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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 April-30 June 1964

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 30 JUNE 1964
TASK NOL-443

1. PROGRESS DURING THE PERIOD

a. 9 and 3 Gc Radar Firings. Three methods of irradiating squibs at microwave frequencies have been tried: in the waveguide, in the near field of a horn, and inside an expanding waveguide (in a horn). As described in the last quarterly report we lack information as to the response of a squib to an adiabatic microwave energy input. Two approaches are being tried to obtain such data: modification of the radar set electrically to force a short train of pulses to be generated at a much higher repetition rate such that the complete pulse train length is short compared to the EED thermal time constant, and design of the squib lead arrangement to couple more power, e.g., use dipoles arranged as reflectors and directors.

Modification of the radar set for a higher repetition rate has not shown great promise. There are, however, a few modification possibilities yet to be explored. Insertion of elements in the horn to act as reflectors or directors have shown considerable promise. One arrangement of dipoles, for instance, gave a three fold power increase as measured by the temperature increase in a bare bridge wire. Aperture plates and a small copper receiving horn have been fabricated and are being tried out.

b. M-100 Matches. The poor resolution in thermal parameters obtained when using the third harmonic phase shift bridge on the M-100 match led to a theoretical analysis of the difficulties. The analysis showed that the frequency being used was too high to effectively measure γ. A few experiments verified this fact. To correct the condition and to make meaningful measurements on the M-100 match a low frequency power amplifier to energize the squibs is being built.

c. Statistical Studies. We have been limited in our computer handling of problems in the normal (Gaussian) probability space because the cumulative distribution function cannot be evaluated or written in closed form. We would have to use tabulated functions, an inefficient method. Specifically, we wish to be able to compute the ordinate expressed in normits, N, corresponding to an observed probability of response, p.

Our solution depends upon the facts (1) that the logistic distribution can be mapped into the normal distribution by an empirical transformation function, and (2) that the ordinate expressed in logits, L, in the logistic probability space can be computed very simply by

$$L = \frac{p}{1-p} .$$

The polynomial which transforms from Logits to Normits, in nested form, is

$$N = L(L^2(L^2(L^2(L^2(E-F\cdot L) - D)+C)-B)+A)$$

where A = 0.62668163
B = 0.01120795
C = 0.000577281
D = 0.000029239
E = 0.000000962574
F = 0.0000000135.

This procedure, for values of P(x) from 0.02 to 0.98, has an error in N of less than 0.2%.

We have adapted the Golub and Grubbs method for handling Go/No-Go data where the stimulus cannot be controlled a priori to the logistic distribution method. There had been some trouble in generating the two estimators, s_m (the standard deviation of the mean), and s_s (the standard deviation of the standard deviation). This problem was resolved, the adaptation finished, and a report covering the method prepared.

Work is now well underway towards developing a method for modifying the Bruceton analysis to incorporate the underlying assumption of a logistic, rather than a normal distribution.

d. Safety Estimates of the Constant-Current Sensitivity of Type A Squib Simulator Assemblies. The Type A Squib Simulator is an EED which has the same bridgewire and explosive configuration (and therefore sensitivity) as certain EED's used in the SHRIKE missile. 195 Type A Squib Simulator Assemblies, Lot 7-360-323 were received for test. They were fired at two levels of constant current (DC) with a 30 second pulse length. Conservative estimates were made of the probability of firing at low steady state currents.

The two point data obtained are given below:

Current*	Observed Response			
Milliamperes	No. Fails	No. Fires	Probability	Logits
110	40	15	0.2727	-0.9808
106	128	9	0.0657	-2.6548

*The error in controlling the levels is less than 0.5%.

A linear-logistic fit of the data was made. In this case the linear logistic fit will give a slightly more conservative estimate than a log-logistic fit (the latter being considered a more exact estimate). Estimates based on the linear logistic fit are:

Current Milliamperes	Estimated Probability of Firing	
	Most Likely	Conservative Safe Level, at 95% Confidence
112.3	0.50	——
90.0	0.00009	0.0009
80.0	0.000001	0.00009

The vendor ran a forty-shot Bruceton on a different lot of the Type A Squib Simulator Assemblies. These data yielded a fifty per cent point of 109.6 milliamperes and a standard deviation of 3.1 milliamperes. The standard deviation quoted is about the same as the variability noted for our linear-logistic fit. The difference in fity per cent firing points is not statistically significant. Yet it is not wise to assume that there will be no batch-to-batch variation. If it is desired to allow for the chance of a rather sensitive batch of squib simulators, we suggest that the stated safe current level be reduced by another 10 milliamperes. The numerical value of this correction is strictly empirical, being based solely on engineering judgment.

e. X248 Motor Accident Investigation.* One of our staff has consulted for NASA (in the field of electrostatic susceptibility of EED's) on the investigation of the rocket motor accident on 14 Apr 1964 at Cape Kennedy. This accident resulted in the death of three men. The deliberations of the official fact finding committee are not yet finished, because an extensive investigative and experimental program was needed to obtain a complete picture, and some of this work is still in process. However, it can be said that initiation by electrostatic energy is by far the most likely cause. There are a number of ways by which the energy could have been dissipated in the EED. There are some general facts that can be stated more or less as lessons taught by the incident:

(1) The sensitivity of an EED, to electrostatic and EMR energy in the leads-to-case mode, cannot be deduced from a knowledge of the EED's sensitivity to normal mode (lead-to-lead) inputs.

(2) While prevention of initiation by electrostatic energy is not an objective of the HERO program,

*This work was not funded by the HERO Task (NOL-443) but is believed to be of interest to it.

the techniques which give RF protection can often give electrostatic protection as well; sometimes immediately, sometimes with a little further thought.

(3) Even though the particular initiator involved in this accident was unusually sensitive to electrostatic energy, it would have been possible to use it safely had a complete Faraday shield existed which enclosed the bridgewire and associated circuitry, or if steps had been taken to preclude formation of static charges.

(4) To design an explosive carrying system for full invulnerability to any normal environment, RF, electrostatic, heat, vibration and shock, a broad field of knowledge must be assembled. Information usually needed is:

The sensitivity of the EED (and other explosive elements) to these environments, either in the intended or the inadvertent mode.

The effect of the system structure on the transmission of environmental energy into the explosive.

The effect of handling and other factors, external to the system, on the system environment.

2. PLANS FOR NEXT PERIOD

Work on radar firing, M-100 Matches, and statistical research will continue along lines set out above.