AN ABSTRACT OF THE THESIS OF

Quyen L. Jones for the degree of Master of Science in Radiation Health Physics presented on June 11, 2004.
Title: Implementation of Radiation Film Dosimetry System To Be Used For The Verification Of a 3-D Electron Pencil-beam Algorithm On a Radiation Treatment Planning System*

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Kathryn A. Higley

Radiation film dosimetry process using the RIT 113 v.4 dosimetry software and the film digitizer VXR-12plus was used to evaluate the accuracy of electron dose calculations of the RAHD radiation therapy treatment planning system at Samaritan Regional Cancer Center. Kodak Ready-Pack EDR-2 film is recommended for dose distribution analysis in clinically practical dose ranges. The pencil-beam algorithm has a limitation for calculating dose in the penumbra region and in the tail region where the dose falls off.


* The research project was performed under the supervision of the Medical Physicist, Elizabeth A.R. Shiner, at the Samaritan Regional Cancer Center in Corvallis, Oregon.

Implementation Of Radiation Film Dosimetry System To Be Used For The Verification Of A 3-D Electron Pencil-Beam Algorithm On A Radiation Treatment Planning System

by
Quyen L. Jones

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Dean of the Graduate School

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Quyen L. Jones, Author

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# 1. INTRODUCTION

The purpose of this thesis is to evaluate the accuracy of the electron dose calculations of the RAHD radiation therapy treatment planning system at the Samaritan Regional Cancer Center. The central core of this thesis is to initiate and implement a film dosimetry process which is used for the verification of the electron beam dose distributions as calculated by the RAHD's electron pencil beam algorithm and modify the algorithm parameters as necessary to match the linear accelerator output. A set of phantoms was also developed for the study of the accuracy of the RAHD system in complex treatments that utilize a combination of electron energies with irregular field shapes in inhomogeneous medium.

RIT 113 (version 4) software[i], in conjunction with a film digitizer Vidar VXR-12 *plus*, was calibrated and used to analyze films that were exposed to different electron beams with different field (cone) sizes. The RIT software created isodose distributions from the films that were then compared to the isodoses from the RAHD treatment planning system. Information on the linear accelerator's beam characteristics which was used as input for RIT 113 film dosimetry and RAHD treatment planning system are provided by the blue water phantom system in association with the OmniPro-Accept software platform[ii]. A set of humanoid phantoms was developed to assess the accuracy of RAHD's dose calculation in

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[i] Radiological Imaging Technology, Inc. , Colorado Springs, CO Tel. 719-590-1077
[ii] Scanditronix Wellhofer North America, Bartlett, TN Tel. 901-386-2242

complex field shapes and surface irregularities. Once the algorithm parameters were successfully modeled within the RAHD, phantoms were scanned with the CT scanner and networked into the RAHD system. From this, more complex electron dose distributions measured by the film dosimetry process and calculated by the treatment planning system were compared. Kodak Ready-Pack XV-2 films and EDR-2 films[iii] were used in the film dosimetry process; their features in responding to electron irradiations were also investigated.

[iii] Eastman Kodak Company – Health Imaging Products, Tel. 800-328-2910

## 2. BACKGROUND

At the Samaritan Regional Cancer Center in Corvallis, Oregon, external beam radiation therapy is used as a means of treating cancer patients. It is currently the most common means of external radiotherapy and involves the application of an electron beam(s) and/or a high energy X-ray(s) produced by a linear accelerator. At the center, a Varian-2100C linear accelerator is used. The Varian-2100C generates either X-rays of 6MV and 18MV or electron beam radiations of 6, 9, 12, 16, and 20 MeV which are precisely directed toward and into a target volume treatment.

RAHD is used at the cancer center for setting up a treatment plan according to a prescription from a radiation oncologist. Because dosimetrists and radiation oncologists rely on RAHD for precise treatment plans designed to deliver high doses to target tumor volumes while sparing the surrounding normal tissue as much as possible, verification of the treatment planning system is vital for ensuring that it accurately models the accelerator output. The radiation treatment planning system must be both accurate and precise in terms of the dosage used and the spatial geometry of the treatment delivery, to within +/- 2-3% of that required [17, 18]. This requirement of accuracy and precision makes quality assurance (QA) a major consideration of any treatment planning system. Small deviations from the actual dosage and spatial geometry of the accelerator can result in harm to healthy tissue, or, a non-effective dose to the tumor. Improving the accuracy and precision of the method of dose calculations therefore not only helps to prevent a detrimental effect to the surrounding healthy tissue, but to improve cancer cure rates. The reported dose must be consistent with existing protocols, i.e., methods of dose specification [17, 18]. In other words, there must be assurance that the calculated dose from the treatment planning system is matched with the measured dose with a deviation within the tolerance.

RAHD calculates plan doses in both 2-D and 3-D utilizing a pencil-beam algorithm. The parameters for the pencil beam algorithm effectively influence the accuracy of the calculated doses output [3]. A film dosimetry process was initiated and implemented to evaluate the accuracy of the algorithm used in the treatment planning system. RIT 113 (version 4) software was used in the film dosimetry process. It is the most advanced film dosimetry available and is widely used in clinical settings. Materials, procedures, and possible preferences in the film dosimetry process were explored during the initiation of the project.

# 3. METHODS AND MATERIALS

## *3.1 Film dosimetry*

Film dosimetry can be used to assist in the verification and modification of the radiation treatment planning system. The iso-dose distrtibutions calculated by the radiation treatment planning system can be compared to actual iso-dose distributions output from the linear accelerator as viewed on an exposed film. In essence, film dosimetry QA can be used to modify the treatment planning system via a "feedback" method by which the parameters of the pencil-beam algorithm (of the RAHD) can be adjusted until the calculated and actual dose distributions match to within the required specifications. Film dosimetry is well established and widely used for determining relative electron beam dose distributions. Film dosimetry is favored for its high spatial resolution and high density/dose resolution that gives the medical physicists the ability to perform fast and accurate dose analysis in numerous clinical QA situations such as multi-leaf collimator test, IMRT, dynamic wedge, and stereotactic radiosurgery. Depending on the technology employed in the process, the range of the integrated spatial dose distribution can be from just a few cGy to several hundreds cGy. In addition, radiographic films allow repetitive readouts and provide a permanent record of the dosimetric measurement. Other advantages include the flexibility to place film in a humanoid phantom, short measurement time, and intrinsically two dimensional measurements [2, 15, 17].

The most common technique in film dosimetry is to sandwich a film within a plastic solid water phantom and expose the film to a radiation beam with the film-plane either parallel or perpendicular to the central axis of the radiation field [2, 8, 15]. Figure 3.1 shows the Vidar-VXR model film digitizer and the Varian 2100C linear accelerator used on the experiment is shown in Figure 3.2. The gantry and table are set at 90° from home position. Film is sandwiched between high density polyethylene phantoms and irradiated with an electron beam parallel to the film-plan.

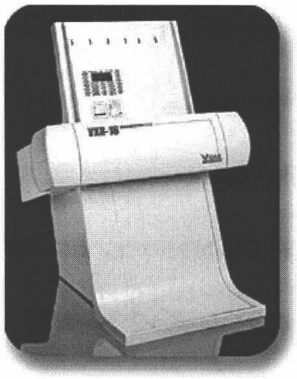


**Figure 3.1** Film digitizer Vidar-VXR model

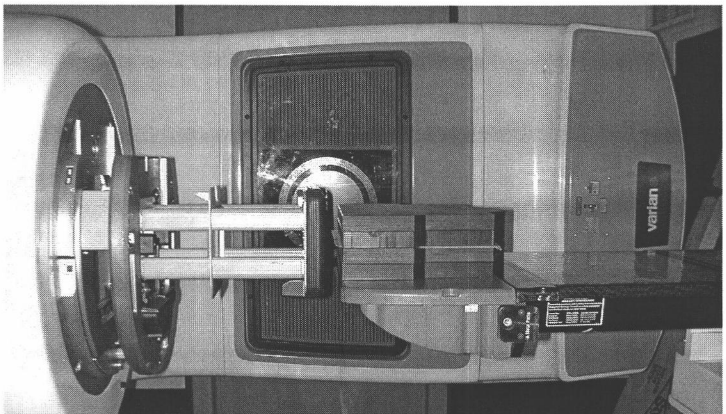


**Figure 3.2** Linear accelerator Varian 2100C used in the experiment and film positioned inside a solid phantom in which the film-plane is parallel to radiation beam

Photographic film consists of a transparent polyester base and is coasted with a radiation-sensitive emulsion which is covered with a protective layer of gelatin to keep it safe from mechanical damage. The emulsion is made of silver halide crystals; typically 95% of silver bromide and 5% of silver iodide, embedded in gelatin. The exact composition of the emulsion varies by manufacturer and types of film. When exposed to a radiation field, the silver halide forms latent images (darkened regions) in the film due to ionization and excitation. Film development is a chemical process that amplifies the latent images by a factor of millions. The dose associated with the quantity of the radiation can be related to the darkening of the film and thus depends on the film emulsion. Some emulsions are fast and require a small amount of radiation to darken the film. Other emulsions are slow and required higher doses to produce the same darkness. Thus, the types of film are chosen depending on application. These darkened regions can be related to the intensity of the incident radiation. The light and dark regions on an exposed film can be quantified by measuring the light transmitted through the film, characterized by an optical density unit at the point of interest on the film. The optical density is measured using a densitometer which consists of a light source on one side of the film and a receptor on the other side to measure the light transmitted. After going through chemical processing, even an unexposed film will attenuate some incident light and is regarded as the background base on the film dosimetry process. This is referred to as fog and produces the film scanner's signal called “dark current”. The net optical density, OD, of a point on the film is defined as:

$$OD = a\log_{10}\left(\frac{S_o}{S}\right) \tag{3.1}$$

where $S_o$ is the scanner signal for the “dark current” and S is the scanner signal for the transmitted light on the film at the point of interest. The optical density depends on the dose by the following equation:

$$\log_{10}\left(\frac{S_o}{S}\right) = aD^{á} \tag{3.2}$$

where a and _ are constants. Taking the nature logarithm both sides of equation (3.2) results in a linear relationship:

$$\ln\left[\log_{10}\left(\frac{S_0}{S}\right)\right] = \ln(a) + á\ln(D) \tag{3.3}$$

A plot of $\ln\left[\log_{10}\left(\frac{S_o}{S}\right)\right]$ against ln(D) generates a straight line with slope _ and intercept at ln(a) [15, 17].

To use a film for dosimetry, it is necessary to know the relationship between dose, optical density, and scanner signal. Some emulsions produce a linear relationship between dose and OD, which is the most favorable case, some are relatively linear over a limited range, and others are non-linear. To start with, a set of OD calibration files is created to correlate the relationship between the scanner signals and an optical density. A film digitizer (scanner) with higher resolution can distinguish a higher range of optical density. A step wedge film composed of bands with graduated shades of gray (up to 32 steps on the Stouffer Step Wedge film) in which the average OD for each shade known is used to establish the OD calibration file. The film digitizer scans the step wedge film and generates a single scanner signal for each density and the RIT software then creates the OD calibration file. Another set of dose calibration files is required to convert the scanner signal of a corresponding OD to a dose at any point of interest. This is done by exposing several films to known radiation doses at specified locations on the films. A plot of net OD against dose, called an H&D curve (after Hurter and Driffied who originated sensitometry) is generated by the software using the OD calibration file and the inputs from the above films. This curve should be independent of the dose rate, energy, and radiation field sizes [15]. The dose calibration file is then used to analyze dose distributions on films.

### *3.2 RIT 113 v.4 film dosimetry system set up*

The film dosimetry process is complex, requiring sophisticated scanning equipment and software. The RIT113 system consists of hardware and software for film analysis. The hardware configuration includes a film digitizer, a computer system, and a printer. The software consists of an image processing platform and various application modules. The exposed films are first scanned in the film digitizer and the images are analyzed with a film analyzing platform software package, converting the scanner signal of a sequence of pixels to optical density units which are then converted to dose. Information for the conversion is acquired from the OD calibration file and the dose calibration file.

At the Samaritan Regional Cancer Center, the software used for radiation film dosimetry is RIT113.version 4, a sophisticated software package widely used for analyzing films. The software is capable of creating depth dose profiles, cross-section analysis, and isodose contouring, as well as generating meaningful data in advanced QA routines such as star shot analysis, radiation/light field coincidence, IMRT treatments, stereotactic plan analysis, MLC QA, patient positioning, interrupted treatment analysis, and asymmetric field analysis. The film digitizer used was a Vidar VXR-12plus. The digitizer operates with 12 bit mode of density resolution, has maximum spatial resolution of 85μm, and is capable of distinguishing 4,096 shades of gray. Other available spatial resolutions are 85, 89, 169, 178, 339, 356, and 423 μm.

The spatial resolution used in this experiment was 169 μm which is the digitizer's optimum operating resolution. The scanner's spatial resolution was calibrated by adjusting the scanner pixel size to match a measured and scanned value using the *scanner spatial calibration* routine from RIT113 v4.

### *3.3 Radiation Treatment Planning System RAHD*

At Samaritan Regional Cancer Center, the RAHD$^{(TM)}$ treatment planning system is used to create a radiation treatment plan based on a prescription from the radiation oncologist. It is a three dimensional, computerized, radiation treatment planning system with sophisticated dose calculation algorithms allowing accurate treatment plans that target cancerous tumors while sparing the surrounding healthy tissue. The RAHD radiation treatment planning (RTP) system uses a CAT scan (computerized axial tomography) to create a three dimensional model of the patient's critical structures and the areas of interest are outlined with the contours in CT images. RAHD generates the treatment volumes with the precise locations of the area to be treated in three dimensions. The images are displayed simultaneously in the same window with all the necessary information for beam placement, including 3D surface rendering and visualization with sagital, coronal, transverse projections, or Beam's Eye Views (BEV) with Multi-Leaf Collimator display, transverse as well as reformatted image options, and Digitally Reconstructed Radiographs (DRR) of the BEV. Because the tumor's volume and location are mapped in three dimensions, the path of the radiation beam can be better targeted toward the tumor, which is especially important when cancerous organs are located in sensitive or complex body areas, such as the prostate, brain, breast, or esophagus.

The RAHD system employs a three-dimensional pencil-beam algorithm developed through the work of Dr. Dennis Leavitt, PhD. at the University of Utah, for calculating electron beam dose distributions. The pencil-beam dose calculation algorithm allows the accurate calculation of heterogeneity effects resulting from irregular external contours or smaller internal heterogeneities. In addition to the beam characteristic profile data, which is measured in water phantom with a NIST calibrated ion chamber system, RAHD requires certain electron beam parameters in order to accurately model the electron beams and calculate the resulted dose distributions (according to the RAHD user's operating menu book). The following parameters are energy dependent and can be modified using a built-in *utility* function within the RAHD-RTP system:

- Energy – mean energy of electrons incident upon the phantom, determined by the formula: $E = 1.919(R_p) + 0.722$;

- Practical Range $R_p$ – determined by extrapolating the depth dose curve to the intersection with the Bremsstrahlung contribution which should be field size independent;
- Drift space – distance from the downstream edge of the beam defining collimator and the standard treatment surface (for a Varian 2100C linear accelerator the drift space is 5cm);
- Sigma-Theta-X (__x) – sigma of the Gaussian distribution of the electron angles (projected onto a planar surface parallel to the beam) for those electrons comprising a pencil beam defined at the plane or the beam defining collimator;
- Scatter Correction Factor – the multiplication factor applied to the linear scattering power of the reference medium (water) in the calculation, typical

adjustment range of 1.0 – 1.4, giving an increase in the penumbra of about 15%;

- Added Margin Width – accounts for the scattering of electrons well beyond the regions immediately accounted for by the pencil-beam algorithm.

Besides the above parameters which are accounted for the electron beam's characteristics, the pencil-beam algorithm integrated in the RAHD-RTP system also requires other energy-dependent correction factors to ensure the calculated depth dose closely matches the measured depth dose in water [3, 4]. The correction factors were determined by the fine-tune method in which the calculated depth doses were forced to fit the measured depth dose in the penumbra region by adjusting the correction factors optimally. These energy-dependent correction factors are:

- SIGC – Sigma for Edge Correction ;
- AZERO – Magnitude of Edge Correction;
- ALAMBDA – Exponential Depth Dependence for Profile;
- FMCS @ $R_p$ (FMCSRP); and
- PKX0 – Field Size at which the conical x-ray background profile goes to zero.

Pencil-beam algorithm calculation models are derived from Fermi-Eyges theory of multiple-Coulomb-scattering [1]. Figure 3.3 shows the schematic view of the set-up for a 2-D pencil-beam algorithm for calculation of the arc electron dose distributions modeled by Hogstrom et al [1, 11]. This is based on the pencil-beam

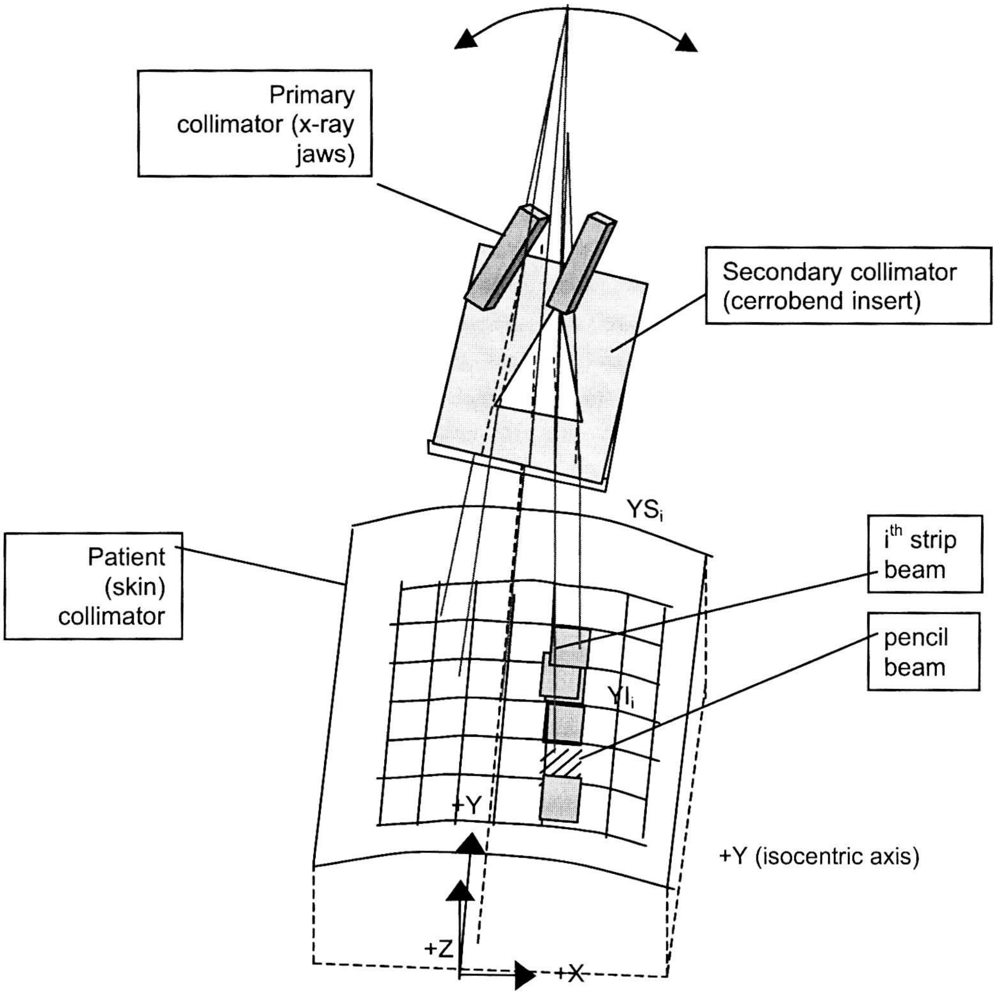



**Figure 3.3** Schematic view of set-up for a 2-D pencil beam algorithm for calculation of arc electron dose distributions modeled by Hogstrom et al. The secondary collimator can be irregular shape. The irradiated area defined by patient collimation is modeled as a single broad beam comprised of a set of pencil beams, which are summed to form strip beams for the dose calculation. This 2-D pencil beam model based on the Fermi-Eyges small angle scattering theory assumed the variations in tissue density outside the plane of calculation to be the same as in the plane of calculation.

approach in which the arc beam is designated as a single broad beam defined by the irradiated patient surface within the skin collimation; the broad beam is constructed from many pencil beams which are summed in the Y-direction to form strip beams as illustrated in Figure 3.3. The electron planar fluence passing through the secondary collimator is independent of the X-coordinate and varies slowly in the Y-direction. Each strip beam is described by an electron planar fluence and an angular distribution. The angular distribution is modeled as Gaussian, with the same mean projected angle and root-mean-square (RMS) spread about the mean projected angle as the actual distribution. By knowing the dose distribution from each strip beam in the plane of calculation of the patient, the dose at any point can be determined by performing a sum of the dose contributions from each strip beam. The dose calculations are performed in planes perpendicular to the isocenter axis. The calculation is repeated in multiple planes to form a three-dimensional dose distribution. Variations over the incident beam, changes due to surface shape and irregular fields, and effects due to inhomogeneities can be taken into account for each pencil beam individually in order to calculate dose distributions. One limitation of the pencil-beam algorithm approach is the inability to predict the off-axis ratios accurately. This is because Fermi-Eyges theory is a small-angle scattering theory and is dealt with along the central ray of each pencil beam only, while neglecting large-angle scattering arising from the electron-electron interactions. Therefore, effects due to narrow inhomogeneities are not predicted accurately that discrepancies of up to about ten percent were reported predominantly in the penumbra region where the dose spreads significantly at the tails of off-axis dose profile [1, 3, 4, 7, 10, 11, 17]. For that reason, the user must understand the details and limitations of the pencil beam approach on the dose calculated from a radiation treatment planning system.

### *3.4 Solid water phantoms used for the pencil-beam algorithm verification*

A set of phantoms was developed for the study of the accuracy of the RAHD-RTP system in complex treatments that utilize a combination of electron energies with irregular field shapes in inhomogeneous medium. In order to verify the performance of the treatment planning system in calculating doses of many clinical treatment situations the phantoms were constructed in different regular and irregular shapes. Dose calculations in complex inhomogeneities were also considered in assembling the phantoms [1, 6, 12, 13, 16]. Because polystyrene phantoms are used for the routine linear accelerator QA at the facility, the phantoms were mainly used in the experiment. The polystyrene phantoms have surface areas as 25cm x 25cm and various thicknesses with the thickest width was 2.8cm.

High-density polyethylene phantoms with specific density approximately 0.95g/cc were used to evaluate the algorithm in calculating dose distributions in treatment situation that model clinical situations [12]. Figure 3.4 illustrates the dimensions of the phantoms. The phantoms are black to prevent light leakage from causing film fog which would interfere with the accuracy of the electron radiation doses. The surfaces which interface with the inserted films are smooth and polish to avoid mechanical artifact caused by roughness. The phantoms were designed to be convertible between regular shapes to various irregular shapes by switching the beam interacting-surfaces to a desired surface. In addition, the phantoms offer the options of treated medium in homogenous or in diverse inhomogenous by filling the gap with different materials such as paraffin, cork, Styrofoam, or air.

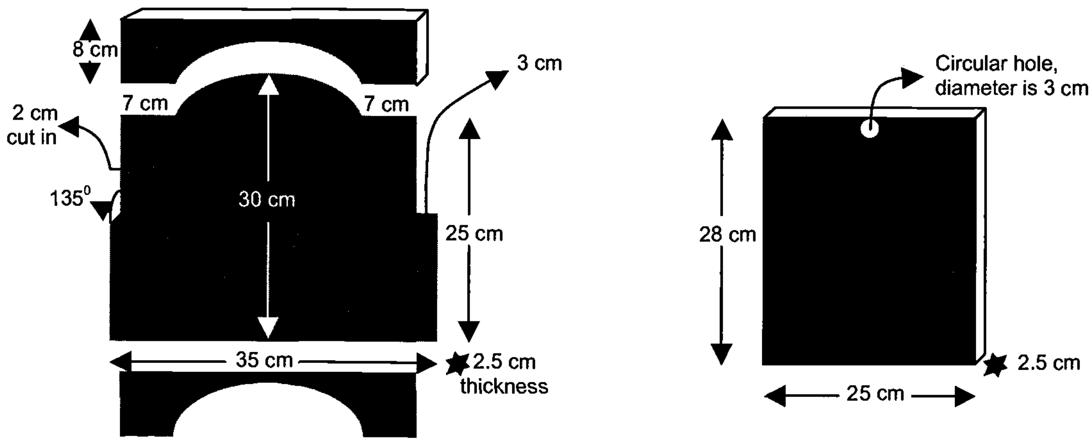



**Figure 3.4** Schematic of irradiation geometry of HDPE phantoms.

Although high density polyethylene (HDPE) is not ideal water equivalent, but the density and mass-stopping power corrections to water can be acquired by the use of Computed Tomography. Computed Tomography can differentiate between tissues of similar density (measured in Hounsfield units) and provide detailed density information which can be used for correcting dose calculation in water and other medium [6].

Regrettably, the set of HDPE phantoms were not used in the experiment to evaluate the performance of the RAHD system in calculating electron dose distributions in complex treatments. Further work is needed to accomplish the verification of the algorithm in three-dimensional dose calculations utilizing these phantoms.

# 4. RESULTS AND DISCUSSION

## *4.1 OD calibration*

To determine the OD calibration curve, a Stouffer Step Wedge film, provided by Radiological Imaging Technology, is used in the *step wedge calibration* process. There are 32 steps (32 shades of gray) in this step wedge film with a single OD value for each of the steps. These OD measurements were calibrated to a NIST standard. Figure 4.1 shows the curve of OD versus A/D scanner (scanner signal value) generated by Excel based on the data from the OD calibration file. Note that RIT113 generated the same curve in BITM format. The OD calibration file with data in word format can be found in Appendix A. This OD

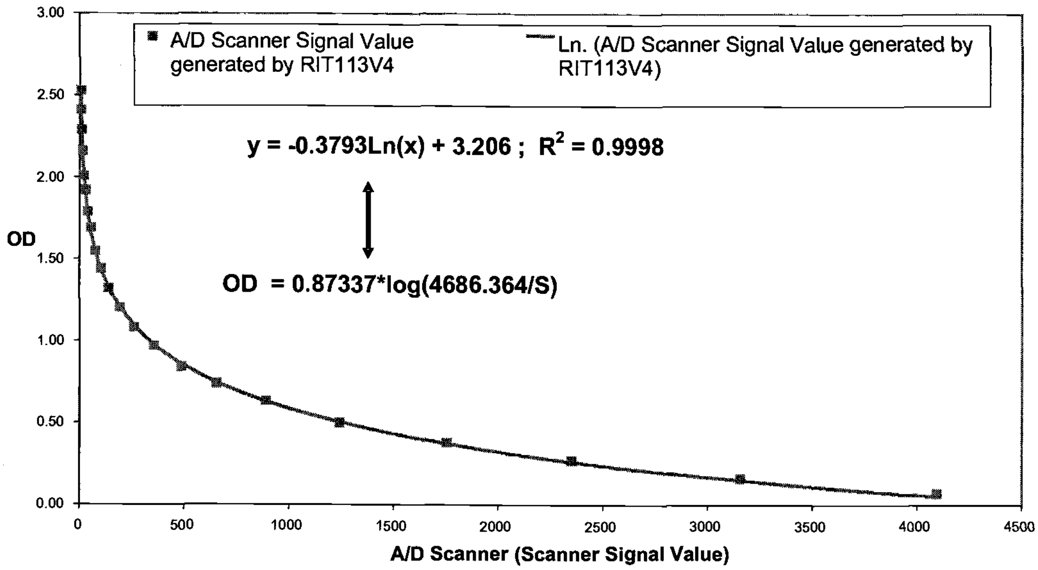



**Figure 4.1** Optical density corresponding to scanner signal values (A/D) from Vidar VXR-12P Film Digitizer and the RIT113V4 Film Dosimetry Software

calibration file was used to develop all of the dose calibration files required for the project film analysis. The scanner signal value (S) of a pixel is related to its OD by the following equation:

$$OD = -0.3793\ln(S) + 3.206 \tag{3.4}$$

with a logarithm regression coefficient $R^2 = 0.9998$.

Equation 3.4 can be rewritten as:

$$OD = -0.3793\left(\frac{\log(S)}{\log(e)}\right) + 3.206 \tag{3.5}$$

$$= \frac{-0.3793}{0.4343}\log(S) + 3.206$$

$$= -0.8734\log(S) + 3.206$$

$$= 0.8734[-\log(S) + 3.6708]$$

$$= 0.8734[-\log(S) + \log(4686.364)]$$

or

$$OD = 0.8734\log\left(\frac{4686.364}{S}\right) \tag{3.6}$$

which is in the form of the optical absorption law.

The above plot indicates that this film scanner does not have the resolution capability to distinguish doses of corresponding optical densities above 2.5; which is the maximum optical density the scanner is able to make a distinction in a range of gray shades. The optical density versus scanner signal's curve can be divided into three regions:

- OD < 0.85: the scanner signals change dramatically with a small change in optical density and the scanner signal is approximately linear with optical density;
- 0.84 < OD < 1.44: non-linear region; and
- OD > 1.44: the scanner signal is not sensitive with even dramatic changes in optical density and the scanner signal is approximately linear with optical density.

Therefore, for the VXR-12plus, dose analysis will be most accurate when using film with an exposure dose that produces gray shades with optical densities less than 0.85.

*4.2 Dose calibration*

Two types of Kodak Ready-Pack films were used in the experiment: XV-2 and EDR-2 films. Because the composition of the emulsions is different between these two types of film, their responses to the same quantity of an electron radiation are different. In other words, with the same irradiated electron dose, the resulting optical density corresponding to that dose is different for the two types of film and thus, the scanner produces different signals for the XV-2 and EDR-2 film.

A water phantom system (Wellhoffer Blue phantom tank) was utilized to collect data representing electron beam's characteristics for each electron energy and cone size (field aperture). The data provides information on the distribution of the deposited electron doses in water including depth dose profile, iso-dose contours, cross-plane dose profile, mean energy, and practical range which were used to determine the electron parameters for the pencil-beam algorithm for each electron energy. The information on depth dose profile for each energy level with every cone size was used in establishing dose calibration files for the film dosimetry process. An exposed film can be analyzed by using the associated dose calibration file with identical electron energy and cone size. Figure 4.2 shows the relationship between the scanner's signal A/D value and dose from EDR-2 film for a 12MeV electron beam using 150MU and the 10cm x 10cm cone.

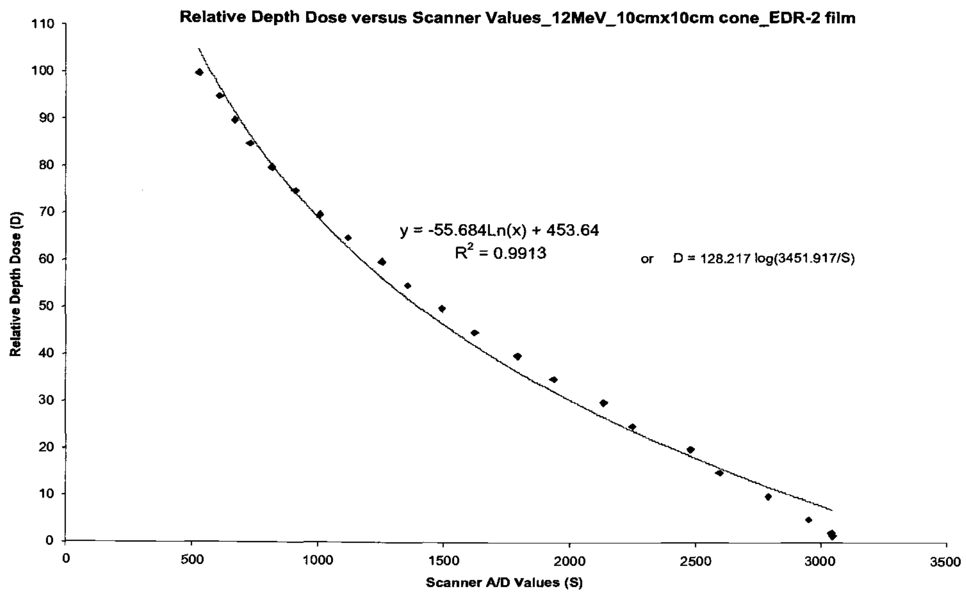



**Figure 4.2** Relationship between scanner's A/D signal values to dose. The data is from EDR-2 film exposed with 150MU using 12MeV electron beam with 10cm x 10cm cone.

The correlation equation for the dose (D) versus scanner signal value (S) curve is:

$$D = -55.684*\ln(S) + 453.64; \quad R^2 = 0.9913 \tag{4.1}$$

$$\text{or} \qquad D = -55.684\left[\frac{\log(S)}{\log(e)}\right] + 453.64$$

$$= \frac{55.684}{0.4343}\left[-\log(S) + \frac{453.64}{0.4343}\right]$$

$$= 128.217 * \log\left(\frac{3451.917}{S}\right)$$

$$\text{Thus,} \quad D = 128.217 * \log\left(\frac{3451.917}{S}\right); \qquad R^2 = 0.9913 \tag{4.2}$$

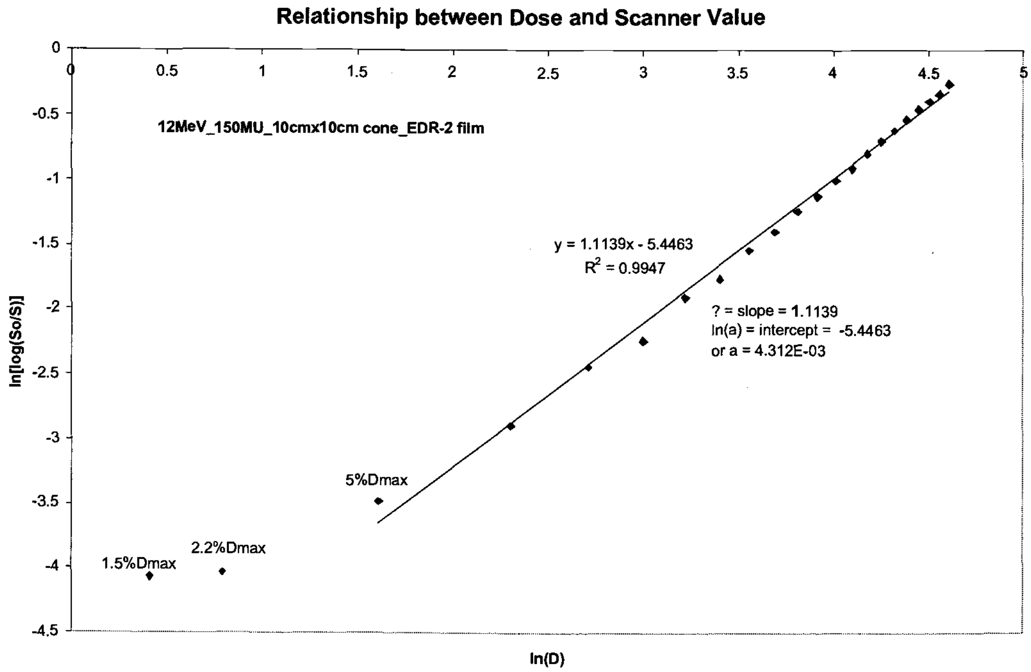



**Figure 4.3** Plot of ln[log($S_0$/S)] versus ln(D) yield a straight line with slope _ and intercepted at ln(a). The scanner does not respond linearly with dose when the dose dropped below 5% of Dmax (~7.5cGy)

$S_0$ value of 3451.917 is given by the equation 4.2. A plot of ln[log($S_0$/S)] versus ln(D) yield a straight line (see Fig. 4.3) with the linear regression coefficient $R^2$ = 0.9947 as discussed in the equation 3.3. The slope of the line is 1.1139 and the intercept at negative 5.4463 gives a value of "a" equal 4.312E-03. Therefore, for each signal acquired from the film digitizer, the corresponded dose in this case can be determined as:

$$\log\left(\frac{S_0}{S}\right) = 4.312E-03 * D^{1.1139}; \qquad R^2 = 0.9947 \tag{4.3}$$

The abrupt curve occurs at low dose regions (below 5% $D_{max}$ which is approximately 7.5cGy in this case) reflecting the differences of the silver halides in responding to the electron beam in the penumbra region.

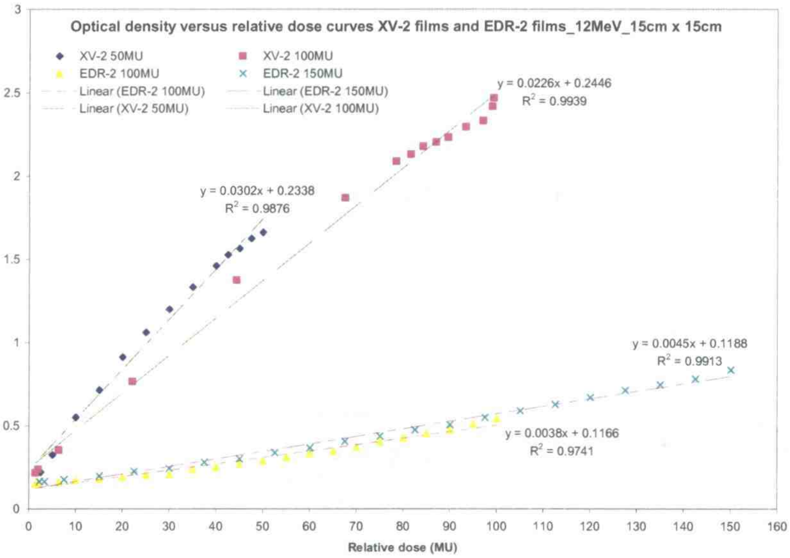



**Figure 4.4** Optical density versus relative dose on XV-2 and EDR-2 films. The films were exposed with 12 MeV electron radiations at various doses on 15cmx15cm field at an SSD of 100cm. Each MU (monitor unit) was calibrated to 1cGy on the linear accelerator.

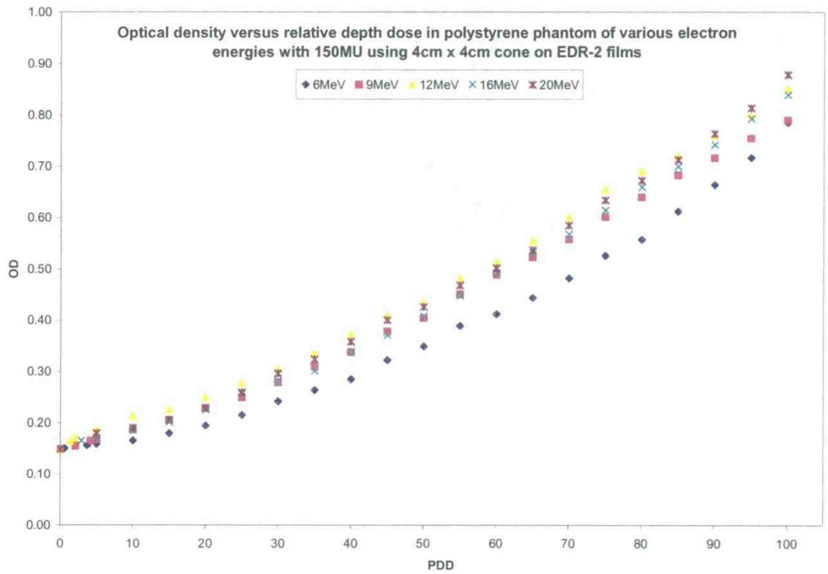
Figure 4.4 presents optical densities corresponding to doses at several dose levels on the two types of films. Optical density increased slowly and approximately linear with dose in the 0-150cGy dose range in EDR-2 films. On the contrary, optical density increased rapidly with dose in XV-2 films and became saturated around 100cGy. The reason of saturation is the film scanner VXR-12plus does not have the resolution capability to distinguish dose higher than 100cGy where the produced optical density is about 2.5 if XV-2 films were used for dose analysis. For this limitation, EDR-2 film is recommended in high electron dose analysis. EDR-2 film is also recommended for its emulsion's response to dose in such the way that the produced optical densities were nearly below the non-linear region to scanner signals while the scanner is able to differentiate small changes of optical density in a wider range of dose. Another advantage of EDR-2 films is that they are less sensitive to chemical processing than XV-2 films. The deviation of doses, shown as the degree of change on the slopes of the lines, caused by variations of processing is stronger in XV-2 films comparing to EDR-2 films as illustrated in Figure 4.4.

### *4.3 Relative depth dose analysis in film dosimetry*

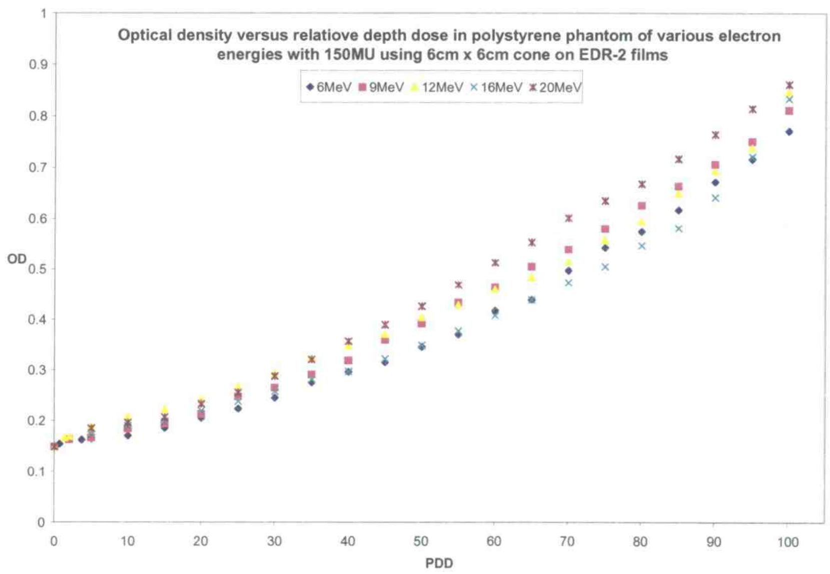
Data was collected in exposing the polystyrene phantom with film sandwiched in between using various cone sizes and various electron energies at 150MU to analyze the relative depth doses on EDR-2 films. All the films came from the same batch and were processed in the same processor with small time space (few minutes) in between exposing and processing. Figures 4.5a-e illustrates the effect of energy levels on the dose responded on the films when the same cone size was used. For small cones, sizes of 4cm x 4cm and 6cm x 6cm the variation due to different electron energy level was greater than for larger cones. However, for the 4cm x 4cm cone the deviation was not very significant except at 6MeV.

Figures 4.6a-e illustrates the effect of cone size on the dose for each electron energy. The 9MeV and 20MeV curves overlap for the relative doses and the size of the cones does not affect the deposited dose significantly. For the 6MeV curves, the 4cm x 4cm and the 6cm x 6cm cones' curves overlap, however, the 10cm x 10cm, 15cm x 15cm, and 20cm x 20cm cones' curves also overlap but in a different region in the plot. In contrast, the deposited doses for the 12MeV and 16MeV differ across all cone sizes.

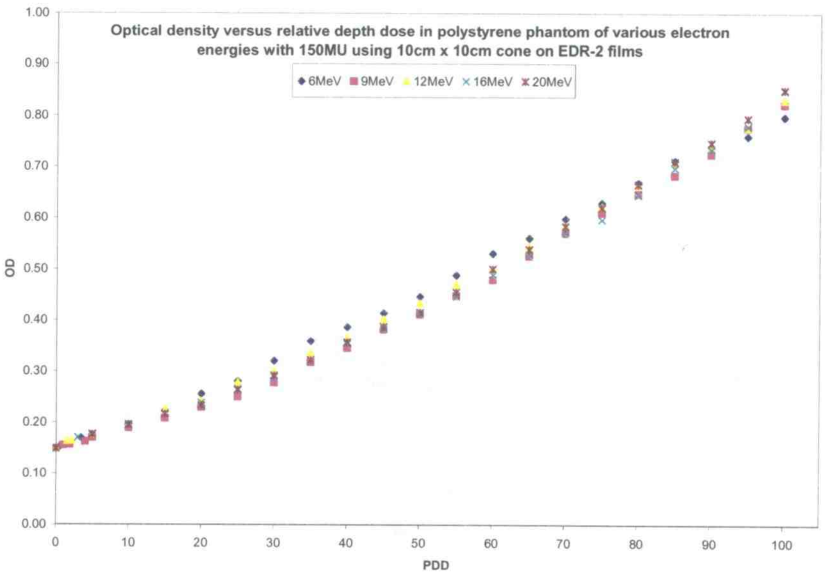
The reason for the discrepancies between the deposited doses when comparing the energy levels and cone sizes is due to the firmware parameters of the linear accelerator. The generated figures can be used in accelerator QA to monitor the performances in producing consistent electron doses in treated volumes routinely if it is desirable. It would be nice to be able to make predictions for a dose distribution based on cone size and beam energy. However, based on this data set it is difficult to predict accurately the relative dose distribution based on cone size and electron beam energy due to the fact there is so much variations contributing in this data set. For example, variation in temperature and chemical concentration during processing can influence the dose versus optical density relationship. For that reason, a set of dose calibration file at each energy level and cone size needs to be created for each dose analysis at the same energy and cone size.



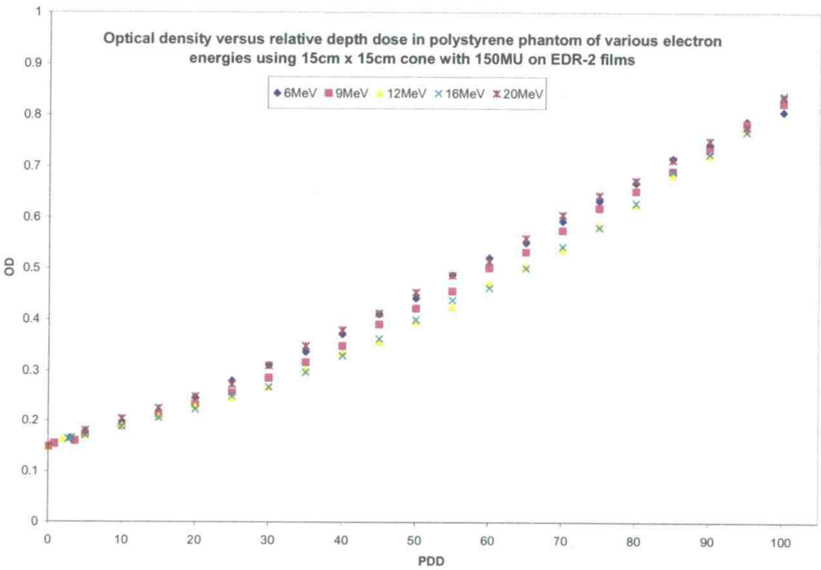

**(a)** 4cm x 4cm cone



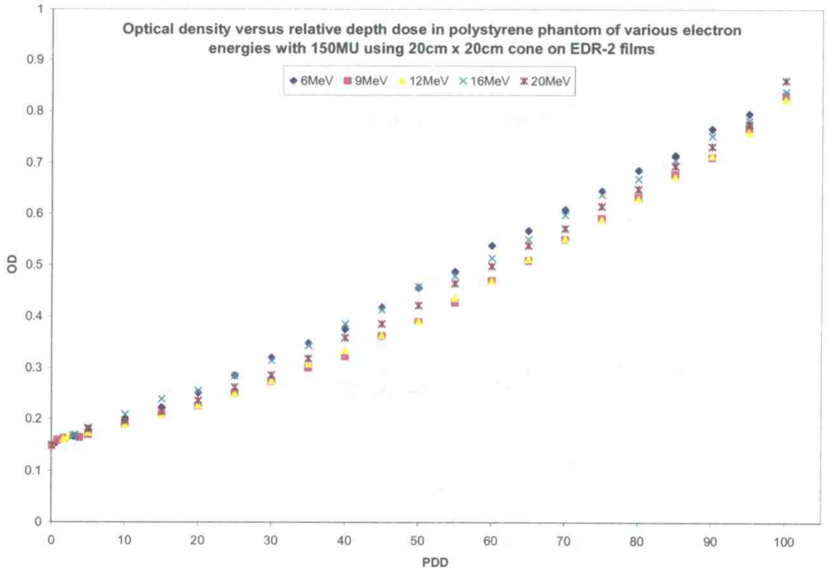

**(b)** 6cm x 6cm cone




**(c)** 10cm x 10cm cone

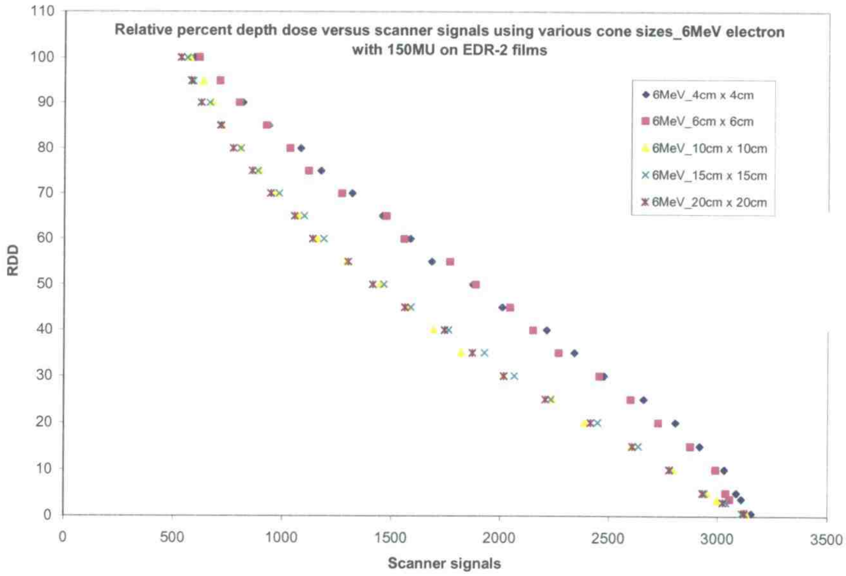



**(d)** 15cm x 15cm cone

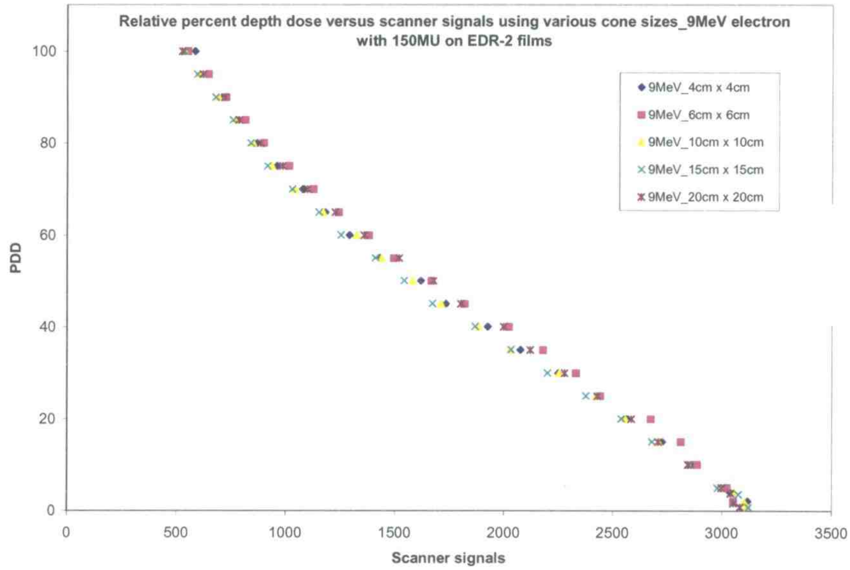



**(e)** 20cm x 20cm cone

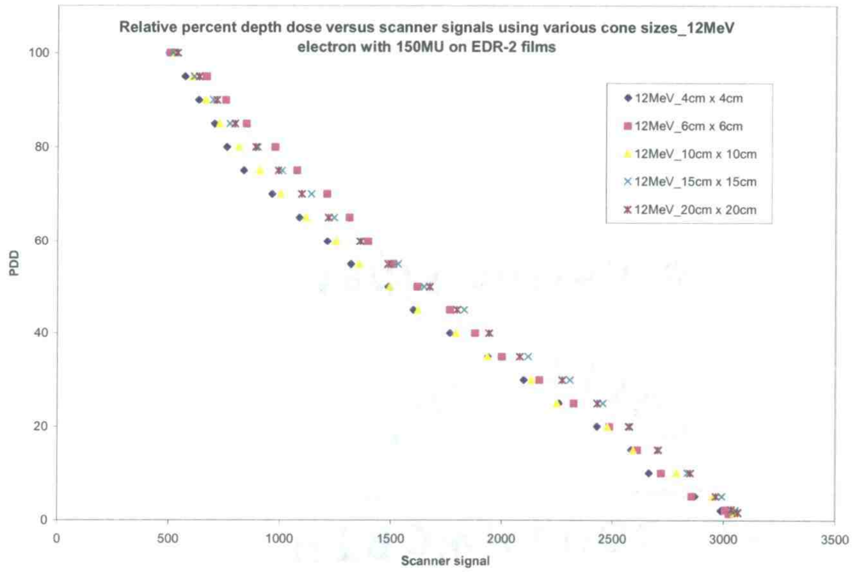
**Figure 4.5a-e** Optical density versus relative percent depth dose curves on EDR-2 films exposed with 150MU of electron radiation at various energy levels using a typical cone size. The plots demonstrate the effect of electron energies on the deposited doses.



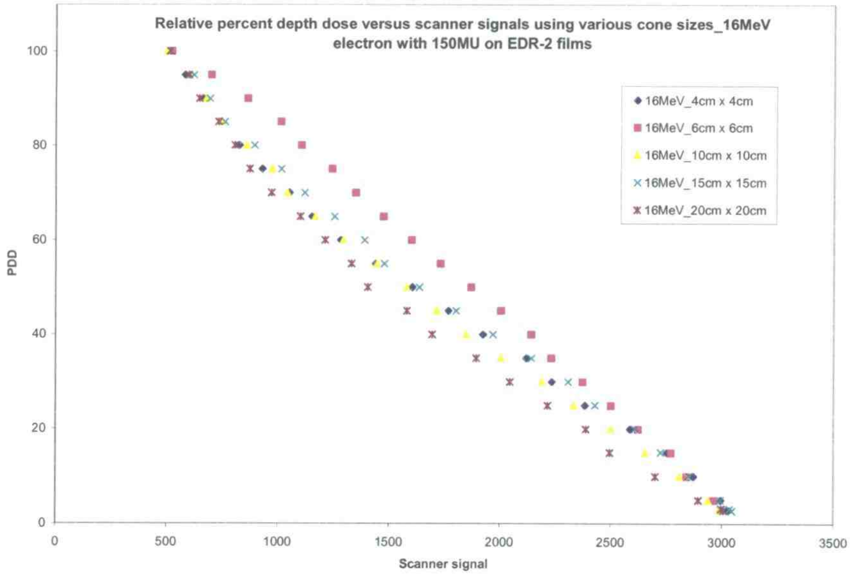

**(a)** 6MeV



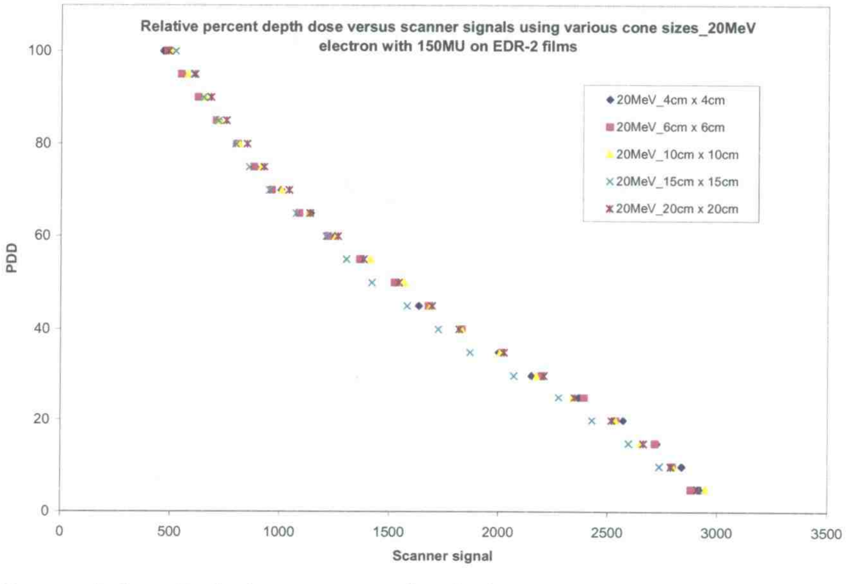

**(b)** 9MeV




**(c)** 12MeV




**(d)** 16MeV

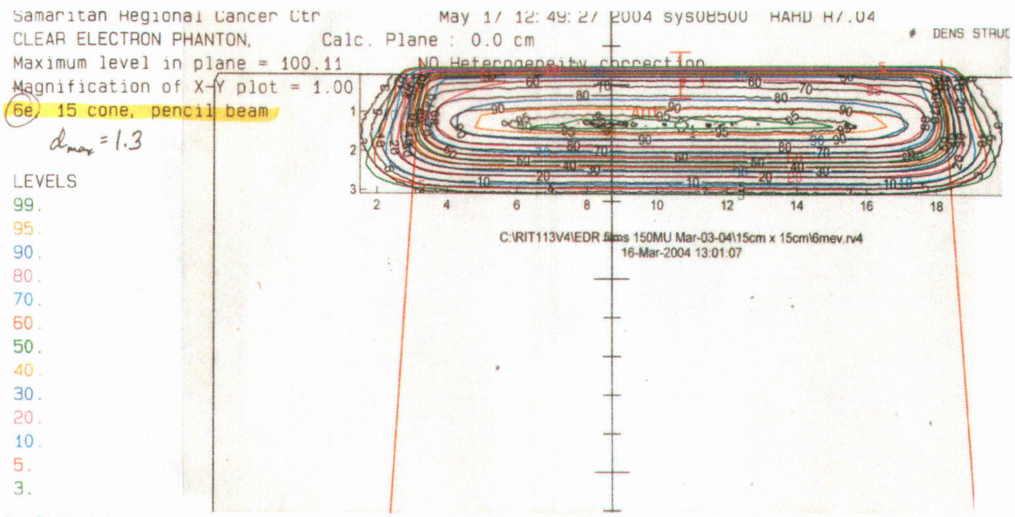



**(e)** 20MeV

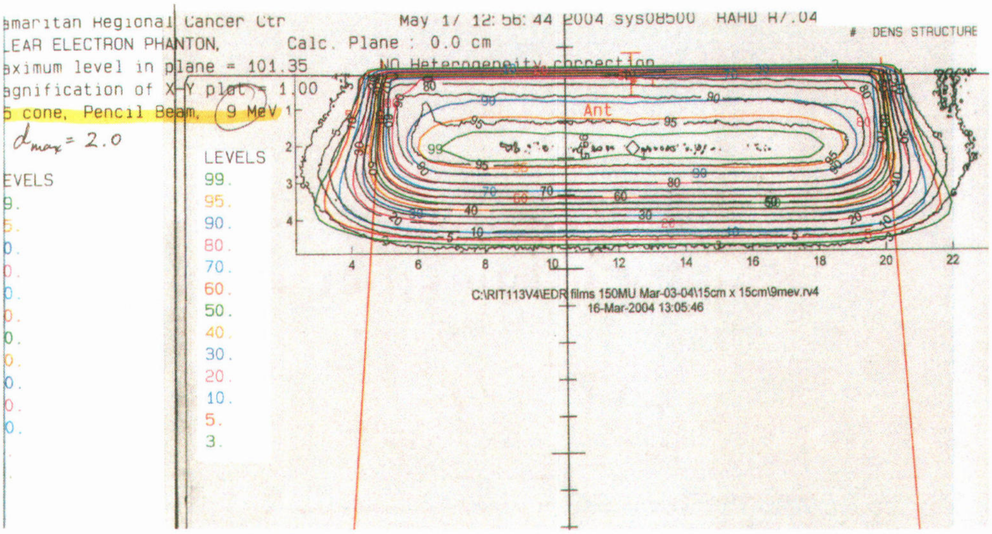
**Figure 4.6a-e** Relative percent depth dose versus scanner signal curves on EDR-2 films exposed with 150MU electron radiation using various cones with different sizes. The plots demonstrate the effect of cone size on the deposited doses.

*4.4 Comparing iso-dose distribution calculated from RAHD and doses measured using the RIT113 system*

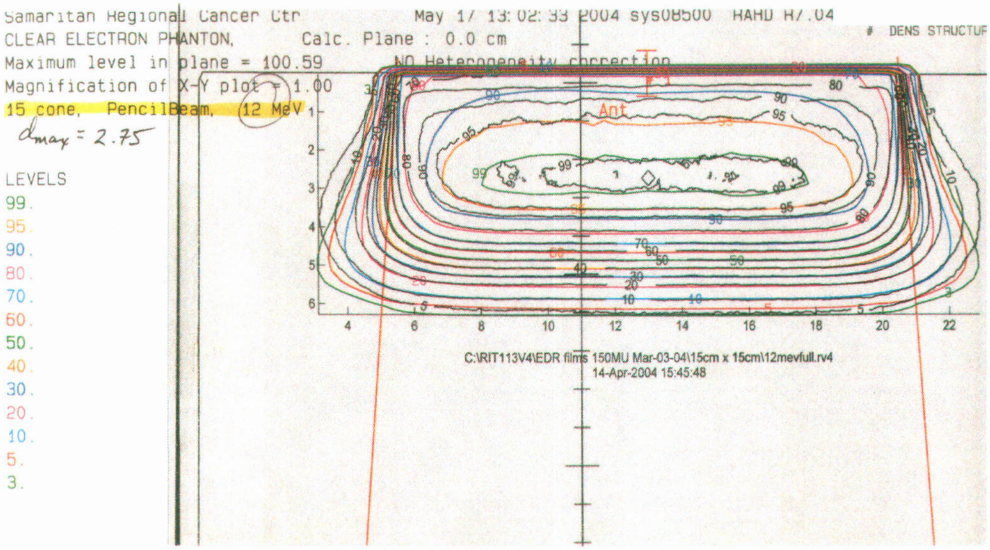
Various electron energy levels were used with a 15cm x 15cm size cone to study the iso-dose distributions on a solid polystyrene phantom. Two blocks of the polystyrene phantom (25cm x 25cm x 2.8cm), with a Kodak ready-pack EDR film sandwiched in between, were scanned in the CT scanner and the generated three-dimension image was transferred into the treatment planning system for dose scenario settings and calculations. The iso-dose distributions created from the two systems are presented in one plot for comparison as shown in Figure 4.7a-e. The iso-dose distributions within the areas of 12cm x 12cm, with iso-centers lying in the central axis of the beam, are in agreement between the two systems. Beyond this region, along the edges parallel to the central axis of the beam and at extended



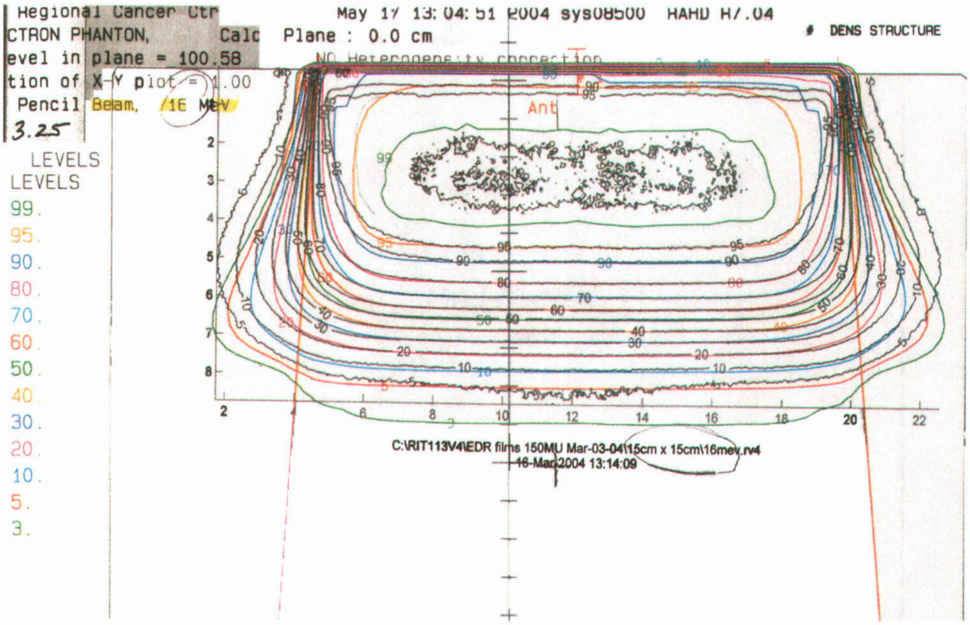

**(a)** 6MeV



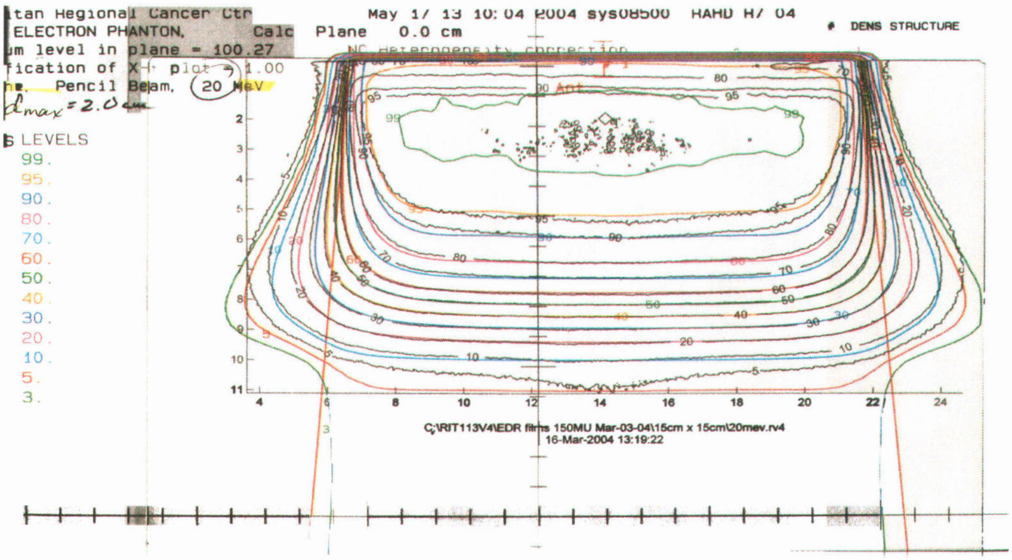

**(b)** 9MeV




**(c)** 12MeV




(**d**) 16MeV




(**e**) 20MeV

**Figure 4.7a-e** Depth iso-dose distributions in polystyrene phantom from linear accelerator Varian 2100C of five electron energy levels at an SSD of 100cm using 15cm x 15cm field cone. Kodak ready-pack EDR films were used in the experiments. The color contours are calculated depth iso-doses, generated from the treatment planning system RADH and the black contours are measured depth ios-doses on films, generated from the film dosimetry system RIT113. **(a)** 6MeV **(b)** 9MeV **(c)** 12MeV **(d)** 16MeV **(e)** 20MeV depth doses of below 5%, the dose distributions became inconsistent between the two systems. Discrepancies up to about 10% were observed for the 16MeV in this region; however the difference was less extreme for the other electron energy beam. Disagreement of within 1mm was perceived for the 20MeV. Because of the inaccuracy of the pencil-beam algorithm in the penumbra region, as discussed previously, discrepancies between the calculated doses and the measured doses are expected in this area. Another factor that contributes to dose discrepancies occurs when the electrons slow down (as when moving through a dense medium due to collisions), lowering the energy of the electrons in the penumbra region. Here, the specific ionization (the number of ion pairs formed per unit distance traveled by the electrons) increases rapidly which is also strongly affected by the difference between the Z (atomic number) of the silver halide in the film and the polystyrene. Because of the higher Z number of the silver halide the dose falls off more slowly in the film than in the polystyrene. Another effect contributing to the discrepancy above the Dmax region is termed bremsstrahlung where X-rays are emitted when the high energy electrons undergo rapid acceleration in the region of a nucleus. Bremsstrahlung is dependent on Z as given by:

$$f_e = 1\text{x}10^{-3}\, Z\, E \tag{4.3}$$

where $f_e$ is the fraction of the energy in the electron beam that is converted into X-rays, Z is the atomic number of the absorber, and E is the energy of the electrons in MeV [5]. Therefore, a higher fraction of the energy of the electron beam is converted to X-rays in the silver halide film than in the polystyrene. It is difficult to calculate the intensity of bremsstrahlung as well as the shape of the bremsstrahlung spectrum but easy to measure.

# 5. CONCLUSION

Radiation film dosimetry is an effective method in verifying the accuracy of dose distribution calculations of the radiation treatment planning system. Kodak Ready-Pack EDR-2 film is recommended for producing a high optical density to dose resolution. A wide range of doses with responsive range up to 400cGy according to the Kodak manufacture which includes clinically practical dose ranges can be achieved in dose distribution analysis. Data providing information on electron beam characteristics plays a key input for generating appropriate pencil-beam parameters for the RAHD system, as well as in creating precise dose calibration files in the film dosimetry. For that reason, collecting data on the beam's characteristics which employs the Blue-Water phantom system should be performed properly in order to avoid errors in the verification of the treatment planning system. The beam data used in a treatment planning system is always collected using a calibrated ion chamber and a water phantom system. All beam calibrations are referenced to water as the "gold standard." However, this data is very limited in its application to treatment planning (i.e. standard, square, electrons are rarely used in cancer treatment). Therefore it is necessary for the treatment planning system to accurately model the electron beam mathematically for it to have legitimate clinical use, such as irregularly shaped fields and tissue inhomogeneity.

From this study, it is shown that the pencil-beam algorithm has a weakness for calculating dose in the penumbra region and in the tail region where the dose fall off. If a cone size 15cm x 15cm is used, the measured central doses within 0.5cm of the field edge are almost matched within 1mm or 2% with the calculated doses. Beyond this region and extended to where the depth dose is below 5%, discrepancies up to 10% were observed for the 16MeV electron beam. For other electron energies (6, 9, 12, and 20MeV) the discrepancies are reduced to less than 5% or within 2mm.

In order to achieve the most reliable verification of the pencil-beam algorithm, the treatment planning system's pencil-beam parameters need to be adjusted to better model the electron beam in the penumbra and the dose fall-off region. Because the pencil-beam algorithm does not model all processes involved with electron transport, the pencil-beam algorithm's correction factors for the penumbra regions need to be adjusted in order to perform the calculations correctly [4]. In addition, the other pencil-beam parameters which represent the electron beam's characteristics in the RAHD system need to be verified in a water phantom. Moreover, further investigation is needed in evaluating the performance of the pencil-beam algorithm for three-dimensional dose calculations, which encounter oblique incident surfaces, irregular shapes, and inhomogeneities [1, 6, 7, 10, 14, 16, 18].

# 6. BIBLIOGRAPHY

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# 7. Appendices

# 7.1. Appendix A

Optical Density Calibration File with the associated OD versus Scanner A/D Values plot and the Stouffer Step Wedge Image

```
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WARNING: Modifying calibration data in this file will change your dosimetric results
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LINAC=
PROCESSOR=
COMMENTS=

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FIRMWARE=5.05
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SCAN_BITS=12
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0.630   888
0.740   655
0.840   487
0.970   354
1.080   261
1.200   195
1.320   140
1.440   105
```

| | |
|---|---|
| 1.550 | 79 |
| 1.690 | 55 |
| 1.790 | 42 |
| 1.920 | 30 |
| 2.010 | 23 |
| 2.160 | 16 |
| 2.290 | 12 |
| 2.410 | 8 |
| 2.530 | 6 |

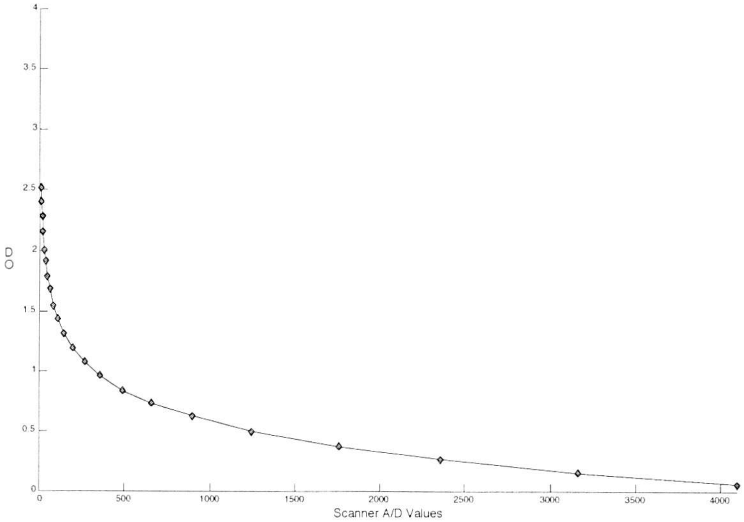


**Figure A.1** Plot generated from the OD calibration file by RIT113.v4 software

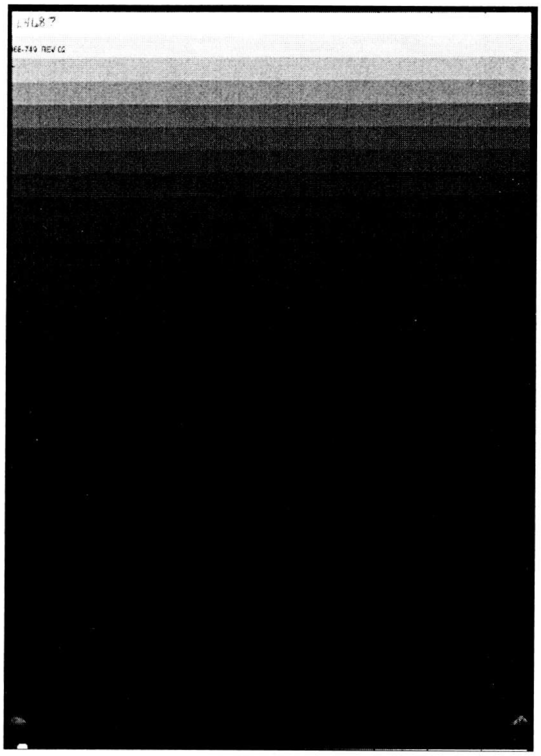

**Figure A.2** Stouffer Step Wedge Film Image has 32 steps (32 shades of gray) – Provided by Radiological Imaging Technology

# 7.2. Appendix B

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 150MU_ 4cm x 4cm cone _ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

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| 90 | 815 | 1.700000e+000 |
| 85 | 934 | 1.810000e+000 |
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| 75 | 1172 | 1.980000e+000 |
| 70 | 1315 | 2.040000e+000 |
| 65 | 1455 | 2.100000e+000 |
| 60 | 1583 | 2.160000e+000 |
| 55 | 1682 | 2.210000e+000 |
| 50 | 1871 | 2.270000e+000 |
| 45 | 2007 | 2.330000e+000 |

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25      2659  2.600000e+000
20      2804  2.680000e+000
15      2916  2.760000e+000
10      3028  2.850000e+000
5       3083  2.960000e+000
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6.300000e-001       888
7.400000e-001       655
8.400000e-001       487
9.700000e-001       354
1.080000e+000       261
1.200000e+000       195
1.320000e+000       140
1.440000e+000       105
1.550000e+000       79
1.690000e+000       55
1.790000e+000       42
1.920000e+000       30
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2.410000e+000       8
2.530000e+000       6
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| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
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| | | |
|---|---|---|
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| 20 | 2428 | 5.540000e+000 |
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| 10 | 2663 | 5.830000e+000 |
| 5 | 2868 | 6.120000e+000 |
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| 7.400000e-001 | 655 |
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| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\4x4\16MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 11:27

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL=  0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=22
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 514 | 1.921734e+000 |
| 95 | 580 | 3.480000e+000 |
| 90 | 663 | 4 |
| 85 | 743 | 4.300000e+000 |
| 80 | 826 | 4.600000e+000 |
| 75 | 929 | 4.850000e+000 |
| 70 | 1051 | 5.100000e+000 |
| 65 | 1152 | 5.300000e+000 |
| 60 | 1281 | 5.530000e+000 |
| 55 | 1438 | 5.800000e+000 |
| 50 | 1604 | 6 |
| 45 | 1767 | 6.200000e+000 |

| | | |
|---|---|---|
| 40 | 1923 | 6.400000e+000 |
| 35 | 2118 | 6.600000e+000 |
| 30 | 2234 | 6.770000e+000 |
| 25 | 2383 | 6.950000e+000 |
| 20 | 2586 | 7.200000e+000 |
| 15 | 2753 | 7.400000e+000 |
| 10 | 2872 | 7.750000e+000 |
| 5 | 2994 | 8.250000e+000 |
| 2.900000e+000 | 3029 | 9 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\4x4\20MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 11:48

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 463 | 1.416014e+000 |
| 95 | 549 | 3.750000e+000 |
| 90 | 626 | 4.450000e+000 |
| 85 | 716 | 4.950000e+000 |
| 80 | 797 | 5.330000e+000 |
| 75 | 882 | 5.620000e+000 |
| 70 | 1003 | 5.950000e+000 |
| 65 | 1137 | 6.280000e+000 |
| 60 | 1248 | 6.520000e+000 |
| 55 | 1365 | 6.800000e+000 |
| 50 | 1526 | 7.100000e+000 |
| 45 | 1634 | 7.350000e+000 |

| | | |
|---|---|---|
| 40 | 1827 | 7.650000e+000 |
| 35 | 1999 | 7.980000e+000 |
| 30 | 2149 | 8.250000e+000 |
| 25 | 2367 | 8.600000e+000 |
| 20 | 2569 | 8.930000e+000 |
| 15 | 2724 | 9.300000e+000 |
| 10 | 2838 | 9.760000e+000 |
| 5 | 2916 | 1.055000e+001 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# 7.3. Appendix C

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 150MU_ 6cm x 6cm cone _ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

```
[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\6x6\6MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected
results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric
results
DATE_CREATED = 2004/ 3/12 12: 0

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL=    0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]
DOSE SCANNER   LOCATION
100    614    1.264500e+000
95     709    1.600000e+000
90     797    1.720000e+000
85     922    1.830000e+000
80     1030   1.900000e+000
75     1116   1.980000e+000
70     1268   2.060000e+000
65     1473   2.140000e+000
60     1555   2.200000e+000
55     1766   2.260000e+000
50     1885   2.310000e+000
45     2043   2.360000e+000
```

| | | |
|---|---|---|
| 40 | 2149 | 2.410000e+000 |
| 35 | 2267 | 2.460000e+000 |
| 30 | 2455 | 2.530000e+000 |
| 25 | 2599 | 2.590000e+000 |
| 20 | 2726 | 2.670000e+000 |
| 15 | 2873 | 2.750000e+000 |
| 10 | 2989 | 2.850000e+000 |
| 5 | 3035 | 2.970000e+000 |

3.700000e+000 3054 3
7.000000e-001 3119 3.300000e+000
0 3.168248e+003 1000

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\6x6\9MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 12:36

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=22
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 551 | 2.022878e+000 |
| 95 | 647 | 2.550000e+000 |
| 90 | 727 | 2.730000e+000 |
| 85 | 814 | 2.870000e+000 |
| 80 | 899 | 2.990000e+000 |
| 75 | 1015 | 3.090000e+000 |
| 70 | 1127 | 3.190000e+000 |
| 65 | 1242 | 3.270000e+000 |
| 60 | 1379 | 3.350000e+000 |
| 55 | 1495 | 3.430000e+000 |
| 50 | 1668 | 3.520000e+000 |
| 45 | 1820 | 3.610000e+000 |

| | | |
|---|---|---|
| 40 | 2023 | 3.690000e+000 |
| 35 | 2179 | 3.770000e+000 |
| 30 | 2331 | 3.840000e+000 |
| 25 | 2443 | 3.930000e+000 |
| 20 | 2675 | 4.040000e+000 |
| 15 | 2812 | 4.160000e+000 |
| 10 | 2886 | 4.270000e+000 |
| 5 | 3021 | 4.430000e+000 |
| 2 | 3051 | 4.700000e+000 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\6x6\12MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 12:59

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 503 | 2.377260e+000 |
| 95 | 667 | 3.500000e+000 |
| 90 | 754 | 3.770000e+000 |
| 85 | 847 | 4 |
| 80 | 976 | 4.200000e+000 |
| 75 | 1075 | 4.350000e+000 |
| 70 | 1210 | 4.480000e+000 |
| 65 | 1311 | 4.600000e+000 |
| 60 | 1395 | 4.700000e+000 |
| 55 | 1509 | 4.800000e+000 |
| 50 | 1617 | 4.900000e+000 |
| 45 | 1764 | 5.030000e+000 |

| | | | |
|---|---|---|---|
| 40 | 1878 | 5.130000e+000 | |
| 35 | 1999 | 5.220000e+000 | |
| 30 | 2168 | 5.330000e+000 | |
| 25 | 2323 | 5.480000e+000 | |
| 20 | 2484 | 5.610000e+000 | |
| 15 | 2611 | 5.740000e+000 | |
| 10 | 2718 | 5.900000e+000 | |
| 5 | 2855 | 6.130000e+000 | |
| 2.100000e+000 | | 3003 | 6.500000e+000 |
| 1.400000e+000 | | 3022 | 7 |
| 0 | 3.168248e+003 | | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\6x6\16MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 13: 6

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 521 | 2.461560e+000 |
| 95 | 700 | 4.250000e+000 |
| 90 | 864 | 4.800000e+000 |
| 85 | 1013 | 5.150000e+000 |
| 80 | 1105 | 5.400000e+000 |
| 75 | 1243 | 5.600000e+000 |
| 70 | 1349 | 5.800000e+000 |
| 65 | 1474 | 5.970000e+000 |
| 60 | 1601 | 6.150000e+000 |
| 55 | 1731 | 6.300000e+000 |
| 50 | 1870 | 6.470000e+000 |
| 45 | 2004 | 6.620000e+000 |

| | | |
|---|---|---|
| 40 | 2141 | 6.780000e+000 |
| 35 | 2231 | 6.900000e+000 |
| 30 | 2373 | 7.050000e+000 |
| 25 | 2501 | 7.200000e+000 |
| 20 | 2623 | 7.400000e+000 |
| 15 | 2771 | 7.600000e+000 |
| 10 | 2841 | 7.850000e+000 |
| 5 | 2963 | 8.270000e+000 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\6x6\20MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/12 13:16

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 483 | 1.820880e+000 |
| 95 | 547 | 4.500000e+000 |
| 90 | 624 | 5.330000e+000 |
| 85 | 707 | 5.860000e+000 |
| 80 | 805 | 6.270000e+000 |
| 75 | 879 | 6.600000e+000 |
| 70 | 960 | 6.860000e+000 |
| 65 | 1086 | 7.140000e+000 |
| 60 | 1217 | 7.400000e+000 |
| 55 | 1364 | 7.650000e+000 |
| 50 | 1522 | 7.900000e+000 |
| 45 | 1678 | 8.120000e+000 |

| | | |
|---|---|---|
| 40 | 1831 | 8.310000e+000 |
| 35 | 2012 | 8.550000e+000 |
| 30 | 2196 | 8.800000e+000 |
| 25 | 2390 | 9.030000e+000 |
| 20 | 2535 | 9.300000e+000 |
| 15 | 2715 | 9.600000e+000 |
| 10 | 2795 | 9.950000e+000 |
| 5 | 2880 | 1.030000e+001 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# 7.4. Appendix D

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 150MU_ 10cm x 10cm cone _ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\10x10\6MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 11:11

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 572 | 1.331940e+000 |
| 95 | 632 | 1.600000e+000 |
| 90 | 671 | 1.720000e+000 |
| 85 | 717 | 1.810000e+000 |
| 80 | 804 | 1.900000e+000 |
| 75 | 891 | 1.970000e+000 |
| 70 | 968 | 2.030000e+000 |
| 65 | 1069 | 2.100000e+000 |
| 60 | 1156 | 2.160000e+000 |
| 55 | 1293 | 2.230000e+000 |
| 50 | 1445 | 2.290000e+000 |
| 45 | 1573 | 2.350000e+000 |

| | | |
|---|---|---|
| 40 | 1691 | 2.400000e+000 |
| 35 | 1819 | 2.450000e+000 |
| 30 | 2014 | 2.510000e+000 |
| 25 | 2238 | 2.600000e+000 |
| 20 | 2388 | 2.670000e+000 |
| 15 | 2604 | 2.750000e+000 |
| 10 | 2792 | 2.850000e+000 |
| 5 | 2949 | 2.950000e+000 |

3.400000e+000 2994 3
6.000000e-001 3129 3.300000e+000
0 3.168248e+003 1000

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\10x10\9MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 11:23

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=24
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 537 | 2.090640e+000 |
| 95 | 606 | 2.510000e+000 |
| 90 | 693 | 2.710000e+000 |
| 85 | 774 | 2.850000e+000 |
| 80 | 850 | 2.970000e+000 |
| 75 | 937 | 3.070000e+000 |
| 70 | 1042 | 3.150000e+000 |
| 65 | 1171 | 3.250000e+000 |
| 60 | 1322 | 3.350000e+000 |
| 55 | 1438 | 3.420000e+000 |
| 50 | 1582 | 3.500000e+000 |
| 45 | 1711 | 3.580000e+000 |

| | | |
|---|---|---|
| 40 | 1884 | 3.660000e+000 |
| 35 | 2029 | 3.730000e+000 |
| 30 | 2253 | 3.820000e+000 |
| 25 | 2423 | 3.920000e+000 |
| 20 | 2557 | 4.020000e+000 |
| 15 | 2710 | 4.130000e+000 |
| 10 | 2850 | 4.240000e+000 |
| 5 | 2994 | 4.430000e+000 |
| 4 | 3055 | 4.500000e+000 |
| 1.900000e+000 | 3101 | 4.700000e+000 |
| 1 | 3114 | 5 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\10x10\12MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 11:31

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 525 | 2.748180e+000 |
| 95 | 605 | 3.550000e+000 |
| 90 | 664 | 3.830000e+000 |
| 85 | 725 | 4.020000e+000 |
| 80 | 813 | 4.200000e+000 |
| 75 | 907 | 4.330000e+000 |
| 70 | 1002 | 4.470000e+000 |
| 65 | 1115 | 4.590000e+000 |
| 60 | 1250 | 4.700000e+000 |
| 55 | 1354 | 4.800000e+000 |
| 50 | 1491 | 4.900000e+000 |
| 45 | 1619 | 5 |

| | | |
|---|---|---|
| 40 | 1790 | 5.130000e+000 |
| 35 | 1933 | 5.230000e+000 |
| 30 | 2132 | 5.350000e+000 |
| 25 | 2247 | 5.450000e+000 |
| 20 | 2476 | 5.580000e+000 |
| 15 | 2591 | 5.700000e+000 |
| 10 | 2787 | 5.870000e+000 |
| 5 | 2950 | 6.140000e+000 |
| 2.200000e+000 | 3041 | 6.500000e+000 |
| 1.500000e+000 | 3045 | 7 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\10x10\16MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 11:41

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=22
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 500 | 3.102240e+000 |
| 95 | 600 | 4.620000e+000 |
| 90 | 676 | 5.050000e+000 |
| 85 | 746 | 5.310000e+000 |
| 80 | 858 | 5.560000e+000 |
| 75 | 973 | 5.780000e+000 |
| 70 | 1041 | 5.920000e+000 |
| 65 | 1165 | 6.100000e+000 |
| 60 | 1292 | 6.250000e+000 |
| 55 | 1444 | 6.400000e+000 |
| 50 | 1578 | 6.550000e+000 |
| 45 | 1714 | 6.670000e+000 |

| | | |
|---|---|---|
| 40 | 1847 | 6.800000e+000 |
| 35 | 2004 | 6.950000e+000 |
| 30 | 2188 | 7.100000e+000 |
| 25 | 2331 | 7.250000e+000 |
| 20 | 2501 | 7.400000e+000 |
| 15 | 2655 | 7.600000e+000 |
| 10 | 2810 | 7.800000e+000 |
| 5 | 2938 | 8.250000e+000 |
| 3 | 2988 | 9 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\10x10\20MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 11:51

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 498 | 2.073780e+000 |
| 95 | 576 | 5.050000e+000 |
| 90 | 653 | 5.850000e+000 |
| 85 | 720 | 6.320000e+000 |
| 80 | 811 | 6.700000e+000 |
| 75 | 914 | 7 |
| 70 | 1006 | 7.250000e+000 |
| 65 | 1132 | 7.530000e+000 |
| 60 | 1252 | 7.760000e+000 |
| 55 | 1411 | 7.980000e+000 |
| 50 | 1567 | 8.170000e+000 |
| 45 | 1686 | 8.350000e+000 |

| | | |
|---|---|---|
| 40 | 1830 | 8.530000e+000 |
| 35 | 2007 | 8.730000e+000 |
| 30 | 2172 | 8.920000e+000 |
| 25 | 2340 | 9.170000e+000 |
| 20 | 2536 | 9.430000e+000 |
| 15 | 2651 | 9.650000e+000 |
| 10 | 2798 | 9.950000e+000 |
| 5 | 2946 | 1.092000e+001 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# 7.5. Appendix E

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 150MU_ 15cm x 15cm cone _ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 03-Mar-04\15x15\6MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 10: 8

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 558 | 1.298220e+000 |
| 95 | 586 | 1.530000e+000 |
| 90 | 663 | 1.680000e+000 |
| 85 | 710 | 1.760000e+000 |
| 80 | 804 | 1.850000e+000 |
| 75 | 882 | 1.930000e+000 |
| 70 | 980 | 2 |
| 65 | 1096 | 2.070000e+000 |
| 60 | 1186 | 2.130000e+000 |
| 55 | 1298 | 2.180000e+000 |
| 50 | 1462 | 2.240000e+000 |
| 45 | 1586 | 2.300000e+000 |

| | | |
|---|---|---|
| 40 | 1760 | 2.360000e+000 |
| 35 | 1926 | 2.420000e+000 |
| 30 | 2063 | 2.480000e+000 |
| 25 | 2231 | 2.550000e+000 |
| 20 | 2447 | 2.620000e+000 |
| 15 | 2635 | 2.700000e+000 |
| 10 | 2779 | 2.790000e+000 |
| 5 | 2936 | 2.900000e+000 |
| 3 | 3035 | 3 |
| 6.000000e-001 | 3109 | 3.300000e+000 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 03-Mar-04\15x15\9MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 10: 0

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 534 | 2.090640e+000 |
| 95 | 594 | 2.490000e+000 |
| 90 | 679 | 2.680000e+000 |
| 85 | 758 | 2.820000e+000 |
| 80 | 839 | 2.930000e+000 |
| 75 | 915 | 3.030000e+000 |
| 70 | 1028 | 3.130000e+000 |
| 65 | 1151 | 3.230000e+000 |
| 60 | 1251 | 3.300000e+000 |
| 55 | 1409 | 3.400000e+000 |
| 50 | 1541 | 3.480000e+000 |
| 45 | 1671 | 3.560000e+000 |

| | | |
|---|---|---|
| 40 | 1867 | 3.640000e+000 |
| 35 | 2031 | 3.720000e+000 |
| 30 | 2199 | 3.810000e+000 |
| 25 | 2375 | 3.900000e+000 |
| 20 | 2538 | 3.990000e+000 |
| 15 | 2678 | 4.100000e+000 |
| 10 | 2852 | 4.220000e+000 |
| 5 | 2977 | 4.410000e+000 |
| 3.600000e+000 | 3073 | 4.500000e+000 |
| 8.000000e-001 | 3118 | 5 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 03-Mar-04\15x15\12MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 10:27

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=22
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 515 | 2.815620e+000 |
| 95 | 611 | 3.540000e+000 |
| 90 | 697 | 3.800000e+000 |
| 85 | 772 | 4 |
| 80 | 898 | 4.180000e+000 |
| 75 | 1007 | 4.330000e+000 |
| 70 | 1138 | 4.460000e+000 |
| 65 | 1241 | 4.580000e+000 |
| 60 | 1358 | 4.690000e+000 |
| 55 | 1529 | 4.800000e+000 |
| 50 | 1647 | 4.890000e+000 |
| 45 | 1828 | 5 |

| | | |
|---|---|---|
| 40 | 1943 | 5.110000e+000 |
| 35 | 2117 | 5.210000e+000 |
| 30 | 2305 | 5.330000e+000 |
| 25 | 2454 | 5.440000e+000 |
| 20 | 2570 | 5.550000e+000 |
| 15 | 2706 | 5.690000e+000 |
| 10 | 2836 | 5.840000e+000 |
| 5 | 2989 | 6.100000e+000 |
| 2 | 3049 | 6.500000e+000 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\15x15\16MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 10:40

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 513 | 3.169680e+000 |
| 95 | 619 | 4.580000e+000 |
| 90 | 693 | 5 |
| 85 | 760 | 5.310000e+000 |
| 80 | 893 | 5.560000e+000 |
| 75 | 1013 | 5.760000e+000 |
| 70 | 1119 | 5.930000e+000 |
| 65 | 1253 | 6.100000e+000 |
| 60 | 1388 | 6.250000e+000 |
| 55 | 1477 | 6.370000e+000 |
| 50 | 1635 | 6.500000e+000 |
| 45 | 1801 | 6.660000e+000 |

| | | |
|---|---|---|
| 40 | 1967 | 6.800000e+000 |
| 35 | 2141 | 6.950000e+000 |
| 30 | 2306 | 7.100000e+000 |
| 25 | 2428 | 7.230000e+000 |
| 20 | 2609 | 7.400000e+000 |
| 15 | 2724 | 7.600000e+000 |
| 10 | 2851 | 7.800000e+000 |
| 5 | 2991 | 8.250000e+000 |
| 3.100000e+000 | 3034 | 9 |
| 2.700000e+000 | 3043 | 1.050000e+001 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\15x15\20MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 10:59

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 519 | 2.090640e+000 |
| 95 | 603 | 5.250000e+000 |
| 90 | 648 | 5.980000e+000 |
| 85 | 715 | 6.450000e+000 |
| 80 | 795 | 6.800000e+000 |
| 75 | 858 | 7.070000e+000 |
| 70 | 949 | 7.300000e+000 |
| 65 | 1071 | 7.530000e+000 |
| 60 | 1208 | 7.800000e+000 |
| 55 | 1301 | 7.980000e+000 |
| 50 | 1418 | 8.200000e+000 |
| 45 | 1580 | 8.400000e+000 |

| | | |
|---|---|---|
| 40 | 1723 | 8.550000e+000 |
| 35 | 1868 | 8.750000e+000 |
| 30 | 2068 | 8.950000e+000 |
| 25 | 2273 | 9.200000e+000 |
| 20 | 2427 | 9.400000e+000 |
| 15 | 2595 | 9.700000e+000 |
| 10 | 2735 | 10 |
| 5 | 2912 | 11 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# 7.6. Appendix F

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 150MU_ 20cm x 20cm cone _ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\20x20\6MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 15:31

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 530 | 1.197060e+000 |
| 95 | 577 | 1.550000e+000 |
| 90 | 623 | 1.680000e+000 |
| 85 | 714 | 1.780000e+000 |
| 80 | 770 | 1.860000e+000 |
| 75 | 857 | 1.940000e+000 |
| 70 | 942 | 2 |
| 65 | 1052 | 2.070000e+000 |
| 60 | 1135 | 2.130000e+000 |
| 55 | 1298 | 2.190000e+000 |
| 50 | 1411 | 2.250000e+000 |
| 45 | 1559 | 2.310000e+000 |

| | | |
|---|---|---|
| 40 | 1742 | 2.370000e+000 |
| 35 | 1871 | 2.420000e+000 |
| 30 | 2015 | 2.480000e+000 |
| 25 | 2206 | 2.550000e+000 |
| 20 | 2415 | 2.630000e+000 |
| 15 | 2607 | 2.720000e+000 |
| 10 | 2777 | 2.800000e+000 |
| 5 | 2929 | 2.900000e+000 |
| 3 | 3022 | 3 |
| 6.000000e-001 | 3119 | 3.300000e+000 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

```
[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\20x20\9MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 15:52

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL=    0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=24
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]
DOSE SCANNER  LOCATION
100   525   1.955760e+000
95    621   2.460000e+000
90    721   2.700000e+000
85    786   2.830000e+000
80    884   2.950000e+000
75    985   3.050000e+000
70    1099  3.150000e+000
65    1226  3.240000e+000
60    1358  3.330000e+000
55    1519  3.400000e+000
50    1676  3.490000e+000
45    1802  3.580000e+000
```

| | | |
|---|---|---|
| 40 | 1999 | 3.660000e+000 |
| 35 | 2120 | 3.730000e+000 |
| 30 | 2278 | 3.820000e+000 |
| 25 | 2429 | 3.900000e+000 |
| 20 | 2585 | 3.990000e+000 |
| 15 | 2707 | 4.090000e+000 |
| 10 | 2844 | 4.210000e+000 |
| 5 | 2996 | 4.400000e+000 |
| 3.800000e+000 | 3038 | 4.500000e+000 |
| 1.700000e+000 | 3050 | 4.700000e+000 |
| 8.000000e-001 | 3081 | 5 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\20x20\12MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 16:12

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL=    0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 536 | 2.680740e+000 |
| 95 | 634 | 3.500000e+000 |
| 90 | 714 | 3.820000e+000 |
| 85 | 796 | 4 |
| 80 | 889 | 4.180000e+000 |
| 75 | 990 | 4.320000e+000 |
| 70 | 1095 | 4.460000e+000 |
| 65 | 1216 | 4.580000e+000 |
| 60 | 1360 | 4.690000e+000 |
| 55 | 1484 | 4.800000e+000 |
| 50 | 1673 | 4.900000e+000 |
| 45 | 1797 | 5.010000e+000 |

| | | |
|---|---|---|
| 40 | 1941 | 5.110000e+000 |
| 35 | 2079 | 5.200000e+000 |
| 30 | 2271 | 5.330000e+000 |
| 25 | 2429 | 5.440000e+000 |
| 20 | 2575 | 5.570000e+000 |
| 15 | 2702 | 5.700000e+000 |
| 10 | 2848 | 5.860000e+000 |
| 5 | 2963 | 6.130000e+000 |
| 2.200000e+000 | 3031 | 6.500000e+000 |
| 1.600000e+000 | 3062 | 7 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\20x20\16MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 3/11 16:23

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 515 | 3.220260e+000 |
| 95 | 598 | 4.630000e+000 |
| 90 | 646 | 5.060000e+000 |
| 85 | 732 | 5.350000e+000 |
| 80 | 806 | 5.550000e+000 |
| 75 | 873 | 5.750000e+000 |
| 70 | 970 | 5.930000e+000 |
| 65 | 1100 | 6.100000e+000 |
| 60 | 1212 | 6.250000e+000 |
| 55 | 1330 | 6.400000e+000 |
| 50 | 1403 | 6.530000e+000 |
| 45 | 1580 | 6.660000e+000 |

| | | |
|---|---|---|
| 40 | 1694 | 6.800000e+000 |
| 35 | 1893 | 6.970000e+000 |
| 30 | 2044 | 7.100000e+000 |
| 25 | 2214 | 7.250000e+000 |
| 20 | 2387 | 7.400000e+000 |
| 15 | 2495 | 7.550000e+000 |
| 10 | 2700 | 7.800000e+000 |
| 5 | 2894 | 8.350000e+000 |
| 3.200000e+000 | 2997 | 9 |
| 2.900000e+000 | 3007 | 1.050000e+001 |
| 0 | 3.168248e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

```
[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 150MU 03-Mar-04\20x20\20MeV.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected
results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric
results
DATE_CREATED = 2004/ 3/11 16:38

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL=    0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=21
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]
DOSE SCANNER   LOCATION
100    486    2.613300e+000
95     609    5.240000e+000
90     682    5.980000e+000
85     753    6.450000e+000
80     848    6.800000e+000
75     926    7.120000e+000
70     1039   7.360000e+000
65     1135   7.590000e+000
60     1263   7.820000e+000
55     1380   8
50     1542   8.200000e+000
45     1694   8.400000e+000
```

```
40      1819    8.550000e+000
35      2023    8.780000e+000
30      2205    9
25      2347    9.200000e+000
20      2516    9.430000e+000
15      2663    9.700000e+000
10      2788    10
5       2910    11
0       3.168248e+003           1000

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]
OD      SCANNER
7.000000e-002       4095
1.600000e-001       3157
2.700000e-001       2350
3.800000e-001       1754
5.000000e-001       1241
6.300000e-001       888
7.400000e-001       655
8.400000e-001       487
9.700000e-001       354
1.080000e+000       261
1.200000e+000       195
1.320000e+000       140
1.440000e+000       105
1.550000e+000       79
1.690000e+000       55
1.790000e+000       42
1.920000e+000       30
2.010000e+000       23
2.160000e+000       16
2.290000e+000       12
2.410000e+000       8
2.530000e+000       6
```

# 7.7. Appendix G

Parallel dose calibration file using Kodak Ready-Pack EDR-2 film _ 100MU_
15cm x 15cm cone _ 12MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\EDR films Jan-18-04\Calibration\12MeV15x15.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 2/18 18: 7

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=23
INTERPOLATION=cubic
FILM=EDR2

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 1130 | 2.730885e+000 |
| 95 | 1236 | 3.510000e+000 |
| 90 | 1355 | 3.800000e+000 |
| 85 | 1427 | 4 |
| 80 | 1531 | 4.180000e+000 |
| 75 | 1628 | 4.330000e+000 |
| 70 | 1764 | 4.490000e+000 |
| 65 | 1884 | 4.600000e+000 |
| 60 | 1956 | 4.700000e+000 |
| 55 | 2086 | 4.800000e+000 |
| 50 | 2196 | 4.900000e+000 |
| 45 | 2303 | 5 |

```
40      2435    5.150000e+000
35      2517    5.250000e+000
30      2727    5.450000e+000
25      2757    5.480000e+000
20      2836    5.550000e+000
15      2915    5.680000e+000
10      2989    5.800000e+000
6.400000e+000           3070    6
2       3123    6.500000e+000
1.400000e+000           3158    7
0       3.164963e+003           1000

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

[OD_DATA]
OD      SCANNER
7.000000e-002           4095
1.600000e-001           3157
2.700000e-001           2350
3.800000e-001           1754
5.000000e-001           1241
6.300000e-001           888
7.400000e-001           655
8.400000e-001           487
9.700000e-001           354
1.080000e+000           261
1.200000e+000           195
1.320000e+000           140
1.440000e+000           105
1.550000e+000           79
1.690000e+000           55
1.790000e+000           42
1.920000e+000           30
2.010000e+000           23
2.160000e+000           16
2.290000e+000           12
2.410000e+000           8
2.530000e+000           6
```

# Appendix H

Parallel dose calibration file using Kodak Ready-Pack XV-2 film _ 100MU_
15cm x 15cm cone _ 12MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Cal Parallel 16-Jan-04\12MeV\XV 99cGy.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 1/16 13: 9

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION= 85
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=16
INTERPOLATION=cubic
FILM=XV

[CALIBRATION_DATA]

| DOSE SCANNER | | LOCATION |
|---|---|---|
| 9.930000e+001 | 7 | 2.930620e+000 |
| 99 8 3 | | |
| 9.702000e+001 | 10 | 3.300000e+000 |
| 9.334000e+001 | 11 | 3.600000e+000 |
| 8.957000e+001 | 13 | 3.800000e+000 |
| 8.699000e+001 | 14 | 3.900000e+000 |
| 8.421000e+001 | 15 | 4 |
| 8.162000e+001 | 17 | 4.100000e+000 |
| 7.845000e+001 | 19 | 4.200000e+000 |
| 6.752000e+001 | 34 | 4.500000e+000 |
| 4.439000e+001 | 125 | 5 |
| 2.204000e+001 | 626 | 5.500000e+000 |

6.360000e+000 1845 6
1.990000e+000 2501 6.500000e+000
1.390000e+000 2646 7
0 3.293994e+003 1000

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal85.cal
OD_NUMBER_POINTS=22

[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3148 |
| 2.700000e-001 | 2344 |
| 3.800000e-001 | 1750 |
| 5.000000e-001 | 1237 |
| 6.300000e-001 | 882 |
| 7.400000e-001 | 648 |
| 8.400000e-001 | 484 |
| 9.700000e-001 | 351 |
| 1.080000e+000 | 258 |
| 1.200000e+000 | 194 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 104 |
| 1.550000e+000 | 80 |
| 1.690000e+000 | 56 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# 7.9. Appendix I

Parallel dose calibration file using Kodak Ready-Pack XV-2 film _ 50MU_ 10cm x 10cm cone _ 12MeV

[RIT113_V4_CAL]
FILE_NAME=C:\RIT113V4\Tom's Films\Calibration\12MeV60MU10x10.cal
WARNING: Do not modify section headings or keywords in this file. Unexpected results may occur.
WARNING: Modifying calibration data in this file will change your dosimetric results
DATE_CREATED = 2004/ 2/12 10:31

[FACILITY_INFO]
FACILITY_NAME=Samaritan Regional Cancer Center
LINAC=LINAC1
PROCESSOR=Processor1
COMMENTS=

[SCANNER_INFO]
SCANNER_SERIAL= 0
INTEGRATION_TIME=12.0
DIGITIZER=VXR12
FIRMWARE=5.05
TOOLBOX=3.1.9.3
SCANNING_RESOLUTION=169
SCAN_BITS=12
LUT=0

[CALIBRATION_INFO]
NUMBER_POINTS=14
INTERPOLATION=cubic
FILM=XV

[CALIBRATION_DATA]

| DOSE | SCANNER | LOCATION |
|---|---|---|
| 100 | 59 | 2.731320e+000 |
| 95 | 65 | 3.550000e+000 |
| 90 | 76 | 3.850000e+000 |
| 85 | 84 | 4 |
| 80 | 100 | 4.200000e+000 |
| 70 | 140 | 4.480000e+000 |
| 60 | 199 | 4.700000e+000 |
| 50 | 288 | 4.900000e+000 |
| 40 | 427 | 5.100000e+000 |
| 30 | 721 | 5.350000e+000 |
| 20 | 1108 | 5.550000e+000 |
| 10 | 1996 | 5.900000e+000 |

| | | |
|---|---|---|
| 5 | 2626 | 6.200000e+000 |
| 0 | 3.354395e+003 | 1000 |

[OD_INFO]
OD_FILENAME=C:\RIT113V4\Cal OD Stepwedge\OD Cal169.cal
OD_NUMBER_POINTS=22

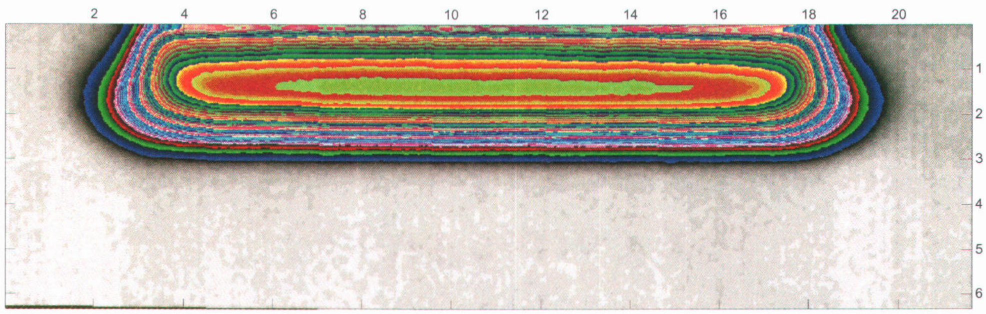
[OD_DATA]

| OD | SCANNER |
|---|---|
| 7.000000e-002 | 4095 |
| 1.600000e-001 | 3157 |
| 2.700000e-001 | 2350 |
| 3.800000e-001 | 1754 |
| 5.000000e-001 | 1241 |
| 6.300000e-001 | 888 |
| 7.400000e-001 | 655 |
| 8.400000e-001 | 487 |
| 9.700000e-001 | 354 |
| 1.080000e+000 | 261 |
| 1.200000e+000 | 195 |
| 1.320000e+000 | 140 |
| 1.440000e+000 | 105 |
| 1.550000e+000 | 79 |
| 1.690000e+000 | 55 |
| 1.790000e+000 | 42 |
| 1.920000e+000 | 30 |
| 2.010000e+000 | 23 |
| 2.160000e+000 | 16 |
| 2.290000e+000 | 12 |
| 2.410000e+000 | 8 |
| 2.530000e+000 | 6 |

# Appendix J

Film images and iso-dose contours on Kodak Ready-Pack EDR-2 film using 150M_ 15cm x 15cm cone_ 6MeV, 9MeV, 12MeV, 16MeV, and 20MeV

**Figure J.1** 6MeV 15x15 cone 150MU EDR film



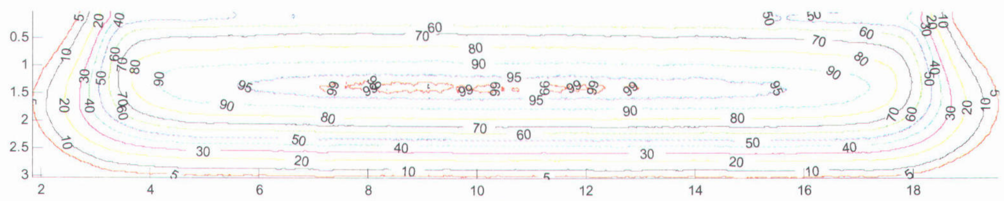
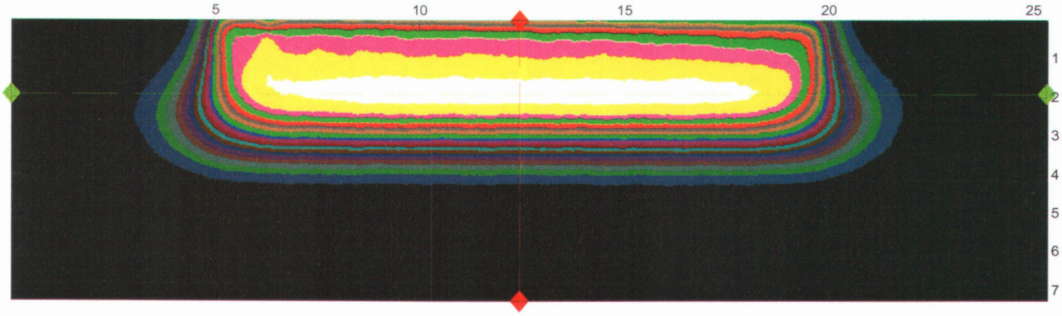


**Figure J.2** 9MeV 15x15 cone 150MU EDR film



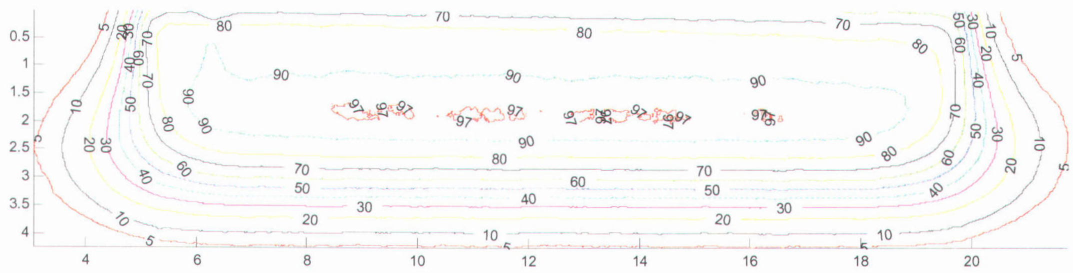
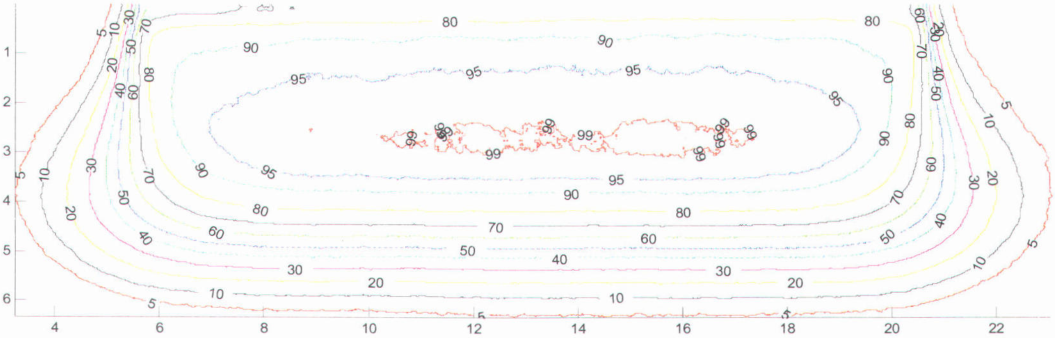


**Figure J.3** 12MeV 15x15 cone 150MU EDR film



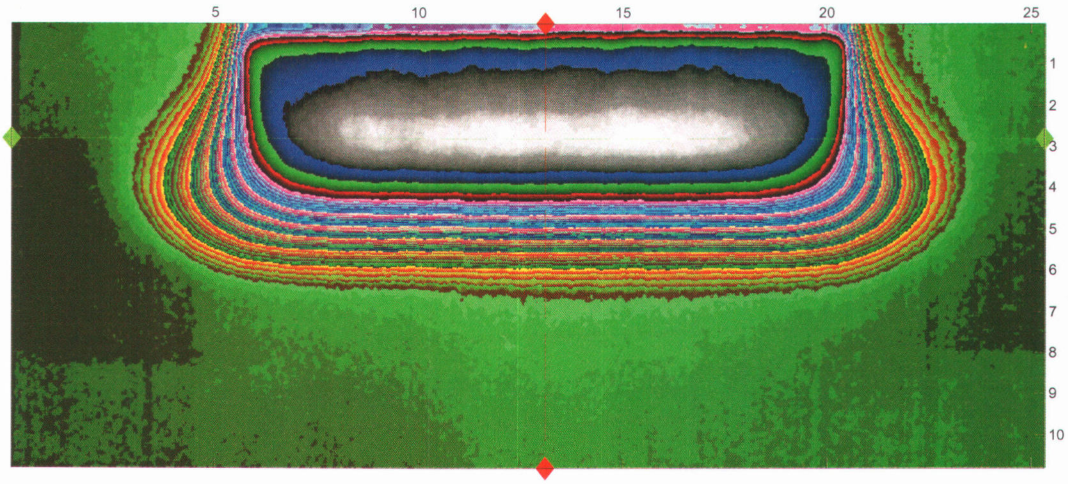
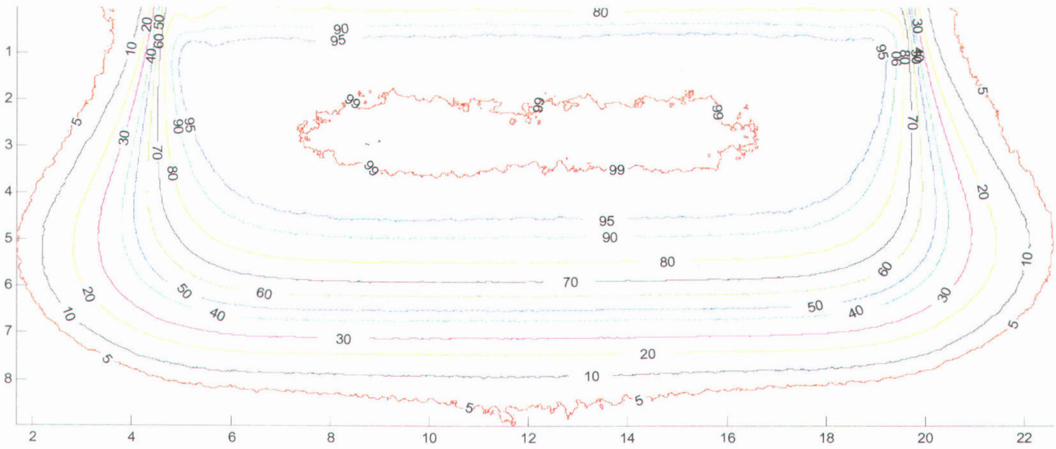



**Figure J.4** 16MeV 15x15 cone 150MU EDR film



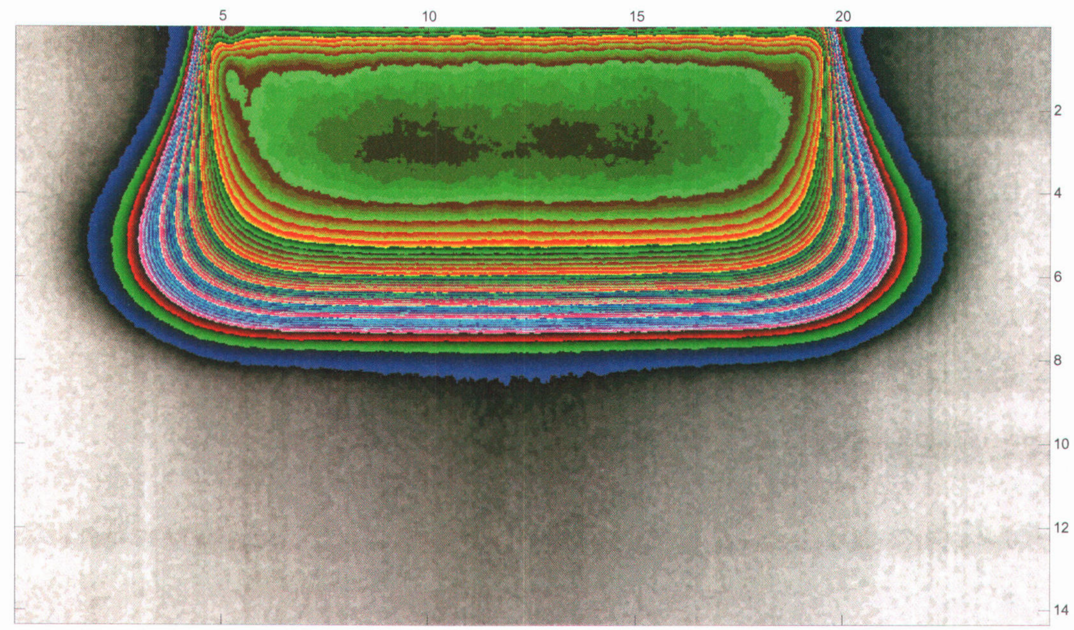


**Figure J.6** 20MeV 15x15 cone 150MU EDR film