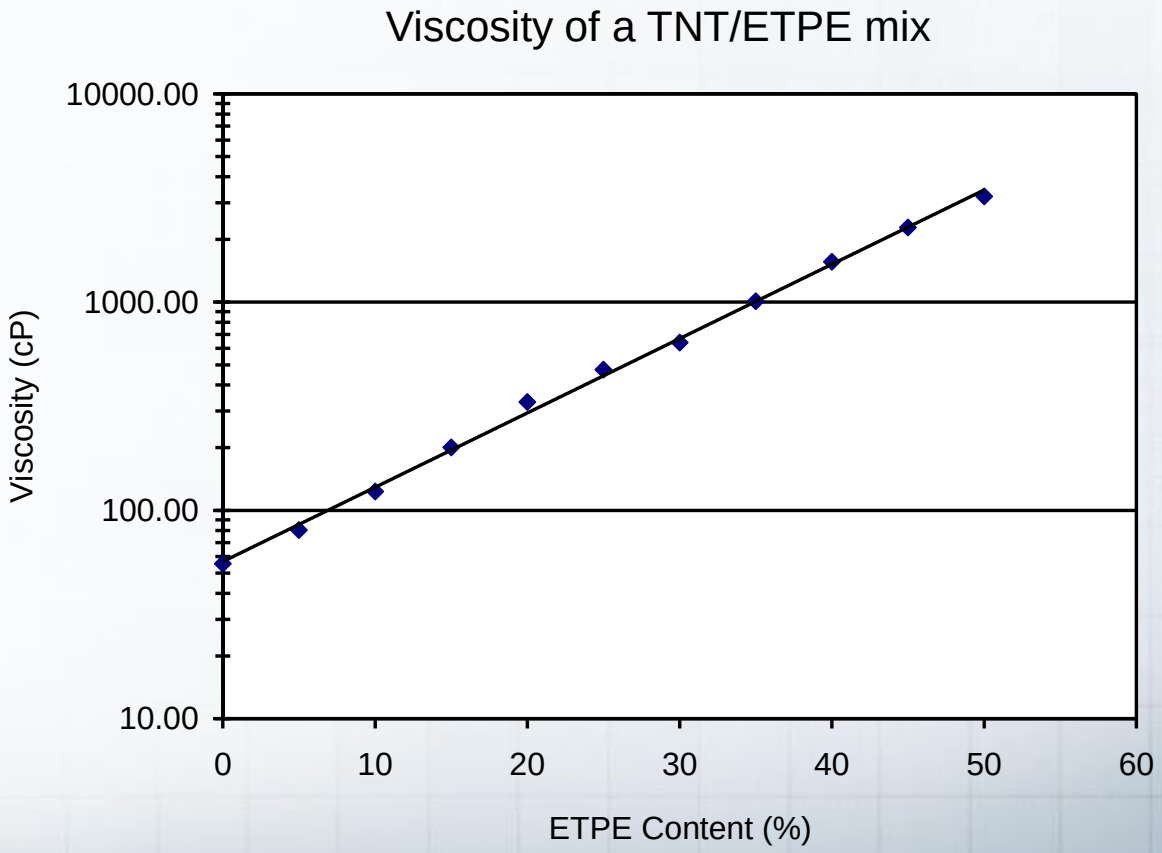
Exudation of the GIM

- It has consequences on the mix
  - A higher molecular weight means a higher viscosity of the polymer
    - Also means a higher viscosity of the GIM mix



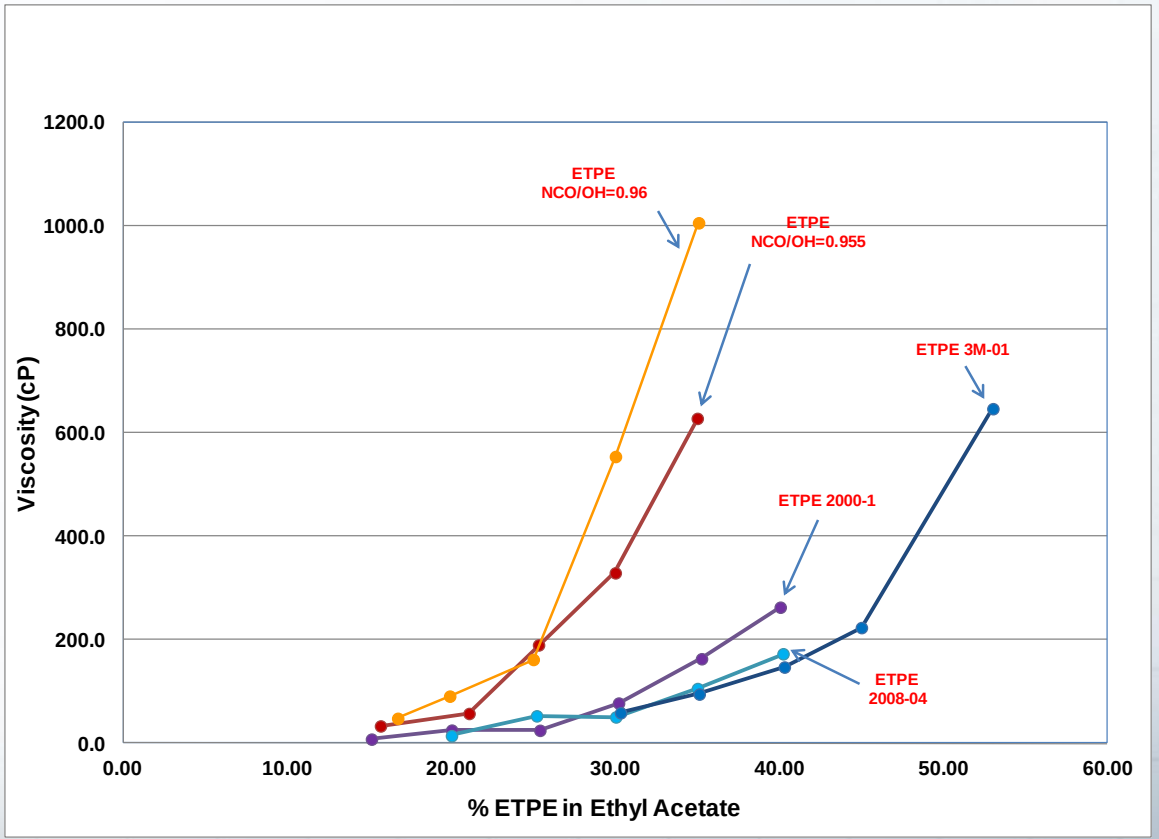
Exudation of the GIM

- We have a solution to the viscosity problem
  - We have to change the composition slightly
    - Add some TNT
      - It has a very strong effect on the mix viscosity



Exudation of the GIM

- Now we need to make the required polymer at a large scale
  - GPC is not very useful
    - We need a new quality control method to assess the ETPE
    - We use the viscosity again
      - Viscosity of an ETPE/Ethyl acetate mix



Conclusions

- We ran into a significant exudation problem with our explosive
  - TNT, HMX and a polymer
- The solution was to increase the molecular weight of the polymer
  - More than ten fold decrease in exudation
- It will influence the viscosity of the mix
  - We are working on this
- We still believe that adding polymers to a melt-cast explosive can significantly reduce its vulnerability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