LA-10172-MS

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LA-10172-MS

UC-45
Issued: October 1984

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# HIGH-TEMPERATURE-STABLE DETONATORS

by

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ABSTRACT

Current experiments in the area of high-temperature-stable detonators involve using HMX, KP, HNS, and PYX explosives. The test devices employ both hot-wire flying-plate and slapper modes of operation. Hot-wire detonators using HMX as the donor explosive, with HMX, KP, and HNS as the intermediate acceptor material and HNS as the booster pellet, were successfully fired at temperatures as high as 225°C. Very limited success was achieved using PYX explosive in a few experiments. The program of investigation also calls for the development of a high-temperature-stable hot-wire device functioning in the DDT mode of operation. PYX explosive--a truly high-temperature-stable explosive--has been initiated to detonation by low-energy slapper foils.

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## I. INTRODUCTION

The development of a detonator that will withstand elevated temperatures is governed by both the temperature regime desired and whether the explosives that are stable at those temperatures can be initiated to detonation. In addition, it must also be determined that practical and realizable amounts of energy will suffice for the proper functioning of the system.

Two methods of explosive initiation are considered in this report, i.e., hot-wire and slapper-foil. In the first, a small wire in contact with an explosive is heated by the passage of current of the order of 1 A. The explosive (donor) is ignited, and the gases that are produced rupture a metallic disc. The flying plate formed strikes a second explosive (acceptor) that is initiated to detonation. In the second, the slapper system, the rapid passage of an electric current through a foil vaporizes it. The resultant expansion process drives material covering the foil into an explosive, which is initiated to detonation. A fraction of 1 J of energy is sufficient for proper functioning.

## II. EXPERIMENTAL DETAILS

### A. Hot-Wire Detonators

The test device is shown in Fig. 1. It functions in the flying-plate mode of operation. Two parallel Nichrome V bridgewires, 0.05 mm in diameter and 2.5 mm long, are resistance-welded to FeNi alloy electrodes embedded in a compressed-glass header. The explosive charge holder is made of Teflon and is 4.4 mm in diameter and 4 mm long. A charge mass of 100 mg gives a loading density of 1.6 g/cm$^3$.

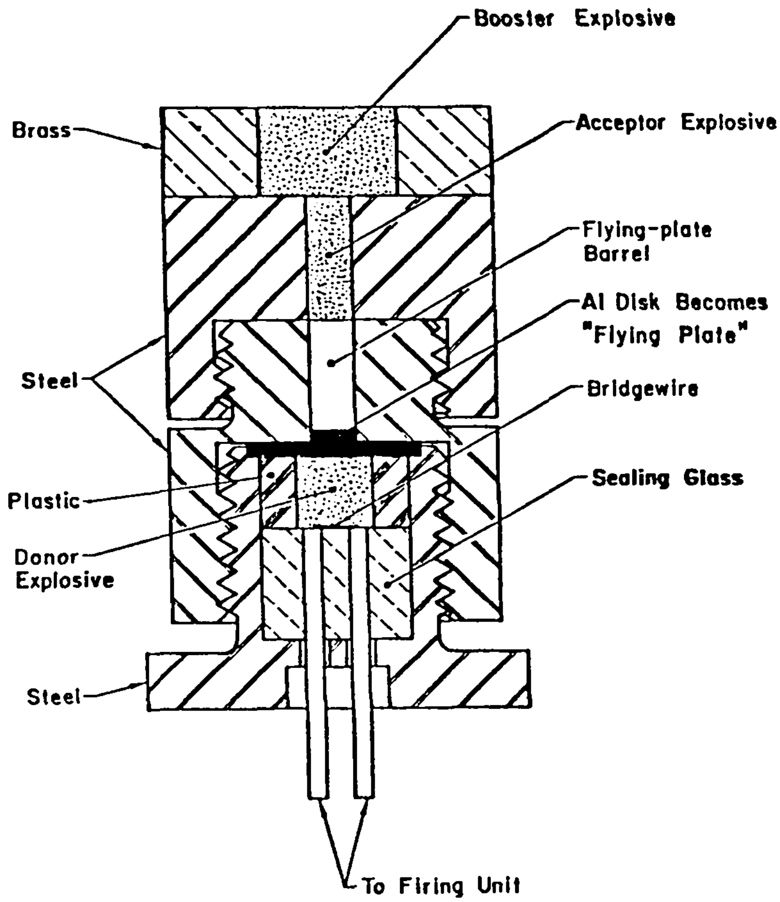


Fig. 1. Flying-plate assembly.

The flying-plate material is 6061-T6Al. The flyer design is called "Top Hat" because 0.2 mm of an overall 1.0-mm-thick shim fits snuggly down inside the flyer barrel forming a "Top Hat." The flyer barrel has a diameter of 2.5 mm and is 7.0 mm in length. The acceptor charge holder has the same dimensions. Both parts are made of 303 stainless steel and are screwed together. The booster pellet is confined in a brass hexagonal ring glued onto the end of the acceptor charge. An aluminum witness block (usually 2024 Dural) is glued onto the metal ring that contains the booster charge.

HMX,* KP,** HNS,† and PYX†† explosives have been investigated. The maximum temperature at which we have done experiments is 250°C. The majority of the testing in hot-wire assemblies was done with HMX explosive. KP and HNS were looked at in some detail; the data on PYX were sparse because of its relative insensitivity. The specific surface ($S_o$) of the explosives differed. HMX used in the donor and the acceptor was 8500 and 3450 $cm^2/g$, respectively. KP donor powder was 7600 $cm^2/g$ and the acceptor explosive 2350 $cm^2/g$. HNS was the fine-particle variety (HNS-1) with the same $S_o$ value of 13 000 $cm^2/g$ in both the donor and acceptor. Large-particle PYX was wet-ground by porcelain balls to an $S_o$ of about 30 000 $cm^2/g$ for this testing.

The donor explosives were all fired at 10 A or more. This is far above the 1-A threshold-current value for HMX, KP, and HNS. Since PYX explosive requires a larger-diameter bridgewire (0.127 mm vs 0.05 mm) for ignition, this current value is only about twice the threshold value.

### B. Slapper Detonators

Figure 2 shows the slapper detonator. Electrical energy from an external source is deposited extremely rapidly in a metallic foil of the order of 0.01 mm thick. There is a rapid production of vaporized metal and plasma. The high pressure accelerates high-tensile-strength insulating material less than 0.1 mm thick placed against the bridge down a barrel a few tenths of a millimeter in length. The impact of the rapidly moving material upon an attached high-density explosive pellet provides enough energy to initiate the explosive to detonation.

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* 1,3,5,7-tetranitro, 1,3,5,7-tetrazacyclooctane.
** potassium picrate.
† 2,2', 4,4', 6,6' hexanitrostilbene.
†† 2,6-bis(picrylamino)-3,5-dinitropyridine.

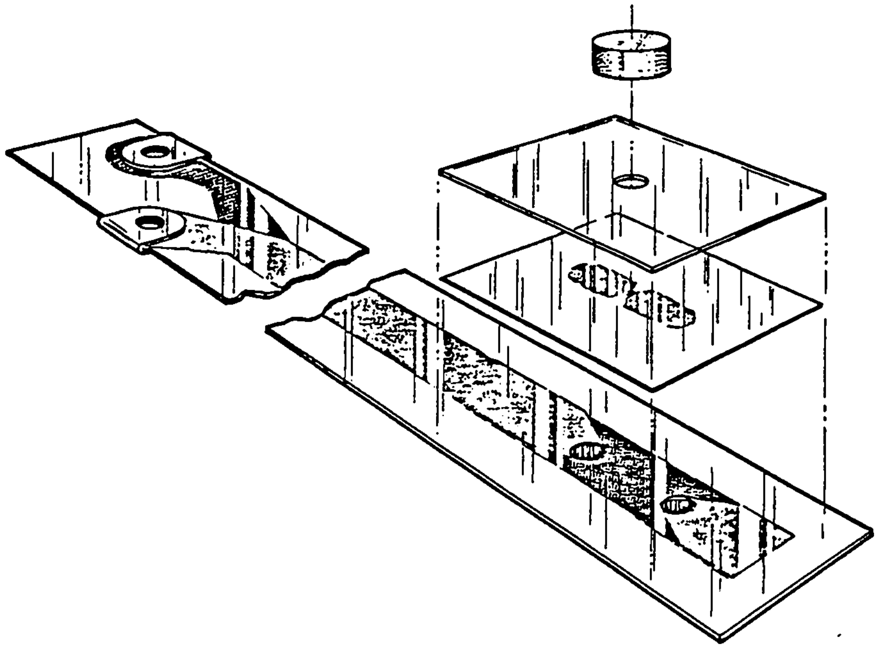

Fig. 2. Slapper detonator.

## III. EXPERIMENTAL RESULTS

### A. Hot-Wire Detonators

1. PYX. At room temperature, +75, and +150°C, PYX decomposes just enough to generate a usable pressure that forms flying plates from aluminum discs. The flying plates have energies great enough to dent both 6061-T6Al and 2024 Dural witness blocks. The system is also sufficiently energetic to ignite PETN acceptor/booster pellet combinations to violent deflagration.

2. KP. KP donors at elevated temperatures of +75 and +100°C caused explosions of larger-particle KP in the acceptor barrel in 12/14 shots, one of which detonated. The success shows that the all-KP, flying-plate detonator will work, but whether the probability of an explosion developing into a detonation is high enough for practical use remains to be seen. Extrapolation of time/temperature data on KP indicates a survival time at 300°C of 30 minutes for all-KP detonators.

3. HNS. HNS is a very heat-stable material. Its melting point is ~315°C, and it has an excellent vacuum-thermal stability behavior.[1] As a donor material, HNS decomposed upon hot-wire heating to form a flying plate but not with sufficient energy to react HNS or KP at 1.0 and 1.2 g/cm$^3$ in the

acceptor barrel. As an acceptor material, initiated by a flying plate driven by another explosive, it performs much better.

4. HMX. While not truly a high-temperature explosive in the same sense as KP, HNS, or PYX (certainly), HMX has a melting point almost 250°C above room temperature and a reasonable vacuum-thermal stability for periods of time of several hours into the 200°C region. It is certainly worth seeing at how high a temperature it will function (Table I).

TABLE I

HIGH-TEMPERATURE, HOT-WIRE DETONATOR PERFORMANCE
AT
ELEVATED TEMPERATURES

| | EXPLOSIVE | | | CYLINDRICAL | |
|---|---|---|---|---|---|
| NUMBER | DONOR | ACCEPTOR | BOOSTER | DENT VOLUME ($cm^3$) | TEMPERATURE (°C) |
| 2 | HMX | KP | PETN | 0.69[a] | + 74 |
| 2 | $S_o$ = 8500 | $S_o$ = 2350 | HNS-1 | 0.39[a] | +100 |
| 2 | $cm^2/g$ | $cm^2/g$ | HNS-1 | 0.47[a] | +150 |
| 2 | " | " | HNS-1 | 0.30±0 | +200 |
| 2 | " | HNS-1 | HNS-1 | 0.32±0.01 | +200 |
| 1 | " | $S_o$ = 13000 $cm^2/g$ | HNS-1 | 0.29 | +225 |
| 1 | " | HMX | HNS-1 | 0.44[a] | +100 |
| 1 | " | $S_o$ = 3450 | HNS-1 | 0.49[a] | +150 |
| 6 | " | $cm^2/g$ | HNS-1 | 0.29±0.02 | +150 |
| 9 | " | " | HNS-1 | 0.32±0.04 | +200 |
| 7 | " | " | HNS-1 | 0.32±0.04 | +225 |

[a]6061-T6Al witness block; all others 2024 Dural.

HMX donors will initiate HMX, KP, and HNS-1 acceptor explosives to detonation by driving flying plates without much difficulty up to +150°C. Following are details of the results of all-HMX devices at higher temperatures.

a. Temperature = 200°C. Seven of ten detonators functioned normally. The detonated HNS-1 booster pellet gave good witness-block dents. One device failed to ignite due to an open bridgewire. One donor did not shear the flyer plate, and one threw the flyer only halfway down the barrel. Although some engineering problems still seem to exist, hot-wire detonators using HMX as donor and acceptor-barrel charges appear usable at 200°C.

b. Temperature = 225°C. At this temperature HMX is basically unstable. Its auto-ignition time appears to be less than 30-45 minutes. The solid decomposed partially, and the pressure buildup spontaneously burst the flyer plate that was recovered at the end of the flyer barrel. The gases evidently caused bridgewires to come loose from their welds in several cases. The HMX of low density (~1.2 g/cm$^3$) in the acceptor barrel sublimed completely in two assemblies. Several others showed typical brownish-colored partial decomposition of the HMX. One device fired spontaneously and gave a good (average) dent in the witness block.

c. Temperature = 250°C. Six detonators "cooked off" and exploded spontaneously at different times of heating (less than 30 minutes). No evidence of initiation to detonation was observed.

B. Slapper Detonators

W. Hemsing and I. M. Garcia (M-7) have found that PYX can be detonated in slapper-type detonators at fairly low energy levels (∿0.3-J stored energy) at ambient temperature. At high temperatures, the required energy should be significantly lower. Therefore, in principle, a detonator capable of withstanding +300°C is at hand. We are endeavoring to make a high-temperature-capable firing system that will avoid the complications associated with providing the cryogenic protection needed by present-day firing systems in underground work.

REFERENCE

1. John F. Baytos, "High-Temperature Vacuum Thermal Stability Tests of Explosives," Los Alamos National Laboratory report LA-5829-MS (January 1975).

Printed in the United States of America
Available from
National Technical Information Service
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