Assessment of Skin Dose from Contamination at OPG – Past, Present, and Future

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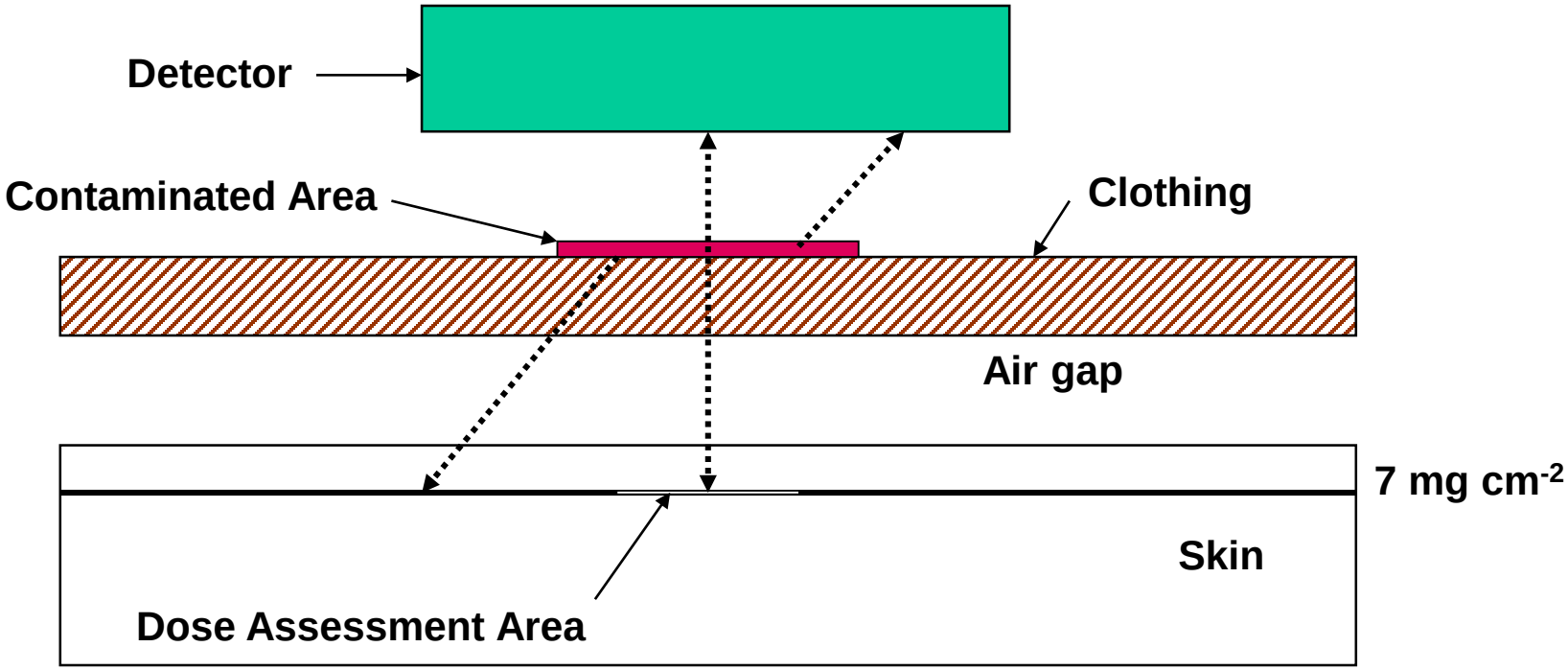
Outline

- Basics of Skin Dose Calculations
- Skin Dose Assessments: Pre 1987
- Hot Particles and Fuel Fleas: 1984 – 1987
- OH Skin Dose Assessments: 1987 – 1997
- ICRP Recommendations, CNSC Limits, NCRP 130
- Development of Current Program: 1997 – 2015
- VARSKIN 2 and DOSESKIN: 1987 – 2018
- Skin Dose Assessment Procedure, Special Cases
- The Future: 2016 - ????

Skin Dose Calculations

Problem Description



OH Skin Dose Assessments: Pre-1987

- **ICRP 26 (1977)**
  - **Irradiation from skin contamination not uniform, does not last long or recur in same place**
  - **For routine purposes, regard contamination as averaged over 100 cm^2**
  - **1000 cpm = 1 mrem/h**
  - **For accidents, get more details, average over 1 cm^2; compare to dose equivalent limit**
  - **For small particles, assess local dose distribution to predict local skin reactions, don't compare to dose equivalent limit**
  - **C-14 particulate**

Hot Particles and Fuel Fleas: 1984 - 1987

- San Onofre Unit 3 Fuel Failures – 1984
- High dissolved noble gas and radioiodine levels
- Fuel “sipping” and reconstitution
- “Hot particle” (“fuel flea”) on collar of inner clothing
- Fuel, not typical activated corrosion and fission products
- US NRC 86 – 23 – Calculate dose to 1 cm^2
- VARSKIN 1 (Traub et al, 1987)
- NCRP 106, Limit for Exposure to Hot Particles on Skin (1989)

OH Skin Dose Assessments: 1987 - 1997

- **Bases for skin dose assessment:**
  - **ICRP 26**
  - **NCRP 106**
  - **Canadian Atomic Energy Control Board Regulations**
  - **Ontario Hydro Radiation Protection Regulations**
  - **Draft "Standard for the Estimation and Recording of Skin Exposure or Dose due to Radioactive Contamination of Skin or Clothing", March 1991, R3, CR Hirning**

OH Skin Dose Assessments: 1987 - 1997

- **Practice:**
  - **NCRP Exposure Limit of 75 µCi - h (10 GBq - s) for point sources on skin**
  - **For point source on clothing or distributed (> 1 cm^2) contamination, determine dose to 1 cm^2**
  - **Quarterly dose limit of 30 rem (300 mSv)**
  - **Contamination level measured by pancake**
  - **Table of protective clothing density and density thickness**
  - **VARSKIN Mod 2 instead of VARSKIN 1 used to calculate doses**

OH Skin Dose Assessments: 1987 - 1997

Point Source Calibration

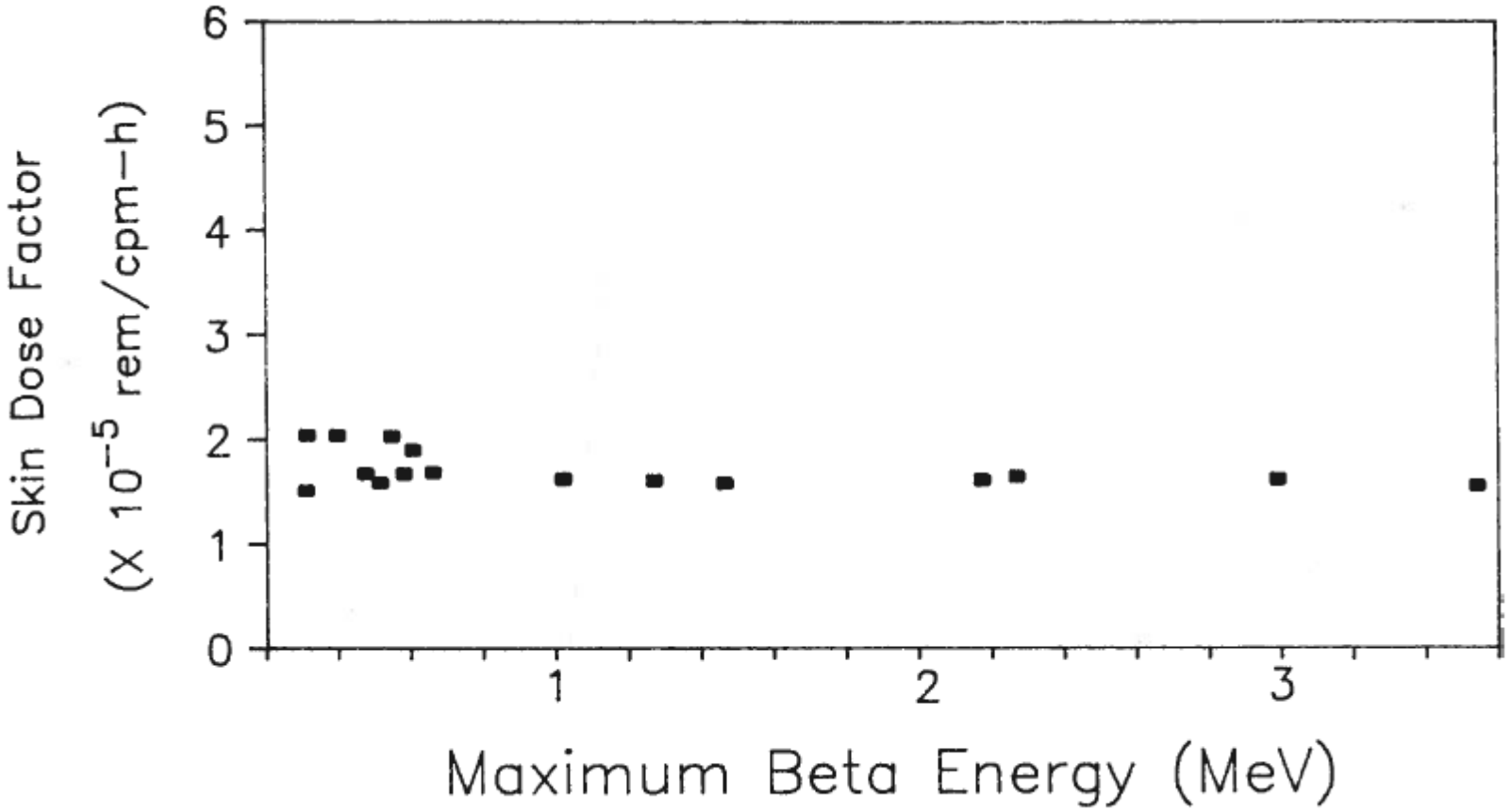
Isotope	Response Factor (cpm/μCi)	Calibration Factor (μCi/cpm)
^{60}Co	250 k	4.0×10^6
^{137}Cs	380 k	2.6×10^6
^{90}Sr-Y	370 k	2.7×10^6

OH Skin Dose Assessments: 1987 - 1997

Distributed Source Calibration

Isotope	Response Factor (cpm/μCi cm^{-2})	Skin Dose Factor (rem h^{-1}/(μCi cm^{-2})	mrem h^{-1} per kcpm
^{60}Co	4.63×10^6	4.13	0.89
^{137}Cs	8.55×10^6	6.46	0.76
^{90}Sr-Y	9.57×10^6	8.0	0.84

Skin Dose Rate Factors for HPs on Skin



J.R. Flood, Radiation Protection Management, May/June 1988

OH Skin Dose Assessments: 1987 - 1997

	Exposure Condition			
	Hot Particle		Distributed Contamination	
	On Skin	On Clothing	On Skin	On Clothing
Exposure/Dose Limit	75 µCi - h	30 rem/qtr	30 rem/qtr	30 rem/qtr
Recording Level	7.5 µCi - h	3 rem	3 rem	3 rem
Action Level	2.5 µCi - h	1 rem	1 rem	1 rem
Action Level (5 h exposure)	0.5 µCi	0.2 rem h^{-1}	0.2 rem h^{-1}	0.2 rem h^{-1}
Pancake Probe at 1 cm (cpm)	125 K	40 K	220 K	520 K
Exposure/Dose Conversion Factor	1 µCi/250,000 cpm	5 mrem h^{-1}/ 1,000 cpm	0.91 mrem h^{-1}/ 1,000 cpm	0.38 mrem h^{-1}/ 1,000 cpm

ICRP 59 and 60 (1992, 1991)

- **ICRP 59, Biological Basis for Dose Limitation in the Skin, 1992**
  - **For hot particles, recommended dose limit of 1 Sv (100 rem) when averaged over a 1 cm^2 at a depth of 100 – 150 µm (10 - 15 mg cm^{-2}) to prevent acute deterministic effects.**
- **ICRP 60, 1990 Recommendations of the ICRP, 1991**
  - **Dose limit of 0.5 Sv (50 rem) over 1 cm^2 at a nominal depth of 7 mg cm^{-2} (70 µm)**
  - **Provides protection for skin of face and lens of eye from lower energy betas**

Skin Dose Limits - CNSC

- **Limit is 0.5 Sv = 50 rem**
  - **Applies to the basal cell layer of the epidermis => depth of 7 mg/cm^2**
  - **To be included in effective doses with a weighting factor of 0.01 for uniform irradiation of skin**
  - **For non-uniform irradiation, limit applies to the average dose to 1 cm^2 of skin in the area receiving the highest dose**

NCRP 130

- **NCRP 130, Biological Effects and Exposure Limits for "Hot Particles", 1999**
  - 10 μm to 3,000 μm
  - for E < 0.5 MeV, hazard is acute epidermal necrosis; for E ≥ 0.5 MeV, hazard is acute ulceration
  - ED_{50} is 5 - 10 Gy to 1 cm^2 ⇒ 5 Gy to 1 cm^2 for HP on skin
  - **0.5 Gy/10 cm^2 for HP on clothing, used for HP on skin**

Update of Skin Dose Standard

- **Standard for Estimation and Recording of Skin Dose from Radioactive contamination on Skin or Clothing; June 1997, June 1999**
  - March 1991 standard not issued, pending new AECB regulations
  - VARSKIN Mod 2 issued in 1992
  - Uncertainty re dose limits: skin of WB, skin of extremities, hot particle
  - Dosimetry Levels and Required Actions
    - Dose Limit (50 rem, 500 mSv)
    - Formal Investigation (5 rem, 50 mSv)
    - Verification (1 rem, 10 mSv)
    - Record dose in Radiation Dose System (100 mrem, 1 mSv)
    - Record basic information (< 100 mrem, 1 mSv)

Calculation of Skin Dose Rates from Contamination Level

- **Memos on Skin Dose Rates from Contamination (March 2000, December 2004)**
  - **Dealt specifically with “hot particles” (DRPs)**
  - **Calculations for ^{60}Co, ^{137}Cs, and ^{90}Sr-Y**
  - **Table of Thickness, density, density thickness and air gap used for calculations for skin and 3 clothing types**
  - **Tables of DRCFs (mrem h^{-1} per µCi) and (mrem h^{-1} per kcpm) calculated with VARSKIN Mod 2, then DOSESKIN**
  - **DRCF (mrem h^{-1} per kcpm) for all 3 radionuclides for DRP on skin ≈ 17 mrem h^{-1}**
  - **Trigger levels for initiating a Personal Contamination Incident Report (PCIR)**

DOSESKIN

- **DOSESKIN, - A Replacement for VARSKIN Mod 2, February 2004**
  - **Review of Operational Aspects of VARSKIN Mod 2, S. Davis, August 1997**
    - **Loss of dose for physically small sources**
    - **Fluctuations at shallow skin depths (< 7 mg cm^{-2})**
    - **Fluctuations in volume averaging**
    - **Variations in radial dose rate**
    - **Gamma dose rate CPE correction**

Skin Dose Assessment Procedure

- Trigger Levels for Performing Skin Dose Assessment Actions
- Dosimetry Levels and Required Actions
- DRCFs (mrem h^{-1} per kcpm) and (mrem h^{-1} per nCi) for DRPs on Skin and Clothing (5 types) for 9 radionuclides/radionuclide mixes, including $^{95}Zr/^{95}Nb$ mixes
- DRCFs (mrem h^{-1} per kcpm) and (mrem h^{-1} per nCi) for DRPs on Shoes
- DRCFs for Noble Gas Progeny for DRPs and LAC
- Correction Factors for $^{95}Zr/^{95}Nb$ Activities Reported by WBCs vs. Actual Activities for various Ratios of $^{95}Nb:^{95}Zr$
- DRCFs (mrem h^{-1} per kcpm) for Whole Body Monitors for typical contamination scenarios
- Dose Assignment rules

Special Techniques and Cases

- **Locating Shielded Contamination**
- **Use of a WBC to measure activity**

Special Techniques and Cases

- **Hot Particle Dosimetry System (HPDS)**
- **Use of a WBC to measure activity**
- **Monte Carlo calculations**

The Future

- **Contamination on hard hats and glasses**
- **Documenting Qualitative Gamma Spectroscopy results**
- **Activity and Skin Dose Calculator (ASDC)**
- **Validating and implementing VARSKIN**

Conclusions

- Skin dose assessment is all about the basics: Time, Distance, and Shielding
- Watershed event: discovery of “hot particles”
- Many changes in and increasing sophistication of ICRP recommendations, regulatory limits, and dose calculations
- Remember the basics:
  - at small source - target distances typical of skin dose from contamination, betas can be qualitatively different from gammas;
  - know your source term