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FUNCTIONING TIME AND RELATED STUDIES OF A 1-AMP/1-WATT DETONATOR

By
Scranton G. Nesbitt

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NAVAL ORDNANCE LABORATORY, WHITE OAK, SILVER SPRING, MARYLAND

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WHITE OAK, MARYLAND

 27 July 1971

FUNCTIONING TIME AND RELATED STUDIES OF A 1-AMP/1-WATT DETONATOR

This report describes the procedures used and the results of functioning characteristic studies of the Mk 101 type detonator. This work was performed under Task ORD-332 001/UF 17 354 314, Explosive Initiation and Safety. The data will be of interest to explosive and electrical system designers concerned with meeting the requirements of MIL-I-23659.

The identification of commercial materials implies no criticism or endorsement of them by the Naval Ordnance Laboratory.

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Captain, USN
Commander

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By direction

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FUNCTIONING TIME AND RELATED STUDIES OF A 1-AMP/1-WATT DETONATOR

INTRODUCTION

1. Recently there has been a great deal of interest shown in the functioning characteristics of the Mk 101 type 1-amp/1-watt insensitive electric detonator. The characteristics of greatest interest are the required firing energy for various types of electrical inputs and the functioning times of the detonator for these inputs.

2. A ribbon-type bridge element is used in the Mk 101 type Detonator to obtain the desired electrical and firing characteristics. Figure 1 shows the bridge element on a glass/kovar plug as it is used in the detonator. The bridge element is photcetched from 1-mil thick Evanohm material. The ribbon part of the element on which the lead azide ignition charge is loaded is 10 mils wide. The "sawtooth" pattern around the perimeter of the element provides a relatively safe electrostatic discharge path from the bridge element to the charge holder. The resistance of the bridged plug is between 1.0 and 1.5 ohms.

3. The Mk 101 type detonator assembly is shown in Figure 2. The ignition assembly of this detonator consists of the conventional glass/kovar plug, the Evanohm bridge element, a plastic insulator, and an aluminum charge holder. Dextrinated lead azide is pressed at 10K psi into the charge holder cavity and onto the bridge element. It is primarily this ignition assembly that determines the functioning characteristics of the detonator. This detonator is a revised version of the WOX-69A detonator that was developed by the Navy about five years ago.[1]* This detonator meets the recommended no-fire requirements of Specification MIL-I-23659.[2] That is, it will pass 1-ampere of current or dissipate 1-watt of power, which ever is greater, for five minutes without initiating. This requirement is designed to help reduce the hazard of initiation from current produced by electromagnetic radiation or other spurious electrical sources.

EXPERIMENTAL ARRANGEMENT

4. Experimental apparatus was built to study the functioning time for constant current and capacitor discharge inputs to the detonator. The constant current input was accomplished with wet cell storage batteries and a solid state constant current regulator.[3] A mercury switch provided a relatively sharp current step to the detonator. A

* References are on page 9.

Millisecond (pulse) Switch* was used for pulsed constant current Bruceton tests. This device provides a sharp square wave current pulse which can be set to any duration from 10 to 250 milliseconds. At a given setting the pulse duration is reproducible within one millisecond.[3]

5. The firing curcuit for the capacitor discharge tests consisted of a variable potential power supply which charged the capacitors through a 10K-ohm resistor. This firing circuit also employed a mercury switch which allowed the capacitors to discharge directly through the detonator.[4]

6. A Tektronix 551 Dual Beam Oscilloscope and a Polaroid camera were used to record the functioning times. The potential drop across the detonator, when the mercury switch closed, provided the triggering signal for the oscilloscope.

7. Several methods are available for determining the time of detonator output. Sensitive mechanical switches, ionization gages, and optical schemes have been used for this measurement in the past. In the tests reported here, an optical method was used. In this method, the light emitted from the detonator when it ruptures was transmitted by a Crofon Light Guide (light pipe) to a silicon photo-duo-diode. The electrical signal from the photo-diode was amplified and transmitted to the input of one channel of the oscilloscope. The functioning time was measured as the time from the beginning of the oscilloscope sweep to the beginning of the light signal. The light pipe transmits radiation of wavelengths from 3,100 to 13,300 angstroms, while the photo-diode responds to radiation of wavelengths from 4,000 to 11,000 angstroms. The "light pipe amplifier"**, which contained the photo-diode, has an overall rise time of four microseconds.[5]

8. It was found that if the light pipe was pointed directly at the end of the detonator, it would pick up enough light to give a sharp output signal on the oscilloscope, even if the light pipe were 10 or 15 cm from the detonator. When used at this distance, a sharp signal was obtained with a minimum of damage to the detection equipment; on the average, less than 1/2 cm of light pipe had to be cut off after each shot.

FUNCTIONING TIMES

Continuous Constant Current Results

9. Even though there are probably not too many actual applications where a true constant current power supply is used to fire an electro-explosive device, constant current functioning data are useful in

*Developed by Professor L. A. Rosenthal of Rutgers University and consultant to the Naval Ordnance Laboratory, White Oak.
**Developed by Professor L. A. Rosenthal.

characterizing such items. The data provide a functioning characteristic by which different devices can be compared. Using an Evanohm bridge element, an Ohm's law conversion of the constant current data should give reasonably good information for constant potential firing sources, because the resistance of the bridge element changes very little as its temperature increases.

10. Constant current functioning times were studied at five current levels ranging from 2.0 to 5.0 amperes. The term "functioning time" refers to the time between the beginning of the electrical input and the rupturing of the detonator cup. The results of these five tests are shown in Table 1. Twenty-five detonators were fired at each of the five current levels.

11. Since the bridge resistance of this detonator is held within the limits of 1.0 to 1.5 ohms, the input power ($P = I^2R$) will be within the limits given in Table 1.

12. In Military Specification MIL-I-23659, previously mentioned in connection with the 1-amp/1-watt no-fire stimulus, there is also an all-fire stimulus given. It states that an electro-explosive device of this general group should function within 50 milliseconds from a 5.0-ampere input. From Table 1 it is apparent that the requirement for the 5.0-ampere stimulus is easily met. Inspection of Table 1 shows in addition that at a 2.0-ampere input (the 5-watt level) the functioning time can be greater than 50 milliseconds. At 2.0 amperes, besides having a rather long average functioning time, 81.7 milliseconds, the spread of the observed functioning times for the detonator is very wide - 32 to 164 milliseconds. From the data it appears that if it were desirable to have relatively accurate control of detonator functioning time, 3.0 amperes would be about the minumum constant firing current which should be considered.

13. From these constant current tests it was also possible to get an idea of how the differences in bridge resistance affect the functioning times. Table 2, which is divided into five sub-tables, one for each current level, shows the relationship between the bridge resistance and the average of the functioning times for the detonators at each resistance level. The detonators for these tests were picked at random, and thus without consideration to bridge resistances. Even though the number of detonators in each resistance level varies widely, there is a definite trend established. As expected, the average functioning time decreases as the bridge resistance increases.

14. Figure 3 is a plot of functioning time versus input power for the 124 items used in the constant current firing tests. This figure shows that the firing time is not simply a function of the firing current but is also dependent on the individual bridge resistance. A curve of average functioning time versus firing current is shown in Figure 4.* From this it is evident that the functioning times for currents below 2.0 amperes would become very long. However,

*Pulsed constant current data from Paragraph 15 also included on this plot.

this type of detonator can function at a current input of 1.5 amperes. When prolonged currents between 1.1 and 1.5 amperes were used, there were cases in which the detonators became hot enough to melt the solder seal between the cup and the plug before the detonator fired. In these cases the cup with the PETN base charge was blown off the ignition assembly by the internal pressure that built up during heating. If the current was continued, the lead azide in the charge holder fired several seconds later. Thus it is recommended that currents less than 1.5 amperes not be used to initiate this type detonator.

Pulsed Constant Current Results

15. Pulsed constant current Bruceton tests were conducted at 2.5 and 3.0 amperes. Tests were not conducted at currents above 3.0 amperes because the appropriate Bruceton step sizes were of the same order of magnitude as the inaccuracy of the pulse length settings. The results of these two tests are given below.

Current (amps)	Sample Size	Pulse Length for 50% Firing (millisec)	σ (millisec)	Observed Functioning Times of Fires (millisec)		
				Average	Minimum	Maximum
2.5	50	26.4*	8.03*	20.6	7.0	30.0
3.0	48	18.1	1.97	16.4	12.1	19.5

* These values should be considered as approximate since the ratio of σ to the Bruceton step size was ~4 and the recommended limit is about 2.5.[6]

16. The information in the last three columns of this table was collected by observing the light output from the detonators that fired in the Bruceton test. In the 2.5-ampere test there were 27 fires out of 50 samples, and in the 3.0-ampere test there were 24 fires out of 48 samples.

Capacitor Discharge Results

17. Capacitor discharge firing circuits are used in many applications, and there has been much interest concerning capacitance-charging potential combinations and the energy needed to initiate the Mk 101 type detonator. Similarly, interest has been expressed concerning the functioning times associated with capacitor discharge initiation.

18. Capacitors ranging from 50μf to 3,000μf were used both in Bruceton tests to find the 50% firing potentials and in tests to find the functioning times at each capacitance for various charging potentials.

19. Table 3 gives the results of the capacitor discharge Bruceton Tests. Logarithmic Bruceton steps were used for the variable charging potentials. Thus the standard deviation is expressed in log units.

20. The Bruceton 50% Firing Potential is the charging potential at which half of the items tested should initiate. The 50% Firing Energy is the energy stored in the capacitor as calculated from the 50% firing potential and the capacitance of the capacitor.

21. Because of the wide range of capacitances needed for these tests, and in consideration of what capacitors were immediately available, more than one type of capacitor had to be used. The two smallest capacitors, 50µf and 100µf, were high quality oil-paper capacitors (meeting MIL-C-25); the 350-µf, 700-µf, and 3,000-µf capacitors were high quality Compuytic[R] aluminum electrolytic capacitors (meeting MIL-C-62); and the 1,000-µf capacitor was a Tantalum electrolytic (non-solid electrolyte) capacitor (meeting MIL-C-3965). At the time of these tests the 1,000µf-capacitor was under consideration for use in a Navy Fuze to fire the 1-amp/1-watt type detonator. Since inquiries have been received about using electrolytic capaictors in actual application, they were used in these tests. However, it should be noted that electrolytic capacitors are not normally considered accurate enough for characterizing electro-explosive devices. Thus, the part of these data generated from this type capacitor should be considered accordingly. When measured at 120 Hz, the electrolytic capacitors used were found to be within approximately 10% of their stated values.

22. In the actual Bruceton test, approximately half of the detonators will fire; however, the charging potential at which they fire will range from one or two Bruceton steps below the 50% Firing Potential to a couple of steps above. The data in the last three columns of Table 3 were obtained by recording the functioning time of those detonators which fired. It should be noted that each number in the "Average Observed Functioning Time" column is not the average functioning time at the 50% potential, but is the average time associated with all the fires. The average of the charging potentials for the fires ranged from about 0.3 to 1.6 Bruceton steps above the 50% potential.

23. As expected, the 50% firing energy increases as the capacitance increases. Since the RC discharge time constant becomes larger as C increases, there is an increasing thermal loss from the bridge element to the surrounding material, particularly to the glass/kovar plug. This leads to the increase in the Average Observed Functioning Times shown in Table 3. The data also show the detonator to act rather adiabatically as far as firing energy is concerned for RC input times of less than ~1.0 millisecond. However, firing time continues to decrease as the firing potential is raised. Besides the value of the capacitance, there are other characteristics of the capacitors which affect the energy required for initiation as well as the functioning time. However, no attempt was made to measure or account for such characteristics as impedance, equivalent series

resistance, power factor, and leakage which are considered to be secondary factors. The solid line of Figure 5 is a plot of the 50% firing potential versus capacitance. The broken line is an isoenergy line of 1×10^6 ergs. Generally, the 50% firing energy increases as the capacitance increases.

24. The results of fixed potential capacitor discharge functioning time tests are given in Table 4. The same capacitors were used in these tests as were used in the Bruceton tests. It was desired that each capacitor be tested at three charging potentials; such that the corresponding stored energies would be 15, 30, and 50×10^5 ergs. However, this was not possible in several cases because of power supply and capacitor charging potential limitations. Fifteen detonators were tested at each charging potential; their functioning times were recorded photographically from an oscilloscope as previously described.

25. There are two numbers given in each space in the charging potential columns. The first number is the charging potential; while the second number, in parenthesis, is the calculated energy stored in the given capacitor at the given potential.

26. The average functioning times in column T_1 are associated with capacitors charged to energies of from 2×10^6 to 7×10^6 ergs above their 50% firing energy. At these energies, which were the lowest studied, the observed functioning times had quite a large spread. However, all the charging potentials listed in column V_1, except the one for the 100-μf capacitor, are considered adequate for the reliable initiation of Mk 101 type detonators for the capacitors used in this study. Of course, at higher potentials the functioning time spreads become smaller and the average functioning time becomes shorter.

TESTS AT EXTREME TEMPERATURES

27. The development testing of a capacitor discharge firing system for the ZAP weapon which contains Mk 101 type detonators (the BBU-7/B detonator*) included low temperature Bruceton tests. In these tests both the firing circuit and the detonators were exposed to the reduced temperatures. The value of a capacitor is temperature dependent. The capacitance of the group of parallel capacitors used in the firing circuit was measured at room temperature (25°C) and at -40°C. The room temperature capacitance, measured at 120 Hz, was 850μf, and at -40°C it was 760μf. The results of two capacitor discharge Bruceton tests are given in Table 5. The 50% firing potential and hence the 50% firing energy did not change significantly as a result of the 65°C temperature change in these tests.

28 Functioning time tests were conducted at extreme temperatures (-54°C and 74°C) on small samples. The results of these tests, using

* The BBU-7/B detonator has the same ignition assembly as the Mk 101, but contains a smaller base charge.

a constant firing current of 5.0 amp and a capacitor discharge firing pulse from a 1,000-uf capacitor at 24.5 volts, are given in Table 6.

29. The capacitor discharge functioning time does not appear to be greatly affected by the changes in temperature. This is in accord with the earlier observation that capacitor discharge firings in this time range appear to be rather adiabatic in nature. The constant current data indicate a 26.8% change in functioning time over a temperature range of 128°C; while the capacitor discharge tests indicate a 10.5% change over the same temperature range. It is expected that for lower constant current values the change in functioning time would increase further. Constant current firing in the ranges considered in this study is not adiabatic; thus the functioning time is dependent on the initial temperature of the bridge element and the explosive.

BRIDGE ELEMENT BURN OUT STUDY

30. Interest has been expressed in knowing at what current a bridge element of the type used in the Mk 101 1-amp/1-watt detonator would burn out. For currents equal to or greater than this minimum burn-out current, it was also of interest to determine approximately how long the bridge element would take to burn out.

31. For most Initiators of the Mk 101 type the continuity of the firing circuit is broken, at least momentarily, when the item fires. This break in continuity occurs because the kind and amount of explosive present in most such items is sufficient to physically break the bridge element. The average functioning time for detonators using the plug-bridge combination considered in this study would also be the average time to firing circuit interruption.

32. This study was not concerned with bridge element breakage caused by the explosive, but with bridge element breakage or burn out from the electrical input. A dc power supply and current regulator were used to produce the constant current inputs. A Tektronix 556 dual-beam oscilloscope was used to measure the time from the beginning of current flow to burn out; measurements were recorded photographically. The tests were conducted by passing the test current through the bridge element for 45 seconds or until the bridge burned out, which ever occurred first.

33. Two groups of bridged plugs were considered in this brief study. In one group, unloaded bridged plugs exposed to the air were used. In the other group, the bridged plugs were pressed into detonator cups, loaded with dry plaster of Paris, and the inert detonators were sealed by soldering.

34. The data taken are listed in Tables 7 and 8. Table 7 shows the results of tests conducted using inert detonators. The bridge elements in these detonators were in contact with pressed plaster of Paris. It was not expected that the thermal properties of plaster

of Paris simulate those of primary explosives, but the plaster of Paris does help keep the bridge element in contact with the glass substratum.

35. Table 8 shows the results of tests in which unloaded plugs with exposed bridges were used. In these tests, there was nothing to hold the bridge element in contact with the glass substratum. As the ribbon-like part of the bridge element heats, thermal expansion causes it to arch up; thus, losing contact with the glass plug. This loss of contact reduced the heat-sink effect on the bridge.

36. Upon examination of the bridge elements used to obtain the data in Table 8, it was observed that every bridge, for which a burn out time was given, had burned out near the center of the ribbon (near Point A in Figure 1). The inert detonators used in obtaining the data for Table 7 were cut open and similarly examined. Of the six bridges that did actually burn out (see Notes - Table 7), three burned out near the center of the ribbon (near point A in Figure 1), and three burned out near the end of the ribbon (near point B in Figure 1).

39. It appears that there are several factors which affect the current at which a 1-amp/1-watt Evanohm bridge element will burn out and the time it will take to burn it out at a given current. These factors include the intimacy of contact with the plug or substratum, the absence or presence of material loaded on the bridge element, the intimacy of contact between the loaded material and the bridge element, the thermal conductivity and heat capacity of the substratum and the loaded material, and the resistance of the element itself.

CONCLUSIONS

40. The Mk 101 type detonators used in this study meet the 1-amp/1-watt no-fire requirement of MIL-I-23659. Functioning times for two types of electrical inputs, constant current and capacitor discharge, have been studied. This type detonator can be reliably initiated by a constant current of 2.0 amperes or greater and by capacitor discharges of 15 x 10^5 ergs from a 50-uf capacitor or 20 x 10^5 ergs from a 3000-uf capacitor. Average functioning times as low as 3.38 millisecond for a 5-ampere constant current input and 0.023 millisecond for a capacitor discharge input from a 50-uf capacitor at a potential of 100 volts were observed. Tables 1 and 3 give complete functioning time results.

41. For the energies considered in this report, it is felt that the 50% firing energy and the functioning time for constant current initiation are more affected when the item is at an extreme temperature than for capacitor discharge initiation.

42. In the bridge element burn out study the exposed bridge elements burned out at lower current levels than the bridge elements pressed against the plaster of Paris. The required energy and time for burn out are greatly affected by the intimacy of contact between the bridge element and its surroundings.

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4. NOLTR 65-115, "An Investigation of Insensitive Initiators II, Development of the WOX-63A Detonator", V. J. Menichelli, 20 July 1965.

5. Personal communication between L. A. Rosenthal and S. G. Nesbitt.

6. Statistical Analysis for a New Procedure in Sensitivity Experiments, AMP Report No. 101-1R, SRG-P No. 40, July 1944.

TABLE 1

CONSTANT CURRENT FUNCTIONING TIMES

CURRENT (AMPS)	FUNCTIONING TIMES (MILLISEC)			POWER LIMITS (WATTS)	
	AVERAGE	MINIMUM	MAXIMUM	1 OHM	1.5 OHMS
2.0	81.7	32	164	4.0	6.0
3.0	12.9	7.5	22	9.0	13.5
3.5	7.84	3.0	10	12.3	18.4
4.0	5.45	3.8	7.2	16.0	24.0
5.0	3.38	2.6	5.0	25.0	37.5

TABLE 2

FUNCTIONING TIMES AS A FUNCTION OF BRIDGE RESISTANCE

R-RESISTANCE IN OHMS	AVERAGE FUNCTIONING TIME-MILLISEC	NUMBER OF DETONATORS AT R
A - 2.0 AMPERES		
1.0	164	1
1.1	111	2
1.2	81.4	15
1.3	69.0	5
1.4	45.0	2
B - 3.0 AMPERES		
1.1	20	2
1.2	14.6	5
1.3	12.9	10
1.4	10.4	7
1.5	7.5	1

R-RESISTANCE IN OHMS	AVERAGE FUNCTIONING TIME-MILLISEC	NUMBER OF DETONATORS AT R
C - 3.5 AMPERES		
1.2	8.9	13
1.3	7.5	6
1.4	5.8	6
D - 4.0 AMPERES		
1.1	6.8	1
1.2	6.0	9
1.3	5.4	9
1.4	4.4	5
E - 5.0 AMPERES		
1.2	5.0	1
1.3	3.7	10
1.4	3.2	9
1.5	2.9	5

TABLE 3

CAPACITOR DISCHARGE BRUCETON RESULTS

CAPACITANCE (μf)	50% FIRING		σ (LOG UNIT)	SAMPLE SIZE	OBSERVED FUNCTIONING TIME OF FIRES (MILLISECONDS)		
	POTENTIAL (VOLTS)	ENERGY (ERGS)			AVERAGE	MINIMUM	MAXIMUM
50	61.7*	9.5×10^{5}*	.0096*	25	.129	.07	.32
100	45.3	10.3×10^{5}	.0212	27	.247	.09	.83
350	24.3	10.3×10^{5}	.0205	25	.691	.47	> .95
700	17.5	10.7×10^{5}	.011	25	1.00	.70	1.6
1000	16.7	13.9×10^{5}	.0125	50	1.15	.70	1.8
3000	10.1	15.3×10^{5}	.0147	25	3.24	1.8	4.7

*(THESE VALUES SHOULD BE CONSIDERED AS APPROXIMATE, SINCE THE RATIO OF σ TO THE BRUCETON STEP SIZE DID NOT FALL WITHIN THE RECOMMENDED LIMITS.[6])

TABLE 4

CAPACITOR DISCHARGE FUNCTIONING TIMES

CAPACITANCE (μf)	V_1 (VOLTS) (E-ergs)	T_1* (MILLISEC)	V_2 (VOLTS) (E-ergs)	T_2 (MILLISEC)	V_3 (E-ergs)	T_3 (MILLISEC)
50	77.5 ($15x10^5$)	.045	100.0 ($25x10^5$)	.023		
100	50.0 ($12.5x10^5$)	.1227	65.0 ($21.2x10^5$)	.0513	100.0 ($50.0x10^5$)	.0238
350	30.0 ($15.75x10^5$)	.2943	41.4 ($30.0x10^5$)	.1137	53.5 ($50.0x10^5$)	.070
700	20.7 ($15.0x10^5$)	.543	25.4 ($22.5x10^5$)	.341	29.3 ($30.0x10^5$)	.211
1000	20.0 ($20.0x10^5$)	.627	24.5 ($30.0x10^5$)	.313	30.0 ($45.0x10^5$)	.214
3000	11.5 ($20.0x10^5$)	2.21	14.1 ($30.0x10^5$)	1.05	18.3 ($50.0x10^5$)	.52

V - CHARGING POTENTIAL

(E) - STORED ENERGY AT GIVEN CHARGING POTENTIAL

*T_1 - AVERAGE FUNCTIONING TIME ASSOCIATED WITH POTENTIAL V_1, ETC.

TABLE 5

LOW TEMPERATURE BRUCETON TESTS

Test Temperature: Detonators	Test Temperature: Firing Circuit	Capacitance at Test Temperature	50% Firing Potential	σ (log units)
25°C	-40°C	760µf	15.59 volts	0.0149
-40°C	-40°C	760µf	15.78 volts	0.011

TABLE 6

FUNCTIONING TIMES AT EXTREME TEMPERATURES

Test Temperature	Constant Current (5 amp)	Constant Current: Number of Samples	Capacitor Discharge (1000µf-24.5volts)	Capacitor Discharge: Number of Samples
-54°C	4.02 millisec	10	0.338 millisec	10
Rm Temp(≈25°C)	3.38 millisec	25	0.313 millisec	15
74°C	3.17 millisec	7	0.306 millisec	9

TABLE 7

BURN OUT STUDY OF 1-AMP/1-WATT BRIDGE ELEMENTS ON GLASS-KOVAR PLUGS IN CONTACT WITH PLASTER OF PARIS

Sample Number	Bridge Resistance (ohms)	Constant Current (amps)	Time to Burn Out or 45 Sec. Test (sec)
1	1.4	1.5	45-Test
2 (a)*	1.5	2.0	39.50
3 (b)	1.5	2.5	23.50
4	1.4	3.0	0.10
5 (c)	1.3	3.0	≈1
6	1.5	3.0	0.14
7 (d)	1.4	3.0	17.60
8	1.4	3.0	0.60
9 (e)	1.4	3.0	0.06

*Notes:

(a) During the current flow, the temperature of this detonator increased and pressure built up inside it. When the temperature was sufficient to soften the solder sealing the cup to the glass-kovar plug, the cup popped off, and the continuity of the circuit was interrupted. However, the bridge did not burn out; the solder holding it to the plug had melted, and the bridge came off intact when the cup popped off.

(b) The solder holding the cup to the plug melted, venting the pressure and allowing the cup to partially move away from the plug. The loss of continuity which occurred after 23.5 seconds was not the result of bridge burn out, but was because the solder melted and the bridge became separated from one of the plug lead wires.

(c) The photographic record of this measurement was lost; the time is an approximation.

(d) The solder seal vented, but the bridge did burn out at 17.60 seconds.

(e) It is suspected that the bridged plug was not in good thermal (or physical) contact with plaster of Paris, thus yielding a relatively short burn out time.

TABLE 8

BURN OUT STUDY OF 1-AMP/1-WATT BRIDGE ELEMENTS ON GLASS-KOVAR PLUGS EXPOSED TO AIR

Sample Number	Bridge Resistance (ohms)	Constant Current (amps)	Time to Burn Out or 45 Sec. Test (sec)
10	1.3	1.0	45-Test
11	1.4	1.2	45-Test
12	1.4	1.4	45-Test
13	1.4	1.6	32.50
14	1.3	1.6	13.00
15	1.4	1.6	0.80
16	1.5	1.6	1.35
17	1.4	1.6	45-Test
18	1.4	1.8	0.44
19	1.4	1.8	0.90
20	1.5	1.8	0.40
21	1.5	1.8	0.18
22	1.3	1.8	3.20
23	1.5	1.8	0.10

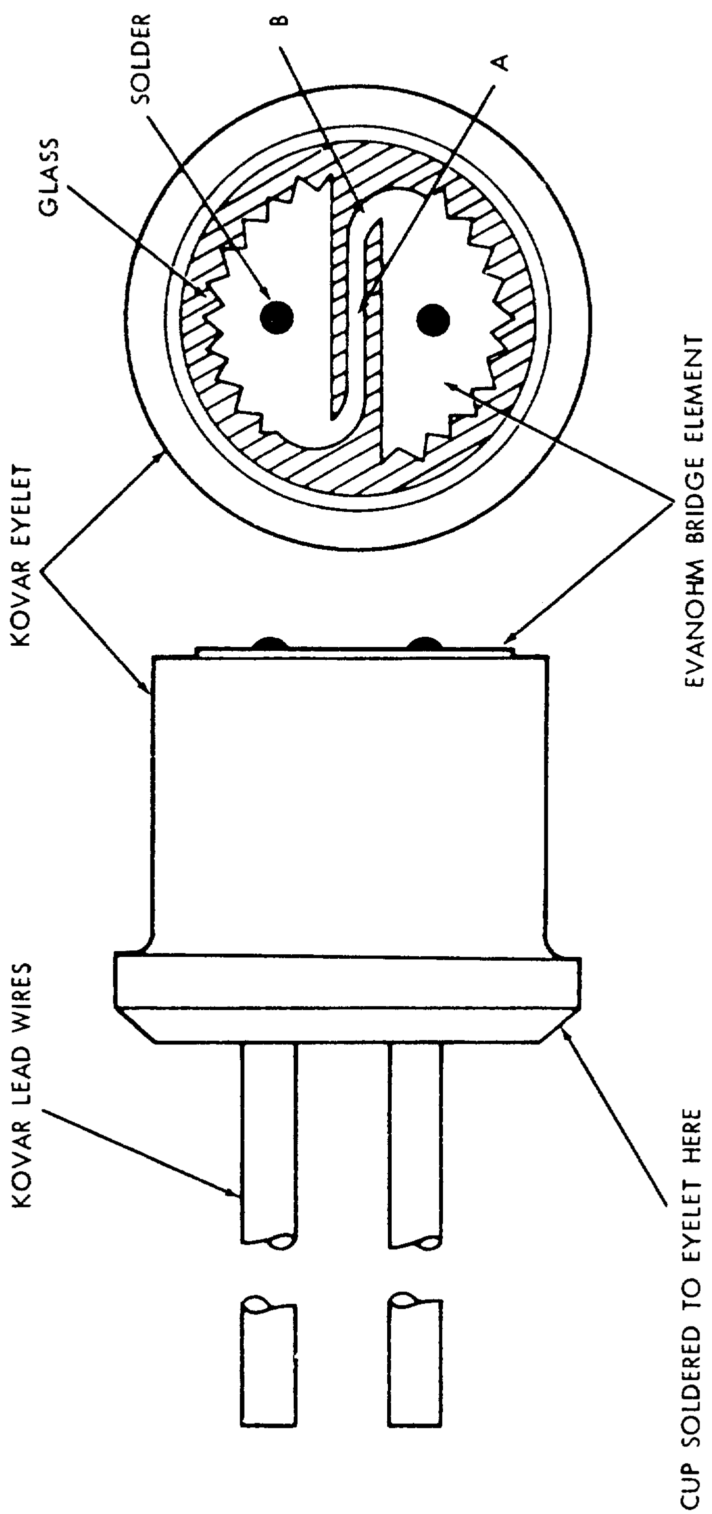

FIG. 1 (U) EVANOHM BRIDGE ELEMENT ON GLASS-KOVAR PLUG (U)

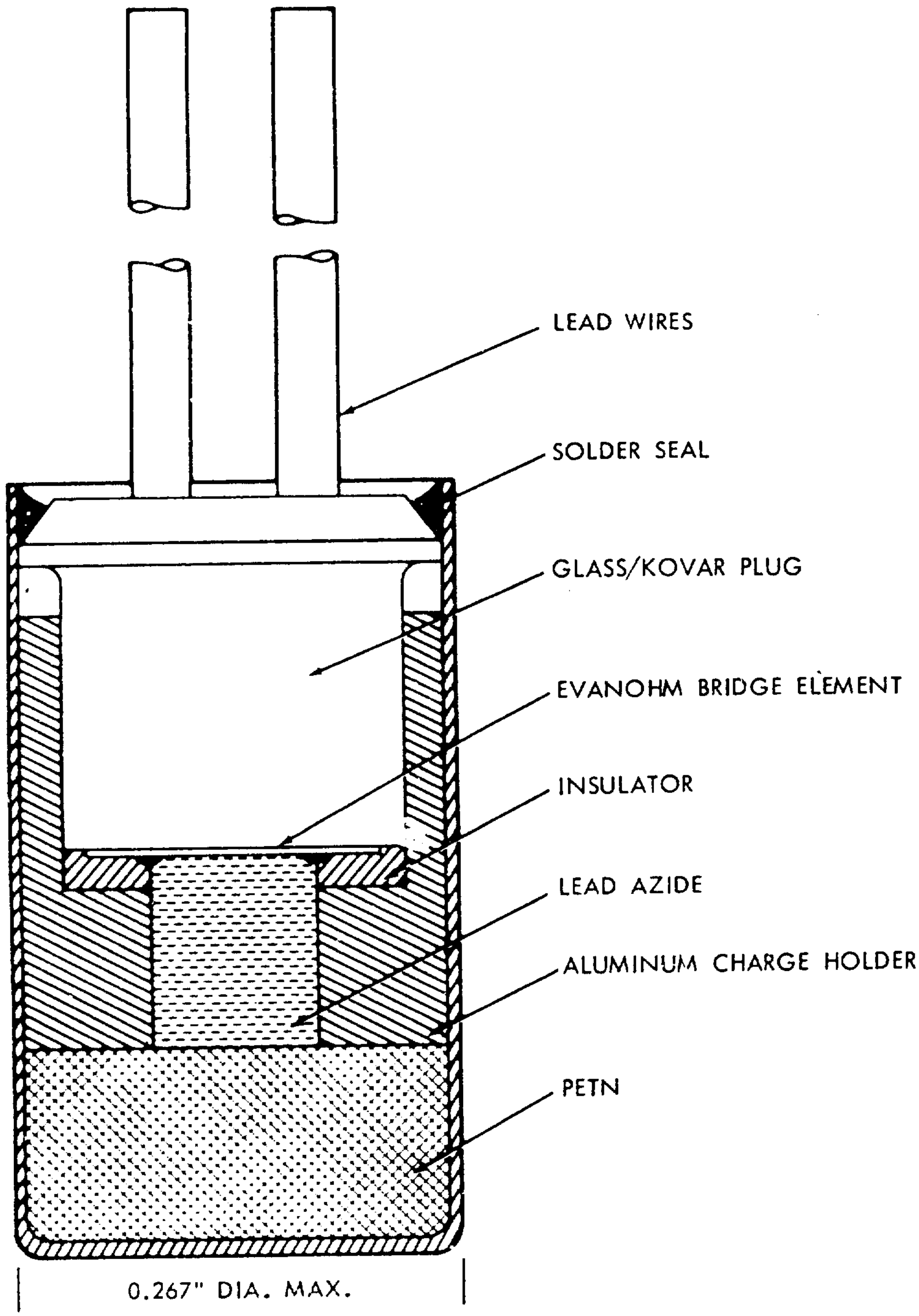

FIG. 2 (U) MK 101 TYPE DETONATOR ASSEMBLY (U)

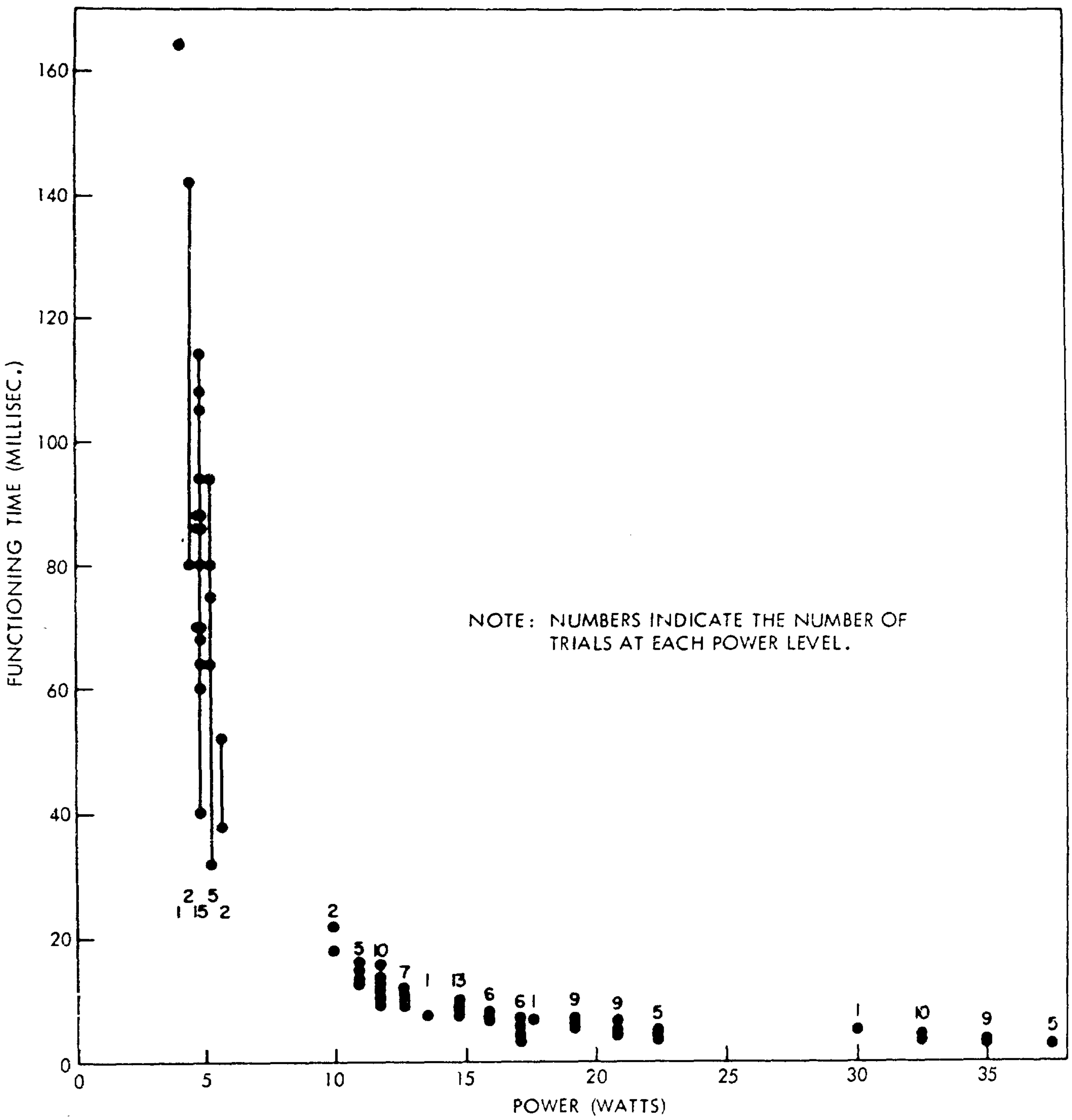

FIG. 3 (U) CONSTANT CURRENT FUNCTIONING TIMES VERSUS INPUT POWER (U)

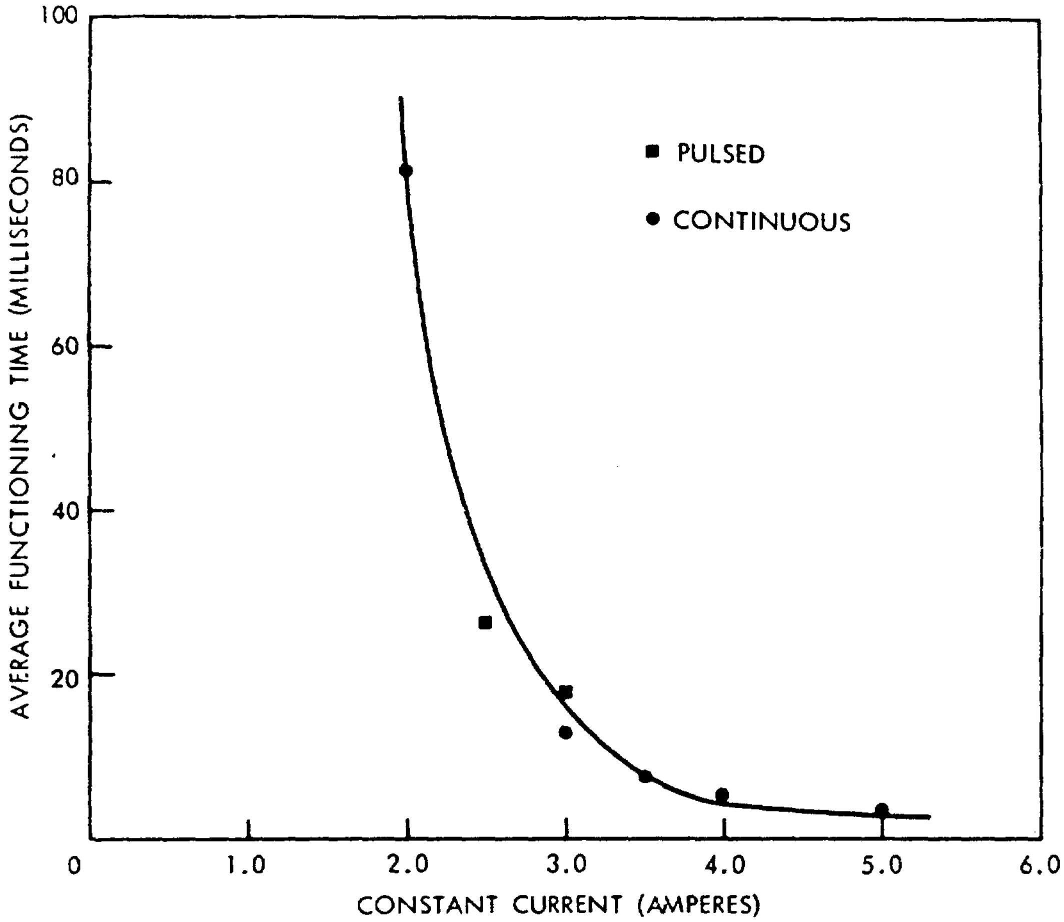

FIG. 4 (U) CONSTANT CURRENT FUNCTIONING TIMES (U)

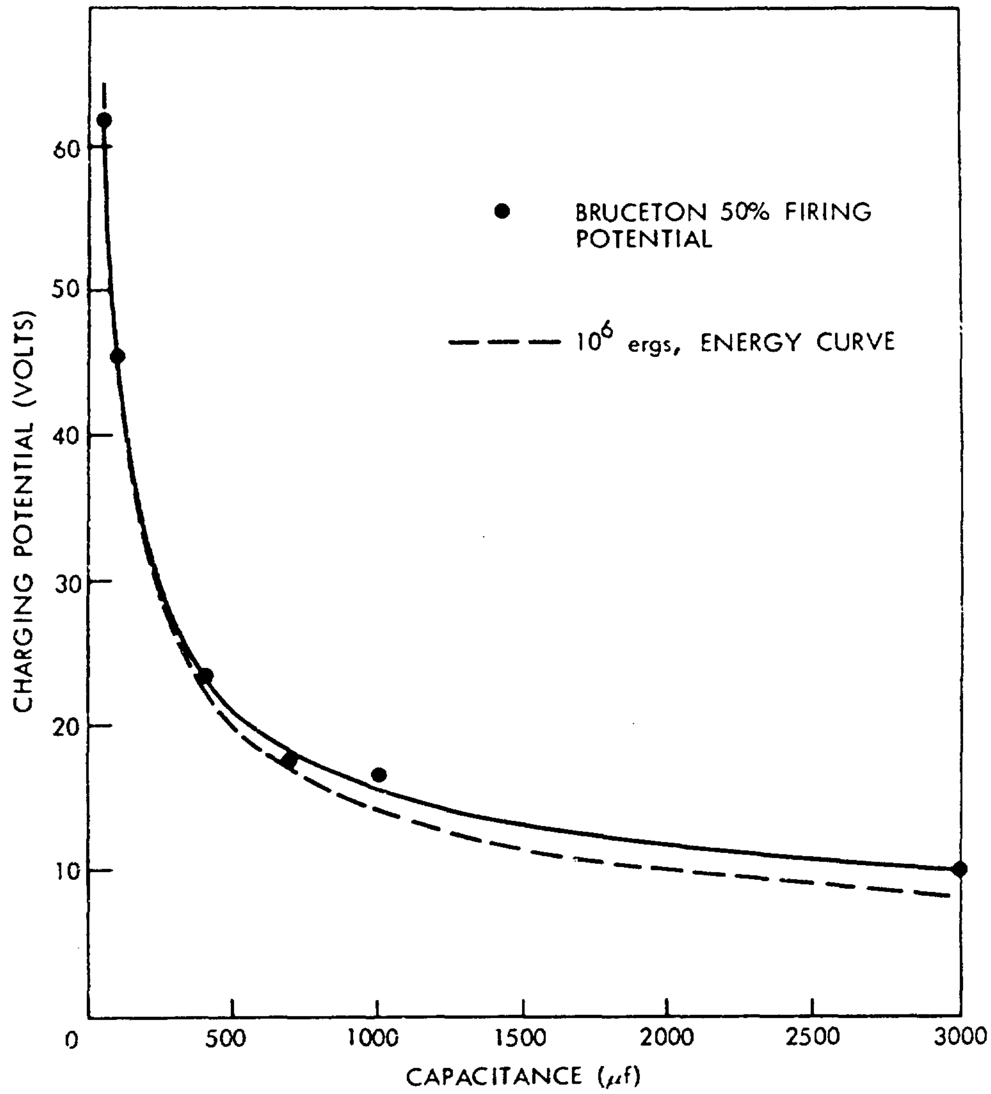

FIG. 5 (U) CAPACITOR DISCHARGE BRUCETON RESULTS (U)