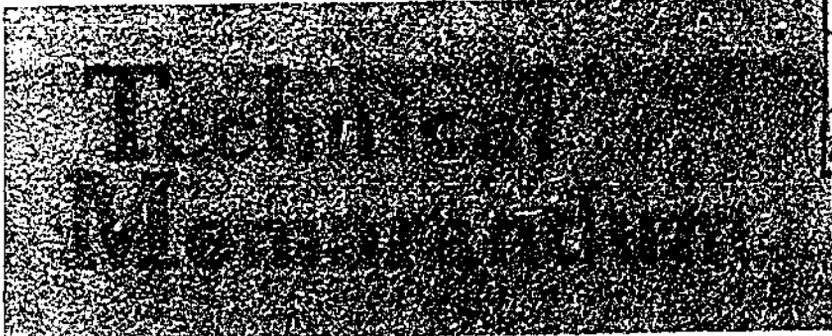
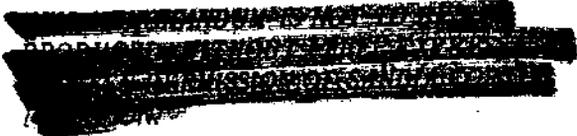


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### A FIRST APPROACH TO THE PROBLEM OF GUIDED MISSILE RELAYS SUBJECTED TO RADIATION

Jay W. Gear, Jr.

#### ABSTRACT

At the request of the Guided Missile Relay Working Group (GMRWC)\* during the meeting of May 18-20, 1955, a preliminary investigation has been made to determine what effect, if any, radiation may have on guided missile relays. The task can be stated as follows:

- A. By means of a brief literature search -
  1. Determine the types and quantities of radiation that guided missile relays might encounter in actual use in radiative fields known to exist.
  2. Record some of the effects that radiation might have on guided missile relays.
- B. Make recommendations concerning -
  1. The type of laboratory test that would be suitable for testing the effects of radiation on guided missile relays.
  2. The best general classes of materials, from the standpoint of resistance to radiation damage, that could be used in new guided missile relay designs.

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TASK

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RESULTS OF LITERATURE SEARCH

A brief literature search (augmented by several verbal discussions) revealed the following information:

- 1. Types, Magnitudes and Duration of Radiation that Guided Missile Relays Might Encounter in Actual Use.
  - a. Nuclear Energy Powered Aircraft (NEPA) - Complete information was not available concerning radiative fields surrounding nuclear powered aircraft. Several reactors and airframe configurations are still in the design

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stage, making it difficult, if not impossible, to predict the type and intensity of fields that will be encountered by guided missile relays. The fields depend in part on the types of reactors, the relative locations and distances between the reactors and the guided missiles, and the shielding between them. Considering these variable factors and known data, it can be roughly estimated that the field strength of radiation at a guided missile carried in a nuclear powered aircraft may be between  $10^7$  and  $10^{13}$  nvt and between  $10^8$  and  $10^{12}$  gamma rays/cm<sup>2</sup>-sec. The unit "nvt" represents an integrated flux having the unit of neutrons/cm<sup>2</sup>-sec., where n equals the total neutrons/cm<sup>3</sup>; v equals the average velocity (cm/sec) of all the neutrons including thermal, epithermal, and fast; and t equals total time in seconds. The time duration of the radiation is of course a variable. However, the duration of many tests performed on specific materials has been in the range of 100 to 1000 hours.

- b. Cosmic Radiation - The intensity of cosmic radiation is relatively small compared to that expected near a NEPA:

<u>Elevation</u>	<u>Approximate Intensity</u>
at sea level:	2 mr/mo. equivalent to $5 \times 10$ gamma rays/cm <sup>2</sup> -sec -
at one mile:	4 mr/mo. equivalent to $1 \times 10^2$ gamma rays/cm <sup>2</sup> -sec
at 20 miles:	20 mr/mo. equivalent to $5 \times 10^2$ gamma rays/cm <sup>2</sup> -sec
at 20 miles with scattering:	160 mr/mo. equivalent to $4 \times 10^3$ gamma rays/cm <sup>2</sup> -sec

- c. Detonation of Nuclear Weapons - Although it is known that very high peak intensities exist for short durations of time, the problem of the vulnerability of guided missile relays to nuclear detonations has not been considered in this paper.

2. Some of the Effects that Radiation Might Have on Relays -

In considering the possible effects radiation might have on guided missile relays, it became apparent during the literature search that essentially no useable data exists concerning results of radiation tests performed on relays of the type used in guided missiles. With this handicap, the next best step was to determine the effects of radiation on individual materials (of which there are some data) and extending these facts to a completed relay. However, this extrapolation can be very misleading inasmuch as two or more materials may behave under radiation perfectly well individually, but in combination may be incompatible. This effect may be due to several reasons, one being the effect of secondary emission of one material on another.

The literature now available on the effects of radiation on materials can be very misleading, especially if the details of the particular test are not stated. For instance, some tests on plastics have been conducted with the plastic immersed in water. Various physical properties of the plastics have changed apparently due to the radiation alone. However, in many cases the damage was due primarily to water absorption which is greatly increased in certain plastics by the presence of a radiative field. Again, damage may be due primarily to heat generated by gamma rays, rather than the gamma rays alone. Many test results fail to include whether the total radiation was an integrated spectral density spectrum of neutron energies, or made up entirely of fast or slow neutrons.

With all the above precautions in mind, some data on the effects of radiation on specific materials subjected to laboratory tests were recorded:

- a. Metals - In general, fast neutrons produce displacement of the atoms from their original lattice sites. Gammas are not effective in producing damage because their primary effect is to produce ionization which is a transient effect in a good conductor. Specific properties of many metals subjected to a total radiation dosage of approximately  $1 \times 10^{17}$  nvt (approximately  $3 \times 10^{12}$  thermal, epithermal and fast neutrons/cm<sup>2</sup>-sec for 100 hours) can be briefly summarized as follows:

- (1) Dimensions - Relatively stable.
- (2) Hardness - Increases slightly. This is due primarily to the atoms locating interstitially, upsetting the normal slip planes. The greater the initial hardness, the less the hardening.
- (3) Tensile Strength - Radiation has about the same effect as cold working the material.
- (4) Stress Relaxation - Spring constants are affected only slightly, in the order of several percent.
- (5) Heat Transfer - No impairment.
- (6) Electrical Resistivity - Increases 1.5 to 2% in copper.
- (7) Microscopic Diffusion - Little effect.

b. Insulators - In general, damage is likely entirely a result of ionization or excitation.

(1) Inorganic

- (a) Glass and Quartz - In a total dosage of approximately  $1 \times 10^{17}$  nvt, some glasses became discolored and more brittle, with the electrical resistivity decreasing. However, glass and quartz are among the best practical insulators under intense radiation.
- (b) Porcelain - Approximately the same as glass.
- (c) Mica - The only apparent damage in one test was a slight bending under radiation.
- (d) Ceroc Wire Insulation - Exposure to  $1 \times 10^{17}$  nvt caused flaking.

(2) Organic

- (a) Plastics - With few exceptions (notably Saran and Vinylite), plastics fail under pile radiation by becoming hard and brittle, thus losing their insulating properties. The materials which have proven to be the more stable after  $2 \times 10^{16}$  nvt are Nylon, Polystyrene, Polyethylene, Phenol Formaldehyde (Bakelite), Polyester Plastic, and Furfural alcohol Polymer (Duralon); while Lucite, Teflon, Saran, Casein, Fluorothene, Vinylite, and all cellulose compounds are essentially unstable. As a rule, no

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pronounced change occurs in volume resistivity, dielectric strength, or arc resistance until the mechanical properties deteriorate completely. Below are listed a few specific plastics with a brief statement as to damage due to an integrated radiation of  $10^{17}$  to  $10^{19}$  nvt:

- 1 Acrylic - Yellowed and swelled. The swelling may have been due to water absorption. The tensile strength and impact strength decreased 50% after  $10^{17}$  nvt.
- 2 Cellulose Acetate - Crumbled badly at  $5 \times 10^{17}$  nvt.
- 3 Cellulose-Acetate-Buterate - Tensile strength and impact strength increased 50% at  $10^{17}$  nvt.
- 4 Kel-F - Crumbled to powder at  $1 \times 10^{17}$  nvt. This crumbling may be caused by fluorine fumes exuded during the test, forming an acid and attacking the Kel-F.
- 5 Teflon - Impact strength increases, then decreases. Crumbled at  $1 \times 10^{17}$  nvt. Crumbling effect may be the same as for Kel-F.
- 6 Nylon - The tensile strength increased slowly. Finally crumbles at  $10^{19}$  nvt. Absorbs oxygen during the radiation.
- 7 Phenolic, mineral-filled (asbestos) - There is little change up to  $10^{19}$  nvt except for darkening. The mineral filler imparts radiation resistance since unfilled phenolic is much less resistant.
- 8 Phenolic, organic-filled (Linen) - Weakens considerably at  $3 \times 10^{18}$  nvt.
- 9 Polyester-Flaskon Alkyd, mineral-filled - Strength increases 50% at  $10^{19}$  nvt. This material is poorer than mineral-filled phenolic.
- 10 Styrene - Little change occurs up to  $10^{19}$  nvt except darkening. This is one of the most stable plastics.

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(e) Cases -

- 1 Nitrogen - Insufficient data. At some radiation level  $N_{14}$  may transmute to  $C_{14}$  which is radioactive and will cause ionization.
- 2 Hydrogen - Insufficient data - At some particular level should ionize.
- 3 Helium - Insufficient data - Should be fairly stable.

(f) Miscellaneous Items -

- 1 Alnico V Magnets - One test at  $1 \times 10^{17}$  nvt produced little effect.

RECOMMENDATIONS

From the above data and stated warnings, no conclusive recommendations can be made at this time. However, until a large quantity of reliable data on materials effects and reactor fields are obtained, the following recommendations can tentatively be made:

- A. Laboratory Tests - Sample quantities of guided missile relays that are expected to operate in a radiative field should be subjected to a laboratory test in a radiative field of various types (including thermal, epithermal and fast neutrons, intensities, and total dosages).

The tests should be controlled so that the threshold of damage and malfunction for each parameter can be established. Damage or malfunction due to secondary or extraneous effects should be controlled, if possible, and recorded. Quantitative data such as operate current, release current, coil resistance, contact resistances, dielectric strength, and insulation resistances should be obtained periodically throughout the test. Residual radioactivity should be recorded as a safety measure subsequent to the test. Any decrease in mechanical strength should be evaluated subsequent to the test by subjecting the relays to shock and vibrational accelerations, and to hermetic seal tests.

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At a later date these thresholds of damage or malfunction can be correlated to specific intensities and dosages of radiation encountered in actual use to assist in selecting the most suitable relay existing at that time.

- B. New Designs for Guided Missile Relays - In light of present data, it is recommended that relays designed to be exposed to high levels of radiation in actual use should incorporate inorganic materials wherever possible. Physical size should be kept small to decrease cross sectional areas and gamma ray heating. As more information becomes available, such as any benefits derived by the use (or avoidance) of additives or impurities in certain materials, these new concepts should be incorporated into design thinking.

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