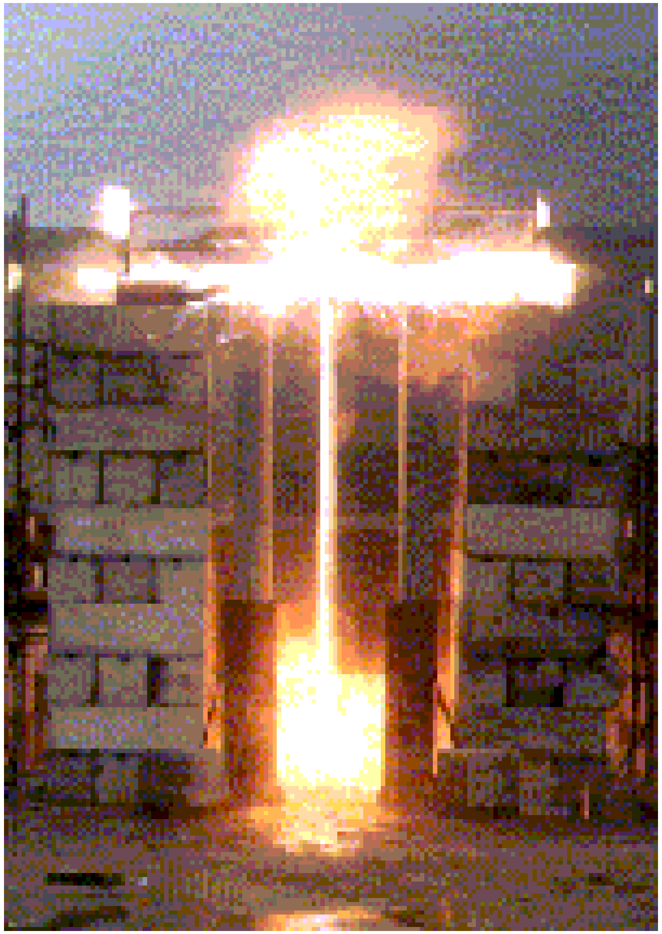
THE POTENTIAL OF FOX-7 EXPLOSIVE IN INSENSITIVE MUNITION DESIGN



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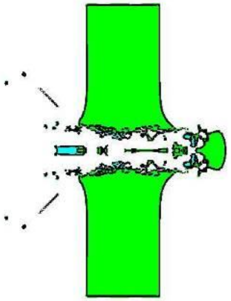


1 Introduction

The UK commitment to effects based planning and operations requires precision weapons to ensure the desired military effects are achieved.

Identifies UK needs:

- Increased flexibility from future weapon systems to ensure that a wide range of targets can be effectively neutralized within increasingly stringent rules of engagement.
- Minimum collateral damage.
- IM compliant.
- To understand the role that explosives and explosives design have in delivering a range of effects from lethal to sub-lethal.

Recent research has sought to develop such an understanding of explosives and explosives design.

1 Introduction

Technical Approach

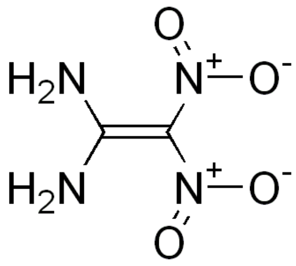
Integrated modelling – experiment, material characterisation methodology

- Detonation product model for QRX080 (95%FOX-7).
- Identify candidate shaped charge & fragmenting warhead designs.
- Model performance using Eulerian hydrocode GRIM and SPLIT-X®.
- Experimental Firings:
  - Cylinder Tests: QRX080
  - Slow Stretching Jet (SSJ) charges: QRX250, PBXN-110, LX14, EDC1S filled

QinetiQ

1 Introduction

Explosives



- FOX-7.
  - 1,1-diamino 2,2-dinitro ethylene
  - Developed by FOI, Sweden
  - Improved hazard response with comparable performance of cast cured RDX formulations.
- QRX080 (95% FOX-7 and 5% binder, particle size 56μm/78μm)
- QRX250, used in CE warheads, reduced particle size 36 μm.
- PBXN-110 (88% HMX/12% HTPB/isodecylpelargonate).
- EDC1S (70.25% HMX/4% RDX/24.75% TNT/1% Wax)

2 Explosive Products Model

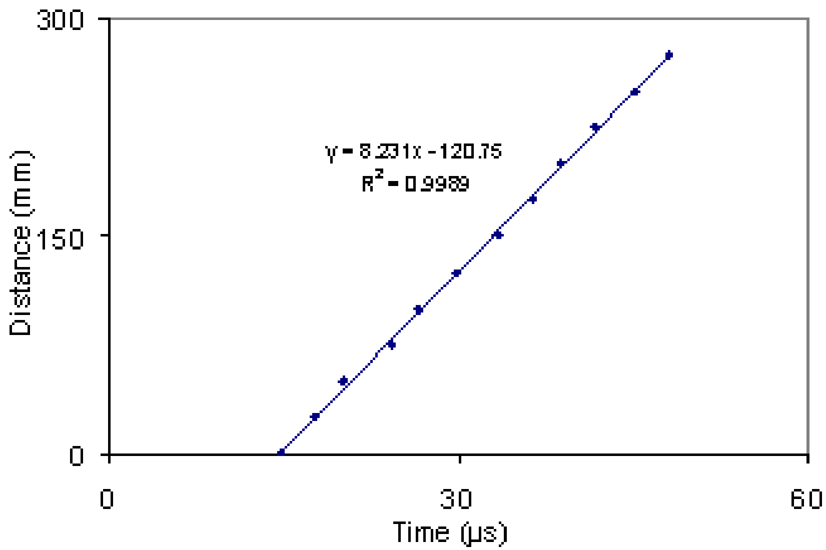
Cylinder Test Experiment.

- Test to measure the transfer of explosive energy to a metal.
- Hollow metal cylinder, usually constructed of ductile copper, filled with the explosive of interest.
- Two sizes, namely a 2.54 cm inner diameter and a 10.16 cm inner diameter.
- L/D = 12
- Jones-Wilkins-Lee (JWL) Equation of State for detonation products fitted to tube radial expansion and measurement of the detonation velocity.
  - Analytic iteration of JWL parameters to provide best fit to the data.
  - Thermo-chemistry code (e.g. CHEETAH) to provide starting point fit. ☑

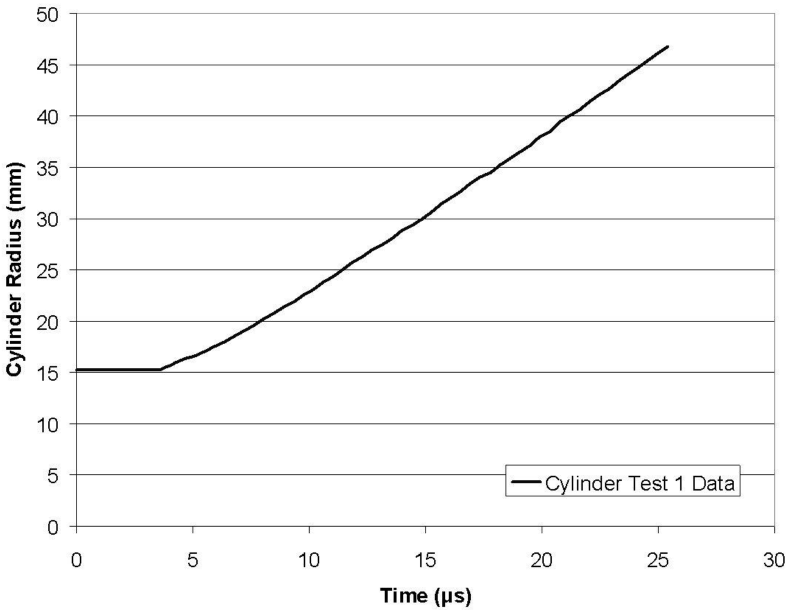
2 Explosive Products Model

Cylinder Test Experiment.

$$f_{ICT}\left(\alpha,\beta,T,A,B\right)=\alpha\left[t-\frac{e^{-\beta T}}{\beta}\left(-e^{-\beta t}\right)\right]+A\left[t-\frac{e^{-BT}}{B}\left(-e^{-Bt}\right)\right]$$



Detonation Velocity Measurement
(8.23 km/s, 8.22 km/s and 8.39 km/s)



Cylinder Wall Expansion History

2 Explosive Products Model

JWL.

JWL Adiabat

$$P_S = Ae^{-R_1\frac{V}{V_0}} + Be^{-R_2\frac{V}{V_0}} + C\left(\frac{V}{V_0}\right)^{-(\omega+1)}$$

EoS (JWL)

$$P = A\left(1 - \frac{\omega}{R_1}\frac{V_0}{V}\right)e^{-R_1\frac{V}{V_0}} + B\left(1 - \frac{\omega}{R_2}\frac{V_0}{V}\right)e^{-R_2\frac{V}{V_0}} + \omega\left(\frac{E}{V}\right)$$

JWLB (Baker et. Al.)

$$P = \sum_{i=1}^{5} A_i e^{-R_i\left(\frac{V}{V_0}\right)} + C\left(\frac{V}{V_0}\right)^{-(\omega+1)}$$

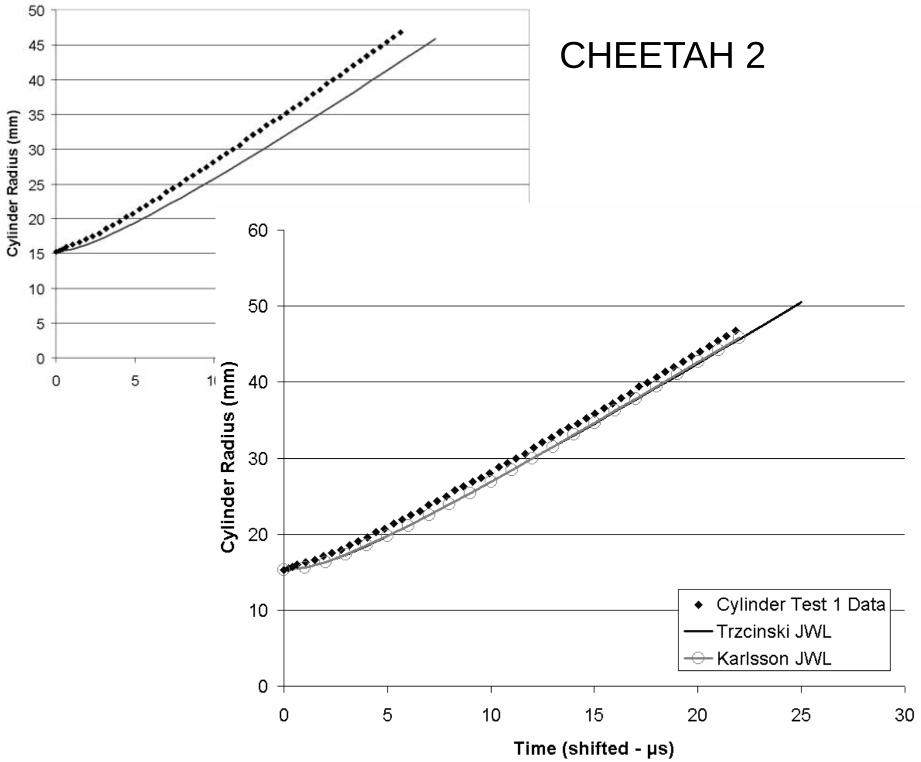
2 Explosive Products Model

Cylinder Test Fitting

JWL Parameter	*QRX080 (95% FOX-7, 5% binder)*	*Trzcinski (100% FOX-7)*	*Karlsson (98.5% FOX-7, 1.5% wax)*
A (GPa)	545.35	1414.339	998.578
B (GPa)	5.97	21.6637	8.778
C (GPa)	1.08	1.23412	Not given
R_1	4.09	5.54	4.928
R_2	1.06	1.51	1.119
ω	0.3143	0.32	0.401
Density ($g.cm^{-3}$)	1.76	1.78	1.756
Detonation Energy ($kJ.cm^{-3}$)	8.665	8.9	8.663

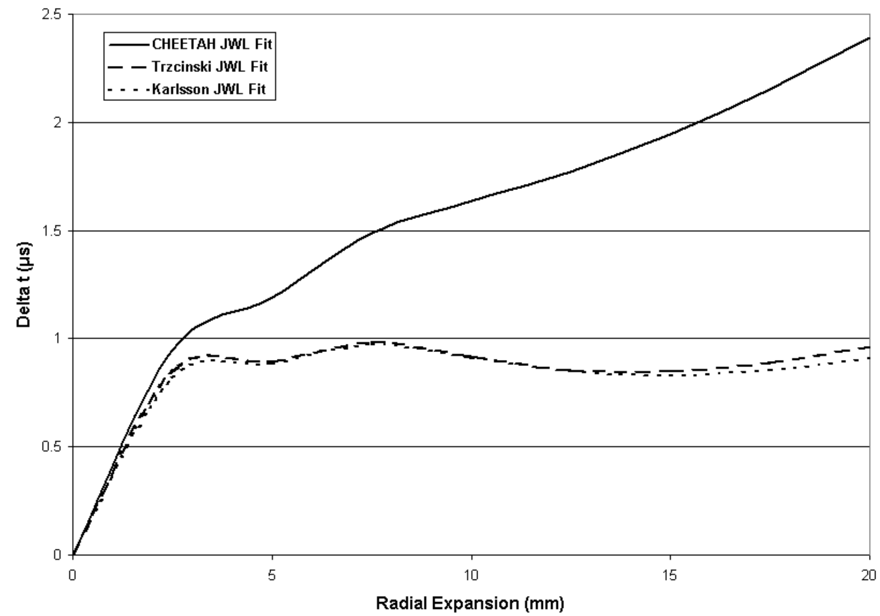
2 Explosive Products Model

Cylinder Test –JWL Fitting.



CHEETAH 2

Radius – time fits



Radial fit time error

2 Explosive Products Model

Conclusions.

- Radial wall motion of the cylinder represents an integration of the products' behaviour, implying the parameter set fitted to the motion is not therefore unique.
- By considering cylinder expansion prior to failure, reasonable JWL fits to the experimental data can be achieved.
- To improve the JWL fit further requires:
  - Further iterative hydrocode modelling
  - Additional cylinder tests capturing early motion data using a VISAR and simultaneous measurements of Detonation Velocity and density.

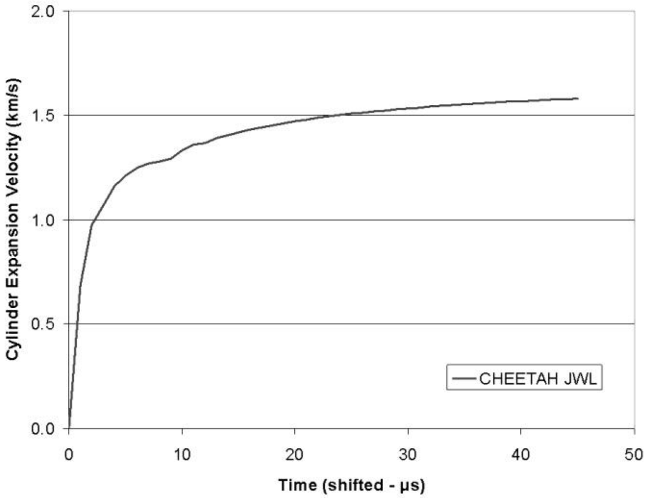
3 Fragmentation

The warhead design process often needs to accommodate a number of conflicting performance requirements, including blast, fragmentation and penetration within associated mass and volume constraints.

Fragmentation

- Use SPLIT-X® to assess potential fragmentation potential of explosive.
- Needs the Gurney energy, E
- Gurney velocity (V) is then:

$$\frac{V}{\sqrt{2E}} = \left[\frac{M}{C} + \frac{1}{2}\right]^{-\frac{1}{2}}$$



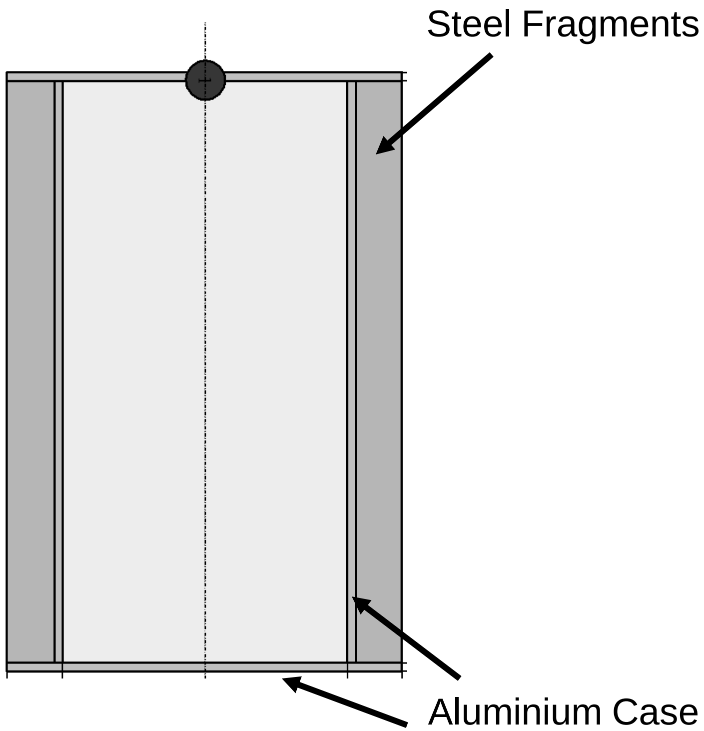
M/C FOX-7 = 3.1; PBXN-110 = 3.3
M=case mass, C=explosive mass

3 Fragmentation

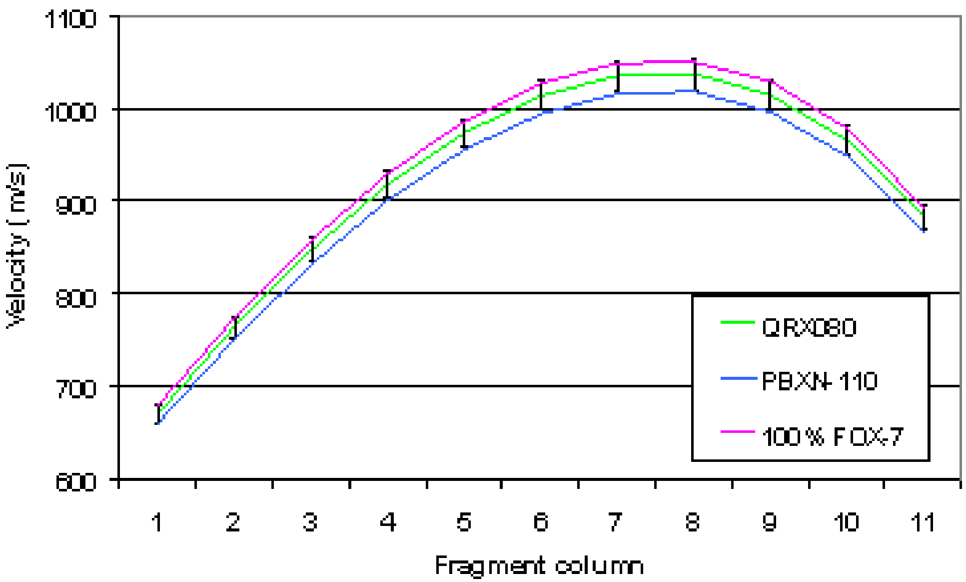
Fragmentation.

- Simple charge

QRX080



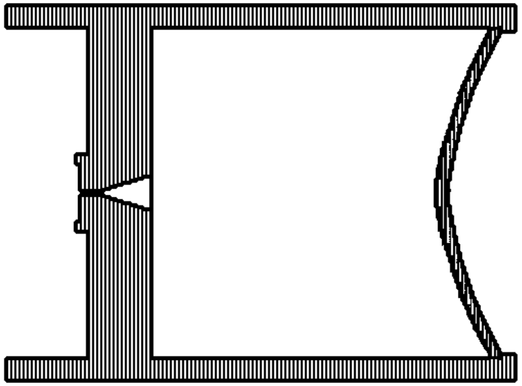
Cylinder Test	*Gurney Velocity (m/s)*	*Gurney Energy (J/g)*
1	2659	3536
2	2668	3559
3	2604	3392



4 Chemical Energy Warheads

Shaped Charges.

- Helte et al.* demonstrated potential of FOX-7 in a conical shaped charge, with jet characteristics superior to Composition B.
- This work explored performance potential of FOX-7 in Slow-Stretching Jet (SSJ) systems.
- Compared performance with PBXN-110, EDC1 and LX14
- Modelling and experimental study.
- Simple charge design.
  - Tulip copper liner
  - 75mm diameter
  - Aluminium body

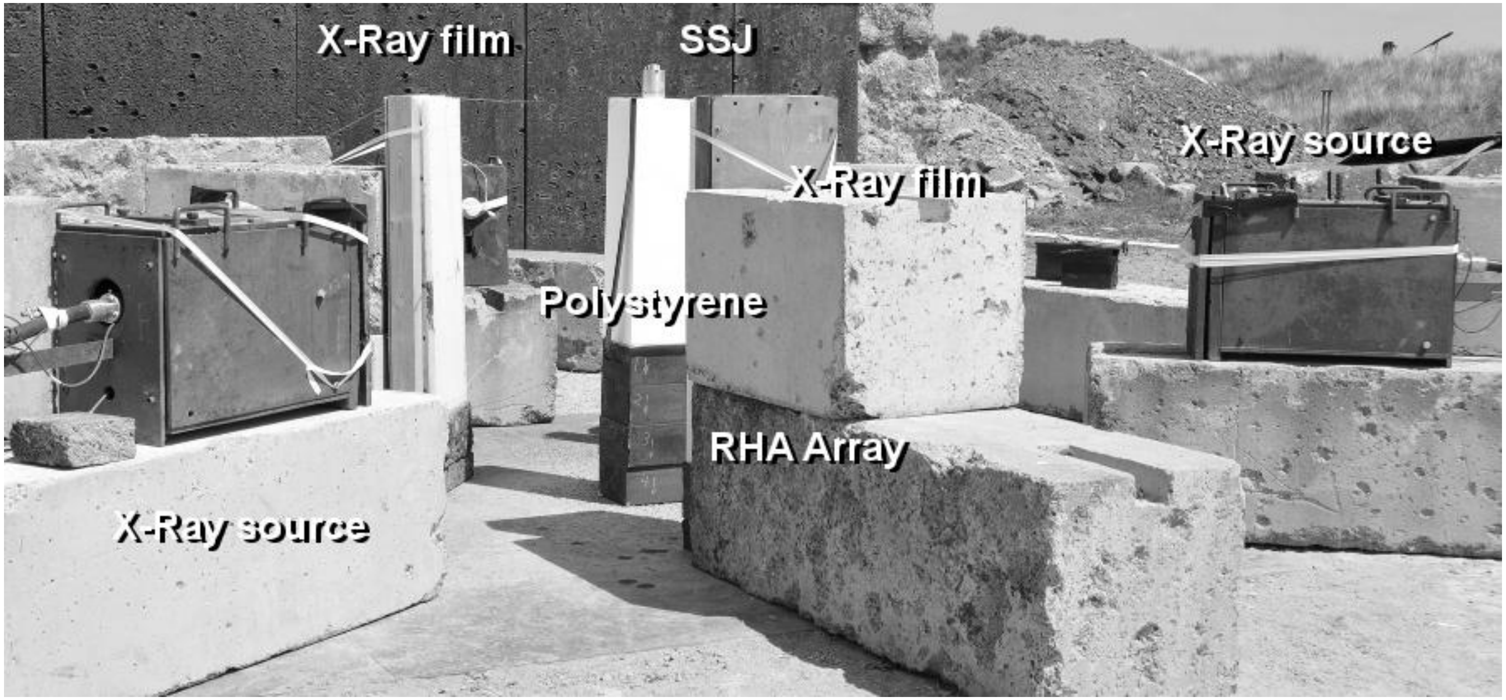


*Helte A. et al., 'Performance of FOX-7 in Shaped Charges', *Proc. 23rd International Symposium on Ballistics*.

4 Chemical Energy Warheads

Experiments

- Heavily instrumented trials arena to visualise the jet and record RHA penetration

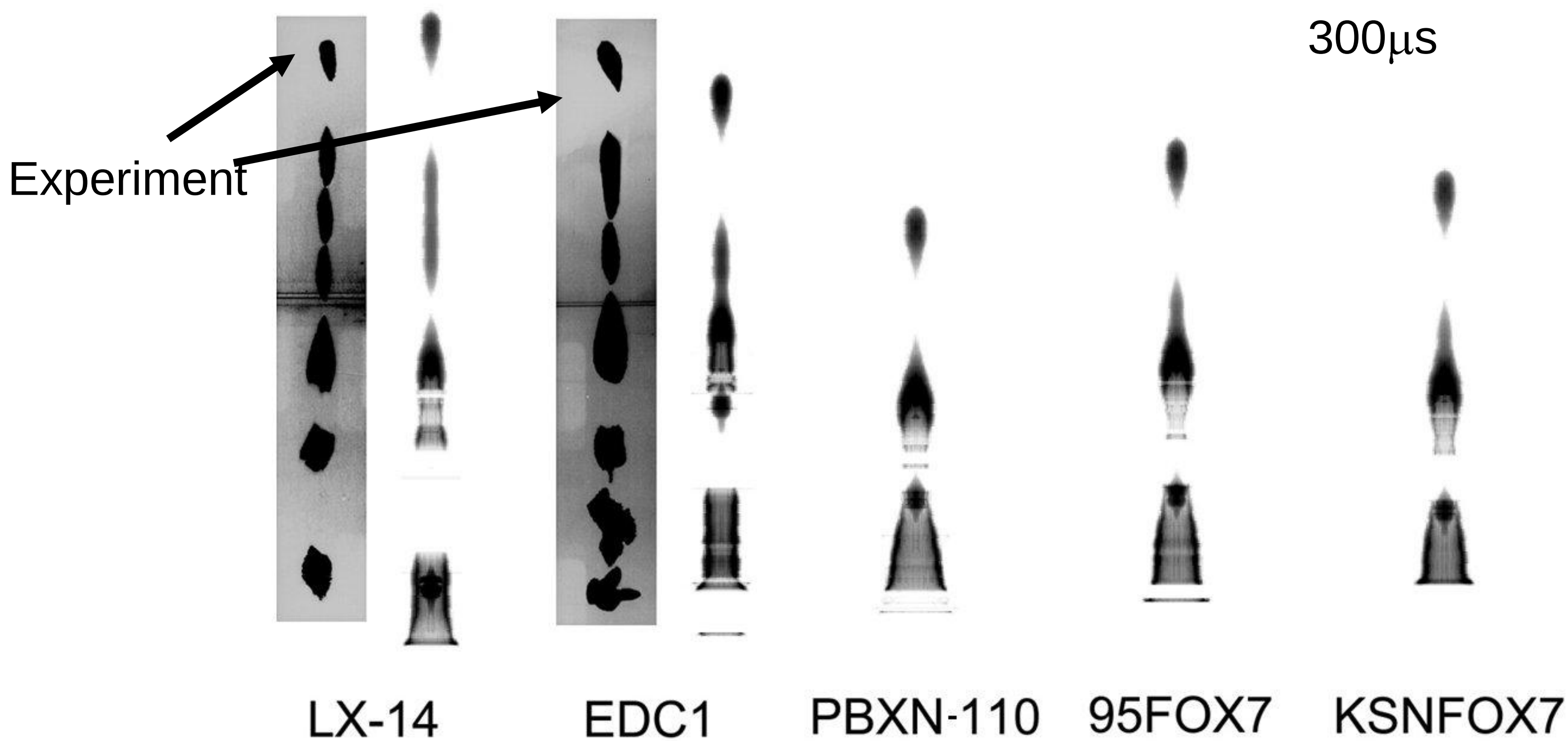


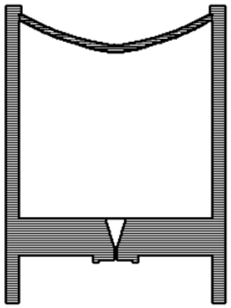
Stand-off = 12 CD (~895mm)

4 Chemical Energy Warheads

Modelling

- GRIM used to predict SSJ characteristics and break-up.



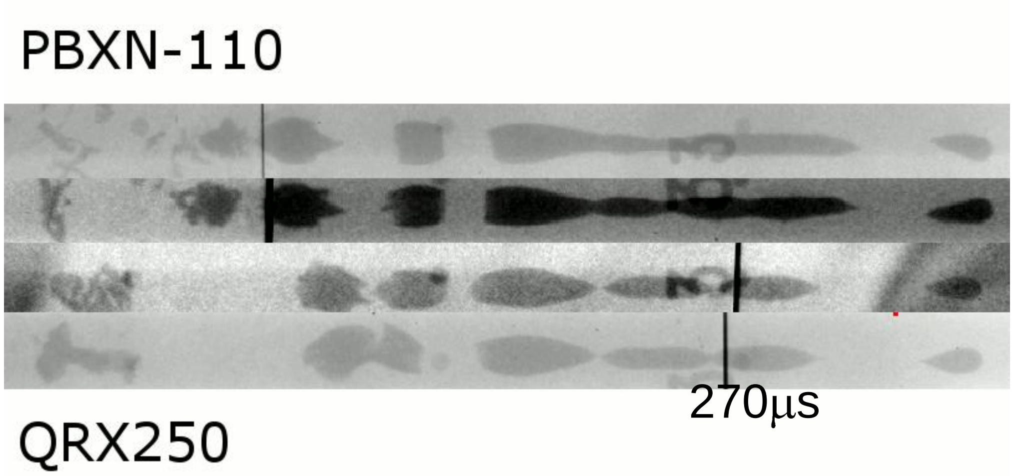


4 Chemical Energy Warheads

Modelling-experiment

- Predicted and experimental tip velocities in good agreement.
- Some subtle differences:
  - PBXN-110 produces a more elongated SSJ, typically composed of up to four ellipsoidal sections.
  - QRX250 SSJ comprised three sections, travelling more slowly.
  - Predicted jet characteristics for QRX250 sensitive to booster pellet size – much smaller booster used in modelling than utilised in trials.

Explosive	***Jet Tip Speed (km/s)***	
	Simulation	Experiment
LX-14	3.02	2.88
EDC1S	2.7	2.7
QRX250	2.58	2.63
PBXN-110	2.44	2.64



5 Conclusions

Research to compare and contrast the performance of FOX-7 compositions with high performance explosives in a SSJ shaped charge has allowed the following conclusions:

- QRX250 (95%FOX-7 5%binder) formulation offers similar performance in a SSJ charge to but not as good as more energetic and sensitive fillings such as LX14 and EDC1S that are not IM.
- Published FOX-7 cylinder test experimental data fit the QRX080 early time data reasonably well.
- The JWL fit produced by CHEETAH 2 does not fit the data as well as the published models.
- Split-X predicts higher fragment velocities for the FOX-7 compared to PBXN-110.
- SSJ performance for PBXN-110 and FOX-7:
  - Very similar jet velocity and RHA penetration.
  - Subtly different physical jet characteristics.

6 Acknowledgments

We would like to acknowledge:

- Colleagues at Fort Halstead in the manufacture and filling of the charges.
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- Our sponsor: UK MOD, Defence Science and Technology Laboratory (Dstl) Programme Office

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