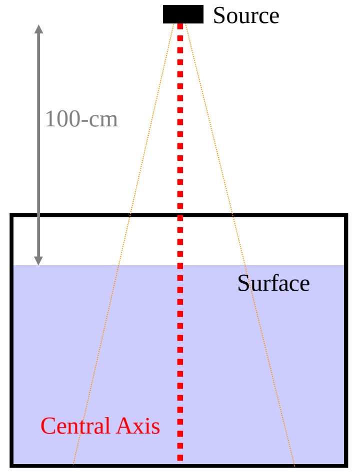
Accelerator Beam Data and Commissioning

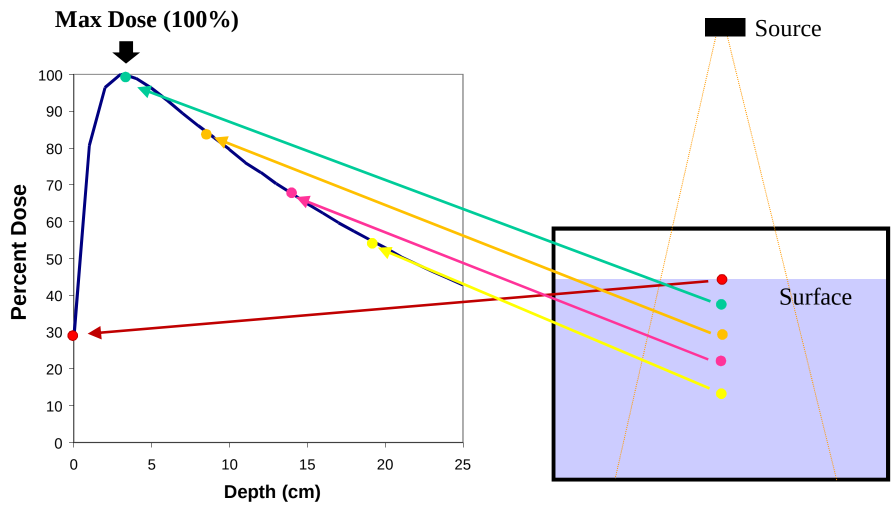
Central Axis Depth Doses

Percent Depth Dose

- One way of characterizing the central axis dose distribution is to normalize the dose at depth with respect to a reference position
- The quantity *PERCENT DEPTH DOSE* is defined as the percentage of the dose delivered at a depth relative to the maximum (*or reference*) dose
- For orthovoltage beams and lower (< *400 kV*) the reference dose is located at the surface



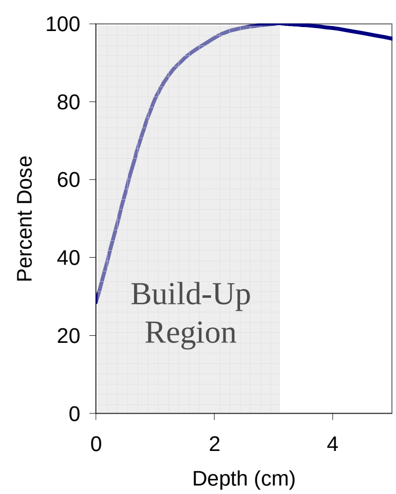
Central Axis Depth Doses



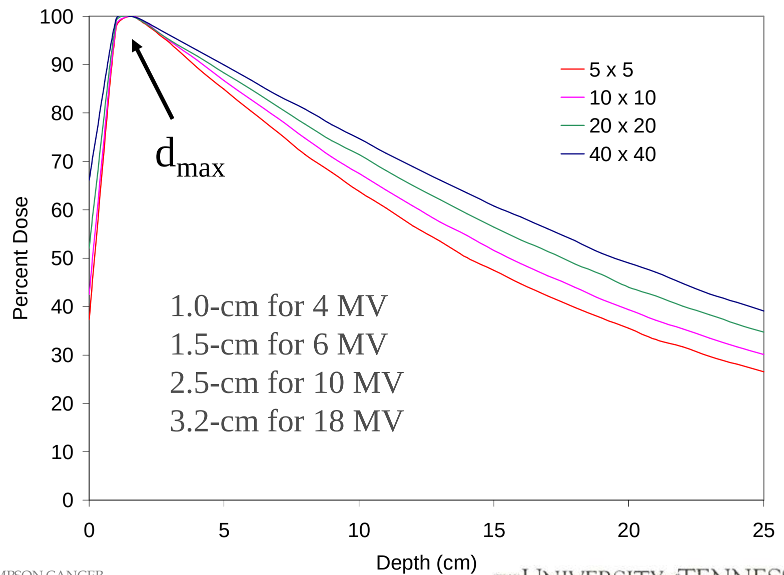
Central Axis Depth Doses

<u>Percent Depth Dose</u>

- There is an initial build-up region between the surface and the point of maximum dose for higher energy x-rays
- This build-up region gives rise to what is clinically known as the *SKIN SPARING EFFECT*
- For megavoltage beams, the surface dose is much less than the maximum dose
- This offers an advantage over lower energy beams that can cause adverse skin reactions



Central Axis Depth Doses



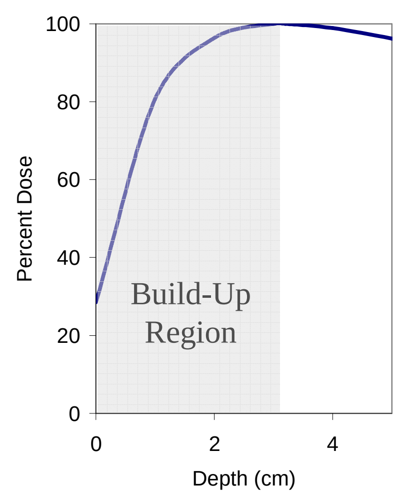
THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Central Axis Depth Doses

Percent Depth Dose

- The high-energy photon beam enters the patient (*or phantom*) and high speed electrons are ejected from the surface and subsequent layers
- These electrons deposit their energy at a significant distance away from their site of origin
- The electron fluence reaches a maximum at a depth approximately equal to the range in the medium
- The photon energy fluence continuously decreases with depth and (*as a result*) the production of electrons decreases with depth



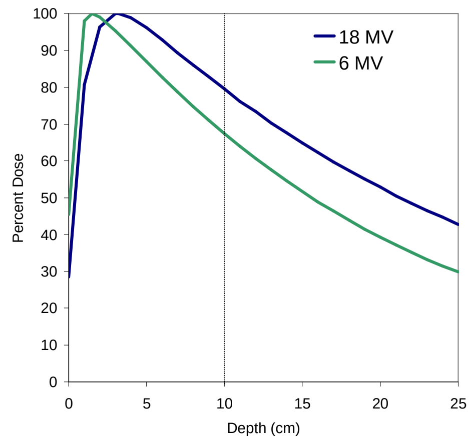
THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Central Axis Depth Doses

Percent Depth Dose

- A number of parameters affect the central axis dose distribution
- The percent depth dose increases with increasing energy
  - *Higher energy beams have greater penetrating power*
  - *The variation with depth is approximately equal to the exponential attenuation*



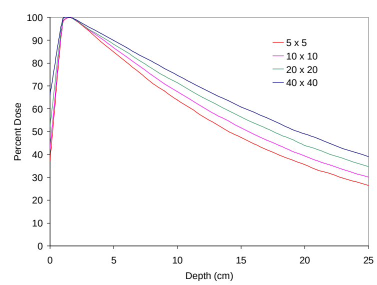
THOMPSON CANCER SURVIVAL CENTER

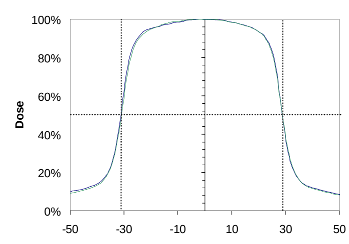
THE UNIVERSITY of TENNESSEE

Central Axis Depth Doses

Percent Depth Dose

- The percent depth doses also change with field size
- The field size can be defined geometrically or dosimetrically
  - *The geometric field size is defined at the plane of isocenter using the light field indicator*
  - *The dosimetric field size is defined as the distance between the 50% dose levels on a place perpendicular to isocenter*





THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE

Central Axis Depth Doses

Percent Depth Dose

- Percent Depth Dose data for radiotherapy is typically tabulated for square field sizes
- Semiempirical techniques have been developed to convert shaped fields into *EQUIVALENT SQUARE* field sizes
- A simple rule of thumb is that a rectangular field is equivalent to a square field if they have the same area/perimeter (*A/P*)

Depth (cm)	4x4	5x5	6x6	7x7	8x8	9x9	10x10
0	0.391	0.402	0.407	0.413	0.422	0.431	0.441
1	0.964	0.965	0.967	0.970	0.970	0.970	0.970
1.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	1.001	1.001	1.001	1.002	1.002	1.001	1.000
3	0.969	0.971	0.975	0.979	0.980	0.980	0.981
4	0.937	0.942	0.946	0.950	0.952	0.955	0.957
5	0.901	0.910	0.915	0.919	0.923	0.926	0.929
6	0.861	0.872	0.880	0.887	0.893	0.896	0.900
7	0.830						0.871
8	0.794						0.842
9	0.763						0.814
10	0.728						0.786
11	0.696						0.757
12	0.668						0.729
13	0.638	0.653	0.666	0.677	0.686	0.695	0.703
14	0.612	0.626	0.638	0.649	0.659	0.668	0.676
15							.649
16							.624
17							.600
18							.577
19							.555
20							.532
21							.511
22							.490
23	0.411	0.423	0.433	0.444	0.453	0.463	0.470
24	0.393	0.405	0.416	0.425	0.434	0.443	0.451
25	0.379	0.388	0.396	0.406	0.417	0.427	0.435

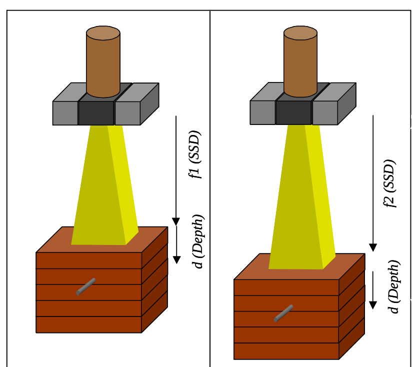
$$\text{EqSq} = \frac{2\,(a \times b)}{(a + b)}$$

$$\text{BlSq} = \text{EqSq}\sqrt{\frac{\%\ \text{Open}}{100}}$$

Central Axis Depth Doses

Percent Depth Dose

- The photon fluence emitted by a point source of radiation varies inversely as a square of the distance from the source
- The Percent Depth Doses increase with Source to Surface (*SSD*) distance because of the inverse square law
- Table are typically measured at a standard SSD, such as 85 or 100-cm
- The *MAYNEORD F FACTOR* is used to convert PDDS between two different SSDs

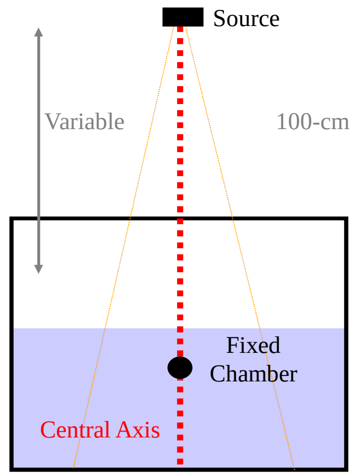


$$F = \left(\frac{f_2 + d_{\max}}{f_1 + d_{\max}}\right)^2 \cdot \left(\frac{f_1 + d}{f_2 + d}\right)^2$$

Central Axis Depth Doses

Tissue Maximum Ratio

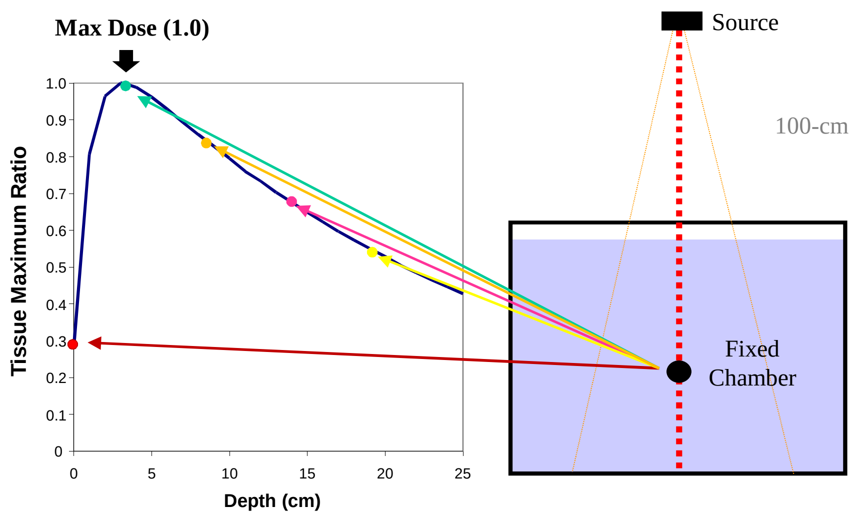
- The TMR is defined as the ratio of the dose at a given point in phantom to the same point at the reference depth in phantom
- This unit was developed for isocentric treatment delivery (*where the isocenter is placed in the treatment volume*)
- The distance between the source and the measurement point is constant
- The TMR varies with energy, field size, etc… the same as PDDs



THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Central Axis Depth Doses



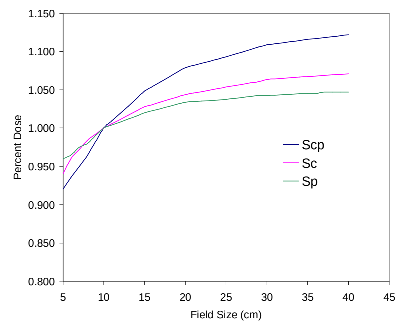
THOMPSON CANCER SURVIVAL CENTER

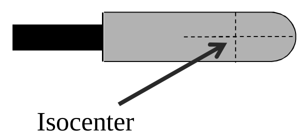
THE UNIVERSITY of TENNESSEE UT

Dose Calculation Parameters

Collimator Scatter Factor

- The beam output (*i.e. machine calibration*) depends on the field size
- As the field size increases, the output increases because of increased collimator scatter which is added to the primary beam
- The collimator Scatter Factor (*Sc)* is common called the *OUTPUT FACTOR*
- It is defined as the ratio of the output for a given field size to that of a reference field size (*typically 10 x 10*)





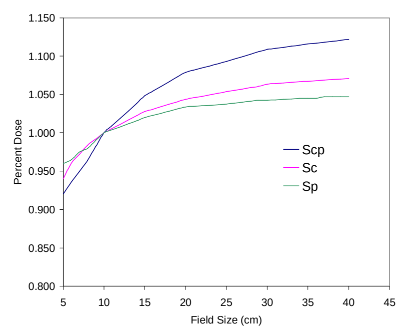
THOMPSON CANCER SURVIVAL CENTER

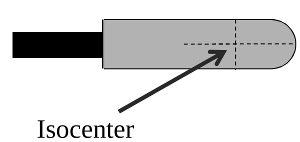
THE UNIVERSITY of TENNESSEE

Dose Calculation Parameters

Collimator Scatter Factor

- The measurement of Sc is performed with the chamber positioned at isocenter
- The chamber is held "*in-air*" on a special stand to prevent scatter from the table
- A build-up cap is placed over the chamber
- The cap provides build-up so that the center of the collecting volume is effectively positioned at the maximum depth for the energy being measured
- Readings are then taken for multiple field sizes



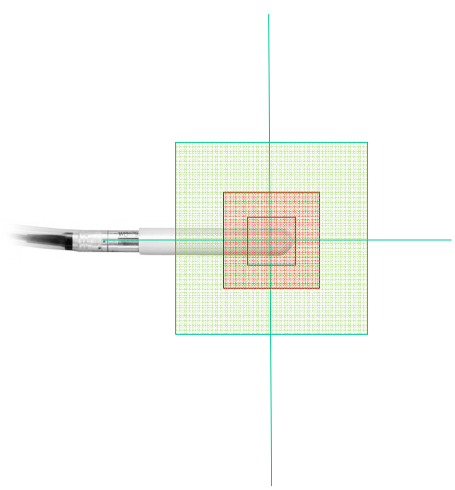


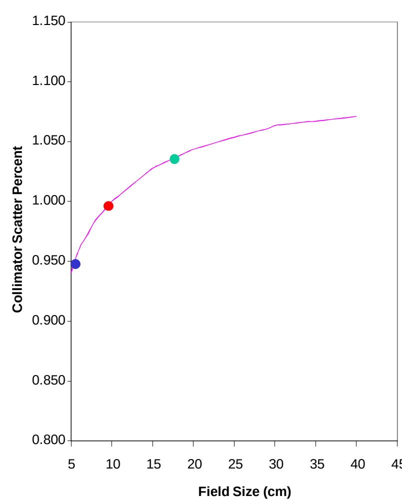
THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE

Dose Calculation Parameters

Dose Calculation Parameters



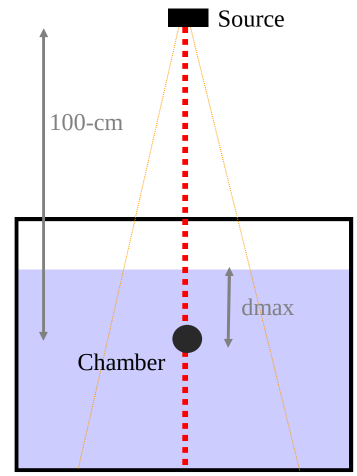


Dose Calculation Parameters

Phantom Scatter Factor

- The phantom scatter factor (*Sp*) takes into consideration the change in scatter radiation originating in the phantom
- It is defined as the ratio of the output for a given field size to that of a reference field size (*typically 10 x 10*)
- Scp measurements are typically made in a water phantom with the chamber positioned at isocenter at dmax
- Readings are then taken for multiple field sizes

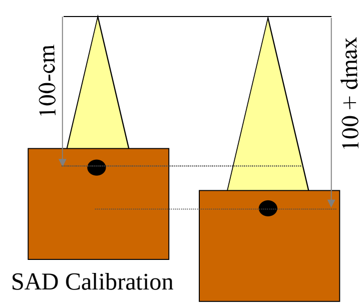
Sp = Scp - Sc



Dose Calculation Parameters

Inverse Square Correction

- Depending on the calibration geometry, a correction factor may be needed for the clinical setup
- Patients are typically treated isocentrically (*SAD*), but linacs are often calibrated SSD
- The target is sufficiently small and distal from the patient/phantom that it can be considered to be a point source

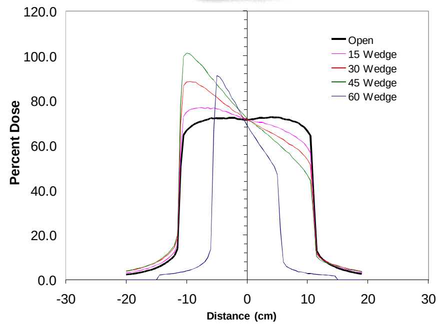


$$INVsq = \left(\frac{SCD}{SSD + d_{max}} \right)^2$$

Dose Calculation Parameters

Wedge Factors

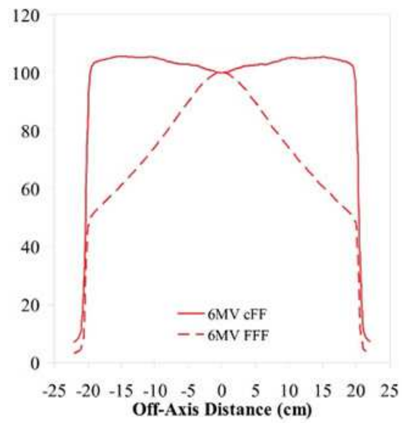
- Physical wedges are used to angle the dose distribution from its normally flat dose distribution
- Physical wedges work by attenuating the photon beam
- The wedge factor is a measurement of this attenuation
- Ratio of ion chamber reading with and without the wedge



Dose Calculation Parameters

Beam Profiles

- The intensity of the dose distribution is not constant across the width of the beam
- Beam profiles must be measured in the “in-plane” and “cross-plane” directions
- Off-axis correction factors are used to correct for this variation in treatment planning
- Flattening Filter Free and Wedges make the beam be less flat across the width of the beam



Beam Data Collection

Accelerator beam data commissioning equipment and procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM

Indra J. Das[a)]
Department of Radiation Oncology, University of Pennsylvania, Philadelphia, Pennsylvania 19104
Chee-Wai Cheng
Department of Radiation Oncology, Morristown Memorial Hospital, Morristown, New Jersey 07962
Ronald J. Watts
International Medical Physics Services, San Antonio, Texas 78232
Anders Ahnesjö
Uppsala University and Nucletron Scandinavia AB, 751 47 Uppsala, Sweden
John Gibbons
Department of Radiation Oncology, Mary Bird Perkins Cancer Center, Baton Rouge, Louisiana 70809
X. Allen Li
Department of Radiation Oncology, Medical College of Wisconsin, Milwaukee, Wisconsin 53226
Jessica Lowenstein
Radiological Physics Center, MD Anderson Cancer Center, Houston, Texas 77030
Raj K. Mitra
Department of Radiation Oncology, Ochsner Clinic, New Orleans, Louisiana 70121
William E. Simon
Sun Nuclear Corporation, Melbourne, Florida 32940
Timothy C. Zhu
Department of Radiation Oncology, University of Pennsylvania, Philadelphia, Pennsylvania 19104

(Received 4 February 2008; revised 18 July 2008; accepted for publication 18 July 2008; published 22 August 2008)

For commissioning a linear accelerator for clinical use, medical physicists are faced with many challenges including the need for precision, a variety of testing methods, data validation, the lack of standards, and time constraints. Since commissioning beam data are treated as a reference and ultimately used by treatment planning systems, it is vitally important that the collected data are of the highest quality to avoid dosimetric and patient treatment errors that may subsequently lead to a poor radiation outcome. Beam data commissioning should be performed with appropriate knowledge and proper tools and should be independent of the person collecting the data. To achieve this goal, Task Group 106 (TG-106) of the Therapy Physics Committee of the American Association of Physicists in Medicine was formed to review the practical aspects as well as the physics of linear accelerator commissioning. The report provides guidelines and recommendations on the proper selection of phantoms and detectors, setting up of a phantom for data acquisition (both scanning and no-scanning data), procedures for acquiring specific photon and electron beam parameters and methods to reduce measurement errors (<1%), beam data processing and detector size convolution for accurate profiles. The TG-106 also provides a brief discussion on the emerging trend in Monte Carlo simulation techniques in photon and electron beam commissioning. The procedures described in this report should assist a qualified medical physicist in either measuring a complete set of beam data, or in verifying a subset of data before initial use or for periodic quality assurance measurements. By combining practical experience with theoretical discussion, this document sets a new standard for beam data commissioning. © *2008 American Association of Physicists in Medicine.*
[DOI: 10.1118/1.2969070]

Key words: accelerator, commissioning, data acquisition

TABLE OF CONTENTS

4186 Med. Phys. 35 (9), September 2008 0094-2405/2008/35(9)/4186/30/$23.00 © 2008 Am. Assoc. Phys. Med. 4186

Scanning Water Tanks

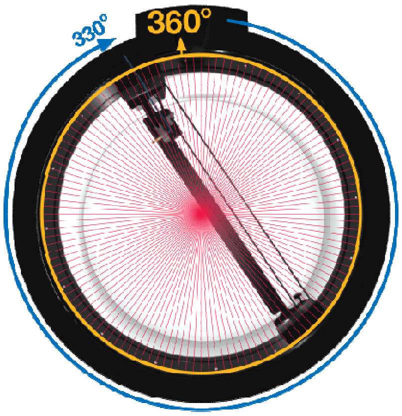
- Task Group 106 of the Therapy Physics Committee of AAPM was formed to review the practical aspects as well as the physics of linear accelerator commissioning
- The report provides guidelines and recommendations on the proper selection of phantoms and detectors, setting up of a phantom

Beam Data Collection

Scanning Water Tanks

- Scanning water tanks are mechanical devices that are used to measure PDDs, TMRs, Off-Axis Profiles, and Output Factors
- They use computer controlled motors to move ionization chambers relative to the treatment beam
- Moving the chamber vertically measures PDDs
- Moving the chamber horizontally measures off-axis profiles

Beam Data Collection



Beam Data Collection

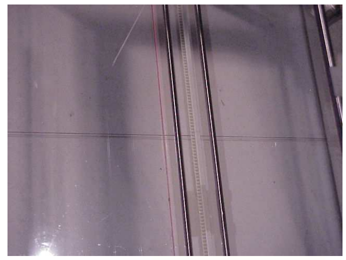
Scanning Water Tanks

- Scanning water tanks typically sits on a lift table
- The lift table has a telescopic mechanism that can mechanically lift and lower the tank
- The lift table must be able to fit at the end of the treatment couch in the treatment vault
- The table must have a leveling mechanism to ensure that the tank is level relative to the water surface

Beam Data Collection

Scanning Water Tanks

- The first step in tank setup is to align the tank
- Cross-hairs are typically located on the tank to mark the geometric center
- The linac primary jaws are opened to the maximum field size, and the light field is used to project the linac crosshairs
- The tank is moved into position until the two sets of crosshairs are aligned



THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

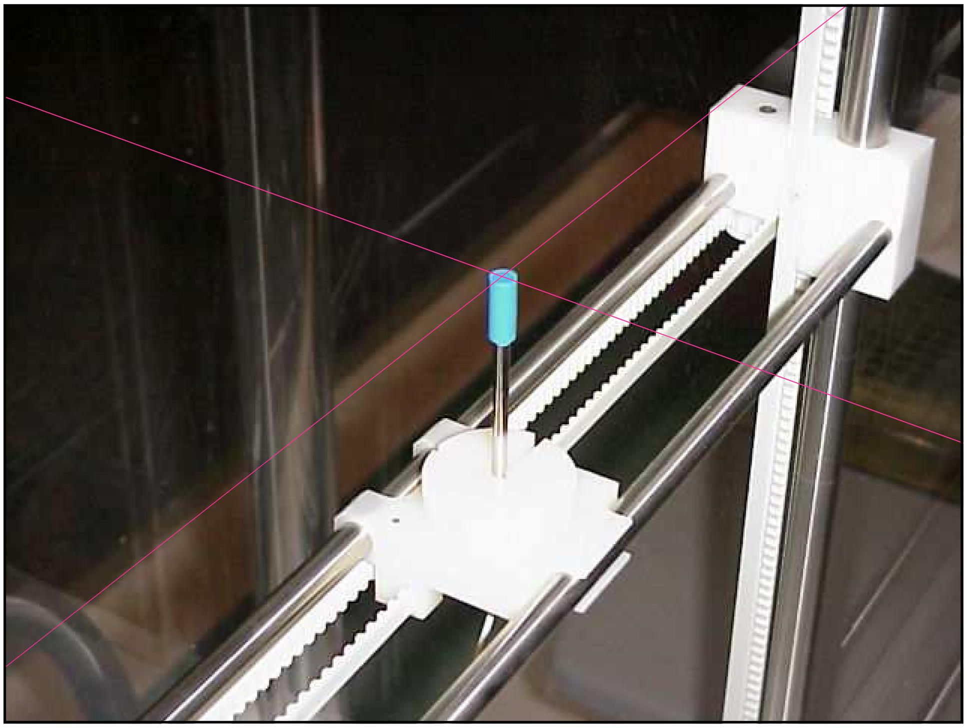
Beam Data Collection

Scanning Water Tanks

- A bubble level is used to make any fine tuning in the tank position
- The chamber is then attached to a special holder
- The chamber is then manually aligned with the central axis crosshairs
- The chamber is then moved vertically to ensure that the linac crosshairs stay centered on the chamber
- The chamber is then moved laterally while watching the crosshair alignment

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT



Beam Data Collection

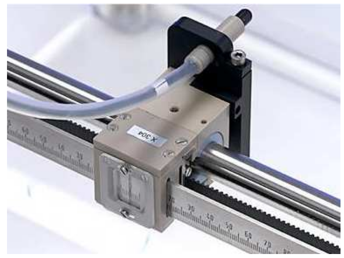
Scanning Water Tanks

- The tank is then filled with water
- The water can be stored in a special water reservoir (~*$15,000*)
- Otherwise, a high-tech water transfer device can be used (~*$15*)
- Seriously, the water must be at room temperature because of your instruments
- Fill the tank until the water level is at isocenter
- Recheck leveling and centering

Beam Data Collection

Scanning Water Tanks

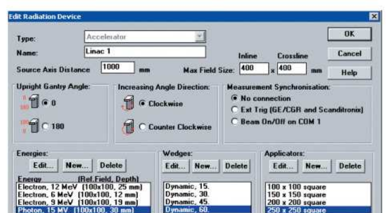
- The primary chamfer is located in the water tank an the motor drive
- A reference probe is mounted near the head of the linac (*outside of the water tank*)
- Measurements are taken simultaneously with the primary and reference probes
- The ratio of the two measurements is used to compensate for minor changes in the output of the machine while the measurements are be made

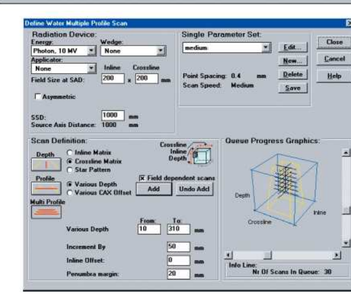


Beam Data Collection

Scanning Water Tanks

- Computer control software is used at the linac console to program the tank
- This software controls the position and velocity of the chamber
- It also integrates and records the chamber signal for each dwell position and time
- Scans are typically batched as that a Depth Dose and ten to twenty profiles are acquired for each field size
- These scans are then electronically transferred to the treatment planning system





Beam Data Collection

Scanning Water Tanks

- Tissue Maximum Ratios are not typically measured
- In order to measure TMRs, the chamber would be stationary and the water level must change
- To accomplish this, one can purchase a special pump to raise and lower the water level
- A linear displacement transducer (*operating by means of the pulse echo principle*) can be used to measure the water level during scanning

Beam Data Collection

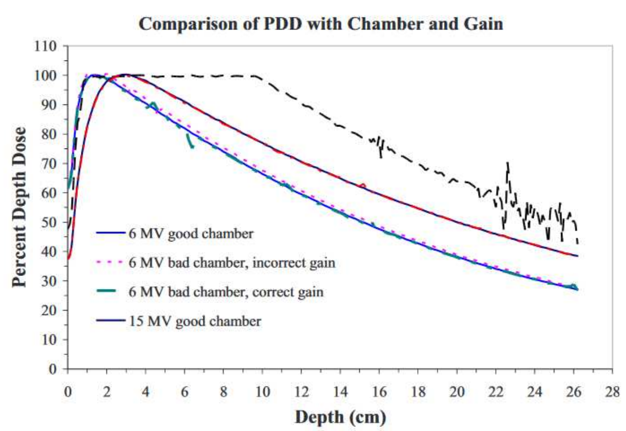


FIG. 2. Comparison of depth doses with good and bad chambers with correct and incorrect bias.

Beam Data Collection

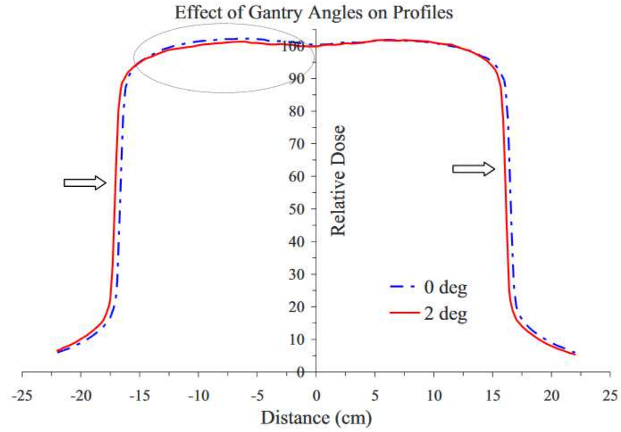


FIG. 8. Effect of gantry angle tilt on the profiles of a 6 MV beam for 30 $\times$30 cm^2 field at 10 cm depth.

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Beam Data Collection

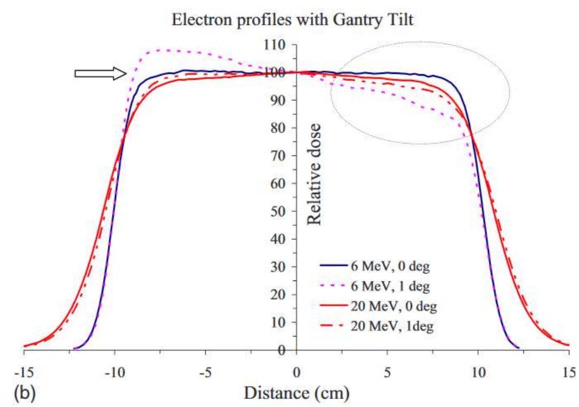


FIG. 7. (a) Beam profiles of a 6 MV beam at different depths with scanning arm tilt for a 4$\times$4 cm^2 field, (b) electron beam profiles at depth of 80% depth dose for 20$\times$20 cm^2 cone with gantry tilt. Arrows and circle are shown to represent the impact of arm and gantry tilt.

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Beam Data Collection

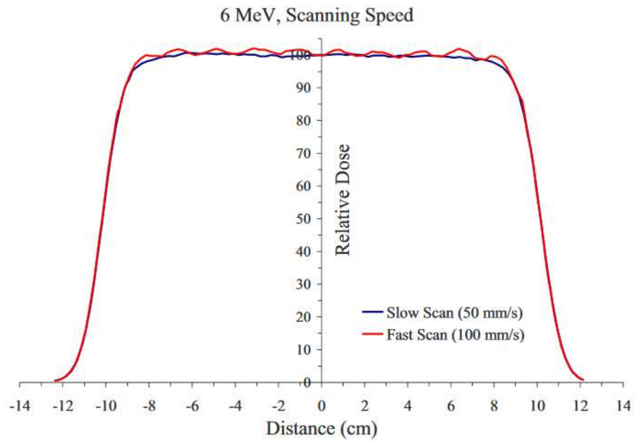


FIG. 9. Impact of scanning speed on the quality of electron profile.

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Beam Data Collection

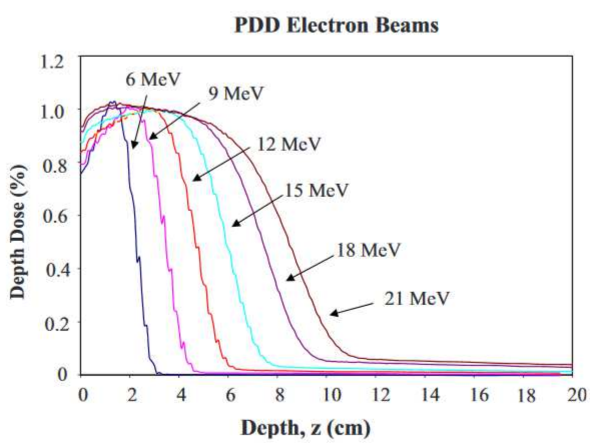


FIG. 12. Effect of water ripple on low energy electron beam depth dose.

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE UT

Questions

THOMPSON CANCER SURVIVAL CENTER

THE UNIVERSITY of TENNESSEE