Legal Stuff

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Personal Dose Equivalent Conversion Coefficients for Photons, Electrons, and Positrons

K.G. Veinot

Y-12 National Security Complex
System of Radiation Protection

Physical Quantities
- Fluence, Kerma, Absorbed Dose

Operational Quantities
- Ambient Dose Equivalent
- Personal Dose Equivalent

Protection Quantities
- Effective Dose Equivalent
- Equivalent Dose
- Effective Dose

Calculated using $Q(L)-L$ and simple phantom. Validated by measurements and calculation.

Calculated using $w_R$, $w_T$ and anthropomorphic phantoms.

Compared by measurement and calculations.

Instrument Response

Conservative Approximation
Personal Dose Equivalent

- Monitoring for individuals
- Defined in the body – multi-valued quantity
- Usually the trunk = 30 cm X 30 cm X 15 cm
- ICRU Slab

ICRU Slab

Unidirectional field

Dosimeter
Use of $H_p(d)$

- Dosimeter calibrations
- Compliance with protection quantities (e.g. skin dose, lens of eye dose, effective (“whole body” dose))
- $H_p(0.07)$ used for skin
- $H_p(3)$ used for lens of eye
- $H_p(10)$ used for effective dose
Calculations

- MCNPX 2.6.0
- ICRU slab phantom (30 cm X 30 cm X 15 cm)
- Parallel broad beam
- Air and vacuum for photons
- Kerma and absorbed dose for photons
- Air kerma for photons
- Vacuum for electrons, positrons
- Fits for photons and electrons
- Tally errors <3%
Protection Quantities

- ICRP-103
- Male and female phantoms
- AP geometry
- ICRP developing advanced LOE model
- Skin voxels large
- DOCAL working group
ICRP-103 Protection Quantity Calculations

- Radionuclide Intake & External Exposure
  - Male phantom
    - Absorbed doses, $D^M_T$
  - Female phantom
    - Absorbed doses, $D^F_T$
  - Equivalent doses, $H^M_T$
  - Equivalent doses, $H^F_T$
  - Sex-averaged equivalent doses, $H_T$
  - Effective dose, $E$
  - Reference Person
  - Reference Female

$w_R$ and $w_T$ represent weighting factors.
Fits to DCFs

- Marquardt-Levenberg algorithm

\[ f(x) = \frac{a}{1 + (b + cx)^2} + \frac{d}{1 + (f + gx)^2} + \frac{h}{1 + (j + kx)^2} + \frac{l}{1 + \exp(m + nx)} + \frac{o}{1 + \exp(p + qx)} \]

- \( f(x) = \) logarithmic (base 10) value of the conversion coefficient and \( x \) equals \( \log_{10}(E) \) with \( E \) having energy units of MeV
Photon $H_p(0.07)$
Photon $H_p(3)$

Conversion Coefficient (pSv cm$^2$)

Photon Energy (MeV)

- □ Hp(3) (Vacuum)
- Vacuum Fit
- ● Hp(3) Kim and Kim 1999
- ✗ Eye Lens ICRP-103/ICRP-110 Avg. (AP)
Photon $H_p(10)$

![Graph showing Photon $H_p(10)$](image-url)

- Hp(10) (Vacuum)
- Vacuum Fit
- Effective Dose (AP)
- H*(10) Pelliccioni 2000
- Hp(10) Kim and Kim 1999

Conversion Coefficient (pSv cm$^{-2}$) vs. Photon Energy (MeV)
Photon Air Kerma, $K_a$
## Photon DCF Fit Values

- Reported in RPD

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<th>Vacuum</th>
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Electron $H_p(0.07)$

[Graph showing the distribution of $H_p(0.07)$ with energy (MeV) on the x-axis and $H_p(0.07)$ (pSv cm$^{-2}$) on the y-axis.]

- Hp(0.07) (Electron)
- Ferrari and Pelliccioni (1994) $H^*(0.07)$
- Chartier et.al. (1996)
- ICRP-103/ICRP-110 Skin (Avg.)
- Fit
Electron $H_p(3)$

Energy (MeV)

$H_p(3)$ (Electron)
Ferrari and Pelliccioni (1994) $H^*(3)$
Chartier et.al. (1996)
ICRP-103/ICRP-110 Eye
Behrens (2009)
Fit
Electron $H_p(10)$

Chartier et al. (1996)

ICRP-103/ICRP-110 E

Fit

Energy (MeV)

$H_p(10)$ (Electron)

Ferrari and Pelliccioni (1994) $H^*(10)$

Chartier et al. (1996)

ICRP-103/ICRP-110 E

Fit
## Electron DCF Fit Values

- Submitting to RPD

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</table>

Min E (MeV): 0.06, 0.7, 2  
Max E (MeV): 1000, 1000, 1000
Positron DCFs

- Some differences in stopping powers of electrons and positrons
- MCNPX does not currently account for these
- Positron DCFs are approximations only
Positron $H_p(0.07)$

Energy (MeV)

Log scale for $H_p(0.07)$ (pSv cm$^2$)

ICRP-103 Skin
Positron $H_p(3)$

![Graph showing the relationship between Energy (MeV) and $H_p(3)$ (pSv cm$^2$) for different energy levels.]
Positron $H_p(10)$

![Graph showing positron $H_p(10)$ as a function of energy (MeV) with data points from various sources including Pelliccioni 2000 (FLUKA) and ICRP 103 E.]
Special Considerations for $H_p(3)$

- Improved eye model
- New cataract risk factors
- In operational settings – eyewear (glasses, safety glasses, contact lenses)
- 0.2 cm polycarbonate lenses
Effect of Glasses on $H_p(3)$
Conclusions

- DCFs calculated
- \( H_p(d) = H^*(d) \) Phantom unimportant?
- Photons – track secondary electrons
- Photons – \( H_p(d) \) conservative until CPE lost
- Electrons - \( H_p(d) \) conservative for most energies
- Positrons – Generally conservative
- Fits to DCFs allow easy conversion for spectra or other energies