Determination of uncertainty components for a system in Radiation Protection Dosimetry

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Abstract. This work is about the theoretical calculation of uncertainties associated to the dosimetry of photons of a $^{137}$Cs source that will be used in a Dosimetry Laboratory. In this case recognition of the influence quantities that provide most uncertainty and the right choice of resolution of auxiliary equipment to obtain the smallest uncertainties according to the laboratory.

1. Introduction
In Latin America there are several SSDL which were established with cooperation by the IAEA and WHO [1] and currently started a more in this area in Nicaragua, Central America. Based on all the experience of other laboratories LNMRI such as Brazil, which has a long track record in implementing ISO 17025, what this work for the purpose of determining prior to the installation more feasible resolutions to reduce of uncertainty. It is through a system of quality management and the implementation of ISO 17025 that is successful written documentation that describes many procedures [2, 3], necessary condition requirement for traceability of other laboratories recently as the SSDL Protection Center and HRPC Radiation Hygiene of Cuba, who in 2011 initiated the calibrations in the field of radiology [4] although in somewhat different areas the basic idea is the same as the definition of the measurand and establishment of correct method and procedure to ensure repeatability and reproducibility. These two LSCD examples demonstrate that each will have its own characteristics in terms however traceability should be traceable to a primary laboratory. To achieve this it is not enough just to calibrate the equipment needed but to know the entire system of the laboratory, this includes air conditioning, positioning system, radiation protection, tests and trials main and auxiliary equipment with appropriate resolutions for uncertainties in the extent be less than 5% not to mention that there must be a system of quality management and the information to the highest standard of quality for customer satisfaction. This motivates a careful strategy intended to give the end product a calibration certificate with a value of the measurand and its associated uncertainty [5, 6, 7].

2. Photon Beam Dosimetry

2.1. Measuring definition
Before calibration on an Dosimetry Calibration Laboratory should be performed first on beam dosimetry using [5]. In this case the beam corresponds to a $^{137}$Cs source, with an activity of 20 Ci for
calibration of area and personal dosimeters. The measurand is the air kerma rate at a point of interest (test point) on a volume of an ionization chamber at reference conditions and considering the input and output time of the source [1], the effect of positioning layer it and needed the camera to reproduce the magnitude air kerma rate.

The equation for our measurement model is:

\[
\dot{K}(1m) = \left( \frac{Q}{T} - \frac{Q_f}{T_f} \right) \varphi(\vartheta, P) N_k f_s K_Q C_f
\]  

Where \( Q \) is the reading made with the electrometer, \( \varphi \) is the correction factor for pressure and temperature, \( N_k \) is the calibration factor for the ionization chamber, \( f_e \) is the factor of the electrometer, \( K_Q \) is the radiation quality and a conversion of \( C_f \) that is equivalent to 3600 X 1000 to produce the units mGy/h.

2.2. Influence quantities

2.2.1. Pressure and temperature correction

The symbol \( \varphi \) represents the correction factor of the environmental conditions in the chamber which depends on the relative humidity, temperature and barometric pressure place. The expression for this correction is

\[
\varphi(\vartheta, P) = \left( \frac{a + \vartheta}{b} \right) \left( \frac{P_0}{P} \right)
\]

Where \( a + \vartheta \) is the thermodynamic temperature expressed \( \vartheta \) in °C, \( P \) is the barometric pressure of the room, \( P_0 \) is the atmospheric pressure, \( a = 293.15 \) K and \( b = 273.15 \) K respectively.

2.2.2. Correction for the transit time from the source

The transit time from the source given by the expression

\[
\Delta T = \frac{(K_n - K_i)}{(nK_i - K_n)}
\]

Where \( \Delta T \) represents the time it takes the source to return to their safe position, \( K_n \) is determined for \( n \) kerma irradiations, \( k_i \) is the kerma for one irradiation, and \( T \) the duration of irradiation.

2.2.3. Correction for electrometer’ leakage

The leakage current will affect the reading of the electrometer as shown in (1), is represented by \( Q_f \), divided by \( T_f \); the readings for leakage could be decreased. It depends of leakage of the camera, sometimes the effect is negligible in this case a correction is not important.

2.2.4. Correction for chamber positioning

This point is crucial because the standards indicate that the camera should be placed according to the manufacturer’s specifications [2, 3] in terms of the geometry of it. Yet another point is the rangefinder on the rail or in this case a very interesting point is the position at 1m once this is achieved must
register a benchmark with light system thus any deviation will be determined according to that point this detail is not written in standard however it is very important to know how to establish reference conditions in positioning.

Given a resolution of 1mm in terms of positioning from source to point of interest if we estimate the relative error percentage would get maximum value calibrations $\pm 0.2\%$ for radiological protection equipment is very small.

3. Determination of uncertainty combined for air kerma rate at 1 m.

To determine the uncertainty associated with our measure must recognize the sources of our uncertainties make the necessary corrections and determine the uncertainty that these effects contribute to it. Very important is to recognize which is the distribution of our variables. To give an idea of these distributions are shown in Table 1 which shows the mean and its corresponding standard deviation.

Once recognized each variable and its distribution determines the combined standard uncertainty associated with our measurand [6] for this we use

$$U(y)_c = \sqrt{\sum_{i=1}^{n} \left( \frac{\partial y}{\partial x_i} \right)^2 u(x_i)^2}$$

(4)

Where, $y$ represents the average value of the measurand and $x_i$ the estimated values of the variable input. An alternative expression assuming a measurand in the form

$$Y = cX_1^{p_1} X_2^{p_2} ... X_n^{p_n}$$

(5)

It is given by

$$\left( \frac{U_c(y)}{y} \right)^2 = \sum_{i=1}^{n} p_i \left( \frac{U(x_i)}{x_i} \right)^2$$

(6)

| Distribution   | Mean and standard deviation                                                                 |
|----------------|------------------------------------------------------------------------------------------|
| Rectangular    | $\mu, y, U(x_i) = \frac{a}{\sqrt{3}}$, where $a$ is the half interval of distribution.    |
| Triangular     | $\mu, y, U(x_i) = \frac{a}{\sqrt{3}}$, where $a$ is the triangular base                   |
| Normal         | $\mu$ is the mean $\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}$, and $\sigma$ is the variance, where $s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{X})^2}{n-1}}$. |

As we can see, finally can be expressed in relative units i.e. a percentage, however it should be mentioned that in (1) variables really are not all look exactly this way (3) but for which if the calculation is correct and to the other is calculated according to (4) but to express uncertainty divided the measurand combined standard uncertainties remain expressed in relative units and relative sensitivity coefficients are 1. The expression that allows us to calculate the relative combined uncertainty is given by:
\[ U_c(\text{rel}) = \sqrt{\left( \frac{U(L)}{L} \right)^2 + \left( \frac{U(T)}{T} \right)^2 + \left( \frac{U(P)}{P} \right)^2 + \left( \frac{U(\theta)}{\theta} \right)^2 + \left( \frac{U(f_c)}{f_c} \right)^2 + \left( \frac{U(N_kk_Q)}{N_kk_Q} \right)^2} \quad (7) \]

\( N_k \) factor multiplied by \( K_Q \) is due to their relationship to these factors and its associated uncertainty.

4. Conclusions
We observe that for such an uncertainty less than or equal to 5% the thermometer should have a resolution of 0.01 °C, the time in the order of 0.01 s or better, and smaller time would be better for the millisecond in the case of humidity is important to maintain the conditions of camera calibration and environmental conditions within the conditions of reference [4, 5]. It is important to assess the effects of moisture and the uniformity of the radiation field.

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