

**Tutorial:****Comprehensive Benchmark Procedures for Commissioning, Quality Assurance and Treatment Delivery for Quality Cancer Therapy Using Co-60 Teletherapy Machine**

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## 1. BASIC OVERVIEW: AN INTRODUCTION

### 1.1 Established Protocols

Assuming that a radiation Oncology Physicist is given the responsibility to use a Co-60 teletherapy machine for radiation therapy, s/he needs to evaluate its performance in order to produce a beam quality for an accurate dose delivery to the concerned anatomy. Therefore, we must comply with the established and proven protocols as well as apply all other available technologies, old and new, to quantify the beam output of the machine. To achieve this, the physicist has to perform a number of elaborate segments of measurements as outlined in this report. Recommendations of international Task Groups are matched and incorporated in the following measurements before accepting, commissioning and delivery of radiation therapy treatments to cancer patients.

### 1.2 Measurement Parameters

Mechanical parameters that relate to Gantry, Couch, Collimators and Field Sizes are expressed in millimeters (mm) and degrees ( $\theta^0$ ) with regards to the appropriate measurement parameters of the components of the machine. Besides, Dosimetric Properties viz. beam profiles, penumbra, PDD (Percent Depth Dose), dose calculations in tissue and treatment delivery encompass various types of measurements in order to conform and quantify with international Task Group recommendations viz. TRS-398 and TG-40 (1994b, 2005) It is imperative that the systematic guidelines enunciated here should be established to assure a quality cancer treatment.

Implementations of quality control on machine, using the protocols TRS-398 and TG-40 prior to the delivery of treatment is a necessity. The implications of such a report, replicating the benchmark guidelines, are enunciated here. Cancer Therapy using Co-60 teletherapy machines, in Bangladesh as well as in other countries, may benefit from the systematic presentations of procedures, tables, figures and measurements as documented in this tutorial. Limits of tolerance in mechanical and dose values, with beam check parameters, are evaluated in this paper. The teletherapy machine is then accepted and commissioned to deliver the prescribed dose to the disease of cancer patients.

### 1.3 Goal

A cobalt therapy machine uses a radionuclide produced in a Nuclear Reactor having a mean  $\gamma$ -energy of 1.25 MeV. Energy of such photons has a skin sparing property as maximum dose is achieved at 5 mm depth below a tissue (i.e. skin) or any equivalent material. The activity of the source decays by about 1.09% per month as the half-life of Co-60 is 5.26 years (Metcalf Peter and Kron 1997). The penumbra is larger, compared to that of Linear Accelerators, as the source diameter is about 2cm (Cunningham 1983). A short source to surface distance (SSD) of 80 cm is used to achieve a reasonable dose rate for treatments, whether palliative or curative.

The series of measurements presented here, to act as a guide to the use of such a machine for cancer therapy, have been aimed at the verification of all machine and radiation characteristics in order to ensure quality cancer therapy.

## 2. MATERIALS AND METHODS

### 2.1 Materials

In the present study, essential measurements for commissioning and acceptance has been carried out following the guidelines, policy and procedures of TG-40 and TRS-398 (1994a, 2005). Table 1 summarizes most of the essential values, with tolerance levels, in the evaluation of the machine which should be established by appropriate procedures of measurement. The objective of this work may, therefore, be taken as a reference for any user or, for that matter, the Nuclear Regulatory Authority (NRA) for the verification of quality performance of the machine, while using it at any Cancer Treatment Center (CTC). Detailed information on materials and methods are compiled here. The

following description pertains to the facilities available at the Radiation Oncology Division, Delta Hospital Ltd., Dhaka, Bangladesh. The procedures cited here can serve as examples for newcomers into this field.

### ***2.1.1 Description of the Co-60 Teletherapy Machines***

Our hospital, Delta Hospital Ltd, has two Co<sup>60</sup> teletherapy machines providing external beams of photons for cancer therapy. Let the names of the two machines be **Cobalt-I** and **Cobalt-II**. These two teletherapy sources differ in their activities and hence the dose rates. The dose rate is an essential parameter in the calculation of prescribed dose. The salient features of these two Cobalt sources are as follows:

#### **Cobalt-I**

Manufacturer : G.E Medical System, USA  
Model : ALCYON II P  
Date of installation : June, 1994  
1st time source change date: March 2005  
2nd time source change date: June 2013  
Present activity of the source: **6974Ci**

#### **Cobalt-II**

Manufacturer : Cis Bio. Int. France.  
Model : CIRUS  
Date of Installation : February, 2002.  
1st time source change date: June 2013.  
Present activity of the source: **8240Ci**

### ***2.1.2 Description of QA related equipment/accessories***

Here at Delta Hospital Ltd, we are using an IBA Farmer type ion chamber FC-65, a WP1D Phantom and Electrometer Dose-1 for absolute dosimetry. The water phantom and ion chamber are also used to scan the beam of radiation in 2D. We also use a small water phantom and solid water phantoms (slabs) together with ion chambers, FC-65, for weekly and monthly check up of dose variations of the *photon beams* from Co<sup>60</sup>. We use Barometer and Thermometer GTD 1100 from GREISINGER electronics, Germany, for pressure and temperature measurements. The temperature and pressure readings are required for dosimetry purposes.

## ***2.2 Methods: Quality Assurance (QA) of Co-60 Therapy Machine***

The methods for different tests and checks are briefly described in the following sections where the section titles describe the checks and the parameters used in our typical tests. The tables within each section show the outputs that our measurements produced, which can be used as a guide. The tolerance values are also indicated. QA is a routine process and the QA related parameters will influence the functional performance and dosimetric accuracy of the applied dose to the patients. These measurements are essential in supporting preventive maintenance and delivery of the prescribed dose (**Rx**) to patients.

### ***2.2.2 Annual or intermittent checks***

Annual or intermittent measurements are made to evaluate the performance of the therapy machine for which tolerance values from Task Groups are given in Table-1 (1994a, 2005).

### 2.2.3 Other Checks and Observations for the machine

We performed the following checks to ascertain the functional integrity of the machine where the cobalt source is driven pneumatically for patient exposure.

- On - Off Procedure : **OK**
- Exposure **On** (Start) and **Off** (end) Time =  $T_2 - T_1 = 3$  **units**, where  $T_2$  and  $T_1$  stand for exit and entry times of the Cobalt source. The time unit is defined as, 100 units = 1 minute. We used  $T_2 = 103$  units and  $T_1 = 100$  units.

If such procedures are followed, delivery of the prescribed dose to the patients will be accurate.

**Table-1:** Functional Parameters for a  $\text{Co}^{60}$  Teletherapy Machine

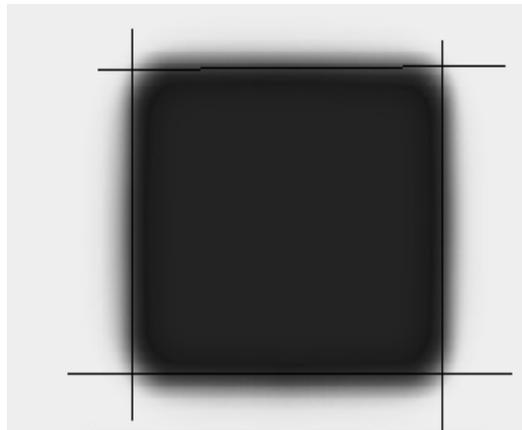
S/L	Procedure	Measured Value/finding	Tolerance Value/finding	Remarks/ Limitations
1.	Operational Parameter	Functional	Functional	
2.	Door Interlock	Functional	Functional	
3.	Emergency off	Functional	Functional	
4.	Radiation room monitor	Functional	Functional	
5.	Audiovisual Monitor	Functional	Functional	
6.	Lasers	1mm	2mm	
7.	Distance Indicator (ODI)	1mm	2mm	SSD=80.1 cm
8.	Light/radiation field coincidence	1mm	2mm	
9.	Coincidence of Gantry, Collimator & Table axis with <i>isocentric</i> rotation	2mm	2mm dia	
10.	Radiation and Mechanical <i>isocenter</i> coincidence	2mm	2mm dia	
11.	Opposing field alignment	Aligned	Aligned	
12.	Table Vertical Movement	1mm	2mm	SS=70-100cm
13.	Table Segment	2mm	2mm	
14.	Field Size Indicator	2mm(5x5 – 25x25)	2mm	AP(x=±2mm,y±2m m) Lat(x±5mm,y±5m m)
15.	Gantry & collimator Angle Indicator	< 1°	1°	
16.	Field light Intensity	Functional	Functional	
17.	Timer Linearity & Consistency & Error	1%	1%	
18.	Central Axis PDD	2%	2%	
19.	Flatness, Symmetry, <u>Penumbra</u> ( $\text{Co}^{60}$ )	3%,3%, 11 mm (for $\text{Co}^{60}$ source)	3%,3%	
20.	Absolute Dose Rate Consistency	1%	2%	

Shielding blocks of various geometrical shapes, may be required for treatment, to define the treatment field for a patient. A common material used is Cerrobend, also known as Lipowitz metal, and consists of 50% Bismuth, 26.7% lead, 13.3% tin and 10.0% Cadmium. Cerrobend has a density of  $9.4 \text{ g/cm}^3$  (i.e., 83% of lead density) and melts at  $70^\circ\text{C}$ . This shield is approximately  $6 \text{ cm}$  thick so as to allow  $\leq 5\%$  primary transmission.

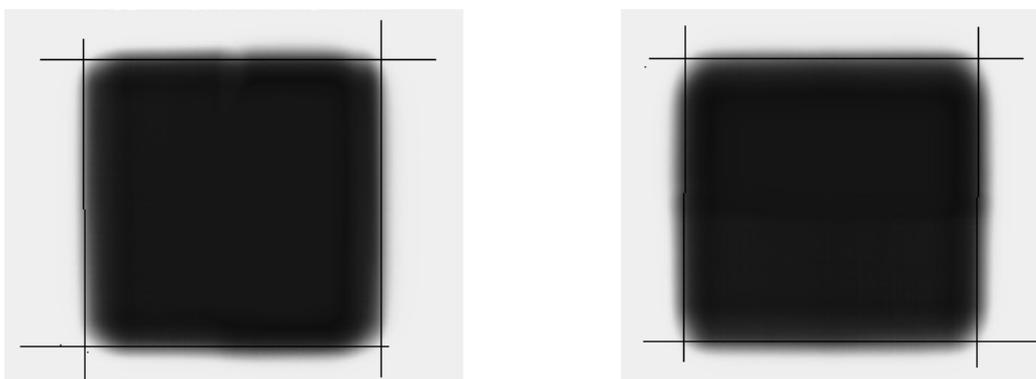
### 3. MECHANICAL

#### 3.1 Coincidence of Light Field Vs Radiation Field (1994b)

To verify this parameter, a CR Film was placed at *isocenter with  $10 \times 10 \text{ cm}^2$*  field size. The corner of the light field and the position of the cross hairs have been marked by lead markers or by pins. The film was exposed to about 1.9 sec for the activity ( $6974 \text{ Ci}$  in our Cobalt I) of this source. The agreement of light field and radiation fields is, within  $\pm 2 \text{ mm}$  as shown in Figure 1.



**Fig 1:** Picture of Radiation field against Light field. Field Size  $10 \times 10$ . Film has been exposed  $\geq$  for 1.9 sec for  $6974 \text{ Ci}$  (*CIRUS*)



**Fig. 2:** Gantry Rotation for alignment check of opposing fields with half mask.  
For Gantry at  $0^\circ$  &  $180^\circ$  (left); for Gantry at  $90^\circ$  &  $270^\circ$  (right)

#### 3.2 Alignment between opposing fields: Rotational Checks of Gantry

To verify this parameter, a CR Film was placed on the smooth and flat surface of the couch at the isocenter. Field size of  $10 \times 10 \text{ cm}^2$  was obtained by moving the collimator. Half of the field size was blocked by lead shields at Gantry ( $\theta^0 = 0$ ) and, after exposure, the Gantry position was rotated by  $180^0$  for another exposure. The light field and the position of the cross hair were marked using lead (Pb) shots. The film was exposed for about 1.9 sec. The light and radiation fields should agree to within  $\pm 2 \text{ mm}$ , which was obtained in our case (Figures 2). This is within the acceptable tolerance value for this measurement (Ref: Table 1). We can also check the lateral alignment for  $90^0$  and  $270^0$  following similar procedures. We recommend any user of Cobalt Machine to perform this measurement.

### 3.3 Accuracy of Optical Indicator

The distance was measured with the 'front pointer' and compared with that of an 'Optical Distance Indicator' (ODI). The results are given in Table 2, which relates to the accuracy of such a measurement (Khan 1984a). Tolerance value is  $\pm 2 \text{ mm}$  (Ref: Table 1).

**Table 2:** Accuracy of Optical Indicator

SSD Indicated by pointer (cm)	SSD Measured with ODI (cm)	Deviation (mm)
80	79.8	2
100	100	0
110	110.2	2
120	120.1	1

### 3.4 Accuracy of Gantry Angle Indicator (1994b, 2004)

Gantry Angles at  $0^0$ ,  $45^0$ ,  $90^0$ ,  $180^0$  and  $270^0$  were determined using a spirit level. The accuracy of the digital readout was checked against the mechanical readout. The results are given in Table 3. Tolerance value is  $\theta \pm 1^0$  (Ref: Table 1).

**Table 3:** Accuracy of Gantry Angle when rotated at various angles

Spirit Level	Digital Readout (Deg.)	Mechanical Readout (Deg.)	Deviation (Deg.)
$0^0$	$0^0$	$0^0$	$0^0$
$45^0$	$44.7^0$	$45^0$	$0.3^0$
$90^0$	$90.5^0$	$90^0$	$0.5^0$
$180^0$	179	$180^0$	$1^0$
$270^0$	$269.8^0$	270	$0.2^0$

### 3.5 Accuracy of Collimator Angle Indicator (1994b, 2004)

With the Gantry Angle at  $90^0$ , a spirit level was placed on the Collimator Housing to check the accuracy of the collimator angle indicators, both digital and mechanical. The results are given in Table 4. Tolerance value is  $\theta \pm 1^0$  (see table 1).

**Table 4:** Accuracy of collimator angle by Digital and Mechanical readout

Spirit Level (Deg.)	Digital Readout (Deg.)	Mechanical readout (Deg.)	Deviation (Deg.)
$0^0$	$0^0$	$0^0$	$0^0$
$45^0$	$45^0$	$44.8^0$	$0.2^0$
$90^0$	$90^0$	$89.7^0$	$0.3^0$

270 <sup>0</sup>	270 <sup>0</sup>	269.8 <sup>0</sup>	0.2 <sup>0</sup>
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### 3.6 Accuracy of Field Sizes (1994b, 2004)

A millimeter graph paper was utilized to measure the field size accuracy. After setting the jaw for X and Y the field light was checked at 80cm, the Source to Surface Distance (SSD) for such a measurement (set at Isocenter, 80 cm). The graph paper was placed on the COUCH at 80 cm. Jaws of the collimator were adjusted to vary the Field Sizes and the corresponding accuracy of the Field Sizes were checked. The results are given in Table 5. Tolerance value or deviation of such measured values of the Field Sizes should be within  $\pm 2\text{mm}$  (see table 1).

**Table 5:** Test for accuracy of Field Sizes

Dial Setting Field size (cm x cm)	Measured Light Field X (for lower jaw ) (cm)	Measured Light Field Y (for upper jaw) (cm)	Deviation of Field Size X (for lower Jaw) (cm)	Deviation of Field Size Y (for upper Jaw) (cm)
4 x 4	3.8	3.8	0.2	0.2
5 x 5	4.9	4.9	0.1	0.1
10 x 10	9.9	10	0.1	0.0
15 x 15	14.9	15	0.1	0.0
20 x 20	19.9	20	0.1	0.0
25 x 25	24.9	24.9	0.1	0.1
30 x 30	29.9	29.9	0.1	0.1

### 3.7 Axis of rotation of collimator

A mechanical study for the axis of rotation of the collimator at gantry angle  $\theta$  was observed by defining the geometric center of the locus of points generated by the light field cross-hair indication at 80cm, when the collimator is rotated through its full rotational range.

### 3.8 Wedge Transmission Factor

Wedge Factor has been measured in water, at a depth of 5 cm, using SSD of 80cm and a field size of 10x10 cm. An IBA Farmer Type ionization chamber was used for the measurements. The following parameters were used in acquiring the data as shown in Table 6 (Khan 1984a).

**Energy:** Cobalt-60. Field Size = 10x10 cm at SSD=80 cm. Ion Chamber was placed at a depth of 5 cm in water. Beam ON Time was fixed at =1 minute for each of the measurements.

**Wedge Factor** is the ratio of readings of the electrometer in Coulomb for the wedged field to that for the open field (no wedge).

**Open Field reading:**  $3.796 \times 10^{-8}\text{C}$  for the activity of 6974.35Ci source of this teletherapy machine. Measured Wedge Factor should be within  $\pm 2\%$  of the manufacturer's value.

**Table 6:** Wedge Transmission Factor

Angle( $\theta$ )	Wedge Size(cm)	M1...X10 <sup>-8</sup> C	M2...X10 <sup>-8</sup> C	Average	Factor	Manufacturer's value
15	8x15	3.149	3.149	3.149	0.839	0.835
30	10x15	2.589	2.589	2.589	0.682	0.682
45	10x15	2.107	2.107	2.107	0.555	0.553
60	10x15	1.468	1.468	1.468	0.368	0.367

### 3.9 Tray transmission factor

Tray transmission factor was measured at 5 cm depth in water for 80cm SSD and 10x10 cm field using IBA Farmer type ionization chamber (Khan 1984a).The following parameters were used. Measured Transmission Factor should be within  $\pm 2\%$  of the manufacturer's value.

**Energy:** Cobalt-60, F.S: 10x10 cm for SSD=80 cm. Ionization Chamber was placed at a depth = 5 cm of water. Beam on Time = 1 minute

**Table 7:** Tray Transmission Factor

Open Field Reading	Reading with Tray	Tray Transmission Factor	Manufacturer's value
3.506 x 10 <sup>-8</sup> C	3.373x 10 <sup>-8</sup> C	0.962	0.96

### 3.10 Radiation isocentric size by Radiographic Image: (Star Shot) (2004)

**Radiation isocenter** size has been evaluated and confirmed radiographically. Figures 3, 4 and 5 depict STAR FILM shots for Gantry, Collimator and Couch to a tolerance of  $\pm 1.0$  mm. Figures for the following components of the machine are listed below.

- i. Collimator Rotation
- ii. Gantry Angles
- iii. Couch Position

#### i: Star Shot for Collimator angle ( $C < \theta$ )

**Procedure:** CR film has been placed at 80 SSD for exposures at Collimator angles of  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ . Exposures have been carried out for 1.9 sec at the centre of film using the isocentric rotation of the collimator. The film has been placed on the top of couch at a *Field Size of 4 cm×30cm*.

#### ii: Star Shot for Gantry Angle ( $G > \theta$ )

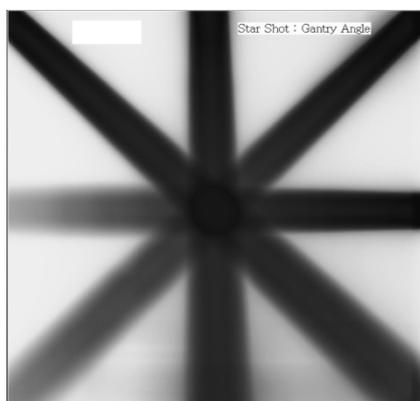
**Procedure:** CR film has been placed at 80 SSD for exposures at Gantry angles  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ . An exposure has been carried out for 1.9 sec at the centre of film with isocentric rotation of gantry. The film has been placed perpendicularly to the Gantry at a Field Size of 4 cm×30 cm in the plane of the rotation of the gantry.

#### iii: Star shot Couch angle ( $C < \theta$ )

**Procedure:** CR film has been placed at 80 cm (SSD) with exposures at **Couch angles**  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ . Exposures have been carried out for 1.9 sec, at the centre of film, with isocentric rotation of the couch. Film has been placed on the top of couch with a Field Size = 4 cm×30 cm. Figure 5 shows the Couch Star Shot as observed on the film.



**Fig 3:** Star shot for collimator at various angles ( $C < \theta$ )



**Fig 4:** Gantry Star Shot,  $G > \theta$



**Fig 5:** Couch Star Shot

### 3.11 Safety Interlock (2004)

#### a. Indicator or Warning Lights

The “*Radiation On*” indicator lights beside the door and in the Treatment Room has been checked and observed to function properly.

#### b. Audio/Video Monitor

Room Audio System which included Video Monitor has been working properly.

#### c. Door Interlock

The door interlock terminates the beam when the door is **opened**. Exposure and beam cannot be turned **on** when for an open door.

#### d. Emergency Buttons

The Emergency Button shut off the machine, when it was activated.

## 4. DOSIMETRY

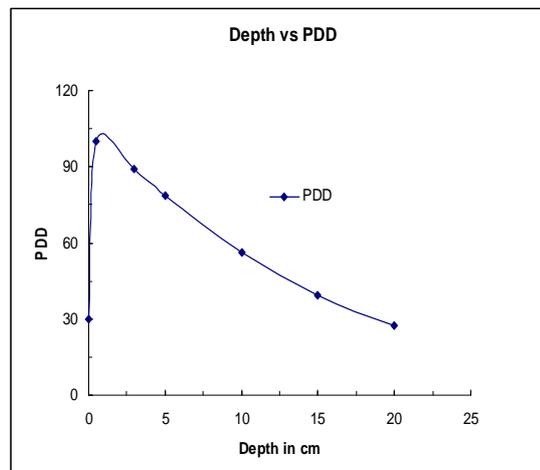
### 4.1 Verification of Percentage Depth Dose (PDD) (1990, Allen and Blagojevic 1996)

Scan of percentage depth dose for *field sizes from 4x4 to 32x32 cm<sup>2</sup>* has been obtained using **RFA-300 Phantom (IBA)**. PDD's for the measured 10x10 cm<sup>2</sup> field are shown for the indicated depths at SSD = 80cm. PDD has been acquired from the scanning data of 3D Phantom RFA300 for 10x10cm<sup>2</sup> field sizes, at different depths, as given in Fig 6. The PDD values have also been acquired at different

depths of water phantom using the ion chamber FC-65 which is tabulated in Table 8. The PDD values in both of these measurements agree with each other, as shown

**Table 8:** Depth vs. PDD dose

Depth ( cm)	Reading Coulomb (C)	PDD (%)
0.5	$4.450 \times 10^{-8}$	100
1	$4.409 \times 10^{-8}$	99.1
3	$4.005 \times 10^{-8}$	90
5	$3.506 \times 10^{-8}$	78.78
10	$2.528 \times 10^{-8}$	56.6
15	$1.726 \times 10^{-8}$	38.8
20	$1.183 \times 10^{-8}$	26.6



**Fig 6:** Percentage Depth dose

**4.2 Profile (2005)**

Scanning of abeam provides the lateral profile which offers a check for the *flatness and Symmetry* of the beam. Table 9, shown below, shows the acquired data of the scans to provide the Symmetry & Flatness criteria of the beam. Flatness and Symmetry should vary within  $\pm 3\%$  from mid line of the profile graph (fig 7).

**Table 9:** Distance vs. Dose (Profile)

Coordinate	Distance from centre (cm)	M. Readings (C)	Dose (%)
X	8	0.162678	4.64
	6	0.5767	16.45
	5.5	1.2299	35.08
	5	2.0951	59.76
	4.5	3.0060	85.74
	4	3.3250	94.84
	3	3.4414	98.16
	2	3.4754	99.13
	0	3.5060	100
X'	-2	3.4783	99.21
	-3	3.4414	98.16
	-4	3.3619	95.89
	-4.5	3.0796	87.84
	-5	2.4047	68.59
	-5.5	1.4753	42.08
	-6	0.7608	21.7
	-8	0.1626	4.64

**Procedure of evaluation is cited as follows:** Comparison of any arbitrary point for evaluation of Flatness and Symmetry which should be equidistant from central axis of the beam. Measurement of Cross Plan Profile (X-axis) has been done with the following set up, viz. SSD = 80 cm, Field size = 10×10 cm<sup>2</sup> for a depth of measurement, d = d<sub>ref</sub> (5 or 10 cm). Ion Chamber has been placed in water at a depth of 5 cm.

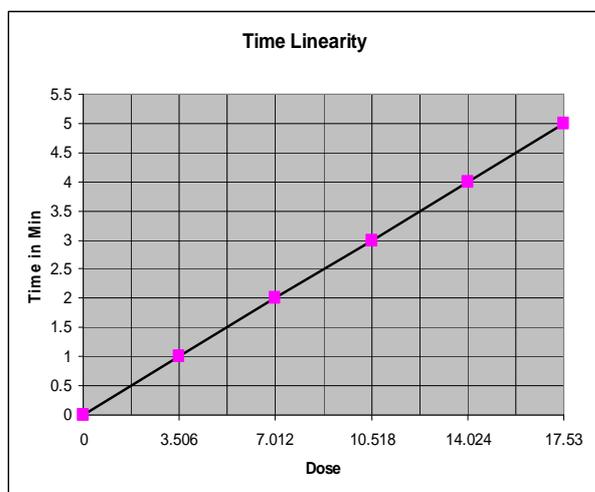
**Equipment:** Phantom, Ion Chamber FC-65 P, Electrometer. Set up of the water phantom has been described in the previous measurement.

**4.3 Beam Quality or Quality index Q:**  $\frac{d_{20}}{d_{10}} = 0.468$

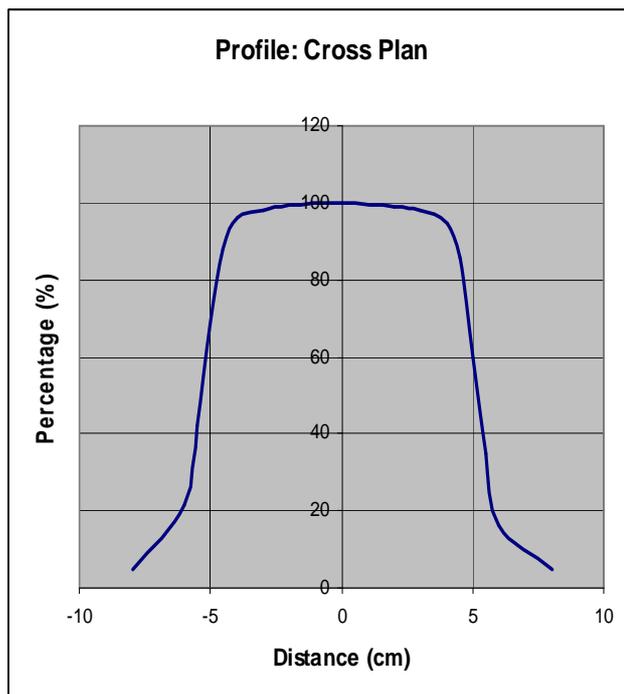
Where **d<sub>20</sub>** = Measured Charge (Coulomb) at 20 cm depth. **d<sub>10</sub>**= Measured Charge (Coulomb) at 10 cm depth. Data from measurements, as obtained in *table 8*, provide the Beam Quality of **0.469**, a deviation of < **1%**, where the acceptable limit is ≤ **2%**.

**4.4 Linearity Check**

*The linearity check*, time vs reading, has been carried out where the output data of the machine is tabulated. We are required to setup the water phantom at **80 cm( SSD)**, where the Field Size = **10×10 cm<sup>2</sup>** at a measurement depth of **5 cm** for the position of the ion chamber. First we measure the output for a time of 0.50 minute followed by an increment, at intervals, of 0.50 minute. The reading of this output data has been plotted as shown in figure 8. The graph should be a linear one which will pass through the origin. After the



**Fig 8:** Time vs. Reading



**Fig7:** Cross Plane Profile

completion of all the mechanical and basic beam parameter checks, the *linearity check* will confirm the functional integrity of the dose delivery by this teletherapy machine. Dose is calculated in terms of *time* to deliver a treatment. The graph should pass through origin (0.0) and hence may be presented in a format as shown in figure 8. The *linearity in time* and *dose* is required for the delivery of prescription dose (Rx) to the patient. Quality Assurance of this study is essential in the therapeutic use of the machine. Table 10 shows the measurement data and the linearity graph as figure 8.

**4.5 Absorbed Dose in Water for D<sub>w</sub>**

The Output of a 10x10 cm<sup>2</sup> field was measured in water Phantom at 80 SSD at a depth of 5.0 cm (D<sub>ref</sub>), for Gamma rays, following the TRS-398 protocol (2005). The dosimetry system used

consisted of a water proof IBA FC65P ion chamber, S/N: 1787 and IBA Dose-1 Electrometer S/N: 13527.

The formula for measuring the absorbed dose at  $D_w$  is:

$$D_w(D_{ref}) = \frac{M_1 \times K_{TP} \times K_{ele} \times K_{Pol} \times K_Q \times N_{DW} \times 100}{PDD @ D_{ref}} \text{----- (1)}$$

where,

- $M_1$  = Measured Reading at  $D_{ref}$
- $K_{TP}$  = Temperature and pressure correction factor
- $K_{ele}$  = Electrometer reading correction factor
- $K_{POL}$  = Polarization correction factor
- $K_{ion}$  = Ion recombination Correction factor
- $K_Q$  = Quality conversion Factor
- $N_{DW}$  = Chamber (FC-65) calibration factor
- PDD = Percentage Depth Dose
- $D_{ref}$  = Depth of measurement
- $D_w$  = Absorbed does rate to water at the reference depth  $D_{ref}$ .

Before starting the measurements, the stability of the dosimeter system should be verified using a check source CS-137. Reasonable time should be allowed for the dosimeter to reach thermal equilibrium. For this, the Electrometer is to be switched on for about 2 hours before starting the measurement. It is always advisable to irradiate the ionization chamber with at least 500cGy, for a consistent and reproducible data.

The leakage current should always be measured before and after irradiation and ensured that it is small, typically less than about 0.1%, of the current obtained during irradiation.

The calibration factor for an ionization chamber is valid only for the reference condition which applies to the calibration. Any departure from the reference condition, when using the ionization chamber in the user beam, should be corrected for the appropriate factors.

**4.5.1 Pressure, temperature and humidity correction factor(  $K_{TP}$  )**

The correction factor  $K_{TP}$  is given by,

$$K_{TP} = \frac{(273.2 + T)}{(273.2 + T_0)} \times \frac{p_0}{p} \text{----- (2)}$$

Where, P and T are the cavity air pressure and temperature at the time of measurements and  $P_0$  and  $T_0$  are the reference values (1990, 1994a).

No correction for humidity is required if the calibration factor was referred to relative humidity of 50% and is used at a relative humidity between 20% and 80%. If the calibration factor is referred to dry air a correction factor should be applied which is given in reference (1990).

In order to measure the machine room *air pressure*, we used a digital barometer name GTD 1100 manufactured by Greisinger Electronics of Germany. We also took *temperature* readings using the same instrument. Besides, for the measurement of phantom temperature we also placed a *mercury thermometer placed within* the water phantom for about 2 hours before starting the measurements for calibration and dosimetry.

**4.5.2 Polarization correction factor ( $K_{pol}$ )**

The effect of polarizing potentials, of opposite polarity, on an ion chamber must always be checked on commissioning and dosimetry. When a chamber is used in a beam that produces a measurable polarity effect, the true reading is taken to be the **mean** of absolute values of readings taken at both polarities. The polarization correction factor accounts for the differences in the collection of charges for the applied, positive or negative, potentials of  $\pm 300$  V. Equation 3, given below, accounts for this correction factor.

$$K_{POL} = \frac{M_+ + M_-}{2M_+} \text{----- (3)}$$

Where,  $M_+$  and  $M_-$  are the electrometer readings, in coulombs, obtained with an applied polarity of voltage, positive and negative, respectively. For routine dosimetry checks like daily, weekly or monthly, it is sufficient to measure ‘ $M$ ’, the electrometer reading, with any polarity of voltage (i.e. positive or negative) but **use** that polarity subsequently in all dosimetry checks.

To be specific, for our objectives of commissioning, QA and treatment delivery we used all the measurements of correction factors, as outlined in equation 1. This is imperative to secure a precise calibration in order to obtain an absolute dose that is delivered by the machine. In our case, we used equation 3, where

- $M_+$  = Reading at voltage +300 V
- $M_-$  = Reading at voltage -300 V

The reading  $M_+$  and  $M_-$  should be made with care, ensuring that the chamber reading is stable following any change in polarity (e.g. some chambers can take up to 20 minutes to stabilize). This may minimize the influence of fluctuations in the output of radiation generators.

**4.5.2 Ion Recombination factor ( $K_s$ )**

The incomplete collection of charge in an ionization chamber cavity, due to the recombination of ions, requires the use of a correction factor  $K_s$ . Two separate effects take place in an ionization chamber viz. i) the recombination of ions formed by separate ionizing particle tracks, termed general (or volume) recombination, which is dependent on the density of ionizing particles and therefore on the dose rate, and ii) the recombination of ions formed by a single ionizing particle track, referred to as initial recombination which is independent of the dose rate. Both of these effects depend on the chamber geometry and on the applied polarizing voltage (1990).The Ion Recombination factor is given by,

$$K_{s=} = \frac{(\frac{V_1}{V_2})^2 - 1}{(\frac{V_1}{V_2})^2 - (\frac{M_1}{M_2})} [V_1/V_2=2] \text{----- (4)}$$

where  $V_1=+300V$ ,  $V_2= +150V$ ,  
 $M_1$  (Coulomb) = reading at +300V,  $M_2$  (Coulomb) = reading at +150V

**4.5.3 Measurements and Results**

**a. Measurement of  $K_{TP}$  (equation 2):**

Equipment used for this measurement has been mentioned earlier. The reference and the measured values are:

- Reference Pressure: 1013.25 hpa      Reference Temperature: 20<sup>0</sup>C
- Measured Pressure: 996.1 hpa      Measured Temperature: 24<sup>0</sup>C

Therefore, Temperature and Pressure correction factor,  $K_{TP} = 1.031104$

**b. Measurement of  $K_S$  (equation 4)**

Measured data are tabulated in Table 11.

**Table 11:** Measurement data required to calculate the recombination of ions

Voltage , V, (Volts)	Meter Reading , Coulomb, (C)
+300	$3.506 \times 10^{-8}$
+150	$3.501 \times 10^{-8}$
-300	$3.510 \times 10^{-8}$

From above, the Ion correction factor,  $K_S: 1.00044$ ----- (equation 4)

**c. Polarity Correction factor,  $K_{pol}$**

Our measured data produced this factor as  $K_{pol}: 1.00052$ ----- (equation 3)

**d. Dose calibration factor,  $N_{DW}$**

This calibration factor is given by IBA certificate. For our device, the value is:

$N_{DW} = 4.77 \times 10^7 \text{ Gy/C}$  ----- (IBA chamber certificate)

**e. Dose at  $D_w$  : 246.22 cGy/min**----- (equation 1)

PDD has been measured at a depth of 5 cm (which is  $D_w$  in our case), and the maximum dose at 0.5 cm depth was determined by using **equation 1**, after incorporating all the correction factors.

**Delta Hospital Ltd.**  
Radiation Oncology Physics Division.

6/20/2013 1:29 PM

Patients Name:  Reg. No:  Machine Dose Rate:  cGy/min

Physician Name:  RT. No:

Machine : Cobalt-II  SSD: 80 cm

**Remarks**

New- Plan

F.N	Tx. Field Name:	Field Y (cm)	Field X (cm)	Eqi. Sqr. F.S (cm)	Gantry Ang.	Collima. Ang.	Field Dose	No. of Frac.	Total Dose	Depth	PDD (%)	Machine Output	GD. (cGy)	TT (min)
1	Ant.	10	10	10.0	0	0	50	20	1000	9.0	60.50	246.22	83	0.34
2	Post	10	10	10.0	180	0	50	20	1000	8.0	64.70	246.22	77	0.31
	Rt. Lateral	10	10	10.0	270	0	50	20	1000	14.0	42.40	246.22	118	0.48
	Lt. lateral	10	10	10.0	90	0	50	20	1000	14.0	42.40	246.22	118	0.48

Shielding:  Wedge :

	Rectangle Shielding size (cm)		Triangle Shielding size (cm)		Wedge Angle (Deg.)
Field 1	Y: <input type="text"/>	Y: <input type="text"/>	Base : <input type="text"/>	Base : <input type="text"/>	<input type="text"/>
	X: <input type="text"/>	X: <input type="text"/>	Height: <input type="text"/>	Height: <input type="text"/>	
Field 2	Y: <input type="text"/>	Y: <input type="text"/>	Base : <input type="text"/>	Base : <input type="text"/>	<input type="text"/>
	X: <input type="text"/>	X: <input type="text"/>	Height: <input type="text"/>	Height: <input type="text"/>	
Field 3	Y: <input type="text"/>	Y: <input type="text"/>	Base : <input type="text"/>	Base : <input type="text"/>	<input type="text"/>
	X: <input type="text"/>	X: <input type="text"/>	Height: <input type="text"/>	Height: <input type="text"/>	
Field 4	Y: <input type="text"/>	Y: <input type="text"/>	Base : <input type="text"/>	Base : <input type="text"/>	<input type="text"/>
	X: <input type="text"/>	X: <input type="text"/>	Height: <input type="text"/>	Height: <input type="text"/>	

Physicist: Dr. Sadiq R. Malik Check By: \_\_\_\_\_

**Fig 9:** A sample of Cobalt Machine Treatment Time ( $TT$ ) Calculation Spread Sheet

**4.6 Cobalt-60 Treatment time calculation spreadsheet to deliver prescription dose delivery**

To calculate the *patient treatment time (TT)* manually, equation 5 below has been used. Use of equivalent square field size, standard *PDD and TMR* values were from BJR25. BJR Supplement 25, 1996 (Attix 1986, Khan 1984b) provides the ‘*TT*’ as,

$$TT = \frac{\text{Prescribe.Dose @ Tumor} \times 100}{(\text{PDD.or.TMR}) \times \text{Output} - \text{factor}} \dots\dots\dots(5)$$

An in-house *Excel Spreadsheet* has been developed at Delta Hospital Ltd. to calculate the treatment Time to deliver the prescribed dose ( $R_x$ ) to the patient. This calculation sheet has been developed and used by us to determine the ‘*TT*’ for each patient and for each field. The *TT* is cross checked manually before delivery of the treatment to patients. A sample of this spreadsheet is given in Figure 9, followed by a brief description.

**A: Brief description of the Spread Sheet**

- i. **This Spread sheet** can be used only for  $^{60}\text{Co}$  at *SSD = 80 cm*
- ii. **SSD or SAD** of Treatment time calculation is done using this spread sheet
- iii. **Machine Dose rate** will be changed every month by 1.09%
- iv. **Equivalent Field size** will be determined after inserting the Y & X field size values.
- v. A **Shielding block** (e.g. rectangle, triangle or irregular shapes), if inserted, the equivalent square field size is calculated.
- vi. **Machine Output, Percentage Depth dose** and **Treatment time** will be generated depending on the equivalent **Square Field Size**
- vii. For a **Given Dose** a value of **0.5cm** is typed in **Depth Field**
- viii. **Caution:** This spread sheet **dose rate** is dependent on computer **date & time**.

**4.7 Constancy Check (1994a)**

Constancy check refers to the repeated measurements at a fixed time of irradiation while collecting the charges as readings as tabulated in table 12. Procedure and set up for such a measurement is given below:

Measurement in water at *SSD = 80cm*, *Field Size = 10x10 cm<sup>2</sup>* at a measurement depth of 5cm for a set time (**t**) = **1 minute**. Number of readings are taken 10-15 times using an **IBA FC-65 P** chamber, **Electrometer Dose-I** and **1Dimensional** water phantom

$$\text{Standard Deviation or Constancy } (\sigma) = \frac{\sqrt{\sum (\bar{X} - X)^2}}{N} \dots\dots\dots(6)$$

Where, **N** = Number of Reading, **X**= Individual Reading,  $\bar{X}$  = Average of all Readings.

The measurements for a time of one minute are tabulated in Table 12.

The differences in individual readings with that of the average value are small, almost negligible, when compared with that of the average value. Therefore, the deviation from the individual data implies constancy in the beam output and hence acceptable for patient treatment.

**4.8 Measurements of Output Factor**

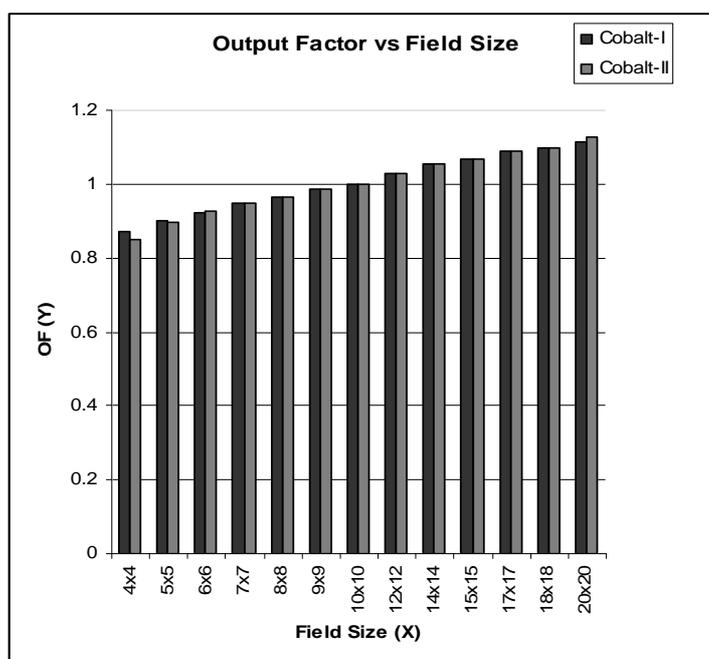
The changes in *the readings* of the electrometer are tabulated in table 13. The data shows that there is a decrement and increment in such readings with the field sizes, smaller to bigger. The output factor is the *ratio* of readings in comparison to that of a *standard field size*, 10 x 10 cm<sup>2</sup>.

For measurement of the output factor, we have used *IBA 1-D Phantom, FC-65P chamber and IBA Electrometer Dose-I*. Firstly, we setup the phantom at 80cm (**SSD**, source to water surface distance)

and placed the chamber at a depth of 5cm. The field size has been set up at 10x10cm<sup>2</sup>. Measured values are tabulated followed by calculating the output factor (OF) for different field sizes as given in table 13. The output factors for different field sizes, 4x4 to 32x32, are calculated with reference to the reading at 10x10field size.

<b>Table 12:</b> Time vs. Deviation from the average value of the electrometer reading				
Time (minute)	Reading X (Coulomb) (10 <sup>-8</sup> )	Average, $\bar{X}$ (Coulomb) (10 <sup>-8</sup> )	$\bar{X} - X$ (Coulomb)(10 <sup>-8</sup> )	Standard Deviation( $\sigma$ ) (Coulomb)(10 <sup>-8</sup> )
1	3.506	3.5058	-0.0002	0.0005
	3.506		-0.0002	
	3.506		-0.0002	
	3.505		0.0008	
	3.505		0.0008	
	3.506		-0.0002	
	3.507		-0.0012	
	3.506		-0.0002	
	3.506		-0.0002	
	3.505		0.0008	

We have two Cobalt-60 radiotherapy machines (I, II).Our main goal is to see the variation of output with the field sizes. Table 13 also presents the Output Factors (**OF**) for the *two machines* and these results are plotted in **Fig.10**. This measurement is useful when one machine breaks down and patients are transferred to the other for treatments. As can be seen, the differences of respective output factors between the *two machines* are very small, almost negligible and hence compatible to each other. Fig. 10 also shows that the **OF** increases with the increase of the field size.



**Fig 10:** Field size vs. output factor for two Cobalt Machines.

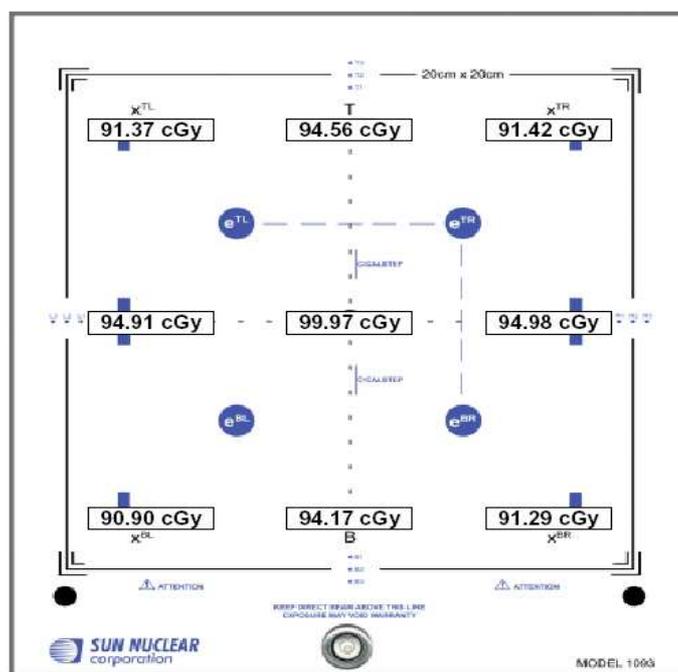
**Table 13:** Field size vs. Output factor (*OF*)

Field Size (cm)	'OF' Cobalt-1	'OF' Cobalt-II
4x4	0.8703	0.8491
5x5	0.9007	0.8960
6x6	0.9235	0.9266
7x7	0.9473	0.9465
8x8	0.9665	0.9665
9x9	0.9856	0.9852
10x10	1.0000	1.0000
12x12	1.0299	1.0310
14x14	1.0558	1.0548
15x15	1.0665	1.0676
17x17	1.0888	1.0888
18x18	1.0976	1.0972
20x20	1.1146	1.1268
22x22	1.1305	1.1300
23x23	1.1360	1.1364
25x25	1.1476	1.1465
27x27	1.1563	1.1556
28x28	1.1608	1.1589
30x30	1.1667	1.1657
32x32	1.1707	1.1697

**4.9 Dose Variation Evaluation with Daily QA-3 Equipment**

This device has **12 Diodes** to checkup the *field size* and **13 Ion Chambers** to evaluate the *central axis dose* and elsewhere as illustrated in Fig. 11.

All of the above mechanical and dosimetry measurements have been completed to substantiate and confirm the acceptance, commissioning and treatment delivery for such a teletherapy machine (Sun). . The dose calibration has been carried out previously and described in above mentioned measurements. Another measurement of dose delivery has been introduced by us using *a new device called QA-3* to show the *central dose* for the Co-60 source. Calibration for this device has been done by us to evaluate the dose at Central Axis (*CAX*) for an SSD of 80 cm and for a field size of 20x20 cm. Here, we use a field size of 20x20 cm. In the device QA-3, diodes are positioned, by the manufacturer, at 20x20 cm area of **Daily QA -3**. Fig 11 shows the dose at various points of the device. This device is made by SUN NUCLEAR corp., USA.



**Fig 11:** Results are shown here by using the **Daily QA-3** of SUN NUCLEAR Device SN: 81374052. The central Axis (*CAX*) is expected to be 100 cGy.

## 5.0 DISCUSSION

Machine parameters are verified and elaborate measurements have been carried out to ascertain the consistent functioning of the machine with the manufacturer's specifications. Measurements reported here are systematically and sequentially presented *in this tutorial to commission a teletherapy machine*. All of the necessary procedures are required to be followed to acquire accurate values for the delivery of exact dose. The treatment machine will then be *certified and commissioned* for the treatment of Cancer Patients. Incidentally, it may be mentioned here that there are about 12 Cobalt Teletherapy Units alone existing in Bangladesh now and more to be installed in the near future (2013). Clinical data have been acquired and used here, which relate to the *standard protocols and tolerance* values of the machine parameters. It is demonstrated here that all of the above work is needed for a precise dose delivery to tumors. It is, therefore, recommended to carry out the measurements, step by step, to accept the teletherapy machine for treatments. Treatment quality and delivery are imperative in the reliable use of the  $^{60}\text{Co}$  Teletherapy Machine in any Cancer Center.

## Acknowledgment

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