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**INVESTIGATION OF TECHNIQUES TO
REDUCE ELECTROSTATIC DISCHARGE
SUSCEPTIBILITY OF EED'S CONTAINING
PLASTIC PLUGS**

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GERALD R. LAIB

RESEARCH AND TECHNOLOGY DEPARTMENT

25 AUGUST 1978

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INVESTIGATION OF TECHNIQUES TO REDUCE ELECTROSTATIC DISCHARGE
SUSCEPTIBILITY OF EED's CONTAINING PLASTIC PLUGS

This report describes the results of a project to investigate techniques for increasing the electrostatic safety of Navy electro-explosive devices. The work was funded by NAVSEA-0332 under Task SF33-354-391, Explosives Materials, Effects and Safety.

The results should be of interest to persons engaged in the development, handling, and use of electroexplosive devices. The identification of commercial materials implies no criticism or endorsement of these products by the Naval Surface Weapons Center.

Julius W. Enig
JULIUS W. ENIG
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I. INTRODUCTION

Many Navy electroexplosive devices (EEDs) are susceptible to accidental or unintentional initiation from a human body electrostatic discharge. Increasing use of synthetic fiber clothing, coupled with the difficulty of obtaining recommended cotton clothing, and increasing assembly of EEDs into weapons or test vehicles away from controlled grounded areas can be expected to increase the potential for accidents in future years, unless corrective measures are taken.

The purpose of this project was to investigate techniques to increase the safety of Navy EEDs to a level where they will be immune to human electrostatic discharge. A protective technique was desired which would not make the EED unduly sensitive to other types of accidental initiation (for example, electrically shorting one lead to the case¹ will provide electrostatic safety but will make the EED susceptible to stray currents and crossed grounds). It was also desired to find a technique that would require a minimum of modification to the various existing EEDs. This report deals specifically with finding a protective technique for EEDs containing a plastic initiator plug. The Mk 70-0 detonator was chosen for this investigation as it is a widely employed example of an EED that uses a plastic plug. (See Figure 1). A report had previously been written on the investigation of techniques to increase the safety of hermetically sealed Navy EEDs.²

II. ELECTROSTATIC DISCHARGE INITIATION MODES

EEDs can be accidentally initiated by an electrostatic discharge in the various modes described below:

- A. Pin-to-Pin - The electrostatic discharge can travel down one pin (or lead) through the bridgewire and out the other pin. This type of initiation corresponds to normal initiation of the EED as effected by the heating of the bridgewire.

1. Hedden, S. E. and Rossbacher, R. I., "Some Notes on the Navy's Current and Future Requirements on Electric Initiators for Power Cartridges," in the Proceedings of Electric Initiator Symposium, Nov 1960

2. Leopold, H. and Rosenthal, L., "Investigation of Techniques to Reduce Electrostatic Discharge Susceptibility of Hermetically Sealed EED's," NSWC/WOL/TR 75-57. July 1975

- B. Pin-to-Case - The electrostatic discharge can pass through the explosive between the pins and outer case. Very small amounts of energy are necessary for initiation since most primary explosives are easily ignited by an arc discharge.
- C. Pin-to-Case (coaxial EED) - The construction of a coaxial EED makes the pin-to-case mode in this type of item correspond to the pin-to-pin mode described above. (The electrostatic discharge travels through the bridgewire between the single pin and the case).
- D. Bridgewire-to-Bridgewire - This type of initiation can occur only in items with dual bridgewires. An electrostatic discharge can jump between the two bridgewires.

Realistically, mode B is the primary problem condition.

III. TEST METHOD

An electrical circuit is usually used to simulate a human being when determining the sensitivity of EEDs to an electrostatic discharge. There is at present no general agreement on the values to use for the test circuit. The values given in reference 3 appear to be widely accepted and were employed for this investigation. Essentially a RC circuit consisting of a 500 picofarad capacitor charged to 25,000 volts and in series with a 5,000 ohm resistance is used. A Kilovan H35 tube was used as a switch. In order for an EED to be considered safe from human body electrostatic discharges, it should not fire when tested with discharges from a test circuit with these parameters. Test voltages other than 25,000 volts were employed where additional information was desired.

IV. SUSCEPTIBILITY OF MK 70-0 DETONATOR TO ELECTROSTATIC DISCHARGE

The Mk 70-0 detonator has a 0.013 mm (0.0005 inch) diameter nichrome bridgewire approximately 0.559 mm (0.022 inch) in length. Ten Mk 70-0 detonators were subjected to a 25,000-volt discharge in the pin-to-pin mode. No initiations were observed. Mk 70-0 type detonators were then made with smaller diameter bridgewires and tested. The results are given in Table 1. These test results indicate that the 0.013 mm (0.0005 inch) is marginally safe to the electrostatic discharge test and that smaller wire diameters should not be used if an EED is to be safe in the pin-to-pin mode. Further tests to determine the margin of safety for the 0.013 mm diameter bridgewire were run by increasing the test voltage and the results are given below:

3. MIL Spec MIL-I-23659C, Initiators, Electric; General Design Specification for

TABLE 1

EFFECT OF BRIDGEWIRE DIAMETER ON PIN-TO-PIN ELECTROSTATIC DISCHARGE
SUSCEPTIBILITY IN MK 70-0 DETONATOR CONFIGURATION

<u>Potential</u>	Bridgewire Diameter		
	<u>0.013 mm</u> <u>(0.0005 inch)</u>	<u>0.0104 mm</u> <u>(0.00041 inch)</u>	<u>0.0094 mm</u> <u>(0.00037 inch)</u>
25,000 volts	0/10 fired	3/3 fired	3/3 fired
22,500 volts		0/4 fired	
20,000 volts		0/3 fired	3/3 fired
17,500 volts			2/3 fired
15,000 volts			0/3 fired

<u>Potential</u>	<u>Results</u>
25,000 volts	0/10 fired
27,500 volts	0/10 fired
30,000 volts	1/10 fired

These tests indicate that a small but adequate margin of safety exists so that the Mk 70-0 detonator will pass the 25,000 volt electrostatic discharge test in the pin-to-pin mode. It should be noted that to deliver electrostatic energy in the pin-to-pin mode requires a well defined discharge path. Grounding one pin or leg of the bridgewire enhances this mode of discharge.

Five Mk 70-0 detonators were then subjected to a 25,000-volt discharge in the pin-to-case mode. All five detonators fired. Short Bruceton type tests were then run with two lots of Mk 70-0 detonators using the voltage as the variable. (See Figure 2.) The Mk 70-0 detonator can be considered to be extremely susceptible to electrostatic discharge in the pin-to-case mode.

V. INVESTIGATION OF PROTECTIVE TECHNIQUES

A description, results, and comments on the different protective techniques considered or explored are given below in the chronological order of evaluation.

Electrodag^R - The application of a conductive coating containing carbon particles, called Electrodag^R + 501 to the back of the initiator plug of hermetically sealed EEDs was found to be a simple and inexpensive method of protection from human electrostatic discharge.² When considered for use with EEDs containing plastic initiator plugs, this technique has several disadvantages. Because the Mk 70 detonator has flexible leads, the Electrodag resistance cannot be maintained from pin-to-case. Flexing the lead can make the resistance vary and/or disrupt the Electrodag^R film.* The Electrodag^R and plug are both black in color making it difficult to judge the thickness of the application. Whereas the Electrodag^R could be painted in a small protective cavity on the hermetically sealed EEDs, on plastic plugs the Electrodag^R is exposed, and the coating can be easily scratched or scraped. Although the technique might be used for some plastic plug designs, it cannot be applied to many of the plastic plug EEDs, necessitating the exploration of other techniques.

*A definite resistance range is required for electrostatic protection. A measurement of resistance in the specified range verifies the presence of the electrostatic protection.

Insulation - A protective insulation technique would involve the placement of a dielectric barrier strong enough to prevent a pin-to-case electrostatic discharge from taking place. For pin-to-case breakdown of the Mk 70-0 detonator, the most obvious and pronounced breakdown path is the short distance between the bridgewire and the force-fitted metal sleeve on the initiator plug. This gap may be smaller and the breakdown voltage lower than expected under certain production conditions. The bridgewire may not be trimmed all the way back to the solder mound or the gap can be shortened by a shaving resulting from the force-fitting of an aluminum sleeve on the plug. (See Figure 3.)

The effect of sleeve material (see Figure 1) on the dielectric breakdown voltage was first investigated. Drawings for the detonator fabrication (LD 486247) call for the option of using either an aluminum or steel sleeve. Short Bruceton type tests were run to determine if the metal difference had any effect on the breakdown voltage (see Figure 4). No significant difference was observed. Anodized aluminum sleeves were tried next to determine if the coating would influence the breakdown voltage. A 0.0076 - 0.0127 mm (0.003 - 0.0005 inch) thick coating failed to effect any improvement (see Figure 4). It is quite probable that the anodizing may be scraped off due to the force fit of the sleeve on the plug.

Various plastics, nylon, Delrin, Lexan, high density polyethylene, and fiber sleeves were then investigated for use as sleeve materials (See Figure 1). Short Bruceton type tests were run with each of the materials to evaluate them, except for Lexan which exhibited visible strains and deformed due to the force fit with the plastic plug. The four materials increase the pin-to-case breakdown voltage to approximately 10 kv. (See Figure 5.) It is not known whether the differences between the plastics are significant due to the small size and different assembly personnel employed. In any event, the substitution of a dielectric material for the metal sleeve will not by itself raise the pin-to-case breakdown voltage to a sufficiently high level to protect the Mk 70-0 detonator. There is also an assembly problem when employing nonmetallic rings. When loading the primary explosive into the sleeve, the loading pressure causes the plastic to expand elastically, and when the pressure is removed, the contraction of the plastic tends to cause the lead azide to flake.

The concept of using an insulation barrier inside the detonator cup was also investigated. A strip of nylon was placed inside the unloaded cup with a 5 mm (0.2 inch) overlap, as shown in Figure 6, for almost the full length of the cup. The initiator plug diameter was cut down so it would not have the usual force fit in the cup and deform or tear the nylon strip as it was pressed into the cup. Three lots of ten detonators each were loaded by three different loaders. One lot passed the 25,000-volt discharge test and the other two lots failed, indicating that the technique is poor since

the loaders were admonished to be as careful as possible during the loading. It would be practically impossible to avoid tearing a thin insulating liner during commercial production. The principle is sound but the reduction to practice is not consistently reliable.

Conductive Gasket - Velostat^R, an electrically conductive polyolefin plastic, is frequently used as a container for static sensitive explosives. The material can be obtained in many forms. Small gasket washers were made to slip over the lead wires and were mounted in the detonator as shown in Figure 7. The lead wires were stripped of the insulating material so that they would make electrical contact with the washer. Twelve detonators were built as shown with the pin-to-case resistance ranging from 80,000 to 1,000,000 ohms and averaging 350,000 ohms. Ten out of twelve fired during the 25,000-volt discharge test indicating that the resistance was probably too high. The manufacturer was then asked to supply a material of approximately 100 ohm-cm nominal volume resistivity. The material was supplied as Custom Materials, Inc. conductive sheet x3210. Fourteen detonators were constructed as in Figure 7 with this material. The pin-to-case resistance ranged from 12,000 to 170,000 ohms and averaged 115,000 ohms. All fourteen passed the 25,000-volt discharge test with the pin-to-case resistance after the test ranging from 650 to 6000 ohms and averaging 1550 ohms. These detonators were then subjected to MIL-STD-331 Test 105.1 (temperature and humidity) for four weeks. The pin-to-case resistance after the four weeks exposure ranged from 20,000 to 750,000 ohms and averaged 130,000 ohms. All fourteen detonators again passed the 25,000-volt discharge test.

The x3210 material was considered satisfactory for detonator protection except for the larger than desired resistance changes. The technique would also have the disadvantage of adding 1.27 mm (0.050 inch) to the length of the detonator.

Another conductive material which can be used as a gasket is Union Carbide^R K-1516 conductive silicone rubber. It has a temperature range of -54 to 260°C, and can be used as a static charge dissipator. The material was obtained in sheet form 2.03 mm (0.080 inch) thick in the B formulation (75% K-1516 conductive

silicone rubber, 25% UC-5 nonconductive silicone rubber) with an electrical resistivity of 40 ohm-cm.

Fourteen detonators were built using the material as a gasket. The pin-to-case resistance ranged from 270 to 550 ohms and averaged 360 ohms. All fourteen detonators passed the 25,000-volt discharge test, dropping to a resistance range of 150 to 230 ohms with an average value of 190 ohms. The fourteen detonators were then subjected to four weeks of MIL-STD-331 Test 105.1. The pin-to-case resistance increased slightly, ranging from 250 to 1900 ohms with an average value of 530 ohms. All fourteen detonators again passed the 25,000-volt discharge test, but after the test seven of the fourteen had pin-to-case resistances of less than the desired 100 ohm isolation level.

Another sample of a less conductive composition was obtained in the C formulation (50% K-1516 conductive silicone rubber, 50% UC-5 nonconductive silicone rubber) with a volume resistivity of 590 ohm-cm. Fifteen detonators were built with this material. The pin-to-case resistance ranged from 20,000 to 5,000,000 ohms and averaged 1,180,000 ohms. Ten of the fifteen detonators failed the 25,000-volt discharge test indicating too high a resistance.

To adjust the pin-to-case resistance, the 40 ohm-cm B formulation K-1516 sheet was thinned to 1.02 mm (0.040 inch) and twelve detonators were built with the thinner conductive gasket. The pin-to-case resistance ranged from 480 to 1500 ohms and averaged 750 ohms. All twelve passed the 25,000-volt discharge test with only a small drop in resistance. The twelve detonators were then subjected to four weeks of MIL-STD-331 Test 105.1. The pin-to-case resistance increased to an average of 3,300 ohms. All detonators passed two 25,000-volt discharge tests with all pin-to-case resistances remaining above 100 ohms, the lowest value being 140 ohms. Six of the twelve detonators were then subjected to five more 25,000-volt discharge tests. All six passed the multiple discharge tests with the pin-to-case resistance remaining constant. The other six detonators were subjected to a penalty 25,000 volt discharge test in which the series resistance was reduced from 5,000 to 2,500 ohms. All six detonators passed this test. The detonators were then subjected to a second penalty test in which the series resistance was reduced to 500 ohms. Two of the six detonators fired on this penalty test which is a severe test.

The thin K-1516 material was considered very satisfactory for detonator protection, having an adequate margin of safety from a human body discharge. The small resistance changes observed with this material are considered very desirable. The technique would require the addition of 1.02 mm (0.040 inch) to the length of the detonator.

Another gasket material investigated was Myst R^R conductive plastic. It is a proprietary, complex inorganic plastic compounded with conductive materials and is mounted on a 0.013 mm (0.0005 inch) thick Kapton substrate. It is manufactured by the Waters Manufacturing Company, Wayland, Massachusetts. The test material supplied had a value of 1000 ohms per square. The Kapton substrate is fairly stiff and it was found difficult to attach the stiff film under the crimp. No pin-to-case resistance reading could be obtained since the thin conductive layer on the film does not contact the wires. Five detonators were made with this film and all five passed the 25,000-volt discharge test. A poor wire contact would not impede the performance since the contact gap would break down under discharge.

The material has the advantage that it would only add 0.014 mm (0.00055 inch) to the length of an item in which it would be employed. Because of the difficulty entailed during the crimping operation, the material was not considered applicable for the Mk 70-0 detonator. The material could, however, be used in other items where it can be used as an insert in a split plug application or on a flat surface. Unless a conductive epoxy or similar material is used to attach the film, resistive measurements to insure that protection exists cannot be made.

Conductive Plastic - It is fairly obvious that the small size of the Mk 70-0 detonator allows very little available space for the addition of protective devices. Because of space limitations, conductive plastics which could be substituted for the present dielectric plug material were investigated. Their use would involve no dimensional changes and no additional assembly operations, except that it would be necessary to remove the insulation layer from the lead wire before it is molded into the plug.

One of the first plastics investigated was manufactured by the Fiberite Corporation, Winona, Minnesota. It is a phenolic molding compound called FM 4005x4648. Its physical properties compare favorably with the present initiator plug material. A lot, consisting of 200 initiator plugs, was commercially transfer-molded using this material. To accommodate the present molds, the bare copper wire size was increased to #24 from #25 to prevent mold leakage (#25 wire without insulation is too small in diameter for the mold). A resistance measurement can be made only in the pin-to-pin mode on the initiator plug itself. The lot had an average pin-to-pin resistance of 130 ohms. It was found upon assembly into the Mk 70-0 detonator that the pin-to-case resistance for this assembly is approximately 50-65% of the pin-to-pin resistance. This material was considered too conductive for use. The low pin-to-case resistance could result in loss of some of the firing signal. Fuze design engineers had previously indicated that a minimum of

100 ohms isolation between pin and case would be desirable. Though the resistance values were too low, a lot of ten detonators was subjected to the 25,000-volt discharge test and all passed. The lot was then subjected to four weeks of MIL-STD-331 Test 105.1. Only minor changes were observed in the pin-to-case resistance. The detonators were then subjected to five consecutive 25,000-volt discharges and all passed. The ten detonators were then fired for functioning and output information. All ten fired on the specification pulse and met the dent specification.

The conductive molding compound obtained from Fiberite is made at its maximum conductivity value. The company indicated that the compound can be diluted with FM 4005, the non-conductive component, to lower the conductivity. A molding compound mix was made of 85% conductive material and 15% non-conductive FM 4005. A lot of 200 initiator plugs was commercially made with this formulation. The average pin-to-pin resistance was 475 ohms; however, 27% of the plugs had resistances less than 200 ohms. Twenty detonators were built with these plugs such that all detonators had a resistance of 100 ohms in the pin-to-case mode. All passed the 25,000-volt discharge test. However, three of the pin-to-case values dropped below 100 ohms (89,91,96 ohms) after the test. The low resistance values indicated that this formulation was still too conductive.

Further dilutions were made to decrease the conductivity. One molding compound mix was made with 80% conductive material and 20% non-conductive FM 4005, and another with 75% conductive material and 25% non-conductive FM 4005. The 80% mix had 7% of the lot under 200 ohms, while the 75% mix had only 2% of the lot under 200 ohms. The average pin-to-pin resistance of the 80% mix was 1930 ohms, and of the 75% mix 2800 ohms. The resistance of both formulations had a wide spread with several very high values. Ten detonators were built with the plugs containing 80% conductive material using close to average resistance values. All passed the 25,000-volt discharge test. Ten detonators were then built using plugs having pin-to-pin resistance values of 3,700 to 13,000 ohms. Three of them fired during the 25,000-volt discharge test, indicating that high resistances are dangerous. Twenty detonators were built with the plugs containing 75% conductive material. One of twenty fired during the 25,000-volt discharge test. Fifteen detonators were then built using plugs having pin-to-pin resistance values greater than 10,000 ohms. Four of the fifteen fired during the 25,000-volt discharge test, again indicating the danger of high resistance values.

To establish a resistance value, a plot of the average pin-to-pin initiator plug resistance versus the percent conductive material was made as shown in Figure 8. In the region of interest, very small changes in composition will give large changes in the resistance value and may be responsible for the resistance dispersion observed. A plot of the volume resistivity versus the percent conductive material is also shown in Figure 8. The results indicate that for this particular composition, a volume resistivity of 400-500 ohm-cm

would be optimum for the formulation. However, the test results show that a screening test would be necessary to eliminate electrostatic discharge sensitive detonators which are likely to occur occasionally at this level. The blending process would be critical; only small changes in composition would offset the ohm-cm value.

To further explore other sources of conductive plastics, Rogers Corporation of Rogers, Connecticut was asked to develop a thermosetting phenolic similar to MIL-M-14F Type MFH modified to have a volume resistivity of close to 1500 ohms. They developed two formulations 'F' and 'L', 250 ohm-cm and 1200 ohm-cm respectively measured by the ASTM D257 disc method. The bar method gave 1650 ohm-cm and 2660 ohm-cm values respectively. Initiator plugs made with the 'F' formulation had an average pin-to-pin resistance of 363 ohms, and those with the 'L' formulation 471 ohms. The resistance spread was much lower than the Fiberite blends and all 200 initiator plugs made from each formulation were usable. Twenty-five detonators were built with each formulation and all passed the 25,000 volt discharge test. All pin-to-case resistances remained above 100 ohms after the test. Both formulations were considered satisfactory for the protection of detonators from electrostatic discharges.

Conductive plastics based on diallyl phthalate are gaining increased recognition for usage in many resistor applications because of their lower cost, excellent physical and mechanical properties, and availability in a range of resistivities. Carbon technology in this field is still both highly specialized and proprietary. A formulation with a volume resistivity, by the bar method, of 900 ohm-cm was developed at the Naval Surface Weapons Center, White Oak Laboratory based upon published data.⁴ See Appendix A. The object was to demonstrate that a viable non-proprietary conducting thermosetting plastic could be fabricated in a laboratory equipped to compound plastic molding materials.

Plugs were molded with this material and yielded an average pin-to-pin resistance of 743 ohms. Twenty-five complete Mk 70-0 units were assembled. The resistance between twisted leads and the metal cup enclosure for these units had an average value of 135 ohms. As a rough approximation this resistance can be expected to be 1/4 of the pin-to-pin resistance.

When the completed EEDs were tested by the standard prescribed method there were no firings. Without the mode of protection, all 25 units would have fired. Upon rechecking the pins-to-case resistance, the average value dropped from 135 ohms

4. Wright, C. L., "Conductive DAP Resins - Guidelines for Prospective Users," *Insulation*, Feb 1968, p. 59

to 87 ohms. The protection was still effective but the pulse had generated more internal conductive paths. Compounding of a stable non-critical conducting thermoset is to be approached with caution.⁵ The formulation of Appendix A was adjusted after several trials to produce the correct resistivity and molding properties.

VI. DISCUSSION AND CONCLUSION

The use of a conducting plastic plug can provide electrostatic discharge protection for the Mk 70-0, plastic plug EED system in a most expeditious manner. No physical dimensions need be changed and the presence of the protection can be monitored at all times. Although conducting plastic gaskets can also provide the required protection, additional manufacturing operations are necessary and a slight increase in length must be accommodated. Removing the lead wire insulation where it is molded into the plastic is the only manufacturing change required in connection with the use of conducting plastic plugs.

A variety of conducting plastic thermosets is available. A low, stable, pin-to-pin resistance of the order of 500 ohms on the molded, virgin, plug is desired. Resistances higher than 2000 ohms are to be avoided. As conductive plastic plug resistance is decreased, a small amount of bridgewire energy must be sacrificed. A good molding material will not be overly critical to molding conditions (i.e., temperature and pressure), will have good pulse performance characteristics, and will possess the appropriate mechanical properties. The resistance is not a critical requirement for protection as long as it is below a nominal 500 ohms (pins-to-case).

The insulation resistance requirements specified to establish the dielectric integrity of the device now become meaningless. Instead, the measurement of a finite resistance is indicative of static protection. In cases where insulation and isolation at the EED is required, it will be necessary to use a dielectric sleeve external to the device enclosure. Certain tough and durable insulating varnishes may be sufficient for this purpose. The sought after 100 ohms resistance between pins and case is a compromise to prevent inadvertent firing through this path.

As further experience with conducting plastics develops, tighter controls on the final molded resistance values are anticipated. The ability to extrapolate from a compression molded test bar to a finished transfer molded plug resistance may be achieved. It would be advantageous to be able to tailor a resistance range through blending in a less empirical manner. The demonstrated protection is not compromised in spite of certain broad tolerances. There is no reason to doubt the applicability and success of this method of electrostatic protection to all varieties of plastic plug electro-explosive devices.

⁵. Discussions with H. Beacham and J. Jessup, FMC Corporation R&D, Princeton, New Jersey 08540

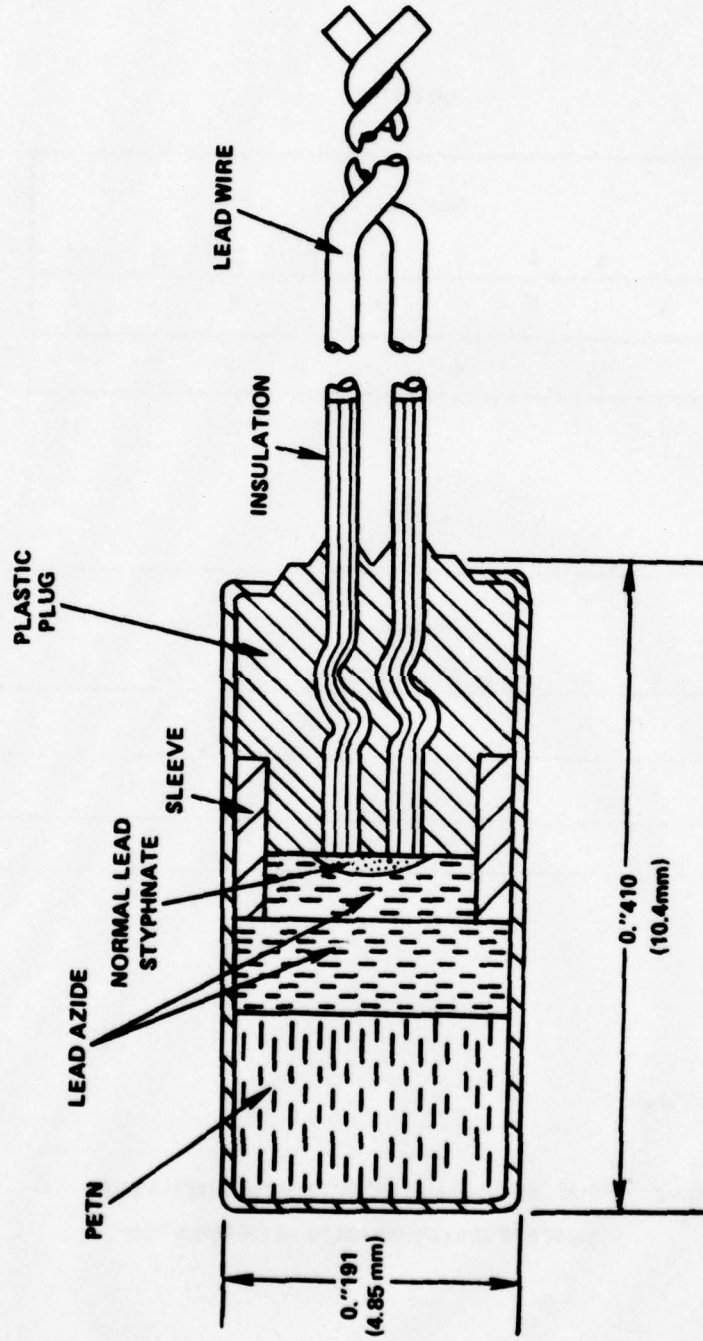


FIG. 1 MK70 MOD 0 DETONATOR

LOT 1

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
5,000 volts		X		X		X		X		X
3,000 volts	0		0		0		0		0	

LOT 2

POTENTIAL *	Shot no.											
	1	2	3	4	5	6	7	8	9	10	11	12
5,000 volts	X		X				X		X			
2,500 volts		0		X		0		0		X		0
0 volts					-						-	

X = FIRE

0 = NO FIRE

- = NO TEST

* 500 pf, 5,000 ohms

FIG. 2 PIN - TO - CASE ELECTROSTATIC DISCHARGE
SUSCEPTIBILITY OF MK70 - 0 DETONATOR

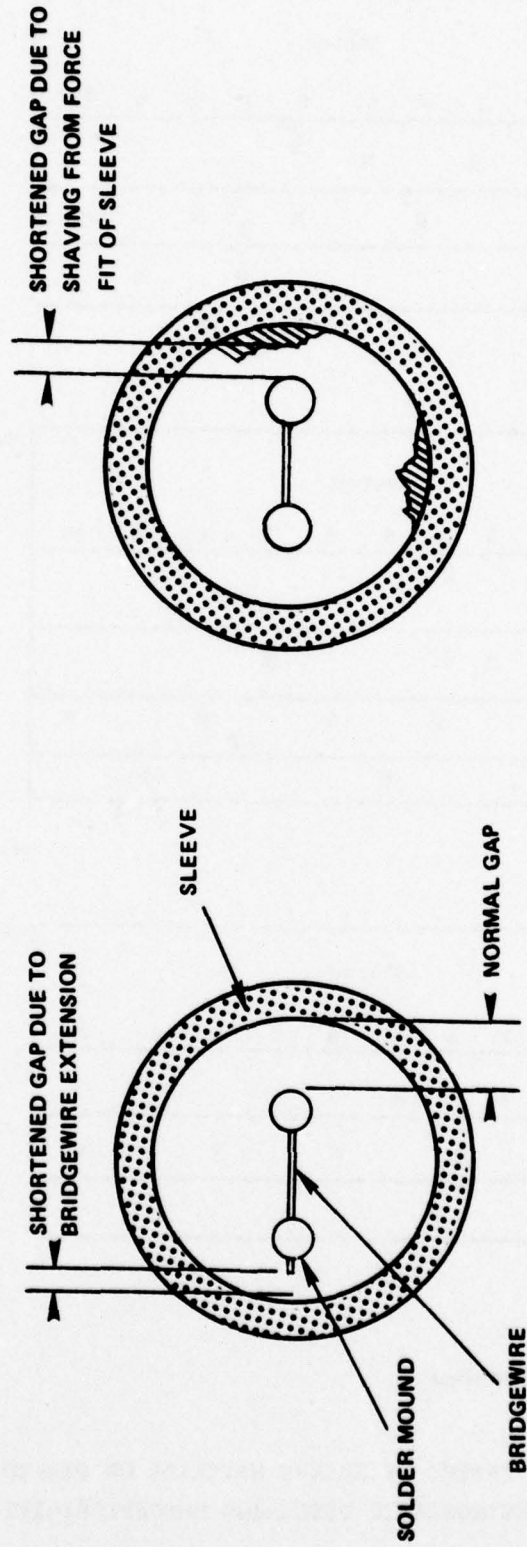


FIG. 3 POSSIBLE CAUSES OF SMALL GAPS

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
7500 volts	X		X		X					
5000 volts		0		0		X		X		0
2500 volts							0		0	

STEEL SLEEVE

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
10,000volts		X								
7,500 volts	0		X				X			
5,000 volts				X		0		X		X
2,500 volts					0				0	

ALUMINUM SLEEVE

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
7,500 volts	X		X		X					
5,000 volts		0		0		X		X		X
2,500 volts							0		0	

ANODIZED ALUMINUM SLEEVE

X= FIRE

0= NO FIRE

* 500 pf, 5,000 ohms

FIG. 4 EFFECT OF SLEEVE MATERIAL ON PIN-TO-CASE
ELECTROSTATIC DISCHARGE SUSCEPTIBILITY

NSWC/WOL/TR 73-82

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
15,000 volts						X				X
12,500 volts			X		0		X		0	
10,000 volts		0		0				0		
7,500 volts	0									

NYLON

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
12,500 volts	X		X				X			
10,000 volts		0		X		0		X		X
7,500 volts					0				0	

DELTRIN

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
20,000 volts										X
17,500 volts							X		0	
15,000 volts		X				0		0		
12,500 volts	0		X		0					
10,000 volts				0						

HIGH DENSITY
POLYETHYLENE

POTENTIAL *	Shot no.									
	1	2	3	4	5	6	7	8	9	10
22,500 volts								X		
20,000 volts					X		0		X	
17,500 volts		X		0		0				X
15,000 volts	0		0							

INSULATING FIBER
MIL - F - 1148

X - FIRE
0 - NO FIRE
500 pf, 5000 ohms

FIG. 5 EFFECT OF DIELECTRIC SLEEVE MATERIAL ON PIN-TO-CASE
ELECTROSTATIC DISCHARGE SUSCEPTIBILITY

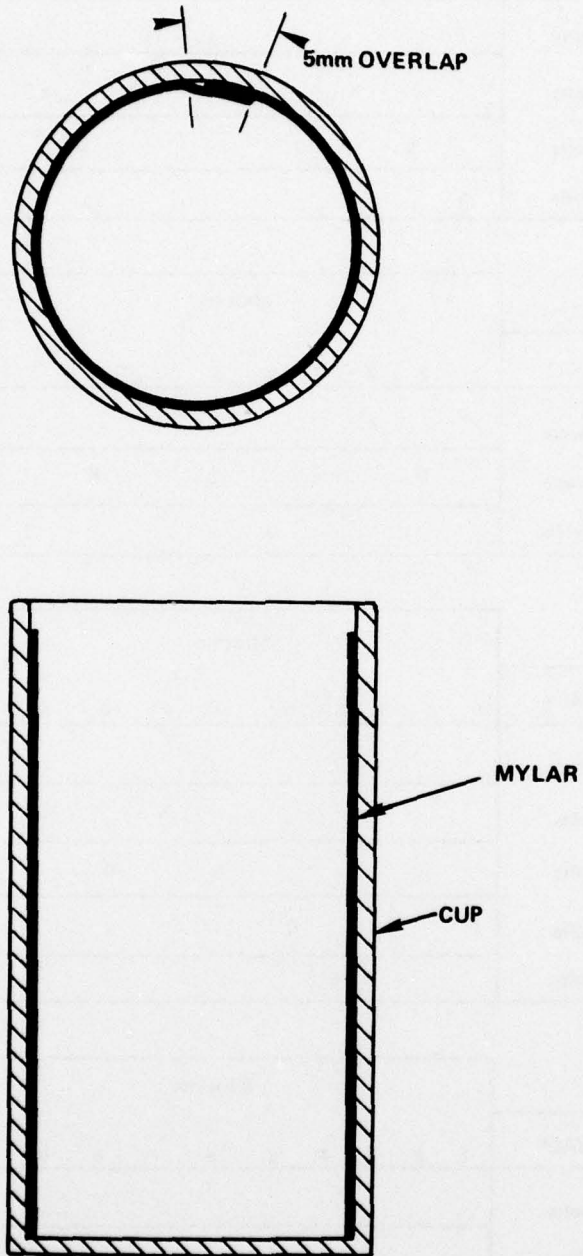


FIG. 6 LOCATION OF INSULATION BARRIER

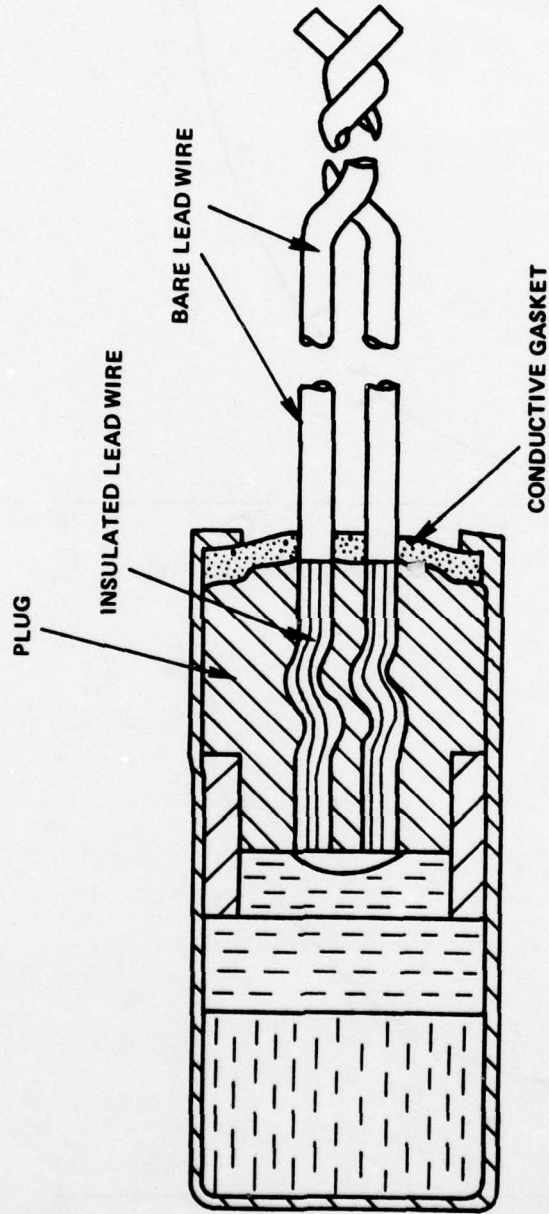


FIG. 7 MK70 MOD 0 DETONATOR WITH CONDUCTIVE GASKET

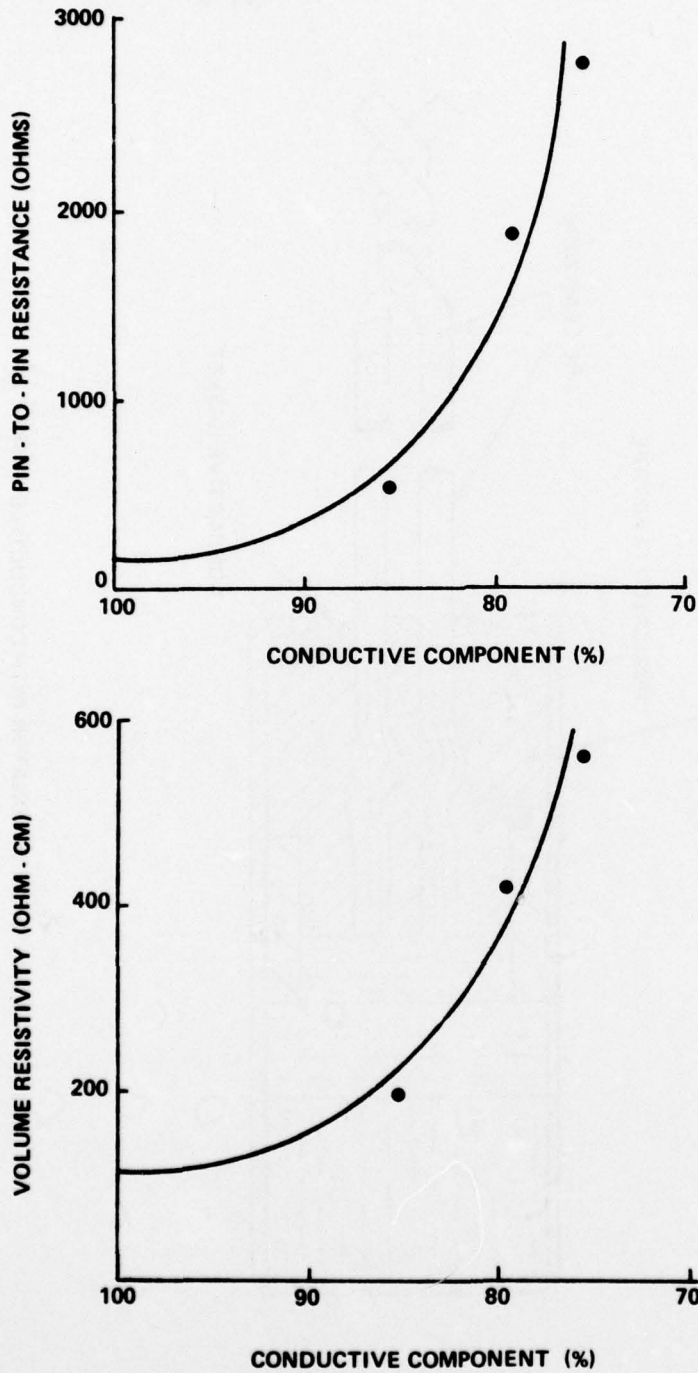


FIG. 8 EFFECT OF FIBERITE CONDUCTIVE COMPONENT ON RESISTANCE

APPENDIX A
CONDUCTIVE DAP RESIN FORMULATION

	<u>Parts by Weight</u>
Dapon M	100
DAIP Monomer	5
Hydroquinone	0.01
Wolastinite P-1	150
Asbury 6553 Graphite	36
Zinc Stearate	2
Conductex SC Black	3
Di-Cup R	5

Compounding Procedure

Add sufficient acetone to a mix of the first seven (7) ingredients to provide a slurry for ball milling.

Mix in ball mill until a homogeneous mixture is obtained.

Pour thin layer of slurry onto a clean drying surface and allow to air dry.

Place dried material on roller mill and add DI-CUP R (dicumyl peroxide). Mill for two (2) minutes. Do not allow roller temperature to exceed 200°F.

Dice material into small pieces and allow to air dry. Store in covered container.

Molding Procedure:

Preform material and insert into 320°F mold. Cure at 320°F for five (5) minutes, and pull hot.

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