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PUERTO RICO NUCLEAR CENTER

RESEARCH IN PHOTOMULTIPLIER TUBE FATIGUE

Prediction, Acceleration and Correction
of
Fatigue Effects in Photomultiplier Tubes

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PREDICTION, ACCELERATION AND CORRECTION OF FATIGUE EFFECTS IN PHOTOMULTIPLIER TUBES

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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.

I. INTRODUCTION

A. General

The so-called fatigue of photomultiplier tubes, that is, 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

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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(4,8) and some empirical logarithmic equations are available(7) from which corrections can be derived. However, the application of these empirical equations requires a knowledge of the permanent fatigue characteristics of the photomultiplier tube being used.

II. EQUIPMENT AND EXPERIMENTAL PROCEDURE

A total of 30 Dumont 6292, RCA 6342 and RCA 5819 photomultiplier tubes were studied. All measurements were made using a thermostated system(9) in which the temperature of operation was 23.00 ± 0.25°C.

Spectral measurements were performed utilizing a single channel analyzer manufactured by Baird Atomics Corporation and a 512 channel analyzer obtained from the Nuclear Data Corporation.

Several gamma ray sources of Cs^{137} were used, with intensities ranging from 1 to 50 μc without collimation, and from 25 to 550 μc, collimated by lead rings. When strong sources were used, an auxiliary weaker source was employed for periodical measurements of the photopeak position. Samples of natural 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.(7)

III. PREDICTION OF FATIGUE EFFECTS

A. Determination of Permanent Fatigue Characteristics of Photomultiplier Tubes

The main fatigue characteristics to be measured are:

fatigue given by the pulse height variation ΔC in the following equation:(7)

$$\Delta C = C - C_o = \sum_{i=1}^{2} m_i \log (10 t + 1) \tag{2}$$

Here, C_o is the position of the photopeak at the beginning of any measurement, and C the channel attained by the photopeak at time t. The slope m_i is equal to $(b_i \Delta C_T + c_i)$. When equation (2) is plotted as in fig. 1, the successive straight lines of a fatigue curve are represented by $i = 1$ from $t = o$ to $t = t_d$ and by $i = 2$ from $t = t_d$ to $t = t_s$. For our purposes, however, the value $i = 1$ is sufficient. Furthermore, the parameters c_1 and $b_1 = c_1/a_1$ 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_i versus the total variation of the photopeak position ΔC_T, obtained experimentally from the difference $C_T - C_o$ (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 $C_T = \underline{\Delta C} + C_a$ is calculated from equation (1), and the straight line between points $\underline{0}$ and C_T then describes the expected fatigue behavior of the phototube (semi-log-plot).

Similarly, the fatigue curve can be predicted analytically with equation (2). Since $\Delta C_T = \underline{\Delta C} + C_a - C_o$, and $\underline{\Delta C}$ 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_o and I determined in the first minute of source measurement.

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 so as to avoid attributing intensities to the wrong isotopes. The correct photopeak positions are indicated by arrows.

B. Correction by simultaneous fatigue 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 spectra.

VI. CONCLUSIONS

The correction or elimination of fatigue effects present in photomultiplier tube measurement 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 paper are useful because they lead to higher precision. The development of fast methods for automatic compensation of fatigue effects would be highly desirable.

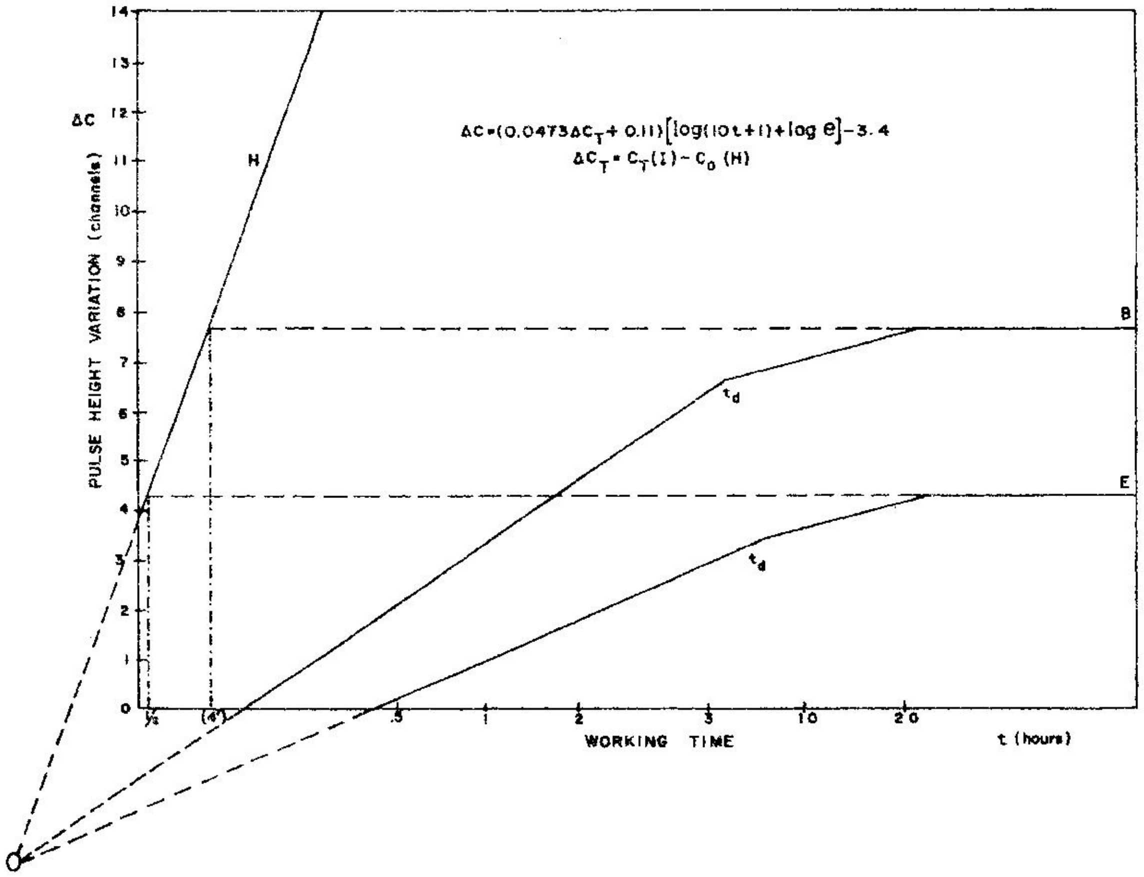

Fig. 1 Variation of a phototube gain with working time plotted versus log (10 t + 1). The stabilization limit of sources B and E (one day) can be attained with a stronger source H in 4 and 0.5 min., respectively.

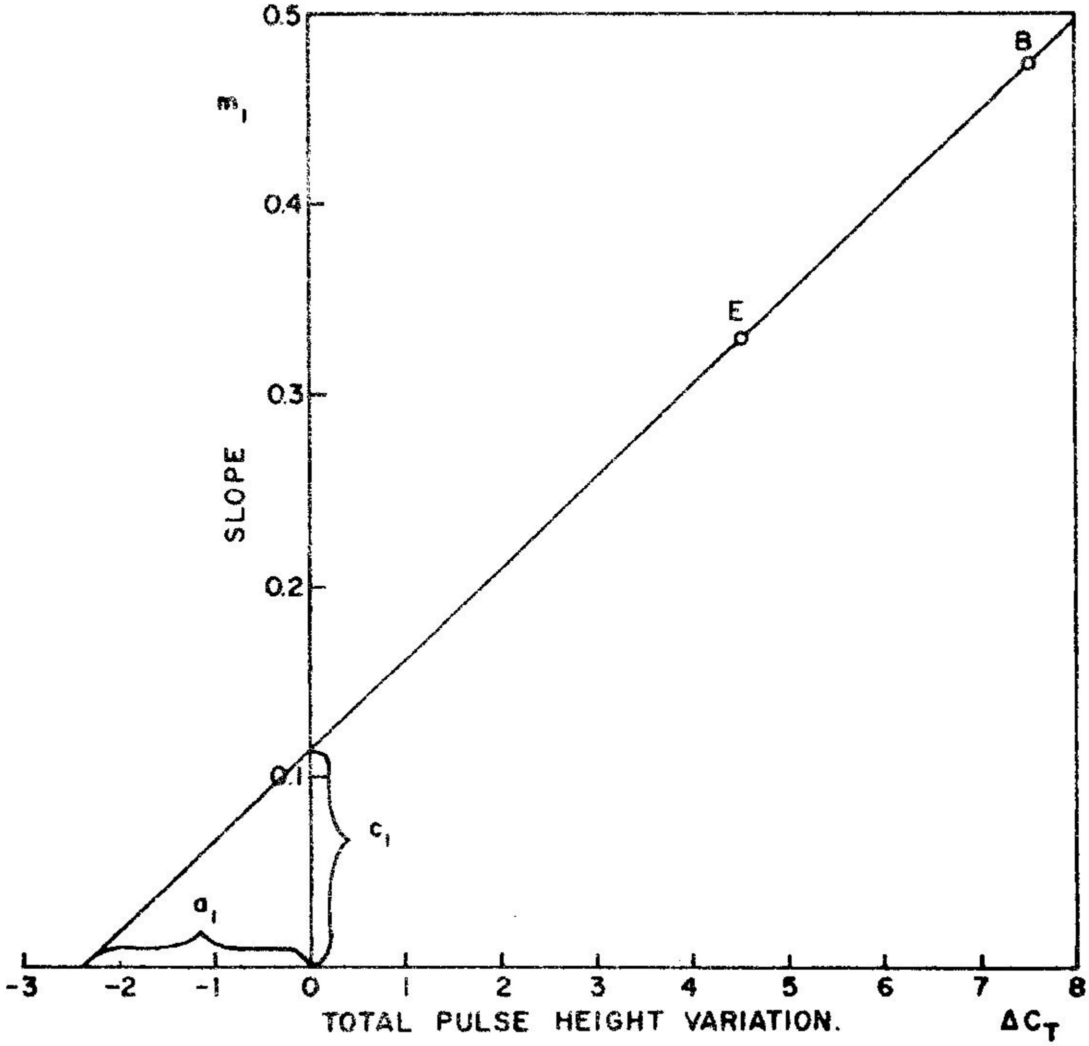

Fig. 2 Determination of parameters b_1 and c_1 of equation 2 from two fatigue measurements of a phototube.

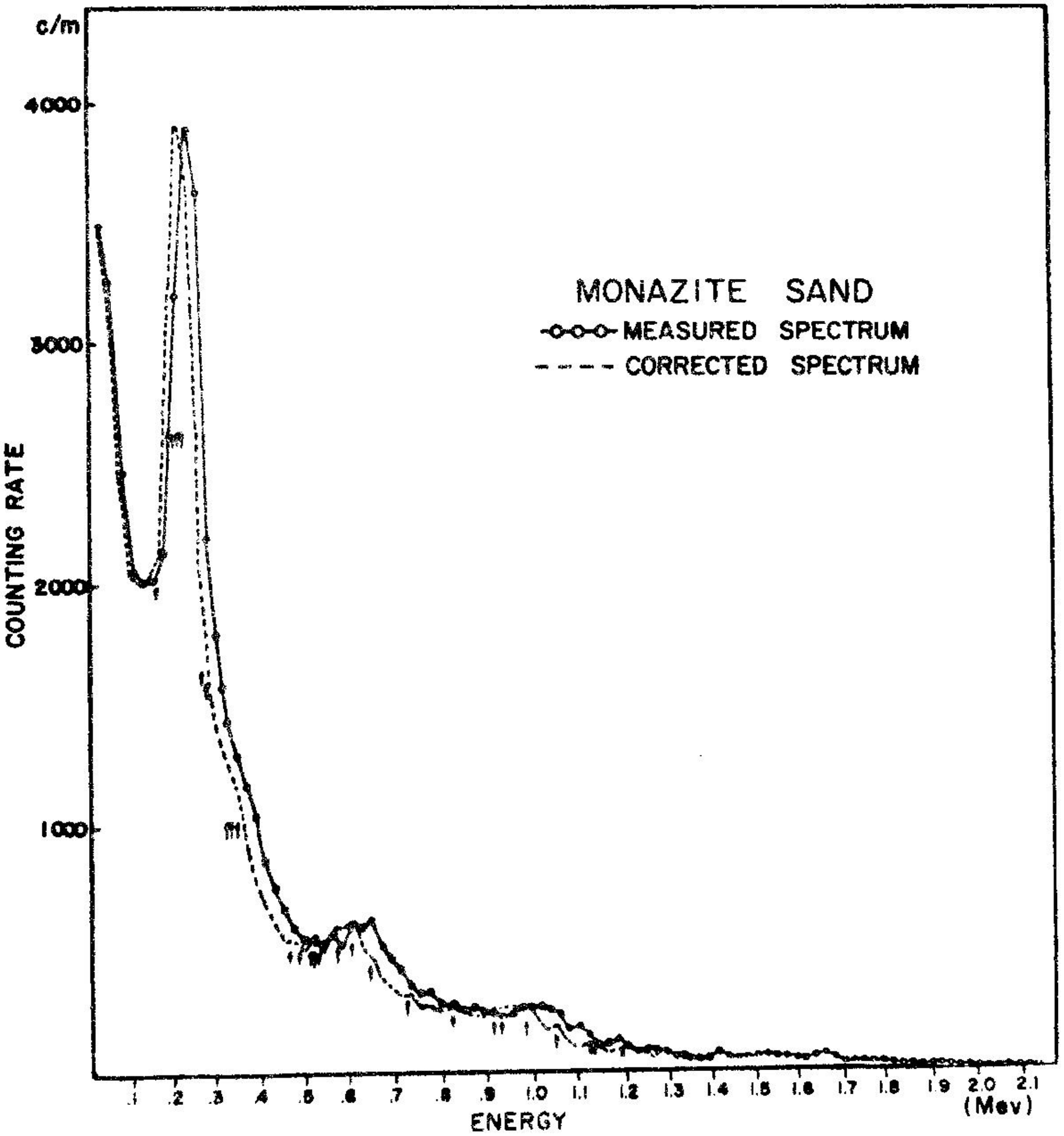

Fig. 3 Gamma ray spectrum of monazite sand. Graphical-analytical methods were used to obtain the corrected spectrum.