Acceptance testing, beam modeling and commissioning of 10 MV and 18 MV photon beams for radiation oncology applications

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Acceptance Testing, Modeling and Commissioning of 10MV and 18MV Photon Beams for Radiation Oncology Applications

Submitted by

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ACCEPTANCE TESTING, BEAM MODELING AND COMMISSIONING OF 10 MV and 18 MV PHOTON BEAMS FOR RADIATION ONCOLOGY APPLICATIONS

A Scholarly Project

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INTRODUCTION

This report describes the process of acceptance testing and commissioning of new photon beams (10 MV beam on Elekta SL-15 linear accelerator and 10 MV and 18 MV beams on Elekta SL-25 linear accelerator) for clinical use at the Medical University of Ohio Department of Radiation Oncology. The SL-15 LINAC previous produced 6 and 15 MV photons beams and SL-25 produced 6, 10, and 25 MV photon beams. The 15 MV beam from SL-15 was required to be changed to 10 MV beam in order to match 10 MV beam from SL-25. The 25 MV beam from SL-25 was required to be changed to 18 MV in order to insure more stable and reliable beam production. During the filter change for 10 MV on SL-15, it was discovered that the filter was not physically identical to the 10 MV filter on SL-25. This necessitated the filter change and commissioning of the SL-25 10 MV beam also. The existing beams were modified to match two photon energies on each unit.

The general steps taken in beam commissioning are:

1. Perform mechanical changes on the LINAC to generate a photon beam of desired characteristics (beam energy and profile).
2. Conduct tests to confirm that the new beam is acceptable.
3. Collect data required by the treatment planning system for beam modeling.
4. Import collected data into ADAC Pinnacle v. 6.2 beam modeling program and make necessary adjustments until the model is acceptable.
5. Calibrate the new photon beams according to the TG-51 Protocol to set the beam output to 1 cGy/MU at d_{max} for 10 x 10 field.
6. Generate sample treatment plans using the newly modeled beam and confirm the measured dose against that predicted by the treatment planning system.
7. Collect all data necessary to perform manual calculation of monitor units, which will serve as secondary verification of MU calculation by the treatment planning system.
8. Commission the beams to be available for clinical treatment.

Equipment Used

- Scanditronix Wellhofer FC-65 Ion Chamber (SN: 740)
- CNMC Exradin A-16 (SN: XAA 040362)
- CNMC Electrometer (SN: 1518023)
- Wellhofer Water Scanner w/ Omni-Pro Accept Software
- Small Water Tank

Mechanical Changes on LINAC and Beam Acceptance Testing

The main mechanical change for a new photon beam is the installation of the correct flattening filter. Additional adjustments were made by Elekta engineers to obtain correct energy (penetrative quality as indicated by PDD_{10}) and optimal flatness and symmetry. The energy and flatness of the beam is adjusted by varying the frequency of the microwave in the steering tube. The symmetry is adjusted by the feedback mechanism between the ion chamber and the steering coil. The acceptance test performed by the MCO medical physics group consists of measurements of the beam energy (percent depth dose curve) and off-axis profiles (to measure flatness and symmetry) and comparing them against the acceptance criteria. If there is no acceptable agreement between the two sets of data, adjustments to the initial settings are made by the engineers until the beam is judged to have acceptable characteristics and the acceptance form is signed by the medical physicists.

Data Collection for Beam Modeling

The ADAC Pinnacle Treatment Planning System requires several types of data to be used in beam modeling. These are: 1) percent depth dose curves; 2) off-axis profiles; 3) output factors for open fields; and 4) output factors for wedge fields. These requirements, specified in the ADAC Physics manual, are shown below. The output factors are specified to be measured at 100 SSD and at depth of 10 cm.

OPEN BEAM, SSD = 100 SSD
PDD from 0 to 35 cm
Profiles at depths, d_{max}, 5 cm, 10 cm, 20 cm, and 30 cm
For field sizes: 2 x 2, 3 x 3, 5 x 5, 10 x 10, 20 x 20, 30 x 30,40 x 40, 5 x 20, 20 x 5

OPEN BEAM, SSD = 90 SSD
PDD from 0 to 35 cm
Profiles at depths, d_{max}, 5 cm, 10 cm, 20 cm, and 30 cm
For field size: 10x10

WEDGE BEAM, SSD = 100 SSD
PDD from 0 to 35 cm
Profiles at depths, d_{max}, 5 cm, 10 cm, 20 cm, and 30 cm
For field sizes: 3x3, 5x5, 10x10, 20x20, 30x30,35x30

OUTPUT FACTORS
Open beams from 1 x 1 up to 40 x 40 at 1 cm increment
Wedge beams at field sizes 2 x 2, 3 x 3, 5 x 5, 10 x 10, 15 x 15, 20 x 20, and 40 x 30
(Note: the reference field size is <u>10 x 10 OPEN</u> beam)

$$\text{Output Factor for Open Field} = \frac{\text{Reading (nC) for a given Open Field Size}}{\text{Reading for Reference fiels size (10 x 10 Open)}}$$

$$\text{Output Factor for Wedge Field} = \frac{\text{Reading (nC) for a given Wedge Field Size}}{\text{Reading for Reference fiels size (10 x 10 Open)}}$$

Beam Modeling in ADAC Pinnacle Treatment Planning System

The ADAC Pinnacle system employs a model approach rather than using the actual measurements to generate external beam treatment plans. A generic machine/beam model serves as a starting point for creating a new beam. This model is compared against the measured data (percent depth dose, off-axis profile, and output factors) and necessary adjustments are made until the modeled beam matches the measured data. The major steps performed in beam modeling are listed below. For a detailed description on all the functions within the ADAC software, consult the ADAC Pinnacle Physics Guide.

1. Convert all Wellhofer scan files to ASCII format. The Omni Pro Accept software contains a function to automatically convert Wellhofer scans to the ASCII format that is recognizable by the ADAC Physics Tool Program.
2. Transfer the ASCII files to ADAC TPS computer via FTP and save all data in corresponding directories.
3. Open the Photon Physics menu in ADAC and import Wellhofer ASCII files into appropriate measurement geometries. The output factors are entered manually into the ADAC software.
4. Review individual Wellhofer scans to verify that they are acceptable to be used in Auto-modeling.
5. Select a generic beam model to be used as the staring point and start the initial calculation which produces the percent depth dose and profiles for the same set of measurement geometries as the measured Wellhofer scans.
6. Compare the calculated beam percent depth dose curve and off-axis profiles to those from the actual user measurements by studying the overlaying plots of the two sets of curves.
7. Determine which of the beam characteristics needs further adjustment and select and execute the appropriate optimization sequence from the Auto-Model library to fine-tune the beam model.

Beam Optimization Using Auto-Modeling Sequences

There are four main parameters that must be correctly adjusted to obtain the match between the two sets of data: 1) energy spectrum which characterizes the spectral distribution of X rays emanating from the LINAC and primarily affects the CAX percent depth dose distribution; 2) electron contamination which accounts for the amount of electron from the LINAC that contributes to CAX dose distribution; 3) In-field parameter which accounts for the off-axis regions close to the CAX; and 4) Out-of-field parameter which accounts for the low-dose regions (i.e., penumbra and tail). The user must inspect and compare all data and determine which characteristics of the computed beam from the model must be improved and make the appropriate adjustment. Since the starting beam models were already close match with the measured data, it was deemed sufficient to utilize the pre-loaded auto-modeling sequences to make adjustments and not make any manual changes. The auto-sequences used in the beam modeling for the three new photon beams and the function of each sequence are described below.

Sequence Name: C_Fine Tune Model
Fine tune a single model for all open fields when the existing model is already close to the desired agreement between computed and measured dose profiles
Sequence Name: D_Tune All In Section
Tunes the electron contamination parameters in conjunction with the spectrum while tuning the entire model. It also separates the X and Y focal spot size tuning.
Sequence Name: Fine Tune Cross Beam
Fine tunes the cross-beam shape parameters.
Sequence Name: Fine Tune EC And Spectrum
Fine tune the beam spectrum in the presence of electron contamination, which obtains a best fit in the buildup region of the depth dose curve while maintaining agreement at deeper depths.
Sequence Name: Fine Tune Modifier Scatter
Fine tunes all aspects of the wedge field models.
Sequence Name: Fine Tune All For Wedge
Fine tunes all aspects of the wedge field models.

Once the desired agreement between the two sets of data was obtained, the new beam model was tested against the actual point measurement for verification.

Calibration of SL-15 10 MV beam according to the AAPM TG-51 Protocol

After the modeling of the new beam is completed in ADAC, the output of the beams from the LINACS must be correctly calibrated to deliver 1 cGy/MU at the depth of maximum dose (2.4 cm for 10 MV and 3.3 cm for 18 MV) at 100 SSD. The AAPM TG-51 Protocol provides the method for achieving the correct calibration. This calibration must be performed prior to conducting the beam verification tests.

Verification of the Modeled Beam

Treatment plans were generated with the new beams in ADAC TPS under different measurement conditions and the dose calculated by ADAC were compared against those actually measured with ion chamber in water phantom. The two sets of data must be in close agreement in order to confirmed that the modeled beam matches the actual beam generated by the LINACS and the new beams can be commissioned for clinical use.

The measured dose was calculated as

$$\text{Dose} = \text{Chamber Reading (nC)} \times C_{T,P} \times N_{W}^{\text{Co-60}} \times K_{Q}$$

where

$$C_{T,P} = \text{Environmental correction} = \frac{760}{\text{P (mm Hg)}} \times \frac{273.2 + \text{T}\,(^{\circ}\text{C})}{295.2}$$

$N_W^{Co\text{-}60}$ = chamber calibration factor: 4.873 cGy/nC for FC-65 chamber as provided by ADCL (calibration date December 2, 2004)

K_Q = quality conversion factor that converts the chamber response to Co-60 gamma rays to that of X-rays of given energy (as indicated by $PDD_{10\ cm}$)

DOSIMETRY BOOK DATA

In addition to the data acquired for beam modeling, various sets of beam data are required to be available for hand-calculation of monitor units. The following sets of data were obtained for the three new photon beams and added to the dosimetry books, which contain all information required for manual check of the monitor units calculated by the treatment planning system. The monitor units are calculated as follows:

$$\text{MU (SSD Technique)} = \frac{\text{Dose (cGy)}}{\text{K (1 cGy/MU)} \times \text{PDD} \times S_c \times S_p \times \text{SSD factor} \times \text{other factors}}$$

$$\text{MU (SAD Technique)} = \frac{\text{Dose (cGy)}}{\text{K (1 cGy/MU)} \times \text{TMR} \times S_c \times S_p \times \text{SAD factor} \times \text{other factors}}$$

Percent Depth Dose Curve and Tissue Maximum Ratio
The Wellhofer Scanner was used to obtain percent depth dose curve from 0 to 30 cm for field sizes 1 to 40 at 1 cm increment. The Omni Pro Accept software was then used to convert the percent depth dose curves to table format and also to tables of tissue maximum ratio. For the 10 MV beam, both PDD (for MU calculation of SSD technique) and TMR (for MU calculation of SAD technique) data were normalized to d_{max} of 2.4 cm and the 18 MV beam data were normalized to d_{max} of 3.3 cm.

Output Factors (S_{cp}, S_c, S_p)
Output factors (S_{cp}) to be used in the dosimetry book were obtained at depth of maximum dose (whereas the output factors for beam modeling were required to be obtained at depth of 10 cm) with SSD of 100 cm.

$$S_{cp}\ \text{(SSD Technique)} = \frac{\text{Reading for given field size at } d_{max}}{\text{Reading for reference field size (10 x 10) at } d_{max}}$$

This factor can then be converted to S_{cp} for SAD technique by inverse square law.

$$S_{cp}\ \text{(SAD Technique)} = \left[S_{cp}\ \text{(SSD Technique)}\right] \times \left[\frac{100 + d_{max}}{100}\right]^2$$

Collimator scatter factors (S_c) were obtained with in-air measurement with the chamber placed at the isocenter (SAD = 100 cm). Since S_c is same for both SSD and SAD techniques, it can be divided into S_{cp} value for corresponding technique to determine the phantom scatter factor (S_p) for each technique.

$$S_P\ (SSD) = \frac{S_{cp}\ (\text{SSD Technique})}{S_c}$$

or,

$$S_p\ (SAD) = \frac{S_{cp}\ (\text{SAD Technique})}{S_c}$$

Wedge Factors

The beam output as attenuated by the 60^o wedge was compared against the output from the open beam of the same field size to obtain the wedge transmission factor.

$$\text{Wedge Factor} = \frac{\text{Reading for a wedge field}}{\text{Reading for reference field (10 x 10 open)}}$$

Off-Axis Wedge Factors are determined from reading the Wellhofer scans for 30 x 30 wedge field size in-plane profile at 10-cm depth. The readings at different off-axis distances are divided into the reading at the central axis to yield the off-axis wedge ratio.

Transmission Factors

Various treatment devices were checked for any beam modification that they may produce (e.g., dot tray, headholder, boards, etc). The output through these devices were measured and compared against open, unmodified beam to calculate the transmission factors.

$$\text{Wedge Factor} = \frac{\text{Reading for a field through modifier}}{\text{Reading for reference field (10 x 10 open)}}$$

RESULTS

A. Results of Acceptance Testing
B. Output Factors for Open Field for ADAC
C. Output Factors for Wedge Field for ADAC
D. TG-51 Calibration
E. Results of ADAC Commissioning Test
F. Output Factors for Open Field for Dosimetry Book
G. Output Factors for Wedge Field for Dosimetry Book
H. Wedge Off-Axis Factor for Dosimetry Book
I. Transmission Factors for Dosimetry Book

Results of Beam Acceptance Tests.

Criteria per Elekta Customer Acceptance Test Schedule

Energy (Penetrative Quality)

Nominal Energy 10 MV: PDD (10 cm) = 73.0 +/- 2

Nominal Energy 10 MV: PDD (10 cm) = 78.5 +/- 2

Uniformity of X-Radiation Fields

Flatness < 6.0 %

Symmetry < 3.0 %

Energy

SL-15 10 MV (Mechanical Change on March 7, 2005)

PDD (10 cm) = 72.8; PDD (20 cm) = 45.3; PDD (10 cm)/PDD (20 cm) = 1.61

SL-25 10 MV (Mechanical Change on April 19, 2005)

PDD (10 cm) = 73.3 PDD (20 cm) = 45.7; PDD (10 cm)/PDD (20 cm) = 1.60

SL-25 18 MV (Mechanical Change on April 19, 2005)

PDD (10 cm) = 78.5; PDD (20 cm) = 51.8; PDD (10 cm)/PDD (20 cm) = 1.51

Flatness and Symmetry (expressed in percentage)

Field Size = 30 x 30; SSD = 100 cm; Measurement Depth = 10 cm

	SL-15 10 MV		SL-25 10 MV		SL-25 18 MV	
Scan direction	Flat.	Symm.	Flat.	Symm.	Flat.	Symm.
G-T	5.7	1.5	2.3	0.7	0.8	0.5
A-B	4.7	0.5	2.1	0.7	1.0	1.1

Output factors for ADAC Commissioning.

Field Size	SL-15 10 MV	SL-25 10 MV	SL-15 18 MV
1 x 1	0.564	0.613	0.556
2 x 2	0.792	0.801	0.782
3 x 3	0.854	0.859	0.861
4 x 4	0.888	0.891	0.901
5 x 5	0.915	0.916	0.927
6 x 6	0.936	0.938	0.946
7 x 7	0.957	0.954	0.959
8 x 8	0.973	0.973	0.977
9 x 9	0.985	0.986	0.986
10 x 10	1.000	1.000	1.000
11 x 11	1.010	1.011	1.011
12 x 12	1.023	1.022	1.021
13 x 13	1.033	1.033	1.027
14 x 14	1.045	1.042	1.036
15 x 15	1.054	1.049	1.042
16 x 16	1.061	1.059	1.049
17 x 17	1.069	1.067	1.054
18 x 18	1.076	1.073	1.061
19 x 19	1.079	1.078	1.065
20 x 20	1.087	1.086	1.069
21 x 21	1.092	1.091	1.073
22 x 22	1.094	1.096	1.078
23 x 23	1.099	1.098	1.081
24 x 24	1.103	1.102	1.082
25 x 25	1.109	1.106	1.087
26 x 26	1.110	1.109	1.090
27 x 27	1.111	1.112	1.091
28 x 28	1.116	1.116	1.095
29 x 29	1.118	1.118	1.097
30 x 30	1.121	1.120	1.099
31 x 31	1.125	1.124	1.101
32 x 32	1.127	1.125	1.103
33 x 33	1.127	1.127	1.105
34 x 34	1.129	1.129	1.105
35 x35	1.129	1.130	1.108
36 x 36	1.129	1.135	1.109
37 x 37	1.130	1.133	1.108
38 x 38	1.133	1.135	1.108
39 x 39	1.132	1.135	1.108
40 x 40	1.134	1.135	1.107

Wedge Output factors for ADAC Commissioning.

Field Size	SL-15 10 MV	SL-25 10 MV	SL-15 18 MV
2 x 2	0.211	0.229	0.215
3 x 3	0.233	0.246	0.238
5 x 5	0.252	0.264	0.256
10 x 10	0.282	0.292	0.282
15 x 15	0.304	0.314	0.298
20 x 20	0.321	0.331	0.314
30 x 30	0.339	0.349	0.328
40 x 30	0.342	0.352	0.331

SL-15 10 MV TG-51 Calibration March 16, 2005

SITE INFORMATION
Institution..........: Medical College of Ohio
Nominal photon energy: 10 MV   Depth of dose maximum: 2.4 cm
Calibration date.....: Wednesday, March 16, 2005
Physicist............:
Accelerator Mfgr.....:
Accelerator S/N......:

CHAMBER INFORMATION
File used: MCO.cbr
Model: PTW N30001 0.6cc
Serial number: 401
Cavity inner radius: 0.305 cm
Calibration factor(Nd): 5.383E-2 Gy/C
Calibration date: 09/17/2002

ELECTROMETER INFORMATION
File used: mco cnmc.elm
Model: CNMC 206
Serial number: 3515403
P(elec): 1.001E+00 C/C or C/rdg
Calibration date: 10/08/2003

MEASUREMENT CONDITIONS
Calibration setup: SSD   Calibration distance: 100 cm
Calibration field size (cm): 10   Number of monitor units: 100
Temp (degrees C): 24   Pressure (mmHg): 753.6
Temp/Pressure correction: 1.015

BEAM QUALITY
Energy >= 10 MV
%dd(10)x = 72.946%
Distance of Pb foil at 50 +/- 5 cm
%ddPb(10)x = 72.946%

Avg M (pos): 13.667 *   Avg M (neg): 13.617
Polarity correction factor (Ppol): 0.998

M(H) raw: 13.667   M(L) raw: 13.637
P(ion): 1.002
kQ: 0.981, using chamber model: PTW N30001 0.6cc

M(raw) used in final calculation: 13.667E+0

DOSE CALCULATION (DOSE IS TO WATER)
Dose per MU at 10 cm depth: 0.7333 cGy/MU
Clinical %DD at 10 cm: 73.5%

Dose (to water) per MU at Dmax: 0.9976 cGy/MU

SL-25 10 MV TG-51 Calibration May 5, 2005

SITE INFORMATION
Institution..........: MCO
Nominal photon energy: 10 MV   Depth of dose maximum: 2.4 cm
Calibration date.....: Tuesday, May 03, 2005
Physicist............: DS
Accelerator Mfgr.....: SL-25
Accelerator S/N......: 5812

CHAMBER INFORMATION
File used: new_mco.cbr
Model: Unlisted chamber
Serial number: 740
Cavity inner radius: 0.310 cm
Calibration factor(Nd): 4.873E-2 Gy/C
Calibration date: 12/02/2004

ELECTROMETER INFORMATION
File used: mco cnmc.elm
Model: CNMC 206
Serial number: 3515403
P(elec): 1.001E+00 C/C or C/rdg
Calibration date: 10/08/2003

MEASUREMENT CONDITIONS
Calibration setup: SSD   Calibration distance: 100 cm
Calibration field size (cm): 10   Number of monitor units: 100
Temp (degrees C): 21.5   Pressure (mmHg): 756
Temp/Pressure correction: 1.004

BEAM QUALITY
Energy >= 10 MV
%dd(10)x = 73.%
Distance of Pb foil at 50 +/- 5 cm
%ddPb(10)x = 73%

Avg M (pos): 15.095 *   Avg M (neg): 15.095
Polarity correction factor (Ppol): 1.000

M(H) raw: 14.8   M(L) raw: 14.735
P(ion): 1.004
kQ: 0.979, using chamber model: Unlisted Chamber

M(raw) used in final calculation: 15.22E+0

DOSE CALCULATION (DOSE IS TO WATER)
Dose per MU at 10 cm depth: 0.7326 cGy/MU
Clinical %DD at 10 cm: 73.1%

Dose (to water) per MU at Dmax: 1.0023 cGy/MU

SL-25 18 MV TG-51 Calibration May 5, 2005

SITE INFORMATION
Institution..........: MCO
Nominal photon energy: 18 MV   Depth of dose maximum: 3.3 cm
Calibration date.....: Tuesday, May 03, 2005
Physicist............: DS
Accelerator Mfgr.....: SL-25
Accelerator S/N......: 5812

CHAMBER INFORMATION   *ELECTROMETER INFORMATION*
File used: new_mco.cbr   File used: mco cnmc.elm
Model: Unlisted chamber   Model: CNMC 206
Serial number: 740   Serial number: 3515403
Cavity inner radius: 0.310 cm   P(elec): 1.001E+00 C/C or C/rdg
Calibration factor(Nd): 4.873E-2 Gy/C Calibration date: 10/08/2003
Calibration date: 12/02/2004

MEASUREMENT CONDITIONS
Calibration setup: SSD   Calibration distance: 100 cm
Calibration field size (cm): 10   Number of monitor units: 100
Temp (degrees C): 21.5   Pressure (mmHg): 756
Temp/Pressure correction: 1.004

BEAM QUALITY
Energy >= 10 MV
%dd(10)x = 79.035%
Distance of Pb foil at 50 +/- 5 cm
%ddPb(10)x = 78.4%

Avg M (pos): 16.37 *   Avg M (neg): 16.37
Polarity correction factor (Ppol): 1.000

M(H) raw: 14.39   M(L) raw: 14.315
P(ion): 1.005
kQ: 0.969, using chamber model: Unlisted Chamber

M(raw) used in final calculation: 16.48E+0

DOSE CALCULATION (DOSE IS TO WATER)
Dose per MU at 10 cm depth: 0.786 cGy/MU
Clinical %DD at 10 cm: 78.6%

Dose (to water) per MU at Dmax: 1.000 cGy/MU

SL-15 10 MV ADAC PINNACLE v. 6.2 COMMISSIONING TEST.

Square Field SSD Technique (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	171.8	172.8	0.55%
10 x 10	5	182.9	184.2	0.67%
25 x 25	5	196.8	198.6	0.91%
5 x 5	10	133.7	134.1	0.28%
10 x 10	10	146.3	146.9	0.44%
25 x 25	10	161.4	163.0	0.99%

Square Field SAD Technique (SSD = 97.8 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	178.9	179.9	0.56%
10 x 10	5	190.7	192.1	0.72%
25 x 25	5	204.9	207.1	1.10%
5 x 5	10	138.5	139.2	0.53%
10 x 10	10	152.0	152.8	0.54%
25 x 25	10	167.9	169.9	1.18%

Rectangular Field SAD Technique (SSD = 97.8 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	187.4	189.6	1.14%
25 x 5	5	185.9	189.9	2.09%
5 x 25	10	148.0	149.3	0.87%
25 x 5	10	146.7	149.5	1.88%

Rectangular Field SSD Technique (SSD = 100 cm; 200 MU delivered)
Field Size

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	180.3	181.9	0.89%
25 x 5	5	178.4	182.3	2.10%
5 x 25	10	142.3	143.6	0.91%
25 x 5	10	141.1	143.9	1.90%

Wedge Field (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
9 x 9	5	50.7	50.3	-0.66%
9 x 9	10	40.5	40.5	0.01%

Square Field SSD Variation (SSD = 90 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	223.7	224.8	0.46%
10 x 10	10	176.3	176.8	0.25%

Square Field Oblique Beam (SSD = 100 cm; Gantry = 90 degree; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	184.7	185.5	0.45%

10 x 10 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
4 cm Inferior	2.2	196.1	201.8	2.84%
4 cm superior	2.2	189.2	199.1	4.95%
4 cm Right	2.2	202.5	199.4	-1.51%
4 cm Left	2.2	198.9	199.7	0.41%

20 x 20 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
8 cm Inferior	2.2	227.1	218.6	-3.90%
8 cm Superior	2.2	222.5	218.5	-1.82%
8 cm Right	2.2	221.7	218.8	-1.30%
8 cm Left	2.2	222.8	218.9	-1.81%

Custom Block (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
BLOCK	5	192.4	185.2	-3.85%
BLOCK	10	156.3	147.6	-5.92%

SL-25 10 MV.ADAC PINNACLE v. 6.2 COMMISSIONING TEST.

Square Field SSD Technique (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	172.5	171.88	-0.34%
10 x 10	5	183.2	182.89	-0.18%
25 x 25	5	196.4	196.8	0.20%
5 x 5	10	134.6	133.92	-0.49%
10 x 10	10	147.0	146.51	-0.33%
25 x 25	10	161.8	161.61	-0.10%

Square Field SAD Technique (SSD = 97.6 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	180.6	179.82	-0.43%
10 x 10	5	192.3	191.55	-0.38%
25 x 25	5	205.8	206.22	0.21%
5 x 5	10	140.2	139.75	-0.33%
10 x 10	10	153.1	152.99	-0.07%
25 x 25	10	168.5	168.89	0.22%

Rectangular Field SAD Technique (SSD = 97.6 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	189.1	189.54	0.25%
25 x 5	5	187.2	188.93	0.91%
5 x 25	10	149.8	149.71	-0.04%
25 x 5	10	148.3	149.24	0.63%

Rectangular Field SSD Technique (SSD = 100 cm; 200 MU delivered)
Field Size

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	180.5	181.21	0.38%
25 x 5	5	178.6	180.54	1.10%
5 x 25	10	143.4	143.54	0.12%
25 x 5	10	142.0	143.04	0.69%

Wedge Field (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
9 x 9	5	52.9	52.11	-1.45%
9 x 9	10	42.5	41.95	-1.24%

Square Field SSD Variation (SSD = 90 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	223.9	223.29	-0.25%
10 x 10	10	176.5	176.46	-0.03%

Square Field Oblique Beam (SSD = 100 cm; Gantry = 90 degree; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	177.6	177.82	0.11%

10 x 10 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
4 cm Inferior	2.2	202.5	201.91	-0.29%
4 cm superior	2.2	203.5	198.71	-2.43%
4 cm Right	2.2	203.1	201.79	-0.66%
4 cm Left	2.2	201.3	197.39	-2.00%

20 x 20 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
8 cm Inferior	2.2	214.7	213.94	0.67%
8 cm Superior	2.2	215.6	214.31	0.39%
8 cm Right	2.2	215.4	214.14	0.40%
8 cm Left	2.2	212.7	213.8	1.49%

Custom Block (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
BLOCK	5	188.7	193.99	3.72%
BLOCK	10	153.3	157.7	3.79%

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Square Field SSD Technique (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	180.1	180.63	0.31%
10 x 10	5	191.8	191.17	-0.32%
25 x 25	5	203.2	204.29	0.55%
5 x 5	10	145.2	145.77	0.39%
10 x 10	10	157.2	157.44	0.18%
25 x 25	10	169.7	170.81	0.67%

Square Field SAD Technique (SSD = 96.7 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 5	5	191.7	192.26	0.29%
10 x 10	5	204.6	203.7	-0.45%
25 x 25	5	216.7	218.02	0.62%
5 x 5	10	154.0	154.64	0.39%
10 x 10	10	166.8	167.12	0.19%
25 x 25	10	180.0	181.57	0.87%

Rectangular Field SAD Technique (SSD = 96.7 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	201.0	199.78	-0.59%
25 x 5	5	199.0	198.99	0.00%
5 x 25	10	162.9	162.42	-0.28%
25 x 5	10	161.0	161.87	0.52%

Rectangular Field SSD Technique (SSD = 100 cm; 200 MU delivered)
Field Size

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
5 x 25	5	188.5	187.6	-0.46%
25 x 5	5	186.5	186.97	0.25%
5 x 25	10	153.6	153.22	-0.25%
25 x 5	10	151.9	152.69	0.52%

Wedge Field (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
9 x 9	5	53.8	53.2	-1.11%
9 x 9	10	43.9	43.77	-0.28%

Square Field SSD Variation (SSD = 90 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	234.0	233.38	-0.25%
10 x 10	10	189.5	189.76	0.12%

Square Field Oblique Beam (SSD = 100 cm; Gantry = 90 degree; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
10 x 10	5	186.2	186.95	0.42%

10 x 10 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
3 cm Inferior	3.3	199.5	200.02	0.25%
3 cm superior	3.3	199.7	200.53	0.39%
3 cm Right	3.3	200.0	200.01	0.03%
3 cm Left	3.3	200.9	199.77	-0.55%

20 x 20 Square Field Off-Axis Measurements (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
8 cm Inferior	3.3	215.3	215.93	0.28%
8 cm Superior	3.3	213.7	215.76	0.94%
8 cm Right	3.3	215.4	216.78	0.63%
8 cm Left	3.3	215.5	216.02	0.24%

Custom Block (SSD = 100 cm; 200 MU delivered)

FS	depth	Dose (cGY) from chamber measurement	Dose (cGy) expected from ADAC plan	% Difference
BLOCK	5	198.7	201.8	1.56%
BLOCK	10	164.8	167.3	1.48%

SL-15 10 MV Output Factors for Dosimetry Book (SSD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.635	0.694	0.915
2 x 2	0.869	0.889	0.977
3 x 3	0.914	0.924	0.989
4 x 4	0.937	0.950	0.986
5 x 5	0.948	0.961	0.986
6 x 6	0.962	0.973	0.988
7 x 7	0.971	0.980	0.991
8 x 8	0.984	0.991	0.993
9 x 9	0.990	0.996	0.994
10 x 10	1.000	1.000	1.000
11 x 11	1.007	1.004	1.002
12 x 12	1.015	1.012	1.003
13 x 13	1.021	1.017	1.004
14 x 14	1.029	1.023	1.006
15 x 15	1.035	1.026	1.009
16 x 16	1.041	1.033	1.007
17 x 17	1.045	1.037	1.008
18 x 18	1.049	1.042	1.007
19 x 19	1.054	1.045	1.009
20 x 20	1.057	1.048	1.008
21 x 21	1.060	1.049	1.010
22 x 22	1.062	1.052	1.010
23 x 23	1.065	1.053	1.012
24 x 24	1.068	1.055	1.013
25 x 25	1.068	1.056	1.011
26 x 26	1.072	1.057	1.014
27 x 27	1.073	1.059	1.013
28 x 28	1.075	1.060	1.014
29 x 29	1.075	1.062	1.012
30 x 30	1.077	1.063	1.013
31 x 31	1.078	1.063	1.014
32 x 32	1.079	1.063	1.015
33 x 33	1.080	1.064	1.015
34 x 34	1.082	1.064	1.017
35 x35	1.082	1.065	1.016
36 x 36	1.083	1.066	1.016
37 x 37	1.082	1.066	1.015
38 x 38	1.081	1.066	1.015
39 x 39	1.080	1.064	1.015
40 x 40	1.078	1.063	1.014

SL-15 10 MV Output Factors for Dosimetry Book (SAD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.666	0.694	0.960
2 x 2	0.911	0.889	1.025
3 x 3	0.959	0.924	1.038
4 x 4	0.983	0.950	1.035
5 x 5	0.994	0.961	1.035
6 x 6	1.009	0.973	1.037
7 x 7	1.018	0.980	1.040
8 x 8	1.032	0.991	1.041
9 x 9	1.039	0.996	1.043
10 x 10	1.049	1.000	1.049
11 x 11	1.056	1.004	1.051
12 x 12	1.065	1.012	1.053
13 x 13	1.071	1.017	1.053
14 x 14	1.079	1.023	1.055
15 x 15	1.086	1.026	1.058
16 x 16	1.092	1.033	1.057
17 x 17	1.096	1.037	1.057
18 x 18	1.101	1.042	1.056
19 x 19	1.105	1.045	1.058
20 x 20	1.108	1.048	1.058
21 x 21	1.112	1.049	1.059
22 x 22	1.114	1.052	1.059
23 x 23	1.117	1.053	1.061
24 x 24	1.120	1.055	1.062
25 x 25	1.121	1.056	1.061
26 x 26	1.125	1.057	1.063
27 x 27	1.126	1.059	1.063
28 x 28	1.128	1.060	1.064
29 x 29	1.128	1.062	1.062
30 x 30	1.130	1.063	1.062
31 x 31	1.131	1.063	1.063
32 x 32	1.132	1.063	1.065
33 x 33	1.133	1.064	1.064
34 x 34	1.135	1.064	1.066
35 x35	1.135	1.065	1.065
36 x 36	1.136	1.066	1.066
37 x 37	1.135	1.066	1.065
38 x 38	1.134	1.066	1.064
39 x 39	1.133	1.064	1.065
40 x 40	1.131	1.063	1.064

SL-25 10 MV Output Factors for Dosimetry Book (SSD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.635	0.694	0.916
2 x 2	0.869	0.889	0.978
3 x 3	0.914	0.932	0.981
4 x 4	0.937	0.950	0.986
5 x 5	0.948	0.959	0.988
6 x 6	0.962	0.973	0.988
7 x 7	0.971	0.980	0.991
8 x 8	0.984	0.990	0.994
9 x 9	0.990	0.995	0.995
10 x 10	1.000	1.000	1.000
11 x 11	1.007	1.007	1.000
12 x 12	1.015	1.014	1.001
13 x 13	1.021	1.020	1.001
14 x 14	1.029	1.025	1.004
15 x 15	1.035	1.030	1.004
16 x 16	1.041	1.035	1.005
17 x 17	1.045	1.040	1.004
18 x 18	1.049	1.045	1.004
19 x 19	1.054	1.048	1.006
20 x 20	1.057	1.051	1.006
21 x 21	1.060	1.051	1.008
22 x 22	1.062	1.052	1.010
23 x 23	1.065	1.054	1.011
24 x 24	1.068	1.055	1.012
25 x 25	1.068	1.057	1.011
26 x 26	1.072	1.058	1.013
27 x 27	1.073	1.059	1.013
28 x 28	1.075	1.060	1.014
29 x 29	1.075	1.061	1.013
30 x 30	1.077	1.061	1.015
31 x 31	1.078	1.061	1.015
32 x 32	1.079	1.062	1.016
33 x 33	1.080	1.062	1.017
34 x 34	1.082	1.063	1.018
35 x35	1.082	1.061	1.019
36 x 36	1.083	1.060	1.021
37 x 37	1.082	1.061	1.019
38 x 38	1.081	1.061	1.019
39 x 39	1.080	1.061	1.018
40 x 40	1.078	1.060	1.017

SL-25 10 MV Output Factors for Dosimetry Book (SAD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.666	0.694	0.961
2 x 2	0.911	0.889	1.026
3 x 3	0.959	0.932	1.029
4 x 4	0.983	0.950	1.034
5 x 5	0.994	0.959	1.036
6 x 6	1.009	0.973	1.037
7 x 7	1.018	0.980	1.040
8 x 8	1.032	0.990	1.043
9 x 9	1.039	0.995	1.044
10 x 10	1.049	1.000	1.049
11 x 11	1.056	1.007	1.049
12 x 12	1.065	1.014	1.050
13 x 13	1.071	1.020	1.050
14 x 14	1.079	1.025	1.053
15 x 15	1.086	1.030	1.054
16 x 16	1.092	1.035	1.054
17 x 17	1.096	1.040	1.054
18 x 18	1.101	1.045	1.054
19 x 19	1.105	1.048	1.055
20 x 20	1.108	1.051	1.055
21 x 21	1.112	1.051	1.058
22 x 22	1.114	1.052	1.059
23 x 23	1.117	1.054	1.060
24 x 24	1.120	1.055	1.062
25 x 25	1.121	1.057	1.061
26 x 26	1.125	1.058	1.063
27 x 27	1.126	1.059	1.063
28 x 28	1.128	1.060	1.063
29 x 29	1.128	1.061	1.063
30 x 30	1.130	1.061	1.065
31 x 31	1.131	1.061	1.065
32 x 32	1.132	1.062	1.066
33 x 33	1.133	1.062	1.067
34 x 34	1.135	1.063	1.068
35 x35	1.135	1.061	1.069
36 x 36	1.136	1.060	1.071
37 x 37	1.135	1.061	1.069
38 x 38	1.134	1.061	1.068
39 x 39	1.133	1.061	1.068
40 x 40	1.131	1.060	1.067

SL-25 18 MV Output Factors for Dosimetry Book (SSD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.586	0.599	0.978
2 x 2	0.818	0.844	0.969
3 x 3	0.889	0.908	0.979
4 x 4	0.923	0.935	0.987
5 x 5	0.934	0.947	0.987
6 x 6	0.949	0.962	0.987
7 x 7	0.962	0.972	0.990
8 x 8	0.976	0.984	0.992
9 x 9	0.985	0.991	0.993
10 x 10	1.000	1.000	1.000
11 x 11	1.005	1.005	0.999
12 x 12	1.012	1.011	1.001
13 x 13	1.019	1.016	1.002
14 x 14	1.027	1.022	1.005
15 x 15	1.032	1.027	1.005
16 x 16	1.037	1.032	1.005
17 x 17	1.043	1.035	1.008
18 x 18	1.047	1.038	1.009
19 x 19	1.050	1.041	1.009
20 x 20	1.055	1.044	1.011
21 x 21	1.057	1.046	1.010
22 x 22	1.059	1.049	1.010
23 x 23	1.062	1.050	1.011
24 x 24	1.066	1.052	1.014
25 x 25	1.066	1.052	1.013
26 x 26	1.069	1.052	1.016
27 x 27	1.072	1.053	1.018
28 x 28	1.071	1.054	1.016
29 x 29	1.071	1.054	1.016
30 x 30	1.076	1.055	1.019
31 x 31	1.077	1.056	1.020
32 x 32	1.078	1.056	1.021
33 x 33	1.079	1.058	1.020
34 x 34	1.078	1.059	1.018
35 x35	1.080	1.059	1.019
36 x 36	1.080	1.059	1.020
37 x 37	1.082	1.059	1.022
38 x 38	1.078	1.059	1.019
39 x 39	1.079	1.058	1.020
40 x 40	1.079	1.058	1.020

SL-25 18 MV Output Factors for Dosimetry Book (SAD Technique).

Field Size	S_{cp}	S_c	S_p
1 x 1	0.625	0.599	1.043
2 x 2	0.872	0.844	1.034
3 x 3	0.949	0.908	1.045
4 x 4	0.985	0.935	1.053
5 x 5	0.997	0.947	1.053
6 x 6	1.013	0.962	1.053
7 x 7	1.026	0.972	1.056
8 x 8	1.041	0.984	1.058
9 x 9	1.051	0.991	1.060
10 x 10	1.067	1.000	1.067
11 x 11	1.072	1.005	1.066
12 x 12	1.080	1.011	1.068
13 x 13	1.087	1.016	1.070
14 x 14	1.096	1.022	1.073
15 x 15	1.101	1.027	1.072
16 x 16	1.107	1.032	1.072
17 x 17	1.113	1.035	1.075
18 x 18	1.117	1.038	1.077
19 x 19	1.120	1.041	1.077
20 x 20	1.126	1.044	1.079
21 x 21	1.127	1.046	1.078
22 x 22	1.130	1.049	1.077
23 x 23	1.133	1.050	1.079
24 x 24	1.138	1.052	1.082
25 x 25	1.137	1.052	1.081
26 x 26	1.141	1.052	1.084
27 x 27	1.144	1.053	1.086
28 x 28	1.142	1.054	1.084
29 x 29	1.143	1.054	1.084
30 x 30	1.148	1.055	1.088
31 x 31	1.149	1.056	1.089
32 x 32	1.151	1.056	1.089
33 x 33	1.151	1.058	1.088
34 x 34	1.150	1.059	1.086
35 x35	1.152	1.059	1.088
36 x 36	1.152	1.059	1.088
37 x 37	1.154	1.059	1.090
38 x 38	1.151	1.059	1.087
39 x 39	1.151	1.058	1.088
40 x 40	1.151	1.058	1.088

Wedge Factors for Dosimetry Book

F.S. ⇒ Energy ⇓	2	3	5	10	15	20	30
SL-15 10 MV	0.273	0.273	0.276	0.282	0.288	0.295	0.301
SL-25 10 MV	0.229	0.246	0.264	0.292	0.314	0.331	0.349
SL-25 18 MV	0.215	0.238	0.256	0.282	0.298	0.314	0.328

Wedge Off-Axis Factors for Dosimetry Book.

F.S. ⇒ depth ⇓	12.0	11.5	11.0	10.5	10.0	9.5	9.0	8.5	8.0	7.5	7.0	6.5
SL-15 10 MV	2.202	2.139	2.073	2.012	1.957	1.905	1.843	1.789	1.737	1.681	1.633	1.582
SL-25 10 MV	2.185	2.126	2.064	2.005	1.949	1.889	1.834	1.779	1.721	1.674	1.624	1.576
SL-25 18 MV	2.212	2.148	2.086	2.016	1.961	1.899	1.840	1.789	1.720	1.666	1.618	1.567

F.S. ⇒ depth ⇓	6.0	5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5
SL-15 10 MV	1.532	1.479	1.431	1.384	1.339	1.288	1.240	1.200	1.157	1.118	1.079	1.038
SL-25 10 MV	1.526	1.476	1.435	1.384	1.338	1.296	1.247	1.203	1.160	1.120	1.081	1.041
SL-25 18 MV	1.509	1.465	1.422	1.373	1.328	1.281	1.237	1.194	1.150	1.116	1.074	1.033

F.S. ⇒ depth ⇓	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0	-5.5	-6.0
SL-15 10 MV	0.973	0.946	0.920	0.896	0.868	0.842	0.815	0.787	0.765	0.742	0.719	0.694
SL-25 10 MV	0.969	0.941	0.912	0.885	0.855	0.831	0.809	0.781	0.755	0.734	0.711	0.685
SL-25 18 MV	0.970	0.941	0.909	0.876	0.850	0.823	0.799	0.777	0.750	0.728	0.702	0.677

F.S. ⇒ depth ⇓	-6.5	-7.0	-7.5	-8.0	-8.5	-9.0	-9.5	-10.0	-10.5	-11.0	-11.5	-12.0
SL-15 10 MV	0.672	0.649	0.624	0.602	0.578	0.559	0.536	0.518	0.498	0.480	0.460	0.444
SL-25 10 MV	0.661	0.639	0.615	0.593	0.572	0.550	0.531	0.513	0.495	0.475	0.457	0.438
SL-25 18 MV	0.653	0.629	0.607	0.585	0.560	0.454	0.525	0.504	0.485	0.468	0.448	0.431

Transmission Factors for SL-15 10 MV and SL-25 10 MV.

Modifier	Factor
Block Tray	0.965
Headholder, Bionix, through plastic part only	0.983
Headholder, Bionix, with plastic headrest	0.978
Headholder, plain, through plastic part only	0.973
Headholder, plain, with plastic headrest	0.967
Headholder, SN 5039 through plastic part only	0.960
Long headholder through plastic part only	0.944
Clear Plastic Headrest	0.998
Breastboard, through the tip	0.916
Breastboard, through the middle	0.902
Tilt board thru the end tip	0.942
Blue Vac Bag	0.998
Blue Belly Board	0.991
Blue Foam Pillow	0.981
Dot Tray	0.901

Transmission Factors for SL-25 18 MV.

Modifier	Factor
Block Tray	0.970
Headholder, SN 5039 through plastic part only	0.976
Long headholder through plastic part only	0.951
Clear Plastic Headrest	0.995
Breastboard, through the tip	0.925
Breastboard, through the middle	0.916
Tilt board thru the end tip	0.942
Blue Vac Bag	0.995
Blue Belly Board	0.988
Blue Foam Pillow	0.982
Reticle	0.968

DISCUSSION

The mechanical changes for the three new beams were successfully performed, as the PDD_{10}, flatness and symmetry of the new beams all met the acceptance criteria. The flatness for the SL-15 10 MV beam was greater than what would have been preferred, but the beam was accepted by the MCO physics group because: 1) it was under the acceptance criteria, and 2) further adjustment to the microwave frequency (to obtain better flatness) would also affect the beam energy and since the beam energy was very close to what was desired, further change was not seen as productive.

The beam data collection was for most parts straightforward. One of the difficulties encountered in percent depth dose curves is the gain-setting for the small field sizes (< 4 x 4). It took a fair amount of practice and trial-and-error in order to obtain optimal gain setting to produce smooth PDD curves. In collecting output factors, it was helpful to plot the measured output data throughout the measurement process because it provides easy and graphic display, from which one can pick out any anomaly that may require repeat measurement. For the smaller fields sizes, in measurement of both percent depth dose and output factors, it was easier and more accurate to use micro-chambers.

The ion-chamber measurements were in close agreement with the calculated dose from ADAC, showing that the data collection, import, and beam modeling were all done correctly. With this confirmation, the ADAC can then be put in use for generating patient treatment plans. Further inspection and comparison of ADAC calculated dose and ion-chamber measured dose for various set-ups between the SL-15 10 MV and SL-25 10 MV beams shows that the two beams are closely matched and can be clinically used interchangeably (no separate MU calculation necessary), except the wedge fields. The difference between the wedge fields is due to the fact that the wedges in each machine are not physically identical and do not produced identical amount of beam attenuation, although the lateral profiles are in close match. It was decided that for wedge fields, a separate MU calculation is needed for treatment plan depending on which machine is being used for patient treatment. For future ion-chamber verification of off-axis plans from ADAC TPS, depth of d_{max} should be avoided, as the measurement is very sensitive to chamber placement. A depth of 5 cm or 10 cm should provide much more stable measurement condition. The off-axis shift should also be carefully selected so that the chamber is well within the radiation field, but far enough from CAX to represent an off-axis point.

CONCLUSION

After initiation of beam energy change with new filter installation, commissioning data collection, beam modeling, and verification, three new photon beams were commissioned and made available for clinical use. The SL-25 18 MV beam provides more stable source of high-range photon energy compared to the previous 25 MV beam, and the matching 10 MV beams on each LINAC provides more convenience in providing two interchangeable beams to treat patients on either LINAC.

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