Warhead Filling and Casing Interactions affect the Blast Field performance

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g effects on Blast

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sentation Outline

ÅObjectives

ÅHistorical Background

ÅRecent Trials

ÅAnalysis

ÅConclusions

g effects on Blast

Errata

I would like to apologise for one typographical error that got through the proof reading:

óAluminium Alloy 6086T6ô

should read

óAluminium Alloy 6082 to Condition T6ô

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jectives

- Currently Engineering models predict Blast output from cased warheads use experimentally derived algorithms, e.g. Fano and Fisher curves
- Such curves are typically based upon TNT explosive with the cast iron or steel cases
- Review Historical Data
- Investigate
  - Ideal and Non-Ideal explosives
  - Brittle and Ductile case materials
- Integrated Trials and EDEN hydrocode Modelling to assess these Engineering models
- Establish a preferred model and its "fit" parameters with applicability for each case

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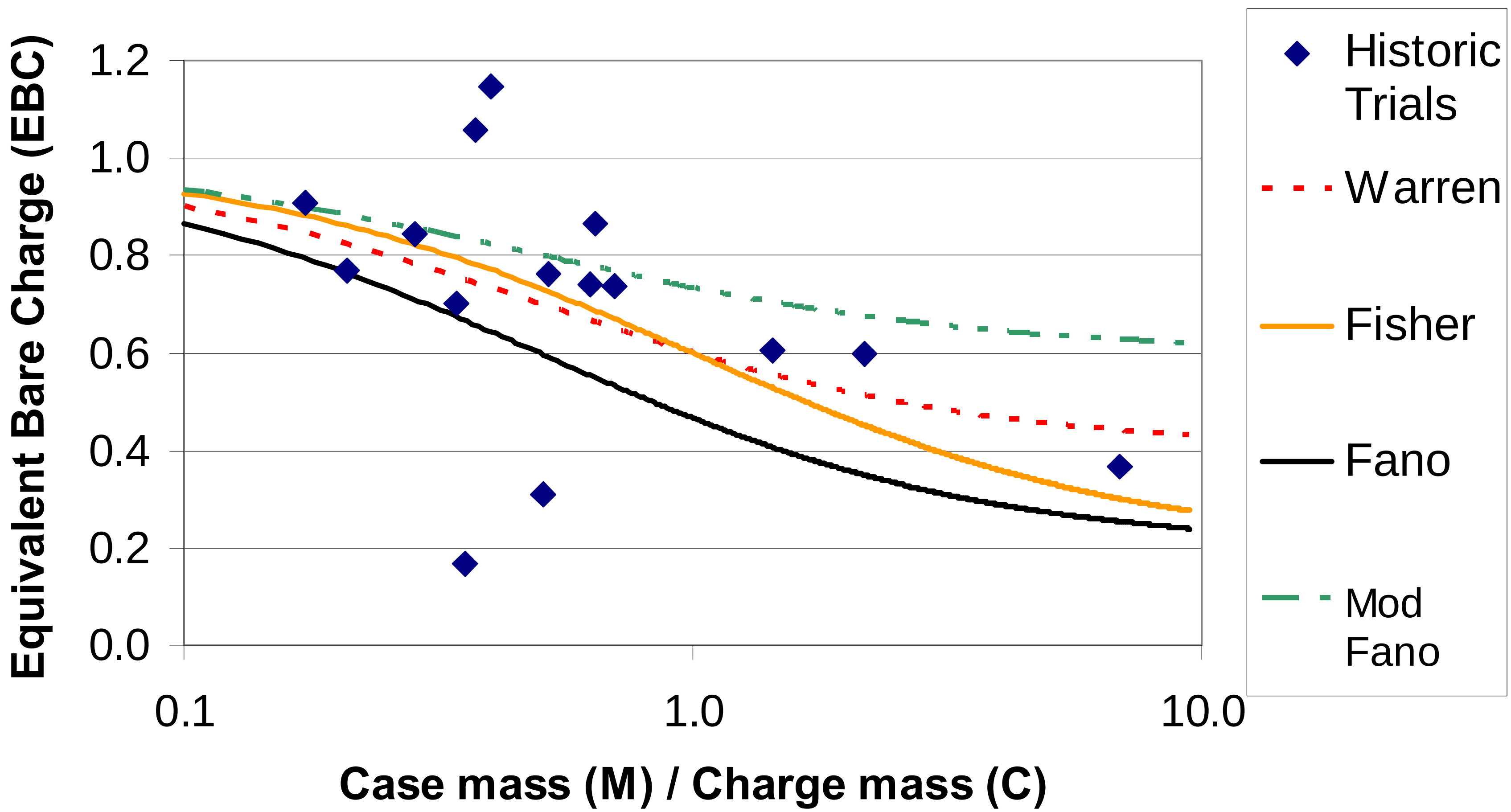
Engineering Models

Fisher	EBC = C x [0.2 + 0.8/(1 + M/C)]
Modified Fisher	EBC = {C + C x [0.2 + 0.8/(1 + M/C)]}/2
Fano	EBC = C x [0.2 + 0.8/(1 + 2 x M/C)]
Modified Fano	EBC = C x [0.6 + 0.4/(1 + 2 x M/C)]
Warren	EBC = C x [0.4 + 0.6/(1 + 2 x M/C)]
US for Pressure	EBC = 1.19 x C x [1 + M/C x (1 ï M_c)/(1 + M/C)]
US for Impulse	EBC = C x [1 + M/C x (1 ï M_c)/(1 + M/C)]

EBC = Equivalent Bare Charge
C = Charge mass
M = Mass of metal (in parallel section)
M_c = M/C if M/C <=1.0 or 1.0 otherwise

or Steel Casings



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ng Case Effects on Blast

- Limited understanding of case effects
- Large scatter of trials data
- Wide choice of 'Engineering Models'
- Limited data
- Need for updated trials with purpose made hardware and extensive instrumentation
- With experimental controls
- Integrated EDEN hydrocode modelling
- Trials designed specifically for the hydrocode modelling

Limitations / Unknowns

ÅExplosive Type

ÅCasing Material

ÅFragmentation Mechanism (Natural / Pre-fragmented)

ÅPressure or Impulse

ÅPressure Considered (Incident / Reflected)

ÅGround / Air

ÅShape (Spherical / Cylindrical)

ÅScaling

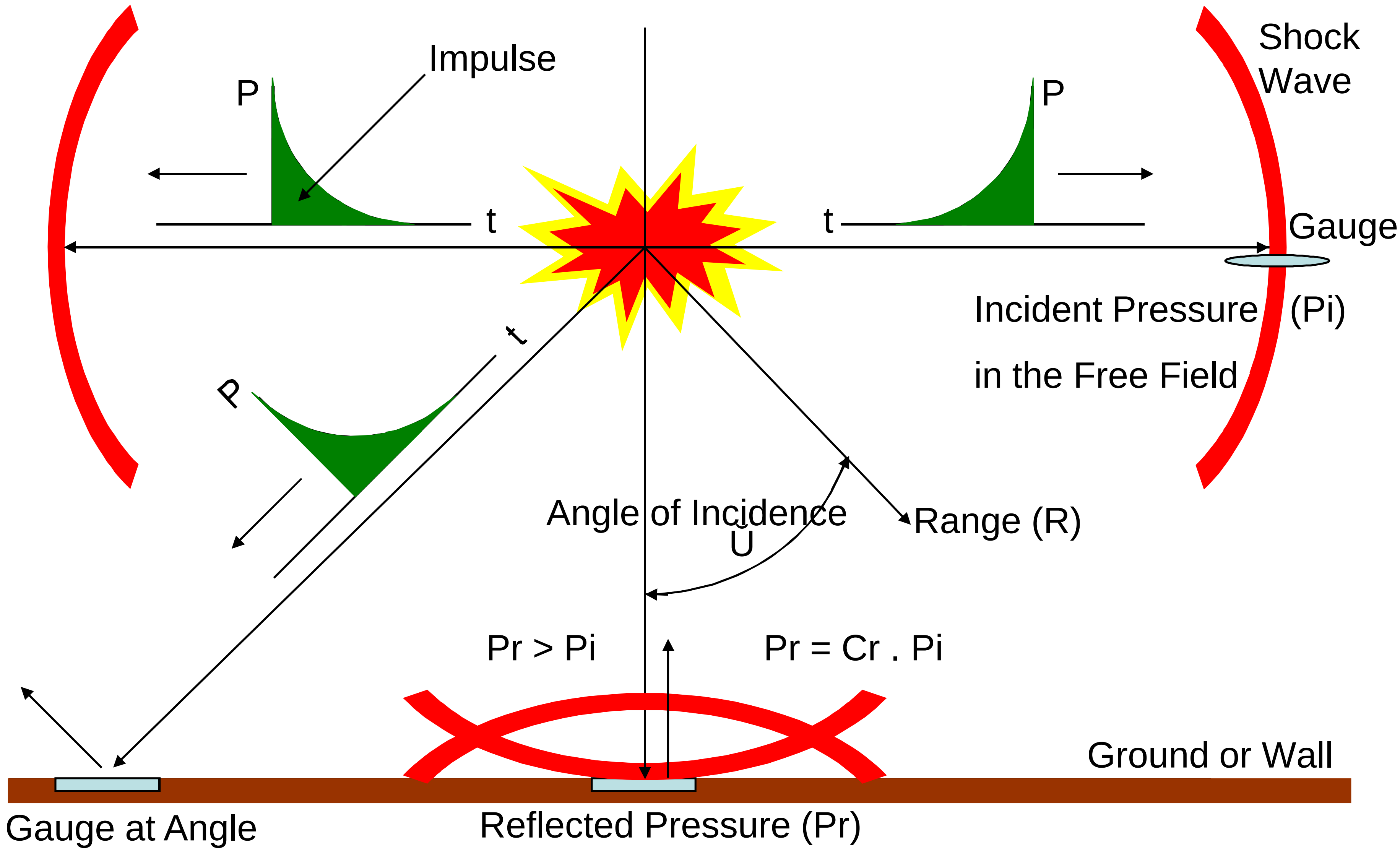
ÅConfinement (Uniformly / Heavy Nose)

ÅInitiation (Central / End)

ÅPosition / Aspect - Best historic trials gauge positions undefined

Typical Issues that Arise

Record Reflected (Pr) pressure, but need to correct to get Incident (Pi) pressure, but itôs both Angle (Ŭ) and Pressure dependent



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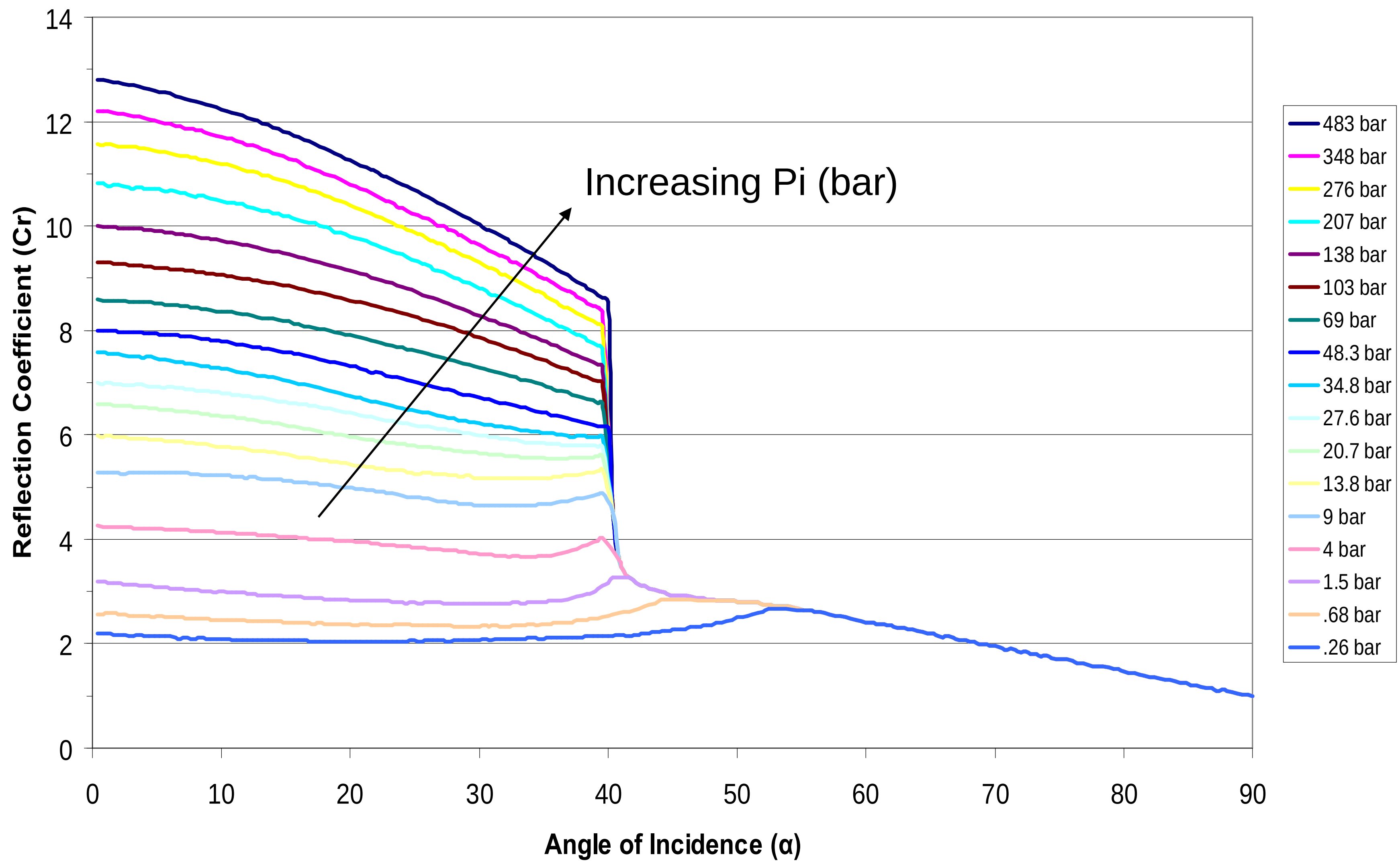
...nst Angle of Incidence with Pressure



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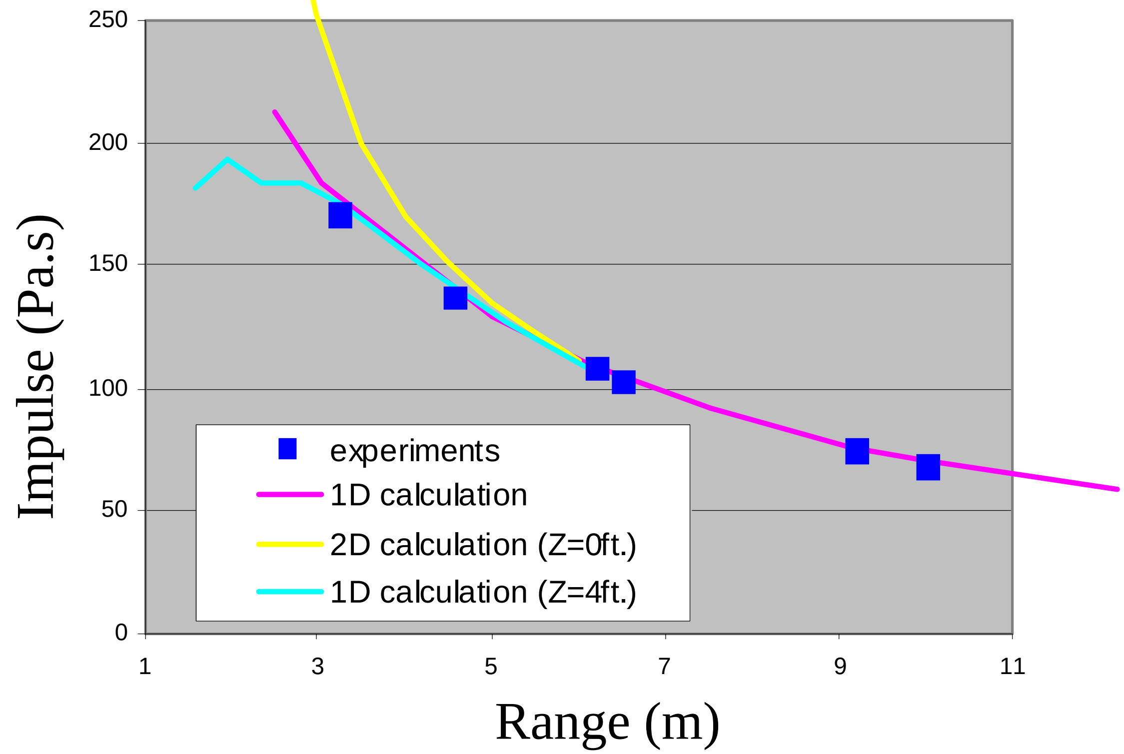
Sheard Analysis

Royal Society, V187, 1944)

Grime and Sheard experiments were found to provide sufficient data about the trial arrangement to attempt to reproduce using the FGE - EDEN hydrocode

Å Explosive = Comp-B
Å L / D = 2 / 1
Å Material = Brass or Steel
Å Charge / Weight =
- 84.4%
- 62%
- 25%
- 5.4%

Å End initiated
Å End plates similar thickness to case



ÅGauge positions are not clearly defined. The assumed positions match the reported data.

w Trials

<u>43 Experimental Firings over 3 years</u>

ÅThree explosive types:

- ï Rx1100 (Ideal) (RDX/Binder 88/12)
- ï Rx1400 (Non-Ideal) (RDX/Al/Binder 66/22/12)
- ï PBX N109 (RDX/Al/Binder 64/20/16)

ÅTwo case materials:

- ï Steel EN24
- ï Aluminium 6082T6

ÅVarying Case mass / Charge mass Ratios (0, 0.5, 2, 5, 10)

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for All Series 1, 2 & 3

Matrix of Trials – All Series 1, 2 & 3									
Configuration		**Case mass (M) to charge mass (C) ratio**						**Total**	
Explosive	**Case**	**0**	**0.5**	**2**	**5**	**8.46**	**10**		
Rx1100	**Bare**	3						3	17
	Steel		2	2	2		2	8	
	Al		2	2		2		6	
Rx1400	**Bare**	3						3	17
	Steel		2	2	2		2	8	
	Al		2	2		2		6	
PBX N109	**Bare**	3						3	9
	Steel		2		2		2	6	
Total		9	10	8	6	4	6	43	

ôIdealô Rx1100 - RDX /Binder 88/12
ôNon-Idealô Rx1400 - RDX/Al/Binder 66/22/12
PBX N109 - RDX/Al/Binder 64/20/16

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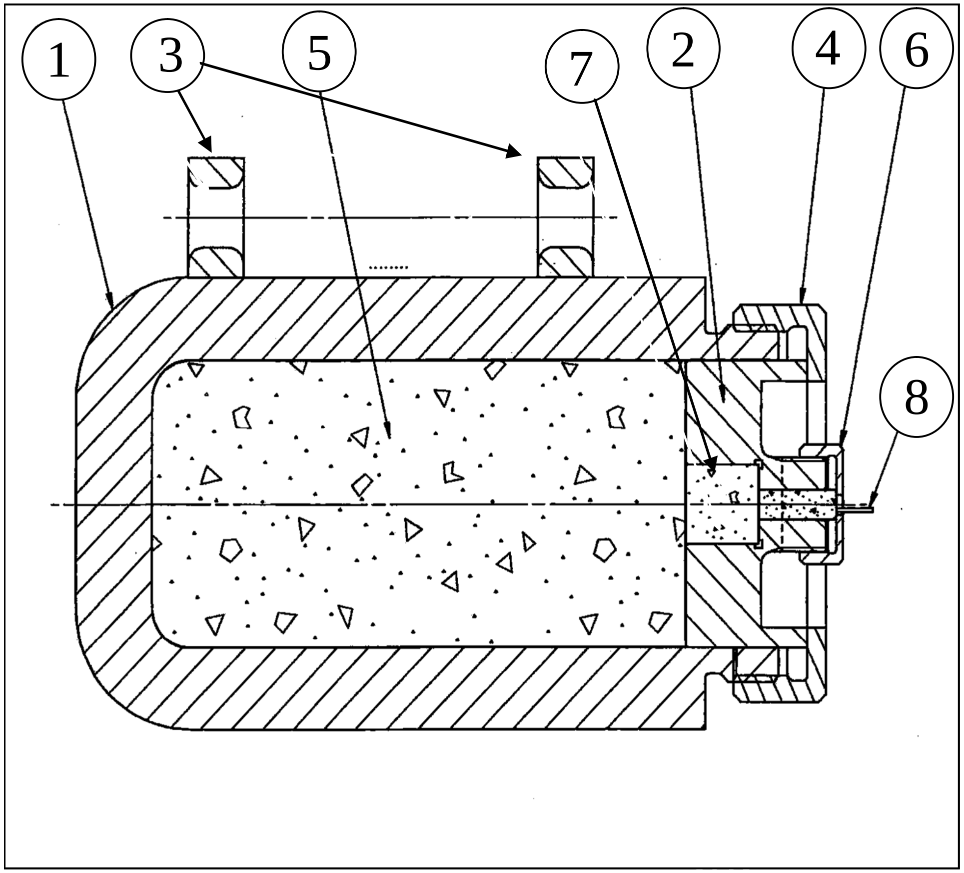
...harge Configuration



Key

1 ï Fragmenting case (Cylindrical)
2 ï Charge closure
3 ï Lifting eyelets
4 ï Clamp ring
5 ï Charge (1kg nominal, L/D =2)
6 ï Detonator clamp ring
7 ï Booster pellet (Debrix 18AS)
8 ï Detonator (RP 80)

Note: Case thickness chosen to achieve correct case mass (M) to charge mass (C) ratio

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...ness - Series 1, 2 & 3

Trial Series 1, 2 & 3					
Case Thickness (mm)	Case Mass to Charge Mass Ratio				
Casing	0.5	2	5	8.458	10
AL 6082T6	4.1	13.6		41.5	
Steel EN24	1.5	5.5	12.1		20.6

ls Schematic

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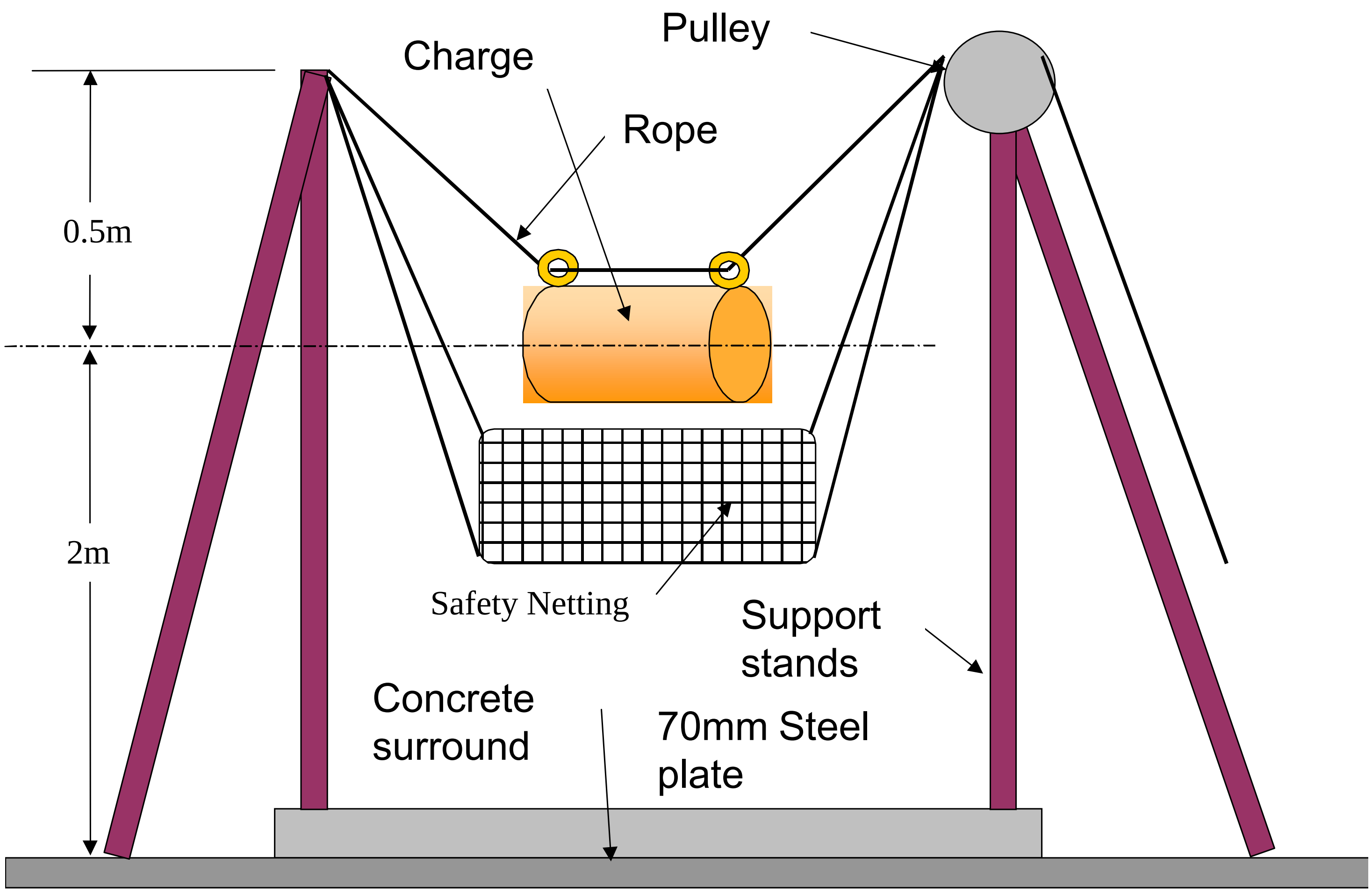
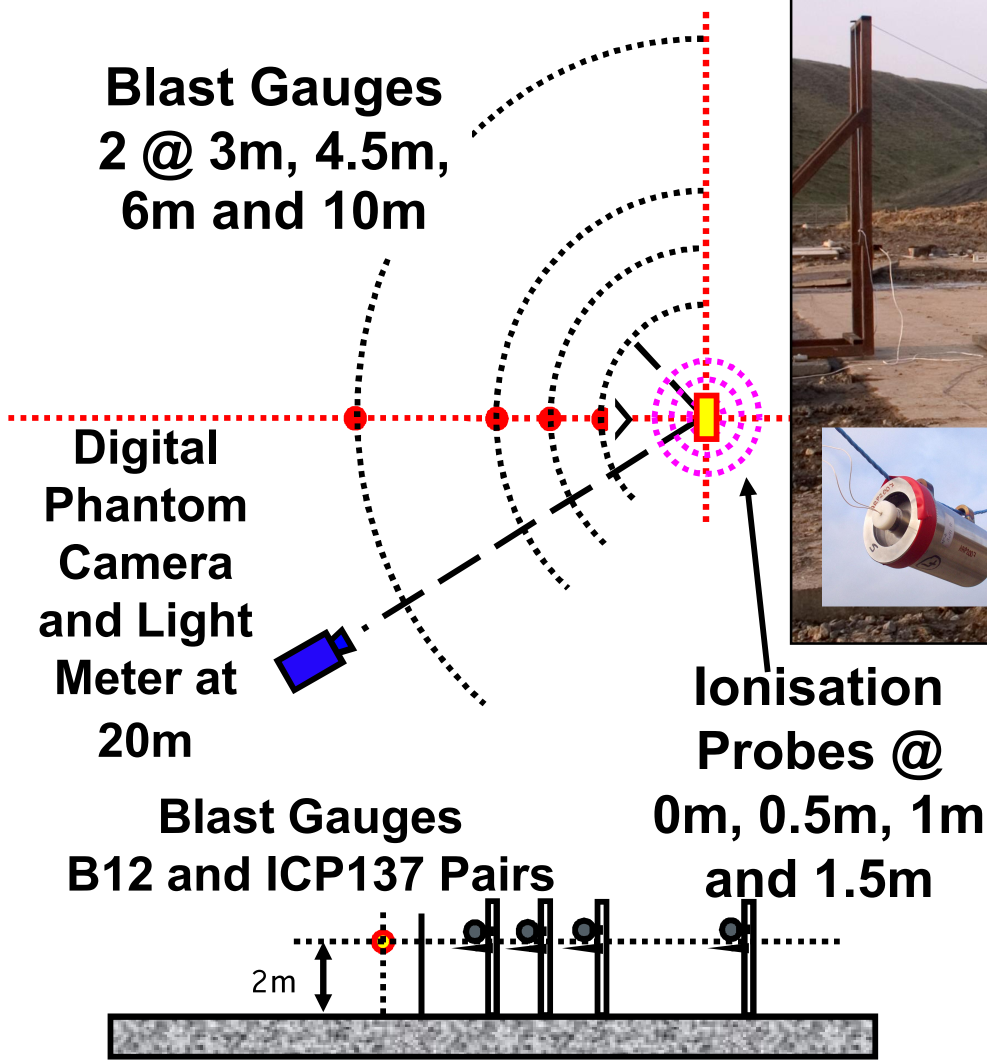
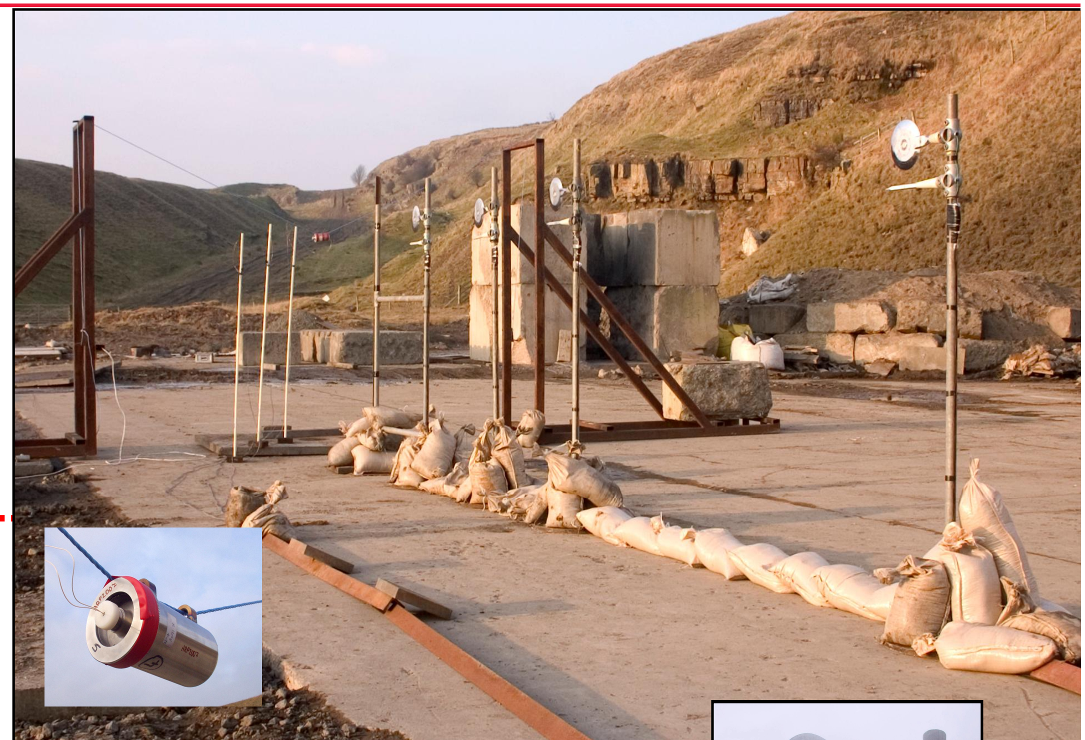


rials Arena



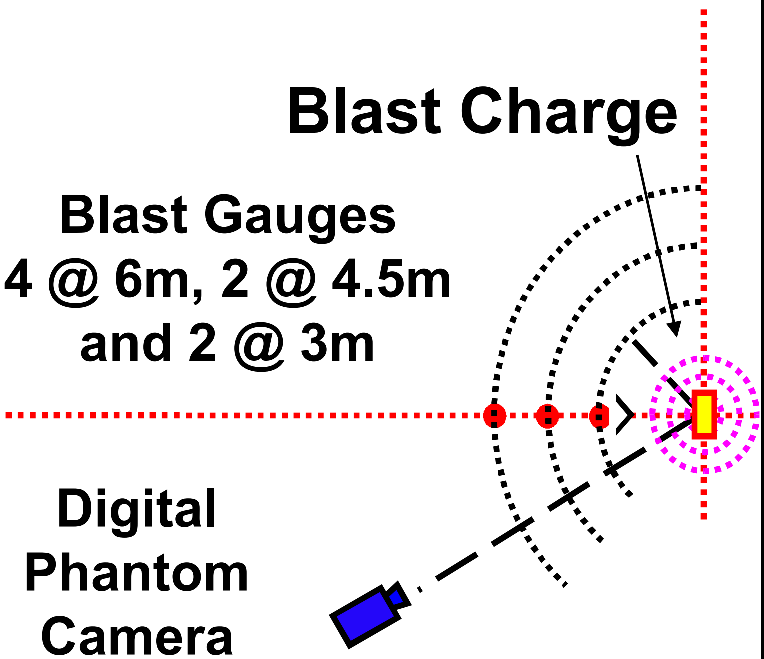


B12 and ICP137 @ 3m, 4.5m, 6m and 10m

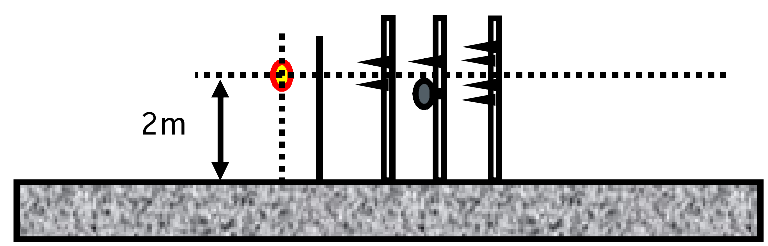
Trials Arena

Blast Charge

Blast Gauges
4 @ 6m, 2 @ 4.5m and 2 @ 3m



Digital Phantom Camera and Light Meter at 20m plus.



Blast Gauges mainly ICP137 Pairs with one B12 / ICP137 combination

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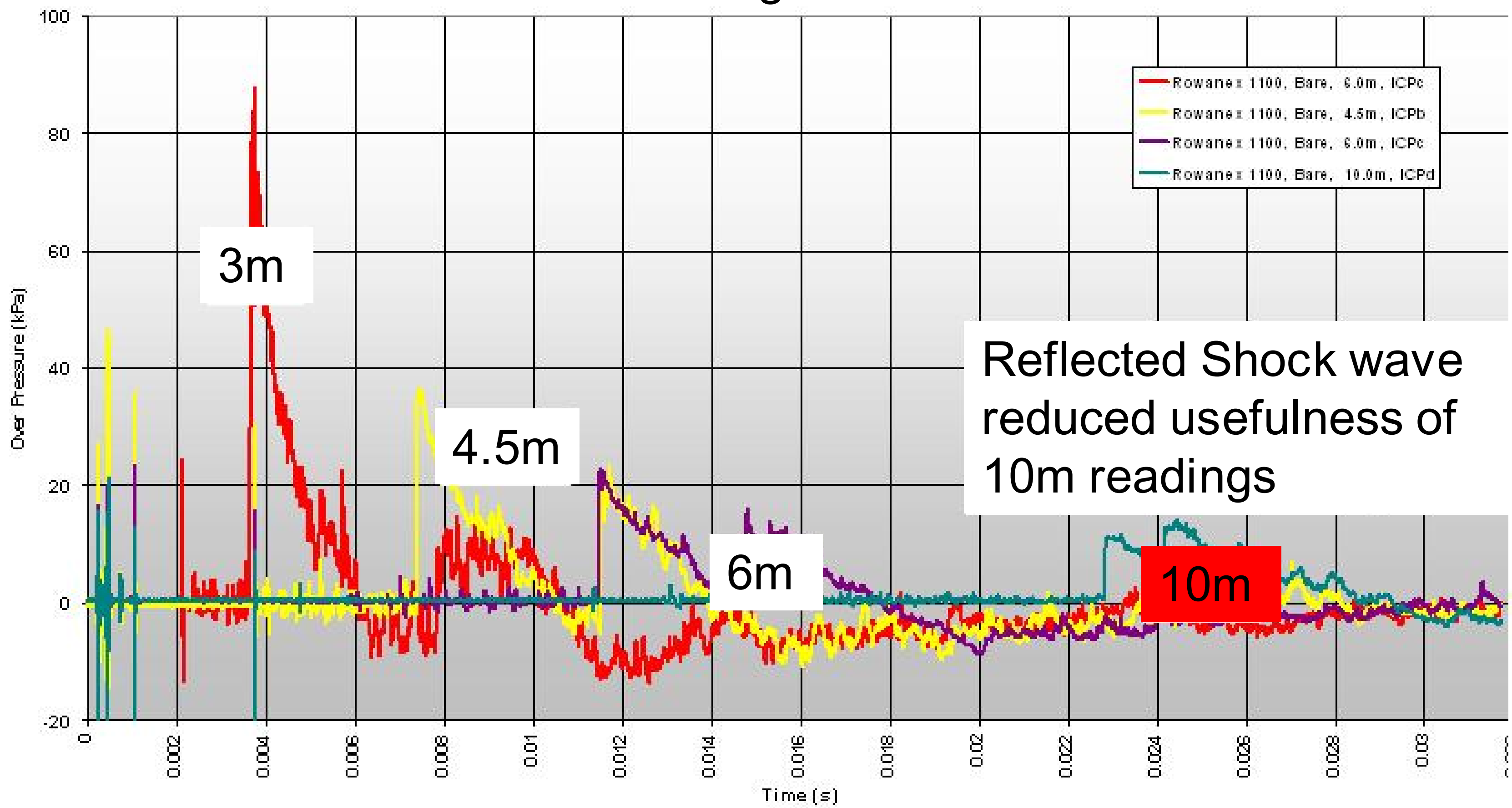
ast Gauge Output

Bare charge data



ÅImpulse data is less sensitive to noise than Incident Pressure

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Cased Results

ÅVery noisy

ÅSignal/noise ratio worse as:

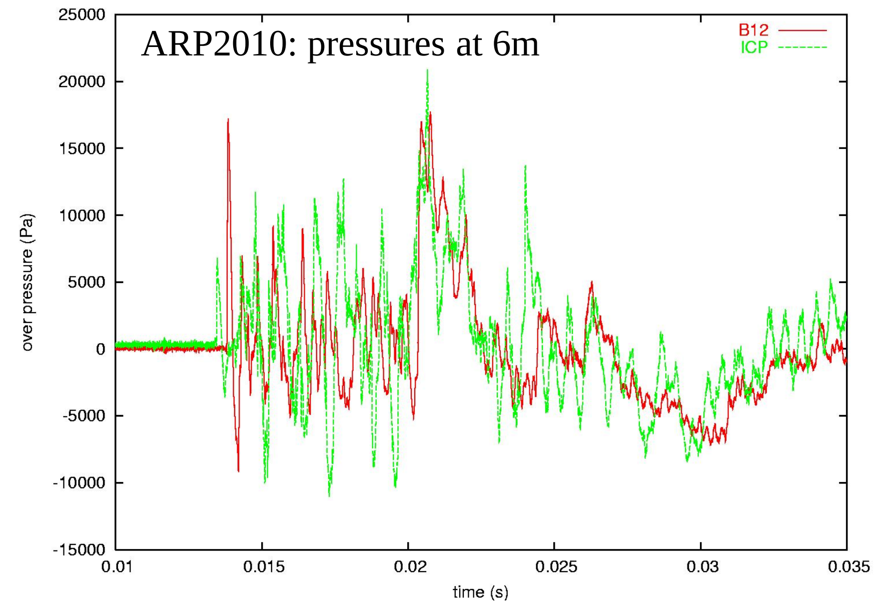
- ï Case mass increases
- ï Increase range

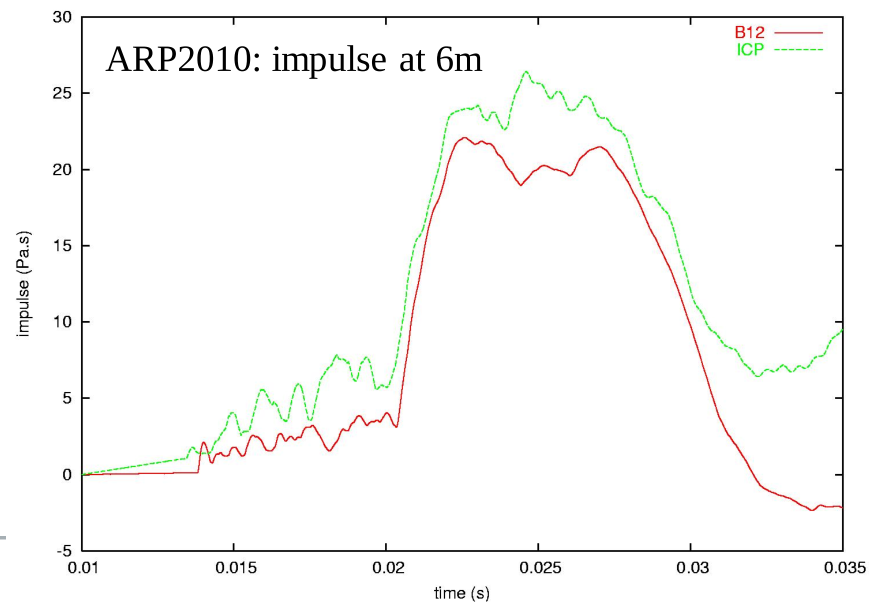
ÅICP results marginally worse than B12 gauges

ÅLittle confidence in peak pressures

ÅNoise integrates to give impulse prior to arrival of signal

- ï Adjust for this in peak impulse calculation





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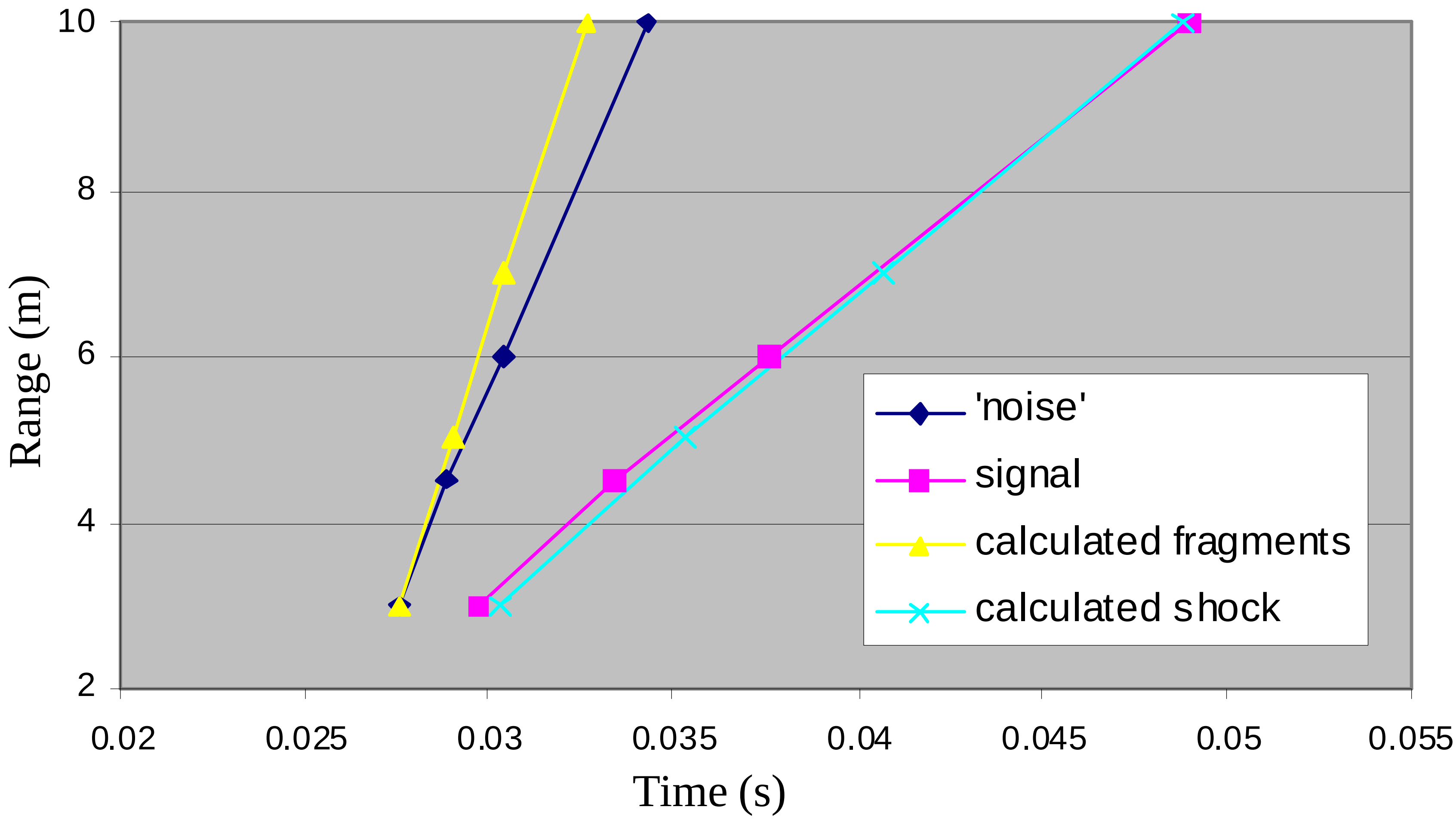
…rom Cased Results



ÅNoise and Blast wave signal with predicted Shock and Fragment position

ating Case Effect

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ÅUse Pressure and Impulse data to compute case effects - i.e. effect case has in reducing Equivalent Bare Charge mass (EBC)

- ï Convert Pressure and Impulse results to EBC masses
- ï Case effect = (EBC from cased result) / (EBC for equivalent bare charge result)

ÅReference curves used to convert Impulse and Pressure results to EBC masses

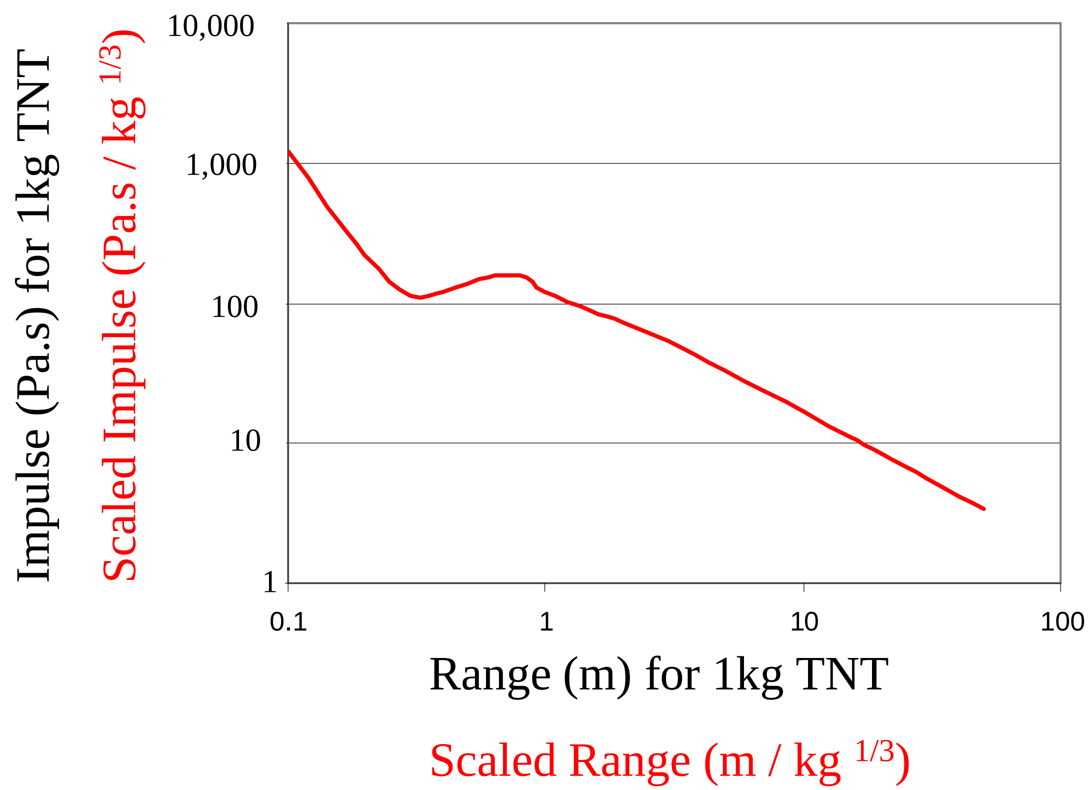
- ï Use results of 1kg Spherical TNT charge calculation as reference

...ge, for Standard 1kg Spherical TNT charge

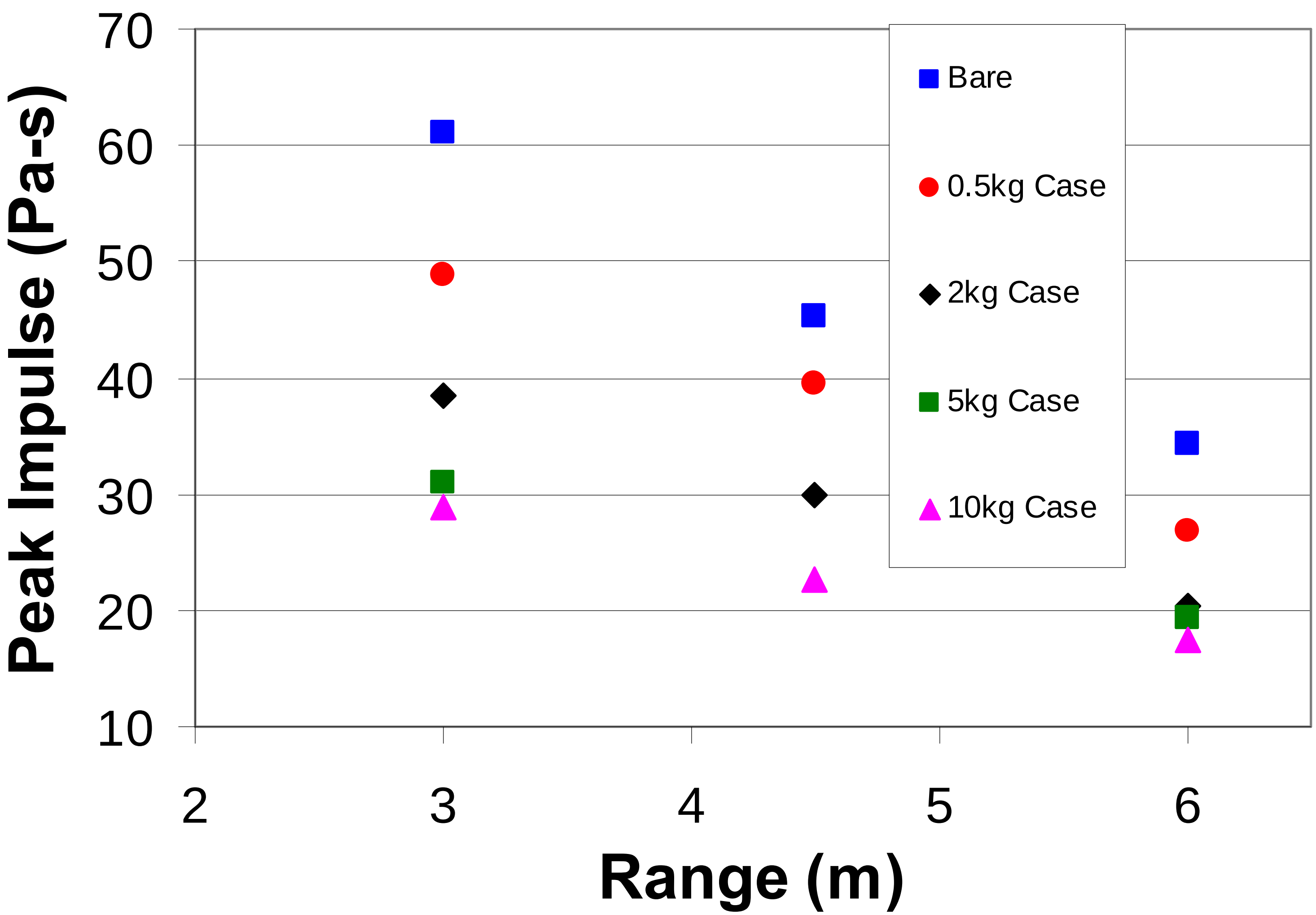
Scaled Range (R_{scl}) and Scaled Impulse (I_{scl}) are used to find the Equivalent bare mass of TNT:

$$R_{scl} = R / C^{1/3}$$

$$I_{scl} = I / C^{1/3}$$



Range (Rx1100/Steel case)



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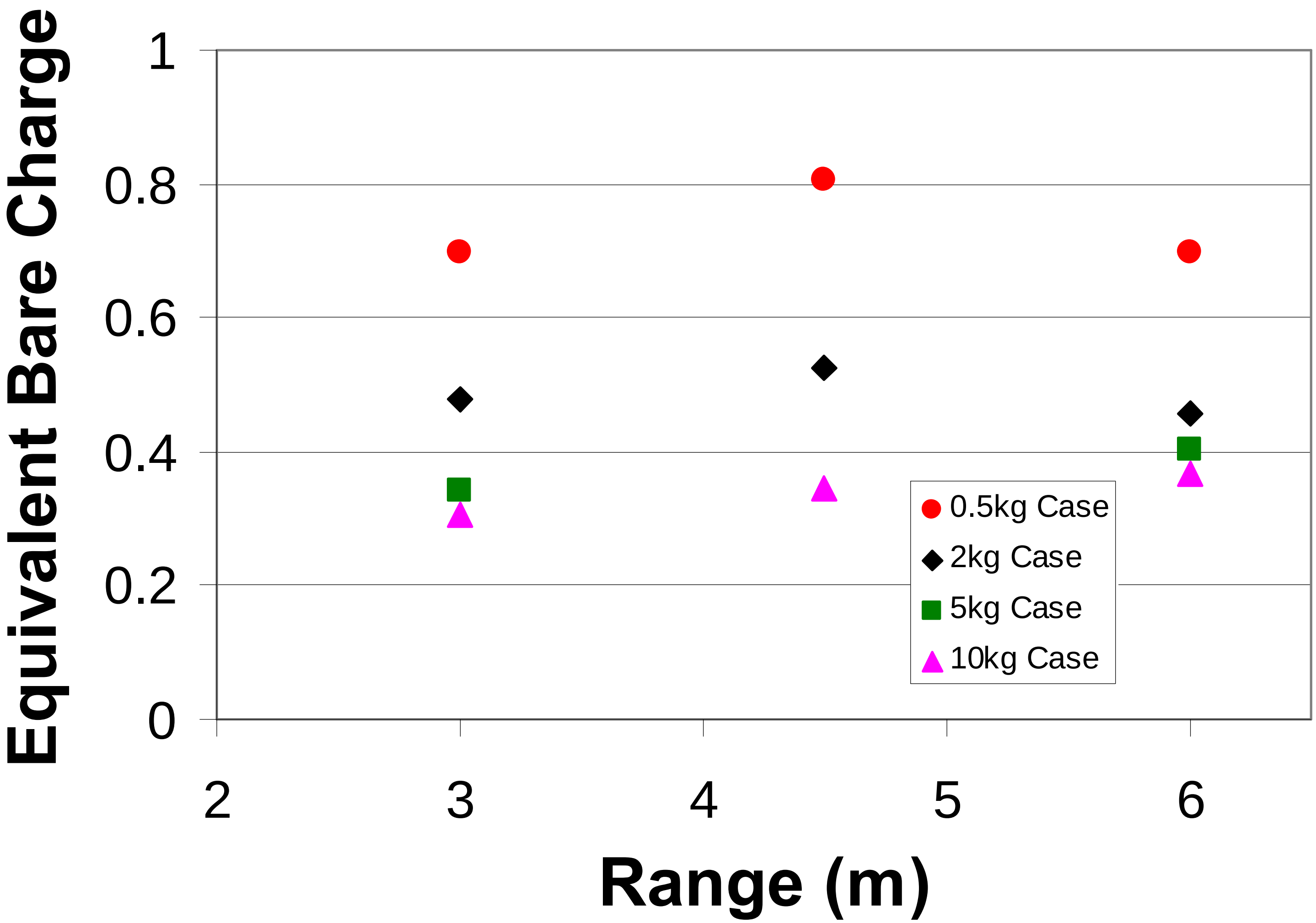
ith Range (Rx1100/Steel case)



/ Fano Equations

ÅHistorically, mainly used Fisher or Fano curves
ÅFit Fisher and Fano equations to the experimental data

ÅFisher

ï Fisher curve

$$\frac{EBC}{C} = 0.2 + \frac{0.8}{\left(1 + \frac{M}{C}\right)}$$

ï Modified Fisher

$$\frac{EBC}{C} = 0.6 + \frac{0.4}{\left(1 + \frac{M}{C}\right)}$$

ï Generalised form

$$\frac{EBC}{C} = \alpha + \frac{1 - \alpha}{\left(1 + \frac{M}{C}\right)}$$

EBC = Equivalent Bare Charge, M = Case mass, C = Charge mass
Ŭ = Experimentally derived ðbest fitô parameter

ÅBest fit is always the Generalised Fisher Equation rather than Fano

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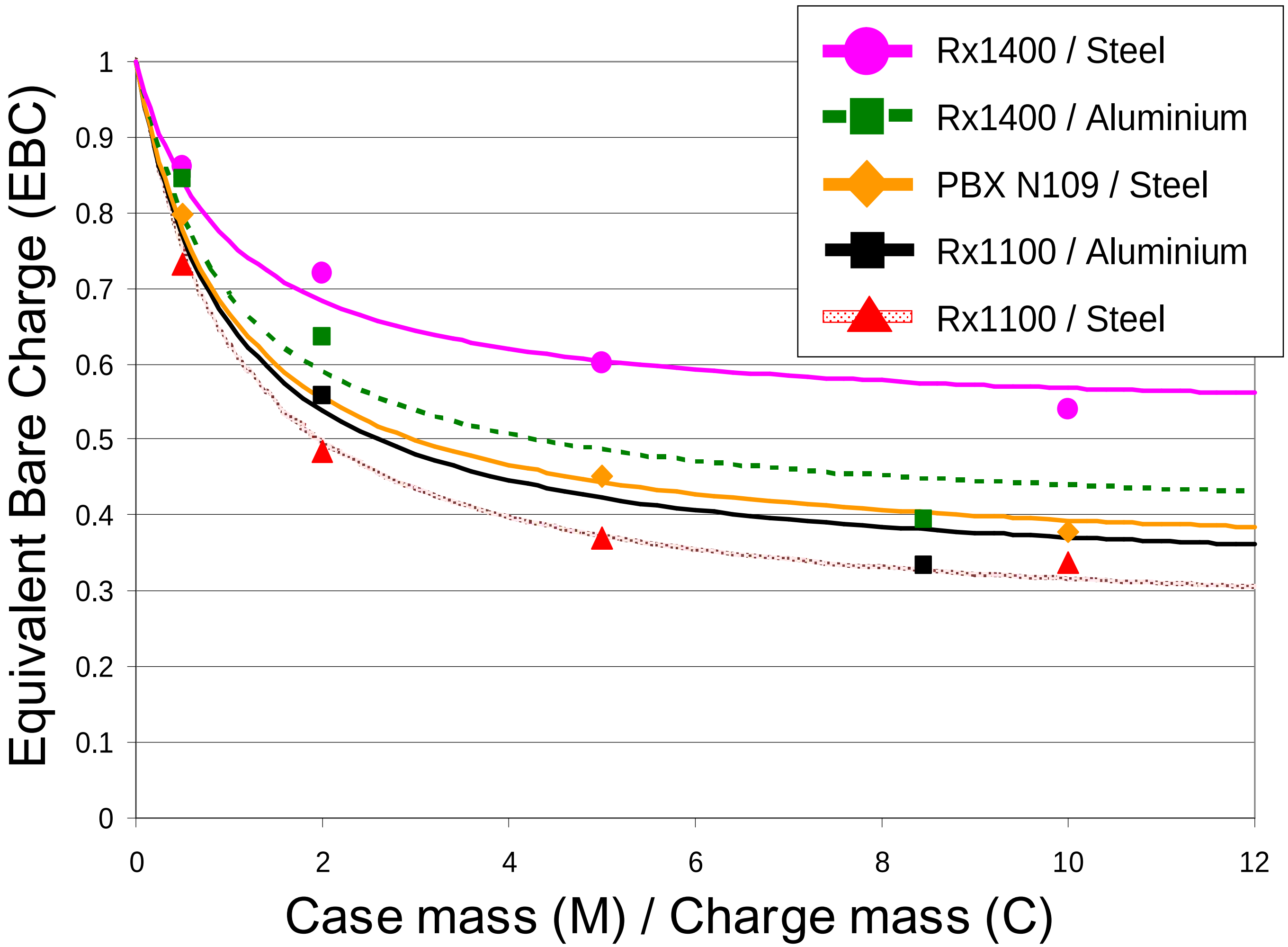
…lent Bare Charge Impulse vs. Case to Charge mass ratio



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…sher – Alpha fit for Series 1, 2 & 3

$$\frac{M_{EBC}}{C} = \alpha + \frac{(1-\alpha)}{\left(1 + M / C\right)}$$

Trial Series 1, 2 & 3 Fitted Results		
Generalised Fisher Alpha	Casing Type	
	Steel	Aluminium
Rx 1100	0.249	0.308
Rx 1400	0.525	0.383
PBX N109	0.333	N/A

Valid for: Case Mass (M) / Charge Mass (C) up to 10:1

N.B. Historically: Standard Fisher, Alpha = 0.2

(Fisher was approximately correct for Steel cased Ideal explosives)

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Results - 1

Å Generalised Fano and Fisher models were fitted to the data. Fisher gave the best fit

   Å Fisher used an Alpha of 0.2, whilst we predict 0.249

   Å Consistent with his use of steel cased Ideal explosives

Å Our results show:

Å a. Ideal explosive systems, Steel cases have more effect than Aluminium cases

Å b. Non Ideal explosive systems, Aluminium cases have the greater effect than steel cases (a great surprise)

Å c. Aluminium cased systems, Ideal Explosive show greater casing effects than Non Ideal explosive systems

Å d. Cases have a greater effect on Ideal explosive charges than on Non Ideal explosive charges

Å e. Case material effect is directly explosive type dependent

Å f. Case effects are more diverse than ever expected

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Results - 2

Å The Combined casing and explosive as a System is crucial to blast performance and which model

Å Casings interact directly with the warhead filling during the early stages of detonation

  Å Effects are often counter-intuitive

Å PBX-N109 results are interesting. Although it is regarded as similar to Rx1400, we see significant differences

  Å Case effects are significantly greater for PBX-N109, Rx1400 outperforms PBX-N109

Å Case effects are dramatic enough to indicate that warhead fillings are often incorrect for blast performance

  Å An optimised warhead could produce a 20% performance improvement. Perhaps a mid life upgrade

on

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- Gauge results are noisy from cased trials
  - Little confidence in Peak Pressure
  - Impulse results are reliable
  - Only Impulses have been used in this paper
- Trials have been performed to measure case effects for five different systems
  - Results show case effects depend on both charge type and case material
- Generalised Fisher equation is the best fit to data
  - Good fit for Steel systems, but less satisfactory for Aluminium systems
- The reasons for this observed charge and case material dependence is not understood
  - Crowley has since proposed a model in which the case effect is a function of the ratio of the case yield stress to the pressure in the unexpanded case

inally

- Thank you for listening

  Any questions?

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