

Neutron Probe LB 6411

for Measurement of the Ambient Dose Equivalent for Neutrons



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System Concept

The LB 6411 neutron probe is designed for measurement of the ambient dose equivalent for neutrons in accordance with the 1991 recommendations of the International Commission on Radiation Protection ICRP. The probe was developed in the course of a technology transfer [1] from the Dosimetry Department of the Nuclear Research Center Karlsruhe.

The results of this cooperation were, first, an optimized energy response in accordance with the new dose equivalent conversion factors defined by ICRP 60 [2], and, second, a significantly improved response, and thus a better detection limit, as compared to conventional „Rem Counters“.

Use

The LB 6411 probe can be used as a portable monitor and as a stationary measuring instrument. Major areas of application are reactors and the nuclear fuel cycle in the nuclear-technical field, accelerators in research, and the use of neutron sources in the industrial field.



Design and Function

The LB 6411 probe consists of a polyethylene (PE) moderator sphere with a composite ^3He recoil proton counter tube, the LB 6410, at its center. The probe also includes a high voltage supply and preamplifier. The probe can be used as a portable monitor, for direct connection to the LB 123 UMo, and as a stationary measuring instrument for connection to the LB 111 Micro-Gamma digital radiation monitor.

The energy dependence of the probe is optimized by neutron absorbers in the moderator and by using a special composite ^3He recoil proton counter tube. Due to the relatively large detector volume and the special gas filling of the LB 6410 counter tube (patent applied for), additional recoil protons are produced in the counting gas; the result is an enhanced sensitivity of ~ 3 counts per nSv (3 counts per 0.1 mrem) in the energy range between 1 and 10 MeV, which is more than 5 times better than that obtainable from detectors of conventional design.

The approximately equal diameter and active length of the cylindrical counter tube results in a close approximation to the spherical symmetry of the moderator.

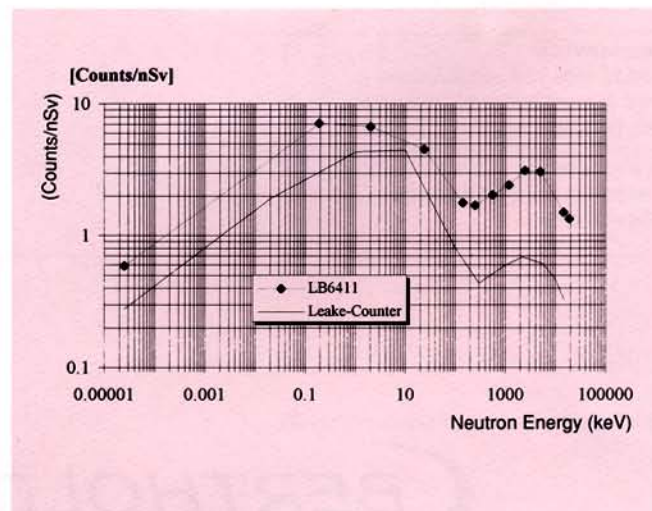
The response for gamma radiation is approx. 10^{-3} counts per nSv (10^{-3} counts per 0.1 μrem). This means a discrimination factor of 3×10^3 .



LB 6411 neutron probe as mobile measuring system connected to the basic unit LB 1230 of the Universal Radiation Protection Monitor LB 123 UMo.

The moderator parameters were determined by a simulation calculation using the Los Alamos neutron transport code MCNP [3]. The design of the detector configuration takes into account all components as well as the proper material composition and mass densities. The geometry was somewhat simplified and the material considered homogeneous. Thereby, it was possible to closely approximate the conversion factors recommended by ICRP 60.

A comparison with a conventional Leake-type counter shows the better response (almost a factor of 5 in the energy range around 2 MeV) as well as the better energy dependence achieved with the LB 6411. For example, the displayed dose rate values differ for 10 keV and 19 MeV by a factor of 3.8 for the LB 6411 and a factor of 14 for the Leake-type counter; in the range between 10 keV and 3 MeV these values differ by a factor of 1.6 for the LB 6411 and a factor of 6 for the Leake counter.



Comparison of sensitivity and response of different detector types

LB 6411 neutron probe as portable monitor used for measuring the neutron dose rate on an industrial Am-Be-source for moisture determination.

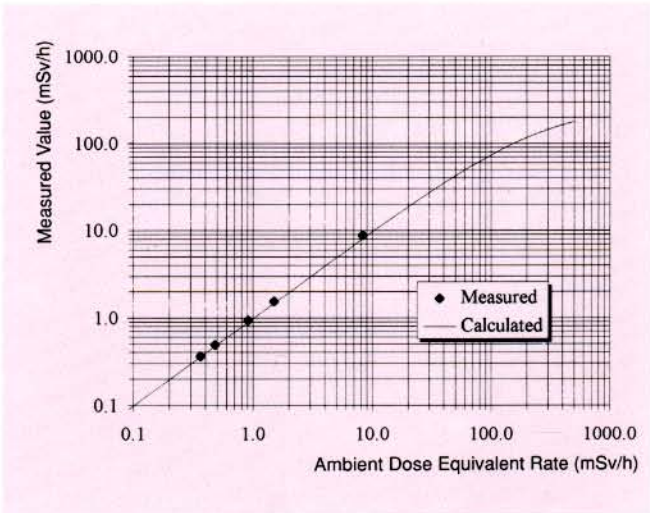


Literature

- [1] B. Burgkhardt, u.a., Optimierung einer Neutronen-Äquivalentdosisleistungsmesssonde; in Strahlenschutz: Physik und Meßtechnik, FS-94-71-T (Koelzer/Maushart Hrsg.), Verlag TÜV Rheinland 1994.
- [2] G. Leuthold, V. Mares, H. Schraube, Calculation of the neutron ambient dose equivalent on the basis of the ICRP revised quality factors, Rad. Prot. Dos., Vol. 40, No. 2, pp. 77-84.
- [3] J. B. Briesemeister, ed., MCNP, A general Monte Carlo code for neutron and photon transport, Version 3A, LA-7396 M, September 1986.

Measurement Range

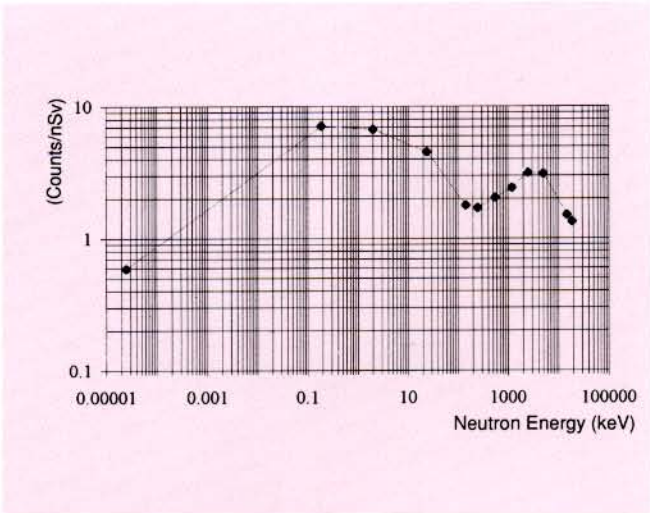
For 0.1 $\mu\text{Sv/h}$ (10 $\mu\text{rem/h}$) the count rate related to the neutron energy in the vicinity of 3 MeV is ~ 0.1 cps. At ~ 0.1 $\mu\text{Sv/h}$ (10 $\mu\text{rem/h}$) ambient level, the extremely low gamma background of 0.05 cps permits measurement of 0.1 $\mu\text{Sv/h}$. The upper limit of the measurement range is ~ 100 mSv/h (10 rem/h).



Measuring range of LB 6411 probe connected to the Monitor LB 123 UMo without dead-time correction.

Energy Dependence

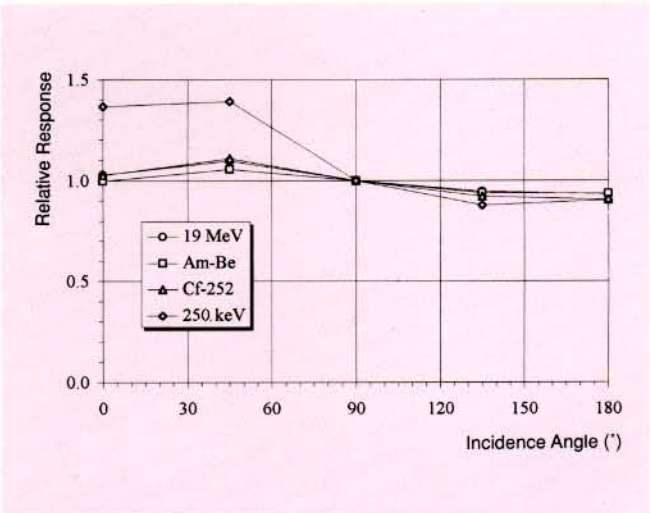
The energy dependent response of the LB 6411 to Ambient Dose Equivalent $H^*(10)$ for neutrons is only $\pm 30\%$ within 50 keV and 10 MeV.



Energy-dependent response of LB 6411 ($H^*(10)$)

Direction Dependence

The optimized spherical geometry of moderator and counter tube results in the energy range between 1 MeV and 20 MeV in a direction deviation of less than $\pm 10\%$ from the preferred direction over the entire angular range. In the bottom semi-sphere the direction dependence stays below 10% even with low neutron energies.



Direction dependence of the LB 6411 probe with preamplifier

Neutron Probe LB 6411

Technical Data

Neutron Monitoring Specifications

Measured quantity:

Ambient dose equivalent $H^*(10)$ rate for neutrons in Sv/h according to ICRP60

Measuring range:

30 nSv/h to 100 mSv/h

Neutron energy range:

Thermal to 20 MeV

Calibration:

bare ^{252}Cf spectrum

Fluence Response:

1.09 cm^2

Ambient dose equivalent $H^*(10)$ response:

2.83 Counts per nSv or 0.79 cps per $\mu\text{Sv/h}$

Calibration Factor:

1.27 $\mu\text{Sv/h}$ per cps

Response functions:

Numerical values of fluence response function and dose rate response function available in the operating manual as functions of neutron energy from thermal energies up to 20 MeV

Reference fluence-to-dose conversion factors:

B.R.L.Siebert and H.Schumacher. Radiation Protection Dosimetry, Vol. 58, No. 3, pp. 177-183, 1995

Energy dependency:

$\pm 30\%$ between 50 keV and 10 MeV

 γ -sensitivity:

$< 40 \mu\text{Sv/h}$ in 10 mSv/h, ^{137}Cs gamma-field

Temperature range:

-10°C to 50°C

Moderator

External diameter:

250 mm

Material:

Low pressure polyethylene with 2% carbon additive

Density:

0.95 g/cm^3

Weight:

9.2 kg

Resistance to aggressive materials:

PE is resistant to diluted acids, lyes and salt solutions.
Below 60°C , PE is insoluble in most solvents.
PE is not resistant to strong oxidation agents.

Resistance to direct sun exposure:

PE becomes brittle when exposed to direct sun light.
This can be avoided by adding carbon.

Counter Tube LB 6410

External dimensions:

$\varnothing 40 \text{ mm} \times 100 \text{ mm}$

Material counter tube housing:

stainless steel 1 mm

Active length:

$\approx 40 \text{ mm}$

Active volume:

$\approx 45 \text{ cm}^2$

Counting gas:

^3He /Methane

Filling volume:

^3He 60 μg (not subject to any export or import restrictions)

Operating voltage:

2700 Volt

Detection efficiency for thermal neutrons:

approx. 90%

Background:

$< 0.02 \text{ cps}$

Dead-time:

5 μs

LB 6411-Pb for High Energies

For high energy applications at several hundred MeV or even higher there is a special version with an external layer of 10 mm lead available. The response to high energy neutrons is enhanced by utilizing spallation neutrons, which are generated in the lead.

References and Patents:

The neutron fluence and $H^*(10)$ response of the new LB 6411 remcounter

B. Burghardt, G. Fieg, A. Klett, A. Plewnia and B.R.L. Siebert

Radiation Protection Dosimetry, Vol. 70, Nos. 1-4, pp. 361-364, 1997

The new Remcounter LB 6411: Measurement of neutron ambient dose equivalent $H^*(10)$ according to ICRP60 with high sensitivity

A. Klett, and B. Burghardt,

IEEE Transactions on Nuclear Science, Vol. 44, No. 3, June 1997

German Patent 19627264 granted Oct-23-1997

German Patent 4344955 granted Feb-16-1995

