The Vulnerability of Munitions to Low Velocity Impact

Dr P Barnes,DOSG
Prof Ian Wallace & Dr J Millett RMCS
Prof N Bourne Univ Man
Prof A Milne, FGE

Agenda

- The Safety Assessment Process
- Munition Testing
- The HAZARDS UK Programme
- Low Velocity Testing
- ELVIS

Risk Matrix – Munitions

DESCRIPTION	I	II	III	IV
FREQUENT	1	1	2	3
PROBABLE	1	1	2	3
OCCASIONAL	1	2	3	4
REMOTE	2	3	3	4
IMPROBABLE	3	3	3	4

Handling The Results

Consequence Table

	Person	Class A Asset	Class B Asset	Class C Asset	Environment
Cat I	DEATH	LOSS			SEVERE DAMAGE
Cat II	SEVERE INJURY	SEVERE DAMAGE	LOSS		MAJOR DAMAGE
Cat III	MINOR INJURY	MINOR DAMAGE	SEVERE DAMAGE	LOSS	MINOR DAMAGE
Cat IV	NO EFFECT	NO EFFECT	MINOR DAMAGE	SEVERE DAMAGE	NO EFFECT

Examples Class A=Ship, A/C; B=APC, Boat; C=Component, Support Equipment

Handling The Results

Likelihood Table

DESCRIPTION	PROBABILITY DESIGNATOR	INDIVIDUAL ITEM	FLEET or INVENTORY
FREQUENT	A	Likely Frequently	Experienced Continuously
PROBABLE	B	Likely to Occur Several Times	Likely to Occur Frequently
OCCASIONAL	C	Likely to Occur Sometime	Likely to Occur Several Times
REMOTE	D	Unlikely but Possible in Lifetime	Reasonably Expected to Occur
IMPROBABLE	E	Not expected in Lifetime	Inlikely but Possible to Occur

Risk

Risk = Probability of Explosive Accident x Consequence of Explosive Accident

Depends on: MDS Nature and likelihood of Stimuli, Sensitiveness

Depends on: MDS Surroundings, Explosiveness

Munition Tests – What they tell us

Test	Probability	Consequence
Slow Cook Off	1	Yes
Fuel Fire	1	Yes
Bullet Attack	No	Yes
Sympathetic Reaction	No	Yes
Fragment Impact	No	Yes
Shaped Charge Jet	No	Yes

Background to Hazard UK

- Poor Confidence in All Up Testing
  - Poor statistical Validity
  - Very High Cost
  - Increasing Environmental concerns
- Doesn't inform probability
- Need Alternative Approach
  - Develop Mathematical Models
  - Small & charge scale testing

Cranfield UNIVERSITY

FLUID GRAVITY

BAE SYSTEMS

QinetiQ

Basic Programme Objectives

- UNDERSTAND the physical and mechanical mechanisms that control the chemistry of energetic materials
- PREDICT the violence of the event for shocks
- PROVIDE risk reduction and better whole life cost studies.

Cranfield UNIVERSITY

FLUID GRAVITY

BAE SYSTEMS

QinetiQ

Hazard UK
Programme Components

- Constitutive Model
- Equation of State
- Experiments
- Burn Model

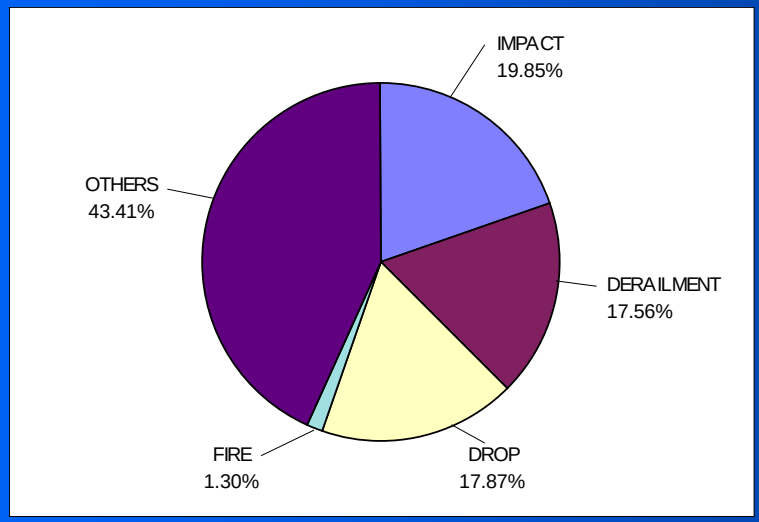
Cranfield UNIVERSITY

FLUID GRAVITY

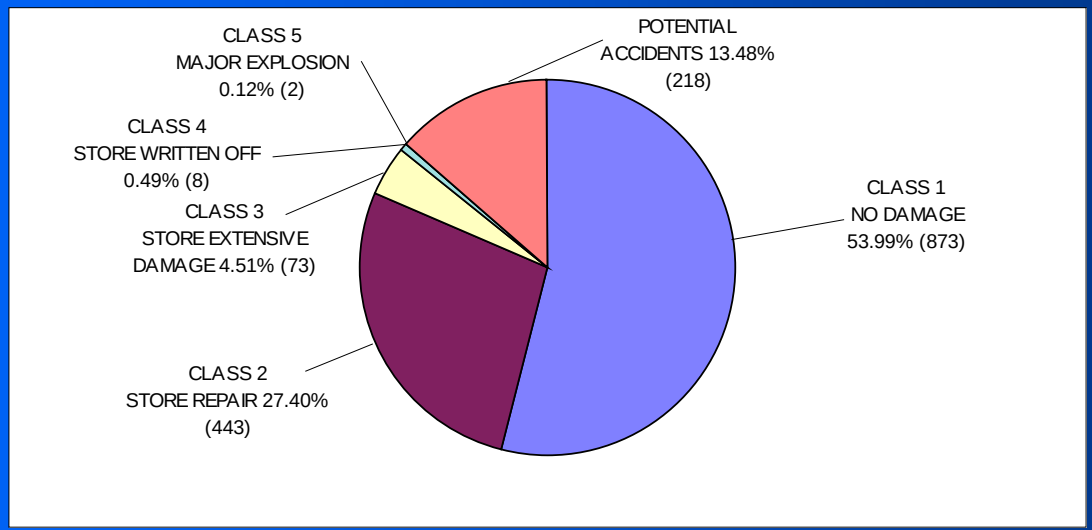
BAE SYSTEMS

QinetiQ

Accidents do Happen!



TYPE OF ACCIDENT



NAV Bedenham

- 1951 Gibraltar
- Drop
- Fire
- Detonation
- 13 Killed
- 200 Injured

F-16 2003

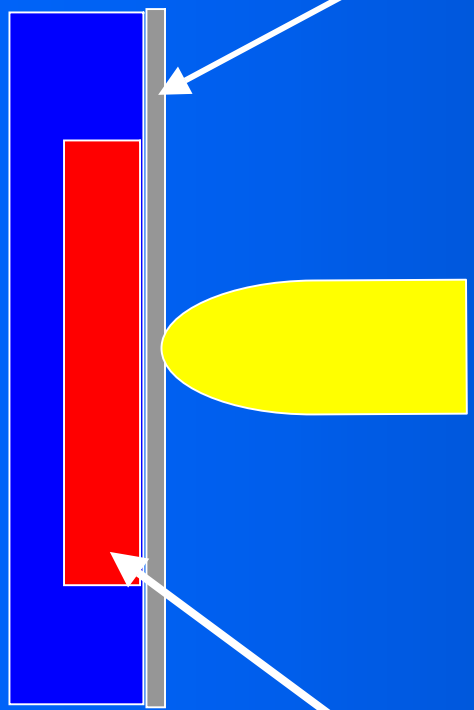
F-16 2003

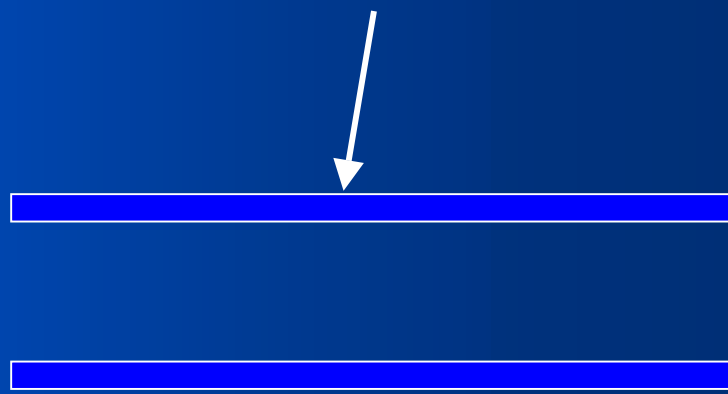
F-16 2003

Spigot Testing

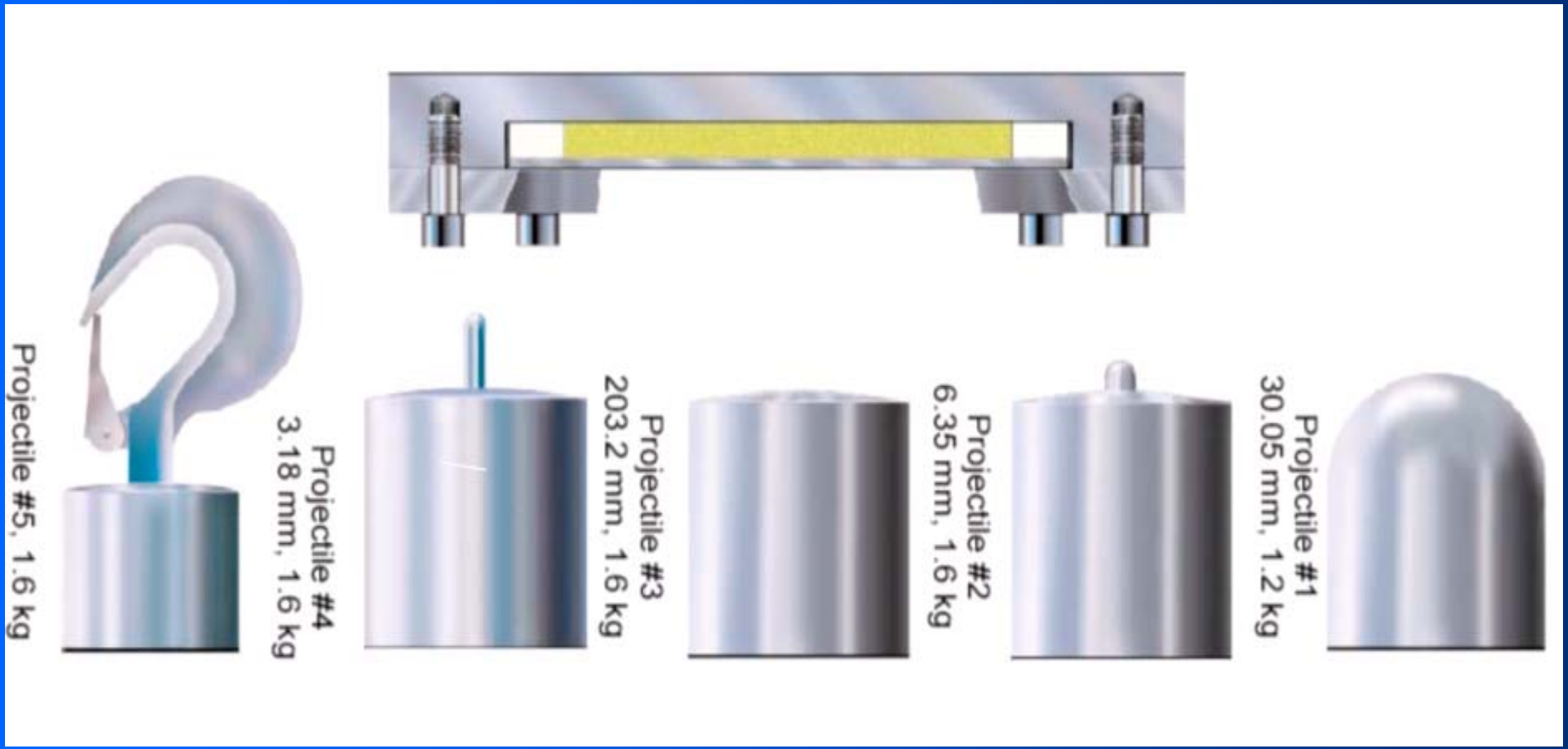
- Credible Stimulus
- But
  - Suffers failings of other all-up tests
  - Expense
  - Environment
  - Significance

ELVIS





Projectile Geometries



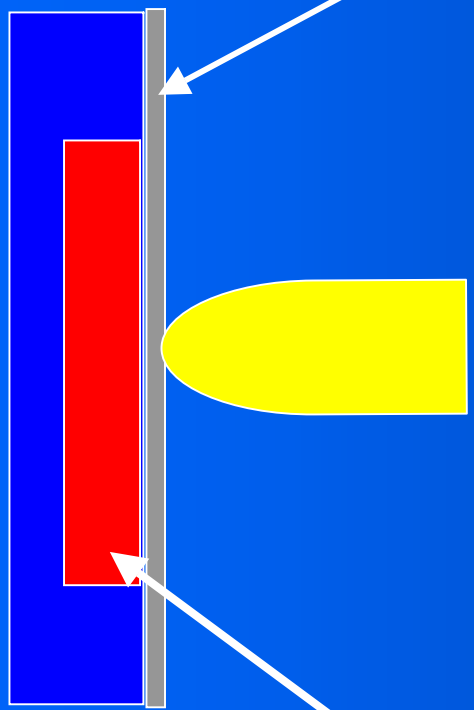
ELVIS Programme

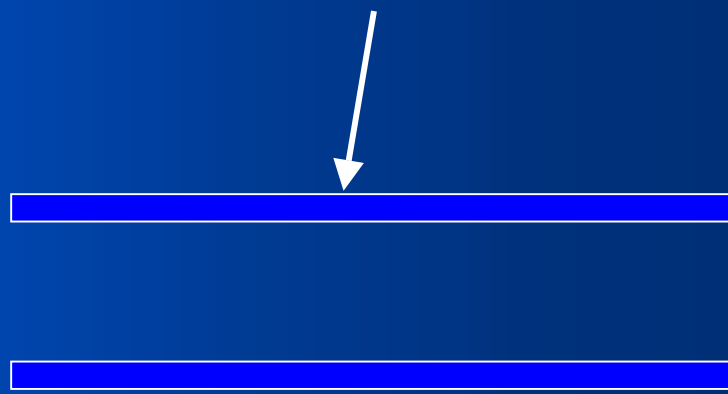
- Key Properties of Materials from HAZARD UK
- Ignition Thresholds
  - Different Explosives
  - Different Target Geometries
  - Different Penetrators
- Microstructure Analysis
- Supports Model Development
- Predictive Capability for Sensitiveness

Mechanisms

- Friction
- Shear
- Strain
- Crush
- Puncture
- Perforation
- Air gap/sleeve
- Initial temperature
- Internal target temperature field

ELVIS





ELVIS VEHICLE/TEST DESIGN FEATURES

- Originally cover plate and surround all copper
- Vehicle secured to substantial back plate to prevent any distortion of surround on projectile impact
- Cover plate firmly screwed into surround to ensure no venting
- Firings carried out between 50 and 100 m/s
- Due to detachment of copper plug from cover plate at impacts above 60m/s, mild steel used as cover plate
- Early projectiles were round nose design, 113 g , dimensions10 x 100 mm
- Latter trials used flat ended projectile (same weight)

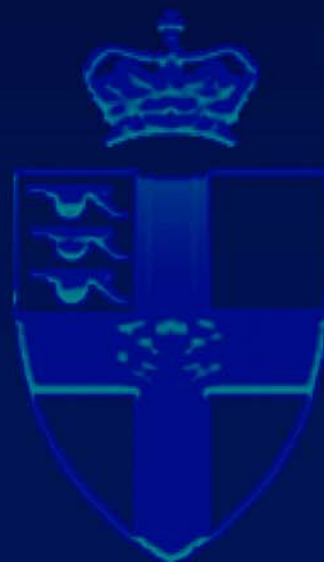
Low Velocity Impact of a PBX

- Trials started on one of three PBXs
- Two PBXs 88% RDX & 12% HTBP (course & fine particle sizes)
- One PBX 66% RDX, 22% AL & 12% HTPB
- Preliminary trials carried out of the coarse 88% RDX composition - as proposed for future UK shell projectile and mortar payload charges
- NOTE needed to determine any response in terms of:
  - discoloration around impact site
  - any smell of reaction
  - repeatable behaviour

100 m s^{-1}. Round Nose Projectile. Steel Cover Plate

Comments

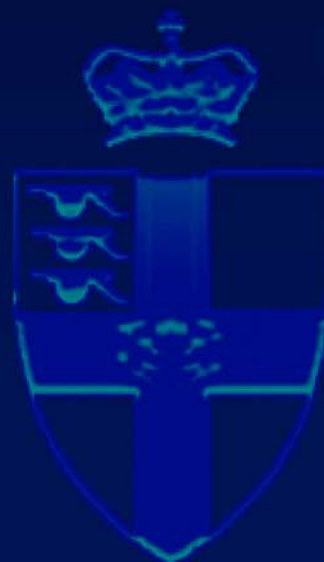
- No discolouration
- No reaction smell



53 m s^{-1}. Square Nose Projectile. Steel Cover Plate.

Comments

- No discolouration
- No reaction smell

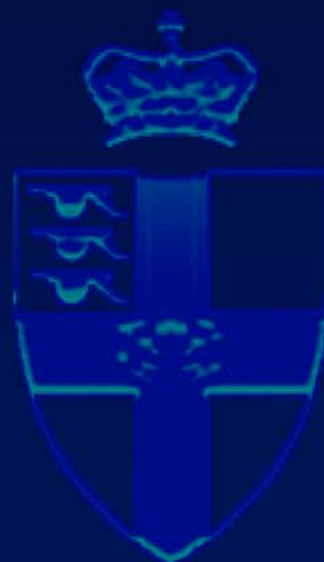


100 m s^{-1}. Flat Ended Projectile. Steel Cover Plate

Close Up of Previous

Comments

- Small amount of discolouration around impact site
- Strong smell of reaction
- Behaviour is repeatable.



Conclusions - Applicability

- Low Velocity Impact
  - Credible Threat to Munitions eg Sidewinder
  - Current test methodologies do not assess susceptibility of munitions to this threat
  - All-Up round tests have limited utility
  - Lab scale testing can be used to assess explosiveness: UK burning tubes & friability tests
  - ELVIS testing may provide measure of sensitiveness. Do not want to go above velocities above 100m/s

Conclusions - IM Policy

- Very encouraging - difficult to get responses from UK PBX to be used as future shell projectile payload charges

Conclusions - Use as a ranking test

- Need to see if the other two PBXs show responses at 100m/s with flat ended projectile, if yes then revert to further trials with round nose projectile
- Due to difficulties in getting any responses may need to have some vehicle redesign
- Need to compare results with other Steven test results eg US PBX 9501, responses around 55m/s

Conclusions -
Scientific understanding/model development

- Basically leaves in all forms of hot spot initiation
- Model validation not accurate at the moment, needs development. Model used is the Khaisairov viscoplastic hotspot model which has been used successfully in UK to predict shock response eg gap test