Calibration Procedures for Hand-Foot Contamination Monitors

Oscar B. Alvarez, Ana F. Maia and Linda V. E. Caldas

Instituto de Pesquisas Energéticas e Nucleares (IPEN)
Comissão Nacional de Energia Nuclear
Av. Lineu Prestes 2.242
05508-000, São Paulo, SP
Brazil
otbalvar@ipen.br, afmaia@ipen.br, lcaldas@ipen.br

Abstract. Hand-foot contamination monitors are widely used for quick contamination measurements on hands and feet of workers in radioactive environments. The ISO 7503-1 standard recommends using reference sources large enough to cover the entire sensitive areas of the probes for the efficiency determination of this kind of monitor. However, most of hand-foot contamination monitors are built in compliance with the IEC 504 standard having too big foot probes (525 cm²) compared with the conventional reference sources (150 cm²). This problem can be solved following the suggestion of the publication HS(G)49, but it presents the disadvantage of being a time consuming procedure. The aim of this study was to establish alternative methods for the calibration of these monitors. The final results showed that it is possible to determine the monitor efficiency using a faster, and even more realistic, method. Therefore, a method is suggested to be used for workplace calibrations, keeping the HS(G)49 method only for periodic calibrations.

INTRODUCTION

Contamination monitoring is one of the most important procedures for radiation protection as well as radiation dose monitoring. For implementation of the proper contamination monitoring, radiation measuring instruments should not only be suitable for the purpose of monitoring, but they should also be properly calibrated [1].

Hand-foot contamination monitors are widely used for quick contamination measurements on hands and feet of workers in radioactive environments. They are available with several kinds of counter tubes such as gas flow proportional counters (for alpha and beta radiation), Xenon filled proportional counters (for beta radiation and low energy X-rays, etc), scintillation counters with ZnS (Ag) (for alpha radiation) or dual phosphors (for alpha, beta and gamma radiation), Geiger-Müller detectors (for beta and gamma radiation), etc.

To comply with IEC 504 standards [2], often the detection areas of hand-foot contamination monitors are 250 cm^2 for hands and 525 cm^2 for feet. As the reference sources [3] available are smaller, usually 15 cm x 10 cm (150 cm^2) in dimensions, the calibration procedure is difficult because the ISO 7503-1 standard [4] recommends the use of reference sources large enough to cover the entire sensitive probe. Even so, the same standard recommends that, in extreme cases, when sources of such dimensions are not available, sequential measurements with smaller distributed sources of at least 100 cm^2 of active area shall be utilized. In compliance with this recommendation, the British standard HS(G)49 [5] suggests a procedure to determine the efficiency taking a measurement and then moving the source to an adjoining area, and repeating the process until covering all the sensitive detector window.

In this paper, the objective was to find an adequate method to determine the efficiency of a hand-foot contamination monitor. For the hand probes, that are much smaller than the feet probes, just one calibration procedure was evaluated because the utilization of a rectangular source (150 cm^2) in the central area of the probe simulates adequately the real positioning of the user hands. However, for the feet probes, four different methods were evaluated: using an available source with an active area smaller than the sensitive detector window (HS(G)49 method); a method recommended by Los Alamos National Laboratory (LANL)(6) that uses a circular source; and also other two alternative methods established in this work. The procedure chosen as most adequate was applied for the routine tests of a hand-foot contamination equipment in its quality control program.

In this work, periodic calibration signifies the calibration made at a metrology laboratory, and routine calibration, the workplace calibration.

MATERIALS AND METHODS

A hand-foot contamination monitor for alpha and/or beta radiation Eurisys/Sirius was used in this study. This equipment has six large proportional detectors, 4 detectors for the hands and 2 detectors for the feet. The detection areas are 250 cm^2 for the hands and 525 cm^2 for the feet.

The equipment efficiency was determined for five beta sources (C-14, Tc-99, Cs-137, Cl-36 and Sr/Y-90), and one alpha source (Am-241). The characteristics of the beta sources are presented in Table 1. The alpha source has the following characteristics: half-life of 432.2 years and surface emission rate of 442 s-1. All these sources present areas of 15 cm x 10 cm, and in the cases of Am-241 and Cl-36 circular sources of 36 mm in diameter were also utilized. The sources are from Amersham, "anodized" variety, and have calibration certificates from Physikalisch-Technische Bundesanstalt (PTB), with the activity nearly uniformly distributed (better than 6%).

TABLE 1. Main characteristics of the beta sources utilized.

Source	Approximate half-life (years)	Surface emission rate (s^{-1})	Average energy (keV)
C-14	5700	406	50
Tc-99	211100	572	85
Cs-137	30.07	586	185
Cl-36	300000	643	246
Sr/Y-90	28.79	1300	934

The instrument efficiency, ε_i, on the reference source is given by the following equation [4]:

$$\varepsilon_i = \frac{n - n_B}{q_{2\pi}} \quad (1)$$

where

n is the total measured count rate from the reference source plus background, in reciprocal seconds;

n_B is the background count rate, in reciprocal seconds;

and $q_{2\pi}$ is the surface emission rate, in reciprocal seconds, of the reference source.

The calibration coefficient, N, for surface contamination monitors is given by the following equation [7]:

$$N = \frac{q_{2\pi}}{n - n_b} \quad (2)$$

The calibration coefficient is the inverse of the efficiency.

In all cases, the measurements were taken by placing each source on the bar grid above the left and right foot probes in a reproducible geometry, and for each case the measurements were repeated ten times.

RESULTS AND DISCUSSIONS

The study was divided in two parts. In the first one, the best calibration procedure for the feet detectors was established among four methods. In the second part the chosen procedure was applied for the calibration of the monitor.

The aim of the first part of the study was to establish an alternative method to determine the efficiency when the recommended source is not available, as happen at the Calibration Laboratory of IPEN. Therefore, studies were performed using circular sources of 36 cm diameter and rectangular sources of 15 cm x 10 cm.

Four methods were tested for the determination of the monitor efficiency. The method A followed the HS(G)49 standard, by covering all the whole sensitive detector window. Figure 1A shows how the source was positioned. Special care was taken in order to avoid overlapping of the covered areas.

In the second test (method B), the efficiency was determined following the method used at LANL (6). In this case, the circular source of 36 mm in diameter was positioned in the central area of the probe (Figure 1B). In method C, the circular source was substituted by the rectangular source to determine the efficiency (Figure 1C).

Lastly, the method D was applied using the rectangular source twice to simulate the area usually covered by the user foot (Figure 1D).

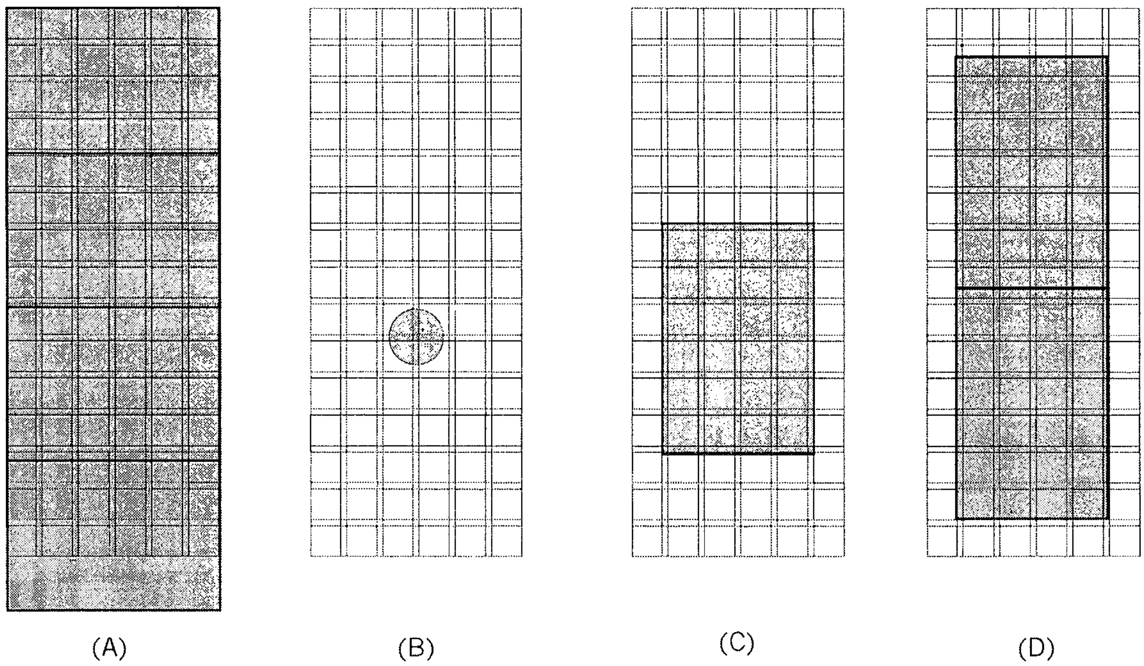

Figure 1. Source positioning in each one of the four calibration methods tested in this work: (a) method A, following the HS(G)49 suggestion; (B) method B, using a circular source as in Los Alamos National Laboratory; (C) method C, using a rectangular source at the central area of the detector; and (D) method D, using the rectangular source twice to simulate the area usually covered by the user foot.

Table 2 shows the efficiencies obtained by the different methods. Although method B shows a higher efficiency, it does not mean that it is the best method, because the covered area represents only 2% of the sensitive window area. Observing the results of the other methods, there is not a great difference between the obtained efficiencies. In the case of the left foot probe, the maximum variation for Am-241 is 10%, and 5.4% for Cl-36; for the right foot probe, the maximum variation for Am-241 is 15%, and 7% for Cl-36.

The main difference among the four methods is the spent time to perform each test; considering that there are two feet detectors and 10 measurements are taken for each one of the six sources, 480 measurements are necessary for method A, 240 measurements for method B and 120 measurements for methods C and D.

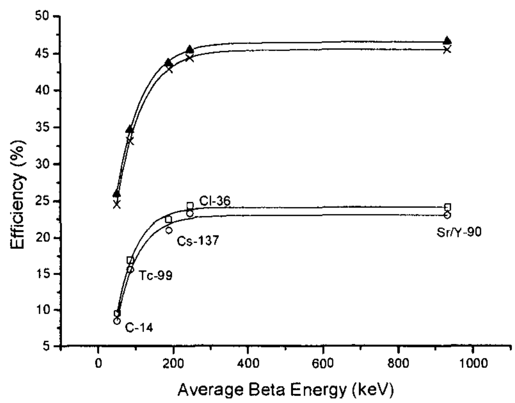

FIGURE 2. Energy dependence curve of a Eurisys/Sirius hand-foot monitor for several beta sources for the left foot probe (∀), right foot probe (,), left hand probe (□) and right hand probe (7).

TABLE 3. Calibration coefficients (dimensionless), with their respective relative combined uncertainty in percentage, obtained for a Eurisys/Sirius hand-foot monitor, using method D.

Source	Left foot	Right foot	Left hand	Right hand
Am-241	5.7 (5.5)	6.0 (5.7)	5.9 (5.5)	6.1 (5.5)
C-14	10.5 (7.2)	11.8 (8.8)	3.9 (4.2)	4.1 (4.1)
Tc-99	5.9 (5.5)	6.4 (5.9)	2.9 (3.8)	3.0 (3.7)
Cs-137	4.4 (5.6)	4.8 (5.8)	2.3 (3.9)	2.3 (3.9)
Cl-36	4.1 (5.5)	4.3 (5.5)	2.2 (3.7)	2.2 (3.7)
Sr/Y-90	4.2 (5.2)	4.3 (5.3)	2.1 (3.6)	2.2 (3.6)

CONCLUSION

The results show that it is possible to determine the monitor efficiency using a faster and even more realistic method by using a smaller source than the monitor sensitive area. However, as the recommended method is the method A, HS(G)49, we suggest using it just for the periodic calibrations, and the method D for the workplace calibrations.

ACKNOWLEDGMENTS

The authors acknowledge the partial financial support of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil.

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