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Original Article

Commissioning and Qual ity Assessment Report of Bhabhatron-II TAW- a Telecobalt Unit

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Abstract

Introduction: By integrating the protocols of AAPM TG-40 and TRS-398 into the commissioning process, a comprehensive and structured approach was achieved. This ensured that the Bhabhatron unit met all required performance benchmarks for clinical use.

Materials and Methods : A Fluke ion chamber survey meter was used for radiation surveys. For output measurements, a 30 × 30 × 30 cm^3 water phantom, FC-65G (IBA) ionization chamber, Dose-1 electrometer, along with a thermometer and barometer were utilized. An SSD rod was employed for mechanical tests. Additional accessories included wedges, trays, films, slab phantoms, and a field size verification sheet.

Results : The output, based on corrected meter readings, was found to be 101.604 cGy/min. All electrical and mechanical parameters were tested and found to be within acceptable tolerance limits.

For leakage radiation measurements:

- Through beam-limiting device: Maximum reading = 0.02 nC (0.099%)
- In the patient plane: Maximum reading = 0.0112 nC (0.055%), with an average percentage variation of 0.0312%
- Outside the patient plane: Maximum reading = 0.0068 nC (0.033%)

All measured leakage values were within permissible limits.

Conclusions : The installation and commissioning of the telecobalt unit were carried out in accordance with the guidelines prescribed by the Atomic Energy Regulatory Board (AERB) and relevant international protocols. The results confirm that the unit meets all safety and performance requirements for clinical use. Furthermore, this work establishes a comprehensive quality assurance (QA) framework to support the safe and effective long-term operation of the telecobalt unit.

Keywords: radiation protection, source strength, performance, safety, quality assurance

Introduction

Cancer remains one of the most significant global health challenges, affecting millions of people worldwide. Treatment strategies vary depending

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on the tumor site and stage of the disease. Among the available modalities, radiotherapy is widely used and plays a crucial role in cancer management.

The Bhabhatron-II telecobalt unit was developed with a maximum source capacity of 555 TBq of Co-60.[1] This system was further enhanced by introducing asymmetric motion of collimator jaws and a motorised wedge, resulting in the upgraded Bhabhatron-II TAW (Tungsten Asymmetric Motorised Wedge).[2]

Among various radiotherapy machines, telecobalt units such as Bhabhatron-II TAW continue to be important in clinical practice due to their cost-effectiveness, simplicity, and reliability. They are particularly suitable for superficial tumors and palliative treatments. The upgraded system incorporates several advanced features, including an electromechanical and software-based anti-collision device, reduced transmission and scatter penumbra, and the capability to store and retrieve patient treatment data for subsequent sessions.

Compared to linear accelerators, telecobalt units offer advantages such as lower initial cost, reduced maintenance requirements, lower power consumption, and minimal downtime.[3] The system is also equipped with an Android-based hand control for patient setup. The Co-60 source is doubly encapsulated within two stainless steel capsules, approximately 2 cm in diameter and length, ensuring safety and containment. The emitted radiation is typically considered monoenergetic, with an average energy of 1.25 MeV.[4]

The machine is provided with different types of trays and wedges of varying angles, along with a motorised wedge integrated into the treatment head. It has a source-holding capacity of 11,500 Ci (250 RMM), with an initial source strength of 3324.87 Ci (72.15 RMM) at the time of installation. A gamma zone monitor was verified for proper positioning and functionality, as it is essential for ensuring radiation safety for personnel.[5] Display monitors are installed on both sides of the treatment couch for operational convenience.

Commissioning of the Bhabhatron-II TAW involves a systematic and comprehensive process, including acceptance testing, output measurement, quality assurance (QA), and clinical validation. Output measurements were performed in accordance with the TRS-398 protocol for absorbed dose determination in external beam radiotherapy.[6]

The overall objective is to establish a structured commissioning framework that ensures optimal machine performance, safety, and reliability, ultimately contributing to improved patient outcomes in radiotherapy.

MATERIALS AND METHODS

A) RADIATION SURVEY : The first test performed after installation of the unit was a comprehensive radiation survey to verify that the shielding barriers were adequate to attenuate both the useful beam and stray radiation to permissible levels.

For this purpose, PMMA slab phantoms were placed on the treatment couch, and the machine was operated with the maximum field size open. Radiation measurements were carried out at various gantry angles and at multiple locations surrounding the treatment unit to assess leakage and scatter radiation distribution.

A Fluke ionization chamber–based survey meter was used to perform the measurements. The workload considered for the shielding evaluation was 1.5×10^5 cGy per week.

B) OUTPUT MEASUREMENT : The water phantom (dimension 30 x 30 x 30 cm^3) was set on the treatment table. Gantry & Collimator were set to be 0°. The water phantom surface was maintained at 80 cm and chamber was set at the depth of 10 cm from the surface. Pressure (P) and temperature(T), were measured before starting the experiment and at the end of the experiment, and the average value for P & T correction were taken. Open field irradiation was performed for 5 min for warm-up and residual ion collection. 10 x10 cm^2 field size was set for absolute measurement. Meter readings were noted for the exposure time of 1 minute.

$$Shutter\ Timer\ Error = \frac{(M_2 - M_1)t}{2(M_1 - M_2)}$$

$$Corrected\ Meter\ Reading = \frac{MR}{1 + \delta t}$$

$$Output = \frac{M_R \cdot N_{D,W} \cdot K_{T,P} \cdot K_{ion} \cdot K_{pol}}{PDD}$$

C) VERIFICATION OF MECHANICAL AND RADIATION ISOCENTRE : Gantry, collimator and couch isocentre were found by rotating gantry, collimator and couch individually and marking the points of rotation. Radiochromic film was exposed from different angles of collimator, couch and gantry to obtain star pattern and radiation isocentre was found.

D) ELECTRICAL TESTS : Door interlocks were checked which are important for safety. Emergency buttons, control panel functionality, source position indicators, motorised components, battery backup in case of power failure; ensuring the source returns back to safe position was checked, audio and visual alarms providing appropriate warnings in faulty conditions were working.

E) MECHANICAL TESTS : All mechanical tests for the couch, collimator, and gantry rotations were performed and verified. The parallelism of opposite jaws, symmetry of opposing jaws, and orthogonality of adjacent jaws were assessed. Optical field overlap was evaluated, along with the accuracy of both the optical distance indicator and the mechanical front pointer. Field size definition was checked across the full range, from minimum to maximum field sizes. Additionally, shifts in the optical field were examined due to vertical motion (from minimum to maximum positions) and rotational motion (from –90° to 90°).

F) CONGRUENCE BETWEEN OPTICAL AND RADIATION FIELD : Gafchromic EBT3 films were set at d_{max} and SSD was set to be 80 cm . Films were exposed for 2.5 min for 10x10cm^2 and 30x30cm$^{2.}$

G) FLATNESS, SYMMETRY AND PENUMBRA : Gafchromic EBT3 film was set at the depth of d_{max} with field size of 10x10cm^2 80 cm from isocentre with SAD setup and was exposed for 2.5 min. Results for flatness, symmetry and penumbra were found by analysing the film.

H) RELATIVE SURFACE DOSE MEASUREMENT : Gafchromic EBT3 films were exposed for field sizes 10 x 10 cm^2 and 30 x 30 cm^2 one by one; once with the build up of 1 mm slab for surface dose and then for 5 mm slab for the d_{max} dose. Results for relative surface dose were found by Panacea medical technologies by analysing the film.

I) LEAKAGE LEVEL MEASUREMENT : Leakage from the source head was measured in beam OFF condition using GM based survey meter at the distance of 5 cm and 1 m.

J) MEASUREMENT OF WEDGE FACTOR : Solid slab phantom was used for the measurement. SSD was set to be 80 cm on the surface of the phantom, chamber was placed at the depth of 10 cm with the field size of 10x10cm^2 and the voltage applied was +300V. First reference meter readings were taken without wedge and after that meter readings were taken for different wedges one by one and wedge factor was calculated.

Meter reading without wedge at 10cm depth is 10.36 nC.

$$Wedge\ Factor = \frac{Meter\ Reading\ with\ Wedge}{Meter\ Reading\ without\ Wedge}$$

K) MEASUREMENT OF TRAY FACTOR : Solid slab phantom was used for the measurement. SSD was set to be 80 cm on the surface of the phantom, chamber was placed at the depth of 10 cm with the field size of 10x10cm^2 and the voltage applied was +300V. First reference meter readings were taken without tray and after that meter readings were taken for different trays one by one and tray factor was calculated.

Meter reading without tray at 10cm depth is 10.36 nC.

$$Tray\ Factor = \frac{Meter\ Reading\ with\ tray}{Meter\ Reading\ without\ tray}$$

Meter reading for 0° gantry was 18.09 nC

Meter reading for 180° gantry was 17.19 nC

M) LEAKAGE RADIATION MEASUREMENT THROUGH BEAM LIMITING DEVICE : First the chamber was set at the reference point and the field size was set to be 10x10cm^2 with the applied voltage of +300V and the meter reading was noted. After that chamber was set at different positions with the field size completely closed and the meter reading was noted.

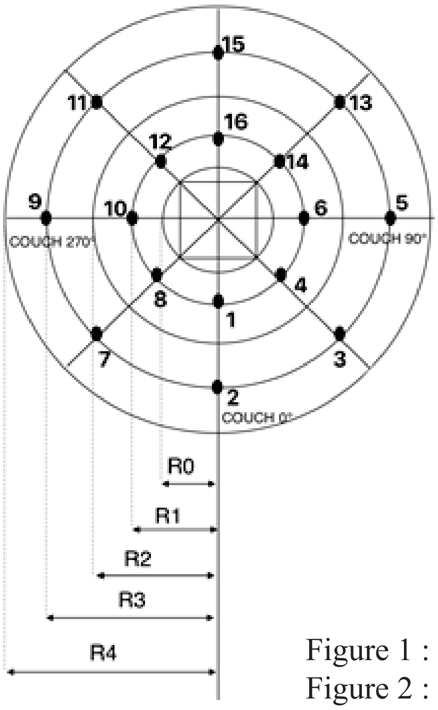
N) LEAKAGE RADIATION MEASUREMENT FOR IN PATIENT PLANE : Chamber was set at the reference position with SSD 80 cm; field size of $10x10cm^2$ and +300V and meter reading was noted. After that meter reading was noted for 16 different points within the radius of 2 m with the field size completely closed. (Figure 1)

O) LEAKAGE RADIATION MEASUREMENT FOR OUT OF PATIENT PLANE : Gantry was set to be 180° with the field size completely closed, chamber was set at the distance of 1 m at different positions one by one and the meter reading was noted. (Figure 2)

P) OUTPUT CONSTANCY MEASUREMENT : Chamber was set directly on couch in air with 0.5 cm buildup cap with field size of $10x10cm^2$ and the meter readings were noted for different gantry angles.

Q) OUTPUT FACTOR MEASUREMENT : Chamber was set at the depth of 10 cm with the applied voltage of +300V and field size of $10x10cm^2$, this was noted as reference meter reading. After that meter readings were noted for different field sizes one by one and output factor was calculated.

$$Output\ Factor = \frac{Meter\ Reading\ of\ Given\ Field}{Meter\ Reading\ of\ Reference\ Field}$$



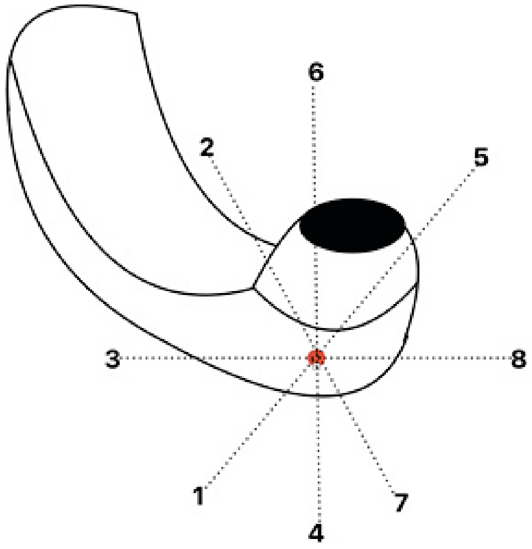


Figure 1 : leakage measurement in patient plane

Figure 2 : leakage measurement in out of Patient plane

RESULTS :

A) Maximum reading found was 27 µR/hr which is 0.5398mR/wk and it is anyhow less than the limits for both radiation workers and general public.(Tolerance for radiation worker is 40mR/wk and for general public is 2mR/wk)

B) $K_{T,P}$ was 1.040. Meter readings were taken for +300V and -300V and K_{pol} was found to be 1.003726.

Meter readings were taken for +300V and +150V and K_{ion} was found to be 1.0006757.

Meter readings were taken with and without interruption for treatment time of 1 min and shutter time error was found to be 0.009182 min.

Corrected meter reading with shutter time error was 11.435 nC.

Output with the corrected meter reading was found to be 101.604cGy/min.

C) Collimator rotation isocentre was found to be 1 mm.(Tolerance : 2mm diameter)

Gantry and couch rotation isocentre was found to be <2 mm.(Tolerance : 2mm diameter)

Coincidence of collimator, couch and gantry axes with isocentre was <2 mm.(Tolerance : 2mm diameter)

Radiation isocentre was found to be <1 mm.(Tolerance : ≤2 mm diameter sphere)

Coincidence between mechanical and radiation isocentre was 1 mm.(Tolerance : 2mm diameter)

D) Door interlocks were functioning properly. Emergency buttons, control panel functionality, source position indicators, motorised components, battery backup in case of power failure; ensuring the source returns back to safe position were functioning properly, audio and visual alarms providing appropriate warnings in faulty conditions were also functioning properly.

E) Parallelism of opposite jaws was found to be 0°(± 1°), symmetry of opposite jaws was found to be 1mm(± 1 mm) and orthogonality of adjacent jaws was found to be 0°(90° ± 1°). Optical field overlap was found to be 0° and 180°: <1 mm(± 1 mm) , 90° and 270° : <1 mm(± 1 mm). Accuracy of optical distance indicator was found to be 1mm(± 2 mm) and accuracy of mechanical front pointer was found to be 1mm(± 2 mm) . Variation in field size definition for field sizes upto 10cm x 10cm was found to be <1mm(± 1 mm) and for field sizes greater than 10cm x 10cm was found to be <2mm(± 2 mm). Shift in optical field due to vertical motion from minimum to maximum position was found to be 2mm(± 2 mm). Shift in optical field due to rotational motion from -90° to 90° was found to be 1mm.(± 2 mm)

F) Optical and radiation film congruence was observed to be 1mm.(± 2 mm)

G) Table 1 : Flatness, symmetry and penumbra

Penumbra	*Penumbra*	*Penumbra*	*Penumbra*
X_-(mm) = 9.2	Y_-(mm) = 10.6	X_+(mm) = 9.2	Y_+(mm) = 10.6
Flatness	*Flatness*	*Flatness*	*Flatness*
X(%) = 1.8	Y(%) = 1.9	Diagonal_1(%) = 3.2	Diagonal_2(%) = 3.2
Symmetry	*Symmetry*	*Symmetry*	*Symmetry*
X(%) = -1.2	Y(%) = 1.7	Diagonal_1(%) = -1.4	Diagonal_2(%) = -1.4

H) Relative surface dose for field size of 10 x 10 cm^2 was found to be 67.8%.(Tolerance : ≤70%)

Relative surface dose for field size 25 x 25 cm^2 was found to be 88.1%.(Tolerance : ≤90%)

I) Leakage at 5 cm was found to be 6.5μSv/hr (Tolerance : 200μSv) and leakage at 1 m was found to be 0.47μSv/hr (Tolerance : 20μSv)and both values are less than the tolerance values.

J) Table 2 : Wedge factor

Wedge angle	*Wedge size*	*Meter reading*	*Wedge factor*	*Manufacturer specified value*	*Deviation*
15°	15W X 20	7.17948	0.6930	0.6905	0.036%
30°	15W X 20	6.26262	0.6045	0.602	0.42%
45°	15W X 20	4.67132	0.4509	0.4475	0.76%
60°	15W X 20	3.46645	0.3346	0.3320	0.78%

K) Table 3 : Tray factor

Type of tray	*Meter reading*	*Tray factor*	*Manufacturer specified value*	*Deviation*
Tray rail	9.7601	0.9421	0.9430	-0.095%
Slotted tray	9.9269	0.9582	0.9580	0.0208%
Slotted tray 90°	10.1289	0.9777	0.9780	-0.0306%

L) Couch transmission factor was found to be 0.9502.

M) For leakage radiation measurement through beam limiting device, maximum meter reading was found to be 0.02nC that is 0.099% (Tolerance : 2%).

N) For leakage radiation measurement in patient plane, maximum meter reading was found to be 0.0112nC that is 0.055% leakage(Tolerance : 0.2%) and average percentage variation of leakage was found to be 0.0312%(Tolerance : 0.1%).

O) For leakage radiation measurement out of patient plane, maximum meter reading was found to be 0.0068nC that is 0.033%(Tolerance : 0.5%).

P) For output constancy measurement, maximum meter reading was found to be 18.13nC that is 1.2% (Tolerance : 2%).

Q) Table 4 : Output factor

Field size	*Meter reading*	*Reference meter reading*	*Output factor*
5 x 5	13.93	15.70	0.8872
10 x 10	15.70	15.70	1.0000
12 x 12	16.13	15.70	1.0273
15 x 15	16.60	15.70	1.0573
20 x 20	17.15	15.70	1.0923
30 x 30	17.71	15.70	1.1280
35 x 35	17.74	15.70	1.1299

DISCUSSION

Every step—from site planning and radiation shielding assessment to machine calibration and performance evaluation—was carried out meticulously, confirming that the unit meets the required technical and safety standards. All obtained results were well within the acceptable limits prescribed by the regulatory board and were consistent with the manufacturer's specifications. The Bhabhatron-II TAW unit has a maximum source loading capacity of 250 RMM, while the source strength at the time of measurement was 72.15 RMM. The measured radiation output of the unit, following the IAEA TRS-398 dosimetry protocol (for a 10 × 10 cm^2 field at dmax under SSD setup), was 101.604 cGy/min at an SSD of 80 cm on 21/10/2024.

One of the key observations during commissioning was the critical importance of precise mechanical and optical alignment in ensuring geometric accuracy and treatment reproducibility. Additionally, the radiation protection survey confirmed that the room shielding and machine design effectively limit radiation exposure to within regulatory limits, thereby ensuring the safety of both patients and staff.

CONCLUSION

The installation and commissioning of the telecobalt unit were carried out in accordance with the guidelines established by the Atomic Energy Regulatory Board (AERB), along with relevant international protocols, ensuring both safety and clinical efficacy. Performance evaluation demonstrated that the unit operates reliably within clinically acceptable limits. Critical parameters—including source alignment, output consistency, mechanical accuracy, and beam uniformity—were thoroughly verified through comprehensive quality assurance (QA) procedures. Dosimetric measurements remained consistent with baseline values, confirming the unit's readiness for clinical application.

This work not only establishes the operational readiness of the telecobalt unit but also defines a robust QA framework to support its long-term clinical use. With the implementation of routine QA checks and periodic recalibration, the unit is expected to maintain consistent treatment quality throughout its service life.

In conclusion, this study highlights that with meticulous planning, strict regulatory compliance, and rigorous quality control, telecobalt units can continue to play a significant and reliable role in modern cancer treatment.

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Conflicts of interests: There is no conflict of interest

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