MASTER

FORMULATION AND PROCESS SAFETY

G. T. West

DEVELOPMENT DIVISION

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ABSTRACT

Five explosives (HMX, TATB, TCTNB, PETN, and Composition B-3) were subjected to shock tests with a booster system. The explosives were tested dry (except CB-3 and PETN) and wet with typical synthesis/formulation solvents in typical synthesis/formulation concentrations. The four materials tested dry all detonated in 4.4 cm inside diameter by 25.4 cm Plexiglas tubes with 0.635 cm walls. HMX was tested at 90%, 67% and 25% (tested at 10.2 cm diameter by 50.8 cm length) concentrations in water, with detonation observed at only the higher two concentrations. TATB was tested wet with water at 70% concentration in both 4.4 and 10.2 cm diameter and failed to detonate in both cases. When tested with toluene at the 75% level it also failed to detonate. TCTNB detonated at 79% concentration with water, but did not detonate with toluene and water at the 15% level. PETN, tested at the 15 and 20% levels in acetone and the 20% level with water, failed to detonate. The CB-3 test, at 40% with Freon TF, detonated.

Results of burn tests involving TATB, TCTNB, PETN, HNS and TNT dry and with typical synthesis/formulation solvents and concentrations are included. Generally, those burns involving solvents initially resembled a "normal" organic-fuel fire and eventually the explosive burned. The "dry" burns resembled the later stage of the above fires. There were no explosions.

DISCUSSION

SHOCK TESTS

A slightly modified version of a previously reported⁽¹⁾ technique was used to determine whether certain explosives and/or explosive/solvent systems would support shock-stimulated detonation under simulated synthesis/formulation conditions. The modifications included the booster (30 g Comp. B-3 instead of 33 g tetryl), and the use of a scaled-up test vehicle (twice the diameter and twice the length). This latter modification was used only when it was suspected that diameter of the smaller vehicle was approaching the critical diameter for the materials tested.

A summary of the test conditions and resulting data is shown in Table I. There was no difficulty in deciding whether a given test resulted in a detonation. Reduction of data obtained from framing camera coverage typically showed detonation velocities of 5500 metres/second or higher, while the "non-detonating" tests showed velocities of less than 3000 metres/second. A qualitative determination was also made by observing the behavior of the plexiglas cylinder as it expanded. The detonations all resulted in significant fracture of the plexiglas with relatively

(1) Darrell Kite, Jr., Safety Hazard Classification of Water-Wet Explosives, Technical Report 3223, Picatinny Arsenal, Dover, NJ, 1975

Table I. Shock Test Results

High Explosive	Condition	Wetting Agent	Approximate	Qualitative Result (Go or No-Go)	Observed Shock Velocity (m/sec)	Test Vehicle Inside Diameter (cm)
			Weight Percent HE			
Class B HMX	D		100	GO	6800	4.4
Class B HMX	W	Water	90	GO	8100	4.4
LX-04 Grade HMX	W	Water	93	GO	7100	4.4
LX-04 Grade HMX	W	Water	67	GO	7200	4.4
LX-04 Grade HMX	W*	Water	25	NO-GO	<2000	10.2
TATB	D		100	GO	7900	4.4
TATB	W	Water	70	NO-GO	2700	4.4
TATB	W	Water	70	NO-GO	<2000	10.2
TATB	W	Toluene	75	NO-GO	<2000	4.4
TCTNB	D		100	GO	8400	4.4
TCTNB	W	Water	79	GO	>10,000	4.4
TCTNB	S	Toluene	14	NO-GO	2100	4.4
TCTNB	W*	Water	15	NO-GO	<2000	10.2
PETN	S	Acetone	20	NO-GO	<2000	4.4
PETN	S	Acetone	15	NO-GO	<2000	4.4
PETN	W*	Water	20	NO-GO	<2000	10.2
CB-3	W*	Freon TF	40**	GO	5500	10.2

D = Dry

W = Wet

S = Solution

*Stirred by electrically-driven polyethylene 3-bladed 3.8 cm diameter impeller on a 40 cm shaft at 18.3 rps.

**Evaporation of Freon TF occurred at significant level (approximately 50%) before shot was fired.

rapid expansion, while the non-detonations showed rather smooth surfaces with relatively slower expansion. Figs. 1 and 2 show typical detonations and typical non-detonations, respectively.

BURN TESTS

Three types of tests were used to study the behavior of certain explosives and/or explosive/solvent systems when exposed to fires that might occur in synthesis/formulation operations.

Test Type A consisted of an explosive/solvent system in an open-top metal can 30.5 cm diameter and 1.9 cm deep. The mixture or solution was ignited by a wick at its surface. The total volume tested was slightly less than 1.5 litres. Visual and framing camera observations were made.

Test Type B consisted of a dry explosive powder in an open-top metal can 15 cm diameter and 17 cm deep. The can was exposed 1 metre above a 19 litre toluene fire. The nominal amount of explosive tested was 1.4 kg.

Only one test of Type C was done. This was a "scaled-up" version of test Type A. A larger (33 cm diameter by 40 cm deep) can containing a 20/80% (by weight) solution of PETN/acetone was ignited by a wick at its surface and observed visually and by framing camera.

The major goal of these tests was to determine if an explosion occurred as a result of the fire.

Table II summarizes conditions of the seven Type A tests. In each case, there were no explosions.

Table II. Type A Burn Tests

<u>Explosive</u>	<u>Solvent</u>	<u>Nominal HE Weight Percent</u>	<u>Residue Description</u>
PETN	Acetone	20	Thin Black Solid
TCTNB	Toluene	12	Thin White Solid
HNS-I	Acetone	24	Thick Carbonaceous Solid
HNS-I	Dimethylformamide	35	Thin Black Solid
HNS-I	Dimethylformamide	5	Thin Black Solid
TNT	Methanol/Tetrahydro- furan	7	Thin Black Solid
HNS Reaction Mixture		~ 2	Brown Liquid

Fig. 1. Typical Detonation as Observed by Framing Camera
(Dry TCTNB on the Left, Dry TATB on the Right)

Fig. 2. Typical Non-Detonation as Observed by Framing
Camera (14% TCTNB/Toluene on the Left, 75% TATB/
Toluene on the Right)

In every case except the last, a "normal" organic fuel fire followed by a "typical" HE fire was observed. The fuel fire lasted 2 to 5 minutes, dependent upon the amount of fuel present. The HE fire lasted 1 to 5 minutes, dependent upon the amount of material present. There were no explosions.

The last test described in Table II resulted in what appeared to be a normal organic fuel fire lasting about 9 minutes. There was no explosion and no HE fire was observed. The liquid remaining in the pan visually resembled the original liquid.

Framing camera coverage and visual observation constituted the sole instrumentation.

Type B burn test conditions are summarized in Table III. There were no explosions observed. Typically, the toluene fire burned about 6 minutes.

Table III. Type B Burn Tests

<u>Explosive</u>	<u>Nominal HE Weight (kg)</u>	<u>Residue Description</u>
TATB	1.4	Thick Carbonaceous Solid
TCTNB	1.4	Thin Black Solid
HNS-I	0.6	Thin Black Solid
PETN	1.1	Thin Black Solid

During the TATB burn, chromel-alumel thermocouples were placed near the can (in the toluene flame) and inside the can near the bottom. Fig. 3 is a plot of the temperatures observed. The flame observed at the top of the can was a very thin orange flame, compared to the more "solid" yellow-orange flames typical of most HE fires. A thick carbonaceous residue was found in the can after the burn.

Only the inside thermocouple was used during the TCTNB burn, and a plot of the observed temperatures is shown in Fig. 4. Very little flame was observed above the can, but a thick grayish-brown smoke, which smelled like UDT persisted for about two minutes. No residue was found in the can.

The PETN burn was more violent than the two above. The thermocouple in the can failed 90 seconds into the burn at a temperature of 1250 C. The flame was more dense and typical of previously-observed HE fires. There was no residue after the burn.

HNS burned the most violently, resembling cone-shaped "fountain" fireworks. The dense orange flame spewed sparks as far as 50 cm above the top of the can. There was a fine black residue found in the can.

The can was not damaged and no explosions were detected at any time during these four tests.

Fig. 3. Flame and HE Temperatures Observed During TATB Burn Type B

Fig. 4. HE Temperatures Observed During TCTNB Burn Type B

Test Type C was done because there was some speculation as to what might occur with more PETN present. The total weight of PETN was 2.7 kg. A "normal" acetone fire was observed for 1 hour and 25 minutes. At that time, a "typical" PETN fire began which ended 2 minutes later. While this burn seemed more violent than that observed in burn Type A, there was no damage to the container except for paint peeling and a slight warping. There were no explosions. A thin yellow and black coating was found inside the container.

CONCLUSIONS

Detonation tests of dry HMX, dry TATB and dry TCTNB showed that these materials will detonate as tested. The "wet" materials tested, with the exception of TATB mixtures, detonated with HE weights at and above 67%. TATB mixtures with water (70% TATB) failed in both diameters, and 75% TATB/toluene failed; 40% Comp. B/Freon TF also detonated, but at least half the Freon TF had evaporated. All mixtures and solutions with explosive concentrations of 25% or less failed to detonate in these tests.

No explosions were observed in any of the burn tests. While HE fires resulted and are themselves quite dangerous and unpredictable, the greatest danger to personnel in synthesis/formulation is posed by the solvents and their associated fire hazards.