Transferable Explosive Formulations

S French, P Bolton, P Jenkins, L Webb, S Miller

peter.bolton@awe.co.uk

AWE, Aldermaston, Reading. UK

Overview

- Background
- Aims
- Ingredient Properties
- Formulation
- Evaluation
- Conclusions
- Future Work

Background

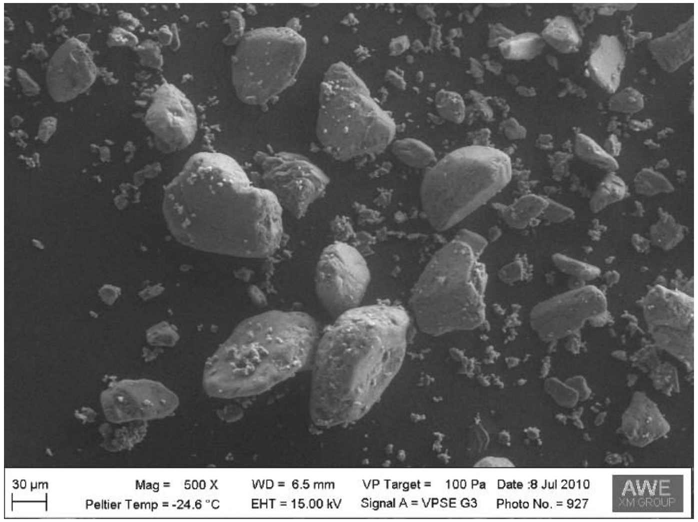
- Transferable explosives must have/be:
  - Low viscosity to allow injection through small diameter channels.
  - Resistance to sedimentation post injection.
  - Homogeneous and without voids, particularly at the interfaces.
- Traditionally transferrable materials are manufactured using energetic liquid carriers
  - Migration, thermal stability, cost and availability are often issues.

Aims

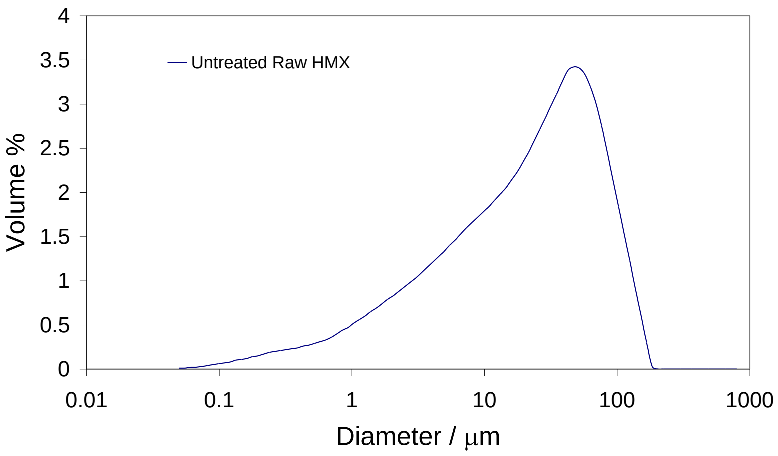
- Produce a thermally stable paste explosive based on HMX capable of initiating an IHE charge
  - Determine optimal HMX loading for manufacture into small channels.
  - Determine critical diameter and velocity of detonation of chosen formulations.
  - Determine ability to initiate an IHE charge (TATB based).

Ingredients

- Filler
  - HMX Type B
- Binder
  - Liquid fluoropolymer
    - Fluorine content: ~ 62%
    - Density: 1.81 g.cm^{-3}
    - Viscosity (20 °C): 85 cSt
    - Tg: -110 °C



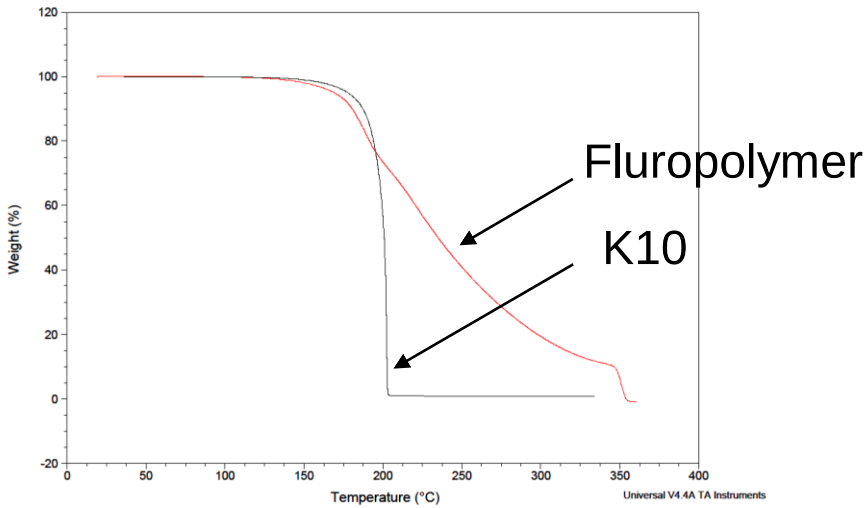
SEM of HMX Type B



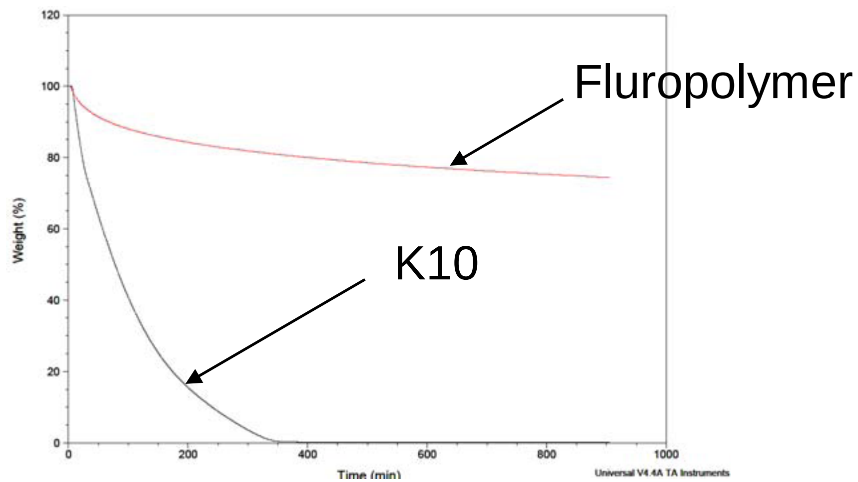
Particle Distribution of HMX Type B

Binder

- Fluoropolymer offers;
  - Improved stability
  - Low toxicity
  - 15hrs at 120ºC
    - K10 – 100% wt loss
    - Fluoropolymer – 26%



Thermal ramp at 10 °C min^{-1}



Isothermal TGA showing thermal stability at 120 °C

Formulation

- Three formulations were manufactured using an IKA HKV1 litre mixer.
  - No solvent.
  - No vacuum.
  - 45 minutes at 40°C.
- Pastes mixed at 230g scale

Formulation Properties

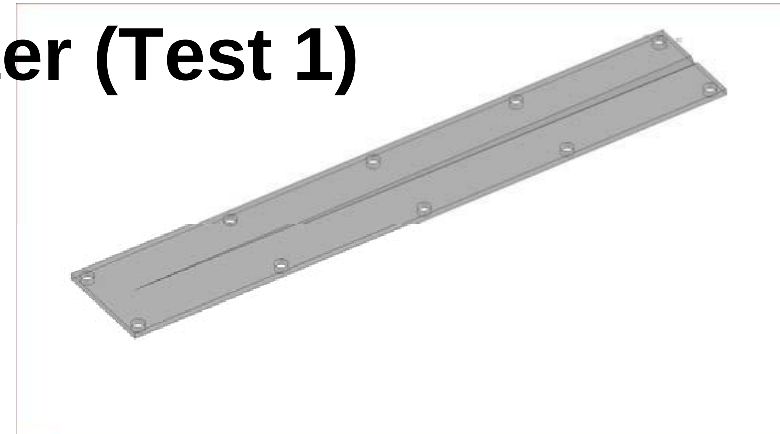
- **A**: 65 wt% HMX: Slurry – does not retain dimensional stability.
- **B**: 70 wt% HMX: Paste like.
- **C**: 75 wt% HMX: Clumpy powder.

Composition	HMX loading / wt%	F of I	Mallet Friction	ESD	Temperature of Ignition / °C
A	65	149	0% All Surfaces	Ignitions at 4.5 J No ignitions at 0.45 J	273.1
B	70	145			275.1
C	75	133			274.2

Powder Hazard Test Results

Evaluation - Failure Diameter (Test 1)

- Formulations assembled into Perspex track plate and attached to aluminium witness plate.
- Initiated by RP-2 detonator.
- Provides initial estimation of critical diameter.
  - **A** did not initiate in this configuration

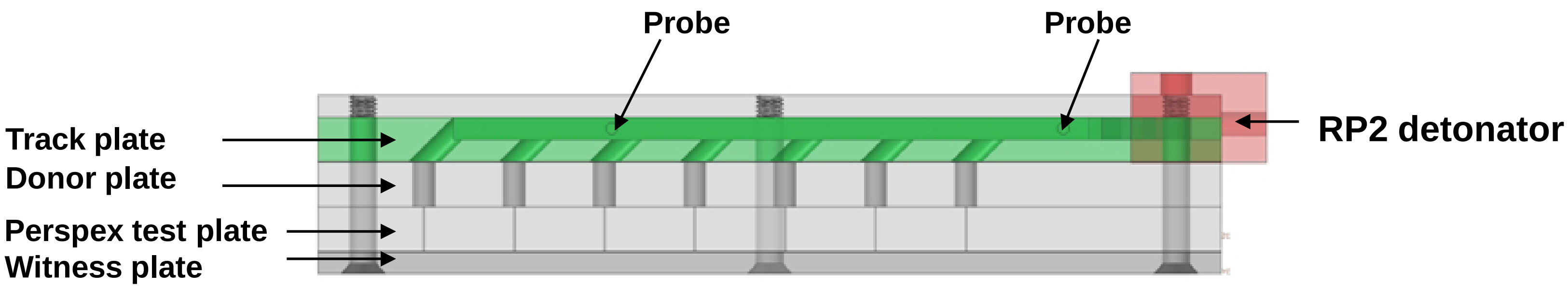


Schematic of witness plate

Formulation C Shot 1 Witness Plate

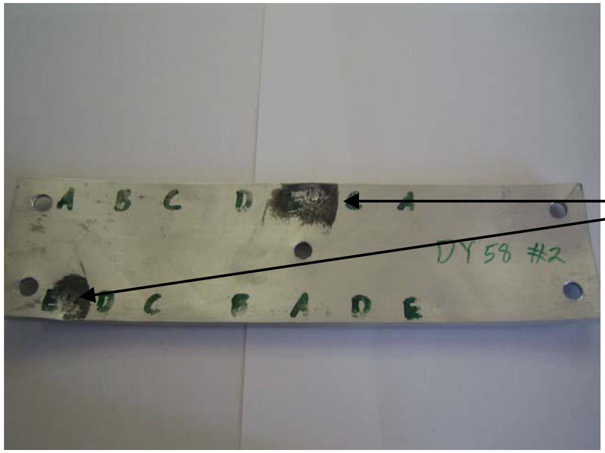
Evaluation - Failure Diameter (Test 2)

- Test Configuration
  - Columns of paste (donor; 10 mm) subjected to a detonation from a wider track of explosive (10 mm)
  - Test plate contains columns of paste with varying diameter
  - 5mm aluminium witness plate bolted to base of assembly
  - Pizo probes were positioned to determine V of D.



Empty assembly for failure diameter test

Failure Diameter Test (2) Results



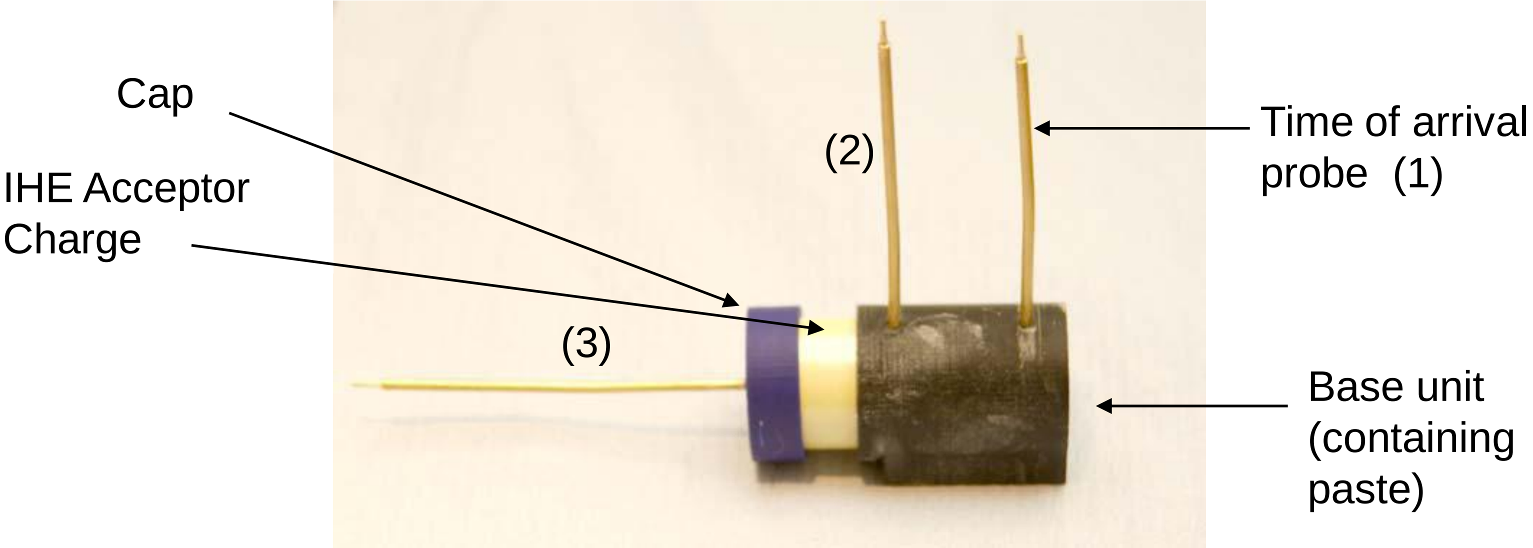
Evidence of detonation

Witness plate for failure diameter test

Composition	V of D / km/s	Failure Diameter / mm
A	No result	No result
B	7.6 ± 1%	3.3
C	7.7 ± 1%	2.7 - 3

V of D and Failure Diameter Results

Evaluation - IHE Initiability Test



- Test Configuration
  - 30mm (length) x 15mm (diameter) cylinder of paste
    - Initiated by RP-2 detonator
  - 20mm (length) x 25mm (diameter) acceptor IHE pellet
  - 3 time of arrival probes – allows estimation of detonation velocity

IHE Initiability Test Results

- **A** not tested.
- **B** and **C** successfully initiated IHE (95% TATB) to full detonation.
  - As observed by trigger of probe at the end of the acceptor.
  - Results indicate that these materials are not significantly different in their initiating properties.
- V of D can be estimated.
  - Based on assumption that IHE is promptly initiated to give constant velocity between the two probes.
  - Compares well with failure diameter and other tests.
  - Timings suggest **B** and **C** have similar initiating properties

	B	**C**
Probe (1)	1.992	2.020
Probe (2)	5.328	No data
Probe (3)	8.216	8.252

Time of arrival data

Conclusions

- Three paste formulations (HMX and liquid fluoropolymer) have been manufactured and critical diameter, velocity of detonation and IHE initiability studies undertaken.
- These offer advantages over traditional energetic liquid based formulations with better thermal stability and lower toxicity.
- Low concentration (65 wt% HMX) formulation did not support detonation.
- Other formulations (70-75 wt%) successfully initiated IHE and have a critical diameter of ~ 3 mm.

Future Work

- Recent work has allowed the HMX loading to be increased ~ 77 wt% by further optimising the particle distribution.
- Option to incorporate cure chemistry into the binders is being investigated.

Acknowledgements

- P Jenkins
- L Webb
- S Miller
- S French
- S Wortley
- J Padfield