Electron Beam Dosimetry of a Medical Linear Accelerator

Kaustav Kashyap Baruah[1], Trishul Subham Keshri[2]

[1]Department of Radiotherapy, Health City Hospital, Guwahati-781022, Assam, India

[2]Department of Radiotherapy, Lakhimpur Cancer Center, North Lakhimpur-787051, Assam, India
Email: *ricky99.2011[at]rediffmail.com*

Abstract: ***A new approach for electron beam dosimetry under reference condition is presented in this report. The main purpose of this study is to describe the procedure for electron beam dosimetry using water phantom performed for medical LINAC in order to ensure that the cancer patient is receiving the given dose correctly that is the maximum dose is received by the tumor and the minimum dose is received by the critical organ or the normal tissue within tolerance limits. The measurements include output calibration of 8MeV and 15MeV electron, percent depth dose (PDD), beam profile of 8MeV electron, beam quality index for electron R_{50} (g/cm^2). From the graph, we can see that the PDD of 8MeV electron for 10 × 10cm² field size increases rapidly to a certain depth called Dmax and then immediately falloff with depth. The symmetry values and flatness values for 8MeV electron were also measured. The output calibration was measured with Advance Marcus Chamber and the beam quality index was measured with 0.125cc cylindrical chamber in a water phantom and found well within tolerance limit.***

Keywords: Radiation Dosimetry, Medical LINAC, Ionisation Chamber, Electron Beam quality index (R_{50})

1. Introduction

High-energy electrons have been used in radiation therapy and advances in radiation dosimetry continue to improve the accuracy of calibrating clinical photon and electron beams for radiation therapy. The nominal energy range for clinical electron beam dosimetry is 5–25 Me V.

While performing electron dosimetry one should be aware of when using ionization chambers that the depth of maximum ionization may not be the depth of maximum dose, as the factors converting percentage depth ionization to percentage depth dose are depth dependent.

Electron beam therapy is suitable for the treatment of superficial lesions and is also best choice for Indra-Operative-Radiation-Therapy (IORT) and also used to treat skin cancer through Total Skin Electron Therapy (TSET). The penetration of electron beams in the tissues is much shallower than that of the x-ray beams and, the depth to which the dose is effective can be varied by changing the energy of the incident electrons, also there is no significant differential absorption for per gram of tissue for electrons in bone as compared to soft tissue. Therefore, electron-beam therapy is used to treat superficial or semi-deep-seated tumors extending (close) to the skin surface. Beyond the depth of the maximum, the dose falls off rapidly.

The aim of the Dosimetry for RT equipment should be :

- To establish optimal machine performance criteria
- To monitor adherence to established protocol
- To ensure that the dose delivered should be accurate
- To minimize machine down time

2. Methods and Materials

Semi flex 0.125cc Ion chamber, Advance Markus Chamber, Unidos E Electrometer, Water phantom, Slab Phantom

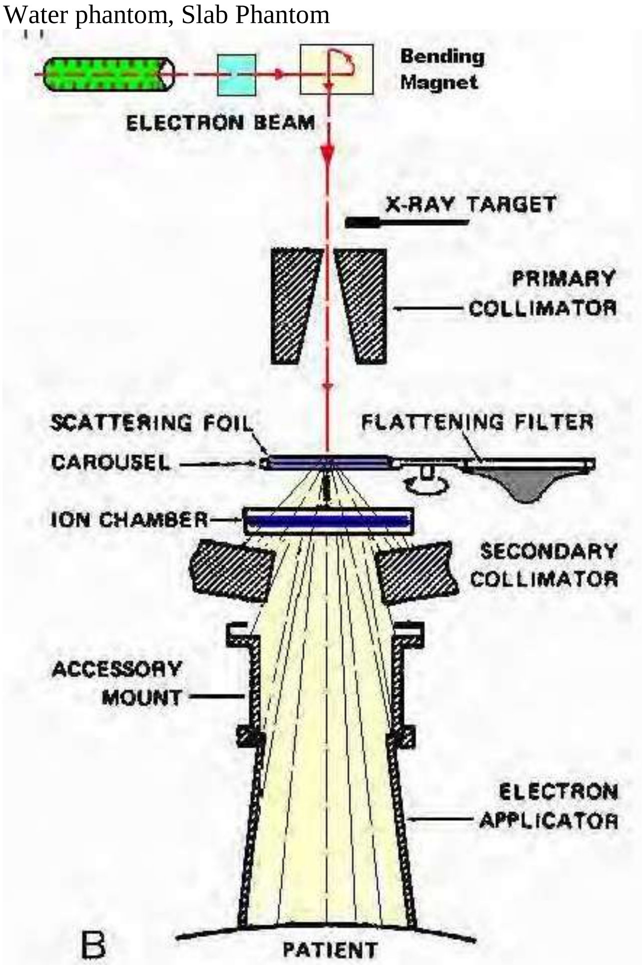

Figure 1: Electron Beam path

DOSIMETRY EQUIPMENTS

Ionization Chamber

A Farmer type ionization chamber is used for calibration of X rays which have energy greater than 80KV and half value layer of 2mm Al. A Farmer type ionization chamber is also used for calibration of high energy photon beam, electron beam, which has energy greater than 10MeV, proton beam and heavy ion beams.

A Farmer type ionization chamber is also very useful at these radiations because of their simple design, sensitivity, high precision, real-time readout, and stability.

Chambers consist of an air-filled cavity and a central electrode and a voltage is applied between the central electrode and the cylindrical chamber walls. The cavity between the electrode and walls is vented to the surrounding air.

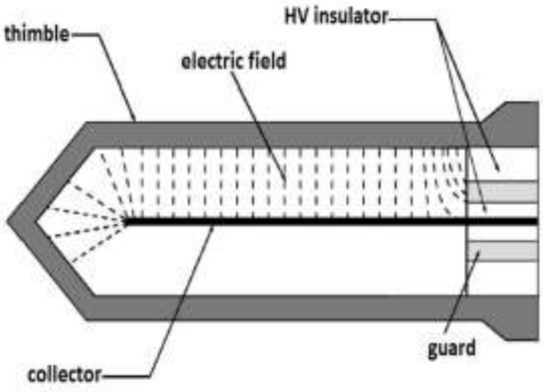

Figure 2: Cylindrical Ionisation Chamber

Phantom

Water is recommended in the IAEA Codes of Practice as the reference medium for measurements of absorbed dose for both photon and electron beams, The phantom should extend to at least 5 cm beyond all four sides of the largest field size,

Figure 3: Water Phantom

Figure 4: Slab Phantom

Waterproof Sleeve for the Chamber

Unless the ionization chamber is designed so that it can be put directly into water, it must be used with a waterproof sleeve. The sleeve should be made of PMMA, with a wall sufficiently thin (preferably not greater than 1.0 mm in thickness)

Electrometer

An electrometer is an electrical instrument used for measuring electric charge or electrical potential difference of a condenser chamber.

Figure 5: PTW UNIDOSE E Electrometer

Electron Beam Parameters

There are many parameters namely practical range (R_p), half value depth (R_{50}), R_{90}, R_q, R_{max} obtained from the depth dose curve that are used in the calibration of the electron

Paper ID: SR24108204432 DOI: https://dx.doi.org/10.21275/SR24108204432

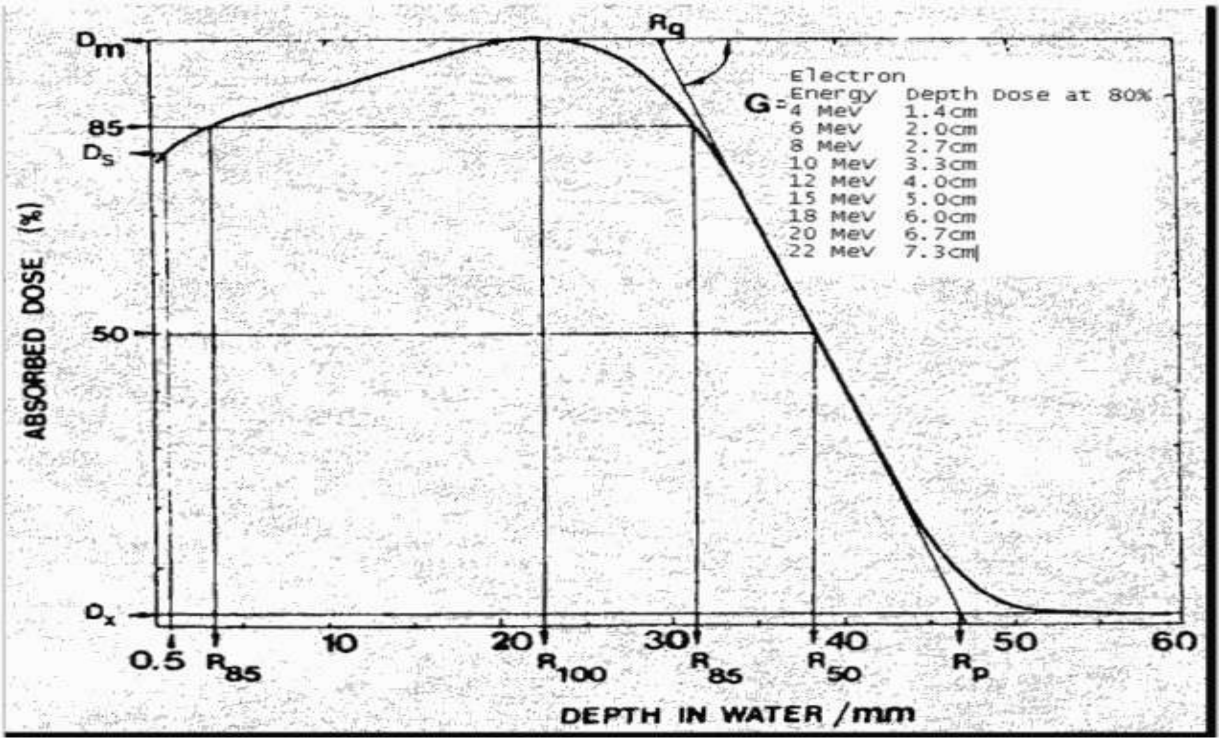

Fig.6: Electron beam PDD curve Showing R_q, R_p, R_{max}, R90, and R50

Practical range (R_p) defined as the depth where the tangent at the steepest point (the inflection point) on the almost straight descending portion of the depth dose curve meets the extrapolated bremsstrahlung background.

Half value depth (R_{50}) is defined as the depth at which the absorbed dose has decreased to 50% of its maximum value.

R_{90} is the depth corresponding to 90% of the PDD. It is also called the therapeutic range of the electron beam.

R_q is the depth where the tangent at the point of inflection intersects the maximum dose level.

R_{max} is the depth at which the extrapolation tail of depth dose curve meets the bremsstrahlung background. It is the largest penetration depth of electron in medium.

Characteristic of Electron Beam

- Electron Beam Profile and Penubra
- Percentage Depth Dose Distribution Curve
- Isodose Curve

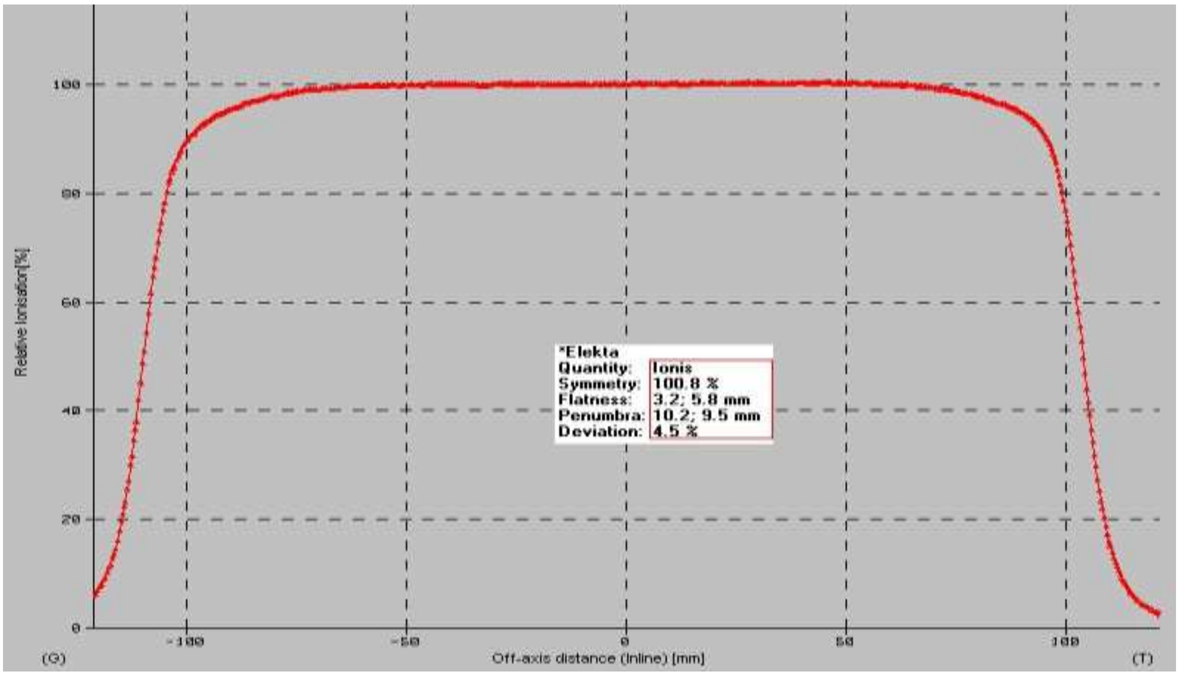

Figure 7: Electron Beam Profile and Penumbra 8 MeV electron beam for 10cm × 10cm

The beam flatness defined as the variation over an area confined within lines 2cm inside the geometric edge of fields. The flatness should not exceed ±5% for field size greater than or equal to 10 × 10 cm^2.

The beam symmetrically on opposite sides about the central axis in a reference plane of crossed beam profile.

The ICRU has recommended that the 80% and 20% isodose lines be used in the determination of the physical penumbra

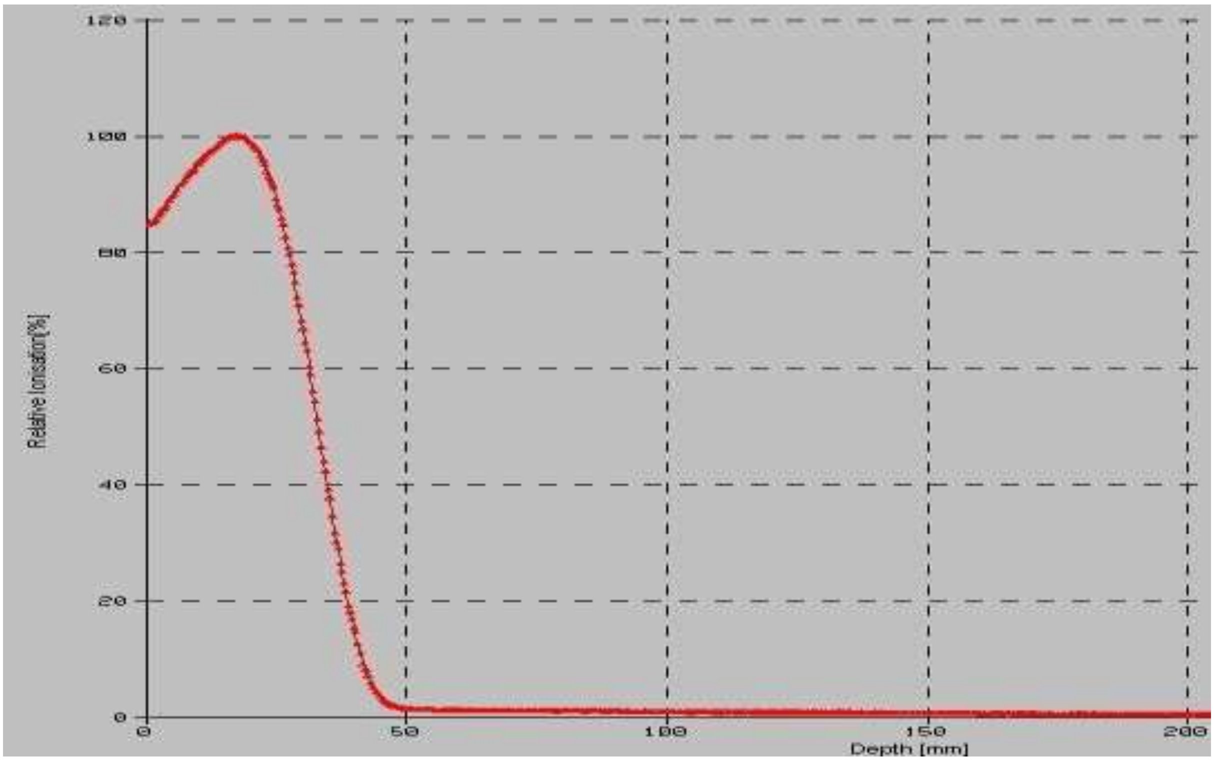

Figure 8: Percentage Depth Dose Distribution Curve 8 Mev Electron Beam

In the range of energy from 6 to 18 MeV. The curve is characterized by a finite range of penetration with a rapid dose fall off towards a slowly decaying X- ray background as the electron traverse deep into the phantom. This behavior tends to disappear with increasing beam energy.

Isodose curves are the lines passing through points of equal dose. Isodose curves are usually drawn at regular intervals of absorbed dose and are expressed as a percentage of the dose at a reference point.

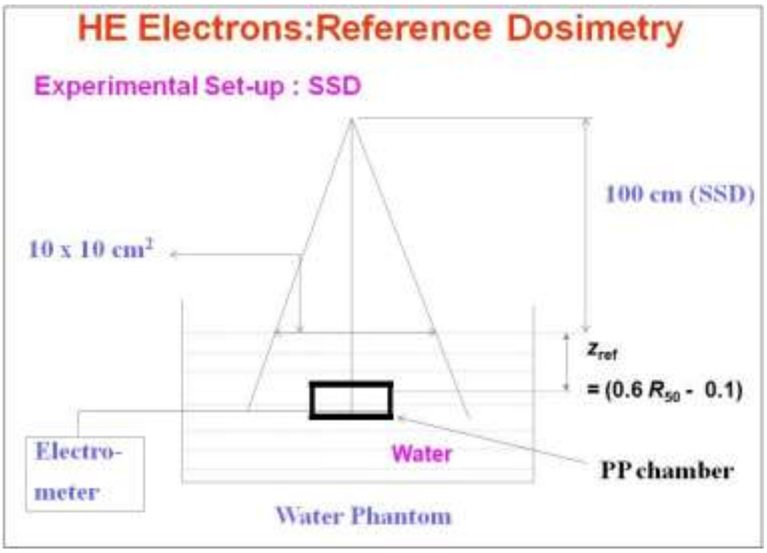

Figure 9: Experimental setup for Electron Beam Quality

Measurement of beam quality ($K_{Q,Q0}$)

For calculation of beam quality $R_{50,ion}$ is measured

R_{50} = 1.029 $R_{50,ion}$ – 0.06 g/cm^2 ($R_{50,ion} \leq$ 10 g/cm^2)

$R50$ = 1.059 R50,ion – 0.37 g/cm2 ($R50,ion >$ 10 g/cm^2)

R_{50} from beam quality table for Roos ionization chamber, $K_{Q,Q0}$ can be calculated.

Paper ID: SR24108204432 DOI: https://dx.doi.org/10.21275/SR24108204432

Table 3: $K_{Q,Q0}$ values from R_{50}

Energy	$R_{50,ion}(g/cm^2)$	R_{50} (g/cm^2)	$K_{Q,Q0}$
8MeV	3.21	3.243	0.93457
15 MeV	6.015	6.1294	0.9100

Table 4: The system generates ionization curve data, from which we convert the curve data in terms of dose to get PDD

Energy	Depth (cm)	PDD
8 MeV	1.745	100.00%
15 MeV	3.460	99.15%

3. Observation

Temperature Pressure correction factor K_{TP}
Standard temperature $(T_0) = 20^0C$
Temperature of measurement date $(T) = 18.60^0C$
Standard Pressure (P_0) = 760 mm of Hg
Pressure of measurement date = 29.28 inch
= 29.28 × 25.40 mm
= 743.712 mm of Hg

$K_{TP} = 273.2 + T / 273.2 + T_0 \times P_0 / P$
$K_{TP} = 1.017$
Chamber calibration factor $(N_{D,W}) = 8.269 \times 10^7$ Gy/C

Table 5: Dosimeter readings for 8MeV Electron

Meter Reading	Average Reading
1.274×10^{-8} C	
1.275×10^{-8} C	1.275×10^{-8} C
1.276×10^{-8} C	

Output $=1.275 \times 10^{-8} \times 8.269 \times 10^7 \times 0.94357 \times 1.017 /1.00$
Output = 100.14 cGy / 100 MU
Percentage of error = 0.14 %

Table 6: Dosimeter readings for 15MeV Electron

Meter Reading	Average Reading
1.296×10^{-8} C	
1.297×10^{-8} C	1.2963×10^{-8} C
1.297×10^{-8} C	

Output =
$1.2963 \times 10^{-8} \times 8.269 \times 10^7 \times 0.94357 \times 1.017/0.9915$

Output =
100.06 / 100 MU

Percentage of error = 0.06 %

4. Conclusion

All the measured parameters are found to be within the tolerance limits specified by AERB. Therefore the machine is performing properly from operational point of view and it will deliver the prescribe dose to the tumor within the acceptable limits and it is now justified to use this LINAC machine for patient dose delivery safely.

References

[1] Khan, Faiz M. "The Physics of Radiation Therapy" 4th Edition.

[2] E. B. Podgorsak. "Radiation Oncology Physics: A Handbook for Teachers and Students" International Atomic Energy Agency (IAEA) Vienna, 2005.

[3] Technical Report Series (TRS) No. 398. "Absorbed Dose Measurement in External Beam Radiotherapy" International Atomic Energy Agency (IAEA) Vienna, 2005.

[4] www.aerb.gov.in "AERB/RSD/RT/GUIDELINES".

[5] Booth and D. W. O. Rogers, PROT: A General Purpose Utility for Calculating Quantities related to Dosimetry Protocols, Technical report PIRS-529, NRC Canada, Ottawa, K1A OR6, 1996.

[6] D. W. O. Rogers, ''Calculation of parallel-plate ion chambers: Resolution of several problems by using Monte Carlo calculations,'' Med. Phys. **19**, 889–899 (1992).

[7] ICRU, Stopping powers for electrons and positrons, ICRU Report 37, ICRU, Washington, D.C., 1984.

[8] P. Andreo, P. R. Almond, O. Mattsson, A. E. Nahum, and M. Roos, ''The use of plane-parallel ionization chambers in high-energy electron and photon beams. An International Code of Practice for Dosimetry, Report by a Consultants Group to the IAEA (IAEA, Vienna) (1997).

[9] D. I. Thwaites, D. T. Burns, S. C. Klevenhagen, A. E. Nahum, and W. G. Pitchford, ''The IPEMB code of practice for electron dosimetry for ra- diotherapy beams of initial energy from 2 to 50 MeV based on air kerma calibration,'' Phys. Med. Biol. **41**, 2557–2603 (1996).

[10] S. C. Klevenhagen, ''Implications of electron backscatter for electron dosimetry,'' Phys. Med. Biol. **36**, 1013–1018 (1991).

[11] M. A. Hunt, G. J. Kutcher, and A. Buffa, ''Electron backscatter correc- tion for parallel-plate chambers,'' Med. Phys. **15**, 96–103 (1988).

[12] C. M. Ma and D. W. O. Rogers, ''Monte Carlo calculated wall correction factors for plane-parallel chambers in high-energy electron beams,'' Med. Phys. **22**, 672 (abstract) (1995).

[13] E. Nahum, Extension of the Spencer-Attix Cavity Theory to the 3- Media Situation for Electron Beams, in ''Dosimetry in Radiotherapy'' (IAEA, Vienna), Vol. 1, 87–115 (1988).

[14] ICRU, Radiation Dosimetry: Electron beams with energies between 1 and 50 MeV, ICRU Report 35, ICRU, Washington, D.C., 1984.

[15] G. X. Ding and D. W. O. Rogers, Energy spectra, angular spread, and dose distributions of electron beams from various accelerators used in radiotherapy, National Research Council of Canada Reprot PIRS-0439, (see http://www.irs.inms.nrc.ca/inms/irs/papers/PIRS439/pirs439.html) (1995).

[16] F. H. Attix ''Application of a commerical solid-water plane-parallel ion- ization chamber to the AAPM TG-21 protocol,'' Med. Phys. **20**, 735–737 (1993).

[17] F. W. Wittka¨mper, A. H. L. Aalbers, and B. J. Mijnheer, ''Experimental determination of wall correction factors. Part II: NACP and Markus plane-parallel ionization chambers,'' Phys. Med. Biol. **37**, 995–1004 (1992).

[18] D. T. Burns, G. X. Ding, and D. W. O. Rogers, ''R_{50} as a beam quality specifier for selecting stopping-power ratios and reference depths for electron dosimetry,'' Med. Phys. **23**, 383–388 (1996).

[19] D. W. O. Rogers, ''A new dosimetry protocol: Summary,'' Med. Phys. 1124 (abstract) (1996).

[20] H.Bilge,N.Ozbek,M.Okutan,A.Cakir,andH.Acar,"Surface dose and build-up region measurements with wedge alters for □ and□ □ MVphotonbeams,"Japanese Journal of Radiology,vol. □ □ ,no.□ ,pp.□ □–□ □ □ □ ,□ □ □ □ .

[21] ISP International Speciality Products, "Gafchromic EBT Self-Developing Film for Radiotherapy Dosimetry," □ □ □ □ , http://online□ .ispcorp.com/ layouts/Gafchromic/content/products/ebt/pdfs/EBTwhitepaper.pdf.

[22] D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, "A technique for the quantitative evaluation of dose distributions," Medical Physics, vol. □ □ , no. □ , pp. □ □ □–□ □ □ , □ □ □ □ .

[23] D.A.LowandJ.F.Dempsey,"Evaluationofthegammadose distribution comparison method," Medical Physics,vol.□ □ ,no.□ ,pp. □ □ □ □–□ □ □ □ , □ □ □ □

[24] H.Bilge,N.Ozbek,M.Okutan,A.Cakir,andH.Acar,"Surface dose and build-up region measurements with wedge □ lters for □ and□ □ MVphotonbeams,"Japanese Journal of Radiology,vol. □ □ ,no.□ ,pp.□ □–□ □ □ □ ,□ □ □ □ .

[25] ISP International Speciality Products, "Gafchromic EBT Self- Developing Film for Radiotherapy Dosimetry," □ □ □ □ , http://online□ .ispcorp.com/ layouts/Gafchromic/content/products/ebt/pdfs/EBTwhitepaper.pdf.

[26] D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, "A technique for the quantitative evaluation of dose distributions," Medical Physics, vol. □ □ , no. □ , pp. □ □ □–□ □ □ , □ □ □ □ .

[27] D.A.LowandJ.F.Dempsey,"Evaluationofthegammadose distribution comparison method," Medical Physics,vol.□ □ ,no.□ , pp. □ □ □–□ □ □ □ , □ □ □ □

[28] H.Bilge,N.Ozbek,M.Okutan,A.Cakir,andH.Acar,"Surface dose and build-up region measurements with wedge □ lters for □ and□ □ MVphotonbeams,"Japanese Journal of Radiology,vol. □ □ ,no.□ ,pp.□ □–□ □ □ □ ,□ □ □ □ .

[29] ISP International Speciality Products, "Gafchromic EBT Self- Developing Film for Radiotherapy Dosimetry," □ □ □ □ ,http:// online□ .ispcorp.com/ layouts/Gafchromic/content/products/ebt/pdfs/EBTwhitepaper.pdf.

[30] D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, "A technique for the quantitative evaluation of dose distributions," Medical Physics, vol. □ □ , no. □ , pp. □ □ □–□ □ □ , □ □ □ □ .

[31] D.A.LowandJ.F.Dempsey,"Evaluation of the gamma dose distribution comparison method," Medical Physics, vol.□ □ ,no.□ , pp. □ □ □–□ □ □ □ , □ □ □ □