Comparison for Air Kerma from Radiation Protection Gamma-ray Beams with Brazilian Network - 2016/2017

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Abstract. The results of the comparison involving 9 laboratories in Brazil are reported. The measured quantity was the air kerma in ^{137}Cs and ^{60}Co, at the level of radioprotection. The comparison was conducted by the National Laboratory Metrology of Ionizing Radiation (LNMRI/IRD) from October 2016 to March 2017. The largest deviation between the calibration coefficients was 0.8% for ^{137}Cs and 0.7% for ^{60}Co. This proficiency exercise proved the technical capacity of the Brazilian calibration network in radiation monitors and the results were used by some in the implementation of the standard ISO/IEC 17025.

1. Introduction

One of the activities inherent in calibration laboratories is the periodic participation in Comparison programs where, among others, it is possible to assess the ability of the qualified technician to carry out a calibration service, in accordance with instructions laid down in procedures documented in appropriate environmental conditions and under control, getting a result consistent with the measurement accreditation as stated by the labs Participation in exercises of this nature, proficiency testing, is one of the requirements of norm ABNT ISO/IEC 17025 BR.

The use of calibrated instruments for the purposes of radiological protection is a requirement that ensures the safe use of the various areas in which we work with ionizing radiation. These calibrations should be made based on measurement standards and following written procedures. The National Laboratory Metrology of Ionizing Radiation (LNMRI/IRD/CNEN) organized and conducted this

comparison exercise from October 2016 to March 2017. The protocol was structured according to the ISO 17043.

The quantity compared is the calibration coefficient in air kerma in ^{137}Cs and ^{60} Co beams. Nine laboratories participated in the comparison exercise. These exercises are important for increasing confidence in the ability of the results of measurements carried out by the Brazilian network of radiation monitors calibration laboratories.

1.1. Participating Laboratories.

- Laboratório de Calibração de Monitores de Radiação – LCMR/LNMRI/IRD
- Instituto de Pesquisas Energéticas e Nucleares - IPEN
- Centro de Desenvolvimento de Tecnologia Nuclear- CDTN
- Centro Tecnológico do Exercito - CTEx
- Departamento de Energia Nuclear da UFPE - DEN/UFPe
- Laboratório de Ciências Radiológicas da UERJ - LCR/UERJ
- Eletronuclear – Eletrobrás Termonuclear S.A.
- MRA Comércio de Instrumentos Eletrônicos Ltda.
- Centro Regional de Ciências Nucleares do Nordeste – CRCN

The Calibration Laboratory of Radiation Monitors LNMRI/IRD determined the calibration factor reference. It been the mean of the calibrations performed during the exercise.

2. Objective

The purpose of the comparison exercise was:

a) Calculate the coefficient of calibration in air kerma and compares them;

b) Determine the performance of the calibration of the qualities S-Cs and S-Co in terms of air kerma of participating laboratories;

c) Identify problems and propose corrective action.

2.1. Instrument Submitted For Comparison - The Transfer Chamber

The ionization chamber PTW LS01 was used as the transfer chamber is spherical graphite walls. Just as the chamber was sent, the laboratories were instructed to make their own measurements as their usual procedures.

The main features of the transfer chamber are:

Manufacturer: PTW
Model: TN32002
Type: Ionization chamber
Series Number: 490
Sensitive volume: 1,000 cm^3
Outside diameter: 140 mm
Electrode diameter: 50 mm
Wall thickness: 3 mm
Potential of high voltage electrode: - 400 V

3. Determination of the calibration factor

Comparison for air kerma was performed indirectly by comparing the calibration coefficients in air kerma the transfer chamber, N_k. The calibration coefficient is determined using the expression:

$$N_k = \frac{\dot{K}_a}{\overline{\left(\frac{M}{t}\right)}.\Phi(T,P).f^e.3600} \quad [Gy/C] \tag{1}$$

Where:

N_k is the factor of chamber calibration in terms of air kerma (Gy /C).

$\dot{K}_a$ is the rate of air kerma measured with a standard chamber

$\overline{\left(\frac{M}{t}\right)}$ is the average reading of the chamber you want to calibrate divided by time;

ϕ(T,P) is the correction factor for temperature and pressure;

f^e is the calibration factor of the electrometer.

The LNMRI used the standard chamber to determinate the reference value of the calibration coefficient, $N_{k,LNMRI}$ against which the results of the measurements of the calibration factor by participants, $N_{k,part}$, were compared. The $N_{k,LNMRI}$ in air kerma was determined with a standard chamber LS01 model TM32002 serial number 104 calibrated in June 2013 at the Physikalisch-Technische Bundesanstalt (PTB).

The calibration coefficient for the transfer chamber was provided in terms of air kerma, in units of Gy /C in referenced standard conditions of temperature, pressure and relative humidity at T = 293.15 K, P = 101.325 kPa h = 65%. Participants did not apply any correction for ion recombination and the relative humidity should be between 30% and 75% during calibration, followed the normal routine of the laboratory with respect to the operator and the equipment used.

4. The standard ionization chambers used

Participated in the comparison exercise seven ionization chambers, as shown in Table 1 All chambers are reference standards calibrated to the energies of ^{60}Co and ^{137}Cs.

Table 1. The standard ionization chambers used by the participating laboratories and by LNMRI.

Laboratories	Standard ionization chambers
LNMRI	PTW TN32002#104
LCR/UERJ	PTW N23361#2923
LCR/UERJ	PTW TN32002#489
ETN	PTW N32002#86
MRA	PTW 32002#309
IPEN	PTW W32002#25
DEN/UFPE	NE 2575#526
DEN/UFPE	PTW TW32002#550
CRCN	NE 2575#518
CDTN	PTW TN32002#382
CTEx	PTW TW32002#527

5. Transfer chamber calibration

The transfer chamber circled among the LNMRI and participants through the planning done by LNMRI together with laboratories. The LNMRI calibrated the transfer chamber to verify the performance, before sending it to the next participating laboratory. Control measures were obtained by LNMRI thus proving the proper functioning of the transfer chamber.

The following terms of reference were recommended:

1 Distance source - Chamber: 200 cm.

2 Operating Voltage: - 400 V.

No deviations from these conditions were reported.

Leakage currents of measurement systems, composed of electrometer and chamber were measured in accordance with the procedures of each laboratory.

The percentage deviation for the calibration coefficient in terms of air kerma, and LNMRI between the participating laboratories should be equal to or less than 2.0%.

6. Results

6.1. Physical quantity to be measured

The quantity chosen to be measured for comparison was the air kerma (K_{ar}), since all the chambers were calibrated in this quantity. The value of air kerma, K_{AR}, was determined for the irradiation conditions with the transfer chamber in each participating laboratory.

The Calibration coefficients of the transfer chamber, N_k obtained by participating laboratories and by the LNMRI are in Table 2 along with their respective uncertainties expanded standard.

Table 2. The calibration coefficient and uncertainties determined by the participating laboratories.

Laboratories	**Calibration Factor N_k ± U (%)**	**Calibration Factor N_k ± U (%)**	**Quantity/Unity**
	Cs-137	**Co-60**	
LNMRI	2,486E+04 ± 2,7%	2,436E+04 ± 2,6%	K_{ar} /Gy.C^{-1}
LCR/UERJ	2,488E+04 ± 4,7%		K_{ar} / Gy.C^{-1}
LCR/UERJ	2,460E+04 ± 4,7%		K_{ar} / Gy.C^{-1}
ETN	2,516E+04 ± 5,1%		K_{ar} / Gy.C^{-1}
MRA	2,504E+04 ± 2,7%	2,458E+04 ± 2,7%	K_{ar} / Gy.C^{-1}
IPEN	2,523E+04 ± 3,7%	2,426E+04 ± 4,2%	K_{ar} / Gy.C^{-1}
DEN/UFPE	2,468E+04 ± 3,4%	2,409E+04 ± 4,6%	K_{ar} / Gy.C^{-1}
DEN/UFPE	2,481E+04 ± 3,4%	2,438E+04 ± 4,6%	K_{ar} / Gy.C^{-1}
CRCN	2,470E+04 ± 2,0%		K_{ar} / Gy.C^{-1}
CDTN	2,470E+04 ± 5,5%		K_{ar} / Gy.C^{-1}
CTEx	2,463E+04 ± 3,0%	2,415E+04 ± 2,8%	K_{ar} / Gy.C^{-1}

OBS: LNMRI – reference

In Figure 1, we can see the values determined for the calibration coefficient of the LNMRI and by the participating laboratories. Error bars are the values of the standard expanded uncertainties submitted by the laboratories.

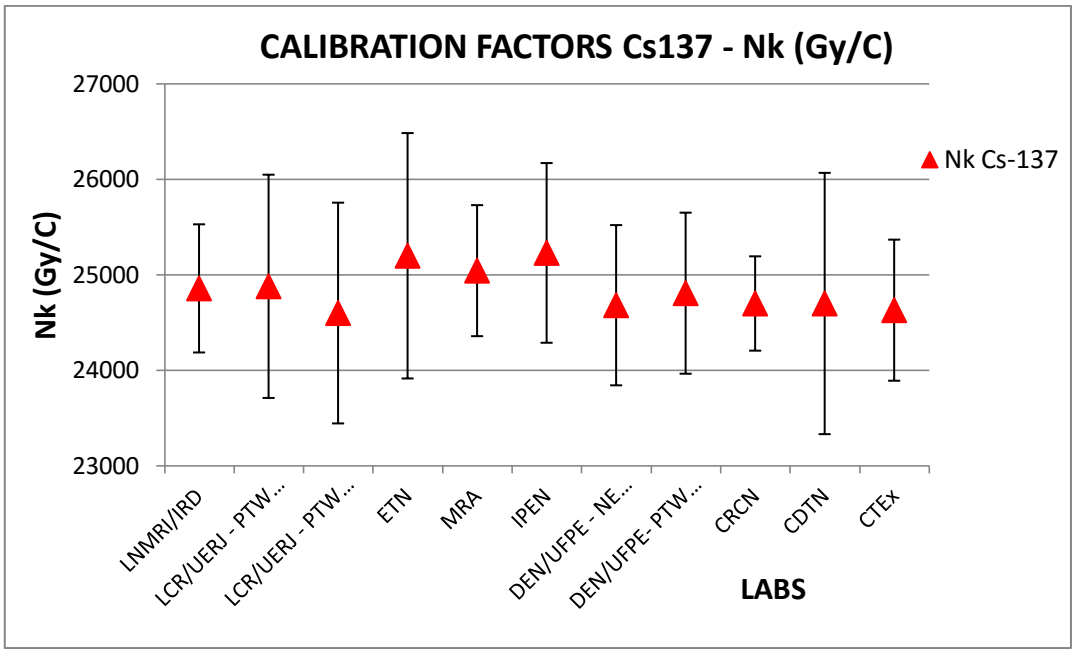

Figure 1. Calibration Factors determined for the transfer chamber by LNMRI and participating laboratories for quality S-Cs

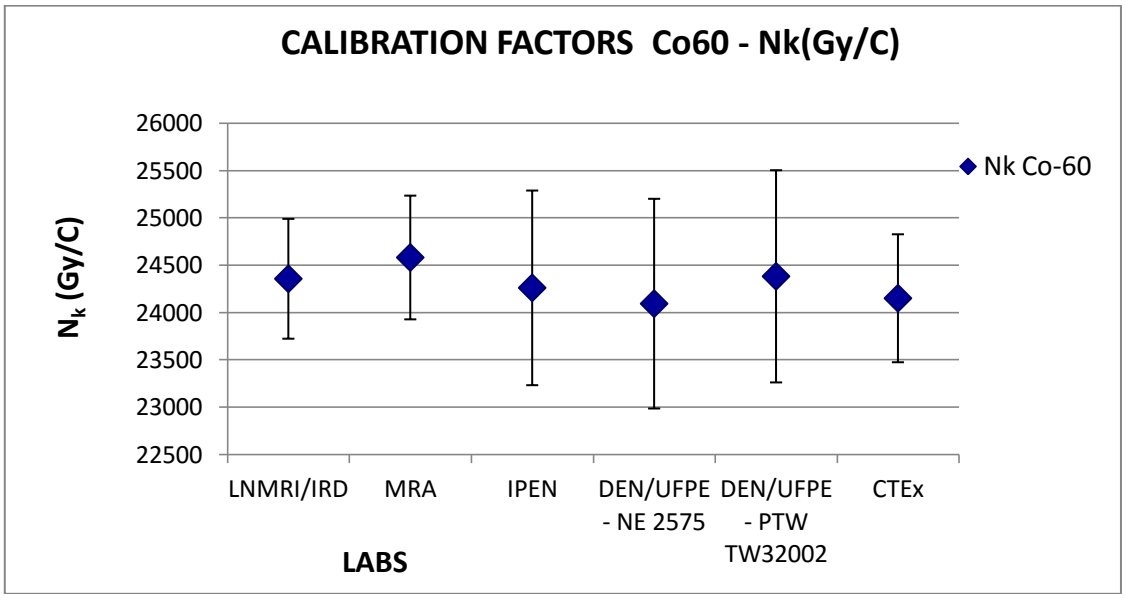

Figure 2. Calibration Factors determined for the transfer chamber by LNMRI and participating laboratories for quality S-Co.

6.2. Normalized response - $N_{k,part}/N_{k,\ LNMRI}$.

All values were normalized to the value of the calibration coefficient in air kerma obtained by LNMRI; the values can be seen in Table 3 and Figure 3 and 4.

Table 3. Resposta normalizada - $N_{k,part}/N_{k,LNMRI}$.

Laboratories	Normalized response $R=N_{k,PART}/N_{k,LNMRI}$	
	Cs-137	Co-60
LNMRI	1,0	1,0
LCR/UERJ - PTW TN32002	0,990	
LCR/UERJ – PTW N23361	1,001	
ETN	1,012	
MRA	1,007	1,009
IPEN	1,015	0,996
DEN/UFPE – PTW TW32002	0,998	1,001
DEN/UFPE – NE 2575	0,993	0,989
CRCN	0,994	
CDTN	0,994	
CTEx	0,991	0,992

The standard deviation between the calibration coefficients is 0.8% for S-Cs quality and 0,7% for S-Co quality. The results are considered to be acceptable for the purpose of this comparison if the expanded uncertainty of the ratio $N_{k,part}/N_{k,LNMRI}$ covers the reference value and $0.98 \leq R \leq 1.02$.

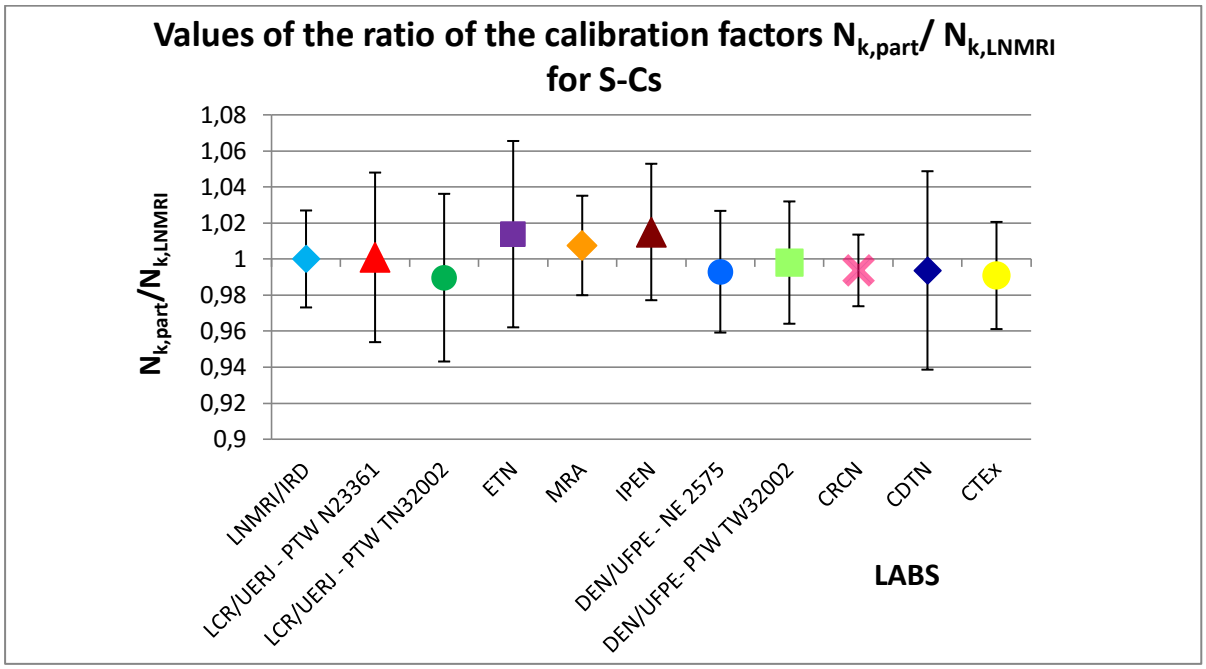

Figure 3. Values of the ratio of the calibration factors $N_{k,part}/ N_{k,LNMRI}$ for S-Cs.

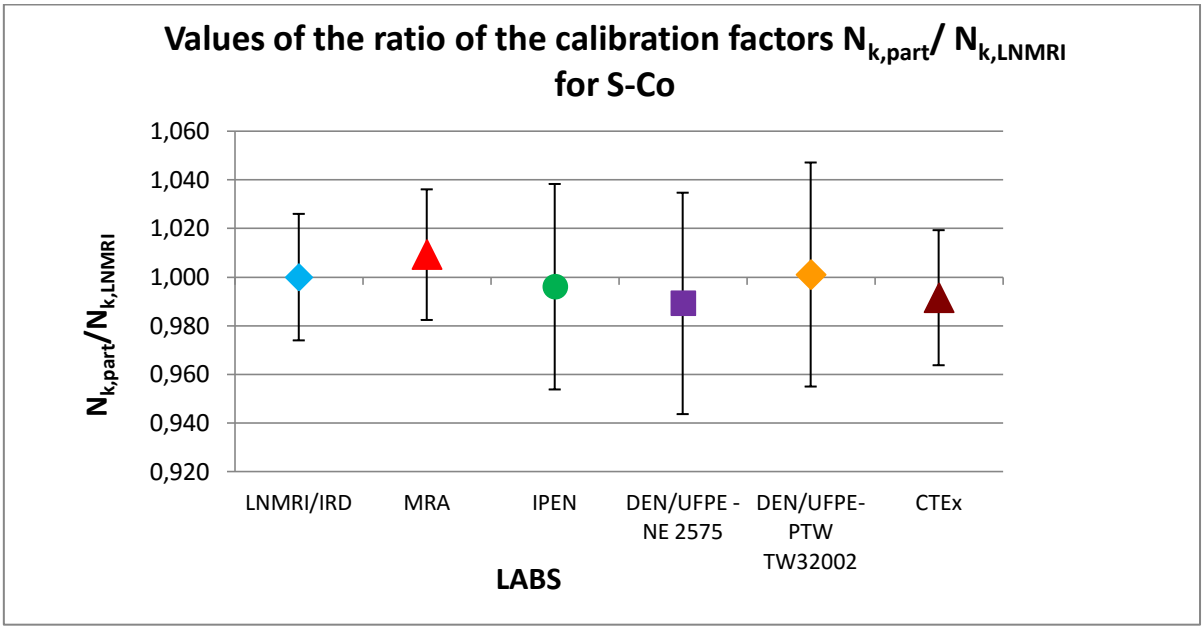

Figure 4. Values of the ratio of the calibration factors $N_{k,part}/ N_{k,LNMRI}$ for S-Co.

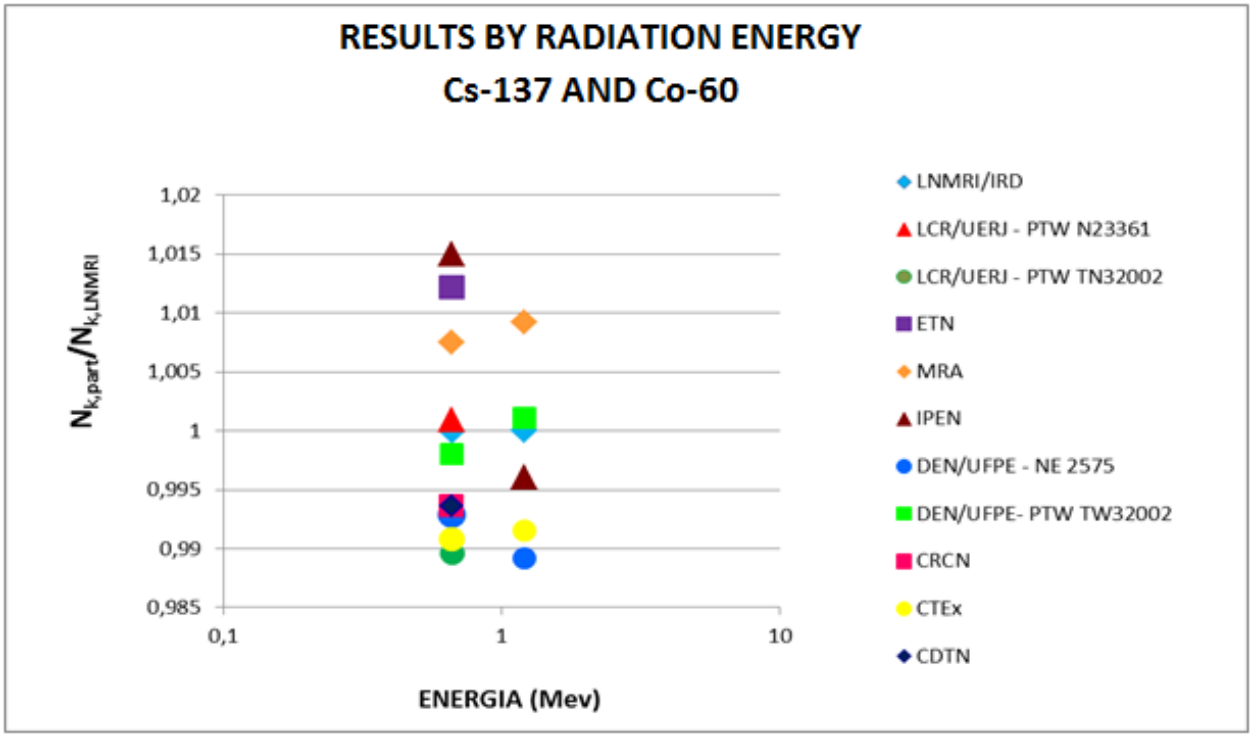

Figure 5. Results by Radiation Energy

6.3. Uncertainties

Uncertainties measures were calculated according to the ISO/IEC Guide 98-3 - "Guide to the expression of uncertainty in measurement". The total uncertainty was obtained by a combination of type A and B uncertainties regarding measurement multiplied by the coverage factor k = 2, which corresponds to a confidence level of 95.45%. The combined uncertainty was calculated by:

$$u_c = (u_A^2 + u_B^2)^{1/2} \quad (2)$$

Where u_A and u_B are type A and type B standard uncertainties.

The components of uncertainty that contributed to the combined standard uncertainty of the calibration of the transfer chamber are raised in dosimetry with standard chamber as positioning, irradiation distance, uncertainty of the calibration standard (certified standard chamber), stability, uniformity field, time factors thermometer, barometer and electrometer, energy dependence, leakage current measurement, repeatability, resolutions depending on the equipment and set up some more, and should take most of the components into account again when calibrating the chamber transfer.

7. Discussion and analysis of results

The results were evaluated by the percentage difference D% using the recommended methodology in ISO/IEC 17043-1, as most reference chambers, if not all, used by the laboratories were calibrated by LNMRI.

The percentage difference is calculated by the equation:

$$D_{\%} = \frac{N_{k,participante} - N_{k,LNMRI}}{N_{k,LNMRI}}.100 \quad (3)$$

Where:

$N_{k,LNMRI}$ = Calibration factor N_k obtained by LNMRI

$N_{k,Participant}$ = Calibration factor N_k obtained by the participating laboratory

The percentage difference for the calibration coefficient in terms of air kerma, and LNMRI between the participating laboratories should be equal to or less than 2.0%. None of the results exceeded the tolerance level.

Table 4. Results of the comparison exercise - Percentage Difference between the reported coefficients of participating laboratories with $N_{k,LNMRI}$.

Labs	D(%) – S-Cs	D(%) – S-Co
LCR/UERJ -TN32002	0,1	
LCR/UERJ –TN23361	-1,0	
ETN	1,2	
MRA	0,7	0,9
IPEN	1,5	-0,4
DEN/UFPE –TW32002	-0,2	0,1
DEN/UFPE – NE 2575	-0,7	-1,1
CRCN	-0,6	
CDTN	-0,6	
CTEx	-0,9	-0,8

The results were within the acceptance limit of ±2.0%, established by LNMRI in the protocol. The acceptance limit was calculated taking into account the existence of the dependence between the

calibrations of the laboratory standards performed by LNMRI. The highest percentage difference was 1.5%, being below the limit of acceptance established by the LNMRI; the index of this exercise was smaller than the previous comparison, even with the inclusion of a laboratory that started to work recently, in the second half of 2016.

Considering the points discussed, it is concluded that the Comparison Exercise presented an excellent result and this shows the competence of the Brazilian laboratories in performing the calibration services.

Only one laboratory was informed that it needs to review its calculation of the uncertainties and their components.

The Comparison Exercise tested the actual measurement capacity of the laboratories performing calibration services of radiation and irradiation monitors in Brazil, since the measurements are performed in the premises and with the laboratory procedures, which allows a greater reliability in the measurements and services Performed by the Brazilian calibration network.

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