AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE

Radiological Physics Center

Detailed Preliminary Report on a Visit to a
Collaborating Institution

Document 1

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Calibration Protocols

The RPC uses the protocol for the calibration of high energy photon and electron beams recommended by Task Group 21 of the American Association of Physicists in Medicine Radiation Therapy Committee (reference 1). The institution uses the TG-21 protocol.

Medium of dose specification: muscle or water

The AAPM TG-21 protocol recommends beam calibration be specified in absorbed dose to water. For cooperative clinical trials, tumor dose is specified as absorbed dose to muscle. The RPC will evaluate the agreement on calibration in the medium specified by the institution (water or muscle). However, in reporting to a clinical study group the RPC will calculate dose to muscle and use that value in evaluating the tumor dose stated by an institution. The absorbed dose to muscle is 0.99 times that to water for both megavoltage photon and electron beams.

1. Acceptability of stated tumor dose calculations.

For each field size measured by the Radiological Physics Center (RPC) on a particular machine, the product of the RPC/Institution ratios for dose rate, depth dose data, tray factors, wedge factors, and correction for medium (water or muscle), if necessary, is calculated, selecting first the minimum ratios and then the maximum ratios which could potentially be combined in calculating tumor dose. The products of these ratios, compiled in the table below, give the range of potential disagreement between the RPC and institution on the calculation of stated tumor dose for cooperative trials. The derivation of these values is detailed in Section 8. The medium for calculations by the RPC is muscle. The medium for calculations by the institution is muscle.

Machine	Radiation Beam	RPC/Inst.	Acceptable
Clinac 4/100	4 MV x-rays	0.99 - 1.06*	No++
Clinac 2500	TBI(24 MV x-rays)	0.96 - 0.98	Yes++
Clinac 2500	electrons	1.01 - 1.02	Yes++
Brachytherapy	Cs-137	0.98 - 1.05	Yes
	Ir-192(HDR)	1.01	Yes

Ratios from 0.95 to 1.05 are considered acceptable.

Please see Section 8 and the Appendix for more details.

*These values exceed the RPC's 5% criterion for tumor dose.

+Values in parentheses reflect information reported to the RPC in an e-mail dated April 6, 2000.

++These beams have been decommissioned.

2. Recommendations.

All recommendations made by the RPC are of a review nature. Changes should be made by the institution only after the institution has determined that changes are warranted. Changes should not be made on the basis of RPC recommendations alone. Such changes should be deliberate, with the full knowledge of all individuals concerned.

It is recommended that the institution:

2.1 Employ depth and field size dependent wedge factors when performing monitor unit calculations. See Section 5.3.3.

2.2 Review the beam model in the ADAC treatment planning system to determine the cause of the discrepancies between measured off axis factors and OCR's generated by ADAC. See Sections 5.1.4, 5.2.4, 5.3.4, and 5.4.4.

2.3 Establish traceability between annual calibrations with ADCL calibrated equipment (standard equipment) and weekly checks performed with field instruments.

2.4 Investigate the discrepancy in horizontal to vertical output on the 6 MV X-ray beam of the Clinac 2500. See Section 9.3.

2. Recommendations (cont'd).

2.5 Investigate the stability of the Clinac 2500's dosimetry system for 6 MeV electrons. See Section 5.5.1.

2.6 Obtain formal training for their dosimetry personnel on the use of the ADAC computer. See Section 9.8.

2.7 Review the system for determining doses at off-axis points in asymmetric fields. See Sections 5.2.3 and 9.6.

2.8 Consider developing written procedures for quality assurance per AAPM TG-40 (reference 5). See Section 9.4.

2.9 Consider developing formal procedures for monitor unit calculations (AAPM TG-40, reference 5). See Section 9.6.

2.10 Review the percent depth dose (PDD) values for small fields and deep depths on the Clinac 4/100. See Section 5.1.2.

2.11 Review the algorithm used in the MU calculations software. See Sections 7 and 9.10.

The institution, in an email dated March 29, 2000 and April 6, 2000, responded and addressed all recommendations. This includes indications that the model in their ADAC treatment planning system had been modified and verified. However, no dosimetry data verifying the new model has been submitted to the RPC. They also have indicated that they have formalized the traceability of the chambers used for routine calibrations.

3. Institution's radiation and treatment planning equipment.

3.1 External Beam

The Clinac 4/100 is a linear accelerator with a nominal x-ray energy of 4 MV. Clinical use of the machine began in September, 1983. The nominal treatment distance is 100 cm.

The Clinac 600CD is a linear accelerator with a nominal x-ray energy of 6 MV. Clinical use of the machine began in April, 1996. The nominal treatment distance is 100 cm.

The Clinac 2500 is a dual energy linear accelerator with nominal x-ray energies of 6 and 24 MV. Clinical use of the machine began in April 1987. The nominal treatment distance is 100 cm. Electron energies of 6, 9, 12, 15, 18 and 22 MeV are also produced.

3.2 Brachytherapy

The brachytherapy equipment includes various sources whose characteristics are summarized below:

The HDR unit is a high dose rate (HDR) remote brachytherapy afterloader from Nucletron. The isotope is ^{192}Ir. The source is replaced quarterly. Clinical use of the unit began in 1994.

Isotope	Source Type	Manufacturer	Length (cm) Phys./Active	Nominal Strength
Ir-192	HDR	Mallinchrodt	0.5/0.3	10 Ci
Cs-137	micro-rad	Gamma Industries	1.4/1.2	5 mg-Ra-eq
Cs-137	tubes		1.4/1.2	5, 10, 15, 20 mg-Ra-eq

3.3 Treatment Planning

The institution's treatment planning system is a Pinnicale from ADAC. The software version at the time of the RPC visit was 3.0du6. ADAC is used for relative dose distributions. Software revisions are immediately supplied and installed. Monitor unit calculations are performed with the institutions in-house software. The institution’s HDR brachytherapy treatment planning system is a Plato from Nucletron. The software version at the time of the RPC visit was10.3.

4. Dosimetry equipment and system intercomparison.

4.1 Barometer and Thermometer Intercomparison.

	RPC	Institution	RPC/Inst.
Pressure (mmHg)	759.5	763.1	
Temperature (°C)	18.1	18.0	
$K_{T,P}$	0.987	0.982	1.01

The institution's pressure readings were obtained from an aneroid barometer. This is checked against a mercury barometer (an appropriate correction for gravity and temperature was applied)$^{+}$. The institution's temperature reading was obtained from a mercury thermometer.

$^{+}$The mercury in the institution's barometer shows noticeable signs of contamination. It is recommended that the mercury be cleaned and the barometer calibrated.

4.2 RPC's Dosimetry Equipment:

Farmer type ionization chambers	
PTW model N23333 acrylic thimble	# 1516
RPC Custom Built Brachytherapy Chamber	# 1
PRM model HDRC-1 HDR Brachytherapy Chamber	# 9117
Keithley model 602 electrometer (CNMC modified)	#401121

The system calibration factors for the RPC Farmer-type chambers and custom brachytherapy chamber, using the indicated Keithley electrometer, are:

Chamber	Isotope	N_K	N_X
External Beam		$(Gy \bullet rdg^{-1})$	$(R \bullet rdg^{-1})$
#1516	Co-60	0.4717	53.67
Conventional Brachytherapy		$[\mu Gym^2hr^{-1} (rdg/sec)^{-1}]$	$[mg\text{-}eq\ (rdg/sec)^{-1}]$
#1	Cs-137(microrad)	3102	428
High Dose Rate Brachytherapy		$[\mu Gym^2hr^{-1}\ rdg^{-1}]$	$[Ci \bullet rdg^{-1}]$
#9316	Ir-192	3.955×10^4	9.818

All values (rdg) are for electrometer settings of 10^{-8} coulomb scale (10^{-7} amp scale for HDR), x1 output, fast feedback at 22°C and 760 mmHg.

4. Dosimetry equipment and system intercomparison (cont'd).

4.3 Institution's Dosimetry Equipment:

Primary System (Field System)

PTW model N23333 acrylic thimble	#1732
Victoreen Model 500 Electrometer	#198

Secondary System (Shelf System)

PTW model N23333 acrylic thimble	#389
Victoreen Model 500 Electrometer	#670

The ion chamber from the institution's secondary system was last calibrated on June 24, 1998, the electrometer was calibrated on July 28, 1998. Both calibrations were performed by the University of Wisconsin Accredited Dosimetry Calibration Laboratory. The secondary system is intercompared annually with the primary system. The last intercomparison was performed on August 27, 1998.

4.4 System Intercomparison: An intercomparison of the institution's primary system (# 1732) with the RPC PTW chamber system was performed by sequential irradiation at the center of a 10 cm x 10 cm field in the 6 MV beam of the Clinac 600C at 100 cm SSD, at 5 cm depth in water. An intercomparison of the institution's secondary system (#389) with the RPC PTW chamber system was performed by sequential irradiation at the center of a 10 cm x 10 cm field in the 6 MV beam of the Clinac 2500 at 100 cm SSD, at 5 cm depth in plastic.

RPC-derived factor	Institution system	Institution factor	RPC/Inst.
5.442†	#1732	5.365†	1.014
5.548†	#389	5.504†	1.008

†R/rdg, nC scale at 22°C and 760 mmHg.

5. Results of measurements. Please refer to Appendix for further details of the RPC measurement techniques.

5.1 Clinac 4/100 linear accelerator, 4 MV x-rays.

5.1.1 Machine Output: Absorbed dose to muscle per monitor unit at d_{max} (1.1 cm⁺), 100 cm SSD (according to mechanical distance indicator), vertical gantry.

Field Size (cm x cm)	RPC (cGy/mu)	Institution (cGy/mu)	RPC/Inst.
6 x 6	0.981	0.962	1.02
10 x 10	1.015	1.000	1.01
15 x 15	1.043	1.031	1.01
20 x 20	1.062	1.052	1.01
30 x 30	1.089	1.078	1.01

The RPC measured an ionization ratio (reference 6) of 0.639 and determined the monitor end effect to be 0.3 mu. The institution determined machine output to be 0.993 cGy/mu at the time of the RPC measurements using their primary system. These data are incorporated into the RPC calculation of machine output. See the Appendix.

⁺A graph of output field size dependence presented to the RPC at the time of this visit presents an inverse square correction of 0.973 corresponding to a d_{max} depth of 1.4 cm, this is inconsistent with percent depth dose (PDD) data presented to the RPC at the time of this visit.

5.1.2 Depth Dose Data: The institution uses its own measured central axis percent depth dose (PDD) data. The RPC factors were normalized to the institution's values at 5 cm depth. The values for the field sizes indicated below are for 100 cm SSD.

Depth (cm)	RPC (PDD)	Institution (PDD)	RPC/Inst.
6 cm x 6 cm			
5	(82.3)	82.3	-
10	60.6	60.2	1.01
15	44.1	43.5	1.01
20	32.1	31.1	1.03*
10 cm x 10 cm			
5	(83.9)	83.9	-
10	63.8	63.5	1.01
15	47.5	47.0	1.01
20	35.2	34.5	1.02
20 cm x 20 cm			
5	(85.8)	85.8	-
10	67.8	67.7	1.00
15	52.4	52.0	1.01
20	40.0	39.5	1.01

*This value exceeds the RPC's 2% criteria for relative measurements. See recommendation 2.10.

5. Results of measurements (cont'd).

5.1 Clinac 4/100 linear accelerator, 4 MV x-rays (cont'd).

5.1.3 Wedge and Tray Transmission for a 10 cm x 10 cm field at 5 cm depth in water, unless otherwise indicated, 100 cm SSD.

Description	RPC	Institution	RPC/Inst.
Wedges (field, depth)			
30° large	0.739	0.745	0.99
45° large	0.512	0.512	1.00
45° small	0.595	0.606	0.98
45° small (10 x 10,20 cm)	0.616	0.606	1.02
45° small (15 x 15, 15 cm)	0.611	0.606	1.01
60° small	0.510	0.507	1.01

5.1.4 In-Air Off-Axis Factors: Measurements were made in a 40 cm x 40 cm field at 100 cm from the target. The position referred to is relative to the central ray, facing the gantry from the foot of the treatment table. Collimator at 180°.

Position	RPC	Institution+	RPC/Inst.
5 cm left	1.022	1.023	1.00
10 cm left/right	1.027/1.038	1.032	0.99/1.01
10 cm toward/away	1.034/1.026	1.032	1.00/0.99
15 cm left	1.033	1.007	1.03*

Average off-axis factor at 10 cm:	mean =1.031
Beam symmetry at 10 cm off-axis:	min/max =1.012

+The institution's values are off center ratios (OCR) extracted from the institutions ADAC treatment planning system at d_{max} depth in a 40 cm x 40 cm field. The OAF should not exceed the OCR by more than 1-1½% for large distances from the central axis. See recommendation 2.2.

5.1.5 Mechanical and Miscellaneous Measurements.

Mechanical and optical distance indicators agree within	1 mm
Mechanical distance indicator and lasers agree within	1 mm
Collimator dials and light field agree within	1 mm
Output ratio [horizontal (@90°) vs. vertical]	1.006
Distance from bottom of accessory holder to 100 cm (according to the mechanical distance indicator)	37.6 cm

5.1.6 The localization film irradiated by the RPC indicates that the light field and radiation field were congruent within 3 mm on all sides. The radiation field appears to be symmetric. See Figure 1.

5. Results of measurements (cont'd).

5.2 Clinac 2500 linear Accelerator, 24 MV x-rays, total body irradiation technique (TBI).

5.2.1 TBI Setup: The TBI point of calibration is at 267.5 cm SAD with the collimator at 90 cm, the gantry at 270° and a collimator field size of 40 cm x 40 cm.

5.2.2 Machine Output: Absorbed dose to muscle per monitor unit at nominal dmax (2.5 cm), for the TBI set-up.

RPC (cGy/mu)	Institution (cGy/mu)	RPC/Inst.
0.1787	0.1827	0.98

5.2.3 Depth Dose Data: The institution uses its own measured central axis tissue maximum ratios (TMR). The RPC factors were normalized to the institutions values at dmax (2.5 cm) in water. The values given are for 267.5 cm SAD using the institutions standard TBI setup.

Depth (cm x cm)	RPC⁺ (TMR)	Institution⁺ (TMR)	RPC/Inst.
2.5	(100)	100	-
10	0.910	0.909	1.00
20	0.754	0.769	0.98

⁺The RPC measured percent depth dose values and converted these to TMR's using an inverse square correction only. This is appropriate for the condition when the phantom is smaller than the beam.

5. Results of measurements (cont'd).

5.3 Clinac 2500 linear accelerator, electrons.

5.3.1 Machine Output: Absorbed dose to muscle per monitor unit measured at the institution's stated depth of maximum dose, unless otherwise noted, 10 cm x 10 cm field, 100 cm SSD, 5 cm from the distal edge of the cone.

Nominal Energy (MeV)	Mean Incident Energy (MeV)	Depth (cm)	RPC (cGy/mu)	Institution+ (cGy/mu)	RPC/Inst.
6*	5.6	1.2†	1.020	1.000 (1.008)	1.02
9	8.3	1.6†	1.013	1.000 (1.005)	1.01
12	11.3	2.2	1.016	1.000 (1.000)	1.02
15	14.2	2.6	1.017	1.000 (1.008)	1.02
22	20.1	1.4	1.019	1.000 (1.006)	1.02

+The dose rates listed are the values used clinically by the institution. The values in parentheses are the dose rates measured by the institution using their primary chamber system at the time of the RPC visit. The RPC dose rates have been adjusted to account for these variations in machine output. See the Appendix.

†The RPC searched for the depth of maximum ionization.

*During the calibration of this beam fluctuations in output (dose/MU) of up to 2% were noted. See recommendation 2.5.

5.3.2 Depth Dose Data: Determination of the depths of 80% and 50% doses on the central axis, 100 cm SSD, 10 cm x 10 cm cone size. The institution's depth dose data were obtained from measurement with an ion chamber in a water phantom.

Nominal Energy (MeV)	%dd	RPC+ Depth (cm)	Institution Depth (cm)	RPC-Inst. (cm)
6	(80%)	2.0	1.9	0.1
	(50%)	2.4	2.3	0.1
9	(80%)	2.9	2.8	0.1
	(50%)	3.6	3.4	0.2
12	(80%)	4.0	3.9	0.1
	(50%)	4.9	4.7	0.2
15	(80%)	5.2	5.1	0.1
	(50%)	6.2	6.1	0.1
22	(80%)	7.0	7.0	0.0
	(50%)	8.9	8.8	0.1

+Interpolated or extrapolated values

5.6.3 The localization film irradiated by the RPC indicates that the 6 MeV radiation field was symmetric. See Figure 5.

5. Results of measurements (cont'd).

5.4.1 Brachytherapy sources.

The RPC measured the source strengths of brachytherapy sources listed below. These Cs-137 micrad source strengths are decayed to December 9, 1998. The institution values for Cs-137 are decayed quarterly and Ir-192 (HDR) is decayed to date of clinical use.

Source Description	RPC+	RPC+ (S_K)	Institution (S_K)	RPC/Inst.
	(S_K)			
Cs 137 micrad sources from Gamma Industries				
G1 174	39.53	5.456	5.492	0.99
G1 195	39.10	5.397	5.492	0.98
G1 134	39.68	5.477	5.492	1.00
G1 168	41.67	5.752	5.492	1.05
G1 141	39.50	5.452	5.492	0.99
G1 142	38.93	5.374	5.492	0.98
G1 134	40.63	5.608	5.492	1.02
G1 202	39.44	5.443	5.492	0.99
G1 204	40.91	5.646	5.492	1.03
G1 199	40.42	5.579	5.492	1.02
G1 203	39.73	5.484	5.492	1.00
G1 200	39.39	5.437	5.492	0.99
Ir-192 (HDR)	3.686×10^4	9.15	9.02++	1.01++

+Units of air kerma strength (S_K) are $\mu Gy \bullet m^2 \bullet hr^{-1}$, kerma to air in air, corrected for air attenuation and scatter. Units of S_X are mg-eq (0.5 mm Pt) for Cs-137, Ci for Ir-192 (HDR). See the Appendix.

++Prior to entering the measured source strengths into the Nucletron computer system the institution's multiplies this value by the ratio of gamma factors between NIST and Nucletron 0.460 and 0.466, respectively. This is the procedure recommended by the University of Wisconsin Calibration Laboratory.

6. Institution's calibration technique.

For 4 , 6 and 24 MV x-ray beam ionizations are measured at nominal SSD in water at 5, 5, and 7 cm depths, respectively. For electron beams, ionization is measured at 100 cm SSD, d_{max} depth in polystyrene.

The institution calculates absorbed dose rate to muscle at 7 cm depth for 24 MV x-rays and d_{max} for all other beams.

PHOTON BEAMS

$$\left(\frac{M}{U}\right) \bullet N_{gas} \bullet \left(\frac{L}{\rho}\right)_{air}^{poly} \bullet P_{wall} \bullet P_{ion} \bullet P_{repl} \bullet \left(\frac{\mu_{en}}{\rho}\right)_{water}^{muscle} \bullet \left(\frac{1}{ddf}\right)$$

ELECTRON BEAMS

$$\left(\frac{M}{U}\right) \bullet N_{gas} \bullet \left(\frac{L}{\rho}\right)_{air}^{poly} \bullet P_{repl} \bullet P_{ion} \bullet \phi \bullet \left(\frac{S}{\rho}\right)_{poly}^{water} \bullet \left(\frac{S}{\rho}\right)_{water}^{muscle}$$

Where:

$\frac{M}{U}$	=	Meter reading corrected to 22°C and 760 mmHg, per monitor unit .
N_{gas}	=	Cavity gas calibration factor.
$\left(\frac{L}{\rho}\right)_b^a$	=	Mean restricted collision mass stopping power ratio.
P_{wall}	=	Wall correction factor.
P_{ion}	=	Ion recombination correction factor.
P_{repl}	=	Replacement correction factor.
$\left(\frac{\mu_{en}}{\rho}\right)_b^a$	=	Mean mass energy absorption coefficient ratio.
$\left(\frac{S}{\rho}\right)_b^a$	=	Mean unrestricted collision mass stopping power ratio.
ϕ	=	Electron fluence correction.
ddf	=	The factor (percent depth dose, tissue-air ratio, tissue-maximum ratio, etc.) used to convert absorbed dose at the calibration depth to that at d_{max}.

7. Review of Patient Dosimetry.

The RPC reviewed the institution's calculation of tumor dose delivery for four reference cases. The RPC also reviewed several patient treatment records and found the institution to be consistent in the application of their dosimetry system.

Reference Case	Treatment Machine(beam)	RPC/Inst.
1. Brain	Clinac 4/100 (4 MV X-rays)	1.01
2. Wedge	Clinac 4/100 (4 MV X-rays)	1.02
3. Lung	Clinac 4/100 (4 MV X-rays)	
Pt. A (central axis)	(MUCalc)	1.05*
	(ADAC)	1.03
Pt. B (lower mediastinum)	(ADAC)	1.02
Pt. C (supraclavicular)	(ADAC)	1.01
4. Breast (NSABP prescription point)	Clinac 600CD (6 MV X-rays)	1.00

The institution's calculations for these reference cases were performed using in-house software for monitor unit calculations and Pinnacle for dose distributions. The RPC used the institution's output, depth dose, wedge and tray transmission factors from the tabular data normally used in manual calculations by the institution. The RPC used its own measured off-axis factors and applied correction for change in beam energy off-axis. The RPC calculations were performed using the Cundiff method et. al. (reference 3) as modified by Hanson et. al. (reference 4).

*These values are marginally within the RPC’s 5% criterion on tumor dose delivery. The institution’s mu calculation system does not apparently separate collimator and phantom scatter. See recommendations 2.2, 2.6, 2.11 and Sections 9.8 and 9.9.

8. Calculation of potential discrepancies in stated tumor dose (RPC/Inst.).

Calculations detailed in this section for each machine indicate the range of the worst case compounded discrepancies (minima and maxima) between the RPC and the institution for tumor dose delivery. These values are the product of the individual RPC/Institution ratios for each parameter in this document. The RPC calculates tumor dose as delivered to muscle. These results are summarized in Section 1.

8.1 Clinac 4/100 linear accelerator, 4 MV x-rays.

Field(cm x cm)	Output	Wedge	Tray	Depth Dose	Muscle/water	Product
20 x 20	1.010	0.982	-	-	-	0.99
6 x 6	1.0.20	1.005	-	1.032	-	1.06*

8.2 Clinac 600CD linear accelerator, 6 MV x-rays.

Field(cm x cm)	Output	Wedge	Tray	Depth Dose	Muscle/water	Product+
6 x 6	1.017	-	-	0.997	-	1.01
asym 20 x 20	1.061	-	-	-	-	1.06*
asym 20 x 20	0.983	-	-	-	-	(0.98)
10 x 10	1.019	1.025	-	-	-	(1.04)

8.3 Clinac 2500 linear accelerator, 6 MV x-rays.

Field(cm x cm)	Output	Wedge	Tray	Depth Dose	Muscle/water	Hor/Ver	Product
6 x 6	1.020	-	-	0.997	-	-	1.02
20 x 20	1.024	1.044	-	0.997	-	1.031	1.10*

8.4 Clinac 2500 linear accelerator, 24 MV x-rays.

Field(cm x cm)	Output	Wedge	Tray	Depth Dose	Muscle/water	Product
20 x 20	1.026	0.992	-	-	-	1.02
20 x 20	1.026	1.020	-	1.001	-	1.05

8.5 Clinac 2500 linear accelerator, electrons.

Energy	Cone (cm x cm)	Output	Cone Ratio	Muscle/Water	Product
9	10 x 10	1.013	-	-	1.01
6	10 x 10	1.020	-	-	1.02

8.6 Clinac 2500 linear accelerator, TBI (24 MV x rays).

Output	Depth Dose	Muscle/Water	Product
0.978	0.981	-	0.96
0.978	1.001	-	0.98

*These data exceed the RPC's 5% criteria for tumor dose.

+The change in min/max tumor dose determination reflects revised mu set procedures by the institution email to the RPC on April 6, 2000.

9. Analysis of discrepancies.

9.1 The discrepancy in the wedge transmission with increased depth or field sizes is due to beam hardening or increased scatter by the wedge, respectively. If the institution's calculation of meter set uses a single transmission factor, irrespective of field size and depth, then the treatment may result in significant discrepancy in dose delivery. The change in wedge transmission can be characterized by a variable transmission factor or by depth dose data specific to the wedge.

9.2 All measured photon outputs at this institution were found to be 2% high ± 1%. This results from a combination of a 1.4% discrepancy in calibration factor between the RPC's dosimetry system and the institutions field system combined with a 0.5% discrepancy in air pressure measurements between the institution and the RPC. The institutions field system, the system used for beam calibrations, is not directly traceable to an ADCL. If the institution switched to their traceable system for calibrations this would remove 0.7% of this discrepancy. The discrepancy in air pressure is most likely caused by contamination of the mercury in the institutions "standard" barometer, having the mercury cleaned and the barometer calibrated would rectify this discrepancy.

9.3 The output of the 6 MV X-ray beam of the Clinac 2500 was found to change by more than 3% when the gantry was rotated from the vertical to horizontal positions. This is beyond the service criteria for this parameter and should be investigated by a linac service engineer. This factor combined with discrepancies in output (see recommendation 9.2) and in wedge factors for large field sizes (see recommendation 9.1) could potentially lead to a 10% overdose to patients treated on this machine.

9.4 "The radiation oncology physicist is responsible for acceptance testing, commissioning calibration, and periodic QA of therapy equipment. In particular the physicist must certify that the therapy units and planning systems are performing according to specifications, generate beam data, and outline ***written*** *QA procedures which include tests to be performed, tolerances, and frequency of the tests."*

9.5 Establishment of Dose Calculation Procedures. "A major responsibility of the radiation oncology physicist is to establish the dose calculation procedures that are used throughout the department and to assure their accuracy." (AAPM TG-40, Ref 5 P. 13)

9.6 The discrepancies with mu calc algorithm are identified in Section 9.7. The discrepancies with ADAC could not be identified at this time.

9.7 The discrepancy in dose rates for off-axis points in asymmetric field is probably due to the institution's failure to include off center ratios in their determination of dose rates at off-axis points. We were not able to get documentation from the institution on their method for calculation off-axis points.

9. Analysis of discrepancies (cont'd).

9.8 The reference cases presented to the RPC demonstrate that the institution's MU calculations software uses the effective field size to determine output factor. This does not take into account the difference in collimation scatter (Sc) and phantom scatter (Sp). In reference cases 1 and 2 this only leads to a 1-2% discrepancy but in reference case 3, due to the large amount of blocking, this leads to a 5% discrepancy.

9.9 Although the discrepancies between the RPC and the institution are not obviously due to a lack of training on ADAC by the dosimetrist, observation at the time of this visit suggested the need for more training.

10. References.

1. Task Group 21, Radiation Therapy Committee, American Association of Physicists in Medicine. "A Protocol for the Determination of Absorbed Dose from High-energy Photon and Electron Beams", *Med. Phys.* **10**:741-771 (1983).
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4. W.F. Hanson, L.W. Berkley and M. Peterson: "Calculative Technique to Correct for the Change in Linear Accelerator Beam Energy at Off-Axis Points", *Med. Phys.* **7**:147-150, 1980.
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Dates of measurements:

December 6 - 11, 1998

Date sent to institution:

Date comments received
from institution:

Measurements by:

____
RPC Physicist

Checked by:

____
RPC Second Physicist

____
William F. Hanson