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We Put Science To Work

Control Testing of the UK National Nuclear Laboratory's RadBall Technology at Savannah River National Laboratory

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April 16, 2010

HPS
Aiken SC

RadBall Technology

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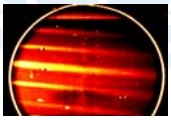

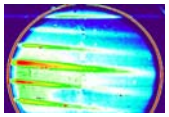

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RadBall Technology

- RadBall is a field deployable radiation mapping device which can locate and quantify radiation hazards from a single position
- This device is currently being developed by the National Nuclear Laboratory (NNL) in the UK
- RadBall consists of a colander-like outer shell that houses a radiation-sensitive polymer sphere

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RadBall Technology

- The PRESAGE™ radiation sensitive polymer material becomes opaque when exposed to radiation (size of a tennis ball)
- Degree of opaqueness depends upon the dose
- Can provide intensity and location of radiation sources

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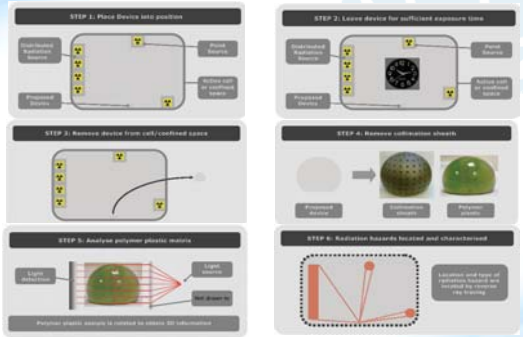
RadBall Process



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Control Testing of RadBall at SRNL

Control Testing of RadBall at SRNL

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Control Testing at the SRS HPICL

- The SRS Health Physics Instrument Calibration Laboratory (HPICL) contains 9 Automated Irradiator Systems (Hopewell Designs)
- Primary purpose of the facility is to calibrate SRS radiation detection instruments and test and verify personnel dosimeters
- The source strengths and exposure rates are known with a high degree of certainty

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Control Testing at the SRS HPICL

- Most exposures were done with the strongest ^{137}Cs and ^{60}Co sources. This decreased exposure time.

	TBq	Ci	Time*
^{137}Cs	45.9	1,240	88.4 min
^{60}Co	178	4,756	3.65 min

*The amount of time to expose RadBall to 3Gy at 1 meter.

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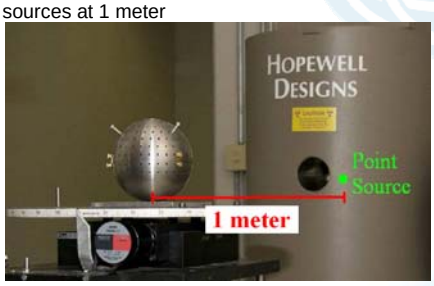
Point Sources

The ^{137}Cs and ^{60}Co sources are considered point sources at 1 meter



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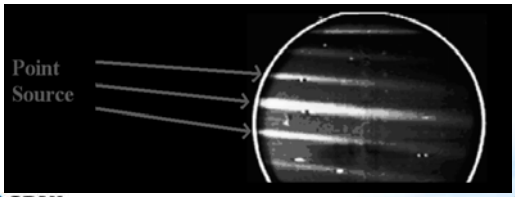
Point Source Exposures

- Cross sectional view of the center of a RadBall exposed to a point source
- Coloring is related to the opacity change
- Tracks are formed due to the small holes in the tungsten shell



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Exposure Parameters

- 45 RadBalls were exposed at the HPICL
- **Sources**
  - ^{60}Co, ^{137}Cs, and ^{241}Am
  - X-rays in the 10s to 100s keV range
- **Exposure times**
  - Exposure times varied to achieve 0.5 to 8.0 Gy
- **Tungsten collimator thickness**
  - 5.0 mm, 7.5 mm, and 10.0 mm
- **Collimator hole sizes**
  - 2.25 mm, 3.0 mm, and 4.0 mm

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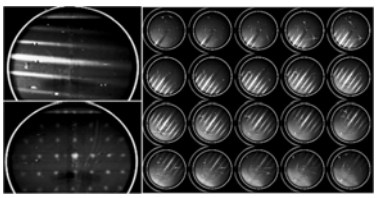
Scanning and Analysis

- Polymer balls were sent to Duke for scanning
- Result is a 3D voxel matrix of attenuation coefficients
- Can be viewed as slices, shown below



RadBall N-2-4, 5.0 Gy of ^{137}Cs with 5 mm tungsten collimator

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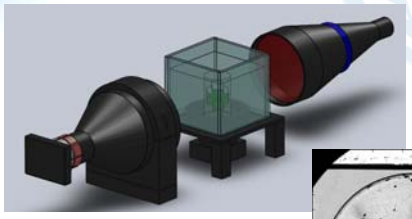
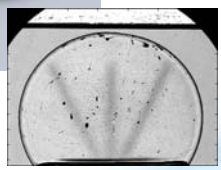
Optical Scanner – Mark Oldham (Duke University)



3D voxel representation is obtained with optical computer-tomography scanner



Scanning Video

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Optimal Absorbed Dose Determinations

- PRESAGE™ polymer is like camera film. It can be over exposed or under exposed
- Determining the optimal absorbed dose range was one of the goals of the SRS testing
- Doses varied from 0.5 to 8.0 Gy
- Doses between 2.0 and 3.0 Gy were determined to be optimal (best contrast)
- Tracks were visible in all ranges after enhancement

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Visual comparison of exposures

N-3-6 **8.0Gy**

N-5-3 **3.0Gy**

N-2-1 **0.5Gy**

Tracks are most easily seen in N-5-3 (3.0 Gy)

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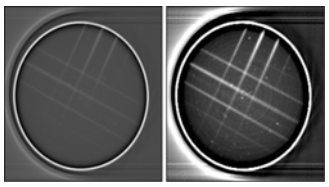
Other Sources

- Most exposures were performed with ^{60}Co and ^{137}Cs
- ^{241}Am and X-Ray sources were used for limited number



RadBall N-4-5

Irradiated with two sources

1.5 Gy 120 keV x-ray and 1.5 Gy 38 keV at 90°

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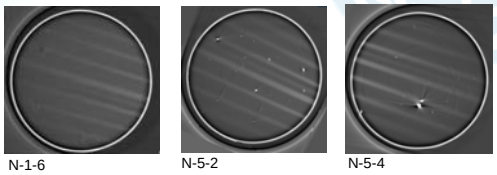
Varying collimator thickness and hole diameter



N-1-6
Source: ^{137}Cs 3.0 Gy
Collimator: 5 mm
Hole Dia: 2.25 mm

N-5-2
Source: ^{137}Cs 3.0 Gy
Collimator: 7.5 mm
Hole Dia: 3.0 mm

N-5-4
Source: ^{137}Cs 3.0 Gy
Collimator: 10 mm
Hole Dia: 4.0 mm

All Collimators had a single 4.0 mm hole facing the source

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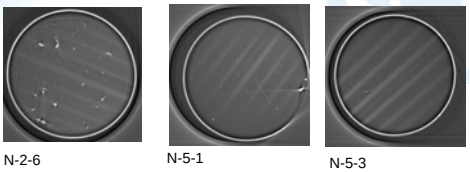
Varying collimator thickness and hole diameter



N-2-6
Source: ^{60}Co 3.0 Gy
Collimator: 5 mm
Hole Dia: 2.25 mm

N-5-1
Source: ^{60}Co 3.0 Gy
Collimator: 7.5 mm
Hole Dia: 3.0 mm

N-5-3
Source: ^{60}Co 3.0 Gy
Collimator: 10 mm
Hole Dia: 4.0 mm

All Collimators had a single 4.0 mm hole facing the source

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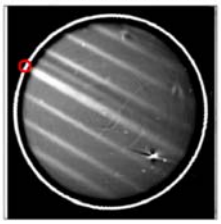
Collimator Hole size

Post Contrast Enhanced Image



Three Tungsten collimators were used. Each collimator had one large 4 mm hole. The other holes were smaller and uniform in size. In most of the experiments the large hole was pointing toward the source. This explains the large center track in many of the cross sections.

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Field Testing in SRNL Shielded Cells

SRNL shielded cells facility

RadBall deployed in hot cell.

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Computer model of shielded cell 9

RadBall N-7-5 was deployed in the hot cell at a raised height of 107 cm above the floor and left for a 72 hour time period with a 10 mm collimator.

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RadBall Position and Orientation Determination System

- Uses sonar to compute distances to each wall (9 m)
- Electronic compass
- Flash memory data storage

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Optimizing RadBall

The PRESAGE polymer responds to photons. Knowing how photons interact with the Tungsten collimator can lead to enhancing the RadBall design.

Therefore, some hand calculations and computer modeling was done.

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Hand Calculations

The density of the Tungsten is $\rho = 19.25\ g/cm^3$

Mean Free Path is μ^{-1}

Energy (MeV)	μ/ρ (cm^2/g) *	μ^{-1}(mm)
1.5	0.05000	10.4
1.0	0.06618	7.85
0.5	0.1378	3.77
0.1	4.438	0.12

The 10 mm thick collimator will be somewhat effective for photons in the 1 MeV range. It will be very effective for photons below 500 keV.

*** Values obtained from http://physics.nist.gov/**

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MCNP Background

Monte Carlo Neutral Particle

Developed and maintained by Los Alamos National Laboratory.

Developed for analyzing the transport of neutrons and gamma rays.

Utilizes Monte Carlo method (Not deterministic)

Can Model transport of neutrons, gamma rays, and coupled transport, i.e., transport of secondary gamma rays resulting from neutron interactions.

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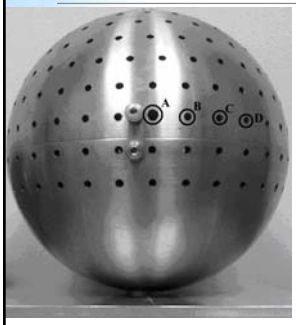
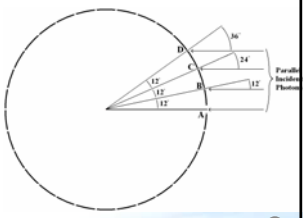
What was modeled



Four of the collimator holes were included in the MCNP model. Hole A was aimed directly toward the isotropic point source.



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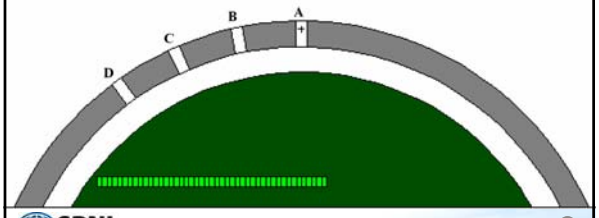
MCNP

40 cells were placed behind the collimator in a row for MCNP tallies. Tallies are one way to analyze the output of a MCNP Simulation.



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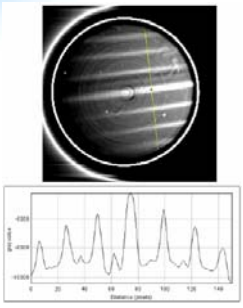
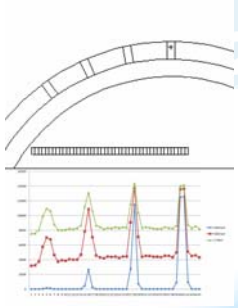
Comparison of Model and Actual Test



N-4-1 ^{137}Cs and ^{60}Co collinear



Blue 200 keV, Red 500 keV, Green 1 MeV

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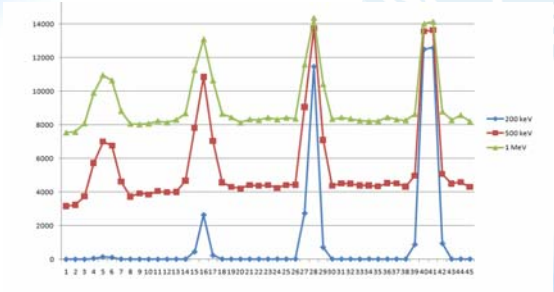
5 mm Tungsten Collimator in MCNP Output



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Questions

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