EXPERIMENTAL MEASUREMENT OF TNT EQUIVALENCY FOR CONTACT CHARGES

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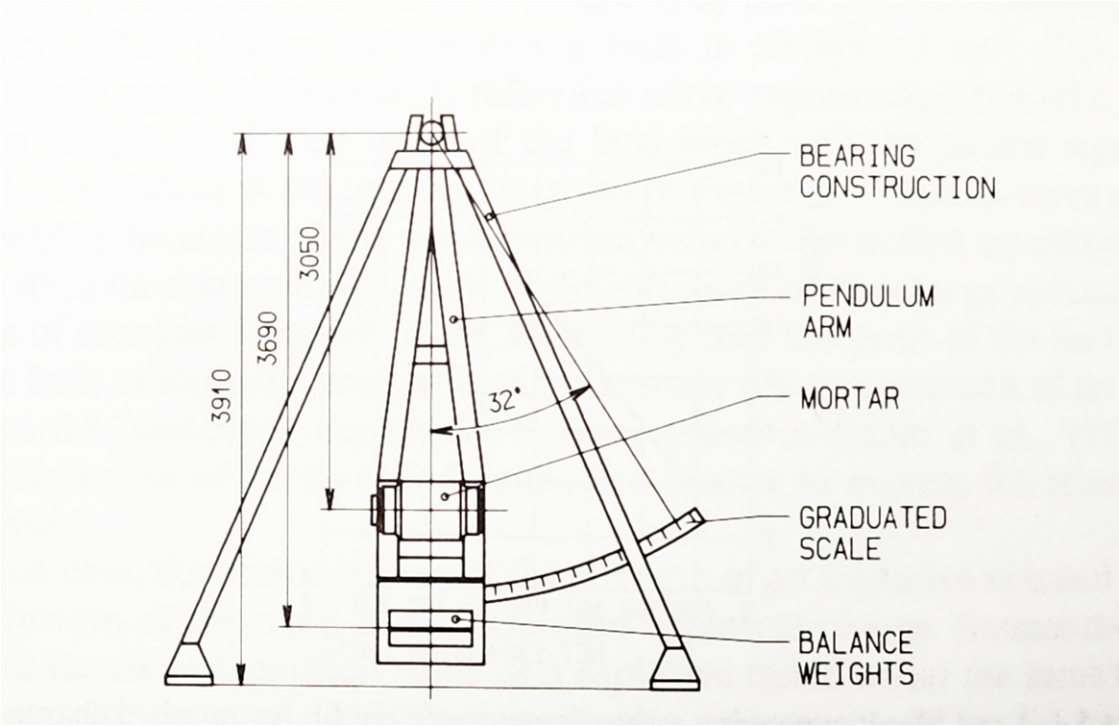
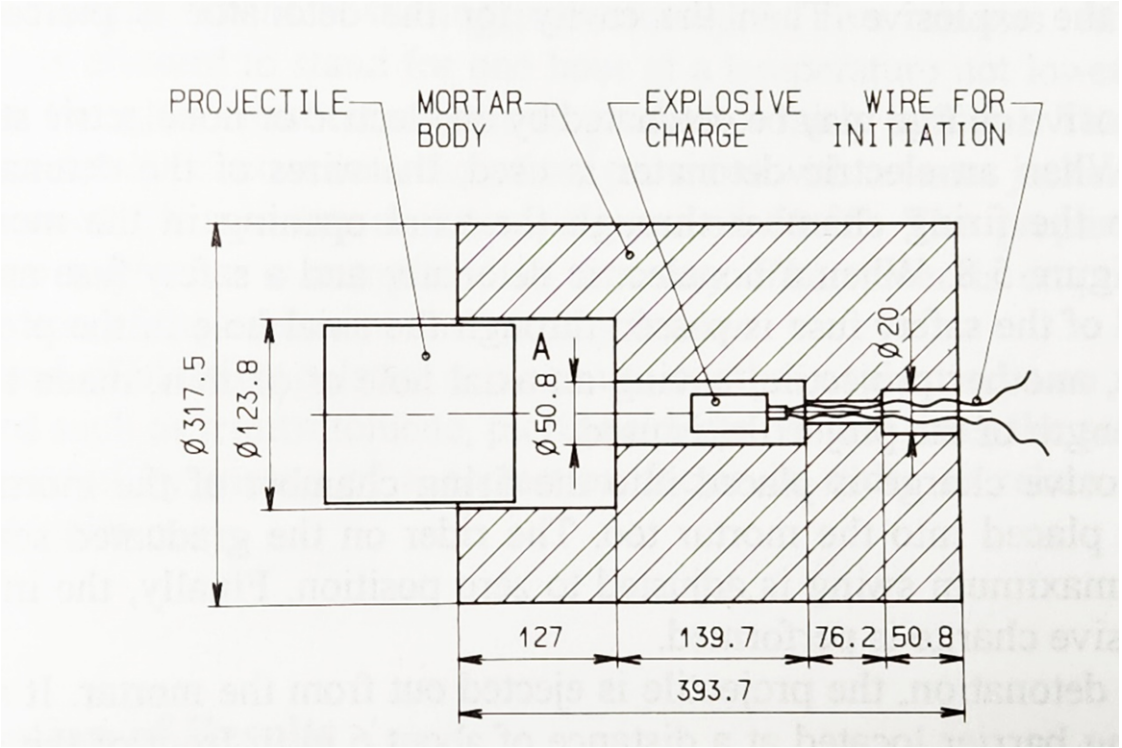
Can a Simple Ballistic Pendulum be Used to Determine TNT Equivalency for Impulse?

The Ballistic Pendulum

First described in Robins B, New Principles of Gunnery (1742)





Suceska M, Test Methods for Explosives (1995)

$$J = m\sqrt{2gr\,(1-\cos\theta)}$$

Why Do We Need to Compare Explosives?

- It is important to be able to predict the explosive effects of charges at different distances.
- We need to be able to compare the effects of different types of explosive with each other
- We need to be able to scale charges to understand how different sized explosive charges can have the same power by moving the point of measurement

- Q. What are the different factors that we can compare?

What is TNT Equivalency? (and why that is useful)

- Allows comparison to be made between different explosives by using TNT as the reference explosive (historically in the UK a blasting gelatin was used)
- We know explosive power is largely based on the VOD and density
- The higher the VOD, the higher the shock pressure, the more brisant the explosive is
- Allows predictions and modelling to be done
- e.g. noise/pressure

Why TNT? Operation Snowball and Others

- 500 Tons TNT
- Suffield Experimental Station
- July 17th 1964

How Do We Determine TNT Equivalency?

Power

- Ballistic Mortar
- Trauzel (Lead Block) Test e.g. PE4 120 (Picric Acid 100)
- Plate Dent Test
- Sand Crush
- Air-Blast e.g. Op Snowball & McIntyre
- Heat of Explosion
- Thermochemical

McIntyre's Tests

McIntyre FL et al, TNT Equivalency of Composition C4 in Shipping and Process Containers, 1981

Many explosives were tested in a standard set of configurations over a number of years by McIntyre et al.

These tests gave sats of data for TNTe.

What the data showed was that the configuration of the charges could play a major roll and the data does not always agree with other sources.

They also found that the TNTe varied depending on whether the measurements were made at Near-Field or Far-Field ranges (fixed Scaled Distance).

Summary of Published TNTe

Explosive	Sand Crush test % TNT	Ballistic Mortar % TNT	Plate Dent % TNT	Pressure % TNT	Impulse % TNT	Range	
C4				137		NA	Masrjian & Fisher (1951)
C4	55.7	130	115			NA	Cooper & Kurowski (1996)
C4				180	470	Near-Field	McIntyre (1981)
C4				100.0	230	Far-Field	McIntyre (1981)
PE4		130		135	130	Far-Field	Wharton, Formby & Merrifield (2000)

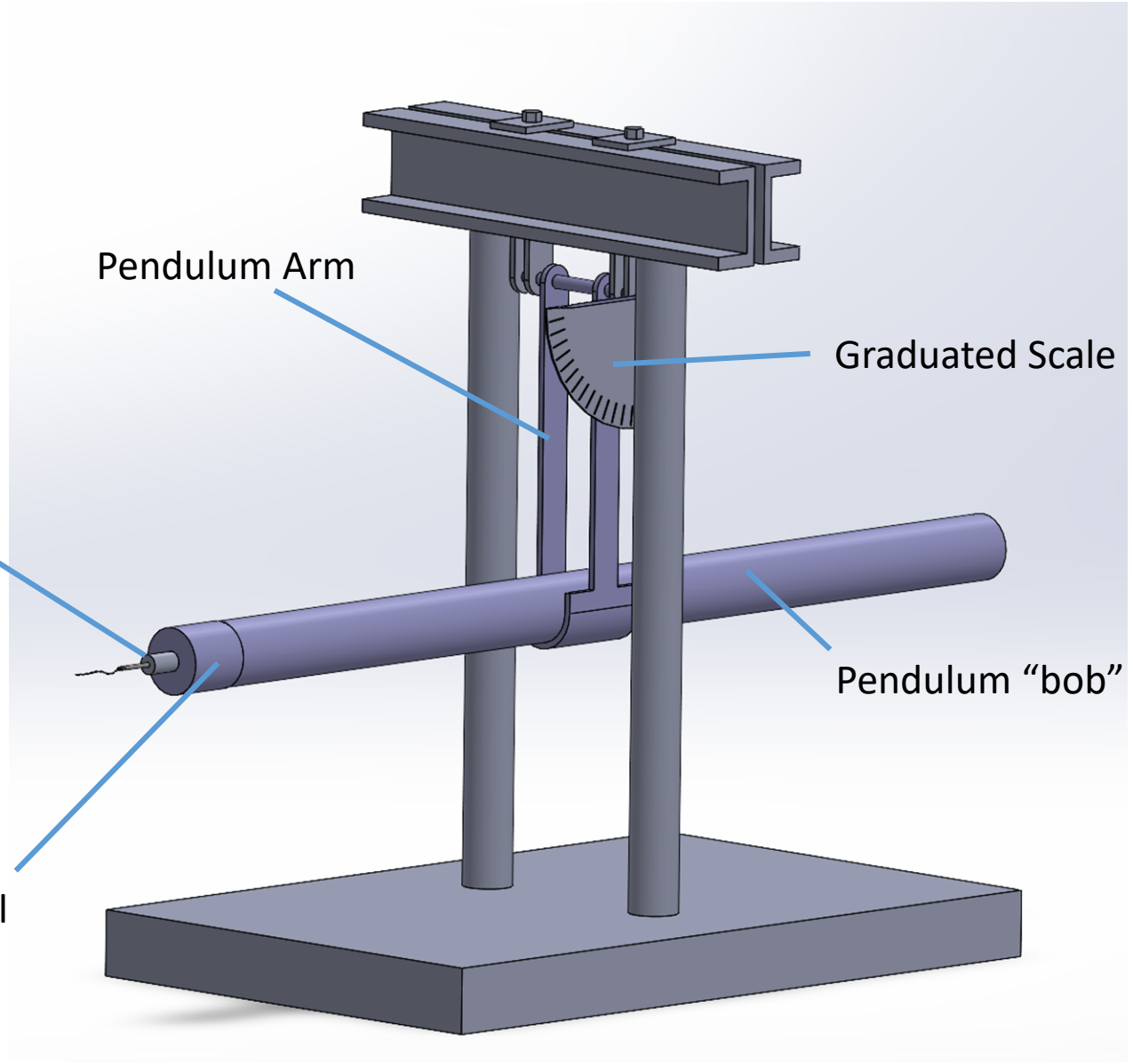
Near-Field: Scaled Distance range 1.19 – 2.14
Far-Field: SD > 3.57

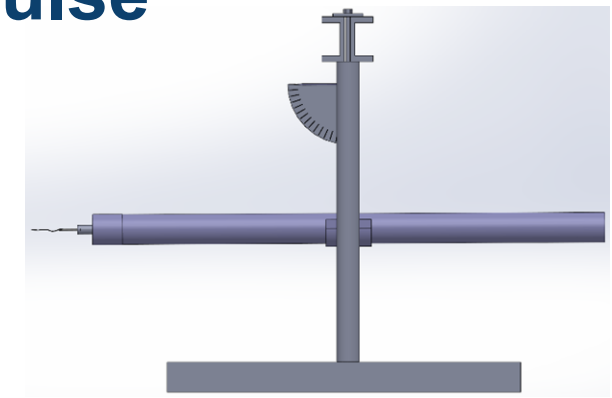
Question: Why is the Impulse so high? Can that be correct?

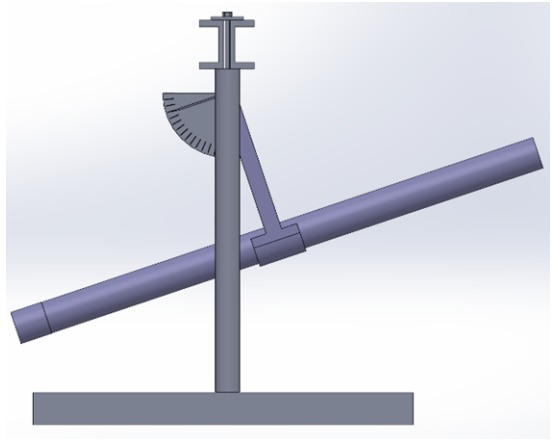
What are the problems with TNT Equivalency?

- What are we actually comparing?
- Each of the tests is measuring something different and they do not all agree with each other (Cooper 1994)
- Units: Ton v Tonne
  - 500 US Tons = 454 Metric Tonnes

Historical Use of Ballistic Pendulum for Impulse

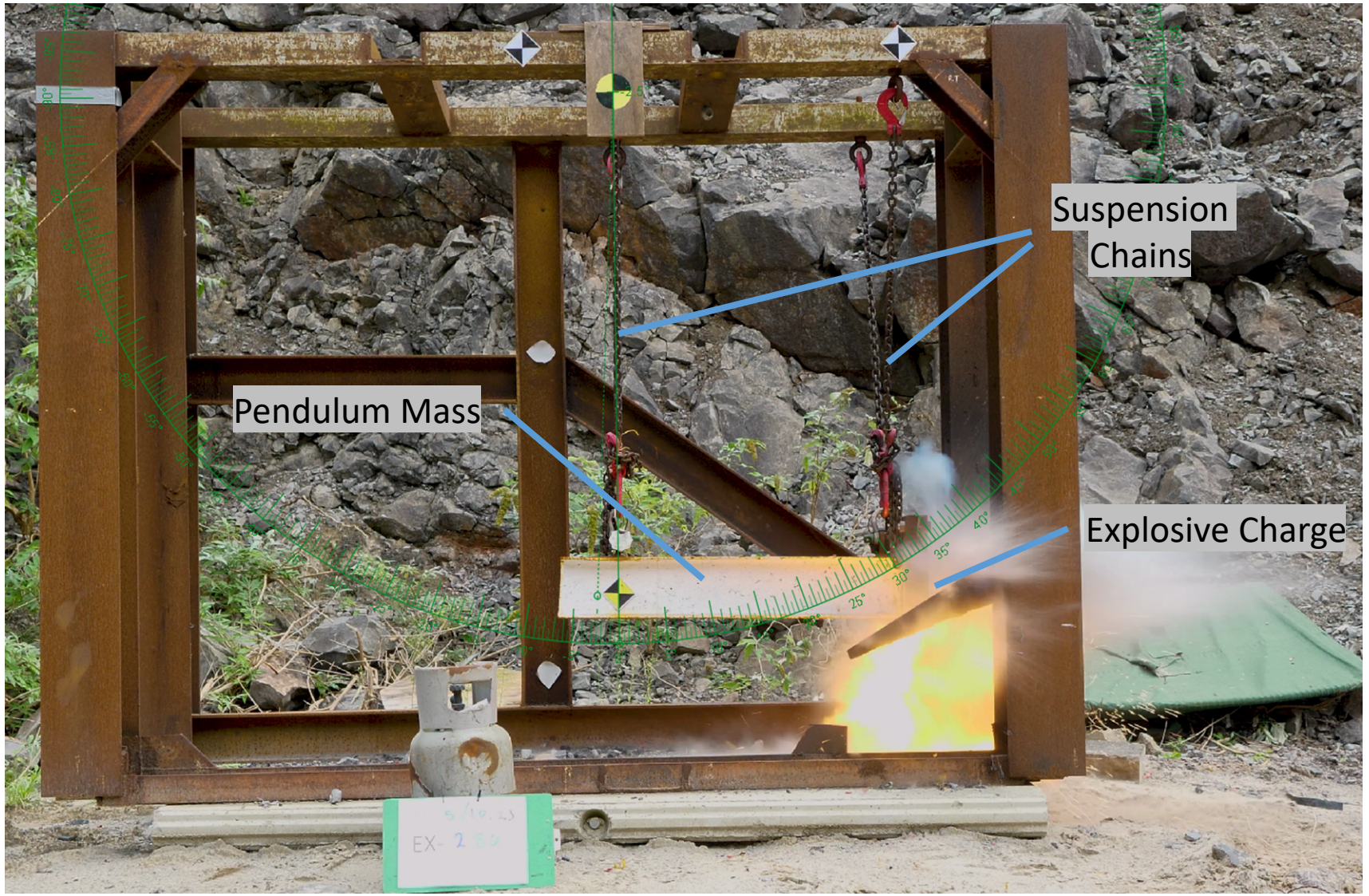


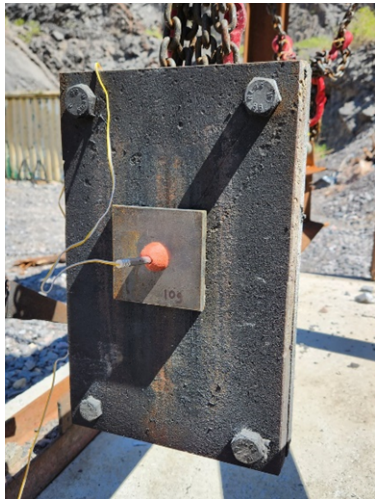




From Baum et al 1959, Moscow

Experimental Set-Up: Modular Ballistic Pendulum





Poladyn charge. Note the sacrificial anvil between the charge and the pendulum mass

PE4

The Experiments

Explosives

- TNT (Cast)
- Poladyn (EGDN Dynamite)
- PE4 – 88% RDX

Shapes

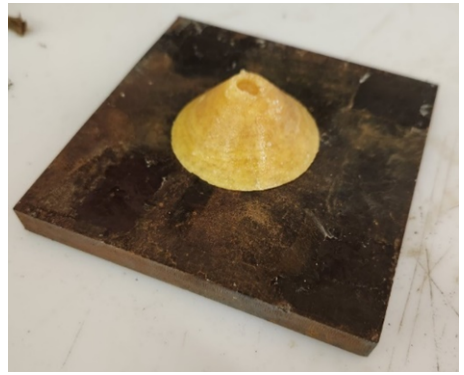
- Cylinder
- Hemisphere
- 60 deg. cone
- 90 deg. cone

NEQs (NEW)

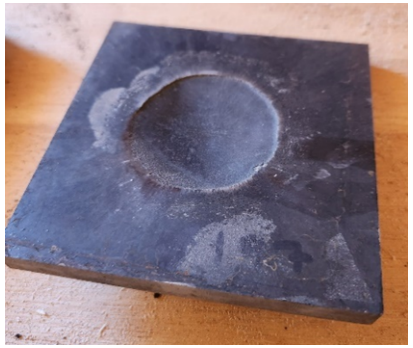
- 10g-70g

Poladyn Hand-Formed Hemispheres (10g-60g)

PE4 90 deg. Cones in sacrificial moulds (10g, 20g, 30g)



Cast TNT 90 deg cone (30g)



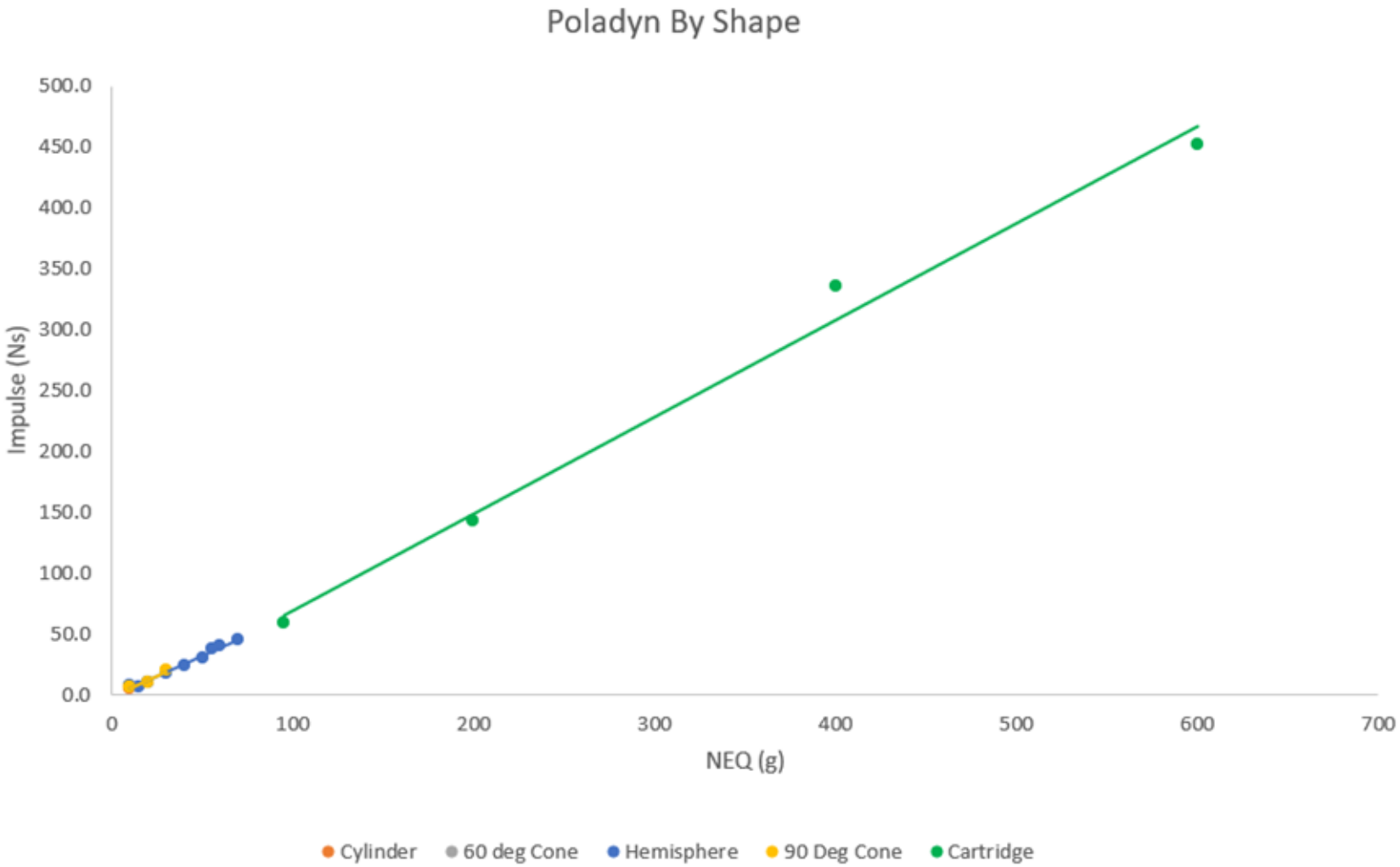
Typical “dent” from plastic explosive

Cast TNT cylinders (10g)

Results

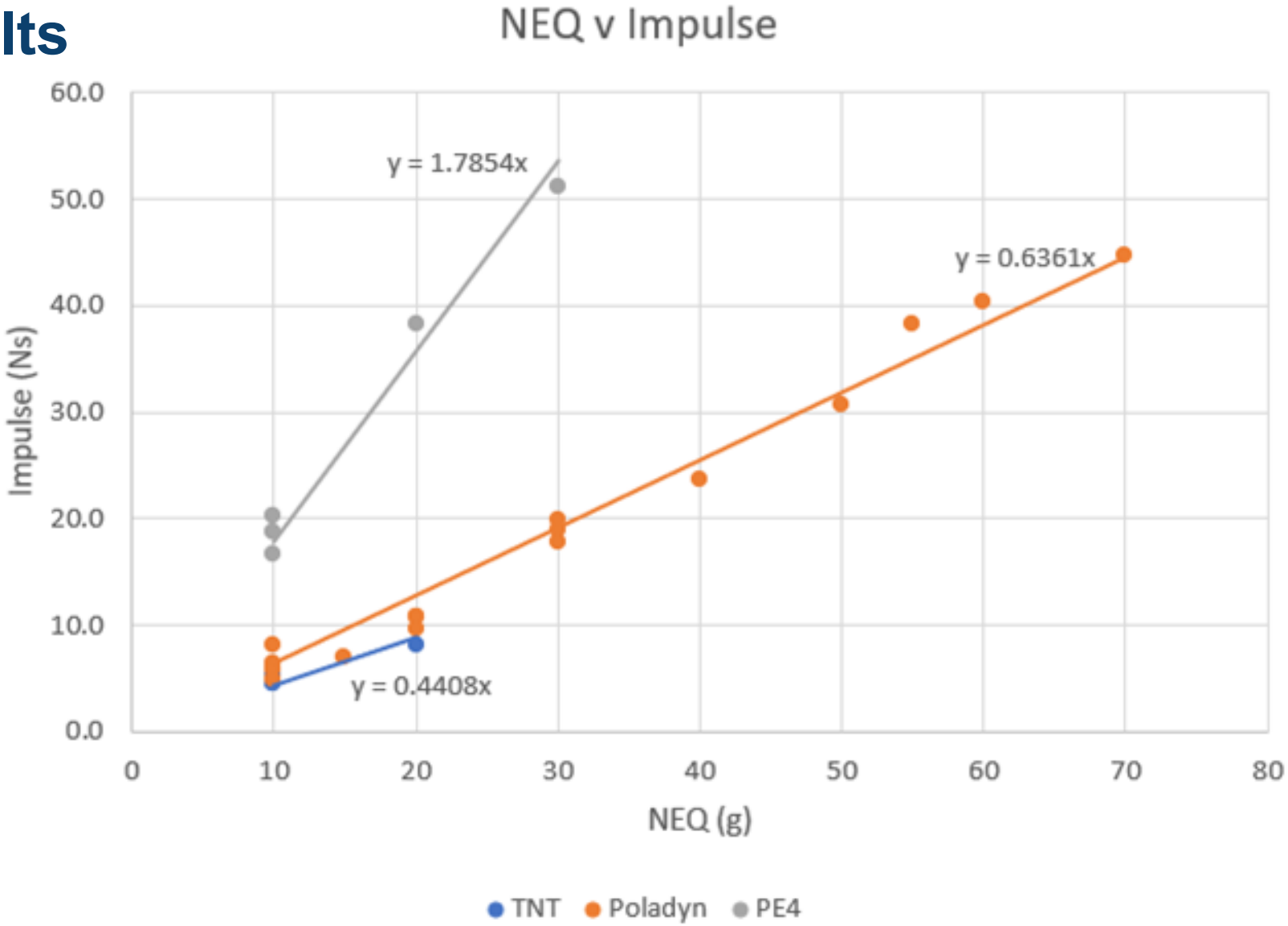
Validating that it was acceptable to use either cones or hemispheres

Charges ranged from 10g to 600g



Comparison of results with different charge shapes Poladyn show that the charge shape has relatively little effect on the impulse measured

Results



Impulse plotted against NEQ for the three explosives tested. All trendlines are set to intercept the origin

Results Cont.

Explosive	NEQ g	Impluse Ns	TNTe
TNT	22.00	9.70	1.00
Poladyn	-	13.99	1.44
PE4	-	39.28	4.05

Calculator based on the previous graph presents the TNTe for the three explosives

Remember that C4 is generally estimated with a TNTe of 1.37!!!

Question: Do I believe these figures?

Yes – The surprisingly high figure for PE4 is comparable to McIntyre's figure of 4.7 so 4.05 credible

Explosive	Most Common TNTe	McIntyre	Alford et al
C4	1.37	4.7	
PE4			4.05
Dynamite	0.98		1.44

No – I would not have expected Poladyn to have been greater than TNT

Problems with Small TNT Charges

TNT was very hard to reliably initiate and so it is quite likely that the TNT did not fully detonate, resulting in a figure that is too low

Different charge shapes and booster configurations were used but small charges were inconsistent in initiating

Previous research tended to use larger charges and tetryl boosters

What does that mean for the traditional Ballistic Pendulum which uses 10g TNT charges

Alternative Explosives

Questions: Is TNTe even the right benchmark?
What are the alternatives?

1. Need something that is readily available
2. Something that can be made in lab – ie. Not a proprietary composition
3. A composition that can be initiated in small quantities without the need of a booster

Alternative Explosives

- Comp-B – RDX / TNT (60:40)
  - military explosive
  - going out of service

- Pentolite – TNT / PETN (50:50) –
  - widely used as a cast booster – readily available
  - can be mixed in lab
  - easy to re-melt and cast
  - inexpensive

Winner?

Pentolite

Summary: TNTe for Impulse

- The ballistic pendulum when used for Impulse with contact charges gave TNTe that are credible
- The experimentation was easy to conduct
- The hardest part was to make small TNT charges that would detonate
- The shape of the charge does not appear to be critical with contact charges

Recommendations

- Consider changing the reference explosive to Pentolite – readily available (commercial cast-boosters), easy to cast and more sensitive

- Consider measuring the dent in the anvils to gauge Brisance – similar to dent-test but less accurate as the pendulum can move

- Carry out further tests with a range of other explosives

  Pentolite, C4, PENO, Emulsion, alternative brands of dynamite etc

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