Dosimeters for Measuring Non-Target Doses

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TG-158 Chapter 4 Measurement Approaches

4.1 Photon Dosimetry
- Thermoluminescent dosimeters (TLDs)
- Optically stimulated luminescent dosimeters (OSLDs)
- Diode dosimeters
- Metal oxide–silicon semiconductor field effect transistor dosimeters (MOSFETs)
- Ion chambers
- Film

4.2 Neutron Dosimetry
- Thermal neutron-based detectors
- Thermal neutron detectors
- Thermal neutron detector–moderator systems
- Rem meters and extended-range rem meters
- Bonner sphere spectrometers and extended-range Bonner sphere spectrometers
- Fast neutron detectors
- Bubble detectors
- Track-etch detectors
- Tissue-equivalent proportional counters (TEPCs)

4.3 Phantoms

MV Photon Dosimetry:

Important Considerations for Out-of-Field Measurements

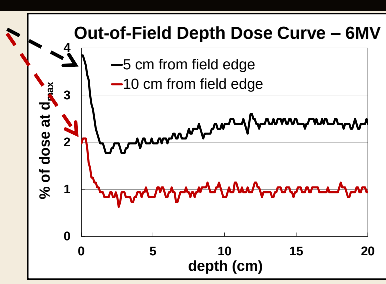
MV Photon Beams
Out-of-Field Photon Measurements

- Four general measurement considerations that are particularly relevant to out-of-field measurements:
  1. Dose at the surface
  2. Energy spectrum
  3. Dosimeter dynamic range
  4. Presence of other particles

For various dosimeters, TG-158 considers specific implications of 4 measurement considerations → TLD, OSLD, Diode, MOSFET, Ion chamber, Film

Dose at the Surface

- The build-up effect at the surface is due to stray electrons.



- The out-of-field dose is up to 5x higher at the patient surface, decreases to ~ d_{max}, and then is relatively constant with increasing depth.

MV Photon Out-of-Field Measurements
Dose at the Surface

- Because the out-of-field dose is up to 5x higher at the patient surface…..

  a dosimeter that is placed on the patient surface will overestimate dose by as much as 5x.

- For out-of-field measurements, dosimeters should be covered by bolus with a thickness of ~ d_{max}.

MV Photon Out-of-Field Measurements
Energy Spectrum Considerations

- The average beam energy is much lower outside the treatment field.
- A dosimeter that is not tissue equivalent will overrespond to this softer radiation relative to its calibration, which will generally be based on the 1º beam.
  - This effect can be sizeable to the point of unacceptable accuracy unless it is accounted for.

TLD/OSLD	Diode	MOSFET	Ion Chamber
• Overresponse **5-30%** compared to in-beam.	• Overresponse **up to 70%** compared to in-beam.	• Overresponse **50-600%** compared to in-beam.	• Overresponse **negligable** compared to in-beam.

MV Photon Out-of-Field Measurements
Dynamic Range Considerations

- Dose levels outside the treatment field are low
  - MU for phantom measurements is often scaled up to achieve an appropriate reading.
  - MU scaling is not possible for in vivo measurements, and an appropriate dosimeter must be selected.

TLD/OSLD	Diode	MOSFET	Ion Chamber
• Attention should be paid to calibration dose level relative to measurement dose level (linearity effects).	• No dynamic range issues.	• Even a high-sensitivity MOSFET in a high-sensitivity voltage setting can measure dose only down to ~ **1 mGy**.	• For long reading periods, should monitor for potential electrometer drift.

MV Photon Out-of-Field Measurements
Other Particle Considerations

- It is important to determine whether measurements are being made in a mixed field.
  - Dosimeters can respond very differently to different types of radiation.

TLD-100
• The standard TLD-100 overresponds to neutrons by as much as 10-12x compared to photons. – A neutron-insensitive dosimeter such as a TLD-700 should be used to measure photon doses for >10 MV. – Separate neutron dosimetry should be conducted to determine the neutron dose.

Neutron Dosimetry:

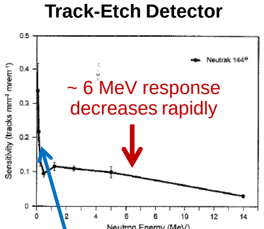
Measurement Challenges

Neutron Dosimetry Measurement Challenges

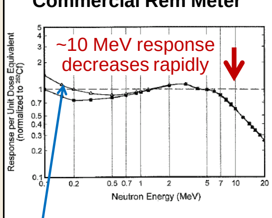
- **Detector response is strongly energy-dependent.**
  - **Sensitive to thermal neutrons:**
    - Passive detectors, e.g., TLD-600s, ^{197}Au activation foils
    - Active detectors, e.g., ^{3}He, ^{10}B, ^{6}Li detectors
  - **Limited response above ~10 MeV:**
    - Bubble detectors
    - Track-etch detectors
    - Thermal neutron detectors within low-Z moderators, e.g., Bonner spheres, commercial rem meters

Limited Response above ~10 MeV

Track-Etch Detector



Commercial Rem Meter



Also, overresponse at very low energies

NCRP, 2005

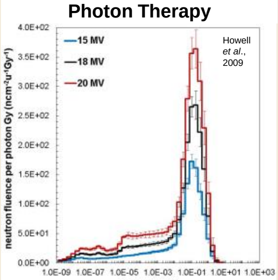
Neutron Dosimetry
What You Need to Know:

- **Neutron detectors have strong <u>energy dependence</u>.**
- **The range of neutron energies being measured must be determined to select the appropriate dosimeter.**
  - **Photon therapy**
  - **Particle therapy**

Neutron Dosimetry

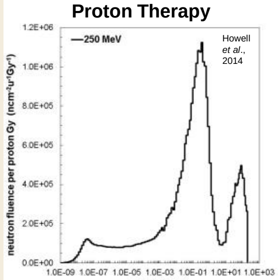
- **Neutron spectra span orders of magnitude in energy.**

Photon Therapy



Thermal → 10MeV

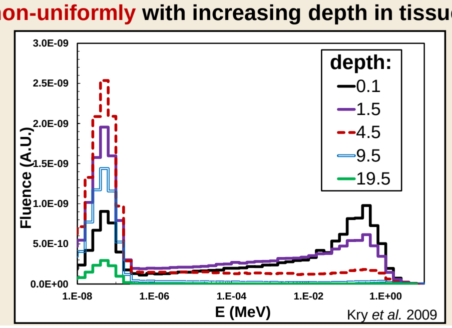
Proton Therapy



Thermal → 250MeV

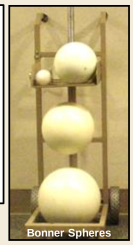
Neutron Dosimetry Challenges
Phantom/Patient Measurements

Neutron energy spectra change dramatically and non-uniformly with increasing depth in tissue.



Neutron Dosimetry Challenges Phantom/Patient Measurements

- **Phantom/Patient measurements are not possible with many neutron detectors because these detectors are too large.**



Concluding Remarks about Neutron Dosimetry

- **Neutron measurements are prone to very large errors.**
- **Therefore, TG-158 has separate recommendations that are <u>application-dependent</u> and based on the necessary accuracy.**
- **These recommendations will be discussed in detail by Dr. Kry.**

References

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Thank You