TA3 – Dosimetry and Instrumentation

EVALUATION OF UNCERTAINTIES IN THE CALIBRATION OF RADIATION SURVEY METER

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ABSTRACT

In order to meet the requirements of ISO 17025, the quantification of the expanded uncertainties of experimental data in the calibration of survey meters must be carried out using well defined concepts, like those expressed in the "ISO-Guide to the Expression of Uncertainty in Measurement". The calibration procedure of gamma ray survey meters involves two values that have to get their uncertainties clearly known: measurements of the instrument under calibration and the conventional true values of a quantity. Considering the continuous improvement of the calibration methods and set-ups, it is necessary to evaluate periodically the involved uncertainties in the procedures.
In this work it is shown how the measurement uncertainties of an individual calibration can be estimated and how it can be generalized to be valid for others radiation survey meters.

INTRODUCTION

At the Calibration Laboratory of IPEN about two thousand radiation survey meters are calibrated each year, including radiation therapy, diagnostic radiology and radiation protection instruments. In order to meet the requirements of ISO 17025[(1)], the quantification of the expanded uncertainties of experimental data must be carried out using well defined concepts, like those expressed in the "Guide to the Expression of Uncertainty in Measurement (ISO-GUM)"[(2)]. The calibration procedure of gamma ray survey meters involves two values that have to get their uncertainties clearly known: measurements of the instrument under calibration and the conventional true values (air kerma rates). Considering the continuous improvement of the calibration methods and set-ups, it is necessary to evaluate periodically the involved uncertainties in the procedures. In this work it is shown how the measurement uncertainty of an individual calibration can be estimated and how it can be generalized to be valid for others radiation survey meters.

METHODOLOGY

Uncertainties of measurements are expressed as relative standard uncertainties, and the evaluation of these uncertainties is classified into type A and type B. The physical quantity of air kerma rate, the true value, is obtained through the indirect measurements performed with a 1000 cm^3 spherical ionization chamber (reference standard), Physikalisch-Technische Werkstätten, model LS01, traceable to the Brazilian Ionizing Radiation Metrology Laboratory (LNMRI). In this case, the integral of the electrical current during a time interval is measured: the charge ($Q \pm \Delta Q$) formed in the chamber active volume when it is submitted to radiation at a defined distance ($x \pm \Delta x$)

and instant ($t \pm \Delta t$). Its uncertainties were previously evaluated by Santos et al(3). The measurement of the instrument under calibration (and its uncertainty) is compared with the true value (and its uncertainty). According to the recommendations of the LNMRI the value obtained with the instrument under calibration (or indication of the measuring instrument as defined by VIM(4)) should not vary more than 10% in relation to the conventional true value(5). Additionally, the uncertainty in its measurements, in the calibration point, should not exceed 20%.

The reference physical quantity, air kerma, was determined to the gamma radiation beam central axis of the STS OB85 irradiator containing two radiation sources: ^{137}Cs (662 keV); ^{60}Co (1250 keV)]. It is expressed in the units of J/kg which is also the radiation unit, the gray (Gy). The operational quantities utilized in survey meters instruments derived from air kerma as personal and ambient dose equivalent are expressed in J/kg or sievert (Sv)(6). The quantity that are not in the SI but are by far the most utilized by many survey meters sent to calibration is the exposure. The SI unit for exposure is C/kg, but the old unit, the roentgen (1R=2.58 10^{-4} C/kg), is still often used.

The first step of this study was the definition all variables involved in the calibration. Then the uncertainties for each one were evaluated. The evaluation was made following the procedures described by the European Co-operation for Accreditation(7). Figure 1 shows the set-up used to gamma radiation survey meters calibration.

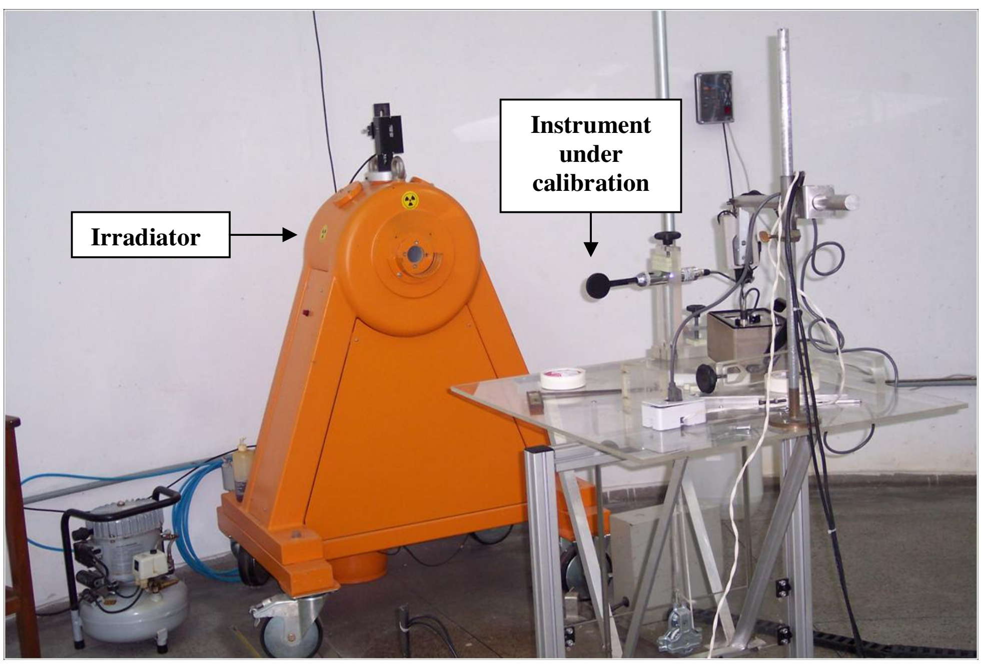

Figure 1. Set-up to calibrate instruments with gamma radiation

The components of the uncertainties involved in the process of calibration are:

a) Air kerma rate determination(true value)(3);
b) Repeatibility of the instruments reading;
c) Resolution on the instrument;

d) Positioning of the instrument in the calibration jig;
e) Temperature and pressure correction factor (non pressurized ionization chambers only).

The uncertainties due to the sources decay were not considered because their contribution to the conventional true value was too small.

The calibration report emitting by the laboratory should contain the following information:

Range	Conventional True Value	Instrument Reading	Radiation Source

The overall uncertainty will be expressed as the quadratic sum of the individual uncertainties of each one of its component.

RESULTS

a. Air kerma rate (true value) uncertainty

The air kerma rates or true value and their expanded uncertainties (Type **B**, 94.45% confidence level), were determined previously [3] and are compound of four sets of values:

1. No filter : 43.8 mGy/h ± 1.42% , k=2
2. With one filter : 3.20 mGy/h ± 1.52%, k=2
3. With two filters : 0.409 mGy/h ± 1.53%, k=2
4. With three filters : 0.0316 mGy/h ± 5.81%, k=2.65

b. Repeatibility of the instrument reading

This is a type **A** uncertainty and is represented by the standard deviation of ten measurements divided by the number of measurements. As an example it was used the values obtained in the calibration of a regular instrument sent to calibration. The obtained value was 2.6 mR/h ± 14% in the range x10. The true value in this point was 2.5 mR/h ± 5.81%.

c. Resolution on the instrument

The uncertainty in the resolution to analogical instruments (used in this study) is defined as the smallest readable value of the instrument range divided by 2; its statistics distribution is rectangular. The obtained uncertainty was 0.05 mR/h (Type **B**).

d. Positioning of the instrument in the calibration jig

A special study was made to evaluate this component. This is a type **B** uncertainty and was considered not changeable in the optical bench range. Its value is 4 mm to a coverage factor of 2 (k=2) and confidence level of 95.45%. It was used two distances as references, the one were the true value was determined and the other were the instrument is being calibrating. Those components come from the equation 1:

$$K_1 = K_0 \, (d_o/d_1) \qquad (1)$$

were :
K_1= Air kerma rates at the calibration distance
K_0= Air kerma rates at the reference distance
d_1= Calibration distance
d_0= Reference distance

e. Temperature and pressure correction factor (non pressurized ionization chambers only)

The survey meters with non pressurized ionization chambers need to have their measurements corrected by the temperature and pressure correction factor (equation 2):

$$ftp = [(273.15 + t)/293.15]*(101.325/p) \qquad (2)$$

where **t** and **p** are, respectively, the temperature and pressure values.

In this case the uncertainty, type **B**, is the quadratic sum of the thermometer and barometer expanded uncertainties. Its value is 0.002, to confidence level of 94.45 and k=2.

The combination of these factors will provide the uncertainty in the calibration of a common survey meter. The instrument used as example is a Geiger-Müller type and it is not necessary to use the temperature and pressure correction factor. The combination was made as related in the Calibration Uncertainty Calculation Sheet, Table 1.

Table 1. Calibration Uncertainty Calculation Sheet
$C_{(i)}$= sensibility coefficient (conversion to the reference unit)
$u_{(i)}$ = standard uncertainty (68% confidence level)
Veff = freedom degree

Calibration Uncertainty Calculation Sheet									
Component	Value		Distribution		$C_{(i)}$		u(i)	V, Veff
				Divisor	Value	Unit	(mR/h)	
Resolution	0.05	mR/h	rectangular	√3	1	-	0.028868	∞
Repeatibility	0.14	mR/h	normal	2	1	-	0.142984	9
True value	0.21	mR/h	normal	2	0.717	-	0.074804	∞
Positioning (d_0)	0.4	mm	normal	2	0.051	mR/(h.cm)	0.010300	∞
Positioning (d_1)	0.4	mm	normal	2	-0.0434	mR/(h.cm)	-0.008723	∞
Confidence level of 95.45%			Combined uncertainty				0.16 mR/h	
Coverage factor k=2.17			Expanded uncertainty				0.4 mR/h	

CONCLUSION

The evaluation of the uncertainties in calibration survey meters is an important task to guarantee confidence in the services provided by the Calibration Laboratory at IPEN. The results presented in this study cover almost 90% of the types of instruments received annually by the Calibration Laboratory and is going to be extended to other models of instruments. The differences may be the type of the detector (Geiger-müller or ionization chamber), the range calibrated and the quantities unit, but the same calculation sheet can be used.

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