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CALCULATIONS IN
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FOREWORD

Minute quantities of radioactive isotopes are sometimes used to enhance the performance of electron tubes. Because of the very low level involved, it is impractical to directly measure the radioactivity. This Publication establishes a recommended practice for calculation of these levels on a per tube basis. It was developed by the JEDEC JT-16 Committee on Government Specifications and Standards and approved for Publication by the JEDEC Electron Tube Council.



INTRODUCTION

Radioactive isotopes are, on occasion, intentionally added by manufacturers of electron tubes to improve tube performance. For this reason, manufacturers may be required to determine the total radioactivity in microcuries per tube ($\mu\text{c}/\text{tube}$) to comply with existing Federal regulations.

It is usually impractical to measure the radioactivity with any degree of precision. The radionuclide is often surrounded by electrodes, spacers, and an envelope such that the geometry considerations preclude a realistic calibration of a measuring device; and the amount of radionuclide intentionally added in the tube is often so small that the amount of radiation is difficult to discern from the normal background radiation that exists in the atmosphere.

Therefore, the radioactivity for electron tubes shall be determined by a calculation technique in terms of the known radionuclides which have been intentionally added to the electron tube to either increase tube life or to improve the overall tube performance.

BASIC THEORY

The number of atoms (dN) in any one radioactive element that will disintegrate in a small interval dt is proportional to the number of atoms (N) present at the beginning of the time period dt .

$$(1) \quad -dN = \lambda N dt$$

The fundamental law of nature which describes the rate of disintegration or decay of a radioactive element is therefore as follows:

$$(2) \quad -\frac{dN}{dt} = \lambda N$$

where λ = a proportionality constant for the particular radioactive element; often called the decay or disintegration constant

N = number of radioactive atoms of the element at any time t

$-\frac{dN}{dt}$ = rate of disintegration (the rate change of N is negative because N is decreasing with time)

Rearranging equation (1) gives:

$$(3) \quad \frac{dN}{N} = -\lambda dt$$

Integrating equation (3) gives:

$$\int \frac{dN}{N} = -\int \lambda dt$$

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(4) $\ln N = -\lambda t + C$
 at $t = 0$; $N = N_0$
 therefore, equation (4) can be rewritten:
 $\ln N_0 = -\lambda(0) + C$
 or $C = \ln N_0$

Referring to equation (4) again and replacing C:

$\ln N = -\lambda t + \ln N_0$
 and $\ln N - \ln N_0 = -\lambda t$

(5) $\ln \frac{N}{N_0} = -\lambda t$ natural logarithmic form to base e

Rewriting equation (5):

$$e^{-\lambda t} = \frac{N}{N_0}$$

(6) or, $N = N_0 e^{-\lambda t}$ exponential form

(7) or, $N_t = N_0 e^{-\lambda t}$ exponential form

Definitions: where N_0 = original number of radioactive atoms of the element at time $t = 0$

$N = N_t$ = number of radioactive atoms after a given decay time t

λ = a proportionality constant (decay constant) for a given radioactive element

t = decay time

Equations (5) (6) and (7) are written in terms of the natural logarithm to the base e ($e = 2.7183$), a fundamental constant which derives from other natural phenomena as well as radioactive decay.

The time T required for 1/2 the number of atoms to disintegrate is defined as the half-life of the radioactive element or "nuclide".