Comprehensive Evaluation of On-position Leakage from Source Head of Bhabhatron-II Telecobalt Unit

S. D. Sharma[1], Rajesh Kumar[1], D. C. Kar[2]

[1]Radiological Physics & Advisory Division, Bhabha Atomic Research Centre, CTCRS, Anushaktinagar, Mumbai, India
[2]Division of Remote Handling and Robotics, Bhabha Atomic Research Centre, Trombay, Mumbai, India

Abstract - **Bhabhatron-II is a new model of telecobalt machine introduced for external beam therapy of cancer patients. It is a fully computer controlled new generation telecobalt machine which has a number of unique features such as 0.5x0.5 cm^2 treatment field, auto patient set-up, remote diagnosis, automatic closure of collimator to 0x0 field in case of functional abnormality. The source head of this telecobalt machine consists of a cast steel shell filled with lead and depleted uranium which can house ^{60}Co source of strength up to 250 RMM (250 Roentgen per minute at 1 meter ≈ 15,000 Ci). Measurement of on-position leakage from the source head of this telecobalt unit was carried out using a specially designed couch mountable tool. PTW 40 cm^3 ionization chamber along with PTW UNIDOS dosimeter (PTW Freiberg, Germany) was used in this work. Measurements were carried out for points located both in-patient plane and other than patient planes. The measured values are much less than the IEC-60601-2-11 recommended tolerances. The measurement results indicate high degree of on-position radiation safety status of the Bhabhatron-II telecobalt machine.**

Keywords – **Bhabhatron, telecobalt unit, head leakage, patient safety, occupational safety**

I. Introduction

Telecobalt machines are prominently used as external beam delivery equipment in almost all the developing countries of the world including India. About 1-million new cancer cases are detected in India per annum. To cope with the increasing burden of cancer patients about 1000 teletherapy machines are required as against currently available 392 teletherapy units (282 telecobalt machines and 110 medical linear accelerators) [1,2]. Considering the large requirements of teletherapy machines, a new model of indigenously developed telecobalt unit, named Bhabhatron-II, was introduced for cancer treatment. For the safety of patients and occupational workers, the design and shielding of the telecobalt machine shall adhere to the radiological safety requirements stipulated in IEC-60601-2-11 in addition to general safety requirements [3-5]. This paper describes a method which was used for comprehensive evaluation of on-position leakage radiation from source head of Bhabhatron-II telecobalt machine.

II. Materials and methods

A. Bhabhatron-II telecobalt machine

Bhabhatron-II is an isocentric (source to isocentre distance = 80 cm) telecobalt machine which incorporates various unique features such as (i) availability of 0.5x0.5 cm^2 treatment field size (ii) fully software controlled operation with record of operation history (iii) automatic closure of collimator to 0x0 field in case of functional abnormality (iv) software controlled collimator, couch and gantry movement (v) auto patient set-up (vi) remote diagnosis (vii) iso-wedge, and (viii) asymmetric collimator. Source head of Bhabhatron-II consists of a stainless steel shell filled with lead and depleted uranium which can house ^{60}Co source of strength up to 250 RMM (250 Roentgen per minute at 1 meter ≈ 15,000 Ci). Cylindrical source capsule of nominal diameter 2.0 cm mounted on a standard source drawer can be loaded in this telecobalt unit. Source movement is controlled by pneumatic drive system. Field limiting devices contains fixed opening primary as well as variable opening secondary collimators. Secondary collimator of this unit includes two pairs of collimating jaws made up of depleted uranium. Two pairs of trimmer bars made up of depleted uranium are also provided beneath lower jaws (X-jaws) to limit the radiation beam penumbra. The collimator jaws are motor driven and can define square/rectangular field sizes at the isocentre in the range of 0x0 to 35x35 cm^2. In case of source stuck, the collimator jaws/trimmers closes to zero automatically which is an improved design aspect towards radiation safety concerns of patients and occupational workers. All movements of the couch, collimator, gantry and field defining jaws are controlled by push-buttons located at couch panel. This unit has a dedicated dual window display monitor installed in the treatment room where mechanical positions of all the systems/ subsystems of the unit are displayed. Control console consists of graphical user interface (GUI) type software. Treatment prescriptions of patients can be loaded on the control console with their distinct identification numbers which can be recalled routinely for treatment delivery. Treatment delivery of a patient by this machine is possible only when the set (or prescribed) values and actual values are within the given tolerances. The machine has been certified by IEC ERTL (Eastern Region Test Laboratory) for its electromagnetic compatibility as stipulated in IEC-60601-1-2 [6]. Further details about

O. Dössel and W.C. Schlegel (Eds.): WC 2009, IFMBE Proceedings 25/III, pp. 383–385, 2009.
www.springerlink.com

the Bhabhatron telecobalt unit are available elsewhere [7].

B. Measurement of on-position leakage

A specially designed tool for measurement of on-position leakage from source head of teletherapy machine was fabricated using aluminium and heavy metal. The tool consists of an aluminium semi circular arc of diameter 2 meter. This arc is mounted on an heavy metal base plate that can be attached to the treatment couch of a teletherapy machine. T-type vertical support is also provided to the aluminium arc to make stable in a given standing position. There are provisions over the circumference of the aluminium arc to hold the various types of detectors such as TLDs (chips/ rods/ powder filled pouches), pocket dosimeter, large volume ion chamber at an angular interval of 30°. Using this tool, seven detectors can be irradiated simultaneously. For the source head leakage measurement of Bhabhatron-II, the tool was positioned at its couch in such a fashion that the centre of the semi circle was in coincidence with the position of the source in its on-position (Fig. 1). In this arrangement, all the seven detector positions were at 1-meter distance from the source. PTW 40 cm^3 ionisation chamber with its ^{60}Co build cap along with PTW UNIDOS dosimeter (PTW Freiburg, Germany) was used in this work.

Fig. 1 Photograph showing experimental arrangement used for leakage measurement from source head of Bhabhatron-II telecobalt unit (couch angle is 0° in this case).

For a given couch angle (say 0°), the ion chamber was positioned at five different locations over the circumference of the aluminium arc one by one and irradiated for 5 minute. The seventh position was in line with the radiation beam axis (designated 180° position of the detector with respect to source On-position) and it was inside collimator zone. Measurement at seventh detector positions was not carried out because the aim of this work was to determine leakage from the source head. In addition, sixth detector position on this tool was the point inside the patient plane. The experiment was repeated for seven different angular positions of the couch namely 135, 90, 45, 0, 315, 270 and 225°. The measurement at 0° detector position was carried out for 0° couch angle only once as this point was fixed in space at all the angular positions of the couch. The data so obtained was the source head leakage in other than patient plane.

The source head leakage in the patient plane was measured at 65 and 155 cm distance from the radiation beam axis. Fig. 2 is the schematic diagram showing measurement positions in patient plane. The black shaded region at the centre of this figure is the collimator transmission zone. In this case, the ionisation chamber was positioned at the given distance and the readings were recorded for seven different angular positions (135, 90, 45, 0, 315, 270 and 225°) of the couch. The gantry of Bhabhatron-II was stationary at 0° and the secondary collimator was fully closed during all the measurements.

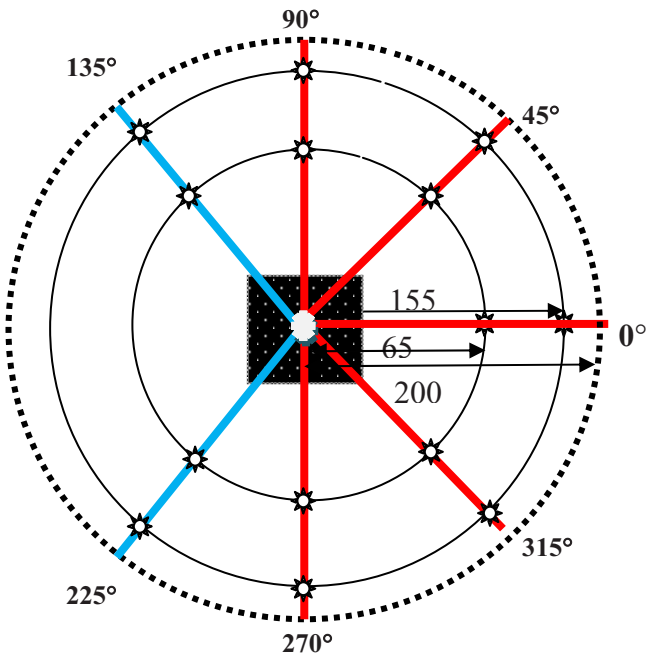

Fig. 2 Schematic diagram showing measurements positions in patient plane at 65 and 155 cm from the radiation beam axis. Black shaded region indicates area under the collimator zone. Indicated angular positions are the couch positions.

The dose rate at 1-meter distance from the source along the radiation beam axis corresponding to depth of dose maximum from the Bhabhatron-II was also measured using the same dosimetry

system. In this case, field size of 20x20 cm^2 was used for irradiating the ion chamber and dose rate for reference field of 10x10 cm^2 was calculated using the output factor of 20x20 cm^2 field determined using a secondary standard dosimeter. Percentage source head leakage at a point was calculated using absorbed dose value determined at this point and the dose rate along the radiation beam axis for10x10 cm^2 field.

III. Results and discussion

Table 1 presents the percentage on-position leakage from the source head of Bhabhatron-II telecobalt unit in other than patient plane measured with the help of specially designed tool. All the values shown in this table are less than 0.1% except one value at 270° couch position and 90° detector position. But all the values are much less than 0.5% (maximum value) which is the IEC-60601-2-11 recommended tolerance for this case. The determination of leakage radiation in a plane other than patient plane is important for the safety of occupational workers.

Table 1. On-position leakage (%) from source head of Bhabhatron-II telecobalt unit in other than patient plane.

Couch position	% source head leakage in other patient plane at source to detector angle				
	0^0	30^0	60^0	90^0	120^0
225^0	---	0.022	0.019	0.026	0.055
270^0	---	0.040	0.077	0.100	0.079
315^0	---	0.062	0.091	0.086	0.046
0^0	0.116	0.046	0.025	0.032	0.099
45^0	---	0.056	0.076	0.076	0.043
90^0	---	0.039	0.055	0.070	0.083
135^0	---	0.022	0.019	0.026	0.055

Measured percentage leakage radiation from the source head of Bhabhatron-II telecobalt unit at different angular positions in patient plane (the plane perpendicular to radiation beam axis) at 65 and 155 cm distance from the radiation beam axis are shown in Table 2. All the values in this table are much less than the IEC-60601-2-11 recommended tolerance of 0.2% (maximum value) in this case. The measurement of leakage radiation in patient plane is important for the safety of the patient during the treatment.

Table 2. On-position leakage (%) from source head of Bhabhatron-II telecobalt unit in patient plane.

Couch position	% source head leakage in patient plane at a distance from radiation beam axis of	
	65 cm	155 cm
225^0	0.012	0.002
270^0	0.015	0.003
315^0	0.010	0.002
0^0	0.022	0.003
45^0	0.009	0.002
90^0	0.016	0.003
135^0	0.010	0.002

IV. Conclusions

Percentage on-position leakage from the source head of Bhabhatron-II was determined both in patient plane and other than patient planes at a number of points. The measured values are much less than the IEC-60601-2-11 recommended tolerances. The measurement results indicate high degree of on-position radiation safety status of the telecobalt machine.

Acknowledgements

The authors wish to express their gratitude to Shri H. S. Kushwaha, Director, Health Safety and Environment Group, Dr. Y. S. Mayya, Head, Radiological Physics & Advisory Division (RP&AD), and Dr. G. Chourasiya, Head, Medical Physics & Training Section, RP&AD, Bhabha Atomic Research Centre, Mumbai for their encouragement and support during this work.

References

1. International Atomic Energy Agency (2008) Setting-up a radiotherapy programme: Clinical, medical physics, radiation protection and safety aspects, STI/PUB/1296, IAEA, Vienna
2. International Atomic Energy Agency (1998) Design and implementation of a radiotherapy programme: clinical, medical physics, radiation protection and safety aspects. IAEA-TECDOC-1040, IAEA, Vienna
3. International Electrotechnical Commission (1988) Medical Electrical Equipment: General Requirement for Safety, IEC 601-1
4. International Electrotechnical Commission (1997) Medical Electrical Equipment: Part 2: Particular requirements for the safety of gamma beam therapy equipment, IEC 60601-2-11
5. International Electrotechnical Commission (2004) Medical electrical equipment - Part 2-11: Amendment 1: Particular requirements for the safety of gamma beam therapy equipment, IEC 60601-2-11- am1
6. International Electrotechnical Commission (2001) Medical Electrical Equipment: Electromagnetic Compatibility-Requirement and Test, IEC 60601-1-2
7. Kumar R., Sharma S. D., Reena P., Deshpande D.D. and Kannan S. (2005) Performance characteristics of indigenously developed Bhbahtron-I telecobalt unit. J. Med. Phys. 30(2): 41 - 47

Address of the corresponding author:

Author: Dr. S. D. Sharma
Institute: RP&AD, BARC
Street: CT&CRS, Anushaktinagar
City: Mumbai - 400094
Country: India
Email: sdsharma_barc@rediffmail.com
sdsbarc@gmail.com