Measurement of the neutron emission rate of an Am-Be(α,n) source AMN-1000-1096 according to the intercomparison program.

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In accordance with the program of Section III of BIPM on carrying out the international comparisons of the national standards of neutron flux units, the neutron source strength was measured in the Laboratory of Neutron Measurements of VNIIM on October 16-30, 2000.

During 1999-2000, for the purpose of preparation to the International comparisons, internal comparisons of the facilities were carried out. The facilities realized different methods of neutron flux measurements: the ***Mn***-bath method, the method of activation of Au foils in water, the method of registration of associated particles /1/. All necessary corrections and constants were determined. The distribution of thermal neutrons in a graphite comparator used in the method of registration of associated particles, was measured using gold active detectors.

To confirm the correctness of the neutron flux measurements by different methods, the neutron fluxes of four radionuclide sources of different composition were measured. The results are summarized in Table 1.

Method	***Ra-Be(γ,n)***	^{252}***Cf***	***Ra-Be(α,n)***	***Pu-Be(α,n)***
Associated particle	$2.87 \cdot 10^5$	$1.119 \cdot 10^7$	$1.083 \cdot 10^6$	$1.540 \cdot 10^7$
Mn-bath	$2.87 \cdot 10^5$	$1.120 \cdot 10^7$	$1.086 \cdot 10^6$	$1.539 \cdot 10^7$
Au foils		$1.118 \cdot 10^7$	$1.078 \cdot 10^6$	$1.533 \cdot 10^7$

Table 1. Results of the comparison of the VNIIM facilities for neutron flux measurements.

The lower limit of the range of the gold foils activation method did not let us make measurements of ***Ra-Be(γ,n)*** source by this method. Nevertheless, the obtained results confirmed the reliability of the VNIIM neutron flux measurements. Due to strong time restrictions, the neutron flux of the ***AMN-1000-1096*** source was measured using only two methods, as the method of activation of gold foils would take a long time.

1. The Mn-bath method.

The value of the full flux of fast neutrons is calculated by the following equation:

$$\Phi = k_1 k_2 \frac{N_o F}{e}(1+l)(1+m)(1+\chi)$$

where

k_1 is the correction on adsorption of the thermal neutrons by impurities;

k_2 is the correction on adsorption of the thermal and fast neutrons by nucleus of the constraction materials;

l is the correction on the neutrons leakage from the moderator;

m is the correction on self-annihilation of the neutrons in the source material;

χ is the correction on the capture of the fast neutrons by S and O_2 nucleus;

$N_?$ is the relative calculation rate;

e is the parameter of the facilities, which is conventionally called as the effectiveness of registration of radioactive ***Mn-56*** by scintillation detector;

F is the a coefficient for the part of thermal neutrons captured by ***Mn*** nuclei in a ***$MnSO_4$*** solution

$$F = 1 + \frac{1}{1+a}\frac{S_S}{S_{Mn}} + \frac{1}{1+a}\frac{S_H}{S_{Mn}}\frac{n_H}{n_{Mn}}$$

where S_{Mn}, S_S, S_H are the thermal cross-sections of manganese, sulphur and hydrogen;

n_{Mn}, n_S, n_H are the quantities of ***Mn, S, H*** nucleus in 1 cm^3 of the solution.

a is the correction for capture of epithermal neutrons by manganese.

The values of the above corrections and constants were determined in the course of preparation to the comparisons.

Two circles of measurements were carried out using the Mn-bath method. Two values of N_o were obtained, that were ***1530.6±0.76*** and ***1530.9±0.74*** respectively.

The components of the measurements uncertainty are shown in Table 1.

Influencing factors	Contribution to the combined uncertainty, %
N_o	0.02
F	0.4
e	0.3
k_1	0.03
k_2	0.02
l	0.12
m	0.03
χ	0.04
Combined uncertainty	1.02

Table 1. The components of the uncertainty for the Mn-bath method.

The combined uncertainty was calculated according to /2/ for the probability of 95%. It was assumed that the uncertainty components were not correlated. The equation for the calculation is :

$$S = 1.960\sqrt{\sum_{i=1}^{5} S_i^2}$$

2. The method of registration of associated particles

The neutron flux F can be determined by means of an all-wave graphite comparator relative to the neutron flux F_0 from the ***$T(d,n)^4He$*** - reaction. F_0 is measured by the method of registration o associated particles. The equation for calculation of the flux is the following:

$$? = ?_? \frac{S}{S_o}\frac{K_{(n,a)}}{K_{?(n,a)}}$$

$S = \int_{a_1}^{a_2} N(r) r^2 dr$ is the area under the curve of thermal neutrons distribution in a graphite sphere with the diameter $2a_2$ = 4m, with a spherical central cavity with the diameter $2a_1$ = 0.4 m, in which the sources are placed.

N(r) is the counting rate of a thermal neutron detector placed at the distance ***r*** from the center.

? ? is the neutron flux from the ***T(d,n)^4He*** -reaction, determined by the method of registration of associated α-particles

? (n,a) is the coefficient for the neutron loss in the graphite from *(n,a)*-reaction. The coefficients *? (n,a)* were determined from the experiments and were calculated by Monte-Carlo method. *? (n,a)* = 1.020 for the ***Am-Be(a,n)*** source, *? (n,a)* = 1.164 for the neutrons from the ***T(d,n)^4He*** -reaction

The contribution of epi-thermal neutrons, when calculating the distribution function *N(r),* was determined by the *Cd* - difference method.

The uncertainty components are given in Table 2

Influencing factors	Contribution to the combined uncertainty, %
? ? – neutron flux from the reaction ***T(d,n)^4He***	0.5
***S/S_o* - ratio**	0.05
? (n,a) for the ***Am-Be(a,n)*** source	0.25
? (n,a) for neutrons from the reaction ***T(d,n)^4He***	0.25
Combined uncertainty	1.20

Table 2. The components of the uncertainty for associated particles Mn-bath method.

The combined uncertainty was calculated according to /2/ for 95% probability. It was assumed that the components of the uncertainty were not correlated. The equation for the calculation is :

$$S = 1.960\sqrt{\sum_{i=1}^{5} S_i^2}$$

We can't present here the final result because the intercomparison has not been finished yet, all the results will be the presented by intercomparison's coordinator. However, we can say, that the results obtained by both of methods, differed by no more, than on 0.3 %, and the final result VNIIM in the final protocol will be given with an uncertainty less than 1 %.

3. Determination of the radiation asymmetry

This procedure was not obligatory for performance of the comparison. Therefore wedon't think it will be unethical, if we present not only the description of measurement procedure, but its result in a graphic manner.

The angle asymmetry of the radiation was determined by means of an all-wave neutron radiometer of a "long counter" type according to the following procedure:

- The source is placed on a thin rotating rod so that its axis go showd along the direction to the detector, and the geometrical center of the source should coincide with the rotating axis of the rod.

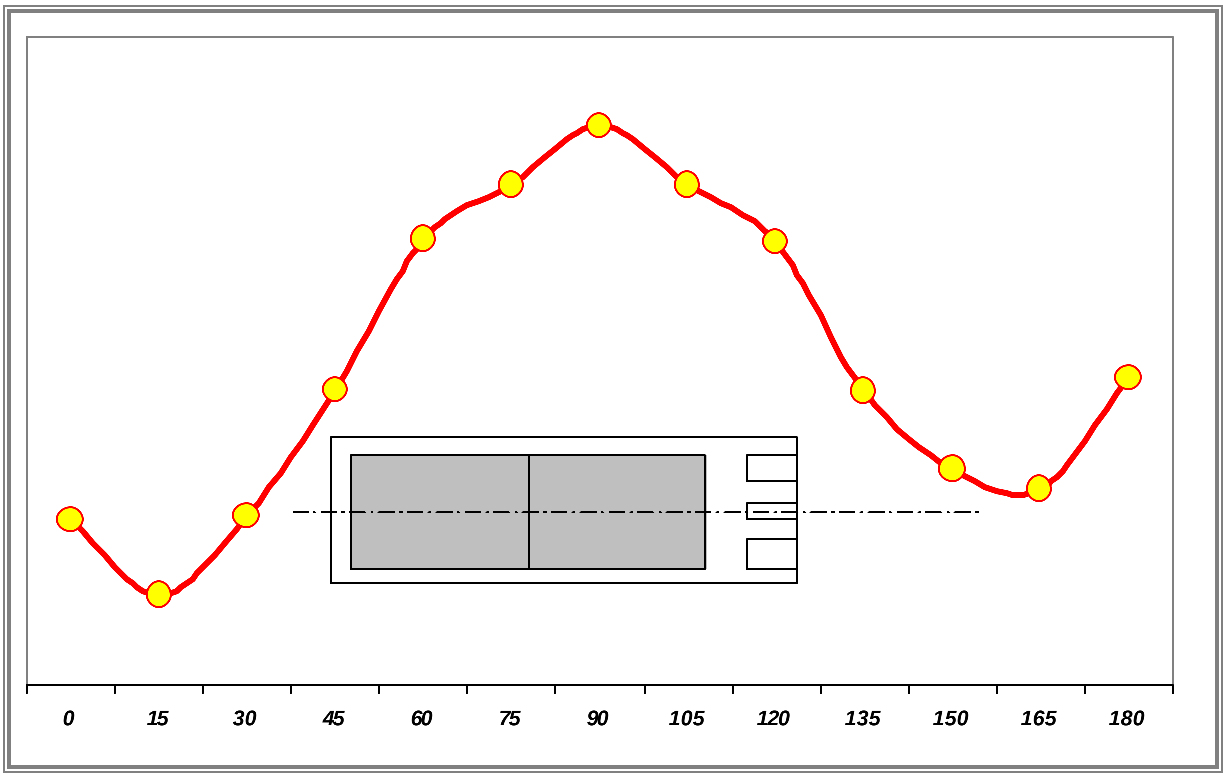
- The source is set at the distance of 1.5 m from the front surface of the detector at the position *J* = ***0°***. ***0°*** is the position in which the front of the source with a serial number faces the detector.
- The counting rate of the detector, ***N(0°)***, is measured. The duration of measurements is chosen so, that the total number of the measured impulses should be not less than 5 $10^{5.}$
- A shadow cone made of boron polyethylene, 50cm high, is placed between the source and the detector. The counting rate ***N?(0°)*** is measured.
- The following difference is calculated:

  *D**N(0°)*** = ***N(0°)*** - ***N?(0°)***.
- The source is rotated by the angle *D J* = ***15°***, then the value *D**N(15°)*** is calculated.
- The later operation is repeated until the value *J* = ***180°*** is reached, the value *D**N(J i)*** being calculated each time.
- The vakue *D**N(J i)*** is calculated by the formula

$$\overline{\Delta N(J_i)} = \frac{1}{4}[\Delta N(0°) + \Delta N(180°)](1 - \cos\Delta J) + \frac{1}{2}\sin\Delta J \sum_{i=2}^{n-1} \Delta N(J_i)\sin J_i$$

- The coefficient of the radiation asymmetry ***K(J i)*** is calculated by the formula

$$K(J_i) = \frac{\Delta N(J_i)}{\overline{\Delta N(J_i)}}$$



R E F E R E N C E S

1. CCRI(III)/99-8
2. "*Guide to the expression of uncertainty in measurement*" (ISO/TAG 4/WG 3: June 1992)