DEVELOPMENT OF THE MK-112 DETONATOR

BY BRYAN A. BAUDLER,
BENNY SIMPSON

RESEARCH AND TECHNOLOGY DEPARTMENT

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NAVAL SURFACE WEAPONS CENTER

Dahlgren, Virginia 22448 • Silver Spring, Maryland 20910

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A new detonator, the Mk-112, has been developed and evaluated as a possible replacement for the Mk 57 MOD 1 detonator. Its use may be necessary in applications where lead wires are desired in place of contact pins. The Mk-112 has also been designed to be protected from the hazards of electrostatic discharge by the application of a conductive coating, Electrodag[R] +501, and a

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) protective varnish to the back of each detonator plug. By doing so, a low resistance electrical contact will be formed between the lead wires and detonator case. These coatings can be applied at a minimal cost and were able to withstand all environmental and mechanical conditions required by MIL-I-23659 for EED design.

FOREWORD

The work described in this report details the development of the Mk-112 detonator. This electroexplosive device was developed as a replacement for the Mk 57 Mod 1 detonator in certain applications. It has also been designed to provide protection against the hazard of accidental initiation through human electrostatic discharge. The results should be of interest to persons engaged in the development, design, and use of electroexplosive devices.

Approved by:

J. F. PROCTOR, Head
Energetic Materials Division

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INTRODUCTION

The Mk-112 detonator was designed in response to a request from the QUICKSTRIKE Program office to fabricate a Mk 57-1 type detonator with lead wires in lieu of contact pins. Its planned use is as an initiator in the EX 35 MOD 0 Arming Device which is a component of the underwater mines Mk 62, EX 63, and EX 64.

As a replacement for the Mk 57-1 detonator, the Mk-112 was required to maintain the same sensitivity as the Mk 57-1. Other characteristics such as output, body size, the hermetic seal, and materials of construction were also to remain unchanged. In addition, the requirements and constraints of MIL-I-23659 were to be met. This specification is used to outline general design features which should be inherent in electroexplosive devices. The major goal of the redesign was to meet the specification requirement that each detonator be protected from the hazards of accidental initiation from human electrostatic discharge.

Because the Mk 57-1 was developed before MIL-I-23659 was written, it was not designed to meet various design features called for in the specification. As a result, certain uniform methods in use today of testing EED's were never employed to analyze functioning characteristics of the Mk 57-1. As mentioned before, newly developed units are now required to withstand the simulated energy delivery from a human body electrosatic discharge. In this respect, they should not be susceptible to initiation when this simulated energy is delivered in various detonator configurations.

The Mk-112, therefore, has been designed to meet both the specification requirements for EED design as well as the QUICKSTRIKE design requirements. As a result, data was generated during its evaluation which should be of use in future design applications for both the Mk-112 and the Mk 57-1 detonators.

DESIGN MODIFICATIONS

Two major changes were made to the Mk 57-1 detonator to fabricate the Mk-112 (see Figure 1).

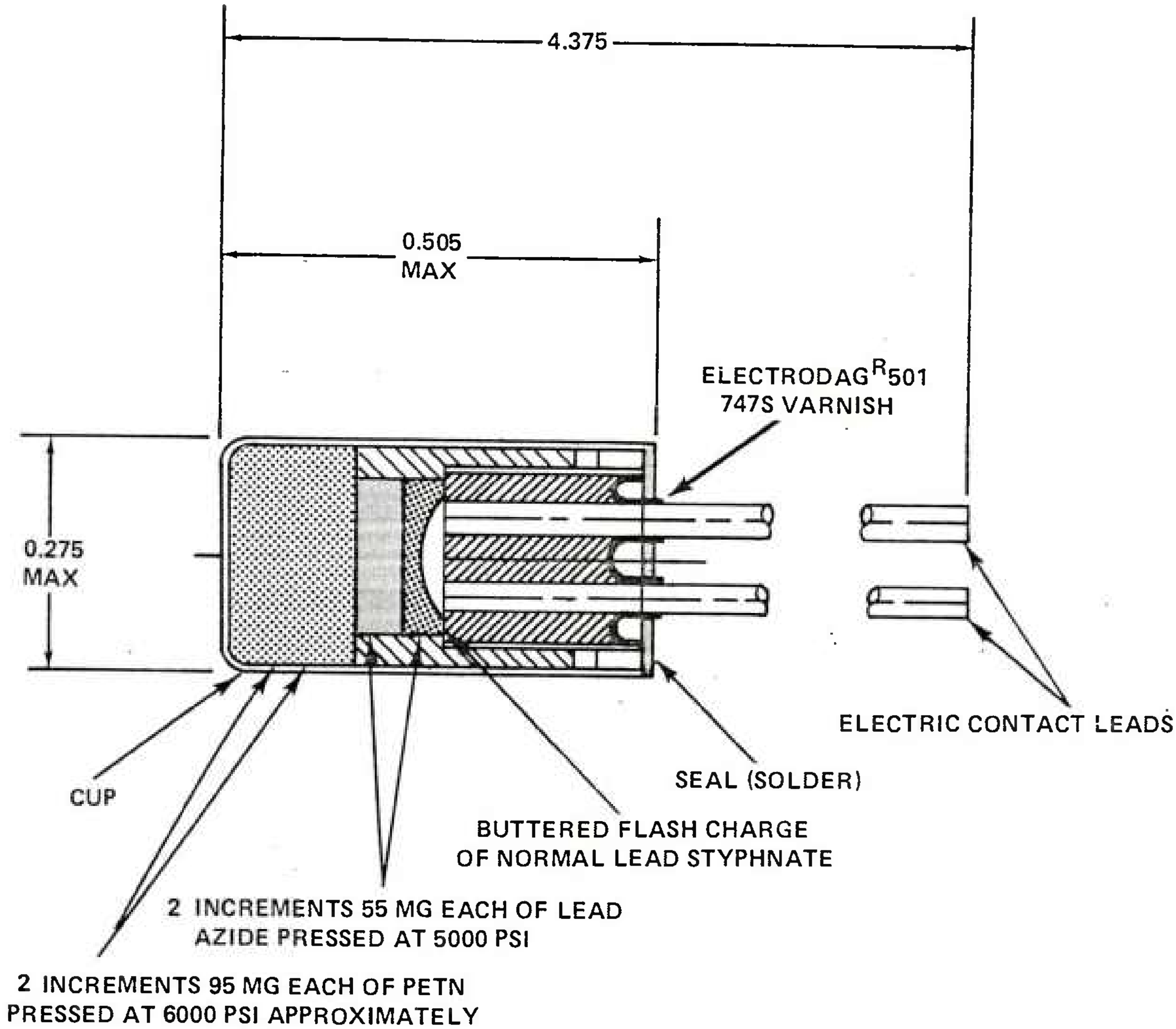

FIGURE 1. GENERAL ARRANGEMENT OF MK 112 DETONATOR.

1. The replacement of the rigid contact pins with 4" long flexible lead wires.

2. The application of a conductive coating and protective varnish to form a low resistance electrical contact between the detonator case and the lead wires.

Redesign of the existing detonator to provide it with lead wires proved to be fairly straightforward. The plug currently used in the Mk 101 detonator (see Figure 2) was found to be an ideal candidate for the replacement of the Mk 57-1 plug. By using an "off the shelf" item, substantial savings were realized in cost and development time.

Both plugs have approximately the same physical configuration except that the Mk 101 plug has 4" long lead wires in place of the 3/8" contact pins. Pin-to-pin spacing on each is similar as well as diameter, length, and materials of construction. Tolerances between the two items varied somewhat, but not enough to effectively penalize any interface. Each plug also fits in the detonator cup in such a way as to allow for the formation of a hermetic (solder) seal on each unit. Because the Mk-112 was to have the same sensitivity as the Mk 57-1, the same bridgewire was utilized in the redesign. The wire is .0008" diameter Nichrome, approximately .055" in length. The resistance range between the leads of the finished detonator is 4.0 to 8.0 ohms.

SUSCEPTIBILITY OF THE MK-112 AND MK 57-1 TO ELECTROSTATIC DISCHARGE

The major focus of the work on the Mk-112 was based on a technique to reduce the hazards of accidental initiation by an electrostatic discharge. To simulate an electrostatic discharge from a human being, an electrical current is delivered to the detonator through the circuit[1] shown in Figure 3. Basically, the circuit consists of a 500 picofarad capacitor charged to 25,000 volts placed in series with a 5,000 ohm resistor. This is then discharged across the detonator in various physical configurations.

Earlier investigations[2] had indicated that the Mk 57-1 detonator was extremely susceptible to initiation when the circuit was discharged between the detonator case and the shorted contact pins. Basically, the delivered energy passes through the detonator case and the explosive load to the bridgewire, and then out through the shorted leads. Detonation occurs when the current arcing from the detonator case to the bridgewire heats the explosive to cause initiation.

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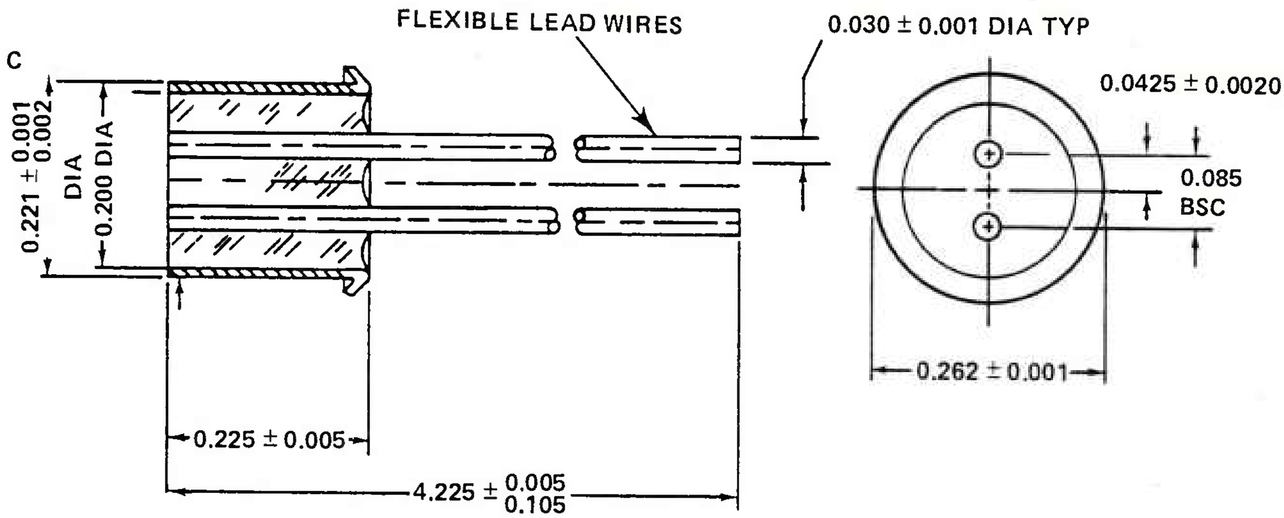
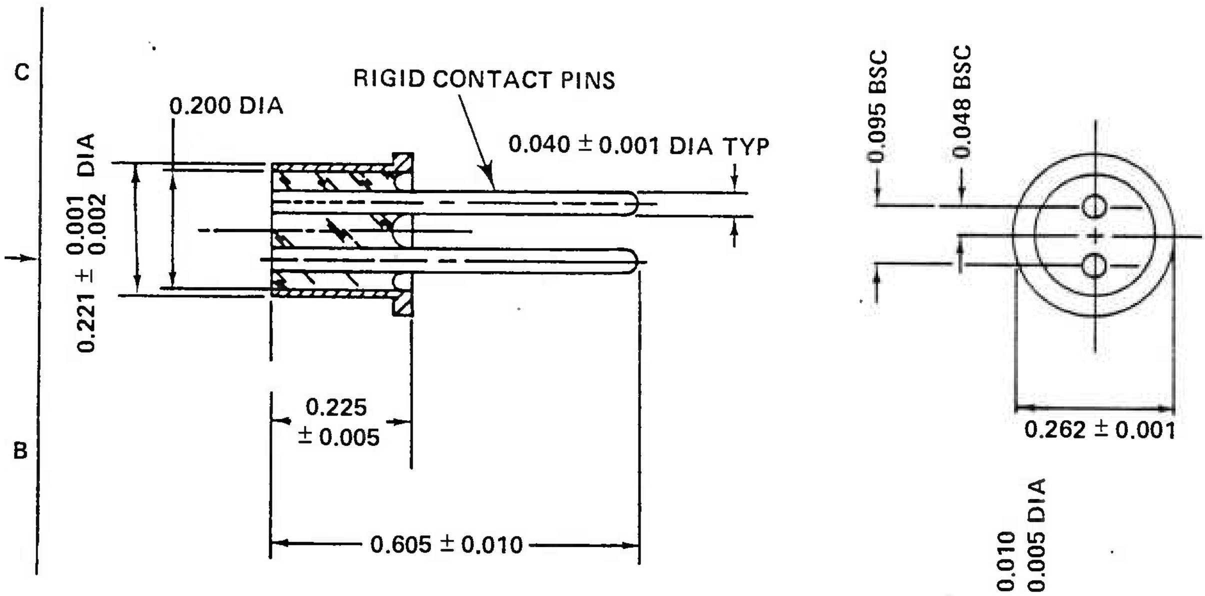
[1] MIL-SPEC-MIL-I-23659C, Initiators, Electric, General Design Specification for

[2] Leopold, Howard S. and Rosenthal, Louis A., "Investigation of Techniques to Reduce Electrostatic Discharge Susceptibility of Hermetically Sealed EED's," NSWC/WOL/TR 75-57, Jul 1975.



MK 101 DETONATOR PLUG.



MK 57-1 DETONATOR PLUG.

FIGURE 2. COMPARISON OF MK 101 AND MK 57-1 DETONATOR PLUGS

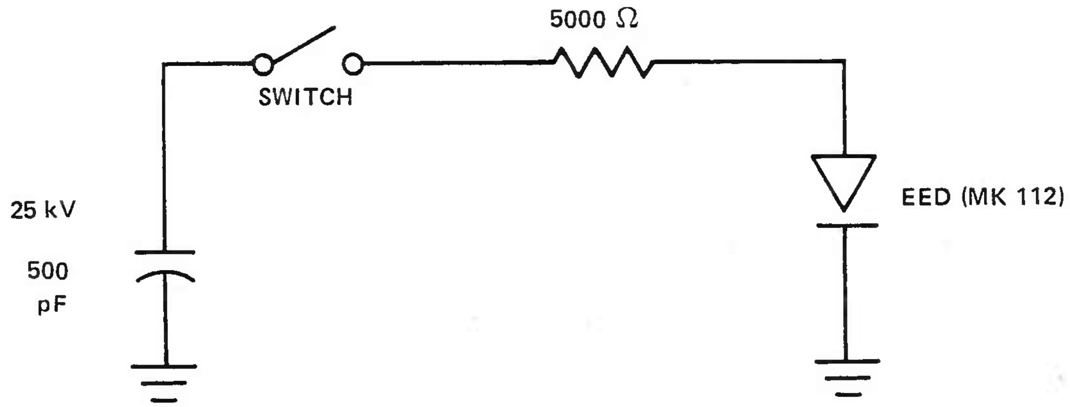


FIGURE 3. CIRCUIT DIAGRAM OF ESD TESTS.

Because the Mk-112 and Mk 57-1 detonators were so similar, it was felt that the Mk-112 would also be susceptible to accidental initiation by an electrostatic discharge. Therefore, a series of electrostatic discharge tests were run on it to determine the extent, if any, of the problem. In our tests, 100% of the Mk-112's initiated when tested at the 25kV level. Subsequent tests were then run at voltages considerably less than the 25kV level. The detonator was found to fire at voltages as low as 5,000 volts. Complete test results can be found in Table 1. It was obvious, therefore, that the Mk-112 failed (which agrees with our conclusions based on earlier work with the Mk 57-1) and some sort of modification was required in its design to pass the requirement for electrostatic discharge protection.

ELECTRODAG® +501

One recommendation for a low cost solution to the problem was to apply a conductive coating to the back of each detonator plug. This coating was applied to both the lead wire/plug interface and the detonator case/plug interface. In doing so, a low resistance path was formed between the shorted lead wires and detonator case. If a unit is exposed to an electrostatic discharge after this modification, the delivered energy would be more likely conducted through the detonator case and conductive coating to the lead wires. In this way, the probability of arcing between the detonator case and bridgewire would be minimized.

TABLE 1. ELECTROSTATIC DISCHARGE SUSCEPTIBILITY OF UNPROTECTED MK-112 DETONATORS

Voltage level*	# Tested	# Fires
25 KV	8	8
20 KV	8	7
15 KV	8	8
10 KV	6	4
5 KV	6	3
3 KV	6	0

*500 picofarad capacitor charged to this level in series with a 5,000 ohm resistor.

The recommended coating, Electrodag^R +501, is manufactured by Acheson Colloids Company. It is essentially a paintlike suspension of colloidal graphite particles in a solution of methyl ethyl ketone and a fluorocarbon resin binder. When the methyl ethyl ketone evaporates, the colloidal graphite particles form a conductive path on the material on which the solution was applied. The viscosity (800 centipoise) is such that it can easily be applied with a paint brush to coat the back of each detonator plug. The resistance between the lead wires and detonator case can then be varied depending upon the thickness of the applied coating and the manner in which it is cured. Curing may either be at room temperature or accelerated at increased temperatures. The resistance of the coating will generally decrease as curing temperature is increased.

Other physical properties[3] are listed below in Table 2.

TABLE 2. PHYSICAL PROPERTIES OF ELECTRODAG^R +501

Color	Black
Density	.874 kg/liter (7.35 lbs/gal.)
Solids Content	14.7%
Flash Point	-2°C (28°F)
Shelf Life	six months
Viscosity	800 cps
Volume Resistivity	2.54 ohm-cm.
Coverage	100 ft^2/gal @ 1 mil thick.
Cost (Feb. 1982)	$40/quart

One of the major attractions of the Electrodag^R +501 is the minimal amount of time and effort required to apply it. An experienced operator can easily apply the coating to several hundred units in a working day. This, in conjunction with the low cost of Electrodag^R +501, makes the cost of the application almost negligible when compared to the total cost of the detonator.

PROTECTIVE LACQUERS FOR ELECTRODAG^R+501

After curing, the Electrodag^R +501 attains a rubber-like texture on the detonator plug. Because each detonator must be able to withstand various environmental and physical extremes, two lacquers were analyzed as protective coatings. The purpose of their use was to provide a hardened coating which would completely cover the Electrodag^R +501 so that it could not be peeled or scraped off during handling.

Two different varnishes were analyzed, Scotchcast Resin #8 and TUFON #747S. The TUFON #747S is extensively used as a sealant for many nonelectric type detonators and explosive components. Each was

[3]"Product Data Sheet," Electrodag^R +501, Acheson Colloids Company, Port Huron, Michigan.

recommended by Leopold (Reference 4), but never fully evaluated to determine their ability to withstand environmental conditions. Nor were they tested to see how they might affect functioning characteristics of the detonator.

Various curing plans and application methods were investigated to determine which varnish would give the best possible protection for the Electrodag^{R}, but yet, not substantially affect functioning characteristics or leads-to-case resistance. Small changes in leads-to-case resistance were desired so that the allowable resistance range for the coatings could be easily characterized.

In the application of Electrodag^{R} +501, the resistance between lead wires and the detonator case was found to decrease as the coating thickness increased. Therefore, if the Electrodag^{R} +501 resistance is found to be unreasonably high, additional Electrodag^{R} +501 could be applied to lower the resistance. Conversely, if this resistance is initially too low, as much of the Electrodag as necessary can easily be removed by the application of methyl ethyl ketone.

Large deviations in resistance (outside the specified range) after the curing of protective varnishes, however, could not be as easily reworked. This could cause the rejection of a substantial proportion of finished detonators, thereby increasing production costs. It was quite important, therefore, to determine curing methods and procedures to minimize changes in leads-to-case resistances.

Various curing plans and methods were investigated to determine the method which would give the most consistent results. These plans and results are shown in Table 3 and Figures 4 and 5.

In this study, the Electrodag was cured two different ways. One plan called for the Electrodag to be applied and then cured at 180^{o}F for 24 hours. The second was to allow it to be cured at ambient temperature for 72 hours. After each curing period, the detonators were then coated with either the Scotchcast or varnish coatings. These were also cured at either ambient or 180^{o}F.

As shown, more consistent results were attained when the Electrodag^{R} +501 was cured at 180^{o}F for 24 hours. The larger resistance changes which occurred when the Electrodag^{R} +501 was cured at ambient temperature suggest that it had still not fully cured. These larger resistance changes can probably be attributed to the continued presence of small quantities of methyl ethyl ketone solvent in the mi

[4] Leopold, Howard S. and Rosenthal, Louis A., NSWC/WOL TR 75-57.

TABLE 3. LEADS-TO-CASE RESISTANCE CHANGES OF VARIOUS CURING PLANS

	Average Resistance Change (Leads-to-Case) of Scotchcast Resin Cured for 48 Hours				Average Resistance Change (Leads-to-Case) of TUFON #747S Varnish Cured for 48 Hours			
	Cured at 70°F		Cured at 180°F		Cured at 70°F		Cured at 180°F	
	No. of Units	Avg. Change (%)	No. of Units	Avg. Change (%)	No. of Units	Avg. Change (%)	No. of Units	Avg. Change (%)
Electrodag® +501 Cured at 180°F for 24 hours	10	28	8	136	10	10	8	24
Electrodag® +501 Cured at 70°F for 72 Hours	12	30	12	110	12	22	12	130

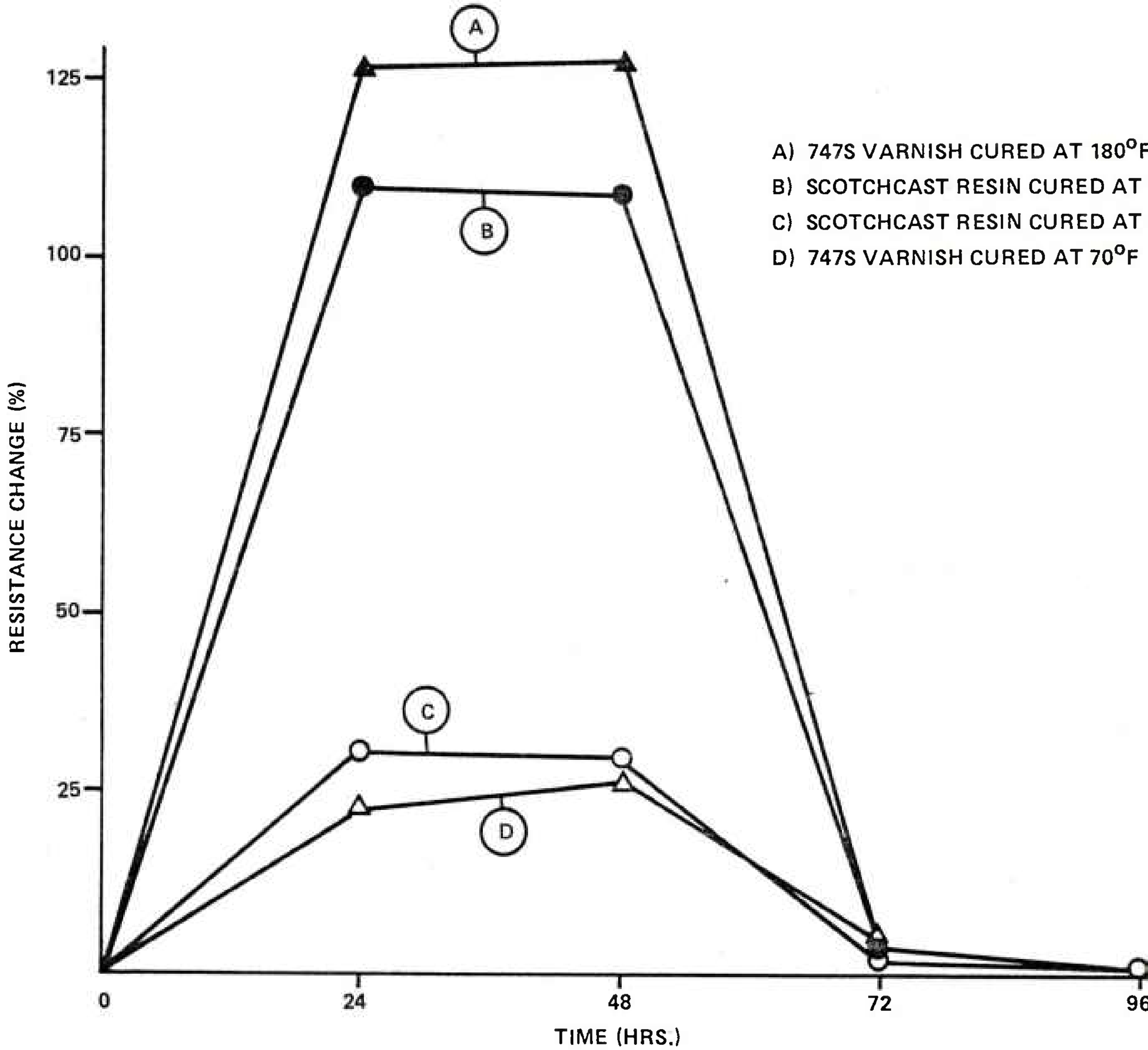


FIGURE 4. AVERAGE RESISTANCE CHANGE (LEADS-TO-CASE) VS. TIME TO CURE. (ELECTRODAG CURED AT 70°F FOR 72 HOURS).

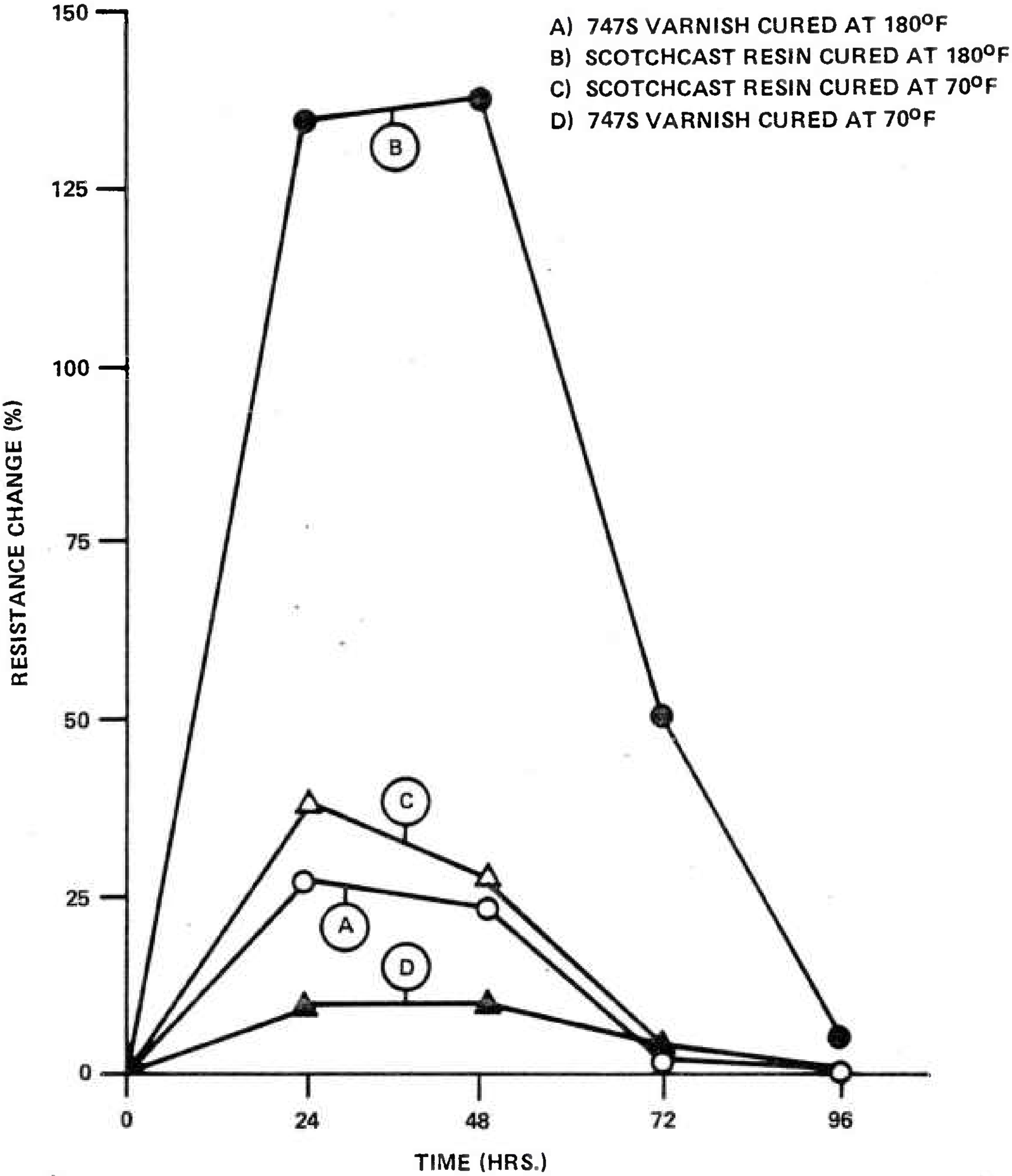


FIGURE 5. AVERAGE RESISTANCE CHANGE (LEADS-TO-CASE) VS. TIME TO CURE. (ELECTRODAG CURED AT 180°F FOR 24 HOURS.)

In general, the Scotchcast Resin #8 caused a greater resistance change than the TUFON #747S varnish. This change became even more pronounced when the coatings were cured at 180°F rather than at ambient temperature. This finding suggested that there may be a compatibility problem between either varnish and the Electrodag[R] +501 at high temperatures.

Based on these results, the recommended curing plan is to dry the Electrodag[R] +501 for a minimum of 24 hours at 180°F and then, coat with 747S varnish at ambient temperature. The varnish should then be allowed to dry for a minimum of 48 hours.

DETONATOR SOURCE

All Mk-112 detonators evaluated in this report were produced by ICI Americas, Inc. of Valley Forge, Pennsylvania. Application of conductive coatings and protective varnishes, however, was performed at NSWC.

ENVIRONMENTAL TESTS

An investigation was made to determine the ability of the Mk-112 (and therefore, the Electrodag and varnish) to withstand the various mechanical and environmental tests associated with the qualification of EED's. Individual lots of six detonators were subjected to the following tests: Aircraft Vibration, 40 Foot Drop, Single Phase Shock, 6 Foot Drop, 28 Day Temperature and Humidity Cycle, and Thermal Shock. An additional 90 inert units were subjected to a long term high temperature storage test. To determine the effects of each test on bridgewire resistance, leads-to-case resistance, and the hermetic seal, leak tests and resistance measurements were made before and after each test. In addition, each live detonator was subjected to a static discharge test after the environmental tests to assure that the units would still be protected from this hazard.* Test results are shown in Table 4.

All units passed these tests as there were no accidental initiations, bridgewire resistances remained fairly constant, and each hermetic seal remained intact. In all but a few instances, leads-to-case resistance increased after each test. Percentage of the change ranged from a 1% decrease to a 49% increase with the average about 22%.** These increases were probably caused by weakening of the bonds between the lead wires and/or detonator case with the Electrodag.

*Detonators subjected to 40 Foot Drop Test are not required to be functional after the test, only to withstand it. Therefore, they were not analyzed after the drop.

**Does not consider units which were fractured.

TABLE 4. ENVIRONMENTAL TEST RESULTS FOR MK-112 DETONATOR

TEST	MIL-STD-AND TEST NUMBER	NUMBER TESTED	NUMBER SURVIVED TEST	LEAK TEST	BRIDGEWIRE RESISTANCE	FUNCTION
40 Foot Drop	MIL-I-23659C Section 4.6.1	6	6	All Passed	4 - 8 OHMS All passed	--*
6 Foot Drop	MIL-I-23659C Section 4.6.2	6	6	All Passed	All passed	All passed
Thermal Shock	MIL-STD- 331 Test 113	6	6	All Passed	All passed	All passed
Single Phase Shock Test	MIL-I-23659C Section 4.6.3	20	20	All Passed	All passed	All passed
28 Day T & H Cycle	MIL-STD 331 Test 105.1	6	6	All Passed	All passed	All passed
High Frequency Vibration (Aircraft)	NOL TR 70-61	14	14	All Passed	All passed	All passed

*Not required to function after test

Note (1) - All units were also subjected to an Electrostatic Discharge Test after the Environmental Test. Each tested unit passed.

As a protective coating, the TUFON #747S varnish was more effective. It remained intact through each test and leads-to-case resistance increases with its use were less extreme than of those coated with Scotchcast. The protective coating of five Scotchcast coated detonators was also found to be fractured after the Shock, Vibration, and 6 Foot Drop Tests. Although the Electrodag coating did not appear to be affected, leads-to-case resistance increased substantially. Resistance of the five units rose from 433Ω, 1253Ω, 496Ω, 789Ω and 155Ω to 2,651Ω 3049Ω, 1227Ω, 2285Ω, and 853Ω respectively. Therefore, from a physical viewpoint, the 747S varnish is the preferred choice as a protective coating.

Long-term storage tests were run to determine if the Electrodag and/or coatings degrade under certain conditions. Tests were conducted for six months at both ambient and 165°F. Each lot contained 44 inert detonators, half coated with Scotchcast and half with 747S varnish. In both cases, slight changes in resistance were measured (both increases and decreases), but these were not large enough to be considered meaningful (see Figure 6).

RESISTANCE RANGE OF CONDUCTIVE COATINGS

One of the goals of the Electrodag analysis was to determine a practical allowable resistance range for the cured coating. If the leads-to-case resistance becomes too low, a significant amount of the firing energy for the detonator may be dissipated through the coating, possibly resulting in a malfunction. However, as the resistance of the coating increases, the protection against electrostatic discharge hazards decreases.* Additionally, as broad a range as possible was desired to simplify the application and minimize the number of rejected detonators.

For an upper limit, a final value of 2,000 ohms for the completed detonator was determined. This was based on the level at which detonators were found to fail the electrostatic discharge test (fire) and the increases in leads-to-case resistance which occurred after various environmental tests. Initial failures occurred at 4,600 ohms although some units passed as high as 18,000. (See Table 5.) Taking into account that the resistance of the conductive coating could increase by as much as 50% after certain environmental tests. A 2,000 ohm ceiling appears to leave an adequate margin of safety.

*As an example, the leads-to-case resistance of the unprotected detonator exceeds 50,000 ohms.

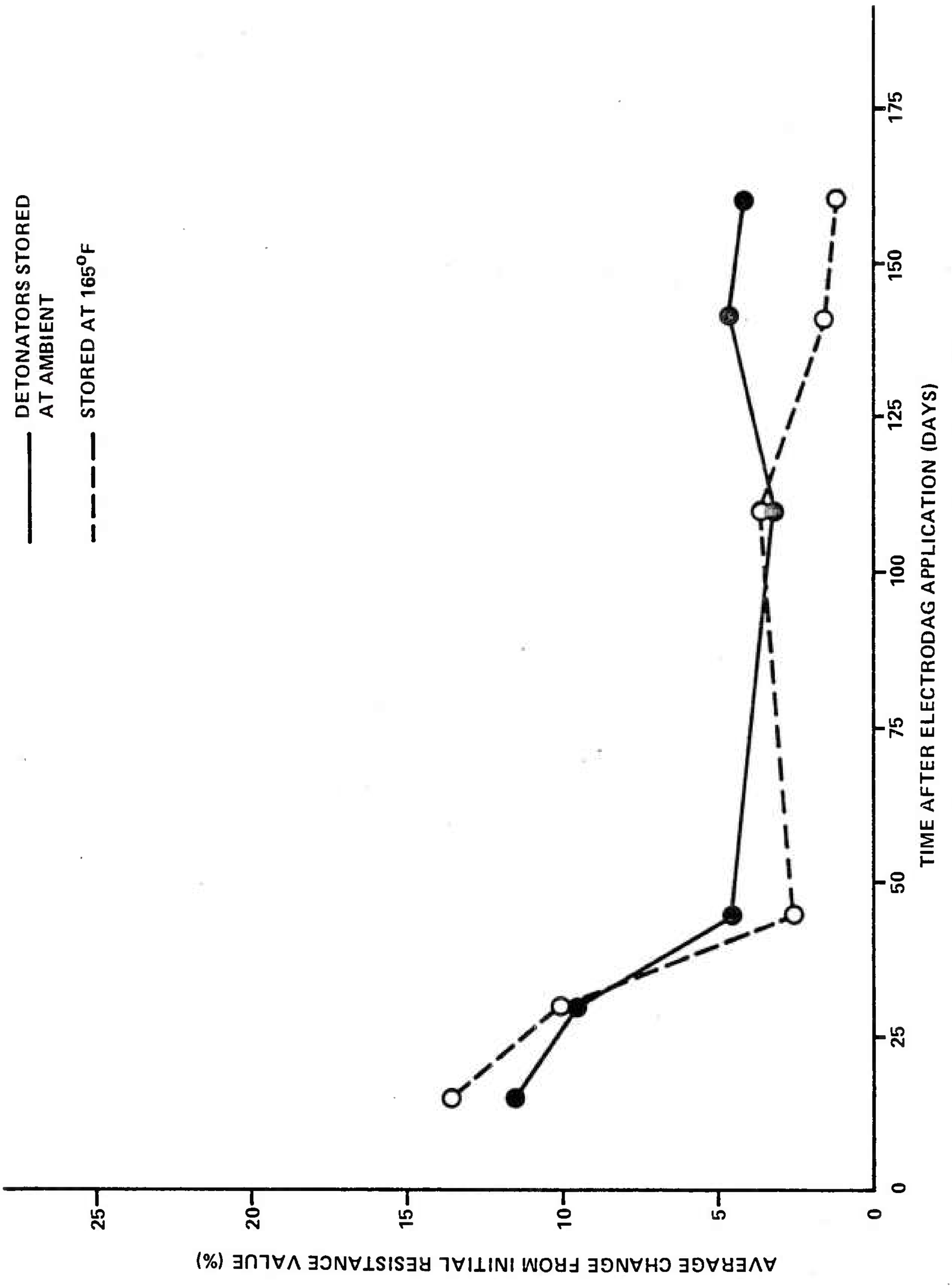


FIGURE 6. AVERAGE LEADS-TO-CASE RESISTANCE CHANGES VS. TIME OF MK 112 DETONATORS COATED WITH ELECTRODAG.

TABLE 5. DETERMINATION OF UPPER RESISTANCE LEVEL FOR ELECTRODAG TO PROVIDE ESD PROTECTION

Detonator #	Initial Leads-to-Case Resistance	Electrostatic Discharge Test (P/F)	Resistance After Test
1	78	P	74
2	107	P	98
3	114	P	94
4	124	P	94
5	130	P	56
6	176	P	116
7	185	P	105
8	219	P	176
9	286	P	232
10	340	P	281
11	359	P	242
12	385	P	232
13	437	P	281
14	545	P	344
15	601	P	391
16	700	P	330
17	780	P	440
18	804	P	724
19	840	P	630
20	867	P	525
21	884	P	619
22	1,065	P	330
23	1,136	P	943
24	1,306	P	844
25	1,319	P	985
26	1,410	P	668
27	1,470	P	620
28	1,498	P	1,832
29	1,830	P	1,347
30	1,930	P	1,249
31	1,947	P	1,533
32	2,238	P	1,213
33	2,530	P	1,850
34	3,645	P	2,063
35	3,980	P	5,740
36	4,146	P	3,218
37	4,401	P	2,216
38	4,670	F	-
39	6,550	P	2,415
40	6,886	P	3,104
41	7,071	P	2,133
42	11,400	P	6,017
43	16,222	P	11,175
44	17,065	F	-
45	18,430	P	9,019

As a guideline in determining the lower resistance limit, the maximum allowable firing energy loss through the Electrodag[R] +501 was set at 4.5%. Using the worst case (Bridgewire resistance of 4Ω), the resistive protection would be required to provide at least 100 ohms isolation between the detonator case and lead wires. This value, however, was felt to be too low based on earlier tests with Electrodag[R] +501. These tests had shown that materials with dispersed carbon as the conductive material showed a resistance drop after being subjected to an electrostatic discharge. Therefore, a resistance mimimum higher than 100 ohms would be necessary if a coated unit happened to be exposed to an electrostatic discharge.

To investigate just how much of a drop occured, forty-five fully coated Mk-112 detonators were subjected to an electrostatic discharge test at 25kV (see Table 5.) Leads-to-case resistance ranged from 78 to 18,430 ohms. All units passed with the resistance drop averaging about 35% and the worst case being about 70% (7,071 ohms to 2,133 ohms). Four detonators with initial resistances of 130Ω, 114Ω, 107Ω, and 124Ω, were found to fall below the 100 ohm mimimum (56Ω, 94Ω, 98Ω, and 94Ω, respectively).

Twenty-four additional detonators were then subjected to three multiple electrostatic discharges, (see Table 6.) Results indicated that the maximum resistance drop was reached after about two discharges with 90-95% of the drop occurring after the first. Based on this data, the recommended minimum resistance level for the finished detonator is 300 ohms.

The leads-to-case resistance limits of 300 to 2,000 ohms, therefore, appear to offer substantial protection from electrostatic discharge hazards as well as having little adverse effects on the detonator firing energy. This range is also broad enough to allow the Electrodag and varnish application to be fairly easy and straightforward. Approximately 90% of the units used in this analysis had initial resistances in this range. This is a fairly high percentage considering personnel inexperienced in the application performed the work. As experience is gained, this percentage should increase, thereby reducing costs by reducing the number of detonators that would need to be reworked.

COMPATIBILITY OF ELECTRODAG AND PROTECTIVE VARNISHES

Due to larger changes in leads-to-case resistance between Electrodag[R] +501 and both protective varnishes at high temperatures, vacuum thermal compatibility tests were conducted.

These tests were also run between Electrodag, the protective varnishes, and Epoxipatch resin. Epoxipatch is used as a potting compound in the EX-35 Exploder and in its application, comes into direct contact with the detonator.

TABLE 6. EFFECT OF MULTIPLE ELECTROSTATIC DISCHARGES ON LEADS-TO-CASE RESISTANCE

#	Initial L/C Resistance (Ω)	Resistance after Discharge #1	#2	#3
1	203	164	159	157
2	207	154	152	150
3	156	109	107	106
4	175	153	149	147
5	327	285	283	273
6	170	158	155	153
7	211	118	112	110
8	256	194	184	178
9	191	108	106	105
10	312	163	160	157
11	430	273	247	232
12*	16,222	6,175	12,371	15,285
13	124	81	81	80
14	175	128	125	123
15	115	112	111	111
16	107	98	102	107
17	253	254	286	293
18	78	69	69	69
19	364	386	367	354
20	173	151	149	146
21	247	228	222	217
22	114	94	92	91
23	78	74	74	74
24	139	118	114	114

*Electrodag was found to have separated from the lead wires

Basically, the test measures the amount of gas evolved after mixing the compounds and then heating at 100°C for selected periods of time. Large amounts of evolved gas suggest the occurrence of a chemical reaction and therefore, possible incompatibility. Results are shown in Table 7.

TABLE 7. COMPATIBILITY TEST RESULTS

Sample*	Gas Evolved After 48 Hours (cc/g)	
1. Dry Electrodag and wet Scotchcast Resin	+0.55	Negligible
2. Dry Electrodag and #7475 Varnish	-0.88	Negligible
3. Epoxipatch and Electrodag (dry)	+3.15	Incompatible
4. Epoxipatch and Varnish (dry)	0.57	Negligible
5. Epoxipatch and Scotchcast (dry)	-0.12	Negligible

*Sample size - 200 mgs of each component

Negative amounts of evolved gas indicate vapor formed which condensed to decrease the observed gas volume. Accepted criteria for the compatibility test are:

1. 1.0 cc/g of gas evolved in 48 hours - Incompatible
2. 0.6 - 1.0 cc/g - Moderate - possible Incompatibility
3. .6 cc/g - Negligible - Materials are Compatible

Results indicate that both Scotchcast Resin and TUFON varnish are compatible with Electrodag[R] +501 and Epoxipatch. Epoxipatch and Electrodag, however, were found to be incompatible. This should not be a problem in this application as the Electrodag is completely covered by the protective coating and should never come into contact with the Epoxipatch.

FUNCTIONING CHARACTERISTICS OF THE MK-112 DETONATOR

The Mk-112 was characterized and compared to the Mk 57 MOD 1 detonator using information obtained from laboratory tests and references 5 and 6.

[5] Bernstein, Bernard, "Electrical Performance Characteristics of the Mk 57 Mod 0 Detonator," NAVORD Report 3899, 8 Nov 1954.

[6] Herd, J. H., "Evaluation Tests of Production Detonators Mk 57 Mod 0 and Laboratory Approval of the Detonator Mk 57 Mod 1," NAVORD Report 3886, 10 Feb 1955.

SENSITIVITY TESTS

To evaluate sensitivity, a Bruceton test was run on seventy five Mk-112 detonators coated with Electrodag and TUFON #747S varnish. Leads-to-case resistance was kept within the recommended 300 to 2,000 ohm limits. Throughout the test, capacitor size was kept constant (3.75 µFd) while the voltage levels were changed by 0.3 log unit increments. A 50% firing energy was found to occur at 26.6 volts (13,266 ergs) with a standard deviation of 1.0 volts. This is within 10% of the reported value for the Mk 57-1 of 27.6 volts (14283 ergs). Therefore, the design goal of similar firing energy requirements for the two detonators has been met. Comparisons of the 1%, 50%, and 99% firing energies for the detonators are shown in Table 8.

TABLE 8. ESTIMATED FIRING ENERGY OF MK-112 AND MK 57-1 DETONATORS
(With 95% Confidence)

MK-112 DETONATOR

Percent Reliability (%)	Estimated Firing Energy Ergs	Volts*
0.1%	9,918	23.0
50%	13,266	26.6
99.9%	17,787	30.8

MK 57-1 DETONATOR

Percent Reliability	Estimated Firing Energy Ergs	Volts*
0.1%	11,072	24.3
50%	14,283	27.6
99%	18,842	31.7

1) Specification All-Fire level for the MK-112 and Mk 57-1 is 30,000 ergs (3.75 µfd @40 volts)

*Applicable with the use of a 3.75 µfd capacitor)

FUNCTIONING TIMES

At an all-fire level of 30,000 ergs (3.75 µFd @ 40 volts), functioning times for the Mk-112 were measured. Time-to-fire calculations were based on the time difference between firing energy delivery and the light flash from the detonator output. At 70°F, the average firing time was 23.9 µsec as compared to 25.4 µsec at 225°F. Lower voltages (i.e., at the 50% firing level) would be expected to have longer firing times. Results are shown in Table 9.

TABLE 9. FUNCTIONING TIMES OF MK-112 AND MK 57-1 DETONATORS

MK-112 Detonator	N	Environmental Test Encountered	Firing Temp. °F	Functioning Time μsec Av.	Min.	Max.
	25	None	70°F	23.9	22.8	26.8
	6	Vibration	70°F	23.7	22.4	25.1
	5	Six Foot Drop	225°F	23.8	20.8	28.7
	6	1,000 G Shock	225°F	26.7	25.8	28.6
MK 57-1	25	None	70°F	22.5	--	--

MAXIMUM NO-FIRE CURRENT

In this series of tests, Mk-112 detonators were exposed to constant current pulses of various amplitudes. Each detonator was exposed to the specific current for 10 seconds. Due to reduced sample sizes, calculations of a maximum no-fire current cannot be stated at any specific level of confidence. From the results shown in Table 10, a maximum no-fire current can be estimated to fall in the 170-180 mA range. Again, this data corresponds to the approximate range determined for the Mk 57-1.

TABLE 10. MAXIMUM NO-FIRE CURRENT TEST

Current (mAmps)	MK-112 Detonator FIRE	NO FIRE	MK 57-1 Detonator FIRE	NO FIRE
195	4	1	9	11
192	-	-	10	10
185	3	2	7	13
180	1	4	-	-
175	0	10	-	-
174	-	-	2	18
170	0	10	-	-
150	-	-	0	20

OUTPUT

Detonator output was measured by the average dent in a standard steel block. Output of the Mk-112 was measured at -65°F, 70°F, and 165°F as shown in Figure 7. Temperature effects did not appear to have any significant effects on output.

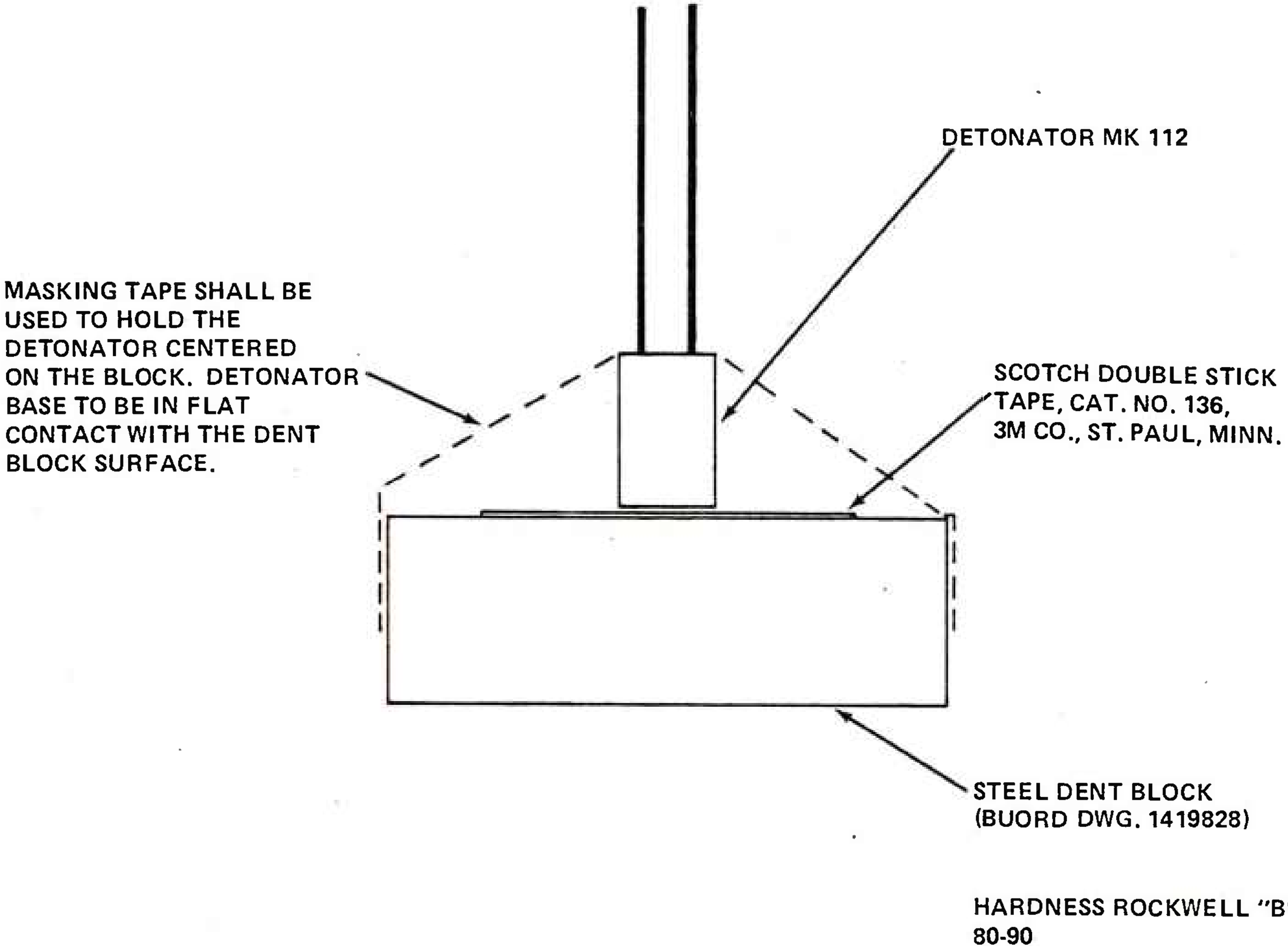


FIGURE 7. OUTPUT TEST ASSEMBLY.

The average dent for the Mk-112 was about .022" at all three temperatures. Results are shown in Table 11.

TABLE 11. MK-112 DETONATOR - OUTPUT TEST RESULTS

Environmental Test Exposed to	N	Firing Temp.	Average Dent (inches)	Minimum Dent (inches)	Maximum Dent
None	20	70°F	.0227	.0217	.0239
None	10	-65°F	.0225	.0217	.0234
Vibration	6	70°F	.0227	.0218	.0238
T & H Cycle	12	-65°F	.0225	.0215	.0231
Thermal Shock	6	70°F	.0226	.0213	.0232
Six Foot Drop	6	225°F	.0221	.0211	.0231
Single Phase Shock	6	225°F	.0219	.0213	.0226

CONCLUSIONS

A new detonator, the Mk-112, has been developed and evaluated as a replacement for the Mk 57 MOD 1 detonator in certain applications. The new design has incorporated flexible lead wires in place of the rigid contact pins currently employed in the Mk 57 MOD 1. All sensitivity and output characteristics between the two detonators appear to be similar. Physical specifications of the Mk-112 detonator are listed in Table 12.

Most importantly, the Mk-112 has been designed to withstand the hazards of accidental initiation from human electrostatic discharge. This has been done through the application of low cost conductive material, Electrodag® + 501, and a protective varnish to the back of each detonator plug. By doing so, a conductive path between the detonator case and lead wires is formed, thereby allowing stray voltages to bypass the explosive load.

As a protective coating, TUFON #747S varnish is recommended. It is used as a moistureproof sealant in many explosive components and its cost is minimal. The use of the coating was necessary in order to protect the Electrodag from the various environmental and mechanical conditions called out for in MIL-I-23659.

By using the Electrodag and varnish, the cost to provide an EED with electrostatic discharge protection is negligible when compared with the total unit cost. Therefore, it is recommended that this application be used on any hermetically sealed EED which may be susceptible to electrostatic discharge hazards.

TABLE 12. CHARACTERISTICS OF MK-112 DETONATOR

EXPLOSIVE LOAD	
1) PETN	190 mgs.
2) Lead Azide	110 mgs.
3) Lead Styphnate Flash Charge	
BRIDGEWIRE	.0008" diam. Nichrome
ALL-FIRE SENSITIVITY	30,000 ergs (3.75 μfd @ 40 volts)
DIAMETER	.275" MAX
LENGTH	.505" MAX, with lead wire length of 4.0"
OUTPUT	Average dent in standard steel block = .021". Minimum of .019"
FUNCTIONING TIME	Less than 30 microseconds
ELECTROSTATIC DISCHARGE PROTECTION	Electrical contact formed between detonator case and lead wires (300-2,000 Ω) using Electrodag® +501

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