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DEVELOPMENT OF A HIGH-ENERGY FLEXIBLE SHEET EXPLOSIVE

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Prepared for:

Picatinny Arsenal

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A non-proprietary flexible sheet explosive having high power and brisance was developed through replacement of a major portion of the inert plasticizer used in the Picatinny Arsenal-developed non-proprietary replacement for DuPont's El 506C, Type II (Refs. 2, 3 and 4) with an energetic liquid nitric ester.

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ABSTRACT

A non-proprietary flexible sheet explosive having high explosive power and brisance was developed through replacement of a major portion of the inert plasticizer used in the Picatinny Arsenal-developed non-proprietary replacement for DuPont's EL 506C, Type II (Refs. 2, 3 and 4) with an energetic liquid nitric ester.

OBJECTIVE

To develop a more energetic non-proprietary flexible sheet explosive useful in various applications and which, for demolition purposes, is at least 20% more powerful than the Picatinny Arsenal-developed non-proprietary RDX and/or HMX-based flexible sheet explosives (Refs. 2, 3, and 4) or DuPont's PETN-based flexible sheet explosive EL 506C, Type II (Ref. 1).

INTRODUCTION

A study of the explosive characteristics of available domestic flexible sheet explosives, as revealed in Refs. 1 and 2, indicates clearly the desirability of developing more powerful flexible explosive compositions for heavy demolition purposes, especially where required for field application.

The obvious means of improving explosive power would be to increase the active material content with accompanying reduction of the amount of inert or non-explosive material present. As the work reported in Refs. 2,3, and 4 has shown, increasing the particulate high explosive above 76% results in a product which is too stiff for ready processing. Therefore, the application of energetic plasticizers to replace the inactive material was used as a basis for this investigation. Many liquid nitric esters could be used for this purpose, but in general, those which are most suitable because of their ability to colloid the nitrocellulose binder are also shock and friction sensitive. Hence, trimethylolethane trinitrate (TMETN) was selected as the principal active plasticizer for investigation. TMETN does not readily colloid nitrocellulose, but this was easily overcome by dissolving TMETN and nitrocellulose in solvents such as ethyl acetate (EtOAc), butyl acetate (BuOAc), or acetone (Me_2CO) and evaporating the solvent leaving a residue of nitrocellulose perfectly colloided with TMETN. However, such a TMETN-nitrocellulose colloid was found to be very stiff making processing difficult or impossible. The presence of a small portion of the inert plasticizer Citroflex A4 (tributylacetyl citrate) was found to alleviate this situation sufficiently and permitted roll-milling of the product.

In essence, the work reported here, which led to issuance of U.S. Patent 3,400,025 deals with the development of a powerful, non-proprietary sheet explosive comprising a fine particulate explosive such as RDX, HMX, PETN or mixtures of these, a binder system comprised of a dynamite grade nitrocellulose with a mixed plasticizer containing a nitric ester such as TMETN and a small portion of an organic ester having a low freezing point such as Citroflex A4, an olive drab pigment, and a stabilizer such as diphenylamine (DPA) and/or ethyl centralite (EC).

MATERIALS

The RDX, HMX, PETN, Citroflex A4, and nitrocellulose were the same lots utilized in the development of a non-proprietary flexible sheet explosive. (Ref 2)

A. Trimethylolethane Trinitrate (TMETN)

The three lots of TMETN utilized in this work were identified as follows:

1. duP P.O. A02-01359, DuPont Corp.
2. Lot No. CH-30, Trojan Powder Co.
3. Lot No. DC-26, Trojan Powder Co.

These TMETN's were partially characterized by the following test results:

Identification	duP	CH-30	DC-26
1. Vacuum Stability (mls of gas evolved)			
90°C	-	1.40	1.01
100°C	7.52	6.11	5.92
2. Explosion Temperature (°C)	-	233	233

B. Trimethylolpropane Trinitrate (TMPTN)

The TMPTN used in the work reported was prepared by the nitration of trimethylolpropane under the direction of Mr. V. Siele. A portion of this material was doubly recrystallized and is referred to as TMPTN(R).

Tests of TMPTN

TMPTN Designation	TMPTN	TMPTN(R)
1. Vacuum Stability (ml. gas evolved)		
90°C	0.56	0.49
100°C	5.76	6.58
2. Crystal density (g/cc).	1.51	-
3. P.A. Impact Test (inches)	17	-
4. Explosion Temperature Test (°C.)	240	-
5. Picatinny Arsenal Friction Pendulum	N.A.	-
6. Ballistic Mortar Test (TNT = 1)	1.25	-
7. Nitrogen content (%)	15.55	-
8. Melting point (°C.)	61	-

Like TMETN, TMPTN did not colloid nitrocellulose readily, necessitating the formation of a colloid by the common solvent and evaporation technique. As long as the temperature of the composition containing nitrocellulose colloided with TMPTN remained above the freezing point of TMPTN, (ca. 61°C) the material remained flexible and rubbery, but when the temperature fell below that point, TMPTN began to crystallize out, and the colloided material hardened with a distinct lightening of color. This was found to be the case even when TMPTN was largely diluted with TMETN showing the utility of TMPTN to be extremely limited.

C. Triethyleneglycoldinitrate (TEGDN)

The TEGDN used in this work was obtained from stock and bore only the designation, trimethylene glycol dinitrate (TEGDN). Characterization tests were not required for this investigation.

D. Diethyleneglycoldinitrate (DEGDN)

The DEGDN used in this work was obtained from stock and bore only the designation, DEGN duP. stabilized. Characterization tests were not required for this investigation.

EXPERIMENTAL TESTS AND RESULTS

Testing of explosives was divided into two categories:

A. Specification Tests.

1. Bullet Impact Ref 9, par. 4.3.7.
2. Density Ref 9, par 4.3.10
3. Cold Temperature (-40°F) Ref 9, par 4.3. 12
4. Rate of Detonation Ref 9, par 4.3. 13
5. Vacuum Stability Ref 9, Ref 10.

B. Non-Specification Tests

1. P.A. Impact Test Ref 10, pg 2-4
2. Explosion Temperature Ref 10, pg 7-8.
3. Friction Pendulum Ref 12
4. Ballistic Mortar Test Ref 11
5. Cap Sensitivity Ref 2.
6. Detonation Continuity in Air Ref 2.
7. Plate Damage Ref 2.

A. Specification Tests

1. Bullet Impact

Composition No.	44	Spec.
	No fire or explosion	No explosion

2. Density (g/cc.)

Composition No.	14	17	34	35	
Density	1.470	1.3878	1.5386	1.5056	
TMD	1.5110	1.4321	1.6299	1.5490	
% TMD	97.29	96.91	94.40	97.20	
Composition No.	37	41	42	44	44*
Density	1.5697	1.6036	1.5356	1.6206	1.6108
TMD	1.6520	1.6761	1.6106	1.6313	1.6313
% TMD	95.02	95.67	95.28	99.35	98.75

*Extruded blocks

3. Cold Temperature (-40°F)

Since all specimens failed at -40°F, the test temperature was raised to -20°F and again all specimens failed. The temperature was elevated to 0°F at which point all specimens met the requirements. The test was conducted at -10°F and again all failed. At -5°F specimens from composition 13 passed while those from compositions 46 and 47 did not.

4. Rate of Detonation (m/sec)

Composition No. *	14	32	34	35
Density	1.470	-	1.539	1.506
Rate of Detonation	7008	7515	7441	7186

4. <u>Rate of Detonation m/sec)</u> (Cont'd)

Composition No. **	37	41	42
Density	1.570	1.604	-
Rate of Detonation	7407	7582	7274

* Specimen cross-section 1/4 x 1/4 inch.
** Specimen cross-section 1/4 x 1 inch.

5. <u>Vacuum Stability</u> (ml. gas evolved)

Composition No.	11	A1	A2	A3	A4	A5
100°C	1.07	1.02	1.31	1.49	1.78	1.71
110°C (24 hrs)	5.95	4.51	5.25	6.43	6.88*	6.13*

Composition No.	B1	B2	B3	B4	B5
100°C	1.59	1.89	1.70	2.14	2.56
110°C (24 hrs)	6.06	5.98	6.18	6.32*	6.10*

Composition No.	C1	C2	C3	C4	C5
100°C	1.68	1.88	1.78	2.63	2.52
110°C (24 hrs)	5.36	5.05	5.57	5.46	5.59

* Test was conducted for 20 hours.

Composition No.	1	6	10	33
100°C	2.73	2.86	1.74	2.29
110°C (8 hrs)	1.95	1.86	-	-

Composition No.	34	37	41	42
90°C	0.62	0.24	0.24	0.33
100°C	1.09	1.33	1.26	1.55

B. Non-Specification Tests

1. P.A. Impact (inches)

Composition No.	32	34	37	41	42
	10	16	13	11	9

2. Explosion Temperature (°C)

Composition No.	32	34	37	41	42
Smoke	262	258	246	262	-
Flame	520	-	-	-	235

3. Friction Pendulum (steel shce)

Composition No.	34
	N.A.

4. Ballistic Mortar Test (TNT = 1.00)

Composition No.	32	34
	1.245	1.23

5. Cap Sensitivity

Composition No.	33	37	38	41	42
	#6	#8	#8	M6	#5

6. Detonation Continuity in Air

Composition No.	44
	M6

7. Plate Damage

Composition 44 designated as FXRNC-2 where the number 2 indicates 20% TMETN was utilized in this test. Three by ten inch sheets of flexible explosive were detonated on steel witness plates using M6 blasting caps. The test results may best be judged by reference to figures 1-16. The advantage of the presence of

TMETN in compositions containing 63% particulate high explosive filler (PETN in the proprietary material and RDX in both FXRNC-1 and FRXNC-2) is clearly illustrated.

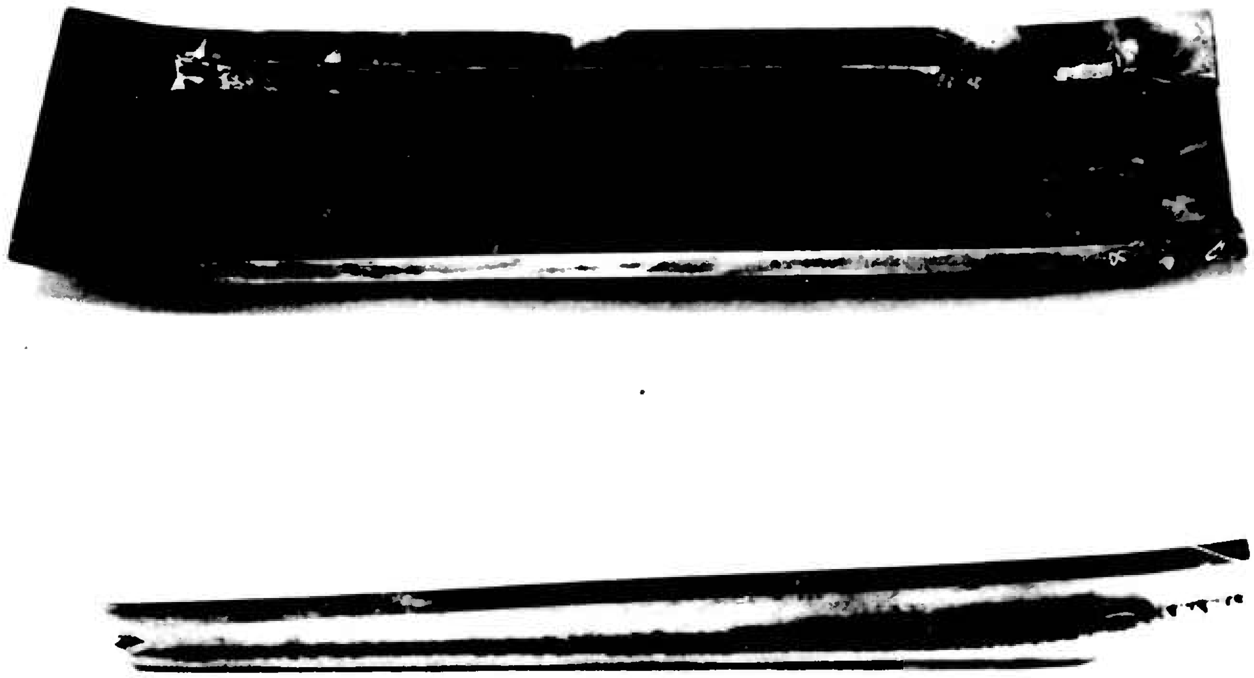

Figure 1

Picatinny Sheet Explosive FXRNC-2 0.08-Inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 2

Picatinny Sheet Explosive FXRNC-2 0.16-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 3

Picatinny Sheet Explosive FXRNC-2 0.25-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

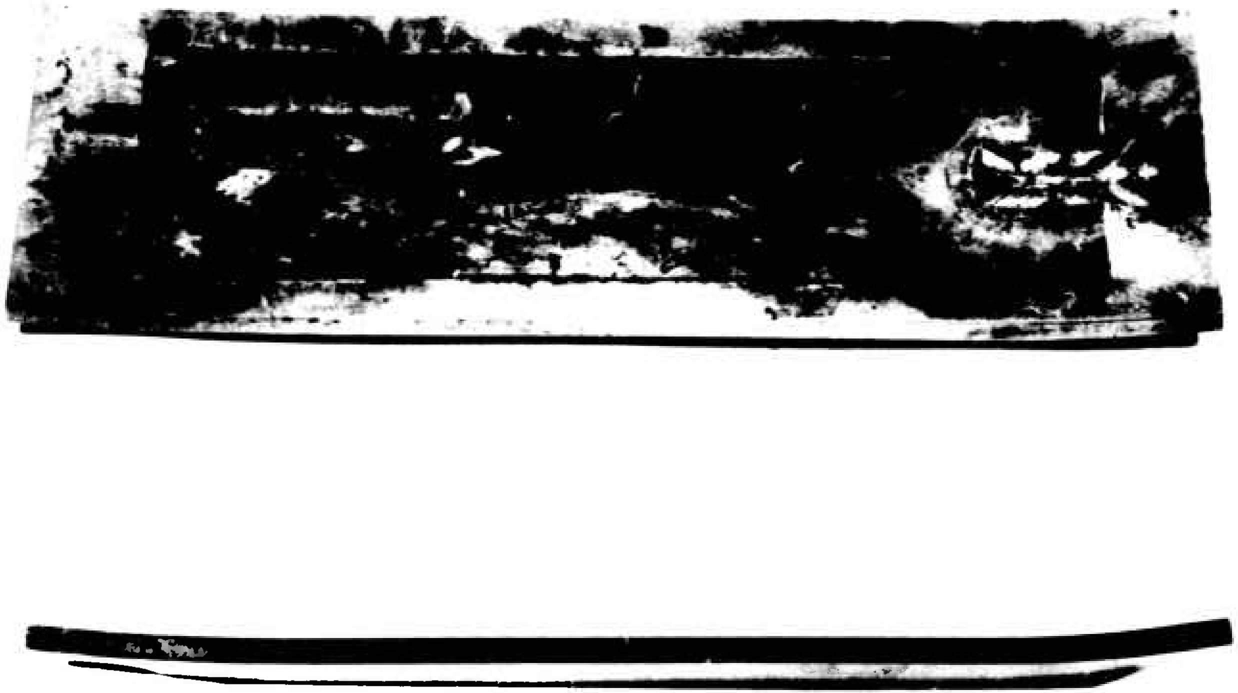

Figure 4

Proprietary Sheet Explosive 0.08-inch Thick
Fired on 1/[illegible]-inch Thick Mild Steel Plate

Figure 5

Proprietary Sheet Explosive 0.16-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 6

Proprietary Sheet Explosive 0.25-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 7

Picatinny Sheet Explosive FXRNC-1 0.08-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 8

Picatinny Sheet Explosive FXRNC-1 0.16-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 9

Picatinny Sheet Explosive FXRNC-1 0.25-inch Thick
Fired on 1/4-inch Thick Mild Steel Plate

Figure 10

Picatinny Sheet Explosive FXRNC-2 0.08-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

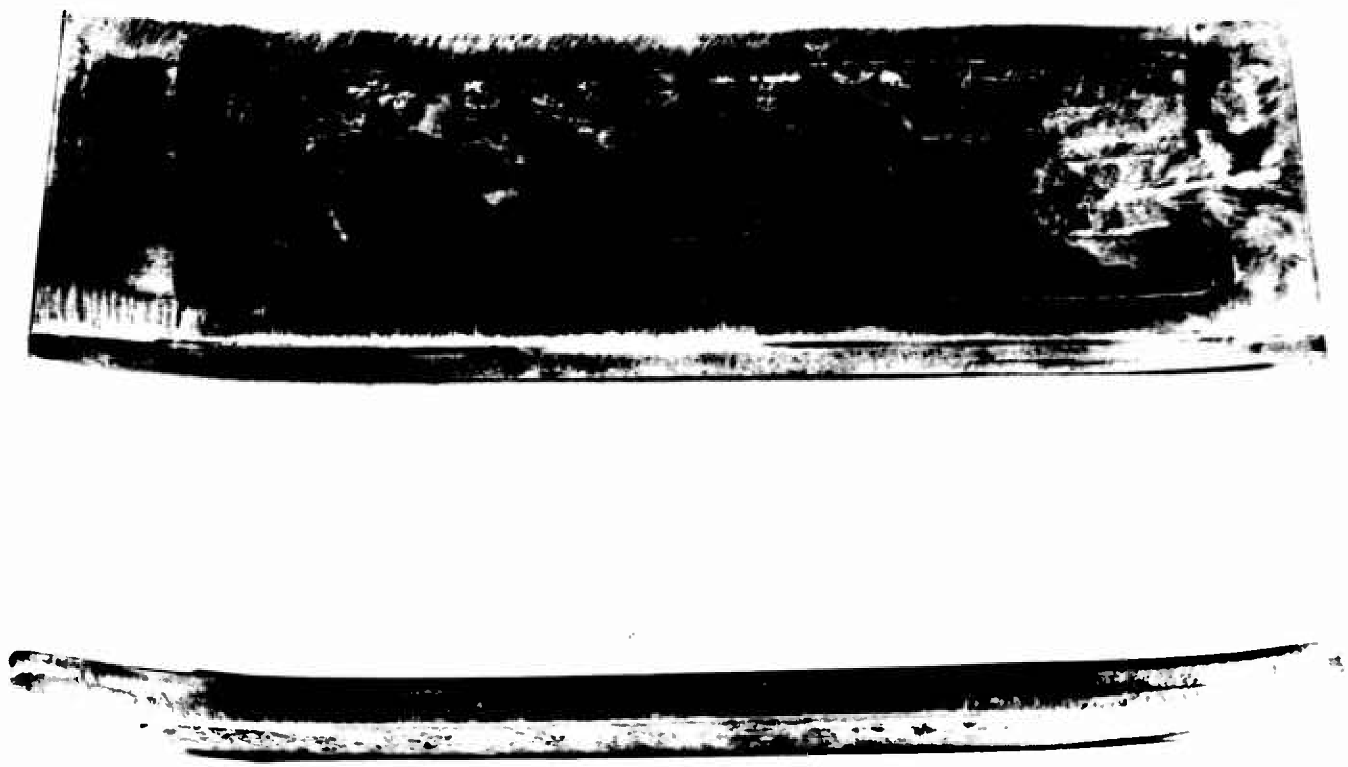

Figure 11

Picatinny Sheet Explosive FXRNC-2 0.16-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

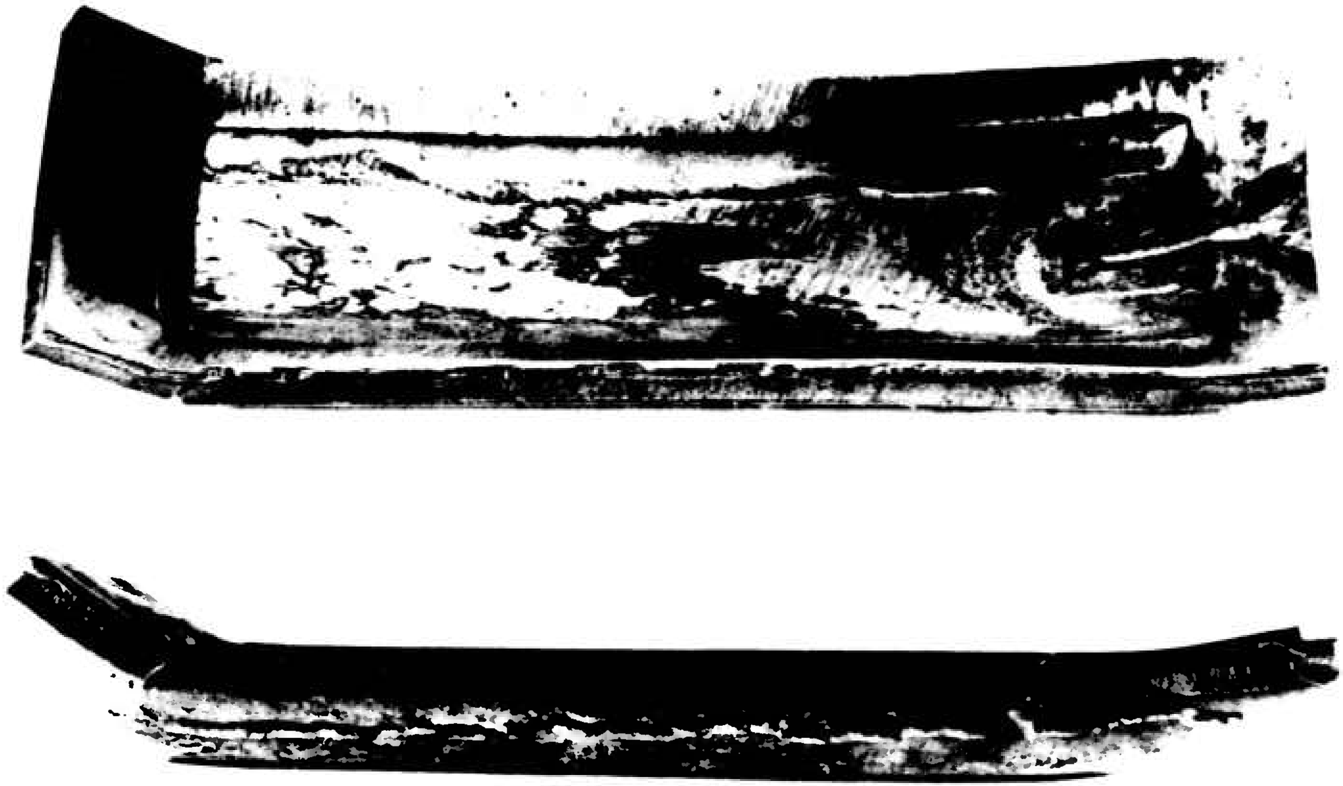

Figure 12

Picatinny Sheet Explosive FXRNC-2 0.25-Inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

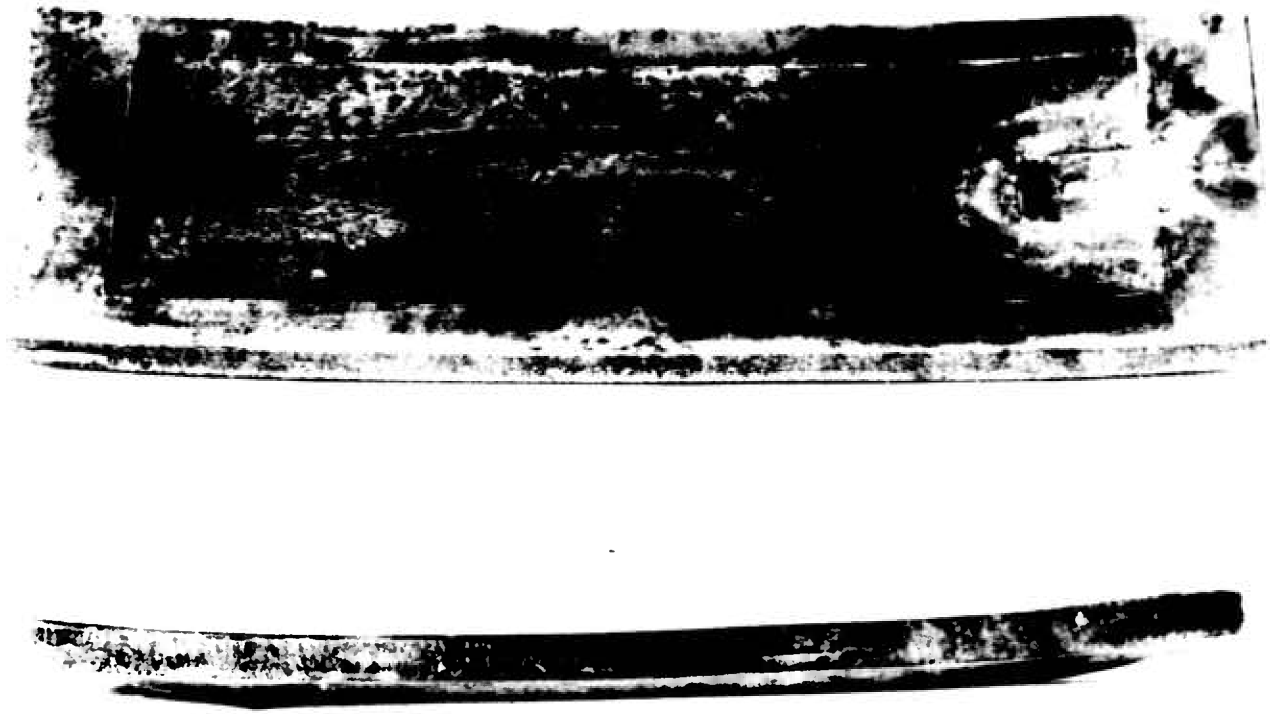

Figure 13

Proprietary Sheet Explosive 0.16-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

Figure 14

Proprietary Sheet Explosive 0.25-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

Figure 15

Picatinny Sheet Explosive FXRNC-1 0.16-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

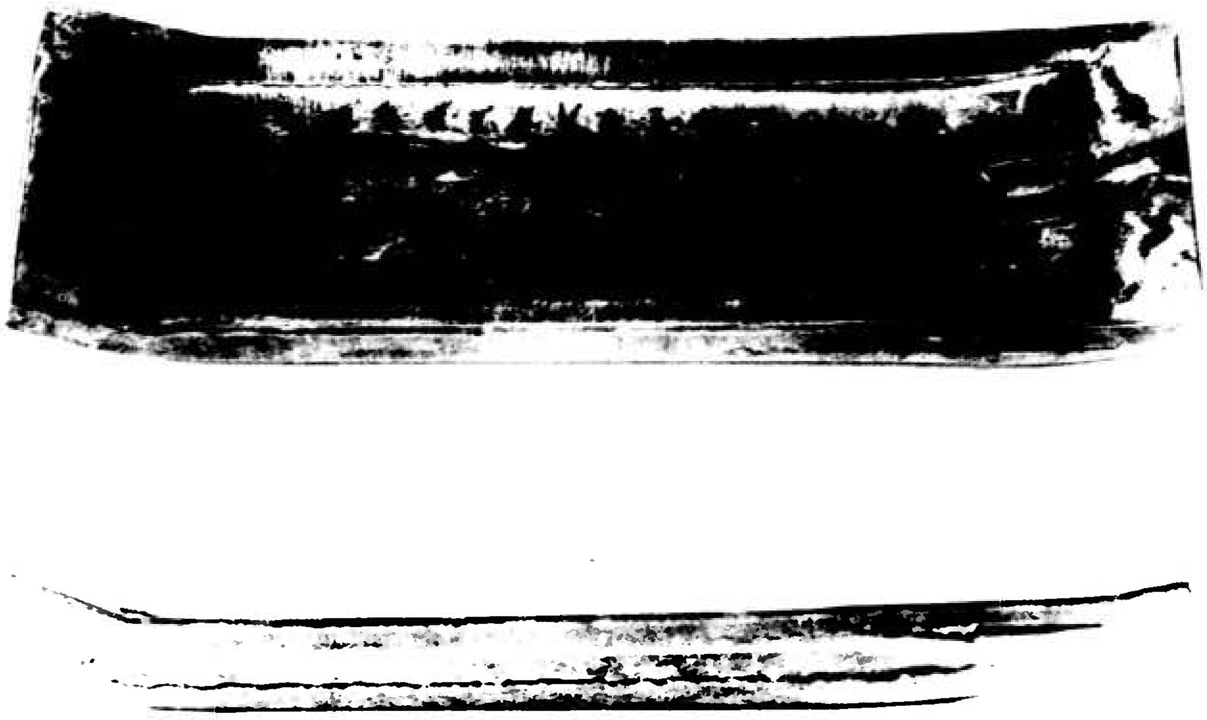

Figure 16

Picatinny Sheet Explosive FXRNC-1 0.25-inch Thick
Fired on 1/2-inch Thick Mild Steel Plate

CONCLUSIONS

The general conclusions that can be drawn from this investigation are:

1) The test results, if plate damage is considered a criteria of demolition effectiveness, show conclusively that the compositions reported herein are superior to both the proprietary sheet explosive and the Picatinny-developed replacement. The results described in this report indicate clearly the advantage, in explosive effect, to be gained by substituting about seventy percent of the inactive plasticizer (Citroflex A4) with the active plasticizer, TMETN.

2) From the limited results obtained with TMPTN, it can be concluded that TMPTN offers little prospect as an active plasticizer for nitrocellulose in compositions of this type.

3) Vacuum stability tests indicate that only DPA at concentration levels of 0.4 to 1.5 percent have an effect on the composition stability.

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11. J.H. McIvor, Ballistic Mortar Test, Picatinny Arsenal Testing Manual 7-2, 8 May 1950.

12. J.H. McIvor, Friction Pendulum, Picatinny Arsenal Testing Manual 7-1, 8 May 1950.

APPENDIX

Experimental Formulations

Composition Nos. 1, 6, 10

	1	6	10
RDX 545-62	31.5 gms.	31.5	31.5
Nitrocellulose (HNC 1534)	4.0	4.0 (HNC 923)	4.0
Citroflex A4	2.1	3.1	4.1
TMETN (duP)	12.0	11.0 (CH-30)	10.0
Pigment	0.4	0.4	0.4
Ethanol	25 ml.	25 ml.	25 ml.

Composition No. 1 was pasty with many small gelatinous lumps throughout. It formed thin sheets but crumbled when consoliaated into 1/4 inch thick sheets.

Composition No. 6 yielded good rubbery sheets but were not perfectly smooth.

Composition No. 10 gave good tough rubbery sheets with smooth surfaces.

Composition No. 11

Same as composition No. 6 except that different lots of nitrocellulose (HNC 923) and TMETN (CH-30) were utilized.

Composition Nos. 11A, 11B, and 11C

In the following three groups of compositions, the effects of stabilizers DPA, EC and mixtures of the two are determined. DPA was added as a 2% ethonal solution and the EC as a 5% ethanol solution. In all cases, including composition No. 11 the control, additional ethanol was added to maintain the level at 50 mls. of ethanol in each batch.

Series A	1	2	3	4	5
% DPA added	0.2	0.35	0.5	0.75	1.0

Series B	1	2	3	4	5
% EC added	0.2	0.35	0.5	0.75	1.0

Series C	1	2	3	4	5
% DPA	0.1	0.2	0.3	0.4	0.95
% EC	0.1	0.2	0.3	0.4	0.05

Composition Nos. 13, 14, 17

	13	14	15
RDX 545-62	31.5 gms.	31.5	21.5
Nitrocellulose (HNC 947)	4.0	4.0	4.0
Citroflex A4	4.1	13.1	4.1
TMETN (CH-30)	10.0	1.0	20.0
Pigment	0.4	0.4	0.4
DPA	0.2	0.2	0.2

In composition Nos. 13 & 17, 15 mls. of ethyl acetate was utilized while in composition 14, 15 mls. ethanol was used.

Composition Nos. 28, 29, 30, 31

	28	29	30	31
RDX 3-57	31.5 gms.	20.7	-	-
Nitrocellulose (HNC 1534)	4.0	4.0	5.9	5.0
TEDGN	4.1	2.0	3.0	-
DEDGN	-	-	-	5.0
TMETN (duP)	10.0	23.0	40.8	39.7
Pigment	0.4	0.3	0.3	0.3
Ethanol	20 mls	20 mls	20 mls	30 mls

All four compositions were hard or crumbly mixes when first prepared, but upon addition of acetone all formed pastes. After aging, the compositions were rolled into rubbery sheets with somewhat uneven surfaces.

Composition Nos. 32, 33, 34, 35

	32-33	34	35
RDX 545-62	63.0%	63.0	63.0
Nitrocellulose	8.0[1]	8.0[2]	8.0[2]
Citroflex A4	6.2	8.2	20.2
TMETN (CH-30)	22.0	20.0	8.0
Pigment	0.8	0.8	0.8
DPA	-	0.3	0.4
ETOAC	100 ml	100 ml	100 ml

1) Nitrocellulose lot HNC 923
2) Nitrocellulose lot HNC 947

Composition Nos. 37-38

	37	38
HMX 655-61	29.6%	63.0
RDX 545-62	33.4	-
Nitrocellulose	8.0[1]	8.0[2]
Citroflex A4	8.2	6.2
TMETN	20.0[3]	22.0[4]
Pigment	0.8	0.8
DPA	0.4	0.25

1) Nitrocellulose lot HNC 983B
2) Nitrocellulose lot HNC 923
3) TMETN lot DC-26
4) TMETN lot CH-30

Composition Nos. 41-42

	41	42
HMX 655-61	63.0%	-
PETN	-	63.0
Nitrocellulose (HNC 983B)	8.0	8.0
Citroflex A4	8.2	8.2
TMETN (DC-26)	20.0	20.0
Pigment	0.8	0.8
DPA	0.4	0.4
ETOAC	150 ml	150 ml

Composition Nos. 44, 46, 47

	44	46	47
RDX 545-62	63%	63.0	63.0
Nitrocellulose (HNC 947)	8.0	8.0	8.0
TMETN	20.0	10.0	19.0
TMPTN	-	-	1.0
Citroflex A4	8.2	10.0	-
Pigment	0.8	0.8	0.8