CHAPTER 4

RESULTS

4.1 Densitometer calibration

The relationship between signal of analog to digital converter (ADC) and optical density from step wedge are shown in Table 4.1 and Figure 4.1. The densitometer curve showed almost linear relation between signals of ADC and optical density over the optical density ranged of 0.2 to 3.0. The saturation of the signal began at optical density of about 3.0. This result suggested that the optical density of the film used should not be more than 3.0.

Table 4.1 The densitometer signal of standard step film for densitometer calibration.

OD	ADC	OD	ADC
0.04	3968	1.99	33543
0.17	4182	2.14	35628
0.33	6678	2.29	37843
0.47	8944	2.43	40180
0.61	11203	2.62	43008
0.78	13951	2.75	44785
0.95	16733	2.90	47058
1.10	19207	3.05	48391
1.25	21749	3.20	50911
1.41	24354	3.37	53016
1.55	26826	3.51	53538
1.69	29097	3.65	54837
1.85	31421		

4.2 Film processor quality control

4.2.1 Construction of the reference H&D curve

The reference H&D curve for automatic film processor Kodak *RP* X-OMAT Model M6B were plotted and shown in Figure 4.2, the optical density were read from the 21 steps of standard step wedge film for five days. The average of five consecutive days was determined and used for plotting the graph. The graph gave the high density (HD), low density (LD), medium density (MD) or speed index of 1.18, density difference (DD) or contrast index of 1.85, base+fog of 0.18 and temperature index of 34.8°C. These values were used as the reference for the quality control of the film processor.

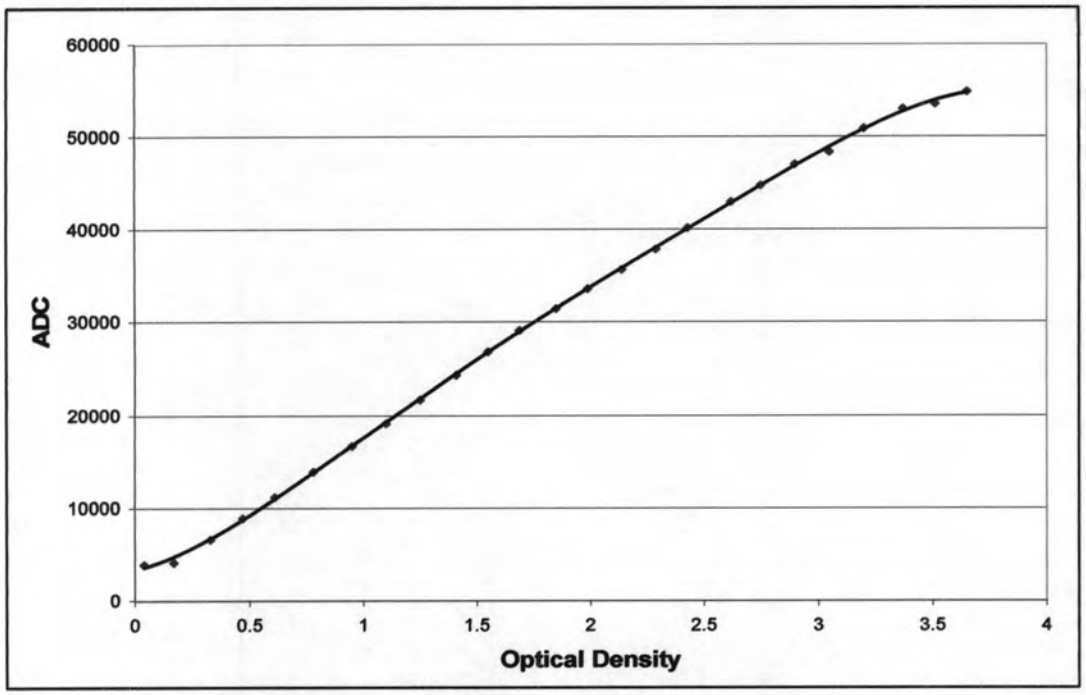


Figure 4.1 The densitometer calibration curve of standard step wedge film

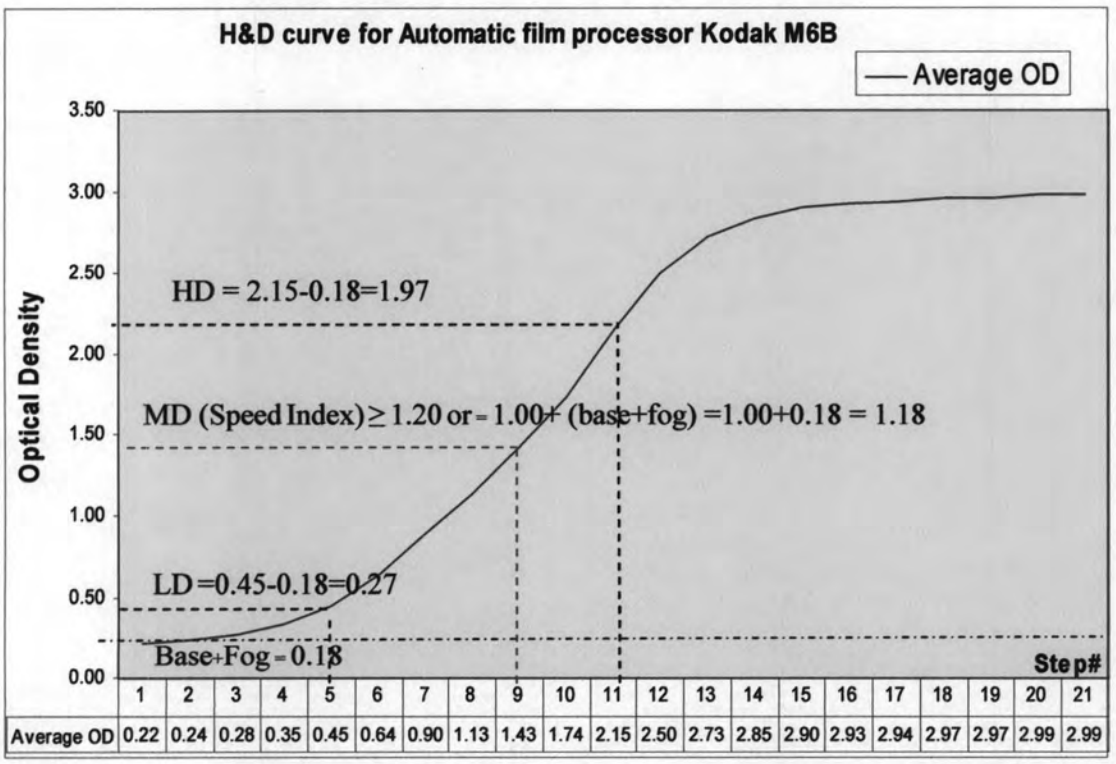


Figure 4.2 H&D curve for Automatic film processor Kodak M6B

4.2.2 Processing control chart

The processing control chart was constructed as shown in Table 4.2 and was used to record and monitor the processor performance parameters. These parameters were measured before the first film was developed, and were compared with the reference values from 4.2.1 with the tolerance of: speed index 1.18 ± 0.2, contrast index 1.85 ± 0.2, base+fog 0.18 ± 0.03, and temperature index 34.8 ± 0.3 to provide the consistent of processor performance. The graphs were plotted for 11 times of measurement and shown in Figure 4.3. The result showed the good performance of the film processor, all the parameters were in the limit.

Table 4.2 Processor control chart

No.	Temperature (°c)	Base+fog	Speed index	Contrast low step	Contrast high step	Contrast index
				5	11	HD-LD
1	34.6	0.182	1.182	0.459	2.153	1.849
2	34.8	0.182	1.182	0.456	2.153	1.863
3	34.7	0.182	1.182	0.453	2.160	1.838
4	35.0	0.182	1.182	0.459	2.225	1.842
5	34.9	0.172	1.172	0.426	2.139	1.874
6	34.7	0.182	1.182	0.422	2.160	1.872
7	34.6	0.182	1.182	0.432	2.149	1.869
8	34.8	0.182	1.182	0.422	2.095	1.814
9	35.0	0.160	1.160	0.398	2.095	1.837
10	34.7	0.177	1.177	0.436	2.175	1.876
11	34.7	0.182	1.182	0.456	2.200	1.843

Temperature index ±0.3

Speed index ± 0.2

Base+fog ± 0.03

Contrast index ± 0.2

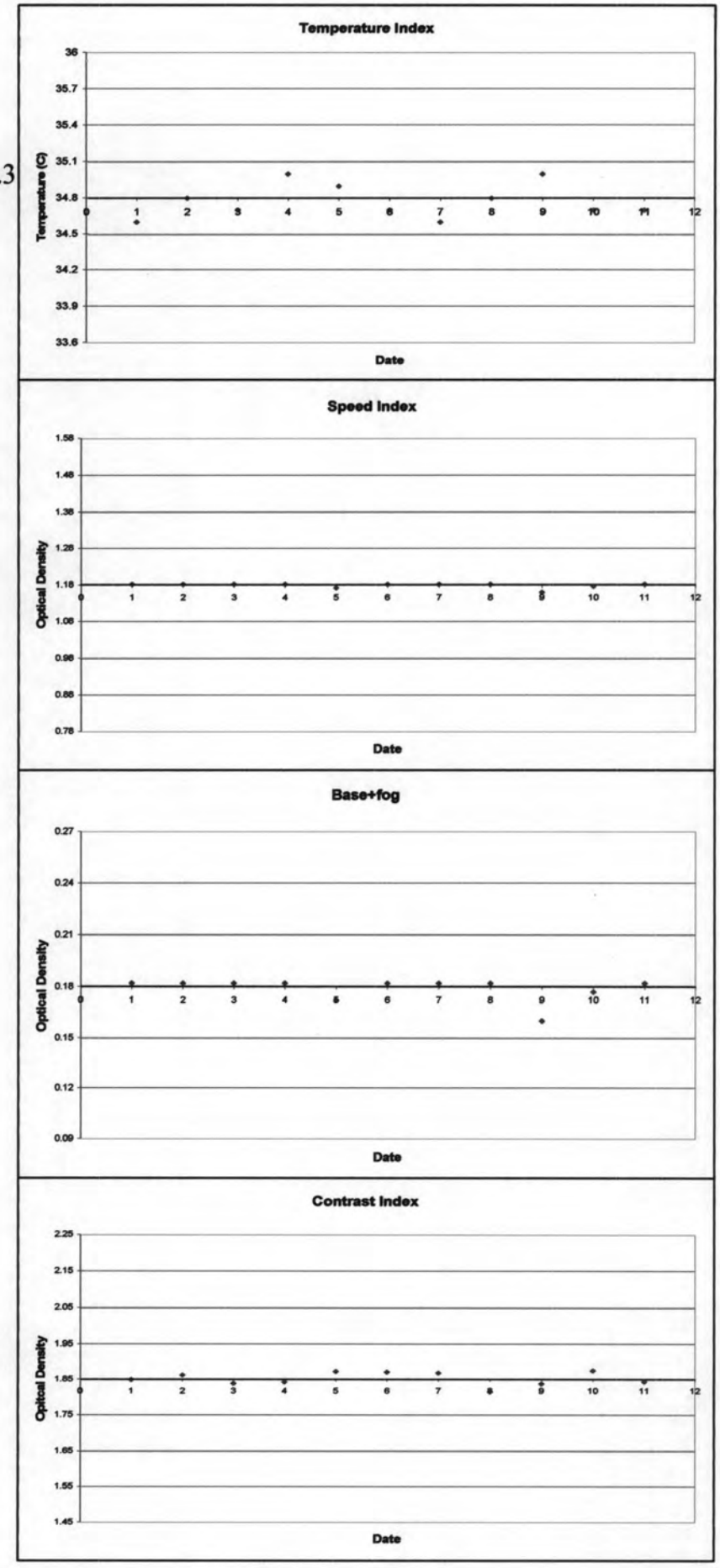


Figure 4.3 Processor performance parameters

4.3 Film reproducibility and accuracy

The reproducible of EDR2 film irradiated with the field size of 10x10 cm^2 at depth of maximum dose (d_{max}), 100 cm source film distance (SAD) and 100 MU for 6 MV and 10 MV x-ray beams of 6 times of measurement are shown in Table 4.3. The percent standard deviations of 0.9% for 6 MV and 1.1% for 10 MV x-ray beams showed good reproducible of 6 times measurement.

Table 4.3 The optical density of EDR2 film for field size of 10x10 cm^2, at d_{max} 100 cm SAD for 6 MV and 10 MV x-ray beams.

Energy	Number							
	1	2	3	4	5	6	Average	%SD
6 MV	0.592	0.598	0.593	0.575	0.578	0.586	0.587	0.9
10 MV	0.576	0.573	0.588	0.555	0.567	0.579	0.573	1.1

The reproducibility and accuracy of EDR2 film was obtained by irradiation one film with the field size of 3x3 cm^2 at d_{max}, 100 cm SAD with the dose ranged from 20 to 450 cGy. For 6 MV, they are shown in Table 4.4 and Figure 4.4 for 9 times of measurement and for 10 MV x-ray beam, they are shown in Table 4.5 and Figure 4.5 for 6 times of measurements. The fitted line represented the average of all data. The percent standard deviations were increased with higher dose of both 6 and 10 MV x-ray beams which were 4.9% and 4.2%, respectively. The good reproducibility and accuracy of the EDR2 film would be obtained when the irradiation dose was below 200 cGy.

Table 4.4 The optical density over the dose 0-450 cGy for 9 measurements for field size of 3x3 cm^2 at 1.5 cm d_{max}, 100 cm SAD for 6 MV x-ray beam.

Dose (cGy)	Net optical density (OD)										
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	Average	%SD
0	0	0	0	0	0	0	0	0	0	0	0.0
20	0.169	0.169	0.173	0.169	0.169	0.165	0.165	0.165	0.173	0.169	0.3
50	0.311	0.311	0.317	0.311	0.300	0.300	0.304	0.307	0.321	0.310	0.7
100	0.556	0.550	0.556	0.553	0.533	0.530	0.536	0.546	0.570	0.549	1.3
200	1.111	1.102	1.108	1.102	1.070	1.060	1.076	1.076	1.105	1.098	1.9
300	1.747	1.736	1.739	1.722	1.676	1.652	1.673	1.694	1.768	1.724	4.0
450	2.551	2.551	2.523	2.497	2.451	2.434	2.448	2.465	2.555	2.514	4.9

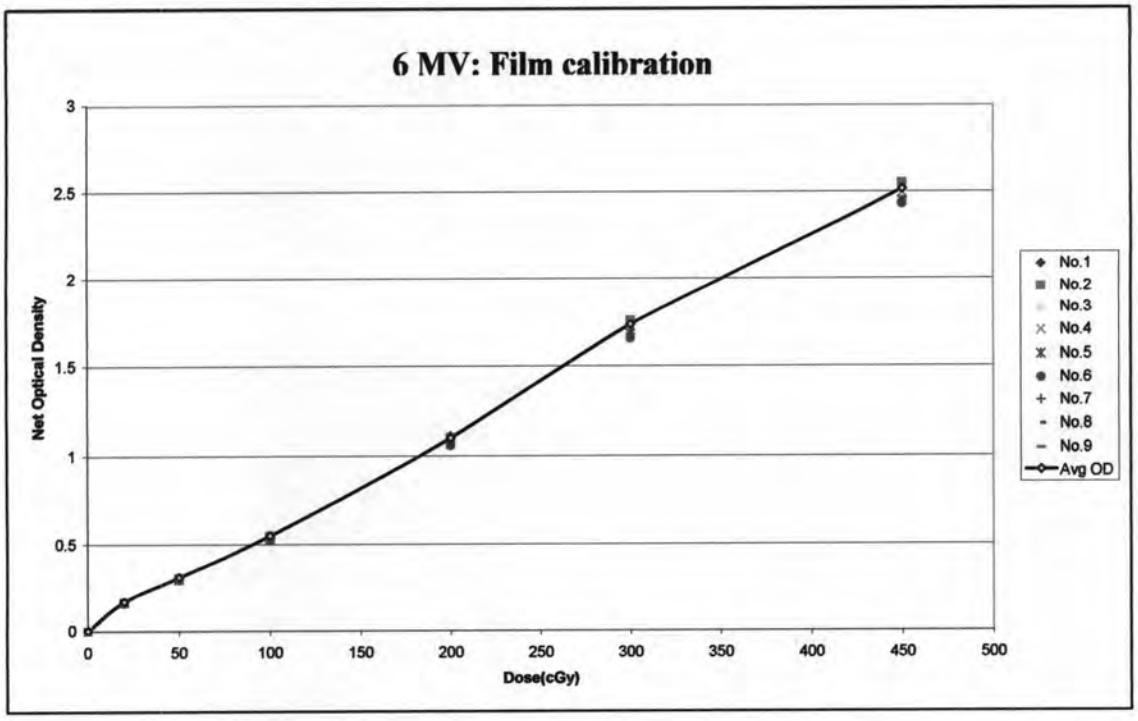


Figure 4.4 Sensitometric curve over the dose 0-450 cGy for 9 measurements for the field size of 3x3 cm^2 at 1.5 cm d_{max}, SAD 100 cm for 6 MV x-ray beam

Table 4.5 The optical density over the dose 0-450 cGy for 6 measurements for field size of 3x3 cm^2 at 2.5 cm d_{max}, 100 cm SAD for 10 MV x-ray beam.

Dose (cGy)	Net optical density(OD)							
	No.1	No.2	No.3	No.4	No.5	No.6	Average	%SD
0	0	0	0	0	0	0	0	0.0
20	0.165	0.165	0.177	0.165	0.169	0.173	0.169	0.5
50	0.297	0.297	0.311	0.29	0.3	0.311	0.301	0.8
100	0.536	0.536	0.553	0.533	0.543	0.556	0.543	1.0
200	1.021	0.996	1.028	0.999	1.018	1.021	1.014	1.3
300	1.704	1.646	1.725	1.69	1.708	1.722	1.699	2.9
450	2.566	2.448	2.508	2.505	2.512	2.555	2.516	4.2

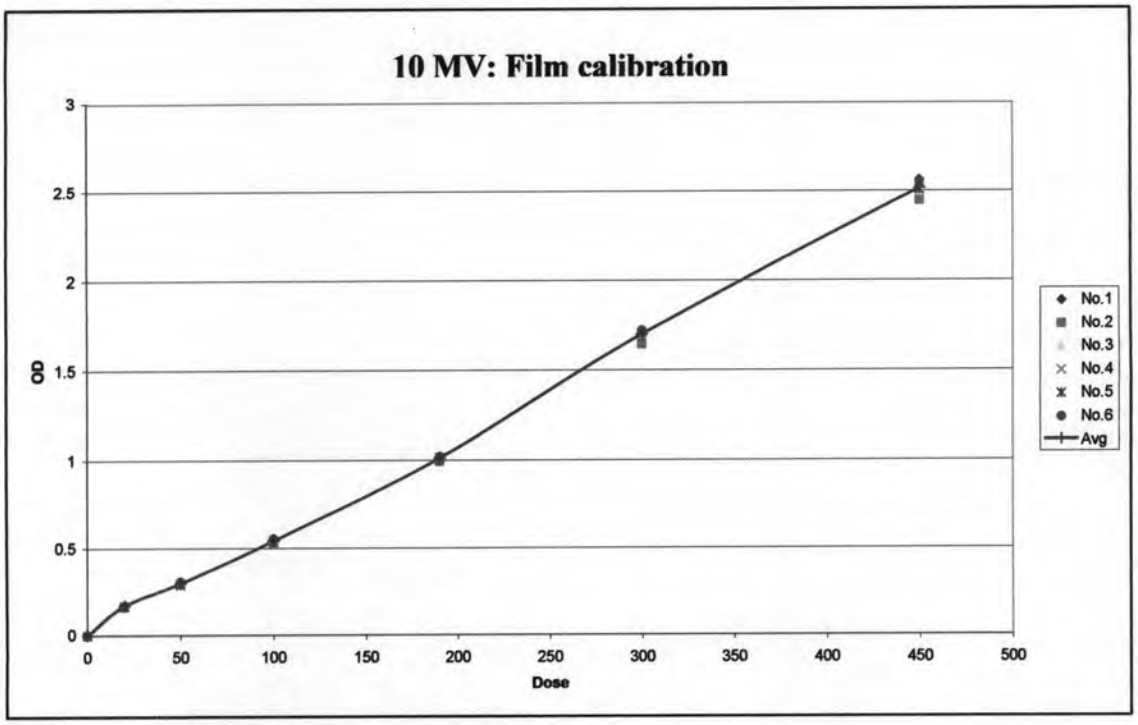


Figure 4.5 Sensitometric curve over the dose 0-450 cGy for 6 measurements for field size of 3x3 cm^2 at 2.5 cm d_{max}, 100 cm SAD for 10 MV x-ray beam.

4.4 Ionization chamber dose measurement

The absorbed dose were checked for monitor unit of 20-450 for field size of 2x2 cm^2 to 15x15 cm^2 of 5, 10 and 15 cm depth, the absorbed doses were calculated using IAEA TRS 398, the results are shown in Table 4.6 and Table 4.7 for 6 MV and 10 MV x-ray beams, respectively. These data will be used for film irradiation.

Table 4.6 Dose delivered to solid water phantom measured from ionization chamber in cGy at 6 MV x-ray beam.

MU	Dose(cGy)											
	Field size (cm^2)											
	2 x 2			3 x 3			10 x 10			15 x 15		
	Depth											
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
20	13.83	9.94	7.284	15.02	10.98	8.05	17.36	13.45	10.20	17.86	14.08	10.97
50	34.58	24.84	18.21	37.56	27.46	20.13	43.40	33.62	25.50	44.65	35.19	27.43
100	69.17	49.68	36.42	75.11	54.92	40.25	86.80	67.24	50.99	89.29	70.38	54.86
200	138.34	99.36	72.84	150.22	109.84	80.50	173.60	134.48	101.98	178.58	140.76	109.72
300	207.51	149.04	109.26	225.33	164.76	120.75	260.40	201.72	152.97	267.87	211.14	164.58
450	311.26	223.56	163.89	337.99	247.14	181.13	390.60	302.58	229.46	401.81	316.71	246.87

Table 4.7 Dose delivered to solid water phantom measured from ionization chamber in cGy at 10 MV x-ray beam.

MU	Dose(cGy)											
	Field size (cm^2)											
	2 x 2			3 x 3			10 x 10			15 x 15		
	Depth											
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
20	14.08	10.87	8.37	15.74	12.24	9.50	18.32	14.69	11.73	18.95	15.42	12.45
50	35.21	27.18	20.93	39.35	30.59	23.74	45.81	36.73	29.32	47.39	38.55	31.12
100	70.41	54.36	41.85	78.70	61.18	47.48	91.62	73.46	58.64	94.77	77.10	62.23
200	140.82	108.72	83.70	157.40	122.36	94.96	183.24	146.92	117.28	189.54	154.20	124.46
300	211.23	163.08	125.55	236.10	183.54	142.44	274.86	220.38	175.92	284.31	231.30	186.69
450	316.85	244.62	188.33	354.15	275.31	213.66	412.29	330.57	263.88	426.47	346.95	280.04

4.5 Film irradiation and sensitometric curves

4.5.1 Fixed depth and varied field size

The optical density of EDR2 films which were irradiated with the doses from 20 to 450 cGy at fixed depths of 5 cm, 10 cm, and 15 cm for filed sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 were shown in Table 4.8 and Table 4.9 for 6 MV and 10 MV x-ray beams, respectively.

The sensitometric curves were plotted as a function of net optical density versus dose, the results are shown in Figure 4.6 to Figure 4.8 for 6 MV x-ray beam and Figure 4.9 to Figure 4.11 for 10 MV x-ray beam. The marker points in figure represented measured data points, and the solid lines represented the fitted data.

All the sensitometric curves for fixed depth and varied field size for both energies showed a relative linearity when the optical density ranged from 0.5 to 2.0 and the doses ranged from 80 to 330 cGy. For 6 MV x-ray beam, the sensitometric curves showed the discrepancy between the field size, the sensitometric curves started to separate from one another at higher dose approximately 300 cGy, they were significantly at the higher dose for all depth studied. For shallow depth (5 cm), the effect of field size was more than those of deeper depth (15 cm). The maximum dose discrepancy between the field size of 2x2 cm^2 and 15x15 cm^2 occurred at 5 cm depth which was 4.2%.

For 10 MV x-ray beam, the sensitometric curves showed less effect of field size compared with 6 MV x-ray beam. The field size played small effect on the depth, all the curves showed almost similar effect of field size at different depths. The maximum dose discrepancy between the 2 x 2 cm^2 and 15 x 15 cm^2 field size occurred at 5 cm depth which was 2.85%, and the greatest difference also tend to occur at higher doses.

The percent dose difference between 2x2 cm^2 and 15x15 cm^2 field sizes are shown in Table 4.10. Percent differences were decreased at the higher depth. The 6 MV the percent difference gave more percent difference than 10 MV x-ray beam.

Table 4.8 Optical density of EDR2 films irradiated at fixed depth varied field size of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 at 5 cm, 10 cm, and 15 cm depth for 6 MV x-ray beam.

Dose (cGy)	Net optical density (OD)											
	Depth											
	5 cm				10 cm				15 cm			
	Field size (cm^2)											
	2x2	3x3	10x10	15x15	2x2	3x3	10x10	15x15	2x2	3x3	10x10	15x15
20	0.165	0.169	0.16	0.156	0.165	0.169	0.16	0.165	0.169	0.173	0.16	0.169
50	0.293	0.307	0.297	0.297	0.297	0.307	0.304	0.304	0.304	0.314	0.3	0.307
100	0.53	0.54	0.533	0.546	0.53	0.536	0.533	0.546	0.533	0.55	0.543	0.556
200	1.05	1.06	1.07	1.095	1.057	1.07	1.079	1.095	1.063	1.086	1.095	1.108
300	1.642	1.67	1.663	1.676	1.639	1.683	1.673	1.683	1.697	1.715	1.711	1.718
450	2.412	2.434	2.497	2.501	2.434	2.43	2.48	2.515	2.469	2.49	2.526	2.53

Table 4.9 Optical density of EDR2 films irradiated at fixed depth varied field size of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 at 5 cm, 10 cm, and 15 cm depth for 10 MV x-ray beam.

Dose (cGy)	Net optical density (OD)											
	Depth											
	5 cm				10 cm				15 cm			
	Field size (cm^2)											
	2x2	3x3	10x10	15x15	2x2	3x3	10x10	15x15	2x2	3x3	10x10	15x15
20	0.169	0.169	0.165	0.165	0.169	0.173	0.16	0.16	0.169	0.173	0.16	0.165
50	0.307	0.314	0.293	0.293	0.304	0.314	0.293	0.293	0.307	0.314	0.293	0.30
100	0.553	0.556	0.533	0.536	0.536	0.553	0.526	0.53	0.543	0.553	0.536	0.54
200	1.089	1.105	1.079	1.083	1.066	1.086	1.07	1.066	1.07	1.099	1.073	1.079
300	1.736	1.75	1.694	1.687	1.687	1.722	1.673	1.666	1.694	1.729	1.687	1.687
450	2.512	2.555	2.537	2.53	2.48	2.526	2.505	2.497	2.473	2.541	2.53	2.533

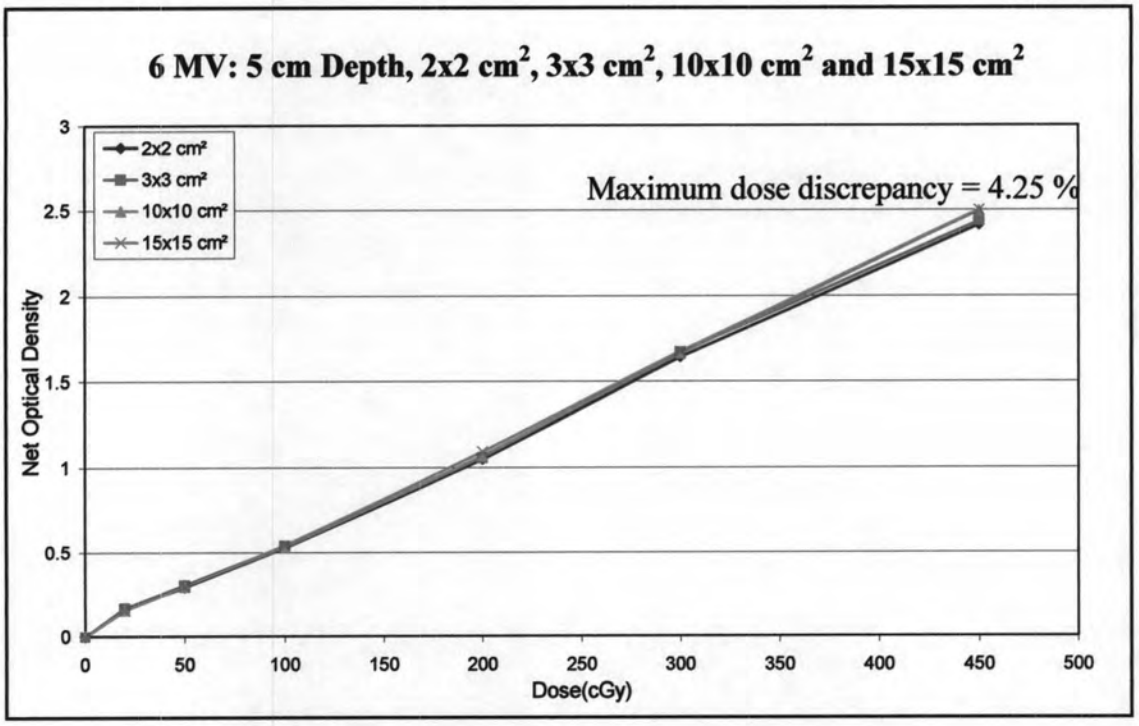


Figure 4.6 Sensitometric curves for depth of 5 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 6 MV x-ray beam

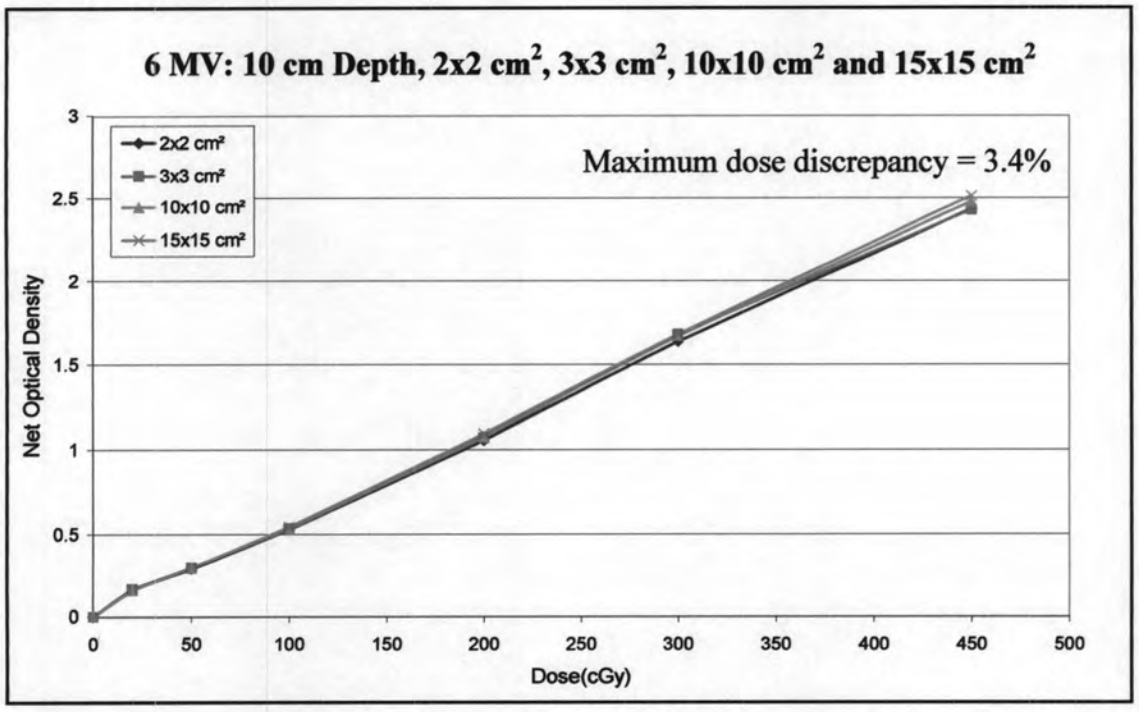


Figure 4.7 Sensitometric curves for depth of 10 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 6 MV x-ray beam

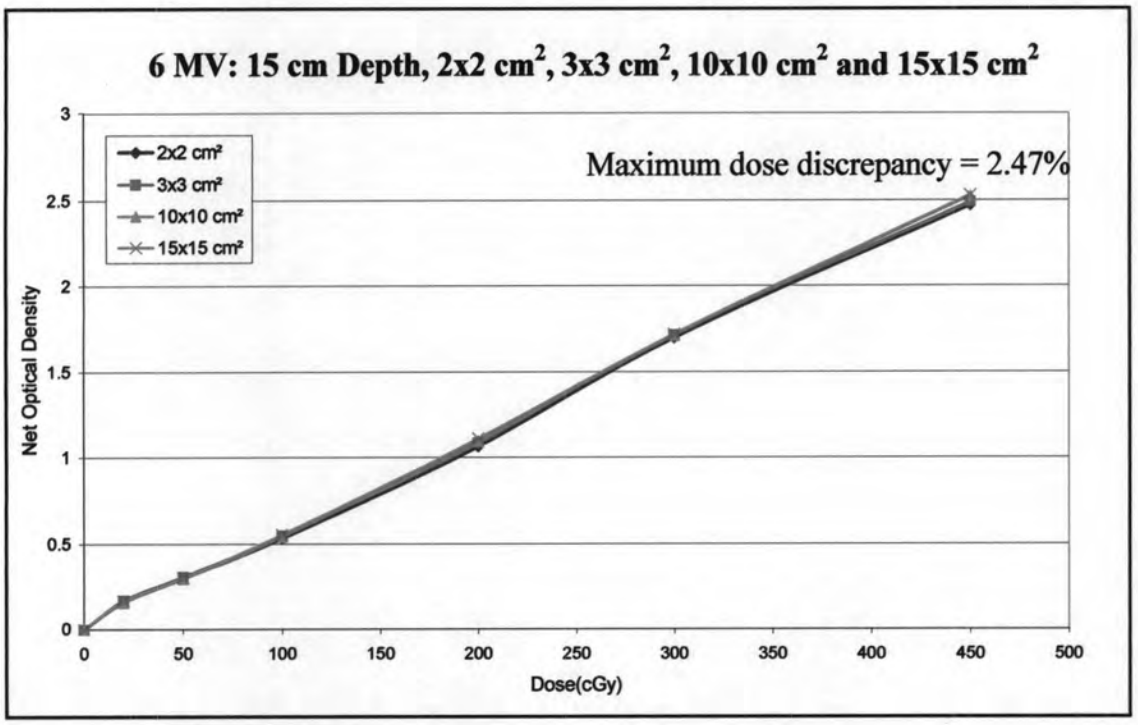


Figure 4.8 Sensitometric curves for depth of 15 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 6 MV x-ray beam

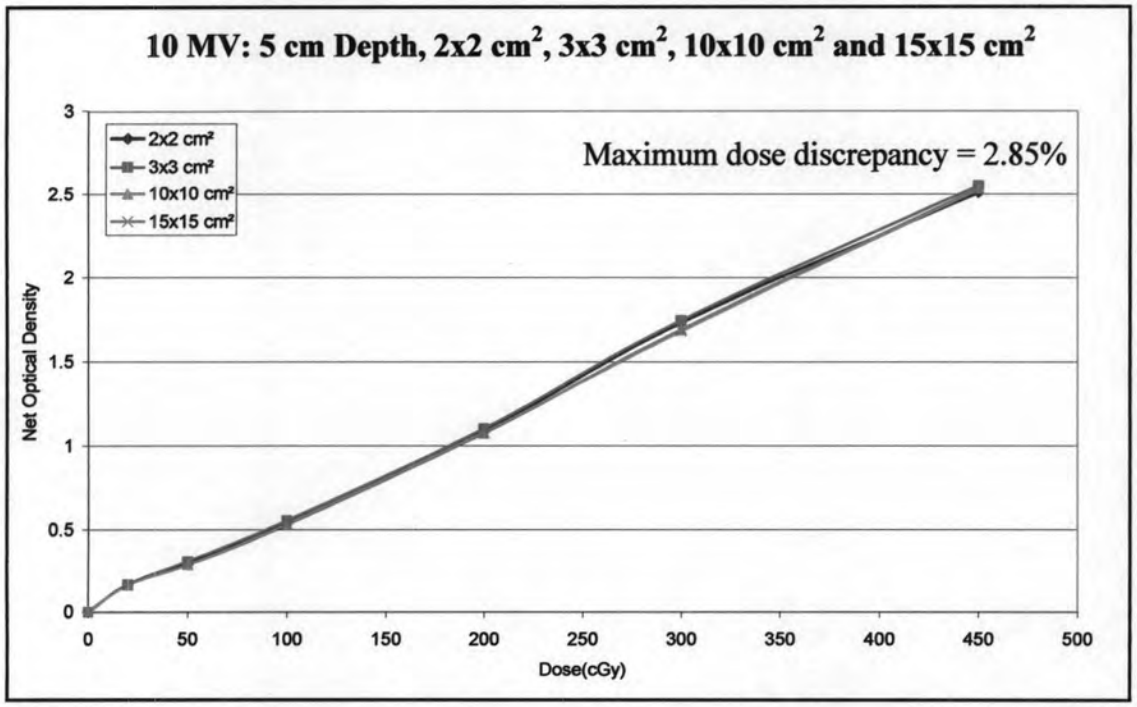


Figure 4.9 Sensitometric curves for depth of 5 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 10 MV x-ray beam

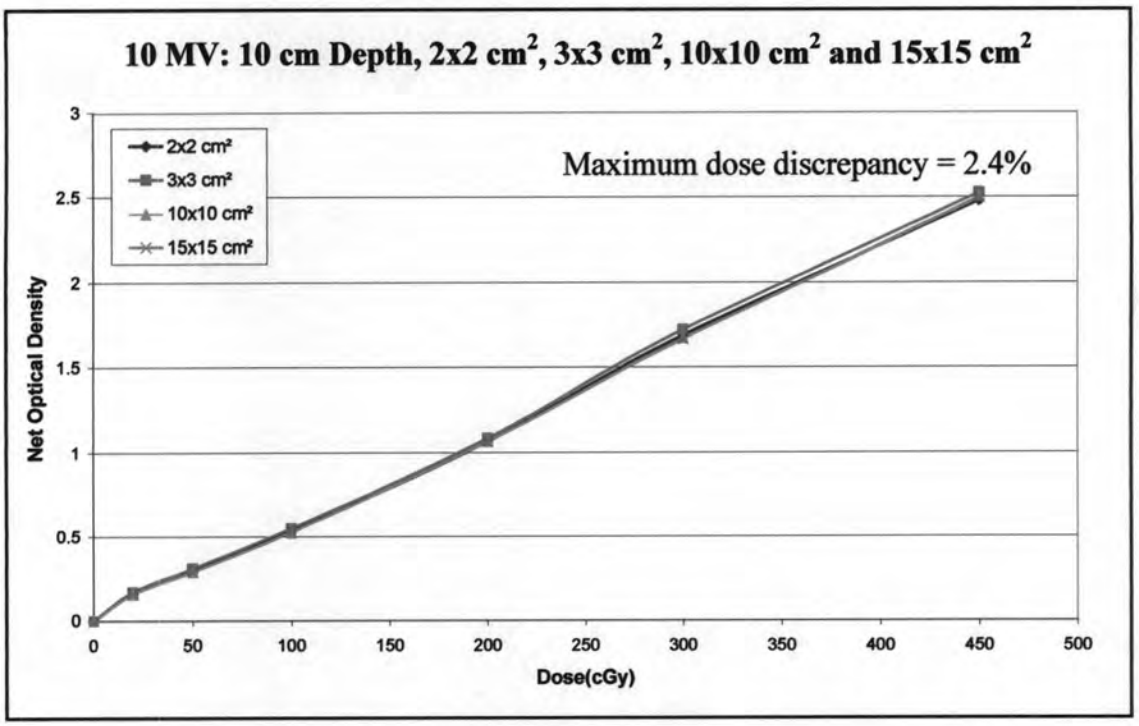


Figure 4.10 Sensitometric curves for depth of 10 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 10 MV x-ray beam

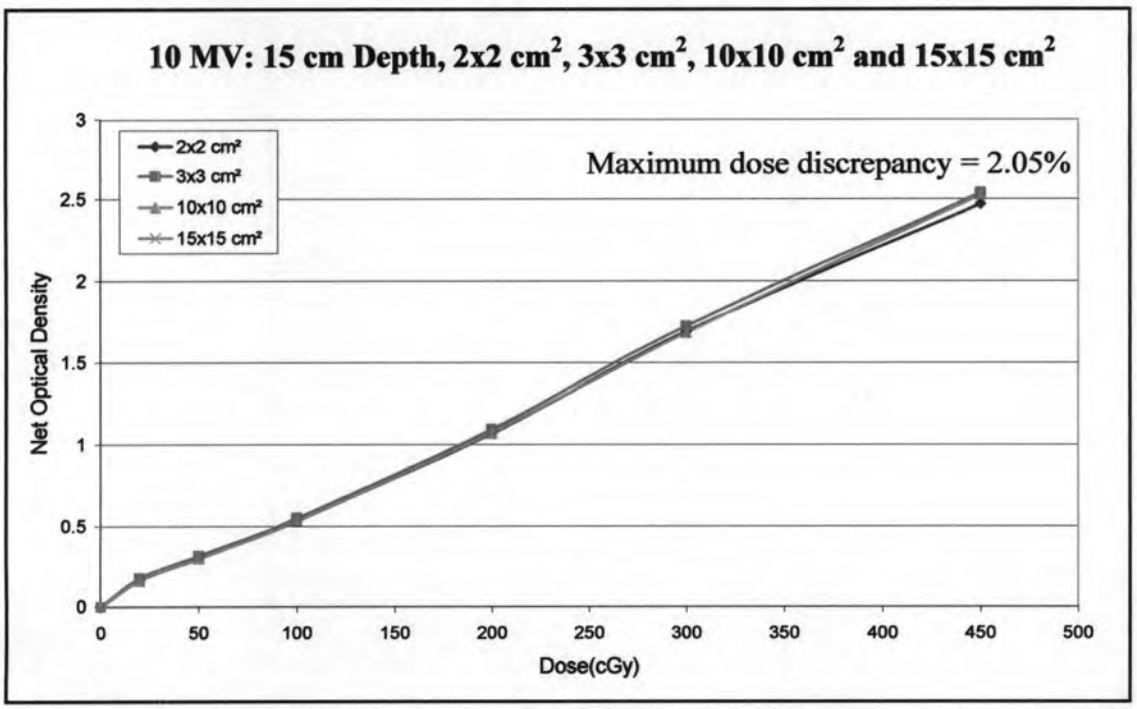


Figure 4.11 Sensitometric curves for depth of 15 cm field sizes of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2, 15x15 cm^2 for 10 MV x-ray beam

Table 4.10 Percent dose difference between field size of 2x2 cm^2 and 15x15 cm^2

Depth (cm)	% difference	
	6 MV	10 MV
5	4.25	2.85
10	3.4	2.4
15	2.47	2.05

4.5.2 Fixed field size varied depth

The optical density of EDR2 films which were irradiated with the dose from 20 to 450 cGy for fixed filed size of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 at the depth of 5 cm, 10 cm, and 15 cm were shown in Table 4.10 and Table 4.11 for 6 MV and 10 MV x-ray beams, respectively.

The sensitometric curves were plotted as a function of net optical density versus dose, the results are shown in Figure 4.12 to Figure 4.15 for 6 MV x-ray beam and Figure 4.16 to Figure 4.19 for 10 MV x-ray beam.

All the sensitometric curves for fixed field size and varied depth showed the linearity of the optical density ranged from 0.5 to 2.0 and the dose ranged from 80 to 330 cGy for both 6 MV and 10 MV x-ray beams, the same result as 4.5.1. For 6 MV x-ray beam, the sensitometric curves showed less dose discrepancy between the different depths for all fixed field size studied compared with the result in 4.5.1. Small field size gave more effect of depth than those of large field size. The dose discrepancy between 5 and 15 cm depth was within 1.6% at field size of 2x2 cm^2.

For 10 MV x-ray beam, the effect of depth was more pronounce at small field size. The dose discrepancy between 5 and 15 cm depths was 3.4 % at field size of 2x2 cm^2.

The percent dose difference between 5 cm and 10 cm depths are shown in Table 4.13. The percent dose differences were decreased with the larger field size, the 10 MV gave more percent difference than 6 MV x-ray beam.

Table 4.11 The optical density of EDR2 films irradiated at fixed field size varied depth, field size of 2x2 cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 at 5 cm, 10 cm, and 15 cm depths for 6 MV x-ray beam.

Dose (cGy)	Net optical density (OD)											
	Field size (cm^2)											
	2 x 2			3 x 3			10 x 10			15 x 15		
	Depth											
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
20	0.165	0.165	0.165	0.173	0.177	0.177	0.169	0.169	0.173	0.169	0.173	0.169
50	0.297	0.297	0.293	0.321	0.324	0.321	0.304	0.311	0.311	0.307	0.311	0.311
100	0.526	0.526	0.523	0.57	0.56	0.56	0.543	0.553	0.556	0.556	0.553	0.556
200	1.063	1.060	1.044	1.111	1.118	1.105	1.099	1.105	1.118	1.111	1.124	1.131
300	1.683	1.680	1.646	1.761	1.779	1.743	1.729	1.732	1.75	1.754	1.757	1.747
450	2.465	2.458	2.423	2.551	2.555	2.515	2.599	2.603	2.573	2.599	2.588	2.573

Table 4.12 The optical density of EDR2 films irradiated at fixed field size varied depth, field size of 2x2cm^2, 3x3 cm^2, 10x10 cm^2 and 15x15 cm^2 at 5 cm, 10 cm, and 15 cm depths for 10 MV x-ray beam.

Dose (cGy)	Net optical density (OD)											
	Field size (cm^2)											
	2 x 2			3 x 3			10 x 10			15 x 15		
	Depth											
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
20	0.169	0.173	0.169	0.165	0.16	0.169	0.156	0.156	0.152	0.16	0.165	0.165
50	0.314	0.311	0.300	0.29	0.286	0.29	0.283	0.283	0.276	0.293	0.297	0.297
100	0.553	0.556	0.540	0.523	0.506	0.506	0.506	0.513	0.513	0.53	0.536	0.536
200	1.095	1.076	1.057	1.018	1.015	1.018	1.038	1.041	1.038	1.066	1.066	1.066
300	1.739	1.708	1.666	1.628	1.612	1.591	1.663	1.656	1.656	1.68	1.687	1.666
450	2.519	2.537	2.480	2.419	2.405	2.367	2.48	2.48	2.455	2.505	2.494	2.508

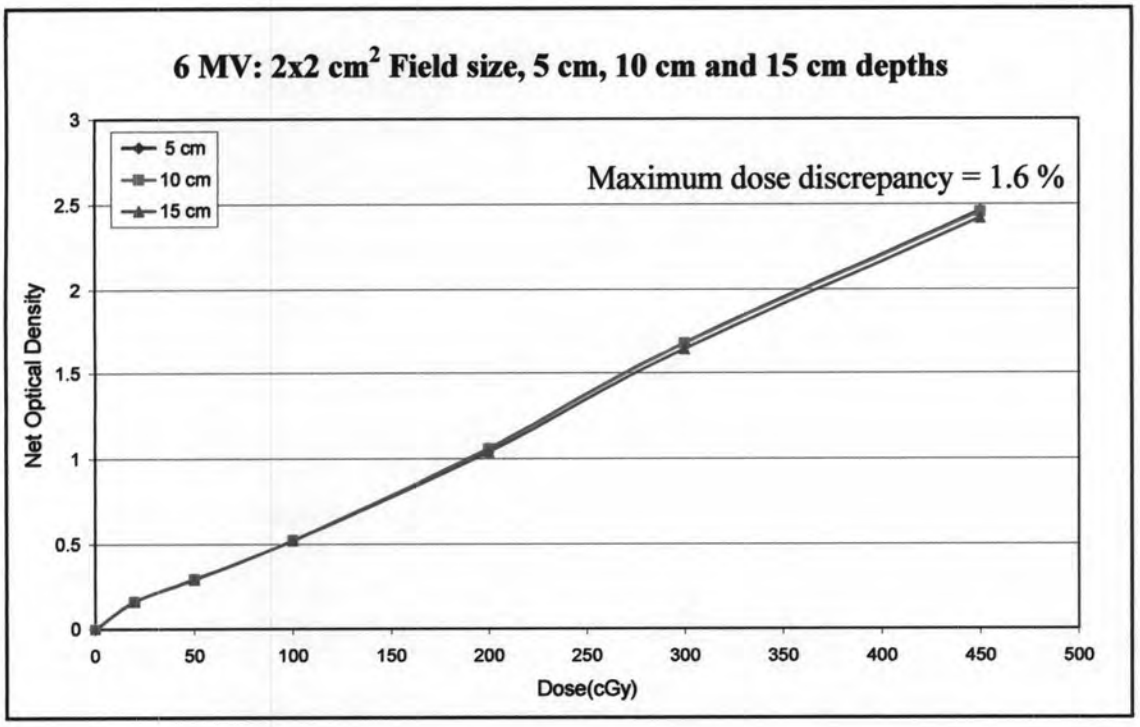


Figure 4.12 Sensitometric curves for field size of 2x2 cm^2 at depths of 5 cm, 10 cm and 15 cm for 6 MV x-ray beam

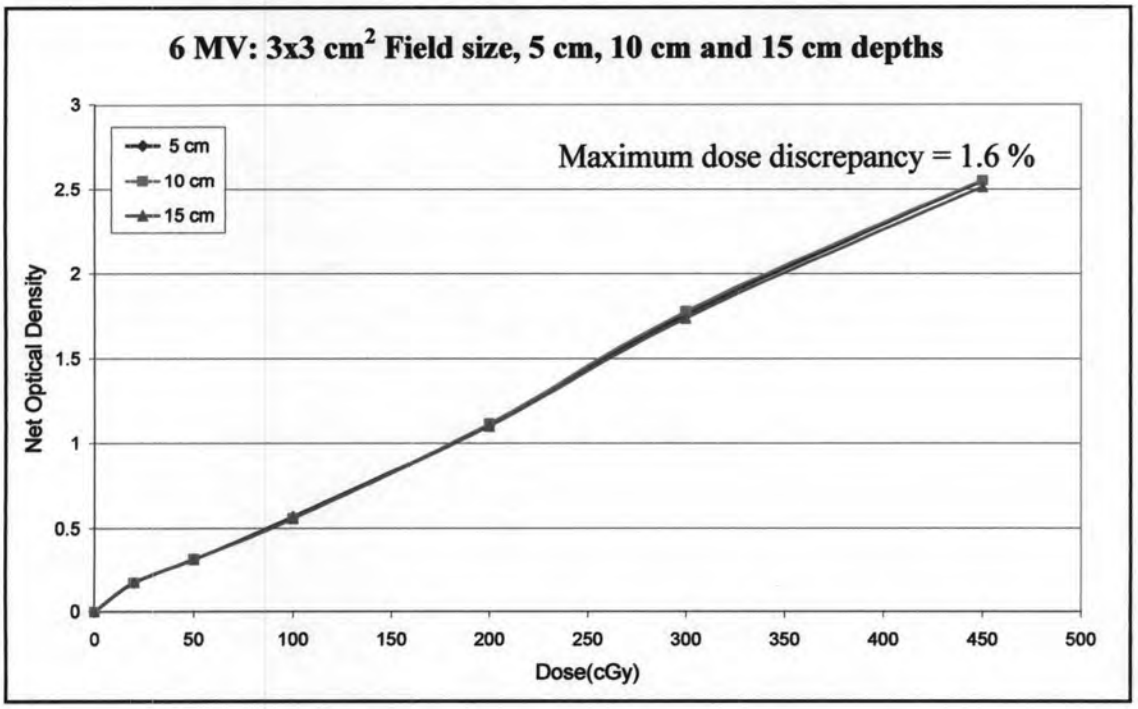


Figure 4.13 Sensitometric curves for field size of 3x3 cm^2 at depths of 5 cm, 10 cm and 15 cm for 6 MV x-ray beam

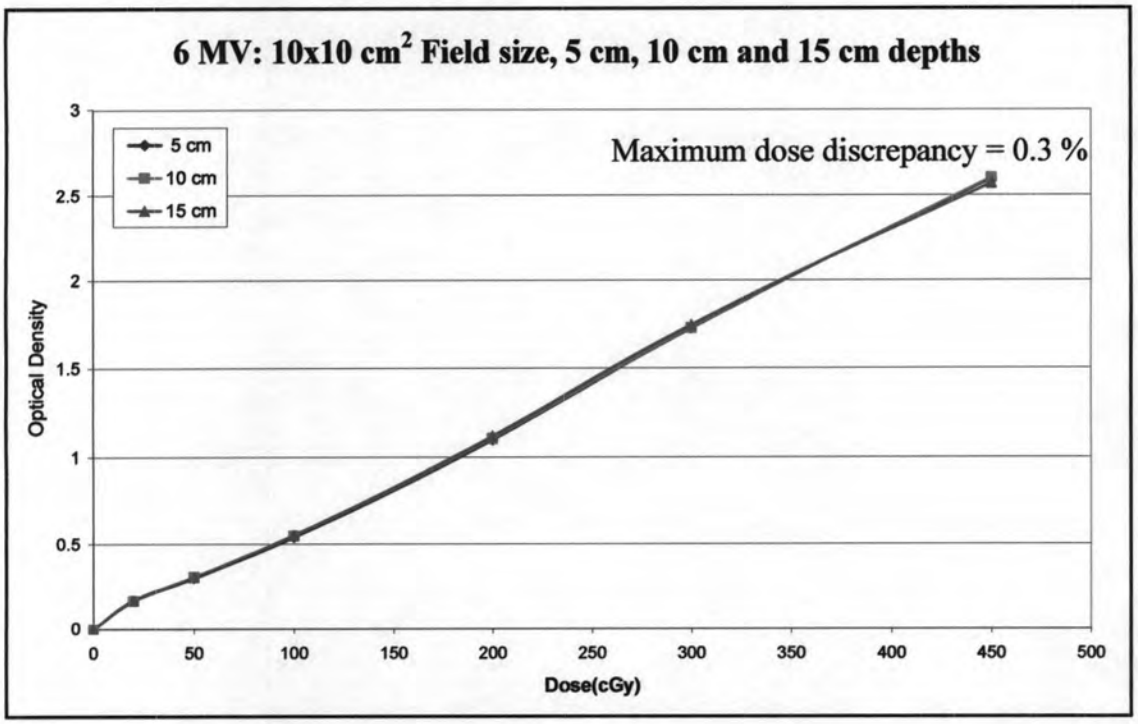


Figure 4.14 Sensitometric curves for field size of 10x10 cm^2 at depths of 5 cm, 10 cm and 15 cm for 6 MV x-ray beam

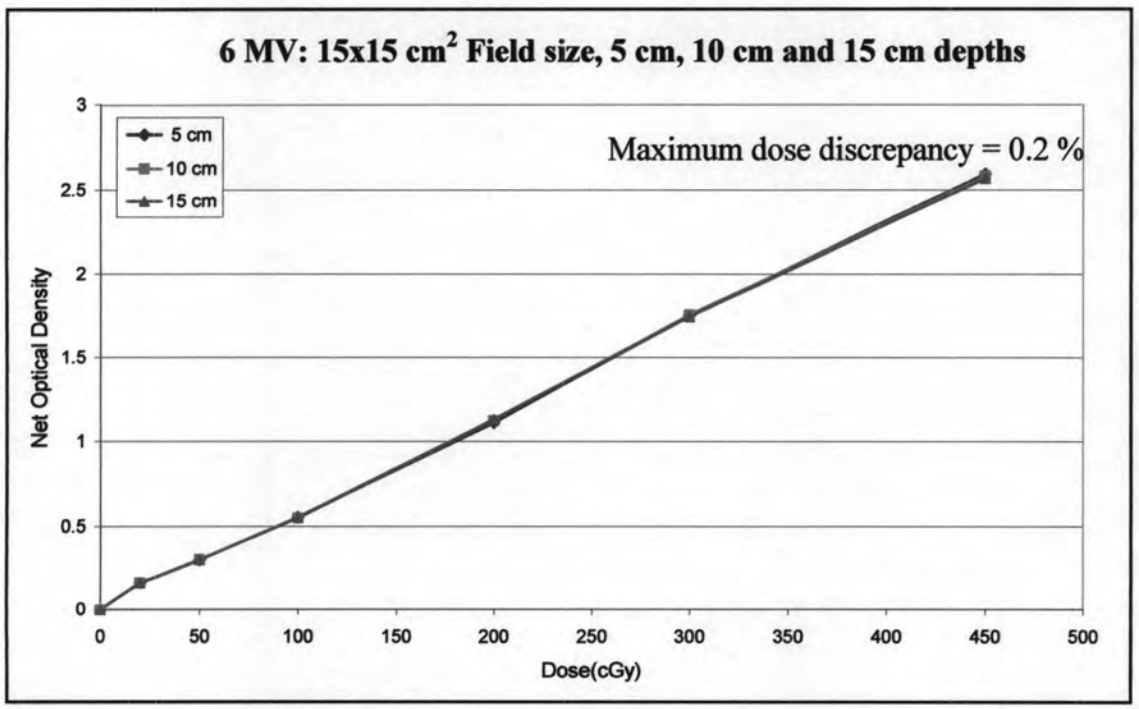


Figure 4.15 Sensitometric curves for field size of 15x15 cm^2 at depths of 5 cm, 10 cm and 15 cm for 6 MV x-ray beam

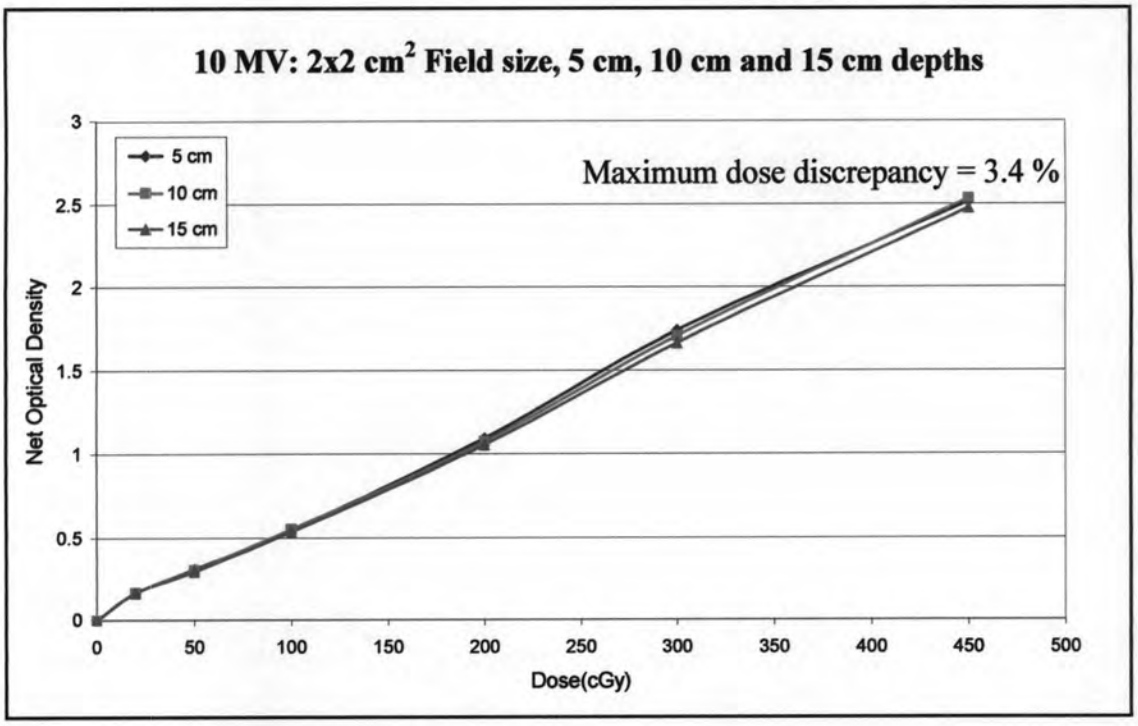


Figure 4.16 Sensitometric curves for field size of 2x2 cm^2 at depths of 5 cm, 10 cm and 15 cm for 10 MV x-ray beam

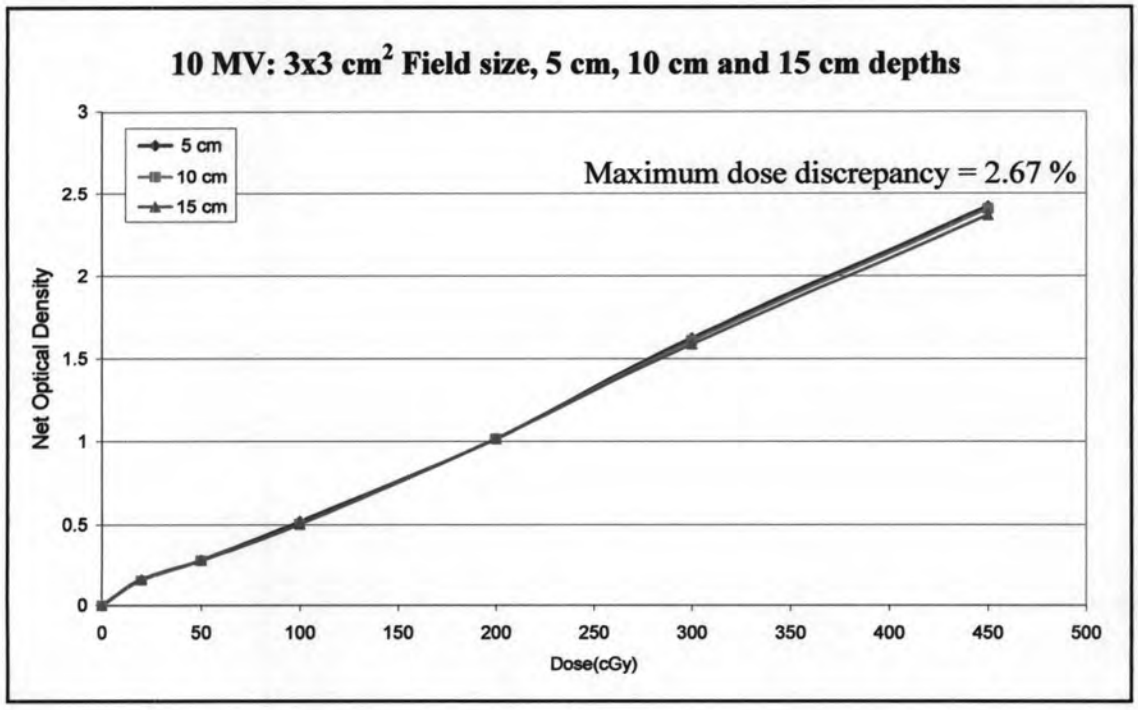


Figure 4.17 Sensitometric curves for field size of 3x3 cm^2 at depths of 5 cm, 10 cm and 15 cm for 10 MV x-ray beam

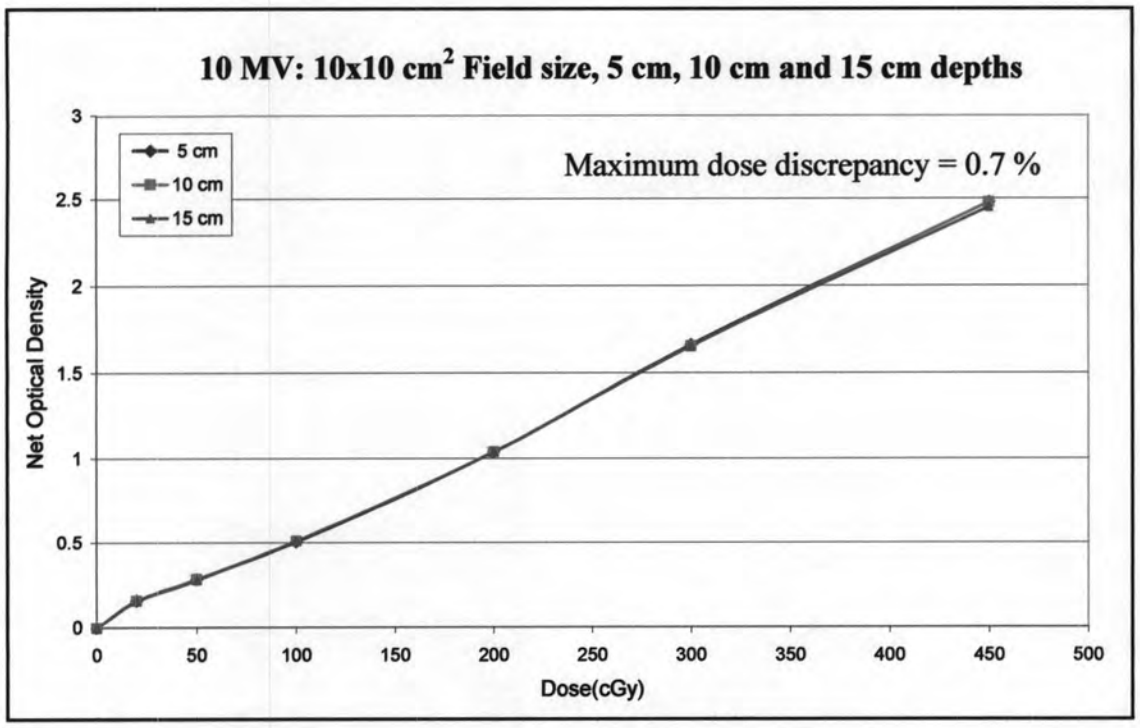


Figure 4.18 Sensitometric curves for field size of 10x10 cm^2 at depths of 5 cm, 10 cm and 15 cm for 10 MV x-ray beam

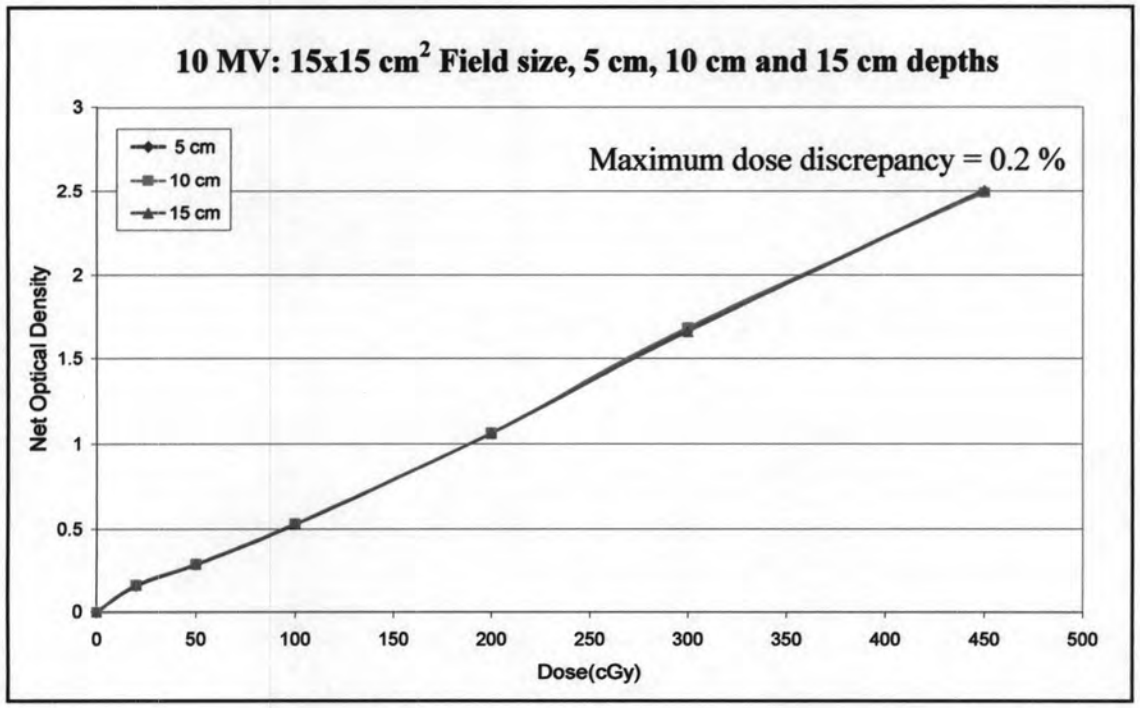


Figure 4.19 Sensitometric curves for field size of 15x15 cm^2 at depths of 5 cm, 10 cm and 15 cm for 10 MV x-ray beam

Table 4.13 Percent dose difference between 5 cm and 15 cm depths

Field size (cm^2)	% difference	
	6 MV	10 MV
2x2	1.69	3.40
3x3	1.65	2.67
10x10	0.30	0.70
15x15	0.20	0.23

4.6 Energy response

The sensitometric curve of EDR2 films which irradiated with the dose from 20-450 cGy for field size of 3x3 cm^2 at d_{max} depth, 100 cm SAD for both 6 and 10 MV x-ray beams. The result is shown in Table 4.14 and Figure 4.20. It was found that EDR2 film has less energy dependence. The maximum dose discrepancy between 6 and 10 MV x-ray beams was only 0.3%.

Table 4.14 The optical density for field size of 3x3 cm^2 at d_{max} depth, 100 cm SAD for 6 MV and 10 MV x-ray beams

Dose (cGy)	Optical density (OD)	
	6 MV	10 MV
0	0.000	0.000
20	0.170	0.169
50	0.310	0.301
100	0.550	0.543
200	1.098	1.075
300	1.724	1.699
450	2.546	2.516

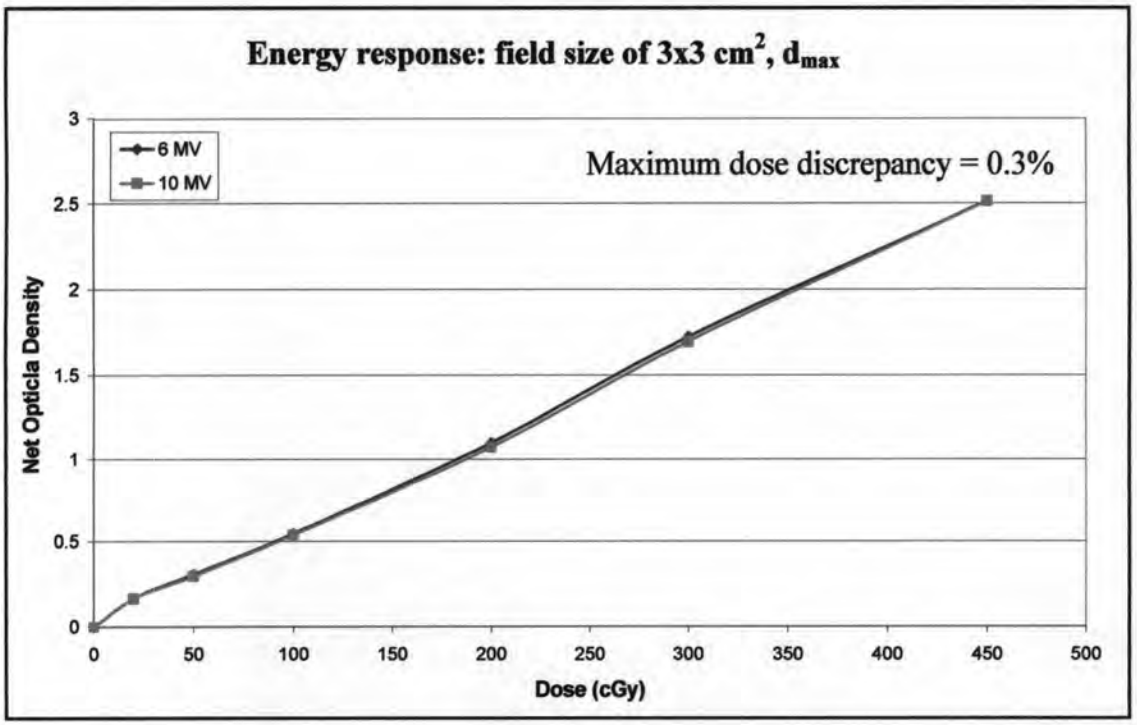


Figure 4.20 Sensitometric curves for field size of 3x3 cm^2 at d_{max} depth, 100 cm SAD for 6 MV and 10 MV x-ray beams

4.7 Percent depth dose

The percent depth doses were measured with EDR2 film in solid water phantom compared with ionization chamber. For field size of 2x2 cm^2 the result are shown in Table 6.15 and Table 6.16 for 6 MV and 10 MV x-ray beams, respectively For 10x10 cm^2, the result are shown in Table 6.17 and Table 6.18 for 6 MV and 10 MV x-ray beams, respectively. It was found that both 6 MV and 10 MV x-ray beams showed less discrepancy at shallow depth, but more discrepancy at the deeper depth especially for small field size. The percent depth dose at 5 cm measured by EDR2 film agreed very well with those measured by ionization chamber, the maximum discrepancy was 2.19% which occurred at field size of 10x10 cm^2 for 10 MV x-ray beam.

Table 4.15 The comparison of percent depth doses measured with EDR2 films to that measured with the ionization chamber for the field size of 2x2 cm^2 for 6 MV x-ray beam.

Depth (cm)	Percent depth dose		% Difference
	Ionization chamber	EDR2 Film	
1.5	100	100	
5	82	82.32	0.36
10	59.1	61.64	4.29
15	43.5	50.19	15.37

Table 4.16 The comparison of percent depth doses measured with EDR2 films to that measured with the ionization chamber for the field size of 2x2 cm^2 for 10 MV x-ray beam.

Depth (cm)	Percent depth dose		% Difference
	Ionization chamber	EDR2 Film	
2.5	100	100	
5	87.96	88.9	1.06
10	68.13	68.8	0.98
15	49.3	53.1	7.71

Table 4.17 The comparison of percent depth doses measured with EDR2 films to that measured with the ionization chamber for the field size of 10x10 cm^2 for 6 MV x-ray beam.

Depth (cm)	Percent depth dose		% Difference
	Ionization chamber	EDR2 Film	
1.5	100	100	
5	86.3	86.24	0.06
10	66.9	69.08	3.26
15	50.7	55.5	9.50

Table 4.18 The comparison of percent depth doses measured with EDR2 films to that measured with the ionization chamber for the field size of 10x10 cm^2 for 10 MV x-ray beam.

Depth (cm)	Percent depth dose		% Difference
	Ionization chamber	EDR2 Film	
2.5	100	100	
5	91.9	89.9	2.11
10	73.7	70.96	3.86
15	58.8	56.26	4.51

4.8 Beam profile

The comparison of EDR2 film and ionization chamber measurement of beam profiles for field size of 2x2 cm^2 at depth of 5 cm for 6 MV and 10 MV x-ray beams are shown in Figure 4.21 and Figure 4.22, respectively, and also the comparison of EDR2 film and ionization chamber measurement of beam profiles for a 10x10 cm^2 at 5 cm depth are shown in Figure 4.23 and Figure 4.24 for 6 MV and 10 MV x-ray beams, respectively. The dose from EDR2 film were obtained from the sensitometric curves and then normalized to the dose at central axis and then superimpose with the beam profile measured by ionization chamber in water phantom. The agreements of profile were in the central region but the discrepancy occurred at the penumbra region. Film gave more sharper dose fall off than ionization chamber due to high resolution of film. The discrepancy in the penumbra region was slightly less for 6 MV compared with 10 MV x-ray beam. The small field gave more discrepancy between EDR2 film and ionization chamber measurement in the penumbra region than larger field.

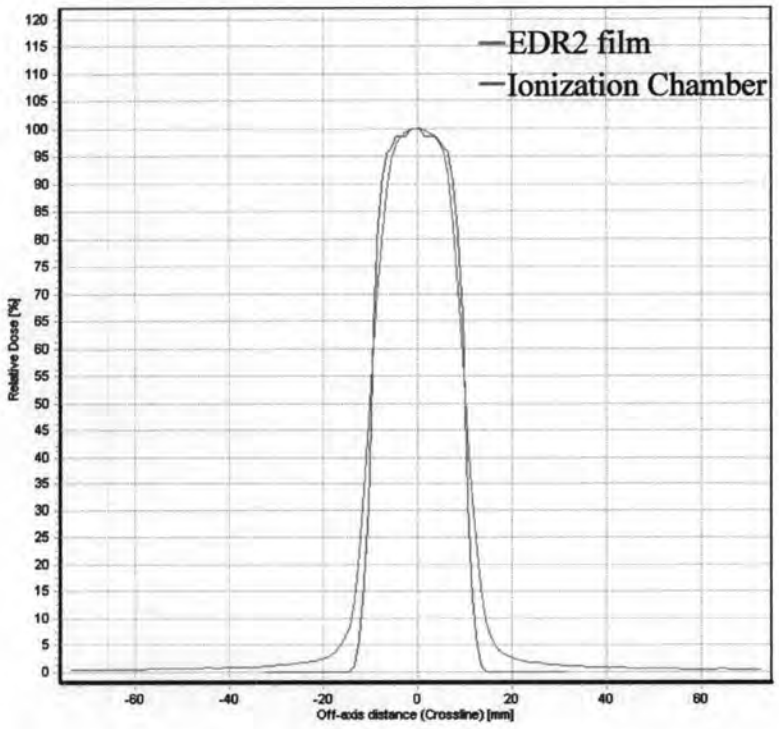


Figure 4.21 Dose profile measured with EDR2 film and an ionization chamber for field size of 2x2 cm^2 at depth of 5 cm for 6 MV x-ray beam

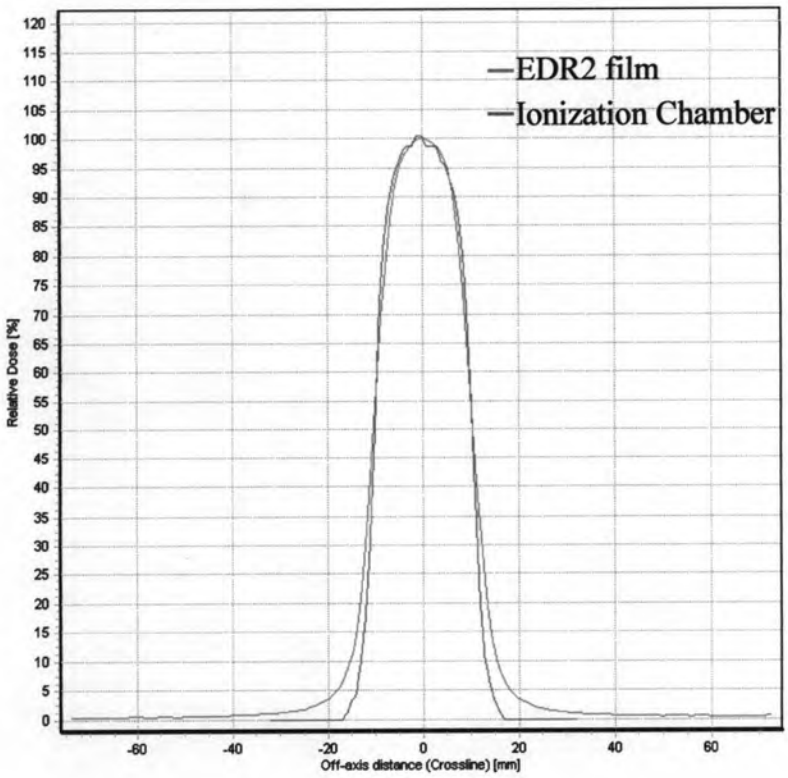


Figure 4.22 Dose profile measured with EDR2 film and an ionization chamber for field size of 2x2 cm^2 at depth of 5 cm for 10 MV x-ray beam

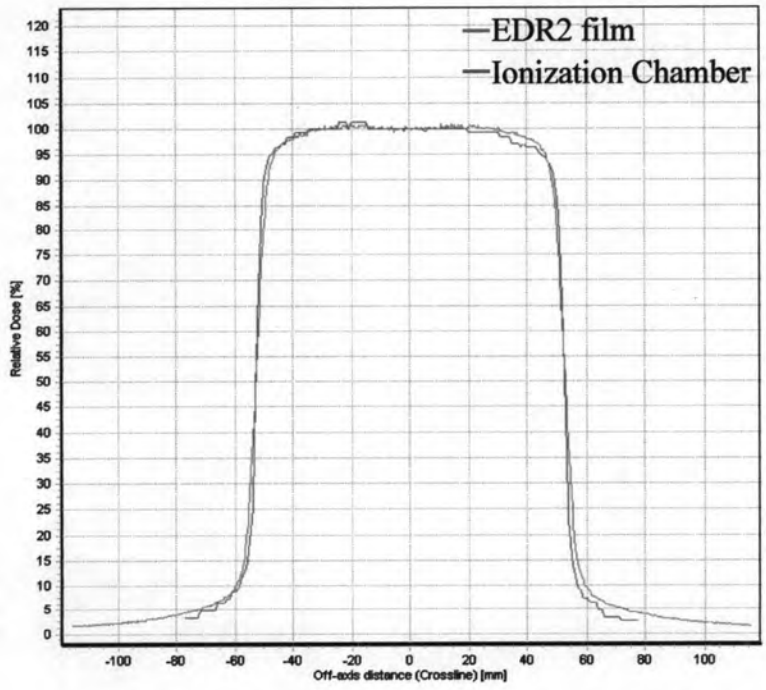


Figure 4.23 Dose profile measured with EDR2 film and an ionization chamber for field size of 10x10 cm^2 at depth of 5cm for 6 MV x-ray beam

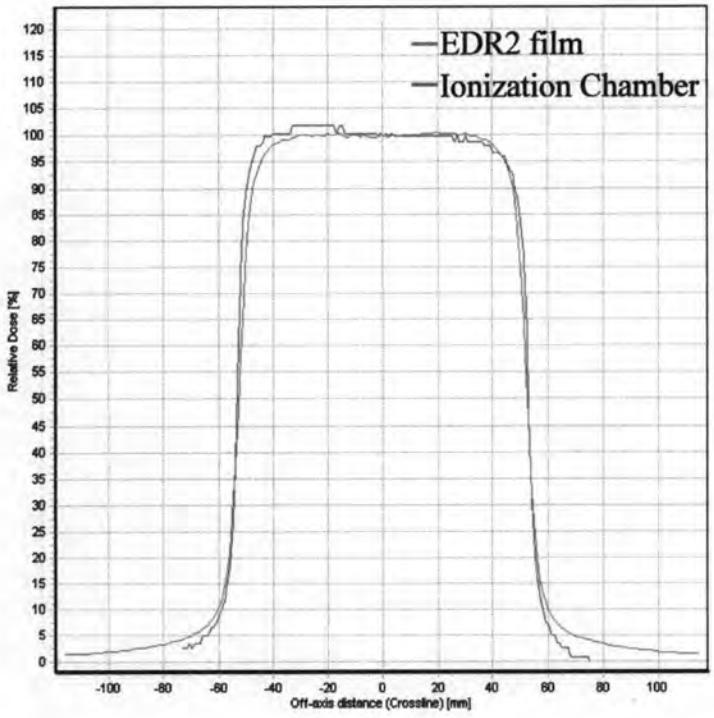


Figure 4.24 Dose profile measured with EDR2 film and an ionization chamber for field size of 10x10 cm^2 at depth of 5 cm for 10 MV x-ray beam

4.9 Optimal film calibration curve for IMRT verification

The goal of film calibration is to convert a film density value obtained from an actual beam measurement into an accurate tissue dose value. Therefore, the measurement setup for film calibration should represent the setup for actual beam measurement in terms of radiation environment, such as the photon fluence spectrum at the location of the film embedded within a phantom.

However, adjusting a calibration condition cannot be an adequate solution for complex IMRT, because a single calibration condition does not suitably represent actual IMRT fields in terms of the similarity of a radiation field. Another requirement for an ideal calibration condition is simplicity of setup, which allows relatively quick and reproducible measurement. One idea was to irradiate a single film with programmed multiple small fields using a multileaf collimator (MLC). As IMRT field size and fluence maps vary from field to field, from treatment site to treatment site, and from patient to patient, there is no simple way of modeling such variability of fluence maps within a phantom and incorporating such a model in a calibration procedure. Therefore, in general, the uses of a relatively small field size, such as 6 x 6 cm^2 or 7 x 7 cm^2 for calibration are recommend [13].

For our study, after the dosimetric properties has been investigated, the small field size of 3 x 3 cm^2 with film placed in solid water phantom at depth 5 cm perpendicular to the beam with the dose range from 20 to 450 cGy were selected to be the optimal condition for the film calibration curves both for 6 and 10 MV x-ray beams. The 3x3 cm^2 was chosen due to the reliable dose measurement, 3x3 cm^2 and 2x2 cm^2 sensitometric curves were not different over the range of dose and depth of

study. The 5 cm depth was selected due to it closed to the depth of head and neck cancer which mostly treated in this institute. The percent depth dose and beam profile measured by film at 5 cm were closely to those measured by ionization chamber.

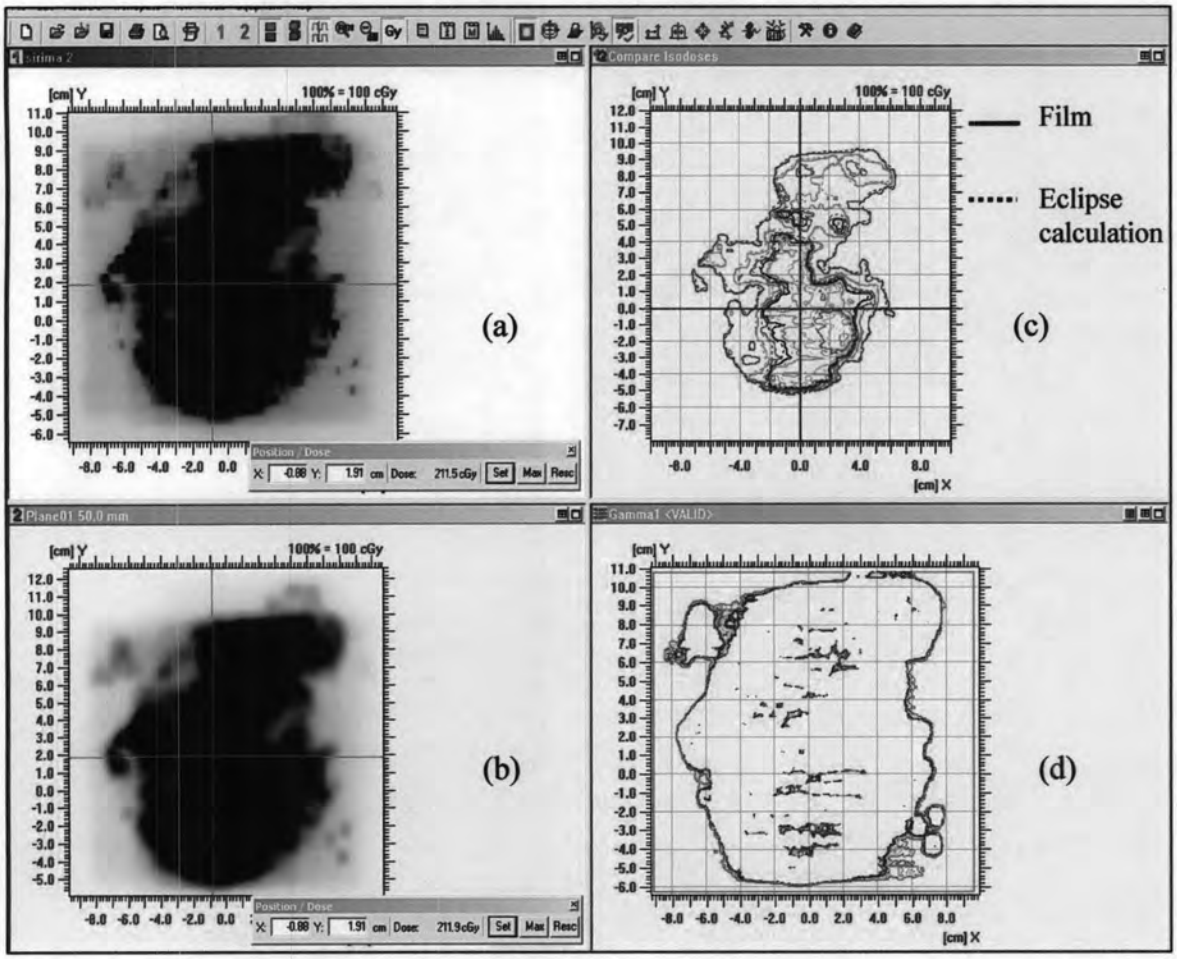
The advantage to choose these parameters irradiated in a single film which can be developed at one time so no effect of film development, film response exposure condition and scanner variations.

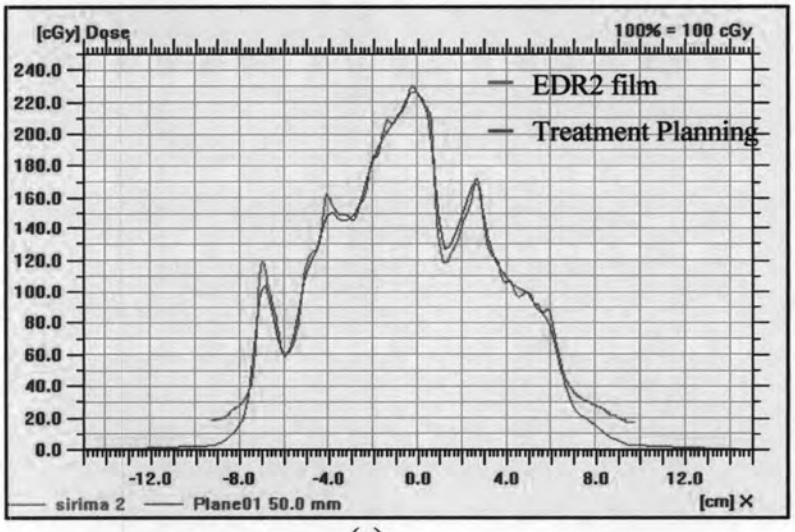
4.10 Verification of clinical IMRT plan

The calibration curve was performed for the dose ranging from 20 to 450 cGy for each time of IMRT plan verification. Two IMRT plans in each energies were chosen for verification in solid water phantom.

The four cases of verification of IMRT plan in solid water phantom for composite plan at fixed gantry angle were demonstrated by looking at the absolute dose distribution, beam profile and gamma value for 6 MV and 10 MV x-ray beams as shown in Figure 4.25 and Figure 4.26, respectively.

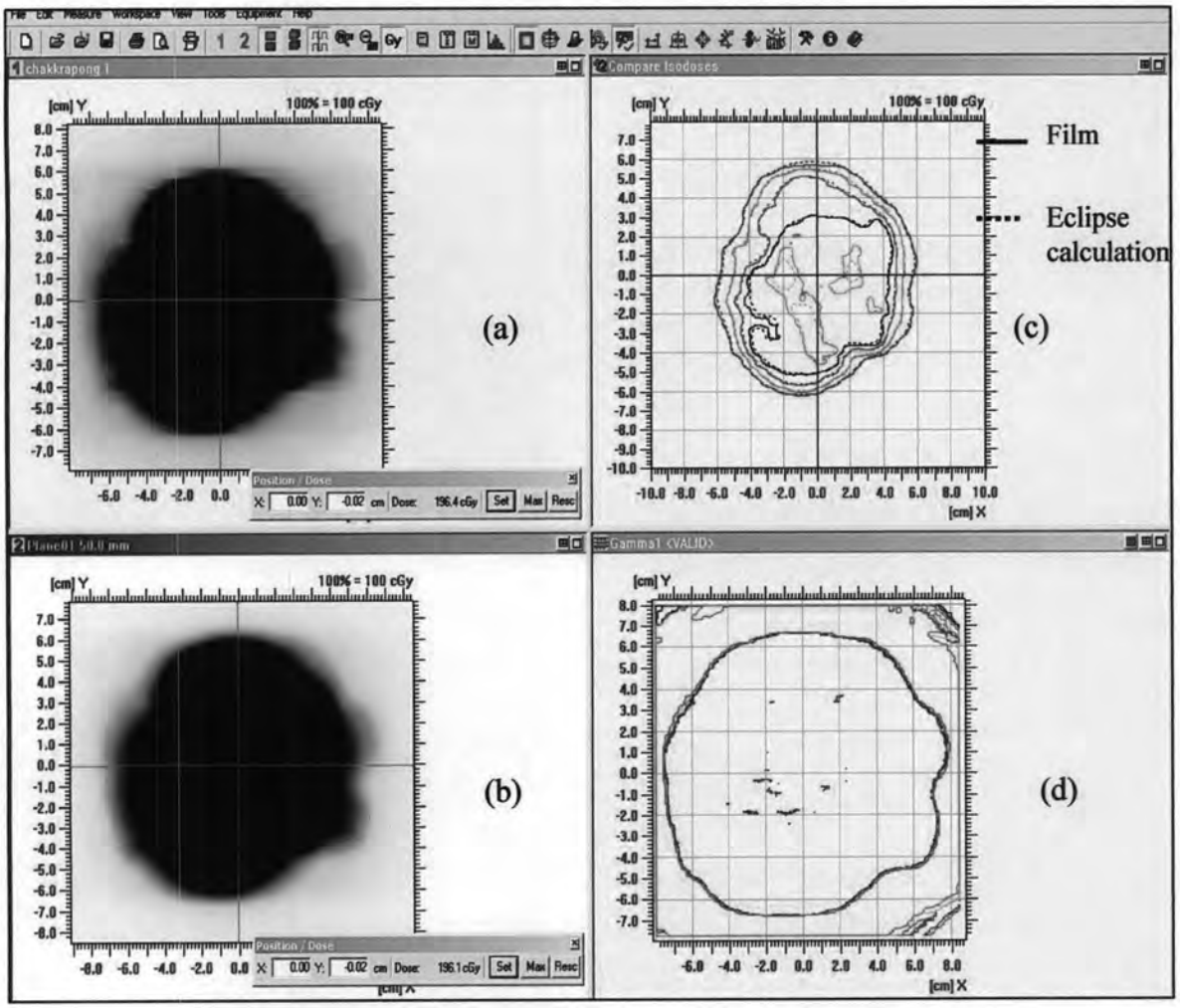
To evaluate the plans in Figure 4.25 and Figure 4.26, fluence map (a) and (b) should looked similar, the cross hair in both fluence map could be moved simultaneously and the absolute dose was recorded for each identical point of fluence from EDR2 film and fluence from treatment planning. The pair of reading dose should be closely to each other, the discrepancy should be within 3%. By this method, the absolute dose could be read at the interesting points over the fluence map. Isodose distribution in Figure (c) showed overlapped between solid line (EDR2 film measurement) and dot line (treatment planning). The gamma evaluation in Figure (d) showed shaded if the value was more than one and doses difference were grater than 3% and distance more than 3 mm. All the case studied showed the good agreement between the measured and the calculated dose. The gamma evaluations mostly were less than 3% of dose and 3 mm of distance.

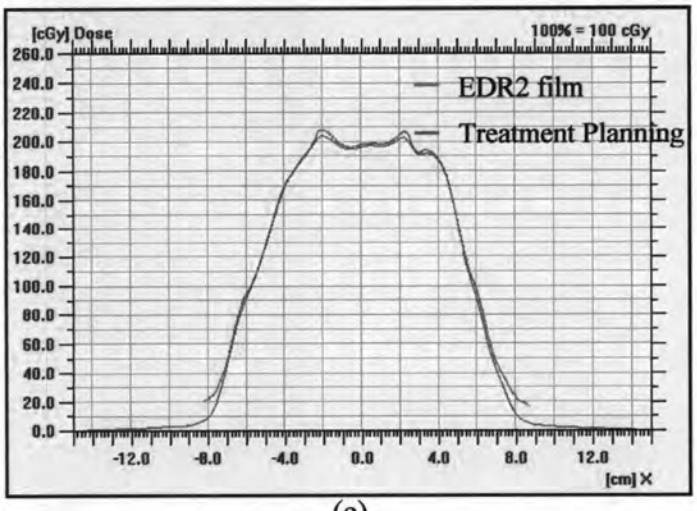




(e)

A. Plan number 1: Nine fields of PTV (planning target volume) low risk nasopharynx plan.



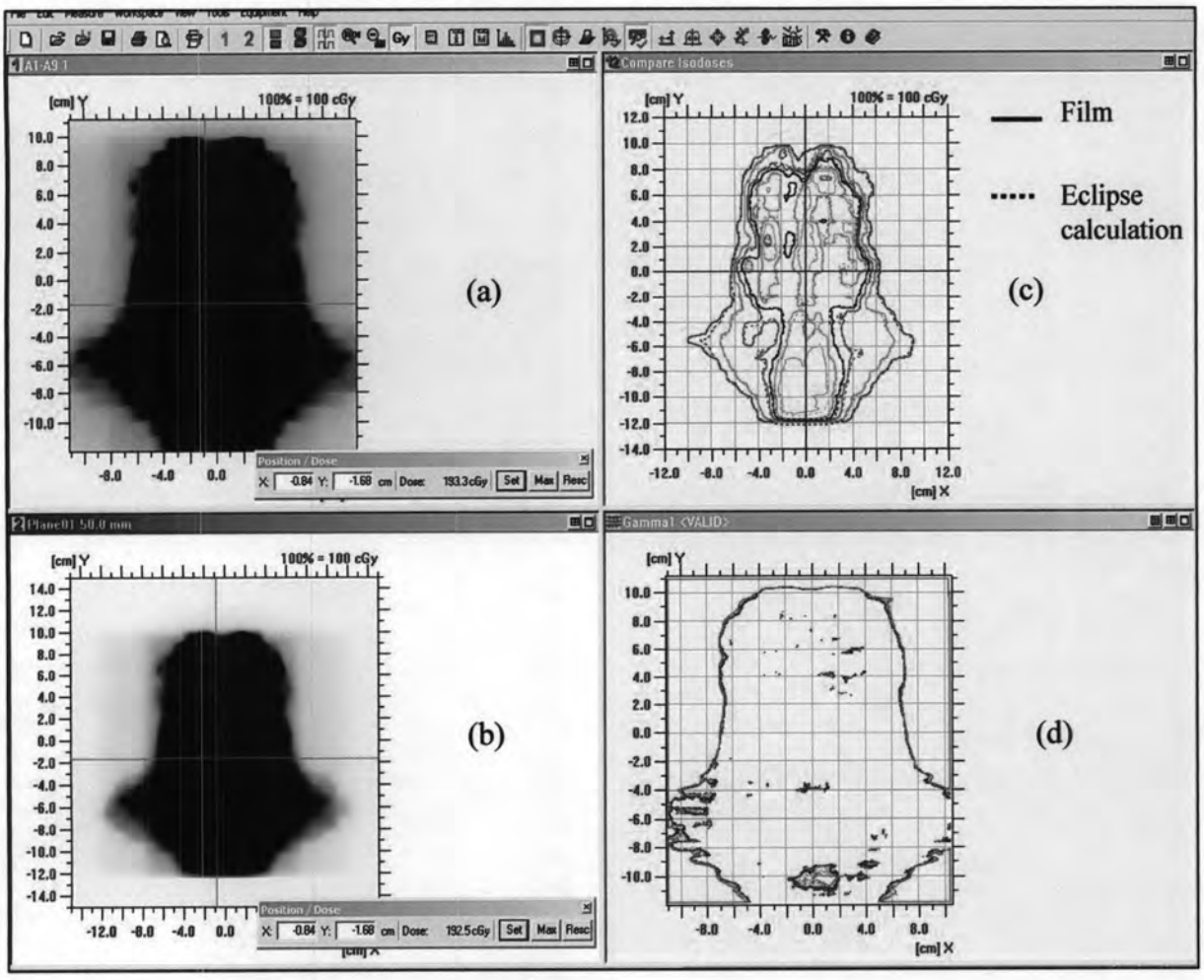


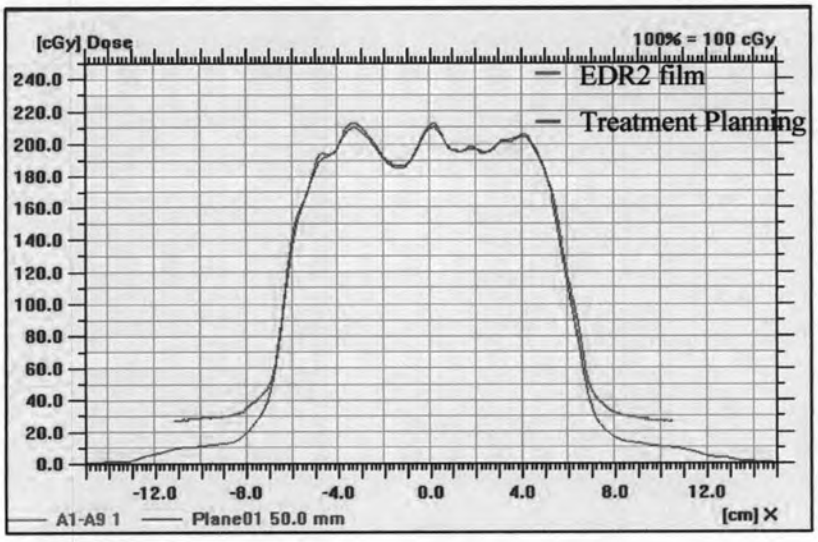
(e)

B. Plan number 2: Nine fields of PTV high risk nasopharynx plan.

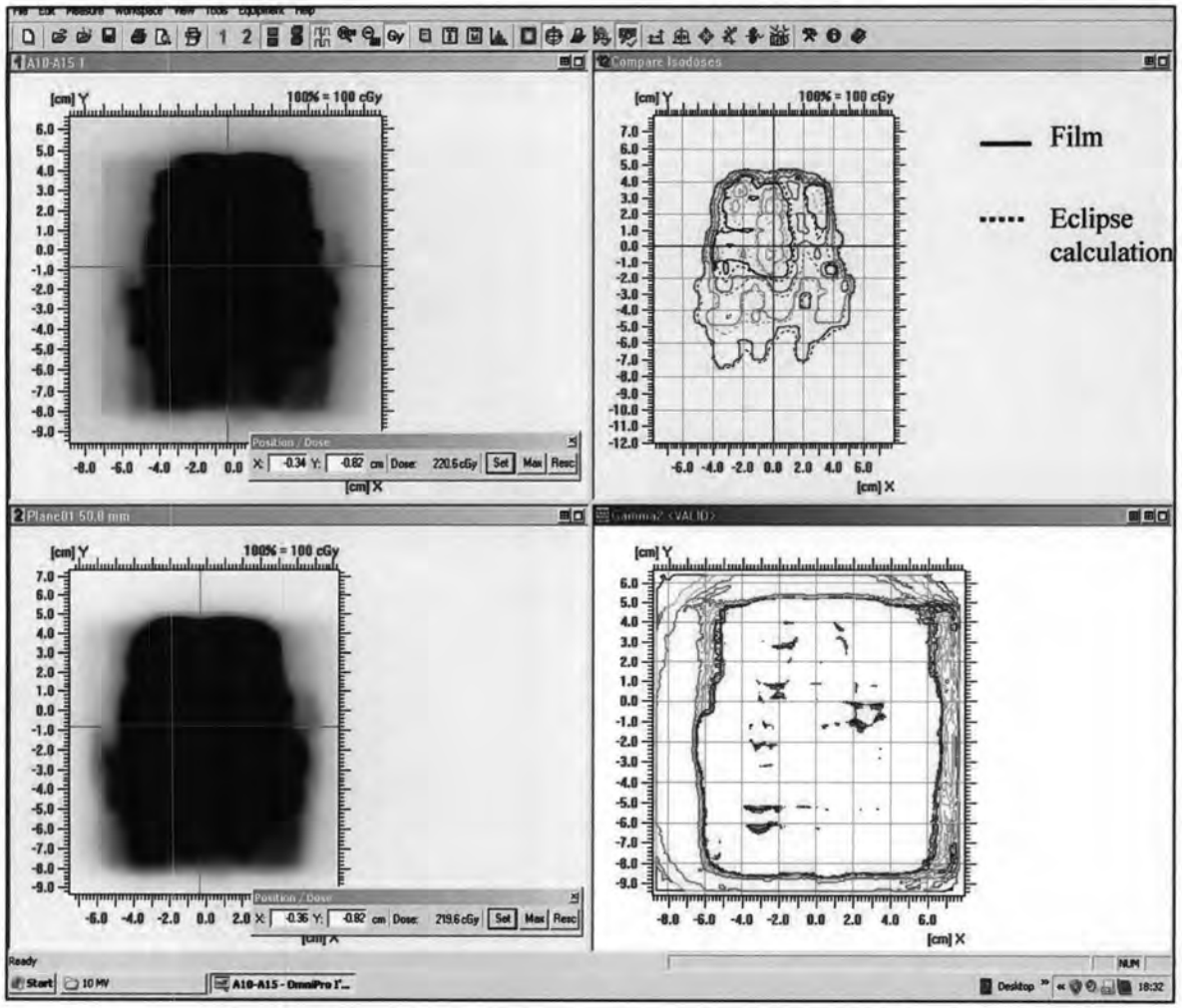
Figure 4.25 Verification of dose distributions calculated by Eclipse treatment planning and measured by EDR2 film for 6 MV x-ray beam for 2 plan of (A) plan number 1 and (B) plan number 2.

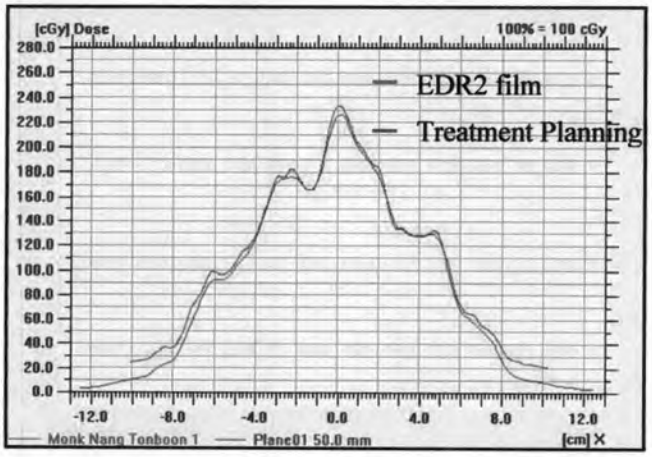
(a) Fluence map from film measurement
(b) Fluence map from Eclipse calculation
(c) Absolute Isodose distribution comparison
(d) Gamma value verification.
(e) Profile comparison between EDR2 film and ionization chamber





A. Plan number 3: Nine fields of PTV low risk nasopharynx plan.





(e)

B. Plan number 4: Nine fields of PTV high risk nasopharynx plan.

Figure 4.26 Verification of dose distributions calculated by Eclipse treatment planning and measured by EDR2 film for 10 MV x-ray beam for 2 plan of (A) plan number 3 and (B) plan number 4.

(a) Fluence map from film measurement
(b) Fluence map from Eclipse calculation
(c) Absolute Isodose distribution comparison
(d) Gamma value verification.
(e) Profile comparison between EDR2 film and ionization chamber