

Silas COTEC Data Report

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Submission date: 19-Dec-2024 12:19AM (UTC+0000)

Submission ID: 246589203

File name: 32635_Silas_Blevins_Silas_COTEC_Data_Report_592935_1787173073.docx (286.05K)

Word count: 1604

Character count: 8418

Munition Identification by means of Trials Data

COTEC FIRING OCTOBER 2024

Silas Blevins | OME Degree Apprenticeship | December 2024

Abstract

The ability to interpret scientific and engineering data about an explosive event even without seeing the munition used is key to forensics and exploitation of explosives. This report discusses a blind trial carried out at the Cranfield Ordnance Test and Evaluation Centre to demonstrate this. Fragmentation, Chemical and Pressure Data are used to identify the explosive article used in the trial as an RGD-5 Hand Grenade.

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1 Introduction

1.1 Background

The ability to identify explosive articles based on their effects is critical to munitions testing and evaluation [1], criminal investigations [2], and evaluation of combat incidents and potential international law violations [3]. This report discusses an explosives trial, carried out at the Cranfield Ordnance Test and Evaluation Centre (COTEC) which was performed without knowledge of the munition used. This allows the role of trials equipment and explosives science to be demonstrated and applied in the identification of the munition

1.2 Munitions Being Considered

The table below describes the munitions considered as potentially being detonated during the trial. It is derived from a document [4] listing potential munitions that was supplied to the trials team in advance of the trial. Some munitions had a Net Explosive Quantity (NEQ) too large for the test site, and so are discounted at this step as it is impossible for them to have been used.

Munition	NEQ (kg)	Case Mass (kg)	Fragment Initial Velocity (ms ⁻¹)	Fragment Area (cm ²)	Explosive Used	Likely to be Fired Munition?
Mk.83 Aerial Bomb	225	229	1950	0.48	Comp.B (TNT/RDX) [5]	No, NEQ Too High
M67 Grenade	0.185	0.213	Not Given	1	Comp.B (TNT/RDX) [5]	Possible
RGD-5 Grenade	0.110	0.200	1567	1	TNT	Possible
81mm Mortar	0.760	1.334	1734	Not Given	TNT	Possible
PG-7VL	0.730	1.6	1831	Not Given	RDX/TNT/HMX	Possible
155mm HE Shell	1.150	3.150	1551	Not Given	Comp.B (TNT/RDX) [5]	No, NEQ Too High
Pipe Bomb	0.2	0.2	1990	Not Given	TNT	Possible

Table 1: Munitions being considered at the start of analysis

2 Chemical Analysis

Swabs were taken of the fragments recovered from the trial site for analysis by Fourier-Transfer Infrared Spectroscopy (FTIR). 50% of these fragments were then washed in isopropyl alcohol, and the other 50% were washed in Acetone. The isopropyl alcohol samples failed to indicate the presence of any explosives, however the acetone samples indicated the presence of trace amounts of TNT, as shown in the figure below.

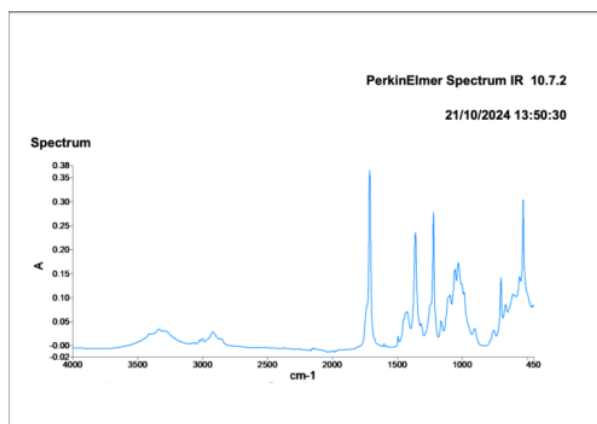


Figure 1: FTIR Results indicating the presence of TNT

Since TNT was detected, but not RDX or HMX, this suggests that the munition was most likely to have a charge made only of TNT, however the relatively low sensitivity of FTIR and the potential for lack of recovery of other explosives means that this is not a guarantee. The table below shows the munitions still being considered after taking these chemical results into account.

Munition	NEQ (kg)	Case Mass (kg)	Fragment Initial Velocity (ms ⁻¹)	Fragment Area (cm ²)	Explosive Used	Likely to be Fired Munition?
Mk.83 Aerial Bomb	225	229	1950	0.48	Comp.B (TNT/RDX)	No, NEQ Too High
M67 Grenade	0.185	0.213	Not Given	1	Comp.B (TNT/RDX)	Possible
RGD-5 Grenade	0.110	0.200	1567	1	TNT	Likely
81mm Mortar	0.760	1.334	1734	Not Given	TNT	Likely
PG-7VL	0.730	1.6	1831	Not Given	RDX/TNT/HMX	Unlikely
155mm HE Shell	1.150	3.150	1551	Not Given	Comp.B	No, NEQ Too High
Pipe Bomb	0.2	0.2	1990	Not Given	TNT	Likely

Table 2: Munitions being considered after Chemical Analysis

3 Fragment Data

3.1 Fragment Velocities

Fragment velocities were measured using velocity foils. These are thin strips of copper placed on top of the witness boards, which send an electrical signal to a computer. Given that the time at which the explosive was initiated is known, the time at which the electrical signal arrived is known, and the distance from the munition to the foil is known, the velocity can be calculated. Using this the average velocity of the fragments at a distance of 1.5m was determined to be 1128ms^{-1} . Whilst it can be assumed that the velocity of the fragment had decreased somewhat due to aerodynamic drag, this effect would be minimal over the 1.5m between the munition and the witness boards. For this reason, the initial velocity from the munition data was assumed to provide a reasonable approximation of the velocity at 1.5m. It is clear from this that the munition was likely to have a lower fragment velocity, suggesting that it was extremely unlikely to be the pipe bomb, and relatively unlikely for it to be the mortar or the PG-7. Therefore it is likely that the munition was one of the two grenades.



Figure 2: Velocity foils attached to witness packs at COTEC

3.2 Fragment Physical Characteristics

The fragments were collected from the trials site and visually examined, as shown in the photo below.



Figure 3: Fragments produced by the munition

Upon analysis, the fragments were determined to be made of steel, and to have an average area of 28.05mm², or 0.28cm². Whilst this is smaller than the 0.1cm² given for the grenades, it is possible not all fragments were collected and that larger fragments may have been lost through embedding in the witness boards. The fragments had an average mass of 1.116g, and a total mass of 154g. In addition the fragments appeared to be natural as opposed to pre-formed. Given that approximately half of the explosion was directed towards the witness stands, it is assumed that the munition possessed a naturally fragmenting steel case of total mass 200-300g. The table below shows which munitions were still being considered after analysis of the fragmentation data.

Munition	NEQ (kg)	Case Mass (kg)	Fragment Initial Velocity (ms ⁻¹)	Fragment Area (cm ²)	Explosive Used	Likely to be Fired Munition?
Mk.83 Aerial Bomb	225	229	1950	0.48	Comp.B (TNT/RDX)	No, NEQ Too High
M67 Grenade	0.185	0.213	Not Given	1	Comp.B (TNT/RDX)	Possible
RGD-5 Grenade	0.110	0.200	1567	1	TNT	Likely
81mm Mortar	0.760	1.334	1734	Not Given	TNT	No, Fragments not consistent with models
PG-7VL	0.730	1.6	1831	Not Given	RDX/TNT/HMX	No, Fragments not consistent with models
155mm HE Shell	1.150	3.150	1551	Not Given	Comp.B	No, NEQ Too High
Pipe Bomb	0.2	0.2	1990	Not Given	TNT	No, Fragments not consistent with models

Table 3: Munitions being considered after Fragment Analysis

Whilst the data in this table strongly suggests the RGD-5 was the munition used, it is necessary to consider the pressure data to see if any additional information can be gained.

4 Pressure Data

Pressure gauges were placed at 1 meter intervals from the munition at distances of 1, 2 and 3 meters. Each gauge recorded the incident overpressure. A pressure calculator provided for this study was used to predict the peak overpressure at each distance, and this is compared to the experimental data in the table below.

	Predicted Peak Pressure (M67)	Predicted Peak Pressure (RGD-5)	Actual Peak Pressure
1.003	259.3	175.9	370.2
2.036	57.6	41.7	50.403
3.016	28.4	21	27.139

Table 4: Comparison of predicted vs Measured Overpressures

This shows that although the actual peak pressures appear to align more with those predicted for the M67 grenade, it is clear that both the modelling and data collection are imperfect, and this data may not be the most useful. The graphs below further illustrate this by showing that both predicted data sets have a very strong correlation with the measured pressures.

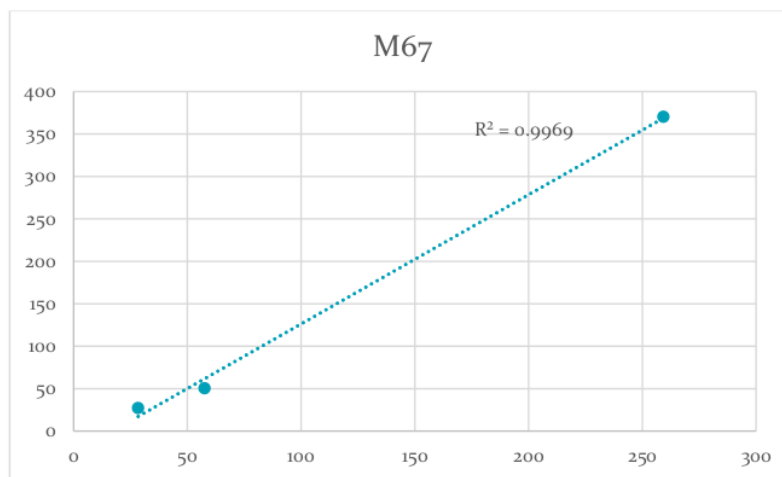


Figure 4: Correlation of M67 Overpressures with Measured Overpressures

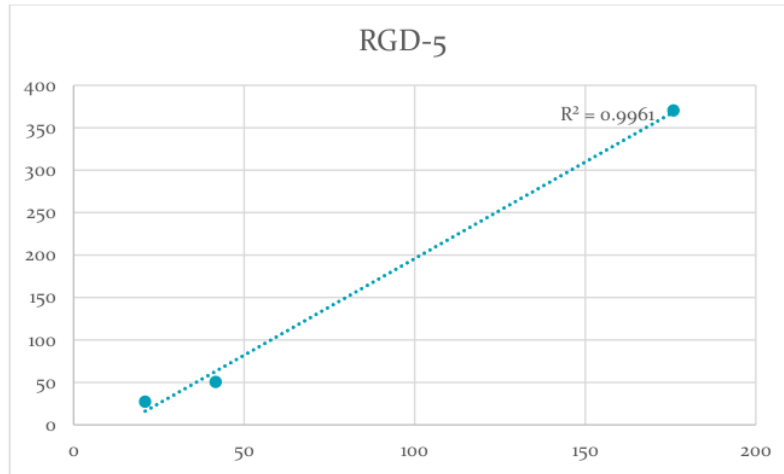


Figure 5: Correlation of RGD5 Overpressures with Measured Overpressures

This shows that the pressure data is largely ambiguous in the context of this trial and would benefit from additional data points to reinforce the data and confirm how well it correlates to the models used.

5 Conclusions

This report shows that a small, steel cased munition, with a main charge of TNT was detonated at COTEC, and that the case of the munition likely weighed 2-300g. This strongly suggests that the munition was either the RGD-5 or the M67 grenade. The fact that only TNT was detected on the fragment lends credibility to the hypothesis that the grenade was an RGD5. For this reason, this report concludes that the munition fired was an RGD-5 hand grenade.

References

- [1] Cranfield Ordnance Test and Evaluation Centre, “Fragmentation Trials,” COTEC, 2024. [Online]. Available: <https://www.cotec.org.uk/capabilities/fragmentation-trials/>. [Accessed December 2024].
- [2] C. Stansfield, “From crime scene to court – the science of explosives,” 17 January 2018. [Online]. Available: <https://quarterly.blog.gov.uk/2018/01/17/from-crime-scene-to-court-the-science-of-explosives/>. [Accessed December 2024].
- [3] CST, “Mauriopol Drama Theatre Spatial Archive,” CST, 2024. [Online]. Available: <https://theater.spatialtech.info/en>. [Accessed December 2024].
- [4] G. Collet, *Types of Munition of Potential Interest*, Swansea: UWTSD, 2024.
- [5] Ministry of Defence, JSP333 Service Textbook of Explosives, London: MOD, 2020.
- [6] UWTSD, *FTIR Sample Results*, Swansea: UWTSD, 2024.

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GRADEMARK REPORT

FINAL GRADE

68/100

GENERAL COMMENTS

Hi Silas,

Very well structured, concise and to the point. You have worked hard on this assignment and clearly understand the objectives of the module. This is on the cusp of 1:1 and just falls short due to the omission of some data on fragmentation/pressure that would have bumped you over the mark. However, extremely well done Silas, I really enjoyed reading this piece of work.

In detail:

1. Excellent structure and abstract. I clearly understand that the report intends to demonstrate and how.
2. You clearly understand how to write a technical report.
3. Excellent use of referencing throughout, which was relevant to the context.
4. Good use of logic in table 1. It would have been nice to have access to a site for Mk 83's!
5. Why did the IPA not work? A useful reference point to Meyer & Kohl perhaps?
6. Why do you know from Figure 1 that this is a TNT sample? Had you thought about annotating

peaks with, say, the absorption expected of an aromatic ring?

7. I very much like your traffic light sequence in the tables. They clearly support your observations and assumptions.

8. I would have liked to see the fragmentation velocity data at each witness plate. This would provide me with a sense of credible and non-credible results. By non-credible I mean sub-optimal velocities due to ricochet for example, or the fragment spread due to geometry. At the moment, I have to take your word for it that the average velocity is in the region of 1128 m/s but what is the SD around that? This would have helped you hone more into the RGD-5.

8. Again, good discussion on the fragmentation, specifically pre-formed analysis. For table 3, and reasons given at point 7 above, I do not think you could currently state '*strongly suggest the RGD-5....*'

9. Three points may not be the best correlation but they are all you have in terms of the data for the pressures.

10. Again, what you could have done is display the pressure data and apply a filter at each gauge to determine the actual pressures achieved. This would have shown you the reflected overpressure dominating the actual peak pressure at 1.003 m. You will find that the predicted pressure for the RGD-5 isn't far out if you considered a surface burst and the ground reflections associated with that - about 290 - 300 kPa.

11. Sound conclusion, well done.

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