A New Algorithm for the Panasonic UD-802

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STANFORD DOSIMETRY

Abstract

In response to the revised standard for whole body dosimeter testing, HPS N13.11-2001, a function style algorithm has been designed for the Panasonic UD-802 dosimeter. This new algorithm, to be implemented at the Callaway Plant, successfully meets the challenges of the new test fields, including mixtures of beta or neutron with low energy photons, as well as accommodating the expanded range of photon energies. The development of the new algorithm and the standard Panasonic algorithm that it replaces are discussed with respect to the revised standard.
Today’s Presentation

- Background
  - Panasonic UD-802 design
  - ANSI N13.11-1983
  - Standard Panasonic algorithm
  - HPS N13.11-2001
- Challenges and solutions
- New algorithm design
- Test results
- Cautions

Panasonic UD-802 Dosimeter

<table>
<thead>
<tr>
<th>Phosphor</th>
<th>Filtration (approx.)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1 Li₂B₄O₇</td>
<td>20 mg cm⁻² plastic</td>
<td>Beta</td>
</tr>
<tr>
<td>E2 Li₂B₄O₇</td>
<td>300 mg cm⁻² plastic</td>
<td>Beta/photon</td>
</tr>
<tr>
<td>E3 CaSO₄</td>
<td>300 mg cm⁻² plastic</td>
<td>Photon</td>
</tr>
<tr>
<td>E4 CaSO₄</td>
<td>900 mg cm⁻² lead</td>
<td>Photon</td>
</tr>
</tbody>
</table>
### Response matrix of the UD-802

<table>
<thead>
<tr>
<th>Field</th>
<th>Energy</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
</tr>
</thead>
<tbody>
<tr>
<td>M30</td>
<td>20</td>
<td>0.765</td>
<td>0.637</td>
<td>10.405</td>
<td>0.378</td>
</tr>
<tr>
<td>NS-25(prelim)</td>
<td>20</td>
<td>0.821</td>
<td>0.762</td>
<td>13.198</td>
<td>0.545</td>
</tr>
<tr>
<td>H50</td>
<td>39</td>
<td>0.817</td>
<td>0.793</td>
<td>11.903</td>
<td>1.302</td>
</tr>
<tr>
<td>NS-80</td>
<td>65</td>
<td>0.772</td>
<td>0.764</td>
<td>7.056</td>
<td>1.424</td>
</tr>
<tr>
<td>H100</td>
<td>83</td>
<td>0.770</td>
<td>0.761</td>
<td>4.572</td>
<td>1.274</td>
</tr>
<tr>
<td>NS-120</td>
<td>100</td>
<td>0.750</td>
<td>0.747</td>
<td>3.364</td>
<td>0.956</td>
</tr>
<tr>
<td>H150</td>
<td>118</td>
<td>0.788</td>
<td>0.775</td>
<td>2.524</td>
<td>0.906</td>
</tr>
<tr>
<td>H300</td>
<td>251</td>
<td>0.905</td>
<td>0.895</td>
<td>1.581</td>
<td>0.914</td>
</tr>
<tr>
<td>Cs</td>
<td>662</td>
<td>0.956</td>
<td>1.000</td>
<td>1.000</td>
<td>1.067</td>
</tr>
<tr>
<td>Co</td>
<td>1250</td>
<td>0.950</td>
<td>0.977</td>
<td>0.901</td>
<td>0.880</td>
</tr>
</tbody>
</table>

### Response curves for the UD-802

[Graph of UD-802 Photon Response]

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The Five Essentials for a Successful Dose Algorithm

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ANSI N13.11-1983

- Pure fields
  - Photons (5 fields from 20-70 keV)
  - Gamma ($^{137}$Cs)
  - Beta ($^{90}$Sr/Y)
  - Neutron
- Mixtures
  - Photons and gamma
  - Beta and gamma
  - Neutrons and gamma

Standard Panasonic algorithm

- Decision style
  - low E photon and gamma
  - or beta/neutron and gamma
- Beta signal = E1-E4
- Neutron signal = E2-E4
- Photon correction based on discrete points

Dose = E2 * correction
Dose = E4+ (E1-E4) * correction or E4+(E2-E4)*correction
HPS N13.11-2001 test fields

- Pure fields
  - Low energy photons – over 50 fields from 20 – 200 keV
  - High energy photons - $^{137}$Cs and $^{60}$Co
  - Betas – 800keV and 2MeV $E_{max}$
  - Neutron – hard or moderated

- Mixtures
  - High and low photons
  - Any photon plus beta
  - Any photon plus neutron

Challenges for standard algorithm

- Photon/beta and photon/neutron mixtures
  - Non-photon response (beta or neutron) not accurately estimated with E1-E4 or E2-E4 (see the response graph)
  - E4 subtracts too little for the very low photon fields, and too much for the others

- Additional photon fields
  - Discrete correction factors not as accurate between points
Solution – a new design

- Function based correction factor to determine photon contribution to E1, E2
  - Use a function that predicts the ratios E1/E4 and E2/E4 based on photon field
  - The fraction of E4 response subtracted from E1, E2 depends on photon energy
- Function based correction factors for photon doses
  - Smooth fit to full range of photon energies

Example Function HdE2

Deep dose correction factor for E2,
Within 2% from 20keV to 60Co
Example function E2E4

Ratio of E2 to E4 photon response. Within 15% from 20keV to 60Co

New algorithm general flow

- Photon field calculations
  1. Characterize photon field (E3/E4)
  2. Calculate photon correction factors
  3. Calculate photon dose estimates using E2 and E4 with correction factors
  4. Calculate estimated photon interference on E1 and E2 using E4 with correction factors
New algorithm general flow (ctd.)

- Non-photon calculations
  1. Calculate non-photon signals, NetE1 and NetE2, by subtracting estimated photon contribution
  2. Characterize field using ratio of NetE1/NetE2
  3. Calculate appropriate correction factor from characterization
  4. Calculate non-photon dose using net responses and correction factors
  5. Test non-photon dose for significance

New algorithm general flow (ctd.)

- Calculate total doses
  1. If non-photon component is significant and interferes with E2, use only E4 for photon dose. Otherwise use combination of E2 and E4 for photon dose.
  2. If non-photon component is not significant, set equal to zero (and use combination of photon dose estimates based on both E2 and E4)
  3. Sum photon dose with any significant non-photon dose.
New algorithm flow - summary

1. Characterize photon, calculate corrections
2. Calculate photon doses using E2 and E4
3. Calculate non-photon responses
4. Characterize non-photon, calculate correction factors
5. Test non-photon for significance
6. Is non-photon significant?
   - yes
   - no
   - Does non-photon interfere with E2?
     - yes
     - no
     - Non-photon set to zero
   - Photon dose taken from combination of E2, E4
   - Photon dose taken from E4 only
7. Total dose = photon + non-photon

Testing

- Photon of the month
  - 4 groups of 5 new energies
  - 90% < 10% bias, all < 20%
- Synthetic testing
  - Use calculated element responses to test to a wide range of mixtures without the time and cost of irradiations
Synthetic testing results

- Synthetic testing to over 130 pure and mixed fields: $^{137}$Cs, $^{60}$Co, $^{90}$Sr/Y, $^{204}$Tl, D$_2$O mod $^{252}$Cf, 8 x ray fields from 20-250 keV
- Ratios of 1:3, 1:1 and 3:1 for mixtures of high and low energy photons, photons and beta, and photons and neutron.
- Single algorithm

Cautions

- The Panasonic UD-802 cannot be relied on to accurately measure neutron and beta in the same issue cycle.
  - There are neutron and beta mixtures that show the same exact responses as photon and beta, but require very different correction factors.
  - Best approach is to use separate badges, one insensitive to either beta or neutron, when in mixed field conditions.

- Different Panasonic systems show different response matrices even for the same dosimeter model. For best results generate your own system-specific matrix.
The Five Essentials for a Successful Dose Algorithm