Monte Carlo Simulation of Radiation Leakage and Design Optimisation for Doorsets of X-Ray Facilities

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A- Summary

With the aim of doreset shielding optimisation, the results of this study show that:

- Radiation leakage may dominate the dose rate behind the door even when the core lead thickness has been correctly specified.
- A door mat solution against radiation leakage from the gap between the door and the floor could be effective but may not be desirable from other practical viewpoints.
- When performing radiation surveys, due consideration should be given to the possible heterogeneous distribution of the radiation field.

B- Design guidelines

WHO 1974  
NCRP 147, 2004

C- Material & Methods

(i) Manufacturing considerations*

- Door weight
- Mechanical integrity
- Standards (e.g. Fire resistance)
- Finishing preferences
- Cost:
  - Materials
  - Fabrication
  - Installation
- Durability and maintenance considerations

* The information provided by WARDRAY PREMISE LIMITED in respect of the manufacturing considerations is gratefully acknowledged.

(ii) Monte Carlo simulations

- 90kVp X-rays, incident on a water phantom (30x30x30cm³) placed at the centre of the examination room
- MCNPX version 2.5.0
  - Photon Flux Mesh Tally
  - Particle Flux Tally – dose function modified
  - Cut-off energy 10keV
  - Relative errors < 5% (1.s.d.)

(iii) Doorset design

- Hardwood
- Lead 2.24 mm (Code 5)
- Fixture and fittings
- Expanding smoke seals
- Lead lined Gypsum wall

D- Results 1- Leakage through the door & floor gap

The lead mat solution:

Leading to reduced dose rate by ≥ 350%

E- Results 2- Optimisation of shielding design

(i) floor level detail (without lead mat)

Un-optimised shielding design  
Optimised shielding design: additional lead incorporated in the door and frame

Leading to improvement in dose rate of ≥ 30%

(ii) Head level detail

Un-optimised shielding design  
Optimised shielding design: additional lead incorporated in the door and frame

Leading to improvement in dose rate of ≥ 45%

(iii) Centre level detail

Un-optimised shielding design  
Optimised shielding design: additional lead incorporated in the door and frame

Leading to improvement in dose rate of ≥ 45%

(iv) Leakage dose rates behind the shielded door*

<table>
<thead>
<tr>
<th>Height of simulation point from the floor</th>
<th>50 cm</th>
<th>100 cm</th>
<th>170 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Un-optimised design: without door mat</td>
<td>16</td>
<td>9.2</td>
<td>8.3</td>
</tr>
<tr>
<td>Optimised design: without door mat</td>
<td>11</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Optimised design: with door mat</td>
<td>3.2</td>
<td>3.1</td>
<td>2.6</td>
</tr>
</tbody>
</table>

* Expressed as the ratio of dose rate behind the shielded door to the dose rate behind the leakage-free barrier 2.24 mm thickness of lead; door to floor gap set at 8 mm.