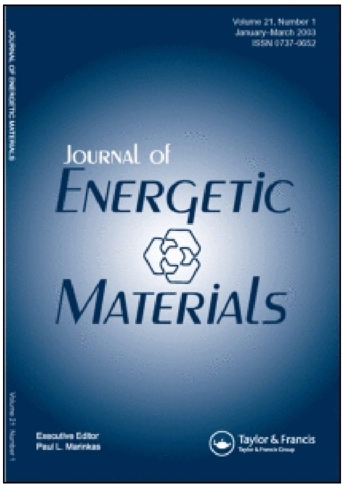

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THE ORIGIN OF PERFORMANCE DIFFERENCES BETWEEN TWO CONDUCTING COMPOSITION (CC) PRIMERS

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ABSTRACT

Performance of model CC primers based on production M52 DEFA and M52A3B1 primers are compared. The relationships between the carbon black content and experimental parameters resistance, resistance spread, energy sensitivity and functioning times are determined. Although both types of primer have comparable energy sensitivity at equal carbon black content, resistances are much higher and functioning times longer for the M52A3B1 type. It is suggested that the longer functioning times result from a slower buildup to fast burning following ignition. The consequences of this for developing a CC primer with low energy sensitivity are outlined.

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INTRODUCTION

Electrical initiation is one of the most common methods employed for ignition of propellant and explosive trains. In this process, electrical energy is degraded to heat which in turn raises the temperature of a small quantity of (usually primary) explosive above its ignition temperature, resulting in ignition. Although various systems could be designed to achieve this, in practice two systems are used almost exclusively: bridgewire (BW) and conducting composition (CC). A BW device consists of a small metallic filament connected across two electrodes and embedded in pressed or plastic bonded explosive. Passage of current heats or explodes the filament and ignites the explosive. CC devices have two electrodes separated by a gap across which is pressed an explosive composition made conductive by admixture of (usually) graphite. Passage of current above a threshold level results in ignition.

The electrical characteristics of both types of devices depend on a number of variables such as electrode configurations, pressing load, filament properties (for BW) and the percentage and physical properties of the conducting material (for CC). In practice, it has been much more difficult to control these parameters for CC systems, resulting in production batches having a wide range of resistances and consequently considerable variation in electrical sensitivity. Despite these technical limitations, CC devices are cheap to produce, robust, operate reliably under extremes of climate, have fast functioning times and can be designed to be very sensitive e.g., reliable function from about 100 μJ. The major application for CC devices is in cartridge case primers for high rate of fire small calibre munitions and fast reaction time/limited power supply electronic fuzes.

CC Primers fall into two broad types based on their fillings. This is illustrated in Table 1 by the M52 DEFA and M52A3B1 Primers. The M52 DEFA, of French design, consists of a conducting increment of lead styphnate/graphite, which is pressed in first, followed by a larger priming increment. The M52A3B1, of US design, consists of a single multi-component filling which serves the dual purpose of initiation and priming. Both types of primers have been in use for over 30 years and the current filling are largely unchanged from the original formulations. Production primers characteristically have wide resistance spread and high sensitivity to ignition by capacitor discharge, with energies for 50% functioning probability generally being below 100 μJ (Table 1)

At MRL we have been undertaking a study to develop a CC primer for 20 mm ammunition which meets the performance specifications of the M52A3B1 but with significantly lower sensitivity than either the M52A3B1 or M52 DEFA. As such it was necessary to understand the origin of performance differences between these two types of primer. This paper presents the results of this investigation.

TABLE 1

A COMPARISON OF REPRESENTATIVES OF THE TWO BASIC TYPES OF CC PRIMERS IN CURRENT SERVICE USE

	M52 DEFA		
Component/Parameter	Conducting Increment	Priming Increment	M52A3B1
Lead styphnate (%)	95.0-95.5	48	40 ± 2.5
Graphite (%)	4.5-5.0	2	
Acetylene black (%)			0.75 ± 0.25
Barium nitrate (%)		12	44.25 ± 2.5
Potassium perchlorate (%)		28	
Calcium silicide (%)		10	13.0 ± 2.5
Gum arabic/styphnic acid (%)			1.0 ± 0.25 ea
Total mass (mg)	30	160	170
Resistance Specification (Ω)	20-250		1 k - 1.2 M
Sensitivity to capacitor discharge (50% level, μJ)	60-120[a]		38 - 56[b]

[a] Data from Ref. 1

[b] Data from Ref. 2

MATERIALS

All particle sizes quoted below were determined on a Malvern particle size analyser. Lead styphnate was type RD1303 with average particle size of 115 µm, prepared as a single batch at MRL.

Carbon black was Tintacarb 140 obtained from Australian Carbon Black. The material as received was passed through a 106 µm sieve to break up balled agglomerates. Average particle size was 9.5 µm. Graphite used in the DEFA primer mix was a 1:1 mixture of Merck synthetic and NK natural obtained from MFF St. Marys.

Barium nitrate was a commercial sample which was ground and passed through a 150 µm sieve then a 106 µm sieve. The material used was a 1:1 mix of material retained on and passed through the 106 µm sieve. Calcium silicide was a commercial sample which was passed through a 75 µm sieve. Potassium perchlorate was a commercial sample which was milled and passed through a 125 µm sieve. Styphnic acid and gum arabic were commercial samples used as received.

Unfilled M52 DEFA primer bodies were from a standard production lot from MFF St. Marys. Production M52 DEFA primers were obtained from MFF St. Marys and M52A3B1 primers from Dynamit-Nobel.

Preparation of M52 DEFA (Type) Primers

Lead styphnate and carbon black were weighed separately in the correct proportions to give a total of 2 g. The materials were then placed on a sheet of paper and fold-mixed until the mixture appeared to be homogeneous.

Experimental primers for measuring energy sensitivity (capacitor discharge) were prepared by pressing the lead styphnate/carbon black mix (46 ± 0.5 mg) into an empty M52 DEFA primer body using an Eltor press at a pressure of 123 MPa (400 kg dead load). Lead nitrate (185 ± 15 mg) was then added on top and pressed at the same pressure. The lead nitrate serves to reproduce the consolidation of a priming increment while minimizing total explosive content.

Experimental primers for measuring functioning times were prepared by pressing the lead styphnate/carbon black mix (46 ± 0.5 mg) as above followed by DEFA primer mix (145 ± 1 mg), prepared as in Table 1, at the same pressing load.

Note that the masses of conducting and priming mixes differ from those for production M52 DEFA (Table 1). In the production method the conducting and priming increments are added successively followed by pressing. It was decided to press each increment separately for greater reproducibility, hence a large conducting increment and smaller priming increment were chosen.

Preparation of M52A3B1 (Type) Primers

An M52A3B1 type primer mix was made using the ingredients detailed in Table 1 but omitting acetylene black. Portions of this mix and carbon black were weighed separately in the correct proportions to give a total of 2g, then fold-mixed on a sheet of paper till the mixture appeared homogeneous.

Experimental primers for measuring energy sensitivity were prepared in M52 DEFA primer empties from these mixtures (46 ± 0.5 mg) and lead nitrate (185 ± 15 mg) exactly as described for the M52 DEFA primers.

Experimental primers for measuring functioning times were prepared by adding the prepared mixture (175 ± 1 mg) to an M52 DEFA empty then pressing twice at 123 MPa.

METHODS

Resistance Measurements

Resistances were measured using a Hioki 3208 Calcu Hi Tester.

Functioning Times

A firing box designed to meet the test specifications of the M52A3B1[3] was constructed at MRL. The basic components of the system are a 160V power supply to charge the 2 μF capacitor and a specially constructed timer to terminate the output pulse from the capacitor after 10 μs. Fast application of energy was achieved by a mercury wetted relay switch. Functioning times were measured using a microsecond timer triggered by a synchronised pulse from the firing box for start and the output from a PBX 25 photocell for stop.

Sensitivity to Capacitor Discharge (Energy Sensitivity)

The firing box used here consisted of a 0.1 μF capacitor which could be charged from 0-300V. Fast application of energy was achieved by a mercury wetted relay switch. The testing procedure was the Bruceton staircase method[4] for sample sizes of 20-25 primers, using constant log(energy) increments of 0.05 or 0.10, or the Probit method[5] for batches of 100-125 primers.

High Speed Photography

The mixes for which burning rates were to be determined were pressed into perspex tubes on a bridgewire device, full details of which have been published previously[6]. The actual devices used were 4.12 mm internal diameter and the bridgewire was nichrome giving a resistance of about 1 Ω. The devices were fired by capacitor discharge (2 μF, 270V) and photographed using a Cordin model 330 ultra-high speed rotating mirror camera operating in the streak mode.

RESULTS AND DISCUSSION

Resistances, energy sensitivity data and functioning times are detailed in Table 2 for lead styphnate mixes containing 1 - 5% carbon black, and M52A3B1 mixes containing 0.75 - 5% carbon black. Data for production M52 DEFA and M52A3B1 primers are also shown for comparison.

Reduction in carbon black content in the lead styphnate mixes results in substantial increases in the resistance with corresponding decreases in the energy required for 50% functioning probability. A particular feature bestowed by this carbon black is the low standard deviations for the resistances. Functioning times also initially decrease but then increase again for 2 and 1% carbon black. Times for the 4% and 3% mixes are about 10% higher than production M52 DEFA primers, but no attempt has been made to optimise this parameter. The 95:5 and 96:4 mixes, which are nominally analogous to M52 DEFA, have quite different resistance and energy sensitivity to production M52 DEFA (Tables 1 and 2). This arises because both the lead styphnate and conducting materials differ from those used in M52 DEFA.

In comparison with the corresponding lead styphnate mix, the M52A3B1 mixes exhibit substantially greater resistances and resistance ranges, but comparable energy sensitivity. However one difference is immediately evident: functioning times reduce drastically when the carbon black content changes from 5% to 1%. The 5% M52A3B1 mix in fact does not pass the specification of function in less than 0.3 ms, and about 16% of the primers failed to fire from the energy delivered. Production M52A3B1 primers function about 10% more quickly than the M52A3B1 type mix

TABLE 2

PERFORMANCE DATA FOR M52 DEFA AND M52A3B1 TYPE PRIMERS

Composition	Resistance [std.dev.] (Ω)	Energy Sensitivity[f] (μJ)	Functioning Times [std.dev] (ms)
Lead Styphnate/Carbon Black			
95:5	9.1 [0.7]	1565	0.059 [0.005]
96:4	14.0 [1.0]	1330	0.049 [0.004]
97:3	24.3 [2.4]	740	0.048 [0.006]
98:2	82.0 [6.6]	215	0.061 [0.012]
99:1	2567 [460]	130	0.061 [0.008]
M52A3B1 Primer (Type)[a]/ Carbon Black			
95:5	16.4 [4.1]	1445	0.301 [0.036][g]
97:3	73.5 [15.1]	650	0.187 [0.053]
98:2	550.6 [162.3]	280	0.154 [0.038]
99:1	449 K [571 K]	210	0.091 [0.024]
99.25:0.75	9/20 11.4 M 11/20 > 20 M	160	0.108 [0.035]
M52 DEFA Primer (production)[b]	76.6 [22.0]	104	0.043 [0.005]
M52A3B1 Primer (production)[c]	121.7 K [57.2 K]	60	0.081 [0.012]
Composite Primer[d]	19.3 [2.5]	not determined	0.058 [0.006]
M52 DEFA Primer Mix[e]	20/20 > 20 M	580	0.052 [0.021]

[a] Nominal composition per Table 1.

[b] From standard production batch ex MFF St. Marys.

[c] From standard production batch ex Dynamit-Nobel

[d] Lead styphnate/carbon black (96:4, 46 mg) then M52A3B1/carbon black (98:2, 145 mg): see text.

[e] Filling as described under "Priming Increment" in Table 1.

[f] For 50% function as obtained by standard Bruceton[2] or Probit[3] analysis.

[g] 2/12 failed to function.

containing 1% carbon black but again no attempt was made to optimize this parameter. Differences between the production M52A3B1 primers (containing 0.75% acetylene black) and the 1% and 0.75% carbon black experimental mixes are largely attributable to the different conducting properties of acetylene and carbon blacks, and the different lead styphnate types.

The reason that such low carbon (acetylene) black contents must be used in production M52A3B1 primers, with the consequent penalties of very high resistances, wide resistance spread and low threshold firing energies, can thus be identified: to achieve desirably short functioning times. The slower functioning times for the M52A3B1 relative to the M52 DEFA type primers containing the same carbon black percent content could result from two sources, ie either the M52A3B1 mix is slower burning, or slower igniting. A comparison of the standard M52A3B1 composition and the M52 DEFA priming mix (Table 1) suggests that the former might be at least part of the answer. The M52 DEFA priming mix contains 20% more lead styphnate, which is very fast burning, and the more energetic potassium perchlorate while the M52A3B1 contains the less energetic barium nitrate.

An attempt to resolve this question was made by preparing experimental "composite" primers consisting of a lead styphnate/carbon black (96:4) conducting increment with an M52A3B1/carbon black mix (98:2) as priming increment. As expected the "composite" primer was significantly faster than the straight M52A3B1/carbon black (98:2) primer (0.058 vs 0.154 ms) but was almost as fast as the 96:4 M52 DEFA primer (0.048 ms). This suggests that much of the slowness of M52A3B1 type primers results from slow transition from ignition to fast burning, with differences in burning rates between the two priming compositions being only a secondary influence. A primer filled only with M52 DEFA priming mix (Table 2) functions as fast as the composite M52 DEFA primers hence slow ignition is not a universal problem in these mixes.

Further investigations were carried out using ultra-high speed photography. Three mixes were studied: M52 DEFA priming mix, M52A3B1 mix containing 2% carbon black, and lead styphnate containing 2% carbon black. However using the equipment available to us (see Experimental), only the DEFA priming mix gave light output sufficient to produce a usable trace. A burning rate of about 560 m/s was obtained. Leopold and McVaney[7] had observed in 1963 that burning lead styphnate does not emit sufficient light for streak photography. Clearly an image-converter type camera, which can operate successfully with much lower light intensities might provide further information on burning rate differences in these three mixes.

CONCLUSION

The performance difference between CC primers of the M52 DEFA type containing separate conducting and priming increments and M52A3B1 type filled only with a single multi-component filling would appear to originate from slower ignition to fast burning time in the latter. Although energy sensitivity (capacitor discharge) of both types of primers is comparable for identical carbon black content, the only practical way of achieving the desired fast functioning times for the M52A3B1 is to decrease the carbon black content to 1% or less. However this results in the obvious penalty of primers which have high resistances and consequently low threshold firing energies. In addition, because multicomponent mixes tend to mix poorly, resistance spread in production batches is large.

With regard to our aim of developing a low sensitivity CC primer, the data presented here clearly point to a mix of the M52A3B1 type as being extremely unlikely to lead to an acceptable product. We are consequently examining two-increment primers of the M52 DEFA type. Although this does involve a production penalty in that two fillings/pressings must be made, compared to one in the M52A3B1, the narrow reproducible resistance spread and lower sensitivity far outweigh any disadvantages.

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