

ACDA6021 - Laboratory Report - Pete Down

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Laboratory Report: Data Capture and Analysis of an OME Item

ACDA6021: Data Capture and Evaluation Assignment

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Abstract

An arena trial was conducted with an unknown munition. Strawboards were used to collect fragments which were then analysed using FTIR to determine the identity of explosive residues. Velocity foils and blast overpressure gauges also collected data during the trial. This report analyses all the available information to identify the munition. The munition was likely an RGD-5 grenade.

Contents

Abstract	1
Contents	1
Table of Figures	2
Table of Tables	2
Table of Equations	2
Introduction	3
Methods and Materials.....	3
Results.....	4
Fragmentation.....	4
Velocities	6
Blast Overpressure.....	7
FTIR Data	9
Discussion	11
Fragmentation.....	11
Velocities	11
Blast Overpressure.....	12
FTIR Data	12
Determining The Type of Munition.....	14
Conclusion.....	15
References	16
Appendix A – Known Information About OME Articles.....	18
Appendix B – Velocity Data	19

Table of Figures

Figure 1: Arena setup for unknown munition, including Blast Overpressure (BOP) gauges, strawboards, and velocity foils.	4
Figure 2: Fragmentation collected from strawboards 2.	5
Figure 3: Velocity foil post-trial. Copper coated fragment can be seen with similar pattern adjacent to location of penetration.	5
Figure 4: Velocity data and calculated average, spread, and determine outlier data.	6
Figure 5: Blast Overpressure at BOP Gauges (1.003m, 2.036m, 3.016m).	7
Figure 6: FTIR trace for fragmentation bathed in 99% acetone.....	9
Figure 7: FTIR trace for 2-Phenol (Acetone) [7].....	10
Figure 8: FTIR trace for TNT [8].....	10
Figure 9: FTIR trace for RDX [9].	11
Figure 10: FTIR trace for HMX [10].	11
Figure 11: Velocity foil layout prior to trial.	12
Figure 12: FTIR trace for phenol [15].....	13

Table of Tables

Table 1: TOA of blast wave, incident overpressure, and first three reflected overpressures.	7
Table 2: TNT equivalence of all charges used in munitions.	8
Table 3: Calculated incident overpressure for each munition at each gauge.....	9
Table 4: Peaks from FTIR trace for fragmentation bathed in 99% acetone.	9

Table of Equations

Equation 1: Mass of bare explosive equivalent charge [2].....	8
Equation 2: Scaled distance [5].	8
Equation 3: Incident overpressure [6].	8

Introduction

The author was involved with an arena trial for an unknown munition and has been tasked with identifying it. The trial was conducted at the COTEC range. The trial setup, equipment, and layout will be described in this report. Data gathered from the trial will be discussed to help identify the munition. The munition is one of the following articles:

- Mk 83 air dropped munition.
- M-67 grenade.
- RGD-5 grenade.
- 81mm Mortar AR-M81.
- RPG PG-7VL.
- 155mm.
- Pipe bomb.

Appendix A contains information about these munitions.

Fragments captured by the strawboards were collected and analysed. This included taking swabs and performing Fourier Transform Infrared (FTIR) analysis to determine the nature of any explosive residue.

Methods and Materials

Arena trials are used to determine the fragmentation performance of a munition. This is done using strawboards – sheets manufactured into a rigid structure by pressing paper together [1]. Fragments become embedded within the strawboards, and as the properties of strawboard are well understood, the penetration performance of the fragmentation can be assessed. In this trial, four sets of strawboards were set up around the munition and one beneath it, see Figure 1. They were 1.2m high and covered an arc of 113°. This layout would not capture all the fragments, assuming fragmentation is omnidirectional. By assuming fragments behave the same way omnidirectionally, average fragment mass could be extrapolated to estimate case mass.

Strawboards may be reused if they have relatively few holes in them. Existing holes are clearly marked prior to the trial meaning unmarked holes have been created by the unknown munition.

Once the trial is completed, the strawboard packs are split into their individual sheets. The number of fragments in each sheet is recorded to determine the depth of penetration. All fragments are then collected in bags for further analysis.



Figure 1: Arena setup for unknown munition, including Blast Overpressure (BOP) gauges, strawboards, and velocity foils.

To assist in the assessment of fragmentation effectiveness, three velocity foils were set up on each strawboard (12 total), see Figure 1. When hit by fragments, the strike time is recorded. As the distance from the munition is also known, the velocity of the fragments can be calculated.

To measure blast overpressure and Time of Arrival (TOA), BOP gauges were set up 1m, 2m, and 3m away from the munition respectively, see Figure 1. They record changes in air pressure due to the blast wave. By using three gauges at known distances, the velocity of the blast wave can be determined.

Fragments were placed into solvents and agitated to remove explosive residues. These were then analysed using FTIR analysis. The solvents used were Isopropyl Alcohol (IPA) and acetone, however the FTIR trace for IPA didn't change indicating no explosive residues were dissolved. The FTIR trace from the acetone sample is therefore used.

Results

Fragmentation

138 fragments were collected from the strawboard pack after the trial, see Figure 2.



Figure 2: Fragmentation collected from strawboards.

The overall mass of the fragments is 154g which gives a mean mass of 1.116g for each fragment. The average area of fragments is 28.05mm².

The fragment material has been determined to be steel. Some fragments appear to be coated in copper, see Figure 3. The copper appears to be from the velocity foils rather than the munition itself.

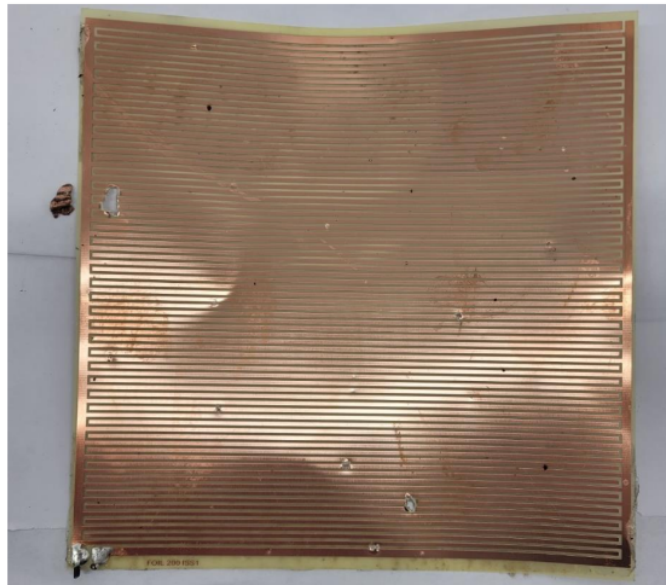


Figure 3: Velocity foil post-trial. Copper coated fragment can be seen with similar pattern adjacent to location of penetration.

The average fragment thickness has been measured to be 1.24mm. This indicates the munition had a case of similar thickness.

Depth of penetration of fragments within each strawboard was not recorded.

Velocities

Appendix B contains the TOA and velocity for each fragment impact against a velocity foil.

Velocity foils were arranged between 1.514m and 1.635m away from the munition. By dividing the distance between the munition and the foil, by the TOA of each fragment, an average fragment velocity can be calculated. As only the TOA and distance is known, neither initial velocity nor velocity at time of impact is measured using this method, and the average velocity over that distance is calculated instead. Figure 4 shows the average velocities calculated.

Foil	Averaged Velocity (ms ⁻¹)
12	341.3
11	465.9
6	705.4
6	730.2
2	787.1
2	841.0
7	1008.4
9	1068.7
9	1109.4
10	1128.3
2	1133.8
3	1186.0
10	1208.8
3	1213.8
3	1230.5
9	1237.2
4	1242.0
8	1279.4
8	1280.8
9	1305.4
1	1312.6
1	1329.5
8	1339.9
4	1342.6
1	1346.4
1	1351.8
10	1360.5
3	1368.1
2	1380.9
2	1394.8
3	1395.9
1	1405.3
1	1424.0
7	1432.6

Max and Min Values	
Minimum Value:	341.3
Maximum Value:	1432.6

Quartile Information	
Quartile 1:	1114.1
Quartile 3:	1350.4
Inter-Quartile Range (IQR):	236.3

Calculate Outliers	
IQR x 1.5:	354.4
Q1 - (IQR x 1.5):	759.7
Q3 + (IQR x 1.5):	1704.8

Average	
Median Value:	1242.0
Mean (full dataset):	1167.3
Mean (without outliers):	1248.2

Spread	
Range (full dataset):	1091.3
Range (without outliers):	645.5
Standard deviation (full dataset):	272.7
Standard deviation (without outliers):	158.4

Figure 4: Velocity data and calculated average, spread, and outlier data.

By calculating the Inter-Quartile Range (IQR), statistical outliers can be determined. This dataset includes four statistical outliers that are below 759.7ms⁻¹. The median is 1242ms⁻¹ and the mean for

the full dataset is 1167.3ms^{-1} . The range shows that there is a difference of 1091.3ms^{-1} between the maximum and minimum average velocity.

Blast Overpressure

Blast overpressure was measured using three Kistler 211B5 pressure sensors at distances of 1.003m, 2.036m, and 3.016m away from the munition respectively. Figure 5 shows the pressure changes measured by the pressure sensors.

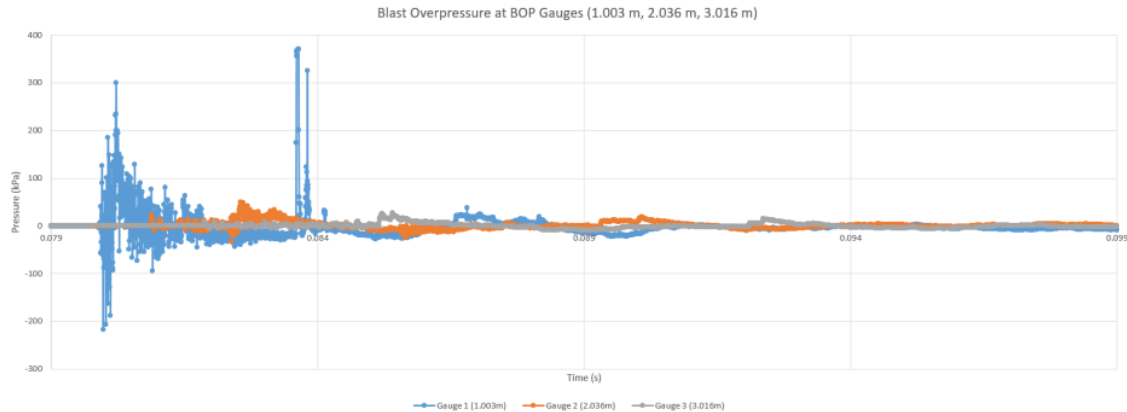


Figure 5: Blast Overpressure at BOP Gauges (1.003m, 2.036m, 3.016m).

Figure 1 shows how the BOP gauges/pressure sensors were set up. Extracting the information about the blast wave from Figure 5, Table 1 shows the TOA, the incident overpressure, and the first three reflected overpressures at each gauge.

	Units	Gauge 1	Gauge 2	Gauge 3
Time of Arrival (TOA)	s	0.0799	0.0809	0.0819
Incident Pressure	kPa	299.82	23.418	9.1390
Time of Incident Pressure	s	0.0802	0.0809	0.0819
1st Reflected Pressure	kPa	370.24	50.403	27.139
Time of 1st Reflected Pressure	s	0.0836	0.0826	0.0854
2nd Reflected Pressure	kPa	325.14	34.120	15.174
Time of 2nd Reflected Pressure	s	0.0838	0.0832	0.0924
3rd Reflected Pressure	kPa	37.386	18.491	2.7920
Time of 3rd Reflected Pressure	s	0.0868	0.0901	0.0975

Table 1: TOA of blast wave, incident overpressure, and first three reflected overpressures.

Using the distance between gauges and the TOA of the blast wave, velocities can be calculated. The average velocity between Gauges 1 and 2 was 1033ms^{-1} and between Gauges 2 and 3 was 980ms^{-1} .

Incident overpressure caused by each munition can be calculated. This requires calculating the mass of bare explosive equivalent charge, then scaled distance, then the incident overpressure.

$$W_b = 1.19 \left(\frac{1 + M_r(1 - M_c)}{1 + M_r} \right) (c)$$

Equation 1: Mass of bare explosive equivalent charge [2].

W_b = The mass of bare explosive equivalent charge.

M_r = The case to charge mass ratio.

M_c = Fragment to charge mass ratio (=1 when $M_r > 1$).

c = Mass of case.

W_b is used to calculate blast effects with the remaining energy left over after the case has been shattered.

Calculating scaled distance requires the TNT equivalence (TNTe). The TNTe factors of Composition B (CompB) and HMX are 1.07 by heat and 1.45 respectively [3] [4]. Table 3 shows the W_b calculated using equation 1 and the TNTe factors values.

Munition	W_b (kg)	TNTe Factor	TNTe Value (kg)
M83	132.6955	1.07	141.9842
M-67	0.1023	1.07	0.1095
RGD-5	0.0464	1.00	0.0464
AR-M81	0.3282	1.00	0.3282
RPG PG-7VL	0.2722	1.45	0.3946
155mm	0.3699	1.07	0.3958
Pipe Bomb	0.1190	1.00	0.1190

Table 2: TNT equivalence of all charges used in munitions.

The scaled distance at each pressure sensor for each munition is calculated using Equation 2.

$$Z = \frac{D}{\sqrt[3]{C_{TNTe}}}$$

Equation 2: Scaled distance [5].

Z = Scaled distance.

D = Distance.

C_{TNTe} = TNTe value of the charge mass.

Incident overpressure at each pressure sensor for each munition is calculated using Equation 3.

$$P_s = \frac{P_a(808) \left(1 + \left(\frac{Z}{4.5} \right)^2 \right)}{\sqrt{1 + \left(\frac{Z}{0.048} \right)^2} \times \sqrt{1 + \left(\frac{Z}{0.32} \right)^2} \times \sqrt{1 + \left(\frac{Z}{1.35} \right)^2}}$$

Equation 3: Incident overpressure [6].

P_s = Incident overpressure.

P_a = Atmospheric pressure.

Z = Scaled distance.

Table 4 shows the incident overpressure of each munition at the distance of each pressure sensor.

Munition	Gauge 1 (1.003 m) (kPa)	Gauge 2 (2.036 m) (kPa)	Gauge 3 (3.016 m) (kPa)
M83	16860.0	6133.3	3065.5
M-67	186.3	39.7	19.6
RGD-5	96.7	23.4	12.7
AR-M81	436.3	85.4	37.6
RPG PG-7VL	502.2	97.9	42.4
155mm	503.3	98.1	42.5
Pipe Bomb	198.7	41.9	20.5

Table 3: Calculated incident overpressure for each munition at each gauge.

FTIR Data

Figure 6 shows the FTIR trace for the fragmentation bathed in acetone.

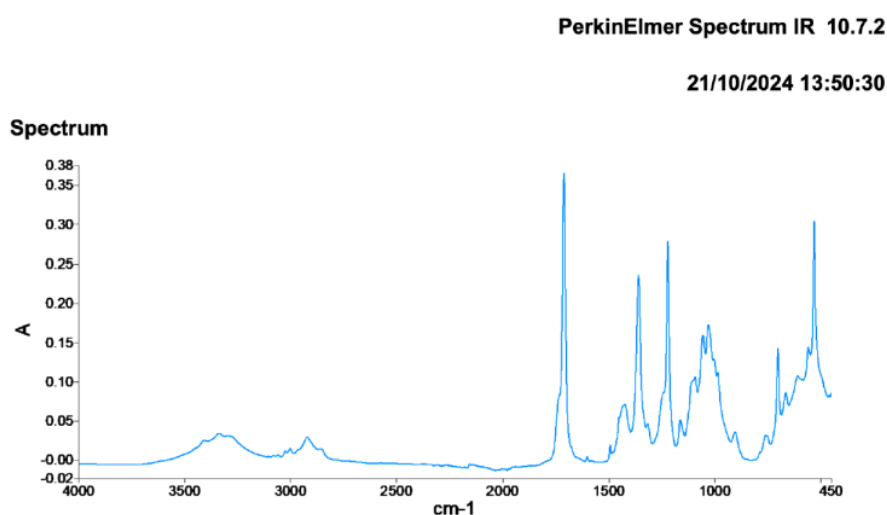


Figure 6: FTIR trace for fragmentation bathed in 99% acetone.

Table 2 shows the peaks from the FTIR trace.

Wavenumber (cm ⁻¹)	Peak Start (cm ⁻¹)	Peak End (cm ⁻¹)	Peak Width (cm ⁻¹)	Absorbance (%)
3350	3200	3500	300	4
2920	2850	2980	130	4
1740	1700	1780	80	37
1450	1425	1475	50	7
1380	1325	1425	100	24
1230	1190	1290	100	28
1030	880	1180	300	17
710	660	760	100	14.5
520	450	650	200	30

Table 4: Peaks from FTIR trace for fragmentation bathed in 99% acetone.

The FTIR trace will show peaks for acetone and either TNT, RDX/TNT, or HMX depending on the munition. Figures 7, 8, 9, and 10 show the FTIR traces for acetone, TNT, RDX, and HMX respectively.

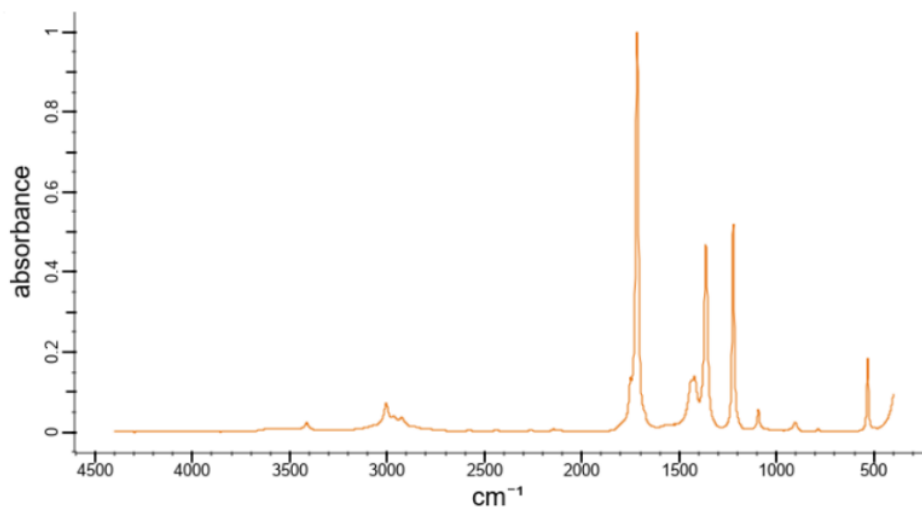


Figure 7: FTIR trace for 2-Phenol (Acetone) [7].

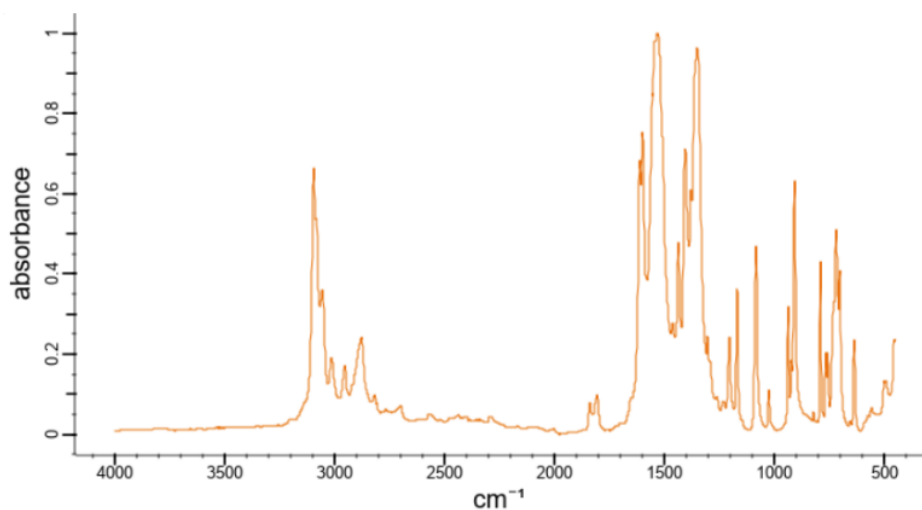


Figure 8: FTIR trace for TNT [8].

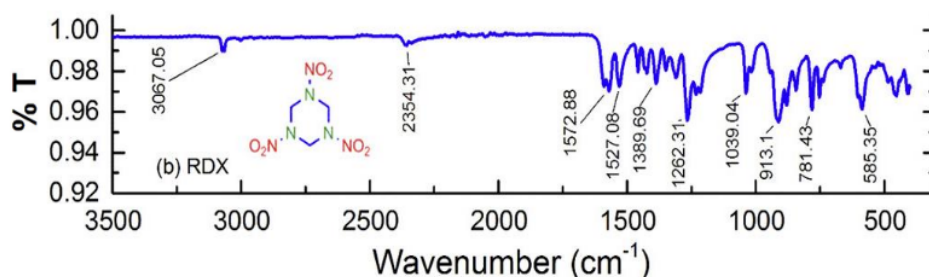


Figure 9: FTIR trace for RDX [9].

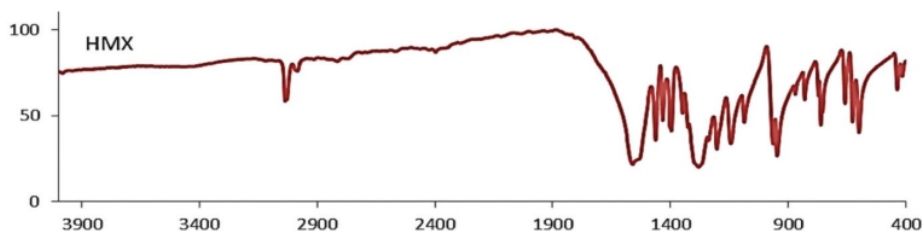


Figure 10: FTIR trace for HMX [10].

Discussion

Fragmentation

Strawboards covered an arc of 113° and were also below the munition. This leaves an arc of 247° and the area above the munition uncovered. Therefore, the total number of fragments is likely between two and five times greater than 138 – between 276 and 690 fragments. This provides an estimated case mass of between 308g and 768g. This estimate relies on the assumption that the munition distributed fragments omnidirectionally. This is a useful, but likely inaccurate assumption as candidate munitions take different forms and contain components such as fuzes that affect the fragmentation nature in that direction.

Velocities

Four of the fragment velocities measured were found to be statistical outliers. Their velocities were significantly lower than average. Figure 7 shows the layout of the velocity foils.



Figure 11: Velocity foil layout prior to trial.

The outlying fragments impacted foils 6, 11, and 12 which are at the top of their respective strawboards. The most likely explanation is that the statistical outliers were larger fragments and thus travelled slower. Therefore, those fragments should not be considered outliers and should be included in analysis of fragment velocity.

The highest fragment velocity was 1432.6ms^{-1} . Without knowing the mass of this fragment, it is difficult to relate to the fragment velocity for each munition as the fragment slow down equation relies on an average fragment mass.

Blast Overpressure

The incident overpressures measured at Gauges 1, 2, and 3 are 299.8kPa, 23.4kPa, and 9.1kPa respectively. The day the trial took place was overcast and the relative humidity was high (no record made). This likely increased the blast wave pressure at distance as cool humid air is denser than hot dry air.

FTIR Data

Acetone is known to be in the sample FTIR trace. The functional groups determined to be relevant are the C=O carbonyl group and the CCC stretch bond. The former absorbs in the 1665cm^{-1} – 1760cm^{-1} region and produces an intense peak which matches the sample peak at 1740cm^{-1} [11]. The latter absorbs at 1228cm^{-1} making it the likely cause of the sample peak at 1230cm^{-1} [12].

The FTIR trace for acetone also closely matched the sample peaks at 3350cm^{-1} , 1450cm^{-1} , 1380cm^{-1} , and 520cm^{-1} although it is unclear which functional groups are responsible for this. The FTIR trace for acetone also had peaks at 3000cm^{-1} , 1095cm^{-1} , and 900cm^{-1} although these are not seen in the sample trace.

Acetone is commonly manufactured using the Cumene process [13]. This also produces phenol (hydroxybenzene) and may contaminate the acetone. Phenol has a O-H stretching vibration functional group which produces a significant peak between 3100cm^{-1} and 3600cm^{-1} , see Figure 12 [14]. If the acetone used had some phenol contamination, the O-H functional group would be responsible for the sample peak at 3350cm^{-1} .

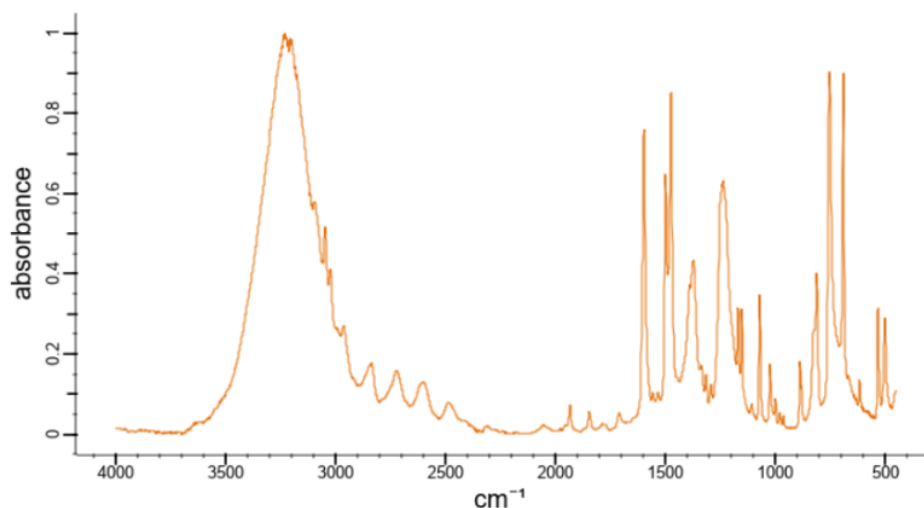


Figure 12: FTIR trace for phenol [15].

The FTIR trace for phenol closely matches the sample peaks at 1450cm^{-1} , 1380cm^{-1} , 1230cm^{-1} , and 520cm^{-1} although it is unclear which functional groups cause this. The FTIR trace for phenol also has peaks at 1600cm^{-1} , 1070cm^{-1} , 800cm^{-1} , 750cm^{-1} , and 690cm^{-1} but there is little evidence of these in the sample trace.

TNT has two functional groups that appear to be represented. The CH_3 symmetrical stretch functional group is responsible for a peak from 2866cm^{-1} – 2926cm^{-1} which matches the sample peak found at 2920cm^{-1} [16]. The NO_2 symmetric functional group is responsible for a peak between 1330cm^{-1} and 1390cm^{-1} which matches the sample peak found at 1380cm^{-1} [16]. The NO_2 symmetric group is found in HMX and RDX also and is therefore unhelpful in determining the explosive residue.

The TNT FTIR trace matches the sample peak at 710cm^{-1} but the functional group for this is unclear. The FTIR trace for TNT also has peaks at 3090cm^{-1} , 1800cm^{-1} , 1600cm^{-1} , 1520cm^{-1} , 1400cm^{-1} , 1170cm^{-1} , 1090cm^{-1} , 900cm^{-1} , 790cm^{-1} , and 620cm^{-1} which are not found in the sample trace.

Besides the NO_2 group already discussed, no relevant functional groups of RDX have been identified. The FTIR trace for RDX closely matches the sample peaks at 1380cm^{-1} , 1230cm^{-1} , and 1039cm^{-1} although the functional groups responsible are unclear. The FTIR trace for RDX also has peaks at 3067cm^{-1} , 2354cm^{-1} , 1572cm^{-1} , 1527cm^{-1} , 913cm^{-1} , 781cm^{-1} , and 585cm^{-1} that are not seen in the sample trace.

Aside from the NO_2 group, no relevant functional groups of HMX have been identified. The FTIR trace for HMX closely matches the sample peaks at 1450cm^{-1} and 1380cm^{-1} although the functional groups responsible are unclear. The FTIR trace for HMX also has peaks at 3035cm^{-1} , 1561cm^{-1} , 823cm^{-1} , and 550cm^{-1} that are not seen in the sample trace.

There is some evidence for each possible explosive material, however the most likely candidate is TNT as two functional groups have been identified as being in the sample trace. This is insufficient to determine whether the explosive residue is just TNT or CompB which is composed of 40% TNT. There is some evidence of RDX being present such as shared peaks with the sample trace, but it is not sufficient to determine if it is present. There is little evidence that HMX is present.

Determining The Type of Munition

The munition is unlikely to be the M83 Bomb due to the nature of the fragmentation. The average mass of fragment was 1.116g which is significantly lower than the 115g per M83 fragment. The estimated case mass is between 308g and 616g whereas the M83 case mass is 229kg. These comparisons are sufficient to dismiss the M83 Bomb as a candidate for the munition.

The M-67 Grenade has a case mass of 213g which is below the estimated mass of between 308g and 768g. With an average fragment mass of 2g, there would only be an average of 107 fragments formed. The estimated number of fragments of the munition is between 276 and 690. The explosive used is CompB which may be consistent with FTIR analysis of the explosive residue. The fragment velocity at 1.5m is 1766ms^{-1} which is significantly higher than the highest measured fragment velocity of 1432ms^{-1} . The measured incident overpressures at Gauges 1, 2, and 3 are 299.8kPa, 23.4kPa, and 9.1kPa respectively. By contrast, the M-67 overpressures were calculated at 186.3kPa, 39.7kPa, and 19.6kPa respectively which is not a good match for the measured data. Overall, the munition is unlikely to be the M-67 Grenade.

The RGD-5 Grenade has a case mass of 200g which is below the estimated mass of between 308g and 768g. With an average fragment mass of 0.29g, there would only be an average of 689 fragments formed. The estimated number of fragments of the munition is between 276 and 690. The explosive used is TNT which may be consistent with FTIR analysis of the explosive residue. The fragment velocity at 1.5m is 1326ms^{-1} which is firmly between the maximum measured velocity of 1432ms^{-1} and the average fragment velocity of 1167ms^{-1} . The measured incident overpressures at Gauges 1, 2, and 3 are 299.8kPa, 23.4kPa, and 9.1kPa respectively. The incident overpressure of 96.7kPa calculated for Gauge 1 is significantly lower than the measured value, but the values for Gauges 2 and 3 are very close at 23.4kPa and 12.7kPa respectively. The M-67 Grenade is a good match for the munition.

The AR-M81 Mortar has a case mass of 1.334kg which is approximately double the maximum expected value. The explosive used is TNT which may be consistent with FTIR analysis of the explosive residue. The fragment velocity at 1m is 1700ms^{-1} which is significantly greater than the measured fragment velocities. The calculated overpressure are significantly higher than the measured values at 436.3kPa, 85.4kPa, and 37.6kPa respectively. The poor fit of the evidence suggests the munition is not an AR-M81 Mortar.

The RPG PG-7VL has an HMX/Wax 95/5 filling. FTIR analysis of explosive residue on fragmentation found no evidence suggesting the explosive was HMX based. The initial fragment velocity is 1831ms^{-1} which is significantly higher than the measured fragment velocities. The average fragment mass of 0.1g is about 10 times smaller than the munition's average fragment mass of 1.113g. These factors suggest that the munition is not an RPG PG-7VL.

The 155mm has a case mass of 3.105kg which is above the expected case mass. The average fragment mass of 2.1 is close the munition's average fragment mass of 1.113g. The explosive used is CompB which may be consistent with FTIR analysis of the explosive residue. The initial fragment velocity is 1551ms^{-1} which is only slightly greater than the measured velocities. Variation and fragment slow down over 1.5m may be sufficient to account for the difference. The calculated overpressures are significantly higher than the measured values at 503.3kPa, 98.1kPa, and 42.5kPa respectively. The incident overpressures and the overall case mass make this a poor fit for the munition data.

The Pipe Bomb has a case mass of 200g which is below the estimated mass of between 308g and 768g. With an average fragment mass of 0.23g, the number of fragments would be 870 which is slightly higher than the upper estimate of 690 fragments. The explosive used is TNT which may be consistent with FTIR analysis of the explosive residue. The initial fragment velocity is 1990ms^{-1} which is significantly higher than the measured fragment velocities. The calculated overpressure are higher than the measured values at 198.7kPa, 41.9kPa, and 20.5kPa respectively. The higher overpressures and the high fragment velocity indicate the munition is not a Pipe Bomb.

Conclusion

The best candidate for the munition is the RGD-5. It fits almost all the experimental data, with the exceptions of a low case mass and a low incident overpressure value at Gauge 1. The case mass could be partially explained by variation in fragment properties skewing the estimated mass. Another contributing factor may be existing fragments within the strawboard as some had been used for previous trials.

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Appendix A – Known Information About OME Articles

This information has been provided to help identify the unknown munition.

	Units	M83 Bomb	M-67 Grenade	RGD-5 Grenade	AR-M81 Mortar	RPG PG-7VL	155 mm	Pipe Bomb
Charge Mass	kg	225	0.185	0.110	0.76	0.730	1.150	0.200
Mass of Case	kg	229	0.213	0.200	1.334	1.600	3.105	0.200
Total Mass	kg	454	0.398	0.310	4.15	1.975	4.255	0.400
Explosive	-	Composition B	Composition B	TNT	TNT	HMX/Wax 95/5	Composition B	TNT
Density of Air	kgm ⁻³	1.23	1.29	1.29	1.23	1.29	1.29	1.29
Average Fragment Area	cm ²	0.48	1.0	1.0	-	-	-	-
Average Fragment Mass	g	115	2	0.29*	-	0.1	2.1	0.23
Fragment Drag Coefficient	-	0.82	0.5	0.5	1.6	-	-	0.5
Number of Fragments	-	1191*	107*	689*	-	-	1479*	870*
Fragment Initial Velocity	ms ⁻¹	1950	1807*	1567	1734	1831.5	1551	1990
Fragment Velocity @1m	ms ⁻¹	-	-	-	1700	-	-	-
Fragment Velocity @1.5m	ms ⁻¹	-	1766*	1326*	-	-	-	-
Fragment Velocity @4m	ms ⁻¹	-	-	-	1600	-	-	-
Fragment Velocity @5m	ms ⁻¹	-	1674	-	-	-	-	-
Fragment Velocity @15m	ms ⁻¹	-	1424	-	-	-	-	-
Fragment Velocity @20m	ms ⁻¹	-	-	-	1150	-	-	-
Fragment Velocity @32m	ms ⁻¹	-	-	-	900	-	-	-
Fragment Velocity @77m	ms ⁻¹	-	-	-	357	-	-	-
Fragment Velocity @92m	ms ⁻¹	1911	-	-	-	-	-	-
Fragment Velocity @230m	ms ⁻¹	-	44	-	-	-	-	-

* Value is calculated.

Appendix B – Velocity Data

Foil ID	Distance from Munition to Foil m	Strike Time 1 from Trigger ms	Velocity of Fragment ms ⁻¹	Strike Time 2 from Trigger ms	Velocity of Fragment ms ⁻¹	Strike Time 3 from Trigger ms	Velocity of Fragment ms ⁻¹	Strike Time 4 from Trigger ms	Velocity of Fragment ms ⁻¹	Strike Time 5 from Trigger ms	Velocity of Fragment ms ⁻¹	Strike Time 6 from Trigger ms	Velocity of Fragment ms ⁻¹
1	1.635	1.14818	1424.0	1.16342	1405.3	1.20954	1351.8	1.21438	1346.4	1.22976	1329.5	1.24564	1312.6
2	1.609	1.15358	1394.8	1.16518	1380.9	1.41908	1133.8	1.91314	841.0	2.04420	787.1	-	-
3	1.570	1.12476	1395.9	1.14754	1368.1	1.27588	1230.5	1.29344	1213.8	1.32382	1186.0	-	-
4	1.531	1.14036	1342.6	1.23266	1242.0	-	-	-	-	-	-	-	-
5	1.605	-	-	-	-	-	-	-	-	-	-	-	-
6	1.606	2.19952	730.2	2.27682	705.4	-	-	-	-	-	-	-	-
7	1.554	1.08476	1432.6	1.54112	1008.4	-	-	-	-	-	-	-	-
8	1.518	1.13296	1339.9	1.18522	1280.8	1.18648	1279.4	-	-	-	-	-	-
9	1.514	1.15976	1305.4	1.2237	1237.2	1.3647	1109.4	1.41664	1068.7	-	-	-	-
10	1.529	1.12384	1360.5	1.26486	1208.8	1.35510	1128.3	-	-	-	-	-	-
11	1.612	3.46030	465.9	-	-	-	-	-	-	-	-	-	-
12	1.587	4.64982	341.3	-	-	-	-	-	-	-	-	-	-

ACDA6021 - Laboratory Report - Pete Down

GRADEMARK REPORT

FINAL GRADE

82/100

GENERAL COMMENTS

Hi Peter,

This was a well written laboratory report, and I particularly liked the abstract, which stated 'likely'. As you know, there were simply insufficient trials to determine a positive identification. You clearly understand how to capture and evaluate data, and draw sound conclusions. Overall, this is strongly deserving of the 82% awarded. Please find constructive comments below.

In detail:

1. Layout good and easy to follow. Great use of figures, tables and equations.
2. You wrote in the past tense for the most part, less reflection, which was the appropriate methodology for the assessment. Try to be consistent though.
3. Strawboards may be re-used but this does invoke error as we observed in this trial with the presence of 'additional' fragmentation that was caught between some of the sheets.
4. What did you mean by BOP? This acronym was introduced but did not have its full name stated. As such a list of acronyms would have been useful. I know what you mean but Marker 2 or the External may not.

5. For Figure 4, try and list all the foil numbers sequentially. You have focused on lowest to highest velocity in column 2, but I do not get a feel what what precisely happened at each location. Unless I misunderstood and you have used total number of fragments in column 1. If so, total please at the bottom or clearer description. I really liked your accompanying tables in Figure 4 as they did give me a feel for what was good and bad data.

6. Yes, it would have been good to have some indication of initial fragment velocity. We can theorise this knowing the explosive and case thickness.

7. Figure 5 and Table 1 were very clear and told me a lot about the blast waves (both incident and reflected). You were the only student to really drill into scaled distance, which can be manipulated using various equations to determine more information about the munitions. Your Wb's are all correct.

8. Your discussion is very detailed, with appropriate assumptions. For example, you did not know the mass of the fragment with the highest velocity, or the distance of the munition above ground to determine the exact nature of the blast waves.

9. Very detailed referencing throughout, which demonstrates how much additional research was conducted. Well done.

10. For the FTIR trace, the key fingerprint relates to the aromatic ring in the TNT, which was the pivotal identifier for TNT.

11. Excellent discussion on the elimination of certain munitions and the drawdown to the

grenades and pipe bomb. The overpressures were actually a good match for the RGD-5 above all others.

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20
