SUMMARY REPORT OF TESTING OF THE PROPELLANT TORCH SYSTEM

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1. INTRODUCTION

The propellant torch system (PTS) was tested against a series of landmines at a Government Test Site between September 22nd and September 25th. A total of 30 torches were tested against a set of mines consisting mainly of actual fuzed mines. The results of these tests are reported here.

2. Propellant Torch Description and Operation

Four types of torches containing different propellant formulations were used in the tests. These are listed in Table 1 below:

Table 1. Propellant Torch Types

Torch Name	TCI Name	Distinguishing formulation ingredients	Propellant Mass (grams)	Configuration
KN	PTS1	Potassium Nitrate		center burn
KP	PTS4	Potassium Perchlorate		center burn / 6 mm diameter nozzle
IO	PTS2	Iron Oxide (thermite)		center burn / 10 mm diameter nozzle
IOZn	PTS5	Iron Oxide Zinc		center burn

The dimensions of all four torches were identical, i.e. about 51 mm (2 in) in diameter and about 155 mm (6 in) in length. The torches consisted of a propellant mixture pressed into a cardboard tube with a fireclay plug at each end. (figure 1) At the front end, a hole is located in the center of the fireclay plug and extends a few centimeters into the propellant. This hole serves as a nozzle out of which the hot combustion products can exit.

Figure 1. Picture of Propellant Torch

The original ignition method for the torch consisted of inserting a piece of QuickMatch (QM) into the nozzle of the torch, then igniting the QM with an electric match. This method proved inadequate, and was replaced by the use of an igniting cord. This method involved folding a short length (approximately 4 to 8 cm) at the end of the igniting cord over itself to increase the cord diameter (Figure 2), then inserting the thickened end of the cord into the nozzle of the torch. An appropriate length of cord was used to set the delay between ignition of the cord and the ignition of the torch.

Figure 2. Picture of Twisted Wire Illustrating the Igniting Cord Configuration for Torch Initiation.

3. Torch Placement

Two torch placement methods were used. For a flush-buried mine, a small trench large enough for the torch was made near the mine (Figure 3a). The torch was then placed in the trench (Figure 3b) and was secured by packing earth around it (Figure 3c) and placing a sandbag. on top.

a)

b)

c)

Figure 3. Torch Placement Method for Flush-Buried Mines Showing a) Small Trench for Torch, b) Torch Placement, and c) Torch Securing (shown without sandbag).

For stake mines, the torch was mounted horizontally in a stand such that hot jet impinged upon the side of the mine (Figure 4). The stand consisted of a bent steel strip mounted onto a wood base. A sandbag was placed on the base of the stand to prevent it from moving due to thrust from the torch during operation.

Figure 4. Placement of Torch for Stake Mine Neutralization.

4. Mines

The mines used for testing consisted of a variety of anti-personnel (AP) and anti-tank (AT) mines as listed in Table 2. When “both” is indicated in the “Fuzed” column, the mine was tested both fuzed and unfuzed.

Table 2. Tested Mines

Mine Name	Type	Fuzed	Explosive and Mass
VS 50	AP blast, plastic casing	both	50g. RDX
	AP blast, plastic casing	yes	23 g. tetryl
SPM-1	AP blast, plastic casing	yes	80 g. trialene
POMZ-2 surrogate	AP fragmentation, steel casing	yes	75 g. TNT
	AP, bounding fragmentation, steel casing	yes	
PMD-6 surrogate	AP blast, wood casing	yes	200 g. TNT
	AT blast, steel casing	both	10 kg (22 lbs) CompB
	AT blast, plastic casing	both	CompB
TMM-1	AT blast	no	5.7 kg TNT
TMD-44 surrogate	AT blast, wood	yes	2.7 kg TNT
	AT, shaped charge	yes	H6

Surrogate mines were used for both the POMZ-2 and TMD-44 mines. The POMZ-2 surrogate consisted of a steel tube closed at the bottom with a outer diameter of 6 cm (2.4 in), height of 13 cm (5.1 in), a side wall thickness of 1.3 cm (0.5 in), a bottom thickness of 25 cm (1 in), as shown in Figure 5. The tube was partially filled with TNT, and a detonator was mounted on top of the mine with a plastic cap (held by hand in Figure 5).

Figure 5. POMZ-2 Surrogate Mine

The TMD-44 surrogate consisted of a plywood box partially-filled with 455 g. (1 lb) bars of TNT (Figure 6.) The plywood walls were about 19 mm (0.75 in) thick and a detonator was mounted inside the box near the center , inserted partially inside a block of TNT.

Figure 6. TMD-44 Surrogate Mine.

5. Test Matrix

A total of 30 mines were tested, and up to 3 mines were tested simultaneously. Due to the difficulty of placing the torch precisely, the uncertainty in the standoff distance was about ±10 mm. The test matrix is shown below in Table 3.

Table 3. Test Matrix

Test	Mine	Type	Fuzed	Explosive mass	Torch used	Standoff
1	none	n/a	n/a	n/a	KP	n/a
2	none	n/a	n/a	n/a	KP	n/a
3		AT blast, steel casing	no	10 kg (22 lbs) CompB	KN	25 mm
4	VS 50	AP blast, plastic casing	no	50g. RDX	KP	51 mm
		AT blast, plastic casing	no	CompB	IO	25 mm
5		AP blast, plastic casing	yes	23 g. tetryl	KN	51 mm
	VS 50	AP blast, plastic casing	yes	50 g. RDX	IO	51 mm
6		AP blast, plastic casing	yes	23 g. tetryl	KP	51 mm
		AP blast, plastic casing	yes	23 g. tetryl	KN	51 mm
	VS 50	AP blast, plastic casing	yes	50 g. RDX	KN	51 mm
7	TMM-1	AT blast	no	5.7 kg TNT	KP	25 mm
		AT blast, plastic casing	yes	CompB	KP	25 mm
		AT blast, steel casing	yes	10 kg (22 lbs) CompB	KN	38 mm
8		AP blast, plastic casing	yes	CompB	KN	25 mm
		AT blast, steel casing	yes	10 kg (22 lbs) CompB	KN/KP	25 mm / 25 mm
9	POMZ-2 surrogate	AP fragmentation, steel casing	yes	75 g. TNT	KP	20 mm
	SPM-1	AP blast, plastic casing	yes	80 g. trialene	KN	25 mm
	TMD-44 surrogate	AT blast, wood	yes	2.7 kg TNT	KN	25 mm
10	POMZ-2 surrogate	AP fragmentation, steel casing	yes	75 g. TNT	IO	20 mm
		AP, bounding fragmentation, steel casing	yes		KP	13 mm
		AT, shaped charge	yes	H6	KP	13 mm
11	SPM-1	AP blast, plastic	yes	80 g. trialene	KN	51 mm
		AP, bounding fragmentation, steel casing	yes		KP	19-25 mm
		AT, shaped charge	yes	H6	IO	13 mm
12	PMD-6		yes	200 g. TNT	IOZn	32 mm
	PMD-6		yes	200 g. TNT	IOZn	32 mm
		AT, shaped charge	yes	H6	IOZn	32 mm
13	POMZ-2 surrogate	AP fragmentation, steel casing	yes	75 g. TNT	IOZn	32 mm
		AP, bounding fragmentation, steel casing	yes		IOZn	32 mm
14	PMD-6		yes	200 g. TNT	IOZn	51 mm
		AT, shaped charge	yes	H6	IOZn	51 mm

6. Results

When the torches were tested against the landmines, the results could be classified into three, somewhat subjective categories:

- a high order explosion,
- a low order explosion or burning,
- displacement of the mine without penetration.

In the case of a high order explosion, the mine would detonate during the neutralization process. The likely scenario in this case is that the fuze would trigger due to excessive heat and initiate an appreciable amount of high explosive still present in the mine. The explosion may be smaller than that of an intact mine since the amount of high explosive present in the mine at the time of the explosion may be reduced due to prior burning by the torch. The resulting explosion is nevertheless strong enough to generate a strong blast wave and a crater.

In low order explosion or burning, the mine typically burns for several minutes, consuming most of the high explosive inside. before the detonator initiates. The result is a small explosion that produces only a weak popping sound at a distance of several hundred feet. The damage from this explosion is negligible, and no crater is produced. When a mine is unfuzed, the high explosive typically burns without an explosion until it is completely consumed. Low order explosion or burning constitutes a successful neutralization of the mine.

For small AP mines that typically weighed less than 1 kg, the mine would be blown away from the location where it was buried due to the high thrust of the torch. The mine would be slightly scorched, but otherwise intact.

The results are summarized in Table 4.

Table 4. Summary of Test Results

Test	Date	Mine	Type	Fuzed	Torch used	Result
1	9/22	none	n/a	n/a	KP	No ignition with 2 quickmatch fuzes in nozzle
2	9/22	none	n/a	n/a	KP	Successful ignition with igniting cord
3	9/22		AT blast, steel casing	no	KN	8 min low order burn
4	9/22	VS 50	AP blast, plastic casing	no	KP	8 sec low order burn
	9/22		AT blast, plastic casing	no	IO	22 min low order burn
5	9/23		AP blast, plastic casing	yes	KN	torch did not ignite
	9/23	VS 50	AP blast, plastic casing	yes	IO	small high order explosion after 1 min of burning
6	9/23		AP blast, plastic casing	yes	KP	displacement of the mine without penetration
	9/23		AP blast, plastic casing	yes	KN	displacement of the mine without penetration
	9/23	VS 50	AP blast, plastic casing	yes	KN	high order explosion after 6 sec
7	9/23	TMM-1	AT blast	no	KP	low order burn for 17 min
	9/23		AT blast, plastic casing	yes	KP	low order explosion after 11:45 min, continued burning until 14:45 min
	9/23		AT blast, steel casing	yes	KN	high order explosion after 5:30 min
8	9/23		AT blast, plastic casing	yes	KN	low order explosion after 15 min, continued burning until 18:40 min
	9/23		AT blast, steel casing	yes	KN/KP	low order explosion after 3 min, continued burning until 4:20 min
9	9/24	POMZ-2 surrogate	AP fragmentation, steel casing	yes	KP	low order burn for 40 sec until detonator popped out
	9/24	SPM-1	AP blast, plastic casing	yes	KN	torch did not ignite
	9/24	TMD-44 surrogate	AT blast, wood	yes	KN	high order detonation after 5 sec
10	9/24	POMZ-2 surrogate	AP fragmentation, steel casing	yes	IO	low order burn for 40 sec until detonator popped out
	9/24		AP, bounding fragmentation, steel casing	yes	KP	low order explosion after 1:20 min, continued burning until another low order explosion at 2:20 min
	9/24		AT, shaped charge	yes	KP	low order explosion after 1:30 min, continued burning of large fragment until 7:20 min, plate intact
11	9/24	SPM-1	AP blast, plastic	yes	KN	displacement of the mine without penetration
	9/24		AP, bounding fragmentation, steel casing	yes	KP	high order explosion after 10 sec
	9/24		AT, shaped charge	yes	IO	high order explosion after 2:40 min
12	9/25	PMD-6		yes	IOZn	high order explosion after 8 sec
	9/25	PMD-6		yes	IOZn	did not ignite (cut igniting cord)
	9/25		AT, shaped charge	yes	IOZn	did not ignite (cut igniting cord)
13	9/25	POMZ-2 surrogate	AP fragmentation, steel casing	yes	IOZn	low order burning for 10-12 sec
	9/25		AP, bounding fragmentation, steel casing	yes	IOZn	high order explosion after 5-6 sec, no bounding
14	9/25	PMD-6		yes	IOZn	low order burning until low order detonator explosion
	9/25		AT, shaped charge	yes	IOZn	low order burning with several low order detonator and propellant explosions

7. Discussion of Results

7.1 AP mines

VS 50: AP blast, plastic casing
This mine was tested three times with three different torches: the KP, IO, and KN. The standoff was maintained at 51 mm (2 in) for all tests. In all cases, the detonator ignited after a certain burn time. For the KP torch, the mine was unfuzed, and almost all the explosive was burned in about 8 sec. For the IO torch, a small high order explosion occurred after about 1 min. of burning. It is believed that a relatively large portion of the high explosive in the mine was burned when the detonator ignited. For the KN torch, a high order explosion occurred after about 6 sec. It is believed that most of the high explosive in the mine was detonated. Hence the IO torch neutralized the mine more effectively than the KN torch since it burned more high explosive before the detonator ignited. The performance of the KP torch on a fuzed mine is not yet known.

AP blast, plastic casing
This small mine was tested with a KP and a KN torch. In both cases, the mine was too light to withstand the thrust of the torch and was displaced 1-2 m from location where the mine was buried. The mines were slight blackened on the surface, but otherwise intact. Consequently, the performance of the torch on this type of mine is not yet known. Reducing the thrust of the torch for future tests may be necessary to avoiding displacing the mine.

SPM-1: AP blast, plastic casing
This small mine was tested with a KN torch. As for the “AP blast, plastic casing” mine, the torch thrust was too large and the mine was displaced with only slight blackening on the surface of the mine. The performance of the torch on this type of mine is therefore not yet known. Similarly, reducing the thrust of the torch for future tests may be necessary to avoiding displacing the mine.

POMZ-2 surrogate: AP fragmentation, steel casing
This surrogate mine was tested with KP, IO, and IOZn torches. For the KP and IO tests, the standoff was about 20 mm (0.78 in), and the torch jet struck the mine at a location about 19 mm (0.75 in) from the bottom of the TNT fill (Figure 7). In both tests, the torch melted and vaporized some TNT near the bottom of the mine, and the pressure built up from the vapor ejected a certain amount of solid TNT as well as the detonator assembly a certain distance away from the mine. After the test, the casing was empty with a hole burned in the side by the torch. For the KP torch test, a 15 mm (0.6 in) diameter hole was burned through the casing wall. The IO torch burned a smaller, 3 mm (0.1 in) diameter hole in the casing wall. These tests were inconclusive as to the torch performance since the detonator in an actual mine is screwed into the casing and would not be ejected.

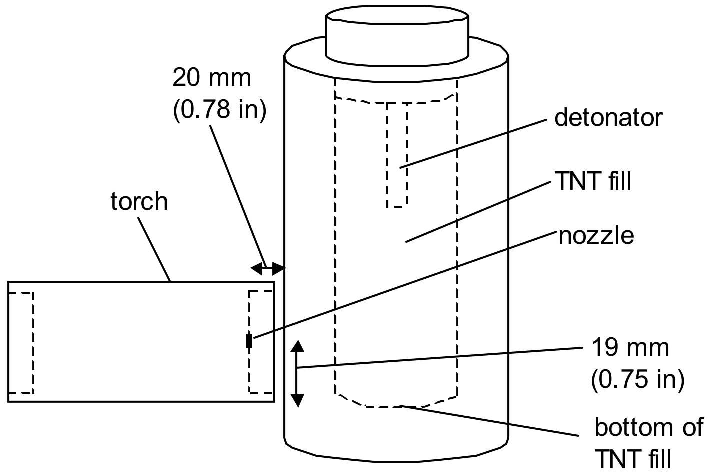

Figure 7. Schematic of Torch Arrangement with Stake Mine.

To remedy the problem of the ejection of the detonator assembly, a steel clamp was used to secure the cap. An IOZn torch was used with a standoff of 32 mm (1.25 in). Burning was initiated for about 10-12 sec, leaving about half of the TNT unburned. The mine casing was penetrated with a very small hole, which became plugged by condensed TNT during the burning process.

A KP torch with a short standoff (less than 20 mm) would likely produce a larger hole, and possibly more explosive burning. However, this test was not conducted with an actual stake mine nor a stake mine surrogate with a well-secured detonator assembly. Thus the performance of the torch against stake mines remains to be determined.

AP, bounding fragmentation, steel casing

This mine was tested three times: twice with KP torches and once with an IOZn torch. The test with a KP torch at a 13 mm (0.5 in) standoff neutralized the mine successfully, effectively penetrating both the outer and inner casings and initiating a sustained burn for about 2:20 min with small pops as the detonators ignited. A second test with a KP torch was conducted, but the standoff was larger at about 13-25 mm (0.5-1.0 in) with an angle of attack of about 20 degrees from the normal of the mine casing. For this test, the mine detonated after about 10 sec. of burning. A third test with was conducted with an IOZn torch at a standoff of about 32 mm (1.25 in). The mine detonated after about 10 sec. of burning, but with no bounding action. Hence it appears that standoff and angle of attack may be critical in consistently neutralizing this type of mine.

PMD-6 surrogate: AP blast, wood casing

This mine surrogate was tested twice with IOZn torches. The first test with a standoff of about 32 mm (1.25 in), detonated after about 6 sec. The second test with a larger standoff of about 51 mm (2.0 in) was burned for a certain time until the detonator alone ignited, and was thus successfully neutralized. The larger standoff of about 51 mm (2.0 in) instead of 32 mm (1.25 in) appears critical in neutralizing the mine.

7.2 AT mines

<u>AT blast, steel casing</u>

Three tests were conducted on this mine: two with KN torches and one with both a KN and a KP torch simultaneously. The first test with a KN torch at a standoff of about 25 mm (1.0 in) was performed on an unfuzed mine, which burned steadily for about 8 min until the explosive was consumed. The second test was performed with a KN torch at a standoff of about 38 mm (1.5 in). In this test, the mine detonated after about 5:30 min with a significant amount of high explosive still in the mine. In the third test, two torches aimed at the mine with a standoff of about 25 mm (1.0 in) for each torch (Figure 8). In this test, the high explosive in the mine was quickly burned in about 4:20 min, with the detonator igniting about 3:20 into the burn with almost no explosive remaining. The detonator explosion launched a small fragment of explosive a couple meters away which continued to burn for about one more minute. Hence two torches appear to effectively neutralize this type of mine.

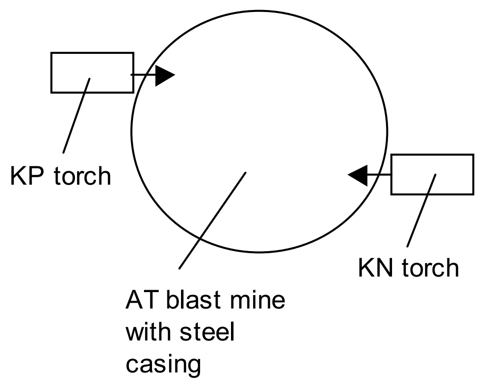

Figure 8. Schematic of Torch Arrangement with Two Torches.

<u>AT blast, plastic casing</u>

This mine was tested with an IO, KP, and KN torch. The standoff was about 25 mm (1.0 in) in all cases, and the torch was aimed off-center so as to not point directly at the fuze. The mine was neutralized successfully in all three tests. The first test with an IO torch was performed on an unfuzed mine, which burned steadily for 22 min until all the explosive and plastic casing extinguished itself. The second and third test with the KP and KN torches burned for about 11:45 min and 15 min respectively until the detonator popped weakly. The mine and plastic casing continued to burn for about 3 min afterwards in both tests.

<u>TMM-1: AT blast</u>

A single unfuzed mine of this type was tested with a KP torch and a standoff of about 25 mm (1.0 in). The mine was successfully neutralized as it burned steadily for about 17 min until the high explosive was consumed.

<u>TMD-44 surrogate: AT blast, wood</u>

A single mine of this type was tested with a KN torch with a standoff of about 25 mm (1.0 in). The mine detonated after about 5 sec, indicating that the detonator was likely struck by the torch flame during the neutralization. Aiming the torch lower at the explosive or attacking from the bottom may alleviate this problem.

AT, shaped charge

Three tests were conducted on this mine with the KP, IO, and IOZn torches. In the first test with a KP torch at a standoff of about 13 mm (0.5 in), the detonator exploded weakly after about 1:30 min. A large mine fragment that was launched about 4.5 m (14.8 ft) continued to burn for about 6 min. The shaped charge plate was intact after the burning, thus the neutralization was successful. In the second test with a IO torch at a standoff of about 13 mm (0.5 in), the mine detonated after about 2:40 min. For the third test with an IOZn torch at a standoff of about 51 mm (2.0 in), the high explosive burned continuously with several small pops from the detonator or pieces of propellant. The top plate was intact and the mine was neutralized successfully

8. Conclusions and Recommendations

1. The KP torch was found to have the strongest penetration ability, as it generated the largest hole in the POMZ-2 surrogate.
2. The IO torch had a much weaker penetration ability than the KP torch, and created slag at the torch nozzle when the standoff was too small (less than about 15 mm).
3. The IOZn did not seem to penetrate as strongly as the IO torch, suggesting that the addition of zinc to the IO formulation may have decreased its performance.
4. The standoff and angle of attack was found to be critical in achieving a successful neutralization, particularly for the AP bounding fragmentation mine which has two casings.
5. Using two torches simultaneously reduced the burn time and increased the likelihood of successful neutralization (e.g. the AT blast, steel casing mine).
6. For light AP mines (less than about 150 g.), the mine was displaced by the torch jet without being penetrated. A torch with a lower thrust may be necessary for these types of mines.