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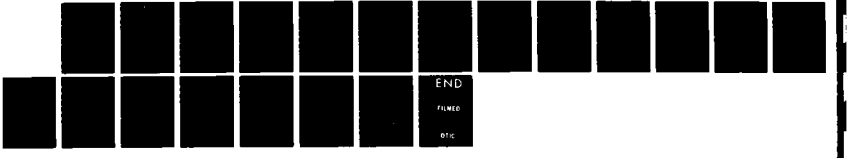

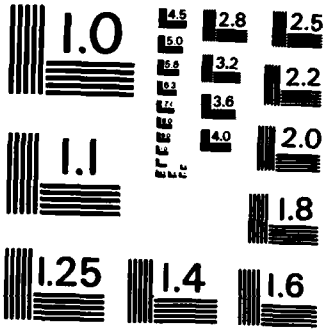

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MELBOURNE, VICTORIA

REPORT

MRL-R-968

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A LOW SENSITIVITY CONDUCTING COMPOSITION PRIMER FOR 20 MM AMMUNITION

R.J. Spear and L.D. Redman

Approved for Public Release

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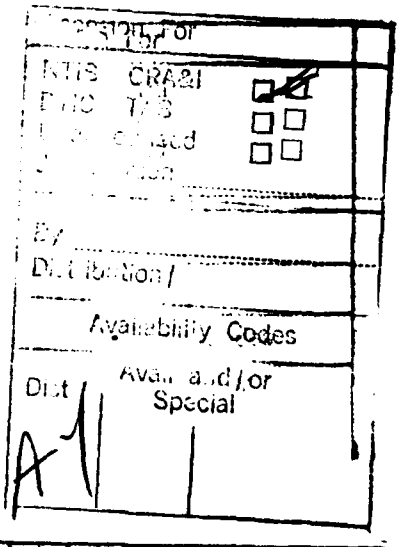

A LOW SENSITIVITY CONDUCTING COMPOSITION PRIMER FOR 20 MM AMMUNITION

1. INTRODUCTION

The RAAF is currently acquiring the F/A-18 tactical fighter. As part of its total armament, the F/A-18 is fitted with 20 mm cannon which fire Raufoss 20 mm ammunition. Local production of Raufoss ammunition is projected to commence within two years. Raufoss rounds are primed with a cap of US design, the M52A3B1, which differs in several major ways from current Australian conducting composition (CC) primers. The M52A3B1 has a single, multicomponent filling which serves the dual purpose of conducting/initiating and priming increments, and the resistances are high and have a large spread. A comparison of the M52A3B1 with locally manufactured M52 DEFA primers is given in Table 1. Limited available data for the sensitivity of M52A3B1 primers [1] suggest that they are more sensitive than normal production batches of M52 DEFA [2] (Table 1). It should be noted that RANs Phalanx ammunition is also primed with the M52A3B1.

Higher primer sensitivity presents a particular hazard for accidental initiation in areas of high RF intensity such as airfields and ship decks. Since the M52 DEFA has given problems throughout its service history both at manufacture and in service use, the higher sensitivity of the M52A3B1 would be expected to lead to more pronounced problems with respect to service introduction and local manufacture.

In 1984 MRL commenced a research programme to develop a CC primer which met the performance specifications of the M52A3B1 but exhibited substantially decreased sensitivity to accidental initiation. In the first stage of this programme, a range of primary explosive and conducting materials were investigated as fillings, and a number of promising compositions were identified [3]. The work reported in this study forms the second stage of the programme and is divided into two sections. The first section is a detailed evaluation of the promising compositions identified previously [3]. Both Tintacarb 140 and 90 performed similarly as conducting components in the feasibility study, and the former was chosen for this extended study because of its slightly narrower particle size range. Merck graphite was also

examined in a less extensive parallel study. Examination included determination of energy sensitivity on large sample sizes to obtain greater confidence in threshold firing levels, power sensitivity and stability on thermal cycling. The second section describes studies on mixes based on the M52A3B1 filling (see Table 1), and includes a full characterisation of M52A3B1 production primers obtained from Dynamit-Nobel.

As in the first stage of this programme, M52 DEFA empties had to be used as test vehicles since M52A3B1 empties were unavailable. Further work on this project has been suspended pending availability of M52A3B1 empties.

2. EXPERIMENTAL

2.1 Materials

Lead styphnate type RD1303 of average particle size 115 µm, Tintacarb 140 (Australian Carbon Black) passed through a 106 µm sieve prior to use, and Merck synthetic graphite were all as used previously [3]. Barium nitrate, potassium perchlorate and calcium silicide were all commercial materials which were passed through a 75 µm sieve. Gum arabic and styphnic acid were commercial materials used as received.

M52 DEFA empties were obtained from MFF St. Marys from a standard production batch. Filled M52 DEFA primers were all Lot 239 from MFF St. Mary's, while the M52A3B1 primers were obtained from Dynamit-Nobel as Lot DAG-9/84.

2.2 Experimental Mixes

All experimental mixes were made by weighing the ingredients in the required amounts to give a total mass of 2 g. Each 2 g batch was then fold mixed on paper till visually homogeneous. The large batches of RD1303 with either Tintacarb 140 or Merck graphite consisted of 12 g total, which were prepared in six 2 g batches as above, then combined and further mixed to ensure uniformity.

2.3 Experimental Primers

Two types of experimental primers were used:

(i) Primers prepared specifically for determination of energy sensitivity, power sensitivity and stability on thermal cycling.

These were produced by adding 46 ± 0.5 mg of the conducting mix to the cap and pressing at 123.5 MPa (400 kg dead load). Lead nitrate (185 ± 15 mg) was then added followed by repressing at the same load. The lead

nitrate serves to reproduce the consolidation of a priming increment while minimizing total explosive content.

A small number of primers were prepared to investigate the effect of pressing load. Each of the RD1303/Tintacarb 140 and Merck graphite compositions was used to produce twenty primers prepared as above except the pressing load was 190.5 MPa (600 kg dead load), and a further twenty each at 82 MPa (245 kg dead load).

(ii) Primers prepared to assess functioning times and their reproducibility so that a direct comparison with results for the M52 DEFA and M52A3B1 primers could be made.

The inert lead nitrate increment lengthens function times without changing sensitivity of the CC mix. In order that a direct comparison with production primers could be made, the lead nitrate as used in (i) was replaced by a priming increment. The RD1303/Tintacarb 140 or Merck graphite primers were prepared by pressing in the conducting mix (46 ± 0.5 mg) at 123.5 MPa followed by DEFA priming mix (145 ± 1 mg, prepared as in Table 1) at the same pressing load. Primers based on M52A3B1 type mixes were prepared by adding the appropriate mix (175 ± 1 mg) to the empty primer and pressing twice at 123.5 MPa.

2.4 Energy Sensitivity Determination

Energy sensitivity was determined using the capacitor discharge firing box described previously [3]. Only the 0.1 μF capacitor was used, and the voltage was varied. Small batches (15-25 samples) were assessed using the Bruceton staircase method [4] with constant logE increments. Primers which failed to function in the initial test were then successively tested at higher voltage ie "ramping", until they fired, thus giving a crude value of the all-fire energy. Larger samples (80-125) were assessed by the Probit method [5] and the results determined by computation. Primers which failed to function during Probit testing were not "ramped" but were destroyed by discharge using the 2 μF capacitor.

2.5 Power Sensitivity Determination

This was carried out using a stabilized power supply as described previously [2].

2.6 Functioning Time Measurements

The firing box used here was constructed to meet the specification of the M52A3B1 primer ie "the cap should function in less than 0.3 ms when fired by a 10 μs energy pulse from a 2 μF capacitor charged to 160 V" [6]. The experimental method was as described previously [3].

2.7 Thermal cycling

The filled primers were placed in aluminium trays inside a thermostatically controlled oven. The oven was set to heat to 40 ± 0.5°C for 12 h, then switched off for 12 h during which time the temperature returned to ambient. No attempt was made to control ambient temperature or humidity. The primers were removed from the oven on the test day, allowed to equilibrate for 2 h, then resistances were measured and sensitivity determined.

3. RESULTS AND DISCUSSION

3.1 Large scale testing of RD1303/Tintacarb 140 and Merck Graphite Mixes

Mixes using RD1303 with 5%, 4% and 3% Tintacarb 140 and 5% Merck graphite were prepared. A total of 200 primers were prepared from each mix at a pressing load of 123.5 MPa with a lead nitrate consolidation increment. Out of this total, 135 were used for energy sensitivity (Probit analysis), 20 for power sensitivity (Bruceton analysis) and 45 for thermal stability testing. A further 12 primers from each mix were prepared with an increment of DEFA priming mix for functioning time measurements. Variation of parameters with pressing load was assessed on 20 primers each pressed at 190.5 MPa and 82 MPa for each mix.

Results for energy sensitivity of primers containing the four mixes are detailed in Table 2. The most significant feature is the high values at the 0.1%, 95% confidence level, all being well above 200 μJ. Achievement of this figure has not been at the expense of an excessively high 50% firing energy. Functioning times are all well under the 0.3 ms specification [6] and can be compared to M52 DEFA at 0.043 ms [3]. Power sensitivity is satisfactory in all cases. The lower value for Merck graphite (0.63 W) probably results primarily from the test method; current is applied for 10 s and Merck graphite mixes tend to give a lot of "late" fires, whereas the Tintacarb mixes either functioned immediately or did not function. Late firing could arise from a change in resistance with consequent change in the applied power, since only voltage is kept constant. Limitations of the experimental technique used here have been discussed previously [3] and the results are probably conservative. For example, the 50% firing energy for M52 DEFA primers obtained using the technique described here is 0.3-0.5 W [2], while results obtained for RF sensitivity using a system where power is controlled give a figure of 1.5 W [7].

Data for stability on thermal cycling (diurnal, ambient to 40°C) are also listed in Table 2. Energy sensitivities remain unchanged within experimental error (only 15 primers were tested) at each stage of thermal cycling over the study period of 6 months and can be compared with the 50% level probit figures at the top of the Table for each primer mix. Resistance changes for both magnitude and standard deviation are small for the Tintacarb mixes, reflecting the carbon black like nature of this material. In contrast the Merck caps exhibit pronounced resistance drift, increasing by a factor of

ten over the study period with the final standard deviation being approx. 50% of the mean.

Results for primers pressed at higher (190.5 MPa) and lower (82 MPa) pressing loads are detailed in Table 3. In general, the primers pressed at 190.5 MPa have lower resistance and require higher energy for initiation than those pressed at 123.5 MPa, while the reverse is true for the primers pressed at 82 MPa. The Tintacarb mixes follow this pattern except for the 5% mix pressed at 82 MPa, which has a 50% functioning energy higher than for those pressed at 123.5 MPa, while the Merck graphite mix has lower 50% firing energies for primers pressed at either 82 or 190.5 MPa. Functioning times, determined on primers with a lead nitrate increment, can be seen compared with identical primers pressed at 123.5 MPa in Table 2. Although standard deviations are large, the general trend is for functioning times to increase in the order 123.5 MPa < 82 MPa < 190.5 MPa pressed primers. Higher pressing load would thus decrease sensitivity, but the penalty would probably be longer functioning times.

3.2 Comparison with M52A3B1 and M52 DEFA Primers, and Recommendation for a Preferred CC Composition for Production

Accurate energy sensitivities (Probit method) [5] and functioning times were determined on production batches of M52A3B1 (ex Dynamit Nobel) and M52 DEFA (ex MFF St. Marys) primers. The results are detailed in Table 4. The energy sensitivity of the M52A3B1 is slightly higher than reported previously [1] (see also Table 1) but amply illustrate the high sensitivity. Surprisingly, the M52 DEFA primers from the production batch tested are only slightly less sensitive. M52 DEFA sensitivity varies from lot to lot (see range quoted in Table 1) and this was obviously a more sensitive production batch. Note that the functioning time of the M52A3B1 is nearly double that of the M52 DEFA.

Clearly all the CC mixes listed in Table 2 have substantially lower sensitivity than both M52A3B1 and M52 DEFA primers. The RD1303/Tintacarb 140 (96:4) mix was chosen as the single candidate for further study because both the 3% and 5% mixes exhibit acceptable performance, and thus provide a margin for production variation. Functioning times are short, resistance drift is small and thermal stability is good. The Merck composition is adequate, but further investigation at lower percentage compositions was not undertaken. The principal reason was the wide range of sensitivity; it can be seen by comparison with the 5% Tintacarb 140/RD1303 mix that the 5% Merck/RD1303 mix has a higher 50% firing level but lower 0.1%, 95% confidence firing level. In addition it had been noted in our earlier study [3] that the sensitivity of the Merck/RD1303 mixes increased sharply as the Merck content fell below 4%, providing less margin for production variation. The pronounced resistance drift and marginally longer functioning times (see Table 2) were also factors in the decision.

A comparison of primers filled with the recommended mix against M52 DEFA and M52A3B1 primers, detailed in Table 4, shows the substantial improvements that can be expected.

3.3 Primers with Modified M52A3B1 Type Fillings

The possibility of modifying the M52A3B1 mix to achieve a low sensitivity filling while maintaining the production advantage of a single filling increment was investigated in a separate study. A secondary aim of this study was to understand the origin of the performance differences between the M52 DEFA and M52A3B1 primers, with particular emphasis on the unexpectedly long functioning times of the latter (see Table 4).

Resistances, energy sensitivity and functioning times are detailed in Table 5 for primers filled with an M52A3B1 type mix (see Footnote a, Table 5) containing 5, 3, 2, 1 and 0.75% Tintacarb 140. For comparison, results for the corresponding RD1303/Tintcarb 140 mixes containing 5,4,3 (repeated from Table 3) 2 and 1% Tintacarb 140 are also listed.

The M52A3B1 type mixes exhibit higher average resistances with significantly higher standard deviations relative to the corresponding RD1303/Tintacarb 140 mix and this difference becomes accentuated as the Tintacarb content decreases. Presumably the higher resistances and standard deviations result from poor mixing in the multicomponent composition. However, energy sensitivity for both mix types is comparable at the same Tintacarb 140 content. The lower energy sensitivity (higher 50% firing energy) for the M52A3B1/0.75% Tintacarb 140 compared with the production M52A3B1 primers (Tables 1 and 4) presumably result from the different material properties of Tintacarb 140 and acetylene black, and different particle size lead styphnate.

A sharp difference can be seen in the functioning times for the two types of primers studied here (Table 5). Reduction of Tintacarb 140 content from 5 to 1% in the M52A3B1 type mix steadily reduces functioning times. Indeed the 5% mix does not pass the specification of function in less than 0.3 ms [6], with 16% actually failing to function. In contrast the RD1303/Tintacarb primers exhibit a relatively small variation of functioning time with Tintacarb 140 content, minimising at 3-4%.

The purpose of such low carbon (acetylene) black contents in the M52A3B1 primers, with the consequent penalties of very high resistances and resistance ranges and low threshold firing energies, is now obvious, i.e. to achieve desirably short functioning times. The slower functioning times observed in this study for the M52A3B1 type primers relative to the RD1303/Tintacarb primers at the same carbon black percent could result from two sources, i.e. the M52A3B1 mix is slower burning, or slower igniting. A comparison of the M52A3B1 composition and the M52 DEFA priming mix (Table 1) suggests that slower burning might be the primary cause. The M52 DEFA conducting and priming mixes contain more lead styphnate, which is very fast burning, and the more energetic potassium perchlorate while the M52A3B1 contains less energetic barium nitrate.

An attempt to resolve this question was made by preparing experimental "composite" primers consisting of a lead styphnate/Tintacarb 140 (96:4) conducting increment with an M52A3B1/Tintacarb 140 mix (98:2) as priming increment (Table 5). As expected, the "composite" primer was

significantly faster than the straight M52A3B1/Tintacarb 140 (98:2) primer (0.058 vs. 0.154 ms) and was almost as fast as the 96:4 primer with M52 DEFA priming mix (0.048 ms). This suggests that much of the "slowness" of M52A3B1 type primers results from slow transition from ignition to deflagration 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 1) functions almost as fast as the RD1303/Tintacarb primers (Table 5), hence slow ignition is not a universal problem of multicomponent systems.

Further study of M52A3B1 type mixes as a single fill in a low sensitivity primer is unwarranted on the basis of the above evidence. However, the results strongly support the use of this filling as a priming increment for an RD1303/Tintacarb 140 conducting increment.

4. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Extensive testing of experimental conducting composition mixes has identified RD1303/Tintacarb 140 as having the best potential for a low sensitivity CC primer to replace the M52A3B1. Mixes having 5%, 4% and 3% Tintacarb 140 all exhibit substantial advantages over both the M52A3B1 and M52 DEFA primers, and further examination should be conducted on the 4% mix since there is adequate margin to allow for production variables. It must also be stressed that a second major factor in achieving the low sensitivity is the particle size of the RD1303 [2,8]. The material used here, average particle size 115 μm, is significantly larger than the RD1303M currently being manufactured at MFF St Marys. If smaller particle size material is used, a significant decrease in threshold firing energies would be expected.

The next stage of the programme will address two major areas. Firstly, M52A3B1 empties will be used as test vehicles to determine optimum filling characteristics. It is worth noting here that the M52A3B1 may not be the most suitable empty primer. It can be seen from the drawing of the M52A3B1 primer (Fig. 1) that the insulator projects above the pole. Since it will be difficult to tolerence the projection distance, and the resistance of the filled primer will depend critically on this distance, control of resistance range will be much more difficult than in the M52 DEFA, also shown in Fig. 1. While this may not be a problem for high resistance primers such as the M52A3B1, it could be a major problem for low resistance primers where it is desired to minimise resistance range. The modification of the M52 DEFA to the slightly wider diameter of the M52A3B1 should be simple, and enquiries regarding the feasibility of local manufacture of empty primers should be made. Perhaps the smaller centre contact diameter of the M52 DEFA may be disadvantageous, and again this should be investigated.

The second major area of future study is propellant ignition, which would be performed at WSRL. An obvious starting point would be to examine primers using RD1303/Tintacarb 140 (96:4) conducting increment and M52 DEFA priming mix and the M52A3B1 filling as alternative priming mixes. Cartridge functioning times and ballistic performance would be examined. It is

suqgested that no attempt be made at present to develop an alternative priming mix unless both M52 DEFA priming mix and M52A3B1 fillings perform unsatisfactorily. WSRL have agreed to perform such tests.

The results to date are very encouraging, and given the appropriate support it would appear that a primer could be developed with significantly better performance than current service models.

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TABLE 1. A comparison of the M52 DEFA and M52A3B1 Primers

Component/Parameter	M52 DEFA Conducting Increment	M52 DEFA 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)	20-500		1 k - 1.2 M
Energy Sensitivity (μJ)			
50% level	60-120[a]		38-56[b]
0.1%, 95% conf. level	~ 12		~ 3

a Data from Ref. [2]

b Data from Ref. [1]

TABLE 2. Test data for Large Scale Batches of Experimental CC Primers based on Lead styphnate RD1303 and Tintacarb 140 or Merck Graphite Fillings.

Test	Composition RD1303-Tintacarb 140 95:5	RD1303-Tintacarb 140 96:4	RD1303-Tintacarb 140 97:3	RD1303-Merck 95:5
Characterisation				
Energy Sensitivity (μJ)				
50% level	1570	1330	740	2290
0.1%, 95% conf. level	435	290	245	365
Power Sensitivity (W)				
50% level	2.10	2.38	2.03	0.63
Functioning time (ms)	0.059	0.049	0.048	0.066
[std. dev.]	[0.005]	[0.004]	[0.006]	[0.003]
Diurnal Cycling				
Primer resistance (Ω) [std. dev.]				
When pressed	8.0[0.6]	12.9[0.9]	24.3[2.4]	7.1[1.8]
1 month	10.9[0.9]	15.7[1.0]	27.6[3.0]	41.7[18.1]
3 months	10.9[1.1]	15.7[1.2]	30.5[3.2]	55.0[25.4]
6 months	13.7[1.3]	18.3[1.4]	32.9[3.6]	67.9[30.8]
Energy Sensitivity (μJ) 50% level				
After 1 month	1760	1245	830	2260
3 months	1760	1125	740	1800
6 months	1890	1335	880	2390

TABLE 3. Characterisation of Experimental CC Primers Pressed at High (190.5 MPa) and Low (82 MPa) Pressing Loads.

Test	Composition RD1303-Tintacarb 140 95:5	96:4	97:3	RD1303-Merck 95:5
Caps pressed at 190.5 MPa				
Resistance (Ω)				
When Pressed [std. dev.]	5.8[0.5]	9.4[0.5]	19.1[2.2]	5.0[0.9]
After 1 week [std. dev.]	6.5[0.6]	10.4[0.6]	21.8[3.4]	38.9[21.8]
Energy sensitivity (μJ) 50% level	2180	1560	880	1760
Functioning time (ms) [std. dev.]	0.115 [0.031]	0.118 [0.045]	0.095 [0.061]	0.138 [0.034]
Caps pressed at 82 MPa				
Resistance (Ω)				
When pressed [std. dev.]	10.2[0.9]	18.8[1.1]	36.4[4.9]	11.9[2.0]
After 1 week [std. dev.]	11.1[1.0]	20.3[1.2]	39.7[7.3]	44.7[20.8]
Energy sensitivity (μJ) 50% level	2180	1150	660	1440
Functioning time (ms) [std. dev.]	0.113 [0.022]	0.096 [0.008]	0.103 [0.039]	0.108 [0.031]
Caps pressed at 123.5 MPa[a]				
Functioning times (ms) [std. dev.]	0.098 [0.020]	0.078 [0.020]	0.098 [0.067]	0.108 [0.031]

a For a direct comparison with the above results, using a lead nitrate increment. Note the shorter functioning times for primers containing DEFA priming mix (Table 2).

TABLE 4. A comparison of the preferred MRL CC Primer Composition with M52 DEFA and M52A3B1 Primers.

Parameter	RD1303-Tintacarb 140 (96:4)	M52 DEFA	M52A3B1
Resistance (Ω)			
Measured [std. dev.]	15.7[1.2] (after 3 mths thermal cycling)	99.1[32.7][a]	123.9k [100.1k][b]
Specification		20-500	1k-1.2M
Energy Sensitivity (μJ)			
50% level	1330	68.2	64.3
0.1%, 95% conf. level	290	5.0	4.9
Power Sensitivity (W)			
50% level	2.38	0.3-0.5	~ 0.25
Functioning time (ms) [std. dev.]	0.049 [0.004]	0.043 [0.005]	0.081 [0.011]

a Production batch ex MFF St Marys

b Production batch ex Dynamit Nobel

TABLE 5. Performance data for M52 DEFA and M52A3B1 Type Primers

Composition	Resistance [Std. Dev.] (Ω)	Energy Sensitivity[b] (μJ)	Functioning Times [Std. Dev.] (ms)
M52A3B1 Primer (Type)[a]/Tintacarb 140			
95:5	16.4[4.1]	1445	0.301[0.036][c]
97:3	73.5[15.1]	650	0.187[0.053]
98:2	550.6[162.3]	280	0.154[0.038]
99:1	449k[571k]	210	0.091[0.024]
99.25:0.75	9/20 11.4M 11/20 > 20M	160	0.108[0.035]
RD1303/Tintacarb 140			
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]
Composite Primer:			
RD1303/Tintacarb 140 (96:4) (46.5 mg) then M52A3B1/Tintacarb 140 (98:2) (145 mg)	19.3[2.5]	not determined	0.058[0.006]
M52 DEFA Primer mix[d]	20/20 > 20M	580	0.052[0.021]

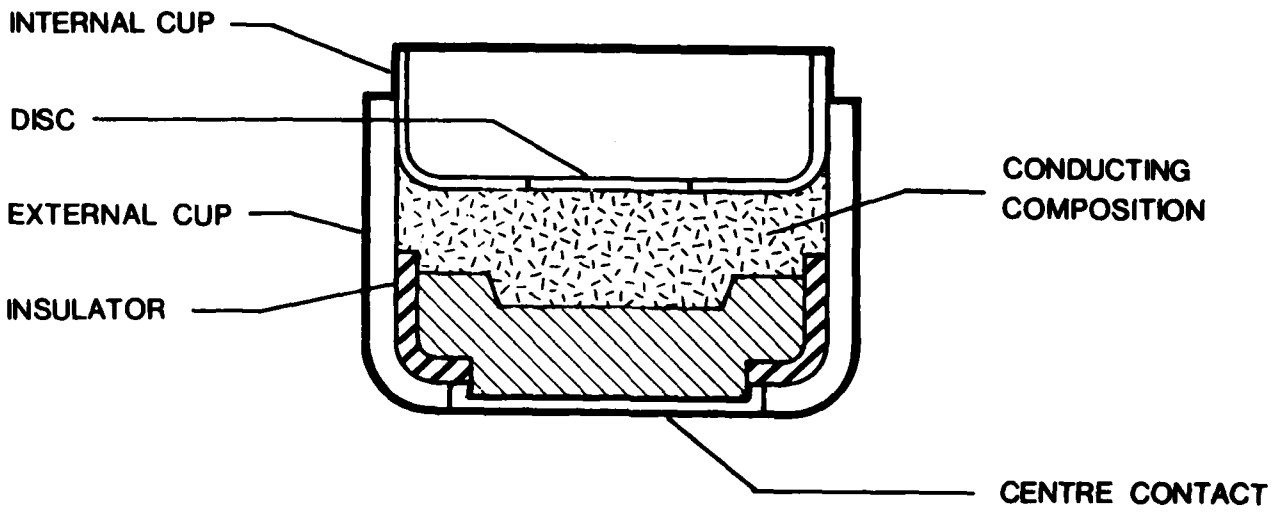
a RD1303 (40%), barium nitrate (44.25%), calcium silicide (13.0%), gum arabic (1%), styphnic acid (1%): see Table 1.

b For 50% function level as determined by Bruceton [3] or Probit [4] analysis.

c 2/12 failed to function.

d Filling described under "Priming Increment" in Table 1.

M52A3B1



M52 DEFA

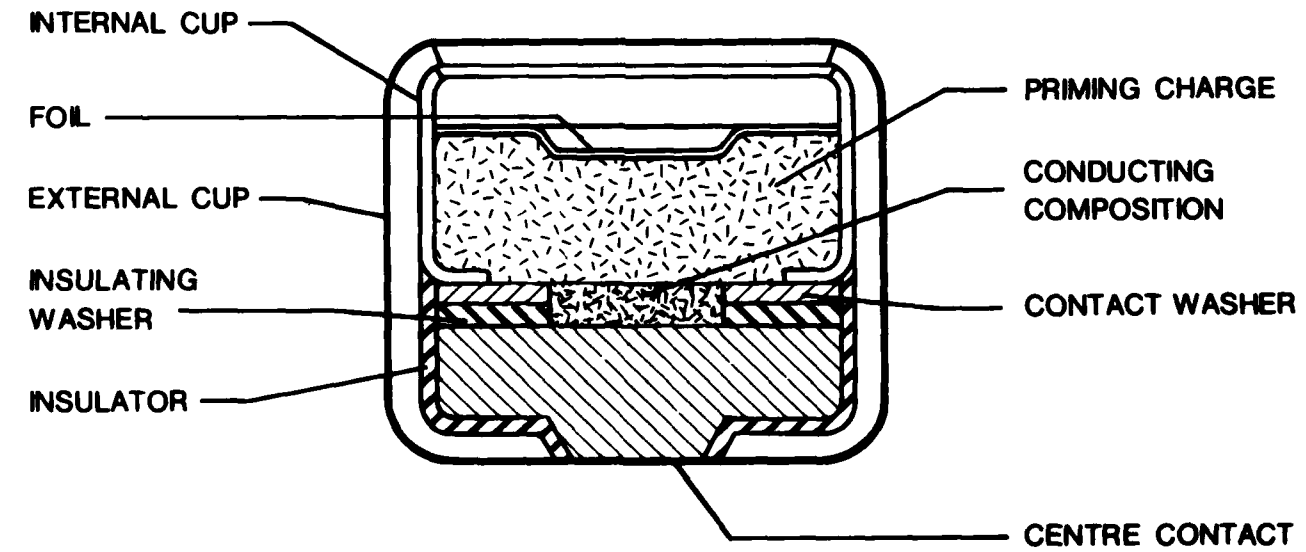


FIGURE 1. Schematic presentation of the M52A3B1 and M52 DEFA CC primers, not to scale.

END

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