Final Report

Testing of T-10 Controlled Detonation Chamber to Assess Its Capabilities to Safely Destroy Incendiary, Riot Control Agent, and Smoke-Producing Munitions

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Executive Summary

This report contains the results of capability demonstrations for the T-10 Controlled Detonation Chamber (CDC) system. Demonstration information, performance testing, and results conform and satisfy requirements in U.S. Army Engineering and Support Center, Huntsville, Alabama (USAESCH), Scope of Work, August, 2004 (Testing of T-10 Controlled Detonation Chamber to Determine Capabilities to Safely Destroy Propellants, Incendiary, Riot Control, and Smoke Filled Munitions). Prior to the beginning of field work, the USAESCH removed propellants from the scope of work.

Field demonstrations were conducted at U.S. Army Arsenal, Redstone, AL from March 21, 2005 through March 25, 2005. The Redstone Arsenal demonstration included, air emission monitoring and worker exposure. The demonstrations were conducted using a standard operating procedures (SOPs) for destruction of the items listed, this report combined with the vetting of the processes and procedures contained within the work plan and this report, provide sufficient data to amend the original Explosives Safety Submission (ESS) to include the use of the T-10 CDC to destroy such Incendiary, Riot Control, and Smoke Filled Munitions.

This report establishes the processes and procedures to safely destroy Incendiary, Riot Control, and Smoke Filled Munitions.

Items:

- M73A Hand Grenades, Riot Control (CS)
- AN-M16 Hand Grenades (1330-G900), Thermite + TH-3
- AM-N8 Hand Grenade, (HC) Smoke
- Cartridge (CTG) 40-mm, Riot Control (CS)

In 1999, the U.S. Army Engineering and Support Center, Huntsville, Alabama (USAESCH), submitted an Equipment-Specific explosives safety submission for a commercially developed, controlled detonation chamber (CDC) manufactured by DeMil International, Inc. On January 31, 2000, the Department of Defense Explosives Safety Board approved the submission, authorizing use of the T-10 CDC to destroy certain high explosive fragmenting ordnance items on Department of Defense sites. One of the purposes of this project was to obtain and develop data for the USAESCH to justify the addition of other non-fragmentation producing munitions to the Explosives Safety Submission.

Demil International developed and received approval from USAESCH for a test/work plan to demonstrate the capabilities of the T-10 CDC to destroy the above list of items. The T-10 selected was a second generation unit constructed out of ¾" AR 500 armor plates, with a vapor seal door, and equipped with decontamination ports. The work plan established the process and procedure for the safe implementation of 37 explosive demolition events. These events included bulk high explosives, baseline open air detonations, and scaleable single and double shot techniques. The demonstration required the use of energetic explosives materials (116 lb, PETN—Data Sheet) and 100 exploding bridge wire detonators to destroy

the munitions. The following type (s) and amount (s) of munitions were destroyed: 24 Thermite incendiary grenades, 8 CS-filled 40-mm Cartridges, 8 CS-filled grenades, and 22 HC-filled grenades.

Open detonations of each fill type were performed to verify that the Standard Operating Procedure (SOP) developed for the demonstration was successful for each type of munitions and should be adopted as the appropriate method to destroy these items in the T-10 CDC. The SOP for wrapping munitions in PETN sheet explosive was an effective means of destroying the munitions in a manner suitable for chamber operations.

The resulting observations of the open detonations of the TH-3 Grenades indicated the TH-3 was destroyed and that the thermite could be safely destroyed within a CDC. In addition, the PETN sheet wrapping technique was confirmed with open detonations of HC (smoke grenades and 40 mm cartridges) and CS (riot control grenades). With this information, DeMil refined and further developed the donor charge wrapping procedure (Standard Operating Procedure) for wrapping grenades and cartridges (one at a time and two at a time). No reactive components of incendiary, riot agent, or smoke munition types remained in the chamber following detonations. The maximum donor explosive used (PETN donor sheet) was approximately 3 lb, well below the T-10 CDC NEW limit of 13 lb of TNT equivalency. The table below summarizes the results and presents the recommendations for destruction of items tested and related items by filler type.

Target Items	Items/ Demonstration Shot	Total Fill Weight (lb)	Demonstrated Donor-to-Filler Ratio	Recommended Donor-to-Filler Ratio[a]	Total Not-to-Exceed Filler Weight per Detonation (lb)
AN-M16 Hand Grenades (1330-G900) Thermite + TH-3	2	2.9	1:1	3:1[b]	2.9
AM-N8 Hand Grenade (HC) Smoke	2	2.11	1.4:1	2.5:1 to 3:1	2.11
Cartridge (CTG) 40-mm Riot Control (CS) and M73A Hand Grenades Riot Control (CS)	1ea	1.27	2.4:1	2.4:1 to 3:1	1.27[c]

[a]The NEW limit of 13 lb TNT equivalent should not be exceeded per detonation.
[b]1:1 ratio is recommended for thin-walled items like grenades.
[c]An equivalent weight of FM smoke fill can also be destroyed using this approach.

Worker exposure (industrial hygiene) samples were collected and the results showed that the chamber was clear of contaminants, including smoke, and there were no residual materials in the chamber that were smoking or burning.

Air emission samples from the T-10 stack were clear of HCl, Cl_2, CS, and HC at method detection limits, on the order of 0.1 mg/L to 0.14 mg/L. Emission results were compared to air quality permits obtained for the T-10 CDC in four Air Quality Districts in California. There were no air emissions that would have exceeded those stringent permitted conditions. These results provide evidence that the organic chemical active ingredient type (or mixture) will meet air quality emission guidelines for permitting of these constituents.

Solid waste generated from all operations was clear of any material that generated smoke or heat upon removal. The only waste that was declared hazardous was the decontamination wash water mixture, which contained lead at 8 mg/L, over the regulatory threshold limit of 5 mg/L. This was based on toxicity characteristic leaching procedure (TCLP) analysis for metals and semivolatile organic compounds (SVOCs). Lead was a common constituent in the primer mix for all of the munitions tested. None of the solid or liquid wastes were characterized as corrosive. However, classification of waste as hazardous or non-hazardous would be job-site specific, and duration of operations would be a factor. Solid waste was also sampled for residual CS and the results were below the method specific detection limit of 10 micrograms per sample.

This report contains details of the demonstration objectives, site description, work plan, test plan, and operator protective measures. Also included are detailed characterization tests for worker exposure, air, water, and solid waste together with quality control data objectives and criteria for each sample type.

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Abbreviations and Acronyms

CDC	contained detonation chamber
CMS	Draeger chip management system
CN	riot agent (2-Chloroacetonephenone)
CS	riot agent (orthochlorobenzylidenemalononitrile)
EPA	U.S. Environmental Protection Agency
FM	smoke—titanium tetrachloride
FS	smoke—chlorosulfonic acid
HAPs	hazardous air pollutants
HC	smoke—hexachloroethane/zinc oxide/aluminum
NEW	Net Explosive Weight
OE	Ordnance and Explosives
PETN	pentaerythritoltetranitrate
PM	particulate matter
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
psig	pounds per square inch, gauge
SAP	sampling and analysis plan
SVOC	semivolatile organic compound
TA-6	Test Area Six
TCLP	toxicity characteristic leaching procedure
TH-3	thermite, mixture of iron oxide and aluminum or Thermate, mixture of iron oxide, aluminum, barium nitrate, and sulfur
USAESCH	U.S. Army Engineering and Support Center, Huntsville (Alabama)
VOC	volatile organic compound

SECTION 1

Introduction

1.1 Project Overview

DeMil International, Inc., was placed under contract (Contract Number DACA87-00-D-0047, Task Order 0015) by the U.S. Army Engineering and Support Center (USAESCH) in August 2004 to develop data to determine the safety of destroying propellants, incendiary, riot control, and smoke-filled munitions. Propellants were later de-scoped from the project.

The field work was conducted from Monday, March 28, through Friday, April 1, 2005. The work was done at the "Hazardous Test Site" in Test Area Six (TA-6) at Redstone Arsenal, Huntsville, Alabama. USAESCH rented range time from Redstone Arsenal to conduct the testing. Redstone Arsenal, TA-6 provided range control support, explosive storage, and the ordnance items to be used in the testing. The ordnance items selected for testing were:

- M73A Hand Grenades, Riot Control (CS)
- AN-M16 Hand Grenades (1330-G900), Thermite + TH-3
- AM-N8 Hand Grenade, (HC) Smoke
- Cartridge (CTG) 40-mm, Riot Control (CS)

1.2 Project Objectives

The overall purpose of this testing was to determine if certain chemical-munition fill types (incendiary, riot control agent, and smokes) could be safely handled and destroyed using the T-10 Controlled Detonation Chamber (CDC). The safe handling and destruction refer to operator safety and explosives safety. The determining factors established to evaluate the successful outcome of a test were the following: all explosives were consumed in the detonation process, and there were no operator exposure hazards to chemicals or explosive byproducts when the operator inspected the T-10 CDC system.

If these target items were successfully destroyed, data from this project could be used, following review and acceptance by the USAESCH, to develop amendments to modify the existing explosives safety submission to provide authorization for DeMil International, Inc., to destroy a broader range of identified munitions in a T-10 CDC.

Analytical data were obtained from worker exposure (industrial hygiene)–type samples that were collected to evaluate exposure hazards. Personnel involved in CDC operations were dressed in OSHA level B PPE. In addition, preliminary chemical characterization data were obtained to assess air emissions generated from detonations as well as CDC solid and liquid waste to determine the appropriate disposable practice.

A work plan and sampling and analysis plan (SAP) were developed to provide relevant data to make a determination as to the ability of the T-10 CDC to safety destroy these munitions from an explosives safety standpoint. Preliminary environmental data were collected for worker exposure monitoring, air emissions, and secondary waste analysis

generated from operations. Recommendations were made to the USAESCH regarding what types of munition fills could be safely destroyed in a T-10 CDC.

1.3 Site Description

Testing was conducted over 5 days at the Redstone Arsenal's Hazardous Test Site, an area in TA-6, which is just south of Martin Road. Redstone is in central north Alabama; its 40,000 acres are bordered by Huntsville (Madison County) on the north and east, with the Tennessee River forming the southern boundary.

FIGURE 1-1
Redstone Arsenal Showing Location of Test Area Six

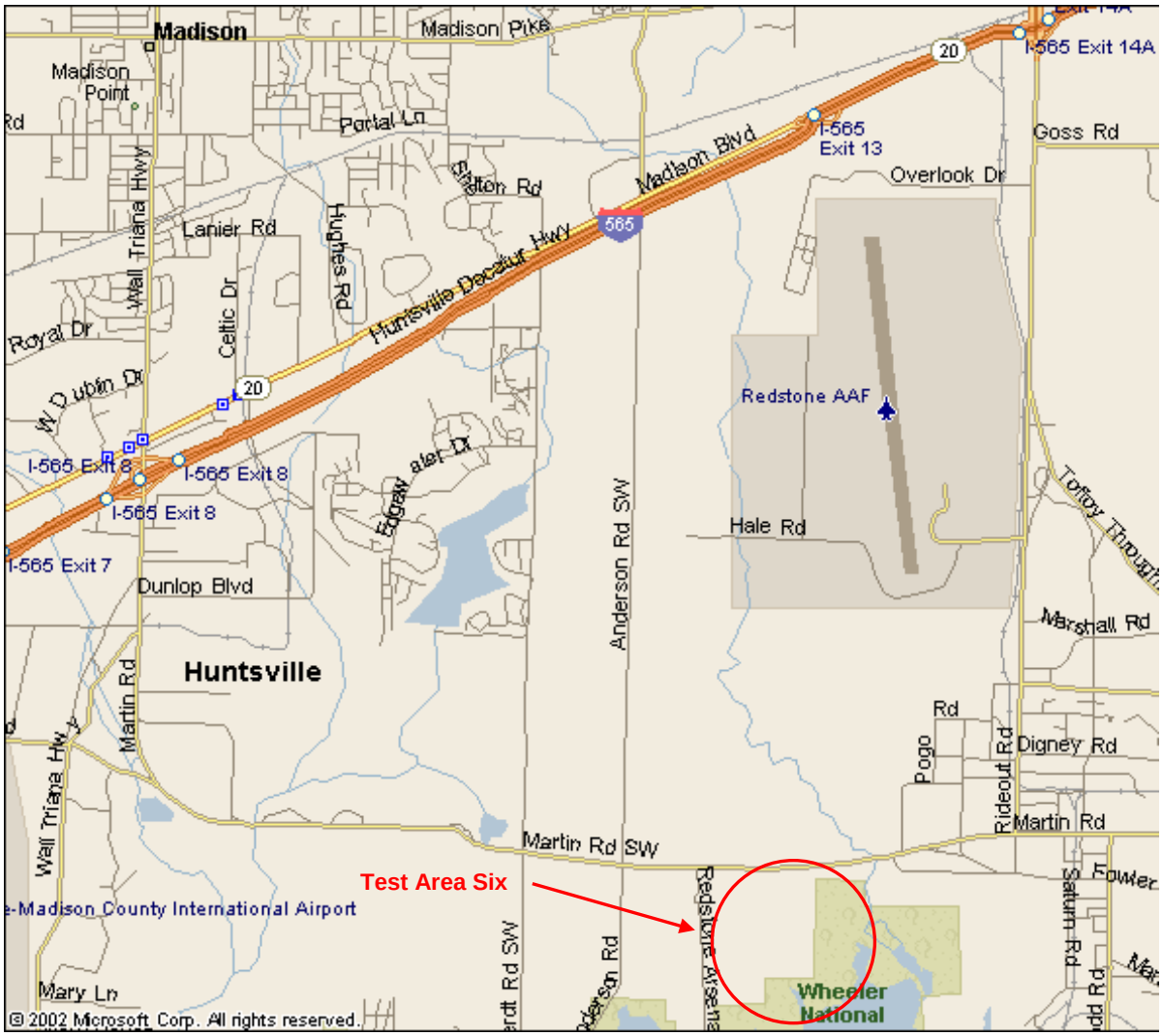

FIGURE 1-2
Aerial View of the TA-6 Hazardous Test Site

SECTION 2

Project Activity Summary

2.1 Development of Type II Work Plan

A Type II Work Plan was prepared in accordance with data item description OE-005-01.01. The work plan originally indicated two potential operational sites within TA-6 in Redstone Arsenal. The primary site was the Hazardous Test Site, and the secondary site was the Bomb Pad. The Hazardous Test Site was used for the project because it was less likely to have interference from other TA-6 activities and because a protective block house and paved areas to place the CDC system on were available. The USAESCH developed the Explosive Siting Plan (Chapter 4 of the work plan).

2.2 Development of Environmental Sampling and Analysis Plan

As part of the Type II Work Plan, DeMil developed an Environmental Sampling and Analysis Plan (SAP) in accordance with data item description OE-005-10.01. Summaries of the worker exposure characterization, air emissions monitoring, and waste analyses are presented in Appendix A of this report.

The SAP is located in Appendix E of the Work Plan. DeMil retained AST Environmental to do the air emissions sampling, worker exposure sampling, and waste characterization sampling. Samples were delivered to various subcontracted laboratories for analysis with adherence to sample holding times and chain-of-custody procedures. The laboratories were responsible for adherence to established, method-specific, quality control procedures. The SAP presented the approach to the test, a shot matrix, and the proposed analytical methods for the analysis.

2.3 Project Work Conducted

2.3.1 CDC Mobilization

DeMil mobilized one T-10 CDC from Crescent City, Illinois to Redstone Arsenal, Alabama the week of March 21, 2005. The T-10 CDC arrived at Redstone Arsenal and was placed on site (Hazardous Test Site, TA-6) on Friday March 25, 2005.

2.3.2 Explosives

DeMil ordered and shipped 250 lb of PETN flex sheet and 50 exploding bridge wire detonators and 50 hot bridge detonators to the ammunition supply point in TA-6. The 50 hot bridge detonators were used on the open detonations for the project. The explosives were delivered as needed to the site by the TA-6 range personnel. A balance of 134 lb of PETN flex sheet was not used in the project and was transferred to the Redstone Arsenal ammunition supply point. No detonators were left at or transferred to Redstone. Details of the explosives usage are located in the shot logs in Appendix B.

2.3.3 CDC Operations

The CDC operations are summarized in Table 2-1. Detonations are detailed in the shot logs in Appendix B.

TABLE 2-1
Summary of CDC Operations

	Detonation Operation		
Day	**Open**	**T-10 CDC**	**Comment**
March 28	Thermite grenades	Bulk high-explosives baseline shots	Baseline shots conducted for setup purposes for the air emissions–sampling equipment
March 29	—	Thermite grenades	
March 30	HC- and CS-filled grenades and projectiles	HC- and CS-filled grenades and projectiles	Twenty-two detonations total; owing to weather concerns, day's testing included that planned for the following day, March 31
March 31	—	—	T-10 CDC cleaned of solid debris (pea gravel and filters removed) and decontaminated with high-pressure water; solid and liquid waste sampled; samples shipped to laboratory for analysis
April 1	—	—	T-10 CDC demobilized from the site
October 5	—	—	Composite sample of pea gravel waste collected for corrosivity (pH) analysis, This sample was collected during decontamination in March but not analyzed due to a laboratory sample log-in error.

2.3.4 CDC Clean-Out and Decontamination

CDC clean-out and decontamination was conducted by Bay Associates. Pea gravel and debris and expansion chamber dust were removed from the CDC system, drummed, and sampled. The Torit filters were removed and drummed. The interior of the blast chamber, expansion tank, and Torit filter system was pressure washed. The decontamination water was captured, drummed, and sampled. A total of seven drums were filled with solid waste and decontamination liquids:

- Drums with pea gravel
- Drums with decontamination water
- Drums with both crushed Torit filter cartridges and used PPE

2.3.5 CDC Waste Sampling and Characterization

The CDC solid waste and the decontamination water were sampled according to the approved SAP per the Type II Work Plan. Samples were logged and shipped to the approved laboratory for chemical analysis. Waste chemical analyses are summarized in Appendix A. The sample of pea gravel waste designated for corrosivity analysis was not analyzed by the laboratory due to a sample log-in error. A second composite sample of the

pea gravel was collected on October 5 and submitted for analysis. Results are reported in Appendix A, Table 2-5.

The only waste that would have been considered hazardous was the decontamination wash water, which contained lead (8 mg/L) above the regulatory threshold limit (5 mg/L). Lead was identified as an explosive component in each of the three types of munitions tested. None of the solid or liquid wastes was determined to be corrosive. Waste drums were labeled and left onsite for disposal by Redstone Arsenal.

2.3.6 CDC Demobilization

Transport permits were obtained 3 days prior to the planned movement of the T-10 CDC. The T-10 CDC was removed from TA-6 on Thursday afternoon and was transported to Crescent City, Illinois, on Friday, April 1, 2005.

2.4 Description of Munitions and Explosives of Concern Items Selected

The following is the list of OE items that were selected for testing in this project. The items were provided by Redstone Arsenal.

- M73A Hand Grenades, Riot Control (CS)
- AN-M16 Hand Grenades (1330-G900), Thermite + TH-3
- AM-N8 Hand Grenade, (HC) Smoke
- Cartridge (CTG) 40-mm, Riot Control (CS)

2.5 Shot Matrix

A shot matrix was proposed as a test matrix driven by the need of the air emissions testing minimum sample volume to be within method reporting limits. It was proposed as a plan with actual shots determined by observations from the open detonations. A minimum of five detonations for each ordnance type was needed to provide an adequate sample for the air emission testing methods. However, in testing two items of the same fill type were detonated simultaneously. This provided more than sufficient material in a detonation for air emission sampling quantitation.

The actual shot history is presented in the shot logs located in Appendix B. The open detonations are summarized in Section 3.1, Open Detonation Summary.

SECTION 3

Project Data

3.1 Open Detonation Summary

3.1.1 Monday March 28

Four open detonations were conducted using hot bridge detonators with the objective of visually observing the successful destruction of the thermite filler in the grenades and developing a donor charge wrapping procedure for the thermite grenades. This evaluation was needed to make a determination of the destruction capabilities of the detonation prior to moving the process into the T-10 CDC. The detonation was evaluated by looking for any surviving burning pieces of thermite. No open burning of thermite grenade fills was performed as was proposed in the original Shot Matrix.

TABLE 3-1
Open Detonation TH3 Data

Shot	Description	Donor Charge (PETN Flex) (lb)
1	1 Thermite Grenade	1.5
2	2 Thermite Grenades	2
3	2 Thermite Grenades	3
4	3 Thermite Grenades	4.5

3.1.2 Tuesday March 29

No open detonations on Tuesday; CDC operations only.

3.1.3 Wednesday March 30

The objective of these open shots was to determine a good donor charge wrapping procedure. These open detonations occurred concurrently with CDC operations.

TABLE 3-2
Open Detonation Smoke and CS Data

Shot	Description	Donor Charge (PETN Flex) (lb)
1	1 HC Smoke Grenade	2.5
2	1 HC Smoke Grenade	2.5
3	4 40MM CS Projectiles	4
4	2 CS Grenades	4
5	4 HC Smoke Grenades	5

3.2 T-10 CDC Shot Log Summary

Table 3-3 summarizes the explosives used and the ordnance items used during the project. See the Shot Logs in Appendix B for details. All of the detonations occurred safely and as planned.

TABLE 3-3
Shot Log Summaries for Week Ending 1 April 2005

Item	No.
Code H items	68
Filler Wt (lb)	3.19
Donor wt (lb)	116.00
Total NEW (lb)	119.18
Water wt (lb)	181.50
Shots	37
Exploding bridge wire detonators used	50
Hot Bridge detonators used	50

3.3 Air Emissions Testing Summary

Air samples from the T-10 exhaust stack were collected during the detonation of CS, HC, and thermite munitions. For each type of item, a single sample was integrated over 8 detonations. Table 3-4 provides a summary of analytical methods performed on the stack gas samples. Additional details are provided in Appendix A and the Sampling and Analysis Plan.

TABLE 3-4
Stack Gas Sampling and Analytical Matrix

Test Items	Target Parameter(s), Analytical Method(s)
CS-filled 40-mm cartridge and grenade	CS; P&CAM Method 304
	Ammonia (NH_3), hydrochloric acid (HCl), chlorine (Cl_2) and HCN (hydrogen cyanide); EPA Method 26/CTM 027/CTM 033
	CVOCs(a)/VOCs; Compendium Method TO-15 (including TNMHC and Tics)
	CO_2 and CO; EPA Methods 3A and 10 (CEMS), respectively
	Volume flow rate
HC-filled grenade	NH_3/HCl/Cl_2/HCN, EPA Method 26/CTM 027/CTM 033
	CVOCs/VOCs; Compendium Method TO-15 (including TNMHC and Tics (this includes hexachloroethane))
	CO_2, CO; Methods 3A and 10 (CEMS), respectively
	Volume flow rate

TABLE 3-4
Stack Gas Sampling and Analytical Matrix

Test Items	Target Parameter(s), Analytical Method(s)
Thermite-filled grenade	CO_2, CO; Methods 3A and 10 (CEMS), respectively
	PM, metals; EPA Method 29 and Gravimetric (for PM) and 6010B (for metals)
	Volume flow rate

Although samples were collected for chlorinated VOCs, the laboratory did not perform the required quantitative analysis due to a sample log-in error.

3.4 Worker Exposure Sampling Summary

The worker exposure monitoring/sampling included ambient air sampling, and personal exposure monitoring at the T-10 System as defined in Table 3-5 below.

Samples for Particulate Matter (PM) and metals were collected using personal sampling pumps that accompanied those who had the greatest potential for exposure—the operators who entered the detonation chamber during operations.

Worker exposure monitoring for total hydrocarbons, HCN, HCl, NH_3, Cl_2, and Phosgene were conducted just inside the chamber entrance. VOCs were monitored using an intrinsically safe flame ionization detector (FID). The HCN, HCl, NH_3, Cl_2, and phosgene monitoring were performed using the Draeger chip management system (CMS, a semi-quantitative substance specific colorimetric analyzer). Total and Respirable PM, and Metals samples were collected incrementally, that is, only when the operators are in the detonation chamber.

Additional details are provided in Appendix A and the SAP.

TABLE 3-5
Industrial Hygiene Sampling and Analysis Matrix

Test Items	Target Parameter(s), Analytical Method(s)
CS, HC, Thermite	Particulate matter (respirable and total); NIOSH Methods 0500/0600
	Metals; NIOSH Method 7300
	Total organic hydrocarbons; field GC (hand held–FID: OVA 1000 or equivalent)
	Semi-quantitative monitoring with hand held instruments to monitor for HCN and NH3 during all test runs and for HCl and Cl_2 during the CS and HC test runs and for Phosgene during HC test run. This will be performed with a substance specific colorimetric analyzer (Draeger CMS).

3.5 Waste Characterization Summary

Following the completion of detonations, solid waste samples were collected from the pea gravel (chamber floor) and dust from the expansion chamber. Liquid samples were collected

from the decontamination water. Samples were analyzed for corrosivity and separate samples were prepared by the Toxicity Characteristic Leaching Procedure (TCLP) and analyzed for SVOCs, and metals. Additionally, the pea gravel and dust samples were analyzed for CS using P&CAM Method 304.

TABLE 3-6
Waste Sampling and Analysis Matrix

Test Items	Target Parameter(s), Analytical Method(s)
Pea gravel, accumulated dust, and decon fluids samples	TCLP metals; 1311/3015 (aqueous)/3050B (solids)/6010B
	SVOCs; 1311/3520C/8270C
	Corrosivity; 9054C Non-Aqueous, 9040B Aqueous
	CS; P&CAM Method 304

As specified in the SAP, collection of solid residue (dust) samples from the APCU was planned; however, there was insufficient dust to collect a meaningful sample.

SECTION 4

Results

4.1 Open Detonation

The reason for performing open detonations was to verify that wrapping munitions in PETN sheet explosive was an effective means of destroying the munitions in a manner suitable for chamber operations. The resulting observations of the open detonations of the TH-3 Grenades indicated the TH-3 was destroyed in the open detonation and that the thermite could be safely destroyed within a CDC. In addition, the PETN sheet wrapping technique was confirmed with open detonations of HC (smoke grenades and 40 mm cartridges) and CS (riot control grenades). Observations are summarized in Table 4.1. With this information, DeMil developed a donor charge wrapping procedure (Standard Operating Procedure) for wrapping the grenades and cartridges (one at a time and two at a time). The Standard Operating Procedures are located in Appendix C.

TABLE 4-1
Summary of Open Detonation Results

Description	Donor Charge (PETN Flex) (lb)	Observation
1 Thermite Grenade	1.5	Complete detonation, no TH3 remained
2 Thermite Grenades	2	Complete detonation, no TH3 remained
2 Thermite Grenades	3	Complete detonation, no TH3 remained
3 Thermite Grenades	4.5	Complete detonation, no TH3 remained
4 40MM CS Projectiles	4	A visible cloud from the detonation. Destruction complete.
2 CS Grenades	4	A visible cloud from the detonation. Destruction complete.
4 HC Smoke Grenades	5	A larger cloud of white smoke than shots 1 and 2. Destruction complete.

4.2 T-10 CDC

With the procedures developed from the open detonations, DeMil International, Inc., moved the detonation processes into the T-10 CDC. The results were that all of the items were completely and safety destroyed in the CDC. Air emission sampling and worker exposure sampling were conducted during these detonations.

4.3 Air Emission Sampling

Results of air emissions were below emission estimates that were generated for developing air quality permits for the CDC Transportation Study conducted in California. California air permitting requirements are among the most stringent in the United States and favorable comparison of T-10 CDC air emissions estimates to these standards are indicative of the likely success of permitting the system in other States. Details of air emissions sampling are provided in Appendix A.

The primary source of CO and VOC emissions were from the detonation of PETN sheet. Emission estimates are largely developed through stack test results of approved regulatory procedures. An emission factor is a common way to develop emission estimates. For this study, emission factors were developed that report the grams of analyte per gram of donor explosive. Emission factors for target analytes in stack gas are provided in Appendix A, Table 2-4. Emission factors are commonly applied in estimating air emissions for air quality permit evaluations. The quantity of donor explosive far exceeds the fill of munitions of this size.

Several of the VOCs identified are hazardous air pollutants (HAPs) as defined under Section 112 of the 1990 USEPA Clean Air Act Amendments. HAPs detected were benzene, ethylbenzene, toluene, and xylenes. However, the quantity of emissions was low and would not require additional controls. The T-10 CDC would not be considered a major source of HAP emissions. The HAP emissions were generated from destruction of PETN sheet explosive based on other T-10 emission studies at Massachusetts Military Reservation and Milan Army Depot. Other HAPs that were identified but fully quantified due to failure of the laboratory to apply the correct instrument calibration scheme to the requested analysis were: methylene chloride, dichlorethenes, trichloroethene, tetrachloroethene, and carbon tetrachloride. Measurements of chlorinated organics have not been undertaken previously in a T-10 CDC. However, based on the limited analytical results, it is not likely that the CDC would require additional controls for these chlorinated organic compounds. Metal HAPs that were associated with the pea gravel as well as detonations were: lead and manganese. Again, there are no additional controls likely. However, an air quality permit may be required by a State or Local permitting authority.

The HC and CS fill types yielded some visible smoke emissions of approximately 1-minute duration for about 80 foot distance. This phenomenon would likely require an air quality permit in many East Coast and West Coast states, only if the emission were visible across the property boundary. Although, there were visible emissions of short duration there was no CS measured in the stack exhaust for the CS fill type.

4.4 Worker Exposure Sampling

There were no measurements of compounds in Table 4.4 that exceeded OSHA threshold limits based on the permissible exposure limit (PEL). There were no instances for which smoke or burning materials were present in the chamber when the chamber door was opened. Explosive operations were safe and explosives and reactive fill materials were not present in the chamber following detonation events for any fill type.

As seen in Appendix A (Table 2-7), respirable dust concentrations were below method detection limit (< 0.3 mg/m^3) in all three sampling runs. Total dust was present above detection limits in the Thermite Test Run only at a concentration of 0.7 mg/m^3 in this test and well below the permissible exposure limit (PEL) of 10 mg/m^3 as silica dust. The only metal above detection limits was zinc in the HC Test Run. The measured concentration was 0.05 mg/m^3 well below the PEL of 5 mg/m^3.

Using the CMS hand held portable analyzers for NH_3, Cl_2, HCl, HCN and phosgene, only ammonia was present above the instrument detection limits. NH_3 was present in the Thermite Test Run (concentrations from ND to 0.7 ppm) and the CS Test Run (concentrations from ND to 2.56 ppm). These results are well below the NIOSH guidance TWA of 25 ppm. Ammonia is a typical component observed in the detonation of PETN-based sheet explosive.

A hand held FID was used to monitor total hydrocarbons in the chamber immediately upon opening the inner chamber door. FID results ranged from 0.0 to 0.6 ppmv for the Thermite and HC Test Runs. During the CS Test Run, the FID provided no response (no detections) for total hydrocarbons. These low levels are expected since the chamber door provides limited access when first opened and the APCU exhaust brings in a steady stream of fresh ambient air that purges the area accessible by the FID instrument's sampling probe.

A complete summary of worker exposure analytical results are provided in Appendix A.

Based on the results of air and worker exposure monitoring for the destruction regime in this test, the level of particulate dust, metals, CS riot control agent, Thermite, HC Smoke generated were below PEL limits, thus indicating a reduction in OSHA Personnel Protective Equipment (PPE) Level "B" to OSHA PPE Level "C" would be appropriate. This level of protection provides workers with exposure control to potential build-ups of residues from repetitive detonations yielding deposits that expose dermal and respiratory receptors to risk from contact generated during set-up, maintenance, and cleaning. However, in the cases of different items or higher mass throughput of similar smoke, incendiary or riot agents, it would be prudent to monitor worker exposure to verify the Level "C" provides the required level protection .

4.5 Waste Characterization

Solid waste samples collected from the pea gravel (chamber floor), and dust from the expansion chamber were characterized for pH, and additional samples were prepared by the Toxicity Characteristic Leaching Procedure (TCLP) and analyzed for SVOCs and metals. Additionally, the pea gravel and dust samples were analyzed for CS using P&CAM Method 304. TCLP results for SVOCs were all below detection limits. TCLP metals that were detected included: barium, cadmium, lead and silver. However, barium concentrations in all three streams are attributed to method blank contamination. Lead was the only parameter exceeding the TCLP criterion. Lead was present in the decontamination wash water at a concentration of 8 mg/L (above the 5 mg/L criterion).

Also, pH of the decontamination water was 4.6 and was inside the required limits of pH <2 or >12.5. The pH of the solid waste (pea gravel and dust) was 7.6. A complete summary of waste characterization results is provided in Appendix A.

SECTION 5

Conclusions and Recommendations

5.1 Conclusions

5.1.1 Operational Considerations

SOPs, including donor explosive configurations, developed for this testing are appropriate for future conventional munition destruction operations of similar size, regardless of fill type. Results of all worker exposure monitoring indicate that, for future operations OSHA level B PPE was indeed protective.

5.1.2 Incendiary Munitions (Thermite TH-3)

Based on results of this testing, Thermite TH-3, can be safely destroyed in the T-10 CDC. Thermite material weight per detonation should be limited to an equivalent of the total of the two items tested, or about 2.9 lb of incendiary mixture (2 x [Iron Oxide, 290 g/Ba Nitrate, 191 g/Al Powder, 165 g/Sulfur, 13 g]).

5.1.3 CS Munitions (Riot Agent)

Based on results of this testing, CS Riot Agent can be safely destroyed in the T-10 CDC. It is recommended that quantitative measurement of chlorinated VOCs in stack emissions be undertaken during future CS detonations to better understand the nature of CVOCs emitted. The mass of CS material per detonation was approximately 200 g. There were no detectable quantities of CS in the air emissions. CS-filled munitions were limited to no more than 1.27 lb of fill mix.

Riot agent CN was not tested in the CDC. Therefore, destruction of CN cannot be verified. However, both CS and CN have an aromatic ring as part of the chemical structure. The boiling point is lower for CN as compared to CS (477°F for CN and 590°F for CS). Likewise the melting point is lower for CN as compared to CS (136°F for CN and 199°F for CS). The vapor pressures for both CN and CS are less than 0.01 mm Hg at 68°F. It would be expected that similar destruction to that shown for CS would be obtained for CN using the PETN wrapping technique. Based on chemical similarities of CS and CN, destruction of CN-filled munitions should be limited to no more than 1.27 lb of fill mix.

5.1.4 Smoke Munitions (HC)

Based on results of this testing, HC smoke munitions can be safely destroyed in the T-10 CDC. It is recommended that quantitative measurement of chlorinated VOCs in stack emissions be undertaken during future HC detonations to better understand the nature of CVOCs emitted. The mass of HC material per detonation should be generally equivalent the two items tested, 2.11 lb [or 2 x (Zn Oxide, 223 g/Hexachloroethane, 214 g/Al Powder, 43 g)].

Other common toxic smoke fills include FS and FM and these material fills were not tested in the T10-CDC. FS, also know as sulfuric oxide, chlorosulfonic acid, or sulfuric anhydride. When exposed to air FS rapidly takes up water and forms white fumes. The smoke typically consists of equal mixtures of sulfur trioxide and chlorosulfonic acid. Sulfur trioxide will rapidly form sulfuric acid on uptake of water and condense into a white cloud. Sulfur trioxide is stable and would not likely be destroyed in the T10-CDC. In addition, the sulfuric acid mist would likely damage the particulate filters of the T10-CDC. FM is commonly known as titanium tetrachloride. In contact with moist air a dense smoke is formed that is comprised of hydrochloric acid, and various oxides of titanium. Since the HC and CS filled items were demonstrated to be successfully destroyed in the T10-CDC it is likely that FM filled items (up to 2.11 lb of fill) would be destroyed with similar effectiveness.

5.2 Recommendations for Future Testing

5.2.1 Operational Considerations and Worker Exposure

Based on the results of air and worker exposure monitoring for the destruction regime in this test, the level of particulate dust, metals, CS riot control agent, Thermite, HC Smoke generated were below PEL limits, OSHA PPE Level "C" would likely have been appropriate. However, in the cases of different items or higher mass throughput of similar smoke, incendiary or riot agents, it would be prudent to monitor worker exposure to verify the Level "C" provides the required protection.

5.2.2 Destruction of Smokes, Incendiaries and Riot Agents

Incendiary Munitions—Because thermite incendiary mixture generates the greatest quantity of heat of any incendiary that DeMil is aware of, DeMil recommends from this study's results that any incendiary of up to 2.9 lb would be safely destroyed in a T-10 CDC system. This recommendation should be verified in the future by pressure measurements in the T-10 CDC expansion chamber where pressure should be limited to less than 14 psig.

HC Smoke—Although the results of this testing indicate the HC fills up to 2.11 lb can be safely and effectively destroyed in the T-10 CDC, DeMil recommends that the anticipated levels of chlorinated VOC emissions be verified by quantitative analysis using Method TO-15 or other equivalent method.

FS Smoke—A different filter media would likely be required for T10-CDC operations destroying FS fills and perhaps a neutralizing solid (for example lime) would be required to mitigate corrosive attacks on the particulate filter and perhaps in the expansion tank. A performance test is recommended for the destruction of this material in the T-10 CDC.

Appendix B
Shot Logs

Appendix C
Standard Operating Procedures

Appendix A
Source Air Emissions Testing, Waste Characterization, and Worker Exposure Monitoring Summary

Appendix D
Project Photographs

Appendix E
Project Scope of Work