Proper Usage of Torch Systems for *In Situ* Landmine Neutralization by Burning for Humanitarian Demining

Researchers at the U.S. Army Research, Development and Engineering Command who work with the Communications-Electronics Research, Development and Engineering Center as part of the Night Vision and Electronic Sensors Directorate, are advancing demining beyond traditional approaches with the use of torch systems for mine neutralization. This article describes trial results for three such torches.

by Dr. Divyakant L. Patel [U.S. Army NVESD]

At present, deminers normally use only two techniques to clear individual mines: manual disarming and destruction by an explosive charge. Manual clearance, in which a mine is found, excavated and manually neutralized without causing detonation, is a very arduous, slow and hazardous operation. Mines may behave unpredictably due to corrosion or other forms of weathering, or may be booby-trapped with anti-handling devices. The second mine-neutralization technique, demolition, is achieved with high explosives like C-4 blocks or explosive charges with similar characteristics. Unfortunately, this approach suffers from serious drawbacks, such as cost, storage, transportation and training. A partial detonation of a mine may leave considerable component parts in the minefield, including the explosive, booster, detonator or case material. Also, destruction cannot be performed where collateral damage is unacceptable, such as locations on or near bridges, public buildings, railroads, water or oil wells, power lines and historic sites.

The Night Vision and Electronic Sensors Directorate under the U.S. Army's Humanitarian Demining Research and Development Program, has been working to develop new non- and low-explosive technologies that have the potential to provide a safer, more reliable and less expensive means of neutralizing mines in humanitarian-demining operations. The HD R&D Program has developed several innovative deflagration (torch) methods using liquid chemicals, propellants, pyrotechnics, thermite and solid reactives. These incendiary systems neutralize surface-exposed mines by burning instead of by detonation. Burning can be an effective means of neutralizing both anti-tank and anti-personnel mines. The materials and construction of mines are essential factors in selecting a safe and effective method of neutralization.

AP and AT Mines

Landmines constitute two general categories: anti-personnel and anti-tank. AP and AT mines are further classified according to fuze type and function. There are three types of AP mines: blast, fragmentation and directional. Most AP blast mines have waterproof plastic cases; some are scatterable and resistant to clearance tools, creating an overblast. Older mines have Bakelite, glass or waxed paper cases, and a few have wooden cases. Most mines contain TNT as a main charge, while some use tetryl, RDX or Composition B. The main charge weight varies from 28–250 g, depending on the size of the mine. Mines usually have a circular, cylindrical or rectangular shape and are initiated by pressures of 2–20 kg. The fuze is located either in the center, sides or base of the mine.

AP fragmentation mines are divided into two categories: bounding mines and stake mines. Most bounding mines are cylindrical and made of 8–12-mm-thick cast iron or steel. These mines are activated with tripwires or pressure prong fuzes, and are unaffected by explosive clearance methods. Most bounding mines contain TNT as a main charge and 100–525 g of explosive. The mine has two fuzes, which are located at the top and bottom. The bottom fuze contains the propellant charge. The mines are waterproof and buried in soil with the top fuze exposed. Bounding mines are initiated by pressure of 1–25 kg.

Stake mines are cylindrical in shape and are made from cast iron or steel with a thickness of 8–12 mm. The mine's main charge is usually 75–410 g of TNT. The stake of the mine is made from wood or metal. These mines are found aboveground and are activated by tripwires. Operating pressures vary from 1–10 kg. Stake mines can be booby-trapped. The fuze is often located on top of the mine. Stake mines with tripwires are also difficult to neutralize with an explosive clearance method based on baric overpressure.

There are two types of AP directional fragmentation mines. The Claymore type is rectangular with one or two detonator wells molded in the top or back surface. They usually contain plastic explosive. The second type is round with a central detonator well. They are found aboveground and initiated with tripwire or electrically command-detonated. The mines usually contain TNT as a main charge of 200 g–12 kg. The directional fragmentation mine case is metal or plastic.

AT mines are classified as blast or shaped charge, with most being blast mines. They have metal, plastic (e.g., Bakelite, polystyrene, polyethylene), resin-reinforced fabric or wood cases. AT mines can be circular, square, rectangular or cylindrical in shape. They contain from one to four fuzes in various configurations. The fuze is typically initiated with pressure. The fuze body material can be brass/copper or zinc base alloy, plastic, aluminum or sheet metal with a thickness of 1–2 mm. Some mines contain shock-resistant fuzes and are scatterable. Shock-resistant mines are difficult to neutralize with explosive-clearance methods based on baric over pressure.

Most AT mines contain TNT or TNT-based explosive such as Composition B, Pentolite (pentaerythritol tetranitrate and TNT) or Amatol (ammonium nitrate and TNT). About 10% of mines contain only RDX, tetryl, PETN or C-4. TNT is an exceptionally stable explosive. It is highly resistant to chemical attack by acids and conventional oxidizers. Burning is generally the preferred method for destroying the main charge of AT mines. Solid TNT cannot be easily ignited with a match flame. However, TNT will generally burn fiercely but without transition to detonation if simply ignited, i.e., without use of a detonator and explosive booster charge to shock-initiate the TNT. Burning mines *in situ* is an alternative neutralization method that can avoid collateral damage.

Low-order mine neutralization, accomplished by burning the explosives, is not a technique deminers commonly use. It is a relatively new approach that may be expensive, requires proper training and may require additional testing on different mine types. Nevertheless, burning can be an appropriate neutralization method for mines, especially in locations that do not allow for manual disarming or demolition. Understanding the burning process of unconfined and heavily confined secondary explosives and various mine cases, such as metallic, plastic and wooden, is essential before developing procedures for such techniques.

Characteristics of Torch Systems						
System	Steel Plate Penetration	Burning Time (sec)	Flame Temp.	Ignition Methods	Thrust (lb)	DOT Class
TDF	1.5 mm	60–70	1927˚C 3500˚F	Electric Match Igniting Cord	0.5	1.4C
PT-1	4.0 mm	25–27	2700˚C 4892˚F	Electric Match Igniting Cord	3.0	1.4C
PT-12	12.0 mm	28–30	2700˚C 4892˚F	Electric Match Igniting Cord	6.0	1.4C

Table 1.

Explosive Burning

The burning process of an unconfined explosive itself is a self-sustaining, exothermic reaction. Due to the heat, the corresponding hot gases, and the fine particles released in the first step, the reaction normally continues in the gas phase with emission of light. The transfer of heat generated by such a reaction is conductive and convective. The explosive charge itself burns layer by layer and the temperature within the charge decreases with distance from the reaction zone.

The burning reaction of an explosive starts if the temperature is raised above its ignition temperature. The ignition temperature of an explosive depends on heat production and transfer. If an explosive is heavily confined, the pressure around it rises and the hot gases have no possibility to escape. The heat transfer becomes more efficient and the burning rate accelerates up to a deflagration, and from there, into a detonation (high order). The burning rate of an explosive depends strongly on the type of explosive, physical condition of the explosive (press versus melt cast), its surface area and its confinement. Several physical and chemical properties also control burning such as melting point, boiling point, decomposition temperature, ignition temperature and explosion temperature. TNT is the main charge of most mines; it melts, boils, ignites and explodes at 81˚C, 210–212˚C, 295–300˚C and 465˚C, respectively.

Torch Systems

The HD R&D Program has developed three mine-neutralization devices to neutralize mines by burning: the Thiokol Demining Flare, Propellant Torch PT-1 and PT-12. In order to use torch systems to neutralize surface-exposed mines, users must know the subject mine's case type and thickness; the fuze type, number and locations; and the type of explosive. To use safely and effectively, the torch device must be able to penetrate the mine case in less than six seconds to avoid detonation of the mine.

Figure 1: SPM-1, AP Thermoplastic case mine with TDF.
ALL PHOTOS COURTESY OF HD R&D

Figure 2: MON-50, AP plastic case directional mine with two TDFs attached to a stand.

Figure 3: TMRP-6, a plastic-case AT mine with two TDFs on ground attacking mine from opposite sides with a metal plate on TDFs at ends.

The preferred device burning time is 25 seconds or longer, and the preferred flame temperature is 1,800–3,000˚C. The burning characteristics of mine-case materials will be discussed later. The parameters of the TDF, PT-1 and PT-12 devices are tabulated in Table 1.

The Thiokol Demining Flare is applicable to AP plastic-case blast mines. The flare is used with and without a stand. When it is used without a stand (a 1-lb stone or weight may be used to brace the back of the flare), it is placed on the ground 4–6 cm away from the mine, aiming to cut the corner of the mine. The flare's flame should never be aimed

Figure 4: TM-46, AT metallic-case mine with two PT-1 torches on the ground with placement of metal plates on them.

Figure 5: PT Mi-Ba-III, Bakelite-case AT mine with two PT-1s that is partially covered by the soil.

Figure 6: PMR-2A, AP stake mine with PT-12 torch on a stand.

at the center of the mine because the detonator explosive is more sensitive to heat and can cause the mine to detonate.

The TDF is also applicable to both types of AP directional mines. Two flares are recommended, using a stand with a 2–3 cm stand-off distance from the detonators and directed toward the concave side (opposite to "front toward enemy" side) of the mine. The TDF will neutralize 80% of metal- and plastic-case AT mines. For

Figure 7: Valmara-69, AP plastic-case bounding mine with PT-12, partially buried in the ground.

Figure 8: AT metal-case shaped-charge mine with PT-12 on a stand.

metal-case mines, two flares are recommended without a stand and opposite to each other, away from the fuze with a stand-off distance of 1–2 cm. Because low-power torches cannot penetrate these cases, this flare should never be used against Bakelite-case or wooden-case AT mines. Figures 1—3 show the applications of TDF against various AP and AT mines.

The Propellant Torch PT-1 is recommended for use against all Bakelite, thermoplastic, and wooden-case AP and AT mines. When it is used against AP mines, no stand is necessary and the flare should have a stand-off distance of 4–5 cm from the mine. Place a 4–5 lb stone or sandbag at the back of the PT-1 torch.

Figures 4 and 5 show the applications of PT-1 against AT and AP mines. The TDF is also effective against Russian metal-case

AT mines; however, when the explosive is unknown or Amatol is present in a mine, use of PT-1 is recommended.

The Propellant Torch PT-12 has the capability to penetrate a 12 mm-thick hard steel plate. This torch was developed for hard-case mines and unexploded ordnance. The torch is applicable to AP bounding and stake mines, and a few metal-case AT mines. For stake mines, the torch is used with a stand and a stand-off distance of 1–2 cm from the bottom portion of the mine. The bounding mine is the most difficult to neutralize by burning because it has an extra propellant fuze inside, but it is possible with proper aiming of the flame on the mine. PT-12 can be used with and without a stand. When it is used without a stand, use a 6–8-lb sandbag at the back of the flare. Figures 6–8 show the applications of PT-12 torch against stake, bounding and AT mines.

Burning characteristics of metal-case mines. Metal-case AP or AT mines are made from steel or cast iron. AP bounding and stakes mines are cylindrical, made from 8–12 mm-thick cast iron or steel. Most AT metal-case mines are made from steel and are 1–2 mm thick. Steel generally does not burn, but it can soften and melt. It melts at about 1,300˚C and boils at approximately 3,000˚C. For neutralizing AP bounding and stake mines by burning, a more powerful torch system is required due to the very thick mine case. A metal-case AT mine with a TNT main charge can be easily neutralized by burning. Any torch system that generates more than 1,300 C can be used against a metal-case AT mine. The torch will easily soften a 1–2 mm-thick metal case where the flame is attacking. At the same time, TNT melts and vaporizes and increases the pressure inside the mine. When it reaches a high pressure, the softened metal part opens to allow vapors to escape. The vapors start burning and the burning continues until all the TNT vapors are gone from the mine. Generally, boosters also burn out and the detonator will pop out at the end. Therefore, any torch system which generates heat at more than 1,300˚C is recommended for low-order neutralization by burning of metal-case AT mines.

Burning characteristics of plastic-case mines. "Plastic" refers to polymer material, and different polymers have different melting points. When burned with a flame, something has to form into a gas. Polymer molecules are far too long to do this in one piece, so one must get them hot enough to actually break up thermally. There are two classes of polymers: thermosetting and thermoplastic. The thermosetting plastic, such as Bakelite, will never soften when heated; it will just decompose. Bakelite is a material based on the thermosetting phenol formaldehyde resin; it was the first plastic made from synthetic components. Therefore, old AP and AT plastic-case mines were made from Bakelite, such as AP mine types PMN, PMN-2, No.-10, GYATA-64, MAI-75, MAT-68 and PPMi-Ba and AT mine types TM-62P, TM-62P2, PTMi-Ba-III, etc.[1] To neutralize these mines, it is necessary to use a powerful torch, such as the PT-1 shown in Figures 4 and 5. The Thiokol Demining Flare (a low-power flare) cannot neutralize Bakelite-case AP or AT mines.

Thermoplastic will soften, then liquify, when heated by a flame and become solid when cooled. If plastics are heated significantly beyond their softening points, they can darken and char. Since plastics are poor conductors of heat, it is difficult to get the whole sample hot enough to melt without crisping the outside surface, e.g., polypropylene, polyethane (PFM-1), polystyrene (M-19), or acrylonitrile butadiene styrene plastic (TMRP-6, TMRP-7). Excluding Bakelite-case landmines, the rest of the plastic-case landmines are generally thermoplastic. Thermoplastic-case AP and AT mines can be neutralized using a less powerful torch, such as the Thiokol Demining Flare, or any other similar torch, and aiming

Most Common Anti-Personnel (AP) Mine Characteristics and Neutralization Requirements								
Origin	Designation	Case Shape Color	Explosive Weight (kg)	Fuse Type No. of Fuses	Activation Pressure (kg) Effect	Booby Trap Possible	No. of Torches Type of Torch	Standard Requirements
China	Type 69	Metal Cylindrical Olive Drab	TNT 0.105	Pressure or Actuvat. One	7–20 or Pull: 1.5–4 Bounding Fragmentation	Yes	One PT-12	No
Czech Republic	PP-Mi-Sr	Steel Cylindrical Olive Drab	TNT 0.325	RO8 or RO1 One	3–6 or Pull: 4–8 Bounding	Yes	One PT-12	Yes Surface or Buried
Serbia (Yugoslavia)	PROM1	Steel Bottle Olive Drab	TNT 0.425	Press or UP- ROM1	9–16 or Pull: 3–5 Bounding Fragmentation	No	One PT-12	Yes Attack at Neck
USSR (CIS)	OZM3	Cast Iron Cylindrical Olive Drab	TNT 0.075	RO8 or MUV2 VPF	2–5 Bounding Fragmentation	Yes	One PT-12	Yes Above ground
USSR (CIS)	OZM4	Cast Iron Can Olive Drab	TNT 0.185	RO8 or MUV2 VPF	2–5 Bounding Fragmentation	Yes	One PT-12	Yes At angle
USSR (CIS)	MON 100	Steel Large Dish Olive Drab	TNT 2.0	MUV or VPF	2–5 Fragmentation	Yes	Two TDF Convex	Yes
USSR (CIS)	POMZ2	Cast Iron Cylindrical Grey/Green	TNT 0.075	MUV or VPF One	2–5 Fragmentation	Yes	One PT-12	Yes Stake mine
Belgium	NR409	Plastic Circular Beige	Trialen, PETN or TNT 0.08	Pressure	8–30 Blast	No	One TDF	No
China	Type 72	Plastic Cylindrical Green	TNT 0.051	Pressure	5–10 Blast	Yes	One TDF	No
Germany	PPM-2	Bakelite Circular Black	TNT 0.11	Piezo Elect One	13 Blast	No	One PT-1	No
Italy	VS-50	Plastic Cylindrical Sand	RDX 0.043	Pressure M-41 One	10 Blast	No	One PT-1	No
Italy	V-69	Plastic Cylindrical Olive Green or Sand	Comp B 0.42	Tripwire or pressure One	10, Pull: 6 Bounding Fragmentation	No	One PT-12	No
USSR	PMN	Bakelite Cylindrical Brown	TNT 0.240	Rubber Plate	8–25 Blast	No	One PT-1	No
USSR	PMN-2	Bakelite Cylindrical Green	RDX/TNT 0.100	Bake P Plate One	5–15 Blast	No	One PT-1	No
Serbia (Yugoslavia)	PMA2	Bakelite Cylindrical Green	TNT 0.10	UPMAH2 Frict	7–15 Blast	Yes	One PT-1	No
Serbia (Yugoslavia)	PMA3	Plastic Circular Black	Tetryl 0.035	Chemi UPMAH3	8–20 Blast	Yes	One TDF	Yes From top
USSR	MON 50	Plastic Rectangular Olive Drab	PVV-5A 0.70	Detonator Two Tripwire	2–5K Directional Fragmentation	Yes	Two TDF	Yes Attack at concave Side
USSR	PMD6	Wood Rectangular Brown	TNT 0.20	MUV or MUV2	1–10 Blast	Yes	One PT-1 or TDF	No

Table 2.

Most Common Anti-Tank (AT) Mine Characteristics and Neutralization Requirements

Origin	Designation	Case Shape Color	Explosive Weight (kg)	Fuse Type No. of Fuses	Activation Pressure (kg) Effect	Booby Trap Possible Fuse Type	No. of Torches Type of Torches	Stand Re-quirements
Former Czechoslovakia	PTMi-k	Steel Circular Olive Green	TNT 5.0	RO-5 or RO-9	330.0 Blast	Yes	2 TDF	No
USSR (CIS)	TM-46	Steel Cylindrical Olive Green	TNT 5.7	MV5 or MVM 2	120–400 21 Tilt Blast	Yes MVSh 46	2 TDF	No
USSR (CIS)	TM-57	Steel Cylindrical Olive Green	TNT/TGA/MS 6.34	MVZ-57 or MUV 2	120–400 21 Tilt Blast	Yes MVsh-57	2 TDF	No
USSR (CIS)	TM-62M	Steel Cylindrical Olive Green	TNT/TGA/ Amatol 7.5	MVCh-62 MVZ-622	150–500 Blast	No	2 TDF	No
USSR (CIS)	TMK-2	Steel Cone Olive Green	TG-50 or TNT 6.5 or 6.0	Tilt-rod MVK-21	8–12 tilt Shaped charge	No	One PT-1	Yes
UK	Mk 7	Steel Cylindrical Brown	TNT 8.89	No. 51	150–275 Blast	Yes L93A1	2 TDF	No
Belgium	PRB-M3	HI Plastic Square Olive Green	TNT/RDX/A1 6.0	M301	250 Blast	No	2 PT-1	No
China	Type 72	Plastic Cylindri-cal Olive Green	TNT/RDX 5.4	Bla Re Ty721	300–800 Blast	No	2 PT-1	No
Former Czechoslovakia	PTMi-Ba-II	Bakelite Rectangular Brown	TNT 6.00	RO-7-II 2	200-400 Blast	Yes	2 PT-1	No
Pakistan	P2 Mk 2	Plastic Square Brown	TNT 5.00	P2Mk21	180–300 Blast	Yes	2 TDF	No
Former Yugoslavia	TMA-5	Plastic Square Olive Green	TNT 5.5	UANU-11	100–300 Blast	Yes	2 PT-1	No
USSR	TMD-44	Wood Box Olive Green	TNT or Picric Acid 5-7	MV-51	200–500 Blast	No	2 PT-12	No

Table 3.

the flame in such a way to allow run-off of the melted plastic to let the thermic energy generated by the torch flame come in direct contact with the explosive charge of the landmine.

Burning characteristic of wood-case landmines. Some old AP and AT mines have wood cases. The types of wood cases used in mines vary by manufacturer. The thickness of wood-case AP and AT mines is less than 6 mm and around 12 mm, respectively. The penetrating power of torch flame on a wooden-case mine depends on the type of wood case, its thickness, density, and moisture content, and the amount of carbon produced on the case during burning. The mines buried in soil for a long period of time might have a rotten case with high moisture content. To remove moisture from the case, use the extra energy from the torch to produce smoke. If the mine case is completely dried, then a low-power torch or any torch system similar to TDF can be used on any wood-case mine. If a lot of carbon is deposited on the case, it is difficult for the flame to penetrate because carbon is a nonconductor of heat. Therefore, a low-power torch is not recommended for AT wood-case mines.

Conclusions

Table 2 (previous page) and Table 3 (above) represent the most common AP and AT mines characteristics and their neutralization requirements using a torch system.

It is important to note that the torch systems described here have the U.N. hazardous classification 1.4C, designated for flammable solids. One can only ship by air and it is costly. To reduce the cost of shipment, packaging and labor, it is our recommendation that the host nation manufacture the torches using a mobile manufacturing method provided by the developer. It is also important to mention that the advice in this article does not constitute field-level guidance and should not be used as part of standard operating procedures without additional investigation.

See Endnotes, Page 115

Dr. Divyakant Patel is the Project Leader of Landmine Neutralization System Developments for the Humanitarian Demining Research and Development Program at the U.S. Army's Night Vision and Electronic Sensors Directorate. He is a physical scientist with more than 20 years' experience in countermine and humanitarian-demining neutralization systems development based on non-explosive and explosive technologies.

Dr. Divyakant Patel
AMSRD-CER-NV-CM-HD
10221 Burbeck Road
Fort Belvoir, VA 22060-5806 / USA
Tel: +1 703 704 2505
E-mail: divyakant.patel@us.army.mil
Web site: http://www.humanitarian-demining.org