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Beam characteristics of the Therapax DXT300 orthovoltage therapy unit

L Gerig†‡§, M Soubra† and D Salhani†§

† Ottawa Regional Cancer Centre, Ottawa, Ontario, Canada
‡ Carleton University, Ottawa, Ontario, Canada
§ University of Ottawa, Ottawa, Ontario, Canada

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Abstract. The operating performance and beam characteristics of a new orthovoltage unit, the Therapax DXT300, have been evaluated. Percentage depth–dose and backscatter tables are presented for several applicator sizes, at 30 cm and 50 cm focal skin distances (FSDs) and for multiple x-ray beam qualities with the tube operating between 100 and 300 kVp accelerating potential. The unit has been found to provide beam characteristics similar to those reported for other orthovoltage therapy machines. The linearity and short- and long-term stability/reproducibility of the unit's internal dosimetry system have also been studied, and results indicate a very stable beam output of better than 1% standard deviation. The data presented in this work should provide the basis for comparison with other units and act as a reference for clinics commissioning the Therapax DXT300 in the future.

1. Introduction

The last few decades have seen significant growth in the number of installed linear accelerators with electron therapy capabilities. This has been associated with a concomitant decline in orthovoltage and superficial x-ray therapy units.

In the Canadian cancer therapy community, there has been a recent reversal in this trend, with at least 10 new orthovoltage or superficial units being ordered/installed in the last five years.

We have recently taken delivery of a new variable-energy orthovoltage unit, the Therapax DXT300, manufactured by Pantak and marketed in Canada by Theratronics International.

In this work we will report on the operating performance and beam characteristics of this unit. Similar studies have been reported for the Phillips RT250 (Kurup and Galsgow 1993, Scrimger and Connors 1986) and for the Siemens Stabilipan 2 (Nimroomand-Rad *et al* 1987). Our data should be of interest to prospective buyers of the Therapax DXT300 and should provide a data base for comparison with other units.

2. Materials and methods

2.1. The Therapax DXT300

The principal components of the Therapax DXT300 orthovoltage x-ray therapy unit include a computerized control console (CPU), a high-voltage control system and generator, a cooling

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Table 1. Clinical applicator cones.

FSD (cm)	Cone identification	Size
30	A	2 cm diameter
	B	4 cm diameter
	C	6 cm diameter
	D	8 cm diameter
	E	8×8 cm^2
50	F	10 cm diameter
	G	6×12 cm^2
	H	10×10 cm^2
	I	12×12 cm^2
	J	12×15 cm^2
	K	10×20 cm^2
	L	20×20 cm^2

system (oil→water or oil→air), a Comet x-ray tube (model No MXR-321), a dosimetry system, and a set of applicators. The unit is provided with either a pedestal wall mount or a ceiling mounted support system.

The x-ray tube has a power rating of 300 kW, and is configured to operate at accelerating potentials between 40 and 300 kVp. For clinical operation the control system ensures that the tube never operates above 3 kW and that the tube current never exceeds 30 mA. The Comet x-ray tube is of metal–ceramic design and has an anode angle of 30° and a 5 mm beryllium window.

To our knowledge the Therapax DXT300 is the first commercially available orthovoltage unit with its own internal dosimetry system. This consists of a PTW Diamentor-M3 250 cm^3 pancake chamber, operating at 500 V bias. In clinical mode the unit can be operated to terminate treatment by dose in terms of monitor units (MU) with timer backup or to terminate by time with a second independent timer as backup in a similar fashion to traditional orthovoltage units.

The ion chamber is located between the slot provided to accommodate the added filtration and the housing slot for the beam applicator (cones). At our centre a 1.6 mm Lexan window has been added on the exit side of the ion chamber to protect it from potential mechanical damage.

The unit as delivered to our centre has 12 applicators: five open ended cones with a focal surface distance (FSD) of 30 cm, and seven closed 50 cm FSD applicators with a 3 mm Perspex end plate. There are also eight beam hardening filters. The individual filters and the cone FSD are coded and recognized by the control system. The applicators and beam hardening filters are listed in tables 1 and 2, respectively.

Table 2. Beam hardening filters.

Filter No	Filter composition
F1	1.65 mm Al
F2	2.40 mm Al
F4	0.1 mm Cu + 2.5 mm Al
F8	0.8 mm Sn + 0.25 mm Cu + 1.5 mm Al

The system provides a mechanism for the user to configure up to eight combinations of generating potential, tube current, and beam hardening filter. These combinations are encoded in software and provide the mechanism for auto-selection of kVp and mA once a beam filter is inserted. To date we have configured four of these combinations, as described in table 3.

Table 3. Measured 1st and 2nd HVLs.

Filter	kVp	mA	First HVL	Second HVL	Homogeneity
F1	100	30	2.43 mm Al	4.17 mm Al	0.58
F2	150	20	4.39 mm Al	8.01 mm Al	0.54
F4	200	15	0.63 mm Cu	1.12 mm Cu	0.56
F8	300	10	3.67 mm Cu	4.48 mm Cu	0.82

2.2. Beam quality

X-ray beam quality was determined by quantifying the beam attenuation by thickness of either aluminum or copper. The attenuator thicknesses were accurately measured by our mechanical engineering department. Ionization measurements were made with a Nuclear Enterprises model 2570 electrometer and model 2571 graphite 0.6 cm^3 ion chamber. These measurements were performed under narrow-beam geometry with the ion chamber at a distance of approximately 85 cm from the source, consistent with the method proposed by the IAEA (1987).

2.3. Relative beam data in water: PDD, profiles, isodose curves

All relative beam data were measured in water using Scanditronix's Therados RFA 300 dosimetry system. Most measurements were made in the integration mode with a scan step size functionally dependent upon the spatial dose gradient. In regions of high dose gradient (i.e. across the applicator edges and at shallow depths) the scan step was 1 mm. In other regions a scan step of 2 mm was used. For the depth–dose measurements a Scanditronix parallel plate waterproof NACP ion chamber with a 0.5 mm graphite ($\rho = 1.05$ g cm^{-3}) window was used. Beam profile data were acquired using a Scanditronix 0.12 cm^3 cylindrical RK ion chamber. Isodose distributions were reconstructed from beam profiles and central axis percentage depth–dose curves using the Therados software.

Relative beam data were measured for each beam quality with the 50 cm FSD applicators. For the 30 cm FSD applicators only the two less energetic beams were studied.

Beam profiles acquired for isodose reconstruction were measured in the X plane (where X plane direction is defined as being perpendicular to the anode–cathode axis, while the In plane direction is parallel to the anode–cathode axis) in depth increments corresponding to approximately 5% depth–dose increments. Beam profiles taken to compare In and X plane were measured at 1.0 cm below the surface, and three other depths corresponding to approximately 80%, 50%, and 20%.

2.4. Backscatter factors

Backscatter factors were measured for all the x-ray beam qualities listed in table 3 using the Scanditronix 0.12 cm^3 cylindrical RK ion chamber. Measurements were made by fixing the ion chamber centrally at the end of each applicator. The system was configured such that for the air measurements no scattering medium was in the vicinity of the detector. For measurements in full scatter condition, the ion chamber was immersed in a water phantom such that the detector midline axis was flush with the water surface, while maintaining the same spatial relationship between the ion chamber and the source/applicator. The ratio of the reading in water to that in air provided the measured backscatter factors for each applicator at each energy.

2.5. Internal dosimetry system

The performance of the Therapax DXT300 internal dosimetry system was tested for dose and dose rate linearity, temperature–pressure correction accuracy, reproducibility and long-term stability. All measurements of the internal dosimetry system were compared against our secondary standard electrometer (Nuclear Enterprise model 2570) and 0.6 cm^3 graphite ion chamber (Nuclear Enterprise model 2571), traceable to the Canadian National Standards Laboratory.

The linearity of the internal dosimetry system was assessed as a function of total dose and tube current. For these measurements the ion chamber was placed on the central axis of the x-ray beam with a well defined geometry. At each of the four beam qualities, the response of the internal ion chamber was compared with the 0.6 cm^3 graphite ion chamber response in the range from 1 to 1000 MU. In addition, a similar comparison was made between the internal dosimetry system and the reference chamber as a function of tube current. For each of the four beam qualities used in this study, the tube current was varied from 0.1 mA up to the maximum allowable; 30 mA for 100 kVp, 20 mA for 150 kVp, 15 mA for 200 kVp, and 10 mA for 300 kVp.

The internal ion chamber is unsealed. The Therapax unit provides a mechanism through the control console software to adjust the monitor system gain in order to compensate for variations in the mass of air in the ion chamber resulting from changes in temperature and pressure. The performance of this system was tested by entering a range of temperature and pressure values and measuring the corresponding change in monitor unit size or calibration factor (cGy per MU).

The long- and short-term stability of the internal dosimetry system was measured at each of the four defined beam qualities. Short-term stability/reproducibility was estimated by comparing 50 consecutive measurements to the NE dosimetry system. The NE dosimetry system has been shown to be reproducible to better than 0.2% as measured against ^{60}Co. Similarly, the long-term stability of the Therapax dosimetry system was determined by a series of absolute calibrations over a period of several months.

2.6. Calibration

Absolute calibration was performed using the NE dosimetry system described above. Measurements were performed in air with the central axis of the ion chamber perpendicular to the photon beam axis and perpendicular to the anode–cathode axis. The ion chamber was positioned as close as possible to the face of the therapy applicator being calibrated. The dose calibration (the number of cGy delivered per monitor unit) at the tissue surface for each energy, D_{rdr} (cGy per MU), was determined (ICRU 1973) as

$$D_{rdr} = M N_x F_t \text{ ISL BSF/MU}$$

where M is the temperature–pressure corrected instrument reading, F_t the cGy/Roentgen conversion factor for tissue, N_x the exposure calibration factor for the instrument, ISL the inverse square correction for chamber standoff, BSF the measured backscatter factor for the cone field size, and MU the number of monitor units delivered.

3. Results and discussion

The measure beam quality of the four accelerating potential and filter combinations are presented in table 3 in terms of the first and second HVLs and the homogeneity factor. It should be noted that the lowest accelerating potential examined in this work is 100 kVp, although the unit is capably of operating at energies as low as 40 kVp. In the range of accelerating potentials from 100 to 300 kVp, and employing only the added filtration provided by the manufacturer, this unit is capable of providing clinically useful beams with qualities (HVL) ranging from 2.43 mm Al to 3.67 mm Cu. It is quite difficult to directly compare the beam quality measured in this work to the beam qualities published by other workers for different orthovoltage units, in particular because different added filtrations were used for similar accelerating potentials. However, general observations can be made and are summarized in tables 4–6 comparing the results of Kurup and Galsgow (1993) and Scrimger and Connors (1986), who have measured the performance characteristics of the Philips RT250 unit, and Nimroomand-Rad *et al* (1987), who have investigated the Siemens Stabilipan 2. It is interesting to note the large variation in HVL between the various commercially available units at the same accelerating potential, while the homogeneity factors at the same accelerating potential are similar for the Therapax and the Siemens.

Representative 10×10 cm^2, 50 cm FSD percentage depth–dose (PDD) curves in water are shown in figure 1 for four beam qualities. Tables 7–12 list the measured PDD for a range of field sizes, at 30 and 50 cm FSD, for the beam qualities of 2.43 mm Al, 4.39 mm Al, 0.63 mm Cu, and 3.67 mm HVL. Over this range of HVLs, the least penetrating beam has its 50% PDD at a depth of 3.1 cm in water for a 10 cm diameter applicator while the most penetrating beam with the same applicator has its 50% PDD at 6.5 cm and delivers 31% PDD at 10 cm deep. In table 13 the depth of the 50% dose determined in this work is compared to data interpolated from that published in the *British Journal of Radiology (Supplement 17)*. As can be seen, for all but the highest energy the data in this work agree very closely with that compiled in the *British Journal of Radiology (Supplement 17)*. At an accelerating potential of 300 kVp and a first HVL of 3.67 mm Cu a difference of 5 mm in depth of the 50% dose is reported. This may be due to differences in beam quality (homogeneity factor) or a difference in the end plate of the closed end applicator as discussed by Tsien and Cohen (1962).

Figure 2 is isodose distributions for the 20×20 cm^2, 50 cm FSD applicator for the four beam qualities measured. These curves are generated from beam profiles measured in the X plane and represent the largest fields clinically available on this treatment unit. Of clinical interest is the energy dependence of the penumbra and the width of the 90% and 95% isodose lines. Tables 14 and 15 list the penumbral width (10%–90% and 20%–80%) at a depth of 1 cm for two 50 cm FSD applicators, a large (20×20 cm^2) and a small (6×12 cm^2) applicator size, respectively, as a function of x-ray energy. Results are shown in the tables for data measured in the In plane and X plane directions.

We have found a difference in the beam profiles measured In plane versus those measured in the X plane. This is demonstrated in figure 3, for a 20×20 cm^2 50 cm FSD applicator, which compares beam profiles measured In plane to those in the X plane at

Table 4. Beam quality comparison at 100 kVp.

Parameter	Scrimger and Connors (1986)	Kurup and Galsgow (1993)	Nimroomand-Rad *et al* (1987)	This work
Filtration	0.2 mm Cu	0.2 mm Cu	2.0 mm Al	1.65 mm Al
First HVL	0.19 mm Cu	0.21 mm Cu	3.0 mm Al	2.43 mm Al
Second HVL	0.33 mm Cu	0.36 mm Cu	0.21 mm Cu	4.17 mm Al
Homogeneity	0.58	0.58	NA	0.58

Table 5. Beam quality comparison at 200 kVp.

Parameter	Scrimger and Connors (1986)	Kurup and Galsgow (1993)	Numroomand-Rad *et al* (1987)	This work
Filtration	0.5 mm Cu	0.5 mm Cu	1.0 mm Cu	0.1 mm Cu + 2.5 mm Al
First HVL	1.0 mm Cu	1.07 mm Cu	1.33 mm Cu	0.63 mm Cu
Second HVL	1.7 mm Cu	1.81 mm Cu	1.73 mm Cu	1.12 mm Cu
Homogeneity	0.59	0.59	0.77	0.56

Table 6. Beam quality comparison at 300 kVp.

Parameter	Nimroomand-Rad *et al* (1987)	This work
Filtration	1.2 mm Sn + 0.25 mm Cu + 1.5 mm Al	0.8 mm Sn + 0.25 mm Cu + 1.5 mm Al
First HVL	3.7 mm Cu	3.67 mm Cu
Second HVL	9.8 mm Cu	4.48 mm Cu
Homogeneity	0.38	0.82

a depth of 1 cm for each of the four beam qualities. Table 16 documents the measured In and X plane beam symmetry, defined as

$$(\text{area}_L - \text{area}_R)/(\text{area}_L + \text{area}_R) \times 100$$

where area_L and area_R are the integrated doses from the beam profile origin to the position of the left and right 50% dose level, respectively, such that the lower the numerical value the more symmetric the beam. From these data it can be seen that the photon beam symmetry is dependent upon the beam axis and energy. The beam symmetry (and flatness) is almost the same in both the X and In plane directions for accelerating potentials of 200 kVp and less. At higher accelerating potentials, the symmetry is significantly better in the plane perpendicular to the acceleration axis of the electron beam. This is undoubtedly due to the fact that the useful photon beam is extracted 90° from the anode–cathode acceleration axis. As the energy increases, the bremsstrahlung radiation becomes more forward directed, resulting in a higher dose rate on the anode side of the x-ray tube. These effects do not influence the beam profile in the X plane direction.

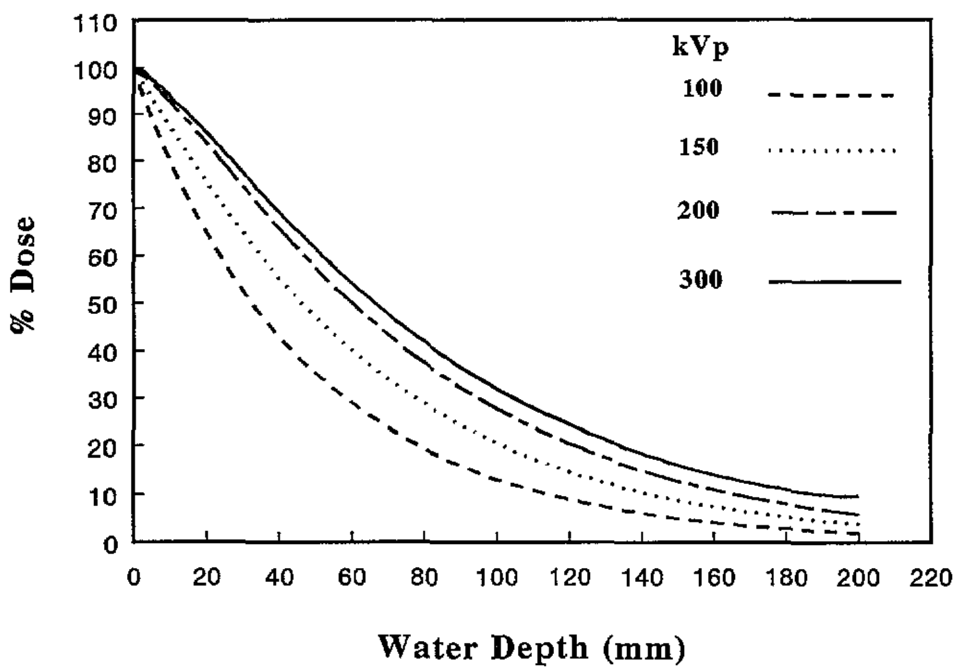

Figure 1. PDD curves in water for a 10 × 10 cm², 50 cm FSD applicator from 100, 150, 200, and 300 kVp x-ray beams.

Table 17 compares the backscatter factors measured in this work to data interpolated from the *British Journal of Radiology (Supplement 17)*. As can be seen the data from this work are quite close to those reported in the *British Journal of Radiology*, with a maximum difference of 2.3%. Recent published data (Carlsson 1993, *British Journal of Radiology (Supplement 17)* 1983, Grosswendt 1990, 1993, Klevenhagan 1989, Kurup and Galsgow 1993, Nimroomand-Rad *et al* 1987, Scrimger and Connors 1986) indicate a range in the

Table 7. PPDs (30 cm FSD): 2.43 mm Al HVL, 100 kVp.

Depth (cm)	Cone A 2 cm diameter	Cone B 4 cm diameter	Cone C 6 cm diameter	Cone D 8 cm diameter	Cone E 8 × 8 cm^2
0	100	100	100	100	100
0.2	93.6	94.5	94.9	95.4	95.1
0.5	84.7	86.8	87.8	88.8	88.2
1.0	71.7	75.2	77.0	78.8	77.8
1.5	60.4	65.1	67.5	69.8	68.6
2.0	50.9	56.2	59.1	61.8	60.5
2.5	42.9	48.6	51.7	56.7	53.3
3.0	36.2	42.0	45.2	48.3	47.0
4.0	25.9	31.3	34.7	37.8	36.6
5.0	18.8	23.5	26.6	29.5	28.6
6.0	14.0	17.7	20.6	23.1	22.4
7.0	10.6	13.5	16.0	18.2	17.7
8.0	8.2	10.5	12.5	14.4	14.1
10.0	5.0	6.4	7.9	9.2	9.0
12.0	2.7	3.9	4.9	6.0	5.7
15.0	1.0	1.8	2.4	3.1	2.9

Table 8. PDDs (50 cm FSD): 2.43 mm Al HVL, 100 kVp.

Depth (cm)	Cone F 10 cm diameter	Cone G 6 × 12 cm^2	Cone H 10 × 10 cm^2	Cone I 12 × 12 cm^2	Cone J 12 × 15 cm^2	Cone K 10 × 20 cm^2	Cone L 20 × 20 cm^2
0	100	100	100	100	100	100	100
0.2	95.6	95.4	95.6	95.8	95.8	95.8	96.0
0.5	89.3	88.9	89.3	89.7	89.9	89.8	90.4
1.0	79.7	79.0	79.8	80.5	80.8	80.6	81.7
1.5	71.1	70.2	70.8	72.3	72.7	72.4	73.9
2.0	63.4	62.3	63.6	64.9	65.4	65.1	66.9
2.5	56.6	55.4	56.9	58.3	58.9	58.5	60.6
3.0	50.5	49.2	50.8	52.4	53.1	52.7	55.0
4.0	40.3	39.0	40.7	42.4	43.2	42.8	45.4
5.0	32.0	31.0	32.8	34.5	35.3	34.9	37.6
6.0	25.9	24.8	26.4	28.1	29.0	28.5	31.4
7.0	20.9	19.9	21.4	23.0	23.8	23.5	26.2
8.0	16.9	16.1	17.5	18.9	19.7	19.3	22.0
10.0	11.2	10.6	11.6	12.7	13.4	13.1	15.5
12.0	7.5	7.0	7.8	8.5	9.0	8.9	10.9
15.0	4.1	3.8	4.2	4.6	5.1	4.9	6.4

reported backscatter factors for photon beams of the same quality. It has been pointed out by several of these authors that the backscatter factors are FSD dependent. Carlsson (1993) has provided a comprehensive assessment of the many factors that can influence the measured backscatter factors. It is well known that although the beam energy is defined by its quality or HVL, beams of the same quality (HVL) can have significantly different photon spectra, and hence it is difficult to compare BSF factors on the basis of the first HVL only. With these considerations it is clear that the measured BSFs in this work are well within the range of the published data, particularly when the FSD dependent corrections are applied.

The performance characteristics of the internal dosimetry system were studied from several aspects. In figure 4, the response of the Therapax dosimetry system is plotted against that of our Nuclear Enterprise (NE) secondary standard for exposures ranging from 1 to 1000 monitor units. These data were measured at the maximum tube current for each

Table 9. PDDs (30 cm FSD): 4.39 mm Al HVL, 150 kVp.

Depth (cm)	Cone A 2 cm diameter	Cone B 4 cm diameter	Cone C 6 cm diameter	Cone D 8 cm diameter	Cone E 8×8 cm^2
0	100	100	100	100	100
0.2	94.7	95.8	96.2	96.6	96.8
0.6	84.9	87.9	88.9	89.9	90.5
1.0	76.0	80.5	82.1	83.6	84.5
1.5	66.2	72.0	74.1	76.2	77.5
2.0	57.6	64.2	66.8	69.2	70.8
2.5	50.1	57.2	60.1	62.8	64.7
3.0	43.6	50.8	54.0	56.8	58.9
4.0	33.0	39.9	43.4	46.1	48.6
5.0	25.1	31.2	34.7	37.2	39.8
6.0	19.2	24.3	27.7	29.9	32.5
7.0	14.8	19.0	22.1	23.9	26.5
8.0	11.6	14.9	17.6	19.2	21.6
10.0	7.1	9.4	11.5	12.6	14.4
12.0	4.4	6.3	7.7	8.5	9.9
15.0	2.1	3.4	4.3	4.5	5.4

Table 10. PDDs (50 cm FSD): 4.39 mm Al HVL, 150 kVp.

Depth (cm)	Cone F 10 cm diameter	Cone G 6×12 cm^2	Cone H 10×10 cm^2	Cone I 12×12 cm^2	Cone J 12×15 cm^2	cone K 10×20 cm^2	Cone L 20×20 cm^2
0	100	100	100	100	100	100	100
0.2	97.1	96.9	97.1	97.3	97.48	97.4	97.7
0.6	91.5	90.0	91.5	92.1	92.2	92.3	93.2
1.0	86.0	85.2	86.2	87.1	87.1	87.3	88.7
1.5	79.5	78.4	79.8	81.0	81.1	81.3	83.3
2.0	73.4	72.1	73.6	75.2	75.4	75.6	78.1
2.5	67.5	66.1	67.9	69.7	69.9	70.2	73.0
3.0	62.1	60.5	62.5	64.5	64.8	65.1	68.2
4.0	52.2	50.4	52.6	54.9	55.4	55.6	59.2
5.0	43.6	41.9	44.0	46.5	47.1	47.3	51.2
6.0	36.3	34.6	37.8	39.2	39.9	40.1	44.1
7.0	30.1	28.6	30.8	33.0	33.8	33.9	37.9
8.0	25.0	23.6	25.7	27.8	28.5	28.6	32.5
10.0	17.3	16.3	18.0	19.7	20.4	20.5	24.0
12.0	12.2	11.4	12.8	14.1	14.6	14.8	17.9
15.0	7.6	6.8	7.6	8.5	8.9	9.0	11.4

beam quality. The linearity of the dose response of the NE system has been verified against ^{60}Co. The relative data comparing the NE and Therapax dosimetry systems were fitted to a line with a fit coefficient of better than 0.999 in all cases. The intercept of the fitted curves with the ordinate was −0.15, 0.08, −0.31, and −0.015 for the 2.43 mm Al, 4.39 mm Al, 0.63 mm Cu, and 3.67 mm Cu beams, respectively (see figure 4). From this it can be concluded that within the clinical range of dose, the Therapax dosimetry system is linear and demonstrates minimal zero error or 'end effect'.

The Therapax dosimetry system was also studied for its dose rate (mA) dependence. Figure 5 is a plot of the ratio of the Therapax dosimetry system response to that of our secondary standard as a function of tube current. These data shows an excellent fit to a line with zero slope. Since the collection efficiency of the NE Farmer chamber has been calculated to have a variation of less than 0.3% over the range of exposure rates of these

Table 11. PDDS (50 cm FSD): 0.63 mm Cu HVL, 200 kVp.

Depth (cm)	Cone F 10 cm diameter	Cone G 6×12 cm^2	Cone H 10×10 cm^2	Cone I 12×12 cm^2	Cone J 12×15 cm^2	Cone K 10×20 cm^4	Cone L 20×20 cm^2
0	100	100	100	100	100	100	100
0.5	95.6	95.0	95.6	96.1	96.0	96.2	97.1
1.0	91.0	89.9	90.9	91.9	91.8	92.1	93.8
1.5	86.2	84.7	86.1	87.5	87.5	87.9	90.2
2.0	81.3	79.6	81.3	83.0	83.0	83.5	86.4
2.5	76.4	74.5	76.5	78.5	78.5	79.1	82.4
3.0	71.6	69.5	71.7	73.9	74.1	74.6	78.4
4.0	62.2	60.0	62.6	65.1	65.4	66.0	70.4
5.0	53.5	51.3	54.0	57.7	57.2	57.7	62.6
6.0	45.6	43.5	46.3	49.1	49.7	51.2	55.2
7.0	38.7	36.8	39.2	42.2	42.9	43.3	48.5
8.0	32.8	31.0	33.6	36.2	37.0	37.3	42.5
10.0	23.6	22.2	24.4	26.6	27.4	27.7	32.4
15.0	10.6	10.0	11.2	12.4	13.0	13.1	16.5
17.5	6.9	6.6	7.4	8.3	8.7	8.6	11.5
20.0	6.5	6.1	6.6	7.0	7.1	6.4	9.5

Table 12. PDDS (50 cm FSD): 3.67 mm Cu HVL, 300 kVp.

Depth (cm)	Cone F 10 cm diameter	Cone G 6×12 cm^2	Cone H 10×10 cm^2	Cone I 12×12 cm^2	Cone J 12×15 cm^2	Cone K 10×20 cm^2	Cone L 20×20 cm^2
0	100	100	100	100	100	100	100
0.5	96.5	96.2	96.6	96.9	96.8	97.1	97.7
1.0	92.8	92.1	92.8	93.5	93.4	93.9	95.0
1.5	88.8	87.9	88.9	89.9	89.8	90.5	92.1
2.0	84.7	83.6	85.4	86.1	86.1	86.9	89.0
2.5	80.5	79.2	80.7	82.3	82.3	83.3	85.7
3.0	76.3	74.9	76.6	78.4	78.5	79.5	82.3
4.0	68.1	64.0	68.6	70.7	71.0	72.0	75.5
5.0	60.2	58.5	60.9	63.3	63.7	64.6	68.6
6.0	52.9	51.1	53.6	56.2	56.9	57.6	62.1
7.0	46.3	44.6	47.2	49.8	50.5	51.2	55.9
8.0	40.4	38.8	41.3	43.9	44.7	45.3	50.2
10.0	30.7	29.4	31.7	34.0	35.0	35.4	40.2
12.5	22.0	20.9	22.8	24.7	25.6	26.0	30.4
15.0	15.7	14.9	16.4	17.9	18.7	19.0	22.7
20.0	9.6	9.2	9.9	10.6	10.9	10.2	12.6

Table 13. The depth of the 50% dose.

HVL	FSD (cm)	Field size	Depth (mm)	
2.43 mm Al	30	8 cm diameter	29.0[a]	29.8[b]
4.39 mm Al	30	8 cm diameter	37.0[a]	37.2[b]
0.63 mm Cu	50	10×10 cm^2	60.7[a]	60.5[b]
3.67 mm Cu	50	10×10 cm^2	71.1[a]	66.3[b]

[a] Interpolated from *British Journal of Radiology (Supplement 17)* (1983).
[b] Present work.

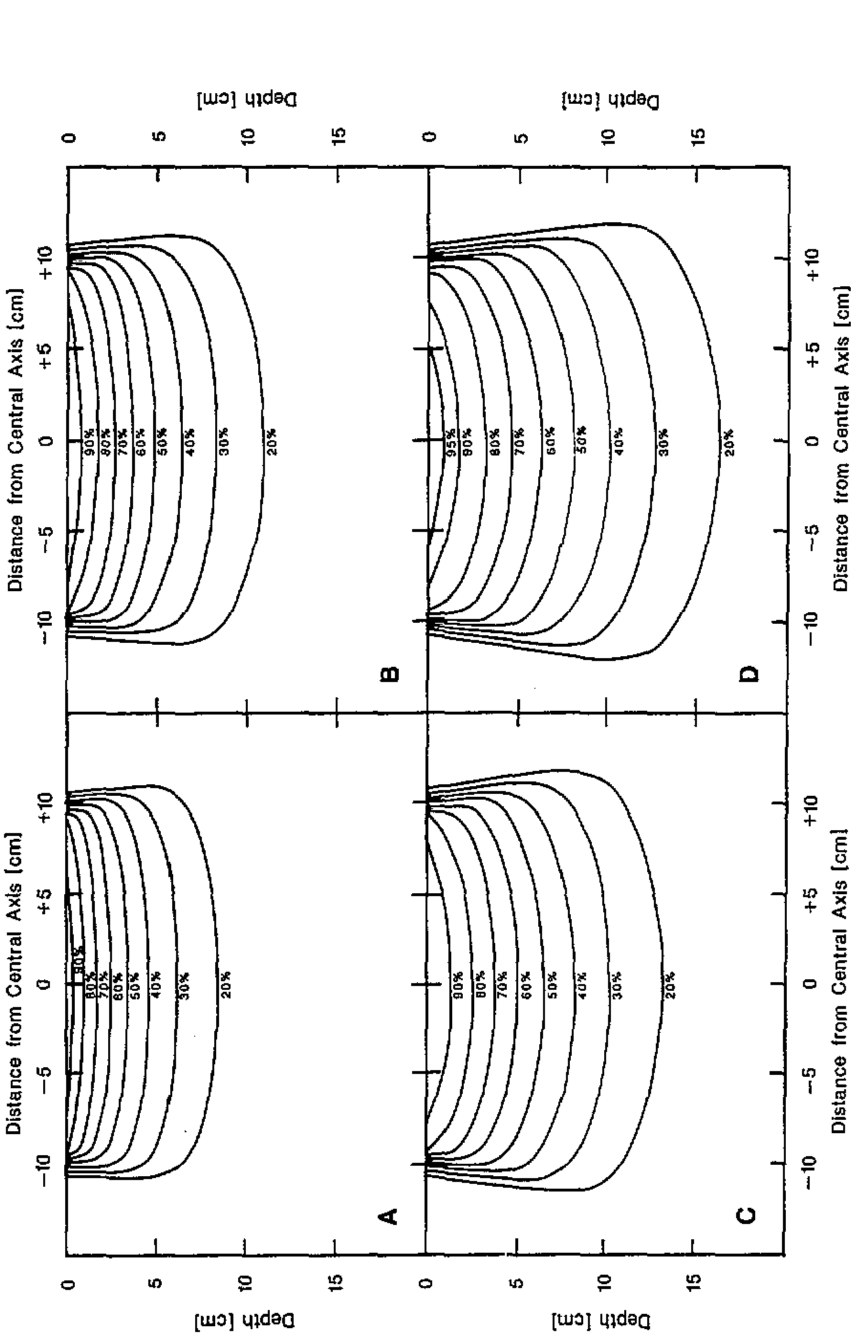

Figure 2. X plane isodose distributions in water for a 20 × 20 cm², 50 cm FSD applicator from (A), 100, (B) 150, (C) 200 and (D) 300 kVp x-ray beams.

Table 14. Penumberal width of 20×20 cm^2.

Energy (HVL) (kVp)	90%–10% (cm)		90%–20% (cm)		80%–20% (cm)	
	X	In	X	In	X	In
2.43 mm Al 100	3.1	3.2	2.2	2.2	0.9	1.0
4.39 mm Al 150	3.8	4.0	2.5	2.5	0.9	1.0
0.63 mm Cu 200	4.5	4.6	2.7	2.8	1.1	1.2
3.67 mm Cu 300	4.5	4.4	2.7	2.5	0.9	1.1

Table 15. Penumbral width of 6×12 cm^2, measured across the applicator in the 6 cm direction and in the X plane.

Energy (HVL) (kVp)	90%–10% (cm)	90%–20% (cm)	80%–20% (cm)
2.43 mm Al 100	1.6	0.7	0.4
4.39 mm Al 150	2.0	0.8	0.5
0.63 mm Cu 200	2.2	0.9	0.5
3.67 mm Cu 300	2.1	0.7	0.5

measurements, the Therapax dosimetry system provides a substantially flat response over the full range of dose rates available from the x-ray tube.

The Therapax dosimetry system has also been studied for its long- and short-term stability. To determine the short-term stability, 50 output measurements were made at each of the four beam energies over a 8 h period. When corrected for room temperature and pressure, the output had a total variation not exceeding ±0.5% with a standard deviation of less than 0.2% for all beam qualities. Long-term stability was studied over a four-month period by performing daily output checks for all the beam energies. These measurements had a total variation of less than ±1.8% with a standard deviation of less than 1.0%, from which we conclude that the Therapax dosimetry system provides a very stable beam monitoring device.

We have noted one potentially significant problem with the dosimetry system, in that it is incapable of reporting dose rates of less than 7 MU min^{-1}. This problem has been reported to the manufacturer and it is hoped it will be resolved in the near future.

A further problem with the dosimetry system is the use of an unsealed ion chamber, which is not automatically temperature–pressure corrected. The manufacturer provides a mechanism by which the operator may enter the room temperature and pressure at the control system to provide software compensation for these changes. This is not automatic however, and it is possible for a situation to occur whereby the temperature–pressure correction factor could easily change by 5% during the course of a treatment day, resulting in a concomitant error in delivered dose to patients.

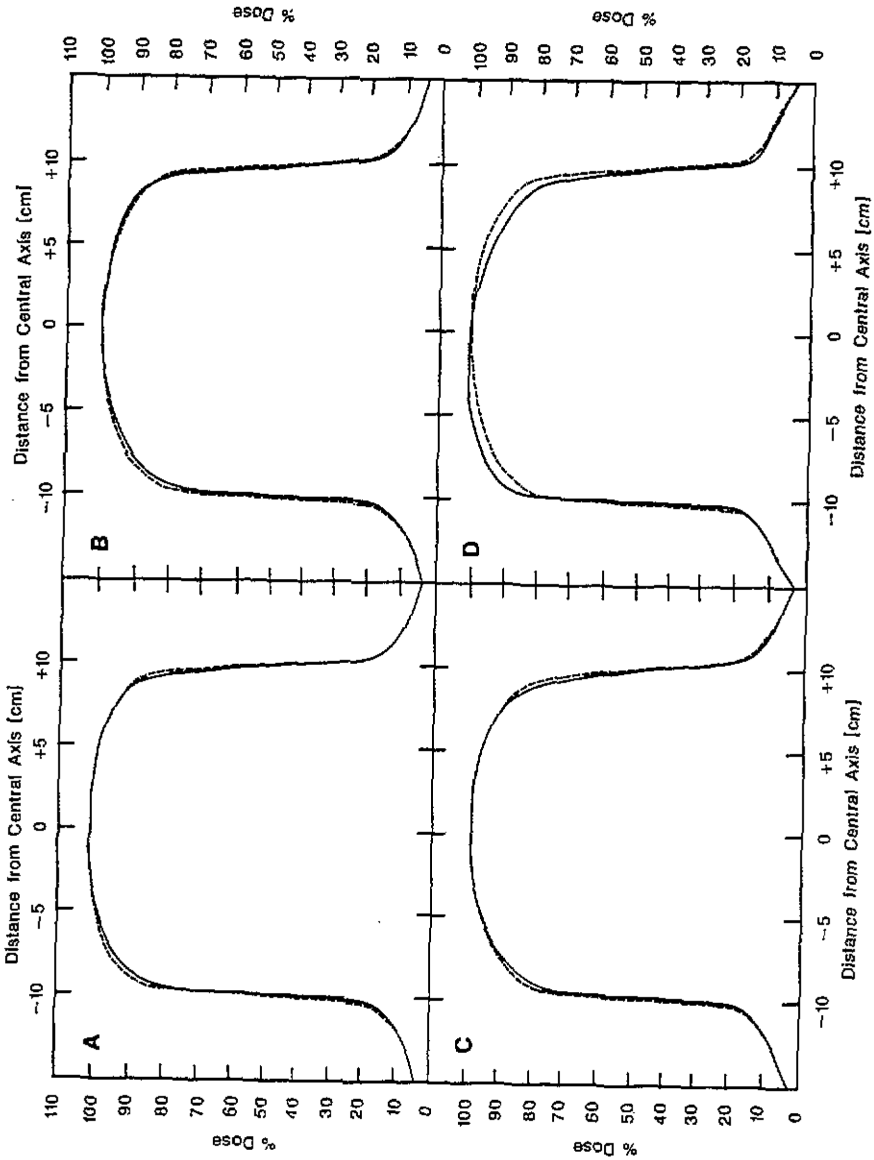

Figure 3. In plane against X plane beam profiles for a 20 × 20 cm², 50 cm FSD applicator from (A) 100, (B) 150, (C) 200 and (D) 300 kVp x-ray beams.

Table 16. Percentage beam symmetry at a depth of 1 cm for In plane and X plane.

	2.43 mm Al (100 kVp)		4.39 mm Al (150 kVp)		0.63 mm Cu (200 kVp)		3.67 mm Cu (300 kVp)	
Field size	X	In	X	In	X	In	X	In
20×20 cm^2	0.81	0.46	0.59	0.03	0.39	0.56	0.15	3.86

Table 17. Backscatter factors.

Field size	FSD (cm)	2.43 mm Al (100 kVp)		4.39 mm Al (150 kVp)		0.63 mm Cu (200 kVp)		3.67 Cu (300 kVp)	
4 cm diameter	30	1.139[a]	1.163[b]	1.163[a]	1.172[b]	1.185[a]	1.174[b]	1.090[a]	1.100[b]
6 cm diameter	30	1.189[a]	1.212[b]	1.223[a]	1.235[b]	1.245[a]	1.236[b]	1.129[a]	1.141[b]
8 cm diameter	30	1.223[a]	1.240[b]	1.266[a]	1.275[b]	1.305[a]	1.292[b]	1.171[a]	1.177[b]
8×8 cm^2	30	1.236[a]	1.250[b]	1.280[a]	1.288[b]	1.328[a]	1.316[b]	1.180[a]	1.194[b]
6×12 cm^2	50	1.236[a]	1.265[b]	1.280[a]	1.296[b]	1.328[a]	1.325[b]	1.180[a]	1.196[b]
10 cm diameter	50	1.253[a]	1.277[b]	1.296[a]	1.320[b]	1.344[a]	1.349[b]	1.191[a]	1.210[b]
10×10 cm^2	50	1.262[a]	1.291[b]	1.339[a]	1.339[b]	1.381[a]	1.361[b]	1.242[a]	1.227[b]
12×12 cm^2	50	1.280[a]	1.306[b]	1.331[a]	1.352[b]	1.401[a]	1.376[b]	1.246[a]	1.255[b]
10×20 cm^2	50	1.289[a]	1.314[b]	1.342[a]	1.371[b]	1.410[a]	1.406[b]	1.254[a]	1.266[b]
12×15 cm^2	50	1.291[a]	1.314[b]	1.365[a]	1.376[b]	1.421[a]	1.414[b]	1.257[a]	1.269[b]
20×20 cm^2	50	1.314[a]	1.321[b]	1.383[a]	1.383[b]	1.475[a]	1.447[b]	1.319[a]	1.304[b]

[a] Interpolated from the *British Journal of Radiology (Supplement 17)* (1983).
[b] Present work.

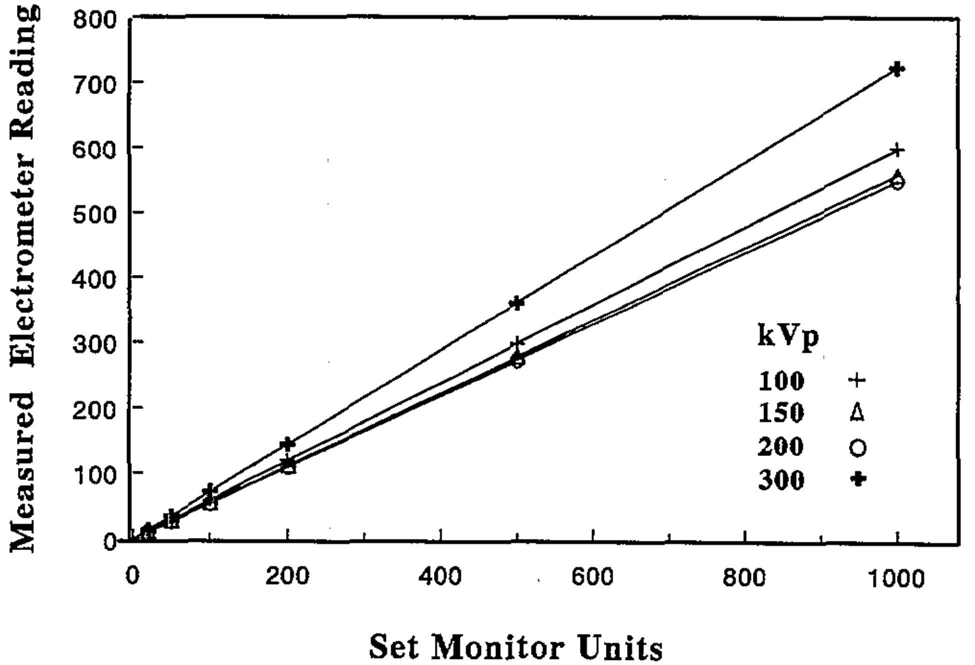

Figure 4. The response of the Therapax DXT300 dosimetry monitor system against a secondary standard system as a function of the number of monitor units.

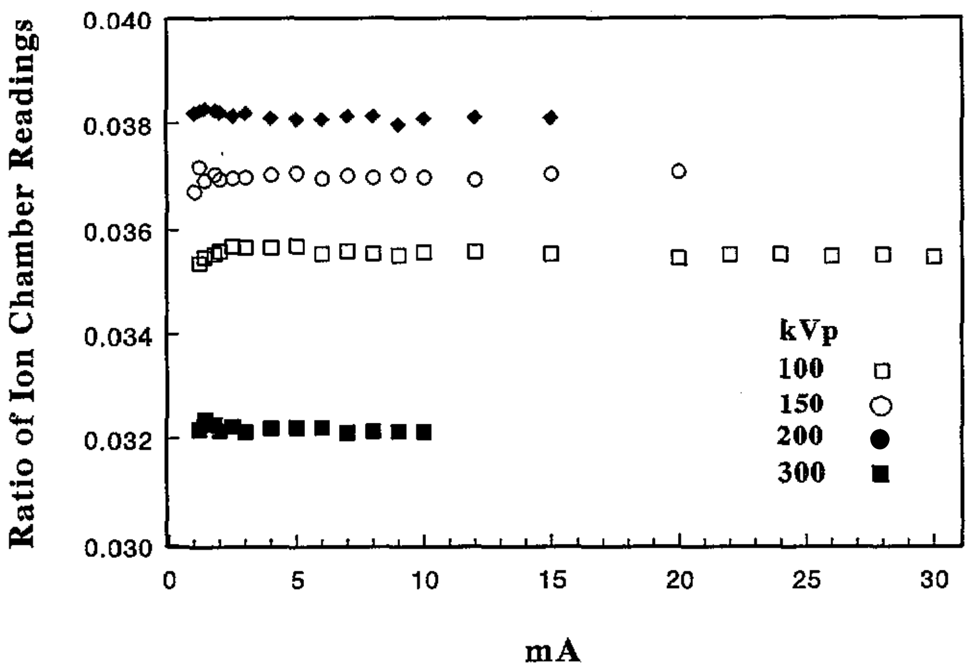

Figure 5. The ratio of the Therapax DXT300 dosimetry monitoring system response to that of a secondary standard system as a function of tube current.

4. Conclusions

The performance and beam characteristics of the Therapax DXT300 have been studied. The unit has been found to provide beam characteristics similar to that reported for other orthovoltage therapy units. The data presented herein should provide the basis for comparison with other units and act as a reference for clinics commissioning the Therapax DXT300 in the future.

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