Evaluation of Plastic Water (Cream Colored) for absorbed dose calibration of photon and electron beams

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Introduction

Plastic Water, in the cream color version, developed by Computerized Imaging Reference Systems Inc., from Norfolk, VA has been evaluated to test its water equivalent characteristics for absorbed dose measurements for the range of clinical energies in use for radiation therapy for both photon and electron beams. The photon energies range from Co-60 to 18 MV X-rays, and the electron energies range from 3 MeV to 20 MeV pulsed electron beams. This evaluation presents the comparison of the dose in Plastic Water (PW) with the dose to natural water (Water) at the depth of maximum for both the photon and electron beams tested. This comparison is presented as the ratios of the dose in the plastic over the dose in water (PW / Water).

Materials, Methods and Calculative Techniques

The same dosimetry system was used for all the measurements in both the plastic and water. A PTW N23333, farmer type ion chamber was used in conjunction with a programmable Keithley electrometer K35617EBS. A 0.46-cm acrylic protective cap was used for all the measurements in water. The plastic had a slab with a cavity for insertion of the cylindrical chamber without the build-up cap. The radiation emitting units and their beam characteristics are presented in Table I. The plastic phantom consisted of 30-cm-square slabs of various thicknesses, ranging from 1 mm to 7 cm. All measurements were made at the depth of maximum ionization and at the center of a 10 cm x 10 cm field size for a constant target-to-surface distance of 100 cm for all beams with the exception of Cobalt-60, which had 80 cm. Quality assurance tests as described in the in the literature by Tello et al[1,2] were used to eliminate any effects due to potential beam output drifts. At least 30 cm of plastic material were under the position of maximum ionization to provide complete backscatter. Plastic and water temperatures were monitored at all times during the measurements sessions, and required temperature corrections were applied to the raw ionization readings. Other methods and procedures were also as described by Tello et al referenced above.

The absorbed dose to water was calculated from ionization measurements in the plastic and water using TG-21 calibration protocol[3] .

Uncertainties

The uncertainties for these measurements are ±0.4% for all cases with the exception of the 3 MeV electron beam where the uncertainty is estimated to be ±1%, measurements for very low energy electron beams are very difficult to make, the 3 MeV energy is not normally used clinically and most standard electron treatment units do not have this capability. The presentation of results for this energy is meant be used merely to illustrate the potential break down of water equivalency that has been observed by Tello et al[1] with practically all water equivalent plastics.

Results

From Figure 1, Photon Beam Evaluation for Plastic Water, we can observe that the ratios PW / Water from Co-60 to 18 MV X-rays remain all within 0.995 and 1.005, in other words the agreement is within ± 0.5%. There seems to be a better agreement al lower photon energies than at higher ones from the observed trendline.

Figure 2 presents, Electron Beam Evaluation for Plastic Water for standard electron beam energies from a Clinac 2100C and a Mevatron XII unit and the 6 and 9 MeV electron beam energies from a Saturne 41 unit. A trendline analysis performed on these data points, shows a deterioration in the agreement at low electron energies, the correlation coefficient for these data points at this low energy end is very poor. When we include the lowest energy of the Saturne 41 unit, the 3 MeV mean incident energy, see Figure 3, provides a disagreement of about 2.5%, the dose being lower in the plastic than in water. However the trendline analysis predicts an agreement within 1% for energies between 5.5 and 7 MeV, and an agreement within 0.5% for energies above 7 MeV. So for practical purposes the agreement is within 1% for the range of electron beam energies used commonly with electron beam treatments. If electron energies below 5.5 MeV are used, the plastic user is cautioned to assess the actual agreement with natural water to avoid any potential discrepancies.

References

1 V. M. Tello, et al, "Evaluation of water-equivalent solid phantom materials for absorbed-dose calibrations of photon and electron beams", presented at the AAPM Southwest Chapter Meeting, October 9-10, 1992.

2 V. M. Tello, et al, "Solid Phantom materials for absolute dose calibration for photon and electron beams", abstract in Med. Phys. 18, 643 (1991) and abstract in Med. Phys, 17, 522 (1990).

3 American Association of Physicists in Medicine, Radiation Therapy committee Task Group 21, Med. Phys. 10, 741-771 (1983).

Table I. Machines, beams, energies and resulting PW / Water ratios at D_{max}.

Unit:	Beam:	IR	Eo(MeV)	PW / Water
Eldorado	Cobalt-60	0.572		0.999
Clinac 4	4 MV X-rays	0.600		0.998
Clinac 2100C	6 MV X-rays	0.671		1.002
	18 MV X-rays	0.781		0.999
	6 MeV electrons		5.5	0.985
	9 MeV electrons		8.3	0.990
	12 MeV electrons		11.5	1.000
	16 MeV electrons		15.2	0.996
	20 MeV electrons		18.8	0.997
Mevatron XII	10 MV X-rays	0.732		1.004
	7 MeV electrons		7.0	0.999
	11 MeV		7.7	1.002
Saturne 41	3 MeV electrons		3.1	0.975
	6 MeV electrons		5.4	0.999
	9 MeV electrons		8.1	0.998

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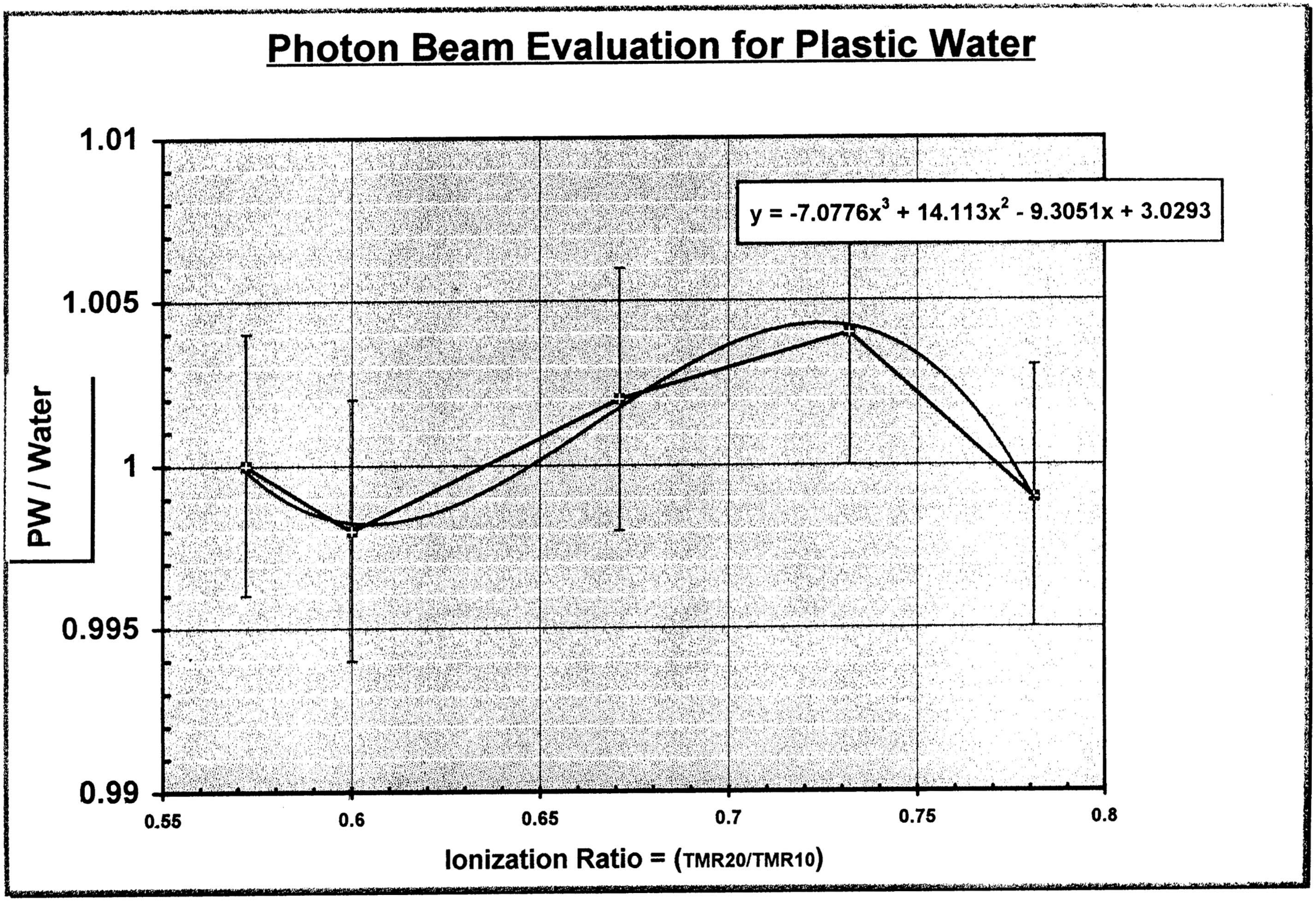

Figure 1

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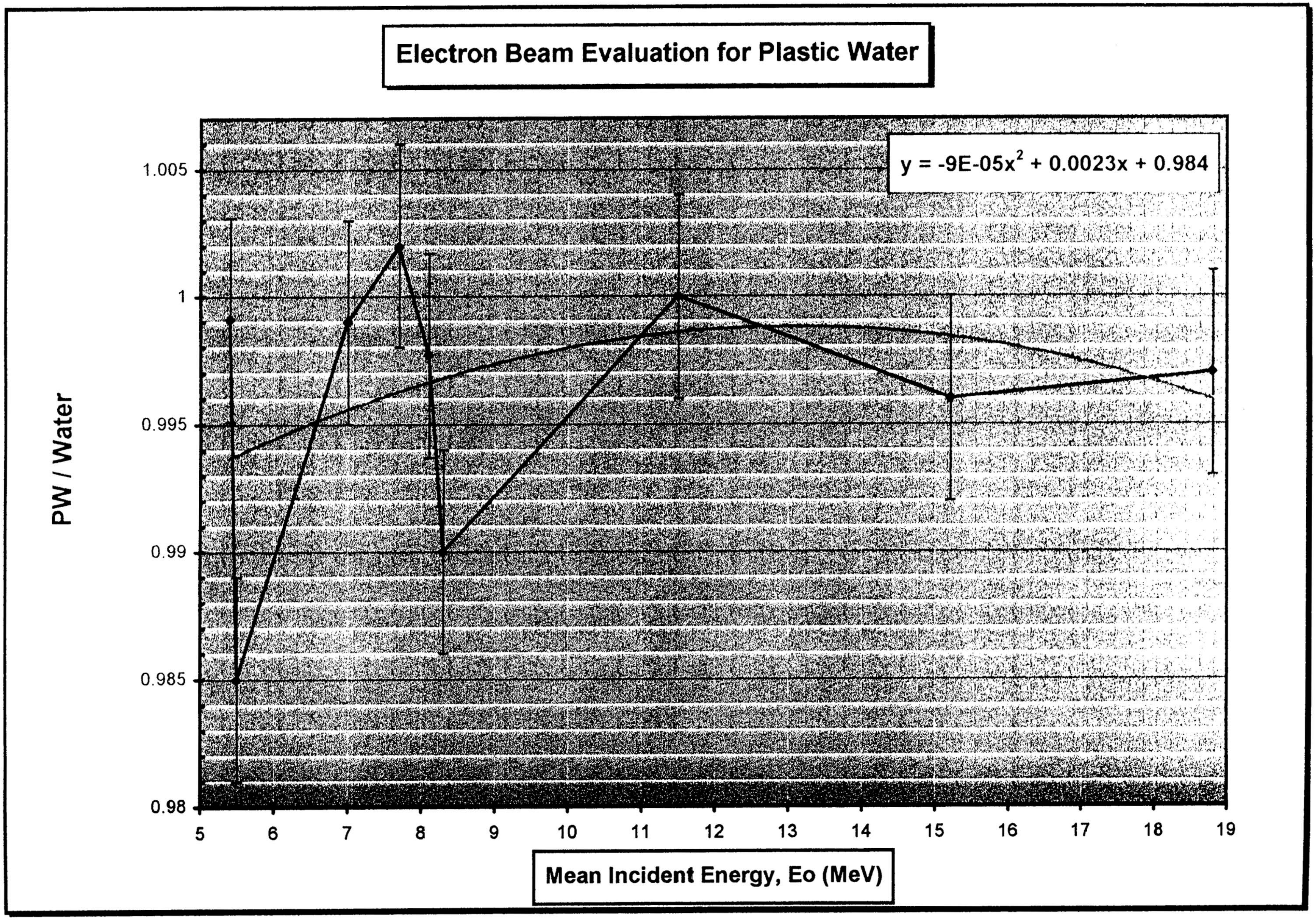

Figure 2

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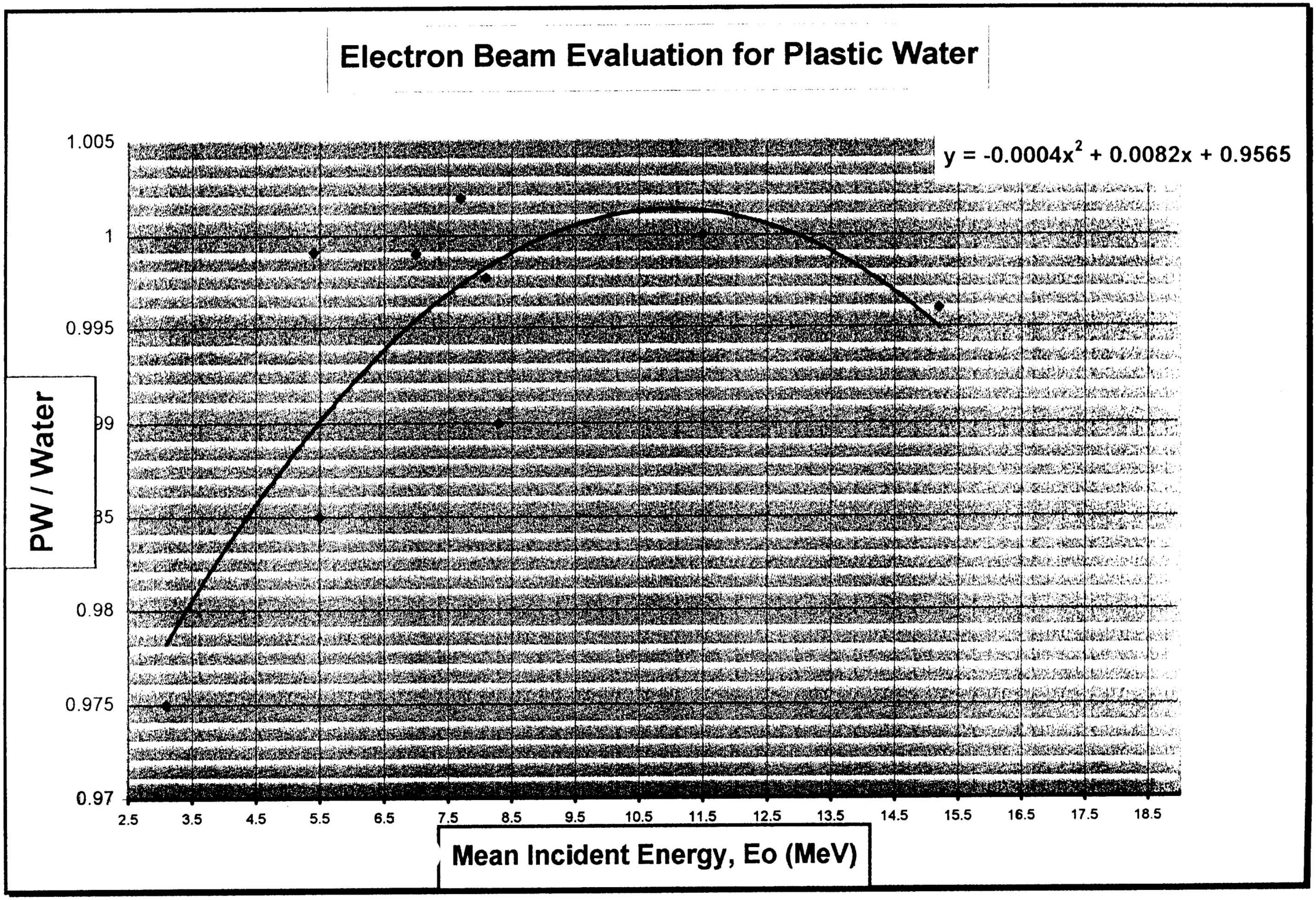

Figure 3