Output Measurement of a Telecobalt Unit (Co-60 Photon Beams)

Aim:
To measure the output of a Telecobalt unit (Co-60 Photon Beams).

Equipment Required:

1. Telecobalt Unit
2. Water/ Slab Phantom
3. Ionization Chamber
4. Electrometer and Connecting cables
5. Thermometer and Barometer
6. Levelling tool (Spirit level)

Theory:

The Telecobalt machine is an equipment that houses a Co-60 radioactive source of activity 10-12 kCi. The Co-60 source is doubly encapsulated with stainless steel material in a cylindrical shape and contains Co-60 radioactive sources in the form of pellets. The typical size of this encapsulation is around 3 cm in length and 2-2.5cm in diameter. The main components of a Telecobalt unit are Gantry, Source head, Collimator, and Patient Support Assembly or treatment couch. The Co-60 source is placed inside a shielded chamber in the source head. During the time of treatment, the Co-60 source is driven toward the collimator, and the shutter is opened for irradiation. The Gantry helps to rotate the unit around the patient. The collimator is a beam-limiting device that defines the radiation beam to a particular area of interest for the patient.

Output of ionizing radiation beams produced by external beam radiotherapy treatment machines must be determined accurately before the machine is used clinically and, moreover, it must also be verified on a regular basis during clinical use to ensure accurate delivery of the prescribed dose to the patient. The output of a Telecobalt machine is the absorbed dose rate to water measured in units of cGy/min at a reference depth in water for a reference field size (e.g., 10cm X 10cm). The output measurement is one of the Quality Assurance tests which is performed to ensure that the absorbed dose to water for an equipment is within acceptable tolerance as recommended by the competent authority (AERB).

IAEA TRS 398- “Absorbed Dose Determination in External Beam Radiotherapy” is the recommended protocol which is usually followed internationally for the measurement of output from a Telecobalt machine. The protocol and formalism for the measurement of output from a telecobalt unit are described here.

The formula gives the absorbed dose to water at a point:

$$D_{w,Q} = N_{D,w,Q_0}\, M_Q\, k_{Q,Q_0}$$

N_{D,w,Q_0} = The calibration factor/coefficient as provided in the calibration certificate
M_Q = Corrected meter reading (The various correction factors on which the meter reading depends are discussed below)
k_{Q,Q_0} = Beam quality correction factor.

Beam Quality Correction factor (k_{Q,Q_0}):

The beam quality correction factor is used when the measurement beam differs from the reference beam where the chamber is calibrated. The values of this correction factor for various chambers are available in IAEA TRS 398. If both the reference beam (In which the chamber is calibrated) and measurement beam are the same then this factor is taken as 1.

Correction for Temperature, Pressure, and Humidity ($k_{T,P}$):

Since the ionization chamber used to measure output is open to ambient air, the mass of the air in the cavity volume will be affected by the surrounding temperature, pressure, and humidity. No correction for humidity is applied if the humidity range is within 20-80%. The correction due to temperature and pressure is given by

$$k_{TP} = \frac{(273.2+T)}{(273.2+T_o)}\frac{P_o}{P}$$

Where T = Temperature at the time of measurement

T_0 = Reference temperature (20^0C)

P = Pressure at the time of measurement

P_0 = Reference pressure (1013.2 mbar)

T_0 and P_0 are the temperature and pressure, respectively, at which the chamber is calibrated, and it is mentioned in the calibration certificate.

Correction for Ion Recombination/ Saturation (k_s):

This error is introduced due to the incomplete charge collection inside the ionization chamber. The two-voltage method is usually applied to calculate the recombination error. The protocol recommends the ratio to be at least 2.

$$k_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)}$$

Polarity Correction (k_{pol}):

The electrometer reading changes when the polarity of the bias voltage applied to the ionization chamber is reversed. The correction factor for change in meter readings due to polarizing potentials of opposite polarity is given by

$$k_{\text{pol}} = \frac{|M_+| + |M_-|}{2M}$$

M_+ = Meter reading with positive bias voltage

M_+ = Meter reading with negative bias voltage

M = Meter reading with the usual bias voltage (used for daily output measurement purposes)

Electrometer Calibration (k_{elec}):

Usually, the ionization chamber and measuring electrometer are calibrated as a single unit. In that case, the electrometer calibration factor k_{elec} is unity. If the electrometer is calibrated separately, the electrometer calibration factor must be multiplied by the uncorrected meter reading (M_{Qunc}) to calculate the corrected meter reading (M_Q). The corrected meter reading after applying all the correction factors is given below.

$$M_Q = M_{Qunc}\, k_{T,P}\, k_{pol}\, k_s\, k_{elec}$$

TRS 398 Protocol for Output Measurement:

Influence Quantity	Reference Value or Characteristics
Phantom material	Water
Chamber type	Cylindrical or plane parallel
Measurement depth, z_{ref}	5 g/cm^2 (or 10 g/cm^2)
Reference point of the chamber	For cylindrical chambers, on the central axis at the center of the cavity volume. For plane-parallel chambers, on the inner surface of the window at its center
Position of the reference point	For cylindrical and plane-parallel chambers, at the measurement depth z_{ref}
SSD or SCD	80 cm or 100 cm
Field size	10 cm × 10 cm

Procedure:

There are various types of water and slab phantoms available commercially. Some phantoms have fixed chamber slots and some have variable slots. The design of the phantoms varies from one another. Here we have given the generalized procedures for absolute dosimetry.

- Place the water phantom (without water) on the treatment couch and perform the necessary alignments by matching phantom markings with the crosshair of the machine and external lasers.
- Adjust the tilt of the phantom with the help of spirit level, placing it on the walls and corners of the phantom.
- Fill the phantom with distilled water carefully without disturbing the phantom.
- Insert the cylindrical ionization chamber into the slot given in the phantom.
- Adjust the ionisation chamber to align the equipment crosshair with the markers of the ionization chamber (The markers are given in the build-up cap given with the chamber).
- Move the ionization chamber to the reference depth/ measurement depth (at 10 cm) from the surface of water after removing the build-up cap (For variable slot type phantoms). For fixed type the slot is made at the recommended depth.
- Adjust the SSD to 80 cm with the help of ODI/Lasers and open the field size to 10cm X 10cm. (Here, we have used SSD setup).
- Place the thermometer and barometer inside/near the water phantom away from the irradiation field (10cm X 10cm). Note down the temperature and pressure before irradiation.
- Set the bias voltage on the electrometer to the voltage mentioned in the calibration certificate.

- Before starting the measurement, eliminate any leakage current that might be present in the connecting cables by pressing the Zeroing button on the electrometer and warm up the ionization chamber by irradiating the chamber to a dose of at least 2 Gy. After completion of the irradiation, press the Zeroing button on the electrometer.
- Irradiate the chamber for 1 min and tabulate the meter readings (Charge collected) as given below. Take at least three readings to minimize the statistical uncertainty in the measurement.
- Calculate the various correction factors $\boldsymbol{k_{T,P}}$, $\boldsymbol{k_s}$, $\boldsymbol{k_{pol}}$, $\boldsymbol{k_{elec}}$ using the formula given above.
- The sample tabulation is given below.

Tabulation and Calculation:

Bias Voltage (V)	M_{Q1} (nC)	M_{Q2} (nC)	M_{Q3} (nC)	Average (M_{Qunc})(nc)
+300	15.70	15.71	15.71	15.71
+150	15.37	15.38	15.37	15.37
-300	-15.97	-15.97	-15.98	-15.97

* M_{Qunc} = Uncorrected meter reading.

From the worksheet given below, we found the following:
Output measured = 1.164 Gy/min
Actual Output = 1.185 Gy/min

$$Error\ (\%) = \frac{Measured - Standard}{Standard}\ X\ 100$$

= 1.7 % (Tolerance = 2%)

Precautions:

- Carefully handle the ionization chamber, phantom, and other accessories.
- Do not touch the connecting cables when a bias voltage is set on the electrometer.
- Do not irradiate the ionization chamber while zeroing the electrometer.
- Do not step on the connecting cables.

5.8. WORKSHEET

Determination of the absorbed dose to water in a ^{60}Co γ ray beam

User: Radiation Therapy Department Date: ______

1. Radiation treatment unit and reference conditions for D_w determination

^{60}Co therapy unit: Tele cobalt Unit

Reference phantom: water Set-up: ☑ SSD ☐ SAD

Reference field size: 10 × 10 cm × cm Reference distance: 80 cm

Reference depth z_{ref}: 10 g/cm²

2. Ionization chamber and electrometer

Ionization chamber model: Farmer 0.6cc Serial No.: 123456 Type: ☑ cyl ☐ pp

Chamber wall/window material: Graphite thickness: 0.08 g/cm²

Waterproof sleeve/cover material: PMMA thickness: 0.5 g/cm²

Phantom window material: ______ thickness: ______ g/cm²

Absorbed dose to water calibration factor $N_{D,w}$ = 0.04194 ☑ Gy/nC ☐ Gy/rdg

Reference conditions for calibration P_o: 101.32 kPa T_o: 20 °C Rel. humidity: 50 %

Polarizing potential V_1: 300 V Calibration polarity: ☑ +ve ☐ −ve ☑ corrected for polarity effect

User polarity: ☑ +ve ☐ −ve

Calibration laboratory: ______ Date: ______

Electrometer model: ______ Serial No.: ______

Calibrated separately from chamber: ☐ yes ☑ no Range setting: ______

If yes, calibration laboratory: ______ Date: ______

3. Dosimeter reading[a] and correction for influence quantities

Uncorrected dosimeter reading at V_1 and user polarity: 15.71 ☑ nC ☐ rdg

Corresponding time: 1. min

Ratio of dosimeter reading and time[b]: M_1 = 15.463 ☐ nC/min ☐ rdg/min

(i) Pressure P: 1010.5 kPa Temperature T: 25.5 °C Rel. humidity (if known): ______ %

$$k_{TP} = \frac{(273.2+T)}{(273.2+T_o)}\frac{P_o}{P} = 1.021$$

(ii) Electrometer calibration factor[c] k_{elec}: ☐ nC/dg ☐ dimensionless k_{elec} = 1.

(iii) Polarity correction[d] rdg at $+V_1$: M_+ = 15.71. rdg at $-V_1$: M_- = 15.97

$$k_{pol} = \frac{|M_+|+|M_-|}{2M} = 1.008$$

(iv) Recombination correction (two voltage method)

Polarizing voltages: V_1 (normal) = 300 V V_2 (reduced) = 150 V

Readings[e] at each V: M_1 = 15.71 M_2 = 15.37

Voltage ratio V_1/V_2 = 2 Ratio of readings M_1/M_2 = 1.022.

$$k_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)} = 1.007$$

Corrected dosimeter reading at the voltage V_1:

$M = M_1/k_{TP}k_{elec}k_{pol}k_s$ = 16.025 ☑ nC/min ❑ rdg/min

4. Absorbed dose rate to water at the reference depth z_{ref}

$D_w(z_{ref}) = M\,N_{D,w}$ = 0.672 Gy/min

5. Absorbed dose rate to water at the depth of dose maximum z_{max}

Depth of dose maximum: z_{max} = 0.5 g/cm²

(i) SSD set-up

Percentage depth dose at z_{ref} for a 10 cm × 10 cm field size: PDD (z_{ref} = 10 g/cm²) = 57.74%

Absorbed dose rate calibration at z_{max}:

$D_w(z_{max}) = 100\, D_w(z_{ref})/PDD(z_{ref})$ = 1.164 Gy/min

(ii) SAD set-up

TMR at z_{ref} for a 10 cm × 10 cm field size: TMR (z_{ref} = ______ g/cm²) = ______

Absorbed dose rate calibration at z_{max}:

$D_w(z_{max}) = D_w(z_{ref})/\text{TMR}(z_{ref})$ = ______ Gy/min

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[a] All readings should be checked for leakage and corrected if necessary.

[b] The timer error should be taken into account. The correction at voltage V_1 can be determined according to

M_A is the integrated reading in a time t_A — M_A = 15.71 t_A = 1 min

M_B is the integrated reading in n short exposures of time t_B/n each ($2 \leq n \leq 5$) — M_B = 15.956 t_B = 1 min n = 2

Timer error, $\tau = \frac{M_B t_A - M_A t_B}{n M_A - M_B}$ = 0.016 min (the sign of τ must be taken into account)

$M_I = \frac{M_A}{t_A + \tau}$ = 15.463 ☑ nC/min ❑ rdg/min

[c] If the electrometer is not calibrated separately set $k_{elec} = 1$.

[d] M in the denominator of k_{pol} denotes reading at the user polarity. Preferably, each reading in the equation should be the average of the ratios of M (or M_+ or M_-) to the reading of an external monitor, M_{em}.

[e] Strictly, readings should be corrected for polarity effect (average with both polarities). Preferably, each reading in the equation should be the average of the ratios of M_1 or M_2 to the reading of an external monitor, M_{em}.

[f] It is assumed that the calibration laboratory has performed a recombination correction. Otherwise the factor $k_s' = k_s/k_{s,Q_o}$ should be used instead of k_s. When Q_o is ^{60}Co, k_{s,Q_o} (at the calibration laboratory) will normally be close to unity and the effect of not using this equation will be negligible in most cases.