



Intern Sized Poster for Dosimetry Research

July 2024

Changing the World's Energy Future

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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).

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

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

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SLC INTERNATIONAL

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

[†]Estimated variable values used in model, time = 0

CT Imaging

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

Relative path of source depicted in blue

Causes discontinuities in Dose vs. Position

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

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

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