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Your Alternative To The Obvious

SNS-PHE Guided Neutron Detector (GNU)

Data Sheet for PHE Guided Neutron Detector Type SNS-PHE-GNU with Electronics

A survey instrument for measuring ambient dose equivalent, *H**(10), for neutrons has been designed [1-3] by Public Health England (PHE). The detector is intended to be a portable device that (with suitable electronics) can be used to measure dose rates from neutrons in the thermal to 1 TeV energy range. In order to reach 1 TeV it was necessary to fit a lead layer around the ^{3}He counter. A model of the detector was constructed and exposed to calibration fields at the metrology laboratories of both PHE and the primary standard facilities of the UK's National Physical Laboratory (NPL). These measurements confirmed [3] that its response characteristics were as predicted. The detector has been tested at CERN. The GNU is fully compliant with the requirements of IEC 61005:2014 and ANSI N42.17A:2003.

FST Electronics (Optional)
Multi-channel analyser 2048 channels, direct on handle of sphere.
MCA shaping time 3µs / 9µs peak time pulse rate up to 100,000 cps.
Readout of measuring values and spectra via USB connection.
10.9 mm colour display with touch functions.
Resolution 480x272 pixels.
Storage of measuring values on Micro SD card.
Battery and mains operation.

References:

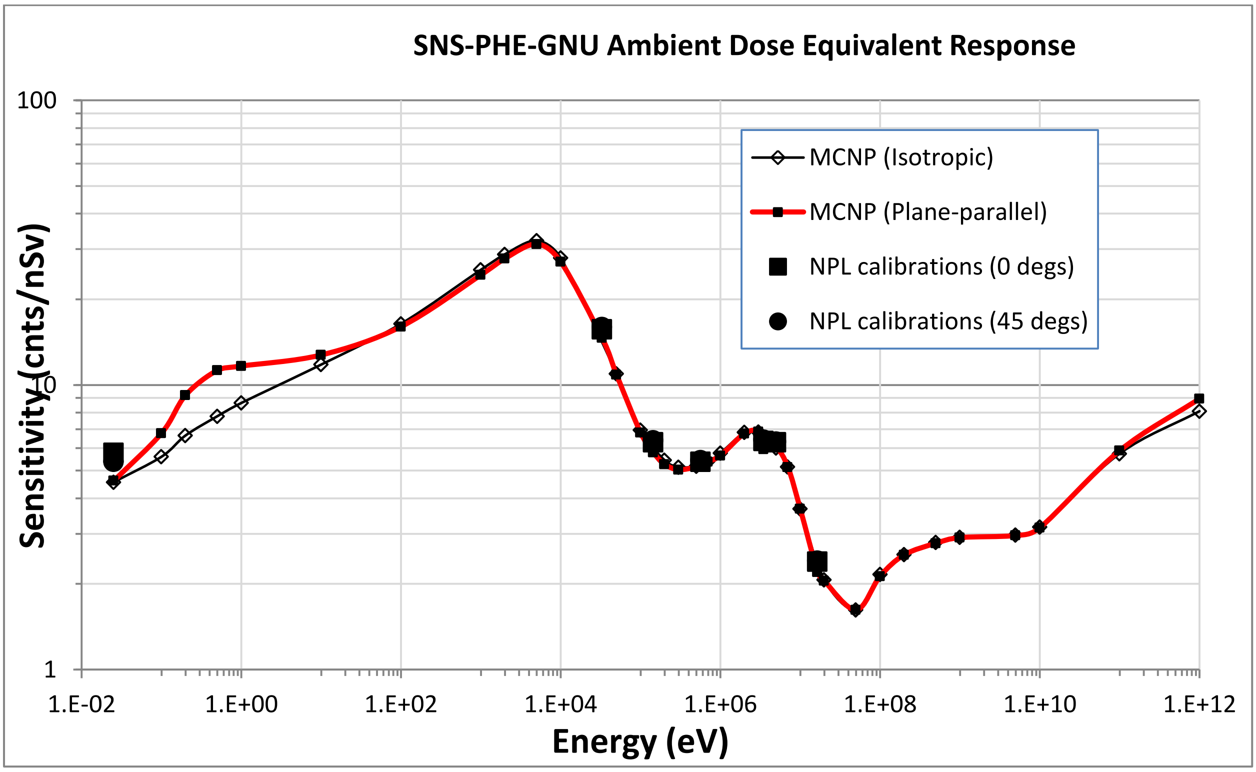
[1] Eakins, J S, Tanner, R J and Hager, L G. *A novel design of survey instrument for neutrons*. Prog. Nucl. Sci. Tech. Vol 4, 687-91 (2014).

[2] Eakins, J S, Tanner, R J and Hager, L G. *Measurements with the new PHE neutron survey instrument*. Radiat. Prot. Dosim. Vol 161, 1-4, 58-61 (2014).

[3] J.S. Eakins, L.G. Hager, J.W. Leake, R.S. Mason and R.J. Tanner, *Calibration of the GNU and HSREM neutron survey instruments*, Neutron Users' Club Meeting, NPL, 20th October 2015. Nuclear Instruments and Methods in Physics Research A 852 (2017) 62–72.

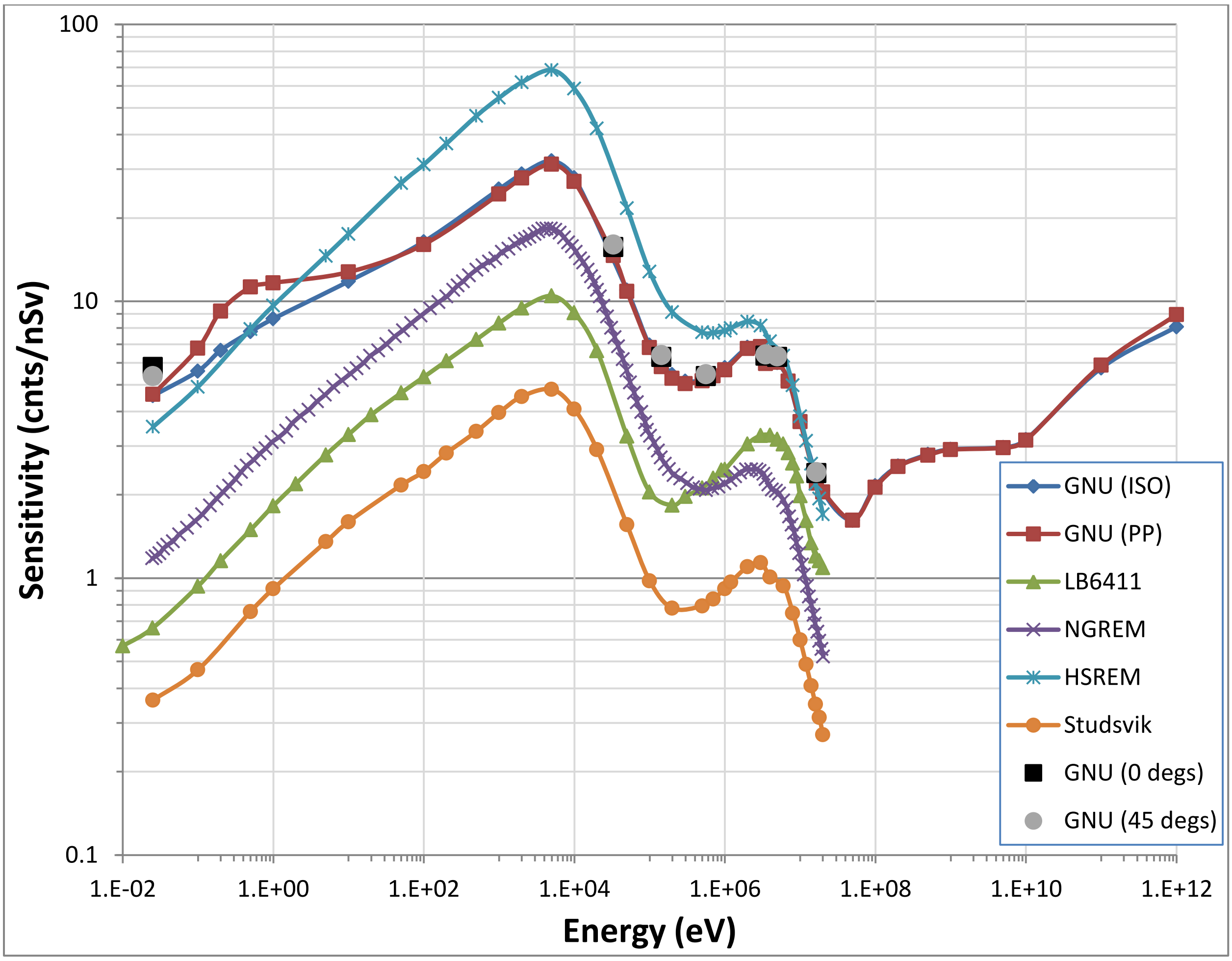
Design:

The instrument was developed using the Monte Carlo modeling software MCNP6, supported by measurements. The device is essentially a 240 mm diameter polyethylene (PE) sphere with a single, central, 50 mm diameter ^{3}He filled proportional counter. The sphere has internal Borotron® PE and lead concentric layers. The outer three shells are penetrated by six air-filled guides that radiate symmetrically along the cardinal directions from the lead layer surrounding the exterior wall of the ^{3}He counter to close to the outside surface of the detector. The guides are capped by hemispherical plugs that reduce differences in directional response for low-energy neutrons. The stem of the ^{3}He counter passes through one of these guides. The PE shells provide moderation of fast neutrons, the Borotron® shell acts as an attenuating layer to help suppress the response to neutrons with ~keV energies, and the air-filled guides channel low energy neutrons directly to the lead-covered ^{3}He counter. The lead layer is fairly transparent to low energy neutrons, but improves the high energy response by the generation of spallation neutrons; its presence also helps to further minimize the photon response of the detector. The guides are capped by hemispherical plugs that reduce differences in directional response for low-energy neutrons. The concept is protected by international patent PCT/EP2008/065612, European Patent 2223156, US Patent 91529,101Bz, Australian Patent 2008322866, Japanese Patent 2014/055850 and a Canadian patent application 2705401 has been made.



Energy Response:

The design improves the under-responses normally exhibited by neutron survey instruments at low and high energies, whilst also reducing the over-response typically exhibited at intermediate energies. Its modeled $H^*(10)$ response characteristic for isotropic fields is shown below. The $H^*(10)$ response of the GNU to neutrons plane-parallel to one of the guides is also shown in the figure. The detector easily satisfies the IEC 61005:2014 standard over the whole energy range from thermal to 20 MeV (the upper limit of the standard) and continues to comply up to 1 TeV. It also satisfies the ANSI N42.17A:2003 standard from thermal to 20 MeV (it is 0.49 at 50 MeV otherwise it would go to 1 TeV). It meets ANSI with a D_2O moderated source. Calibration of the GNU at different energies was achieved using the primary standard facilities at NPL (UK). Eight exposures were performed: 25 meV (thermal distribution) plus 33 keV, 0.144, 0.565, 1.2, 3.5, 5 and 16.5 MeV, quoted as being effectively mono-energetic to within a few %. The device responded as expected, with measured and modeled results agreeing well as shown above. The high energy response of the GNU was tested during measurements at the CERF facility at CERN. In addition, simulated workplace fields and ^{241}Am-Be distribution exposures, along with ^{60}Co gamma discrimination tests, were performed in-house at PHE: measured and modeled results again were in good agreement.



Sensitivity:

The detector responds to neutrons of all energies from ~25 meV (thermal) to 1 TeV. The modeled sensitivity at 1 MeV (isotropic field) is 5.76 counts per nSv, i.e. 1.6 counts per sec per μSv/h, for a nominal fill-gas pressure of 5 bar. Sensitivities at thermal, 5 keV and 20 MeV energies (isotropic fields) are 4.56 nSv^{-1}, 32.2 nSv^{-1} and 2.07 nSv^{-1} respectively. For ^{241}AmBe the measured sensitivity is 7.938 counts per nSv (2.205 cps per μSv/h)

Polar Response:

The spherical geometry of the detector ensures that an excellent polar response is obtained. There will be a variation in the region of the ^{3}He counter connector, but most instruments are designed so that the electronics/ batteries are located in this area. Nevertheless, if the guide that contains the stem of the LND is directed towards a ^{241}Am-Be source, the measured response is found to be only ~17 % different from the result for an exposure with this guide directed away from the source.

EMC Response:

The EMC response will depend on the electronics used. If used as part of an integral instrument then refer to the supplier's specification. If the detector is to be operated with separate electronics then SNS may be consulted for details of tests performed.

Pulsed Neutron Response:

All neutron detectors using polyethylene moderators have a limited capability to measure pulsed neutron dose rates because the diffusion times within the assembly spread the neutrons out in time. The capability increases with an increase in the neutron burst repetition rate. Above about 1000 Hz the radiation is effectively continuous. Intense bursts at low Hz values are the most difficult to measure and an alternative monitor may be required. Users should consult SNS if they wish to measure pulsed neutron dose rates.

Gamma Response:
The gamma rejection ratio is calculated to be better than 3000:1 for gamma energies up to 7 MeV (e.g. ^{16}N produced in the coolant of nuclear reactors) at dose rates up to 10 mSv/h. Note that the rejection ratio at high gamma ray energies is limited by (γ,n) reactions with the deuterium and carbon-13 traces present in all polyethylene and spallation neutrons from the lead shield. Below 3 MeV the detector should easily satisfy the BS EN 61005:2004 tests for photon radiation. For ^{60}Co exposures, a response of less than 1.3×10^{-4} has been measured.

Dimensions and weight:
The sphere is 240 mm diameter and the overall mass is 8 kg. FST electronics with display screen are available as an optional extra: this increases the overall weight to 10.1 kg (including batteries).

Construction materials:
The moderator is commercial grade polyethylene (950 kg/m^3). The attenuator is Borotron® (1005 kg/m^3) and the lead alloy shield is lead-antimony (96% Pb + 4% Sb).

Helium-3 counter:
The LND counter (filled with 5 bar ^3He and a CO_2 quench gas) is fitted with a PET 137 connector.
The LND body is stainless steel with an OD of 50.8 mm.

Operating conditions (mfr)	**Noise (background) counts**
Operating Voltage: 1091 (1000 - 1250) V Amplifier charge sensitivity: 1×10^{-13} Coulombs Capacitance: 10 pF Plateau: 1% max/100 V Operating temperature: -50 to +100 °C	Background counts, typically < 2 in 5 minutes Because of its high neutron sensitivity, background counts of up to 10 cpm (depending upon altitude and latitude) can be expected.

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