Quality Assurance of HDR Brachytherapy Unit

AIM:

1. To measure the Air Kerma Strength (AKS) or Reference Air Kerma Rate (RAKR) of the High-Dose Rate Brachytherapy source (Ir-192).
2. Find the timer error and the percentage of error in the calculation timer error.
3. Find the percentage of error in timer linearity and end error.

Equipment Required:

1. HDR Brachytherapy unit
2. Well type Ionization chamber
3. Electrometer and Connecting cable
4. Thermometer & Barometer

Theory:

ICRU Recommendation-

The recommended quantity for the specification of brachytherapy source strength is the Reference Air Kerma Rate (RAKR), defined as the air kerma rate in the air at a reference distance of 1m from a point source or 1m along the line of perpendicular bisector for a line source, corrected for air attenuation and scattering. Unit of RAKR is **μGy/h.**

AAPM Recommendation-

The source strength of the high-dose-rate brachytherapy sources is specified in units of Air Kerma Strength (AKS) or Reference Air Kerma Rate (RAKR). The air kerma strength S_k is given by,

$$S_k = \dot{K}_d \, d^2 \quad \text{(Unit: μGym}^2\text{/h)}$$

$\dot{\boldsymbol{K}}_{\boldsymbol{d}}$ = Air kerma rate in vacuum (measurement should be corrected for photon attenuation and scattering in air and any other medium interposed between the source and detector as well as photon scattering from any nearby objects including walls, floors, and ceilings and due to photons of energy greater than δ)

d = Distance from the source center to the point of measurement along the transverse plane of the source

δ is the cut-off energy that excludes low energy or contaminant photons (e.g., characteristic X-rays originating in the outer layers of steel or titanium cladding) that increases $\dot{K}_d$ without contributing significantly to dose at distances greater than 0.1 cm in tissue.

Measurement of the source strength is very important because the treatment time for the dose delivery is calculated from the value of the source strength (RAKR/ AKS). This is one of the mandatory Quality Assurance tests that must be performed regularly and during new source replacement. To measure the source strength of a Brachytherapy source, a Well-type ionization chamber (detector) calibrated from a PSDL/SSDL is used. An electrometer connected to the detector measures the charge or current when the radioactive source is moved into the active volume of the detector. The source strength in terms of Reference Air Kerma Rate (RAKR) is given by

$$RAKR = M_u \, N_{k,air} \, k_{T,P} \, k_{ele}$$

M_u is the uncorrected meter reading on the electrometer
$N_{k,air}$ is the Air Kerma Rate calibration factor
$k_{T,P}$ is the temperature and pressure correction factor
k_{ele} is the electrometer calibration factor

Air Kerma Rate calibration factor ($N_{k,air}$):
The calibration factor is provided by the Standard Calibration Laboratory (PSDL/SSDL) to the user ionization chamber.

Correction for Temperature, Pressure and Humidity:
Since the ionization chamber used to measure source strength 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 (k) = Temperature at the time of measurement
T_0 (k) = Reference temperature during calibration
P = Pressure at the time of measurement
P_0 = Reference pressure (1013.2 mbar)

Electrometer Calibration:

If the ionization chamber and measuring electrometer are calibrated as a single unit, then the k_{ele} is taken as unity; otherwise, if they are calibrated separately, then the appropriate electrometer correction factor (k_{ele}) should be used.

1. Procedure for source strength measurement:

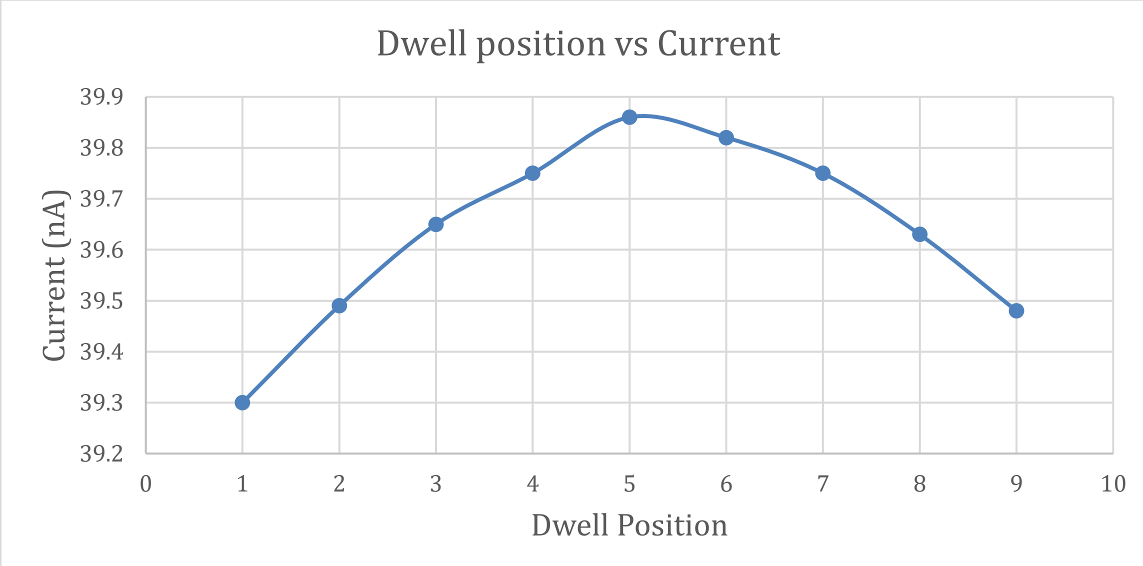
- Connect the well-type ionization chamber to the electrometer using the connecting cables. Run the electrometer in current mode and set the range as high.
- Set the bias voltage on the electrometer as mentioned in the calibration certificate.
- Now, to eliminate any leakage current that might be present in the connecting cables, press the Zeroing button on the electrometer.
- Keep the thermometer and barometer near the detector.
- Connect the source channel of the HDR brachytherapy unit to the well-type ionization chamber by using the guide tube.
- Measure the current at each position (in steps of 1mm) of the active length of the detector.
- Plot a graph of the Current vs source position and find out the maximum response position of the detector (A typical graph is shown below).
- Move the source to the maximum response position and note down the current reading on the electrometer. Take at least 3 readings at this position.
- Note down the temperature and pressure after measurement.

Observation and Calculation:

1. Find the maximum Response Position

Dwell Position/ Source Position	Current I (nA)		
	I1	I2	I3
1			
2			
3			
4			
5			
6			

7			
8			
9			



2. Measurement at Maximum Response position (For 60 seconds)

I_1 (nA)	I_2 (nA)	I_3 (nA)	I_{avg} (nA)

$k_{T,P} = \frac{T}{T_0}\frac{P_0}{P}$	Calibration factor, N_K

Source strength, RAKR = $I_{avg} N_K k_{T,P} k_{ele}$	Error (%) = $\frac{(Quoted - Measured)}{Quoted}$ X 100 %

2. Procedure for Timer Error:

- Connect the Gynec Transfer tube channel distance 1 to the well-type chamber.
- Program a treatment with the dwell position at the maximum collection point.
- Set the dosimeter in charge mode and set the range as High.
- Execute the treatment and note the charge accumulated from the dosimeter (R1).
- Again, execute the same treatment but this time press the interrupt button in TCP midway during the treatment.
- Continue the interrupted treatment by pressing the start button in the TCP.
- Note down the charge accumulated from the dosimeter (R2).
- Repeat the above steps for 3 trials.

Tablution:

Particulars	Charge (micro-Coulomb)			
	Trial 1	Trial 2	Trial 3	Average
Without interruption (R1)				
With interruption (R2) at 30 seconds				

Timer Error = $\frac{(R2-R1)\,t}{(2R1-R2)}$	% of Error = $\frac{\text{Timer Error} * 100}{60}$ (Tolerance ± 1%)

3. Procedure Timer Linearity and End Error:

- Connect the Gynec Transfer tube channel 1 to the well-type chamber
- Program a treatment with the dwell position at the maximum collection point.
- In the electrometer, go to SETUP and set the time interval to 180 seconds.
- Set the dosimeter in charge mode and set range as High
- Execute the treatment and start the dosimeter by pressing the INT button once the source reaches the dwell position.
- When the source reaches the distal dwell position it changes to red color and the Dwell Time window in the TCS will start counting
- Note down the charge accumulated from the dosimeter.
- Repeat the steps and take 3 readings and tabulate as shown in table 3.1 below.
- Calculate the current from the average meter reading.
- Repeat the steps for dwell times 90 sec, 120 sec, 150 sec and 180 sec and tabulate the readings as shown in the table 3.2 below.
- Plot the set time in the x-axis and the measured time in the y-axis. Find the slope and intercept from the plot. End error can be found from the intercept of the plot.

Table 3.1

Time Set	Charge in micro coulomb (for 180 sec)				
	Trial 1	Trial 2	Trial 3	Average	Current
190 Sec					

Table 3.2

Time Set	Charge in micro Columb				Time measured = Average charge / Current
	Trial 1	Trial 2	Trial 3	Average	
60					
90					
120					
150					

Timer Linerity (%) = (1 – slope) X 100

End Error =

Conclusion: