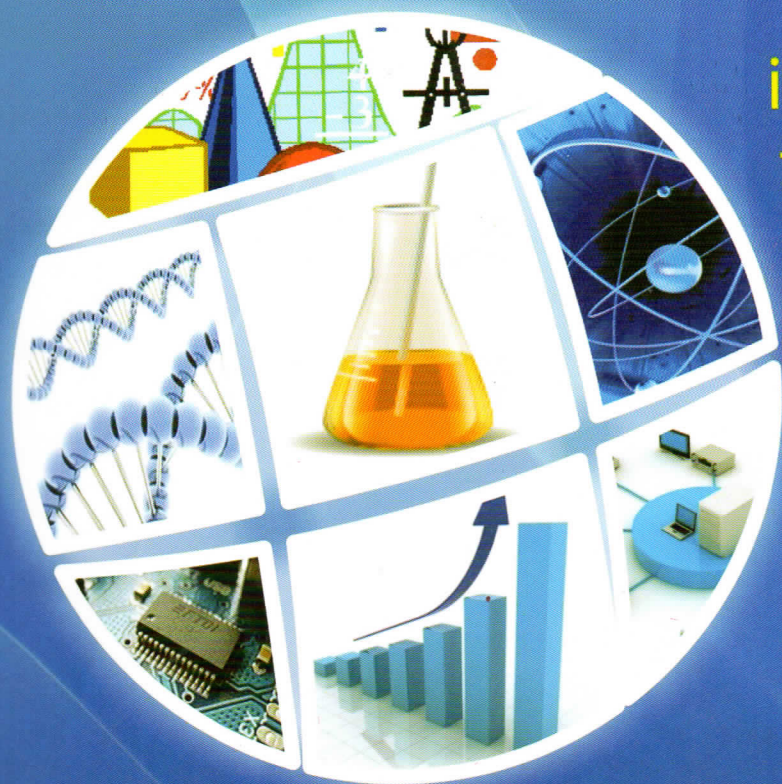


4th iSNPiNSA



International Seminar on New Paradigm
and Innovation on Natural Sciences
and its Application



Innovation
in Applied Science
for Environmental
Resource
Sustainability

PROCEEDINGS



Diponegoro University
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*The 4th International Seminar on
New Paradigm and Innovation on Natural Sciences and its
Application 2014*

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***“Innovation in Applied Sciences for Environmental
Resource Sustainability”***

Dr. Jatni Eko Endro Suseno, M.Si

Dr. Eng. Hendri Widiyandari, M.Si

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Distance Optimization between Two Irradiation Fields for Electron Beam Junctions of Linear Accelerator

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ABSTRACT

The optimal distance between two electron-beam irradiation fields which experienced beam junction by the variations of electron energy and distance between those fields with the ICRU tolerance of dose distribution (95% - 107%) has been determined.

The measurement of relative absorbed dose was done for the electron energy as much as 5, 7, 8, 10, 12, and 14 MeV in the area of $10 \times 10 \text{ cm}^2$ within distance variation of 0; 0,2; 0,4; 0,6; and 0,8 cm between the electron-beam irradiation fields. The data was then analyzed and described in graph to illustrate the correlation between relative absorbed dose to the axis points of the electron-beam irradiation fields at the crossline scanning (X-axis) and inline scanning (Y-axis).

The result has shown that the dose distribution at the beam junction was optimum. To the crossline direction, the electron energy 5, 7, 8, and 10 MeV had the optimum distance at 0,2 cm and the electron energy 12 and 14 MeV had the optimum distance at 0,4 cm. While to the inline direction, the electron energy 5 MeV had the optimum distance at 0 cm, the electron energy 7, 8, 10, and 12 MeV had the optimum distance at 0,2 cm and the electron energy 14 MeV had the optimum distance at 0,4 cm.

Keywords: beam junctions, electron beam, relative absorbed dose, radiotherapy, Linac.

1. INTRODUCTION

Radiotherapy is a cancer therapy based in ionizing radiation to eliminate cancer cells by applying measured radiation dose to the target and minimizing the radiation effect to the surrounding healthy tissue. Radiotherapy treatment is a palliative treatment, which is reducing pain to increase patients' life quality.

The energy from electron has been used for radiotherapy treatment since 1950. At the beginning, the radiation used betatron using linear accelerator and Van de Graff generator using low energy electron. Since 1970, the usage of high energy linear accelerator has produced multi-energy electron and photon beams. The acceptable range of the electron energy for radiotherapy treatment is 6 – 29 MeV. In this range, electron energy can be beneficial for superficial tumor treatment (irradiation of the organ's surface) with the variations of the dosage reduction for tumor [1].

One of the high-energy devices used in radiotherapy is Linear Accelerator (Linac). Linac is able to produce two energy outputs that are used in radiation, naming photon and electron. Electron energy is used in superficial radiation. Therapy applications on long therapy fields and on surfaces with different slopes are done using more than one therapy fields. The therapy applied on long field radiation is designed to be done using more than one radiation fields because the examined area is bigger than the applicator, while the therapy on surface with different slopes is also done using more than one radiation fields because perpendicular beam is needed to distribute the dose equally.

For the time being, the radiation on more than one radiation fields has been done without any distance between those fields. During the radiation on more than one fields, beam junctions are likely to be happened. In beam junctions, there are hot spot and cold spot. Hot spot is the area outside the target that receives higher dose than the target (more than 107%), while cold spot is the area in the target that receive less than 95% of prescribed dose [1]. The optimum dose that should be accepted by the target is 95% - 107% of the prescribed dose [2]. This research examined the optimum distance of the beam junctions between two irradiation fields in Linear Accelerator.

2. THEORIES

Linac is a device which has some discreet components to fasten the high-energy electron using radiofrequency waves before the electron hits the target to produce X-ray. After that, the X-ray profile is flattened or collimated and measured clinically. Linac is able to produce various energy of X-ray or multi-energy or can produce X-ray and

electron [3]. Linac is very efficient because getting more than one energy; both photon and electron can be obtained without expanding the room [4]. The electron energy used in clinic practice usually ranges between 6 - 20 MeV. In this energy, the electron beam can be used as a treatment to superficial tumor in less than 5 cm. Some of the applications of electron beam therapy are skin and lips cancer treatment, chest wall irradiation in breast cancer, setting dose measurement to node and neck and head cancer treatment [1].

The radiation dose on certain field is illustrated by dose profile or isodose. Dose profile can be obtained from crossline and inline scanning. Crossline scanning is performed to obtain the beam flatness and proportion to the X axis while inline scanning is performed to obtain the beam flatness and proportion to the Y axis [5]. In labelling jaw collimator, crossline scanning is started from X1 to X2, while inline scanning is started from Y1 to Y2. Labeling jaw collimator can be seen in Figure 2.

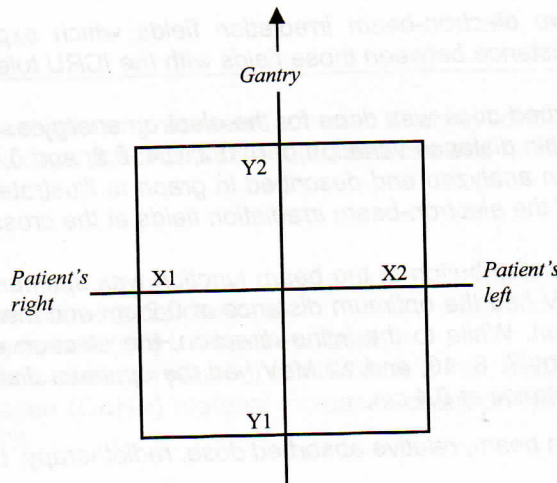


Figure 1: Labelling jaw collimator [6]

In the radiation using more than one radiation fields, a beam junction is likely to be happened. The beam junction may cause hot spot and cold spot area. The beam junctions can be seen in Figure 2.

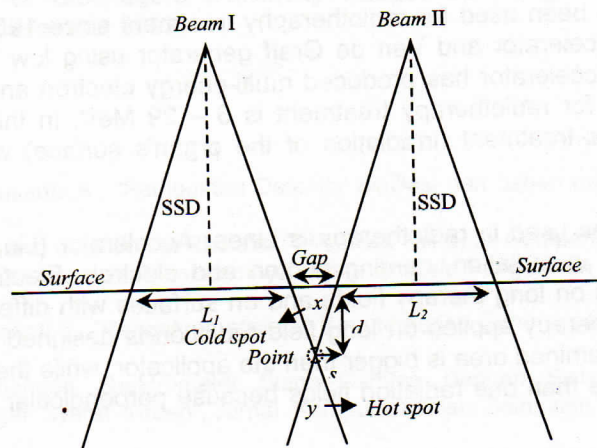


Figure 2: Beam junctions [1]

The ionizing radiation might cause damage to the tissue, so the radiation dose that is applied in certain volume must be distributed equally or homogenously based on ICRU regulation that states the maximum dose is within 95% - 107%. The application of radiation dose must obtain the objective of the treatment that is curative and palliative. Overdose might damage normal tissue that also might cause necrosis in the tissue while underdose might cause recurrence [7].

3. RESEARCH METHOD

3.1 Tools and Materials

The research was done using *Siemens* Linear Accelerator (Linac), type Primus M Class 5633, that produces the output 6 MV photon energy and 5, 7, 8, 10, 12, 14 MeV electron energy. The other tools were ionization detector, water phantom, computer control unit (CCU), applicator, computer, thermometer and barometer.

3.2 Research procedure

Before the electron beam radiation, acrylic box was filled with aquadest DM by pumping the water from reservoir to the acrylic box to reach about 50 cm depth.

After the acrylic box was filled with water, the next step was setting the tools like placing the applicator the the head Linac, setting the reference detector at the center of the cut-out area of three applicators, setting the field detector at the servo mechanism inside the phantom. After that, both detectors were then connected through coaxial cable to the CCU that was connected to the computer.

Before the radiation, the input variables were set using OmniPro Accept 7. Those variables are the data of Linac temperature and room pressure, field detector direction, dose reading range, and d_{maks} normalization. In this research, the detector was set to crossline mode which means that the detector was expected to move from X1 axis to X2 axis, and inline mode that means that the detector was expected to move from Y1 axis to Y2 axis. After the variable setting, the next step was electron beam radiation. The radiation was done at 5, 7, 8, 10, 12 and 14 MeV electron energy that applied to the distance of 0; 0,2; 0,4; 0,6; and 0,8 cm between the radiation fields. The radiation area is 10x10 cm² each. Then the software OmniPro Accept 7 also displayed the movement of the detector in the water so that the research can be monitored. All the data obtained from the research was automatically displayed on the screen, then analysed in the form of table and charts to display the correlation between relative dose to crossline and inline axis.

4. RESULT AND DISCUSSION

The measurement of relative absorbed dose in radiation with two irradiation fields using 5 MeV electron energy (the depth :1,1 cm inside the water phantom), 7 MeV (the depth 1,5 cm inside the water phantom), 8 MeV (the depth : 1,8 cm inside the water phantom), 10 MeV (the depth : 2,3 cm inside the water phantom), 12 MeV (the depth : 2,5 cm inside the water phantom), 14 MeV (the depth : 2,7 cm inside the water phantom), dose profile for the energy 5, 7, 8, 10, 12, and 14 MeV to the crossline direction is presented in figures 3 a, c, e, g, i, and k, while to the inline direction is presented in figure 3 b, d, f, h, j, and l.

From figure a – l, it can be seen that cold spot increases as the distance of the field increases. In figure a, at the distance 0 cm the beam junctions at axis (-5) – (3) experienced hot spot. At 0,2 cm, the beam junctions at axis (-19) – (19) got the dose. The distance at 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at axis (-7) – (11), (-9) – (15), and (-11) – (19).

In figure b, at the distance 0 cm the beam junctions at axis (-21) – (19) got optimum dose. At 0,2 cm; 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-7) – (-1), (-13) – (11), (-15) – (15), and (-13) – (17).

In figure c, at the distance 0 cm from the beam junctions at axis (-7) – (5) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-3) – (7), (-5) – (11), and (-7) – (15).

In figure d, at the distance 0 cm from the beam junctions at axis (-5) – (3) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-9) – (7), (-11) – (13), and (-15) – (15).

In figure e, at the distance 0 cm from the beam junctions at axis (-7) – (7) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-1) – (7), (-5) – (11), and (-7) – (15).

In figure f, at the distance 0 cm from the beam junctions at axis (-5) – (5) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-5) – (9), (-9) – (13), and (-9) – (17).

In figure g, at the distance 0 cm from the beam junctions at axis (-9) – (9) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (1) – (3), (-5) – (9), and (-7) – (13).

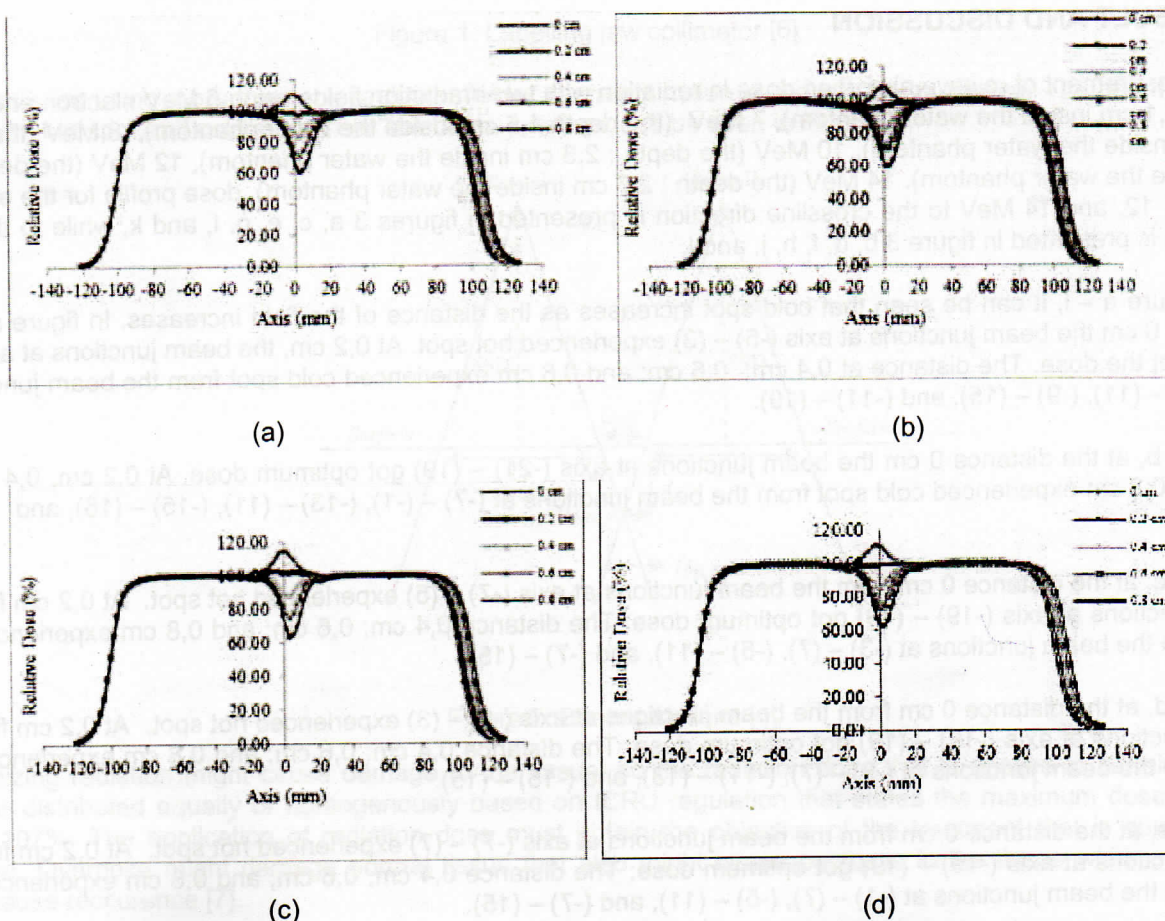
In figure h, at the distance 0 cm from the beam junctions at axis (-7) – (7) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-3) – (5), (-7) – (11), and (-9) – (15).

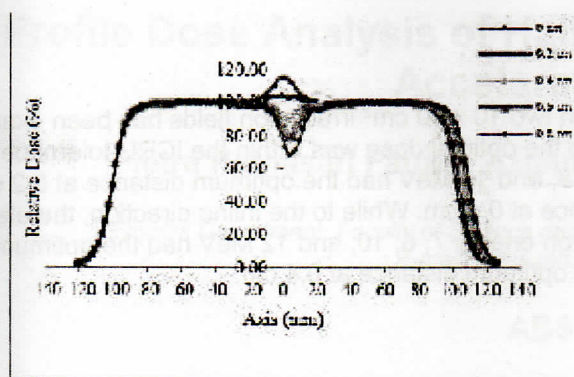
In figure i, at the distance 0 cm and 0,2 cm from the beam junctions at axis (-11) – (7) and (-5) – (3) experienced hot spot. At 0,4 cm from the beam junctions at axis (-17) – (19) got optimum dose; The distance 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-5) – (9) and (-7) – (11).

In figure j, at the distance 0 cm from the beam junctions at axis (-9) – (7) experienced hot spot. At 0,2 cm from the beam junctions at axis (-19) – (19) got optimum dose; The distance 0,4 cm; 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-3) – (3), (-7) – (9), and (-9) – (13).

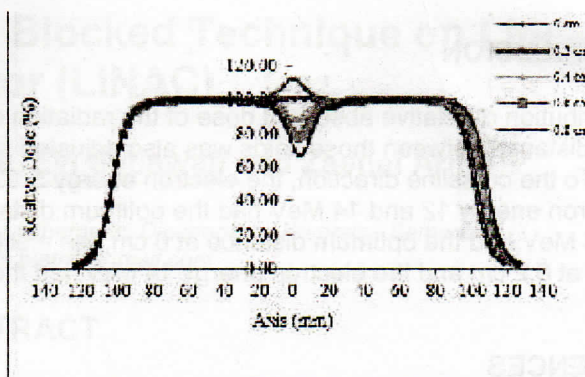
In figure k, at the distance 0 cm and 0,2 cm from the beam junctions at axis (-13) – (9) dan (-7) – (5) experienced hot spot. At 0,4 cm from the beam junctions at axis (-17) – (19) got optimum dose; The distance 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-5) – (7) dan (-7) – (11).

In figure l, at the distance 0 cm and 0,2 cm from the beam junctions at axis (-11) – (9) dan (-1) – (3) experienced hot spot. At 0,4 cm from the beam junctions at axis (-17) – (19) got optimum dose; The distance 0,6 cm; and 0,8 cm experienced cold spot from the beam junctions at (-5) – (9) and (-7) – (13).

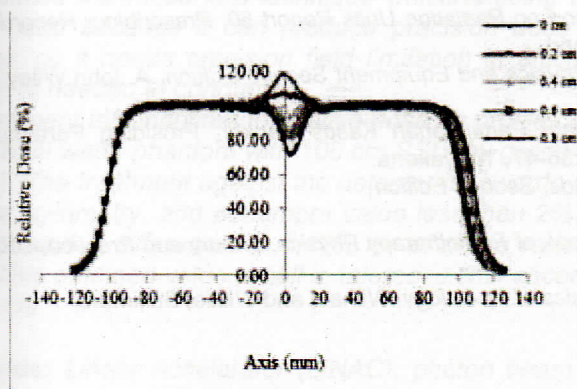




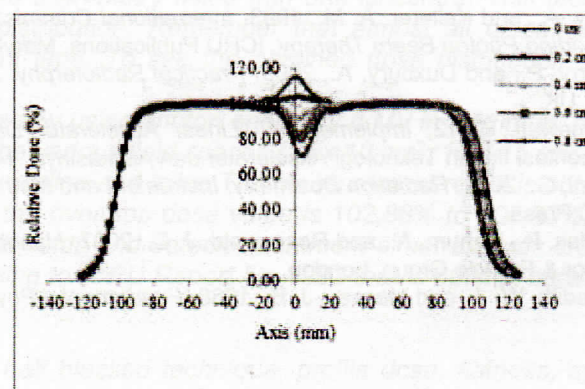
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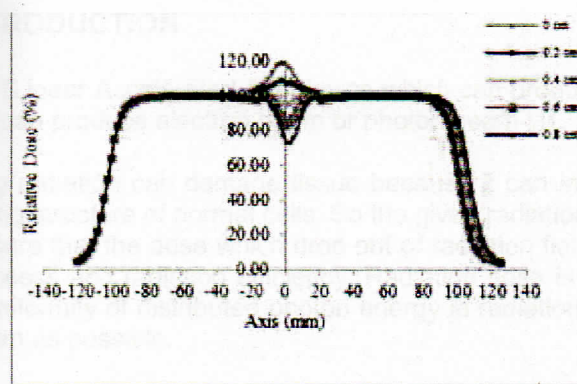
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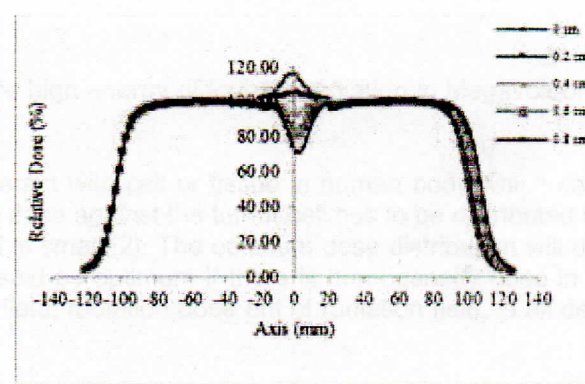
(g)



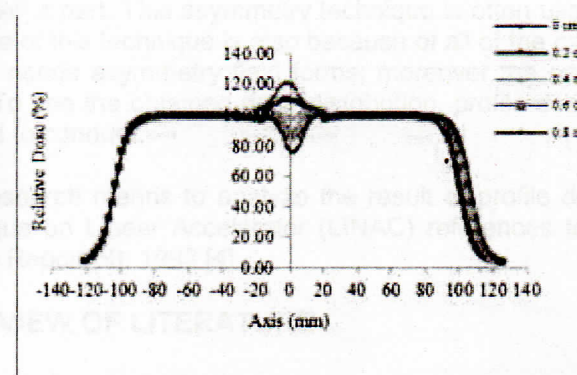
(h)



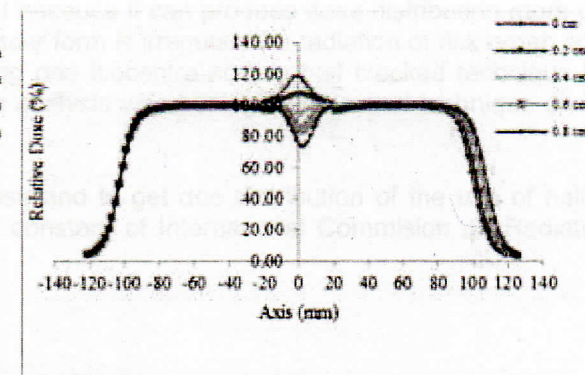
(i)



(j)

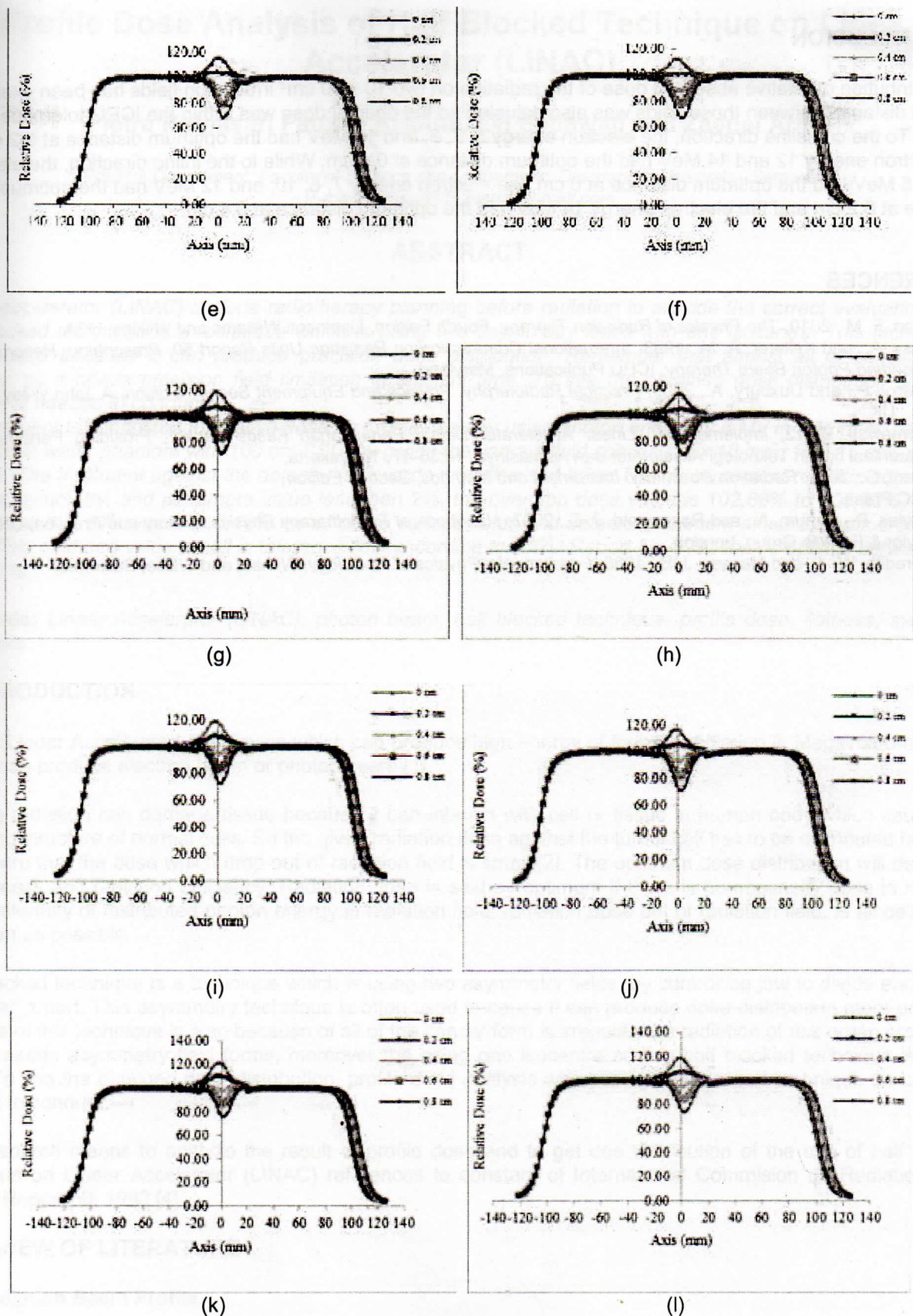


(k)



(l)

Figure 3: Dose profile for certain amount of energy
 (a) 5 MeV crossline, (b) 5 MeV inline, (c) 7 MeV crossline, (d) 7 MeV inline, (e) 8 MeV crossline, (f) 8 MeV inline, (g) 10 MeV crossline, (h) 10 MeV inline, (i) 12 MeV crossline, (j) 12 MeV inline, (k) 14 MeV crossline, (l) 14 MeV inline on two electron beam irradiation fields on the area of $10 \times 10 \text{ cm}^2$



(e)

(f)

(g)

(h)

(i)

(j)

(k)

(l)

Figure 3: Dose profile for certain amount of energy
 (a) 5 MeV crossline, (b) 5 MeV inline, (c) 7 MeV crossline, (d) 7 MeV inline, (e) 8 MeV crossline, (f) 8 MeV inline, (g) 10 MeV crossline, (h) 10 MeV inline, (i) 12 MeV crossline, (j) 12 MeV inline, (k) 14 MeV crossline, (l) 14 MeV inline on two electron beam irradiation fields on the area of 10x10 cm²

5. CONCLUSION

The distribution of relative absorbed dose of the radiation on two $10 \times 10 \text{ cm}^2$ irradiation fields has been examined and the distance between those fields was also adjusted so the optimal dose was within the ICRU tolerance (95% - 107%). To the crossline direction, the electron energy 5, 7, 8, and 10 MeV had the optimum distance at 0,2 cm and the electron energy 12 and 14 MeV had the optimum distance at 0,4 cm. While to the inline direction, the electron energy 5 MeV had the optimum distance at 0 cm, the electron energy 7, 8, 10, and 12 MeV had the optimum distance at 0,2 cm and the electron energy 14 MeV had the optimum distance at 0,4 cm.

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