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INTERPRETATION OF DOSE FROM N¹⁶ RADIATION WITH THE HANFORD FILM BADGE DOSIMETER

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INTERPRETATION OF DOSE FROM N^{16} RADIATION
WITH THE HANFORD FILM BADGE DOSIMETER*

I. C. Nelson, W. V. Baumgartner, L. G. Faust

Personnel working close to recirculating coolant circuits in Hanford's production reactors often have dosimeter film which show an unusual darkening pattern. Four filters are used in the Hanford Film Badge Dosimeter⁽¹⁾ and the darkening across the film with exposure to radiation normally increases behind the tantalum, iron, plastic, and open window filters, respectively. Films in question often have more darkening behind the tantalum filter than either the iron or plastic. The darkening in the open window may or may not be greater. This unusual condition is attributed to exposure to high energy radiation from N^{16} for which electronic equilibrium conditions are not met in the dosimeter.

The radiation is the result of a (n,p) reaction taking place on the oxygen in the recirculating primary coolant line. The resulting N^{16} nucleus decays with a 7.4 second half-life to O^{16} whose decay from excited states produces a 6.13 Mev gamma ray and to a lesser extent, a 7.13 Mev gamma ray.⁽²⁾ The film dosimetry was evaluated and a method was developed to estimate the dose to individuals exposed to both radiation from N^{16} and gamma rays of lower energy (but greater than about 100 keV). The method suffers from a lack of sufficient data upon which precise statements can be based; however, it appears adequate pending further experimentation.

Film badge dosimeters were exposed to 6 Mev gamma radiation from a positive ion accelerator producing the $F^{16}(p,\gamma)O^{16}$ reaction at 340 keV. The dose received by the dosimeter was determined by dose rate measurements with a Cutie Pie dose rate meter which was essentially at electronic equilibrium for the high energy gammas as calibrated with radium gammas. The dosimeters contained duPont 508 and 1290 film and were shielded to remove low energy components. The data obtained are presented in Table I.

*Work performed under Contract No. AT(45-1)-1350 between the Atomic Energy Commission and General Electric Company.

TABLE I

Measured Film Densities From 6-7 Mev Radiation

Net Average Values (duPont 508 Film)
Arbitrary Densitometer Units

<u>Dose</u>	<u>Ta</u>	<u>Fe</u>	<u>Pl</u>	<u>OW</u>
15 mR	483	307	299	265
45 mR	1199	823	810	795

The data are plotted and calibration curves constructed in the graph of figure 1. The calibration curve for tantalum shielded densities is a line expressible as $\log (\text{density Ta}) = 0.875 \log (\text{dose } N^{16}) + 1.629$, for doses from 10 to 100 mR.

Similarly, the calibration curve for the plastic shielded readings is expressible as $\log (\text{density plastic}) = 0.875 \log (\text{dose } N^{16}) + 1.454$. Density points of the plastic calibrations are 68% of the tantalum density points.

Regular radium gamma calibration data were used for the "lower energy gamma rays". The radium gamma calibration may be described as $\log (\text{dose Ray}) = 0.935 \log (\text{density Ta-Ray}) - 0.343$. If the net amount of darkening behind the tantalum shield due to N^{16} gamma rays is taken as x , the net amount of darkening behind the plastic shield would be $0.68x$. The net darkening behind the tantalum or plastic calibration shield due to gammas represented by the radium gamma would be tantalum shield density, D_{Ta} minus x . The total net darkening behind the plastic shield, D_{Pl} , due to both radiations would be $0.68x + D_{Ta} - x$, which leads to the expression $x = 3.12 (D_{Ta} - D_{Pl})$.

The line taken as describing the calibration for tantalum density versus N^{16} dose can be described by $\log (N^{16} \text{ dose}) = 1.14 (\log x - 1.629)$; however, in practice it is more convenient to simply draw the curve and refer to it. Having determined the dose due to N^{16} , the dose due to lower energies (greater than 100 keV) may be obtained by comparing the density $D_{Ta} - x$ to the radium

gamma calibration curve. The total dose was simply considered to be the sum of the two components.

As an example, consider a film whose net shielded density readings are tantalum 1228, iron 1012, plastic 966 and open window 1091. A comparison of the tantalum density to the radium gamma calibration would yield a dose of 350 mR. Applying the formula $x = 3.12 (D_{Ta} - D_{Pl})$ yields $3.12 (1228 - 966)$ or 816 density units attributable to N^{16} . The corresponding dose amounts to 30 mR. The remaining density due to lower energies is 412 units, is equivalent to 130 mR - Ray. The sum is 160 mR rather than 350 mR. The factor of overestimation is directly dependent on the relative amount of radiation from N^{16} present. Current radium gamma calibration data should be used in developing personnel exposures.

One precaution that must be kept in mind in applying this method is that film aging and other fogging effects may often cause greater darkening at the edges of film than toward the center and consequently, with the shield placement as in the Hanford dosimeter, the higher density reading may be due to these effects rather than to high energy gamma rays. Inspection of the film will readily determine the case at hand. Shielded areas on the film are well defined when due to high energy gamma, whereas they are undefined when darkening is due to fogging.

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