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From: Commander, U. S. Naval Ordnance Laboratory, White Oak
To: HERO Distribution List No. IIID

Subj: Guided Missile Propulsion System, Hazards of Electro-
magnetic Radiation to Ordnance (HERO); RF Character-
istics of Electro-Explosive Devices, Task NOL-443

Ref: (a) Dahlgren Project Order #PO-1-0020 of 14 June 1961

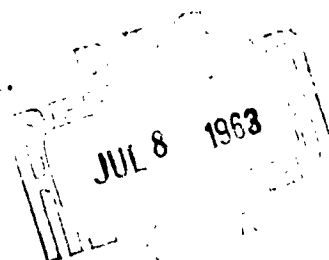
Encl: (1) Quarterly Progress Report for the period 1 January
to 31 March 1963 on subject task

1. Enclosure (1) is forwarded herewith in compliance with
reference (a).

R. E. ODENING

(Signature)
A. LIGHTBODY
By direction

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U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

QUARTERLY PROGRESS REPORT
ON
GUIDED MISSILE PROPULSION SYSTEM
HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO)
RF CHARACTERISTICS OF ELECTRO-EXPLOSIVE DEVICES
TASK NOL-443

Period Covered
1 January 1963-31 March 1963

Explosion Dynamics Division
Explosions Research Department

REPORT ON PROGRESS OF GUIDED MISSILE PROPULSION SYSTEM
HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO)
RF CHARACTERISTICS OF ELECTRO-EXPLOSIVE DEVICES
FOR THE QUARTER ENDING 31 MARCH 1963
Task NOL-443

1. PROGRESS DURING THE PERIOD .

a. Sorting of EED's. (Two-Temp. Method).

Two controlled temperature chambers were used, one set at about -3°C and the other at about $+76^{\circ}\text{C}$. Twenty-four sets of leads were made of #14 copper wire and their resistances measured as a function of temperature (with the emergent length kept constant). The EED resistance was measured first at the higher temperature and then at the lower temperature. The temperature of each EED was measured simultaneously with the resistance measurement by an individual thermocouple in contact with the EED body. While the EED is maintained at the cold temperature, a DC current is fed into the EED bridgewire. The current amplitude is adjusted to obtain an approximate 0.100 ohm resistance increase. The parameters M and γ can then be computed by

$$M = \frac{R_H - R_C}{T_H - T_C} \quad , \quad \text{and} \quad \gamma = \frac{I^2 R_P M}{R_P - R_C}$$

- where R_H , R_P and R_C are the heated, powered, and chilled EED resistance values corrected for lead resistance; and T_H and T_C are the hot and cold temperatures.

C_p was measured by subjecting the EED (at ambient temperature) to a 50usecond, 2.5 ampere, constant-current pulse. The oscillographic record yields R_A and R_F , the EED resistances before and after the pulse. The energy of the pulse (assuming a straight line R_A to R_F) is given by

$$E = \frac{I^2 t (R_A + R_F)}{2}$$

where t =the pulse duration. The temperature elevation due to the pulse is given by

$$\theta = \frac{R_F - R_A}{M}$$

The heat capacity can be evaluated by

$$C_p = \frac{E}{\theta} = \frac{I^2 t M (R_F + R_A)}{2 \cdot (R_F - R_A)}$$

Two hundred eleven Squibs Mk 1 Mod 0 were tested using the schemes described above, with the following results:

	γ $\mu\text{watts}/^{\circ}\text{C}$	C_p $\mu\text{joules}/^{\circ}\text{C}$	M $\mu\text{ohms}/^{\circ}\text{C}$
$\bar{x}$	508.2	3.815	944.5
s	28.0	0.30	66.9
max.*	576.1	4.587	1135.3
min.	396.9	3.005	787.2
unit #539	580.9	4.839	1168.9
*Not including #539			

Unit #539 was considered a sport. It quite obviously did not fall in the C_p and M distribution of the remaining 210 units. Furthermore, attempts to repeat measurements on that unit indicated that it was unstable.

From the data above it can be seen that the standard deviation of γ was 28 or about 6% of the mean. This standard deviation, which also is known as the standard error, includes the variability inherent in the γ parameter and the experimental error of the measurements. By making intentional numerical alterations in typical data it is easy to compute the expected effect of some of the individual measurement errors on the final answer.

1. A thermocouple error of 0.1 millivolt (2°C) will make a 2.5% error in M and γ .
2. An EED resistance error (at upper temperature) of 0.01 ohms will make a 13% error in M and γ .
3. A 2 milliampere error in EED current (about 1%) will make a 2% error in γ .

In order to determine the composite experimental error, twenty four of the units (selected at random from the main group of two hundred eleven) were run through the γ and M measurement procedure to obtain a second (replicate) group of data. A different twenty four unit random sample was used to obtain replicate C_p data. An analysis of variance (which compares the reproducibility between original and replicate readings, unit by unit, with the overall variability) gives a basis for estimating the experimental error. These analyses are being at present carried out.

Once the experimental error is known it will then be able to set up three classifications: high, low, and intermediate, where the intermediate, or ambiguous, group will contain those units whose values are so close to the mean that they cannot be truly classified as high or low.

b. Sorting of EED's (Electrothermal Phase-Shift Bridge Method.)

Primer Mk 114 bridge subassemblies and certain initiators made by a commercial vendor have been measured on the electrothermal phase-shift bridge, classified on C_p and fired by capacitor discharge. The hope was that a quick and meaningful sort could be made assuming a single value of the temperature coefficient of resistance for all units. No correlation could be found between the sorting and the sensitivity. However the instrument error (which is thought to be about 5%) has not been determined experimentally. It is possible that the true variability of C_p has been masked by the instrument error. An 8 second Delay Primer, WOX 79A, is being measured on this instrument with data being taken to permit a study of the instrument error.

c. "All-Fire", "No-Fire" Level Concepts.

Much time and discussion has been devoted to acquainting people with this general problem area. Reports, and a paper for the HERO Congress are in process of preparation covering this topic. Much of the information contained therein is knowledge which has been in existence but which apparently has not been collected together. As a sort of a preview, or stop gap, and in order to help those new in the field towards avoiding some of the oft-tripped-over stumbling blocks the following outline of logic is submitted (without proof in the interest of brevity):

1. If a level (other than zero stimulus) exists at which absolutely no units will fire, there is no way to measure the level or even prove that it exists. Similarly, a finite stimulus level at which every unit will fire can neither be measured nor its existence proved.
2. There is no standard definition of an "All-Fire" or "No-Fire" level. The ones that have been encountered have really been estimates of probabilities any where from 1% to 0.0033% and at confidence levels ranging from 50 to 99%.
3. Estimates of extreme probability functioning levels must ordinarily be made by extrapolation

since prohibitive sample sizes are required for direct demonstration.

4. The Bruceton data collection plan is optimized for estimates near the 50% point. Many different distributions which could be fit equally well to centrally collected Bruceton data would lead to widely divergent estimates of "All-Fire", or "No-Fire" points.
5. The Bruceton data collection plan tends to underestimate the standard deviation particularly for small sample sizes (under 100). This would introduce a hazardous bias in safety estimates and over-optimistic estimates of reliability.
6. There are data collection plans optimized for making estimates of remote functioning levels. These plans, which should be used instead of the Bruceton, locate the testing levels closer to the desired level of estimation and farther away from the mean, thereby reducing extrapolation error.
7. Even with optimized data collection plans, the most sophisticated statistics, and high quality instrumentation, the problem is still not in complete control since so little is known about batch-to-batch variation except that it can lead to major errors in estimates.

d. High-Speed Computations.

The high-speed computer programs have been used to calculate the sensitivity parameters of 10 EED's. The data are being made available to NWL under separate cover.

e. Correction.

Item 1f, page 4, lines 7 and 8 of the HERO Quarterly Progress Report for period 1 October to 31 December 1962 twice used the word "reversed" for "recovered".

2. PLANS FOR NEXT PERIOD

a. Sorting of EED's.

Measurement errors will be estimated. Sorting criteria for the two hundred eleven Squibs Mk 1 will be established and firing carried out. The use of the electrothermal phase-shift bridge as a sorting tool will be studied.

b. Reports.

A number of reports are in various stages of preparation. Considerable effort will be devoted to getting them on the way to publication.

c. Special EED designs.

Work will be instituted to develop replacement EED's with sensitivities designed to compensate for the insertion losses at firing frequencies caused by fixes such as the RIG.