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THE IGNITION AND DEFLAGRATION OF POTASSIUM PICRATE (KP) AND KP/EXPLOSIVES MIXTURES: LOW-VOLTAGE, NONPRIMARY DETONATORS

by

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ABSTRACT

Potassium picrate (KP) has been examined as a material which can be easily ignited to deflagration by a hot wire for application in low-voltage detonators which contain no primary explosives. KP can be ignited by a 0.05-mm-diam Nichrome wire at the 1-A/1-W level.

KP mechanically blended with PETN or HMX in 10/90% by mass mixtures exhibit similar hot-wire ignition behavior to pure KP. These deflagrating mixtures generate higher pressures than pure KP and are therefore more useful as donor charges for accelerating an impact plate onto an acceptor charge or for driving a stress wave into a deflagration-to-detonation transition charge.

Ignition and deflagration of KP and KP/explosives mixtures have been studied in terms of their dependence on explosive, electrical, and configuration parameters. These results are applied to the development of detonators of two types, flying plate detonators and deflagration-to-detonation transition detonators.

I. INTRODUCTION

Potassium picrate (KP) is a high-temperature stable, crystalline substance that can be ignited to deflagration by a rapidly heated bridgewire. The voltages and currents necessary are in the area of several volts and amperes. KP mixed with secondary high explosives such as PETN and HMX also can be ignited at these same levels.

The development of the deflagration in ignited KP/high explosive mixtures depends greatly upon density and degree of confinement. High-density (ca 1.6 g/cm^3) mixtures confined in thick-walled steel or brass generated a maximum pressure of around 0.3 GPa in a volume of about 1 cm^3, in several milliseconds.

We have not found pure KP useful in detonators. KP mixed with PETN or HMX, however, can be used as initiators of other explosive charges in low-voltage detonators containing no primary explosives.

II. KP MIXES AS DONOR CHARGES

KP mixed with PETN or HMX can be used as donor charges in hot-wire detonators in two ways. In the first, which is called "deflagration-to-detonation-transition" (DDT) initiation, the deflagrating donor charge is coupled directly to a confined secondary explosive charge. This transition charge must be of such type, density and size that the deflagration will change into a detonation. The second, which is called "flying-plate" (FP) initiation involves igniting the donor and using the pressure generated to shear a metal disk.[1] This flying plate moves across an air gap and impinges on an acceptor explosive. The acceptor explosive must be of such type, density and physical dimensions that it is shock initiated to detonation by the impacting flying plate.

A. Deflagration-to-Detonation-Transition Initiation

Figure 1 is a diagram of the assembly used in DDT initiation experiments. The igniter wire is Nichrome V, usually 0.05-mm diameter and 1-mm long. The donor charge normally is 7.6-mm diameter and 6.8-mm long. Coupled to the donor pressing is the transition charge. Its diameter is significantly smaller than that of the donor; it is 2.5 mm. In this charge the deflagration becomes a detonation. An acceptor pellet is placed against the face of the transition charge.

Table I shows the results of a rough survey of the KP/PETN donor composition at two densities with a low-density PETN transition charge. It appears only KP/PETN donors of

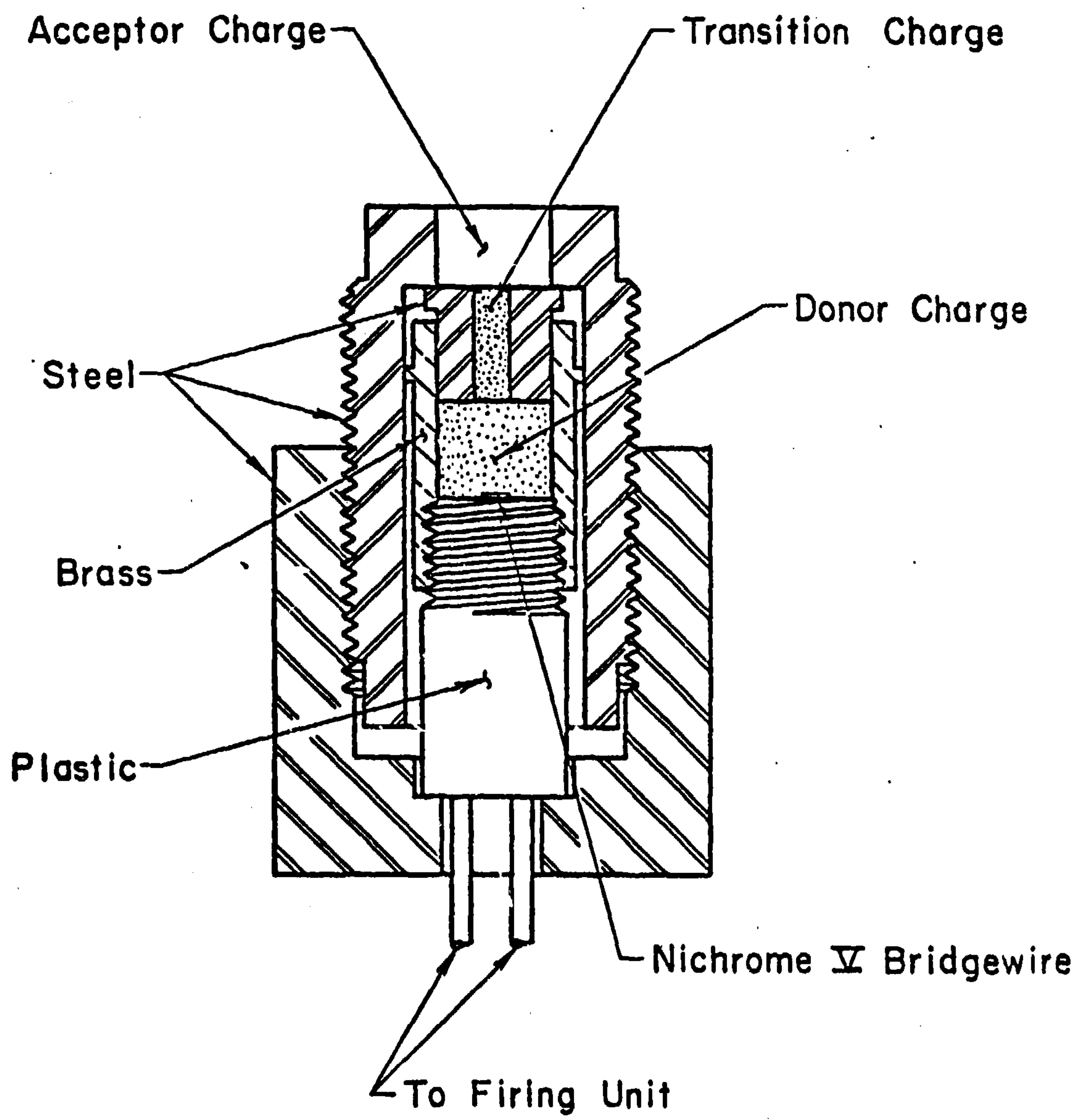


Figure 1 Deflagration-to-Detonation Transition (DDT) Assembly: Reduced-Diameter Transition Charge

TABLE I

EFFECT OF DONOR CHARGE COMPOSITION AND LOADING DENSITY ON DDT REACTION

REDUCED-DIAMETER TRANSITION CHARGE

Transition Charge	Acceptor Charge
PETN S_o^P = 330 m^2/kg	PETN S_o^P = 330 m^2/kg
Density = 1.0 g/cm^3	Density = 1.6 g/cm^3
Diameter = 2.5 mm	
Length = 6.4 mm	
	Ignition Voltage = 2.5 V

Donor Charge			Result
Explosive	(% by mass)	Density (g/cm^3)	D=Detonation ND=Ignition but no Detonation
KP	100	1.6	ND
"	100	1.2	ND
KP/PETN	90/10	1.6	ND
" "	50/50	1.6	ND
" "	25/75	1.6	D
" "	10/90	1.6	D
" "	90/10	1.2	ND
" "	50/50	1.2	D
" "	25/75	1.2	D
" "	10/90	1.2	D

less than 25% KP at high density, 1.6 g/cm^3, and below 50% KP at 1.2 g/cm^3, function satisfactorily.

KP/PETN 10/90 (% by mass) mix has been most extensively investigated as a donor. KP/PETN 10/90 mix, PETN, RDX, and HNAB at different densities have been used successfully as the transition charge. High-density PETN or 9407 PBX have been used as the acceptor charges. The criterion for achievement of detonation in the acceptor explosive was the production of a dent in a 20/24 Dural "witness" plate (18-mm thick), placed across the face of the acceptor charge. Table II shows these data.

KP mixed with HMX also has been investigated as a donor charge. Mixtures of composition 10/90% by mass KP/HMX, at a density of 1.6 g/cm^3, have been found to ignite satisfactorily. Table III shows the data with PETN of four different densities as the transition charge.

With both these donor charges there seems to be a maximum density of the transition charge that will build up to detonation in this configuration. This is consistant with the picture of the DDT mechanism drawn by Sulimov, where one aspect is the combustion products penetrating through pores into unreacted explosive, preheating the material and helping the initiation of a low-velocity detonation.[2]

The abrupt change in diameter between the donor and transition charges could cause the shearing effect shown by Campbell in 1976 to be necessary for the transition from burning to detonation in the propellant FKM at high-density.[3] Although in our system this may be helpful, it appears not to be necessary. DDT reactions have been generated without this discontinuity. Figure 2 shows the assembly used with KP/PETN 10/90 mix of density 1.2 g/cm^3. Here the donor and transition charges are the same diameter with the latter of slightly shorter length (5.0 mm vice 6.8 mm). Two detonations were obtained in four experiments. The two that failed appeared to be caused by incomplete burning of the donor. From these results we infer that the DDT that occurs with no change in donor/transition charge diameter is marginal. Since we have no difficulty in achieving DDT when the transition charge is smaller in diameter than the donor we conclude that here there is a margin over threshold conditions.

The effect of changing the length of the donor charge also has been investigated. KP/PETN 10/90 mix was the explosive as both the donor and small-diameter transition charge. With a density of 1.2 g/cm^3, the donor length could not be decreased significantly below 6.8 mm. With a donor density of 1.6 g/cm^3 its length could be shortened

TABLE II

EFFECT OF TRANSITION CHARGE EXPLOSIVE TYPE AND DENSITY ON DDT REACTION

REDUCED-DIAMETER TRANSITION CHARGE

Donor Charge	Transition Charge	Acceptor Charge
KP/PETN = 10/90% by mass	Diameter = 2.5 mm	PETN[a]
KP S_o^P = 250 m^2/kg	Length = 6.4 mm	Density = 1.6 g/cm^3
PETN S_o^P = 330 m^2/kg		

Ignition Voltage = 2.5 V

Donor Charge Density (g/cm^3)	Transition Charge Explosive	Transition Charge Density (g/cm^3)	Result D=Detonation ND=No Detonation
1.6	PETN[a]	0.6	D
1.6	"	0.8	D
1.6	"	1.0	D
1.6	"	1.2	D and ND
1.6	"	1.4	ND
1.2	"	0.8	D
1.2	"	1.0	D
1.2	"	1.2	D
1.2	"	1.4	ND
1.6	KP/PETN 10/90	1.1	D
1.6	" "	1.2	ND
1.6	" "	1.4	ND
1.6	" "	1.6	ND
1.2	" "	1.2	D[b]
1.2	" "	1.2	D[b] [c]
1.6	HNAB[d]	0.8	D
1.6	"	1.0	D
1.6	RDX	0.8	D
1.6	"	1.0	ND

[a] PETN: Reprecipitated from acetone with water; S_o^P = 330 m^2/kg
[b] Ignition Voltage: 40 V
[c] Dent observed in Al slug used in place of acceptor pellet
[d] HNAB: Reprecipitated from acetone with ethyl alcohol; S_o^P = 600 m^2/kg

TABLE III

EFFECT OF TRANSITION CHARGE DENSITY ON DDT REACTION

REDUCED-DIAMETER TRANSITION CHARGE

Donor Charge	Transition Charge	Acceptor Charge
KP/HMX = 10/90 % by mass	PETN[a]	PETN[a]
KP S_o^P = 200 m^2/kg	Diameter = 2.5 mm	Density = 1.6 g/cm^3
HMX S_o^P = 350 m^2/kg	Length = 6.4 mm	
Density = 1.6 g/cm^3		

Transition Charge Density (g/cm^3)	Result D=Detonation ND=No Detonation
0.6	D[b]
0.8	D[c]
1.0	D[c] and ND[b]
1.2	ND[b]

[a]PETN: Reprecipitated from acetone with water; S_o^P = 330 m^2/kg
[b]Ignition Voltage = 40 V
[c]Ignition Voltage = 3 V and 40 V

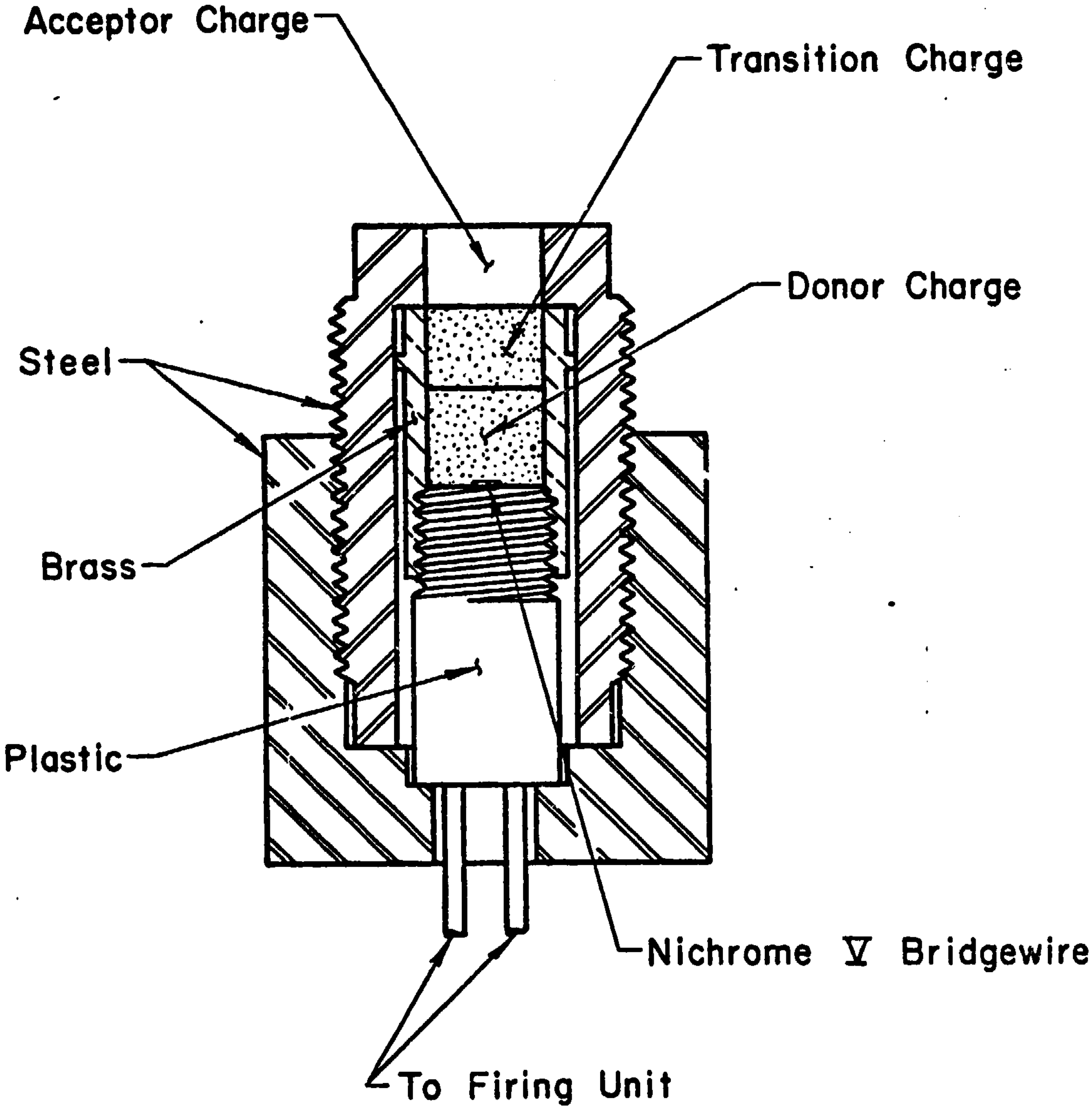


Figure 2 Deflagration-to-Detonation Transition (DDT) Assembly: Equal-Diameter Transition Charge

to slightly less than 4 mm. Failures were the result of no ignition of the donor, thought to be due to inadequate confinement near the wire.

We have recently shown that DDT reactions will occur in pure PETN and HMX if the conditions are correct. We find these to be (1) high donor charge density with low transition charge density, and (2) a large ratio of donor-charge to transition-charge diameter. For PETN the particle size is relatively unimportant; for HMX a high specific-surface material is needed for adequate donor ignition.

B. Flying-Plate Initiation of Acceptor Charge

One assembly used in flying-plate initiation experiments is shown in Figure 3. The igniter wire is again Nichrome V, 0.05-mm diameter and 1-mm long. The donor charge dimensions are 7.6-mm diameter and 6.8-mm long.

As in the DDT reactions pure KP is deficient as a donor charge. Only the thinnest of aluminum disks could be sheared and these did not initiate acceptor pellets. KP/PETN mixtures of 50/50 composition or more PETN, at loading densities 1.2 g/cm^3 or above, all drove flying plates that did initiate high-density PETN, RDX and 9407 PBX pellets 7.6-mm diameter by 5.0-mm long. These results are shown in Table IV. Only limited success was achieved with KP/HMX donors.

Experiments in which the aluminum flyer impacted on an acceptor charge whose diameter was reduced to 2.5 mm - the same as the flyer diameter - were successful with both types of donors. Data obtained using KP/HMX 10/90 mix donors at two densities are shown in Table V. It is evident that HMX and HNAB acceptor pressings - at several loading densities - can be used to initiate large high-density 9407 PBX booster pellets.

Both KP/PETN and KP/HMX 10/90 mixes will initiate small-diameter (ca 1 mm) high-density mild detonating fuse (MDF). Lead-sheathed PETN and aluminum-sheathed HNS both have been detonated by KP/PETN-driven flying plates. PETN MDF has been set off by KP/HMX-driven flying plates. MDF, in turn, will initiate high-density secondary explosives.

Another flying-plate device (Figure 4) also has been used. This design has side-entering leads. Hopefully this will allow additional rear confinement. The donor-charge length is 6.2 mm in the second assembly instead of 6.8 mm. The donor diameter is the standard 7.6 mm.

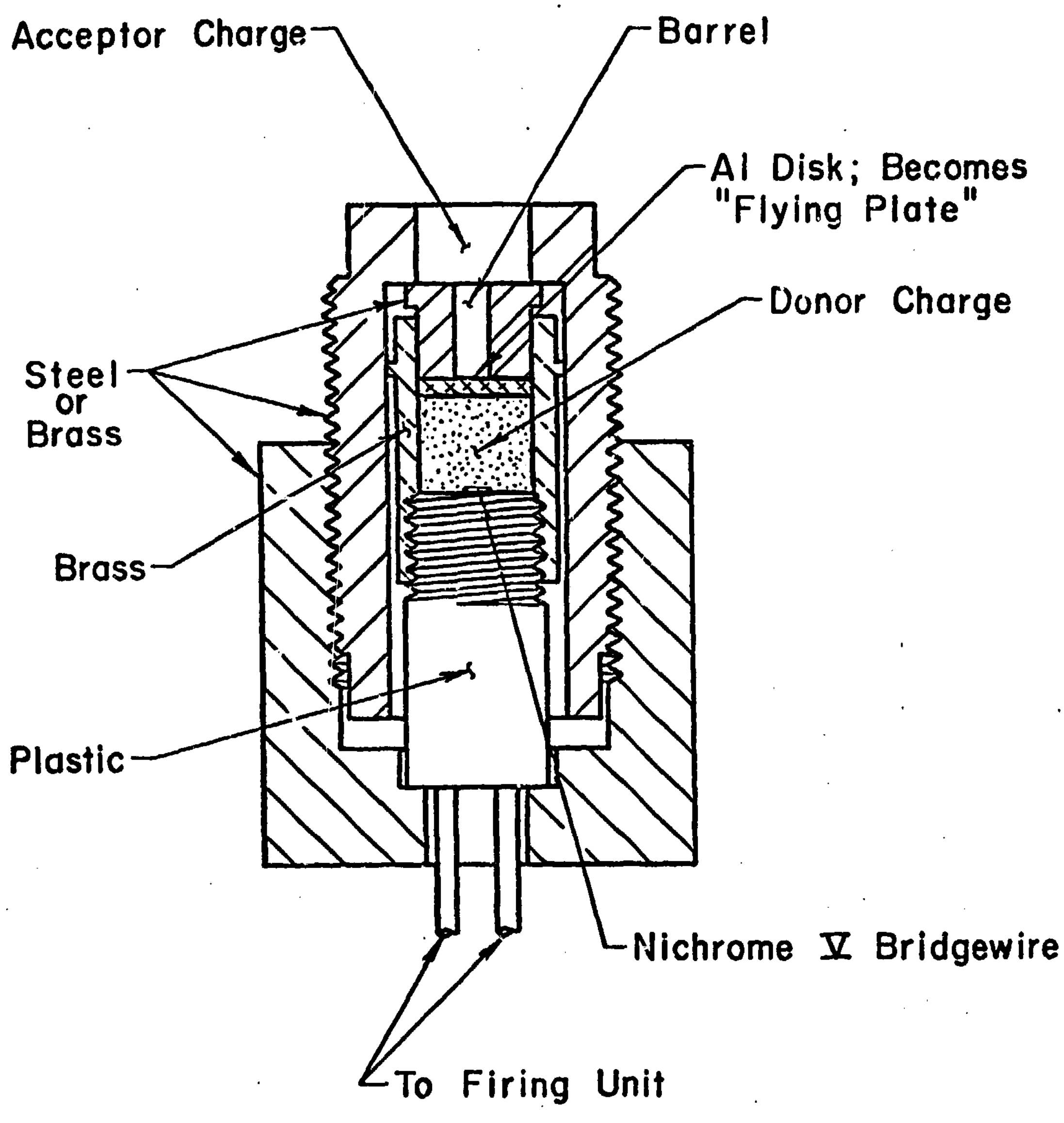


Figure 3 Flying-Plate Initiation Assembly

TABLE IV

FLYING-PLATE INITIATION OF ACCEPTOR EXPLOSIVES

LARGE-DIAMETER CHARGES

Donor Charge

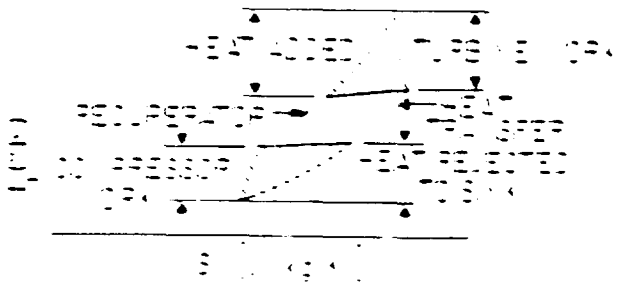
KP/PETN Mixes
KP S_o^P = 250 m^2/kg
PETN S_o^P = 320 m^2/kg

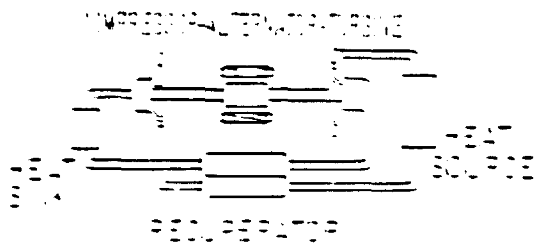
Flying Plate

Flyer Material = 6061-T6 Al
Flyer Barrel: Diameter = 2.5 mm
Length = 6.4 mm

Donor Charge KP (% by mass)	PETN (% by mass)	Density (g/cm^3)	Thickness (mm)	Acceptor Explosive Density 1.6 g/cm^3	Ignition Voltage (V)	Result D=Detonation ND=No Detonation
90	10	1.6	1.27	PETN	40	ND[a]
90	10	1.2	1.27	"	40	ND
50	50	1.6	1.27	"	40	D
50	50	1.6	1.27	"	3	ND[a]
50	50	1.2	1.27	"	40	D
50	50	1.6	1.27	9407 PBX	3	ND[a]
25	75	1.6	1.27	PETN	40	D
25	75	1.2	1.27	"	40	D
25	75	1.6	1.27	9407 PBX	3	ND
10	90	1.6	1.27	PETN	3	D
10	90	1.6	1.27	"	3	D
10	90	1.6	1.27	"	40	D
10	90	1.6	1.27	"	40	D
10	90	1.6	1.27	"	40	D
10	90	1.2	1.27	"	3	D
10	90	1.2	1.27	"	3	D
10	90	1.6	1.27	9407 PBX	3	D
10	90	1.6	1.27	" "	40	D
10	90	1.6	1.27	" "	3	D
10	90	1.6	1.27	" "	3	ND
10	90	1.6	0.64	" "	3	D
10	90	1.6	0.64	" "	3	ND
10	90	1.2	1.27	" "	3	ND
10	90	1.2	0.64	" "	3	ND
10	90	1.6	1.27	RDX	40	D

[a]Disc not ruptured





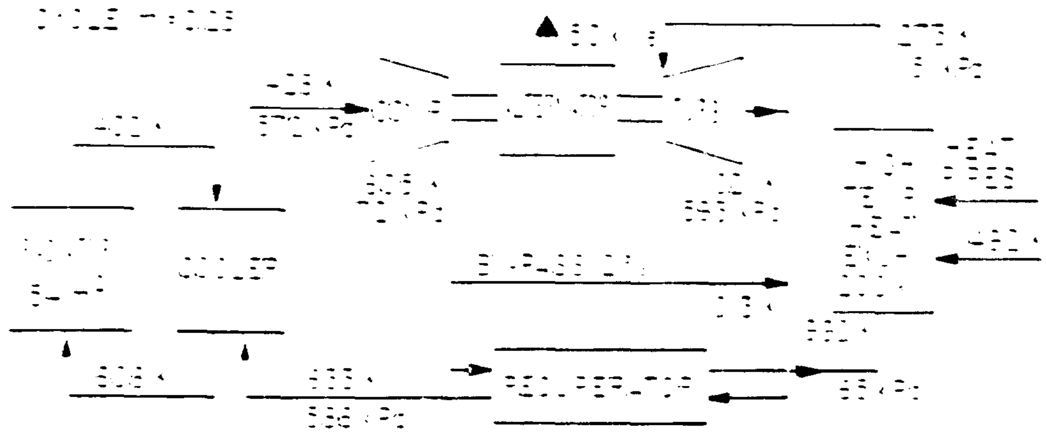


TABLE V

FLYING-PLATE INITIATION OF ACCEPTOR EXPLOSIVES

REDUCED-DIAMETER CHARGES

Donor Charge

KP/HMX = 10/90% by mass

Densities = 1.4 and 1.6 g/cm^3

KP S_o^P = 220 m^2/kg

HMX S_o^P = 360 m^2/kg

Acceptor Charge

Diameter = 2.5 mm

Length = 6.4 mm

Booster Charge

9407 PBX

Density = 1.6 g/cm^3

Ignition Voltage = 2.5 V

Flying Plate

Flyer Macerial = 6061-T6 Al

Flyer Thickness = 0.64 mm

Flyer Barrel: Diameter = 2.5 mm

Length = 6.4 mm

Acceptor Charge			Result
Type	S_o^P (m^2/kg)	Density (g/cm^3)	D=Detonation
HMX	360	0.8	D
"	360	1.0	D
"	360	1.2	D
"	360	1.4	D
HNAB	<100	0.8	D
"	<100	1.0	D
"	<100	1.2	D
"	<100	1.4	D

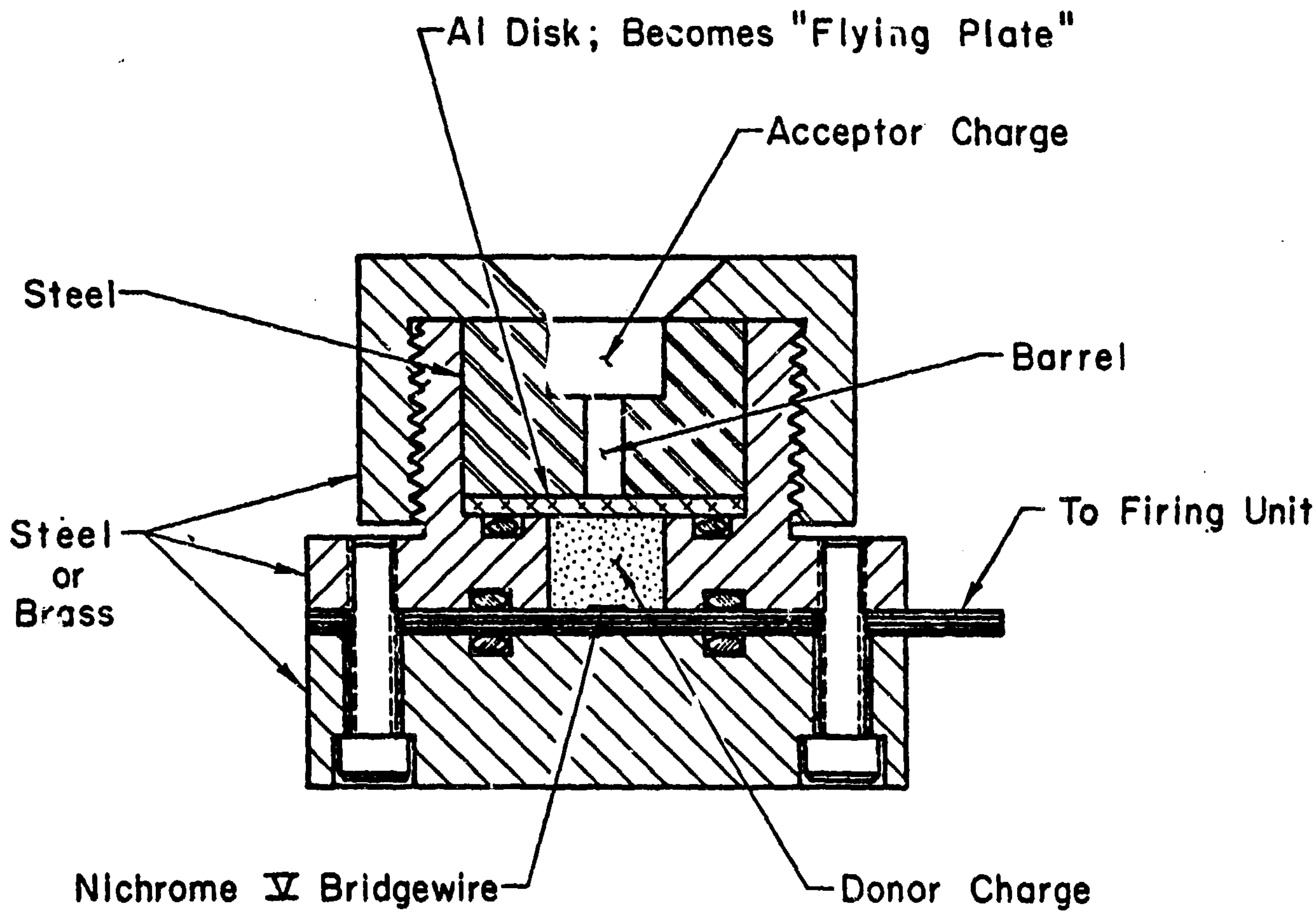


Figure 4   Flying-Plate Initiation Assembly:
Reinforced Back Confinement

Experiments using both KP/PETN and KP/HMX 10/90 mix donors to drive flying plates to initiate 7.6-mm diameter by 5.0-mm long PETN booster pellets as well as MDF have been carried out successfully. These results are shown in Table VI.

TABLE VI

FLYING-PLATE INITIATION OF PETN AND HNS MDF ACCEPTOR EXPLOSIVES

Donor Charge

KP/PETN and KP/HMX Mixes
Density = 1.6 g/cm³

Flying Plate

Flyer Material = 6061-T6 Al
Flyer Thickness = 1 mm
Flyer Barrel: Diameter = 2.5 mm
Length = 5.2 mm

Acceptor[a] MDF Explosive	Booster[a] Pellet Type	Booster[a] Density (g/cm³)	Ignition Voltage (V)	Result D=Detonation
Donor Explosive:	KP/PETN 10/90 Mix	$\bar{S}_o^p$ = 250 m²/kg		
HNS	PETN	1.6	40	D
"	9407 PBX	1.6	3	D
PETN	PETN	1.6	40	D
Donor Explosive:	KP/HMX 10/90 Mix	$\bar{S}_o^p$ = 300 m²/kg		
---	PETN 2 pellets long	1.3	40	D
HNS	9407 PBX	1.6	40	D
"	9407 PBX	1.6	40	D
"	9407 PBX	1.6	40	D

[a]MDF = Lead-sheathed PETN (5 grain/ft): ID = 0.8 mm; Length = 3.8 mm; Density >1.7 g/cm³

MDF = Aluminum-sheathed HNS-II: ID = 1.2 mm; Length = 1.38 mm; Density >1.7 g/cm³

Booster = 9407 PBX: Diameter = 7.6 mm; Length = 5.2 mm; Density≈1.6 g/cm³

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