Test and evaluation of pyrotechnical mine neutralisation means

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Final Report

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Abstract:

The trials conducted by Germany, as part of the International Test and Evaluation Program for Humanitarian Demining (ITEP), were aimed at developing a non-explosive method of non-contact antitank mine clearance using ignition charges or (thermite) demining flares.

No method of safe non-explosive (low order) clearance of AT mines using ignition charges and (thermite) demining flares in different test arrangements could be found.

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1 Task Description

The investigation conducted as part of the „International Test and Evaluation Program for Humanitarian Demining" was aimed at developing a non-explosive („low order“) method of contactless AT mine clearance using ignition charges or (thermite) demining flares.

2 Summary of Results

Due to the use of different ignition charges and (thermite) demining flares the results cannot be summarized. The individual test results would have to be differentiated according to the test setup under the respective parameters. On principle, it must be said that no method could be developed enabling the clearance of AT mines to be carried out in a safe, non-explosive and noncontact manner. In addition, the DM29 ignition charge, fire, EOD, PT was unsuitable for igniting the TM-46 AT mine because of its nondirectional flame and insufficient penetration capability. Thus it was excluded from further testing.

3 Description of Test Items

The following items of ammunition were used:

• AT mine	♦ TM-46 and TMH-46 with MVM fuze
• Demolition charge	♦ 8 kg, cylindrical, TNT
	♦ 8 kg, cylindrical, PETN
	♦ 8 kg, cylindrical, TR8870
	♦ 8 kg, cylindrical, Composition B
• Ignition charge or (thermite) flare:	♦ DM29 ignition charge, fire, EOD, PT
	♦ FireAnt A210
	♦ Hyper Heat Mine Flare (HMF)
• Ignition device:	♦ Igniter, electric, DM29

In addition, DM12B1 demolition charges and DM42 blasting caps were used for destroying remains of explosives.

3.1 TM-46 (TMH-46) AT Mine

Figure 1: TM-46 AT mine without fuze, the brown spots are preservative grease

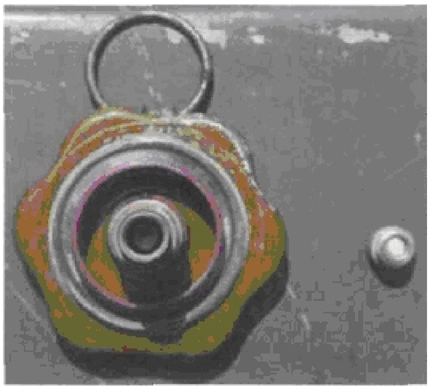

Figure 2: MVM fuze with MD-6 detonator (at the right-hand side of the figure).

The TM-46 and TMH-46 AT mines are mines of Soviet design which were in service with the former NVA (National People's Army of the former GDR). The TM-46 mine has a sheet steel case in the center of which the tetryl booster charge is located. The main charge surrounding the booster charge consists of TNT with a weight of 5.7 kg. The TMH-46 mine has an additional booster charge opposite to the carrying handle into which an antilift device can be installed. Apart from the lettering and the lid at the underside both mines are identical in appearance. The mines are equipped with the mechanical MVM fuze. The MD-6 detonator required for detonating the mine is a separate component which has to be screwed into the MVM fuze before the mine is laid. The explosives of the MD-6 detonator are listed in section 6.1.1.

Since the explosive train is in line even in the disarmed state after assembly, the safety pin with pull ring was not removed.

3.2 Demolition Charges

The demolition charges mentioned before were unsheathed charges of different high explosives. They will be described in more detail in section 5.3 in connection with the explanation of the test objective and implementation.

3.3 Ignition Charge and (Thermite) Flares

The determined compositions of the incendiary mixtures of all three test items are conventional pyrotechnic compositions. The DM29 ignition charge, fire, and the Hyper Heat Mine Flare (HMF) did not contain any toxic substance such as lead, cadmium, mercury or arsenic which might produce reaction fumes that would present a danger to the personnel and the environment. The barium contained in the incendiary mixture of the FireAnt A210 produces reaction fumes as well as combustion residues which present a danger to the environment and the personnel.

Figure 3: Comparison of the sizes of the ignition charge and (thermite) flares used

From top to bottom: DM29 ignition charge, fire, EOD, PT with igniter, electric, DM29
Hyper Heat Mine Flare with electric match
FireAnt A210

3.3.1 DM29 Ignition Charge, Fire, EOD, PT

The DM29 ignition charge is a German product. It contains the following pyrotechnic components:

• approx. 25 %	magnesium	incendiary mixture
• approx. 30 %	potassium nitrate	
• approx. 45 %	binder	

This ignition charge can be ignited both electrically by means of the DM29 electric igniter and nonelectrically by means of the DM21 safety fuze. It is the smallest of the three test items.

3.3.2 FireAnt A210

The FireAnt demining flare is a British product which contains the following pyrotechnic components:

- approx. 43 % aluminum
- approx. 50 % barium nitrate
- approx. 7 % binder

The FireAnt flare is ready for use and can be ignited only electrically. When the foil covering the electrical ignition device is opened, the flare is destroyed. The burn time of the flare is approx. 27 seconds.

3.3.3 Hyper Heat Mine Flare

The Hyper Heat Mine Flare (HMF) is a thermite demining flare of US design of the following chemical composition:

- approx. 68 % iron(III) oxide
- approx. 26 % aluminum
- approx. 6 % binder

The thermite flare is ignited by means of a provided electric match. Connecting the electric match to the thermite flare is not too difficult, although it requires some skill. According to the experience gained in the handling of this thermite flare up to now electric ignition is the only ignition method possible. Due to some misfires ignition by means of the igniter, electric, DM29 was also tested. The thermite flare was ignited without difficulty. No attempt was made to ignite the flare using the safety fuze. The burn time of the flare is approx. 45 seconds.

4 Time Schedule and Required Effort

According to the implementation program dated 27 January 2004 the processing of the task started on 01 February 2004 and is to end on 31 December 2004. The following important resources were planned to be used in order to fulfill the technical task:

- Test preparation and implementation, evaluation and reporting
- Determination of the thermal signature during the burning of the ignition charge and (thermite) flares and the mines
- Video monitoring of each test as detail shot and long shot
- Chemical-technical testing of the ignition charge and (thermite) flares and the MD-6 detonator.

Other personnel and materiel resources to be mentioned in this connection are firefighters, medical service, ammunition filling and transportation.

The burning tests were performed in the period from 10 May 2004 to 04 June 2004 (1^{st} test campaign) and from 07 September 2004 to 17 September 2004 (2^{nd} test campaign) at the WTD 91 in Meppen, Germany. In the course of the second test campaign a conference was held at the WTD 91 in Meppen with a Swedish delegation as part of the

International Test and Evaluation Program of Humanitarian Demining (ITEP) during which the current test results of the German side were presented and discussed.

5 Details of Task Execution

The following task packages had to be handled according to the task description:

- burning behavior of the ignition charge and (thermite) flares consisting of
  - ♦ Chemical-technical testing
  - ♦ Determination of the thermal signature during burning
  - ♦ Determination of penetration performance in the laminar steel or aluminum target
- Parameter optimization using the TM-46 AT mine as a target with the following configurations:
  - ♦ Parameter 1: Number of ignition charges and (thermite) flares (2 or 4 items) in an axially symmetrical arrangement
  - ♦ Parameter 2: orientation of the ignition charges and (thermite) flares with regard to the mine as
    - surface-laid or largely excavated mine
    - buried mine, minimally uncovered
- Initiation tests of experimental demolition charges using a thermite flare

For each combination of parameters 4 tests with comparable test setup were required. Parameter 1 (number of ignition charges and (thermite) flares) was supplemented in consultation with the requesting section to the effect that only one ignition charge or (thermite) flare can be used.

Demining Flare			TM-46		Demolition Charge			
Type	Arran-gement	Num-ber	Surface-laid	Buried	TNT	PETN	TR8870	Comp. B
HMF	radial	1	4	4	4	4	4	4
		2	4	4	-	-	-	-
		4	4	-	-	-	-	-
	tang.	4	6	-	-		-	-
FireAnt	radial	1	4	-	-	-	-	-
		2	4	-	-	-	-	-
		4	5	-	-	-	-	-

Table 1: Summary of the Complete Test Configurations and Number of Tests

Thus a total of 55 tests with mines and experimental demolition charges was carried out.
The demining flares had to be arranged with regard to the mines and experimental demolition charges such that the flare was lying horizontally aiming at mid-height of the main charge. In the first section of the test series the flares were pointing to the center of the mine (radial arrangement). After some mines had been detonated by this arrangement the flares were arranged tangentially in the second test series pointing at approximately the half of the radius of the mine (see **Figure 4**).
All flares were ignited electrically by their connected or provided ignition devices. The DM29 ignition charge, fire, PT, EOD, was only ignited using the igniter, electric, DM29. In more than one case the ignition devices were connected in series and connected to the firing cable. The demolition accessories used are listed in section 8.

Figure 4: Tangential arrangement of 4 HMF flares (tests 56 - 65)

5.1 Burning Behavior of the Ignition Charge and (Thermite) Flares

5.1.1 Chemical-Technical Testing (CTU)

Chemical-technical testing was aimed at analyzing qualitatively and quantitatively the explosives of the ignition charge and (thermite) flares (referred to as “flares” in the following) and the detonator of the MVM fuze of the TM-46 AT mine. In addition the ignition temperature of the MD-6 detonator was to be determined.

5.1.2 Determination of the Thermal Signature

To determine the burning behavior of the respective flare a thermal imaging camera was used for recording the thermographic history. Simultaneously photos were taken during burning to represent the burning behavior optically. For this purpose the flare was laid on a paving stone pointing diagonally upwards and the thermal imaging camera was adjusted to a position laterally oblique to the exit port of the plume. The photos were taken laterally to the flare at a distance of 7 m.

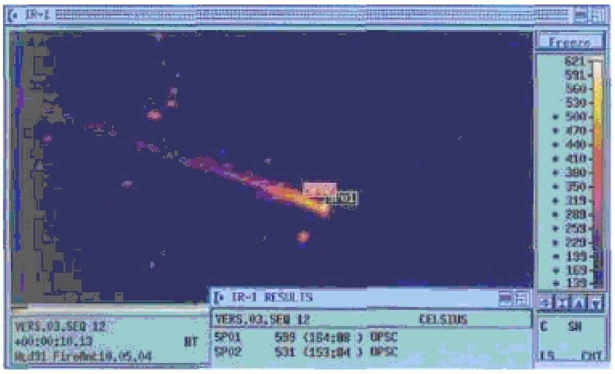

Figure 5: Thermographic photo of the burning of a FireAnt A210 flare 10 seconds after ignition

Figure 6: Typical Burning Behavior of a Thermite Hyper Heat Mine Flare

5.1.3 Determination of the Penetration Performance in the Laminar Target

These tests were aimed at determining the penetration performance of the different flares three times against a laminar sheet steel or, if required, aluminum target. Since the casing of AT mines is normally rather thin, the laminar sheet steel target was made of 1 mm thick sheet steel. The air gap between the two steel sheets was 20 mm, but was enlarged up to 100 mm in some cases. The aperture of the flares at the target side was positioned at right angles to the laminar target structure. The standoff was between 15 and 40 mm, depending on the flare used. During the tests the thermal imaging camera continued to record the temperature history.

Figure 7: FireAnt A210 Flare against a laminar sheet steel target

5.2 Parameter Optimization Using the TM-46 AT Mine as a Target

This refers to the number of flares with which a surface-laid or buried mine can be cleared (see **Table 1**). Parameter 1 determines whether the mine shall be ignited by means of 2 or 4 flares. Parameter 2 indicates whether the mine is surface-laid or largely excavated or if it is buried and only minimally uncovered.

The differences between the various parameters are illustrated by the following figures:

Figure 8: Minimally uncovered TM-46 with 2 HMF flares (tests 48, 49, 50 and 54)

Figure 9: Surface-laid TM-46 with 4 FireAnt A210 flares (tests 38 - 42)

Figure 10: Surface-laid TM-46 with 2 HMF flares (tests 26 - 29)

Figure 11: Minimally uncovered TM-46 with 1 HMF flare (tests 47, 74 – 76)

5.3 Initiation Tests of Experimental Demolition Charges by means of one Thermite Flare

These tests were aimed at demonstrating whether and to what extent different high explosives can be ignited without being detonated or deflagrated in the process. For this purpose charges with an explosive weight of 8 kg each were made up a laboratory using the high explosives PETN, TNT, TR8870 and Composition B. In this connection the following requirements had to be met:

- the height/diameter ratio must be 1:3
- the cast charges must be detonable by a centrally inserted booster charge.

The PETN (**p**enta**e**rythrite **t**etra**n**itrate) experimental demolition charges were converted from the DM12B1 demolition charge in service with the Bundeswehr. The other charges were cast, provided with a booster charge and finally turned to the correct shape and weight under safety conditions. A 50 g TNT pellet was used as the booster charge. The TR8870 charges were Torpex-like compositions consisting of TNT, RDX, aluminum and phlegmatizer in a ratio of 41:30:24:5. The charges consisting of Composition B contained the explosives TNT and RDX and a phlegmatizer in a ratio of 39.5:59.5:1.

The experimental demolition charges were always ignited by one flare only, positioned laterally to the center of the charge.

Figure 12: TNT demolition charge with one laterally positioned HMF flare (tests 51 - 53 and 55)

6 Results and Assessment

As mentioned in the beginning, no safe non-explosive mine-clearing method could be developed and proven.

6.1 Results concerning the Burning Behavior of the Ignition Charge and (Thermite) Flares

6.1.1 Chemical-technical Testing

The analyses have already been mentioned in the description of the test items.

The detonator contains the following explosives: approx. 57 mg lead trinitroresorcinate, tetrazene, barium nitrate and antinomy sulfide (composition 1), approx. 190 mg lead azide (composition 2) and approx. 110 mg tetryl (composition 3).

The ignition temperature is approx. 213 °C after approx. 9 ½ minutes.

6.1.2 Results of the Thermal Signature Measurements

The assessment of the burning of the ignition charge/flares without laminar target and mine resulted in the following average maximum temperatures:

- DM29 Ignition Charge, Fire, EOD, PT approx. 1370 °C, approx. 32 sec.
- FireAnt A210 approx. 1420 °C, approx. 27 sec.
- Hyper Heat Mine Flare: approx. 1790 °C, approx. 45 sec.

6.1.3 Results of the Penetration Performance in the Laminar Target

During the measurements to determine the thermal signature it became already clear that the DM29 ignition charge, fire, PT, EOD does not form a directional plume. It was therefore unsuitable for burning through both a single sheet and a laminar sheet steel or aluminum target. The ignition charge was therefore excluded from the subsequent mine penetration performance testing.

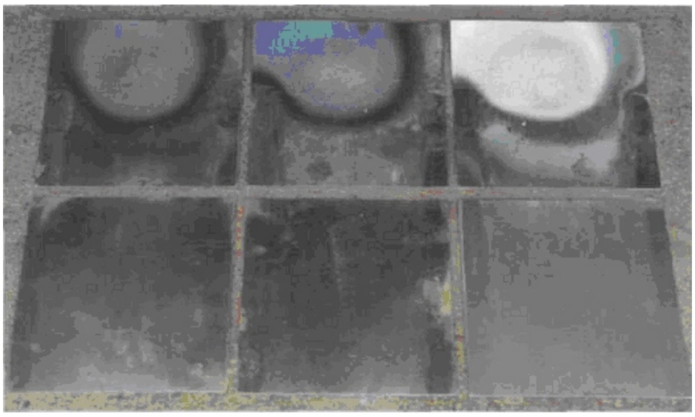

Figure 13: The three laminar target subjected to the effects of the DM29 ignition charge (tests 11 – 13)

The FireAnt A210 flare was very well capable of burning through a laminar sheet steel target. Even after the air gap between the sheets had even been enlarged up to 100 mm a hole was still created in the second sheet. Due to the thin plume, however, the holes were rather small. At a 40 mm standoff the average size of the hole in the first sheet was 20 x 25 mm. The hole in the second sheet was only insignificantly smaller.

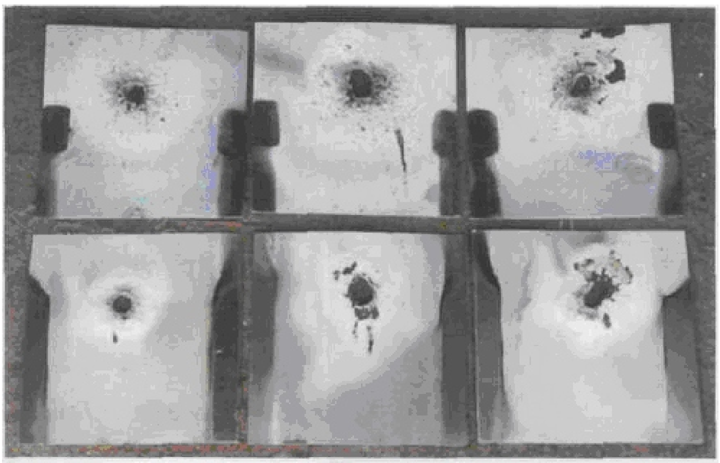

Figure 14: Sheets of the three laminar targets penetrated by the FireAnt A210. The white coating consists of aluminum (tests 14 - 16)

The Hyper Heart Mine Flare only penetrated the first sheet of the laminar steel sheet target. The hole created, however, was substantially larger than that produced by the FireAnt A210. Its average size at a 15 mm standoff was 25 x 40 mm (according to manufacturer's data).

Figure 15: Penetration performance of the HMF against three laminar targets The very thick white coating consists of aluminum oxide. The second sheet (lower row) has not been penetrated (tests 20 – 22).

6.2 Results of the Parameter Optimization Using the TM-46 AT Mine as a Target

On principle it can be said that surface-laid mines of such design can quite well be ignited by an HMF. In each of 4 tests conducted the mine completely burnt out. In addition, each of the 4 tests conducted with 4 items of FireAnt A210 placed around the mine in a star-shaped arrangement resulted in burning. With all other configurations tested, the mines detonated or deflagrated and burnt out in this process.

Figure 16: Burnt out TM-46 mine ignited by 1 HMF (test 43)

Since all tests were monitored by video both as detail shot and as long shot the burning behavior could partially be very well observed. It could be clearly recognized how the pressure plate of the mine into which the fuze was screwed raised slowly during burning. Shortly afterwards deflagration often occurred. In those cases where the burnings had been successful it turned out that the detonator in the fuze had reacted. Due to its distance to the booster charge, however, it was no longer capable of initiating this charge.

The fact that the detonator had reacted was clearly indicated by fragment penetrations of the pressure plate of the mine from the inside outwards (see **Figure 16**).

The thermographic records were primarily used for controlling whether heat is still present or unobservable burning occurs.

Buried mines are not so easily ignited. On the one hand the mines have to be excavated to such an extent that the casing is partly uncovered, on the other hand a groove must be created in which the flare can be positioned and to subsequently provide space for the burning TNT to where it can flow and expand.

These tests were exclusively conducted using the HMF as test item. Moreover, the behavior of the buried mine could not be observed in these tests. Even a thermal signature record revealed little about the reaction inside the mine.

When no visible flame and no pillar of smoke was to be seen any longer and after an additional waiting period of at least 15 min the test items and mines were inspected for the results every time after burning.

8 tests with buried mines were conducted in total; in three tests the mine burnt out and in one test it deflagrated. In the remaining 4 tests the mine detonated.

Summary of the Results in relation to the Flare Used							
HMF							
1, lateral		2, opposite		4, star-shaped		4, tangential	
Method of Laying		Method of Laying		Method of Laying		Method of Laying	
surface-laid	buried	surface-laid	buried	surface-laid	buried	surface-laid	buried
4 tests	4 tests	4 tests	4 tests	4 tests	-	6 tests, 4 usable results	-
4 x burning	3 x burning 1 x det.	3 x burning 1 x det.	1 x defl. 3 x det.	2 x burning 2 x det.	-	1 x burning 3 x det.	-
FireAnt A210							
1, lateral		2, opposite		4, star-shaped		4, tangential	
Method of Laying		Method of Laying		Method of Laying		Method of Laying	
surface-laid	buried	surface-laid	buried	surface-laid	buried	surface-laid	buried
4 tests	-	4 tests	-	5 tests, 4 usable results	-	-	-
1 x burning 3 x defl.	-	1 x burning 2 x defl. 1 x det.	-	4 x burning	-	-	-

Table 2: Summary of the Results

The following figures show the remains of burnt out and deflagrated TM-46 AT mines, each ignited by means of 2 HMF or 2 FireAnt A210.

Figure 17: Lower part of the casing of a deflagrated TM-46 AT mine (test 28), ignited by 2 HMF placed opposite to each other (see **Figure 10**)

Figure 18: Interior view of the pressure plate of the deflagrated TM-46 AT mine shown above. The detonator's detonative reaction is clearly indicated by the fragment penetrations and impacts.

Figure 19: Lower part of the casing of a burnt out and deflagrated TM-46 AT mine (test 34), ignited by 2 FireAnt A210 placed opposite to each other

Figure 20: Inside of the pressure plate of the casing shown above In this case the detonator did not react. A fuze not subjected to the impact of the flares is shown at the right-hand side of the figure for comparison.

These figures show examples of the results of buried mines.

Figure 21: TM-46 with one HMF and …

Figure 22: ... … subsequent to burning

Figure 23: The mine shown above after excavation. The fuze was unscrewed immediately after the mine had been uncovered (test 76).

Figure 24: Remains of a deflagrated mine ignited by 2 HMF. The pressure plate was propelled away taking with it the soil covering the plate (test 54).

The comparison of the holes created by the flares shows that the hole produced by the HMF is substantially larger than that caused by a FireAnt A210. The FireAnt flare creates a rather small hole in the mine casing. Four FireAnt are consumed for the complete burning without deflagration. In contrast, an HMF burns a very large hole into the mine. Ignited by an HMF the mine burns out. A dependency due to the size of the hole and the supply of thermal energy can thus be suspected. The tests using the 4 tangentially arranged HMF (see Figure 4) did not yield the result hoped for. It had been assumed in this case that the mine would burn, since the heat of the thermite flares is not directly aimed at the fuze and the booster charge. In the four tests yielding usable results three mines detonated. The results of the complete tests indicate tendencies which in the end can only be substantiated by a large number of additional tests using the same test configurations.

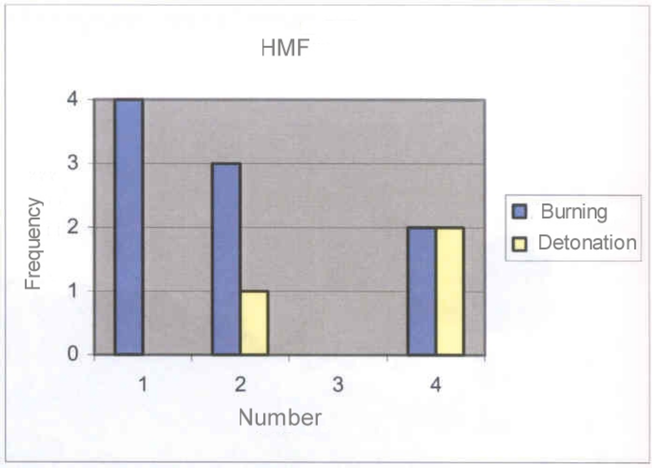

Figure 25: Tendencies found in HMF testing

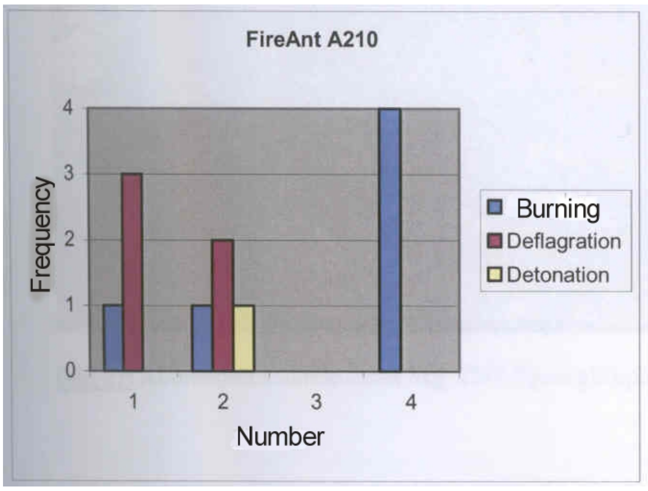

Figure 26: Tendencies found in FireAnt A210 testing

6.3 Results of the Initiation Tests of Experimental Demolition Charges Using a Thermite Flare

All experimental demolition charges burnt completely. The reaction during burning, however, were partially very violent when using the charges consisting of the TR8870 explosive, probably because of the 24 % aluminum component.

1 HMF, arranged laterally			
TNT	PETN	TR8870	Composition B
4 Tests			
4 x burning	4 x burning	4 x burning, partially very violent	4 x burning

Table 3: Results of the Burning Tests with Experimental Demolition Charges

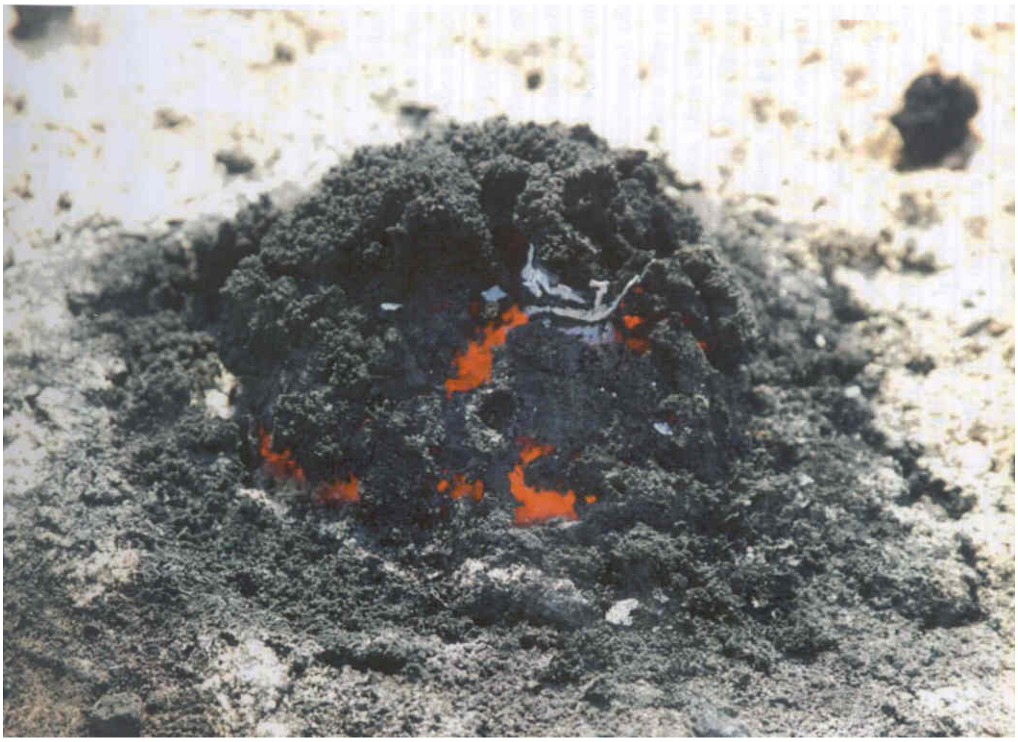

Figure 27: Combustion residues of an 8 kg TNT demolition charge (test 52), see **Figure 12**

Summary of Results (1st Campaign)									
Ser. No.	Test No.:	Date	Type of Mine	Demining Flare	Number, Position, Method of Laying	Burn Time [mm:ss]	Deflagration after [mm:ss]	Detonation after [mn:ss]	Remarks
1	26	17.05.04	TM-46	HMF	2, opposed, mine surface-laid	09:28			
2	27	18.05.04	TMH-46	HMF	2, opposed, mine surface-laid			03:24	
3	28		TM-46	HMF	2, opposed, mine surface-laid	14:15	07:34		large TNT fragments distributed
4	29		TM-46	HMF	2, opposed, mine surface-laid	13:50			
5	30	24.05.04	TM-46	HMF	4, star-shaped arrangement, surface-laid			01:16	
6	31		TM-46	HMF	4, star-shaped arrangement, surface-laid			02:15	
7	32		TM-46	HMF	4, star-shaped arrangement, surface-laid	06:50			
8	33		TMH-46	HMF	4, star-shaped arrangement, surface-laid	06:46			
9	34	25.05.04	TM-46	FireAnt	2, opposed, mine surface-laid	11:00	06:10		Fuze intact
10	35		TM-46	FireAnt	2, opposed, mine surface-laid	10:30			
11	36		TM-46	FireAnt	2, opposed, mine surface-laid			04:51	
12	37		TMH-46	FireAnt	2, opposed, mine surface-laid	09:30	06:24		Fuze intact
13	38	26.05.04	TM-46	FireAnt	4, star-shaped arrangement, surface-laid	09:30	4:56		Unusable, 2 FireAnt propelled away
14	39		TM-46	FireAnt	4, star-shaped arrangement, surface-laid	08:10			
15	40		TM-46	FireAnt	4, star-shaped arrangement, surface-laid	09:00			
16	41	27.05.04	TM-46	FireAnt	4, star-shaped arrangement, surface-laid	07:50			
17	42		TM-46	FireAnt	4, star-shaped arrangement, surface-laid	07:20			
18	43		TM-46	HMF	1, radial to the mine, mine surface-laid	16:45			
19	44	28.05.04	TM-46	HMF	1, radial to the mine, mine surface-laid	18:16			
20	45		TMH-46	HMF	1, radial to the mine, mine surface-laid	20:00			
21	46	01.06.04	TM-46	HMF	1, radial to the mine, mine surface-laid	16:15			
22	47		TM-46	HMF	1, radial to the mine, mine buried			10:20	
23	48	02.06.04	TMH-46	HMF	2, opposed, mine buried			01:59	
24	49		TMH-46	HMF	2, opposed, mine buried			03:10	
25	50		TMH-46	HMF	2, opposed, mine buried			03:08	
26	51	03.06.04	DC, 8kg, TNT	HMF	1, radial to the DC (demolition charge), DC surface-laid	09:00			
27	52		DC, 8kg, TNT	HMF	1, radial to the DC, DC surface-laid	09:40			
28	53		DC, 8kg, TNT	HMF	1, radial to the DC, DC surface-laid	09:00			
29	54		TM-46	HMF	2, opposed, mine buried	11:25	2:14		Range of ejected pressure plate approx. 22 m
30	55	04.06.04	DC, 8kg, TNT	HMF	1, radial to the DC, DC surface-laid	10:30			

Table 4: Results of the 1st Test Campaign

Summary of Results (2nd Campaign)									
Ser. No.	Test No.	Date	Type of Mine	Demining Flare	Number, Position, Method of Laying	Burn Time [mm:ss]	Deflagration after [mm:ss]	Detonation after [mm:ss]	Remarks
31	56	07.09.04	TM-46	HMF	4, tangential to the mine, mine surface-laid	05:48			
32	60	08.09.04	TM-46	HMF	4, tangential to the mine, mine surface-laid	10:00			Unusable, 1 HMF misfired
33	61		TM-46	HMF	4, tangential to the mine, mine surface-laid			00:57	
34	63		TM-46	HMF	4, tangential to the mine, mine surface-laid			01:00	
35	64		TM-46	HMF	4, tangential to the mine, mine surface-laid			10:01	Unusable, 2 HMF misfired
36	65		TM-46	HMF	4, tangential to the mine, mine surface-laid			00:54	
37	67	09.09.04	TM-46	FireAnt	1, radial to the mine, mine surface-laid	12:16	09:28		Fuze intact, TNT fragments distributed
38	68		TM-46	FireAnt	1, radial to the mine, mine surface-laid	17:00	07:36		Fuze intact
39	69		TM-46	FireAnt	1, radial to the mine, mine surface-laid	20:08	08:29		Fuze intact
40	70		TM-46	FireAnt	1, radial to the mine, mine surface-laid	15:45			
41	74	13.09.04	TM-46	HMF	1, radial to the mine, mine buried	24:10			
42	75		TM-46	HMF	1, radial to the mine, mine buried	Approx. 28:00			Flame extinction cannot be recognized
43	76		TM-46	HMF	1, radial to the mine, mine buried	23:13			
44	77	14.09.04	DC, 8kg, PETN	HMF	1, radial to the DC, DC surface-laid	08:24			
45	78		DC, 8kg. PETN	HMF	1, radial to the DC, DC surface-laid	08:02			
46	79		DC, 8kg, PETN	HMF	1, radial to the DC, DC surface-laid	08:30			
47	80	15.09.04	Dc, 8kg, PETN	HMF	1, radial to the DC, DC surface-laid	05:16			
48	81		DC, 8kg, TR8870	HMF	1, radial to the DC, DC surface-laid	02:45			very violent burn
49	82		DC, 8kg, TR8870	HMF	1, radial to the DC, DC surface-laid	06:45			very violent burn
50	83		DC, 8kg, TR8870	HMF	1, radial to the DC, DC surface-laid	06:25			very violent burn
51	84	16.09.04	DC, 8kg, TR8870	HMF	1, radial to the DC, DC surface-laid	03:20			very violent burn
52	85		DC, 8kg, Comp B	HMF	1, radial to the DC, DC surface-laid	07:26			
53	86		DC, 8kg, Comp B	HMF	1, radial to the DC, DC surface-laid	07:21			
54	87		SK, 8kg, Comp B	HMF	1, radial to the DC, DC surface-laid	07:17			
55	88	17.09.04	Dc, 8kg, Comp B	HMF	1, radial to the DC, DC surface-laid	07:44			

Table 5: Results of the 2nd Test Campaign

The values listed in Table 4 and Table 5 are results from the tests with mines and demolition charges. The tests for determining thermal signature and penetration performance including those conducted during the mine tests are not included in these two tables. This is why the test numbers are not always sequential.

7 Further Results and Findings

DM29 Ignition Charge, Fire

According to reports and talks AT mines have successfully been ignited by this ignition charge. For this purpose two ignition charges had been placed on the edge of the mine. This test configuration has not been considered for these tests since the user contacts the mine in placing the ignition charge.

FireAntA210

According to the current state of knowledge the FireAnt A210 demining flare is no longer produced. Thus it can be excluded from further investigations in possible later tests.

Hyper Heat Mine Flare

The rather demanding handling required when inserting the electric match was already mentioned in section 3.3.3. In the course of the first test campaign the ignition malfunctioned once (= 2), whereas in the second campaign it malfunctioned eight times in total (= 20%). Due to the high misfire rate in the second test campaign the electric match was measured electrically. The results of the measurement of 10 electric matches were as follows:

Resistance:	2.0 Ohm ± 2.5%
No-Fire-Limit:	0.2 A
All-Fire-Limit:	0.5 A
Type classification:	Bridge wire fuze, type A, sensitive
Evaluation/Remark:	The misfires which occurred are probably due to the high initiating energy of the blasting machine. The burning was completed within such extremely short time that the reaction of the subsequent igniter train could not take place.