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MATERIALS EXPLOSIVES DIVISION

A.R.D.E. MEMORANDUM (MX) 30/59

REVIEW ON June 89

Conducting composition detonator; Design and development

P. Bessent

INV. 90

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Fort Halstead. Kent.

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2. Electric fuzes —Gt. Brit.
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SUBJECT: Conducting Composition Detonator; Design and Development (U)

TO: Commanding Officer
US Army Ordnance Technical Intelligence Agency
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A.R.D.E. MEMORANDUM (MX)30/59

Conducting composition detonator; Design and development

P. Bessent (X2)

June 1959

Summary

The experimental work involved in the development of a conducting composition detonator is described. The resulting detonator has three outstanding characteristics. It is physically small, being only 0.25 inch diameter and 0.5 inch long. The sensitivity is adequate to ensure firing on the energy available in a V.T. Fuze, 100% firing on less than 40 microjoules. The Firing Interval achieved is very short and regular, being less than 2 microseconds.

The influence of factors in the mechanical design, particularly upon resistance and sensitivity to condenser discharge, are considered in detail.

Approved for issue:

L. Northcott, Principal Superintendent "MX" Division

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1. INTRODUCTION

The experience gained in the development of the conducting composition (C.C.) cap now used in the 30 mm Aden gun had shown that a very rigid assembly could be provided, which was practically all metal and contained no plastic moulding [1]. Such an assembly would be expected to withstand the effects of expansions and contractions over a wider range of temperature than would a conducting film system. The filling would employ the same techniques as used for fuze detonators and multiple filling methods might be applicable. There was considerable scope for introducing variants, particularly in the disposition of the electrodes, the percentage of conducting material in the mix and the consolidation of the filling.

Thus, it was decided to investigate the possibility of developing a C.C. detonator which would have an electrical sensitivity of the same order as that of the Graphite Bridge Igniter (Fuze, electric, F85).

2. EARLY DEVELOPMENT

The experimental work described in this report commenced after the receipt in August 1950 of the first large batch of components to design ARE 8481 as detailed by C.E.A.D. The final design was evolved by the end of 1951 and a filling trial at Chorley was carried out early in 1953.

2.1 Materials

In addition to the robustness of the assembly, one requirement considered as essential in a C.C. system is that the conducting mix shall be as free from segregation as possible during its handling in the filling factory. In the cap this had been achieved by D/ERDE by the development of RD 1303. In the present case, it was decided to use the same commercial grade of graphite as in the C.C. cap, with lead azide. A request to D/ERDE to develop a form of lead azide which would give a non-segregating mix, led to the provision of RD 1339, a pure lead azide of suitable particle size which was used in this work. It was proposed to include an increment of tetryl to increase the power of the detonator so that it might possibly initiate directly a high density tetryl pellet.

2.2 Design

In order to obtain a small detonator and to simplify the design, it was decided to have an insulated pole with a circuit return through the body as in the 30 mm C.C. cap. The first design is shown in Fig. 1. There are five empty components, metal body and pole piece, insulating cup and washer, and a closing disc. The first sets of components were made in the Section Workshop. Metal components were of plain brass, the insulating cup of black fibre, and the washer of paper. Attention was given to obtaining a satisfactory method of assembly, and the turn over of the body on to the insulating cup was done in three stages as in the electric cap. A number were filled and fired with promising results.

Subsequently to this, C.E.A.D. made a request for a small electric detonator, which originally was to fire from a 6 volt battery, but was later required to fire from a low energy condenser discharge. The design Fig. 1 was referred to C.E.A.D. for completion of detail, and it was decided to have the brass bodies and pole pieces silver plated, to avoid contact resistance between them and the spring connectors to be used. C.E.A.D. arranged for a large batch of sets of components to be made and delivered to this branch for assembly and experimental filling. It was found that a rigid assembly could be assured if the turn over of the body in the assembly was made with a drift of the correct contour and of good surface condition in one operation at a dead load of 1000 lb. This suggestion proved the basis for an award to the fitter concerned.

2.3 Filling Trials

The resistance of each detonator filled was recorded to obtain the resistance range in each batch made. The firing tests for electrical sensitivity were carried out in a circuit containing a charged condenser of good quality, a special type of low-loss closing switch (the lead block switch) and the detonator. The same charging voltage of 44.7 volts was used throughout, unless stated otherwise, so that different energies were obtained by changing the capacity of the condenser used. The energies quoted are the energies available on the charged condenser before discharge occurs. In order to obtain an indication of changes in electrical sensitivity from small batches of detonators, the energy level used for test was selected to give less than 100% firing, preferably around 50%. As the electrical sensitivity was improved by changes in design or method of filling, the energy level for test was lowered.

Fillings were made with various percentages of graphite and in brass and silver plated brass assemblies. The filling was an increment of 30 mgms. of azide mixture and 30 mgms. of tetryl, each pressed at 175 lb. dead load. To obtain an indication of the relation between firing energy and percentage fired, 100 brass detonators and 50 silver plated detonators were filled under the same conditions. The resistance range obtained was:- brass 13.5 - 250 ohms, mean 79:5; silver plated 2.4 - 57.5 ohms mean 27. The results of tests of the brass detonators are shown in Table 1, but owing to the low resistance, no firing was done with the silver plated detonators.

TABLE 1

Brass components
Lead Azide (XCZ12) + 8% graphite

1000 ergs

Resistance Range (ohms)	Energy (microjoules)	Number fired
35 - 100	100	5/10
20 - 140	150	6/10
35 - 90	200	8/10
30 - 140	250	9/10
35 - 250	300	9/10
25 - 125	400	8/10
35 - 140	500	10/10

A later batch of lead azide was used in further fillings with results as shown in Table 2.

TABLE 2

Lead azide (XCZ18). Tested at 100 microjoules

Graphite Content by weight	Brass		Silver plated	
	Resistance Range (ohms)	Number fired	Resistance Range (ohms)	Number fired
8%	8-32	1/10		
7½	15-46	2/10		
7	50-1200	4/10		
6½	50-6700	16/21	3.4-140	5/10
6	2000-150000	7/10	12-755	6/10
5½			22-150000	12/20
5			24-INF.	4/10

2.4 Remarks

(a) Under similar conditions, the mean resistance with brass components was considerably greater than with silver plated ones. This effect was considered to be due mainly to the difference of the contact resistances between the pressed composition and the metal electrodes.

(b) It was observed that with silver plated components, batches where the mean resistance was relatively large frequently contained a sample with low resistance, so that the spread was in general greater than for brass components.

(c) The difference of the resistance range for the 8% mix in Tables 1 and 2 is very marked. The process for making the azide was under development at the time, and the particle size of XCZ18 was smaller and more uniform than that of XCZ12.

(d) In the firing test of a batch, the misfires occurred most frequently in the lower part of the resistance range, suggesting that electrical sensitivity tended to decrease as the resistance decreased.

3. MODIFIED ELECTRODE SYSTEM

3.1 Design

As it was desired to obtain an electrical sensitivity of 100% firing at less than 40 microjoules, it was clear from Tables 1 and 2 that the existing design needed modifying. Consideration led to the design shown in Fig. 2. When a powder is pressed in a cavity, the adhesion to the walls is considerably better than to the base, so that by using the walls as the electrode surfaces, it was thought that the contact resistance would be less affected by the stresses set up by long storage, rough usage or temperature cycling. By placing the annular discharge gap approximately centrally up the azide increment column, a more symmetrical distribution of the electrical forces about the gap on applying voltage would be obtained and this should be favourable. To obtain this effect the pole piece was recessed 0.025 inches.

3.2 Filling Trials

For the initial fillings with this design, the results are shown in Table 3.

TABLE 3

Lead azide XCZ18

Graphite Content	Brass			Silver plated		
	Resistance Range (ohms)	Energy (micro joules)	Number fired	Resistance Range (ohms)	Energy (micro joules)	Number fired
6½%	20-340	100	10/10			
6	22-3550	50	8/10			
5½				44-6150	50	10/10
5½				16-4000	40	9/10
5½				29-3500	30	6/9

These results show a definite improvement on those of the earlier design in electrical sensitivity, but some further increase was required. For the next stage in the development the testing energy was reduced to 30 microjoules.

3.3 Further Modifications

In further fillings with the 5½% mix, it was found that there was a wide range of resistance extending from 1 ohm up to several thousand ohms, with an occasional higher value, and most of the batches of 10 filled detonators showed this effect. As typical of this effect the individual resistance of one batch were 0.8, 1.4, 15, 32, 90, 140, 225, 235, 305 and 4360 ohms. Detonators with resistances of 70 ohms or more usually fired on 30 microjoules. Consequently efforts were made to narrow the resistance range of a batch to avoid the production of low resistance detonators.

3.3.1 Electrode Spacing

The electrode used in the work described in para. 2 is shown diagrammatically in Fig. 3(a). The bodies used had a bore of diameter around 0.128in. A paper washer nominally 0.0044 in. thick was used and under the assembly load, this was reduced to about 0.0035 in.

Fig. 3(b) shows the arrangement dealt with in paras. 3.1 and 3.2 The recess had a diameter of 0.125 in. - 0.001 and a depth of 0.025 in + 0.003.

On assembly some eccentricity of the three components was possible and this could have any value up to about 0.003 in. between the body and the pole piece. In cases where there was considerable eccentricity, the position of the edge of the washer relative to the two electrodes would vary around the annulus and would be inset in some part of it. To test the effect of this, assemblies were made up as in Fig. 3(c) where the washer was inset all round the cavity. Two batches were filled with a 5½% azide mix, one with 0.002 in. paper washers and one with 0.0044 in. paper washers. The resistances as measured were:-

0.002 in. washer 0.05, 0.05, 0.05, 0.35, 0.5, 0.7, 1.3, 1.6, 1.6, 2.6 ohms

0.004 in. washer 0.11, 0.11, 0.2, 0.5, 0.9, 0.9, 1.12, 1.5, 2.6, 2.6 ohms

Bearing in mind that the resistance is made up of multiple parallel paths distributed around the annulus, it appeared that where some part of the washer was inset between the electrodes, low resistances could be expected and it would be necessary to avoid such insets. To meet this requirement, the bore of the body was enlarged and the washer hole of larger diameter was retained.

Some experimental work was in hand on the 30 mm. electric cap and about this time it was found that when the same mixture of RD 1303 (lead styphnate) and graphite was filled into caps, one batch with 0.002 in. paper washers and one with 0.010 in. fibre washers, a higher resistance range was obtained with the 0.010 in. washers. On testing these by condenser discharge at different energy levels, it was found that those with 0.010 in. washers all fired at energies from 125 microjoules upwards whereas those with 0.002 in. washers needed 700 microjoules before they would all fire; at 200 microjoules where 0.010 in. washers fired 10/10, 0.002 in. washers fired only 3/10. This work suggested that an 0.010 in. vulcanised fibre washer would be expected to increase the electrical sensitivity of the detonator.

The commercial grade of graphite used had a considerable proportion of particles with a length of 0.001 in. and a small proportion with greater lengths extending up to 0.003 in. With a gap of 0.0035 in. it would be possible on occasions to get two of the longer particles bridging the gap directly at one point and leading to low resistances. 0.010 in. fibre is reduced by the assembly load to between 0.007 in. and 0.008 in. and the chance of a chain of graphite particles directly bridging the gap at one point would be greatly reduced.

The resultant spacing is shown in Fig. 3(d).

3.3.2 Filling Trials

Some preliminary trials of detonators with the spacing arrangements of Fig. 3(b) and 3(d) were carried out with 0.0044 in. paper and 0.010 in. fibre washers directly compared. The results showed much higher resistances for the 0.010 in. washer and firing of all the latter at 30 microjoules.

The surface condition of the bore in the body would be expected to affect the consolidation of the powder on pressing and the finish up to this stage had not been good, quite prominent toolmarks occasionally being present. In this further work, the bodies were hand-reamered before plating. The effect of this treatment was to lower the resistance range.

The first extended filling produced a batch of 80 (Fig. 3(d)) and in view of the expected increase in electrical sensitivity, tests were carried out at several energy levels.

The resistance range for 76 was 70 - 2750 ohms, with a mean value of 620 ohms; the other four values were 32, 46, 4000 and 7900 ohms.

The firing results are shown in Table 4.

TABLE 4

Lead azide XCZ20 + 6% Graphite 40 mgms.
Tetryl 30 mgms.

Resistance Range (ohms)	Energy (microjoules)	Number fired
180-2450	31.5	10/10
112-4000	25.3	10/10
112-2450	19.9	10/10
112-1120	17.0	9/10
112-1630	11.1	10/10
140-1300	5.6	5/10

These results indicate the improvement in sensitivity which is now well within the desired range.

Further fillings with a 5½% mix gave a resistance range from 90 to 2350 for 37 with one at 7400 ohms and a mean value of 820 ohms. Of these 13/20 fired at 5.6 microjoules.

3.3.3 Completely filled Detonators

Up to this point, fillings had been confined to one increment of azide mix and one increment of tetryl only in order to reduce the time taken in filling. Fillings were now undertaken of the complete detonator as in Fig. 2, except that the electrode system was as in Fig. 3(d). The azide increment of 40 mgms. was followed by a tetryl increment of 30 mgms. A second increment of tetryl was pressed in of such weight that a small amount was left in the funnel which was broken off and the surface of the tetryl was repressed. 175 lb. dead load was used for all these pressings. A brass disc was placed on the surface of the tetryl and the flange of the body was turned over on to the disc; for this a load of 250 lb. was required.

A batch of 50 detonators was filled in this way. The resistance was recorded at each stage in the filling. The way in which the resistance changed between pressing the azide mix and the tetryl and between pressing the tetryl and closure are shown below. The changes were in general small, but cases where the change was greater than 50% of the original resistance are termed large.

Azide to tetryl 32 decreased, 6 unchanged, 12 increased (large changes:- 4 decreased, 1 increased)

Tetryl to closure 3 decreased, 5 unchanged, 42 increased (large changes:- 13 increased).

The final resistance range was from 70-5250 ohms for 47 with three at 23000, 29000 and 74000 ohms.

Firing tests at various energy levels were carried out and any that failed were tested at 20 and then at 40 microjoules and finally were connected to a 120 volt dry battery. Table 5 shows the results.

TABLE 5

Azide mix XCZ30 + 5½% Graphite

Resistance Range (ohms)	Energy (microjoules)	Number fired	Number fired in subsequent tests		
			20 (micro joules)	40 (micro joules)	120 volts
112-3550	5.6	2/10	2	3	3
90-2200	11	8/10	-	-	2
475-5250	17	9/10	1	-	-
112-3200	20	9/10	-	-	1

Two features are noticeable. Firstly, pressure on the pressed filling was more likely to decrease the resistance whereas pressure on the top of the body usually caused increase in resistance.

Secondly, the sensitivity was adversely affected as compared with the series given in Table 4. 9/40 failed at 20 microjoules and 6 at 40, whereas all would have been expected to fire at less than 40. The load needed to make a satisfactory closure on the metal disc was 275 lb., as against 175 lb. to consolidate the filling and as this was applied last, it may have occasionally affected the contact resistance between the electrodes and the pressed fillings.

A further batch was filled in which 10 had one increment of tetryl and no closure and 20 were filled and closed as above. When tested, 9 unclosed detonators fired at 5.6 microjoules and 1 at 10, and 9 of the closed ones fired at 5.6, 5 at 10, 2 at 20 and 4 at 120 volts.

Another batch was filled in which 30 had one increment of tetryl and no closure and 30 had a second increment of tetryl broken off and repressed and no closure. 24/30 fired in the first instance and 25/30 in the second at 5.6 microjoules.

The principal significance of these results was the reduction of sensitivity of the closed detonators and particularly the presence of some of much lower sensitivity, 10 out of 60 were in this category. Consequently the design was reconsidered.

4. FINAL DESIGN

It appeared from the preceding work desirable to change the method of closure to avoid applying heavy loads after the filling is consolidated. Fig. 4 shows the design of the assembly as finally adopted. The filling consists of an increment of 40 mgms. of the azide mix, and two increments each of 30 mgms. of tetryl. Subsequently, however, the tetryl was all pressed in one increment. The weight of filling is arranged so that its surface is inset 0.03 - 0.04 in. within the body. A thin oversized metal cup is pressed into contact with the explosive face under a load of 50 lb. and is sealed by one drop of varnish, RD 1177, dropped into the recess. By this method, the closing load of only 50 lb. is applied directly to the explosive column, which has previously been consolidated under a load of 175 lb.

As mentioned in para. 3.3.2, regularity of consolidation of the filling would be assisted by the provision of a good surface in the bore of the body and for this purpose, the design requires the bore to be finished by the repassing process from the cavity in the body upwards.

4.1 Factory Filling Trial

It was decided to arrange with DOF/F for an experimental filling trial at Chorley. An order for empty assemblies was placed and D/ERDE arranged for a full scale batch of lead azide (RD 1339) to be made on the azide plant at Chorley. Some preliminary fillings were carried out on assemblies available to establish the incremental weights to give an inset on the explosive filling of 0.03 in. approximately. At the pressing load of 175 lb. the incremental weights were 40 mgms. (0.62 grain) azide mix and two increments of tetryl each 30 mgms. (0.47 grains).

The trial at Chorley was unsuccessful. The first ten fillings gave the following results:-

R_1 resistance after pressing azide increment

R_2 resistance after pressing both tetryl increments.

R_1 H, 700, 4450, H, H, H, 900, 1500, 1120, H.

R_2 H, 700, 4450, 0, H, H, 900, 1800, 1000, H.

(H resistance greater than 100,000 ohms.)

Ten fillings were made with a load of 250 lb. and all gave resistance greater than 100,000 ohms.

A further batch at 175 lb. gave similar results. A check on the pressing load and incremental weights and lengths showed no discrepancies and the trial was stopped.

A sample of the azide mix was sent from Chorley to A.R.D.E. and filled into assemblies made up locally. The resistance were satisfactory, in the range from 70 to 1800 ohms, and similar to the values obtained from a local mix.

The assemblies supplied to Chorley were critically examined and found to be unsatisfactory. There were two main defects. The edge of the pole piece recess and the edge of the internal bore of the body which formed the electrode system as in Fig. 3(d) were in a number of examples irregularly chamfered causing a considerable increase in the electrode gap. The turnover of the body to hold the pole piece had not been done to the correct contour, but to a smaller radius of curvature. The result was that the inner edge of the turn-over cut deeply into the fibre. These defects would account for the unsatisfactory results obtained in the filling trial. Attempts to re-form the turn-over to the correct contour only resulted in further penetration of the fibre cup and the assemblies had to be scrapped.

The defects were brought to the notice of the suppliers of the empties and an order placed for empty components which it was proposed to examine and assemble in this establishment. At the time that these components were delivered a request was received for the provision of an electric igniter to replace the fuze electric F.85[2]. This was required on the highest priority. In the circumstances, it was decided to adopt the detonator design for the igniter and to use the available empty components for its development. In consequence, no further factory filling trials of the C.C. detonator were carried out. However, the experience gained with factory filling of igniters indicates that the filling of detonators could also be carried out, as the same techniques could be used.

5. ADDITIONAL EXPERIMENTAL WORK

Various tests were carried out on detonators during the development to gain further evidence of their properties.

5.1 Plating of Components

A batch of detonators were made up with the body and pole piece gold-plated and one with a rhodium flash. They were stored with a batch of silver-plated detonators under normal conditions in a laboratory for two years to establish whether the type of plating affected the resistance stability. The resistance was measured at intervals. The results are shown in Table 6.

TABLE 6

	Nature of Plating		
	Silver	Gold	Rhodium
Initial Range	112-10000 ohms	70-9250	140-9250
Final Range	140-4600	50-9250	140-10000
No resistance change	4/40	8/39	10/40
$\frac{R_1 - R_2}{R_1}$ (Mean	.225	.15	.14
$\frac{R_1 - R_2}{R_1}$ (Max.	.54	.44	.47

The gold and rhodium plating showed some reduction in resistance change, but in view of the satisfactory results with silver-plating, it was not considered necessary to take any further action with the other platings.

5.2 Power

Detonators were made up in bodies of the Fig. 2 type with the top fin turned off to give a flat top. The filling was 40 mgms. of azide mix and two increments of tetryl, the second one being broken off and re-pressed the pressing load being 175 lb. This left the surface of the filling practically flush with the end of the detonator. This was closed by securing a brass disc 0.0076 in. thick over the top face of the detonator. The detonator was mounted with an air gap of 0.05 in. separating it from a tetryl pellet 0.5 in. long, 0.59 in. diameter and density 1.55. The pressure bar was used to show the efficiency of detonation attained by the tetryl pellet. The detonator was fired by a condenser (0.05 μ Fd) charged to 45 volts and the pressures recorded were:-

24.4, 24.6, 24.3, 25.5, 25.4, 25.1, 25.5, 24.3, 24.4, 24.7,

24.9, 25.1, 23.7, 24.9, 24.0, 24.0 tons per sq. in.

Mean 24.7 C.V. 2.1%

It was clear from these results that the detonator could initiate full detonation of a tetryl pellet of density 1.55 across an air gap of 0.05 in.

5.3 Hot Storage

Two small trials were carried out during the development to indicate the effect of hot dry storage.

(a) Ten detonators were stored at 76°C (169°F) continuously for nine days.

Initial Resistance R_1 (ohms)	112	140	140	160	225	225	255	320	1000	1200
Final Resistance R_2 (ohms)	140	140	250	160	225	290	475	435	1000	1300
$\frac{R_1 - R_2}{R_1}$	0.2	0	0.8	0	0	0.3	0.85	0.35	0	0.08

9/10 fired at 20 microjoules, whereas the controls gave 10/10 at 20 and 9/10 at 17 microjoules.

(b) Sixteen detonators were stored in an oven which was heated to 70°C (158°F) for 8 hours and then allowed to cool overnight for five days each week for a period of 39 weeks giving a total of 195 cycles. The resistance measurements are shown in Table 7.

TABLE 7

Initial Resistance R_1 (ohms)	Final Resistance R_2 (ohms)	$\frac{R_1 - R_2}{R_1}$	Initial Resistance R_1 (ohms)	Final Resistance R_2 (ohms)	$\frac{R_1 - R_2}{R_1}$
45	140	2.1	1000	2250	1.25
70	160	1.3	1500	5400	2.6
140	250	0.8	1630	3400	1.1
320	475	0.5	3200	5650	0.75
435	1500	2.45	4000	9250	1.3
515	1000	0.95	5250	5400	0.03
730	1800	1.45	6200	35000	4.6
925	2000	1.15	7400	49000	5.5

16/16 detonators fired at 20 microjoules.

Where any change occurred in the first trial the effect of steady heating was to cause fairly small increases in resistance. In the cycling trial all resistances increased, usually to a considerable extent, and the two highest resistances showed very large increases. It is thought that these changes, being all in one direction, are due to an increase in the contact resistance between the electrodes and the pressed column brought about by the different coefficients of expansion of the metal and the pressed filling. Although considerable changes occurred in the resistance, the indications are that the electrical sensitivity was not affected.

As the detonator can readily be sealed by allowing one drop of varnish to spread itself in the cavity above the filling and one drop to flow around the annular cavity between the pole piece and the body it is thought that the same results would be obtained on a hot moist cycling trial.

5.4 Electrical Sensitivity

As stated at the end of para. 3.3.3 the last detonators filled before the final design was made gave 49/60 or about 80% firing at 5.6 microjoules. As the final design changed only the method of closure, a similar sensitivity would be expected.

When a supply of satisfactory components to the final design became available, a few sensitivity trials were carried out, but the work had to be stopped as the components were all required for the development of the C.C. igniter.

The filling up to this point had all been carried out with a 5½% graphite content in the azide mix and a pressing load of 175 lb. Subsequently some fillings were made at a pressing load of 350 lb. with the same mix. While the fillings at 175 lb. gave about 80% at 5.6 microjoules, filling at 350 lb. gave 20/20 at 5 microjoules in spite of the much lower level of resistance which could be expected to reduce the sensitivity. In a batch pressed at 350 lb. and tested at increasing levels until firing occurred, one fired at 0.6 microjoules, two at 1.1, one at 3.1, three at 4.1 and two at 5.8 and in a single pulsing test 2/5 fired at 0.6, 4/4 at 1.6, 3/5 at 2.6 and 4/5 at 3.6.

The sensitivity can, however, be reduced if required by an increase in graphite content. A group with a 6½% mix at 350 lb. gave 10/10 at 90 microjoules, 7/10 at 60 and 3/10 at 30.

These results indicate that this design of detonator can give the highest sensitivity likely to be required for any Service application, that an increase of pressing load leads to greater inherent sensitivity and that an increase in graphite content reduces the sensitivity.

5.5 Thyratron firing

A few trials were carried out on one batch of detonators to compare the sensitivity using the lead block switch and using a triggered thyratron as the switch. The thyratron was biassed to 7.4 volts and the condenser was discharged through the thyratron and the detonator by shorting the grid to earth.

A difficulty arises because the actual voltage drop on the thyratron during discharge could not be determined and an estimated value of 20 volts was assumed in the results given in Table 8.

TABLE 8

Lead switch		Thyratron type CV 123				Thyratron type CV 2182	
		Charging volts 90		Charging volts 60		Charging volts 90	
Energy (micro joules)	Number fired	Energy (micro joules)	Number fired	Energy (micro joules)	Number fired	Energy (micro joules)	Number fired
20	10/10	22	10/10	4.8	5/5	22	5/5
17	9/10	14.7	10/10	4.0	5/5	14.7	5/5
11	10/10	7.3	10/10	3.2	4/5	7.3	5/5
5.6	34/40	4.9	3/7	2.4	3/5	4.9	3/5

The energy quoted for the lead switch is that available in the condenser and is dissipated through the igniter. In the thyratron circuit, the energy quoted is that dissipated in the igniter assuming the remainder is dissipated in the thyratron when its voltage drop is taken at 20 volts. The two types of thyratrons at 90 volts gave comparable sensitivity to the lead switch.

For a thyratron circuit with 90 volts applied, a 0.006 microfarad condenser would be expected to give satisfactory firing as this is the condenser giving the energy of 14.7 microjoules shown in the Table.

5.6 Firing interval

During the course of the development work some measurements were made of the firing interval with condenser discharge firing. The first event on the timing apparatus was the closing of the switch in the firing circuit and the second event was the ionisation of a graphite B or graphite C head held against the face of the detonator. In these trials three different timing equipments were used, a microsecond chronometer, a high speed sweep oscillograph and a spiral sweep oscillograph. The detonators had the normal fillings of a $5\frac{1}{2}\%$ azide mix and tetryl, but were not closed. The results are shown below.

TABLE 9

Microsecond chromometer

Lead block switch Volts 45

Capacity	Energy (microjoules)	Firing Intervals (microsecs)
.02 mf.	20	1.5, 1.55, 1.65, 1.8, 2.05
.017	17	1.4, 1.4, 1.5, 1.5, 1.6
.011	11	1.3, 1.5, 2.2, 2.3, 3.0
.0056	5.6	1.9, 1.9, 2.2, 2.5, 3.4
.0056	5.6	2.2, 2.2, 2.45, 2.45, 2.45, 2.55, 2.6

High speed sweep

10 mf at 300 volts (0.45 joules) triggered through thyratron.

1.2, 1.2, 1.2, 1.3, 1.3, 1.3, 1.5, 1.5, 1.6, 1.7 microsecs.

Spiral sweep

TABLE 10

Lead block switch

Volts	Capacity (microfarads)	Energy (microjoules)	Firing Intervals (microsecs)
240	2	57600	1.06
60	.011	19.8	1.45
59	.006	10.9	1.25, 1.35, 1.35, 1.35, 1.41, 1.43, 1.60, 1.67, 1.68, 1.88
200	.5	10000	1.41, 1.57
400	.04	3200	1.33, 1.43, 1.47
200	.04	800	1.42, 1.65, 1.66
100	.04	200	1.64, 1.8, 1.8

These results relate to five different batches of detonators. They indicate that a firing interval of less than 2 microsecs can be consistently obtained and that it tends to decrease as the voltage and energy is increased. Even in the region where the energy used does not give 100% firing as is the case with 11 and 5.6 microjoules in Table 9, the firing interval is not greatly extended.

5.7 Range and distribution of resistance

In bridge wire initiators, the variations in diameter of the bridge wire are quite small and the spread in resistance is mainly due to variations in the actual length of the bridge. The spread allowed by specification is about 20% in Naval initiators and about 50% in commercial initiators. In a C.C. system, by suitable selection of the variables, any resistance from a few ohms up to very high values may be obtained. In the case where the variables are nominally fixed, differences in resistance from round to round will be caused mainly by variations in the electrode disposition in the assembly, in the graphite distribution, or in the consolidation of the mix. The measured resistance is the resultant of a large number of parallel paths and a very much greater spread of resistance will occur than in the bridge wire case except possibly where the resistance is small.

Some indication of the resistance spread was obtained in the development trials. Four batches were filled of 80, 80, 80 and 100 detonators with 5½% mix and 175 lb. pressing load in assemblies which were similar to the final design and the resistance distribution for each batch is shown in Table 11. In addition, the results for 77 detonators filled at 350 lb. pressing load are shown in Table 12.

TABLE 11

Resistance Distribution

5½% mix at 175 lb. pressing load

Batch	% of total included in resistance range (ohms) stated							
	Under 70	70 to 250	250 - 500	500 - 1000	1000-2000	2000-3000	3000-5000	500-10000	Over 10000
A	2.5	37.5	22.5	16.2	10	8.8	0	2.5	0
B	2.5	31.3	17.5	15	7.5	5	5	8.7	7.5
C	1.2	20	20	20	18.7	8.8	3.8	5	2.5
D	1	16	11	13	22	4	6	11	16

TABLE 12

5½% mix 350 lb. pressing load

Range (ohms)	20 - 40	40 - 70	70 - 100	100 - 150	150 - 200	200 - 300	300 - 500	500 - 700	1600 - 3200
%	10.5	21	24.5	13	9	4	5	8	5

At 175 lb. the range is wide and the distribution varies considerably between the batches, due probably to the variations mentioned above. The results at 350 lb. are the grouped results of seven small batches. In the four batches at 175 lb. there were 95, 81, 91 and 72% between 70 and 5000 ohms, but there were 2.5, 16, 7.5 and 27% over 5000 ohms. At 350 lb. there were 67.5% between 40 and 200 ohms as against 25% at 175 lb. and the range was very much narrower, being effectively from 20 to 700 ohms. These results illustrate the trend to lower mean resistance and a narrower range as the pressing load is increased.

The selection of a particular mix and pressing load would depend on the performance characteristics required. However, as stated in para. 5.4 the results suggest that an increase of pressing load leads to greater inherent sensitivity, i.e. the same sensitivity at a lower resistance value. Thus it would appear desirable in the case of the 5½% mix, to use the higher pressing load, since this would enable an acceptance resistance range to be fixed which should make the rejection rate in filling quite small.

6. SAFETY CONSIDERATIONS

The design of the detonator incorporates a thick-walled body into which a robust pole-piece and its insulation is inserted under pressure, thus producing a very strong and rigid assembly. This assembly is able to withstand very considerable mechanical rough usage thus conferring on the detonator a considerable factor of safety in normal handling.

With the level of electrical sensitivity attained, an electrostatic or an electromagnetic hazard may exist. When, at a later date, the C.C. igniter was developed for factory production, a shorting slip of silver-plated spring steel strip (somewhat like a fountain-pen clip), was designed, which gripped the body of the assembly and made contact with the pole piece. Such a clip should be fitted on the detonator assembly before filling is started and should be retained on the detonator until it is fitted into its component for use.

The detonator is sufficiently robust to enable the shorting clip to be removed and the detonator inserted in its housing exclusively by mechanical means. Such an operation could be arranged to take place behind a suitable screen ensuring safety of the operatives involved. When assembled into its housing, provision should be made by shorting or by other means to ensure that no charged body can discharge through the detonator. By this means, the electrostatic hazard may be averted.

The electromagnetic hazard is related to the environment of the detonator and the circuit to which it is connected; the hazard therefore can only be evaluated in relation to these factors.

7. CONCLUSIONS

The development of a C.C. detonator system has been described. It has been shown that an electrical sensitivity can be obtained which is likely to be adequate for any Service requirement. There is evidence that the mean sensitivity could be set to any value in quite a wide range. The firing interval in a condenser discharge circuit is less than 2 microsecs. with quite small voltages and energies. There is evidence that the functioning characteristics should not be affected by temperature cycling up to 70°C.

The filling could be done by a process similar to that used for fuze detonators either single or multiple filling. As the body does not expand when the filling is being pressed, the filling mould has only to locate the initiator correctly. The mould can be made to take the empty assembly with a shorting clip in position, thus avoiding a static hazard during the filling operation. The detonator has a filling of about 100 mgms. (1.5 grains). Owing to the considerable radial and rear tamping, it gives a powerful forward impulse which can initiate a high density tetryl pellet over a small air gap.

There should be no difficulty in waterproofing the detonator efficiently by the application of one drop of varnish at the annular space between the pole piece and the body and at the end of the filling.

8. ACKNOWLEDGEMENTS

The design shown in Fig. 1 was originated by Mr. W.S.Hall who also developed the method of assembly and filling.

The experimental work was carried out mainly by Mr. J.S. Ellis, assisted in the earlier stages by Mr. P.W.W. Fuller and later by Mr. P.F.Morley.

CEAD prepared detailed drawings of the components and arranged for supplies of components and empty assemblies.

The lead azide R.D. 1339 was developed and made by Messrs. G.W.C. Taylor and A.T. Thomas (ERDE) who made and supplied the graphite mixes as required.

9. REFERENCES

(1) Bessent, Hall and Mills, ARD Report 31/47

(2) Groocock and Hall, ARDE Memorandum (MX)8/59

FIG. 1

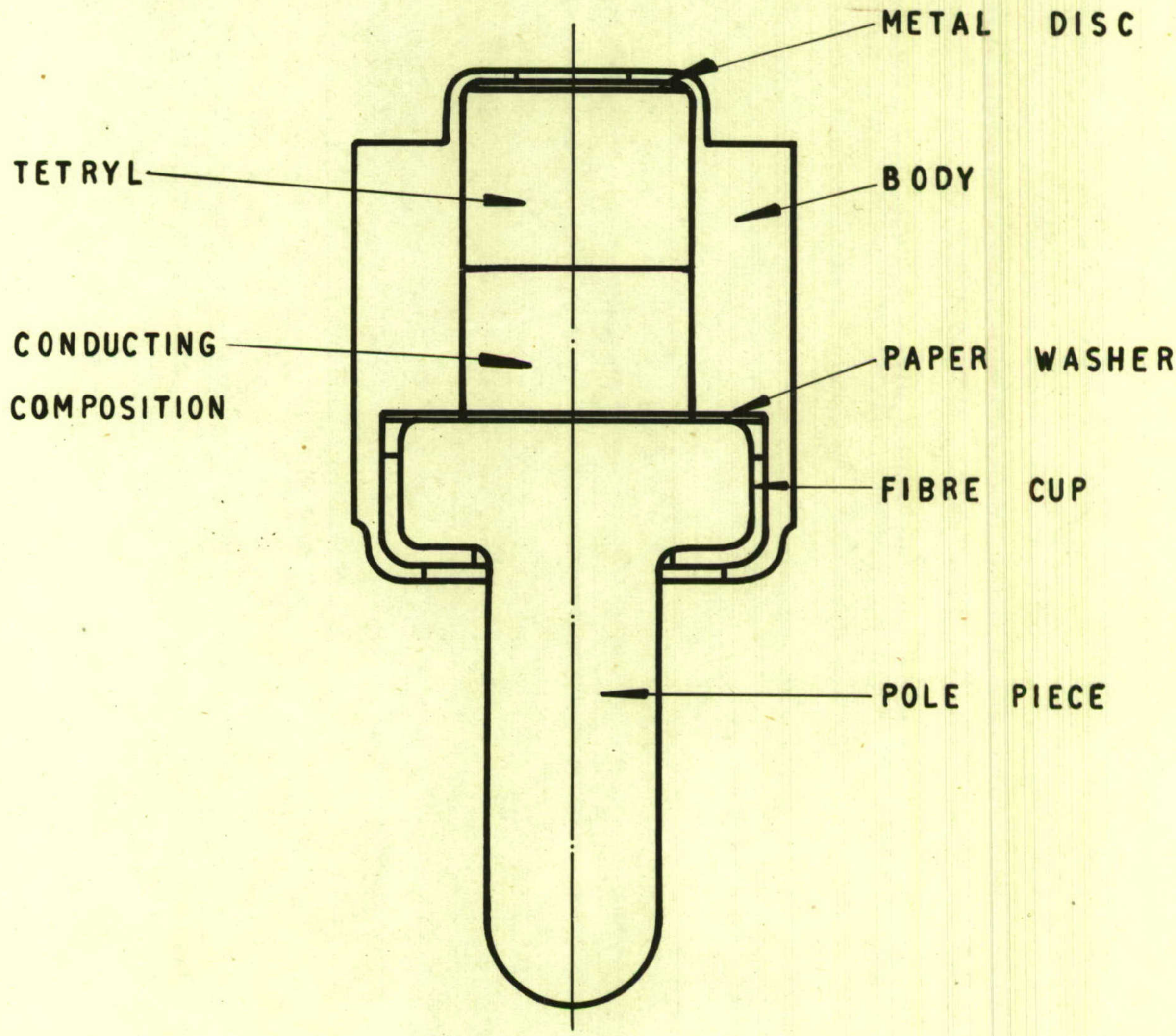

FIG. 1 SMALL ELECTRIC DETONATOR BRIDGELESS TYPE

SCALE 10/1

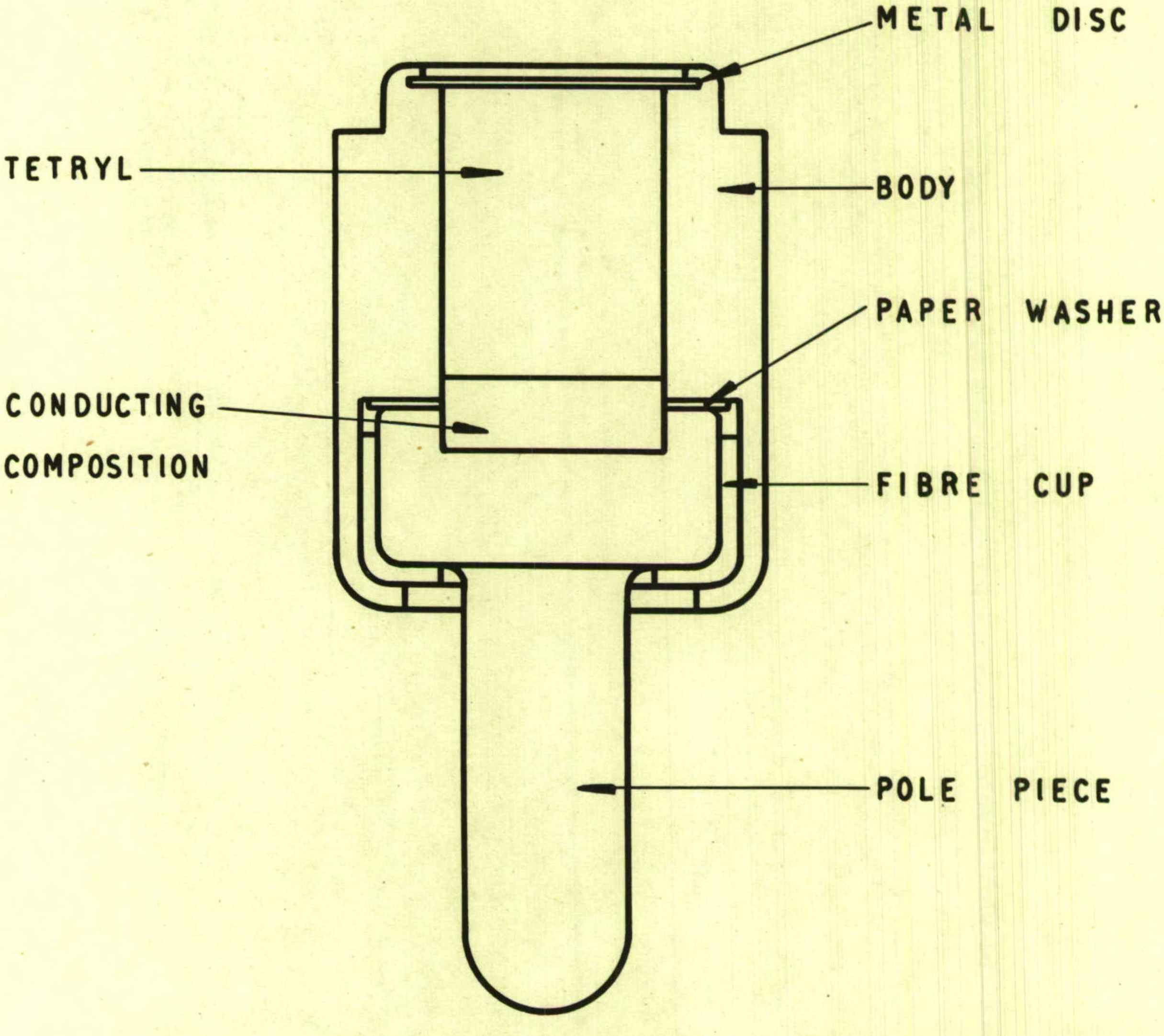

FIG. 2 SMALL ELECTRIC DETONATOR TYPE 2

SCALE 10/1

FIG. 3

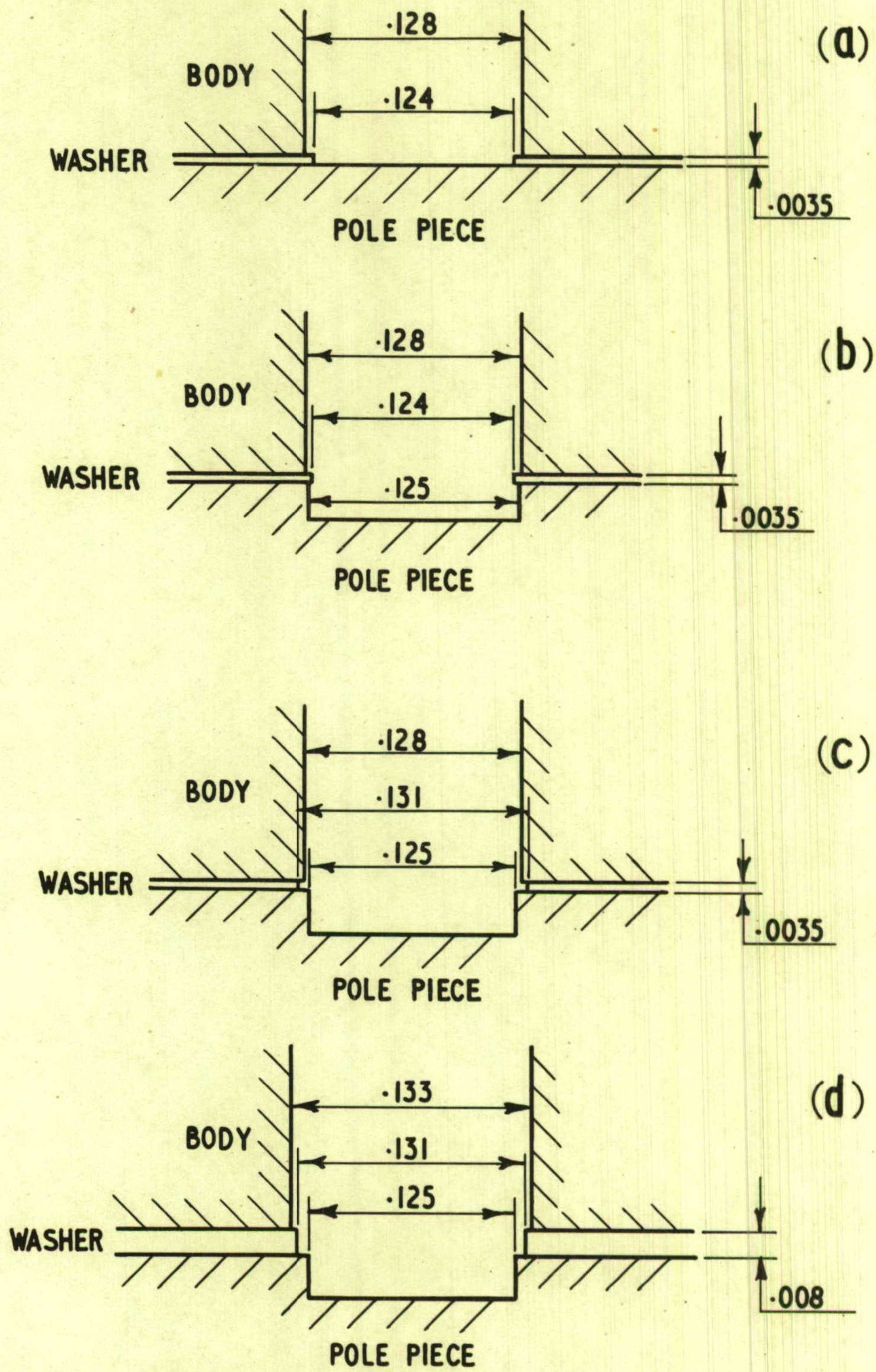

FIG. 3 ELECTRODE SPACING
(DIAGRAMMATIC)

DIMENSIONS IN INCHES

FIG.4

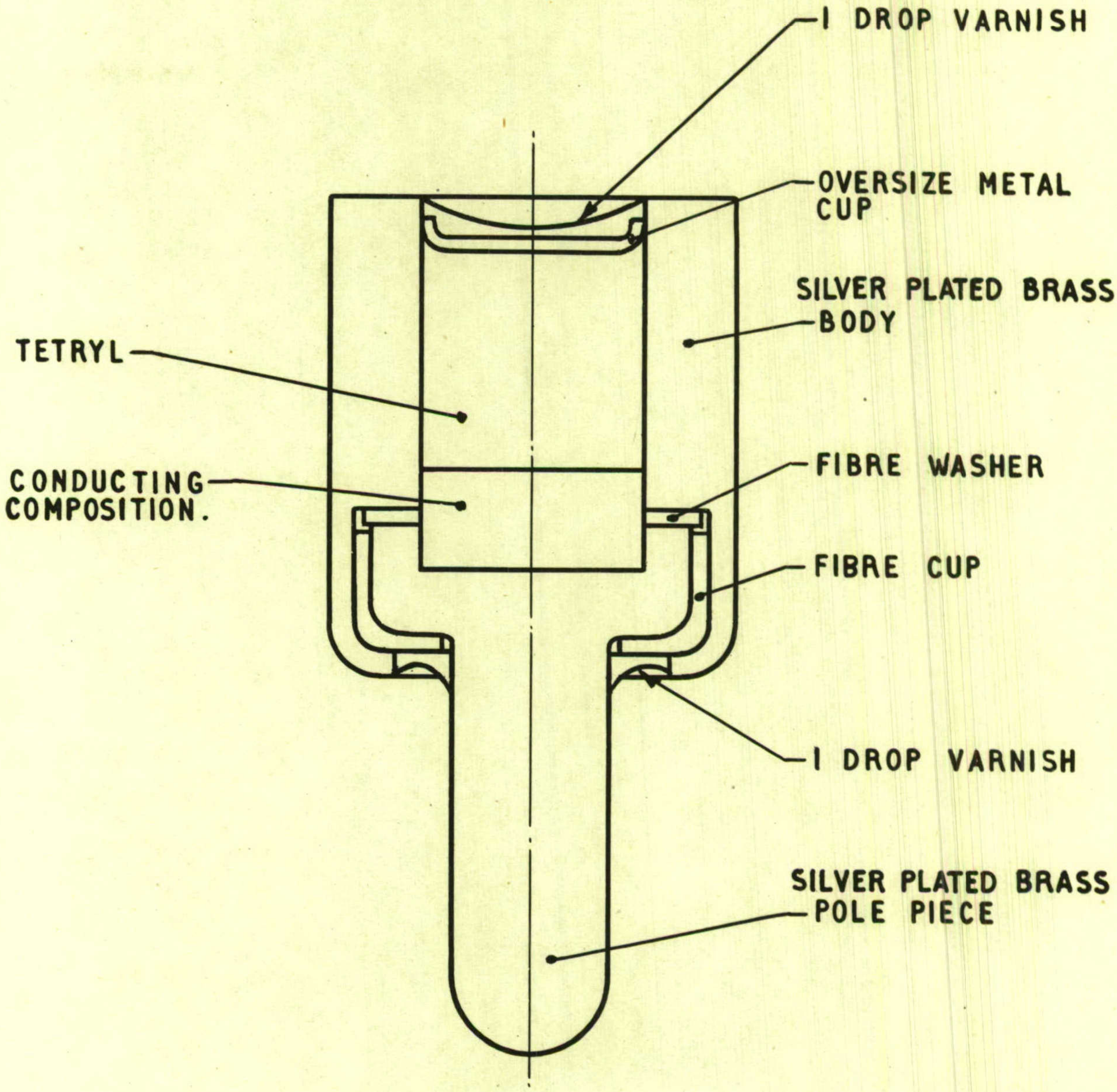

FIG.4 FINAL DESIGN

SCALE 10/1

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