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Technical Memorandum

RESPONSE OF A THIN CRYSTAL NaI(Tl)
SCINTILLATION PROBE TO PLUTONIUM-238 X RAYS

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ABSTRACT

This memorandum reports the results of an investigation into the response of a wound monitor to X rays from ^{238}Pu . The purpose of the wound monitor is to provide information for the guidance of medical personnel during treatment of potentially contaminated wounds.

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RESPONSE OF A THIN CRYSTAL NaI(Tl)
SCINTILLATION PROBE TO PLUTONIUM-238 X RAYS

Sandia Laboratory, Albuquerque, New Mexico, uses a thin crystal NaI(Tl) scintillation probe for the detection of plutonium contamination in puncture wounds. The detecting system is maintained next to the Medical Decontamination Facility in Building 831.

The detecting unit used in the wound monitor is a Nuclear-Chicago Model DS8-21 miniature NaI(Tl) scintillation probe.* Enclosed in the probe is a 1/2-inch-diameter by 2-millimeter-thick crystal protected by a 0.005-inch beryllium window, a 10-stage photomultiplier tube with S-11 spectral response, and a transistorized preamplifier.¹ The preamplifier has been adjusted to give a positive output pulse for use with a single-channel analyzer.

The readout unit is composed of RIDL high-voltage, scaler-timer, and single-channel analyzer modules mounted in a rack. The chief mode of operation for wound monitoring is DIFFERENTIAL, wherein pulses falling within certain voltage amplitude limits are accepted as representative of a given photon energy.

A Nuclear Data 512-channel analyzer was attached in parallel to the RIDL detecting system to determine the RIDL threshold and window settings (Figure 1). The multichannel analyzer provided a rapid picture of the gamma-ray spectrum. In order to use this particular multichannel analyzer with the RIDL readout unit an "inverter" had to be designed. The inverter changed the polarity of the RIDL voltage pulses from positive to negative and also reduced their amplitude so they would not saturate the 512-channel analyzer. The RIDL amplifier output was connected to the Nuclear Data 0 to -3 volts negative input via the inverter.

It was determined that the wound monitor worked best at 1200 volts with a fine gain of 1.0 and a coarse gain of 0.5. In the DIFF mode, the 17-keV peak was located between a threshold of 75 and a window width of 180; the 99.6-keV peak had a threshold of 660 and a window width of 500.

A semilogarithmic spectrum of ^{238}Pu is shown in Figure 2. Distinctly seen are the 17-keV, 45-keV, and 99.6-keV peaks. Also, the spectrum for ^{239}Pu is shown with its 17-keV peak and the 60-keV ^{241}Am peak.

The plutonium sources used in these experiments were made by the Environmental Health Chemistry Laboratory. A $^{238}\text{PuO}_2$ particle was dissolved in aqua regia acid and then aliquots of the acidified plutonium were electrodeposited on 1/2-inch-diameter stainless steel plates. Calibration of the sources was done in a solid-state alpha detector. In all, eight sources were made ranging in size from $3.0 \times 10^{-4} \mu\text{Ci}$ to $7.4 \times 10^{-1} \mu\text{Ci}$ (0.0075 MPBB to 18.5 MPBB). The sources consisted of approximately 81-percent ^{238}Pu and 15-percent ^{239}Pu . The remainder was other

*The use of a brand name does not imply endorsement.

Figure 1. Connecting Nuclear Data Multichannel Analyzer to Wound Monitor

Figure 2. X and Gamma Ray Photon Spectra of ^{238}Pu and ^{239}Pu

isotopes of plutonium.² Table I presents some ²³⁸Pu radiological information pertinent to this investigation.^{2, 3, 4}

TABLE I
Radiological Information About ²³⁸Pu

Radiological half life	89.6 years
Specific activity	16.8 Ci/g
Maximum permissible	0.0024 µg
Body burden (MPBB)	0.04 µCi
Alpha emissions	
[Energy (MeV)/percent of emissions]	
5.495 MeV	72%
5.452 MeV	28%
5.352 MeV	0.09%
L-X rays 17 keV average	13%
Gamma rays	
[Energy (keV)/percent of emissions]	
45 keV	$3.4 \times 10^{-2}\%$
99.6 keV	$8 \times 10^{-3}\%$

Monitoring for ²³⁸Pu contamination in wounds is made very difficult by the high absorption of 17-keV X rays in plutonium and tissue.^{5, 6} In addition it is impossible to determine the shape of the wound contaminant prior to taking medical action. For these reasons the wound monitor is used chiefly for qualitative analysis. That quantitative work which may be reported is always in terms of equivalent levels for surface deposited plutonium. The actual contaminant activity may be orders of magnitudes larger than the equivalent surface activity levels. No attempt is made to estimate the magnitude of the absorption processes.

The data presented in Figure 3 was collected with the aforementioned high-voltage, threshold, window, and gain settings. The length of each sample count was determined by specifying the maximum fraction standard deviation to be less than 5 percent.⁷ A maximum fractional standard deviation of 10 percent was used for the two smallest standards.

No data could be collected with the 45-keV and 99.6-keV gamma rays because of their low frequency of emission.

A meaningful net sample count rate (R_g) is a count rate that meets one of the following criteria:

Figure 3. Response of Scintillation Probe to ^{238}Pu 17-keV X Rays

$$R_{s_1} \geq 3\sigma_B . \quad (1)$$

$$\frac{R_{s_1} + R_{s_2}}{2} \geq 2\sigma_B . \quad (2)$$

An initial count rate (R_{s_1}) of less than σ_B or an average count rate of less than $2\sigma_B$ is interpreted as indicating the absence of wound contaminants. One standard deviation of the background count rate is:

$$\sigma_B = \sqrt{\frac{R_B}{t_B}} , \quad (3)$$

where R_B is the background count rate (counts per minute), and t_B is the length of the background count (minutes). R_{s_1} and R_{s_2} are the first and second counts of the wound, respectively.

In addition to measuring the response of the wound monitor to 17-keV X rays, some absorption-transmission studies were also concluded. Materials studied were water, lucite, bologna, and moistened bologna ("tissue"). During these experiments the source to detector distance was held constant so that no corrections for geometry were required. A spherical particle attached within a thin-walled glass vial was used instead of the plated sources.

Table II presents the absorption coefficients and half-value thicknesses measured. The value for "tissue" compares favorably with results obtained by other experimentors.^{9, 10}

TABLE II

Absorption Coefficients and Half-Value Thickness
Measured for 17-keV X Rays Through Tissue-Like Materials

	$\mu(\text{cm}^{-1})$	$X_{1/2}(\text{cm})$
H ₂ O	0.96	0.72
Lucite	0.83	0.84
Bologna	1.0	0.67
Moistened bologna	1.1	0.62

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