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EMERGENCY DESTRUCTION SYSTEM FOR RECOVERED CHEMICAL MUNITIONS

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ABSTRACT

At the request of the U.S. Army Project Manager for Non-Stockpile Chemical Materiel, Sandia National Laboratories is developing a transportable system for destroying recovered, explosively configured, chemical warfare munitions. The system uses shaped charges to access the agent and burster followed by chemical neutralization to destroy them. The entire process takes place inside a sealed pressure vessel. In this paper, we review the design, operation, and testing of a prototype system capable of containing up to one pound of explosive.

INTRODUCTION

The DoD is required under the provision of Public Law 102-484, Section 176 to safely destroy all United States non-stockpile chemical warfare materiel (NSCM). The U.S. Army is the DoD executive agent tasked with destroying the chemical weapon stockpile. United States chemical warfare materiel (CWM) is broadly classified into the chemical stockpile and all other chemical materiel.

The Army intends to field Munitions Management Device (MMD) systems capable of destroying CWM recovered from small quantity burial sites. Each MMD system has a specific mission based on the type of CWM located at each site. The MMD systems cover all scenarios for recovered CWM except for explosively configured, fused, and unsafe for transport. At the request of the U.S. Army Non-Stockpile Chemical Materiel program manager (PMNSCM), Sandia is developing a transportable Emergency Destruction System (EDS) to fill this role. The mission of PMNSCM is focused on non-stockpile chemical warfare materiel.

The EDS is designed for use in emergency scenarios with recovered World War I and World War II vintage munitions that are deemed unsafe for mechanical handling or transport. The EDS mission is to safely contain the munition blast and fragments, and destroy the chemical agent without insult to the environment.

The operational scenario for EDS consists of Explosive Ordinance Disposal personnel hand carrying a single recovered munition and placing it in the EDS vessel. The vessel is sealed and leak tested then the munition is opened with shaped charges. Neutralization chemicals are added and the vessel is heated and agitated to destroy the agent and any explosive residue. The system is then emptied and prepared for the next munition. The effluent from the chemical neutralization process would likely be classified a RCRA hazardous waste

DISCLAIMER

Sandia has designed and assembled a prototype system that is currently being tested with explosives and surrogate chemicals. The design and operation of the system and results of completed tests are presented in this paper.

SYSTEM DESIGN

The prototype system, shown in figures 1 to 4, is mounted on a 10,000 pound-rated trailer. It includes the explosion chamber, tanks and plumbing for storing and transferring neutralization chemicals, electrical power distribution panels, and a hydraulic system for oscillating the chamber.

The 6.5 cubic foot explosion chamber was fabricated from a 316 stainless steel forging and is designed to contain repeated detonations of up to one pound of explosive (TNT equivalent). This is roughly one half the capacity of the full size system. The vessel relies on a Grayloc all metal seal to contain the detonation and the chemical agent. A Viton o-ring provides a backup seal. The vessel includes high voltage electrical feedthroughs for the detonators and low voltage feed throughs for internal instrumentation such as strain gages and pressure transducers. Ports for adding and draining fluids use high temperature, bellows valves with metal-to-metal seals.

The vessel is heated with twelve 1-kW band heaters using a feedback control system. It takes 3 to 4 hours to heat the fluids to 100°C. Fluid temperature can be controlled within +/- 2°C.

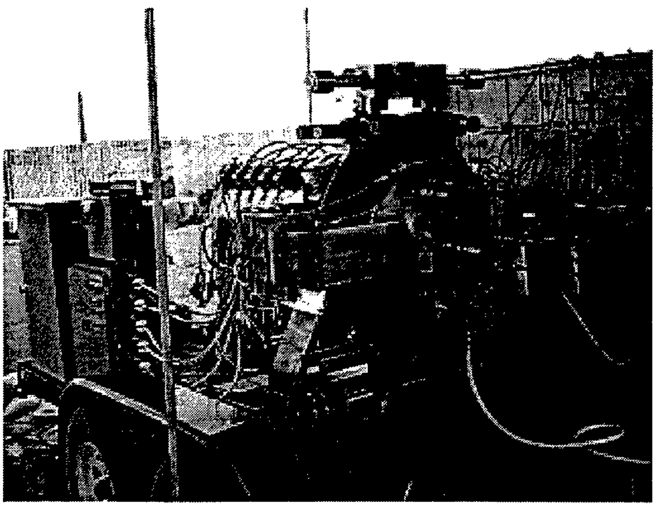
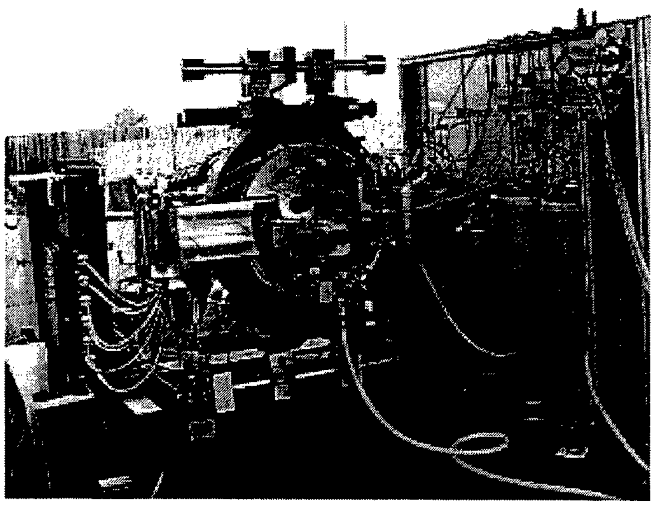


Figure 1



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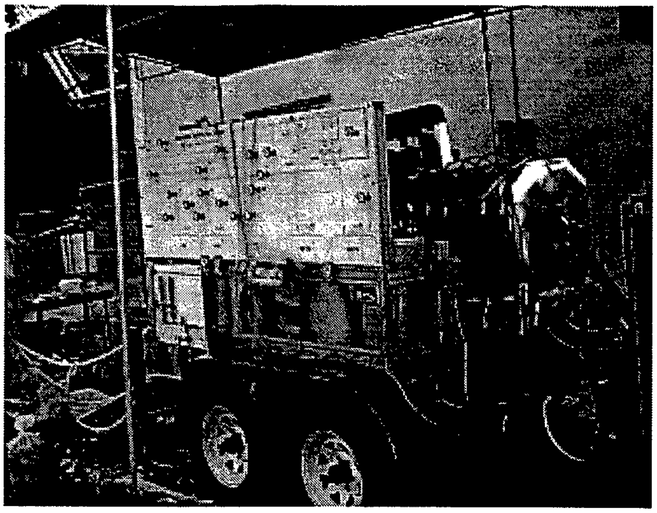

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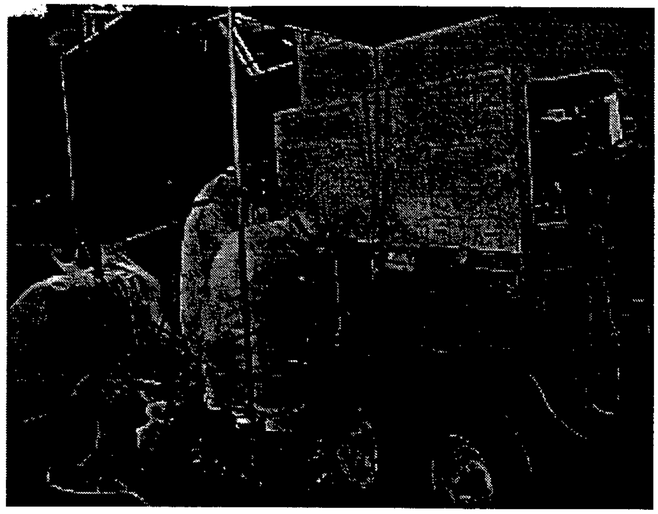

Figure 4

ACCESSING MUNITIONS WITH SHAPED CHARGES

Once the munition has been recovered and placed into the EDS vessel, a system for exposing the contents of the munition and destroying the burster is required before chemical neutralization can take place. These requirements are accomplished with a combination of shaped charges. The use of shaped charges is a simple, safe, repeatable, and understood practice. Shaped charges were chosen over mechanical, chemical and thermal mechanisms because they require minimal access through the containment vessel wall, they are exceptionally reliable, and their design parameters are well characterized.

The explosive opening system consists of five sub-systems: a Linear Shaped Charge (LSC) munition opener, a pair of Conical Shaped Charge (CSC) burster destruction charges, a fragment suppression system for minimization of damage to the EDS vessel from blast and fragments during opening and burster destruction, a high voltage modular firing system, and a monitoring system for verification of shaped charge and burster initiation. Testing of these subsystems has been focused on the 75 mm Mk II artillery round. However, plans are in process to accommodate the 4.2 inch Mortar Cartridge and Livens Projectile.

In practice, a recovered munition will be identified, cleaned and exposed for movement. The munition will then be positioned in the pre-assembled bottom half of the fragment suppression system. The pre-assembled upper half of the fragment system will be placed on top to complete the system, and the entire unit will be positioned inside the EDS vessel (Figures 5 to 8). The final fire system connections will be made, and the vessel door will be closed.

LINEAR SHAPED CHARGE (LSC): The purpose of the LSC is to open the main body of the munition and expose the contents for neutralization. Of primary concern is the requirement to make a complete cut in the munition, separating it into two pieces. A single pre-formed length of copper LSC is used to perform the cut. Multiple cut systems were considered, but rejected for reliability issues.

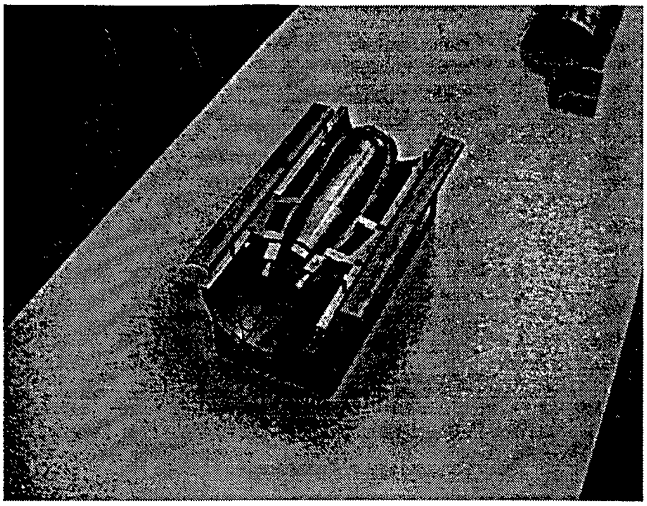
Figure 5

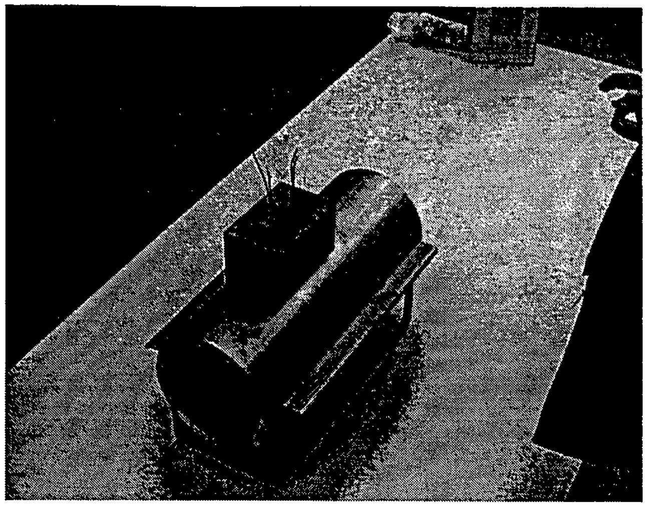
Figure 6

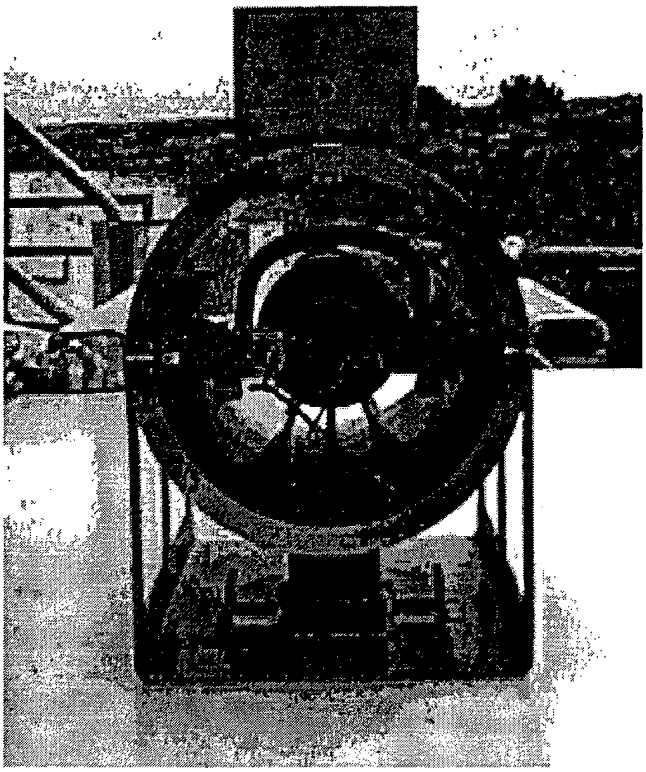
Figure 7

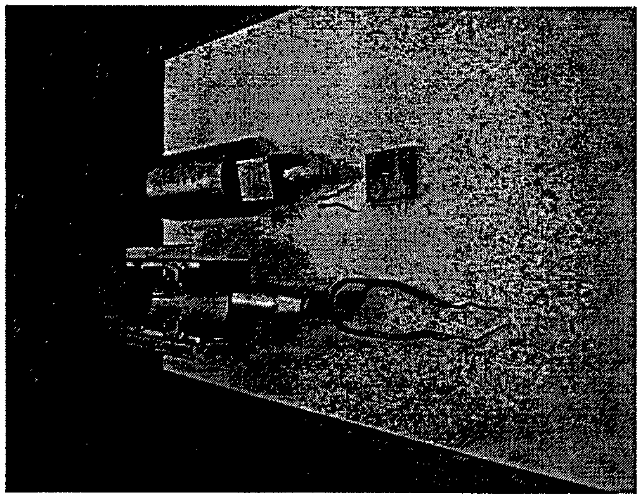
Figure 8

Detonators are connected to the LSC at each end. Cables are connected to the detonators, strain relieved, and then electrically shorted until the unit is positioned into the EDS vessel.

CONICAL SHAPED CHARGE (CSC) BURSTER INITIATOR: The purpose of the CSC charges is to break open the burster charge canister present in the munitions and detonate the burster explosives. A pair of copper CSC's are positioned onto the upper half of the fragment suppression system above the case of the target munition providing a pre-determined standoff distance. Simultaneous with the LSC opening charge the CSC's are fired in the direction of the burster.

While it is known that the burster explosives type will be either Tetryl, TNT, or a combination of both, it is not known whether the TNT is cast or pressed, nor is it known to what density the material was manufactured. Also, the effects of aging may be pronounced. The explosives could be contaminated by the agent inside the munition thus changing their detonation properties. All of these issues lead to an uncertainty as to the detonation sensitivity of the burster explosives.

The design of the CSC will be such that the criteria for reliable detonation of the burster explosives by shaped charge impact will be exceeded. It is not necessary that the CSC completely destroy the burster explosives because the chemical neutralization process will also destroy unreacted explosives.

The CSC chosen to perform the burster destruction is a charge designed by Tracor Aerospace. It is a 40 gram, Composition A-3, multi-tapered copper CSC. The selection of this CSC was based on the initiation requirements of TNT by CSC and the necessity for precision and repeatability.

FRAGMENT SUPPRESSION SYSTEM: A fragment suppression system is necessary to mitigate high velocity fragments potentially incident on the interior of the EDS vessel during opening. Fragments will be generated by the LSC, and CSC's, the burster charge case and case of the munition itself.

The core of the fragment suppression system is a steel cylinder separated into two lengthwise sections. The cylinder is connected to a cradle assembly that allows for positioning of the system inside the EDS vessel. A three sided steel support is positioned inside the lower half of the cylinder and supported with steel rings. The steel support and rings provide shock absorption in the downward direction to protect the lower portion of the EDS vessel. A steel block is positioned between the lower half cylinder and the cradle bottom to provide a stopping mechanism for the CSC in case of complete penetration through the system by the CSC jet.

The LSC and CSC's are attached to the lower and upper halves of this cylinder prior to the placement of the recovered round in the system. The detonators are attached to the charges, strained relieved to the cylinder, and then electrically shorted for safety.

Once the system is pre-assembled in the above manner, the munition is brought to the EDS vessel and placed into the cylinder of the fragment suppression system, and the system is placed into the vessel.

FIRING SYSTEM (and Detonators): The firing system is used to initiate the LSC opening charge and the CSC burster attack charges. The firing system is a high voltage Capacitor Discharge Unit (CDU) capable of reliably firing 4 detonators (1.5 x 40 mil Exploding Bridge-Wire) over cable lengths of up to 50 feet. The fire system is modular so that parts can be tested and replaced easily. Two systems have been designed using different components to increase the availability of major, hard to find components. The operating parameters of the two systems are identical.

The firing system consists of a 1 micro-Farad (μF) CDU, a high voltage trigger module, a high voltage power supply, a control module, monitoring and diagnostics equipment, and safety controls. The entire system is integrated into an easily accessible panel. A second, redundant system is mounted in the same panel.

The CDU consists of a 1 μF, 3kV capacitor triggered from a 150 Volt trigger module. A high voltage power supply transforms 24 Volts DC to 3000 Volts and 150 Volts for the power to the CDU and trigger module respectively. A control module makes the connection from the Power, Arm and Trigger signals to the appropriate modules.

The CDU charge voltage is monitored by an LCD meter mounted in the fire system panel. The outputs from the CDU and the trigger module are monitored by BITE indicators. These indicators must be manually re-set after each firing. Also located on the fire system panel are shorting connectors for the detonator cables and continuity meters for detonator connection checks.

An operator can remove the entire fire system from the EDS vessel by use of the 50 foot detonator cables. Also the operator can remove the control module an additional 50 feet from the fire system panel for operation.

For safety, the detonators selected to initiate the shaped charges are Reynolds type RP-1 and RP-2 Exploding Bridge-Wire detonators. These detonators are very insensitive to any type unexpected or undesirable energy (static, impact, etc.). A high energy firing system like the one used in this system is required to initiate these detonators.

DETONATION MONITORING SYSTEM:

The initial goal of the monitoring system was to provide some level of confidence that no un-reacted explosives remains inside the EDS vessel after the shaped charges have been detonated. This would require monitoring of shaped charges as well as the burster explosives.

Several real-time methods were considered: pressure gage arrays, accelerometers, etc. As well, post detonation methods were investigated: gas sampling for explosives reaction products.

A system of monitoring only the shaped charges with photo-diode circuits and high speed counters may be adopted. The condition of the burster explosives after CSC attack will be determined during the neutralization phase via liquid sampling.

AGENT NEUTRALIZATION

Any system for a CWM requires destruction of the agent and energetics to levels such that the waste can be safely transported. Neutralization is a low-pressure and low-temperature method to effectively remove the acute toxicity of the agents by transforming them to less toxic species. The end products of neutralization reactions are mixtures of aqueous and/or combustible organic species (Angostino, P. A., 1988). Neutralized agents, perhaps containing metals such as lead, mercury, or arsenic, are still toxic but can be transported as commercial hazardous waste. The EDS will rapidly mitigate the extreme hazard of potentially unstable explosives proximate to chemical agents in a container of unknown quality.

The agent and the energetics are separate chemicals with different hazards. Either may exist in a partially or completely degraded state having properties different than when manufactured. Considering the number of different agents that might be found in different CWM, assured destruction is a complex task. We combined the different agents into groups of chemicals having similar reactivities. The groupings are shown in Table 1. We have a specific plan for each of the potential agents and for unknowns.

Table 1: Agent Groupings

Agent Group	Individual Agents
Organics:	acrolein, bromoacetone (BA), bromobutanone (bromessigester), bromobenzyl cyanide (CA), chloroacetone, chloroacetophenone (CN), mustards (H, HD, HS, HT), chloroacetophenone/chloropicrin/chloroform (CNS), dichloroethylthiodiethylether (Vesicant T).
Chloride Family:	phosgene (CG), chloropicrin (PS), /$SnCl_4$(NC), $SnCl_4$, $TiCl_4$ (FM), chloropicrin/phosgene (PG), cyanogen chloride (CK),.
Organo-arsenics:	lewisite (L), Phosgene/diphenylchloroarsine (PD), diphenylchloroarsine (DA).
Oxidizer:	chlorine (Cl_2)

Three neutralizers that will be used for EDS are mono-ethanolamine (MEA), aqueous hydroxide, and aqueous bisulfite (and their combinations). In our laboratories, a 4-5 times excess of neutralizer destroyed exposed and agitated non-Army-only agents within a few hours. Most reactions were much quicker. If the agent has polymerized or degraded, the neutralization may take longer.

The organics and organoarsenics groups will be neutralized using MEA alone or in combination with aqueous hydroxide. Arsenic is a special hazard because of its persistent toxicity even after total neutralization of the original chemical agent. The organics often yield multiple species upon basic hydrolysis or aminolysis. These materials may be hazardous wastes, but will not have the handling and transportation restrictions associated with the highly toxic starting materials. The chloride group will be neutralized with aqueous hydroxide. Most of the finished neutralized material will be non-combustible. The speed of neutralization is limited by the solubility of the material in the neutralizing medium. In the EDS scenario, the system is heated to near the boiling point and agitated. Heat and agitation accelerate the reactions mostly by enhancing mixing. Inorganic chlorides may yield voluminous precipitates of oxides/hydroxides under these conditions, so agitation and excess neutralizer are required. Chlorine will be neutralized by aqueous bisulfite. This reaction is spontaneous and limited only by the solubility of chlorine gas in the aqueous phase. In the absence of dissolved metals, the products of bisulfite neutralization are non-hazardous. In all cases, hydroxide or a thermal treatment might additionally be needed to destroy remaining energetics.

We have verified destruction of the non-Army-only agents in our laboratories. Studies with the Army-only agents have been performed by others for the NSCM projects and we will use these data as well as historical data. In our laboratory experiments, samples of the agents were exposed to the appropriate neutralizing agent and the reaction was monitored at room temperature. If the reaction did not proceed at a rate such that >90% of the starting material was consumed in one hour, the reaction was heated to 40-50 °C. The gross reaction was monitored by ^{1}H and ^{13}C NMR spectroscopy. Final destruction of agent was monitored by Gas Chromatography Mass Spectrometry (GCMS) and or Liquid Chromatography Mass Spectrometry (LCMS). Destruction beyond 99.9% efficiency was not quantified because the non-Army-only agents are chemicals of commerce and could be handled at these concentrations.

All of the neutralizing reactions are exothermic. Some reactions (such as phosgene or chloroform with hydroxide) generate sufficient energy to be a concern in a continuous process. With the large thermal mass of the thick-walled vessel, the heat of the reaction will only aid in warming the vessel and will not create dangerous overpressures. Excess heat production can also be controlled by adding neutralizing chemicals at a controlled rate.

Besides the chemical agents, all energetics must be neutralized. The shaped charges are designed with a dedicated conical shaped-charge to pierce the burster at the same time as they open the shell. This yields an extremely high probability of detonating the burster charge. Unfortunately, there is never a complete guarantee that the explosives will detonate because these munitions may have sat buried for greater than 50 years in uncontrolled conditions and may have undergone dramatic (perhaps unseen) chemical and physical degradation. We anticipate that the shaped-charge will detonate, or at least initiate burning of, the energetics. Traces of unreacted explosives (likely TNT or tetryl) may remain after the initial detonation.

We performed experiments where TNT or tetryl and individual chemical agents were exposed in solution to MEA. The MEA (used in excess) always neutralized the explosive as well as the chemical agent within one hour at 40 °C. These experiments are prejudiced towards rapid reaction because all the reaction occurs in solution. Actual reaction inside EDS would be slower as solubility limits the reaction rate. Aqueous hydroxide efficiently destroys nitrated aromatics only if the particle size is small and the reaction is agitated. Reaction can be very slow if insufficient reaction interface is available. Neutralization of explosives in the EDS system is meant only to clean up traces of explosives not as a method of bulk explosives destruction.

SYSTEM TEST RESULTS AND PLANS

A series of tests are underway to qualify and demonstrate the system. The first set of tests demonstrated the chemical neutralization capability of the system. The second set will evaluate the explosive containment.

The first neutralization test used oil of wintergreen (OOW) as a surrogate for the chemical agent. OOW has been used by the army as a surrogate. It is useful because it reacts with both the MEA and NaOH neutralizers to form two different products. All aspects of the system worked as expected. The effluent was analyzed using both LC/MS and NMR. The concentration of OOW was below the detection limit of 20 ppm.

In the second test we neutralized one pound of chlorine with sodium bisulfite. Chlorine is one of the agents that EDS is designed to destroy. The chlorine was generated inside the EDS vessel using a reaction of calcium hypochloride and methane sulfonic acid. Again the system worked as expected and the concentration of chlorine in the effluent was below the detection limit.

A series of tests are schedule during March and April of 1998 to evaluate the explosive containment capability of the EDS system. During these tests we intend to demonstrate the ability of the system to open a 75 mm artillery round filled with surrogate agent. We will also qualify the vessel for one pound of explosive by detonating a 1.25 pound bare charge.

CONCLUSION

The emergency destruction system will provide the capability to dispose of recovered, explosively configured, chemical munitions in a safe manner. The vessel and its support system will open a variety of munitions and neutralize their explosive and highly toxic contents without any release of contained material to the environment. A prototype system has been fabricated and is now being tested. The neutralization capability has been successfully demonstrated with chlorine gas and surrogates in the actual vessel. The explosive opening system and the capability of the vessel to contain the detonation will be demonstrated during the next few months.

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