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Basic Physics of IED's

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References:

M. A. Meyers, *Dynamic Behavior of Materials*, Wiley-Interscience, 1994

P. W. Cooper, *Explosives Engineering*, Wiley-VCH, 1996

W. P. Walters and J. A. Zukas, *Fundamentals of Shaped Charges*, John Wiley and Sons, 1989

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Artillery Shell IED

http://www.defenselink.mil/news/Nov2005/20051109_3279.html

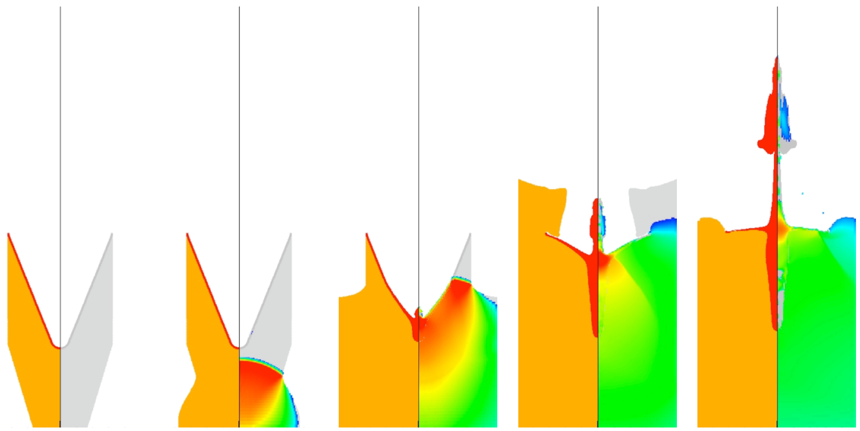
- old munitions readily available in Iraq
- simple detonator turns an artillery shell, etc., into an IED

- explosive energy used to break case apart
- energy dispersed in all directions
- fragment size scales with shell thickness
- fragment velocity related to Gurney velocity

$$V = \sqrt{2E}\left(\frac{M}{C}+\frac{3}{5}\right)^{-1/2} \quad \text{where} \quad \sqrt{2E} \approx D / 2.97$$

D = detonation velocity (7 km/s for TNT)

Shaped Charges



- developed in early 1900's
- widespread use in WW II
- commercially used in cutting, demolition, and oil production
- elongating jet formed from liner material (metal, glass, powder)

- jet experiences extreme conditions but remains solid:

$$\varepsilon \sim 10$$
$$\dot{\varepsilon} \sim 10^4 - 10^7\ s^{-1}$$
$$P \sim 200\ GPa$$

- rules of thumb (Walters & Zukas and Cooper):

  $V_{tip} \sim D$

  $V_{tail} \sim 0.25D$

  δ typically 4-6 CD (but can be as high as 10-12)

Shaped Charges: Penetration

- Bernoulli's equation gives the pressure at the jet tip as

$$P = \frac{1}{2}\rho_j\left(V_j - V_T\right)^2$$

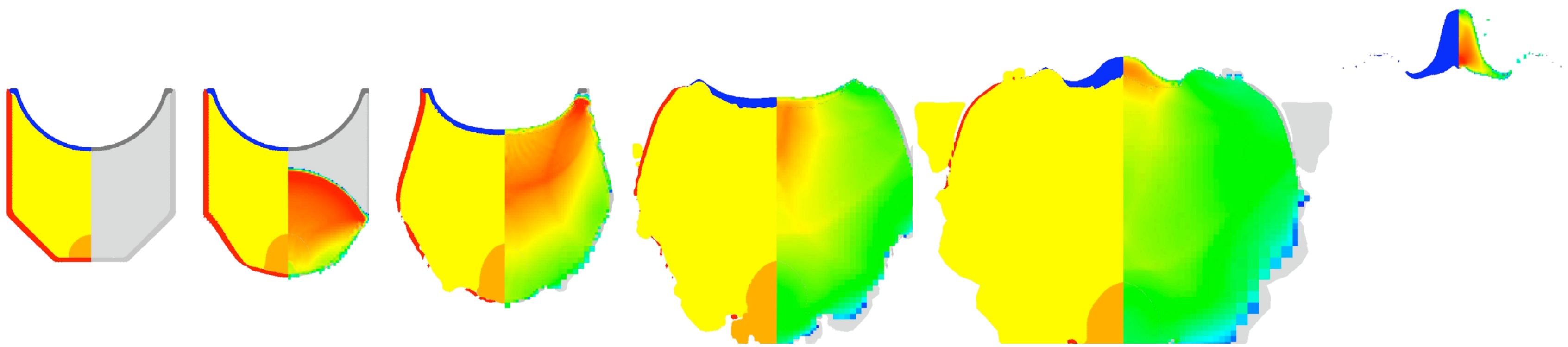
- assuming incompressible fluid behavior, one can derive an estimate of the penetration depth

$$\delta = L_j\left(\frac{\rho_j}{\rho_T}\right)^{1/2}$$

- optimal standoff usually 2-6 charge diameters*
- breakup of jet greatly reduces penetration depth
- high precision needed to achieve optimal performance**
- copper is common liner material, but many others have been used

EFP - Explosively Formed Projectile

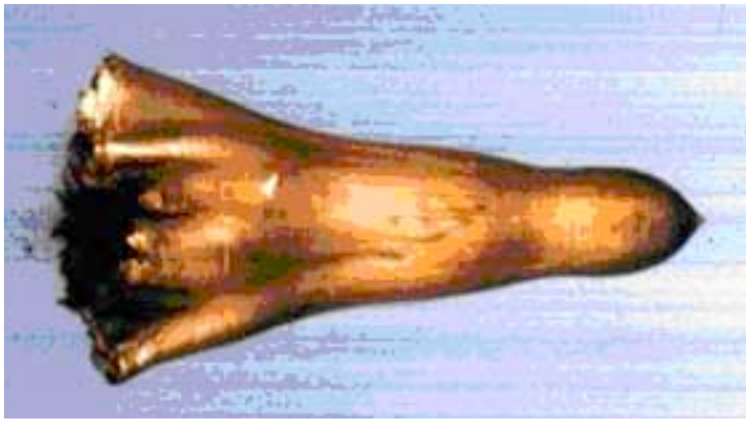
also called explosively formed penetrators and self forging fragments



- creates slug of metal, usually at velocities of 2-3 km/s
- optimized designs can fly for 10's of meters
- multiple configurations possible (fold forward, fold backward, W-fold)

Example EFP's

copper EFP



http://www.military.com/soldiertech/0,14632,Soldiertech_EFP,,00.html

http://www.afosr.af.mil/News/nr_2006_38_hypersonicResearch.html

tantalum EFP

http://www.afrlhorizons.com/Briefs/Dec04-MN0407.html

- stretching can lead to breakup
- thickness can be tailored to give desired shape
- fins improve aerodynamic stability and can induce spin