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THIN-FILM ELECTRIC INITIATOR
III. APPLICATION OF EXPLOSIVES AND PERFORMANCE TESTS

by

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ABSTRACT

The match-like electric initiator is a chemically deposited thin-film-bridge version of the conventional hot bridge-wire initiator and is being developed to effect a cost-saving and an increase in shock resistance. This report describes the application of the explosive to the bridge and the performance and aging tests of the completed initiator.

Initiators having 10-by 10-mil bridges on polyimide substrates were uniform and stable and were consistently fired when pulsed by the XM429 rocket-fuze firing circuit, using 23 V. They did not change in resistance during a 1300-hr aging test at 80°C. Qualitative energy output tests indicated that the device is capable of initiating a lead azide relay.

More extensive performance tests are planned. Some modifications, including a stiffer substrate, a replacement for the thin-film copper leads, and smaller bridge geometries for lower firing voltages will be tried.

CONTENTS

ILLUSTRATIONS

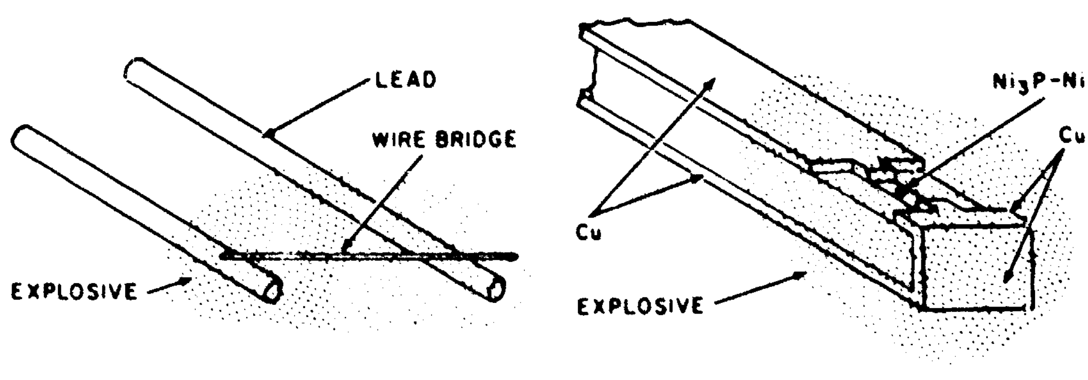
ILLUSTRATIONS (Cont'd)

1. INTRODUCTION

The use of thin-film technology shows promise of significantly reducing the cost of fuze initiators. The HDL device to be discussed (ref 1) is so designed that the wire bridge of conventional electric initiators is replaced by a thin-film chemically deposited nickel-phosphorus alloy resistor having a very small area and deposited on an insulating substrate (fig. 1). The conductor leads are replaced by thin films of copper electroplated over nickel. The film bridge area is coated with lead styphnate by dipping the end of the substrate into a slurry of the explosive. It is believed that this dipping step can be inexpensively accomplished using existing or only slightly modified paper-match-making machinery. The overall shape and the explosive-coated tip give the device the appearance of a match, hence the name "match-like" initiator.

The ignition mechanism of the match-like initiator is assumed to be thermal (ref 2). When the nickel-phosphorus resistor heats up, the temperature of the explosive increases to a sufficient value to cause detonation. Other mechanisms are possible (ref 3). One such mechanism is initiation by spark when the thin-film resistor becomes discontinuous. Although experimental results seem to indicate that the ignition process is thermal, further testing is necessary to verify this assumption.

Several substrate materials were investigated (ref 4). Polyethylene has to be oxidized to make it accept and bond to a metal plating, and the resultant roughened surface yielded ragged and nonuniform



conventional wire bridge initiator thin-film match-like initiator

Figure 1. Conventional and new initiator.

bridge resistors. Glass yielded bridge resistors with satisfactory appearance but was used for comparative purposes only, since glass substrates were considered less desirable for subsequent cutting and processing than a plastic. Current work involves the use of polyimide film, which, although more flexible than desired for easy processing and handling, possesses adequate surface smoothness.

There are several requirements that the thin-film bridge must meet to function effectively. It must be of such geometry that the energy available in a firing capacitor will be sufficient to raise the temperature of the bridge plus a critical volume of the explosive coating to the detonation temperature of the explosive. The bridge must be capable of withstanding this detonation temperature without becoming discontinuous for at least the induction period of the explosive. The bridge and conductor materials must not chemically react with the explosive, even after extensive storage at elevated temperatures. Finally, the match must be capable of initiating an explosive train to high-order detonation.

The purpose of this report is twofold. First, the application of the explosive to the otherwise-complete match is discussed. (General procedures for fabrication of the bridges have been presented elsewhere [ref 4] although the bridge geometries described therein do not include the square bridges included in this work.) Second, the experiments performed with the complete initiator to determine its capabilities are described and the results of these tests are presented.

2. EXPERIMENTAL METHODS

2.1 Explosive Materials

Experiments were performed with various explosives before lead styphnate was chosen for the initiator. Milled, basic lead styphnate and polyvinylalcohol (PVA) lead azide were supplied by the Naval Ordnance Laboratory, White Oak, Md. Tetracene, RDX, and PETN were obtained from Ordnance Products, Inc. North E[illegible], Md.

2.2 Preparation of Matches

2.2.1 Preparation of Explosive Slurries

The explosives were dried according to the standard procedure of D. R. Hartter (ref 5). A small sample of the dried explosive was weighed into a conductive (for safety) mixing bowl and enough binder solution added so that the resulting slurry contained approximately 1 percent by weight of binder. The binder was a solution of 1 percent polyvinylalcohol in water, i.e., 10 mg PVA/cc solution. The explosive and binder were mixed with a nonsparking spatula until a uniform slurry was obtained. In one case, 100.0 mg of basic lead styphnate was weighed into a conductive mixing bowl and 0.11 cc of the 1 percent PVA binder solution was added. The resulting slurry contained 1.1 percent binder (100 x 1.1 mg/101.1 mg).

2.2.2 Application of Explosive Slurries

After an explosive slurry was prepared as described above, the ends of the matches containing the thin-film bridge were dipped into the slurry. Using small alligator clips, the matches were hung on a wire to allow the water to evaporate. By repeating the dipping, the desired amount of explosive was placed on the bridge. In a few cases, the bridges were not at the ends of the matches but toward the center. For these cases, the explosive slurry was applied over the bridge with a small spotting tool, a piece of wire with a loop in the end.

The above-described procedure was employed in the application of slurries to bridges on polyethylene, polyimide, and glass substrates.

2.3 Testing

2.3.1 Stability of Bridge Resistance on Aging

Polyethylene-substrate units, uncoated and explosive-coated, were aged at ambient conditions. The resistances of the bridges were checked daily.

Aging tests of uncoated and explosive-coated, heat-treated and non-heat-treated, bridges on polyimide and glass substrates were carried out for at least 1000 hr at 80°C. These tests were to determine the stability of the units under accelerated aging conditions, and, especially whether heat treatment, the presence of the explosive and the type of substrate affected their stability. One-half of each group of units, polyimide substrate and glass substrate, was heat treated at 300°C for 15 min (ref 4). One-half of the units in each of these four groups was then dipped in basic lead styphnate, giving eight groups. A plate of ten samples from each group was placed in an oven at 80°C for at least 1000 hr and resistance readings were taken periodically. The aging temperature of 80°C was chosen because it is the highest temperature at which the sensitivity of lead styphnate to initiation is not changed on prolonged storage (ref 6), and it was desired to accelerate the aging as much as possible for the tests. An identical plate from each group was kept at ambient conditions as a control. Thus, for the polyimide-substrate units, one of each of the following plates was placed in the oven at 80°C and one identical plate was kept at room temperature:

(1) Heat-treated, styphnate coated;

(2) Heat-treated, no styphnate;

(3) No heat treatment, styphnate coated; and

(4) No heat treatment, no styphnate.

Eight plates of glass-substrate units were identically treated.

The oxide layer that formed on the copper leads was removed by rubbing them with a solution of ammonium chloride.

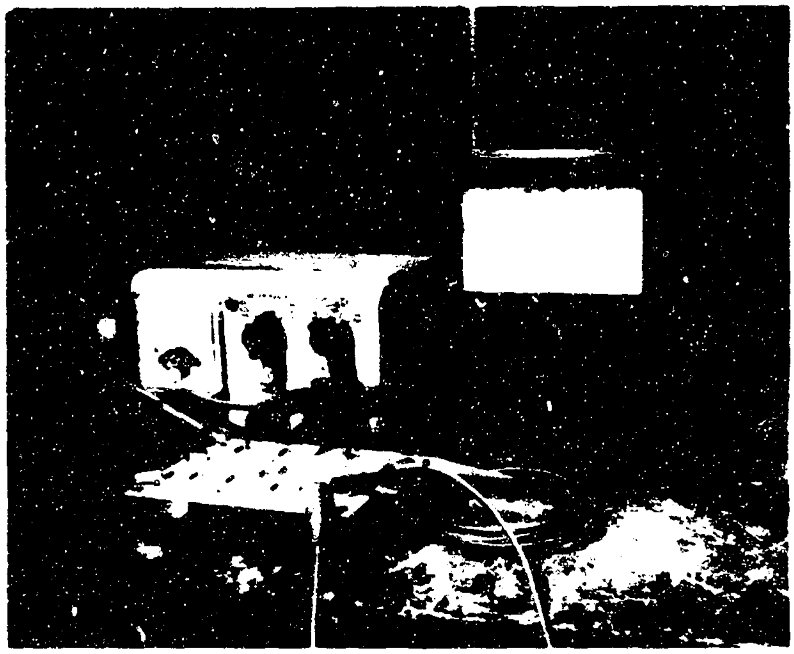
2.3.2 Detonation Apparatus

The detonation assembly is shown in figure 2. In operation, a match to be fired was placed in a plastic box to shield against the explosion, and this box was placed inside a foamed plastic shield to deaden noise, as shown in figure 2b. By means of screws in the face of the small plastic box, electrical connections were made to the 2.75-in. rocket-fuze firing-circuit (fig. 3), which was chosen to represent a possible application. The voltage required to charge the 6.8-μF firing capacitor (usually 23 V) was provided by a Hewlett-Packard variable power supply.

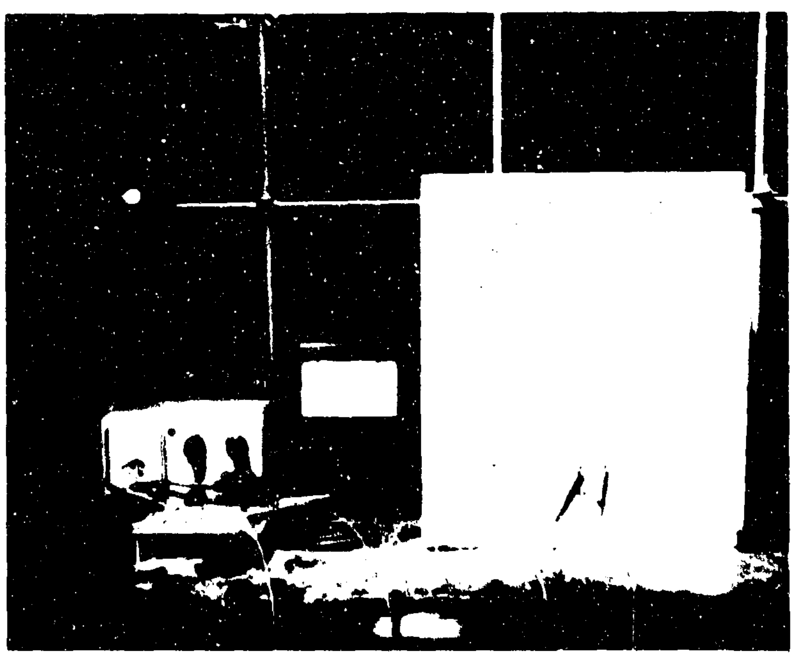
The destruction of the bridge was easily followed on a dual-beam oscilloscope equipped with a Polaroid camera. The oscilloscope was connected to the firing circuit as shown in figure 3. The upper beam recorded the voltage across the match; the deflection of the lower beam was proportional to the current passing through the match. The time required for the current to drop to zero was designated as the bridge destruction time. Figure 4 shows a typical oscilloscope trace, with a bridge destruction time of 25 μsec. The initial spike in the current trace is due to lead inductance in the circuit and is of no significance.

2.3.3 Energy Output by Dent Test

A program was initiated to measure the explosive energy output of the match-like initiator. The matches were placed against a 65-mg M-6 lead azide relay, which in turn was connected to a tetryl lead. After placing this train against a standard aluminum dent block (ref 7), and firing the match with the firing circuit described in section 2.3.2, the order of detonation was determined by measuring the depth of dent in the block.



a. Power supply, ohmmeter and, firing circuit.



b. Circuit connected to test sample in plastic box.

Figure 2. Apparatus for detonating thin-film-bridge initiators.

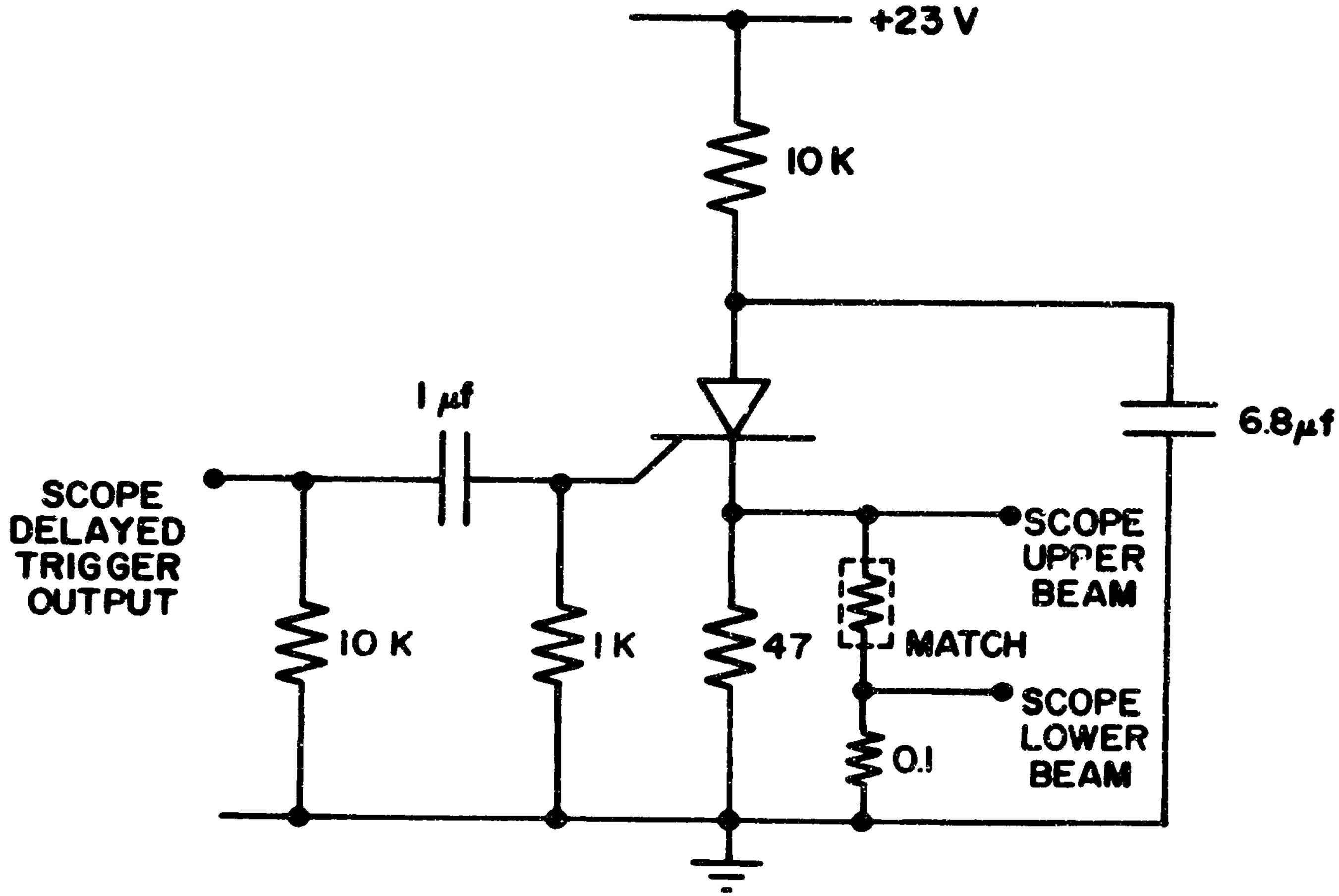


Figure 3. Rocket-fuze firing circuit used to detonate match-like initiators.

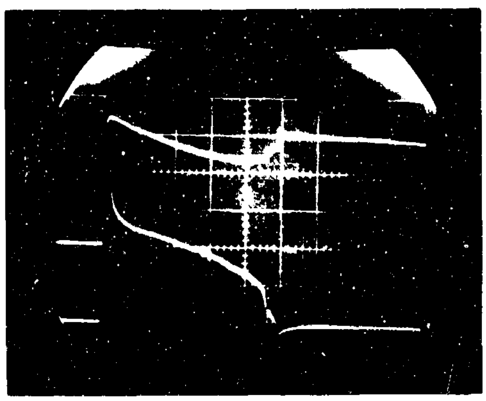


Figure 4. Typical oscilloscope trace of the destruction of a match-like initiator-bridge. The sweep speed is 5μs/cm; the upper trace is the bridge voltage at 5V/cm; the lower trace represents the bridge current at 1A/cm (0.1V/cm across a 0.1-Ω resistor).

2.3.4 Bridge Geometry Versus Firing Voltage

Firing tests on the matches were conducted using the firing circuit described in section 2.3.2. The main purpose of this test was to determine if a match having a certain resistance and bridge geometry would initiate the explosive. Each match was tested first at a firing voltage of 23 V (this is the value used in the 2.75-in. rocket fuze). If detonation did not occur, higher voltages (up to 30 V, the maximum of the power supply) were sometimes tried.

For some of these tests, oscilloscope traces of the voltage and current were obtained. They provided information on how fast the bridge was destroyed, and thus the energy required to initiate the explosive for each geometry. These data aided in determining the optimum bridge geometry. However, interpretation of results was complicated by the fact that, in some cases, the bridge was destroyed by simply burning out without initiating the explosive. For the tests that were not instrumented, only GO or NO-GO results were obtained — the explosive was or was not initiated.

3. DISCUSSION OF RESULTS

3.1 Stability of Bridge Resistance on Aging

3.1.1 Polyethylene Substrates

Thin-film bridges prepared on 20-mil-thick high-density polyethylene using a human-hair pattern (ref 4) were generally very crude; the edges of the bridge were not well defined. If the resistance of such 2-by 5-mil bridges were initially below 5 ohms, they were relatively stable on room temperature aging. However, higher initial resistance values led to drastic changes on room-temperature aging, sometimes as much as 100 percent in one day, and always to a higher value.

Bridges 6 by 12 mils in area, made from a photographic pattern (ref 4), showed better definition but ragged edges were still present. Groups of these units, either non-coated or explosive-coated, when kept at ambient conditions for several months, showed an undesired increase in resistance. Like the samples with less well defined bridges, those samples that had an initial low resistance tended to be much more stable.

3.1.2 Polyimide and Glass Substrates

To get better definition of the bridge resistors, and thus matches with stable resistances, polyimide film, which has a very smooth surface, was tried as a substrate. A further advantage of polyimide is its stability at high temperature, which allowed the bridges to be heat treated to approximately 300°C (ref 4) before the explosive was applied. Past experience indicated that heat treatment tends to stabilize thin-film resistors. A disadvantage of the polyimide is that it is available in a maximum thickness of only 5 mils; therefore, matches made using this substrate lack rigidity.

The resistance of bridges aged at 80°C appeared to increase, but it was subsequently discovered that the oxide layer that formed on the copper leads caused the increase; hence, it was removed. Table I shows the average resistance values for the cleaned, polyimide-substrate matches that were aged for 1300 hr (many had been fired after 1000 hr aging). These results show that the only significant resistance changes occurred in the group of polyimide-substrate matches that had been heat-treated at 300°C, not styphnate-coated, and aged in the oven. No reason can be given for this change. A comparable group on glass substrate showed no significant change. However, from the results of this aging test it is reasonable to conclude that heat treatment is not necessary and, in fact, may be undesirable. Therefore, the high temperature properties of polyimide are not essential. As mentioned previously, matches made on polyimide substrates are thin and flexible. Because this could conceivably cause manufacturing and assembly problems, it may be desirable to substitute a more rigid material that still possesses a smooth surface.

Matches on glass substrates showed the same slight increase in resistance when aged at 80°C, again probably due to oxide formation. No anomalously large resistance change occurred for any of the glass-substrate matches. Matches kept at room temperature showed no resistance change. The oxide was not removed from the glass substrate matches because they were included in the test only to determine whether the substrate influenced the aging effect, and no significant aging effect was observed.

3.2 Energy Output by Dent Tests

Table II shows the results of nine tests made to determine the output of the initiator. High-order detonation was attained with a firing voltage of 23 V one out of two times when two lead azide relays were used in front of the tetryl lead. The other time it was necessary to use 110 V to initiate the match due to high bridge resistance; however, detonation was high order. Also, when only one lead azide relay was used, high order detonation occurred once out of seven attempts using a firing voltage of 23 V.

The limited number of dent tests shows that matches coated only with basic lead styphnate will initiate a lead azide relay. No attempts were made to control the amount of explosive placed on the match. In addition, the explosive train (match, lead azide relay, and tetryl lead) was only taped together. This assembly certainly did not take advantage

Table I. Results of 1300-hour aging tests on polyimide-substrate initiators

	No. in group	Average resistance, Ω		
		Before aging	After aging	Percent change
<u>Group aged at 80°C</u>				
Styphnate coated, heat treated	6	5.60	5.63	+0.5
Styphnate coated, not heat treated	7	5.99	6.04	+0.8
No styphnate, heat treated	13	5.75	7.41	+29
No styphnate, not heat treated	14	6.05	5.99	-1.0
<u>Group aged at room temperature</u>				
Styphnate coated, heat treated	4	5.45	5.60	+2.8
Styphnate coated, not heat treated	8	3.56	3.53	-0.8
No styphnate, heat treated	10	5.66	5.74	+1.4
No styphnate, not heat treated	10	3.80	3.85	+1.3

Table II. Depth of dent tests on polyimide-substrate initiators

Bridge resistance (ohms)	Explosive on match	Number of lead azide relays	Firing voltage (V)	Results	Dent (mils)
9	Basic lead styphnate	1	23	Go—high order	48.0
12	Basic lead styphnate	1	23	Styphnate burned; did not initiate azide relay	--
28	Basic lead styphnate	1	23(a) 110(b)	No go Go—low order	-- 1.6
15	Basic lead styphnate	1	23(a) 110(b)	No go Go—low order	-- 2.3
8	Basic lead styphnate	1	23	Go—low order	5.0
8	Basic lead styphnate	1	23	Go—low order	3.7
7	Basic lead styphnate	2	23(a) 110(b)	No go Go—high order	-- 57.0
13	Lead styphnate, lead azide, and tetrazene	1	23	Go—low order	4.3
18	Lead styphnate, lead azide, and tetrazene	2	23	Go—high order	59.0

of the full explosive output from the match. Under more controlled test conditions, it may be found that the match-like initiator will reliably initiate an explosive train to high-order detonation.

3.3 Bridge Geometry Versus Firing Voltage

3.3.1 Polyethylene Substrates

As mentioned previously, thin-film bridges on 20-mil-thick polyethylene were generally very crude; the edges of the bridge were not well defined. Firing test results for lead styphnate-coated matches having a 2- by 5-mil bridge-resistor pattern, with the 2-mil dimension defined by a human hair, are shown in figure 5. A firing voltage of 23 V was used throughout these tests. The resistance values were chosen to be close to those for the T-77 wire-bridge initiator, but sufficiently varied to determine the effect of such variations on initiation. None of the matches with a resistance above 15 ohms would initiate the explosive, whereas matches in the 1- to 5-ohm resistance group exhibited 100-percent detonation. Several matches were dipped in PVA lead azide. None of the matches would initiate this explosive, so all further work was carried out using basic lead styphnate as the primary dip.

Figure 6 shows the percent detonations as a function of resistance for matches with 6- by 12-mil bridge resistors made by means of a photographic pattern. A higher percentage of these matches detonated but stability of the bridge resistance was still a problem.

Various high explosives were applied over several of these 6- by 12-mil bridge-resistor matches after the usual application of basic lead styphnate. Match-like initiators dipped in styphnate, azide, and then either RDX, PETN, or tetracene, detonated all three charges easily. Consecutive dips of styphnate and RDX were also detonated. When PETN was applied directly on the styphnate and the match fired, the PETN did not detonate.

3.3.2 Polyimide Substrates

A qualitative firing test was made using 6- by 12-mil bridges laid down on polyimide and covered with basic lead styphnate. These matches fired reliably at 23 V when their resistance was about 6 to 7 ohms.

The results of extensive firing tests of bridges of increasing areas on polyimide substrates are shown in table III. If the explosive did not initiate at 23 V, and the bridge did not burn out, the voltage was raised and the match fired again. This was repeated until the match fired, or the maximum voltage of the power supply, 30 V, was reached.

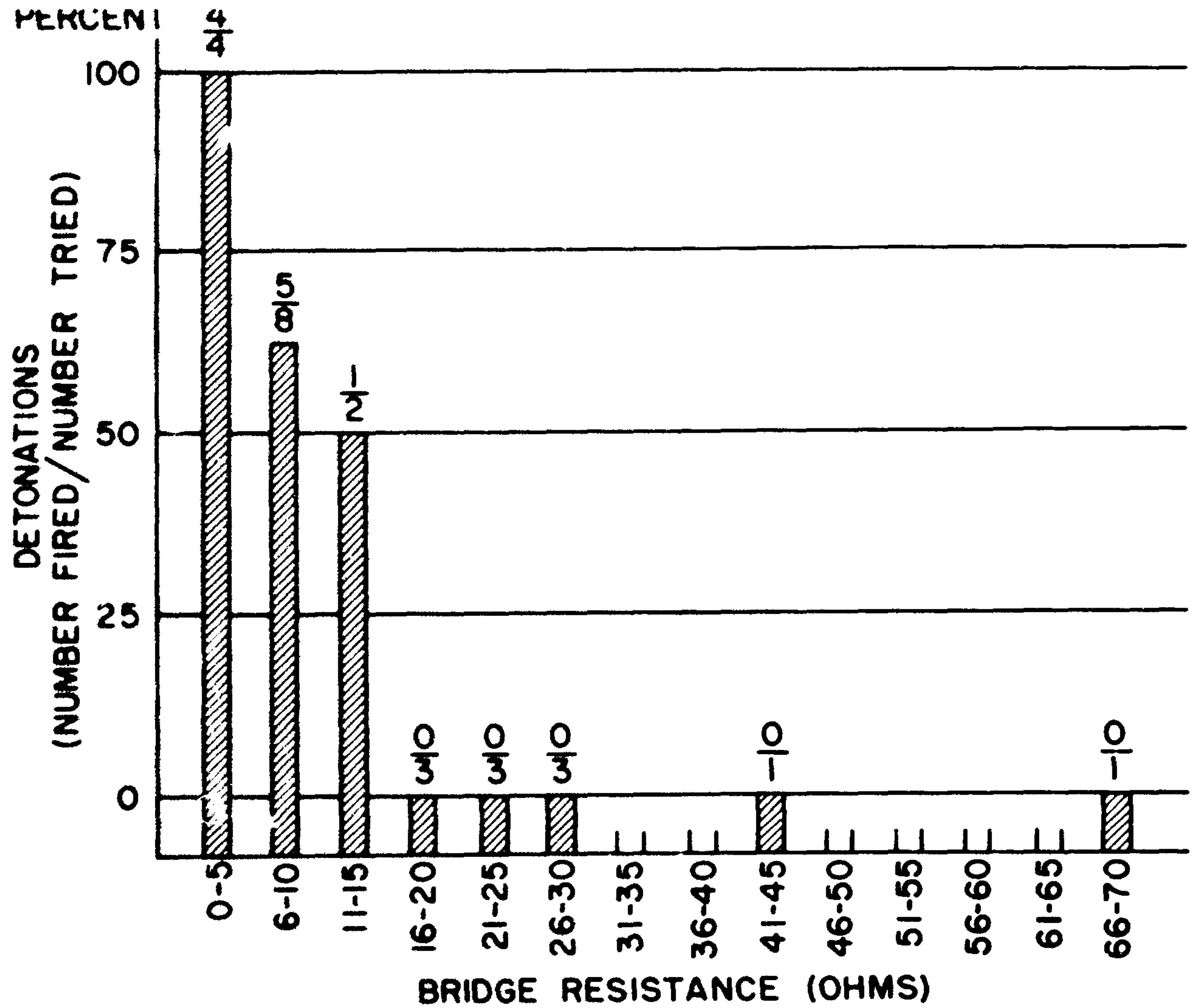


Figure 5. Percent detonations as a function of bridge resistance for 2 x 5 mil nickel resistors on 20-mil-thick high-density polyethylene substrates.

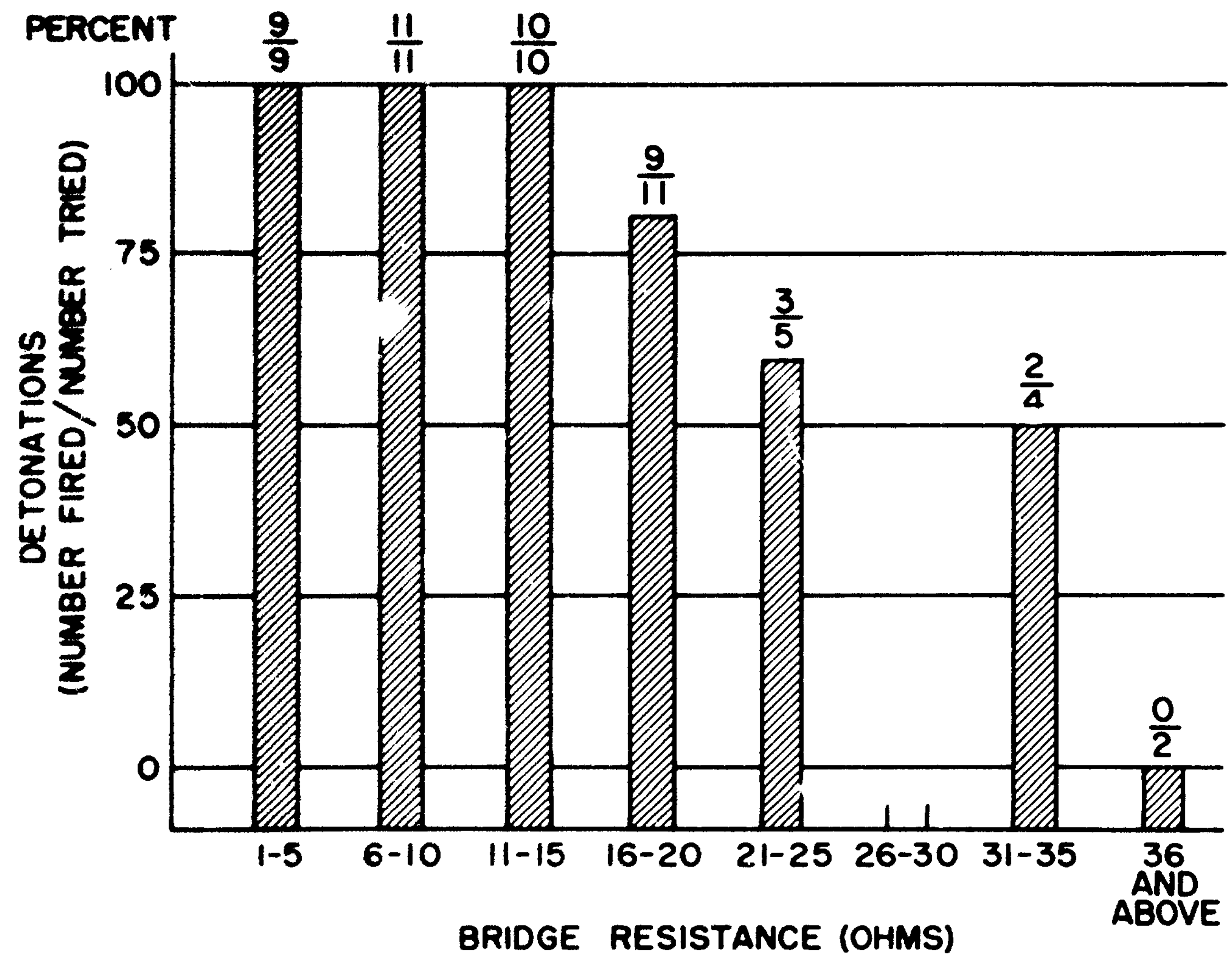


Figure 6. Percent detonations as a function of bridge resistance for 6 x 12-mil nickel resistors on 20-mil-thick high-density polyethylene substrates.

Table III. Firing test results on bridges on polyimide-substrate initiators

Area (mils)	Resistance (ohms)	Firing voltage (V)	Firing results	Destruction time (μsec)
5 x 5	4.5	23	Go	3.0
"	4.5	"	Go	2.5
"	5.5	"	Go	1.4
"	5.8	"	Go	1.2
"	5.8	"	Go	1.8
"	6.0	"	No go(a)	0.2
"	7.0	"	Go	2.0
"	7.5	"	Go	1.7
"	8.0	"	Go	--
"	8.5	"	Go	3
"	8.5	"	Go	--
"	8.5	"	Go	2.3
"	11.7	"	Go	--
"	12.0	"	No go(a)	--
"	12.8	"	No go(a)	--
"	15.0	"	Go	1.0
"	21.0	"	Go	--
"	26.5	"	Go	3
"	28.0	"	Go	1.0
10 x 10	4.5	23	Go	--
"	5.0	"	Go	12.0
"	6.0	"	Go	6.0
"	6.8	"	Go	--
"	7.0	"	Go	3.0
"	7.5	"	Go	7.0
"	8.0	"	Go	9.0
"	8.5	"	Go	7.0
"	8.5	"	Go	5.6
"	9.0	"	Go	6.2
"	9.2	"	Go	0.4
"	9.5	"	Go	5.6
"	10.0	"	Go	--
"	11.0	"	Go	3.8
"	12.0	"	Go	8.0
"	13.8	"	Go	--
	13.8	"	Go	--
"	23.0	"	Go	4.0
"	25.0	"	Go	3.0

Note: Footnotes appear at end of table.

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Table III. Firing test results on bridges on polyimide-substrate initiators—(Cont'd)

Area (mils)	Resistance (ohms)	Firing voltage (V)	Firing results	Destruction time (μsec)
20 x 20	4.0	23	No go	--
	4.0 (b)	30	Go	>90
"	4.5	23	No go	--
	4.5 (b)	30	No go	--
"	5.0	23	No go	--
	5.0 (b)	27	No go	--
	5.0 (b)	30	No go	--
"	5.5	23	No go	--
	5.5 (b)	30	Go	≫9
"	6.0	23	No go	--
	6.0 (b)	27	No go	--
	6.0 (b)	30	Go	>>9
"	6.0	23	No go	--
	6.0 (b)	30	Go	>90
"	6.5	23	No go	--
	6.5 (b)	30	Go	38.0
"	6.5	23	No go	--
	6.5 (b)	27	Go	70.0
"	8.0	23	Go	11.0
"	9.0	23	Go	18.0
"	10.0	23	No go	--
	6.0 (b)	30	Go	22.0
"	10.5	23	No go	--
	7.0 (b)	30	Go	>45
"	12.5	23	Go	>45
"	13.0	23	No go	--
	12.5 (b)	25	No go	--
	12.5 (b)	27	Go	--
"	13.2	23	No go	--
	13.2 (b)	27	Go	--
"	13.3	23	Go	8.0
"	13.4	23	No go	--
"	20.0	23	Go	6.0
"	21.0	23	Go	--
"	30.0	30	Go	2.0
40 x 40	4.2	23	No go	--
	4.2 (b)	30	No go	--
"	4.3	23	No go	--
"	4.4	23	No go	--
"	4.4	23	No go	--
	4.4 (b)	30	No go	--

(Cont'd on next page)

Table III. Firing test results of bridges on polyimide-substrate initiators —(Cont'd)

Area (mils)	Resistance (ohms)	Firing voltage (V)	Firing results	Destruction time (μsec)
40 x 40	4.5	23	No go	--
	4.5 (b)	30	No go	--
"	4.5	23	No go	--
	4.5 (b)	30	No go	--
"	12.0	23	No go	--
	12.0 (b)	25	No go	--
	12.0 (b)	27	No go	--
	12.0 (b)	30	No go	--
"	12.0	23	Go	--
"	13.2	23	No go	--
"	14.4	23	No go	--
	14.4 (b)	30	No go	--

(a) Bridge burned out

(b) Indicates resistance after pulsing at previous voltage.

Definition of these bridges was obtained by using a square photographic pattern. The area of the bridge was varied in an attempt to find the optimum bridge size. Resistance values were chosen on the basis of experience gained with the polyethylene matches.

In most cases the matches with 5- by 5-mil bridges initiated the explosive at 23 V. For the three cases in which initiation did not occur, the bridges themselves became discontinuous. This indicates that the energy required to burn out the 5- by 5-mil bridge is about the same, and sometimes less, than that required to initiate the explosive. Destruction times for these bridges were always 3 μsec or less.

All matches with 10- by 10-mil bridges detonated at 23 V. The destruction times varied from 3 to 12 μsec. Apparently, heat flow for this geometry is such that enough energy is transferred to the explosive to initiate it before the bridge becomes discontinuous. Thus, the 10- by 10-mil geometry looks promising for an application with the 2.75-in. rocket fuze or similar firing circuit.

Matches having 20- by 20-mil bridges usually would not fire at 23 V; in fact, only 30 percent detonated at this voltage. In contrast to matches with 5- by 5-mil bridges, which either burned out or fired at 23V, matches with 20- by 20-mil bridges that did not fire at this voltage changed very little in resistance. This indicates that the energy supplied to the bridge was dissipated before the heat could damage the bridge resistor. As the voltage was raised, more energy was supplied to the resistor, and most of the remaining matches with 20- by 20-mil bridges initiated the explosive at 30 V. The bridge destruction times for these matches varied but usually were over 20 μsec.

Ten matches with 40- by 40-mil bridges were fired. One match detonated at 23 V, but the remaining matches would not initiate the explosive or burn out even when the voltage was raised to 30 V. Again, the energy supplied to the resistor was dissipated before initiation of the explosive could take place. The one match that initiated the explosive at 23 V probably had a flaw in the resistor, effectively lowering the bridge area.

In summary, the 10- by 10-mil bridges produced 100-percent detonations. The 40- by 40-mil bridges were essentially 100-percent NO-GO. The 5- by 5-mil and the 20- by 20-mil bridges were borderline cases. Thus, the optimum geometry for this application must be close to 10- by 10-mils. Bridge destruction times for the 10- by 10-mil resistors were all between 3 and 12 μsec. Smaller resistors had shorter destruction times and larger resistors had longer destruction times, as would be expected.

Although other ignition mechanisms are possible, it is thought that the ignition process of the match-like initiator is thermal. According to this theory (ref 8), initiation will occur if enough energy is conducted to the explosive to heat a large enough portion of it (critical volume) to a high enough temperature (critical temperature), and keep it at that temperature for a sufficient length of time (induction period). As the total energy released by the bridge is constant for a bridge of a given resistance, the temperature rise in the explosive will vary with the bridge geometry, because the volume over which the heat is distributed is proportional to the bridge area. If this area is too large, the temperature in the explosive will never reach the critical temperature. On the other hand, if the bridge area is too small, the temperature rise within the resistor itself will be so great that the nickel-phosphorous alloy film itself may become discontinuous, cutting off the flow of heat into the explosive before enough of it can reach and maintain the critical temperature for a sufficient length of time. It should be pointed out that the critical temperature and volume, and the induction period, are all interrelated, but this does not affect the validity of this discussion.

If the foregoing assumptions on the ignition process are correct, the firing test results are readily explainable. In the case of many of the 5- by 5-mil bridges, the resistor itself became discontinuous, because of the high temperature reached, before enough explosive could be heated.

Resistors made with the 40- by 40-mil pattern would not initiate the explosive, and no resistance change was noted, even at 30 V. Here, energy was supplied to a large area, resulting in a smaller temperature rise; therefore, initiation did not occur. Furthermore, the energy delivered was insufficient to heat the resistor to a temperature that would cause a resistance change.

Matches having a 20- by 20-mil bridge were borderline between GO and NO-GO. Several matches that were fired at 23 V but did not initiate the explosive showed an increase in resistance. This indicates that enough energy was supplied to damage the resistor but not enough to heat the explosive to a sufficiently high temperature.

Every polyimide match with a 10- by 10-mil bridge resistor initiated the explosive at 23 V. The energy supplied to this resistor is not great enough to cause burnout before a hot spot of the critical temperature and dimensions can be created.

Depending on the energy rel[illegible] [illegible]her firing circuits will require thin-film resistors of compatib[illegible] [illegible]ea. In other words, there is an optimum bridge-area-to-energy ratio for each combination of match-like initiators and firing circuits. Thus, the 10- by 10-mil initiator may not function properly if another firing circuit is used.

3.4 Future Work

Copper reacts with lead azide in the presence of moisture to form an extremely sensitive copper azide (ref 6). Although lead azide is not placed directly on the match, it will be present in the explosive train. For this reason, attempts will be made to replace the copper leads with a tin-lead alloy. Since this is not a basic change, no difficulties are anticipated.

A more extensive program is being planned to determine the explosive energy output of the match-like initiator. This study will establish the capabilities of the match.

To evaluate the assumption that the initiation mechanism is thermal, matches with smaller bridge areas will be fired. If these matches fire at lower voltages, the initiation mechanism must be thermal rather than a spark.

Other explosive slurries, such as normal lead styphnate — Egyptian lacquer, will be tried in an attempt to lower the sensitivity to initiation.

The high-temperature properties of polyimide are not needed; therefore, other more rigid, and hence more readily processible, substrates will be considered.

4. CONCLUSIONS

(1) Heat treatment of the bridge-resistors was not necessary to produce matches with stable resistances, even under accelerated aging conditions.

(2) Match-like initiators spotted with basic lead styphnate were capable of initiating a lead-azide relay.

(3) The optimum bridge geometry for the match-like initiator, using the 2.75-in. rocket-fuze firing-circuit at 23 V, was 10- by 10-mils.

(4) Further testing is planned to determine the most suitable substrate, optimum bridge geometries for lower firing voltages, the output capabilities of the initiator, and a replacement for the thin-film copper leads.

5. REFERENCES

(1) Apstein, M., "Electric Initiator," U.S. Patent Appl. Ser. No. 665,692.

(2) Lucey, G.K., HDL Report No. TR-1376, "Low-Power Explosion of Thin-Film Resistors," January 1968.

(3) Clark, S.A., "Thin-Film Electric Initiator, IV. Mechanism of Explosion," HDL report TR-1415.

(4) Hebb, E.L., "Thin-Film Electric Initiator, I. Fabrication of Cu/Ni Bridges," HDL report TR-1412.

(5) Hartter, D.R., "Department of the Army, HDL Standard Operating Procedure," SOP-910-65-2, Sept. 65.

(6) Ordnance Engineering Design Handbook 177, Explosives Series, "Properties of Explosives of Military Interest," Section 1, May 60.

(7) MIL-STD-331, "Detonation Output Measurement by Steel Dent," 10 Jan 1966. (Aluminum dent block was substituted for the steel).

(8) Bowden, F.P. and Yoffe, A.D., "Initiation and Growth of Explosives in Liquids and Solids," Cambridge University Press, New York, 1952.

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13. ABSTRACT

The match-like electric initiator is a chemically deposited thin-film-bridge version of the conventional hot bridge-wire initiator and is being developed to effect a cost-saving and an increase in shock resistance. This report describes the application of the explosive to the bridge and the performance and aging tests of the completed initiator.

Initiators having 10-by 10-mil bridges on polyimide substrates were uniform and stable and were consistently fired when pulsed by the XM429 rocket-fuze firing circuit, using 23V. They did not change in resistance during a 1300-hr aging test at 80°C. Qualitative energy output tests indicated that the device is capable of initiating a lead azide relay.

More extensive performance tests are planned. Some modifications, including a stiffer substrate, a replacement for the thin-film copper leads, and smaller bridge geometries for lower firing voltages will be tried.

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