



Intern Sized Poster for Dosimetry Research

August 2024

Changing the World's Energy Future

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<http://www.inl.gov>

**Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517**

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Abstract

Federal regulations mandate that **personal dosimetry devices** — like **optically stimulated luminescence (OSLs)** — **must be worn** by all US Department of Energy (DOE) and associated radiation workers to track their occupational dose. Unfortunately, the inadvertent passage of **OSLs through x-ray security scanners can compromise their validity**. With the advent of high energy, advanced resolution security technology used in airports, this once insignificant issue now requires that Radiological Control (RadCon) be able to accurately discern non-occupational dose to effected OSLs. This presentation will discuss the principles, methods, and, rather interesting, models for **establishing the corrective dose estimates at the Idaho National Laboratory (INL), and its implication across the DOE**.



Introduction

Santa Fe, NM: Carry-on **Santa Fe, NM: Checked** **Preliminary trials (high variance!)**

Dose range (mrem): 0, 10, 20, 30, 40, 50, 60, 70, 80

Eugene, OR: Carry-on **Eugene, OR: Checked**

Low Dose Single X-ray Projection: 1974

Explosive Detection System (EDS) Dual Energy (DE) X-ray Projection:

Attenuation is dependent on photon energy and the medium's Z_{eff} (atomic number). We can characterize materials by solving for their Z_{eff} (Unfortunately, water and explosives' Z_{eff} are very close).

$Dose_{E(keV) \in (10,200)} \propto Exposure \propto \frac{S f e^{-\mu_r r}}{4\pi r^2}$

DE CT **Carry-ons** **2024**

Computed Tomography (CT) of Checked Bags:

DE CT uses the Z_{eff} and volume-density to distinguish between liquids and explosives:

2 rotating gantries

Methods

1: 3D Printing and Theoretical Analysis

Attachment for OSL clip

Choosing the right materials

2: Assembly & Calibration

Cross-section Test Rig

Scintillator Testing at HPIL

4 Ci Gamma Well Irradiator

3: Salt Lake City (SLC) TSA Testing

1. CT Checked Bag

2. Projection Carry-on

3. CT Carry-on

• 300 OSL Tests

• Scintillator Tests

Theoretical Predictions

Resonance and Projection Imaging

1 mm² Interference Pattern Averaged Over cm² (Abs. Val.)

Cross-sectional Dose Relative to Average[†] (No Inverse Square)

0.1 mm² Interference Pattern Averaged Over cm² (Abs. Val.)

Horizontal Position (mm)

Height (mm)

Short wavelength resonance is mitigated by the size of the OSL detector (1 cm²)

Per SLC TSA: Horizontal X-ray Generator, 2 Offset and Angled X-ray Generators, Vertical X-ray Generator

CT Imaging

Time (y-axis) Dependence of X-rays Incident on Cross-section (xz-plane)^{†††}

Relative path of source depicted in blue

Range of Cross-sectional Dose^{††} With Inverse Square (10 cm Precision)

... but doesn't look like the experimental findings

Causes discontinuities in Dose vs. Position

$$\pm vt \cot(\theta_A) \leq \sqrt{(R \cos(\omega t) - x)^2 + (R \sin(\omega t) - z)^2}$$
$$x^2 + z^2 \leq r_m^2$$

Dose(x, z) $\propto \sum_{k=1}^{k/2} \int_{t_{2n-1}}^{t_{2n}} e^{-\mu \sqrt{(R \cos(\omega t) - x)^2 + (R \sin(\omega t) - z)^2 + (vt)^2}} dt$ when $\sin(\theta_A) \sqrt{-2R \cos(\omega t) - 2R \sin(\omega t) + R^2 + x^2 + z^2} - vt \cos(\theta_A) = 0$

Cross-sectional Dose Relative to Average^{††} No Inverse Square (10 cm Precision)

Cross-sectional Dose Relative to Average^{††} No Inverse Square (5 cm Precision)

^{††}Interpolated

^{†††}Estimated variable values used in model

Experimental Findings

Cross-sectional Dose^{††} (mrem)

Projection Carry-on, CT Carry-on, CT Checked, CT Checked - View 2

Suggests normal distribution

High variance

Luggage Dose^{††} (mrem)

Projection Carry-on, CT Carry-on, CT Checked, CT Checked - View 2

Dose appears to be independent of position

Attenuations, Orientations, Energy Spectra, & Exposures Tests

Reference Bag, Cross-section, Array(luggage)

normal suitcase shielding can be neglected

orientation can be neglected

High Energy Beta

52 87 keV

Exposure vs. Time

Dual Energy Peaks

Conclusion

Recommendations for Radiological Control

Projection Carry-on: **13.5 mrem[§]**

CT Carry-on: **52.2 mrem[§]**

CT Checked: **62.5 mrem[§]**

$\mu = 15.786$
 $\sigma = 1.1019$

$\mu = 106.34$
 $\sigma = 27.096$

$\mu = 105.81$
 $\sigma = 21.665$

§With 97.5% confidence that the true mean dose is greater than the recommendation

Limitations and Future Works

Additional Airports & Scanners

Proprietary and Security Concerns

Shallow Dose Variance in CT