Calibration of a Small Volume Ionization Chmaber for ^{60}CO Gamma Beams with Low and High Activity Sources

Assef Firnando F., Sri Inang Sunaryati, Nurman R. and Gatot Wurdiyanto

Center for Technology of Radiation Safety and Metrology, National Nuclear Energy Agency of Indonesia,
Jalan Lebak Bulus Raya No. 49, Kotak Pos 7043 JKSKL, Jakarta 12070

Abstract. *This paper describes the measurement for calibrating a PinPoint 3D chamber type of PTW 31016 serial number 004507 with volume of 0.016 cc in term of absorbed dose to water for ^{60}Co gamma beams using low and high activity sources. Measurement has been carried out using a Substitution Methods at the reference condition. A 0.6 cc ionization chamber type of TW 30013 serial number 6367 was used as a standard chamber connected to Farmer type of NE 2570/1B serial number 1182 and Webline type of T 10022 serial number 268 electrometers with traceability to the Bureau International des poids measures (BIPM) France. Testing on the calibration result were also described based on the determination of the absorbed dose to water at the reference conditions for a 10 MV photon beam and ^{60}Co gamma beams.The results obtained show that the absorbed dose to water calibration factor for the PinPoint3D chamber connected to a Farmer electrometer were $N_{D,w}$= 2803.2 mGy/nC and $N_{D,w}$= 2533.2 mGy/nC each for low and high activity sources, while connected to Webline were $N_{D,w}$ = 2534.64 mGy/nC dan $N_{D,w}$ = 2516.0 mGy/nC each for low and high activity sources. The test results for the absorbed dose to water determination for a 10 MV photon beam and Co-60 gamma beams show good agreement by 0.95% and 1.68%. As Summary, the calibration of the PinPoint 3D chamber for ^{60}Co gamma beams using low and high activity sources obtained good results, except for a low activity source, if the PinPoint 3D chamber connected to a Farmer electrometer.*

Keywords: calibration, small volume ionization chamber, photon beam,
^{60}Co gamma beam and absorbed dose to water calibration factor.

Introduction

The development of radiotherapy treatment techniques in Indonesia especially its application for small field sizes has been growing rapidly. The determination of absorbed dose to water from these small field sizes need small volume ionization chambers (Alfonso, 2008).

Some of small volume ionization chambers were available commercially such as : PTW chambers type 31010-0.125cc, type 31014-0.015cc, type 31015-0.030 cc and PinPoint 3D chamber type 31016 – 0.016 cc (Malcom & Mc Ewen, 2010).

In the International Atomic Energy Agency publication Technical Report Series No. 398 : Absorbed Dose Determination in External Beam Radiotherapy ; An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water First Edition, these chambers can not be found. While in the next edition some chambers has been found (IAEA, 2000; IAEA, 2006).

The chambers were calibrated against the standard ionization chamber type TW 30013 volume 0.6 cc. The chamber was connected to Farmer type 2570 1/B and PTW Webline electrometers. The resolution for each electrometer is not the same. The resolution for Farmer type of NE 2570/1B is 5000 fC, while Webline type of T 10022 electrometer is 10 fC (Introduction Manual, 1986; User Manual, 2006).

The ^{60}Co gamma beam from an Alcyon tele-therapy unit which used as a radiation source for calibrating ionization chamber has activity of 24,70 TBq (667.52 Ci) with the absorbed dose rate to water at the reference condition around 125 mGy/min, while a new ^{60}Co teletherapy unit has activity up to 461.9 TBq (12,483 Ci) with the absorbed dose rate to water at the reference condition around 2,000 mGy/min. This condition is inopportune because ideally these chambers should be calibrated nearly the same with its uses (Rajagukguk & Firnando, 2015).

This paper describes the calibration of a smallvolume PinPoint 3D ionization chamber type 31016-0.016 cc against a 0.6 cc type TW 30013 ionization chamber for ^{60}Co gamma beams with low and high activity sources. Testing on the calibration result to determine the absorbed dose to water for a 10 MV foton beam produced from a Varian IX Silhouette linear accelerator machine and ^{60}Co gamma beams from a Leksell Gamma Knife Perfexion machine were also described.

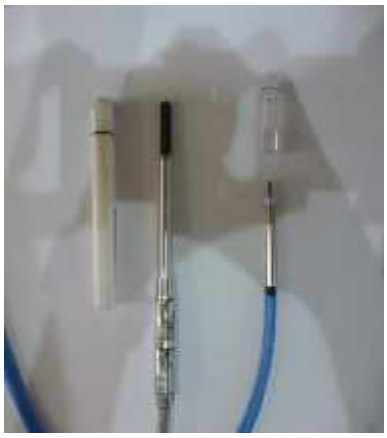

Figure 1. Small volume ionization chamber Pinpoint type PTW 31016 volume 0.016 cc and standard ionization chamber type TW 30013 volume 0.6 cc.

Teory

Calibration Using ^{60}Co Gamma Beam

Calibration of the chamber in term of absorbed dose to water were performed using a Substitution Method. The Standard ionization chamber and the chamber under calibration were irradiated successively inside a water phantom at the source to the phantom surface distance of 100 cm with the field size at the phantom surface of 10 cm x 10 cm and the depth of 5 cm[8]. The calibration factor in term of the absorbed dose to water of the chamber under calibration was obtained using equation 1.

$$N_{D,w} : \frac{M_{Standar} \cdot N_{D,w\,Standar}}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

where

$N_{D,w}$: calibration factor of the chamber under calibration in term of absorbed dose to water (mGy/nC)

$M_{D,w\,Standar}$: reading of the standard ionization chamber correctted for air pressure and room temperature (nC)

$M_{D,w\,Standar}$: calibration factor of the standard ionization chamber in term of absorbed dose to water (mGy/nC)

M : reading of the chamber under calibration correctted for air pressure and room temperature (nC)

Determination of Absorbed Dose to Water for Photon Beam

The absorbed dose to water determination for photon beam of radiation quality Q at the reference depth, z_{ref} by using an ionization chamber having an absorbed dose to water calibration factor, $N_{D,w}$ is given by (IAEA, 2000).

$$D_{w,Q} = M_Q . N_{D,w.} k_Q \quad \ldots\ldots\ldots\ldots (2$$

Where

$D_{w,Q}$: absorbed dose to water for photon beam of radiation quality Q (mGy)

M_Q : dosemeter reading for dosemeter under calibration corrected for air temperature and temperature, polarity effect and recombination ion (nC)

$N_{D,w}$: chamber calibration factor in term of absorbed dose to water for ^{60}Co gamma (mGy/nC)

k_Q : radiation quality photon beam factor for the chamber equal 1.00 for ^{60}Co

Experimental Methods

Calibration of a Small Volume Ionization Chamber

The chambers used in this experiment were a chamber of type TW30013 serial number 6367 as a standard chamber and a PinPoin 3D type 31016 serial number 004507 as a chamber to be calibrated. Both chambers were connected to a Farmer electrometer of type NE 2570/1B with serial number 1182 and a PTW Webline electrometer of type of T 10022 serial number 268.

The calibration measurements were performed on an Alcyon ^{60}Co unit for a low activity source with activity of 24,70 TBq (667.52 Ci), while a ^{60}Co Gamma Beam 100-80 External Beam Therapy System with activity of 456,4 TBq (12.335 Ci) was used for a high activity source.

All measurements were carried out inside a 30cm x 30cm x 30cm water phantom with the center of the chamber positioned at a depth of 5 cm. Irradiation of the chambers were carried out with a field size of 10cm x 10cm at the source to the surface distance of 100 cm. The irradiation set-up using both radiation sources are shown in Figure 2.

a b

Figure 2. Irradiation set-up using an Alcyon ^{60}Co machine owned by the Secondary Standard Dosimetry Laboratory of PTKMR-BATAN used as a low activity calibration source (a) and a ^{60}Co Gamma Beam 100-80 External Beam Therapy System owned by the Dr. Kariadi General Hospital Medical Centre, Semarang used as a high activity source (b)

a b

Figure 3. A Varian IX Silhouette linear accelerator machine a) and a Leksell Gamma Knife Perfection machine which were used for the testing of the chamber calibration factor.

Testing of The Calibration Result

Testing of the calibration result were based on measurement to determine the absorbed dose to water for a 10 MV photon beam produced from a Varian IX Silhouette linear accelerator machine owned by Santosa Hospital Bandung Kopo and ^{60}Co gamma beams from a Leksell Gamma Knife Perfexion machine owned by Gamma Knife Centre Indonesia Siloam Hospital, Karawaci. A Varian IX Silhouette linear accelerator machine and a Leksell Gamma Knife Perfexion machine can be seen in Figure 3, while the irradiation set-up of the measurement for testing of the calibration result were presented in Figure 4.

Measurement for determining the absorbed dose to water for a 10 MV photon beam produced from a Varian IX Silhouette linear accelerator machine has been performed inside a 30cm x 30cm x 30cm 1D Scanner water phantom at the depth of 10 cm, the source to the phantom surface distance of 100 cm and the field size at the phantom surface of 10cm x 10cm (IAEA, 2003). While Measurement for determining the absorbed dose to water in ^{60}Co gamma beams from a Leksell Gamma Knife type Perfexion has been measured at the centre of the 16mm helmet of the gamma knife using a polystyrene spherical dosimetry phantom (IAEA, 2003). All the readings were corrected for air pressure and temperature. For the testing of the calibration factor of the PinPoint type PTW 31016 connected to Webline electrometer, a 0.6 cc type TW 30013 connected to a Farmer type 2570/1B serial number 1182 electrometer and a 0.125cc Semiflex chamber type 31010 serial number 004507 connected to a PTW Unidos electrometer type T10001 serial 1184 were used as comparisons.

a b

Figure 4. The irradiation set-up of the measurement for the testing of the calibration result of a small volume ionization chamber type PTW 31016 serial number 004507.

Table 1. Measurement of a small volume ionization chamber type PTW 31016 serial number 004507 against a TW 30013 serial number 6367 connected to Farmer electrometer using a low activity ^{60}Co gamma beam.

Reading of the Standard Dosemeter (nC/min) TW 30013 + Farmer	Reading of the dosemeter under calibration (nC/min) PTW 31016 + Farmer	Calibration Factor of the Standard Dosemeter $N_{D,W}$ (mGy/nC)	Calibration Factor of the chanber under calibration $N_{D,W}$ (mGy/nC)*
2.802	0.04516	45.18	2803.20

*The Expanded uncertainty of ± 1.3 % at the 95 % confidence level for the reported calibration factor [11]

Table 2. Measurement of a small volume ionization chamber type PTW 31016 serial number 004507 against a TW 30013 serial number 6367 connected to webline electrometer using a low activity ^{60}Co gamma beam.

Reading of the Standard Dosemeter (nC/min) TW 30013 + Webline	Reading of the dosemeter under calibration (nC/min) PTW 31016 + Webline	Calibration Factor of the Standard Dosemeter $N_{D,W}$ (mGy/nC)	Calibration Factor of the chamber under calibration $N_{D,W}$ (mGy/nC)*
2.802	0.04998	45.18	2533.22

Table 3. Measurement of a small volume ionization chamber type PTW 31016 serial number 004507 against a TW 30013 serial number 6367 connected to Farmer electrometer using a high activity ^{60}Co gamma beam.

Reading of the Standard Dosemeter (nC/min) TW 30013 + Farmer	Reading of the dosemeter under calibration (nC/min) PTW 31016 + Farmer	Calibration Factor of the Standard Dosemeter $N_{D,W}$ (mGy/nC)	Calibration Factor of the chamber under calibration $N_{D,W}$ (mGy/nC)*
29.153	0.6242	54.27	2534.64

Table 4. Measurement of a small volume ionization chamber type PTW 31016 serial number 004507 against a TW 30013 serial number 6367 connected to webline electrometer using a high activity ^{60}Co gamma beam.

Reading of the Standard Dosemeter (nC/min) TW 30013 + Webline	Reading of the dosemeter under calibration (nC/min) PTW 31016 + Webline	Calibration Factor of the Standard Dosemeter $N_{D,W}$ (mGy/nC)	Calibration Factor of the chamber under calibration $N_{D,W}$ (mGy/nC)*
29.,304	0.6321	54.27	2516.00

Table 5. Determination of the absorbed doses to water for a 10 MV photon beam using a 0.6 cc ionization chamber type

Chamber	Reading nC/min	$N_{D,W,Qo}$ mGy/nC	$K_{Q,Qo}$	$PDD_{(Zref)}$ (%)	$D_{w,Q(Zmax)}$ mGy/200MU**	Deviation (%)
0.6 cc	27.742	54.27	0.9812	73.70	2004.45	0.945
0.016 cc	0.593	2515	09806	73.70	1985.51	

**The expanded uncertainty ± 2.2% at the 95% confidence level for the reported absorbed dose to water rate

Table 6. Determination of the absorbed doses to water for ^{60}Co gamma beams using a 0.125 cc ionization chamber type

Chamber	Reading nC/min	$N_{D,W,Qo}$ mGy/nC	$D_{w,Q}$ mGy/min***	Deviation (%)
0.125 cc	25.628	85.53	2186.1	1.68
0.016 cc	0.881	2515	2228.5	

***The expanded uncertainty ± 1.5% at the 95% confidence level for the reported absorbed dose to water rate

Results and Discussion

The calibration result of a small volume ionization chamber type PTW 31016 serial number 004507 against a TW 30013 serial number 6367 using low and high activity ^{60}Co gamma beams are presented in Table 1 to Table 4.

From Table 1 and 2, it can be seen that the calibration using a low activity ^{60}Co of a small volume ionization chamber type PTW 31016 serial number 004507 connected to the same electrometer either Farmer or Webline obtained a significant deviation of 9.0%, whilst Table 3 and 4 show that the measurement result using a high activity ^{60}Co is slightly different less than 1.0%. Compared Table 3 and 4 with Table 2, it can be seen that the result show a good agreement within 1%. From Table 1 to Table 4 it can be concluded that Farmer electrometer is not good enough if connected with pinpoint if the radiation source too low because its resolution.

The measurement result for testing the calibration factor of a pinpoint type PTW 31016 connected to Webline electrometer for a 10 MV photon beam compared to a 0.6 cc type TW 30013 connected to Farmer type 25701B electrometer can be seen in Table 5, while a semiflex 0,125 cc connected to a PTW Unidos electrometer type T10001 was used for ^{60}Co gamma beams and the result were presented in Table 6.

From Table 5 and 6 it can be seen that the determination of the absorbed dose to water using a small ionization chamber type of PTW 31016 serial number obtained good agreement less than 2 .0 % not only for a 10 MV photon beam but also for ^{60}Co gamma beams (IAEA, 1997).

Conclusion

The experiment show that for a low activity source, the small volume ionization chamber can not be connected with a low resolution electrometer. The ^{60}Co radioactive source still can be used for calibration of radiation measuring instrument used for therapy level, but the activity of the source has approach the limit value of the recommended. So the source should be replaced as soon as possible.

Acknowledgments

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