Fuji Electric- RADIATION
Bringing Innovating Technology for Customer Solutions
CHARACTERISTICS of Light Weight Neutron Survey Meter

Key Features:

Light Weight 5.1 lbs

Energy Range:
  Thermal – >15 MeV

No He3 or BF3 Detector

Capable of measuring H*(10)
NSN3 Detection Principles

- Proportional gas counter consisted of methane gas of 3.94 atm and nitrogen gas of 0.98 atm. The detector is almost a spherical shape of approximately 13-cm dia.
- Effective volume is approximately 1400 cm³. The weight of this detector is approximately 720 g.
- The neutrons are measured using the mixed gas.
  - Fast: elastic scattering reaction of hydrogen of the methane gas
  - Slow/Thermal neutrons - using the 14N(n, p)14C reaction of nitrogen gas. The proton energy in this reaction is 626 keV.
- By using these two reactions the neutron ambient dose equivalent can be obtained from thermal neutrons up to about 15 MeV.
Measurement Principle of NSN3

Detector gas

- CH₄ and N₂

Organic mixed gas

Energy Characteristics

- Fast neutron
  - Elastic scattering of Hydrogen (Recoil proton)

- Thermal neutron
  - \(^{14}\text{N}(n,p)^{14}\text{C}\) reaction of Nitrogen

Neutron sensitivity per reference neutron flux [count/(n/cm²)²]

Neutron energy [MeV]
NSN3 Detector
Characteristic Responses

Organic Gas Mixtures Ratio Characteristics

Characteristic Response of Mixed gas Detector vs Neutron Energies
Relative Energy Response

Normalized to $^{241}$Am-Be neutrons as a function of fluence-averaged neutron energy in various reference neutron fields having continuous energy spectra (moderated by graphite, concrete and D$_2$O), together with mono-energetic and quasi-mono-energetic neutron reference fields up to 250 MeV.
HV & Discriminator Determination

- Neutron sensitivity: 0.65 cps/μSv

Applied Voltage [V] vs. Neutron Sensitivity [cps/(μSv/h)]

Shaping time: 0.5μs

HV1350; Discriminator 400keV

Larger sensitivity is better
Lower discrimination level is better
Energy Resolution Determination

- Energy resolution

$^{14}\text{N}(n, p)^{14}\text{C} : 626\text{keV}$

**Shaping time: 1.5\(\mu\text{s}\)**

- Peak: 600\text{keV}
- FWHM: 170\text{keV}
- Energy resolution: 28\% (FWHM)

**Shaping time: 0.5\(\mu\text{s}\)**

- Peak Energy: 620 \text{keV}
- FWHM: N/A
- Energy resolution: N/A

KEK thermal neutron standard
Neutron Measurements (1)

Neutron Spectrum

γ noise component

Thermal neutron reaction components

Recoil Proton

Discriminator
400keV

Maximum 4300keV

Count value [counts/keV/(c/cm²)]

Deposited Energy [keV]
Neutron Measurements (2)

- Monochromatic neutron by Accelerator) neutron spectrum

\[ \gamma \text{ Gamma Noise Component} \]

\[ \text{Thermal Neutron Reaction} \]
\[ ^{14}\text{N}(n,p)^{14}\text{C} \quad 626 \text{ keV} \]

\[ H(n,n) \]

\[ \text{Deposited Energy [keV]} \]
\[ \text{Count value [counts/keV/(c/cm^2)]} \]

Scatter corrected

\( \text{Discriminator 400keV} \)
Neutron Spectrum (monoenergetic neutron)

Discrimination Level
400 keV

Recoil Proton

Scatter Corrected

γ noise component

Count value [counts/keV/(c/cm²)]

Deposited Energy [keV]

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NSN3 Relative Response

Relative response (Cf-252 ref.)

Energy [MeV]

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Improving Energy Response - expressed in G-function

Neutron dose $H$ is expressed as follows with ICRP 74 conversion factor [$\text{pSv cm}^2$] $h(E)$ and neutron spectrum $\Phi(E)$.

$$H = \int_{0.025\text{eV}}^{15\text{MeV}} h(E) \Phi(E) \, dE$$

$$H = \int_{0.025\text{eV}}^{1\text{MeV}} h(E) \Phi(E) \, dE + \int_{1\text{MeV}}^{2\text{MeV}} h(E) \Phi(E) \, dE + \int_{2\text{MeV}}^{15\text{MeV}} h(E) \Phi(E) \, dE$$

$$= A \int_{400\text{keV}}^{1\text{MeV}} P(L) G(L) \, dL + B \int_{1\text{MeV}}^{2\text{MeV}} P(L) G(L) \, dL + C \int_{2\text{MeV}}^{15\text{MeV}} P(L) G(L) \, dL$$

- $P(L)$: pulse-height distribution for neutron
- $L$: the pulse height of the detector
- $A, B, C$: Factor for each zone
- $G(L)$: $G(E)$-function responding to the pulse height
- $E$: Neutron Energy
We are now applying the G-function method [10] using the actual neutron field spectra at nuclear facilities [11] in the energy region below 400 keV.
NSN3 Comparison to ICRP60

• At three distances using a 1 Ci AmBe neutron source
  – 50 cm, 75 cm and 100 cm

<table>
<thead>
<tr>
<th>Distance from source (cm)</th>
<th>NSN3/HAWK</th>
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</thead>
<tbody>
<tr>
<td>50</td>
<td>0.929</td>
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<tr>
<td>75</td>
<td>0.941</td>
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<tr>
<td>100</td>
<td>1.089</td>
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</tbody>
</table>

• HAWK TEPC values using ICRP60 quality factors.

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## Gamma Rejection (Cs-137)

<table>
<thead>
<tr>
<th>Gamma Dose (mrem/hr)</th>
<th>Reading (mrem/hr)</th>
<th>% of Reading</th>
<th>% of reading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>20.00%</td>
</tr>
<tr>
<td>1,000</td>
<td>0.76</td>
<td>0.08%</td>
<td>15.00%</td>
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<tr>
<td>1,250</td>
<td>1.25</td>
<td>0.10%</td>
<td>10.00%</td>
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<tr>
<td>2,500</td>
<td>12.9</td>
<td>0.52%</td>
<td>5.00%</td>
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<tr>
<td>5,000</td>
<td>153</td>
<td>3.06%</td>
<td>0.00%</td>
</tr>
<tr>
<td>6,000</td>
<td>265</td>
<td>4.42%</td>
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</tr>
<tr>
<td>8,000</td>
<td>637</td>
<td>7.96%</td>
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</tr>
<tr>
<td>10,000</td>
<td>1193</td>
<td>11.93%</td>
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<tr>
<td>20,000</td>
<td>4500</td>
<td>22.50%</td>
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</tr>
</tbody>
</table>

Independently tested within Shepherd Model 89 Box Calibrator
Thank You

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