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Gurney Method

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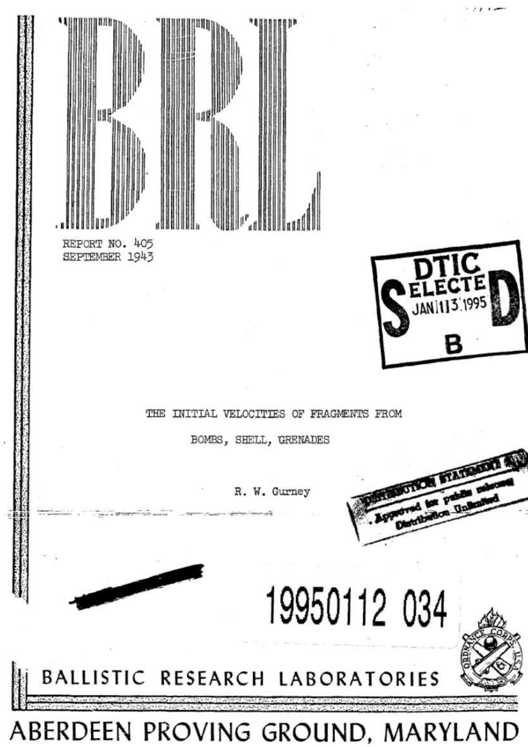
Outline

- Overview of Gurney Method
- Explosively-Driven Metal
- Gurney Equations
- Geometries
- Gurney Example
- Restrictions

Overview of Gurney's Method

- In 1943, the British physicist R. W. Gurney developed, while assigned to Ballistic Research Laboratories, simple **closed formed** algebraic mathematical equations that very successfully predict the terminal velocity of metal fragments produced by cylindrical and spherical bombs, shells, and grenades
- Through these equations, he successfully predicted and matched the terminal fragment velocity for bombs weighing 3000-lbs down to grenades weighing 1.5-oz within 10% or less
- Gurney found that the governing relationship was the mass ratio (C/M) or (M/C)
  - The liner mass (M)
  - The main explosive charge mass (C)



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REPORT NO. 405
SEPTEMBER 1943

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THE INITIAL VELOCITIES OF FRAGMENTS FROM
BOMBS, SHELL, GRENADES

R. W. Gurney

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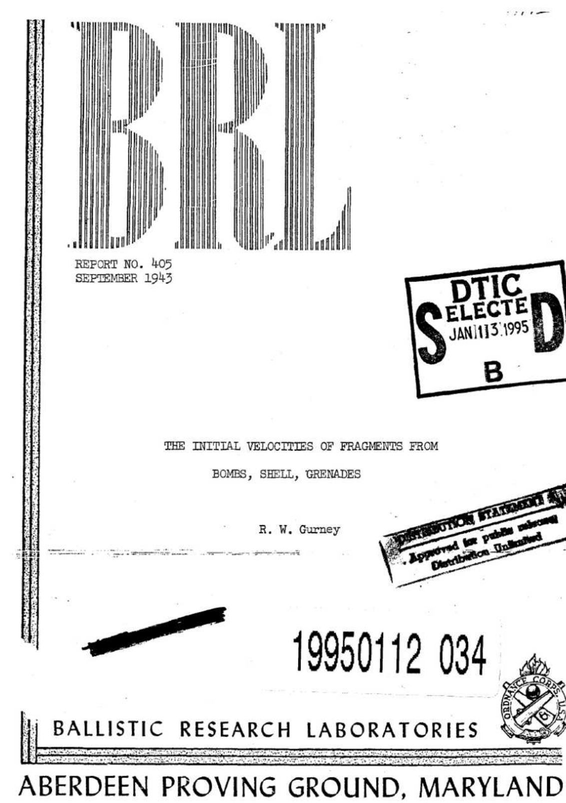
Overview of Gurney Method

- The assumptions used to develop the cylindrical and spherical closed form equations where
  - The explosive potential (chemical) energy of the explosive charge before detonation (initial state) is converted directly into the kinetic energy (KE) of the metal fragment and the expanding detonation products after detonation (final state)
- Therefore, a specific energy (energy per unit mass) characteristic of a given explosive is assumed to be converted from chemical energy in the initial state to kinetic energy in the final state is called the **Gurney Energy**
  - E or E_g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Overview of Gurney Method

- Gurney used the Energy and Momentum balance equation to derive the specific algebraic equation used for different Explosive/Metal configurations
  - Energy

$$CE = \frac{1}{2} M v^2 + \frac{1}{2} \rho_{\exp} \int_0^{Y_0} \left[v(y) \right]^2 dY$$

  - Momentum

$$0 = -Mv + \rho_{\exp} \int_0^{Y_0} v(y) dY$$


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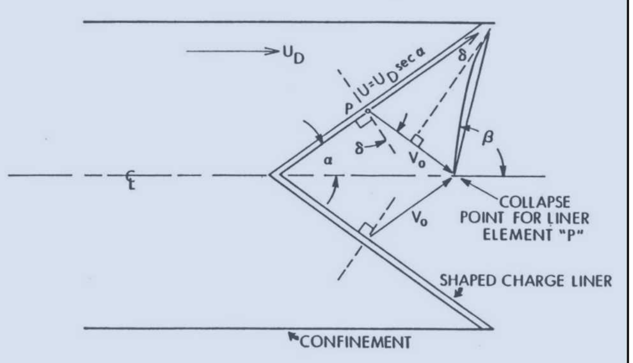
Overview of Gurney Method

- Although, these equations are one-dimensional in nature, these equation are commonly used to accurately predict (<10%) complex explosive configuration such as the liner collapse speed for shaped charges and metal plate during explosive welding

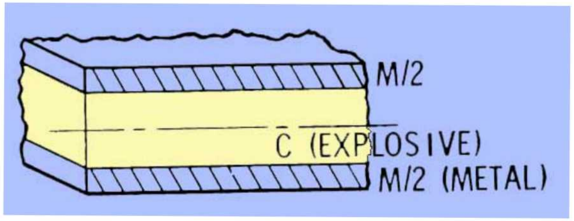


Shaped charge liner is collapsed by explosive, forming high velocity jet *(2.5 – 3x the liner wall velocity)*

Symmetric Geometries equations

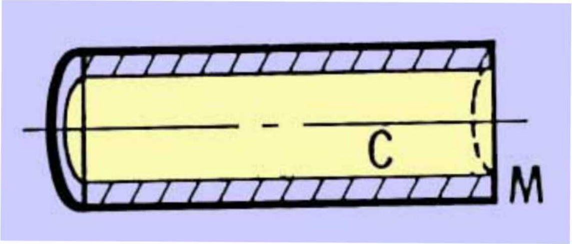
- Sandwich

$$\frac{v}{\sqrt{2E}} = \left[\frac{M}{C} + \frac{1}{3}\right]^{-\frac{1}{2}}$$



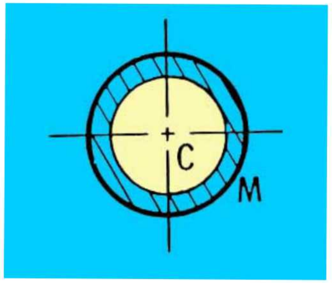
- Cylindrical

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



- Spherical

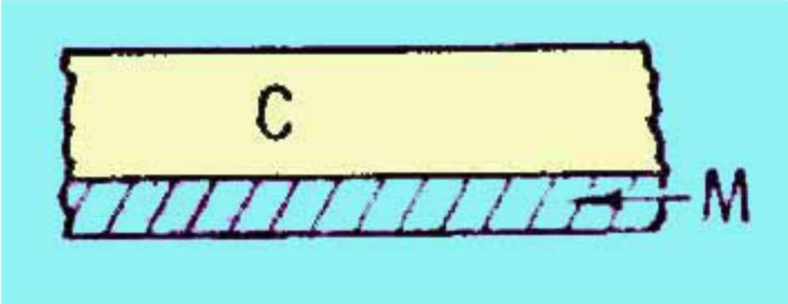
$$\frac{v}{\sqrt{2E}} = \left[\frac{M}{C} + \frac{3}{5}\right]^{-\frac{1}{2}}$$



Asymmetric Geometries equations

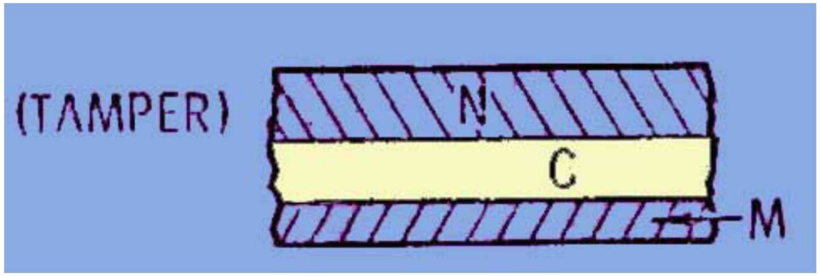
- Open-Faced Sandwich

$$\frac{v_M}{\sqrt{2E}} = \left[\frac{\left(1+2\frac{M}{C}\right)^3+1}{6\left(1+\frac{M}{C}\right)} + \frac{M}{C}\right]^{-\frac{1}{2}}$$

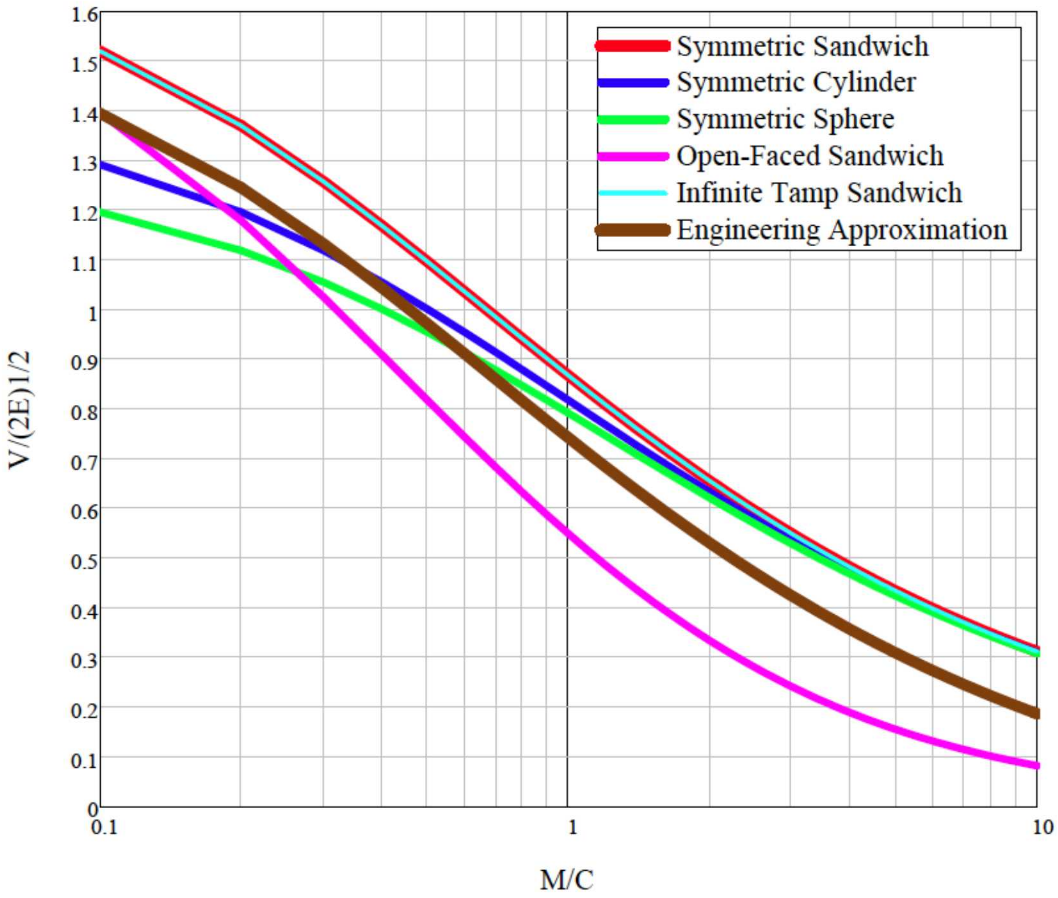


- Asymmetric Sandwich

$$\frac{v_M}{\sqrt{2E}} = \left[\frac{1+A^3}{3(1+A)} + \frac{N}{C}A^2 + \frac{M}{C}\right]^{-\frac{1}{2}} \qquad A = \frac{1+2\frac{M}{C}}{1+2\frac{N}{C}}$$



- Metal Velocity/Loading Factor



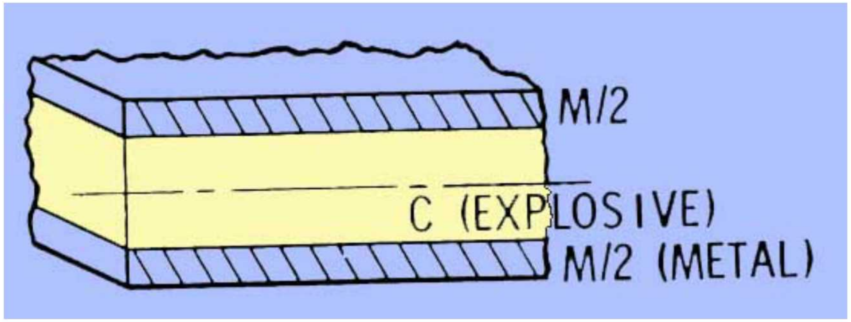
Engineering approximation

$$\frac{v}{\sqrt{2E}} = \left[\frac{M}{C} + \frac{1}{3}\right]^{-\frac{1}{2}} - \frac{1}{8}$$

Symmetric Example

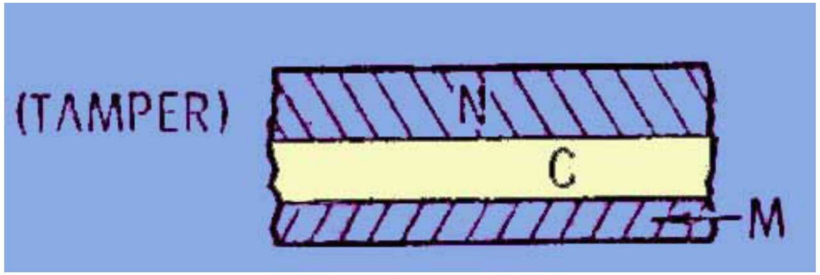
- Problem: two ¼" steel plates sandwich with ½" thick Detasheet™ explosive
  - Symmetric sandwich
  - $M/C = 2.555$
  - $\sqrt{(2E)} = 2.357$ km/s
  - $V = \sqrt{(2E)}(2M/C + 1/3)^{-1/2}$ (geometry specific)

- Plate velocity = 3,314 ft/s



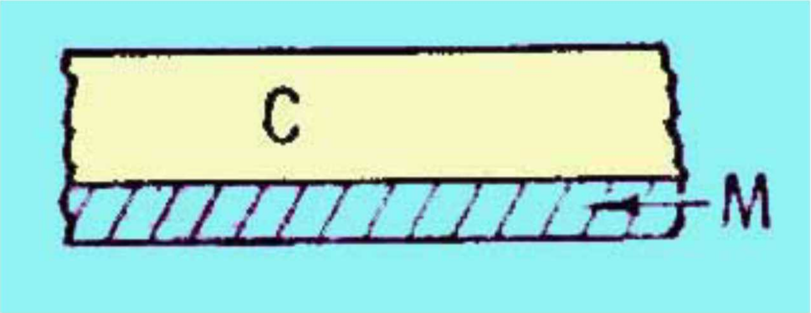
Tamping with 1-in Water

- 1-in Water Tamp
  - Plate velocity = 2,916 ft/s

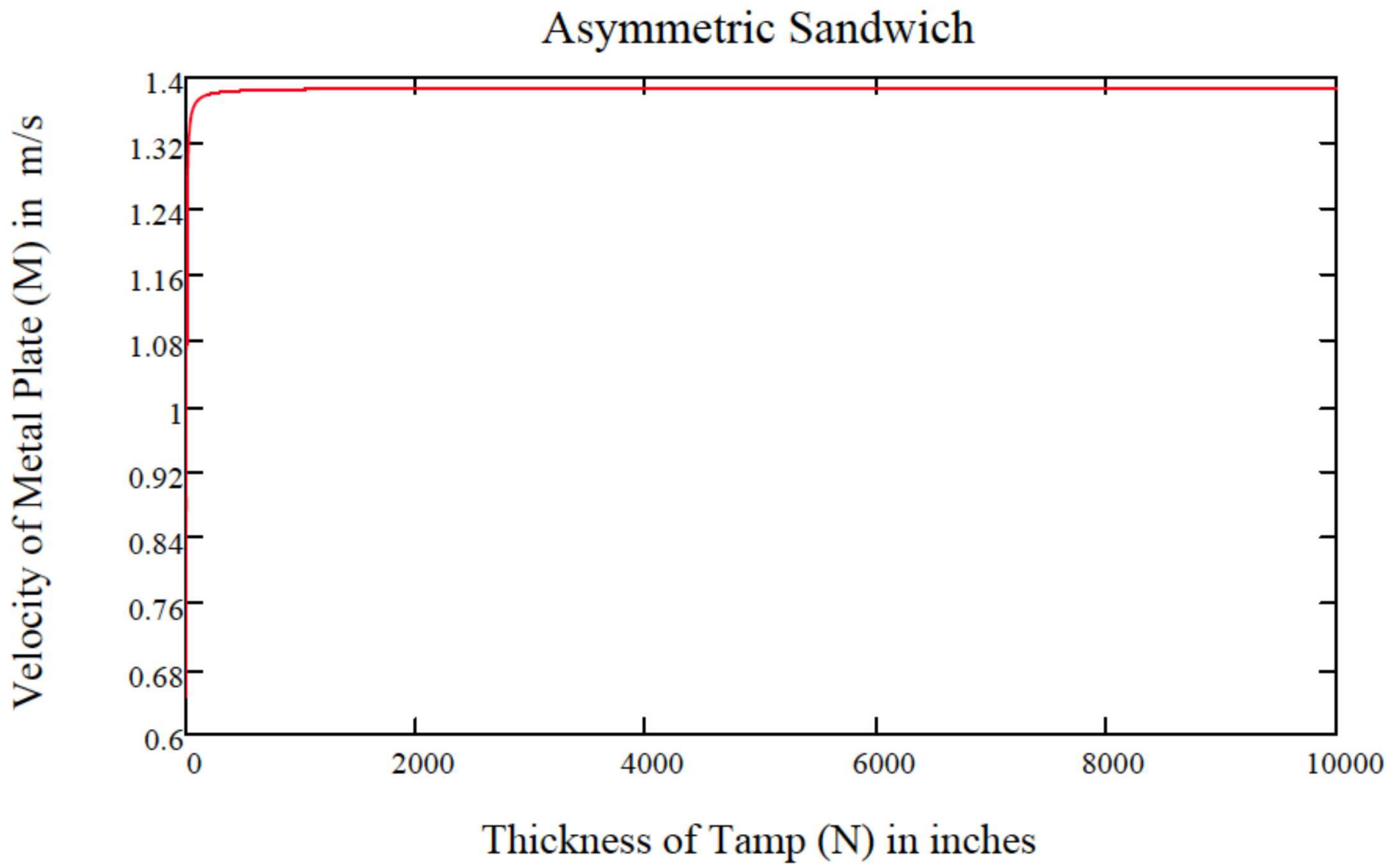


- Infinite Water Tamp
  - Plate velocity = 4,549 ft/s

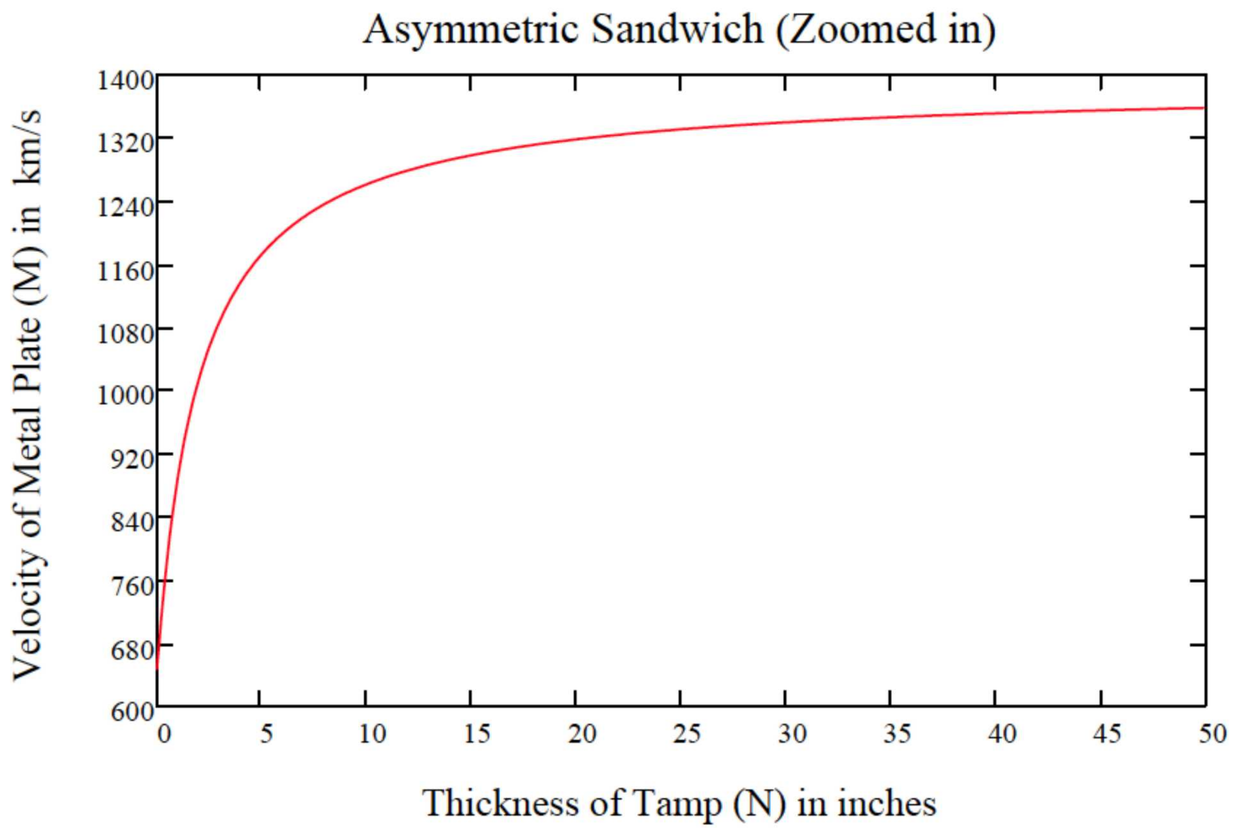
- No Tamp
  - Plate velocity = 2,121 ft/s



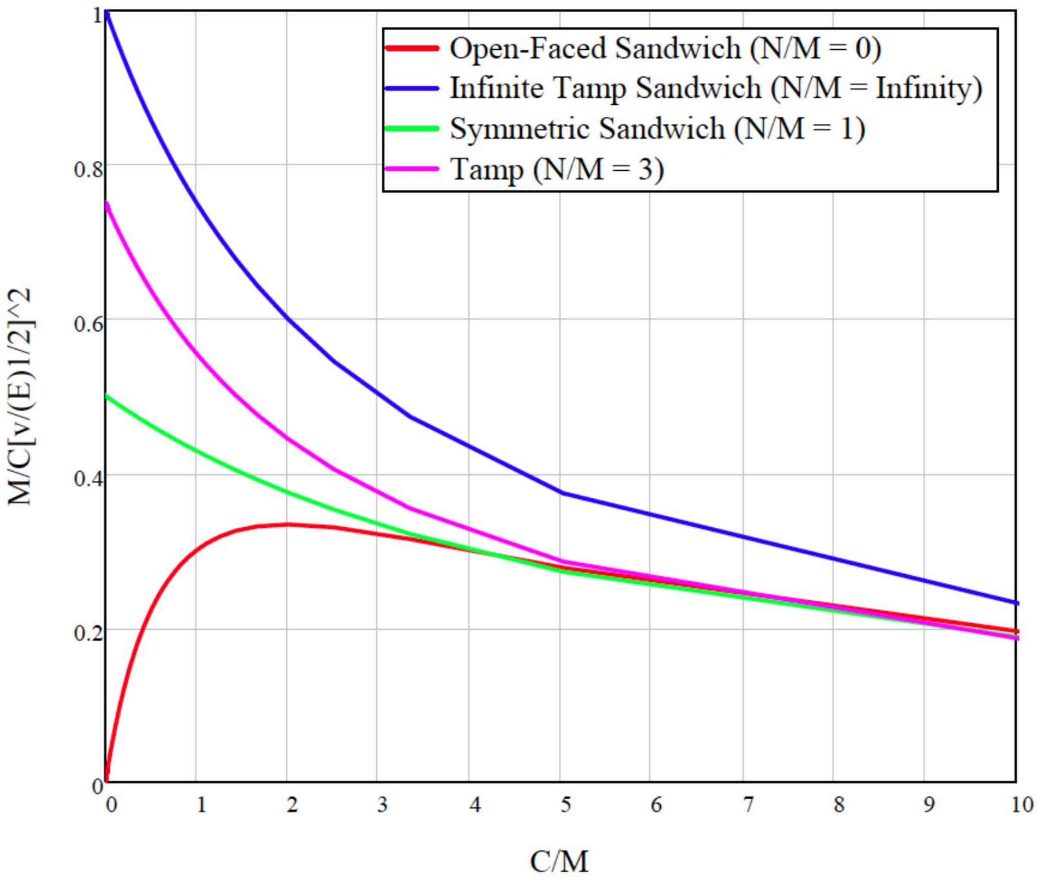
• Water Tamping



- Water Tamping



• Gurney Efficiency



• Gurney Energy

OUTPUT OF EXPLOSIVES

Density, g/cm^3	Explosive	ΔH_d, kcal/g	E, kcal/g	$E/\Delta H_d$	$\sqrt{2E}$, km/s	I_{sp}, ktaps/(g expl/cm^2)
1.77	RDX	1.51	1.03	0.68	2.93	254
1.63	TNT	1.09	0.67	0.61	2.37	205
1.72	Comp B	1.20	0.87	0.72	2.71	235
1.59	Comp C-4	1.40			2.71	
1.76	PETN	1.49	1.03	0.69	2.93	254

ΔH_d is heat of detonation, measured in calorimeter.

E is Gurney energy, i.e. kinetic energy produced per gram explosive.

$\sqrt{2E}$ is Gurney velocity, a characteristic of an explosive at a given density.

I_{sp} is specific impulse imparted from untamped explosive to a very heavy body on which it rests. $I_{sp} = \sqrt{1.5\,E}$

1 ktap = 1000 dyne-sec/cm^2.

Questions?