Anna Crowley

The effect of munition casings on reducing blast overpressures

A.B.Crowley

Outline

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Equivalent bare charge

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Why?

Require to assess the potential hazard from stored munitions.

Estimates based on the total net explosive quantity (NEQ) are inherently pessimistic and overly restrictive.

Concept of effective NEQ or equivalent bare charge introduced.

Effective NEQ

Mass of bare explosive to yield the same blast overpressure at the same distance from the source. Sometimes called equivalent bare charge.

Following the Gurney approach to metal acceleration, with Gurney energy E_G defined as the kinetic energy of casing material and product gases after detonation

ENEQ assumed to depend on the ratio of casing mass M to charge weight C.

Equivalent bare charge formulae

Fano I

$C_b/C = 1\text{-}f + f/(1+2M/C)$

where $f = E_G/E_0$

Fano II

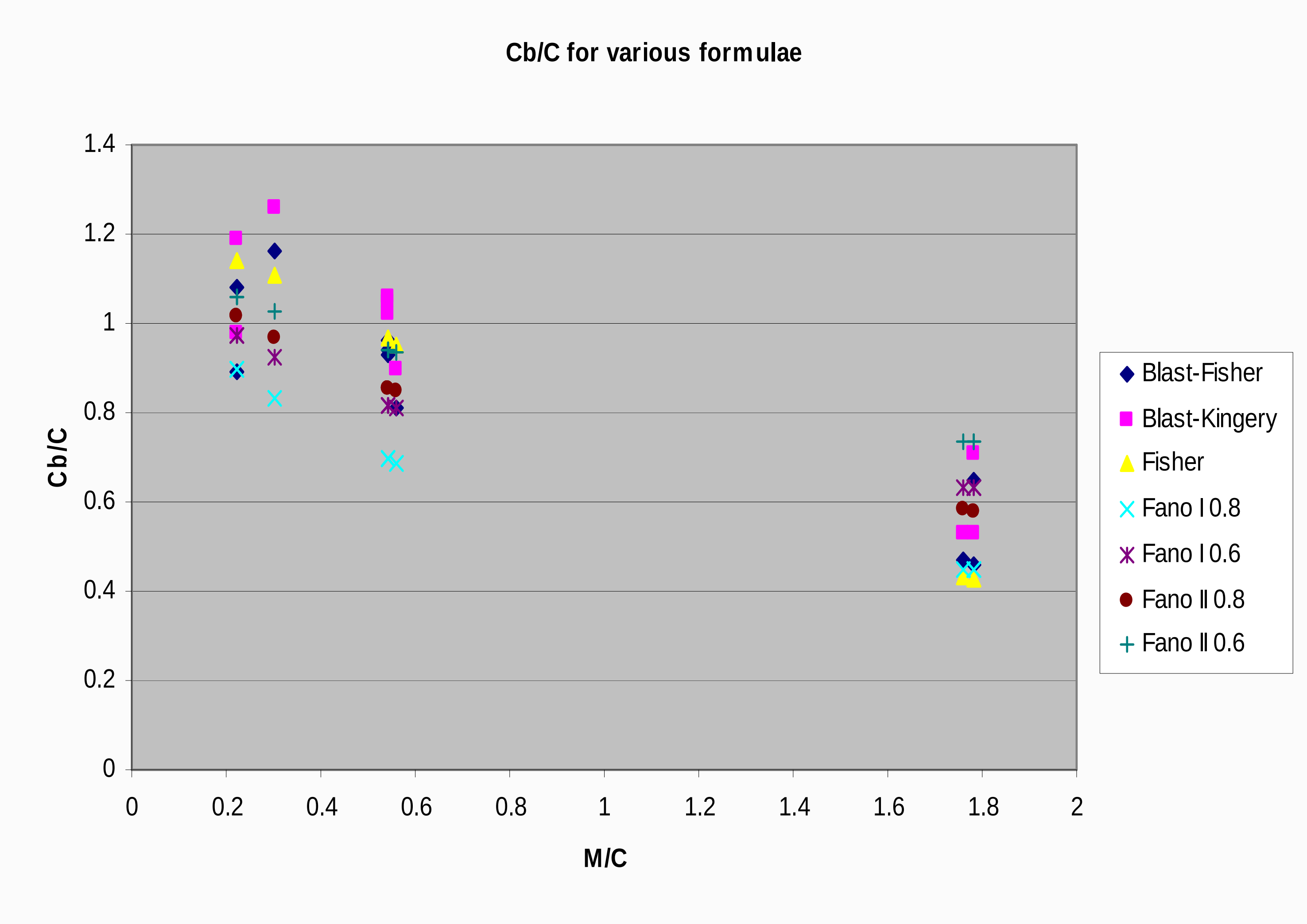
$C_b/C = 0.2 + 0.8/(1+M/C)$

if f = 0.8

Fisher

$$\frac{C_b}{C} = 1.19 \left\{ \frac{1 + M/C\,(1-M')}{1+ M/C} \right\}$$

Steel cased TNT filled bombs (Fisher 1953)



Recently added blast overpressure results measured in trials of a variety of UK munitions,

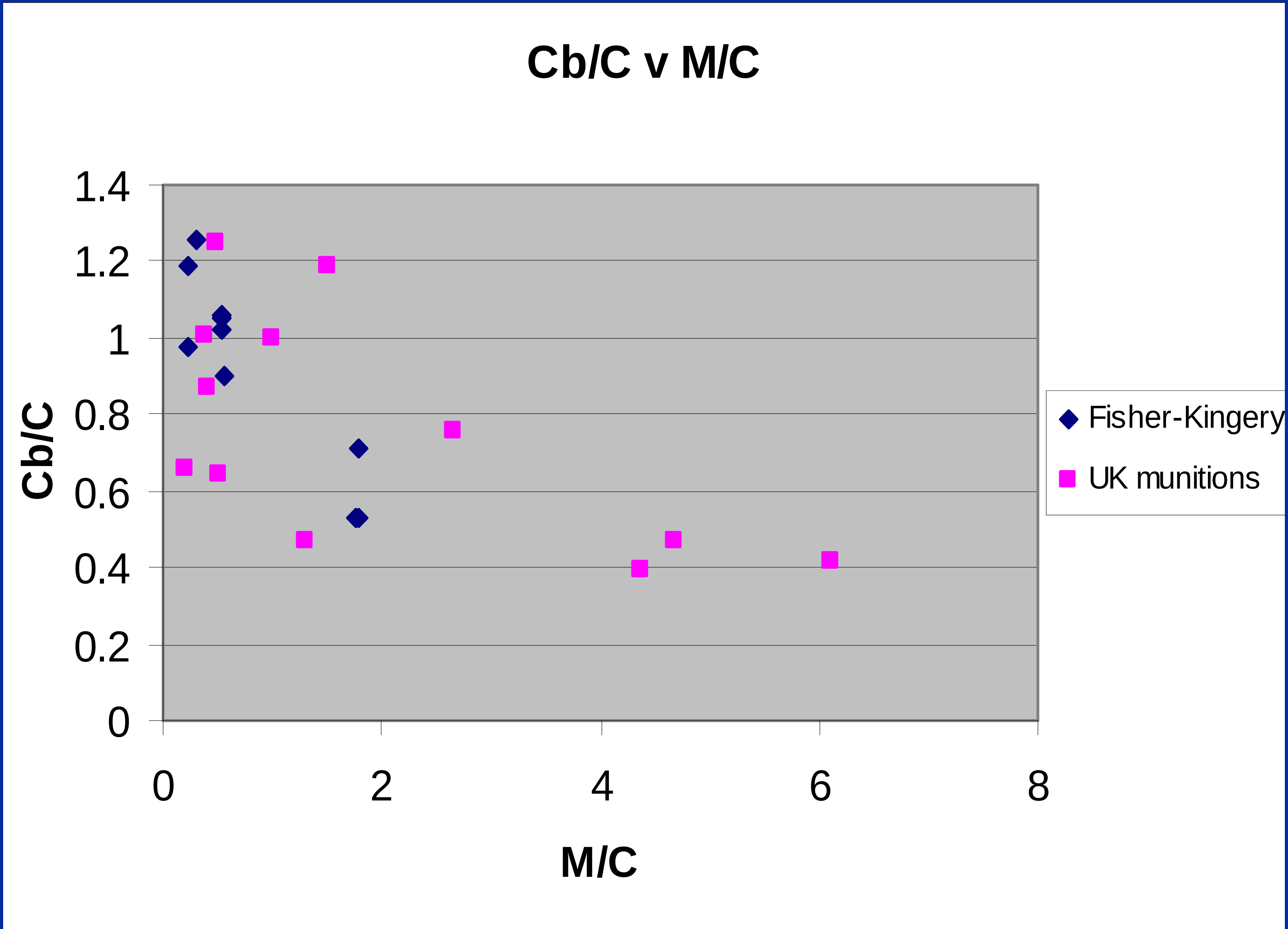
Different casing materials

Variety of explosive fills

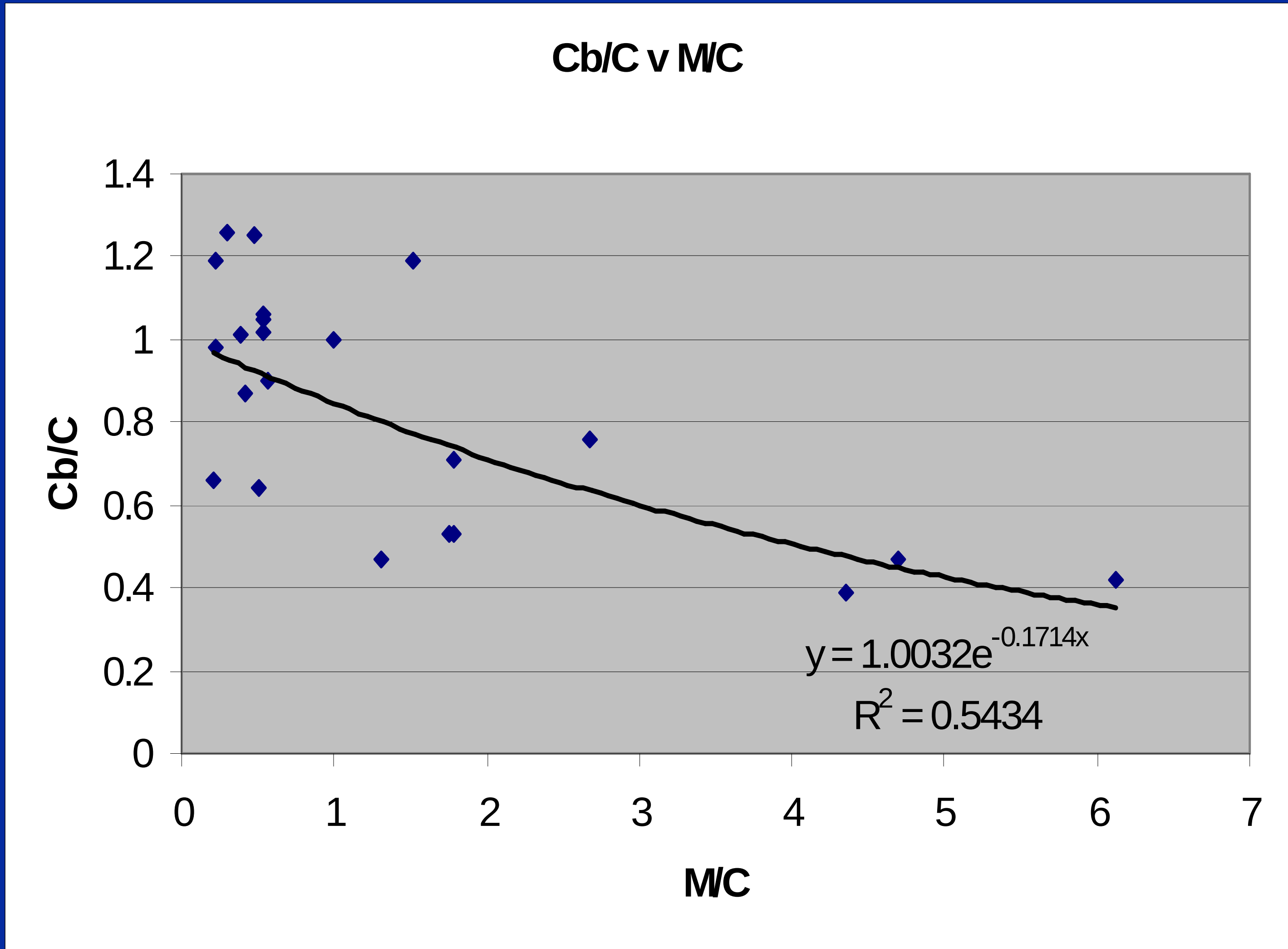
Bombs, artillery shells, depth charges, missiles

Much wider range of M/C

Fisher + UK munitions 1



Fisher + UK munitions 2



Best fit to combined data is given by

$$C_b/C = 1.0032 \exp(-0.1714\ M/C)$$

But the correlation coefficient is so low that its use cannot be justified.

Concerns

- The scatter of munition data
- Equations in terms of M/C only are of limited value
- The derivation indicates that the value of f for the explosive should enter the equivalent bare charge formula
- f varies with explosive composition
- Experimental evidence that the Gurney energy of an explosive varies with casing material

Variation of f with composition

Cranfield UNIVERSITY

Explosive	Det.Vel. (km/s)	Gurney E. (kJ/kg)	Heat.det. (kJ/kg)	f $=E_G/E_0$
TNT	6.86	2977	4519	0.659
RDX	8.70	4004	5356	0.748
HMX	8.83	3920	5711	0.686
PETN	8.26	4292	4795	0.895
RDX/TNT 60/40	7.92	3672	5000	0.734
Tritonal (80/20)	6.70	2690	7406	0.363
Cyclotol(75/25)	8.25	3892	5125	0.759
Tetryl	7.57	3125	4602	0.679
Comp A-3	8.14	3458	5106	0.677

E_G from cylinder tests in steel and copper cylinders (from Backofen)

Explosive	E_G from steel cylinder (kJ/kg)	E_G from copper cylinder (kJ/kg)
Comp. A-3	2918	3458
Cyclotol (75/25)	2691	3892
Comp. B	2668	3645
TNT	2081	2808
Tetryl	2440	3125

Conservation of energy

$$E_0 = E_G + E_S + E_{int}$$

Assuming products

i) expand adiabatically from C-J state;

ii) obey perfect gas law with constant γ

$$E_G + E_S = E_0\left[1-2\left(\frac{\gamma}{\gamma+1}\right)^{\gamma}\left(\frac{\rho}{\rho_0}\right)^{\gamma-1}\right]$$

Gurney energy is related to degree of expansion and casing material properties will influence ρ/ρ_0 at rupture

Rupture

Fragmentation is assumed to occur when the inner region of compressive hoop stress disappears, and interior pressure is equal to the yield stress σ_y

$$P = P_0 \left({r_f}/{r_0} \right)^{-2\gamma} = \sigma_y$$

Using mass conservation to relate the density and radius at rupture yields

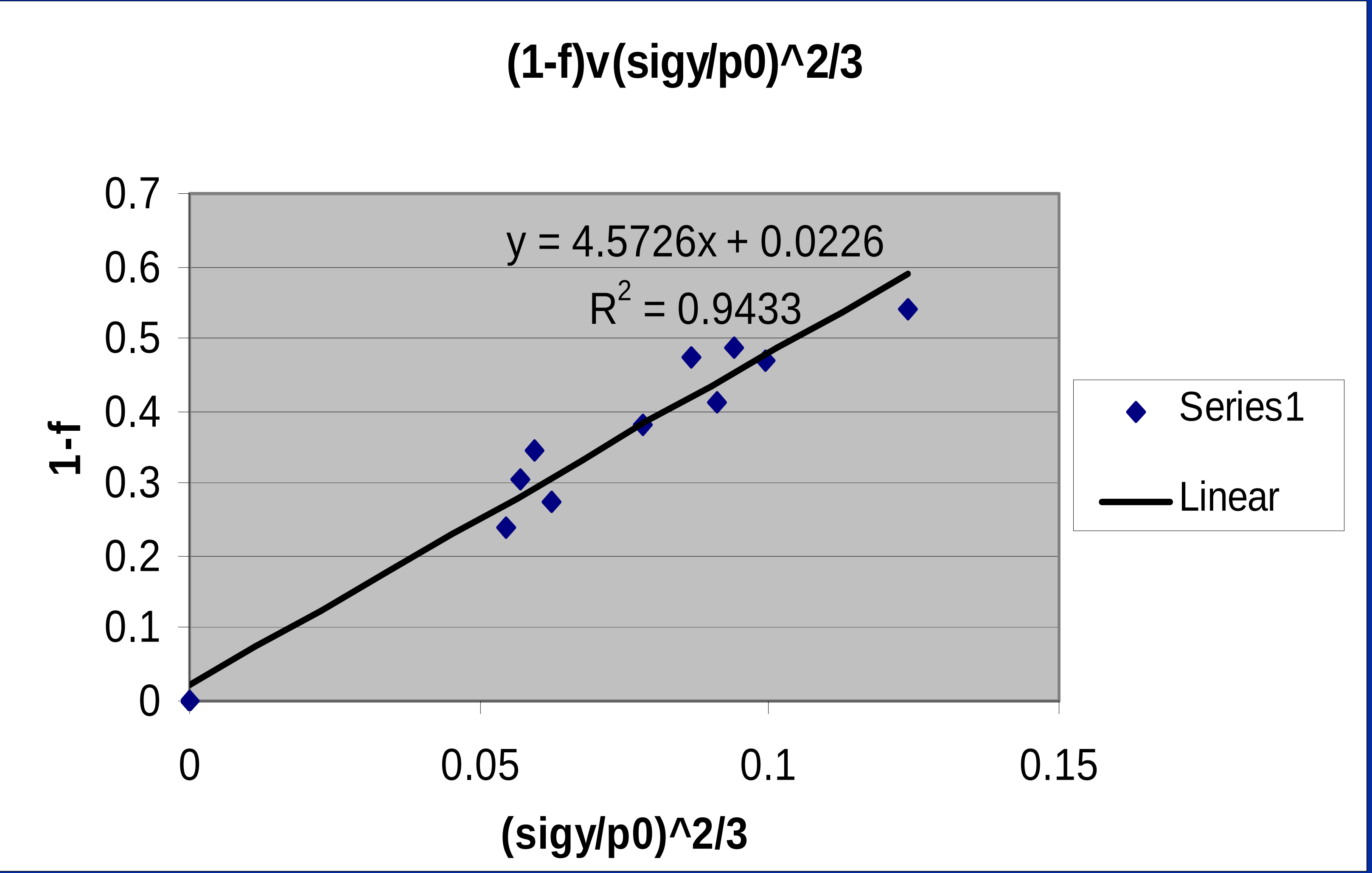
$$E_G + E_S = E_0 \left[1 - 2 \left(\frac{\gamma}{\gamma+1} \right)^{\gamma} \left(\frac{\sigma_y}{P_0} \right)^{\gamma-1/\gamma} \right]$$

And so if E_S is neglected

$$f = E_G/E_0 = \left[1-2\left(\frac{\gamma}{\gamma+1}\right)^{\gamma}\left(\frac{\sigma_y}{P_0}\right)^{\gamma-1/\gamma}\right]$$

Re-examine the data for Gurney energy in copper and steel casings, using yield stress of 175 MPa, 350 MPa respectively:

Results 1



(1-f)v(sigy/p0)^2/3
y = 4.5726x + 0.0226
R2 = 0.9433
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1-f
0
0.05
0.1
0.15
(sigy/p0)^2/3
Series1
Linear

Results 2

$$f \cong 1 - 4.57\left(\frac{\sigma_y}{P_0}\right)^{2/3}$$

i) The fraction of the energy appearing in the form of Gurney energy is related to the ratio σ_y/P_0.

ii) As 4.57 > 0.844 ($= 2\left(\frac{\gamma}{\gamma+1}\right)^{\gamma}$) , this suggests the energy absorbed by the casing is not negligible, and accounts for the difference.

Conclusions

- ENEQ should vary with nature of explosive through f.
- f shows good correlation with σ_y/P_0.
- Strain energy of casing is not negligible.
- Need good experimental programme to develop this further.
- Need to re-assess potential hazard from stored munitions in the light of these findings.