Comite Consultatif pour les Rayonnements Ionisants (CCRI)
Consultative Committee for Ionizing Radiation
Mesures Neutroniques (Section III)
Neutron Measurements

PROTOCOL FOR THE CCRI(III)-K11 COMPARISON OF NEUTRON FLUENCE MEASUREMENTS IN MONOENERGETIC NEUTRON FIELDS

Introduction

In the past, Section III of the CCRI regularly organized comparisons of neutron fluence measurements in the monoenergetic neutron fields recommended by ISO [1] used for the determination of the energy-dependent response of neutron sensitive devices. The last comparison of neutron fluence in monoenergetic neutron fields (CCRI(III)-K10) was performed at the PTB in 2001 and was published in 2007 [2]. During the period from 1993 to 1996, the CCRI(III)-K1 comparison was conducted for fluence measurements of 24.5 keV neutrons. A publication of the agreed results was published in *Metrologia* in 2010 [3].

Since CCRI key comparisons should be repeated at least every ten years, a comparison of fluence measurements of neutrons at about 24 keV and comparisons in the energy range from a few hundred of keV up to about 20 MeV are urgently needed.

The aim of this exercise is to compare measurements of the fluence of monoenergetic neutrons with energies of 27.4 keV, 565 keV, 2.5 MeV and 17 MeV.
The energy 27.4 keV is preferred to 24 keV as it allows the use of the ^{45}Sc(p,n) reaction at 0°. The 565 keV, 2.5 MeV and 17 MeV proposals are complementary energies to those in the K10 comparison. Despite not being an ISO recommended neutron energy, 17 MeV seems a better and easier choice than 19 MeV for reference fluence measurements following the results of the EUROMET.RI(III)-S2 comparison (to be published soon).

This protocol is similar to that of the CCRI(III)-K10 comparison. All measurements will be performed in the same neutron fields, this time produced at the LNE-IRSN facility named AMANDE. The participating laboratories (see Appendix 1) will use their primary (or calibrated secondary transfer) instruments which are specified for the determination of neutron fluences and which are (or are at least traceable to) their national standards.

The comparison will be coordinated by the LNE-IRSN as the hosting laboratory.
The results obtained by the participants will be reported to the evaluator appointed for the comparison, who in turn will compile a report with all the results for circulation

to the participants and for discussion at the Section III meeting following that held in 2011. Assuming approval of the results by the members of Section III, the final report of the results will be submitted to *Metrologia* for publication. In addition, the results will be sent to BIPM for inclusion in of the KCDB of the CIPM MRA.

The Monoenergetic Neutron Fields

The desired monoenergetic neutrons will be produced in the low-scatter experimental hall of the AMANDE facility using a 2 MV Tandetron accelerator and the following reactions:

^{45}Sc(p,n)^{45}Ti for 27.4 keV neutrons at 0 deg.
^{7}Li(p,n) ^{7}Be for 565 keV neutrons at 0 deg.
T (p,n) ^{3}He for 2.5 MeV neutrons at 0 deg.
T (d,n) ^{4}He for 17 MeV neutrons at 0 deg.

The neutron production is monitored by time, beam charge and count rates of two neutron monitors located at 17° and 103° respectively with respect to the ion beam direction. Since the measurements will be performed in open geometry the monitor rates must be corrected for inscattering from the systems positioned in the field, i.e. shadow cones and instruments of the participants. For this purpose ”free field“ measurements must be carried out regularly.

Quantity to be measured by the participants

The participants shall determine the fluence Φ of the desired monoenergetic neutrons at 1 m distance to the target in vacuum corresponding to the counts of the most suitable monitor.
The neutron fluence determined by the participant at a certain distance in air must be corrected for:

- room-return neutrons, i.e. neutrons scattered into the detector from air, floor, ceiling walls and structures within the experimental hall. This correction is generally determined by additional measurements with shadow cones and/or by distance variation methods (if necessary at all).
- flux attenuation in air due to out-scattering and absorption, and
- target scattered neutrons as calculated (see reports of the hosting laboratory).

Quantity to be evaluated

The neutron fluence Φ at 0 deg. and 1 m distance (in vacuum) will be related to the corrected counts M_c of the monitor best suited for the particular neutron field investigated. The measured monitor counts will be corrected for inscattering from the systems positioned in the field. The corrected monitor counts and the associated uncertainties will be provided by the hosting laboratory.

The key comparison reference value $C_r(E_n)$ will be determined as the weighted mean of the reciprocal calibration factor C_m defined as the ratio of the corrected monitor counts M_c and the neutron fluence in vacuum Φ, i.e $C_m = M_c / \Phi$, and may be used to calculate the degree of equivalence for each participating laboratory.

Duties

Deliveries of the hosting laboratory

The LNE-IRSN as the hosting laboratory has to deliver a report comprising:
- a characterization of the neutron producing reactions, i.e. projectile and target parameters and their estimated uncertainties;
- relative energy distributions of the undisturbed direct and the target-scattered neutrons as calculated with a coupling between two codes: TARGET [4] (neutron emission) and MCNP [5] (neutron transport);
- a set of monitor rates corrected for inscattering from shadow cones and instruments as far as this is significant, i.e. > 0.5% contribution.

Deliveries of the participating laboratories

The laboratories participating in the comparison exercise must send a final report to the evaluator comprising:
- a description of the primary (or secondary transfer) instruments employed in the framework of this comparison including the procedure used to determine the energy dependent response by calculation and/or experimental calibration, e.g. against primary standards of the laboratory, and the corresponding uncertainties;
- description of the measurements and the analysis procedure including all corrections required to determine the fluence of the desired monoenergetic neutrons at 1 m distance to the target in vacuum and the corresponding uncertainties;
- calculation of the calibration factor for the recommended monitor and the complete uncertainty budget according to GUM [6] recommendations (one standard deviation, i.e. $k = 1$)

As a participating laboratory, the hosting laboratory will perform measurements during the entire comparison period (one per week), to prevent any unexpected variation from one measurement group to another.

Deliveries of the evaluator

On the basis of the results obtained by the laboratories and compiled in their reports, the evaluator will calculate the key comparison reference value for each neutron field as a weighted mean value.

The evaluator will compile a report for circulation to all participants for comments and for discussion of the results. This or a revised report will then be discussed at the

next CCRI(III) meeting. Provided the members of Section III of CCRI approve the evaluated results, a final report will be prepared for publication in *Metrologia*.

Excel tables with the results obtained by the participants and their associated uncertainty budgets, and the evaluated key comparison reference values with their uncertainties, and the evaluated degrees of equivalence will also be submitted to the BIPM for inclusion in the KCDB of the CIPM MRA.

Time-Table

The intention is to conduct, analyse and evaluate this comparison exercise within 12 months.

1. 05/09/2011 – 21/10/2011: measurements at the AMANDE facility, Cadarache (south of France), in four to five groups:
   05-09/09/2011: LNE-IRSN + 2 participants
   12-16/09/2011: LNE-IRSN + 2 participants
   19-23/09/2011: LNE-IRSN + 2 participants
   26-30/09/2011: LNE-IRSN + 2 participants
   03-07/10/2011: extra week for unexpected problems or additional participants
   10-14/10/2011: extra week for unexpected problems or additional participants
   17-21/10/2011: extra week for unexpected problems or additional participants

2. 31 December 2011: report of the LNE-IRSN comprising the field parameters and the tables of corrected monitor rates required for the analysis

3. 31 March 2012: final reports of the participants, approved by their institutions, at the disposal of the evaluator
   (note: the reports will be requested once the LNE-IRSN report has been sent to the BIPM)

4. 30 June 2012: compilation of the results submitted by the participants and the evaluated key comparison reference values to be circulated to the participants for comments and approval

5. 31 October 2012: final report of the evaluator sent to all members of CCRI (III) for discussion and approval.

6. April 2013: next meeting of CCRI(III)

References

[1] ISO-standard 8529- part 1 (2001)
ISO-standard 8529- part 2 (2000)
ISO-standard 8529- part 3 (1998)

[2] J Chen et al, *International key comparison of neutron fluence measurements in mono-energetic neutron fields: CCRI(III)-K10* 2007 *Metrologia* **44** 06005

[3] D J Thomas et al, *International key comparison of 24 keV neutron fluence measurements (1993–2009): CCRI(III)-K1*, 2010 *Metrologia* **47** 06014

[4] D. Schlegel, *TARGET User's Manual*, Laboratory Report PTB-6.41-1998-1

[5] Denise B. Pelowitz, ed., *MCNPX User's Manual, Version 2.6.0*, Los Alamos National Laboratory Report, LA-CP-07-1473 (November 2007),

[6] GUM: *Guide to the expression of Uncertainties in Measurements,* International Standards Organization (ISO), Geneva, 1995

Appendix 1a: Participating laboratories and their contact persons

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