The Abdus Salam International Centre for Theoretical Physics
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International Organization for Medical Physics

School on Medical Physics for Radiation Therapy:

Dosimetry and Treatment Planning for Basic and Advanced Applications

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Dosimetry Exercise

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Calibration at a 6 MV photon beam with a linear accelerator

Remark 1: Calibration here means:

Determination of absorbed dose to water per 100 monitor units in a water phantom at reference conditions

using
the IAEA Code of Practice TRS398

Remark 2: Use Excel for calculation and plotting

Objectives:

1. To learn of how to set up the measuring equipment
2. To be able to differentiate between a depth dose measurement and a calibration measurement
3. To know how a charge measurement obtained by using some monitor units has to be **manually** converted into dose in water per 100 MU under reference condition

Introduction: General Dosimetry Formalism

- The absorbed dose to water in a water phantom for a beam of quality Q (here 6 MV photons) is obtained by the fundamental expression:

$$D_{w,Q} = M_Q \; N_{D,w,Q_o} \; k_{Q,Q_o}$$

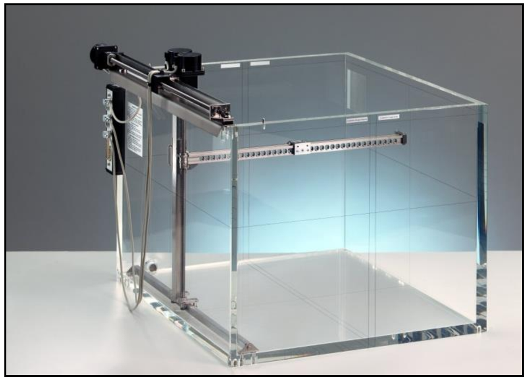
Discussion of the meaning of the three quantities

Q is the so-called **quality index** for high energy (HE) photons

The quality index Q for HE photons is defined as:

tissue–phantom ratio TPR
in water at depths of 20 and 10 g/cm^2,
for a field size of 10 cm $\times$ 10 cm
and an SCD of 100 cm

M_Q is the **chamber reading** (= measured charge) at the quality ***Q*** (=6 MV photon energy)



The chamber reading $\boldsymbol{M}_Q$ is obtained:

- with a water phantom

- an ionization chamber

- an electrometer

N_{D,w,Q_o}

is the **calibration factor** of the ionization chamber as given in the certificate:

Please note:

1) The calibration factor refers to a certain beam quality Q_0 which usually is a Co-60 beam.

2) The calibration factor refers to reference conditions

Calibration Certificate

Calibration laboratory for ionising radiation quantities	Calibration mark	000877 04-06

Object : Ionization chamber

Manufacturer : Scanditronix Wellhöfer, Germany

Type : CC04

Serial number : 6602

Beam quality : **Co-60**

Absorbed dose to water calibration factor : $N_{D,w} = 9.462 \times 10^{8}$ Gy/C

Measurement uncertainty : U = 2.2 %

Reference conditions : T_0 : 20.0 °C p_0: 101.325 kPa R.H.: 50 %

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, which for a normal distribution provides a level of confidence of approximately 95%.

The secondary standard of this laboratory is traceable to the PTB in Braunschweig (German Federal Institute of Physics and Metrology).

Calibration reported in this certificate was carried out in accordance with the procedures described in the IAEA TRS 398 Code of Practice.

Measuring conditions:

Phantom size :	30 cm × 30 cm × 30 cm
Phantom material :	water
Source to phantom surface distance (SSD) :	100 cm
Field size at the phantom surface :	10 cm × 10 cm
Depth in phantom of the reference point of the chamber :	5 g cm^{-2}
Reference point of the IC :	on the chamber axis at the centre of the cavity volume
Chamber orientation :	the beam axis perpendicular to the chamber axis
If the chamber stem has a mark, the mark is oriented towards the radiation source	
Waterproof sleeve (PMMA) :	NO
Sleeve Serial Number:	-
Polarizing potential of collecting (central) electrode :	300 V
Dose rate :	1.0 Gy min^{-1}

Recombination correction has not been applied

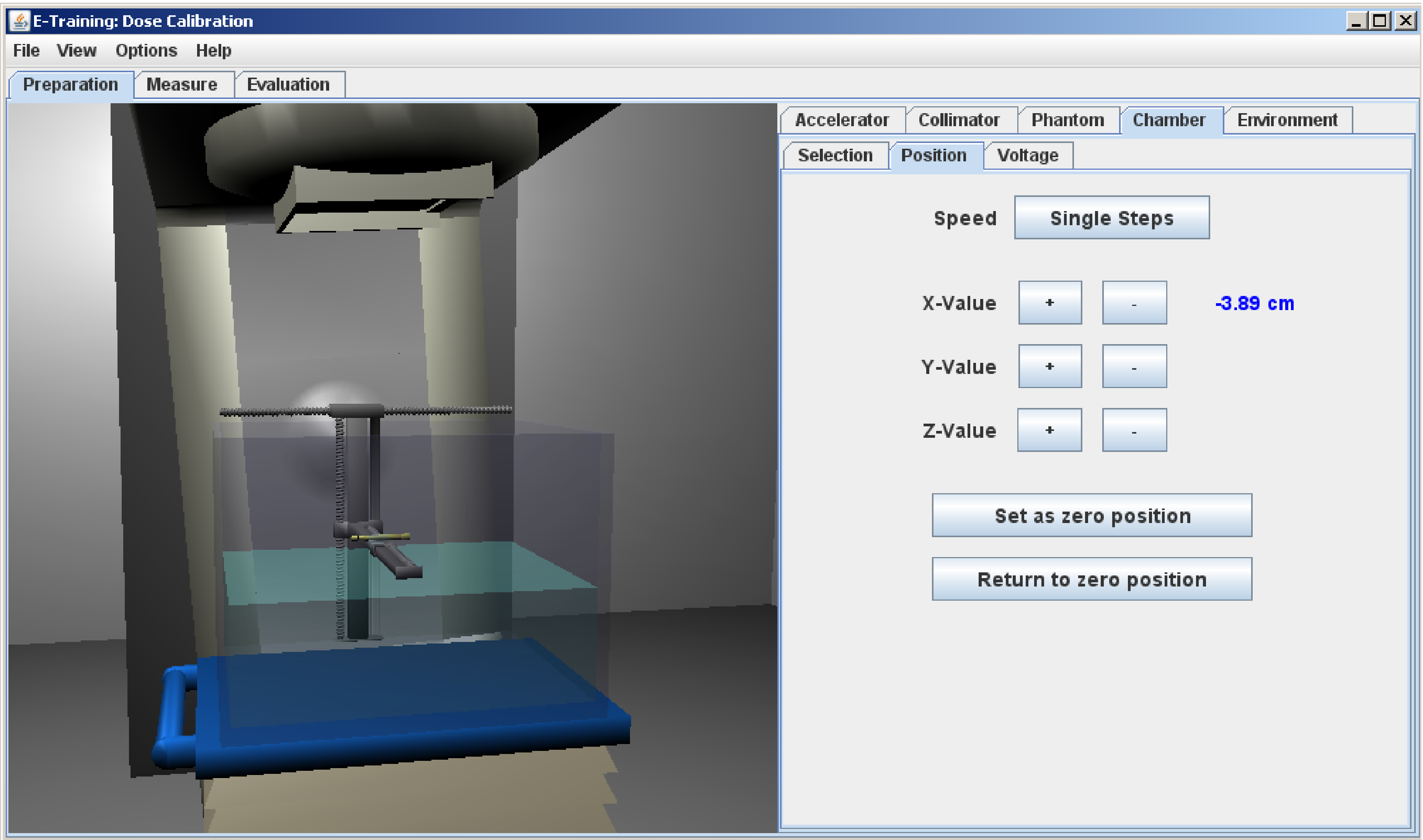
Date of calibration	Head of the Dosimetry Laboratory	Calibration performed by
28.04.2006	i.v. [signature] Dr. Igor Gomola	[signature] RNDr. Jozef Zeman

k_{Q,Q_o} is the so-called **beam quality factor (beam quality correction factor)**

Because the beam quality used at calibration (Q_0: Co-60) is **not the same** as that at the measurement (Q: 6 MV photons), this correction factor is required.

The beam quality factor is obtained from a table which is supplied with the dosimetry protocol (TRS 398).

We use virtual equipment: 1) Simulation Program



Virtual Equipment

further equipment:

- thermometer
- barometer

Main preparations to be performed:

1. Prepare the virtual accelerator:

   - set gantry angle at zero
   - set collimator angle at zero

   } select angle and press start continuously

   - select type of radiation and energy
   - select reference field size

   - switch on the laser lines which mark the isocenter of the machine (use menue Options, left upper corner)

Main preparations to be performed:

2. Prepare water phantom:

   - needs water filling
   - needs adjustment of water surface to laser lines

   - measure temperature and air pressure
     (see Environment, utmost right

Main preparations to be performed:

3. Prepare chamber:

   - adjust reference point of chamber to central ray
   - position the chamber correctly to zero depth
   - set correct voltage and polarity

Some more details on the ionization chamber type to be used for the exercise:

PTW Farmer Type 30013

Calibration factor:	N = 5.233 Gy/C
Radius of sensitive volume:	r = 3.1 mm
Voltage to be applied:	400 V
Polarity:	as used with calibration measurement

Main steps of the beam calibration:

1. Determine the quality index Q
   - **determine a PDD and use the depth dose method**

2. Determine the quality correction factor
   - use interpolation between table values

3. Determine charge under reference conditions at 100 monitor units (MU)

   - measure charge
   - apply correction factors

4. Finally obtain the output value, i.e. the absorbed dose in water per 100 MU at the reference point

Note:

In high energy beams, cylindrical chambers are used for both, for

a) depth dose measurements

b) calibration measurements

Thus depth dose measurements and beam calibration can be performed with a single chamber type.

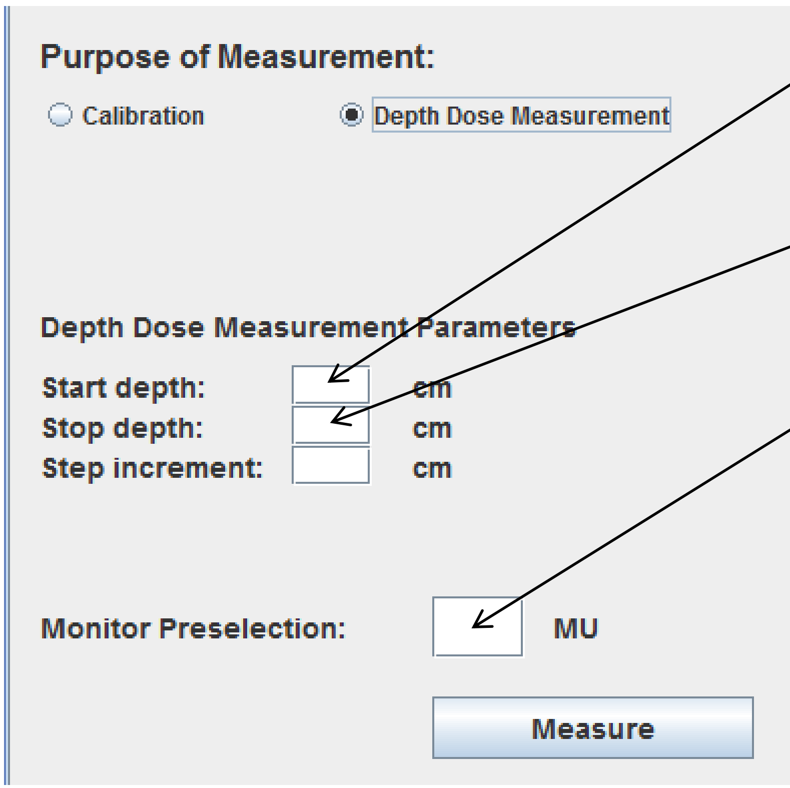
However, they must be positioned in different ways:

a) for depth dose: **effective point** at measuring depth

b) for calibration: **central axis** at measuring depth

1 Determine the quality index Q with the PDD method

Depth dose measurements with this virtual accelerator are performed in the following way:



Start depth must be greater than 0.5

Stop depth must be greater than start depth

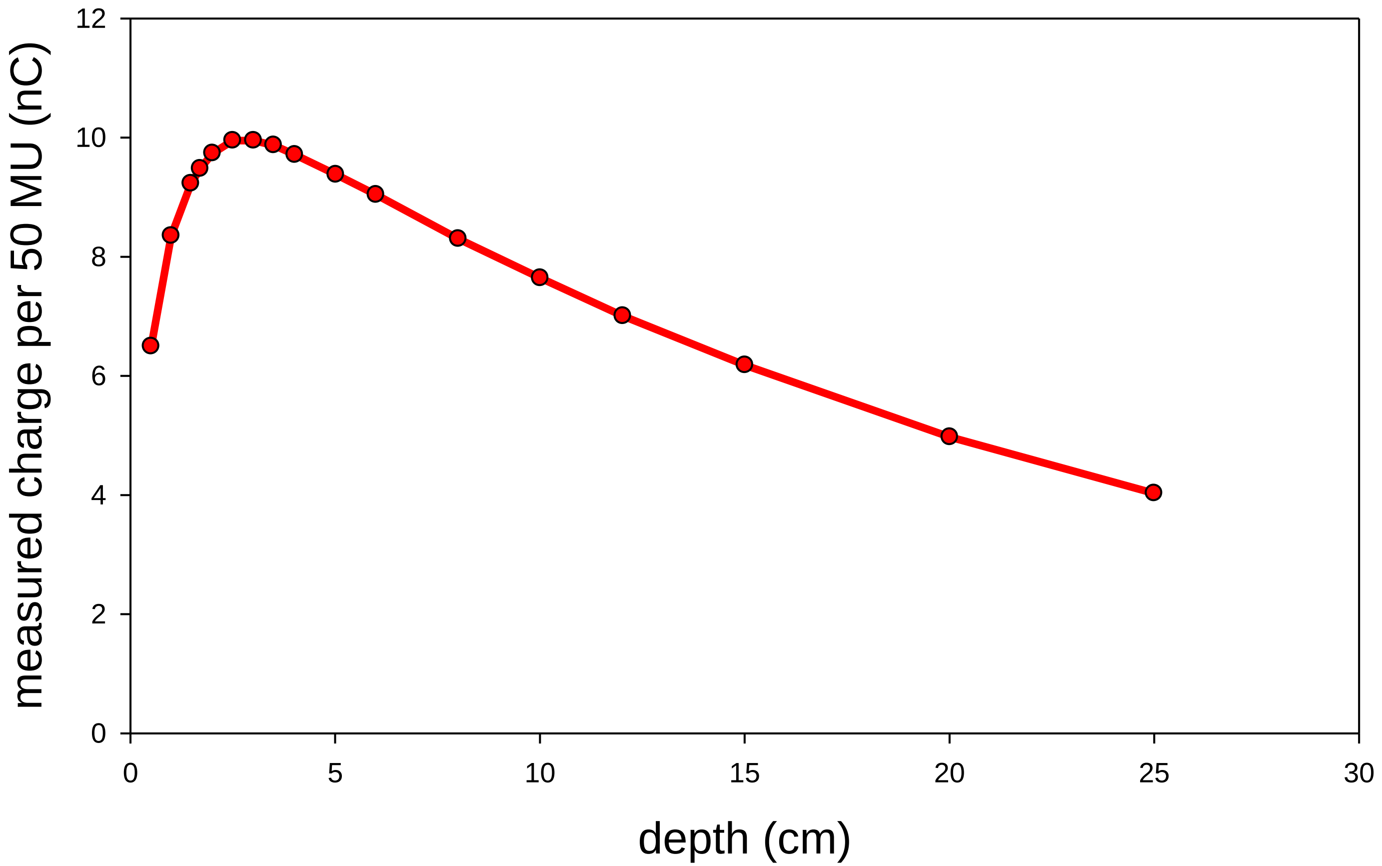
MU required for each single depth (no continuous measurement)

Results can be copied and paste into an EXCEL file

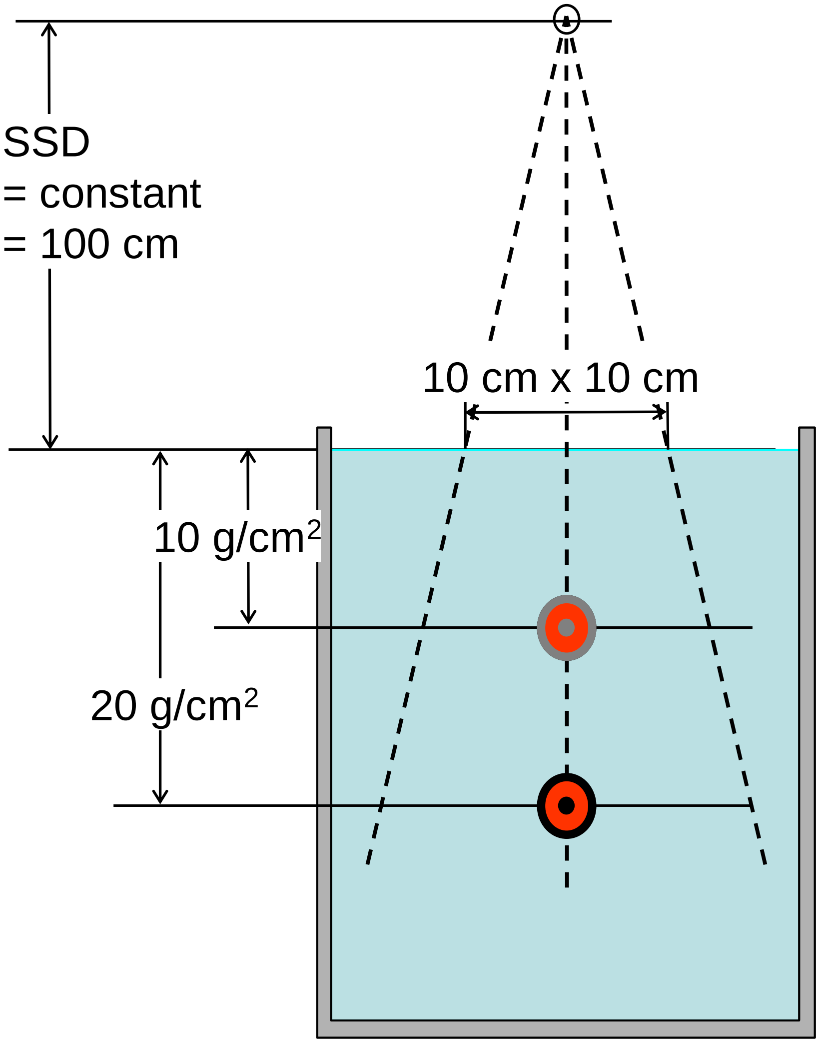
Example of a depth dose measurement at central ray

Water Temperature: 20.60 °C

Air Pressure: 98.18 kPa



1 Determine the quality index Q with the PDD method



Example:

$$M_{10} = 7.238 \text{ nC}$$

$$M_{20} = 4.189 \text{ nC}$$

$$\Rightarrow \quad PDD_{20,10} = \frac{M_{20}}{M_{10}} = 0.579$$

1 Determine the quality index Q with the PDD method

Formula: $$Q \equiv TPR_{20,10} = 1.2661 \cdot PDD_{20,10} - 0.0595$$

$$PDD_{20,10} = 0.579$$

$$Q \equiv TPR_{20,10} = 0.673$$

2 Determine the quality correction factor k_Q

Values of the quality correction factor k_Q are always given in tables in the dosimetry protocol as a function of Q

Therefore we needed the determination of the beam quality index Q before.

2 Determine the quality correction factor k_Q

IAEA TRS 398
CALCULATED VALUES OF k_Q FOR HIGH-ENERGY PHOTON BEAMS, FOR VARIOUS CYLINDRICAL IONIZATION CHAMBERS AS **A FUNCTION OF BEAM QUALITY $TPR_{20,10}$**

Measured value

Quality index	0.62	0.65	0.673	0.68	0.70
PTW 30006/30013	0.997	0.994		0.990	0.988

by linear interpolation: 0.991

3 Determine the charge per 100 MU at reference point

field size:	10 cm x 10 cm
SSD:	100 cm
phantom:	water phantom
measurement depth in water:	10 cm
positioning of chamber:	central electrode at measuring depth

3 Apply correction factors: a) Air density correction

- reference water temperature T_0=20°C
- reference air pressure (absolute!!!) P_0=101.325 kPa)

Example:

measured water temperature: T = 20.6 °C

measured air pressure (absolute!!!): P = 98.18 kPa

air density correction:

multiply measured M with:

$$\frac{(273.2+T)}{(273.2+T_o)}\frac{P_o}{P}=1.034$$

3 Apply correction factors b) Saturation correction

used polarizing potential: 400 V

saturation is 100% ???

measure charge under identical conditions with the lower voltage of 100 V

voltage	charge in nC
400.0	14.627
100.0	14.441

3 Apply correction factors b) Saturation correction

$$k_s = a_o + a_1\left(\frac{M_1}{M_2}\right) + a_2\left(\frac{M_1}{M_2}\right)^2$$

TABLE 4.VII. QUADRATIC FIT COEFFICIENTS, FOR THE CALCULATION OF k_s BY THE "TWO-VOLTAGE" TECHNIQUE IN PULSED AND PULSED-SCANNED RADIATION, AS A FUNCTION OF THE VOLTAGE RATIO V_1/V_2 [76]

	Pulsed			Pulsed scanned		
V_1/V_2	a_0	a_1	a_2	a_0	a_1	a_2
2.0	2.337	-3.636	2.299	4.711	-8.242	4.533
2.5	1.474	-1.587	1.114	2.719	-3.977	2.261
3.0	1.198	-0.875	0.677	2.001	-2.402	1.404
3.5	1.080	-0.542	0.463	1.665	-1.647	0.984
4.0	1.022	-0.363	0.341	1.468	-1.200	0.734
5.0	0.975	-0.188	0.214	1.279	-0.750	0.474

3 Apply correction factors c) Polarization correction

- reference polarity ????

used polarizing potential: +400 V

polarity effect ???

3 Apply correction factors c) Polarization correction

- reference polarity ????

used polarizing potential: +400 V
polarity effect ???

The polarity effect for photon beams usually is very small.

In such a case where no information on the polarity used at calibration is given, it is better **not** to perform any correction. It may be a wrong correction!

Measurement uncertainty : U = 2.2 %

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28.04.2006		

3 Apply correction factors: Summary of all corrections

Measured charge per 100 MU	14.627 nC
air density correction factor	1.034
Saturation correction factor	1.004

$$M_Q(\text{corrected}) = 14.627 \cdot 1.034 \cdot 1.004 \quad = \quad 15.187$$

4 Get calibration factor

Calibration Certificate

000877

Calibration laboratory for ionising radiation quantities

Calibration mark 04-06

Object :

Manufacturer :

Type :

Serial number :

Beam quality : **Co-60**

Absorbed dose to water calibration factor : $N_{D,w} = 5.233 \times 10^7$ Gy/C

Final calculation

$$D_{w,Q} = M_Q \; N_{D,w,Q_o} \; k_{Q,Q_o}$$

M_Q (corrected) $=$ 15.187

$N_{D,w}$ $=$ 5.233 10^7 Gy/C

k_Q $=$ 0.991

$D_{w,Q}$ $=$ 0.788 Gy/100 MU