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# Problems with neutron instrumentation from a practical point of view

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# The end users' view

- Fluctuating indication and slow response times at operating dose rates
- Differences in indication between types
- Expensive
- Mostly heavy
- Mostly big
- External cables and not very weatherproof

## The general approach to any sort of dose rate monitoring

- Two options
  - Reproduce the quantity, i.e. have the equivalent of a mass of tissue buried in a mass of tissue

    e.g. microdosimetric detectors
  - Or take any convenient detection mechanism and batter it into giving the right answer.

    e.g. moderated detectors, dual proportional counters, some scintillators

# Reasons for the users' perceptions – Fluctuating indication and slow response times

- Not many neutrons/$m^2$/Sv compared to photons.
- ICRP 74, E
  - 1 MeV neutrons, $3.55 \times 10^{13}$
  - 1 MeV photons, $2.23 \times 10^{15}$
  - Ratio of 63
- Penetrating in most conventional detector materials – air, steel, aluminium, most scintillators
- Hence poor sensitivity – typically 0.2 $s^{-1}$ $microSv^{-1}$ h compared to 0.8 to 5 for a typical gamma GM monitor

# Differences in indication between types

- We're looking at an energy range of $10^9$ for practical monitoring even in simple situations
- For photons it's 2000
- No other sensor is obliged to cover such a range!
- Dose equivalent per unit fluence has a difficult shape – a factor of 100 change
- Wide differences in real measurements between respectable instruments for fields with a significant ev to 100 keV component

# Effective dose

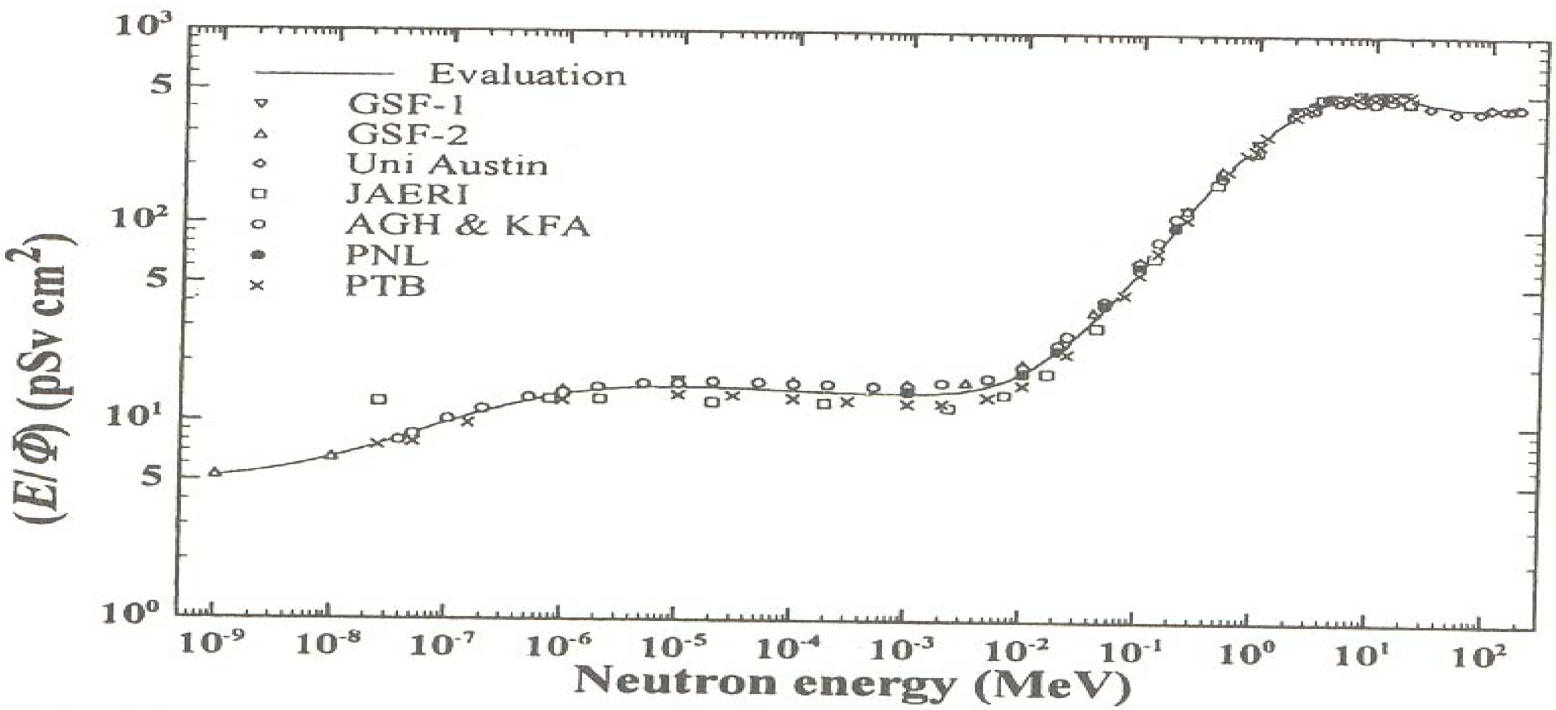


Fig. A.56. Evaluated and original data for the effective dose from neutrons in AP geometry.

# An example

- Factor of 3 on a waste cask between
  - Similar geometry and size
  - One used with axis parallel to container, the other at right angles.


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## Expensive

- Unusual detection materials – enriched isotopes
- Sometimes large moderators
- High development and type testing costs
- Low volume production

# Big and heavy?

- Moderator based detection – detectors with a high thermal response and a 1/v energy dependence need moderation to produce a correct response for energetic neutrons – about 12 $g/cm^2$ polyethylene
- Mass of moderator is proportional to $1/(\text{density})^2$
- Density = 1, so heavy.

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# External cables

- Often use external cables with high voltages feeding a low charge threshold pulse detector
- Source of noise and background
- Don't like getting wet
- Get hooked on things!

# Outdoor use

- Site perimeter fences and waste store walls
- Spent fuel flasks
- Oil exploration platforms
- Many not weather proof

# Detection mechanisms

- “billiard ball” neutron – proton collisions
- $^{10}B + n \rightarrow {}^{7}Li$ + alpha + 2.792 or 2.310 MeV
- $^{6}Li + n \rightarrow {}^{3}H$ + alpha + 4.78 MeV
- $^{3}He + n \rightarrow {}^{3}H + p$ + 0.765 MeV
- Activation (n, gamma) reactions
- Induced fission – 200 MeV liberated per event

## Microdosimetric instruments – reproducing the quantity

- Reproduce the quantity –tissue equivalent proportional counter
- Count rate and pulse size used
- An example - Rem 500
- Low sensitivity – about 6% of moderator instruments
- Poor low energy response
- Gamma rejection is much more difficult

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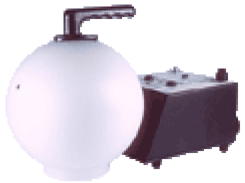
# Practical instruments – not reproducing the quantity

- Single detector, moderated $BF_3$ and $^3He$ proportional counters and Li(Eu)I scintillators
- Heavy, big – manual handling restrictions
- Monitoring points have to be below waste level for in the hand use



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# Prescila from Ludlum

- Dual scintillator – relatively light, 2 kg + ratemeter
- Gamma rejection not as good as $BF_3$ and $^3He$ based types

# Canberra Dineutron

- The Ski boot
- Light
- Dual $^{3}He$ detectors 63 mm and 107 mm diameter moderators
- Comparison of counts gives a measure of the energy spectrum

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# Canberra Dineutron

- Interesting energy and polar responses

# Summary

- It’s difficult to get monitoring staff to make good quality measurements at operational dose rates
- Differences between instruments can lead to real problems
- For all barring the simplest of situations, a knowledge of the energy and angular distribution helps a lot to explain differences and improve estimates
- Reliability tends to be poor

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