SURVEY METERS RESPONSE EVALUATION AT NON-REFERENCED NEUTRON FIELD

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Abstract: The Neutron Laboratory of the IRD initiated studies of instrumentation response used to detect neutron dose, in the presence of different neutron spectra, with the purpose to evaluate these instrumentation performance. The results demonstrate the complexity of making measurements in the mixed neutron/photon field produced in electron linear accelerator

Key words: survey meters, clinical accelerator, neutron source.

1. INTRODUCTION

The clinical importance and usage of linear accelerators in cancer treatment increased significantly in the last years. Coupled with this growth came the concern about the use of accelerators operating at energies above 10 MeV which produce therapeutic beam contaminated with neutrons as result of high-energy photons interact with high-atomic-number materials such as tungsten and lead in the accelerator itself [1].

The main nuclear reaction involved in producing neutrons is the (γ, n) reaction generated in the giant dipole resonance process. There are two distinct neutron groups produced in this process: evaporation neutrons or neutrons produced via the giant photonuclear resonance process in heavy nuclei, and neutrons produced by direct interactions between photons and neutrons in the nucleus. Most of the neutrons produced are evaporation neutrons emitted isotropically. The photoneutron spectrum energy has a peak close to the nuclear temperature (typically between 0.4 and 1.0 MeV) and the average energy is about twice the nuclear temperature in MeV [2]. The average energy of the neutrons emitted from the accelerator head lies generally in the range of 1–2 MeV [3]. Inside the treatment room, in the patient treatment position, the neutron spectrum is similar to a strongly moderated fission spectrum. At other positions, the neutron spectrum is degraded due to interactions with the machine components, walls and concrete floor.

The use of system to detect neutron dose in these facilities allows performing the area monitoring to neutron to evaluate radiation protection condition in the facilities [4]. However, many users disregard or unknown important information about technical characteristics of these instruments. These characteristics (resolution, angular response, energy dependence, dead time, etc.) can affect the measurements uncertainty, causing misinterpretations about radiation levels. Furthermore, unknown measurement fields, which are not ISO 8529-1 referenced [5], can introduce misleading in the instrument response resulting in underestimate or overestimate measurements.

The Neutron Laboratory (LN) of the Instituto de Radioproteção e Dosimetria (IRD) is responsible for absolute standardization of neutron sources and calibration of survey meters in Brazil [6]. In order to assist users of clinical accelerators installed in Brazil, the LN initiated studies on calibration process of these survey meters to evaluate measurements.

2. OBJECTIVE

To perform measurement in a facility with radiation therapy accelerator of 15 MV using four different models of neutron survey meters previously appraised with several neutron spectra, aim ensure the measurement reliability.

3. SURVEY METERS EVALUATION

To evaluate the survey meters response in different measurement condition and inquire possible influence due to interference in the measurement, this work realizes the following steps:

3.1. Neutron source test

The neutron tests were performed in scattering low laboratory at LN with the following neutron source: ^{252}Cf(f,n), ^{252}Cf+D2O and ^{238}PuBe(α,n), with respectively average energy over to 4.16 MeV, 2.13 MeV, 0.55 Mev and 4.2 MeV. Sources were standardized in the well-known Manganese Sulphate Bath (MSB) absolute primary system. MSB is the main method used in several metrological laboratories to measure the neutron source emission rate. MSB also yields calibration uncertainties better than 1%. The scattering low laboratory was built to reduce neutron scattering and uncertainties in instruments calibration. Neutron source test procedure consists of comparison between the standard value of the ambient dose-equivalent rate and average value from survey meter readings in the field's point of interest.

3.2. Measurements in non-referenced neutron field

Measurement was made near to linear accelerator Varian 2300 C/D at the Instituto Nacional de Câncer (INCa), on treatment table plane at 100 cm to isocentre. The energy of the primary electron beam was 15 MeV and the photon beam obtained was collimated to an area of 10 x 10 cm² and the beam intensity in isocentre ranged from 100 to 500 $cGy.min^{-1}$.

The survey meters model used to make measurements were: two spherical polyethylene moderators (NRD - neutron rem detector) surrounding a BF_3 counter tube, one cylindrical polyethylene moderator surrounding a BF_3 counter tube (Andersson-Braun type) and one cylindrical polyethylene moderator surrounding a He_3 counter tube (Andersson-Braun modified type). Survey meters were calibrated with the neutron source ^{241}AmBe(α,n). The cylindrical moderator has a bigger effect on the directional response than in the case of the spherical polyethylene moderator. Thus, a small difference in the measurements should be expected.

An ionization chamber Victoreen 450 B was used in same measurement position to evaluate the gamma dose. All the measurements were recorded with a camera for subsequent data collection.

3.3. Gamma rejection check

This check was realized in cobalt irradiator for purpose to evaluate survey meters response in a gamma radiation field. Survey meters were exposed to 16 $cGy.min^{-1}$ gamma dose rate and the measurement was recorded with a camera.

4. RESULTS

4.1. Neutron source test

For the survey meters response from different spectra was observed to ^{252}Cf + D_2O and ^{238}PuBe (α,n) sources high percent difference between instrument response and reference values from standardization neutron source, as shown in the following pictures.

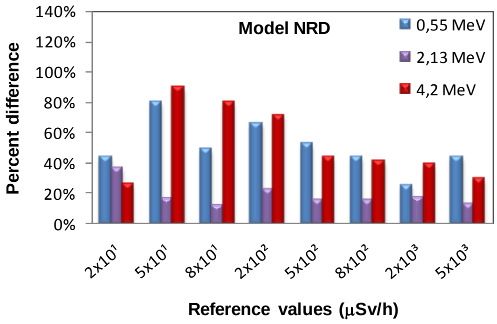

Fig. 1. Percent difference to NRD survey meter model.

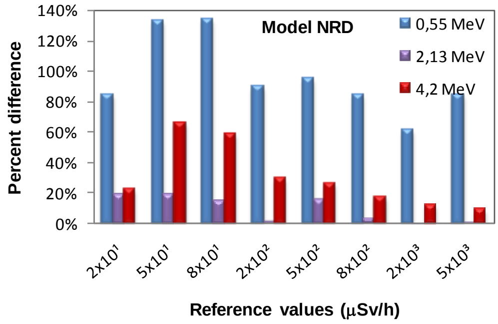

Fig. 2. Percent difference to NRD survey meter model.

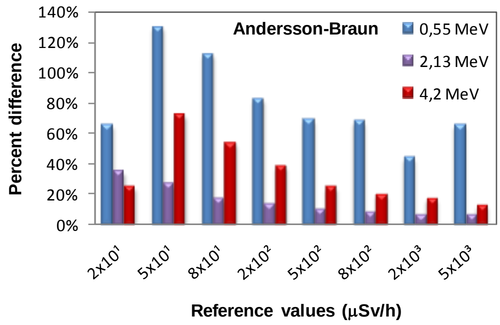

Fig. 3. Percent difference to Andersson-Braun survey meter model.

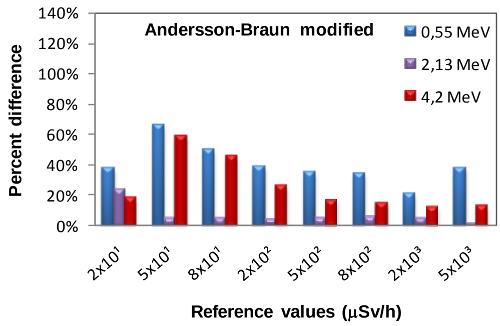

Fig. 4. Percent difference to Andersson-Braun modified survey meter model.

Percent difference to ^{252}Cf source was lower than other sources. To ^{238}PuBe(α,n) source there was high discrepancy in survey meters response, despite ^{238}PuBe(α,n) spectrum has average energy near source spectrum ^{241}AmBe (α,n). This discrepancy occurred due to expansive sources spectra ^{238}PuBe (α,n) which comprehend energy from 10^{-10} near to 10² MeV and to ^{252}Cf + D_2O which comprehend energy from 10^{-7} near to 10² MeV. Andersson-Braun modified survey meter model showed low percent difference to all the sources, which indicates lower energy dependence than others survey meters models.

4.2. Measure in non-referenced neutron field

Measurement made at 100 cm to isocentre showed divergence in the response survey meters, as following table 1.

Table 1. Measurement at non-referenced neutron field.

Isocentre dose rate ($cGy.min^{-1}$)	Andersson-Braun modified	NRD	Andersson-Braun	NRD
	$mSv.h^{-1}$	$mSv.h^{-1}$	$mSv.h^{-1}$	$mSv.h^{-1}$
100	4.89 ± 0.05	10.88 ± 0.23	9.38 ± 0.12	16 ± 2
200	9.93 ± 0.06	21.28 ± 0.25	19.15 ± 0.18	28 ± 2
300	15.03 ± 0.16	32.39 ± 0.33	29.11 ± 0.2	44 ± 2
400	20.26 ± 0.16	43.38 ± 0.26	39.02 ± 0.2	60 ± 2
500	25.54 ± 0.19	54.11 ± 0.27	48.97 ± 0.26	68 ± 2

Gamma rejection check was made to verify if the measurement divergence were due to gamma radiation interference. All survey meters were exposed to 16,2 $cGy.min^{-1}$ gamma dose rate and only Andersson-Braun survey meter model readout 24 $\mu Sv.h^{-1}$ dose rate. Measurements made by ionization chamber were below the exposure value, as following table 2.

Table 2. Ionization chamber measurements.

Ionization chamber measurements ($cGy.min^{-1}$)	Isocentre dose rate ($cGy.min^{-1}$)				
	100	200	300	400	500
	2.7 ± 0.3	5.2 ± 0.5	7.5 ± 0.8	10.8 ± 1.1	13.3 ± 1.3

5. CONCLUSION

Neutron source test presents discrepancy between response survey meters and reference values, which were higher to $^{252}Cf + D_2O$ source. This discrepancy was related with energy dependence survey meters. Andersson-Braun modified survey meter model shown the lowest energy dependence.

The measurement performed in non-referenced neutron field showed discrepancy which was not produced by gamma radiation interference. The gamma dose in non-referenced field was lower than gamma dose rejection check, resulting in minor inferences due to gamma radiation.

Measurement influence due to energy dependence could be the reason in measurement discrepancy, which explained the lower readout to Andersson-Braun modified survey meter model, which presented less energy dependence. Next, some simulation studies from these survey-meters will be made to a better understanding central measurement aspect that could not be answered here.

AKNOWLEDMENTS

The Neutron laboratory would like to express its thanks to Delano Valdivino Santos Batista the head of radiotherapy sector at INCa and medical physics staffs for their support in action.

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