Use of radionuclide sources in neutron metrology

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Overview

Neutron source types

Applications in neutron metrology

Alternatives
Types of radionuclide neutron source

- Encapsulated $^{252}$Cf or mixture of $\alpha$ or $\gamma$ emitter and target material (e.g. $^{241}$Am and Be, $^{226}$Ra and Be)
- Produce neutrons via spontaneous fission, ($\alpha$,n) or ($\gamma$,n) reactions
- Place source in Mn bath to measure emission rate
- Rates up to $\sim 10^9$ s$^{-1}$ from a $^{252}$Cf source ($\sim 12$ mSv.h$^{-1}$ at 1m)
- Approximately a point source
- Cylindrical geometry so not isotropic
- Sources have broad energy spectra
- Can modify spectrum → thermal or workplace fields

![Anisotropy profiles](image)

![Spectra of calibration fields and a typical reactor spectrum](image)
Applications in neutron metrology

Reference standards for neutron fluence and neutron dose

- Fundamental method in use at all NMIs and secondary labs with neutron facilities (cannot measure neutron dose directly)
- Source with emission rate and anisotropy calibration placed a fixed distance from a device in a low scatter area
- Determine fluence from decay corrected emission rate, anisotropy factor and air attenuation
- Determine dose from spectrum-averaged fluence to dose conversion coefficients
- Can produce simulated workplace fields using D$_2$O sphere and/or shadow block

Conversion coefficients, from ICRP Publication 74 or ICRU Report 57, for ambient dose equivalent $H^*(10)$ and for $E_{(A-P)}$
Applications in neutron metrology

Thermal neutron fields
- Use one or more radionuclide neutron sources (Am-Be or Pu-Be) in a graphite or PE assembly
- Requires characterisation to determine fluence and dose
- Very stable field
- Low intensity
- Low maintenance
Applications in neutron metrology

Activation foils

- Metal foil placed in neutron field
- Activity of foil measured later by $\beta$, $\gamma$ or $\beta-\gamma$ counting
- Neutron fluence derived from activity and spectrum-averaged cross-section
- Select foil based on neutron energy
  - Gold or manganese for thermal neutrons
  - Iron or aluminium for 14.8 MeV neutrons
- Usually short half-lives and low activities
Applications in neutron metrology

As part of quality system

- Verifying performance
- Demonstrating long term stability
- For example:
  - Mn bath using Ra-Be or Am-Be source
  - Mn bath NaI detectors using $^{137}$Cs sources
  - Long counters using Am-Be sources
  - Activation foil beta counters using $^{60}$Co source
  - Bonner sphere detectors using an Am-Be source
Applications in neutron metrology

Determining efficiency of Mn bath system

- Mn-56 solution produced in reactor or other thermal field
- Standardised by coincidence counting or in ion chamber
- Enables neutron emission rate to be derived from NaI count rate
- Measurements made several times per year
Alternatives to radionuclide neutron sources

- **Accelerators**
  Large, expensive, high maintenance, output traceable to radionuclide sources

- **Portable DT or DD generators**
  Smaller, less expensive, low maintenance, output traceable to radionuclide sources, are they reliable enough for metrology?

- **Reactor**
  Very expensive, high maintenance, only thermal neutrons

- **Neutristor**
  Very small, new technology, inexpensive, low output, limited lifespan
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