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FINAL YEAR PROJECT

*"THE EFFICACY OF EXPLOSIVE TRACE DETECTION KITS FOR
IDENTIFYING UNKNOWN SAMPLES DURING BREAKDOWN OF
ORDNANCE, MUNITIONS, AND EXPLOSIVES"*

by

Andrew R Hurley

1st Supervisor: Jenni Steen

2nd Supervisor: Dave Holley

Project submitted as part of the requirements for the award of BEng (Hons)

"OME: Breakdown and Disposals."

22nd of March 2024

Declaration of Originality

I, Andrew Robert Hurley declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

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1 ABSTRACT

- 1.1.1.1 This paper investigates the effectiveness of Explosive Trace Detectors (ETDs) in identifying pure and impure samples of energetics found during munitions breakdown processing. Presenting an in depth discussion surrounding the challenges faced by the Munitions Breakdown Team (MBT) in identifying unknown samples and the potential benefits of using ETDs in this context.
- 1.1.1.2 The research found that 1 mg of energetic sample, pure or impure, is an adequate sample size to indicate positively with the automated colourimetry ETD. The use of ETDs within the munitions breakdown context will save time and money for QinetiQ and its customers.
- 1.1.1.3 Further research is recommended to ascertain whether two separate explosives on one swab would be distinguishable from one another, and expansion to the reports knowledge by using the Expray dropper bottles covering chlorate, bromate and peroxide based energetics.

2 KEYWORDS

- 2.1.1.1 – *Explosive Trace Detection, Munitions Breakdown, Automated Colourimetry.*

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5 LIST OF ABBREVIATIONS

5.1.1.1	BTCA	– Breakdown, Testing and Critical Analysis
	DB	– Double Base
	DSA	– Defence Safety Authority
	ETD	– Explosive Trace Detector
	GC/IMS	– Gas Chromatography/Ion Mobility Spectrometry
	GLP	– Good Lab Practice(s)
	HE	– High Explosive
	HPMS	– High Pressure Mass Spectrometry
	HSE	– Health and Safety Executive
	IMS	– Ion Mobility Spectrometry
	KBr	– Potassium Bromide
	MBT	– Munitions Breakdown Team
	NC	– Nitrocellulose
	NG	– Nitroglycerine
	NQ	– Nitroguanidine
	OME	– Ordnance, Munitions and Explosives
	PPE	– Personal Protective Equipment
	RD1303	– Lead Styphnate
	RD1337	– Lead 2,4 Dinitroresorcinat
	SB	– Single Base
	S3	– Safety and Suitability for Service
	TB	– Triple Base
	VP	– Vapour Pressure

6 PREFACE

6.1 Introduction

6.1.1.1 Explosives have had civilian and military applications since the 10th century, evolving from gunpowder fireworks to lethal packages used during wartime by armed forces worldwide [1]. In recent years within the United Kingdom, these items of Ordnance, Munitions and Explosives (OME) have undergone various trials and tests to demonstrate their Safety and Suitability for Service (S3) within the armed forces [2].

6.1.1.2 The Munitions Breakdown Team (MBT) at QinetiQ Fort Halstead are vital to the Breakdown, Testing and Critical Analysis (BTCA) activities conducted on OME. The Breakdown team are responsible for thoroughly inspecting all OME received from stock, in-service and post-trial. The OME is reverse engineered to acquire components and explosive compositions for thorough inspection, testing and critical analysis [3].

6.1.1.3 Identifying unknown samples encountered during the breakdown process is described as "safety critical" by the customer (Ministry of Defence, BAE, MBDA etc.) and employer [4]. The current process to identify unknown samples is a time consuming laboratory process requiring specialist equipment and expertise. During the identification process, the breakdown process is stopped until the unknown sample can be identified and a suitable, safe way to continue is established [5].

6.1.1.4 Law enforcement agencies and military personnel have used explosive detection kits widely to identify potential explosives in various settings [6]. However, their efficacy in identifying samples found during the disassembly of OME remains unknown, with no current testing or research.

6.2 Aim

6.2.1.1 This research aims to investigate and assess the effectiveness of explosive trace detectors in identifying the known-pure sample (bare energetic) and known-impure samples (energetics combined with oil, greases and other debris) along with their capacity for identifying unknown samples that arise during the breakdown process.

6.3 Objective

6.3.1.1 This paper will discuss the current literature on explosive detection devices, the challenges faced by the Munitions Breakdown team in identifying unknown samples, and the potential benefits of using explosive detection devices in this context. The findings of this research could have significant implications for improving the safety and efficiency of OME disassembly operations.

7 LITERATURE REVIEW

7.1 Safety and Suitability for Service (S3)

7.1.1 Breakdown, Testing and Critical Analysis (BTCA)

7.1.1.1 BTCA is a crucial process used in the management and safety assessment of OME. The primary objective of BTCA is to evaluate and understand the life limitations and potential risks associated with OME by examining their components, construction, and design in a systematic manner [2].

7.1.1.2 Safety Assurance: OME, by nature, are hazardous, incorporating many dangerous materials. They can cause severe injuries, destruction, and loss of life if not handled, stored, and transported safely. BTCA helps ensure these materials are designed and constructed with the highest safety standards, minimising the risks of accidents, misfires, or mishandling [7].

Risk Identification: BTCA aims to identify vulnerabilities, weaknesses, and potential failure points in OME. By analysing the critical components and failure modes, experts can pinpoint means of unintended initiation of the OME and material failures within the design [8].

Compliance: Various national, international, and industry-specific regulations and standards govern the design, manufacture, storage, and transportation of OME. BTCA is an essential tool to assess and demonstrate compliance with these regulations, ensuring that the OME meet safety, environmental, and security standards per the Health and Safety Executive (HSE) and Defence Safety Authority 03-OME documentation [2].

Reliability and Performance: OME are used in critical applications, including military operations and defence systems. BTCA helps assess the reliability of these products, ensuring that they perform as expected in various conditions, which is particularly important for defence and security applications [9].

Root Cause Analysis: In the event of an accident or failure involving OME, BTCA processes can be used to investigate the incident's root cause. Though a long process, it can greatly aid in determining the source of an incident and the factors contributing to its occurrence leading to improvements in design and safety protocols.

Life Cycle Management: OME typically have a “shelf life”, as their safety and performance can change over time due to factors like ageing, environmental conditions, or handling. BTCA evaluates OME throughout its life cycle, ensuring continued safety and reliability.

Risk Mitigation: Once vulnerabilities are identified through BTCA, appropriate mitigation measures can be developed and implemented to reduce the risks associated. These mitigations/control measures could involve design changes, safety protocols, storage improvements, or changes in handling procedures [8].

Decision Support: The data generated from BTCA is valuable for making informed decisions regarding the use, storage, transport, and disposal of OME. This information helps agencies and organisations to manage their OME stores in a way that minimises risks and maximises safety.

Public Safety: Ensuring OME's safe handling and management is vital for military use, defence purposes, and the general public's safety. Accidents involving OME can have catastrophic consequences and, in worst-case scenarios, affect civilians. Hence, BTCA contributes to public safety and security to ascertain OME's safe use and operation [10].

7.1.1.3 In summary, Breakdown Testing and Critical Analysis (BTCA) on Ordnance, Munitions, and Explosives (OME) is a systematic process that critically assesses the safety, reliability, compliance, and overall risk associated with these hazardous materials. It helps prevent accidents, protect lives, and ensure OME's secure and effective use in various applications.

7.1.2 Munitions Breakdown

7.1.2.1 Munitions breakdown as part of BTCA is critical to the retrieval of energetic components/compositions to allow samples for critical analysis/testing to be conducted. It serves several other vital functions, especially in managing and ensuring the safety of OME. Along with the above points (2.1.1), the other essential functions of munitions breakdown are given below.

7.1.2.2 Munitions breakdown is involved in assessing the quality and consistency of OME production. OME will be visually and radiographically inspected, often repeatedly as the store is taken from all up round; to sub-assemblies; to individual components. This process ensures that the munitions are manufactured to meet specific safety and performance standards. Should the quality be sub-standard, this information can then be used to refine the design and construction of the OME for enhanced safety and performance.

- 7.1.2.3 Like other products, munitions can change over time due to ageing or environmental conditions. Munitions breakdown can be part of a broader life cycle management strategy to ensure the continued safety and reliability of munitions. Investigating age-related faults such as nitroglycerine leeching from propellants to mechanical failure such as a sheered bolt.
- 7.1.2.4 Munitions breakdown can also be used for training. It provides valuable insights into the internal workings of munitions, which can be used for educational and training programs for personnel involved in handling and managing munitions.
- 7.1.2.5 In summary, munitions breakdown as part of BTCA is a comprehensive process that plays a vital role in assessing munitions' safety, quality, and performance. It helps prevent accidents, improve design, ensure compliance, and support the safe handling and use of munitions in various applications.

7.2 Explosive Trace Detectors

7.2.1 Technical Overview

- 7.2.1.1 Explosive trace detectors (ETDs) are chemical detection units that screen and quickly identify explosive residues. In its standard application with anti-terrorist personnel and security teams, this technology relies on the fact that persons who handle explosives will leave trace residue on items they have interacted with. A fingerprint can potentially have an explosive particle mass of 100 µg, with ETDs capable of <1 µg detection limits [11].
- 7.2.1.2 The analysis process is designed to be simple to use and read, allowing rapid results. The tested item can be wiped with an adhesive swab, collecting particles off the surface, or placed into a dish/cavity. The instrument inserts, scans, or sprays the sample for analysis without sample preparation. Within a minute, the ETD will indicate to the user positive or negative for the presence of explosives [12].
- 7.2.1.3 ETDs are currently available to purchase on the commercial market and utilise several different measurement technologies; some also utilise multiple detector technologies, where special considerations are needed relating to use; this is discussed further below [12].

7.3 Vapour-Based Technology

- 7.3.1.1 Vapour-based trace explosive detection is fundamental for understanding vapour pressure (VP). The VP of a chemical compound is a measurement of its tendency to evaporate. The higher the VP of a solid explosive compound, the higher the concentration will be in the air saturated with the compound in vapour form [13].

7.3.1.2 Generally, for explosive compounds VP doubles with every 5 °C increase in its temperature. Upon insertion into the instrument, the sample temperature is raised to increase the VP of the explosive compound, increasing the quantity of vapour available for detection. Due to some explosive compounds having naturally low VPs, these may be undetectable even when heated. [12]

7.3.2 Ion Mobility Spectrometry (IMS)

7.3.2.1 Ion Mobility Spectrometry (IMS) is a technique used to separate ions in the gaseous phase based on differences in their mobility under an electric field [14]. It has historical use for analysing explosives, illicit drugs, and chemical warfare agents [15].

7.3.2.2 In an IMS-based ETD, the compounds' vapours travel to inside the instrument where they are exposed to an ionisation device, fragmenting the vapour into one or more distinct ions [16]. These ions enter one end of the instrument's "drift tube" drawn by electrostatic forces into an ion collector at the other end. Different ions travel through the tube at different rates and are collected at differing times. This time difference is measured and represented as an IMS spectrum (a plot of the number of ions collected versus drifted time). When measured this way, many explosive compounds can be identified by the unique IMS spectra they produce.

7.3.2.3 On-board spectrum analysis software compares the samples' IMS spectrum against a library of IMS data from various compounds and elements, to identify the compound present. However, this comparison process is limited to being only able to recognise known IMS spectra in the registered database [17].

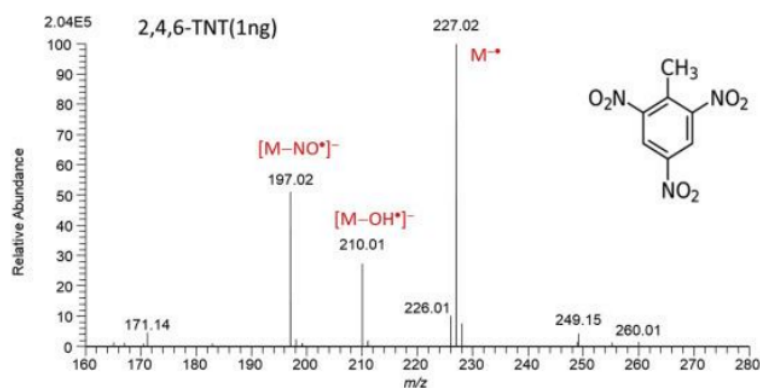


Figure 1 - IMS Spectra for TNT (Trinitrotoluene 2,4,6) [36]

7.3.3 Gas Chromatography-Ion Mobility Spectrometry (GC-IMS)

7.3.3.1 Gas Chromatography-Ion Mobility Spectrometry (GC-IMS) is an analytical technology that combines gas chromatography (GC) and ion mobility spectrometry (2.3.2 - IMS). GC-IMS is mainly used to detect trace volatile and semi-volatile organic compounds in different substrates [18]. GC-IMS combines the high separation capability of GC and the rapid response of IMS, making it a robust and easy-to-handle technique. It is widely used and common among trace detectors. The general principles of GC-IMS are presented in several studies; it has been applied to food flavour analysis, drug detection, explosive detection, disease detection/surveillance, and environmental protection [19].

7.3.3.2 Vaporised explosives compounds first enter the GC segment of the instrument, where they pass through a chromatographic column - a narrow metal tube containing materials (with high temperature stability such as silicon based oils) named the "stationary phase" that binds to the chemical compounds passing through it. Within that column, chemical compounds are separated based on their volatility; more volatile compounds (those that boil at a lower temperature) pass through the column quicker than less volatile compounds. [20].

7.3.3.3 As the separated energetic compounds leave the column, they enter the instrument's IMS segment where their spectra are determined (as described above 2.3.2). Energetic compounds are identified on the dual basis of their retention times on the chromatographic column and their IMS spectra.

The GC separation is one of the significant advantages of this technique, allowing for the separation of individual compounds during analysis [21].

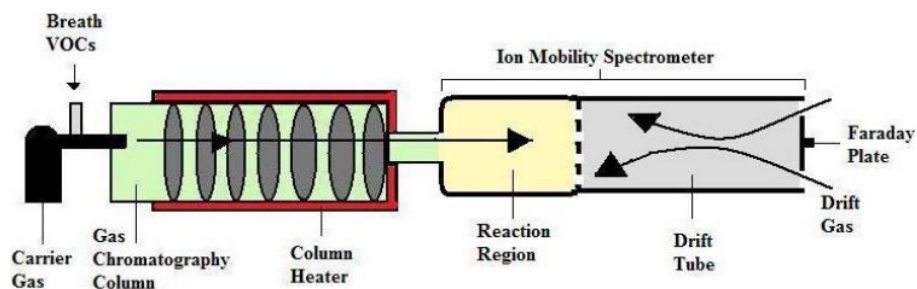


Figure 2 - GC-IMS Diagram [36]

7.3.4 High-Pressure Mass Spectrometry (HPMS)

7.3.4.1 High-Pressure Mass Spectrometry (HPMS) is an ion measurement technique like IMS (2.3.2). An HPMS-based ETD is a miniature version of a benchtop laboratory mass spectrometer. Benchtop mass spectrometers require heavy, power-intensive turbo-pumps to achieve a sufficiently low pressure for ion measurements. However, the HPMS-based ETD design allows it to make ion measurements at a pressure that, while still relatively low, can be obtained using a small, battery-powered vacuum pump [22].

7.3.4.2 Sample ionisation is achieved using a corona discharge device, the ions that are produced enter the low-pressure portion of the instrument. From there, the ions are guided by electrostatic forces to the mass analyser to be measured. The mass analyser sequentially samples and counts the stream of ions arriving in order of their masses. Measurement data can be represented as a mass spectrum.

The HPMS instrument's analysis software automatically compares the measured mass spectrum against a mass spectrum library of chemical compounds [23]. When matches are found, those explosives compounds are indicated as having been detected.

7.3.5 Chemiluminescence

7.3.5.1 Chemiluminescence refers to chemical reactions that produce light. In an ETD, explosive compound vapours are heated to a high temperature, causing them to degrade into simple gaseous compounds [24]. The thermal degradation products pass to the detector, where a sensor detects chemiluminescent reactions with the thermal degradation products of nitrogen and peroxide-based explosive compounds. The light output is measured, and at a certain level, the ETD's internal software indicates that an explosive compound has been detected – "Go" or "No-go" [24].

7.3.5.2 A flaw with this system is that it is designed purely for the indication of the presence of an explosive (nitrogen or peroxide-based). No explosive identity is indicated to the user, so further testing would need to be done should more information on the explosive be required.

7.3.5.3 Chemiluminescence-based ETDs are also limited to detecting nitrogen and peroxide-based explosives, due to other explosive compounds' inability to be thermally degraded into chemical compounds that undergo chemiluminescent reactions with the detector cartridge sensor material. Additionally, the detector cartridges must be periodically replaced from wear, depending on the frequency of samples analysed; which can be costly and time consuming, and therefore not ideal for field work [25].

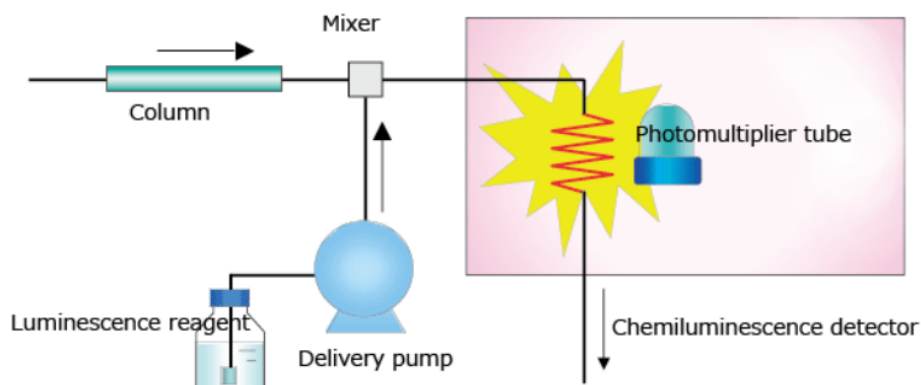


Figure 3 - Chemiluminescence Detector Diagram [34]

7.4 Non Vapour-Based Technology

7.4.1 Automated Colourimetry

- 7.4.1.1 Colourimetry detection kits are widely used to detect explosives, narcotics and toxic chemical compounds. Users will observe colour changes when a sample containing compounds of interest reacts with the reagent chemicals supplied with the test kit. The colour change occurs when a reagent spray comes in contact with the sample on the test paper [26].
- 7.4.1.2 The item to be screened is wiped with a manufacturer-provided detector card and, once sprayed with specific reagents for compound identification, will provide a colour-changing response to indicate whether a compound of interest is present. Colourimetry detection kits can also indicate what compound it could be, depending on the vibrancy of the indicated colour.
- 7.4.1.3 For energetics, the reagents react with nitroaromatic compounds, nitroamines, nitroesters and inorganic nitrates. These compounds cover a large majority of explosive compositions though further reagents can be purchased to test for specific energetic makeups such as bromates, chlorates and peroxides [27].
- 7.4.1.4 These quick and low-technology kits are advantageous as they allow use in all environments (field work, lab work, building security etc.), though relying on human observation and handling which increases the potential for human error [28].

7.5 Comparative Analysis of ETDs

7.5.1 Comparative Table of ETD Technology

Detector Technology	Analysis Modes	Detectable Compounds	Analysis Results	Detection Limits	Analysis Time	Power System	Price Average*
IMS [29]	Swab/ Vapour	Nitrogen- and Peroxide-based	ID (within available libraries)	1 ng	<25 s	Battery	£21,500
GC-IMS [30]	Swab/ Vapour	Nitrogen- and Peroxide-based	ID (within available libraries)	1 ng	20-120 s	Power supply/Mains	£31,000
HPMS [31]	Swab/ Vapour	Nitrogen- and Peroxide-based	ID (within available libraries)	1 ng	~60 s	Battery	£56,000
Chemiluminescence [32]	Swab/ Vapour	Nitrogen- and Peroxide-based	Go/No-Go	10 ng	2-8 s	Battery	£20,000
Automated Colourimetry [33]	Swab	Nitrogen-, Peroxide-, Chlorate- Based and Bromates**	Go/No-Go + Type	20 ng	>1 s	N/A	£400

Table 1 - ETD Comparative Analysis

* - Taken from four devices on the market using the same detector technology in 2023

** - To test for peroxides, chlorates and bromates, dropper bottles must be purchased on top of the regular kit.

7.5.2 ETD Considerations for Munitions Breakdown

7.5.2.1 Due to the HSE [34] and DSA-OME policies [2], the explosives area at QinetiQ Fort Halstead where munitions breakdown processing is undertaken has contraband rules in-place to limit the potential hazards that could enter the explosive site. Contraband items include electronic devices with removable batteries, or that could emit in the electromagnetic spectrum. These devices are not permitted as standard, though the business can run tests and request dispensation for use in-area. However, due to the variety of stores being processed, asking for dispensation may take a long time and could limit work if there was a greater potential to interfere on particular stores. This policy, therefore, removes all bar one of the potential detection systems (Table 1) from use on-site.

7.5.2.2 Automated colourimetry is non-electronic and requires no power, so this detection system is permitted on-site. It can be used during breakdown processing without increased hazard to the on-site OME, environment or personnel.

8 EXPERIMENTATION AND METHODOLOGY

8.1 Samples

8.1.1 Sampling Considerations for ETD's

8.1.1.1 Regarding the sample mass requirements for ETDs, data within Table 1 states that the smallest recorded sample limit would be 20 ng; the most significant sample size limit on all detector types.

8.1.1.2 20 ng is very small and unlikely to be seen during a munitions breakdown process; samples are often in the milligram range (visible to the naked eye). According to the data within Table 1, all ETDs have no limitation with sample sizes around 1 mg; however, demonstration of this will be necessary to prove usefulness during processing.

8.1.2 Sampling Considerations for Munitions Breakdown

8.1.2.1 The samples recovered during any munitions breakdown processes are rarely pure energetics. They can be contaminated with various contaminants, such as dirt, debris, sealants, and oils. Due to this, the ETD chosen will require further testing to prove the reliability of impure sample detection.

8.2 Experiments

8.2.1 Minimum Sample Mass Experimentation

8.2.1.1 Determining the minimum sample mass relevant for munitions breakdown with an automated colourimetry ETD involves a series of experiments establishing the detection limit. Below is the primary experimental methodology.

8.2.1.2 During setup, there is a requirement to source a representative set of explosive compounds to test - including energetics likely to be found within OME undergoing munitions breakdown processing (See 8.4).

- All tests are to be conducted in triplicate; the samples of the chosen energetic will be prepared into suitable masses. Beginning with the smallest mass of 0.001 g and increasing successively with 0.005 g, 0.010 mg should no positive indication be given. The ETD has failed if there is no positive indication of energetics at 0.010 g.
- Accurate mass measurements will be measured with Fisher Scientific scales (DRAE 339449, Calibrated 16/08/2023, Due 08/2024).
- All explosives shall be handled and weighed using polypropylene-conducting weighing boats in accordance with local procedures and regime conditions.

- Expray 1: 100 ml Bottle, Date Opened 12/2/2024, LOT:01510/38/2023, EXP DATE:12/2025
- Expray 2: 100 ml Bottle, Date Opened 12/2/2024, LOT:01520/38/2023, EXP DATE:12/2025
- Expray 3: 60 ml Bottle, Date Opened 12/2/2024, LOT:01530/33/2023, EXP DATE:12/2025

8.2.1.3 Methodology:

- Take photographs of each swab before and after testing.

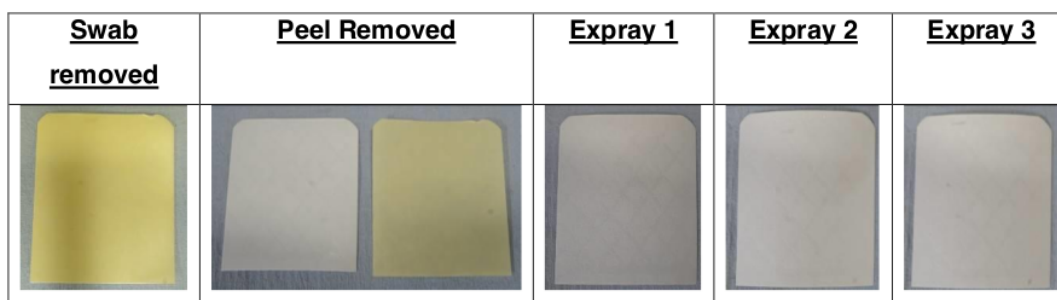


Figure 4 - Blank Swab Processed

- Measure the colourimetric response against a colour chart of the three sprays (without explosives) to establish the baseline or background reading. This reading serves as a reference for subsequent measurements.

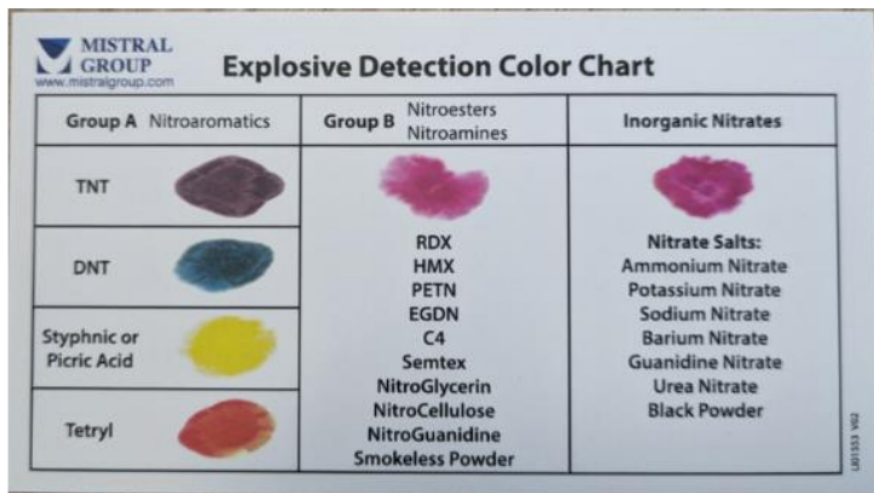


Figure 5 - ETD Colour Chart

- Start with the smallest mass of energetics (1 mg) and swab using the kit's provided swab. Record the colourimetric response and photograph with each ETD spray before using the next spray (repeat until all sprays have been used or a positive indication witnessed).
- 8.2.1.4 Continue the above process, increasing the sample mass and repeating until the ETD detects the energetics reliably or reaches the maximum sample size (10 mg), indicating the detection limit or test failure.
- 8.2.1.5 Statistical Analysis:
- Conduct triplicate measurements at each sample mass to account for variability and establish a reliable detection limit.
- 8.2.1.6 Repeat with Other Explosives:
- Repeat the experiment with different energetic compounds to determine the concentration limit on each explosive.
- 8.2.1.7 Data Analysis:
- By analysing the data, it should be possible to determine the smallest sample size at which the ETD reliably detects common energetics found during breakdown. Sample size may vary for different energetics; however, there will be a minimum mass that will be reliable on all tested energetics besides anomalies.

8.2.2 Minimum Concentration for Contamination Experimentation

8.2.2.1 Determining the minimum concentration for a sample required using an automated colourimetry ETD involves a series of experiments. Below is the primary experimental methodology.

8.2.2.2 Experimental Setup:

During the experimental setup, a representative set of energetic compounds must be sourced to test, including energetics that are likely to be found within OME being processed for breakdown (See 8.4).

- Prepare mixtures of the chosen energetics using the minimum detection limit mass found in 2.7.1 and increasing quantities of diluent (Potassium Bromide - KBr).
- Start with a low explosive to greater diluent ratio, increasing successively to create a range of samples. Ensure accurate concentration measurements.
- Accurate mass measurements will be measured with Fisher Scientific scales (DRAE 339449, Calibrated 16/08/2023, Due 08/2024).
- All weighing and handling of explosives shall be carried out using a polypropylene conducting weighing boat in accordance with local procedures and regime conditions.
- Expray 1: 100 ml Bottle, Date Opened 12/2/2024, LOT:01510/38/2023, EXP DATE:12/2025
- Expray 2: 100 ml Bottle, Date Opened 12/2/2024, LOT:01520/38/2023, EXP DATE:12/2025
- Expray 3: 60 ml Bottle, Date Opened 12/2/2024, LOT:01530/33/2023, EXP DATE:12/2025

8.2.2.3 Methodology:

- Take photographs of each swab with the mixture present, then again after each Expray used to record colour response (*See Figure 4 in 3.2.1.3*).
- Measure the colourimetric response against a colour chart of the diluent (KBr) to establish the baseline or background reading. *This reading serves as a reference for subsequent measurements (See Figure 5 in 3.2.1.3).*

- Start with the highest ratio of energetic and KBr (1:99 = 1 %), and swab using those provided within the kit.
- Spray with each ETD spray, record the colourimetric response, and take photographs of the results before using the next spray (repeat until all sprays have been used or the colourimetric response has been recorded)
- Continue the above process, reducing the solution ratio (1:99, 1:19, 1:9, 1:3, 1:1) until the ETD records a colourimetric response. This point indicates the limit of detection for contaminated samples.

8.2.2.4 Statistical Analysis:

8.2.2.5 Conduct triplicate measurements at each sample mass to account for variability and establish a reliable detection limit, e.g. all three tests at “α ratio” pass, end of the test. Alternatively, if only two out of three tests at “1:99 ratio” passed, increase to “1:19 ratio” repeat test in triplicate.

8.2.2.6 Repeat with Other Explosives:

- Repeat the experiment with different energetic compounds to determine the concentration limit on each explosive and note if there are any variations.

8.2.2.7 Data Analysis:

- By analysing all the datasets from the differing explosive compositions, it should be possible to determine whether contaminated samples can be reliably detected, potentially proving the kit useful to the MBT.
- This concentration may vary for different energetics, depending on their characteristics and the sensitivity of the ETD.

8.3 **Health and Safety**

8.3.1 Experiment/Trial Health and Safety

8.3.1.1 All primary hazards have been risk assessed, hazard stated and listed (*See Annex 11.1 & Section 3.4*); all personnel commencing this trial will be given a safety brief and follow technical peer review and risk assessments as can be found within the job folder and peer review, this includes PPE, Handling and weighing samples, chemical disposal and Good Lab Practices (GLP).

8.4 Energetic Samples

8.4.1 RDX

- 8.4.1.1 1,3,5-trinitro-1,3,5-triaza-cyclohexane, colloquially known as RDX or Hexogen, is a white solid crystalline high explosive. It is a standard explosive found in various mixtures and compositions and used frequently in all types of OME. $C_3H_6N_6O_6$ is a nitroamine – should indicate pink on Expray 2 [35].



Figure 6 - RDX Crystals

8.4.2 HMX

- 8.4.2.1 1,3,5,6-tetranitro-1,3,5,7-tetra-aza-cyclo-octane, HMX or Octogen is a white solid crystalline high explosive. It is commonly found within OME for warheads, stemming, detonators, and sometimes rocket motors. $C_4H_8N_8O_8$ is a nitroamine – should indicate pink on Expray 2 [36].



Figure 7 - HMX Powder

8.4.3 TNEB

- 8.4.3.1 1-ethyl-2,4,6-trinitrobenzene, or TNEB for short, is a high explosive used as an energetic plasticiser within explosive mixtures and compositions such as Rowanite 8001. TNEB is a yellow crystalline solid; it is nitroaromatic - should indicate orange on Expray 1 [36].



Figure 8 - TNEB Crystals

8.4.4 DADN

- 8.4.4.1 1,5-Diacetyl-3,7-dinitro-1,3,5,7-tetra-azacyclooctane, DADN, is an intermediary High explosive, a derivative of HMX. It is a white crystalline solid material classed as a nitroamine – should indicate pink on Expray 2 [37].



Figure 9 - DADN Powder

8.4.5 NC200W

- 8.4.5.1 NC200W is a single-base nitrocellulose propellant used in igniters and flash generators in general munitions. It is a solid-grain propellant characterised as a nitroester - should indicate pink on Expray 2.



Figure 10 - NC200W Pellets

8.4.6 WC855

8.4.6.1 WC855 is a double-based (nitrocellulose and nitroglycerine) propellant in ball grain form, used as the main propellant in 30 mm HEDP cartridge ammunition. This propellant is characterised as a nitroester - should indicate pink on Expray 2 [38].



Figure 11 - WC855 Pellets

8.4.7 WC859

8.4.7.1 WC859 is a double-based (nitrocellulose and nitroglycerine) propellant in ball grain form, used as a main propellant in 20 mm Penetrator cartridge ammunitions. This propellant is characterised as a nitroester – should indicate pink on Expray 2 [38].



Figure 12 - WC859 Pellets

8.4.8 N06

8.4.8.1 N06 is a triple-based (nitrocellulose, nitroglycerine, and nitroguanidine) solid stick propellant used in artillery shell bag charges and ejection charges within illuminating rounds. As a triple-base propellant, it would be classed as a nitroester - it should indicate pink on Expray 2.



Figure 13 - N06 Propellant

8.4.9 NS 34-10

8.4.9.1 NS 34-10 is a triple-based (nitrocellulose, nitroglycerine, and nitroguanidine) solid stick propellant used in artillery shell bag charges and ejection charges within artillery illum rounds. As a triple-base propellant, it would be classed as a nitroester - it should indicate pink on Expray 2.



Figure 14 - NS 34-10 Propellant

8.4.10 RD1303, Ba(NO₃)₂, CaSi₂ mix

8.4.10.1 The lead styphnate, barium nitrate, and calcium silicide mix is a primary cap-conducting composition within 30 mm ammunition primer caps. The styphnic acid within the Lead Styphnate is nitroaromatic - should indicate yellow on Expray 1 [35].

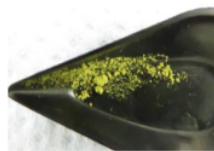


Figure 15 - RD1303 Mix

8.4.11 RD1337

8.4.11.1 Lead 2,4-dinitro-resorcinate is a primary explosive found in various OME detonators and initiators. It is an orange solid crystalline composition, characterised as nitroaromatic - it should indicate yellow on Expray 1 [36].



Figure 16 - RD1337 Sample

9 RESULTS

9.1 Minimum Sample Size

9.1.1 High Explosives

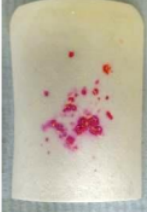
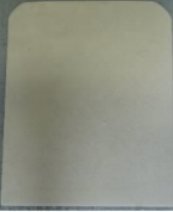
<u>Name</u>	<u>Sample</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Sample Size</u>
RDX				N/A	1 mg
HMX				N/A	1 mg
TNEB			N/A	N/A	1 mg
DADN				N/A	1 mg

Table 2 - Minimum Sample Size Results - High Explosives

9.1.2 Propellants

<u>Name</u>	<u>Sample</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Sample Size</u>
NC 200W (SB)				N/A	1 mg
N 06 (TB)				N/A	1 mg
NS 34- 10 (TB)				N/A	1 mg
WC 855 (DB)				N/A	1 mg
WC 859 (DB)				N/A	1 mg

Table 3 - Minimum Sample Size Results - Propellants (SB: Single Base, DB: Double Base, TB: Triple Base)

9.1.3 Primary Compositions

<u>Name</u>	<u>Sample</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Sample Size</u>
RD1303, Ba(NO ₃) ₂ , CaSi ₂ mix					1 mg
RD1337			N/A	N/A	1 mg

Table 4 - Minimum Sample Size Results - Primary Compositions

9.2 Minimum Concentration

9.2.1 High Explosives

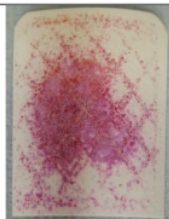
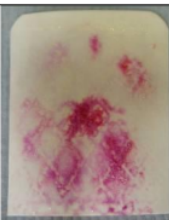
<u>Name</u>	<u>Mixture</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Mixture Ratio</u> <u>(Exp:KBr)</u>
RDX				N/A	1 mg:99 mg
HMX				N/A	1 mg:99 mg
TNEB			N/A	N/A	1 mg:99 mg
DADN				N/A	1 mg:99 mg

Table 5 - Minimum Concentration Results - High Explosives

9.2.2 Propellants

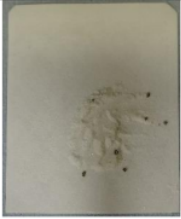
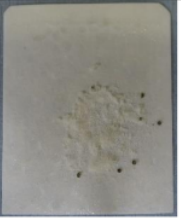
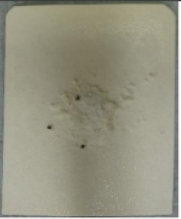
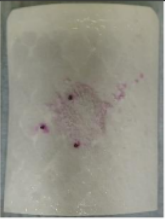
<u>Name</u>	<u>Mixture</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Mixture Ratio</u> <u>(Exp:KBr)</u>
NC 200W (SB)				N/A	1 mg:99 mg
N 06 (TB)				N/A	1 mg:99 mg
NS 34-10 (TB)				N/A	1 mg:99 mg
WC 855 (DB)				N/A	1 mg:99 mg
WC 859 (DB)				N/A	1 mg:99 mg

Table 6 - Minimum Concentration Results - Propellants

9.2.3 Primary Compositions

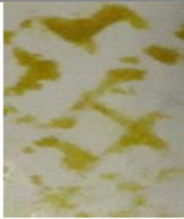
<u>Name</u>	<u>Mixture</u>	<u>Expray 1</u>	<u>Expray 2</u>	<u>Expray 3</u>	<u>Mixture Ratio</u> <u>(Exp:KBr)</u>
RD1303, Ba(NO ₃) ₂ , CaSi ₂ mix					1 mg:99 mg
RD1337			N/A	N/A	1 mg:99 mg

Table 7 - Minimum Concentration Results - Primary Compositions

10 DISCUSSION

10.1 Experimentation Learning

10.1.1 The ETD

10.1.1.1 During testing, an issue arose regarding the adhesive used on the swabs; as it is a wide criss-cross pattern across the swab, not all of the sample would stick to the surface, especially on larger samples masses (E.g. the KBr mixtures). This issue meant that upon use of the Exsprays, the pressure behind the spray would propel some of the sample off the swab before sufficiently wetting and sticking it down. As a result, further clean-up was required after each test to avoid cross-contamination; however, this will not be an issue when in service as the energetic will still indicate positive if present.

10.1.2 Weighing

10.1.2.1 When using the scales (Fisher Scientific—DRAE 339449, calibrated 16/08/2023, due 08/2024), accurate readings for all of the samples could take a considerable length of time. The sensitivity could cause fluctuations in the measurement for various reasons, such as increased airflow nearby, mass or pressure on the desktop nearby, and the location of the sample on the weighing plate.

10.1.2.2 Due to these variations, consistency when measuring was paramount. All laboratory doors were closed, shutters on the scales closed (with the exception of the top shutter parted open slightly to allow equalisation of pressures), the polypropylene weighing boat had to be placed as centrally as possible, and a consistent measurement readout for five seconds before taking the mass reading.

10.2 Minimum Sample Size

10.2.1 High Explosives

10.2.1.1 During the experimentation, four different HE (High Explosive) compositions were tested three times, each returning a positive indication with 1 mg samples. While most returned a vibrant colour in line with what was expected from the colour chart (3.2.1.6—Figure 5), DADN indicated very faintly with a light pink. This result could prove an issue when in service: users who are used to vibrant indications may not recognise a faint positive indication e.g. inexperienced or untrained users.

10.2.1.2 During testing, the user made this error, continuing to spray with the 3rd Exspray when unnecessary, as it proved hard to read in comparison to the vibrant colour indications seen in previous tests, sufficient training to all users would alleviate this error.

10.2.1.3 From the twelve tests, it was noted that fine-powder samples are more visible than large crystal samples, as the powder is spread across the swab at a greater surface area. There is also more surface area of energetic to react with the Expray. However, the more crystalline samples, while having a smaller surface area across the swab, are still very vibrant in colour locally and easily identified by the user. All sample types are visible once sprayed at 1 mg.

10.2.2 Propellants

10.2.2.1 During experimentation of the minimum sample size, five different propellant compositions were tested: 1 x SB, 2 x DB, and 2 x TB. Each of these were tested in triplicate, totalling fifteen experiments.

10.2.2.2 During this testing, all propellants indicated positive throughout all tests, though it was noted that grain propellants showed minimal colour indication when sprayed; while still vibrant, they indicated locally around the individual grains (similar to 5.2.1.2). Surface area was noted as a key variable for vibrancy and visible area of colour in propellants. All sample types were visible once sprayed at 1 mg.

10.2.3 Primary Explosives

10.2.3.1 Testing the RD1303 mix initially proved an issue due to a human error when reviewing the results. The mixture is a yellow/green colour (See 4.1.3) and should be indicated on Expray 1; however, Expray 1 reacting with styphnic acid results in a yellow indication on the swab. The user missed this yellow indication, assuming it was still the colour of the mixture now wetted by the spray. This error then led to Expray 2 being sprayed, which gave no indication. Expray 3 was then used per the instructions, resulting in a positive result due to the barium nitrate within the composition reacting to Expray 3 as an inorganic nitrate.

10.2.3.2 The user then continued to the next sample of the triplicate; however, Expray 2 unexpectedly reacted with this sample resulting in a pink indication of a nitroamine or nitroester which should not have been present. It was learnt after the fact that during the breakdown and drilling of the composition from its primer cap, a nitrocellulose disc rests on top of the mixture; it is likely that during drilling some of this disc contaminated the mixture, resulting in a positive pink indication of nitrocellulose from Expray 2.

10.2.3.3 After reviewing the results and photographs, it is clear that the lead styphnate within the mixture did indicate on Expray 1, and thus, no further sprays should have been used. For the primary explosives, two samples were found creating a total of six tests for minimum sample size, both indicated on Expray 1 as expected. All samples were visible once sprayed at 1 mg.

10.3 Minimum Concentration

10.3.1 Potassium Bromide

10.3.1.1 Potassium bromide (KBr) was the diluent for the concentration mixtures. Its non-reactivity with all the energetics and Exsprays used made it perfect for the experiments.

10.3.1.2 KBr is, however, a slightly sticky substance, causing some delay and issues when weighing and grinding in the pestle and mortar. This is because we do not want to lose any KBr mass to keep the concentration ratio as accurate as possible.

10.3.1.3 Overall, KBr proved an excellent imitation for contaminants such as dirt, grease and oil as it was gritty and sticky with no ability to indicate on the swab.

10.3.2 High Explosives

10.3.2.1 Four samples were used for HEs, creating twelve tests. In all tests, the mixture of KBr and HE increased the indication of the energetic on the swab, making it easier to identify and detect. This is likely due to the energetic being ground and mixed into the KBr, thus increasing the total reactive surface area. All samples were visible at a 1% concentration.

10.3.3 Propellants

10.3.3.1 During the experimentation of the minimum concentration size, five samples of propellant were used, creating fifteen tests in total: 1 x SB, 2 x DB, and 2 x TB.

10.3.3.2 The ball powder propellants (WC855, WC859, NC200W) proved difficult to grind into the KBr, often only crushing slightly; this may present a more accurate representation of how the sample would be found in munitions breakdown (non-homogenous), but does mean the tests are not comparative to the same homogeneity of other energetic mixtures used in the experiments. All samples were visible at a 1% concentration.

10.3.4 Primary Explosives

10.3.4.1 Testing the primary explosives raised one unexpected problem surrounding humidity. To handle the primary explosives, conducting conditions had to be in place: 65%< relative humidity and conducting boots worn. The KBr in high humidity absorbed the moisture in the atmosphere rapidly, causing agglomeration; when ground down with the primary explosives, the mixture would agglomerate together rather than being smooth.

10.3.4.2 Due to this, when it came time to test the mixture with the Exsprays, the mixture lay agglomerated on the swab, and the pressure from the Exsprays often caused the mixture to

leave the swab. This required extra cleaning and time to make the area safe and free from contamination before the next test.

10.3.4.3 Two samples were used for the primary explosives, creating six total tests; all tests were successful, indicating Expray 1 for styphnic acid. All samples were visible at a 1% concentration.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusion

11.1.1.1 Having completed 33 minimum sample tests on 11 samples of various energetic materials, it is evident that 1 mg of energetic sample is an adequate sample size to indicate positively with the automated colourimetry explosive trace detector. An ETD within munitions breakdown could be possible where the sample size is concerned and types of energetics are seen throughout processing. Staff would require training to know what a positive indication looks like and how to identify the group from which the energetic sample is characterised.

11.1.1.2 Continuing with 33 minimum concentration tests on 11 samples of various energetic materials, all samples indicated at a readable level, some more so than when tested as a pure sample. This result confirms that swabbing a sample with any contaminant during breakdown processing will still allow for a positive indication of any energetic present.

11.1.1.3 Due to the trials undertaken, there is evidence that automated colourimetry ETDs would benefit the MBT at Fort Halstead. The team will save time on unknown sample identification during breakdown processing using an ETD, reducing overall processing delays as well as a reduction in cost for the customer and QinetiQ.

11.2 Recommendations

11.2.1.1 During the concentration experiment, instead of grinding the sample and KBr together, mixing the KBr and sample together to coat the larger grains, avoiding a more homogenous mixture, could produce a different indication response due to the reduced surface area. Continuing this experimentation may yield more accurate results for contamination or amplify the current results, leading to more confidence in the ETD kit.

11.2.1.2 Further research could be done to ascertain whether two separate explosives on one swab would be distinguishable from one another or indistinguishable, should they be indicated at all. The results of this experiment would not lessen the results of this report but rather increase the range of abilities these ETD kits have in the broader BTCA context.

11.2.1.3 Testing of the Expray dropper bottles that indicate the presence of chlorates, bromates and peroxides would benefit and support this research encompassing a greater variety of energetics.

12 ACKNOWLEDGEMENTS

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14 ANNEX AND SUPPORTING DOCUMENTS

14.1 Technical Peer Review



OFFICIAL SENSITIVE

QINETIQ/MS/WD/FO1604149

Fort Halstead Peer Review Form																				
Job Title.	Explosive Trace Detection within Munitions Breakdown Trial																			
Job Number.	1125	SAP Code.	N/A	Date of Review.	22/01/2024															
Technical Lead.	Andrew Hurley		Project Manager.	N/A																
Providing Manager.	Graham Foster		Responsible Manager.	N/A																
Technical Review Attendees.	David Tod – Chairman Eamon Colclough – HAM L1 Rep Rob Endors – Safety		Declan Williams – Chemist Mathi Gupta – Munitions Scientist Andrew Hurley – Technical Lead/Presenter																	
Brief Scope and Objectives of Activity.																				
The procedures will be conducted in accordance with the HRS 1029 (Chemical, Physical and Mechanical Characterisation of Energetic Materials) and HRS 1574 (A28). Identifying unknown samples encountered during the breakdown process is described as "safety critical" by the customer (Ministry of Defence, BAE, MBDA etc.) and employer (QinetiQ). The current process to identify unknown samples is time consuming and requires specialist equipment and expertise. If an unknown sample is discovered during the inspection/breakdown process, then the activity will STOP until the unknown sample can be identified. Law enforcement agencies and military personnel have widely used explosive detection kits to identify potential energetic materials. However, their efficacy in detecting samples found during the disassembly of OME remains unknown. Westminster Group, Mistral group branded, Expray Explosive Detection Kit is to be trialled to ascertain minimum sample size and sample concentration for a positive result. Contents: - Swab pack x2 - Expray 1 (tests for ~~Nitroaromatics~~ – TNT, DNT, Tetryl etc.) - Expray 2 (tests for ~~Nitroesters & Nitroamines~~ – RDX, HMX, NG, NC etc.) - Expray 3 (tests for Inorganic Nitrates – Black powder, potassium nitrate, ammonium nitrate etc.)																				
Explosive Data This table includes an initial list of energetics and will be updated as new energetics are used. <table border="1"> <thead> <tr> <th>Explosive</th> <th>Hazard Type</th> <th>NEQ</th> </tr> </thead> <tbody> <tr> <td>HE (RDX, HMX, etc.)</td> <td>1</td> <td><100 mg</td> </tr> <tr> <td>Pyrotechnic (BPN, etc.)</td> <td>1 or 3</td> <td><100 mg</td> </tr> <tr> <td>Propellant (Single base, Double base etc.)</td> <td>1 or 3</td> <td><100 mg</td> </tr> <tr> <td>Primary (RD1303, RD1652, etc.)</td> <td>1</td> <td><50 mg</td> </tr> </tbody> </table>						Explosive	Hazard Type	NEQ	HE (RDX, HMX, etc.)	1	<100 mg	Pyrotechnic (BPN, etc.)	1 or 3	<100 mg	Propellant (Single base, Double base etc.)	1 or 3	<100 mg	Primary (RD1303, RD1652, etc.)	1	<50 mg
Explosive	Hazard Type	NEQ																		
HE (RDX, HMX, etc.)	1	<100 mg																		
Pyrotechnic (BPN, etc.)	1 or 3	<100 mg																		
Propellant (Single base, Double base etc.)	1 or 3	<100 mg																		
Primary (RD1303, RD1652, etc.)	1	<50 mg																		
Date task last carried out.	Similar Task 2023	How many times/how often has the task been conducted before?	Twice with the Ex-pen kit (similar chemicals as Expray)																	
Task previously conducted elsewhere? If so where.		N/A																		
Lessons learned (to include positive observations and opportunities for improvement).																				
A safety brief highlighting the hazards and risks associated with the trial to be given to all working on the trial.																				
A guidance sheet will be generated once the process has been completed.																				
Full Description of activity.																				



**Use of Expray Kit:**

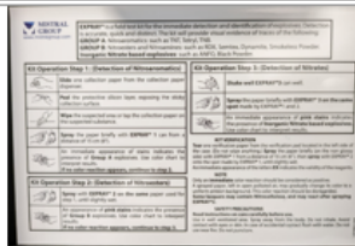
The ETD kit will be used following the manufacturer's instructions, any deviation from these instructions will be documented.

Minimum Sample Size:

Determine the minimum detection limits of the kit by using various sample sizes of neat energetic compositions. Sample sizes: 1 mg tested first, if material is not detected then the sample size will be increased up to a maximum of 10 mg. (Test in Triplicate)

Minimum Concentration Size:

Determine the minimum concentration of pure energetic composition to diluent (KBr). The minimum detection limit obtained from the sample size will be diluted and then tested, reducing the overall risk of net energetic composition being handled (ALARP). Concentration percentages: 1% & 10% (Test in Triplicate)



Details of stop criteria.	Any event that is outside the scope of the programme or which appears anomalous to the competent persons performing the activity will lead to a safety stop.
Details of route of disposal of any test items or arisings.	Sample residues will be disposed of as contaminated waste and then disposed following local procedures.

Competencies required for this process as listed in the FHD competency database.	Persons.	Required Competency.	
	All staff with L2 or higher for required competencies and L1's under supervision of a L2 or L3.	-Working in explosive areas (all) -Handling/Weighing of Initiatory materials -Handling/Weighing of HE -Handling/Weighing of Pyrotechnics -Handling/Weighing of Propellants	
Personal Protective Equipment Required			
~~Proban~~ treated Laboratory Coat (EN ISO 11612)	☒	Disposable Dust and Vapour Mask (EN 149 FFP3)	☐
~~Non-xx~~ 2 piece suit or Overalls (EN ISO 11612)	☐	Full Face Respirator	☐
Silvered Flash Suit and Head Protection	☐	Kid Leather Gloves (EN 388)	☐
Safety Helmet (EN 397)	☐	Nitrile Gloves (EN 374)	☒
Ear Defenders (EN 352)	☐	Thermal Gloves (Heat) (EN 407)	☐
Detonator' Safety Visor	☒	Thermal Gloves (Cold) (EN 511)	☐
Safety Visor (EN 166)	☒	Kevlar Gloves (EN 388)	☐
Safety Goggles (EN 166)	☐	Wrist Strap	☐
Safety Glasses (EN 166)	☒	Conductive Safety Shoes (EN ISO 20345 200 Joules)	☒
Disposable Dust Mask (EN 149 FFP2)	☐	Non-conductive Safety Shoes (EN ISO 20345 200 Joules)	☒
Other Please Specify	Safety visor worn when handling initiatory compositions unless behind safety shield. Nitrile gloves SHALL be worn during Expray activities.		

Summary of COSHH and Hazard Issues

Due to the small quantities of EXPRAY used, <1ml per spray action, the risk of exposure to the chemicals is considered negligible. The ~~Expray~~ kit SHALL be used in a well ventilated area.

Though the CRA0611288 has a risk rating of Medium, due to the quantities being used this task would not be rated higher than Low.

RDX:

- H350/1 Exposure to carcinogens
- H370/3 Substances may cause organ damage

HMX:

- H340/1 May cause genetic defects
- H350/1 May cause cancer
- H360/1 May cause harm to unborn child
- H370/3 Substances may cause organ damage

BPN:

- H302 Harmful if Swallowed
- H272 may intensify fire; oxidiser

Single base:

- H201 Explosive; mass explosion hazard (1.1)
- H315 Causes skin irritation.
- H319 Causes serious eye irritation.

Double Base:

- H200 Unstable explosive
- H201 Explosive; mass explosion hazard (1.1)
- H300 Fatal if swallowed.
- H310 Fatal in contact with the skin.
- H315 Causes skin irritation.
- H319 Causes serious eye irritation.
- H330 Fatal if inhaled.
- H373 May cause damage to organs through prolonged or repeated exposure.
- H411 Toxic to aquatic life with long lasting effects.

RD1303:

- H350/1 May cause cancer
- H360/1 May cause harm to unborn child
- H372/3 May cause damage to organs through prolonged exposure

RD1652

- H271 May cause fire or explosion; strong oxidiser.
- H302 Harmful if swallowed.
- H332 Harmful if inhaled.
- H411 Toxic to aquatic life with long lasting effects.

Electrostatic Precautions
to be taken.

Antistatic/Conducting (Dependant on the materials ESD)

QinetiQ Documentation.

Procedure Title.	Procedure DIIS / OF Number.	Review Date.
Disposal of Initiatory Materials by Chemical Destruction	ENG/WI210227/MS	06/11/2024
Disposal of Secondary Explosives by Chemical Destruction	ENG/WI211171/MS	06/11/2024
Risk Assessment Title.	Risk Assessment DIIS Number.	Review Date.

Risk assessment for X48, A28, F8 and their associated unlicensed buildings	QJNETIQ/MS/WD/RA024135	13/10/2024
Handling and Preparation of Energetic materials, use of Test Equipment and General Risk Assessment for X50 and X15.3 Laboratories.	Qjnetiq/MS/WD/RA1402234	20/03/2024
COSHH Assessment Title.	COSHH Assessment DIIS No.	Review Date.
Common solvents used on a range of activities	QJNETIQ/MS/WES/CRA0903311	30/05/2024
Breakdown, sample preparation, EMTAP, chemical analysis and disposal (either chemically or by burning) of energetic compositions removed from detonators, squibs, fuzes, safety and arming and igniters	QJNETIQ/D&TS/WPNS/CRA0608005	25/11/2024
Breakdown, Critical Examination, Sample Preparation, Chemical Analysis, Mechanical Testing, Small Scale Sensitiveness Tests and Firing of PBX, High Explosives and High Explosive Devices	QJNETIQ/EMEA/TS/CRA0709454	06/06/2025
Breakdown, Sample Preparation, Chemical and Mechanical analysis and Small Scale Sensitiveness Tests on Pyrotechnic Compositions	QJNETIQ/D&TS/WPNS/CRA0611288	04/11/2024
Breakdown, Critical Examination, Sample Preparation, Chemical Analysis, Mechanical Testing, Small Scale Sensitiveness Tests and Firing of Nitrate ester based propellants.	Qjnetiq/MS/WES/CRA0902329	25/01/2024 (currently under review, will be updated before activity commences)

Authorisation to Proceed.			
Technical Approval.	D.Tod Print	 Signature	30/01/2024 Date
L1 HAM Chair Confirm completion of actions.	HRS 1029 & HRS 1574 Print	N/A Signature	N/A Date
Responsible Manager.	N/A Print	N/A Signature	N/A Date
Providing Manager.	HRS 1029 & HRS 1574 Print	N/A Signature	N/A Date

14.2 Experimentation/Trial Notes

Job: 1125 ① 12/2/24

Explosive Trace Detection Within Mustang Breakdown

To be done raw parcels agreed @ both reviews 22/1/24

Expiry 1

100ml Bottle. Date opened 12/2/24

Lot: 01510/38/2023

Exp DATE: 12/2025

Expiry 2

100ml Bottle. Date opened 12/2/24

Lot: 01520/38/2023

Exp DATE: 12/2025

Expiry 3 (QMS)

100ml Bottle. Date opened 12/2/24

Lot: 01530/38/2023

Exp DATE: 11/2025

Blank

- 1) Swab *sample* (none used for blank) using kit provided swabs
- 2) Expiry 1 - Negative
- 3) Expiry 2 - Negative
- 4) Expiry 3 - Negative

Scales - Ohaus Scientific Scales (Calibrated 16/8/23) - Due 8/24

DRAE 33944.9

②

RDX (MS) (1/24 X Cryst, Powder, QMS ID 162706) 1:11

Test #	Expiry 1	Expiry 2	Expiry 3	Sample Wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using a Conductivity polypyrrole weighing boat on Ohaus Scientific DRAE 33944.5 Scales (Calibrated 16/8/23) - Due 8/24

Wt of RDX 0.001g

- 2) Swab Sample using kit provided swabs
- 3) Expiry 1 - Negative
- 4) Expiry 2 - Positive - PINK

Test 2

- 1) Weigh out 1mg of Sample using a Conductivity polypyrrole weighing boat on Ohaus Scientific DRAE 33944.5 Scales (Calibrated 16/8/23) - Due 8/24

14.2.1.1

③

Wt of RDX = 0.001g

- 2) Swab Sample using kit provided swabs
- 3) Expiry 1 - Negative
- 4) Expiry 2 - Positive - PINK

Test 3

- 1) Weigh out 1mg of Sample as per Test 1

Wt of RDX = 0.001g

- 2) Swab Sample using kit provided swabs
- 3) Expiry 1 - Negative
- 4) Expiry 2 - Positive - PINK

④

Continued 13/2/24

HMX (MS) (1/40, Syn-3/5/22) 1:11

Test #	Expiry 1	Expiry 2	Expiry 3	Sample Wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using Conductivity polypyrrole weighing boat on Ohaus Scientific Scales DRAE 33944.5 (Calibrated 16/8/23) - Due 08/24
- 2) Swab Sample using kit provided swabs
- 3) Expiry 1 - Negative
- 4) Expiry 2 - Positive

Test 2

- 1) as per Test 1
- 2) as per Test 1
- 3) as per Test 1
- 4) as per Test 1

14.2.1.2

14.2.1.3

⑤

Test 3

- As per Test 1
- As per Test 1
- As per Test 1
- As per Test 1

DADN (MS) (7, Synth-23/4/22) I:ID

Test #	Expiry 1	Expiry 2	Expiry 3	Sample wt	
1	X	✓ Violet pink	X	0.001g	Light violet Phenolphthalein
2	X	X	X	0.001g	
3	X	✓ Violet pink	—	0.001g	

- Weigh out 1mg of Sample using Conducting polypropylene weighing boats on Fisher Scientific Scales DHA6339449 (calibrated 16/12/23) - Dec 08/24
- Swab Sample with kit provided swab
- Expiry 1 - Negative
- Expiry 2 - ~~Negative~~ Positive

⑥

5) Expiry 3 - Negative

Test 2

- as per Test 1
- as per Test 1
- as per Test 1
- ~~Expiry 2~~ - Negative
- as per Test 1

Test 3

- as per Test 1
- as per Test 1
- as per Test 1
- as per Test 1

Test 4

- Weigh out 5mg of Sample using a Conducting polypropylene weighing boats on Fisher Scientific Scales DHA6339449 (calibrated 16/12/23) - Dec 08/24
- Swab Sample using kit provided swab

14.2.1.4

⑦

Test #	Expiry 1	Expiry 2	Expiry 3	Sample wt
4	X	✓ Violet pink	—	0.001g
5	X	✓ Violet pink	—	0.001g
6	X	✓ Violet pink	—	0.001g

- Expiry 1 - Negative
- Expiry 2 - Positive - Violet pink

Test 5

- As per Test 4
- As per Test 4
- As per Test 4
- As per Test 4

Test 6

- as per Test 4
- as per Test 4
- as per Test 4
- as per Test 4

⑧

INEB (MS) (50 X-ray) I:ID

Test #	Expiry 1	Expiry 2	Expiry 3	Sample wt
1	✓ Orange	—	—	0.001g
2	✓ Orange	—	—	0.001g
3	✓ Orange	—	—	0.001g

Test 1

- Weigh out 1mg of Sample using Conducting polypropylene weighing boats on Fisher Scientific Scales (calibrated 16/12/23) - Dec 08/24 DHA6339449
- Swab Sample using kit provided swabs
- Expiry 1 - Positive - Orange

Test 2

- as per Test 1
- as per Test 1
- as per Test 1

Test 3

- as per Test 1
- as per Test 1
- as per Test 1

Continued 4/2/24 (9)

RDX /92 (KX) (KX-gel, Powder, Qmas ID 162706) 1:1D

Test #	Expt 1	Expt 2	Expt 3	Expt 4	KBr wt	Concentration
1	X	✓ Pink	—	0.001g	0.099g	1%
2	X	✓ Pink	—	0.001g	0.099g	1%
3	X	✓ Pink	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 0.099g (99mg) of KBr on ^{Scotch} Fisher Scales (Calibrated 16/8/23) - Due 08/24 DRAE 339449
- 2) Using pestle & mortar, grind KBr until smooth
- 3) Weigh out 1mg of Sample on Fisher Scientific Scales DRAE 339449 (Calibrated 16/8/23) - Due 08/24
- 4) Grind together KBr & Sample to create a 1% Concentration mixture
- 5) Subo mixture using kit provided Subo
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

(10)

Test 2

- 1) as per Test 1
- 2) as per Test 1
- 3) as per Test 1
- 4) as per Test 1
- 5) as per Test 1
- 6) as per Test 1
- 7) as per Test 1

Test 3

- 1) as per Test 1
- 2) as per Test 1
- 3) as per Test 1
- 4) as per Test 1
- 5) as per Test 1
- 6) as per Test 1
- 7) as per Test 1

14.2.1.5

(11)

HMX (KX) (KX-gel, 3/5/22) 1:1D

Test #	Expt 1	Expt 2	Expt 3	Sample wt	KBr wt	Concentration
1	X	✓ Pink	—	0.001g	0.099g	1%
2	X	✓ Pink	—	0.001g	0.099g	1%
3	X	✓ Pink	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 99mg of KBr using ~~Scotch~~ Fisher Scientific Scales DRAE 339449 (Calibrated 16/8/23) - Due 08/24
- 2) Using pestle & mortar, grind KBr until fine/smooth
- 3) Weigh out 1mg of Sample using Fisher Scientific Scales DRAE 339449 (Calibrated 16/8/23) - Due 08/24
- 4) Grind KBr & Sample together to create 1% mixture
- 5) Subo mixture using kit provided Subos
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

(12)

Test 2

- 1) As per Test 1
- 2) As per Test 1
- 3) As per Test 1
- 4) As per Test 1
- 5) As per Test 1
- 6) As per Test 1
- 7) As per Test 1

Test 3

- 1) As per Test 1
- 2) As per Test 1
- 3) As per Test 1
- 4) As per Test 1
- 5) As per Test 1
- 6) As per Test 1
- 7) As per Test 1

14.2.1.6

(13)

DADN (MC) (7 Synth-25/4/22) 1:10

Test #	Expt 1	Expt 2	Expt 3	Sample wt	KBr wt	Concentration
1	X	✓ v light pink	—	0.001g	0.099g	1%
2	X	✓ v light pink	—	0.001g	0.099g	1%
3	X	✓ v light pink	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 99mg of KBr using Scales (Page 1)
- 2) Using pestle & mortar to grind KBr into fine/smooth
- 3) Weigh out 1mg of Sample in polypropylene conducting test and Scales (Page 1)
- 4) Grind KBr & Sample together with pestle & mortar to create 1% concentration mixture
- 5) Swab mixture with Kit provided Swab
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - v light pink

(14)

Test 2

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per Test 1
- 5) As per Test 1
- 6) As per Test 1
- 7) As per test 1

Test 3

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1
- 5) As per test 1
- 6) As per test 1
- 7) As per test 1

14.2.1.7

(15)

INEB (MC) (ISO crystals) 1:10

Test #	Expt 1	Expt 2	Expt 3	Sample wt	KBr wt	Concentration
1	✓ orange	—	—	0.001g	0.099g	1%
2	✓ orange	—	—	0.001g	0.099g	1%
3	✓ orange	—	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 99mg using Scales (Page 1) of KBr
- 2) Using pestle & mortar grind KBr into fine/smooth powder
- 3) Weigh out 1mg of Sample using polypropylene conducting test and Scales (Page 1)
- 4) Grind together Sample & KBr using pestle & mortar
- 5) Swab mixture using Kit provided Swabs
- 6) Expt 1 - Positive - orange

Test 2

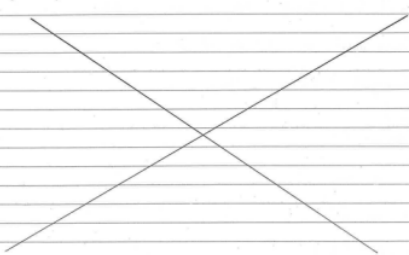
- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1

(16)

- 5) As per test 1
- 6) As per test 1

Test 3

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1
- 5) As per test 1
- 6) As per test 1



14.2.1.8

(17)

15/2/24

continued

WC 855 (MS) 1.5c

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using polypropylene conducting boat, on Scale (page 1)
- 2) Swab using kit provided Swab
- 3) Expt 1 - Negative
- 4) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1

(18)

Test 3

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1

WC 859 (MS) 1.5c

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using polypropylene weighing boat
- 2) Swab Sample with kit provided Swab
- 3) Expt 1 - Negative
- 4) Expt 2 - Positive - Pink

14.2.1.9

(19)

Test 2

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1

Test 3

- 1) As per test 1
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1

His 858 (MS) - Negative! (Don't test further, not possible)

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	X	X	0.001g
2	X	X	X	0.001g
3	X	X	X	0.001g

(20)

Test 1

- 1) Weigh out 1mg of Sample in polypropylene conducting weighing boat (Plus) using Scale (page 1)
- 2) Swab sample using kit provided Swabs
- 3) Expt 1 - Negative
- 4) Expt 2 - Negative
- 5) Expt 3 - Negative

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "

14.2.1.10

(21)

Test #	Expt 1	Expt 2	Expt 3	Sample wt
4	X	X	X	0.005g
5	X	X	X	0.005g
6	X	X	X	0.005g

Test 4

- 1) Weigh out 5mg of Sample in PWB using Scales (Page 1)
- 2) As per test 1
- 3) As per test 1
- 4) As per test 1
- 5) As per test 1

Test 5

- 1) As per test 4
- 2) "
- 3) "
- 4) "
- 5) "

Test 6

- 1) As per test 4
- 2) "
- 3) "
- 4) "
- 5) "

(22)

NC 2000W 1.3C

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using a PWB or Scales (Page 1)
- 2) Swab Sample using Kit provided Swab
- 3) Expt 1 - Neg
- 4) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "

14.2.1.11

(23)

NS 06 1.3c

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using a PWB or Scales (Page 1)
- 2) Swab Sample using Kit provided Swab
- 3) Expt 1 - Negative
- 4) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "

(24)

NS 34-100 1.3c 1.55mm big cleaver

Test #	Expt 1	Expt 2	Expt 3	Sample wt
1	X	✓ Pink	—	0.001g
2	X	✓ Pink	—	0.001g
3	X	✓ Pink	—	0.001g

Test 1

- 1) Weigh out 1mg of Sample using PWB or Scales (Page 1)
- 2) Swab Sample using Kit provided Swab
- 3) Expt 1 - Negative
- 4) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "

14.2.1.12

25

1503
Contract 19/2/24 - RD TEST (MS)

Test #	Expt 1	Expt 2	Expt 3	Wt Sample	Wt KBr	Concentration
1	✓ ~~10~~ ?	✗	✓ Pink	0.001g	0.001g	1%
2	✓ ~~10~~ ?	✗	✓ Pink	0.001g	0.001g	1%
3	✓ ~~10~~ ?	✗	✓ Pink	0.001g	0.001g	1%

Test 1

- 1) Weigh out 1mg of Sample using Pub & Scales (Page 1)
- 2) Sub Sample using kit provided Swabs
- 3) Expt 1 - ~~10~~ - Yellow? - local stylized
- 4) Expt 2 - Negative - Nitroalkene
- 5) Expt 3 - Positive - Pink - Amin Nitrate

1) As per test 1
2) "
3) "
4) "
5) "

1) As per test 1
2) "
3) "
4) "
5) "

26

(K) (MC)

Test #	Expt 1	Expt 2	Expt 3	Wt Sample	Wt KBr	Concentration
1	✓ ~~10~~ ?	✗	✓ ~~10~~ ?	0.001g	0.001g	1%
2	✓ ~~10~~ ?	✓	✓ Pink	0.001g	0.001g	1%
3	✓ ~~10~~ ?	✗	✓ Pink	0.001g	0.001g	1%

Test 1

- 1) Weigh out 99mg of KBr using Scales (Page 1)
- 2) Grind KBr using Pestle & Mortar into fine powder
- 3) Weigh out 1mg of Sample using PUB & Scales (Page 1)
- 4) Grind KBr & Sample together to create 1% mixture
- 5) Sub mixture using kit provided Swabs
- 6) Expt 1 - ✓ - Yellow
- 7) Expt 2 - Negative
- 8) Expt 3 - Positive - Pink

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) Expt 2 - Positive - Pink
8) Expt 3 - Positive - Pink

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) "
8) "

14.2.1.13

27

N 06 (MC)

Test #	Expt 1	Expt 2	Expt 3	Wt Sample	Wt KBr	Concentration
1	✗	✓ Pink	—	0.001g	0.001g	1%
2	✗	✓ Pink	—	0.001g	0.001g	1%
3	✗	✓ Pink	—	0.001g	0.001g	1%

Test 1

- 1) Weigh out 99mg of KBr using Scales (Page 1)
- 2) Grind KBr using pestle & mortar until fine powder
- 3) Weigh 1mg of Sample using PUB & Scales (Page 1)
- 4) Grind KBr & Sample together to make 1% mixture
- 5) Sub mixture using kit provided Swabs
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) "

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) "

28

NS 34-100

Test #	Expt 1	Expt 2	Expt 3	Wt Sample	Wt KBr	Concentration
1	✗	✓ Pink	—	0.001g	0.001g	1%
2	✗	✓ Pink	—	0.001g	0.001g	1%
3	✗	✓ Pink	—	0.001g	0.001g	1%

Test 1

- 1) Weigh out 99mg of KBr using Scales (Page 1)
- 2) Using Pestle & mortar grind KBr until fine powder
- 3) Weigh out 1mg of Sample using PUB & Scales (Page 1)
- 4) Grind KBr & Sample together to make 1% mixture
- 5) Using kit provided Swabs, sub mixture
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) "

1) As per test 1
2) "
3) "
4) "
5) "
6) "
7) "

14.2.1.14

29

Notes for RD303 PC

- Spring 1 = Yellow for ^{leaf} Sy. plants ← Hard to see
- Spring 2 = Pink for nitrocellulose paper
- Spring 3 = Pink for Barium nitrate

30

Continued 27/2/24

WC 855 - 187138 (1.5c) (Mc)

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample	Wt of KBr	Concentration
1	X	✓ Pink	—	0.001g	0.099g	1%
2	X	✓ Pink	—	0.001g	0.099g	1%
3	X	✓ Pink	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 0.099g of KBr using Scales (Page 1)
- 2) Grind KBr using pestle & mortar
- 3) Weigh out 0.001g of Sample in PWB using Scales (Page 1)
- 4) Grind Sample & KBr together
- 5) Swab mixture with Kit provided Swabs
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

14.2.1.15

31

WC 859 (Sample, Phlox) (1.5c) (Mc)

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample	Wt of KBr	Concentration
1	X	✓ Pink	—	0.001g	0.099g	1%
2	X	✓ Pink	—	0.001g	0.099g	1%
3	X	✓ Pink	—	0.001g	0.099g	1%

Test 1

- 1) Weigh out 0.099g of KBr using Scales (Page 1)
- 2) Grind KBr using pestle & mortar
- 3) Weigh out 1mg of Sample in PWB using Scales (Page 1)
- 4) Grind Sample & KBr together
- 5) Swab mixture with Kit provided Swabs
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

32

NC 200W (Mc) 188669 1.5c

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample	Wt of KBr	Concentration
1	X	✓ Pink	—	1mg	99mg	1%
2	X	✓ Pink	—	1mg	99mg	1%
3	X	✓ Pink	—	1mg	99mg	1%

Test 1

- 1) Weigh out 99mg of KBr using Scales (Page 1)
- 2) Grind KBr in pestle & mortar
- 3) Weigh out 1mg of Sample in PWB using Scales (Page 1)
- 4) Grind Sample & KBr together
- 5) Swab mixture with Kit provided Swabs
- 6) Expt 1 - Negative
- 7) Expt 2 - Positive - Pink

Test 2

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

Test 3

- 1) As per test 1
- 2) "
- 3) "
- 4) "
- 5) "
- 6) "
- 7) "

14.2.1.16

33

201/3/24

Continued ...

RD 1337 (MS) - Lead 2,4 dithiocarbamate

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample
1	✓	✗	—	0.001g
2	✓	—	—	0.001g
3	✓	—	—	0.001g

1) Weigh out 1mg of Sample in PHSB using Scales (Page 1)
2) Swab Sample using Kit provided Swabs
3) Expt 1 - Positive - Yellow

Test 2

1) As per test 1

2) " "

3) " "

Test 3

1) As per test 1

2) " "

3) " "

34

RD 1337 (MS)

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample
1				0.001g
2				0.001g
3				0.001g

14.2.1.17

35

RD 1337 (MC)

Test #	Expt 1	Expt 2	Expt 3	Wt of Sample	Wt of KBr	Concentration
1	✓	✗	—	0.001g	0.001g	1%
2	✓	✗	—	0.001g	0.001g	1%
3	✓	✗	—	0.001g	0.001g	1%

1) Weigh out 0.01mg of KBr using Scales (Page 1)
2) Grind KBr using pestle & mortar
3) Weigh out 1mg of Sample using PHSB on Scales (Page 1)
4) Grind Sample & KBr together using pestle & mortar
5) Swab matrix with kit provided Swabs
6) Expt 1 - Positive - Yellow

Test 2

1) As per test 1

2) " "

3) " "

4) " "

5) " "

6) " "

Test 3

1) As per test 1

2) " "

3) " "

4) " "

5) " "

6) " "

14.2.1.18

14.3 Experimentation/Trial Photo List

Date 12/1/24 Breakdown Photo List of ETD in Mantles Breakdown Job file No 1125

Jpeg No.	S/N	Photo Description
0.1	Blank	Blank - removed
0.2	"	" - Blank removed
0.3	"	" - Empty 1
0.4	"	" - Empty 2
0.5	"	" - Empty 3
0.6	ROX (MS)	Test 1 - Sample in Conductivity boat
0.7	"	" - Sample - long of Sample
0.8	"	" - Sample - long of Sample
0.9	"	" - Sample - long of Sample
1.0	"	Test 2 - Sample in Conductivity boat
1.1	"	" - Sample - long of Sample
1.2	"	" - Sample - long of Sample
1.3	"	" - Sample - long of Sample
1.4	"	Test 3 - Sample in Conductivity boat
1.5	"	" - Sample - long of Sample
1.6	"	" - Sample - long of Sample
1.7	"	" - Sample - long of Sample
1.8	HMX (MS)	Test 1 - Sample in Conductivity boat
1.9	"	" - Sample - long of Sample
2.0	"	" - Sample - long of Sample
2.1	"	" - Sample - long of Sample
2.2	"	Test 2 - Sample in Conductivity boat
2.3	"	" - Sample - long of Sample
2.4	"	" - Sample - long of Sample
2.5	"	" - Sample - long of Sample
2.6	"	Test 3 - Sample in Conductivity boat
2.7	"	" - Sample - long of Sample
2.8	"	" - Sample - long of Sample
2.9	"	" - Sample - long of Sample
3.0	DADN (MS)	Test 1 - Sample in Conductivity boat
3.1	"	" - Sample - long of Sample
3.2	"	" - Sample - long of Sample
3.3	"	" - Sample - long of Sample
3.4	"	" - Sample - long of Sample
3.5	"	Test 2 - Sample in Conductivity boat
3.6	"	" - Sample - long of Sample
3.7	"	" - Sample - long of Sample
3.8	"	" - Sample - long of Sample
3.9	"	Test 3 - Sample in Conductivity boat
4.0	"	" - Sample - long of Sample
4.1	"	" - Sample - long of Sample
4.2	"	" - Sample - long of Sample
4.3	"	Test 4 - Sample in Conductivity boat
4.4	"	" - Sample - long of Sample
4.5	"	" - Sample - long of Sample
4.6	"	" - Sample - long of Sample
4.7	"	Test 5 - Sample in Conductivity boat
4.8	"	" - Sample - long of Sample
4.9	"	" - Sample - long of Sample

14.3.1.1

Date Breakdown Photo List of Job file No

Jpeg No.	S/N	Photo Description
5.0	DADN (MS)	Test 5 - Sample in Conductivity boat
5.1	"	" - Sample - long of Sample
5.2	"	" - Sample - long of Sample
5.3	"	" - Sample - long of Sample
5.4	"	" - Sample - long of Sample
5.5	"	Test 1 - Sample in Conductivity boat
5.6	"	" - Sample - long of Sample
5.7	"	" - Sample - long of Sample
5.8	"	" - Sample - long of Sample
5.9	"	Test 2 - Sample in Conductivity boat
6.0	"	" - Sample - long of Sample
6.1	"	" - Sample - long of Sample
6.2	"	Test 3 - Sample in Conductivity boat
6.3	"	" - Sample - long of Sample
6.4	"	" - Sample - long of Sample
6.5	ROX (MS)	Test 1 - KBr in Conductivity boat
6.6	"	" - KBr ground
6.7	"	" - KBr ground
6.8	"	" - KBr ground
6.9	"	Test 2 - KBr in Conductivity boat
7.0	"	" - KBr ground
7.1	"	" - KBr ground
7.2	"	" - KBr ground
7.3	"	Test 3 - KBr in Conductivity boat
7.4	"	" - KBr ground
7.5	"	" - KBr ground
7.6	"	" - KBr ground
7.7	"	Test 4 - KBr in Conductivity boat
7.8	"	" - KBr ground
7.9	"	" - KBr ground
8.0	"	Test 5 - KBr in Conductivity boat
8.1	"	" - KBr ground
8.2	"	" - KBr ground
8.3	"	" - KBr ground
8.4	"	Test 6 - KBr in Conductivity boat
8.5	"	" - KBr ground
8.6	"	" - KBr ground
8.7	"	" - KBr ground
8.8	"	Test 7 - KBr in Conductivity boat
8.9	"	" - KBr ground
9.0	"	" - KBr ground
9.1	"	" - KBr ground
9.2	"	Test 8 - KBr in Conductivity boat
9.3	"	" - KBr ground
9.4	"	" - KBr ground
9.5	"	" - KBr ground
9.6	"	Test 9 - KBr in Conductivity boat
9.7	"	" - KBr ground
9.8	"	" - KBr ground
9.9	"	" - KBr ground

Date 12/1/24 Breakdown Photo List of ETD in Mantles Breakdown Job file No 1125

Jpeg No.	S/N	Photo Description
10.1	HMX (MS)	Test 1 - KBr in Conductivity boat
10.2	"	" - KBr ground
10.3	"	" - KBr ground
10.4	"	" - KBr ground
10.5	"	Test 2 - KBr in Conductivity boat
10.6	"	" - KBr ground
10.7	"	" - KBr ground
10.8	"	" - KBr ground
10.9	"	Test 3 - KBr in Conductivity boat
11.0	"	" - KBr ground
11.1	"	" - KBr ground
11.2	"	" - KBr ground
11.3	"	Test 4 - KBr in Conductivity boat
11.4	"	" - KBr ground
11.5	"	" - KBr ground
11.6	"	" - KBr ground
11.7	"	Test 5 - KBr in Conductivity boat
11.8	"	" - KBr ground
11.9	"	" - KBr ground
12.0	"	" - KBr ground
12.1	"	Test 6 - KBr in Conductivity boat
12.2	"	" - KBr ground
12.3	"	" - KBr ground
12.4	"	" - KBr ground
12.5	"	Test 7 - KBr in Conductivity boat
12.6	"	" - KBr ground
12.7	"	" - KBr ground
12.8	"	" - KBr ground
12.9	"	Test 8 - KBr in Conductivity boat
13.0	"	" - KBr ground
13.1	"	" - KBr ground
13.2	"	" - KBr ground
13.3	"	Test 9 - KBr in Conductivity boat
13.4	"	" - KBr ground
13.5	"	" - KBr ground
13.6	"	" - KBr ground
13.7	"	Test 10 - KBr in Conductivity boat
13.8	"	" - KBr ground
13.9	"	" - KBr ground
14.0	"	" - KBr ground
14.1	"	Test 11 - KBr in Conductivity boat
14.2	"	" - KBr ground
14.3	"	" - KBr ground
14.4	"	" - KBr ground
14.5	"	Test 12 - KBr in Conductivity boat
14.6	"	" - KBr ground
14.7	"	" - KBr ground
14.8	"	" - KBr ground
14.9	"	Test 13 - KBr in Conductivity boat
15.0	"	" - KBr ground

14.3.1.2

Date Breakdown Photo List of Job file No

Jpeg No.	S/N	Photo Description
15.1	WC 855 (MS)	Test 1 - Sample in Conductivity boat
15.2	"	" - Sample - long of Sample
15.3	"	" - Sample - long of Sample
15.4	"	Test 2 - Sample in Conductivity boat
15.5	"	" - Sample - long of Sample
15.6	"	" - Sample - long of Sample
15.7	"	Test 3 - Sample in Conductivity boat
15.8	"	" - Sample - long of Sample
15.9	"	" - Sample - long of Sample
16.0	"	Test 4 - Sample in Conductivity boat
16.1	"	" - Sample - long of Sample
16.2	"	" - Sample - long of Sample
16.3	"	" - Sample - long of Sample
16.4	"	Test 5 - Sample in Conductivity boat
16.5	"	" - Sample - long of Sample
16.6	"	" - Sample - long of Sample
16.7	"	" - Sample - long of Sample
16.8	"	Test 6 - Sample in Conductivity boat
16.9	"	" - Sample - long of Sample
17.0	"	" - Sample - long of Sample
17.1	"	" - Sample - long of Sample
17.2	"	Test 7 - Sample in Conductivity boat
17.3	"	" - Sample - long of Sample
17.4	"	" - Sample - long of Sample
17.5	"	" - Sample - long of Sample
17.6	"	Test 8 - Sample in Conductivity boat
17.7	"	" - Sample - long of Sample
17.8	"	" - Sample - long of Sample
17.9	"	" - Sample - long of Sample
18.0	"	Test 9 - Sample in Conductivity boat
18.1	"	" - Sample - long of Sample
18.2	"	" - Sample - long of Sample
18.3	"	" - Sample - long of Sample
18.4	"	Test 10 - Sample in Conductivity boat
18.5	"	" - Sample - long of Sample
18.6	"	" - Sample - long of Sample
18.7	"	" - Sample - long of Sample
18.8	"	Test 11 - Sample in Conductivity boat
18.9	"	" - Sample - long of Sample
19.0	"	" - Sample - long of Sample
19.1	"	" - Sample - long of Sample
19.2	"	Test 12 - Sample in Conductivity boat
19.3	"	" - Sample - long of Sample
19.4	"	" - Sample - long of Sample
19.5	"	" - Sample - long of Sample
19.6	"	Test 13 - Sample in Conductivity boat
19.7	"	" - Sample - long of Sample
19.8	"	" - Sample - long of Sample
19.9	"	" - Sample - long of Sample

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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