Calculation of Shielding for Interventional Rooms with Added Copper Filtration.

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1 Introduction

The specification of shielding for fluoroscopic facilities in the UK is based on the determination of scatter incident on a barrier using a simple formula linking kerma area product and scatter kerma. Additional filtration of up to 0.6mm copper is often used in interventional procedures. The existing formula does not take this into account. The spectral and transmission characteristics of the scattered radiation resulting from a primary x-ray beam filtered with additional copper are not known.

2 Aims:

1. to identify how the scatter kerma from beams filtered with zero to 0.99 mm of copper varies with angle at 85kV.
2. to determine the broad beam transmission characteristics of the radiation scattered from the filtered beams and compare it with conventional primary transmission.
3. to identify the implications of the above for realistic shielding calculations

3 Methods

An anthropomorphic Rando phantom was positioned so that the tube focus was 80 cm from the surface of the phantom, in the same geometry as used in the study by Williams (BJR 1996). The x-ray beam was centred at the level of L3 and the field size set to 17.5 cm wide by 22 cm high at the surface . A selection of copper plates between 0.125 and 0.990 mm were used to filter the x-ray beam. To measure the scattered air kerma, an 1800 cc ionisation chamber was placed at a distance of 1m from the centre of the phantom. Exposures were made at angles 30° to 150°. The scatter kerma to KAP ratio (called SF and measured in μGy/Gycm²) was determined. All measurements were made at 85kV.

The experiment was also was simulated using the general purpose MCNP5 code. An x-ray beam incident on an elliptical cylindrical water phantom was modelled . The geometry for experiment and simulation is shown in figure 1.

The scattered spectra obtained from the simulation were used as the input spectra in a broad beam Monte Carlo transmission simulation at 85kV through 0.1 to 2.5 mm lead.

4 Results

Figure 2 shows examples of the variation of the modelled and measured SF with angle. The SF follows an 'S' shaped curve, increasing with angle. Scatter curves for all filters have a similar shape. The calculated and measured values follow the same general shape in terms of variation with angle, but the measured values are greater by an amount which is largely independent of angle and is due to leakage and collimator scatter.

Figure 3 is typical of the x-ray spectra obtained from the simulations and shows the scattered spectra at 30° to 150° for an added filtration of 0.125 mm copper. The figure shows that the spectra become progressively softer as the angle of scatter is increased and also the increase of overall scatter fluence with scattering angle. The vertical axis values are scaled to scattered fluence (mm^{-2}) per Gy cm^2 in the primary beam .

Figure 4 shows that the HVL of the scattered radiation decreases with scattering angle. It also shows that the HVL of the scattered radiation increases with the amount of added filtration and is always less than the HVL of the primary unfiltered exit beam.

Figure 5 shows that there is less transmission of 150° scattered radiation than 30° scatter at 85 kV. At any angle the amount of scatter depends on degree of added filtration. Primary beam transmission falls between that observed for 30° and 150° scatter irrespective of the amount of added filtration above a barrier thickness of approximately 0.5 mm lead .

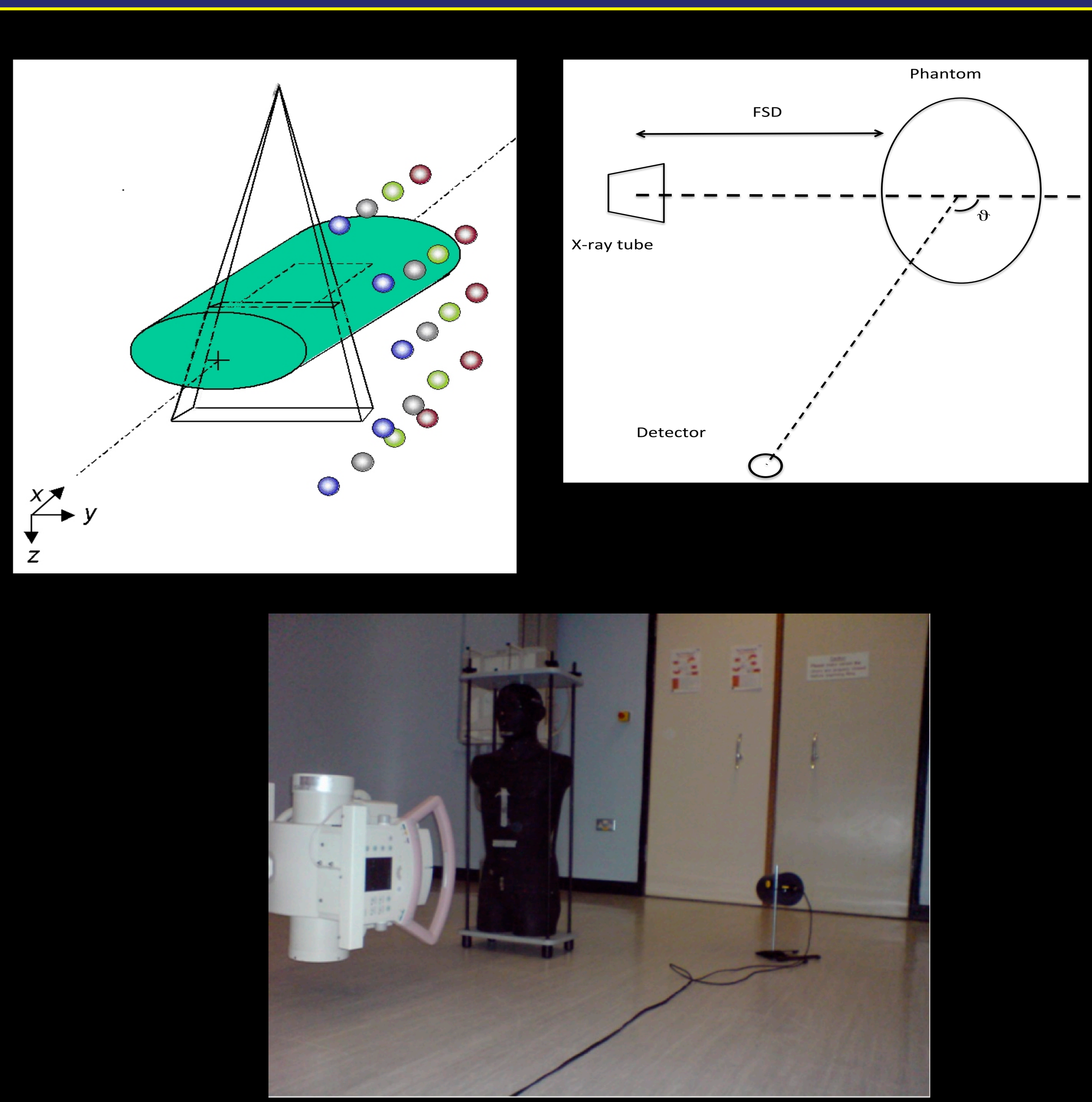

Figure 1 Geometry used experiment and simulation.

5 Implication for shielding

Above 0.5 mm thickness of lead, the Archer equation can be used to model the transmission of scattered radiation from filtered beams using existing coefficients.

Williams' equation gives an SF of 5.1 μGy(Gycm^2)$^{-1}$ at 85kV. We have shown that the use of 0.6mm additional Cu filtration results in an increase in the scatter fluence of up to 60%.

Analysis of the Archer transmission equation shows that dx/dS=1/αS, where x is the thickness of shielding material required, S is the scatter kerma for a given workload and α is a dimensionless quantity used in the Archer equation.

At 85 kV, α is 3.504 mm^{-1} for lead so $\Delta x \approx 0.285 * \Delta S/S$ mm lead. Thus, a 60% increase in total scatter kerma will result in an increase in shielding specification of 0.17 mm lead. This will not have any impact on shielding design.

6 Conclusion

It is both practical and conservative to use an SF of 8 μGy(Gycm^2)$^{-1}$ for shielding calculations in situations where up to 0.6mm additional copper filtrations is used. Existing coefficients can be used to determine the thickness of barrier required.

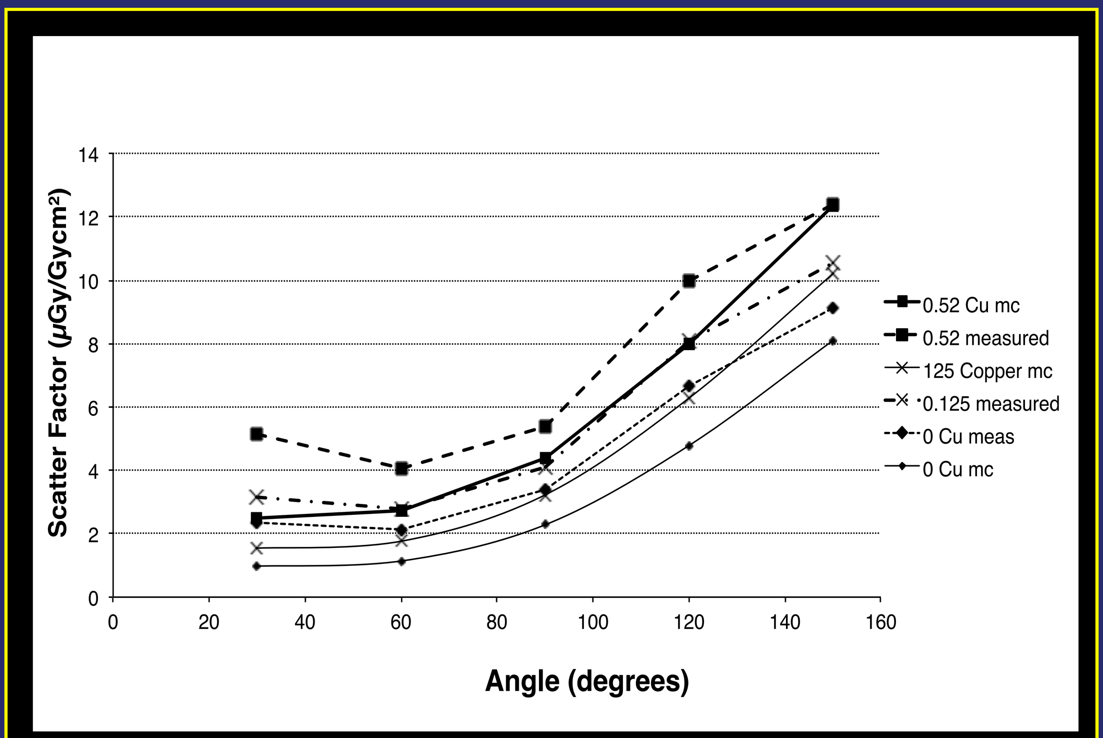

Figure 2 Measured and modelled SF.

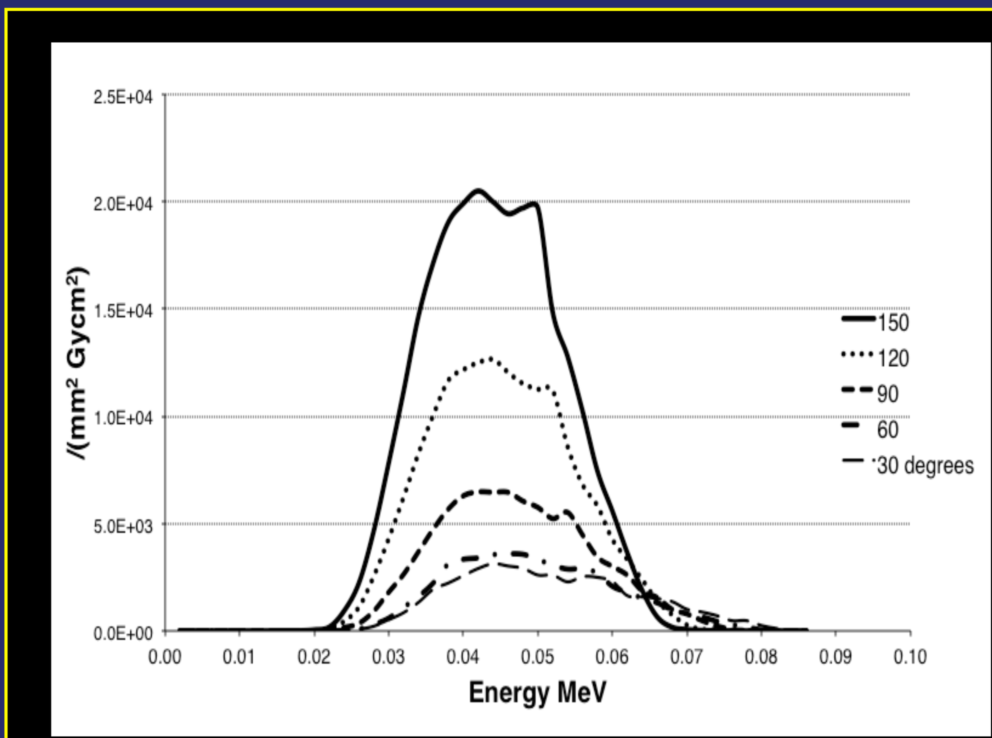

Figure 3 Scattered Spectra - 0.125 mm Copper

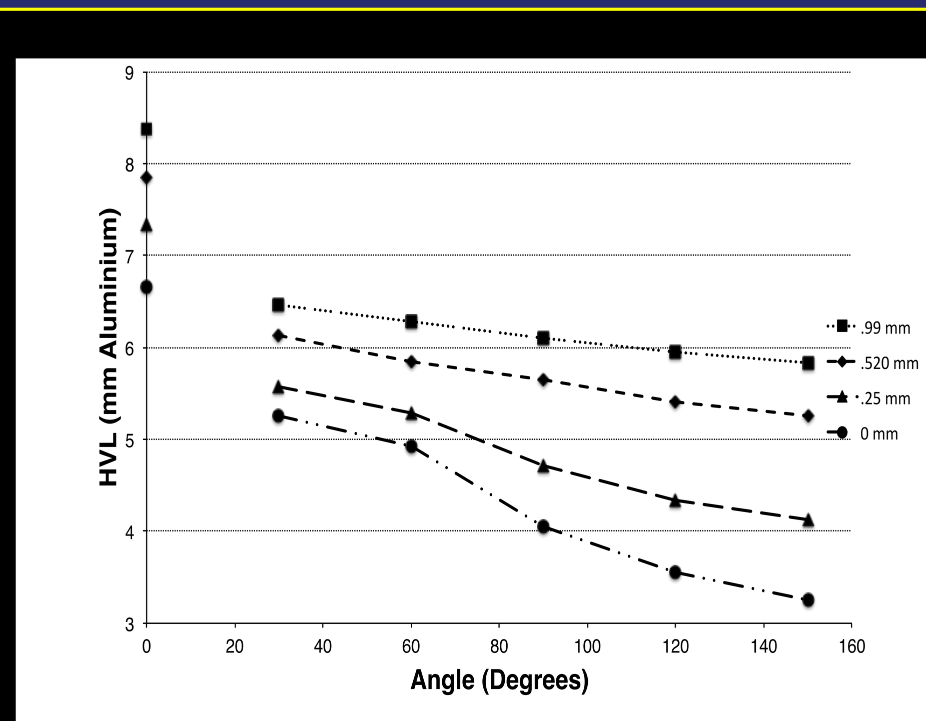

Figure 4 HVL of Scattered and Primary Radiation.

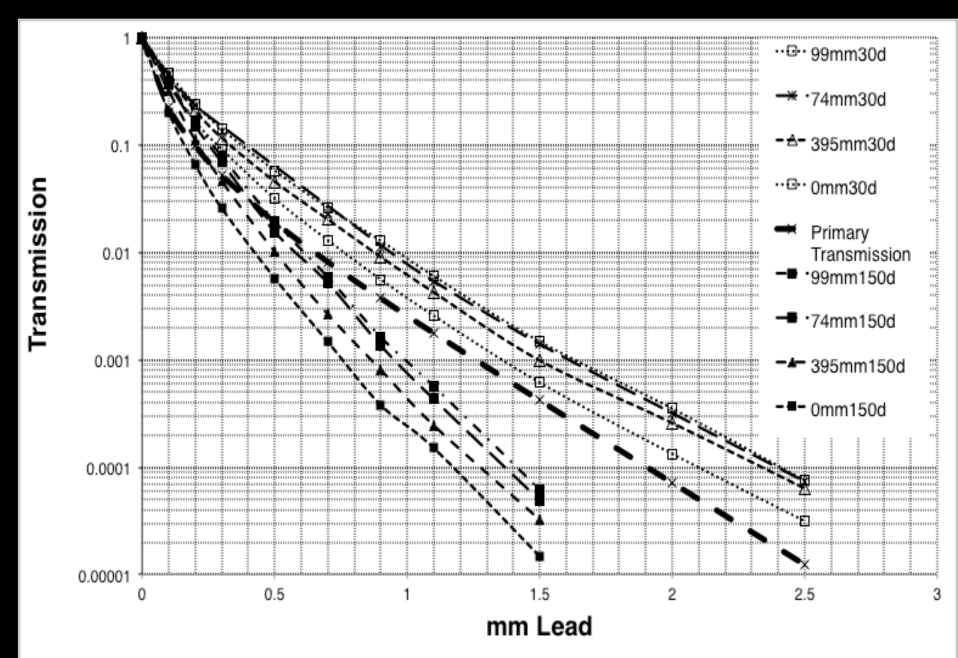

Figure 5 Transmission through lead.

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