

Task 1

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Data Capture & Evaluation
Explosives Forensic Investigation Report

UWTSD

BEng
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Academic Integrity Declaration

I declare that:

- The thesis submitted has been written by me alone.
- The thesis submitted has not been previously submitted to this university or any other.
- That all content, including primary and/or secondary data, is true to the best of my knowledge.
- That all quotations and references have been duly acknowledged according to the requirements of academic research.

I understand that to knowingly submit work in violation of the above statement will be considered by examiners as academic misconduct.

Abstract

This report investigates an explosives trial that took place at the Cranfield Ordinance Test and Evaluation Centre (COTEC). This trial consisted of an unknown item of ordinance being detonated in a controlled arena with trial equipment present. This equipment allowed for data and samples to be collected from the trial for forensic analysis to be conducted. This was done to allow for the ordinance donated to be identified. In this report the method and equipment of the trial will be stated and the results discussed. From the results gathered as part of this investigation and with the aid of several forensic investigating methods an opinion of what ordinance was used will be stated.

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1 Introduction

1.1 Overview of Trial

This report investigates an explosives trial at the Cranfield Ordinance Test and Evaluation Centre (COTEC) on Tuesday the 15th of October. This trial consisted of an unknown item of ordinance being detonated in a controlled arena with trial equipment present [1]. This equipment allowed for data and samples to be collected from the trial for forensic analysis to be conducted. This was done to allow for the ordinance donated to be identified. In this report, the method and equipment of the trial will be stated, and the results will be discussed. From the results gathered as part of this investigation and with the aid of several forensic investigating methods an opinion of what ordinance was used will be stated.

1.2 Aim of Trial

The trial conducted at COTEC aimed to identify an Ordinance Explosives and Munitions (OME) item by blast/fragmentation measurement, and swab analysis of explosive residue collected. This trial was set up collectively by the student group after being briefed by staff from the Defence Science and Technology Laboratory on data-capturing tools. Additionally, lectures and instruction were provided by COTEC staff on how to correctly set up a blast/fragmentation trial and to do so in a safe manner.

2 Method & Materials

2.1 Equipment Used

To gather the data to be analysed several different forms of data-gathering equipment were used. To capture physical samples from the trial strawboards were used. The strawboard used in the forensic trial consisted of paper pressed together in a rigid structure, these layers were bundled together in stacks of 20. In the trial to allow for the capture fragmentation and prevent any full penetration each section consisted of 4 bundles of strawboard as shown in Figure 1.



Figure 1

To record data regarding the velocity of the fragmentation generated by the explosive detonation “velocity foils” were also used. This equipment is an example of contact velocity measurement and is purpose-built for COTEC trials. These foils work by using a board covered in a thin copper track as shown in figure 2.



Figure 2

The final piece of equipment used in the trial was pressure sensors. The dynamic pressure sensors in the trial were made by PCB Piezotronics [3]. An example of the blast gauge assembly with the sensor and mount can be seen in Figure 3.



Figure 3

2.2 Trial Setup

As previously stated, the trial was conducted at the COTEC range and was done at the forward battery. The specific area chosen for the test was a concrete pad previously used for high-altitude artillery firing. This platform provided a hard surface close to the main building of the forward

battery to set up the trial. This allowed for increased ease of setup as the trial could be conducted a short distance away in the blast-hardened shelter preventing the need for additional cabling.

To set up the arena the group split into several teams to complete tasks concurrently. For the trial a series of metal stands were first placed against concrete blocks, this allowed for a solid support to place the strawboard panels to be placed on. These were arranged in an arc 113° wide to capture a large sample fragmentation and secured to the frames with pallet straps as shown in Figure 4.



Figure 4

While the strawboard was being set up in the arena another team prepared the blast gauges by attaching the nylon bush to the “mushroom” and securing the pressor sensor in the middle. These blast gauges were then secured to scaffold poles at incremental distances away from the OME stand, being 1m, 2m, and 3m away respectively as shown in Figure 5. The velocity foils were then attached to the strawboard using an adhesive backing with three being placed on each board to capture velocity data. To elevate the OME off the ground a spare strawboard pack was placed on the ground, the blast gauges were then adjusted so they were in line with where the OME would be. Additionally, the blast gages were staggered away from each other to the right to ensure uninterrupted readings from the blast wave. The distance between the gages and the OME stand was then checked with a laser measure to ensure distances were accurate.



Figure 5

After all data-gathering equipment was in place cables were then connected to the velocity foils and blast gauges were relayed back to the control room for the trial. These were then connected to the data recording equipment and control equipment. To protect the cables connecting to the pressure gages steel beams were placed over the top to prevent damage from fragmentation. The blast gauges were then tested before the trial to confirm functionality by lightly tapping the sensor. After this was complete the trial was ready to be carried out, the final arena setup can be seen in Figure 6. All members of the trial then returned to the control room and the unknown OME was placed on the centre of the stand and then detonated.



Figure 6

2.3 Post-Trial Data Gathering

After conducting the trial photos were first taken before disturbing the trial arena. After these photos were taken samples of fragmentation were collected from the strawboard. This was done by removing the straps securing the boards and removing the boards layer by layer. Using several hand tools and a knife. Every fragment that was found was then placed into plastic bags. The process of collecting the fragments can be seen in Figure 7. Additionally, the results gathered from the velocity foils and blast were then transferred from the data recorder to spreadsheet format.



Figure 7

3 Results

3.1 Fragmentation and FTIR Results

The fragments that were collected from the trial can be seen below in Figure 8. These fragments were made from steel and had a density of 7860 kgm^{-3} . A total of 138 fragments were collected with a mass of 154 g. This meant the average mass was 1.116 g additionally the average fragment area was 28.05 mm^2 and average thickness was 1.24 mm.



Figure 8

The results of the FTIR can then be seen in Figure 9. This shows the results from the swabs and analysis. Several peaks are shown that share similarities to that of a TNT FTIR sample.

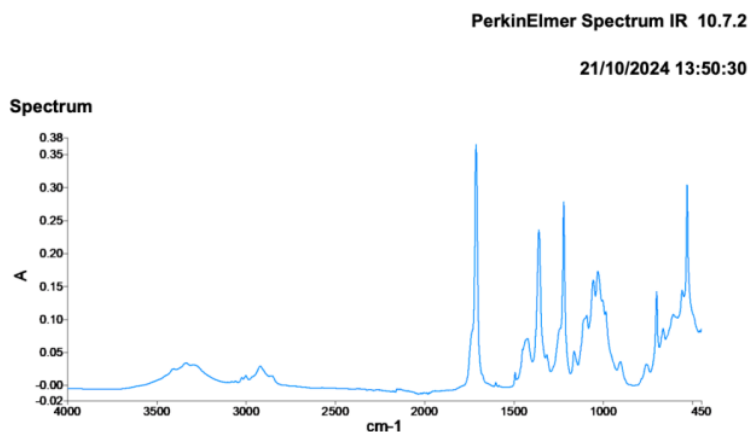


Figure 9

3.2 Velocity Results

The effect that the fragmentation had on the strawboard and velocity foils can be seen in Figure 10. From a visual inspection the fragmentation is widely distributed across the area. Because of this



Figure 10

most of the velocity foils were able to get one or more readings apart from one that was not hit.

Figure X shows the data gathered from the velocity foils, this table displays the Foil ID, which bay it was mounted on, the strike times, and the distance of the charge to the foil. Using the formular $v = d / t$ the velocity of the fragments at the point of impact can be calculated. By calculating this an average fragment velocity was then worked out for each individual foil. This can be seen in Figure 11 and was then plotted on the graph in Figure 12. Using the average velocity for each foil the mean of the averages was worked out as 1034.08m/s. This can also be seen plotted on the graph in figure 12 as the orange line.

Bay 1 Foil ID	Initial Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Distance from charge to foil (m)	Average Velocity (m/s)
1	1.14818	1.16342	1.20954	1.21438	1.22976	1.24564	1.635	1360.437
2	1.15358	1.16518	1.41908	1.91314	2.04420		1.609	1045.460
3	1.12476	1.14754	1.27588	1.29344	1.32382		1.570	1273.226
Bay 2 Foil ID	Initial Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Distance from charge to foil (m)	
4	1.14036	1.23266					1.531	1290.339
5	No Strike						1.605	
6	2.19952	2.27682					1.606	717.550
Bay 3 Foil ID	Initial Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Distance from charge to foil (m)	
7	1.08476	1.54112					1.554	1183.603
8	1.13296	1.18522	1.18648				1.518	1299.413
9	1.15976	1.2237	1.3647	1.41664			1.514	1172.553
Bay 4 Foil ID	Initial Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Additional Strike Time from Trigger (ms)	Distance from charge to foil (m)	
10	1.12384	1.26486	1.35510				1.529	1225.226
11	3.46030						1.612	465.856
12	4.64982						1.587	341.304
								1034.088

Figure 11



Figure 11

Figure 12

3.3 Blast Gauge Results

The data that was captured by the blast gauges was recorded first as voltage before being converted into pressure measured in kPa. This data was then transferred into excel so that the data could be plotted on graphs, however when first done the noise from the data set made these graphs hard to interpret. To Avoid this issue exponential smoothing was used, this was done by using a smoothing constant of 0.2 and equation shown in Figure 13. The set of original graphs can be seen on the left side and the filtered graphs on the right of Figure 14. This shows the recorded overpressure for each of the 3 gauges against time.

1	title=n1156083.dat Chi 2 3) (scaled) (zeroed)					
2	; Baseline offsets: 1) -136.68 2) 0.51216 3) 1.3526			Can be ignored		
3	; Applied scaling: 1) 0.008126 2) 0.008640 3) 0.008799			Sensitivities of each gauge (mV/kPa)	Smoothing Constant	0.2
4	xorg=-0.08			Sampling interval (4µs)		
5	xinc=4E-6			Gauge 1 Smoothing	Gauge 2 Smoothing	Gauge 3 Smoothing
6	Gauge 1 (1.003m)	Gauge 2 (2.036m)	Gauge 3 (3.016m)			
7	-0.638	0.070643	-0.052025	$=A7*SGS3+(1-SGS3)*D6$	0.0141286	-0.010405
8	-0.65722	0.035321	-0.052025	-0.2335944	0.01836708	-0.018729
9	-0.65722	0.052982	-0.069366	-0.31831952	0.025290064	-0.0288564
10	-0.65722	0.070643	-0.069366	-0.386099616	0.034360651	-0.03695832
11	-0.65722	0.070643	-0.052025	-0.440323693	0.041617121	-0.039971656
12	-0.676	0.088303	-0.052025	-0.487458954	0.050954297	-0.042382325
13	-0.65722	0.052982	-0.034683	-0.521411163	0.051359837	-0.04084246
14	-0.65722	0.035321	-0.034683	-0.548572931	0.04815207	-0.039610568
15	-0.65722	0.070643	-0.034683	-0.570302345	0.052650256	-0.038625054

Figure 13

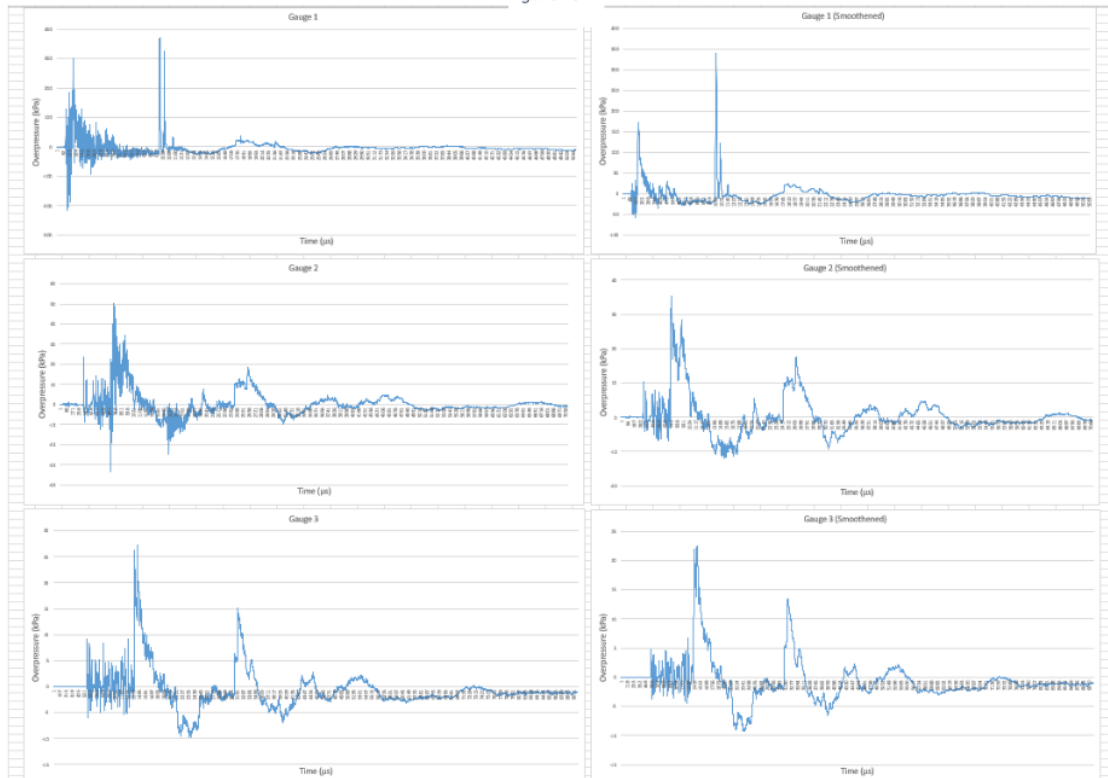


Figure 14

To only plot results relevant to the detonation only some of the data generated from the gauges was used. This was because the gauges started recording at the same time the signal was sent to detonate the charge, therefore there was a gap between the start of the recording and when the blast wave reached the gauge. An enlarged image of the results from the 3 gauges can be seen in Figure 17. The results show that it took approximately 79.92ms for the wave to reach the first gauge. Similarly, the pressure data after the event had ended is also not included.

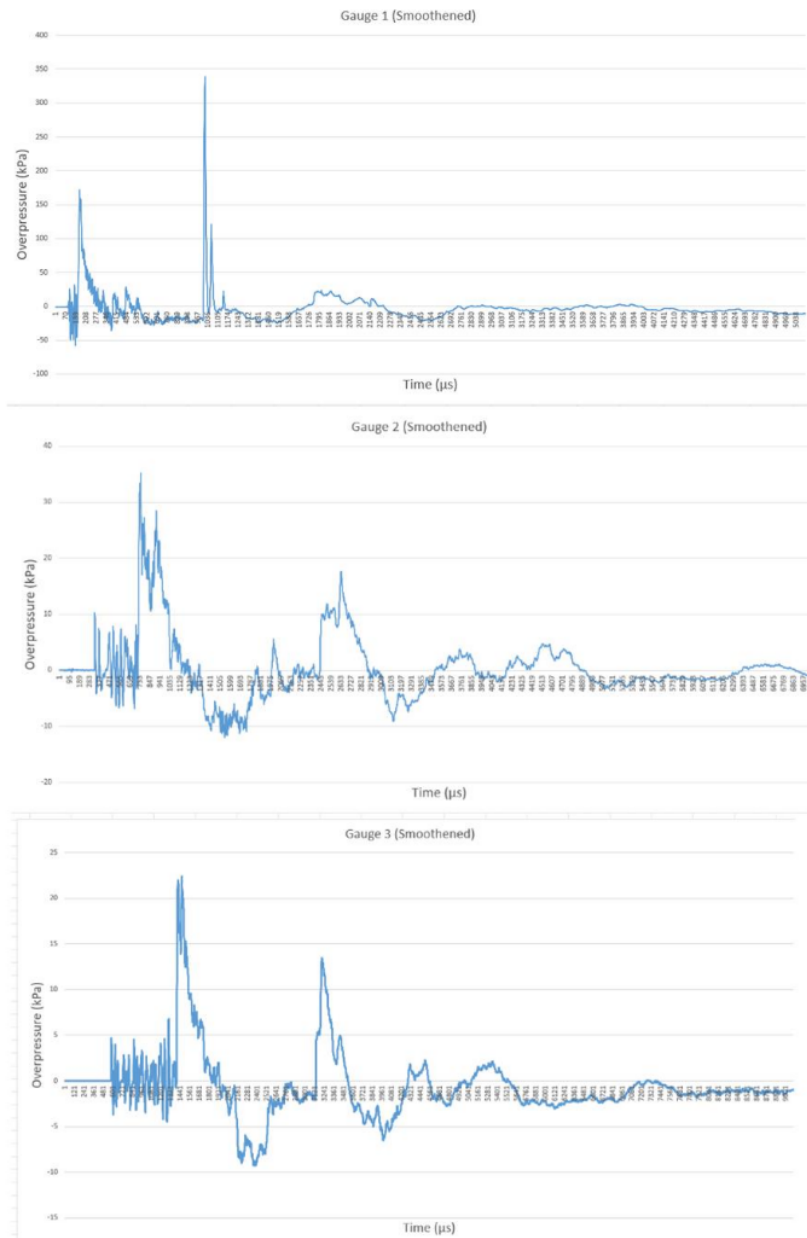


Figure 15

4 Discussion

4.1 Interpretation of results

From the results gathered Several key pieces of information can be found that are useful in identifying the munition used. This includes the type of fragments collected, Distribution of fragmentation, Velocity of fragmentation, velocity, of the blast wave, and chemical traces found. From the fragmentation collected this is an example of a preformed fragmentation weapon, this is due to the size and consistency of the fragments. Additionally, the fragmentation was confirmed to be steel with traces of copper, likely from the copper tracks of the velocity foil. With the average fragmentation size being 1.116g this also suggests a relatively small weapon. The FTIR results also indicate a trace of a secondary explosive such as TNT or HMX. This can be seen in Figure 18 which shows an example of a TNT FTIR graph.

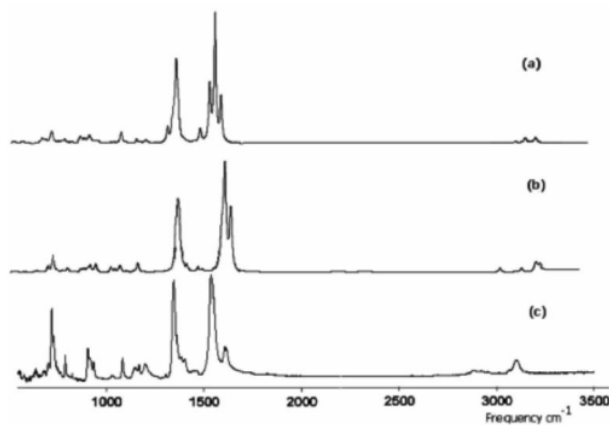


Figure 16

The results of the velocity testing have yielded a result of 1034.08m/s as the average velocity for fragmentation. However, this includes several anomalous results that struck the target much later than others. This could potentially be due to a ricochet traveling slower to impacting the ground first as no ricochet trap was used in the arena. Therefore, a more accurate fragment velocity would be 1200m/s.

The results of the blast gauges show that the blast wave reached an initial peak overpressure of 175kPa for the first blast gauge. The pressure on the gauge then rises above 340kPa which is likely due to the blast wave being reflected and concentrated on the first gauge. The results from the blast gauge show that it took approximately 79.92ms, 80.91ms, and 81.91ms to reach the 1st, 2nd and 3rd gauges. Therefore the velocity of the pressure wave can be worked out as traveling 1043.43m/s.

4.2 Ordinance Identification

Several munitions were listed as of potential interest this includes a Mk 83 air dropped munition, M-67 grenade, RGD-5 grenade, 81 mm Mortar AR-M81, RPG-7VL, 155mm, and a pipe bomb. From this list of munitions several can be easily discounted. The first of these is the Mk 83 air dropped munition; this is because the NEQ far exceeds the licence for the range. Additionally, the quantity of explosives used in the Mk 83 would have destroyed the arena. Another easily discounted munition is the 155mm shell as the fragmentation collected in the trial is far smaller than that which would be created by a large calibre shell. Additionally, the 81mm Mortar AR-M81 and the RPG PG-7VL as the stated fragment velocity is much higher than the recorded velocity.

Out of the final three stated munitions the pipe bomb is also an unlikely match as the stated fragment velocity is much higher than the recorded velocities at 1990m/s. Between the two final munitions both are very similar however the results gathered indicate a stronger probability of the RGD-5 grenade being the munition shown in figure 19. This is due to the stated velocity of fragments being closer to the recorded velocity in the RGD-5. Additionally, the average fragmentation mass is closer to the RGD-5 rather than the M-67. Finally, the FTIR results point to TNT being used as the explosive rather than Composition B.0



Figure 17

5 Conclusion

5.1 Summary of Trial

The trial conducted at COTEC utilised a variety of data capture techniques that were able to help identify an unknown munition. From the results gathered in the trial and the analysis that has since been conducted several different indicators have been shown that suggests this munition was an RGD-5 grenade. This grenade is an example of a post WW2 soviet anti-personnel fragmentation grenade and is still widely used. The conclusion is based on the data that has been gathered from fragmentation, velocity, and pressure all of which support this conclusion. The other potential munitions that the trial could have been conducted on have also be discounted by the results gathered due to distinct differences.

References

- [1] Cranfield, "Cranfield Ordnance Test and Evaluation Centre (COTEC)," [Online]. Available: <https://www.cranfield.ac.uk/Centres/Centre-for-Defence-Chemistry/Cranfield-Ordnance-Test-and-Evaluation-Centre?form=MG0AV3>. [Accessed 29 11 2024].
- [2] P. Q. S. B. R. H. R. C. James Read, "Sustainable and economical alternatives to fragment capture materials in explosive and ballistic trials," 23 February 2024. [Online]. Available: <https://dspace.lib.cranfield.ac.uk/server/api/core/bitstreams/181438a6-3a30-4112-b99d-aef24a8e3a95/content>.
- [3] COTEC, "Instrumentation," Cranfield University , [Online]. Available: <https://www.cotec.org.uk/instrumentation/>. [Accessed 10 12 2024].

Task 1

GRADEMARK REPORT

FINAL GRADE

64/100

GENERAL COMMENTS

Hi Alexander,

This was a good assignment, which identified the main culprit through logical interpretation. You have clearly understood the objectives of this coursework and how to capture and evaluate data. Please see my constructive comments below. A solid 2:1 mark here.

In detail:

1. Abstract okay, but you have misspelt ordnance. Probably your spell checker. Also, there is no harm saying that blast and fragmentation collection equipment was the trial equipment.
2. A good structure but please do not include a summary within a conclusion - see 5 and 5.1. A big no no of academic writing. Also, where is your list of tables and figures?
3. OME or OEM? Check para 1.2. To be doctrinally correct, we are looking at the 'M' of OME in this trial.
4. After you state *Figure 1*, use a colon and provide a caption of what the figure is representing.
5. Good use of trial imagery throughout. Well done.

6. If you can, try and use 'superscript' for your powers of units. mm² looks really odd, as does kgm⁻³.

7. 'one that was not hit' is not a scientific explanation at Level 6. Try 'one velocity foil was not perforated'.

8. I think you mean Figure 11 for Figure X. If you get used to using cross-references in word, then all of your tables and figures will automatically update by number.

9. Figure 11 is a bit small and clumsy to read. Why, for example, are there gaps for additional strike times in some areas and not in others?

10. Ultimately, your page with figures X(11) and 12 is confusing to follow. I have read it a couple of time now. The key information is the average velocity of 1034 m/s, although this will also account for erroneous measurements from fragment ricochet (velocities below, say 700 m/s).

11. To Avoid.....To avoid.....

12. The equation shown in Figure 13 is not very clear I'm afraid. If you have to use an equation, state it in the text and use the appropriate equation editor.

13. gathered Several.....collected,
Distribution.....Velocity of fragmentation....

14. For the FTIR analysis, you could have identified the absorption peaks, particularly the aromatic ring for TNT, which discounts RDX/HMX etc. You

should have used the FTIR trace in Figure 9, identifying the peaks as necessary.

15. You state the average velocity as 1034 m/s, but then state that 1200 m/s is a more accurate value. How do you know this? This is where you could have mentioned the anomalies with the lower velocities and then compared the higher velocities to the munitions of interest.

16. Yes, good knowledge of incident and reflected blast overpressure. The smoothing factor makes this much clearer. Therefore, what were are looking for is a munition with natural fragmentation that produces a peak incident overpressure of 175 - 200 kPa and velocities of 1200 m/s at specific distances. This discounts all but two grenades and the pipe bomb. Since para 14 above discounts Comp B, we are left with the RGD-5 and the pipe bomb.

17. Good knowledge to discount the obvious munitions that it could not be. Comp B.0? I agree your assessment of RGD-5 because of the fragmentation velocity, fragmentation size and explosive fill. You would also have expected to see a larger variance in fragmentation size from the pipe bomb and an obvious difference in steel quality etc.

18. Reasonable use of references. Could have cited more, specifically the equations used.

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