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Determination of total scatter correction factor for non-square fields and fields with wedge.

Dissertation submitted in partial fulfillment for the award of the Bachelor's Degree of Health Science in Medical Radiation.

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2004

CERTIFICATE

This is to certify that the dissertation entitled

" Determination of total scatter correction factor

for non-square fields and fields with wedges "

is the bonafide record of research work done by Ms Siti Aishah bt Ramly

during the period of January 2004 to March 2004.

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Date: 18 April 2004

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Date: 18 April 2004

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ABSTRACT

The aim of this study is to determine the total scatter correction factor for open and wedged rectangular fields for 6MV photon beam from Siemens MXE2 linear accelerator. The total scatter factor, Scp consists of two components, the collimator scatter correction factor, Sc and phantom scatter correction factor, Sp. This study also determines for wedge factor of square and non-square fields from the same source.

For open fields, measurements for Scp and Sc of square and non-square fields were carried out. The charge for each field size is normalized to the charge of 10cm x 10cm field size both obtained from the electrometer at 10cm depth. Sc was measured in mini phantom in air while water phantom was for Scp measurement. The value of Sp is derived from the formula, Scp/Sc (1). To obtain the value of Sc, Scp and Sp for square and non-square fields of wedged fields, the procedure is the same as for the open fields. Subsequently, the wedge factor is obtained by taking the ratio of the charge when the wedge is inserted to the charge when the wedge is not inserted for each field size. For wedged field only 30 degrees wedge was utilized.

The data shows that the total scatter correction factor for non-square fields both for the open and wedged fields are almost the same as the square fields for the field sizes investigated. This would mean that Scp, Sc and Sp for non-square fields could be estimated by using the value of their equivalent square.

The wedge factor for square fields and non-square fields agreed within 54% and 55%. Adding the wedge into the beam caused the value of total scatter correction factor to decrease by 54% and 55% compare to the open fields.

INTRODUCTION

In radiotherapy, patient with cancer is treated with photon beams or treatment beams. Treatment beams contain not only the relatively high-energy photon beam from the target but also a combination of photons and electrons scattered from the collimation system (1). The dose at a point can be thought of as being a combination of primary radiation that is coming directly from the source and secondary or scattered radiation that is coming from scatter interactions within the patient or phantom (1). This scattered radiation includes total scatter correction factor. Thus, it is very important to measure total scatter correction factor or output factor to make sure that the accuracy of dose calculations increases.

Photon beam treatment planning systems typically split the Scp, the total scatter correction factor into two components, Sc that is the collimator scatter correction factor and Sp that is the phantom scatter correction factor (7). It is usually for the blocked fields where the wedges, blocks or tray is put for the treatment purposes. As for open fields, there is no need to measure the Sc and derive Sp because it just only needs the field size correction factor, C_{fs} to enclose the total scatter correction factor, Scp. The Scp is equal to the C_{fs} when the open field is used and the measurement point is at depth of maximum dose, d_{max}.

The total scatter correction factor, Scp is defined as the dose rate at a reference depth for a given field divided by the dose rate at the same point and depth for the reference field size (1). Total scatter correction factor, Scp is measured using water tank for all field size. The collimator scatter correction factor, Sc is also called the head scatter factor and may be defined as the ratio of the output in air for a given field to that for a reference field (1). The collimator scatter correction factor, Sc is also measured for all field size but by using mini phantom in air. Both measurements are made using source to axis distance, SAD method or source to skin distance, SSD method. Only one method is chosen and used.

While for phantom scatter correction factor,Sp the value was derived from the equation of Scp/Sc (1). Sp may be defined as the ratio of the dose rate for a given field at a reference depth to the dose rate at the same depth for the reference field size with the same collimator opening (1). It is difficult to measure Sp directly because it depends on field size of the patient or phantom surface because from the definition Sp is related to the changes in the area of the phantom irradiated for a fixed collimator opening (1). The standard method to determine Sp is to measure Scp and Sc for symmetric fields.

Field size is the important parameter in treatment planning to treat cancer patients using radiotherapy and usually all of the physics data such as the depth dose, tissue maximum ratio and the output factor are measured for square field size. These data are fed into the treatment planning computer for the calculation of dose distribution and monitor unit. It is assumed that the output factor for the square fields and the rectangular fields is the same (2). An equivalent square field will have the same total scatter correction factors and scatter effects as the rectangular field (2) and there are several ways of determining the equivalent square field. From a practical standpoint, a published table of equivalent square fields is usually simply verified for each new treatment machine to establish its simplicity. An alternative approach to equivalent squares fields use approximation from the equation 2ab/a+b, where a and b is the length and width of the rectangular field size (4). Although the results of estimate the equivalent square from the published table and the approximation from the equation are slightly different, either methods yields an acceptable values.

Wedge is the common, non-customized compensating device that is used to distort the isodose distribution by tilting isodose lines through a specific angle (2). Wedge is sometimes used to compensate for sloping body surfaces (2). It is also used to good effect for areas of great obliquity such as neck, breast tangents and other anatomic areas where hot spots, regions of maximum dose occurrence could occur (2). When using wedge for the treatment purposes, the scatter radiation to the patients will be different. Therefore, the wedge also affects the value of the total scatter correction factor. The presence of a wedge filter also decreases the output of the linear accelerator that is taken into account in treatment calculations (1). This effect is characterized by the wedge transmission factor or wedge factor, defined as the ratio of outputs with and without the wedge, at a point along the central axis of the beam (1). This factor can be measured in air or in phantom at the depth of maximum dose, d_{max} or now can be measured at new reference depth at 10cm.

REVIEW OF LITERATURE

In 1984, total scatter correction factor for wedged or blocked fields is originated from Khan and his approach is to measure the total scatter correction factor at depth equal to 10cm for all field size.

In 1998, NCS Report 12 is about the determination and use of scatter correction factors of megavoltage photon beams. The relationship between the equations for application in isocentric treatment set-up and in fixed source-surface distance set-up is discussed. Scp, Sc and Sp data sets are presented for different types of treatment machines and for a wide range of photon beams, with photon beam qualities ranging from ^{60}Co to 25 MV.

In 1999, Dave Rogers has written about the comparison of calculated and measurement beam output factor. The kerma output factors is calculated using equation for field sizes from 7cm x 7cm to 30cm x 30cm relative to the reference field size of 8cm x 8cm. the calculated output factors with a relative uncertainty of 0.2% are compared to the measured values. The 10% variation in output factor is clearly observed and reproduced by the calculations. The calculated values agree with the measurements to within 0.1%.

In 2002, Yang Yong *et. al*, has done the study about the accurate determination of the head scatter factor, Sc for intensity modulated radiation therapy, where the segmented fields are often very irregular and much less than the collimator jaw settings. In this work, Sc value of calculation algorithm for symmetric, asymmetric, and irregular open fields shaped by the tertiary collimator (a multileaf collimator or blocks) at different source-to-chamber distance is reported. The results were compared with measurements. The study found that most of the calculated Sc value agreed with the measured values to within 0.4%.

OBJECTIVES OF THE STUDY

The objective of this study is to determine total scatter correction factor for square and non-square fields of open and wedged fields for 6MV photon beam. Total scatter correction factor is determined both for the open and wedged fields is due to the differences of total scatter correction factor for both fields. The differences are revealed in the data obtained from this study. The determination of total scatter correction factor for wedged fields in this study used wedge 30 degrees in angle. Wedge factor is also determined for square and non-square fields and the data is obtained and revealed in this study. This is to know the effects of adding the wedge that affects the total scatter correction factor.

This study also wants to proof that the total scatter correction factor for square field is equivalent to rectangular fields. It is to verify the assumptions that there is a square field size that is equivalent to rectangular field size in term of having the same total scatter correction factor.

MATERIALS AND METHODS

The materials used in this project were divided into two parts of measurements. For measurements of Sc, the materials used were the RK cylindrical ionization chamber, mini phantom, styrofoam and Victoreen electrometer. While for measurements of Scp, the RK cylindrical ionization chamber, water tank, water phantom and Victoreen electrometer were utilized. For both measurements, 6MV photon beam was from MXE2 linear accelerator.

The MEVATRON linear accelerator shown in Figure 1 is the device most commonly used for external beam radiation treatments for patients with cancer. Even though the manufacturer is from different company but the basic design is almost the same. The digital MEVATRON system consists of MEVATRON unit, collimator, handcontrol, treatment table and control console. The digital MEVATRON function is to deliver a uniform dose of high-energy x-ray to the region of the patient's tumor. These x-rays can destroy the cancer cells, while sparing the surrounding normal tissue. It used microwave technology to accelerate electrons and then allowed these electrons to collide with a heavy metal target (3). As a result of these collisions, high energy x-rays were scattered from the target. A portion of these x-rays was collected to form a beam that matches the size and shape of the patient's tumor (3).

Figure 1. Digital MEVATRON linear accelerator

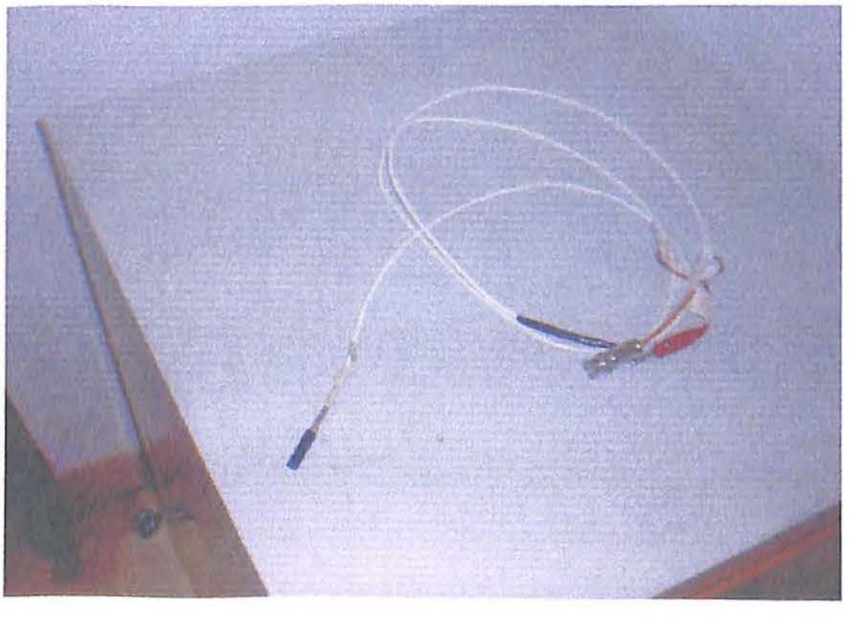

Figure 2. RK cylindrical ionization chamber

The RK chamber shown in Figure 2 and is a cylindrical, unsealed air ionization chamber intended for use in water phantom measurements of electron and photon beams energy greater than 1 MV (6). The encapsulation is waterproof with a ventilated chamber allowing adaptation to air pressure variations. A dot on the capsule identifies the center of the measuring volume. The RK chamber can also be used with a Perspex build-up cap for in-air measurements. The cap thickness provides a total surface density of 0.45 +/- 0.05 g cm^{-2} (6).

The Victoreen electrometer that is shown in Figure 3 is easy to use for radiotherapy measurements because it is intuitive, simple, straightforward and also have few buttons that control all operations and it is shown in Figure 3.

Figure 3. The Victoreen electrometer that is used to measure charge

The water phantom used is transparent, liquid, cheap and readily available. It is the main constituents of many human tissues and is tissue equivalent. The atomic number effective, z_{eff} is 7.51 and density, ρ is $1 g/cm^3$ (1). The water tank that is used for Scp and wedge factor measurements is shown in Figure 4. This tank does not have to be leveled on the treatment couch, since the scanning mechanism is leveled on top of the water tank.

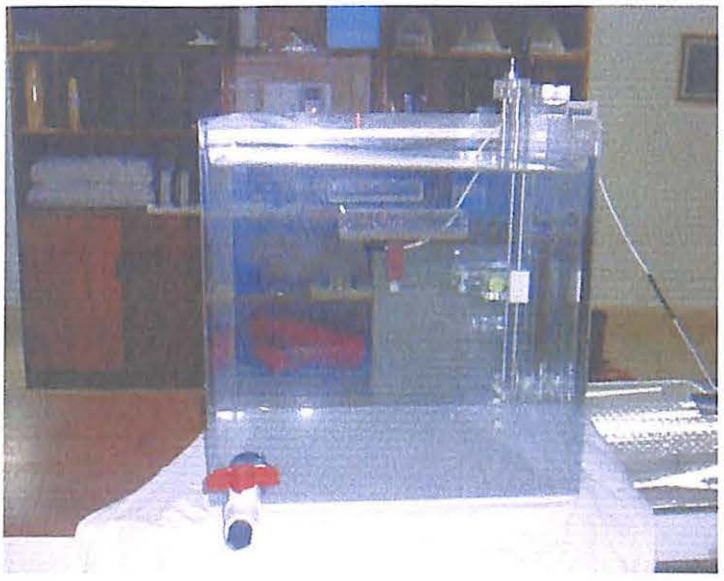

Figure 4. Water tank that is used to measure total scatter correction factor, Scp and wedge factor.

The narrow cylindrical beam-coaxial (mini) phantom used is made of Perspex material and it is shown in Figure 5. The dimensions is 3cm x 3cm so the field size use must exceed its dimensions. It is made commonly for measuring the head scatter factor (8). The mini phantom can be placed in two ways to take measurement that is in upright and horizontal position. It has a cavity to put the chamber inside. The length is about 15cm.

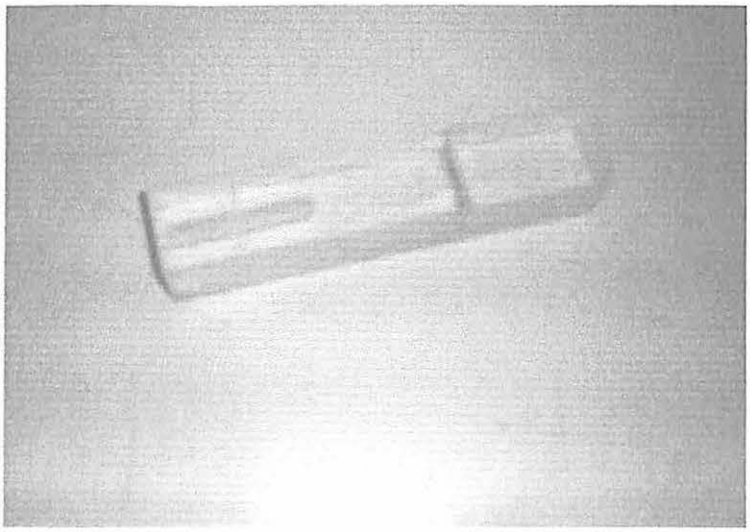

Figure 5. Mini phantom that is used to measure collimator scatter correction factor, Sc.

Wedge is made of steel and is mounted on a wedge plates that is used to modify the photon beam contour. The high portion of the wedge is referred to as the heel and the low portion is referred to as the toe (2) that is shown in Figure 7. The wedge is inserted into accessory holder and must interlock with the field size. There are two types of wedges, full beam and half beam wedges (5). The one used in this project was the full beam wedge, 30 degrees in angle that is shown in Figure 6. Full beam wedges are available in four angles, 15, 30, 45 and 60 degrees and the maximum for use is size 25cm x 30cm (5).

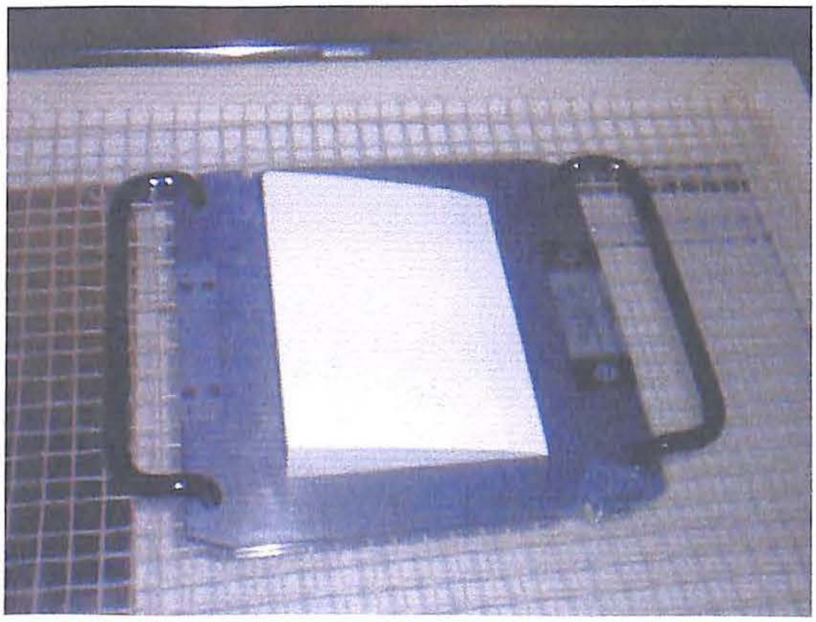

Figure 6. Wedge 30 degrees in angle

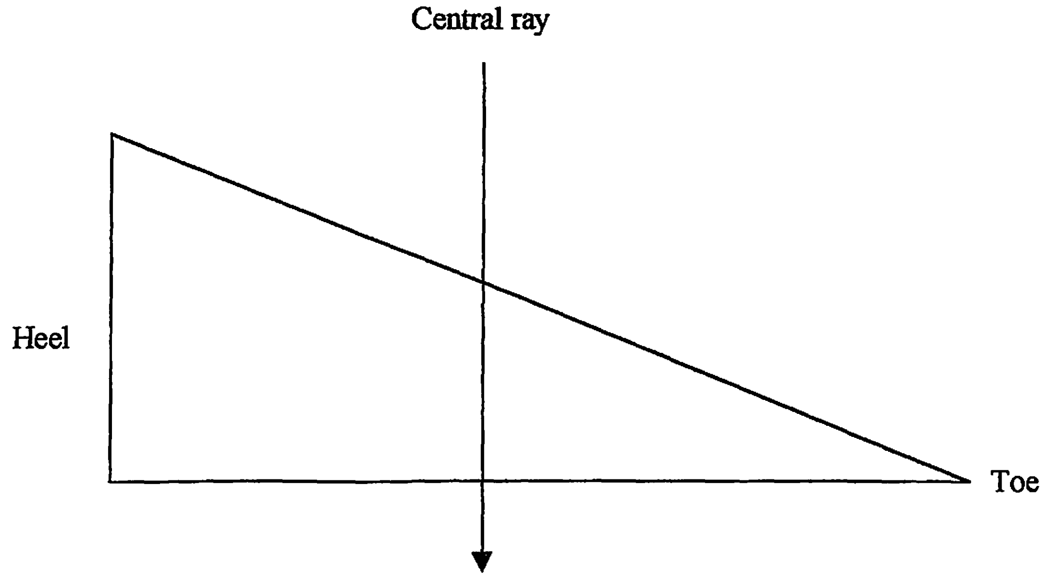

Figure 7. Schematic diagram of wedge vocabulary

Even though the materials used for measuring Sc and Scp were different but the methods of measuring were almost the same. For Sc, the mini phantom was used and RK chamber is put inside the cavity of mini phantom. The mini phantom was put on treatment table in upright position and to stabilize the mini phantom on the treatment table, the styrofoam was used that is shown in Figure 8. The reference point is at the center of RK chamber. So, the reference depth 10cm was from the surface of the mini phantom to the center of the RK chamber. SSD technique equal to 100cm was used that is from the source to the surface of the mini phantom. The schematic diagram of measuring the collimator scatter correction factor is shown in Figure 9. It is noticed that, the field size used must be bigger than the dimensions of the mini phantom. For each field size, each charge was collected twice using the Victoreen electrometer and mean charge was obtained. It was then normalized to mean charge obtained at 10cm x 10cm field size. The field size of interest was adjusted from the control console outside the treatment room.

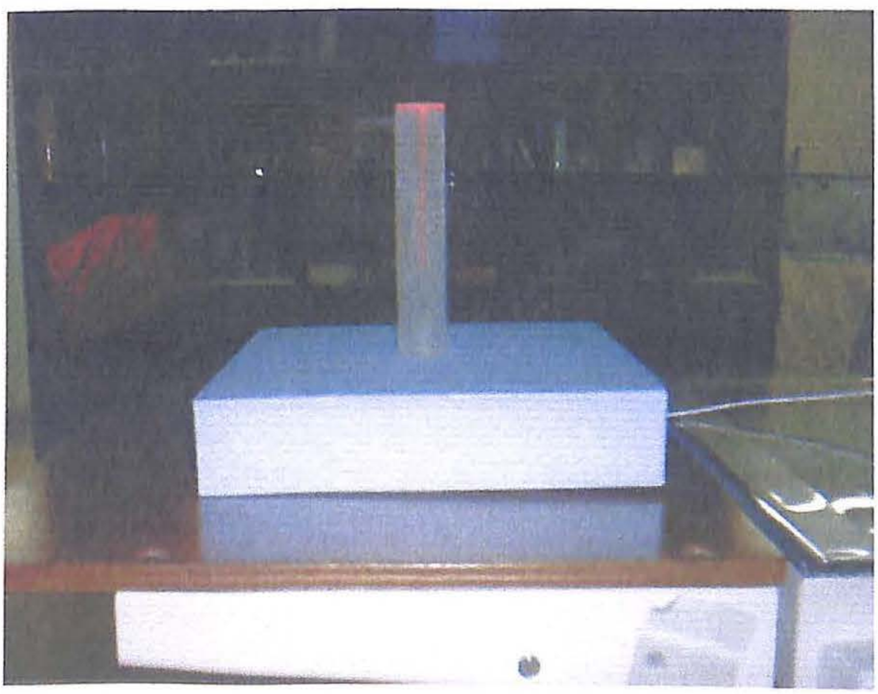

Figure 8. Setup for measuring collimator scatter correction factor, Sc.

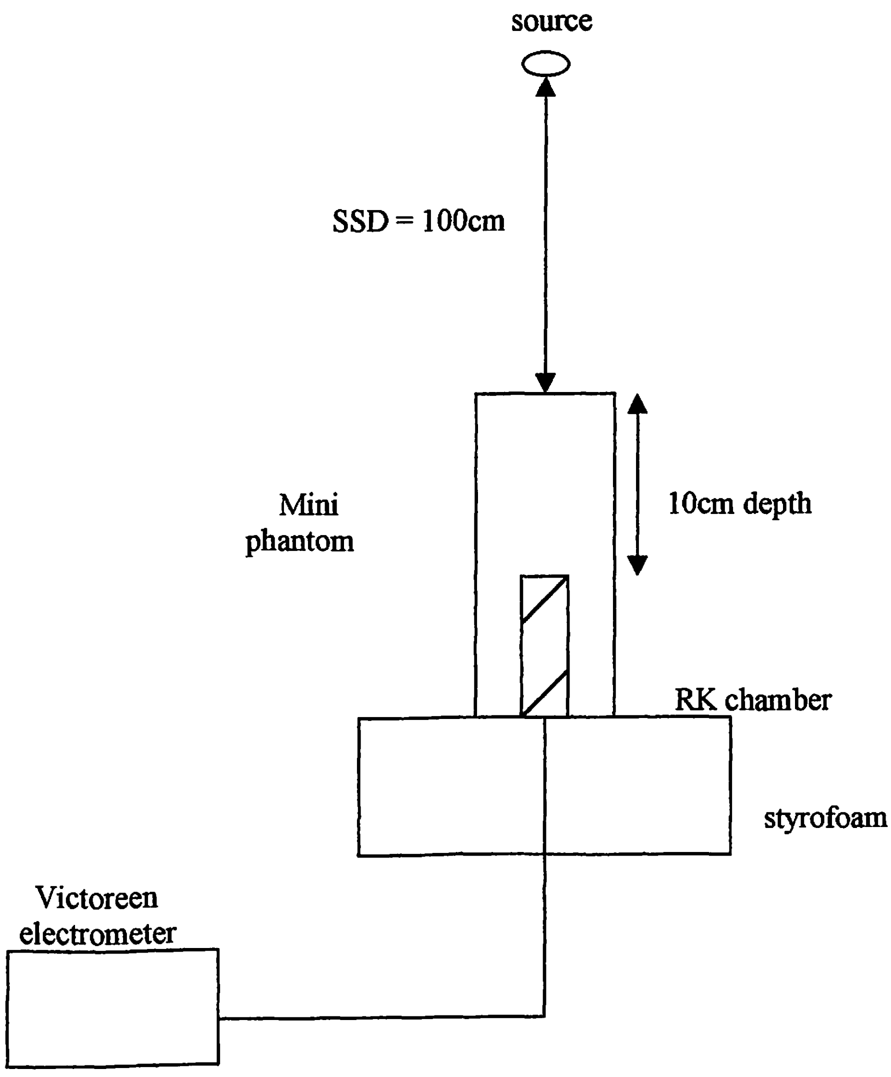

Figure 9: Schematic diagram for measuring collimator scatter correction factor, Sc.

For measuring Scp, the water tank was filled for about $30cm^3$ and was put on the treatment table under the linear accelerator head. The RK chamber was installed to the holder of the water tank. The reference point is at the center of RK chamber located at the surface of the water and this is 0cm depth. From 0cm depth, RK chamber was immersed and lowered in the water until 10cm depth using the scanning mechanism on top of the water tank that is shown in Figure 10. The technique used also SSD method, 100cm from the point source to the center of RK chamber at the surface of the water. The schematic diagram of measuring total scatter correction factor is shown in Figure 11. The charge was collected twice using the Victoreen electrometer from each field size of interest and the mean charge was obtained. It was normalized to reference field size, 10cm x 10cm to obtain Scp. When the measurement of Sc and Scp was taken, the value of Sp can be derived from the formula of Scp/ Sc (1).

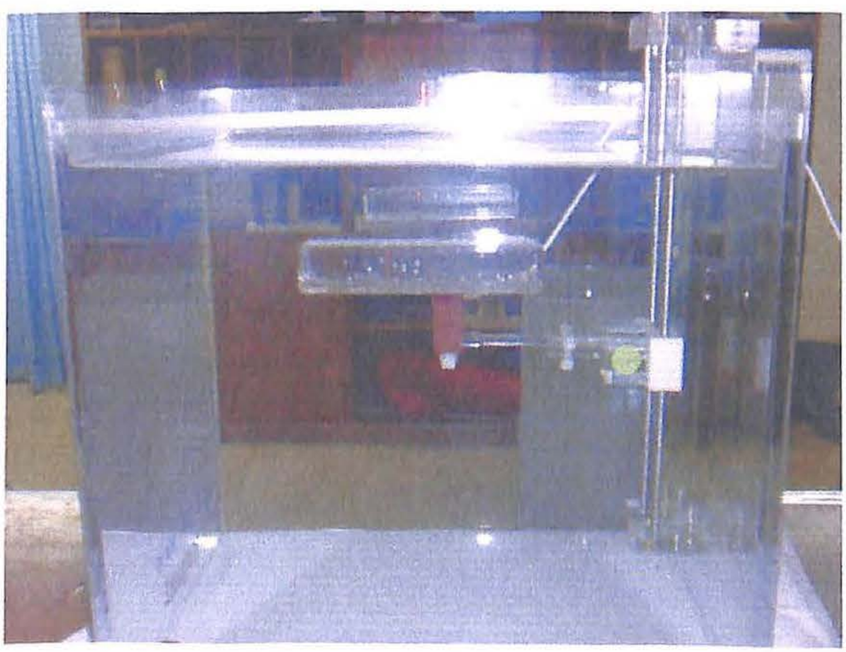

Figure 10. Setup for measuring total scatter correction factor, Scp

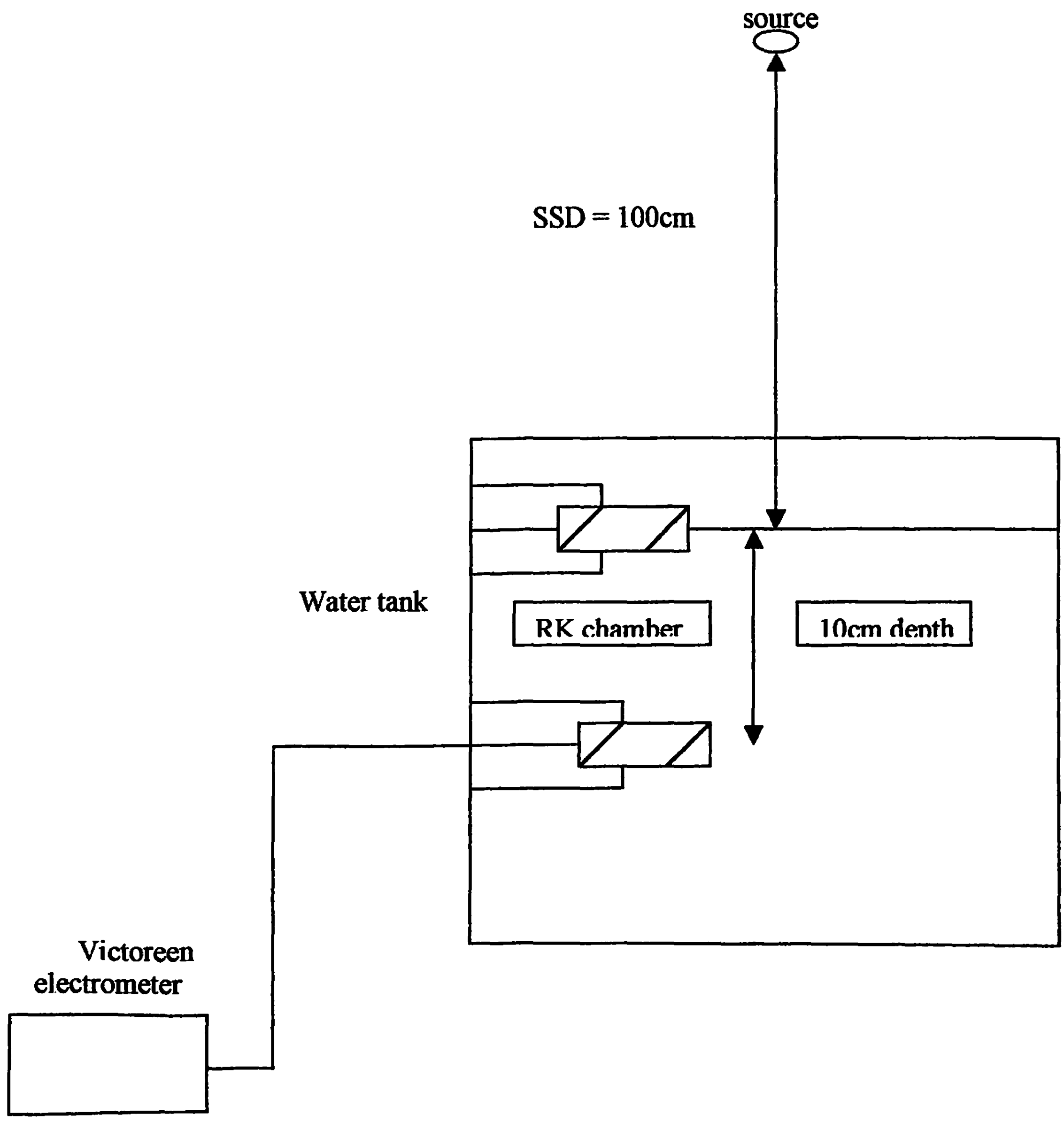

Figure 11: Schematic diagram for measuring total scatter correction factor, Scp.

To determine the total scatter correction factor for fields with wedge, the setup for the measurements of Scp and Sc is the same as for the open fields except that wedge 30 degrees was inserted into the accessory holder of MXE2 linear accelerator head. The calculation of Sp was also the same.

The setup for measuring wedge factor was the same as for the setup for measuring Scp except that the measurements was taken when the wedge was inserted and when the wedge was not inserted for the same field size. The ratio is taken and it is called the wedge transmission factor or wedge factor.

For the setup of this project, it is based on IAEA Protocol TRS 398 2000 where the reference field size is 10cm x 10cm and the reference depth is at 10cm. The reference or standard field size used is always 10cm x 10cm. The reason to use 10cm depth as the reference depth is that the depth must be deep enough to let the absorbed dose penetrates more deeper and can measured the charge efficiently (1). The depth cannot be in the build-up region that is the region between the surface and the point of maximum dose because the initial build-up dose becomes more pronounced as the energy increases (1). The electron fluence and absorbed dose increases with depth until it reaches maximum. Thereafter when the depth is deeper there is also no electron contamination occur because it is well known that radiation used in radiotherapy is contaminated with secondary electrons that happens at surface dose approximately 0.5mm depth (1). Moreover the wedge is mostly used for treating superficial tumors not more than 10cm deep (1).

RESULTS

In this project, 6MV photon used was the source that comes directly from MXE2 linear accelerator. The monitor unit applied was 200 and the voltage used was about +/- 200V. The reference condition is at 10cm depth and 10cm x 10cm field size that used SSD method. The temperature and pressure inside the treatment room, the room for taken the data is 20°C and 100.9 cPascal. The data is taken for about a week. The earlier condition did not changed much that made the data accepted even though it is done for several different days. The non-square fields for all square fields is determined from the equation 2ab/a+b, where a and b is the length and width of the field sizes (4) as mentioned before.

The results are divided into three parts, Part I, Part II and Part III. Part I reveals the value of Scp, Sc and Sp for square and non-square fields of open fields. The square and non-square fields are categorized and arranged according to small fields, middle fields and large fields. The small fields used 5cm x 5cm, 8cm x 8cm and 10cm x 10cm of square fields. The lengths and widths of rectangular fields used are within the range of 4cm to 26cm. Then, the middle fields used 15cm x 15cm, 18cm x 18cm and 20cm x 20cm of square fields. The lengths and widths of rectangular fields used are within the range of 11cm to 28cm. While large fields used 25cm x 25cm, 28cm x 28cm and 30cm x 30cm of square fields and the lengths and widths of rectangular fields used are within the range of 18cm to 40cm. Table 1 shows the charge taken from the electrometer and the value of Sc obtained for square and non-square fields of open fields. Table 2 shows the charge taken from the electrometer and the value of Scp obtained for square and non-square fields of open fields. Table 3 shows the charge taken from the electrometer and the value of Sp obtained for square and non-square fields of open fields. The comparison of these values between the non-square fields with their square fields of open fields is shown in Table 4. The comparison is in the percentage ratio value.

Part II indicates the value of Scp, Sc and Sp for wedged fields. The square fields used are 5cm x 5cm, 6cm x 6cm, 7cm x 7cm, 8cm x 8cm, 9cm x 9cm, 10cm x 10cm and 11cm x 11cm. The lengths and widths of rectangular fields used are within the range of 4cm to 12cm. The maximum field size that can be used when wedge is inserted is 12cm x 12cm. Table 5 shows the charge taken from the electrometer and the value of Sc obtained for square and non-square fields with wedge. Table 6 shows the charge taken from the electrometer and the value of Scp obtained for square and non-square fields with wedge. Table 7 shows the charge taken from the electrometer and the value of Sp obtained for square and non-square fields with wedge. The comparison of the value of Sc, Scp and Sp between square and non-square fields with wedge are shown in Table 8 in the form of percentage ratio value.

Part III is the section that shows the effects of adding the wedge into linear accelerator head in this project. The square fields used are the same as square fields used in Part II. The charge taken from the electrometer both when the wedge is inserted and when the wedge is not inserted and also the value of wedge factor for square and non-square fields obtained are shown in Table 9. Table 10 shows the comparison of the value of wedge factor for square and non-square fields in the form of percentage ratio value.

It is assumed that the results in this study are accepted if the values of the data did not exceed +/-10%.

Part I

Table 1. Sc for square and non-square fields of open fields.

Square fields (cm^2)	Non-square fields(cm^2)	Q_1 (nC)	Q_2 (nC)	Mean Q (nC)	Sc
5x5		3.907	3.905	3.9060	0.9638
	4x6	3.888	3.888	3.8880	0.9594
	4x7	3.899	3.903	3.9010	0.9626
	4x8	3.906	3.911	3.9085	0.9645
8x8		4.020	4.016	4.0180	0.9915
	5x16	3.970	3.969	3.9695	0.9795
	5x17	3.974	3.970	3.9720	0.9801
	5x18	3.975	3.974	3.9745	0.9808
	5x19	3.980	3.977	3.9785	0.9817
	5x20	3.976	3.975	3.9755	0.9810
	5x22	3.978	3.973	3.9755	0.9810
	5x24	3.976	3.979	3.9775	0.9815
	5x26	3.979	3.978	3.9785	0.9817
	6x11	3.988	3.986	3.9870	0.9838
	6x12	3.990	3.991	3.9905	0.9847
	6x13	3.997	3.993	3.9950	0.9858
	6x14	3.997	3.994	3.9955	0.9859
	7x9	4.001	3.998	3.9995	0.9869
	7x10	4.009	4.010	4.0095	0.9894
10x10		4.050	4.055	4.0525	1.0000
	7x16	4.025	4.023	4.0240	0.9930
	7x17	4.029	4.023	4.0260	0.9935
	7x18	4.030	4.023	4.0265	0.9936
	7x19	4.030	4.025	4.0275	0.9938
	7x20	4.029	4.031	4.0300	0.9944
	8x12	4.035	4.040	4.0375	0.9963
	8x13	4.045	4.053	4.0490	0.9991
	8x14	4.056	4.051	4.0535	1.0002
	8x15	4.051	4.051	4.0510	0.9996
	9x11	4.055	4.055	4.0550	1.0006
	9x12	4.066	4.058	4.0620	1.0023

Square fields (cm^2)	Non-square fields(cm^2)	Q_1 (nC)	Q_2 (nC)	Mean Q (nC)	Sc
15x15		4.113	4.114	4.1135	1.0151
	11x22	4.090	4.090	4.0900	1.0093
	11x24	4.085	4.084	4.0845	1.0079
	12x19	4.086	4.093	4.0895	1.0091
	12x20	4.094	4.093	4.0935	1.0101
	13x17	4.103	4.100	4.1015	1.0121
	13x18	4.097	4.102	4.0995	1.0116
	13x19	4.100	4.096	4.0980	1.0112
	14x16	4.107	4.103	4.1050	1.0130
	14x17	4.102	4.103	4.1025	1.0123
18x18		4.135	4.133	4.1340	1.0201
	14x24	4.120	4.118	4.1190	1.0164
	14x26	4.119	4.124	4.1215	1.0170
	15x22	4.125	4.123	4.1240	1.0176
	16x20	4.124	4.128	4.1260	1.0181
	17x19	4.129	4.130	4.1295	1.0190
	17x20	4.134	4.132	4.1330	1.0199
20x20		4.149	4.148	4.1485	1.0237
	16x26	4.140	4.134	4.1370	1.0209
	16x28	4.143	4.140	4.1415	1.0220
	17x24	4.140	4.140	4.1400	1.0216
	18x22	4.144	4.138	4.1410	1.0218
	19x22	4.145	4.141	4.1430	1.0223

Square fields (cm^2)	**Non-square fields(cm^2)**	**Q_1 (nC)**	**Q_2 (nC)**	**Mean Q (nC)**	**Sc**
25x25		4.167	4.165	4.1660	1.0280
	18x40	4.166	4.164	4.1650	1.0278
	19x36	4.167	4.172	4.1695	1.0289
	19x38	4.170	4.169	4.1695	1.0289
	20x32	4.170	4.171	4.1705	1.0291
	20x34	4.172	4.170	4.1710	1.0292
	22x28	4.173	4.173	4.1730	1.0297
	22x30	4.172	4.173	4.1725	1.0296
	24x26	4.169	4.172	4.1705	1.0291
28x28		4.180	4.183	4.1815	1.0318
	22x38	4.177	4.180	4.1785	1.0311
	22x40	4.184	4.182	4.1830	1.0322
	24x34	4.180	4.179	4.1795	1.0313
	26x30	4.178	4.178	4.1780	1.0310
30x30		4.186	4.189	4.1875	1.0333
	24x40	4.182	4.184	4.1830	1.0322
	26x36	4.183	4.185	4.1840	1.0324
	28x32	4.181	4.181	4.1810	1.0317

Table 2. Scp for square and non-square fields of open fields.

Square fields (cm^2)	Non-square fields(cm^2)	Q_1 (nC)	Q_2 (nC)	Mean Q (nC)	Scp
5x5		4.548	4.540	4.5440	0.8869
	4x6	4.512	4.508	4.5100	0.8803
	4x7	4.564	4.557	4.5605	0.8901
	4x8	4.587	4.588	4.5875	0.8954
8x8		4.934	4.926	4.9300	0.9622
	5x16	4.833	4.847	4.8400	0.9447
	5x17	4.850	4.852	4.8510	0.9468
	5x18	4.860	4.860	4.8600	0.9486
	5x19	4.864	4.865	4.8645	0.9494
	5x20	4.866	4.868	4.8670	0.9499
	5x22	4.879	4.884	4.8815	0.9528
	5x24	4.890	4.890	4.8900	0.9544
	5x26	4.895	4.897	4.8960	0.9556
	6x11	4.876	4.870	4.8730	0.9511
	6x12	4.890	4.893	4.8915	0.9547
	6x13	4.907	4.904	4.9055	0.9575
	6x14	4.920	4.925	4.9225	0.9608
	7x9	4.904	4.903	4.9035	0.9571
	7x10	4.937	4.930	4.9335	0.9629
10x10		5.125	5.122	5.1235	1.0000
	7x16	5.045	5.043	5.0440	0.9845
	7x17	5.050	5.058	5.0540	0.9864
	7x18	5.063	5.066	5.0645	0.9885
	7x19	5.062	5.065	5.0635	0.9883
	7x20	5.081	5.080	5.0805	0.9916
	8x12	5.082	5.085	5.0835	0.9922
	8x13	5.085	5.098	5.0915	0.9938
	8x14	5.097	5.103	5.1000	0.9954
	8x15	5.109	5.120	5.1145	0.9982
	9x11	5.100	5.101	5.1005	0.9955
	9x12	5.125	5.129	5.1270	1.0007