Can Currently Developed Deflagration Systems Neutralize Hard Case Mines?

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ABSTRACT

Neutralization of landmines is dangerous and complicated work. For Humanitarian Demining, the most common neutralization method is demolition using small explosive charges. Although common practice, demolition has several disadvantages. Deminers need non-explosive mine neutralization technologies that are safer, more reliable and less expensive. To meet this need, several innovative non-explosive neutralization methods have been developed at the U.S. Army Communications Electronics Command (CECOM) Night Vision and Electronic Sensors Directorate (NVESD). The DoD Humanitarian Demining Research and Development program, and the NVESD Countermine Division have both developed solutions for non-explosive mine neutralization. These projects include thermite, a Mine Incinerator, Humanitarian Demining Flares and chemicals. These systems are designed to neutralize mines by deflagration instead of detonation. Burning or combustion of the mine's main charge is achieved with chemicals, thermite, pyrotechnics, and propellants. Here I discuss deflagration (low-order, nonexplosive) methods to destroy landmines using propellant, thermite and pyrotechnics. The Humanitarian Demining Flare, made by Thiokol, is based on propellant mixtures. The Mine Incinerator is based on a new type of thermite mixture, and FireAnt is based on pyrotechnic mixtures. The first two methods were developed under the DoD Humanitarian Demining R&D Program. The United Kingdom's Defense Establishment Research Agency (DERA) developed the FireAnt. The effectiveness of each system on fragmentation and bounding fragmentation mines will be described separately. Each of these techniques has advantages and disadvantages, typically dependent on cost, level of reliability and terrain. The new technologies in mine destruction may eventually make demining safer, reliable and less expensive.

INTRODUCTION

A landmine is a deadly effective explosive device. There are two general categories of landmines, Anti-tank (AT) and Anti-personnel (AP). They are further classified according to the type of case material (metallic, plastic and wooden) and fuze type (pressure fuze, steak, bounding, scatterable or command detonated). AP mines were developed during WWII to protect anti-tank (AT) mines from mine detection and removal.

For the last three decades landmines have been widely used in civil wars to disrupt the economy and cause maximum distress, death and dislocation of communities. AP mines kill and maim thousands of innocent civilians (many of them children) each year. There are up to 100 million mines in 70 countries. Landmines are an attractive weapon because they are inexpensive (3-30$ each), easy to make, easy to obtain and available in large numbers.

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BACKGROUND

Once detected, mines are typically neutralized by demolition using high explosives such as C-4 or TNT. These explosives are very hazardous and costly, and they require specialized training in handling and use. A significant disadvantage to explosive neutralization of a metallic mine is the large amount of metal fragments produced by the blast. These fragments cause numerous false alarms when metal detectors are used. Explosive neutralization cannot be applied to mines found near bridges, power lines, water plants, public buildings, road and rails because this action often creates a large crater depending on size and type of mine. Also, explosive neutralization is ineffective against blast hardened mines such as the PMN-2.

New non-explosive technologies have the potential to provide safer, faster, more reliable and less expensive means for neutralization in humanitarian demining operations. Several innovative methods have been developed under NVESD Research and Development programs to neutralize landmines rather than destroy or detonate them. Two key programs are the DoD Humanitarian Demining R&D Program which NVESD is executing for the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict (OASD(SO/LIC)), and NVESD Countermine Division R&D projects. New methods/equipment include rigid foam, thermite, Mine Incinerator, Humanitarian Demining Flare and chemicals. Except for rigid foam, these systems neutralize mines by deflagration instead of detonation. Burning or combustion of the main charge of a mine is achieved by a chemicals, thermite, pyrotechnics, and propellants. This paper discusses deflagration achieved by the last three methods. The effectiveness of each system against fragmentation and bounding fragmentation mines will be described separately. Both types of mines are mostly hard case metallic mines and found in several countries. I will first provide an overview of stake and bounding fragmentation mines.

OVERVIEW OF FRAGMENTATION MINES (STAKE MINES)

Stake mines (also called picket mines) are typically placed 12” to 20” above the ground. They are normally activated with metal tripwires, and typically mounted on a wooden or metal stake. One or more tripwires activate them. As little as 1.0 kg of pressure on one tripwire is enough to detonate the mine. Activation pressures vary from 1 to 18 kg depending on fuze type. Most of these mines have cast iron casings containing a main charge of about 75 gm of TNT. Some mines contain 100 gm or more of TNT. When activated they send iron fragments in all directions. They can potentially kill any person within a four meter radius, and cause serious injury at greater distances. These mines cannot be detected with a metal detector.

Some stake mines can also be buried for pressure actuation with their fuzes just above ground or at ground level. They are often booby-trapped using a hand grenade with the safety pin removed. Neutralization of these mines is generally done by reinserting a safety pin, cutting the tripwire using normal tripwire clearance procedures, and then removing the fuze. Removing the igniter and detonator from the mine body can disarm this type of mine. Neutralization of this type of mine is relatively simple as long as one has knowledge of the various fuze types used in them.

The POMZ-2 was first designed in the former USSR during WWII. It is one of the most successful mines in the world. The POMZ-2 mine is copied and produced by various countries. It is fortunate this type of mine is simple in construction and operation, because once discovered removal and disposal procedures is identical for almost all of them. The POMZ-2 and POMZ-2M (modified version) mines are widely used.

All stake mines require tall vegetation such as long grass, bush or jungle areas for camouflage. In a normal fenced minefield, they are typically placed in rows to protect rows of AT and AP mines. They are also used extensively in the nuisance minefield role, for route protection and for ambush operations. These mines are emplaced manually. Table 1 displays representative AP metallic fragmentation mines (stake mines).

Table 1 AP Metallic Fragmentation Mines (Stake Mines)

Country of Origin	**Designation**	**Shape**	**Amount & Explosive**	**Traction on Tripwire**	**Stake material**
Former Cze-choslovakia	PP-Mi-Sb*	Cylindrical	75 gm TNT	1-10 kg	Wooden
Former Cze-choslovakia	PP-Mi-Sk	Cylindrical	75 gm TNT	1-10 kg	Wooden
Serbia (Yugoslavia)	PMR1	Cylindrical	75 gm TNT	3.0 kg	Wooden
Serbia (Yugoslavia)	PMR-2A	Round	100 gm TNT	3.0 kg	Wooden
Serbia (Yugoslavia)	PMR-3 (new)	Round	410 gm Plastic	2-7 kg	Metal
Serbia (Yugoslavia)	PMR-4	Round	200 gm TNT	2-4 kg	Wooden
Former USSR	POMZ-2	Cylindrical	75 gm TNT	1-3 kg	Wooden
Former USSR	POMZ-2M	Cylindrical	75 gm TNT	1-3 kg	Wooden

* Concrete case

AP BOUNDING FRAGMENTATION MINES

Also developed during the WWII, bounding fragmentation mines are also known as "bouncing betties". Although tripwires operate the majority of these mines, several are also initiated by pressure fuzes or by command detonation. Most of these mines contain 65 to 590 gm of TNT, are cylindrical in shape and have thick cast iron or steel cases.

These mines are generally on the surface or buried in loose soil. Activation could be from a tripwire attached to one or more spikes protruding from the ground, or from a pressure fuze slightly above the surface. Fuze actuation results in the mine body being fired into the air by a propellant charge, sometimes after a short time delay to allow the victim to step clear. When the mine is well above ground level, typically 0.5 to 1.5m, a secondary fuze system detonates the main charge.

The effective range depends on several factors such as the size of charge, height of detonation, case thickness and efficiency of fragmentation. All bounding fragmentation mines scatter fragments (shrapnel) in a 360-degree horizontal arc. These fragments often cause fatal injures to those nearby and severe injuries at distances up to 40 meters.

Bounding fragmentation mines are neutralized using two general procedures depending on the actuation mechanism. A tripwire activated mine can be neutralized by following identical procedures for stake mines. .

Table 2 represents AP metallic fragmentation bounding mines found in various countries.

Table 2. AP Metallic Fragmentation Bounding Mines

Country origin	Designation	Shape	Amount Explosive	Traction on tripwire	Initiation Pressure
China	Type 69	Can shaped	105 gm TNT	1.5-4 kg	7-20 kg
Former Cze-choslovakia	PP-Mi-Sr	Cylindrical	325 gm TNT	4-8 kg for RO1 fuze	3.6 kg for RO8 fuze
Former Cze-choslovakia	PP-Mi-Sr-11	Cylindrical	325 gm TNT	4-8 kg for RO1 fuze	3.6 kg for RO8 fuze
Italy	Valmara-69 *	Cylindrical	420 gm Comp.B	6 kg	10.8 kg
Serbia (Yugoslavia)	PROM-1	Bottle-shaped	425 gm TNT	3-5 kg	9-16 kg
USA	M-16	Can-shaped	521 gm TNT	1.4-4.5 kg	3.6-20 kg
USA	M-16A1	Can-shaped	513 gm TNT	1.4-4.5 kg	3.6-20 kg
USA	M-16A2	Can-shaped	590 gm TNT	1.4-4.5 kg	3.6-20 kg
Former USSR	OZM-3	Cylindrical	75 gm TNT	2-5 kg	
Former USSR	OZM-4	Cylindrical	185 gm TNT	2-5 kg	
Former USSR	OZM-72	Large tin can	500 gm TNT	2-5 kg	

* Plastic case mine

DEFLAGRATION SYSTEMS

The Humanitarian Demining R & D Program has investigated several deflagration systems. This paper concentrates on three of them. The Humanitarian Demining Flare and the Mine Incinerator were developed under Humanitarian Demining program. FireAnt was developed by DERA and produced by Pains Wessex Ltd., U.K. The R&D Program tested all three systems at Fort A.P. Hill, VA at different times as the technologies were developed. We tested all three systems against the most widely used mines from Tables 1 and 2, and 1/8”, ¼” and ½” thick steel plates. I will discuss the performance of each technology against metal plates and mines separately.

HUMANITARIAN DEMINING FLARE (THIOKOL FLARE)

The Humanitarian Demining Flare neutralizes mines by quickly burning through the casing and igniting the explosive fill without detonation. The flare is made from surplus solid rocket propellant manufactured by Thiokol for the Space Shuttle Program. The solid propellant produces a low-thrust flame with an average temperature in excess of 3500^0F (1927^0C). The burn time of the flare will increase or decrease by decreasing diameter and increasing a height of flare. The present Thiokol Flare is 5 inches long, one inch in diameter and burns for approximately 70 seconds. The dynamic effects of the plume during the first 20 seconds of burn can be increased by drilling a small blind hole along the axis of the flare. An electric match or time delay pyrotechnic fuze is inserted in the hole to ignite 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.

Due to resource constraints, one POMZ-2 stake mine and one PROM-1 bounding mine were selected from Table1 and Table 2 for test targets. The POMZ-2 top was placed approximately 30 cm above ground with no tripwire attachment. The flare was set horizontally on a stand pointing at the middle portion of the mine case separated by 0.5 inches as shown in Figure 1. A time fuze initiated the flare. As the flare burned, it penetrated halfway into the case. Because of the high temperature of the case, the TNT melted and flowed through the bottom of the mine and onto the stake as shown in Figures 1A and 1B. The flare, however, failed to neutralized the mine.

The PROM-1 is a steel cased, bottled-shaped mine. The central tube of the mine is filled with propellant. It contains 425 gm of Composition B or TNT. It can be activated by a trip wire or by a pressure fuze. The mine was buried such that only the top portion was exposed as shown in Figure 2. The flare was placed on a stand and aimed at the shoulder of the mine separated by a 0.5". The shoulder is the thinnest section of the steel casing. The flare was ignited by a time fuze. During flare burning the top of mine was ejected and main explosive charged burned. The empty mine casing was recovered and is shown in Figure 2A. The mine was successfully neutralized. Plastic case mines from both tables 1 and 2 are easily neutralized by the flares.

Figure 1

Figure 1A

Figure 1B

Left: Stand mounted flare positioned to the side of an unfuzed live POMZ-2. Center: Following the flare burn, melted TNT flowed out of the bottom of the mine. On the right, another view of the same POMZ-2 – the flame penetrated halfway into the mine case.

Figure 2

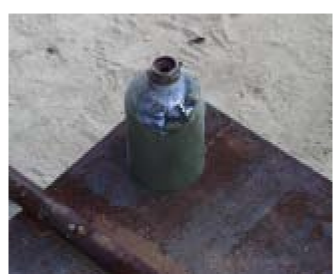

Figure 2A

Left: Stand mounted flare with time fuze aimed at the shoulder of a PROM-1. Right: Same PROM-1 after neutralization. The top of the mine was ejected and the main charge burned.

FIREANT (A210) OR MINE CLEARANCE FLARE

FireAnt is a pyrotechnic device designed to burn the explosives contained within a mines' casing. It contains a composition of Aluminum, Barium nitrate and polyvinyl chloride(PVC). This 80 gm composition is sealed in a 9.33" (23.7 cm) long, 1.53" (3.9 cm) diameter cardboard cylinder. An electrical match is inserted in the pyrotechnic mixture at the bottom of the cylinder. A battery or a demolition device ignites the electrical match. The mixture burns at 1500^0C (2732^0F) for 23-24 seconds. AP and AT mines can be neutralized by placing a FireAnt 2.5-3.0 cm from the mine case at the correct angle, using a flexible picket and ignited by a demolition device. The high temperature flame generated by the FireAnt burns through the mine casing and into the explosive. The FireAnt performed well against exposed plastic, rubber and thin metal skinned AP and AT mines. The FireAnt flame penetrated a one mm thick steel plate in 15 seconds but it cannot penetrate through 1/8" (0.125" or 0.3175 cm or 3.175 mm) thick steel plates.

FireAnt was not tested against any Table 1 mines. These mines have cast iron or steel cases one-half inch thick or greater except for the plastic case PMR-U. The availability of these mines is limited, and data from the steel plate tests indicated FireAnt would not be effective against them. FireAnt will neutralize the PMR-U.

We selected one M-16 and one PROM-1 mine from Table 2. FireAnt failed to penetrate the

Figure 3

Figure 4

Figure 4A

Figure 3: Stand mounted FireAnt aimed at the shoulder of a PROM-1.
Figure 4: FireAnt aimed on an M-16, and in Figure 4A, after burning on the M-16.

case of either mine. The FireAnt was placed at an angle on top of the M-16 case. For the PROM-1, FireAnt was placed at an angle and aimed at the shoulder of the mine from a stand. FireAnt cannot neutralize any mine from Table 2.

MINE INCINERATOR (MI)

This is a new approach for neutralizing mines by deflagration in lieu of explosives. The MI is based on a novel, self-propagating solid-state reaction (new thermite) which produces reaction products in a liquid phase and generate temperatures up to 4000K. The Flammable solid reactants mixture is easily molded at 110^0C and will ignite at 350^0C. The device is made from plastic and their 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. An AT mine is neutralized by placing the Mine Incinerator on it, while an AP mine is neutralized by placing the MI above the mine on a stand. The MI is ignited remotely with electric power. Once the mine incinerator is ignited, reactants start burning and produce liquid components having a high temperature. 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 mine incinerator is capable of penetrating ¼" thick steel plate.

The current mine incinerator cannot neutralize the POMZ-2 mine. However, a device with double the amount of reactants may be successful. This would make the MI more expensive. The current MI is not designed for side attack above ground. Therefore it cannot be used against fragmentation stake mines.

We tested the Mine Incinerator against the OZM-72, which is a bounding fragmentation mine. The MI was placed on a stand directly above the mine and initiated electrically. After 10 seconds, as the OZM-72 case became hot, a low order detonation of the propelling charge occurred. The tripwire fuze did not trigger the main explosive charge (660 gm of TNT), which was propelled from the main case. The mine was thus partially neutralized. Most of the mines in Table 2 have thick steel or iron cases. It is possible the mine incinerator may cause neutralization by high order detonation instead of deflagration. Further investigations are needed with the MI before conclusions can be made on its performance against AP bounding fragmentation mines.

Figure 5A: Prototype MI over OZM-72 mine.

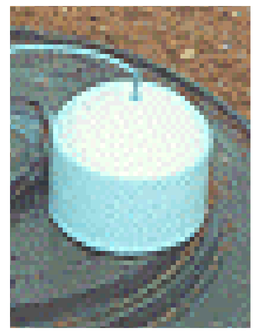

Figure 5B: Production type MI.

TABLE 3: COMPARISION AMONG THREE SYSTEMS

PARAMETERS	Thiokol Flare	FireAnt (A210)	Mine Incinerator
Mine neutralization	Deflagration	Deflagration	Deflagration
Materials used	Rocket propellant	Pyrotechnic	
Initiation method	Electric match Or Safety fuze	Built in with an Electric match	Built in with a glow bridge wire
Estimated flame tem.	3500 F	2732 F	>4500 F
Burning time Sec.	70	23	10 - 15
Shape	Cylindrical	Cylindrical	Cylindrical
Case material	High temp. plastic	Cardboard	Plastic
Weight in gm	110.00	80.00	210
Placement	1.5 to 3 cm from mine	1.5-3 cm from mine	Contact with mine
DOT classification	1.3 C	1.3 G	4.1
Power requirement	Batteries	Batteries	Batteries
Maximum steel penetration	1/8"	1/16"	1/4"
Performance against Blast mine	Good	Only thin case Metal and plastic	Good

PARAMETERS	Thiokol Flare	FireAnt (A210)	Mine Incinerator
Perfor. against frag. Stake mines	Explosive melt and Flow on stake	No effect	Not design for these type mines
Perfor. against bounding mines	Low and high order	No effect on mine case	Low and high order
Human factor	Easy to use, minim. Operational skills	Easy to use, minim. oper. skills	Easy to use, minim. Operational skills
Transportation requirements	Cargo plane only, Explosive truck	Cargo plane only Explosive truck	No requirements
Storage requirements	Same as explosive	Same as explosive	No requirements
Availability and cost	Yes, mass production<$10.0	Yes, $8.5	Yes, mass production <$10.0
Application to UXO	Some	No	Some
Company	Thiokol, USA	Pains Wessex, UK	Hutchinson, USA

CONCLUSION

Three different deflagration systems, the Humanitarian Demining Flare, FireAnt and Mine Incinerator were investigated for their ability to neutralize AP stake mines and bounding fragmentation mines. FireAnt was unable to neutralize either type of mine, while the Humanitarian Demining Flare and the Mine Incinerator had mixed results. The Humanitarian Demining Flare penetrated 1/8" thick steel plate while the Mine Incinerator penetrated ¼" thick steel plates. Both systems can neutralize all blast AP and AT mines. Increasing reactive materials and increasing burn time may neutralize both types of mines. The present Mine Incinerator design is not suitable for stake mines.

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