2024 inac INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE
XXIII ENFIR XVI ENAN VIII ENIN X JR. POSTER XI ExpoINAC
Nuclear Energy:
Assuring Energy, Health and Food
May 06 - 10, 2024
Escola de Guerra Naval (EGN) | Rio de Janeiro - RJ

# Technical Protocol for Proficiency Test for Calibration of Ambient Dose Equivalent (Rate) Meters in ISO Neutron Reference Fields

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## 1. Introduction

The use of radiation must be justified, optimized and limited. Applications with neutrons cover areas such as the energy sector with fission reactor, oil prospecting, among other areas. All the equipment must be calibrated for proper use. Therefore, the calibration of neutron survey meters is mandatory according to CNEN NN 3.01 [1].

The Neutron Metrology Laboratory (LN), created in 1973, is one of the research laboratories of the National Ionizing Radiation Metrology Laboratory (LNMRI) of the Institute of Radioprotection and Dosimetry (IRD). LN is the only Primary Reference Laboratory in Latin America in the area of neutron metrology, being responsible for the custody and maintenance of the Brazilian Neutron Fluency Standard, and for realizing the neutron fluence magnitude. In carrying out its institutional mission, it develops research in the areas of metrology and neutron dosimetry, also promoting the dissemination of operational quantities (ambient dose equivalent and individual dose equivalent) for neutron measuring instruments used by industries, research centers and universities nationally and internationally, ensuring their traceability.

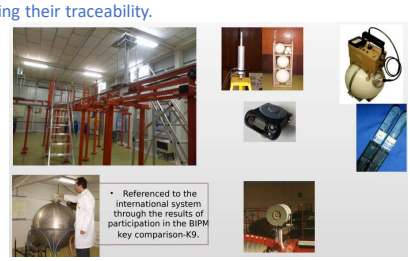


Figure 1: Areas of actuation of Neutron Metrology Laboratory

In this context, LN is committed to regularly participating in key comparisons organized by BIPM in order to maintain its traceability.

In contrast, it is also requested to promote proficiency testing through interlaboratorial comparisons with Secondary Standard Dosimetry Laboratories (SSDLs), in order to evaluate the participating laboratory's ability to irradiate passive dosimeters and calibrate survey meters. This demand was reinforced in 2018, due to the CNEN edital 01/2018 - UASG 113204 that established the conditions to the technology transfer to other institutions of the process related to irradiation of passive dosimeters and calibration of survey meters with neutron field.

## 2. Methodology

This proficiency test proposed by LN is aimed at laboratories that perform calibration of ambient dose equivalent (rate) meters in ISO neutron reference fields in accordance with ABNT NBR ISO 8529 standards [2] and follows the ABNT NBR ISO/IEC 17043:2011 directives [3].
For that, two different LN/LNMRI transfer instruments are circulated among the participants in a sequential scheme. At the beginning, it is determined their reference values of the calibration factor (Nref) and after each participants measurement, they returning to LN for stabilities checks using the same source and the same set up in order to guarantee the repeatability of the measurement conditions.


Figure 2: (A) Ludlun Model 2363 with 42-41L detector, (B) Thermo Cientific FH40G-L / FHT 752

Participants must determine the calibration factor (Ni) of the transfer instruments in terms of ambient dose equivalent rate, at least for 3 (three) rates of the measuring range: 50 uSv/h, 500 uSv/h and 5000 uSv/h, to the spectrum chosen by the laboratory.

The calibration factor "N" is calculated through the ratio between the reference value of the quantity and the value read by the instrument, both values corrected for all applicable factors (anisotropy, geometric factor, attenuation in air, scattering, etc.). The calibration factor is equivalent to the inverse of the equipment response, when the response is determined under reference conditions. The calibration factor is the factor by which the meter reading is multiplied to obtain the actual measured value of the quantity [4].
The neutron fields (spectra) available for the proficiency test are specified below.

Table: 1 – Moderated sources

| Spectrum | Source strength | Moderator | | | |
|---|---|---|---|---|---|
| | | Diameter (mm) | Height (mm) | Geometry | Thickness of Cd shell. |
| Cf252(D2O) | 120.7 ug | 300 cm | - | spherical | 0.5 mm |

Table: 2 - "Bare" neutron sources

| Spectrum | Source strength | Anisotropy | | Source of traceability | Size (mm) Diameter x height | Geometry |
|---|---|---|---|---|---|---|
| | | Factor | uA(%) | | | |
| Am241-Be9 | 185 GBq | 1.0164 | 0.2 | (Long Counter) | 35 x 35 | cylindrical |
| Cf252 | 120.7 µg | 1.0107 | 0.14 | (BSM) | 5,53 x 11.94 | cylindrical |
| Pu238-Be9 | 1850 GBq | 1.0351 | 0.10 | (BSM) | 57.7 x 10.7 | cylindrical |
| Am241-B | 3.7 GBq | - | - | (BSM) | 17.4 x 19.4 | cylindrical |

The neutron fields proposed in this document are included in the LNMRI Measurement and Calibration Capability (CMC) lines registered with the Bureau International des Poids et Mesures (BIPM), available at https://www.bipm.org/kcdb/cmc/quick-search.

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## 3. Statistical analysis of results

Normalizing the measured values to the LN/LNMRI reference value, we have that xi = Ni/Nref and xref = 1, where:
The deviation (Di) between the normalized value measured by the participating laboratory (xi) and the normalized LN/LNMRI reference value (xref) is defined by Equation 1 [5]:

$$D_i = x_i - x_{ref} = x_i - 1 \qquad (1)$$

Therefore, the normalized error can be written as follows:

$$E = \frac{D_i}{\sqrt{((u_{x_i})\text{^}2+(u_{x_{ref}})\text{^}2)}} \qquad (2)$$

Interpretation of E value:
The closer the "E" value gets to zero, the better the performance achieved by the participating laboratory.
For |E| >2 the result is "Out of Control".
For 1< |E| < 2 the result is considered "Acceptable", but a warning remains.
For |E| ≤ 1 the result is considered "Good".

## 4. Final evaluation of the proficiency test

Each participating laboratory will receive a Test Report containing its performance evaluation. In the final report, all results from participating laboratories will be presented in coded form.

## Reference

[1] Dadalt M. Lucas, Caracterização dosimétrica de laboratório de calibração de detectors de neutrons utilizando Monte Carlo, 2021, USP
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[5] G. Ratel, Evaluation of the uncertainty of the degree of equivalence, Metrologia 42 140-144 (2005).

ISBN: 978-65-594-1256-3