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*II Secondary Explosive
Time Plate Detonators*



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All-Secondary Explosive Flying-Plate Detonators

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ALL-SECONDARY EXPLOSIVE FLYING-PLATE DETONATORS

by

Robert H. Dinegar

ABSTRACT

PETN and HMX explosives can be ignited by a hot wire. When deflagrated under confinement, they generate gas pressures sufficient to rupture thin aluminum disks. These flying plates reach a velocity high enough to initiate secondary explosives upon impact. The mass and size of the PETN or HMX donor charge can vary considerably, and the igniter will function if the explosive is highly compacted. Short lengths of PETN, HMX, and HNS can be used as acceptor explosives and be initiated to detonation by a flying plate over a wide range of pressing densities. Flyer barrels between 3.5 and 7.0 mm long and with diameters of 2.5 and 3.8 mm have proved satisfactory. Additional tests strongly indicate that an acceptor-charge diameter that is smaller than that of the flying plate is an important condition.

I. INTRODUCTION

This report centers on experiments utilizing secondary explosives in flying-plate detonators. PETN and HMX were the donor (flying-plate driver) charges. PETN, HMX, HNS, PYX, and TATB were tried as acceptor charges. The mechanical assemblies were of two types, the relatively large SE-1 and the much smaller ER-322.

The SE-1 detonator is shown in Fig. 1. The housing walls are 1.2-mm-thick brass. The bridgewire is Nichrome V (80% nickel and 20% chromium). It is 0.05 mm in diameter and soldered between electrodes that are 1 mm apart in an asbestos-filled diallyphthalate plastic head. The electrical resistance of the assembly

is 0.6 Ω . The explosives pressing is loaded into the brass-walled cavity over the bridgewire. The aluminum disk, which is sheared by the gas pressure, is 6061-T6 aluminum material, 0.65 mm thick, 7.6 mm in diameter, and fits over the face of the donor explosive charge. The flyer barrel is 2.5 mm in diameter and 6.4 mm long. The acceptor-charge holder generally measures 2.5 mm in diameter and 6.4 mm in length. The confining material is 303 stainless steel.

The ER-322 detonator is shown in Fig. 2. The bridgewire material is Tophet C (51% nickel, 15% chromium, 24% iron), 0.05 mm in diameter, and resistance-welded between Fe/Ni alloy electrodes that are 2.4 mm apart and embedded in a compressed-glass header. The resistance was measured as 0.9 Ω . The explosive is loaded on top of the bridgewire in a Lexan charge holder 4.4 mm in diameter and 4.0 mm long. The 6061-T6 aluminum flying-plate thickness was varied between 0.25 mm and 1.00 mm with a diameter of 9.6 mm. It was glued onto the charge holder/header assembly. The flyer barrel had a diameter of 2.5 mm and a length of 7.0 mm. The acceptor-charge holder measures 2.5 mm in diameter and is 7.0 mm long. The confining metal is 303 stainless steel.

The specific surface (S_o^P) of the explosives differed. The S_o^P value of the PETN* was varied by changing the rate of mixing water with PETN/acetone solutions. The HMX samples** were the beta (β) polymorph material, wet-ground to the desired fineness by 2.5-cm-diam porcelain balls. The small-particle-size (large specific surface) HNS (labelled HNS-1) and the TATB used came from the Pantex Plant of the Silas Mason Co., Inc.⁺ The PYX material was synthesized at Los Alamos.⁺⁺

II. SE-1 FLYING-PLATE SYSTEMS

The successful all-PETN systems consisted of 1.6-g/cm³ density donor charges between 2.5 and 7.0 mm long. The acceptor-charge densities

*PETN = pentaerythritol tetranitrate ($C_5H_8N_4O_{12}$)
Trojan Powder Company, 17 North 7th, Allentown, PA 18101.

**HMX = 1,3,5,7-tetranitro-1,3,5,7-tetrazacylooctane ($C_8H_8N_8O_8$)
Holston Defense Corporation, P. O. Box 749, Kingsport, TN 37662.

⁺HNS = 2,2', 4,4', 6,6'-hexanitrostilbene ($C_{14}H_6N_6O_{12}$)
TATB = 2,4,6-trinitro-1,3,5-benzenetriamine ($C_6H_6N_6O_6$)
Mason and Hanger, Silas Mason Co., Inc., Pantex Plant,
P. O. Box 30020, Amarillo, TX 79177.

⁺⁺PYX = 2,6-bis(picrylamino)-3,5-dinitropyridine ($C_{17}H_7N_{11}O_{16}$)
Michael D. Coburn and Jannie L. Singleton, "Picrylamino-substituted Heterocycles. V. Pyridines (1,2)," J. Heterocycl. Chem. 9, 1039 (1972).

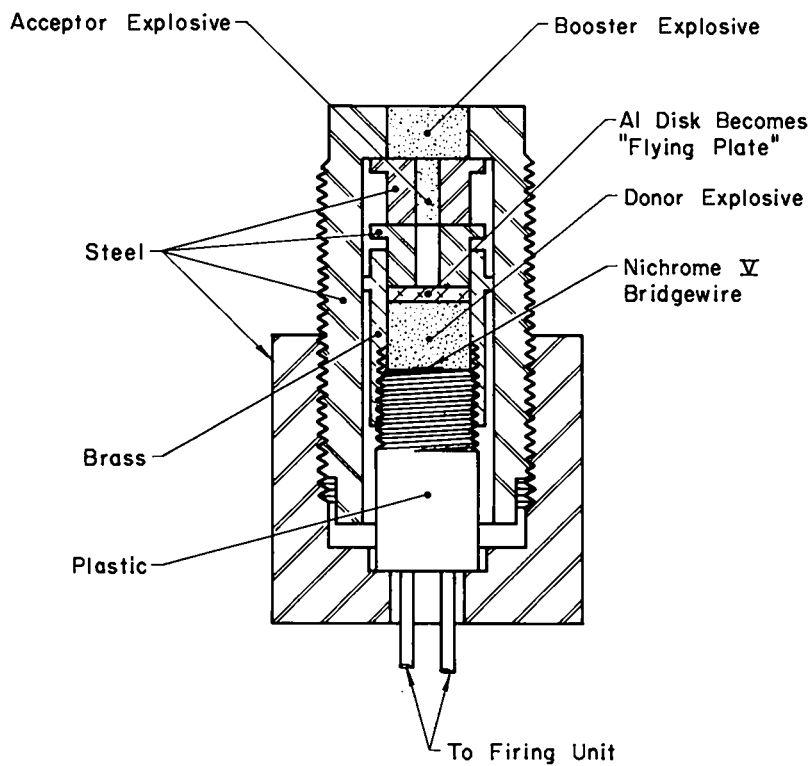


Fig. 1. Flying-plate assembly (SE-1 type).

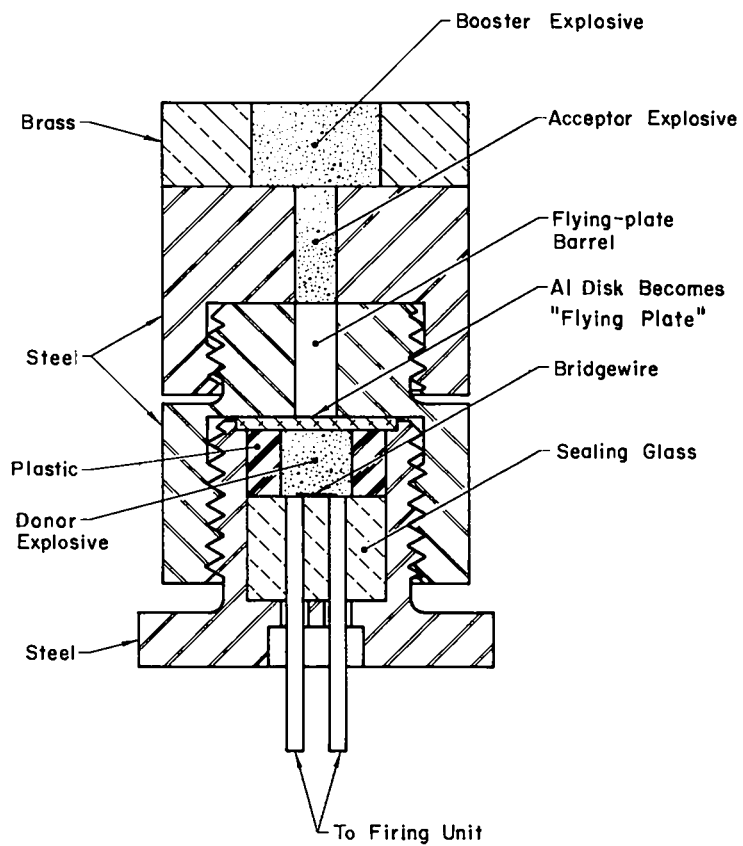


Fig. 2. Flying-plate assembly (ER-322 type).

varied from 0.8 to 1.2 g/cm³. Their dimensions were 2.1 and 2.5 mm in diameter and 6.4 mm long. The S_o^P of the PETN samples used for donor charges ranged from 3000 to 19000 cm²/g. It ranged from 3000 to 8400 cm²/g in the acceptor.

The successful all-HMX systems consisted of 1.4- and 1.6-g/cm³ donor charges between 2.5 and 7.0 mm long. The acceptor-charge densities varied from 0.8 to 1.4 g/cm³. The charge diameters were 2.5 and 4.1 mm, and the charge lengths were 6.4 mm. The HMX had an S_o^P of 8300 cm²/g.

Both the PETN and the HMX systems used a booster pellet (diameter = 7.6 mm, length = 11.4 mm) of high-density PETN or plastic-bonded RDX (PBX 9407) and a 2024 Dural witness plate. Tables I and II list the combinations that function satisfactorily.

III. ER-322 FLYING-PLATE SYSTEMS

The donor charge of PETN used material with an S_o^P of 3650 cm²/g loaded to a density of 1.6 g/cm³. The charge mass was 100 mg. Three values of the PETN ($S_o^P = 3650$ cm²/g) acceptor-charge density were investigated--1.0, 1.2, and 1.4 g/cm³. Aluminum (6061-T6) flying plates of thickness 0.5 or 1.0 mm were used. Both flyers initiated the acceptor charges to detonation. The volume of the dent depth in the 19-mm-thick 2024-aluminum witness block appears to become larger as the acceptor-charge density is increased. Assemblies with high-density (1.6-g/cm³) PBX 9407 booster pellets attached to the downstream face of the acceptor charge dented 19-mm-thick 2024-aluminum witness blocks. The booster explosive was confined in a brass ring. Table III lists the combinations that functioned satisfactorily.

HMX explosive is considerably more heat stable than PETN. It has, therefore, potentially a wider range of application in hot-wire detonators. ER-322 flying-plate systems using HMX as the donor explosive were examined in some detail. The donor material had an S_o^P value of 8300 cm²/g and a loading density of 1.6 g/cm³. The dimensions of the acceptor-charge holder were the same as in the PETN experiments. The aluminum flying plates were 0.25, 0.50, 0.75, and 1.00 mm thick. In addition, a flyer design called "Top Hat" was included and found to be quite effective. In this design, 0.2 mm of the overall 1.0-mm flyer fits snugly down inside the flyer barrel forming the "Top Hat."

TABLE I
SE-1 FLYING-PLATE INITIATION OF PETN

Bridgewire	Flying Plate	Booster Explosives
Nichrome V	6061-T6 aluminum	PETN or PBX 9407 ³
Diameter = 0.05 mm	0.65 mm thick	Density = 1.6 g/cm ³
Length = 1 mm	Barrel Diameter = 2.5 mm	
	Barrel Length = 6.4 mm	

DONOR			ACCEPTOR		
S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)	S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)
3200	512	7.6	3200	26.0	2.5
	1.6	7.0		0.8	6.4
3200	512	7.6	3200	32.0	2.5
	1.6	7.0		1.0	6.4
3200	512	7.6	3200	38.0	2.5
	1.6	7.0		1.2	6.4
3200	278	7.6	4900	21.0	2.1
	1.6	3.8		1.0	6.4
8400	512	7.6	8400	26.0	2.5
	1.6	7.0		0.8	6.4
8400	512	7.6	3200	26.0	2.5
	1.6	7.0		0.8	6.4
8400	512	7.6	3200	32.0	2.5
	1.6	7.0		1.0	6.4
8400	512	7.6	3200	38.0	2.5
	1.6	7.0		1.2	6.4
8400	185	7.6	3200	26.0	2.5
	1.6	2.5		0.8	6.4
18600	512	7.6	3200	26.0	2.5
	1.6	7.0		0.8	6.4
18600	512	7.6	3200	32.0	2.5
	1.6	7.0		1.0	6.4
18600	512	7.6	3200	38.0	2.5
	1.6	7.0		1.2	6.4

TABLE II
SE-1 FLYING-PLATE INITIATION OF HMX

Bridgewire			Flying Plate			Booster Explosives		
Nichrome V			6061-T6 aluminum			PBX 9407		
Diameter = 0.05 mm			0.65 mm thick			Density = 1.6 g/cm ³		
Length = 1 mm			Barrel Diameter =					
			2.1/2.5/4.1 mm					
			Barrel Length = 6.4 mm					
DONOR			ACCEPTOR					
S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)	S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)			
8300	512	7.6	8300	26.0	2.5			
	1.6	7.0		0.8	6.4			
8300	512	7.6	8300	32.0	2.5			
	1.6	7.0		1.0	6.4			
8300	512	7.6	8300	38.0	2.5			
	1.6	7.0		1.2	6.4			
8300	278	7.6	8300	38.0	2.5			
	1.6	3.8		1.2	6.4			
8300	185	7.6	8300	21.0	2.5			
	1.6	2.5		1.0	6.4			
8300	185	7.6	8300	66.0	4.1			
	1.6	2.5		0.8	6.4			
8300	185	7.6	8300	83.0	4.1			
	1.6	2.5		1.0	6.4			
8300	185	7.6	8300	100.0	4.1			
	1.6	2.5		1.2	6.4			
8300	185	7.6	8300	116.0	4.1			
	1.6	2.5		1.4	6.4			
8300	454	7.6	8300	66.0	4.1			
	1.4	7.0		0.8	6.4			
8300	454	7.6	8300	83.0	4.1			
	1.4	7.0		1.0	6.4			
8300	454	7.6	8300	100.0	4.1			
	1.4	7.0		1.2	6.4			
8300	454	7.6	8300	116.0	4.1			
	1.4	7.0		1.4	6.4			

TABLE III

ER-322 FLYING-PLATE INITIATION OF PETN

<u>Bridgewire</u>	<u>Flying Plate</u>	<u>Booster Explosive</u>
Tophet C	6061-T6 aluminum	PBX 9407
Diameter = 0.05 mm	0.50 or 1.0 mm thick	Density = 1.6 g/cm ³
Length = 2.4 mm	Barrel Diameter = 2.5 mm	
	Barrel Length = 7.0 mm	

<u>DONOR</u>			<u>ACCEPTOR</u>		
S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)	S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)
3650	100	4.4	3650	36.0	2.5
	1.6	4.0		1.0	6.4
3650	100	4.4	3650	43.0	2.5
	1.0	4.0		1.2	6.4
3650	100	4.4	3650	50.0	2.5
	1.6	4.0		1.4	6.4

Flying plates of all thicknesses initiated HMX ($S_o^P = 8300 \text{ cm}^2/\text{g}$) in the acceptor barrel sufficiently to produce only a very small dent in the 2024-aluminum witness block. High-density PBX 9407 booster pellets were not initiated to detonation. This was true for all three values of the acceptor loading density--1.0, 1.2, and 1.4 g/cm^3 .

When the acceptor charge was HMX of larger particle size ($S_o^P = 3450 \text{ cm}^2/\text{g}$), the output dent in a 2024-aluminum witness block appeared to become deeper with increase in charge density, and all three acceptor densities initiated attached PBX 9407 pellets confined in brass rings. The flyer used was 1.0 mm thick, either flat or "Top Hat" in shape. Those flyers that were 0.25 and 0.50 mm thick did not function satisfactorily.

Of the three other explosives (HNS, PYX, TATB) tried as acceptor charges, only HNS ($S_o^P = 12700 \text{ cm}^2/\text{g}$) initiated PBX 9407 booster pellets to detonation. Table IV gives successful HMX and HNS combinations.

The length and diameter of the flying-plate barrels used to initiate PETN and HMX acceptor charges were varied, and the effect on the initiation of attached booster pellets was studied. The fixtures are designated as modified ER-322 assemblies. The donor charge is identical with that previously described except that Nichrome V wire was the bridgewire instead of Tophet C. The average resistance of these donors was 1.00 Ω with a range of 0.15 Ω . Both the flying plate and the acceptor barrels were slightly more massive assemblies of 303 stainless steel. The thickness of the aluminum flying plates varied between 0.25 and 1.0 mm. The lengths of the flying-plate barrels were 3.5 and 5.0 mm; the two diameters were 2.5 and 3.8 mm. All assemblies functioned satisfactorily with PETN of 3650- cm^2/g specific surface. Table V shows these combinations. With HMX as the detonator explosive, both barrel lengths were satisfactory with all flyer thicknesses, if the acceptor diameter is 3.8 mm. Detonators with 2.5-mm-diam acceptor barrels required aluminum flyers of thickness greater than 0.25 mm for proper functioning. Table VI shows these successful results.

IV. DIRECT INITIATION OF LARGE PELLETS

It would be convenient if high-density pellets could be initiated to detonation directly by a flying plate. We have had only very

TABLE IV

ER-322 FLYING-PLATE INITIATION OF HMX AND HNS

<u>Bridgewire</u>	<u>Flying Plate</u>	<u>Booster Explosives</u>
Tophet C	6061-T6 aluminum	PBX 9407
Diameter = 0.05 mm	1.0 mm-thick "Top Hat" or Flat	Density = 1.6 g/cm ³
Length = 2.4 mm	Barrel Diameter = 2.5 mm	
	Barrel Length = 7.0 mm	

<u>HMX DONOR</u>			<u>ACCEPTOR</u>		
S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)	S_o^P (cm ² /g)	Mass (mg) and Density (g/cm ³)	Diameter and Length (mm)
				<u>HMX</u>	
8300	100 1.6	4.4 4.0	3450	36.0 1.0	2.5 6.4
8300	100 1.6	4.4 4.0	3450	43.0 1.2	2.5 6.4
8300	100 1.6	4.4 4.0	3450	50.0 1.4	2.5 6.4
				<u>HNS</u>	
8300	100 1.6	4.4 4.0	12700	36.0 1.0	2.5 6.4
8300	100 1.6	4.4 4.0	12700	43.0 1.2	2.5 6.4
8300	100 1.6	4.4 4.0	12700	50.0 1.4	2.5 6.4

TABLE V
 FLYING-PLATE INITIATION OF PETN
 IN
 MODIFIED ER-322 ASSEMBLIES

Bridgewire	Donor	Booster Explosive
Nichrome V Diameter = 0.05 mm Length = 2.4 mm	$S_o^P = 8300 \text{ cm}^2/\text{g}$ Mass = 100 mg Density = 1.6 g/cm^3 Diameter = 4.4 mm Length = 4.0 mm	PETN Density = 1.6 g/cm^3

FLYING PLATE			ACCEPTOR		
6061-T6 Aluminum	Barrel		S_o^P	Mass (mg)	Diameter and
Thickness (mm)	Diameter (mm)	Length (mm)	(cm^2/g)	and Density (g/cm^3)	Length (mm)
0.25	2.5 and 3.8	3.5 and 5.0	3650	36.0 1.0	2.5 7.0
0.50	2.5 and 3.8	3.5 and 5.0	3650	36.0 1.0	2.5 7.0
0.75	2.5 and 3.8	3.5 and 5.0	3650	36.0 1.0	2.5 7.0
1.00	2.5 and 3.8	3.5 and 5.0	3650	36.0 1.0	2.5 7.0

TABLE VI

FLYING-PLATE INITIATION OF HMX
IN
MODIFIED ER-322 ASSEMBLIES

Bridgewire		Donor		Booster Explosive	
Nichrome V		$S_o^P = 8300 \text{ cm}^2/\text{g}$		PBX 9407	
Diameter = 0.05 mm		Mass = 100 mg		Density = 1.6 g/cm ³	
Length = 2.4 mm		Density = 1.6 g/cm ³			
		Diameter = 4.4 mm			
		Length = 4.0 mm			

FLYING PLATE			ACCEPTOR		
6061-T6 aluminum	Barrel		S_o^P	Mass (mg)	Diameter and
Thickness	Diameter	Length		and	Length
(mm)	(mm)	(mm)	(cm ² /g)	Density	(mm)
				(g/cm ³)	
0.25	3.8	3.5 and 5.0	3450	36.0	2.5
				1.0	7.0
0.50	2.5 and 3.8	3.5 and 5.0	3450	36.0	2.5
				1.0	7.0
0.75	2.5 and 3.8	3.5 and 5.0	3450	36.0	2.5
				1.0	7.0
1.00	2.5 and 3.8	3.5 and 5.0	3450	36.0	2.5
				1.0	7.0

limited success in achieving the elimination of the small-diameter acceptor-explosive intermediate charge. Using HMX ($S_o^P = 8300 \text{ cm}^2/\text{g}$) donors and 1.0-mm-thick "Top Hat" flying plates in our ER-322 assembly, we found the following:

(1) PETN pellets of 1.3-g/cm^3 density and 7.6 mm in diameter x 5.0 mm long can be initiated to detonation whether the pellet is confined in brass rings or not. The confined pellets gave significantly deeper dents in the 2024-aluminum witness block.

(2) PETN and HMX pellets of this size and compacted to a density of 1.6 g/cm^3 are not initiated to detonation by the flying plate, whether they are confined in brass or not.

It appears that the acceptor-charge/flying-plate diameter ratio as well as both the density and confinement of acceptor charge all contribute significantly to achieving detonation.

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