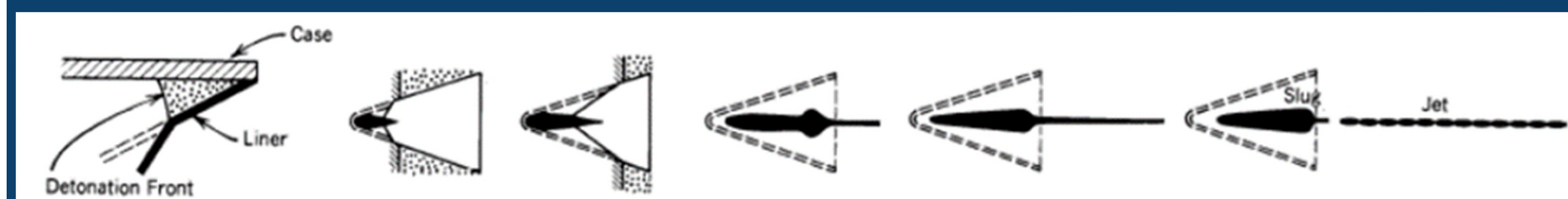




An investigation on the effects of multi-layer charge liners on EFP formation and performance

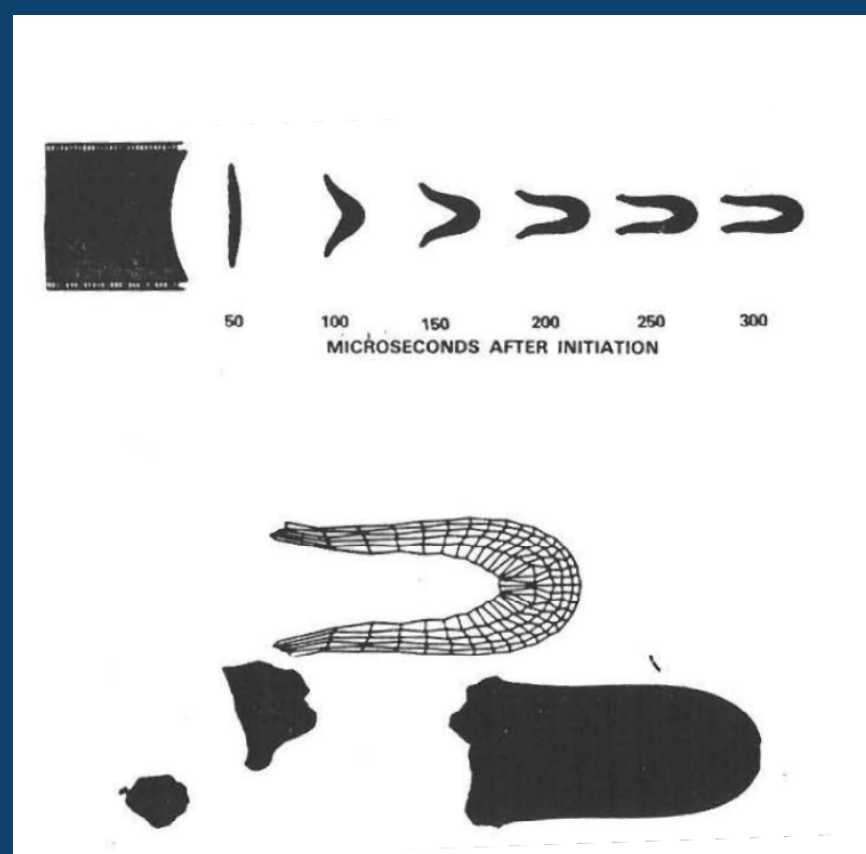
Introduction

Directed Energy Warheads have been used extensively in conflicts around the world, in particular, Shaped Charges (SC) and Explosively Formed Projectiles (EFP). Shaped Charges have a complex formation mechanism that requires very high precision.



This image depicts the shaped charge formation mechanism which creates a high velocity jet (up to 10,000 m/s) and a slower moving slug following behind [1].

However, EFPs undergo a 'folding' of the large cone angle liner instead of the inversion seen in shaped charges.



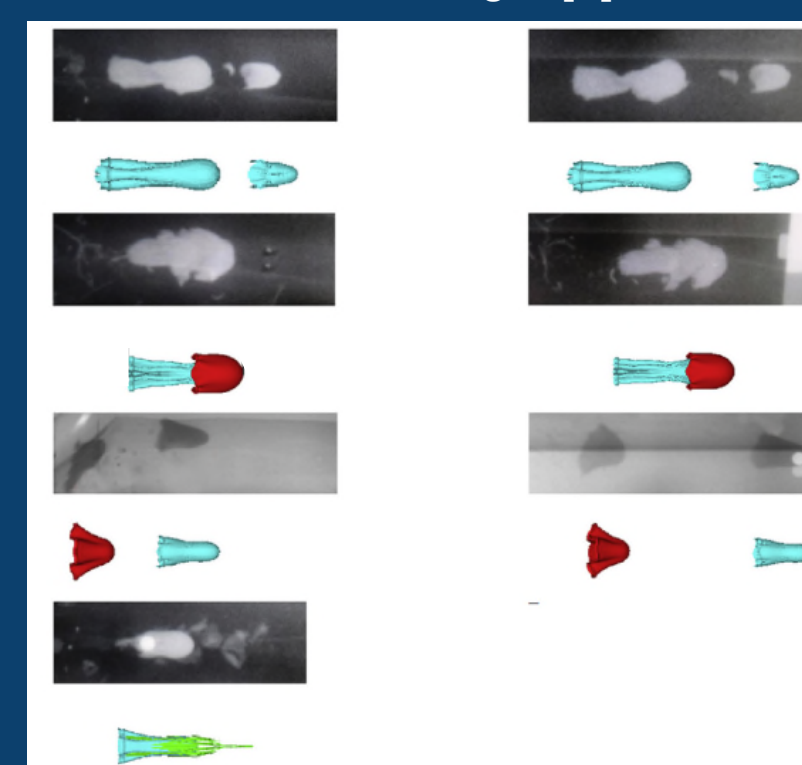
Recently, investigations into the effectiveness of dual lined EFP charges have been conducted through both modelling and experimental work. This approach can lead to the formation of a tandem EFP effect in some configurations with a complex formation sequence.

The formation can be separated into the following distinct phases:

1. Impact
2. Propulsion
3. Slide
4. Free Flight [2]

Shown to the right are the results from previous testing on dual lined EFP charges and the resulting EFP

formations in free-flight [2]



Aims and Scope

Aims - to investigate the relationship between:

- layering charge liners and the ability to form a coherent EFP; and
- having layered charge liners and the damage ability of the resulting EFP (penetration depth and crater size).

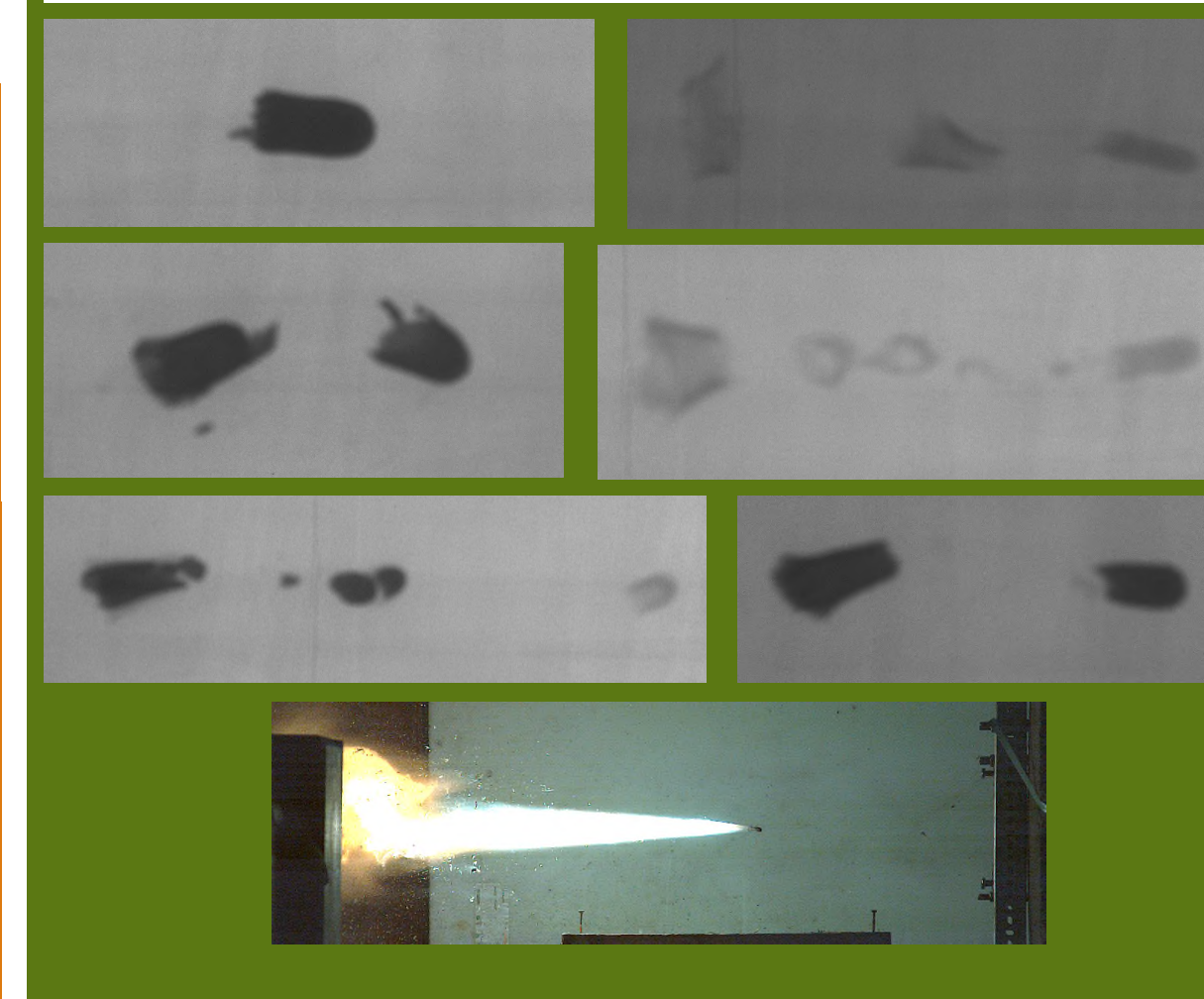
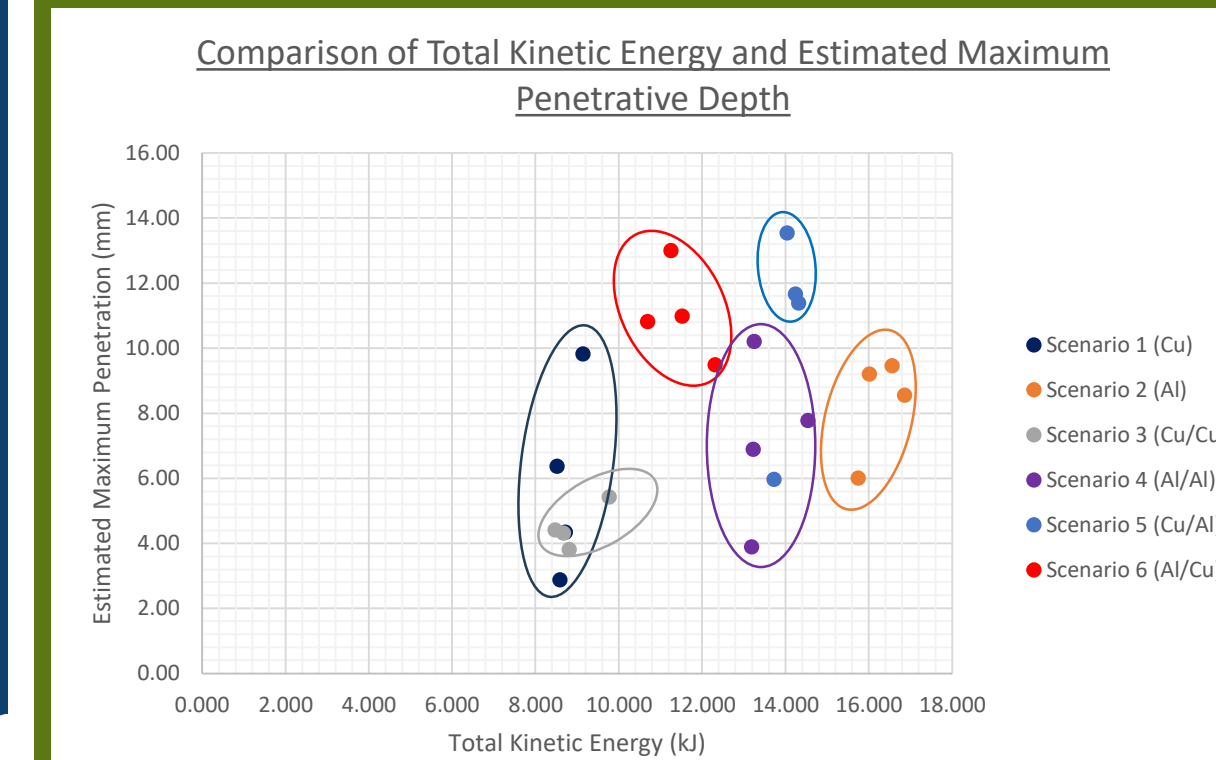
Project scope:

- assess the formation characteristics of an EFP charge with a novel dual liner approach.
- Performance definition: EFP velocity, formation characteristics (Length to Diameter Ratio L/D), depth of penetration and crater diameter.

Shown are the liner configurations

Serials	Scenario No.	Number of Liners	Liner Material 1	Liner Material 2	Liner 1 Thickness (mm)	Liner 2 Thickness (mm)
1 to 4	1	1	Copper	-	2	-
5 to 8	2	1	Aluminium	-	2	-
9 to 12	3	2	Copper	Copper	1	1
13 to 16	4	2	Aluminium	Aluminium	1	1
17 to 20	5	2	Copper	Aluminium	1	1
21 to 24	6	2	Aluminium	Copper	1	1

Results



References

- [1] W. P. Walters and J. A. Zukas, Fundamentals of Shaped Charges, New York: John Wiley & Sons, 1989.
- [2] H. -b. Ma, Y. -f. Zheng, H. -f. Wang, C. Ge and C. -h. Su, "Formation and impact-induced separation of tandem EFPs," *Defence Technology*, vol. 16, no. 1, pp. 668 – 677, 2020.

Shown in results:

- Graph of kinetic energy vs depth of penetration
- X-ray images of EFP formation for all charge types
- High-speed imagery of pyrophoric burn from dissimilar liner material configuration

Discussion In-Brief

Double copper lined EFP charges:

- Reliably formed coherent projectiles.
- Had unstable flight characteristics resulting in a 22% reduction in penetration.

Single and double aluminium liners:

- Were unable to reliably form coherent projectiles due to particulation.
- Stable flight characteristics
- An observed reduction in depth of penetration of 13% (likely from reduced L/D)

Configurations with dissimilar metals:

- Show greater penetrative ability;
- Reliable plate perforation;
- Desirable in-flight stability, despite lower velocities and kinetic energy.
- Significant back spall of the target plates;
- Presence of a gold-coloured compound believed to be a copper/aluminium alloy.



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