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# THE ASSESSMENT OF THE MEASURING PERFORMANCES OF A STANDARD INSTRUMENT FOR ABSORBED DOSERATE IN THE MEDICAL APPLICATIONS OF THE IONIZING RADIATION

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**Abstract** – The assessment of the measuring performances of the measurements is an important aspect in the activity of any laboratory. As for a calibration laboratory, which uses a standard instrument, in order to calibrate other instruments, the assessment of the metrological characteristics of the standard is one of the most important technical requirements of the Quality Management System. We present in this paper the method that we used for this aim in the Calibration Laboratory of the "Horia Hulubei" National Institute of the R&D Physics and Nuclear Engineering (IFIN-HH). For the monitoring the standard of Romania for the absorbed dose rate (D); the results of this monitoring and some conclusions regarding these results are also included.

**Keywords**: standard, measuring traceability, calibration,

## 1. INTRODUCTION

The medical applications of the ionizing radiation are based on the effects produced by the radiation; due to its interaction with the human tissue these effects are, mainly, depending on the energy released by the radiation in the medium of interaction. This is the reason for which the energy released by the ionizing radiation in a given medium (including the different human tissue), is a quantity of high interest for the medical physicists, as well as for the physicians working in radiotherapy.

The effects of the interactions of the ionizing radiation with a medium are also strongly dependent of the medium itself. As in the human body, around 80% of the mass is represented by water, the energy released by a ionizing radiation in a water is the most important aspect of the clinical dosimetry.

The measurement of this energy is the main task of the clinical dosimetry; the accuracy of these measurements is also an important task of the ionizing radiation metrology.

The accuracy of any measurement is strongly influenced by the calibration of the measuring instruments. In the measurement of the quantities specific to the ionizing radiation, the calibration mean to give the correction factors for the response of the instrument, against the conventionally true value of the measured quantity and, also, the uncertainties of this response and of the correction factors. Due to this reason, for any measuring instrument, the user must have these information and use them when reporting the results of a measurement.

The measurement process for any quantity involve therefore two aspects:

- to deliver the correct numerical value of the measured quantity;
- to deliver the measurement uncertainty.

In order to assure the correct measurement of a quantity, any measuring instrument must have a traceability [1]; this traceability is performed by calibration. The assessment of the measuring performances of the instrument, during the time interval between two successive calibrations can be done by recording the instrument's reading, obtained in the same conditions, and analysing how much these reading differ from the reading which was obtained (in the same conditions) when the instrument came back from the calibration laboratory.

As we already stated, water is the major component (as mass concentration) of the human body. In order to characterize the energy released by the ionizing radiation to water, the quantity of interest is the absorbed dose to that medium (m)

$$D_m = \frac{dW}{dm} \qquad (1)$$

The rate of energy absorbtion per mass unit of the medium is called the absorbed dose rate to the medium, $\dot{D}_m$ and is given by the equation /2/:

$$\dot{D} = \frac{dD}{dt} \qquad (2)$$

At present, despite the fact that a number synthetic materials were created in order to simulate different human tissues from the point of view of energy deposition by the ionizing radiation, the absorbed dose to water, $D_w$ is still the most important quantity for the clinical dosimetry.

For this reason, the Calibration Laboratory for Ionizing Radiation of the "Horia Hulubei" National Institute of Physics and Nuclear Engineering (IFIN-HH) has a standards instrument, dedicated also to the calibration of the field instruments used in clinical dosimetry, in terms of "absorbed dose in water", $D_w$, or of it's rate (the absorbed dose rate to water, $\dot{D}_w$).

## 2. THE STANDARD INSTRUMENT FOR ABSORBED DOSE RATE MEASUREMENT

The process of measurement of any quantity involves two aspects:

- the indication of the numerical value of the measured quantity;
- the evaluation of the measurement uncertainty

In order to assure the correct measurement of a quantity, this measurement must have a traceability. This traceability is accomplished by calibration. If an instrument is dedicated to the calibration of the other instruments measuring the same quantity, it is a standard and it's traceability must be assured by calibrations and intercomparasions.

The standard measuring instrument of IFIN-HH is a dosimeter/doseratemeter UNIDOS, with six ionization chambers. These ionization chambers are the detectors of the instrument and allow the measurement of some specific quantities (the dose equivalent – H/the dose equivalent rate - $\dot{H}$ , the absorbed dose – D/ the absorbed dose rate - $\dot{D}$, the air kerma – $K_a$ / the air kerma rate - $\dot{K}_a$) in different measuring ranges. It consists of the detectors (the ionization chamber TM 32003, M 23361, TM 30013 and T 34035) and the electronic unit (UNIDOS type 10001). This unit includes:/4/

- the DC voltage supply, for the polarization of the ionization chamber;
- the electrometer, which measures the ionization current;
- the computing unit, which convert the ionization current to the measured quantity, according the code of the detector and the adequate calibration factor; the same unit calculates the correction factors for air temperature and pressure, where the values of these quantities are introduced in the programme of the instrument.

For the assessment of the measuring performances of this instrument, the electronic unit together with the ionization chamber M 30013-0530 (the waterproof chamber) were used. The measuring device is periodically calibrated in terms of $\dot{D}_w$ at PTB, in Germany; during the time between two consecutive calibrations, the laboratory must monitories the operation of the instrument [1]. One of the reasons for monitoring operation is to identify, as early as possible, any changes in the measuring performances of the instruments, changes which may require a new calibration.

## 3. THE EXPERIMENTAL METHOD

The assessment of the operation of UNIDOS as a standard measuring instrument for the rate of the absorbed dose to water, $\dot{D}_w$, can be done by monitoring the instrument's response, in identical conditions. For this function the instrument has the configuration presented in the previous chapter (electronic unit and the ionization chamber M30013 – 0539). The response of the instrument is obtained in the presence of a radioactive source (always the same) in a given irradiation geometry, very reproducible. When the environmental conditions (air temperature and pressure) are not constant, appropriate corrections were made.

For the monitoring of the $\dot{D}_w$ standard's operation, we used a radioactive source of (Sr-Y)-90, emitting ß-ray (Fig.1).

Using this radioactive source and the experimental arrangement presented in the next section, we recorded the response of the standard instrument, immediately after the calibration and then, at different moments (generally to each three months).

For each determination of the instrument response, a set of ten values of $\dot{D}$, statistically independent, were recorded. For these values, which where automatically corrected for the air temperature and pressure, the average value of $\dot{D}$, $\overline{D}$ was calculated, as well as the standard deviation of a single value, $s_{n-1}$, and the standard deviation of the average value, $s_n$. The values of $\overline{D}$ and $s_n$ , given in Table 1, were used to draw the graphic from Fig. 2.

TABLE 1

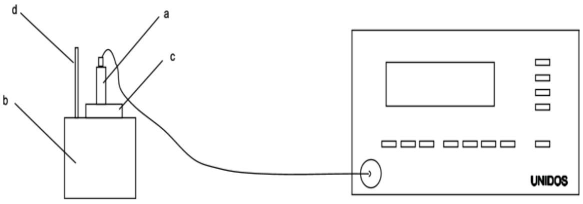
| No of months | $\dot{D}$ (µGy/s) | $\dot{D}$+$s_n$ (µGy/s) | $\dot{D}$-$s_n$ (µGy/s) | $\dot{D}_{ref}$+2% (µGy/s) | $\dot{D}_{ref}$-2% (µGy/s) |
|---|---|---|---|---|---|
| 0.00 | 854.35 | 856.06 | 852.64 | 871.43 | 837.26 |
| 3.02 | 866.34 | 868.07 | 864.61 | 871.43 | 837.26 |
| 5.65 | 854.64 | 856.35 | 852.93 | 871.43 | 837.26 |
| 11.73 | 859.53 | 861.25 | 857.81 | 871.43 | 837.26 |
| 18.40 | 861.68 | 863.40 | 859.96 | 871.43 | 837.26 |
| 20.30 | 860.56 | 862.28 | 858.84 | 871.43 | 837.26 |
| 22.60 | 863.16 | 864.89 | 861.43 | 871.43 | 837.26 |
| 43.73 | 867.68 | 869.42 | 865.94 | 871.43 | 837.26 |
| 46.16 | 862.20 | 863.92 | 860.48 | 871.43 | 837.26 |
| 48.39 | 862.11 | 863.83 | 860.39 | 871.43 | 837.26 |
| 52.30 | 866.11 | 867.84 | 864.38 | 871.43 | 837.26 |
| 54.60 | 868.35 | 870.09 | 866.61 | 871.43 | 837.26 |
| 58.97 | 856.41 | 858.12 | 854.70 | 871.43 | 837.26 |
| 59.99 | 857.09 | 858.80 | 855.38 | 871.43 | 837.26 |
| 62.46 | 866.57 | 868.30 | 864.84 | 871.43 | 837.26 |
| 70.97 | 852.43 | 854.13 | 850.73 | 871.43 | 837.26 |
| 74.55 | 864.18 | 865.91 | 862.45 | 871.43 | 837.26 |
| 78.06 | 857.47 | 859.18 | 855.76 | 871.43 | 837.26 |
| 80.33 | 861.72 | 863.44 | 860.00 | 871.43 | 837.26 |
| 81.18 | 861.12 | 862.84 | 859.40 | 871.43 | 837.26 |

## 4. THE EXPERIMENTAL ARRANGEMENT FOR THE $\dot{D}_w$ STANDARD INSTRUMENT MONITORING

The assessment of the $\dot{D}_w$ standard instrument between two consecutive calibrations was done by monitoring the instrument response, in identical conditions. The response of the instrument was produced using a radioactive source of (Sr-Y)-90, emitting ß-ray, in given and very reproducible geometry, as shown in Fig. 1.

Using this radioactive source and the experimental arrangement produced in the next section, we recorded the response of the standard instrument, immediately after the calibration and then, at different moments (generally at every three months).

In Fig. 1, we present a sketch of the experimental arrangement used for the monitoring operation.



a – M 30013-0530 ionization chamber

b – special shielded device for cheching the dose-ratemeter , which contains (Sr-Y)-90 radioactive source

c – removable shield

d – thermometer

e – UNIDOS electronic unit

**Fig. 1**

The sketch of the experimental arrangement

As we previously stated during all the measurements, the same radioactive source and the same irradiation geometry were used.

## 5. RESULTS

We used the assessment method and the experimental arrangement described previously. In this section, we give the results which were obtained for a long time monitoring, from September 2003 to June 2010. During these measurements, the standard instrument used, as a radiation detector, the ionization chamber M 30013 – 0130, having a sensitive volume of 0.6 cm$^3$. The results of the measurements ($\dot{D}_w$) are given in Table 1 (column 2). Columns 5 and 6 contain data for the accepted limits of the instrument readings (the average value, $\bar{D}$, $\bar{D}$+2% ,
$\bar{D}$-2%). Columns 3 and 4 contain the average values, $\bar{D}$, with the standard deviations of these values ($\bar{D}$+0.5% , $\bar{D}$-0.5%).

For each measurement, the average values of $\dot{D}$ were corrected also for the disintegration of (Sr-Y)-90 source. The graphic presentation of the data from Table 1 is given in Fig. 2.

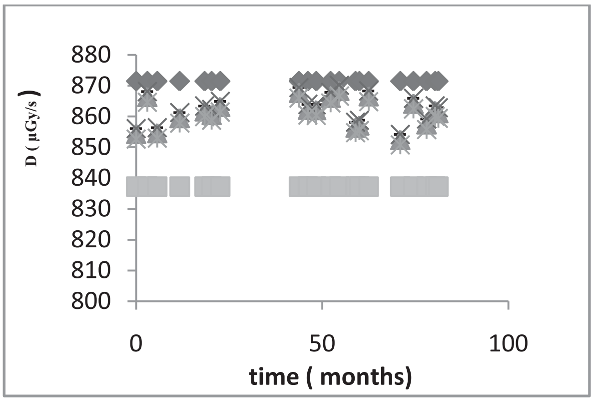


**Fig. 2**

In Table 2 we present the same data and also the values of the ratio $\dot{D}/\bar{D}_{ref}$ at different moments; $\bar{D}_{ref}$=854.35 µGy/s is the reference value of the instrument reading, obtained immediately after the calibration; $\dot{D}$ is the reading of the instrument, in identical conditions, at different times during the monitoring. The graphic of $\dot{D}/\bar{D}_{ref}$ us time is given in Fig. 3.

TABLE II

| **No crt** | **No of months** | **$\bar{D}_{ref}$ (µGy/s)** | **$\dot{D}$ (µGy/s)** | **$\dot{D}/\bar{D}_{ref}$** |
|---|---|---|---|---|
| 1 | 0.00 | 854.35 | 854.35 | 1.000 |
| 2 | 3.02 | 849.35 | 861.10 | 1.014 |
| 3 | 5.65 | 844.72 | 845.01 | 1.001 |
| 4 | 11.73 | 834.49 | 839.55 | 1.006 |
| 5 | 18.40 | 823.40 | 839.46 | 1.009 |
| 6 | 20.30 | 820.26 | 826.22 | 1.008 |
| 7 | 22.60 | 816.48 | 824.90 | 1.010 |
| 8 | 43.73 | 782.61 | 794.82 | 1.016 |
| 9 | 46.16 | 778.80 | 785.96 | 1.009 |
| 10 | 48.39 | 775.32 | 782.36 | 1.009 |
| 11 | 52.30 | 769.27 | 779.86 | 1.014 |
| 12 | 54.60 | 765.73 | 778.28 | 1.016 |
| 13 | 58.97 | 759.05 | 760.88 | 1.002 |
| 14 | 59.99 | 757.50 | 759.93 | 1.003 |
| 15 | 62.46 | 753.76 | 764.55 | 1.014 |
| 16 | 70.97 | 741.01 | 739.35 | 0.998 |
| 17 | 74.55 | 735.7 | 744.17 | 1.015 |
| 18 | 78.06 | 730.54 | 733.21 | 1.004 |
| 19 | 80.33 | 727.82 | 733.50 | 1.009 |
| 20 | 81.18 | 725.98 | 731.73 | 1.008 |

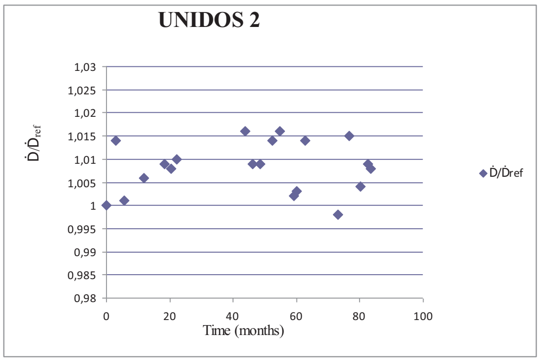


**Fig. 3**

The values of the ratio $\dot{D}/\dot{D}_{ref}$ during the monitoring

## CONCLUSION

From the data presented in Table 1 and Table 2 and the curves from Fig. 2 and Fig. 3 one can see that this method of monitoring the operation of our standard instrument for absorbed dose indicates that the instrument mentained its metrological characteristics. The response of the instruments varied slowly, in the range ± 0.02 of the reference value, so, the additional uncertainty due to this fact did not exceeded this value of 2%.

We consider that the monitoring of the operation of a standard instrument, imposed by the requirements of the international ISO/IEC 17025:2005, is an useful instrument in the Quality Management System of any calibration laboratory, in order to assure the traceability of the calibrations and a good accuracy of these calibrations.

## ACKNOWLEDGEMENT

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