In-Situ Landmine Neutralization by Chemical versus Thermal Initiation Deminer Preferences

Divyakant L. Patel and Sean P. Burke

US Army, CERDEC
Night Vision & Electronic Sensors Directorate
Fort Belvoir, Virginia 22060-5806, USA
E-mail: info@nvl.army.mil

Abstract

This paper describes currently developed chemical and thermal landmine neutralization methods under the DoD Humanitarian Demining Research and Development (HD R&D) Program. It includes a table showing the differences among current detonation or demolition techniques, and among chemical and thermal systems. Comparative elements include the neutralization mechanism; neutralization effects; time required to neutralize mines; explosive, standoff, operational, transportation and storage requirements; quality control; reliability; human factors; effectiveness; applicability to buried mines; applicability to UX; and cost.

1 Introduction

Millions of "post-conflict" landmines remaining in the ground are causing a serious humanitarian crisis. There are two general categories of mines, Anti-tank (AT) and Anti-personnel (AP). Landmines are further classified according to the type of case material (metallic, plastic and wooden) and fuse type. AP mines were developed during WWII to protect AT mines from mine detection and removal. Unfortunately, AP mines remaining in the ground after a conflict ends, unable to discriminate between civilians and soldiers, are a severe threat to the former. Mines kill or maim nearly 10,000 people every year, most of whom are innocent civilians. Mines prevent growth and development in emerging or rebuilding countries, impede infrastructure development, disrupt humanitarian aid shipments, and destroy the morale of civilians living close to the minefields.

At present only two techniques are used to clear individual mines, manual clearance and destruction (demolition). Manual clearance is a very difficult, slow, tedious and hazardous operation. Mine neutralization by demolition is achieved with C-4 or TNT blocks. Unfortunately, this approach suffers serious drawbacks such as safety, cost, effective destruction, storage, transportation, and training. Also, demolition is not suitable for mines placed on or near structures such as bridges, public buildings, railroads, water or oil wells and power lines. Explosive destruction is not a good method for post-clearance quality control. Furthermore, explosives could be stolen by terrorists and used against innocent civilians.

Burning mines in-situ is an alternative neutralization method that can avoid these problems. The US Army Communications and Electronics Research, Development and Engineering Center (CERDEC) Night Vision and Electronic Sensors Directorate (NVESD), under the DoD Humanitarian Demining (HD) R&D Program, has been working to develop new non-explosive technologies to provide a safer, faster, more reliable and less expensive means for neutralization in HD operations. NVESD R&D Programs have developed several innovative non-explosive mine neutralization methods based on a single chemical, binary chemicals, thermite, pyrotechnics, propellants, and solid reactive. These systems neutralize mines by burning instead of by

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**
4. TITLE AND SUBTITLE **In-Situ Landmine Neutralization by Chemical versus Thermal Initiation Deminer Preferences**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Communications Electronics Command,Night Vision and Electronic Sensors Directorate,10221 Burbeck Road,Fort Belvoir,VA,22060-5806**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**6**	

detonation. Certain chemicals, propellants, thermite and pyrotechnics achieve burning or combustion of a mine's main charge. These systems are described below in chemical and thermal methods.

2. Chemical Systems

2.1 Background

Burning is generally the preferred method for destroying the main charge of mines. The main charge of about 90% of all mines is TNT or TNT based explosives such as Tetryl, Comp.B, Amatol and Pentolite. The remaining 10% contain RDX, PETN, C-4, liquid explosives etc. TNT is an exceptionally stable explosive. It is highly resistant to chemical attack by acids and conventional oxidizers. Solid TNT cannot be easily ignited with a match flame. The chemical transformation of TNT can proceed by one of four general mechanisms: (1) Heterogeneous chemical reaction or inerting TNT; (2) Simple burning in the air; (3) Autocatalytic decomposition, and (4) Detonation. Chemical transformation of TNT (processes 1 through 3) appears to be an attractive option for in-situ neutralization of most types of mines. Heterogeneous chemical reaction is not applicable for demining purposes because it is costly and time consuming. Simple burning is suitable for demining purposes and is discussed in the Flare Systems section. Autocatalytic decomposition is used to develop Chemical Systems, which are discussed here. The HD R&D Program considered three different chemical approaches for rapid neutralization of mines in-situ using a minimum amount of hypergolic, pyrophoric and binary chemicals. A number of hypergolic chemicals known since 1970 such as diethyl amine (DEA), diethylenetriamine (DETA), pyridine, pyrole etc. are suitable to neutralize TNT and TNT based explosives by autocatalytic decomposition. Diethylzinc and triethylaluminum are pyrophoric liquids and are a good hypergol with TNT and TNT based explosives. The hypergolic and pyrophoric chemicals are not applicable to mines containing RDX, PETN, C-4 etc. As a result, the HD R&D Program recently investigated binary chemicals, which on mixing neutralize a wider range of explosives.

2.2 Delivery Systems

2.2.1 Bullet with Chemical Capsule (BCC)

The BCC [1] uses diethylene triamine (DETA) in a plastic bottle placed just above the mine, over an area where the main charge is located. The BCC delivery mechanism is a simple tripod as shown in Figure 1. A bullet, shot through the capsule and into the mine, ruptures the capsule, penetrates the mine casing and enters the explosive charge, carrying the dispersed chemical into the explosive charge inside the mine. Within seconds a highly exothermic, hypergolic autocatalytic self-destruction of the explosive charge takes place and the explosive starts to burn. Neutralization of the mine is completed within minutes, the specific time depending on the size and type of explosive, and type of mine case. The BCC is effective against thin case AP and AT mines, but the delivery system design issues, the requirement for thorough cleaning after each use and the large quantity of DETA required are issues that would not be acceptable for field use. To address these issues, CERDEC-NVESD awarded a contract to develop the Reactive Mine Clearing System (REMIC).

Fig 1: Bullet with Chemical Capsule (BCC)

2.2.2 Reactive Mine Clearing (REMIC) System

REMIC [2] was designed using CTH hydrocode. It contains two main components; a liner charge top component, and chemical reservoirs at both sides of the bottom portion. The linear cutting charge is designed to cut through the mine case, thereby exposing the explosive fill without detonating it. The linear charge cuts a larger opening in the mine case than the BCC. It consists of an aluminum or copper sheet linear shaped charge liner, detasheet explosive, and Teflon reservoirs for the DETA. The REMIC is suspended above mine at a specified standoff distance as shown in Figure 2 and is initiated remotely by a blasting cap or detonating cord. Once the device is initiated, it produces a high velocity jet, which opens the mine case. Next, the hot gas from jet breaks the chemical reservoirs and chemical enters into the mine. The DETA reaction is similar to the BCC system but burning time is 50% less due to the wider opening of the mine case. Though the REMIC proved to be simple to operate, it is not effective against hard case metallic and plastic

Fig 2: REMIC device (left) and burning mine (right)

mines, and since it uses DETA alone applicability is limited to mines containing TNT or TNT-based explosive. Teflon, used for constructing chemical reservoirs, is harmful to the human and environment when it is depolymerized at high temperature. To address these problems REMIC has been modified to use binary chemicals. The modified system is in two configurations known as small REMIC-II and large REMIC-II.

2.2.3 Small Reactive Mine Clearance–II (REMIC-II)

The small REMIC-II [2] was developed to fine tune the original REMIC to neutralize thin-cased AT and AP mines. The device is made of a castable polyurethane (Figure 3). Total weight is approximately 62 grams. The system uses a binary chemical neutralizer, one solid (oxidizer) and one liquid (solvent). On mixing, both chemicals are hypergolic. There are four 1mL glass tubes, two containing solid and two containing liquid. They are located at the bottom of the device with two pairs at each side, one on top of the other. The linear cutting charge uses a 2mm thick PETN- based detasheet explosive driver mated to a curved 1 mm thick piece of aluminum. The device is placed above the explosive section of a thin case AP or AT mine at a standoff. Initiation is remote, done by inserting an electric blasting cap. Once the cap is initiated, the linear shaped charge jet perforates the mine casing, while the explosive by-products of the cutting charge fracture the tubes and direct the chemicals into the mine. Once the binary chemicals combine inside the mine, burning begins with sufficient heat to initiate burning of the explosive in the mine. The system is effective against Comp. B and RDX, but it is not good for mines containing TNT.

Fig 3: Small REMIC II

2.2.4 Large Reactive Mine Clearance-II (REMIC-II)

The large REMIC-II [2] body is cast in two identical polyurethane halves, connected by four small pins. Total weight is ~ 500 grams. Four 8.5mL size glass tubes contain the same chemicals and tube arrangement as in the small REMIC-II. The 0.94mm thick copper liner is a shallow, curved plate that upon detonation develops a linear cutting jet. The linear

Fig 4: Large REMIC II

cutting charge uses a 6 mm thick RDX-based detasheet explosive driver mated to a curved liner. The device is designed to neutralize hard case mines containing any explosive. It can also be used against thin case mines using one of several "stripper" plates. The thickness of the mine case determines which stripper plate to use. Figure 4 shows the device above a VS-50 mine. Large REMIC II is an effective mine neutralization system against all types of mines. Disadvantages are it uses an explosive, a strong oxidizer and solvent. The system has three different storage requirements, and the standoff distance requirement varies, depending on mine case thickness. Thermal or flare based technology has strong potential to neutralize all types of mines without these disadvantages.

3 Thermal or Flare Systems

3.1 Humanitarian Demining (HD) or Thiokol Flare

The HD Flare [3] is based on a propellant, thermite and binder mixture. The solid propellant produces a low-thrust flame with an average temperature in excess of 3500^0F (1927^0C). The HD Flare is 5" long,

Fig 5: HD Flare vs. TM-46 AT mine

one inch in diameter and burns for 60 seconds. The flare has one inch deep, ¼" diameter hole that increases propel power for an initial 20 seconds. An electric match or time delay pyrotechnic fuze, inserted in the hole, ignites the flare remotely. The flare is set up on a stand or placed directly on ground with a half-pound stone on it at the rear. The flare is placed 1.5 to 3 cm from a mine, positioned either above it or to the side where the explosive is known to be, and away from the fuse. The HD Flare is applicable for all thin case AP and AT mines, but mostly the latter. Figure 5 shows a TM-46 AT mine and a HD Flare on the ground with a time fuse for ignition. The Flare is commercially available.

3.2 Mine Incinerator (MI)

The MI [3] is based on a novel, self-propagating solid-state reaction which produces reaction products in a liquid phase and generate temperature up to 4000^0K. The flammable solid reactants mixture is easily molded at 110^0C and will ignite at 350^0C. The device is made from plastic. Dimensions are 2.75 inches high and 2.25 inches in diameter. The device weighs about 210 gm. The bridge wire is inserted in the device during the molding process. AT mine neutralization is accomplished by placing the MI on it as in Figure 6. For AP mines, the MI must be placed above the mine on a stand. The MI is ignited remotely with electric power. Once the MI is ignited, reactants start burning and produce high temperature liquid components. The high temperature liquid penetrates mine's case, then comes in contact with the explosive and causes it to start burning. Duration of the burn depends on the amount of explosive and type of mine case. The current MI is capable of penetrating ¼" thick steel plate. It is good for neutralizing AT mines

Fig. 6: Mine Incinerator

3.3 Propellant Torch System (PTS)

The prototype crude PTS [4] contains propellant, metal powder and oxidizer. The chemical mixture is inside a steel metal pipe. Ignition is by glow plug. The system proved to be effective against tested mines,

Fig 7: Propellant Torch System

but it will not neutralize stake mines, bounding mines or hard case AT mines. A refined PTS, which can neutralize all types of mines and most UXO, is currently under development. The table following this report compares the three mine neutralization methods discussed in this paper.

4. Summary and Conclusions

To summarize, we investigated seven non-explosive technologies, four chemical and three thermal systems for low order mine neutralization. In test, each system successfully demonstrated the feasibility of neutralizing a mine by burning. Several constraints were identified in chemical systems, such as reliability, repeatability and use of explosives. At present none of chemical systems meet military countermine or HD requirements. Current thermal methods are reliable for neutralizing AT mines but they failed to neutralize hard case AP mines. A refined PTS, which can neutralize all mines and most UXO, is currently under development. Deminers can make their own choice from the table for selecting non-explosive methods best suited for their needs.

Acknowledgments

The authors would like to thank Mr. John Fasulo and his Countermine Division Team members for their help in experimentation support, and Mr. Thomas Henderson and Mr. Matthew Henderson of Camber Corporation for editorial support.

References

[1] D. L. Patel, B.D. Briggs, A.J. Tulis, J.L. Austing, R. Dihu and A. Snelson, "Chemical System for In-Situ Neutralization of Landmines in Peacetime" Proc. of the Tech. and Mine Problem Symposium, pp6.61-6.66, 1996, Monterey, CA, USA.

[2] D.L. Patel, J. Dillon and N. Wright, " In-Situ Landmine Neutralization Using Chemicals to Initiating Low Order Burning of Main Charge, 29th International Pyrotechnics Seminar Proceeding, pp 463-475, 2002, Westminster, CO, USA.

[3] D. L. Patel , " Can Currently Developed Deflagration Systems Neutralize Hard Case Mines?", UXO/Countermine Forum Conference Proceeding, April 9-12, 2001, New Orleans, USA.

[4] D.L. Patel, "Rocket-Concept PTS for the Non-Detonative Neutralization of Mines and UXO", Technologies of Mine Countermeasures, pp 661-684, 2001, Sydney, Australia.

TABLE 1: Comparison among three Mine Neutralization Methods

Parameters	Chemical	Thermal	Demolition
Mine neutralization	Burning	Burning	Detonation
Standoff requirements	4” above mine surface	One inch	Close to mine
Neutralizing time	Depend on several factors	5 to 20 min.	Instantaneous
Neutra. effect	Metal case remain	Metal case remain	Clutters with crater
Operational requirements	Remotely & 100 meter from mine	Remotely, 100m from mine	Remotely, 100 m from mine
Total weight	<1 lb	< ½ lb	1 to 2 lbs
Effectiveness	Depend on device	Thin case AP & AT mines	Most of mines
Quality control	Very good	Very good	Not good
Neutralization judgment	Extinguishing flame	Extinguishing flame	Hearing big bang noise
Power requirements	Batteries for blasting machine	Batteries for blasting machine	Batteries for blasting machine
Logistic requirement	Maximum	Minimum	Maximum
Applications	Independent of mine location	Independent of mines locations	Depend on mines location
Human factors	Some operator skill required	Minimum skill required	Certified EOD specialist
Explosive used	20 to 40 gm of detasheet or RDX	No explosive	C-4 or TNT Blocks
Initiation	Squib and electric cap	Electric match or time fuse	Electric cap or detcord
Storage requirements	Explosive, solid & liquid	No requirements	Explosive storage
Buried mines	Yes, exact location	No	Yes, up to some depth
UXO	Yes, up to ½” thick	Only 3mm thick	Yes
Cost (mass production)	$10.00/mine	$9-13/mine	$15.00/mine