

PRNG 36 PUERTO RICO NUCLEAR CENTER RESEARCH IN PHOTOMULTIPLIER TUBE FATIGUE Prediction, Acceleration and Correction of Fatigue Effects in Photomultiplier Tubes BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40-11-1833) FOR U.S. ATOMIC ENERGY COMMISSION ---Page Break--- PREDICTION, ACCELERATION AND CORRECTION OF FATIGUE EFFECTS IN PHOTOMULTIPLIER TUBES L. Cantarell and E. Almodóvar Work performed at Puerto Rico Nuclear Center, Mayagüez, P.R. under U.S. Atomic Energy Commission Contract AT-(40-11)-1833, April 1964 ---Page Break--- PREDICTION, ACCELERATION AND CORRECTION OF FATIGUE EFFECTS IN PHOTOMULTIPLIER TUBES L. CANTARELL AND E. ALMODÓVAR PUERTO RICO NUCLEAR CENTER* MAYAGÜEZ, PUERTO RICO ABSTRACT Practical methods for correcting the effects of fatigue in photomultiplier tube measurements are discussed. Also, a method is presented for reducing the time required for the saturation or stabilization of phototubes from several hours to a few minutes. Two methods are proposed for the correction of fatigue effects. One method proceeds from the experimental predictability of fatigue effects by means of plots or empirical equations with a margin of error of 1%. The other method proceeds from the synchronized measurement of fatigue together with the spectrum measurement. Fatigue of photomultiplier tubes, characterized by the abnormal variations with time in tube gain, is a persistent source of error affecting phototube measurements. In nuclear spectrometry, for instance, when a single channel analyzer is used, fatigue continuously changes the phototube gain over the measurement period, and a distorted spectrum is obtained. If the gain variation is operated for the U.S. Atomic Energy Commission by the University of Puerto Rico. ---Page Break--- The main difficulty in correcting fatigue effects in the past has been that the phenomenon was relatively unknown and, until recently, could not be reproduced. At present, the phenomenon is better known and some empirical logarithmic equations are

available) from which corrections can be derived. However, the application of the empirical equations requires a knowledge of the permanent fatigue characteristics of the photomultiplier tube being used. TL. BOUQUEMARNT AND EXPERIMENTAL PROCEDURE A total of 30 Dunwat 6292, RCA 6242 and ROA 8819 photomultiplier tubes were studied. All measurements were made using a thermostated system in which the temperature of operation was $23.00 \pm 0.25\%$. Spectral measurements were performed utilizing a single channel analyzer manufactured by Baird Atomic Corporation and a 512 channel analyzer obtained from the Nuclear Data Corporation. Several gamma ray sources of Cs-157 were used, with intensities ranging from 1 to 50 without collimation, and from 25 to 5804, collimated by lead rings. When strong sources were used, an auxiliary weaker source was employed for periodical measurements of the photopeak position. Samples of neutral materials such as roots, leaves, sand, etc., were measured without previous chemical treatment. A detailed description of equipment and procedures was given in an earlier study. THE PREDICTION OF FATIGUE EFFECTS A. Determination of Permanent Fatigue Characteristics of Photomultiplier Tubes The main fatigue characteristics to be measured are: ---Page Break--- fatigue given by the pulse height variation Δc in the following equation: 7) Because $e + S_m \text{ top } G_e + 1) @$ in Here, c is the position of the photopeak at the beginning of any measurement, and C the channel attained by the photopeak at time t . The slot sm 0 equal to $(0, D_0y + eq)$. When equation (2) is plotted as in fig. 1, the successive straight lines of a fatigue curve are represented by $= 1$ from t_0 to $t = t_g$ and by $= 2$ from $t = t_y$ to $t = t_y$. For our purposes, however, the value $\{= 1$ is sufficient. Furthermore, the parameters c_y and $b_y = c_y/a$ are likewise evaluated from the fatigue curves measured to determine the other characteristics of the phototube, by means of a plot of the slopes m_j versus the total variation of the photopeak position Δc ,

obtained experimentally from the difference $C_y - C_y$ (See fig. 2). B. Prediction of Fatigue Behavior

of Photomultiplier Tubes Once the permanent fatigue characteristics have been determined for a phototube, any abnormal gain variations which may occur during measurements can be predicted graphically. The intensity I of the source to be measured is determined in about one minute of measurement. The final saturation limit $C_y = AC + 6$ is calculated from equation (1), and the straight line between points 0 and C_y then describes the expected fatigue behavior of the phototube (see og-plot). Similarly, the fatigue curve can be predicted analytically with equation (2). Since $A_{er} = AG + O_y = G_p$, and AC can be calculated from I by means of equation (1), the fatigue behavior of the phototube given by equation (2) is known from the values of C_y and I determined in the first minute of source measurement. ---Page Break---

Figure 3 shows a γ -ray spectrum of monazite sand obtained with a single-channel analyzer. The corrected spectrum (dotted lines) was obtained by applying the methods described above. It should be noted that in the region from 0.5 to 1.0 MeV, corrections are necessary to avoid attributing intensities to the wrong isotopes. The correct photopeak positions are indicated by arrows.

3. Correction by simultaneous measurement Fatigue can be measured continuously from the anode current variation registered on a recorder, or by repeated measurements of the photopeak position of a standard weak source between measurements of different samples. The former method is convenient for spectra which are determined with a single-channel analyzer, the latter method is recommended when a multichannel analyzer is used. Corrections based on the synchronized fatigue measurements are then applied to the measured spectrum.

VE. CONCLUSIONS The correction or elimination of fatigue effects present in photomultiplier tube measurements is absolutely necessary if high precision in nuclear spectrometry is to be obtained. The long waiting

Periods required for stabilization of the measuring system, as recommended by the manufacturers, can be avoided by accelerating the process with standard stronger sources. The methods for correcting fatigue discussed in this are useful because they lead to higher precision. The development of fast methods for automatic compensation of fatigue effects would be highly desirable. ---Page Break---

Schematic representation of Fig. 1 Variation of phototube gain with working time plotted versus $\log(10t + 1)$. The stabilization time of sources Band 5 (one day) can be attained with a stronger source in 4 and 0.5 min., respectively. ---Page Break---

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TOTAL PULSE HEIGHT VARIATION. Fig. 2. Determination of parameters b_i and c_t of equation 2 from two fatigue measurements of a phototube. ---Page Break---

COUNTING RATE. Fig. 3

MONAZITE SAND -©0-0-MEASURED SPECTRUM =-- CORRECTED SPECTRUM ENERGY

(Men gamma ray spectrum of monazite sand. Graphical-analytical methods were used to obtain the corrected spectrum. ---Page Break---