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VARSKIN

A software package to estimate ionizing radiation dose to layers of the skin resulting from hot-particle exposure.



10 CFR 20.1201 Occupational dose limits for adults.

(a) The licensee shall control the occupational dose to individual adults ...


(2) The annual limits ... are:

- (i) A lens dose equivalent of 15 rem (0.15 Sv), and
- (ii) A shallow-dose equivalent [to skin] of 50 rem (0.5 Sv) ...

(c) ... The assigned shallow-dose equivalent must be the dose averaged over the contiguous 10 square centimeters of skin receiving the highest exposure. The deep-dose equivalent, lens-dose equivalent, and shallow-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance ...


[56 FR 23396, May 21, 1991, as amended at 60 FR 20185, Apr. 25, 1995; 63 FR 39482, July 23, 1998; 67 FR 16304, Apr. 5, 2002; 72 FR 68059, Dec. 4, 2007]

The Driving Regulation




- VARSKIN was originally developed nearly 30 years ago (1987) to allow the NRC to confirm skin-dosimetry submitted by licensees
 - intended as a tool for calculating tissue dose at depth resulting from radiological contamination of skin
- The highest localized skin dose will be realized when a “hot particle” exposes the various layers of skin tissue
- Five different source configurations are available
- Electron and photon dose calculations for 838 nuclides

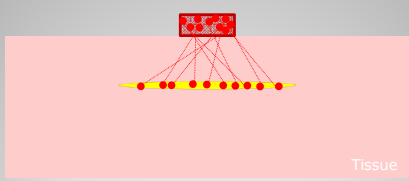
VARSKIN




- VARSKIN (Traub et al., 1987)
- VARSKIN Mod 2 (Durham, 1992)
 - → SADDE calculations added (Reece et al., 1989)
- VARSKIN 3 (Durham, 2006)
 - → volumetric-source backscatter factors
 - → basic photon model added
- VARSKIN 3.1 (Durham, 2009)
 - → correction of error in photon energy database
- VARSKIN 4 (Hamby et al., 2011)
 - → rigorous treatment of photon dosimetry
 - → no need for code “installation”
- VARSKIN 5 (Hamby et al., 2013)
 - → overhaul of energy-loss assumptions for electron dosimetry

VARSKIN history






“Point kernel” concept



- Photon dosimetry considers:
 - point-kernel methodology
 - with secondary charge buildup, attenuation, and off-axis scatter
 - convergence-maximized numerical integration
 - multiple source geometries
 - point, disk, cylinder, sphere, slab
 - skin dose calculated to an infinitely thin disk at a user-specified depth
 - averaging areas between 0.01 and 100 cm²
 - variable dose averaging techniques
 - 2D averaging areas (regulatory compliance)
 - 3D averaging volumes (detector simulation)

VARSKIN photon model




The VARSKIN point-kernel photon dosimetry model:

$$\dot{D}(d, \theta) = E_0 \cdot \frac{S}{4\pi d^2} e^{-\mu d} \cdot \frac{\mu_{tr}}{\rho} \cdot f_{cpe}(d, E) F_{oa}(\theta, E)$$

Labels in the diagram:


- Source Strength (S)
- Material Attenuation ($e^{-\mu d}$)
- Buildup Correction ($f_{cpe}(d, E)$)
- Photon Energy (E_0)
- Geometric Attenuation ($\frac{S}{4\pi d^2}$)
- Probability of Energy Transfer ($\frac{\mu_{tr}}{\rho}$)
- Off-axis Correction ($F_{oa}(\theta, E)$)

Elements of the photon model



- Electron dosimetry constructs energy absorption distributions from the original beta emission spectrum
 - including conversion electrons and Auger electrons at their proper energy
 - but, not use the "dummy" tritium distribution
 - resulting in a more appropriate electron energy spectrum incident on the skin
- Kinetic energy loss is better estimated through new:
 - energy scaling
 - range/depth scaling
- A new backscatter correction model is applied

VARSKIN electron model




The VARSKIN point-kernel electron dosimetry model:

$$\dot{D}_\beta \left[\frac{\text{Gy}}{\text{sec}} \right] = \frac{A \left[\frac{\text{dis}}{\text{sec}} \right] \cdot Y \bar{E} \left[\frac{\text{J}}{\text{dis}} \right] \cdot F_\beta}{4\pi \cdot \rho \left[\frac{\text{kg}}{\text{cm}^3} \right] \cdot r^2 \left[\text{cm}^2 \right] \cdot X_{90} \left[\text{cm} \right] \cdot \text{BSCF}}$$

Labels in diagram:
 Source Strength (A), Electron Energy Distribution (Y·Ē), Normalized Depth-Dose Distribution (F_β), Tissue Density (ρ), Dose Depth (r²), 90% of Electron Range (X₉₀), Backscatter Correction (BSCF).


Elements of electron model



- Hot particle on skin:
 - Slab geometry assumed
 - 999 x 150 x 14 μm thick
 - density of 7.2 g/cm³
 - 156 kBq of ⁶⁰Co
- Dose rate over 1 cm² @ 7 mg/cm²

	Electrons	Photons	Total (rad/hr)
VARSKIN Mod 2	9.77	-	9.77
VARSKIN 3	8.65	1.53	10.2
VARSKIN 3.1	8.65	0.840	9.49
VARSKIN 4	8.65	0.364	9.01
VARSKIN 5	10.5	0.364	10.9


Results by version

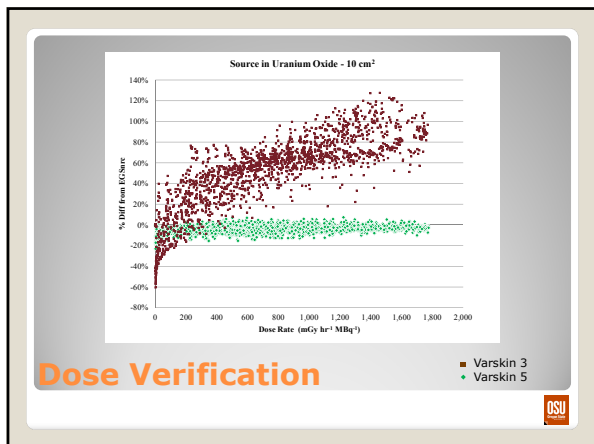


Source in Tungsten Alloy - 10 cm²

Legend: ■ Varskin 3, ● Varskin 5

Dose Verification





- Available once Users group initiated
 - Incorporated into RAMP
 - Software distribution issues
 - Working out how the users group will look
 - software support, maintenance, etc
 - initiation of the VARSKIN User's Group
 - Once User's Group is established, VARSKIN will be part of RAMP
- Next steps**
- OSU

- A User's Group is being initiated, and ... with continued funding:
 - FAQs
 - Issue tracking
 - News/documentation
 - User wiki
 - Topical forums
 - Webinars
- Software support**
- OSU

