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Commissioning of a 6MV Elekta Compact Linear Accelerator for Clinical Treatment

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Abstract:- The main aim of this study to present the dosimetric aspects of Commissioning performed on an Elekta Compact with high dose rate for clinical treatment. Acceptance and Commissioning Tests were performed for 6MV photon energy on the Elekta Compact machine. Dosimetric tests were performed and Mechanical datas were measured and evaluated. The measurements includes output calibration, beam quality measurement, percent depth dose (PDD), in plane beam profile, cross plane beam profile couch transmission factor, tray transmission factor, wedge transmission factor. The mechanical isocenter check w.r.t gantry, collimator and couch were also measured and all found within limit. The PDD of 6MV for 10 × 10cm² field size increases at first up to a certain depth and then gradually falloff with depth. The in- plane flatness symmetry values and cross-plane flatness symmetry values for 6MV were measured and found not much difference between them. The in-plane penumbra values are higher than the cross-plane penumbra values for each field sizes (5x5 cm², 10x10 cm², 30x30 cm²). The output calibration and beam quality index were measured with 0.6cc Farmer Chamber in a water phantom and found within acceptable limit. Couch transmission factor, tray transmission factor, wedge transmission factor were all measured with suitable dosimeter. The radiation treatment to patient depends on the commissioning data modeled in the treatment planning system. These sets of commissioning data will be helpful to others to perform Elekta Compact commissioning which will definitely improve patient safety.

Keywords:- *Quality Assurance, Absorbed dose, Beam quality, Flatness, Symmetry, Penumbra.*

I. INTRODUCTION

We live in an era in which the technology of radiation therapy is evolving at an unprecedented rate. It is necessary to have an organized a dosimetry for a medical linear accelerator of such complex technology to ensure safe and efficient use of this technology for the direct benefit of patient.

Radiation therapy is the treatment of malignant disease, using ionization radiations. Radiation can be used to kill cancer cells very effectively. Depending on the type and stage of cancer, radiotherapy is carried out by either curative treatment (to cure cancer and reduce the risk of it recurring) or by palliative treatment (to relieve symptoms such as pain, pressure or bleeding). The main aim of radiation therapy performed for medical linear accelerator is to ensure that the patient is receiving the prescribed dose properly that is the tumor is receiving maximum dose and the normal tissue or critical organ is receiving the minimum dose within the tolerance limit.

Dosimetry in radiotherapy embodies in itself all those procedures that ensure consistency and accuracy in dose delivery as prescribed by radiation oncologist, and correct fulfillment of dose prescription with regard to dose to the target volume, together with minimal dose to normal tissue, and adequate patient monitoring aimed at determining the end result of the treatment. Clinical studies and retrospective data analysis have proved that the dose delivered to the tumor must be within ±5% of the prescribed dose to achieve meaningful and acceptable tumor control. This requires that a delivered dose must be accurate within ±2% or better. Realization of this objective demands development and implementation of dosimetry, treatment planning and dose delivery technique.

II. METHODS AND MATERIALS

PTW Semiflex Ionisation chamber 31010, PTW Farmer Ionisation Chamber 30013, PTW Unidos E Electrometer, IBA RFA dosimetry system, Survey meter, Leaser Alignment Test Tool

III. ABOUT ELEKTA COMPACT

Elekta Compact is a dependable, high throughput system for busy treatment centers. It is simple to operate, robust and reliable, allowing more patients to be treated quickly and effectively. Its modular design enables new functions and features to be added easily, making it a sound stand-alone investment for today and a solid foundation to build on for the future. By working alongside more advanced linear accelerators, it takes the workload of more conventional cases including IMRT deliveries to allow the others to focus on more advanced treatment techniques.

Table 1: Machine specification of Elekta Compact

Make	Elekta
Model	Compact
Energy	6MV
Jaws movement	Symmetric and asymmetric movement
Jaws over travel	Y jaws in clinical mode
Minimum field size without wedge	$0.5 \times 0.5cm^2$
Maximum field size without wedge	$39.0 \times 39.0\ cm^2$
Minimum field size with wedge	-------------
Maximum field size with wedge	$39 \times 29\ cm^2$
Wedge	Motorized wedge 60°

IV. RADIATION FIELD ANALYZER (RFA)

Radiation Field Analyzer is a type of three dimensional phantom which is also known as isodose plotter. This three dimensional RFA allows the scanning of the radiation field in orthogonal direction with the help of diodes or ionization chambers in the radiation field without changing the phantom setup.

A. Requirement of an RFA:

- The scanner of the RFA should be able to scan maximum field size ($40 \times 40 \times 40cm^3$) in all the three directions. The water tank should be at least 10cm larger than all the scan in each dimension.
- The RFA should be positioned with radiation detector centered on the central axis of the radiation beam.
- After the leveling of the gantry with the vertically downwards direction of the beam, leveling of the transverse mechanism can be accomplished by scanning the radiation detector along the central axis of the radiation beam indicated by the image of the cross hair.
- The traversing mechanism should have an accuracy of movement of 1mm and a precision of 0.5mm.

B. Phantom Setup:

- Setup the collimator and gantry angle ay 0°
- Match the light field cross hairs and the cross mark in the bottom of the phantom.
- Fill the phantom with water up to the mark down in the RFA.
- Check the leveling using sprit level and adjust the screws.
- Pour the remaining water and check the leveling.
- Set the chamber parallel to the water surface and save the maximum positions of the three coordinates to protect the chamber from collision with the wall of RFA.
- Set the SSD 100cm at the water surface and set the chamber at isocentre.
- The reference chamber should be in the field at the corner 2cm inside.

C. Symmetry:

The beam symmetry (S) is usually determined at d_{max} which represents the most sensitive depth for assessment. A typical symmetry specification is that any two dose points in the beam profile, equidistance from central axis point are within 2% to each other.

$$S = (D_{max}/D_{min}) \times 100\%$$

Tolerance = 2%

D. Flatness:

Beam flatness (F) is assessed by finding the maximum D_{max} and minimum D_{min} dose point values in the beam profile within the central 80% of the beam width.

$$F = (D_{max} - D_{min}) / (D_{max} + D_{min}) \times 100\%$$

Tolerance = 3%

E. Penumbra

The term penumbra, in a general sense, means the region, at the edge of a radiation beam, over which the dose rate changes rapidly as a function of distance from the beam axis.

There are two types of Penumbra –

- Transmission penumbra
- Geometric penumbra

The extent of this penumbra will be more pronounced for larger collimator openings because of greater obliquity of the rays at the edges of the blocks. This effect has been minimized in some designs by shaping the collimator blocks so that the inner surface of the blocks remains always parallel to the edge of the beam. Although the transmission penumbra can be minimized with such an arrangement, it cannot be completely removed for all field sizes.

Another type of penumbra is called geometric penumbra which arise due to the size of the source.

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Table 2: Measured Parameters using RFA

Energy 6MV									
Field Size	**Depth**	**In plane**				**Cross plane**			
		Flatness	Symmetry	Penumbra Left in mm	Penumbra right in mm	Flatness	Symmetry	Penumbra Left in mm	Penumbra right in mm
5x5 cm²	Dmax = 1.61 cm	0.95%	1.25%	5.59	5.67	1.05%	1%	5.31	5.22
	10 cm	1.76%	1.09%	6.44	6.69	1.72%	1.1%	5.98	6.16
10x10 cm²	Dmax = 1.61 cm	1.05%	1.16%	5.64	5.70	1.34%	1.69%	5.62	5.57
	10 cm	2.19%	1.2%	7.29	7.06	2.61%	1.82%	7.03	7.03
30x30 cm²	Dmax = 1.61 cm	4.89%	0.8%	5.68	5.52	5.43%	1.63%	5.12	5.43
	10 cm	2.34%	0.84%	9.09	8.81	2.49%	1.4%	8.27	8.7

- *Discussion:*

The above measured datas are within acceptable limit.

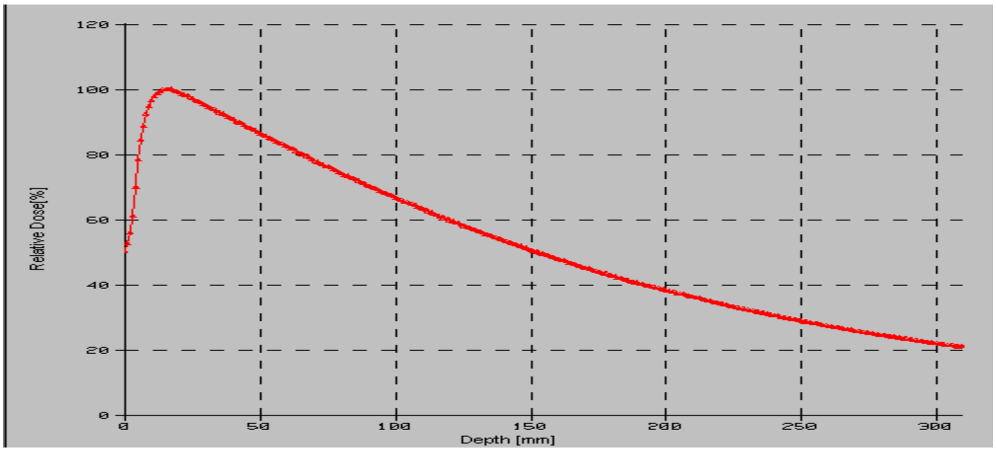

Fig. 1: PDD of 10 × 10cm² at 10cm depth

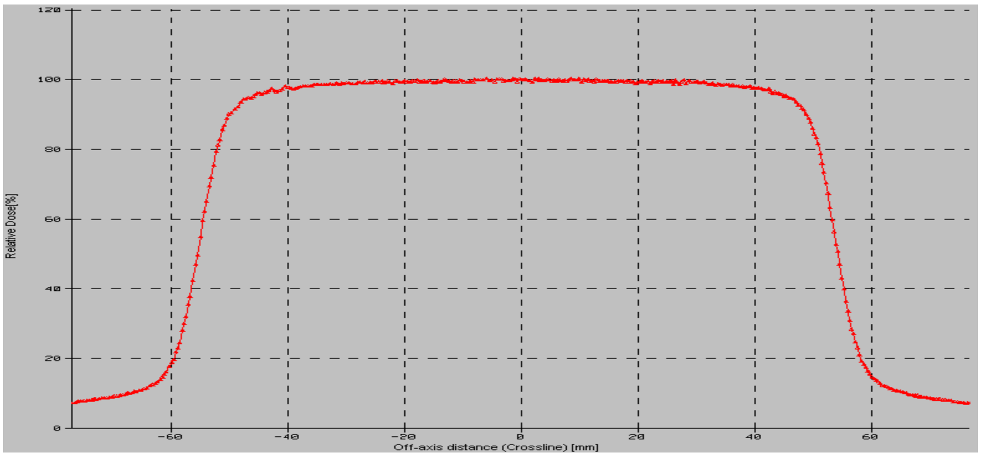

Fig. 2: Profile of 10 × 10 cm² at 10 cm depth

V. BEAM QUALITY MEASUREMENT

A. About Beam quality-

Beam quality means penetrating power of the beam. For high energy photons produced by clinical accelerators the beam quality is specified by the tissue phantom ratio $TPR_{20\ 10}$.This is the ratio of the absorbed doses at depths of 20 and 10 cm in a water phantom, measured with a constant SCD of 100 cm and a field size of 10 cm × 10 cm.

The most important characteristic of the beam quality index $TPR_{20\ 10}$ is its independence of the electron contamination in the incident beam. It is also a measure of the effective attenuation coefficient describing the approximately exponential decrease of aphoton depth dose curve beyond the depth of maximum dose As $TPR_{20\ 10}$ is obtained as a ratio of doses; it does not require the use of displacement correction factors at two depths when cylindrical chambers are used. Furthermore, $TPR_{20\ 10}$ is in most clinical set-ups not affected by small systematic errors in positioning the chamber at each depth, as the settings in the two positions will be affected in a similar manner.

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Table 3: Reference condition for photon beam quality ($TPR_{20\ 10}$)

Influence Quantity	Reference characteristic
Phantom material	Water
Chamber type	Cylindrical or plane parallel
Measurement depth	20g/cm² and 10g/cm²
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 of the chamber	For cylindrical and plane-parallel chamber, at the measurement depth.
SCD	100 cm
Field size at SCD	10×10 cm²

B. Beam Quality Index ($TPR_{20\ 10}$) Calculation-

Measurements are done using RFA.

- Chamber = PTW Farmer chamber
- Electrometer = PTW Unidos E electrometer
- SAD = 100 cm
- Field size = 10 × 10 cm²
- Depth = 10 g/cm² and 20 g/cm²
- Monitor Unit = 100 MU.

Beam Quality Index ($TPR_{20\ 10}$) can be calculated using the following formula

$TPR_{20\ 10} = M_R$ at 20cm depth / M_R at 10 cm depth.

Table 4: Measured Readings for Beam Quality ($TPR_{20\ 10}$)

SL. No	M_R at 20 cm depth (nC)	M_R at 10cm depth (nC)
1	9.805	14.6775
2	9.805	14.6775
3	9.805	14.6775

$TPR_{20\ 10}$ =9.805 (nC) / 14.6775 (nC)

$TPR_{20\ 10}$ = 0.668

Beam Quality Correction factor for PTW FC 0.6cc is **0.9916**.

Standard value for $TPR_{20\ 10}$ for 6MV is **0.676 ± 0.009**

- *Discussion:*

The value $TPR_{20\ 10}$ is well within acceptable limits.

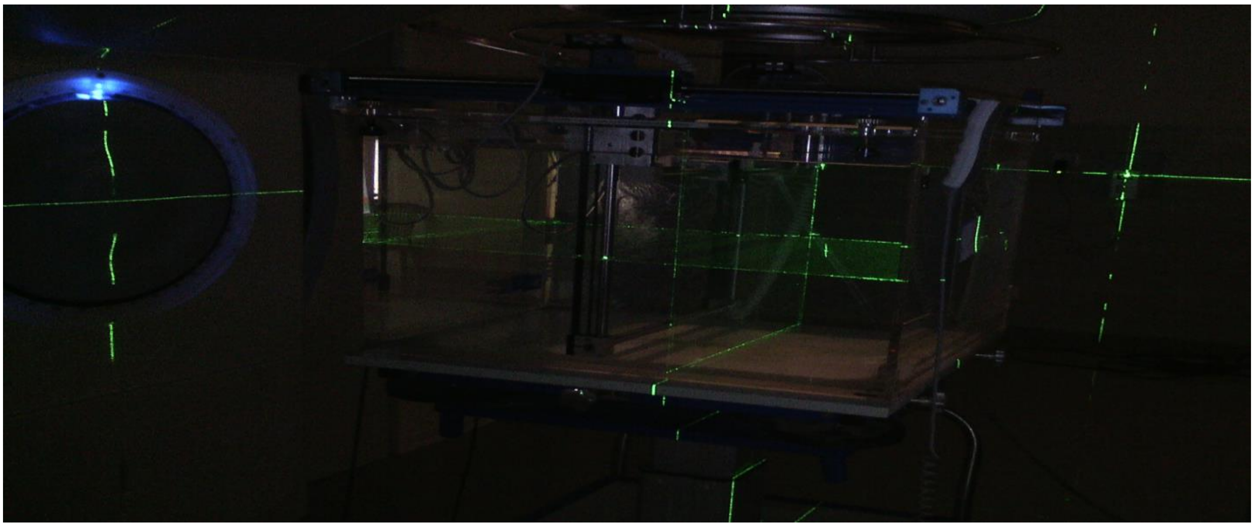

Fig. 3: $TPR_{20\ 10}$ setup using Radiation Field Analyzer (RFA)

VI. QUALITY ASSURANCE TEST

Q.A is set of plane and systematic procedures which are necessary to provide adequate confidence that a product or service will satisfy given requirement for their quality.

Classification of Q.A is done as follows-

- Electrical Test
- Mechanical Test
- Radiation Dosimetry Check.
- Survey of Installation.

A. Electrical Test:

It consists of safety checks which include-

- *Interlocks :*

- **Door interlock**: It prevents irradiations from offering when door is open.

- **Radiation beam off interlock**: It halts irradiation but not stops the motion of treatment unit or patient treatment table.
- **All motion disable interlock:** This stops the motion of the treatment unit but they donot stops machine irradiation.
- **Emergency stop interlock:** This interlock disables power to the motor that drives the treatment and treatment table motion and disable power to some of the radiation producing elements of the treatment unit.

➢ *Warning light:*

When radiation is ON Red light must be in On condition, when radiation is OFF Green light must be in OFF condition and during processing Yellow light should be ON.

➢ *Patient Monitoring Equipment:*

Audio-Video equipment verification is needed for proper functioning of the patient monitoring.

➢ *Light field display:*

It should work properly to match with the radiation field.

➢ *Control console display and functioning:*

It should work properly.

➢ *Hand Pendent:*

It should work properly.

B. Mechanical Test:

➢ *Gantry Rotation:*

- A spirit level should be used to check the 0º gantry position for the absolute measurement.
- Rotate gantry to 0°, 90°, 180° and 270° according to the mechanical scale.
- Note readings from the treatment control panel or the display monitor andcompare to the mechanical readings.

Observation = **0.5°**
Tolerance =**1°.**

➢ *Discussion*

The above observed value is within acceptable limit

➢ *Couch Rotation:*

- Rotate the table to, for example, 0°, 90°, and 270° about the isocentre and compare the reading at the control panel or the display monitor to the mechanical reading on the table.

Observation = **0.5°**
Tolerance = **1°**

➢ *Discussion*

The above observed vale is within acceptable limit.

➢ *Collimator Rotation:*

- Rotate the gantry to approx. 90° or 270°.
- Align the light field edges at 0° collimator angle with appropriate horizontal or vertical marks (e.g. set up with the help of a spirit level for absolute measurements) on the treatment room wall.
- Note the collimator reading at the treatment control panel or the display monitor and the reading on the mechanical scale on the treatment head.
- Repeat the above at 90° collimator angle.

Observation = **0.5°**
Tolerance = **1°.**

➢ *Discussion*

The above observed value is within acceptable limit.

➢ *Parallelism of the Jaws*

- With an arbitrary isocenter marked and a square field size opened (say 10x10 cm^2) is matched on the graph paper placed on the couch at 100 cm SSD with gantry and collimator 0^0.
- The opposite jaws of the optical field projected on the graph paper are checked so that they are parallel to each other.

Observation =**1°**
Tolerance = **±1°**

➢ *Discussion*

The above observed vale is within acceptable limit.

➢ *Orthogonality of the adjacent jaws*

- With the same setup as above we can similarly check the orthogonally of the adjacent jaws and its variation for square and rectangular field opening.

Observation =**1°**
Tolerance = **±1°**

➢ *Discussion*

The above observed value is within acceptable limit.

➢ *Symmetry of Jaws*

- The measurement setup is same as previous one.
- Here a square or rectangular field size is opened and the symmetry is checked.
- Say suppose a field of 10x10 cm^2 is opened, then from isocenter to the field edge its distance should be symmetric on both sides, i.e. 5 cm each side.

Observation = **0.5mm**
Tolerance=**±1mm**.

➢ *Discussion*

The above observed value is within acceptable limit.

➢ *Optical field overlap*

- This time the graph paper is placed perpendicular to the treatment couch plane and parallel to gantry axis of rotation.
- Field of dimension 10x10 cm^2 is opened and is matched with the marked isocenter and field borders at 100 cm SSD with gantry 90^0 and collimator 0^0.
- Next the same field is matched again with gantry angle 270^0 at 100 cm SSD without disturbing the graph paper setup.
- And the deviation of overlap is noted for the two gantry angles.

Observation = **0.5mm**
Tolerance =**±1mm.**

- *Discussion*

The above observed value is within acceptable limit.

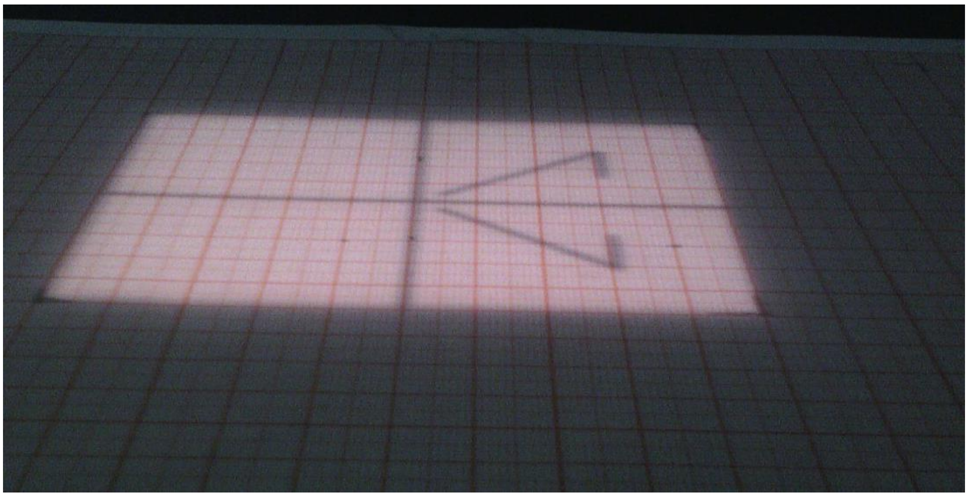

Fig. 4: Figure shows Parallelism of jaws, Orthogonality of jaws, Symmetry of jaws and Optical field overleap, Field size verification

- *Mechanical Isocenter check (w.r.t. collimator rotation)*

- A graph paper is attached at the flat surface on the couch and an arbitrary isocenter is marked at 100cm SSD with gantry vertical.
- Optical cross-hair is matched with the marked isocenter.
- Now the collimator is rotated in both direction with its extreme limits and the deviation is observed throughout the procedure.

Observation **= 0.5mm**
Tolerance = **within 2mm dia sphere**

- *Discussion*

The above observed value is within acceptable limit.

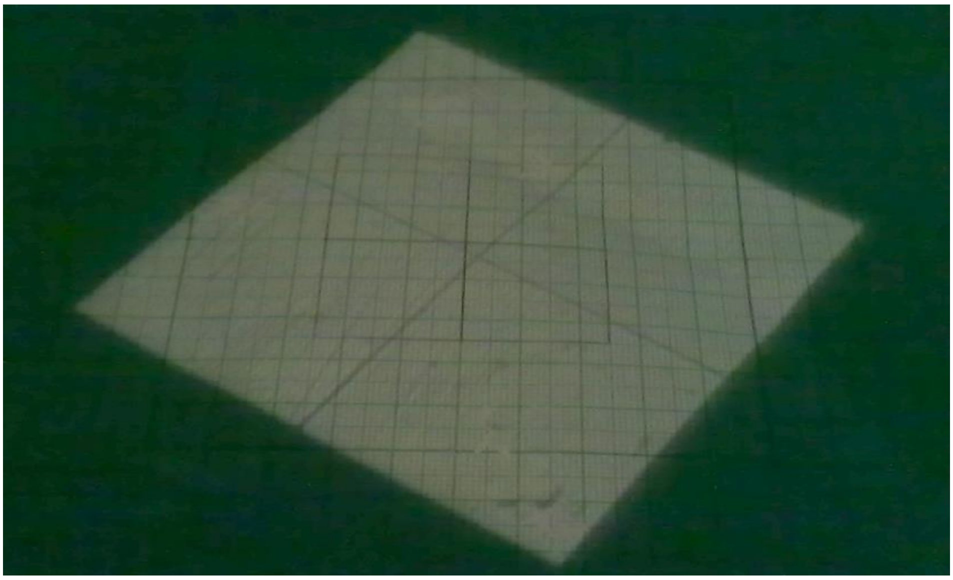

Fig. 5: Mechanical Isocenter w.r t. collimator

- *Mechanical Isocenter check (w.r.t. gantry rotation)*

- A pin is attached on the couch such that its tip is matched with the optical field cross-hair.
- The pin should be attached in such a way that during the full rotation of gantry (360^0) its tip is always seen in the light field.
- The deviation between pin tip and light field cross-hair is observed in each gantry angle, usually at 0^0, 90^0, 180^0 and 270^0

Observation = **1mm**
Tolerance **= within 2mm dia sphere.**

- *Discussion*

The above observed value is within acceptable limit.

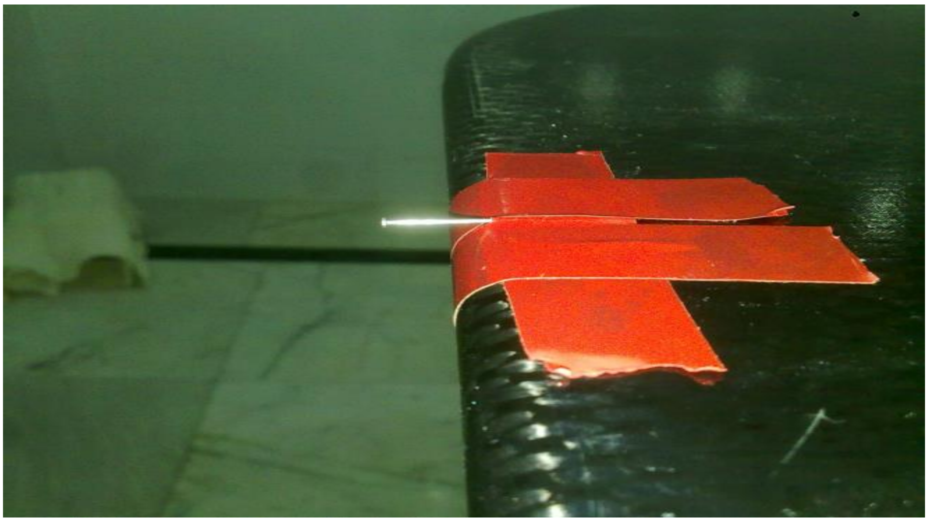
Fig. 6: Mechanical Isocenter w.r.t gantry

➢ *Mechanical Isocenter check (w.r.t couch rotation)*

- A pin is attached on the couch such that its tip is matched with the optical field cross-hair.
- The pin should be attached in such a way that during the full rotation of couch its tip is always seen in the light field.
- The deviation between pin tip and light field cross-hair is observed in each couch rotation angle.

Observation = **1mm**
Tolerance= **within 2mm dia sphere.**

➢ *Discussion*
The above observed value is within acceptable limit.

➢ *Optical Distance Indicator (ODI)*

- Place 5 or 6 Perspex sheet each of thickness 1cm on the couch.
- Set SSD at 100cm.
- Now remove the sheets one by one and check whether ODI changes accordingly.
- The same can be done by adding 6 sheets one by one.

Observation = **1mm**
Tolerance = **±1.5mm**

➢ *Discussion*
The above observed value is within acceptable limit.

➢ *Field Size Verification*

- Fixed a graph paper on the couch and set it on isocentre.
- Open different field sizes andcheck them on graph paper.

Observation = **0.5mm for field size < 10 × 10 cm²**
=1mm for field size > 10 × 10 cm²

Tolerance =**±1mm for field size 10×10cm² and**
= ±2mm for field size > 10×10cm².

➢ *Discussion*
The above observed value is within acceptable limit.

➢ *Leaser Alignment*

- Place Leaser alignment test tool on the couch
- Level with spirit level.
- Match the leaser with this test tool.

Observation = **0.5mm**
Tolerance = **±1 mm**

➢ *Discussion*
The above observed value is within acceptable limit.

C. Radiation Dosimetry Check

➢ *Output Calibration*
Measurements are done using Radiation Field Analyzer.

- Set the gantry and collimator at 0°.
- The ionization chamber of volume 0.6cc is kept at a depth of 10cm from the surface of water phantom.
- Set SSD at 100cm and set the isocenter at the central axis of ionization chamber.
- Now irradiate the chamber for 100MU by opening the field size of 10×10 cm².
- Measure the electrometer reading in terms of charge and also measure the temperature and pressure.

➢ *Calculations*
Temperature = **19.2 C°**
Pressure = 29.34 × 25.4 mm of Hg **= 745.236 mm of Hg.**
K_{TP}= (273.2 + T/ 273.2 + T_0) × (P_0 / P).
= (273.2 + 19.2/ 273.2 + 20) × (760 mm of Hg/ 745.236 mm of Hg)
=**1.0173**
$N_{D\,W}$ =**5.35 × 10^7 Gy/C.**
$K_{Q\,Qo}$ = **0.9916**
PDD_{10} = **66.7%**

Table 5: Measured Readings for Output Calibration

SL. No	Meter Reading (nC)	Meter reading (nC)	Meter Reading (nC)	Average reading (nC)
1	12.39	12.38	12.38	12.383

The formula for output calculation is given as-

Output = $(M_R \times K_{TP} \times N_{DW} \times K_{Q\,Qo}) / PDD$

$= (12.39 \times 1.0173 \times 5.35 \times 10^7 \times 0.9916) / 0.667$

=100.19 cGy / 100 MU

Percentage of variation = ((100 – 99.89) / 100) × 100%

= **0.19%**

Tolerance =**±3%.**

➢ *Discussion*

The percentage variation in output calibration is well within acceptable limit.

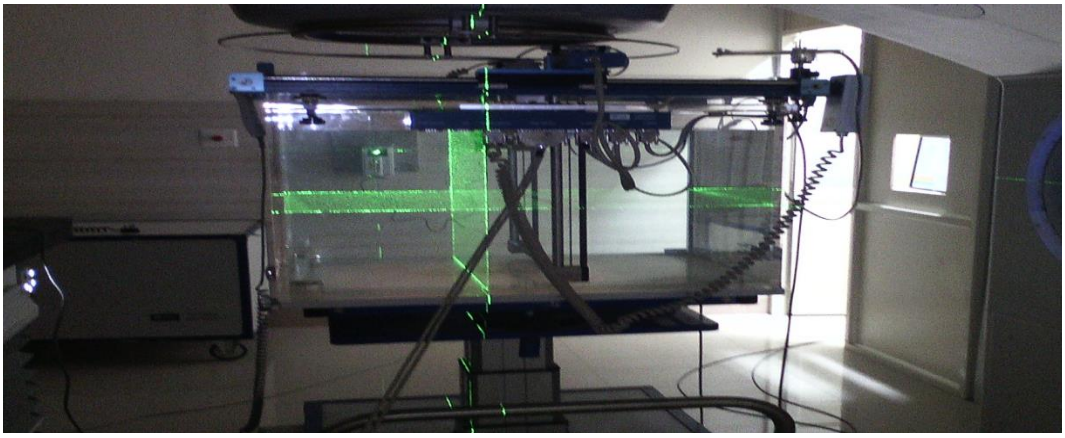

Fig. 7: Output Calibration using Radiation field Analyzer (RFA)

➢ *Congruency between Optical and Radiation field:*

- Keep a film a on the couch at SSD 100cm.
- Now open 10×10 cm² field size and make pin pricks all the four corners and the center of the optical film.
- The film is then exposed to radiation and developed.
- Radiation field should match with the pin pricks.

Observation = **0.5 for field size up to 10 × 10 cm²**

=1mm for field size >10 × 10 cm²

Tolerance = **±1mm up to field size 10×10 cm².**
= ±2mm > field size 10×10 cm².

➢ *Discussion*

The above observed values are well within acceptable limit.

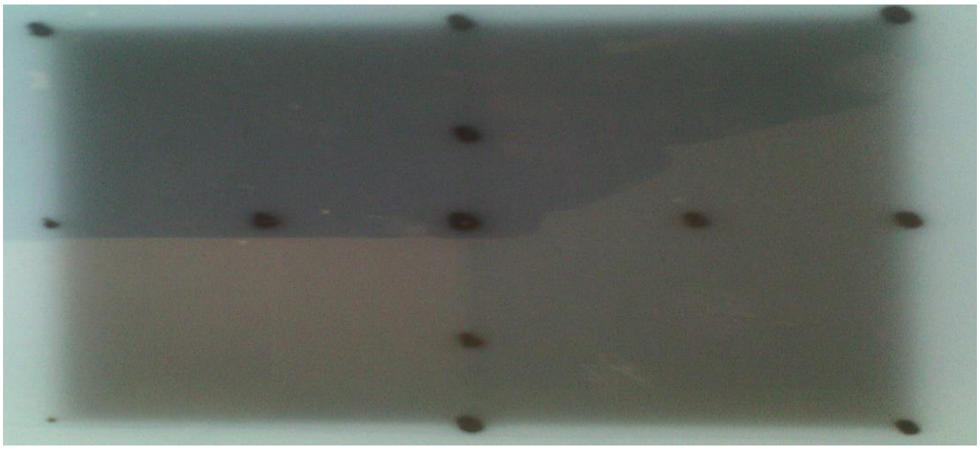

Fig. 8: Congruency between Radiation and Optical Field (10 × 10 cm²)

➢ *Radiation isocentere check*

It should be checked with respect to gantry collimator and couch.

- A film is placed between two plastic phantoms perpendicular to gantry axis of rotation
- Make pin pricks at the center of the cross wire.
- The film is then exposed by opening a field size of 40×2 cm² for different gantry collimator and couch.
- The processed film should show a star pattern.
- The point where the entirecentral axis intersects is isocentre.

Observation = **1mm.**

Tolerance – **The point should be within 2mm of the isocentre indicating by pin pricks.**

➢ *Discussion*

The above observed vales are well within acceptable limit.

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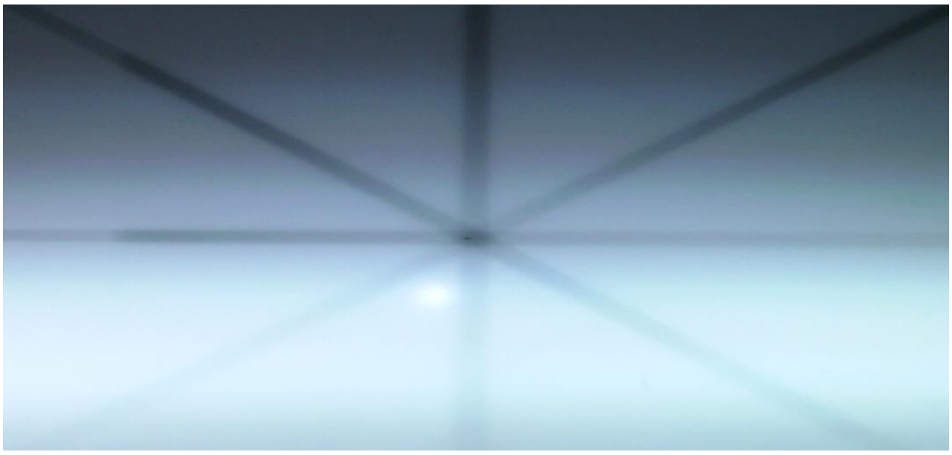
Fig. 9: Radiation Isocenter w.r.t gantry (Star Pattern)

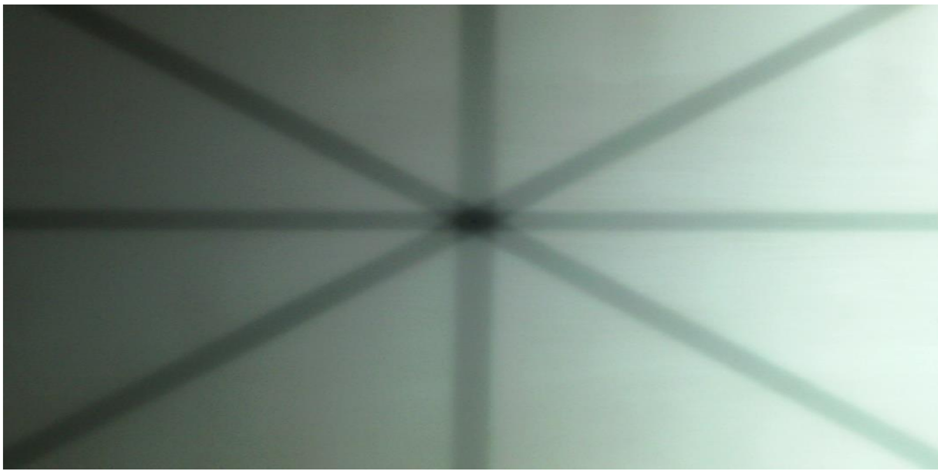
Fig. 10: Radiation Isocenter w.r.t collimator (Star Pattern)

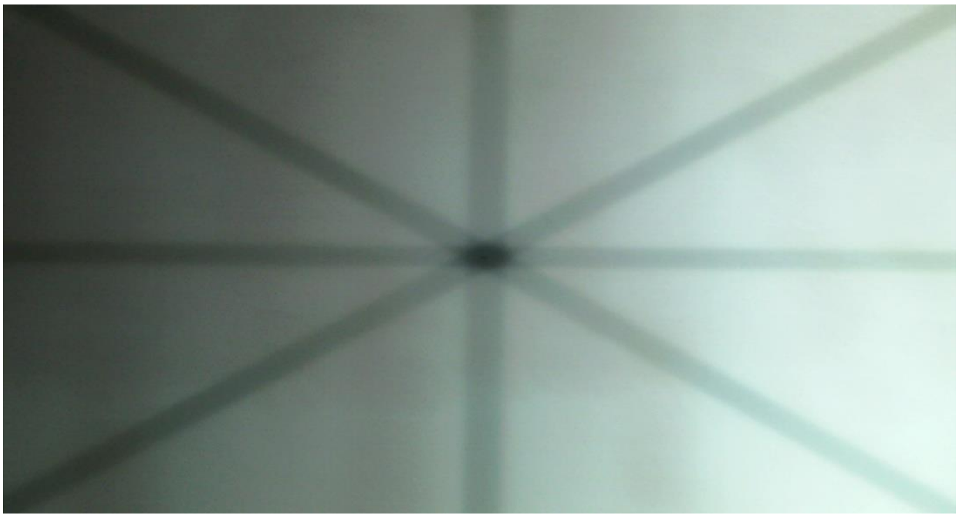
Fig. 11: Radiation Isocenter check w.r.t couch (Star Pattern)

➢ *Wedge Factor*

Measurements are done using Radiation Field Analyzer (RFA).

- First make the gantry and collimate 0°.
- A RFA is placed with an ionization chamber at 10 cm depth, SSD 100 cm at water surface.
- Now electrometer readings are taken for dose rate 350MU/min of with wedge and without wedge.
- Without wedge reading is taken making collimator 270°, i.e. chamber is perpendicular to the wedge direction.
- Ratio of the electrometer reading of with wedge by without wedge gives the wedge factor for that particular wedge filter.
- This process is repeated for the various wedges

Table 6: Measured Readings for Wedge Factor

SL.No	Meter readings with wedge			Meter readings without wedge		
	Meter reading (nC)	Meter reading (nC)	Average (nC)	Meter reading (nC)	Meter reading (nC)	Average (nC)
1	3.261	3.262	3.2615	12.235	12.235	12.235

The formula for wedge factor is = M_R with wedge/M_R without wedge

=3.2615 / 12.1235

W.F= 0.2666

Tolerance **= manufacture stated value**

➢ *Discussion*

The calculated wedge factor is well within acceptable limit.

➢ *Couch Transmission factor*

- First set the gantry and collimator at 0°.
- Ionization chamber is set with leaser at chamber center.
- A field size of 10 x 10 cm^2 is opened.
- At first electrometer reading is taken for 300 MU without couch.
- Again reading is taken for 300 MU at gantry position 180^0 (Under the couch).
- From both electrometer reading, couch transmission factor can be calculated.

Table 7: Measured Readings for Couch Transmission Factor

SL.No	Meter Reading(M_R) with couch			Meter reading (M_R) without couch		
	Meter reading (nC)	Meter Reading (nC)	Average (nC)	Meter reading (nC)	Meter reading (nC)	Average (nC)
1	8.774	8.776	8.775	9.006	9.006	9.006

The formula for couch transmission factor is = M_R with couch / M_R without couch

= 8.775 / 9.006

C.F =0.9743

Tolerance **= manufacture stated value**

➢ *Discussion*

The calculated couch transmission factor is well within acceptable limit.

➢ *Tray Transmission Factor*

Measurements are done using Radiation Field analyzer (RFA).

- First make the gantry and collimator 0°.
- SSD 100 cm, ionization chamber at 10 cm depth in water phantom.
- Field size 10x10 cm^2 is opened.
- Reading is taken for 100MU, first with the tray and next without the tray.
- From both the electrometer readings tray factor can be calculated.

Table 8: Measured Readings for Tray Transmission Factor

SL.No	Meter Reading with Tray			Meter Reading without Tray		
	Meter reading (nC)	Meter reading (nC)	Average (nC)	Meter reading (nC)	Meter reading (nC)	Average (nC)
1	11.574	11.58	11.575	12.235	12.235	12.235

The formula for tray transmission factor is = M_R with Tray / M_R without Tray

= 11.575 /12.235

T.F. =0.946

Tolerance **= manufacture stated value**

➢ *Discussion:*

The calculated tray factor is well within acceptable limit.

➢ *Dose Linearity for Photon Beam Energy*

- First set the gantry and collimator at 0°.
- SSD 100 cm, ionization chamber at 10 cm depth in water phantom
- Field size 10×10 cm^2 is opened.
- Dose rate is 350MU/min.
- Readings are taken for 50MU,100MU,150MU,200MU,250MU,300MU,350MU , and 400MU
- Divide the MRby the corresponding MU.

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Table 9: Measured Readings for Dose Linearity

MUs	**Meter Reading (nC)**	**Ratio(MR/MUs)**
50	6.120	0.1224
10	12.235	0.12235
150	18.37	0.12247
200	24.51	0.12255
250	30.645	0.12258
300	36.755	0.12252
350	42.925	0.12264
400	49.045	0.1226

Linearity = (0.12264 – 0.12235 / 0.12264 + 0.12235) × 100%
= **0.1224%**

The tolerance for dose linearity is **1%**

- *Discussion*
The dose linearity is well within acceptable limit.

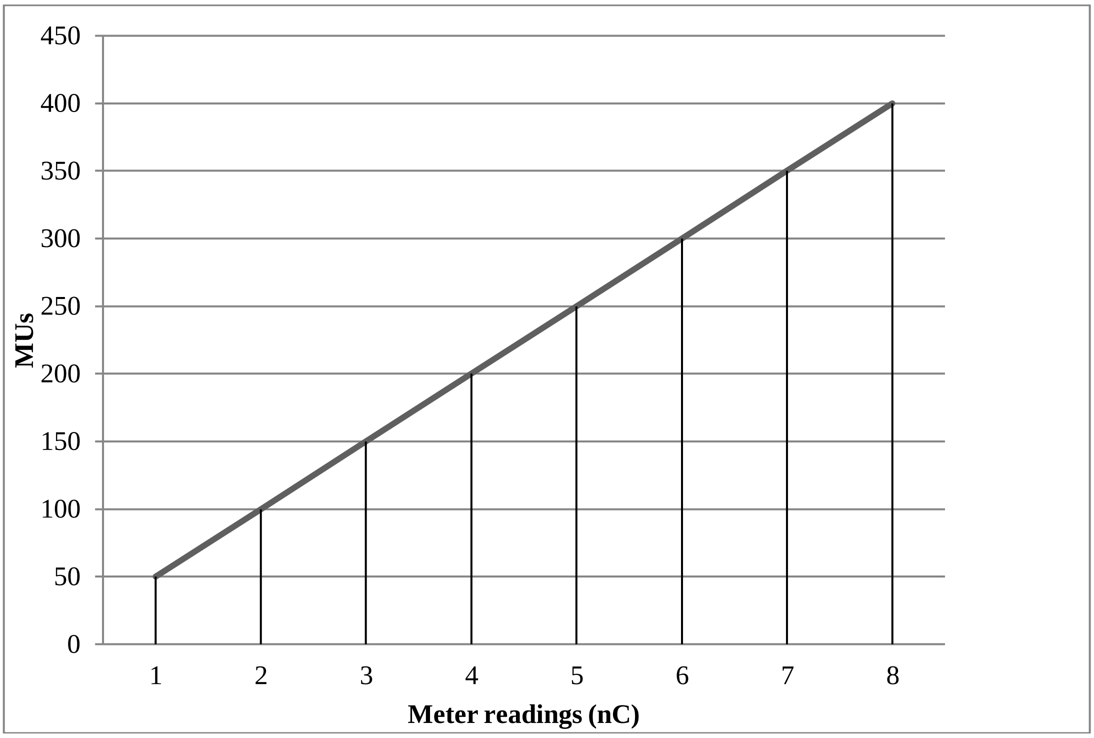

Fig. 12: Graph showing dose linearity

- *Photon Leakage Radiation through beam limiting device*

- Useful Beam Reading
- ✓ In air measurement
- ✓ PTW semi flex chamber (0.125 cc) with brass cap
- ✓ On 24 point patient plane leakage measurement sheet
- ✓ 10 × 10 cm² field size.
- ✓ 100 cm SCD and 100MU

Table 10: Measured Readings for Useful Beam

Sl.No	Meter Reading (nC)	Meter Reading (nC)	Average (nC)
1	17.56	17.56	17.56

- *X-Jaw Transmission*
X = 0.5 cm
Y = 39.8 cm

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Table 11: Measured Readings for X-Jaw Transmission

SL.No	Meter Reading (nC)	SL.No	Meter Reading (nC)	Maximum (nC)	Average (nC)
1	0.129	13	0.033		
2	0.127	14	0.033		
3	0.113	15	0.084		
4	0.114	16	0.082		
5	0.114	17	0.086		
6	0.113	18	0.084	0.139	0.0914
7	0.139	19	0.034		
8	0.137	20	0.035		
9	0.118	21	0.086		
10	0.116	22	0.083		
11	0.115	23	0.085		
12	0.113	24	0.084		

Maximum Transmission = (0.139 / 17.56) ×100%
= **0.79%**

Average Transmission = (0.914 / 17.56) ×100%
= **0.5%**

Tolerance for Average Transmission = **<0.75%**

Tolerance for Maximum Transmission = **<2%**

- *Discussion*
  The above values are within acceptable limit.

- *Y Jaw Transmission*
  X = 39.8 cm
  Y = 0.8 cm

Table 12: Measured Readings for Y-Jaw Transmission

SL.No	Meter Reading (nC)	SL.No	Meter Reading (nC)	Maximum (nC)	Average (nC)
1	0.138	13	0.080		
2	0.138	14	0.079		
3	0.139	15	0.089		
4	0.166	16	0.047		
5	0.163	17	0.052		
6	0.137	18	0.092	0.169	0.106
7	0.139	19	0.081		
8	0.139	20	0.084		
9	0.139	21	0.094		
10	0.169	22	0.049		
11	0.156	23	0.048		
12	0.132	24	0.091		

Maximum Transmission = (0.169 / 17.56) ×100%
=**0.952%**

Average Transmission = (0.106 / 17.56) ×100%
= **0.060%**

Tolerance for Average Transmission = **<0.75%**

Tolerance for Maximum Transmission = **<2%**

- *Discussion*
  The above calculated value is within acceptable limit.

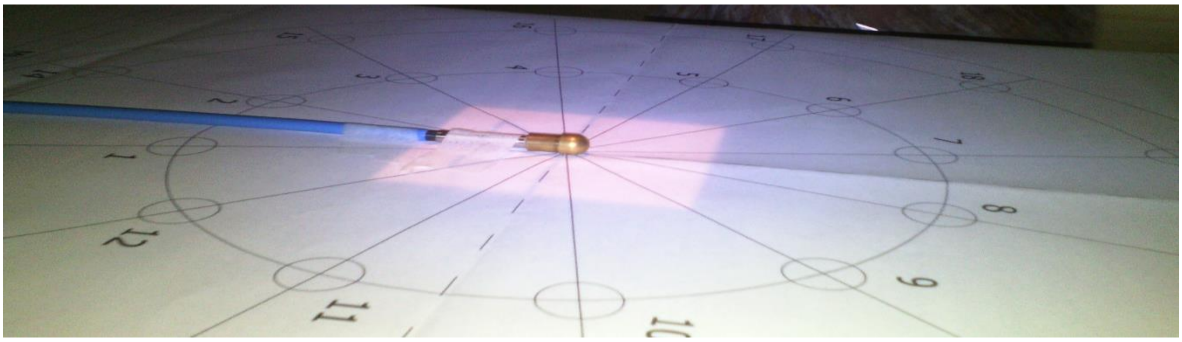

Fig. 13: Leakage through Beam Limiting device

➢ *Photon Leakage Radiation in the patient plane:*

- In air measurement
- Ionization Based Survey Meter is used
- 350 MU is delivered
- Useful beam is 350MU/min
- Readings are taken at 1m from the isocenter in the patient plane.
- 350MU/min = (350 × 60) R/hr.

= **21000 R/hr.**at isocenter

Table 13: Measured Readings for Leakage Radiation in the patient plane

SL.No	Couch Rotation (degree)	Survey Meter Readings (mR)	Maximum(mR)	Average(mR)
1	0	64		
2	10	55		
3	45	40	64	46.5
4	90	30		
5	-45	40		
6	-90	50		

Maximum Reading **=** 64mR = 3.84R/hr.
= (3.84 / 21000) ×100%
=0.0182%

Average Reading = 46.5mR = 2.79R/hr.
= (2.79 / 21000) ×100%
= **0.0133%**

Tolerance for Average Reading = **<0.1%**

Tolerance for Maximum Reading = **<0.2%**

➢ *Discussion*

The above calculated value is within acceptable limit

➢ *Head Leakage Radiation outside patient plane*

- In air measurement.
- Gantry is 180°.
- Measurements are taken with Survey Meter in integrated mode.
- 350 MU is delivered
- Useful beam is 350MU/min
- Readings are taken at 1m at different angles.
- Field size is 10×10 cm²

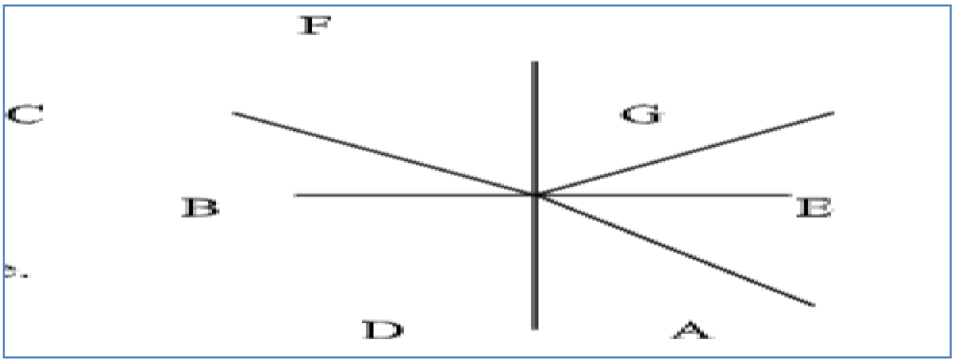

Fig. 14: Measured positions for Head Leakage outside PP

Table 14: Measured Readings for Leakage Radiation outside patient plane

SL.No	Positions	Survey Meter Readings (mR)	Maximum (mR)
1	A	104	
2	B	104	
3	C	103	104
4	D	104	
5	E	104	
6	F	104	

Maximum Leakage Reading = 104mR = 6.24R/hr.

= (6.24 / 210000 ×100%

= 0.029%

Tolerance for Maximum Reading = <0.2%

➢ *Discussion*

The above calculated vale is within acceptable limit.

D. Survey of installation

Instrument used – Survey Meter
All readings are in uR/hr.
Field size – 40 × 40 cm².

Table 15: Measured Readings for Survey

SL.No	Positions	Gantry angles			
		0	90	180	270
1	Door (without phantom)	29	40	51	54
2	Primary wall 1 (without phantom	34	290	27	63
3	Primary wall 2 (without phantom)	80	22	34	360
4	Celling (without phantom)	26	40	400	25
5	Charge room (without phantom)	23	24	23	27
6	Door (with phantom)	71	52	42	78
7	A.C room (with phantom)	31	18	30	19
8	Console (with phantom)	11	41	14	43
9	Secondary wall gantry side (with phantom)	23	126	20	45
10	Secondary wall couch side (with phantom)	31	18	30	19

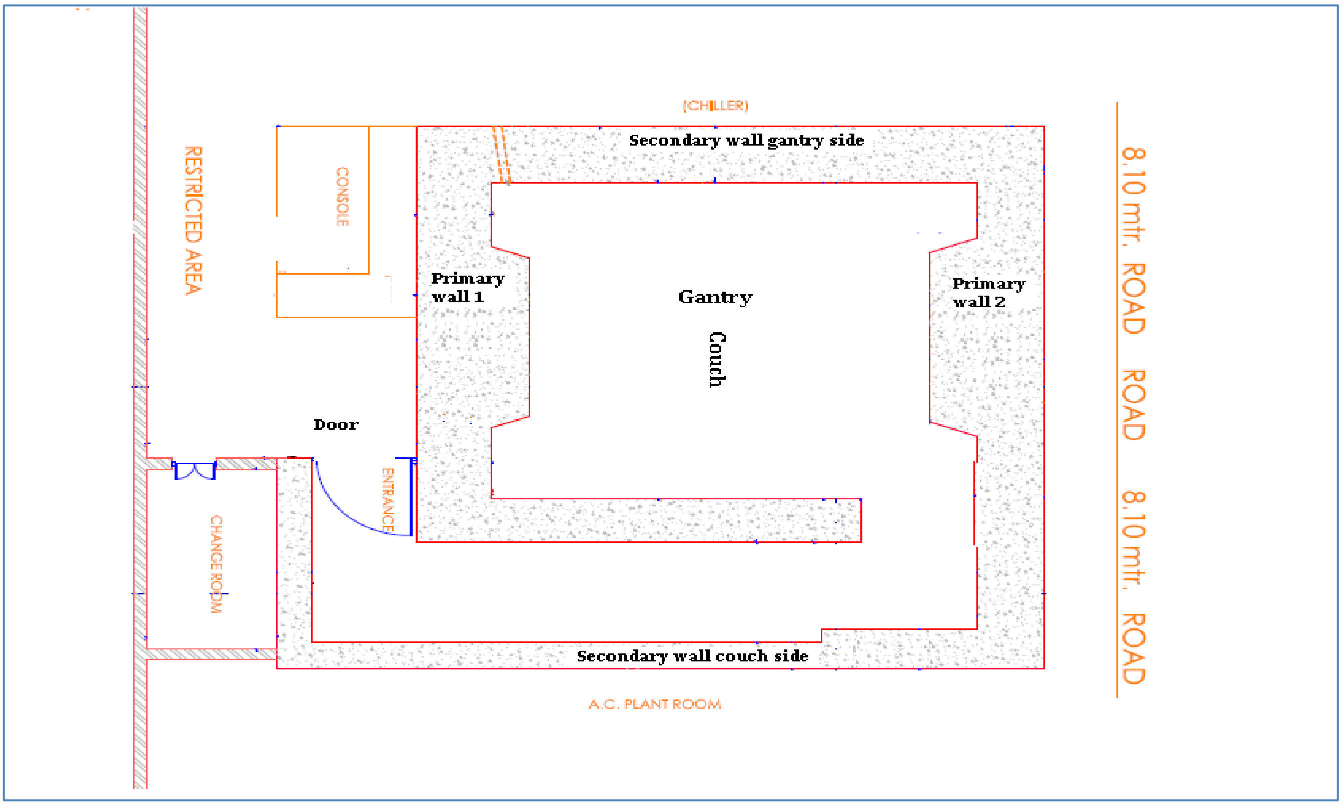

Fig. 15: Layout of 6MV Elekta Compact LINAC

Table 16: Performance test results of Linear Accelerator Unit

Sl.No	Parameter	Observation	Tolerance
1	Whether all the interlocks and emergency switches are working satisfactorily	Yes	Provided
2	Whether all the important indicators (like beam OFF, ON, Emergency) are provided in the control console	Yes	Provided
3	Orthogonality of adjacent Jaws	1°	±1°
4	Parallelism of opposite Jaws	1°	1°
5	Symmetry of opposite Jaws	0.5mm	±1mm
6	Reproducibility of MLC leaf positions from a test position	Not Applicable	
7	Accuracy of asymmetric jaw during over-travel	0.2mm	1mm
8	Optical and Collimator axes coincidence	0.5mm	1mm
9	Accuracy of Isocentre due to Gantry Rotation	1mm	<2mm diameter sphere
10	Accuracy of Isocentre due to collimator Rotation	0.5mm	<2mm diameter sphere
11	Accuracy of Isocentre due to Couch Rotation	1mm	<2mm diameter sphere
12	Coincidence between radiation and mechanical isocenter	1mm	<2mm diameter sphere
13	Accuracy of Optical Distance Indicator (ODI)	1mm	±1.5mm

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14	Accuracy of Laser beam indicator	0.5mm	±1mm
15	Accuracy of Mechanical Front Pointer	0.5mm	±2mm
16	Accuracy of optical field size definition for field size ≤10 cm x10 cm	0.5mm	±1mm
17	Accuracy of optical field size definition for field size >10 cm x10 cm	1mm	±2mm
18	Optical & Radiation Field Congruence	1mm	2mm
19	Optical field overlap due to collimator rotation (0° to 180° and 90° to 270°)	0.5mm for 90° and 270°	1mm
20	Cross-wire centering vs. collimator rotation	0.5mm	2mm
21	Cross-wire centering vs. gantry rotation	1mm	2mm
22	Gantry Rotation speed (.1 to 1 RPM)	0.1	1RPM
23	Accuracy of angular scale	0.5°	0.5°
24	Wedge position reproducibility	Not applicable	2mm
25	Tray position reproducibility	0.5mm	2mm
26	Table top sag	1.5mm	2mm
27	Electron applicator position reproducibility	Not Applicable	
28	Accuracy of table vertical motion	0.5mm	2mm
29	Accuracy of table lateral motion	0.5mm	2mm
30	Accuracy of table longitudinal motion	0.5mm	2mm
31	Accuracy of source to axis distance (SAD)	0.5mm	2mm
32	Quality Index for 6MV Photon Beam(s).	0.668	0.676
33	Depth of maximum absorbed dose to water (dmax) for 10 cm x10 cm field size for all the photon beam energy(ies) available	1.61cm	Manufactured stated value
34	Percentage Depth Dose values (PDD) at 10 cm depth for 10 cm x10 cm field sizefor different photon beam energy (ies) available	66.7%	Manufacture specified value
35	Beam flatness for Photon Beam energy (ies) available	2.61%	3%
36	Beam flatness for Electron Beam energy (ies) available	Not Applicable	
37	Symmetry of the radiation field for Photon Beam energy (ies) available	1.82%	2%
38	Symmetry of the radiation field for Electron Beam energy (ies) available	Not Applicable	
39	Dose Linearity for Photon Beam Energy (ies) available	0.12%	1%
40	Dose Linearity for Electron Beam Energy (ies) available	Not Applicable	
41	Penumbra for Photon Beam Energy (ies) available	7.03mm-7.03mm	Manufacture specified value
42	Penumbra for Electron Beam Energy (ies) available	Not Applicable	
43	Wedge factor for 10×10 cm^2 wedges available	0.265	Manufacture specified value
44	Tray factor for all the tray available	FS (10 X 10 : 0.946)	Manufacture specified value
45	Couch transmission factor	0.9743	Manufacture specified value
46	Maximum photon leakage radiation through beam limiting devices (Secondary collimator) at NTD	X- jaw treansmission-0.79% Y- jaw transmission – 0.952	2%
47	Average photon leakage radiation through beam limiting devices (Secondary collimator) at NTD	X jaw transmission 0.591% Y jaw transmission 0.006%	0.75%
48	Maximum photon leakage radiation through MLCs (when either pair of jaws is replaced with MLCs	Not Applicable	
49	Average photon leakage radiation through MLCs (when either pair of jaws is replaced with MLCs	Not Applicable	
50	Maximum photon leakage radiation through MLCs (when MLCs are used as tertiary jaws)	Not Applicable	
51	Maximum photon leakage radiation in the patient plane	0.0183%	Maximum=0.2%
52	Average photon leakage radiation in the patient plane	0.013%	Average =0.1%
53	Maximum neutron leakage radiation in the patient plane	Not Applicable	

54	Average neutron leakage radiation in the patient plane	Not Applicable	
55	Maximum percentage leakage radiation due to photon at 1 m from the path of electrons between electron gun and the target or electron window, and the reference axis other than patient plane	0.02%	0.2%
56	Maximum percentage leakage radiation due to neutron at 1 m from the path of electrons between electron gun and the target .	Not Applicable	

VII. CONCLUSION

All the data and measurements taken for the acceptance and commissioning process of the 6MV Linear Accelerator unit were found to be well within tolerance. Measured data were evaluated against the published data of different competent authorities, like AERB, IAEA TRS-398 and vendor provided data for reference. After approval of the machine from the authority (AERB) it can be used for clinical purpose, i.e. treatment of the cancer patients.

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