CHARACTERISATION OF NEUTRON REM DETECTOR OUTPUT USING INTEGRAL PULSE HEIGHT DISTRIBUTION AND COUNTING CURVE

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Outline

• Introduction.
  ➢ Application of Neutrons
  ➢ Neutron dosimetry
  ➢ Properties of BF$_3$ rem counter
  ➢ Characteristics Reference sources
  ➢ Pulse Height Distribution and Counting Curve

• Outcome of the Investigation
• Characterisation
• Results
• Conclusion
Application Neutrons

- Radiation Protection purpose, the exposure from neutrons need to be monitored.
- Survey instruments

Nuclear Energy Production

Medicine

Research
Neutron Dosimetry

- Dosimetry of neutron requires:
  - understanding of the neutron fields and
  - characteristics of the measuring instruments.

**Neutron Source**
- Energy distribution
- Room Scatter contribution

**Measuring Instrument**
- Energy response

- Am-Be 241
- Average Dose equivalent energy (4.4 MeV)
Characteristics Reference Calibration sources (Am-Be 241)

- (500 mCi, 5 Ci, 50) Ci
- Reference calibration field (ISO Standard 8529-1)
- (Neutron Source strength traceable to Primary Standard Laboratory)

➢ ADE Rate 9 - 2000 uSv/hr
Eberline Smart Portable ESP-1 (NRD)

- Cadmium-loaded polyethylene sphere
- 22 cm diameter
- With a BF$_3$ filled tube at the centre (BF$_3$ counter)
Properties of BF$_3$ rem counter

• Usually operated in the proportional region,
  ➢ Useful in discriminating gamma photon background.
• Its response (count per neutron) as a function energy,
  ➢ approximated the neutron fluence to dose equivalent conversion factors.
• Filter compensation is applied to reduce over-response,
  ➢ So that the response follows the ICRP radiation weighting factors $w_R$. 
Properties of BF3 counter cont.

Dose Equivalent Rate Measurements
Relative Fluence Response

ICRP 21 Recommended Curve

Rebball or "Snoopy" response

Relative Response per Unit Fluence

Neutron Energy (MeV)
Detection of neutron (BF3 counter)

- Neutrons are uncharged particles.
- Boron-10 gas, ➢ has high \((n, \alpha)\) reaction cross-section.
- The thermal neutrons captured by the boron nuclei produce charge particles.
Pulse height distribution

- Every particle that deposits energy in fill, gas produce a signal pulse.
- Usually, the amplitude of the registered pulses is not the same.
- The variation depends on the differences in the radiation energy of the pulses detected.
Pulse height distribution cont.

➢ “Textbook” version of the BF$_3$ counter pulse height spectrum.

- **Prominent Features**
  - Wall effect (Interaction charged particles fill air and detector wall))
  - Contribution of the Gamma rays
  - Counting Plateau
Counting curve

• The high voltage (HV) supply,
  ➢ provides the bias voltage to the detector for proper operation.
• In a situation whereby this value has drifted or adjusted,
  ➢ a counting curve maybe be recorded to select an appropriate operating voltage
  ➢ this curve is obtained by recording the number of pulses or count rate as a function of applied voltage (gain / amplification).
Counting curve Cont...

- Prominent Feature
  ➢ Counting Plateau
In general

- The integral pulse height distribution and the counting curve are characterised by regions of minimum slope, known as counting plateaus.
- These regions represent the areas of operations in which minimum sensitivity drifts may be achieved.
Investigation (Abnormal behaviour)

➢ From previous certificate
Characterisation

• The best way to determine the operating voltage of a BF$_3$ detector is
  ➢ to generate a characteristic curve (count rate versus high voltage).
  ➢ the operating voltage of the BF$_3$ detector should be selected on the plateau just above the knee.
Characterisation Cont.

• Low level discriminator was set at the proper level.

• Counting rate as a function of high voltage.

• An operating point is then selected which normally corresponds to a flat region or “plateau” on the resulting rate versus voltage curve.
Characterisation Cont.

![Graph showing count rate (normalised) vs applied high voltage (V) for different activity levels: 500 mCi, 5 Ci, 50 Ci. The graph illustrates the relationship between voltage and count rate for these activity levels.](image)
Results (Post Characterisation)

![Graph showing ambient dose equivalent rate vs. CF for different years](image)

- **CF** vs. **Ambient Dose Equivalent Rate (uSv/h)**
- **Graph Key:**
  - Black square: 2018
  - Red circle: 2016
  - Green triangle: 2001
Conclusion

• The characterisation of neutron rem detector output using the integral pulse height distribution and counting curve was successful.
• The integral pulse height distribution is unrelated to neutron energy.
• It is simply a function of the detector construction.
• This method has proven to be essential for solving problems relating to the output of the detector.
• It is also appropriate to investigate the output properties of other detectors such as the Geiger-muller counters and Multi Wire Proportional Counters.
References


