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TRANSMISSION & LEAKAGE MEASUREMENT OF NOVEL TELECOBALT MACHINE BHABHATRON-II

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ABSTRACT: The Telecobalt machines are extensively used in developing countries due to its lesser cost, lesser power consumption and easy maintenance. The high activity source can be extensively used for at least 6-8 years due to its long half-life. Installing a Telecobalt unit comprises of fixing the machine in the treatment room, ensuring its mechanical motions, source loading and all other related Quality Assurance Checks. The Bhabhatron-II, an indigenous Telecobalt machine is installed at Acharya Tulsi Regional Cancer Centre, produced in India by Department of Atomic Energy, Mumbai. This paper describes about the installation & Commissioning of Bhabhatron-II and their related Quality Checks. The necessary Radiation Quality Assurance checks such as Combined Jaw Transmission, Individual Jaw Transmission, and ON Position Leakage in patient plane, Leakage in other than patient plane are measured. The collimator transmission of combined jaw and, Individual jaws (X & Y) are measured and they are 0.024%, 0.347% & 0.635% of the useful beam respectively. The ON position leakage in patient plane is measured by forming an imaginary circle of 2m radius @ SAD; the leakage level is 0.005% which is 5.42% of the recommended limit by I.E.C. The ON Position leakage level in other than patient plane is measured by a special apparatus which partially simulates a sphere of 1m radius. The leakage level is 0.347% of the Dose Rate measured at 1m. The Dosimetric instruments which are available in routine radiotherapy department are used. The TLD Disks are used to measure the ON Position Leakage in other than Patient plane. The measured readings are well under the Tolerance recommended by A.E.R.B India. The machine has been approved by the regulatory board and dedicated for Treatment purpose.

INTRODUCTION: The purpose of this paper is to address the process of Installation and commissioning of Bhabhatron-II, an indigenous Telecobalt Machine at our centre. The Telecobalt machines are extensively used in developing countries due to its lesser cost, lesser power consumption and easy maintenance [1].

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As most of the Telecobalt machines are available with symmetrical collimators and physical wedges,[2] Bhabahtron-II machine differs from other Telecobalt Machines not only as an indigenous product but also in the mode of computer controlled operation and asymmetric properties.

The Collimator motions, Exposure Times are computer controlled [3] and the Patient Treatment can be executed with the dedicated Treatment Control Console. The Source Head of this unit, Primary collimator, Secondary collimator & Trimmers are made of Tungsten material The Y Jaw is asymmetrical also with a provision for

motorized wedge. In case of source struck, the collimators automatically close to the minimum level and reduce the exposure. Bhabhatron-II, an indigenous machine which was developed by the D.A.E. India differs significantly from other conventional Telecobalt Machines. The Head shielding is provided by Tungsten which removes the safe disposal issues of Depleted Uranium and their subsequent follow up.

The collimator & Trimmers are also made of Tungsten material. The execution of patient treatment can be performed with dedicated Console Computer. The patient plan parameters can be loaded in the console; the no of fractions to be delivered, Collimator Values, Collimator Rotation can be loaded in the console.

The no. of patients treated per day with time & date are stored in the Patient History. The 'BEAM ON' shall be performed with mouse click. Usage of such type of new modality machines which differs a lot from other conventional machines needs proper evaluation and assurances before left for patient treatment purpose.

We describe here the method of Radiation Quality Assurance Test performed for this indigenous machine and their results. The Collimator Transmission (Individual & Combined Jaws), Head Leakage in Source OFF Condition, ON Position Leakage in Patient Plane & Other than patient plane are the important Radiation Quality assurance checks to be performed to ensure the safety of the patients and operators. The recommendations for Tolerance given by A.E.R.B and IEC were adopted for our measurements. The detectors such as Thimble Chamber, Pocket Dosimeter and TLD Disks were used for this Quality Assurance checks

MATERIALS AND METHODS:

The Quality Assurance checks are performed as per the recommendations of A.E.R.B and I.E.C. Following the installation of a Unit, the Medical Physicist have to perform a series of operations or checks to dedicate the unit for Treatment Purpose. We describe only about the Radiation checks as other mechanical and electrical checks are easy to perform in routine. The transmission of X Jaws, Y Jaws & combined Jaws are measured by calibrated Ion Chamber. The calibrated Ion chamber is placed in air with build-up cap and the Dose Rate of reference field size (10x10) is measured. The series of measurements in the points are made as per the diagram no 1. The transmission of Individual jaws & combined jaws should not exceed 2% & 0.5% of the output of the reference field size respectively [3-4].

The ON position leakages are measured with the Pocket Dosimeter and TLD Disks. The measurements in other than patient plane measurements were performed by making the source to remain at the centre of an imaginary sphere with the radius of 1m at source ON condition.

The TLD Disks are placed at various points on the imaginary sphere and the measurements are performed. The irradiated TLD Disks are read in the TLD reader and the readings are obtained by correlating it with the calibrated values. The patient plane measurements are performed at various points in a circle of 2m radius centered at Isocentre. The calibrated Pocket Dosimeter (Dosi Rad) is placed in these points and the measurements are performed.

The ON Position leakages in patient plane & other than patient plane are related with the Exposure Rate measured at 1m from the source. The Head leakage at OFF condition is measured by using Pressurized Ion Chamber based survey meter and GM Counter based survey meter at 1m from the centre of the source and 5 cm from the surface of the source head.

Collimator Transmission combined Jaws (X & Y jaws):

The transmissions of combined Jaws are measured for the points as shown in the **Figure 1**. The X & Y Jaws transmissions are measured by closing both the Jaws to the minimum level. Any residual opening shall be covered with adequate amount of shielding material. The below diagram was developed by considering the maximum field size of 35 x 35 cm. The hypotenuse, 24.75 cm is found by using Pithogerous Theorem Hypotenuse = $\sqrt{(17.5^2 + 17.5^2}$ = 24.75 cm. An imaginary circle is formed by considering this hypotenuse as radius and the outer and major circle is formed as shown in the diagram.

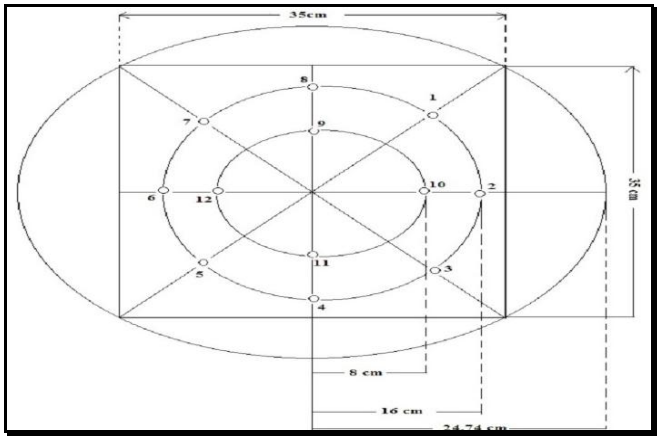

FIGURE: 1

The other two inner circles are formed by obtaining the 1/3rd & 2/3rd of the Hypotenuse which will form the circles with radii of 8cm and 16cm respectively. The measurement points were fixed as depicted in the diagram which will form 12 points for measurement. A thimble chamber is used for this measurement. Initially the chamber is placed in air and the measurement is made for 10x10 cm^2 field size. The chamber is fastened in the couch at Isocentre with build-up cap. The digital displays of couch values are adopted to displace the chamber for the required distance from the Isocentre. The provision of digital display in this machine is not only useful for precise patient setup but also for the Quality Assurance checks.

Collimator Transmission individual Jaw (X & Y Jaws):

The transmissions of X JAWS & Y Jaws are measured for the points as shown in the **Fig 2**. The X & Y Jaws transmissions are measured by closing one of the Jaws and opening the alternate Jaws. The squares in the diagram are obtained by considering the 1/3rd & 2/3rd of the maximum radius 24.75cm as described.

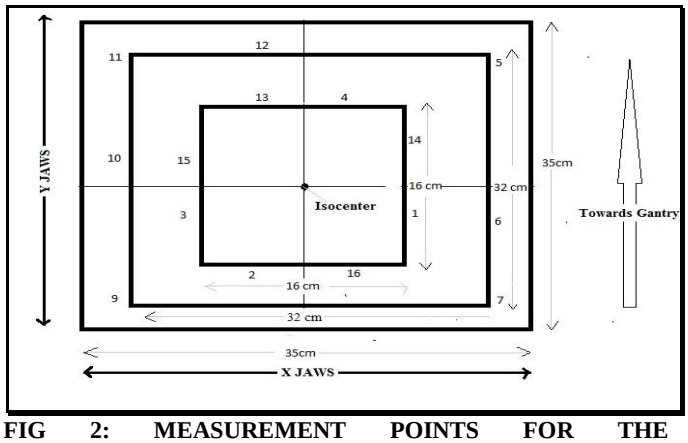

FIG 2: MEASUREMENT POINTS FOR THE TRANSMISSION OF INDIVIDUAL JAWS

On Position Leakage in patient Plane (16 Point Measurement):

Procedure of Measurement: A wooden plain rod of length 2m is prepared to mimic the radius of 2m circle in the patient plane. The radii R1 & R2 are obtained by solving the equation as per I.E.C guidelines[5]. The On Position leakage measurements are measured for the points shown in the diagram.

a) $R_1 = R_0 + ¼ (2-R_0) = 0.6865m$

b) $R_2 = R_0 + ¾ (2-R_0) = 1.562$ m

Where $R_0 = 0.2475$m obtained as the hypotenuse of the right angled triangle having sides as 17.5 cm

These two radii 0.6865m & 1.562 m are marked in the wooden rod from the Isocenter as shown bellow. The detector is placed in these points and the measurements are made with collimators closed to the minimum level.

The angle of the couch was adopted to measure the angle of the circle and the measurements are performed. The rod is kept at the couch and the couch is moved to 90 degree and 270 degree which will complete the measurement of 10 points. The DosiRad pocket dosimeter under valid calibration is used for this measurement. The readings are as comparable with the measurements performed by Rajesh Kumar et al[2]

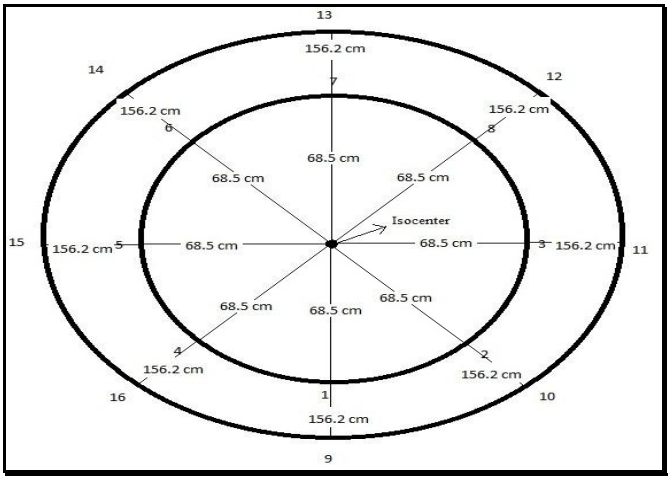

FIG 3: MEASUREMENT POINTS FOR ON POSITION LEAKAGE IN PATIENT PLANE

The measurements in the angles of 225 and 135 are achieved by keeping the couch in 45 Degree and 315 respectively and by moving the plain wooden stick so that the distal end of the stick from Isocenter at 45 degree becomes the proximal end at 225degree and the radius of 2m is once again

reproduced. The same procedure has been repeated for the 135 Degree point measurements. Adequate support was given to the stick to hold the detector and the measurements are made for 135 & 225.

On Position Leakage in other than patient plane:

The ON Position Leakage was measured by specially developed apparatus which has the measurements as Shown in Fig.4. The radiation levels are measured from 1m distance from the centre of the source at various places (at ON Position), which will naturally form measurements over a sphere. Making the measurements in an imaginary sphere at source ON condition seems cumbersome. To achieve these following steps were performed.

- Two wooden stick of length 141.4cm are developed; they are attached at right angles to each other.
- The distance between the ends of two wooden sticks should be 200cm.
- Considering a circle of Diameter of 200cm the arch length was calculated for the semicircle.

The Arch length 314cm was simulated by thin plastic sheets and is placed over the wooden sticks of length 141.4cm.

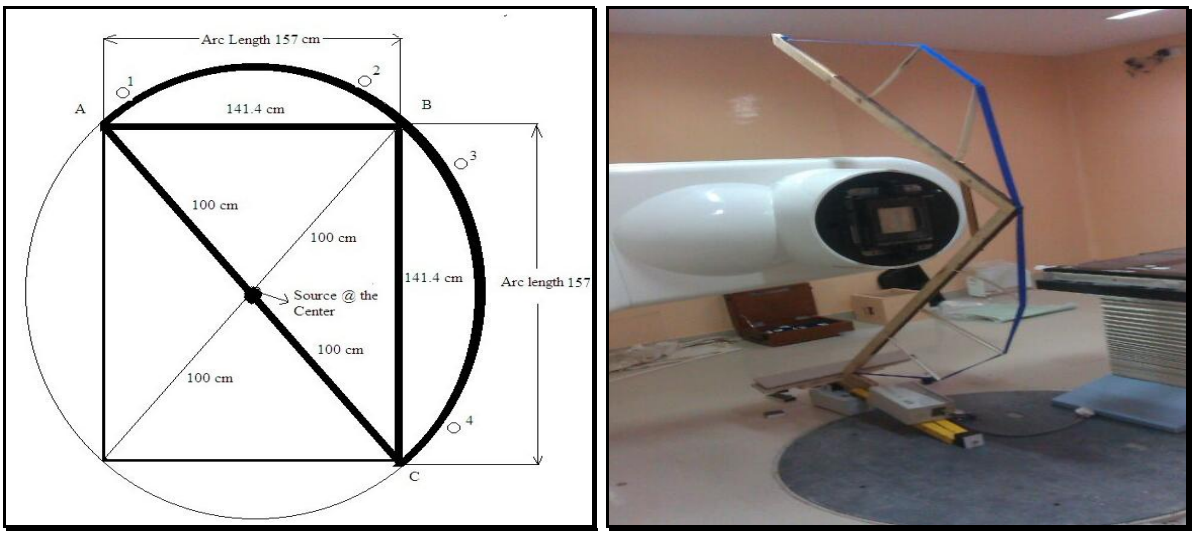

FIG 4: MEASUREMENT POINTS FOR ON POSITION LEAKAGE IN OTHER THAN PATIENT PLANE

The above design will form a semicircle of diameter 200cm with an Arc length of 314cm. The wooden sticks are as similar to the chord of the circle which intersects each other perpendicularly. One end of the apparatus is placed at 1m from the source along the central axis.

The other end of the apparatus will be placed at 1m above the source. The Jaws are closed for minimum field size. The TLD Disks were placed at various points on the thin plastic sheets simulating the circle and the measurements are performed.

The readings are repeated for various points by moving the circles so that it forms a sphere. The TLD Disks are read with the help of the TLD Reader 10091 from Nucleonix, India. The calibrated TLD disks against Co-60 energy are used. The ideal properties of the TL disc such as reproducibility, linearity is ensured and the discs passing these tests are selected for this measurement. The measured readings are compared with the exposure rate measured at 1m from the source.

OFF Position Leakage from source Head

The OFF position leakage in the source OFF condition is measured at a distance of 5cm from the surface of the source Head and 1m from the centre of the source. The OFF position leakage should not exceed 20mR/hr at 5cm from the outer surface of the source Head and should be less than 2mR/hr at 1m from the centre of the source. The pressurized Ion Chamber based survey meter from Victoreen is used for the leakage. The average OFF Position Leakage from the source head are 6.68 & 1.30 µSv/hr for 5cm from the surface of the source head & 1m from the centre of the source respectively.

DISCUSSIONS:

Collimator Transmission:

Our Measurements ensured that the Transmission of individual and combined Jaws are under the Tolerance limit specified by IEC and AERB. The average Transmission values of X Jaws, Y Jaws and their transmission when they are combined can be seen in the **Table 1, 2** and **3** respectively.

The average Transmission of X Jaws and Y Jaws are 17.35 and 31.65 percentage of the recommended tolerance. It shall be noted that the Y Jaw transmits more than 14% of X Jaws but it is well within the tolerance limit.

TABLE 1: TRANSMISSION OF COMBINED JAWS

Detector Position	Average (nC/min)	% of Transmission of combined Jaws
1	0.027	0.011
2	0.011	0.023
3	0.004	0.008
4	0.016	0.033
5	0.015	0.031
6	0.009	0.018
7	0.014	0.028
8	0.026	0.053
9	0.006	0.013
10	0.005	0.011
11	0.006	0.012
12	0.022	0.045
Average		**0.024 %**

The measured nC shall be considered as $I_{0.}$. The other I values, Transmitted readings, are measured by placing the Thimble chamber at various points as shown in the diagram. The measured readings are related with the 10x10 open beam values and the readings are tabulated which is shown in the **Table1**.

The average percentage of transmission is calculated by the Formula ($I/ I_0 * 100$). The average percentage of transmission is 0.024 with standard deviation of 0.015%. The average transmission is much lesser i.e 4.72% of the prescribed tolerance (0.5% of the useful Beam) with lesser standard deviation.

TABLE 2: TRANSMISSION OF X JAWS

Detector Position	Average (nC/min)	% of Transmission
1	0.154	0.316
2	0.084	0.171
3	0.193	0.395
4	0.107	0.22
5	0.238	0.486
6	0.29	0.593
7	0.204	0.417
8	0.055	0.114
9	0.202	0.414
10	0.282	0.577
11	0.285	0.583
12	0.103	0.211
13	0.096	0.196
14	0.151	0.310
15	0.18	0.368
16	0.092	0.188
	Average	**0.347 %**

TABLE 3: TRANSMISSION OF Y JAWS

Detector Position	Average (nC/min)	% of Transmission
1	0.368	0.754
2	0.428	0.876
3	0.311	0.636
4	0.406	0.830
5	0.282	0.577
6	0.292	0.598
7	0.295	0.604
8	0.389	0.796
9	0.274	0.560
10	0.214	0.437
11	0.214	0.437
12	0.213	0.435
13	0.405	0.83
14	0.221	0.452
15	0.219	0.452
16	0.435	0.891
	Average	**0.635%**

The transmission of individual jaws are measured by creating additional points, which will give total 16 points to measure (refer **Fig 2)**. The ion chamber is placed in these points with respect to the Isocenter. The digital display of couch values is followed to place the chamber in the points. The obtained values are compared with the useful open beam values (48.45nC/min) 10 x 10 @ normal treatment distance and the Transmission factors are calculated.

The percentage of transmission for X Jaws and Y Jaws are 0.347 & 0.635 of the useful beam with standard deviation of 0.157 and 0.077 respectively. From assessing the standard deviation of these transmission data, the Y jaw transmission is much uniform when compared to the X Jaw transmission.

The measurements performed by G. Shani et al showed that the Percentage of Transmission of Y Jaws & X Jaws are 1.85& 1.4 respectively and at some point the maximum Transmissions were exceeding the Tolerance limit 2.1% for Y Jaws. The combined Jaws Transmission was not addressed by G. Shani et al for Bhabhatron II. As the Telecobalt source produces higher Geometric Penumbra due to its larger source diameter, lesser amount of Transmission ensures lesser dose delivery in the field Umbra region. The higher transmission of collimators will add extra dose to non Target area which necessitates the lesser Transmission in collimators.

On Position Leakage in patient Plane:

The ON position leakage in the patient plane is a significant parameter related to radiation safety of patients during treatment. This ensures that the patients won't receive any excess radiation apart from the irradiated area. The higher level of leakage may contribute to secondary malignancies. Our leakage levels are well within the prescribed limit of I.E.C & A.E.R.B.

TABLE 4: ON POSITION LEAKAGE IN PATIENT PLANE

Detector Position	Couch Angle	Average(cGy/min)	% of Transmission
1	0	0.007	0.003
2	45	0.009	0.004
3	90	0.049	0.02
4	315	0.01	0.004
5	270	0.018	0.007
6	225	0.011	0.004
7	0		
8	135	0.035	0.014
9	0	0.002	0.001
10	45	0.003	0.001
11	90	0.01	0.004
12	135	0.01	0.004
13	0		
14	225	0.003	0.001
15	270	0.01	0.004
16	315	0.003	0.001
	Average	**0.011 cGy /min**	**0.005%**

The percentage of leakage was calculated by dividing the obtained average reading of each point by the 10 x 10 useful beam output 246cGy/min @80.5 cm. The leakage level in patient plane is 0.005% with standard deviation of 0.005.

The obtained average transmission is much lesser than the tolerance limit **(**0.1% of the useful beam (10 x 10 field size) (Dose rate measured at normal treatment distance)

The leakage levels were 0.005% of the recommended tolerance limit (0.1% of useful beam for 10 x 10 cm2 field size and with dose rate measured at normal treatment distance). This leakage level ensures that the equipment can be used even with higher source activity. The measurement procedures are simplified by using available Pocket Dosimeter & Survey meter. The pressurized Ion chamber shall be used in the integrated mode to collect the readings for complete irradiation time. The calibrated pocket dosimeter is also used simultaneously and placed along with the Pressurized Ion Chamber; the observed readings in both the detectors are in good agreement and ensured that the leakage level measurements are measured accurately.

On Position Leakage in other than patient plane:

The ON Position leakage in other patient plane ensures that no excess leakage radiation comes from the source head. The leakage radiation of Telecobalt Machine shall not exceed 0.5% of the maximum workload at a distance of 1m from the centre of the source. The Barrier thickness for the room is calculated considering 01% of useful beam. This ensures that the ON position leakage level is less than 0.5% at 1 m. Any radiation generating equipment with leakage level more than 0.5% of the useful beam shall be evaluated seriously, as it may increase the exposure level.

TABLE 5: ON POSITION LEAKAGE IN OTHER THAN PATIENT PLANE

Detector Position	Dose (cGy/min)	% of Leakage
1	0.104	0.316
2	0.071	0.171
3	0.161	0.395
4	0.087	0.22
5	0.08	0.486
6	0.073	0.593
7	0.06	0.417
8	0.051	0.114
9	0.068	0.414
10	0.066	0.577
11	0.074	0.583
12	0.056	0.217
	Average	**0.375 %**

The percentage of leakage is 0.375% of the exposure rate at 1m. As the Ion Chamber is not much sensitive enough to measure the small amount of leakage radiation we selected $CaSo_4$: Dy

Thermoluminsecence Detector (0.8mm thick &13mm dia). As the semiconductor material is more sensitive than the Gas filled detectors, the leakage radiation of radiations can easily be measured. Prior to using this Thermoluminsecence Detector all the Disks shall be calibrated against the Co-60 Energy. Our measurements ensured that the Leakage levels are well within the recommended limit.

CONCLUSIONS: Bhabhatron II mainly differs from other conventional Telecobalt Machine as it is a computer controlled one. Hence one should ensure its safety features prior to usage on patients. Ensuring Radiation Safety is the primary role of Medical Physicist involved in the installation & commissioning process. The Quality assurance tests were performed as per the A.E.R.B guidelines which were described in the above discussions. All the Quality Assurances were under the recommended Tolerance limit. Bhabhatron-II being a computer controlled machine satisfies the necessary and basic safety requirements for Clinical usage.

The above performed tests were submitted to the Regulatory Board and the same has been accepted for patient Treatment. The patients received the treatment through computer controlled execution. The plan parameters such as Field size, Collimator, Gantry and Couch parameters can be loaded for individual patients along with the Treatment Time.

The source stays in ON Position till the programmed time and returns to OFF Position after delivering the Treatment. This ensures that the patient receives accurate Treatment when the patient setup is maintained. Providing a computer controlled Treatment in a Telecobalt Machine is a remarkable achievement in the Medical Physics era with the help of Technology.

Configuring this machine in the T.P.S and executing the Treatment through 3-D Planning will give a huge benefit to the patient. Implementation of Multi leaf collimator in this advanced machine is expected. Even though the Telecobalt Machines has disadvantages of Penumbra, Periodic reduction of Dose Rate etc., implementation of computer controlled Treatment Delivery, Asymmetric Jaws, motorized wedge, Record of Patient History, Battery backup of six hours etc has remarkably enhanced the Quality of treatment in the field of Radiotherapy. This machine suits for developing countries provided if the combined cost of the radioactive material and the treatment machine is lesser to a significant level when compared with the low energy LINAC.

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