ICTP SChool On MEdical PHysics For RAdiation THerapy: DOsimetry And TReatment PLanning For BAsic And ADvanced APplications

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Dosimetry Exercise

G. Hartmann
EFOMP & German Cancer Research Center (DKFZ)
g.hartmann@dkfz.de

Exercise: Beam calibration at a 15 MV photon beam

Remark 1: Beam 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

Introduction: Formalism

- The absorbed dose to water at the reference depth z_{ref} in water for a reference beam of quality Q_0 and in the absence of the chamber is given by:

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

Discussion of the meaning of the three quantities

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

M_Q is the **chamber reading in beam of quality *Q*** and corrected for influence quantities to the reference conditions used in the standards laboratory.

N_{D,w,Q_o} is the **calibration factor** in terms of absorbed dose to water of the dosimeter obtained from a standards laboratory

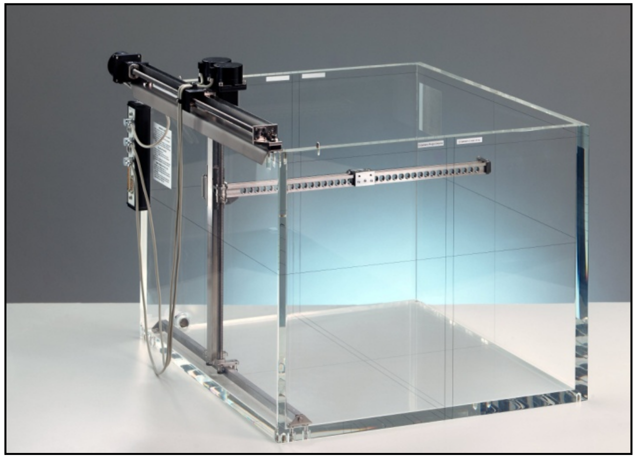
k_{Q,Q_o} is the **beam quality factor** which corrects for the effects of the difference between the reference beam quality Q_o and the actual user quality Q

We are using a virtual equipment

- High Energy Photon Beam:
  15 MV accelerating potential

- Ionization chamber:
  PTW Farmer Type 30013

- water phantom:

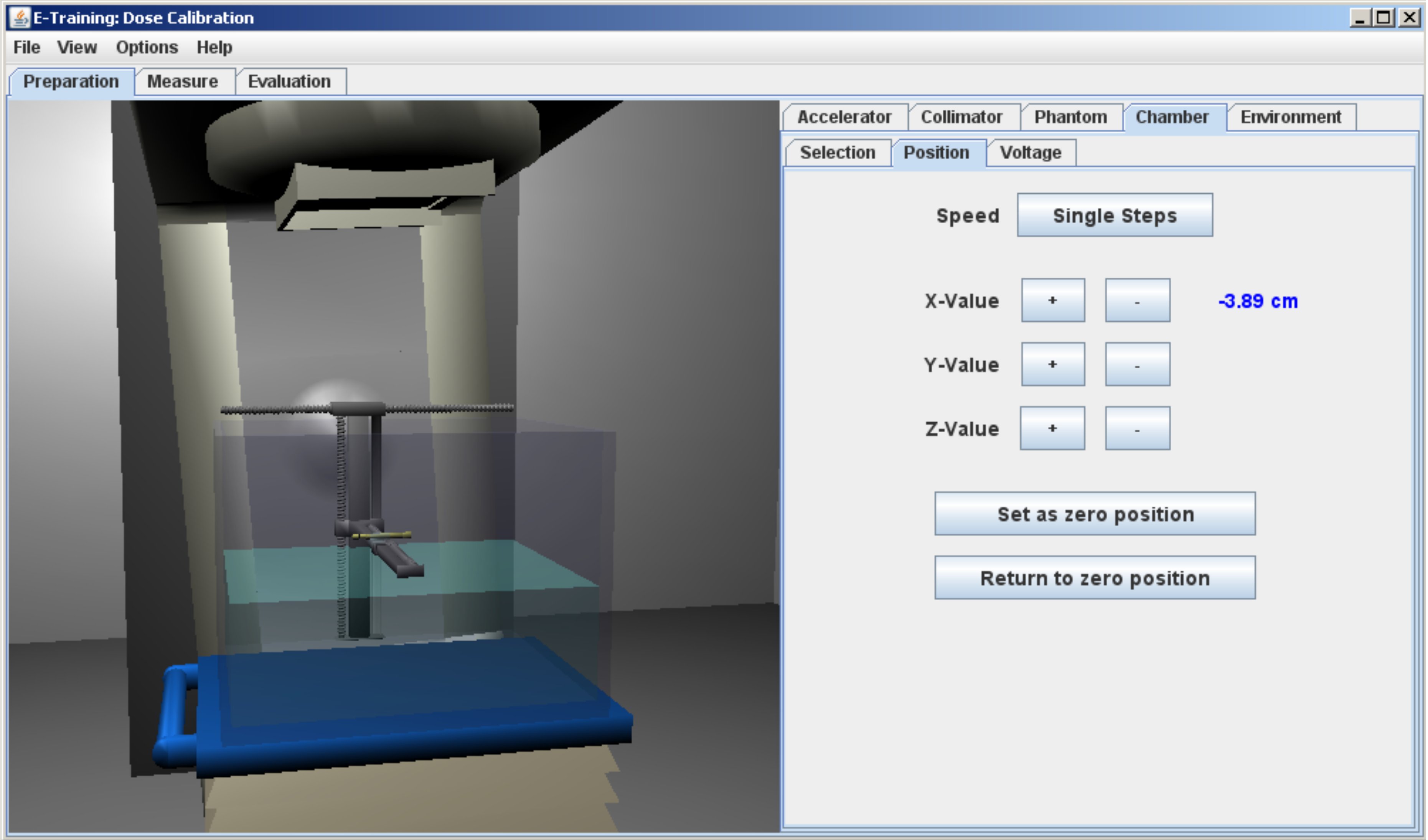


Virtual Equipment

further equipment:

- electrometer
- thermometer
- barometer

Virtual Equipment: Simulation Program



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

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

Main steps 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

2. Prepare water phantom:
   - needs water filling
   - needs adjustment of water surface to laser lines (laser lines may be switched on with OPTIONS)
   - measure temperature and air pressure (see Environment, utmost right

Main steps to be performed (cont):

3. Prepare chamber:
   - adjust reference point of chamber to central ray
   - position the chamber correctly to zero depth
   - voltage and polarity

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

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

6. Determine charge under reference conditions
   - measure charge
   - apply correction factors

7. Finally obtain calibration value

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.

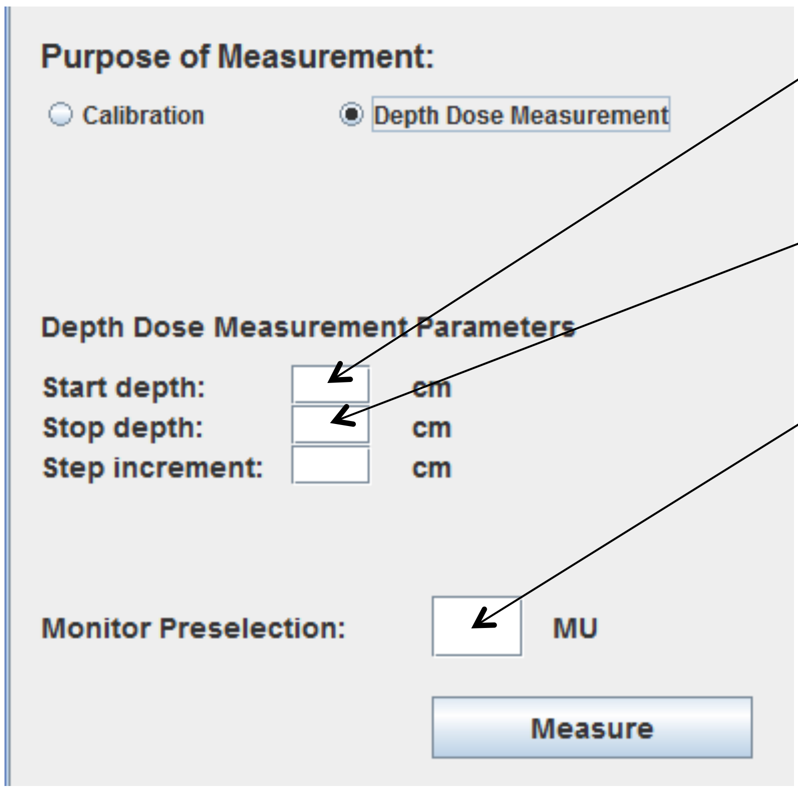
However, they must be positioned in different ways:

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

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

Note:

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



Start depth must be greater than 0.5

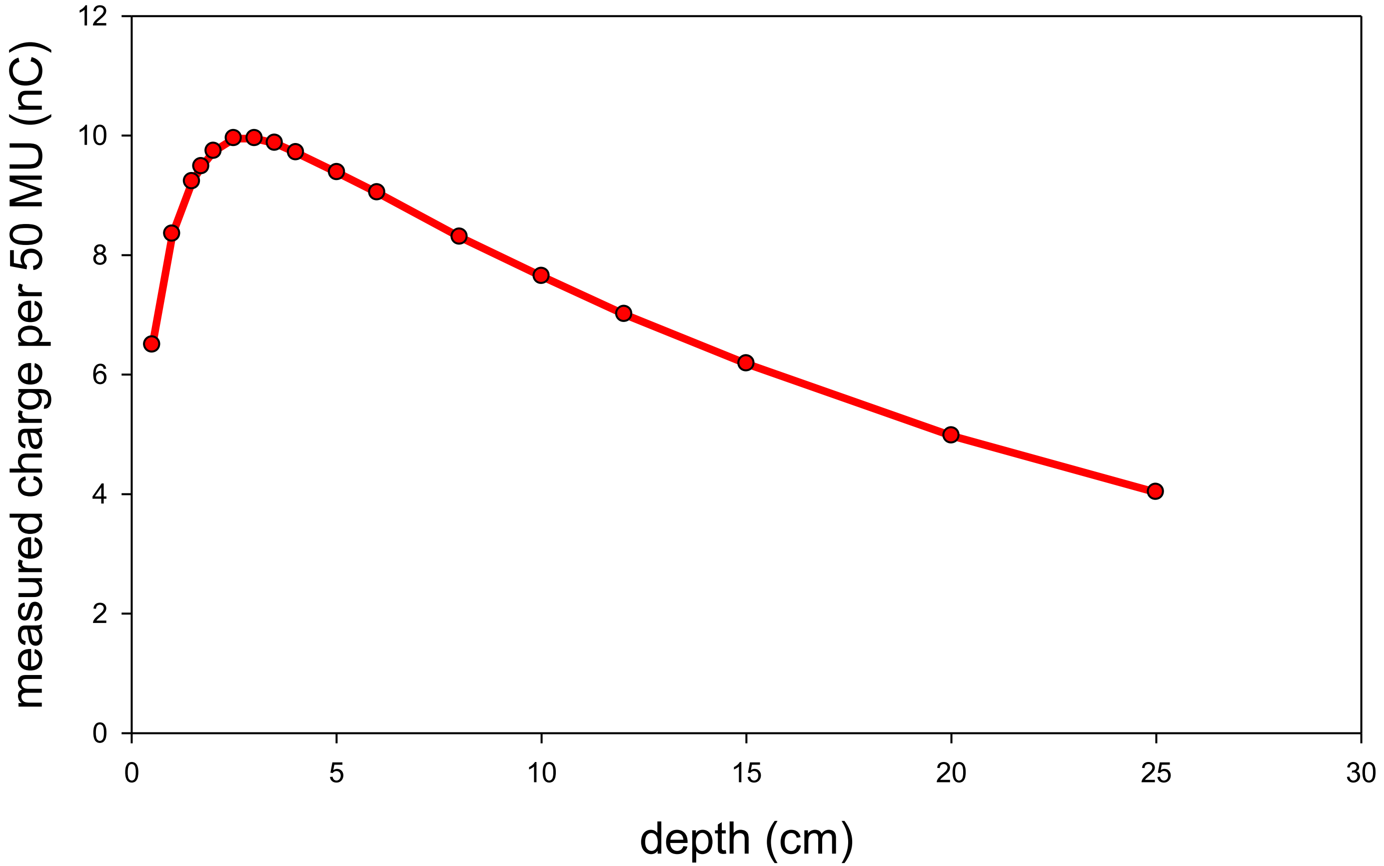
Stop depth must be greater than start depth

MU required for each single depth (no continuous measurement)

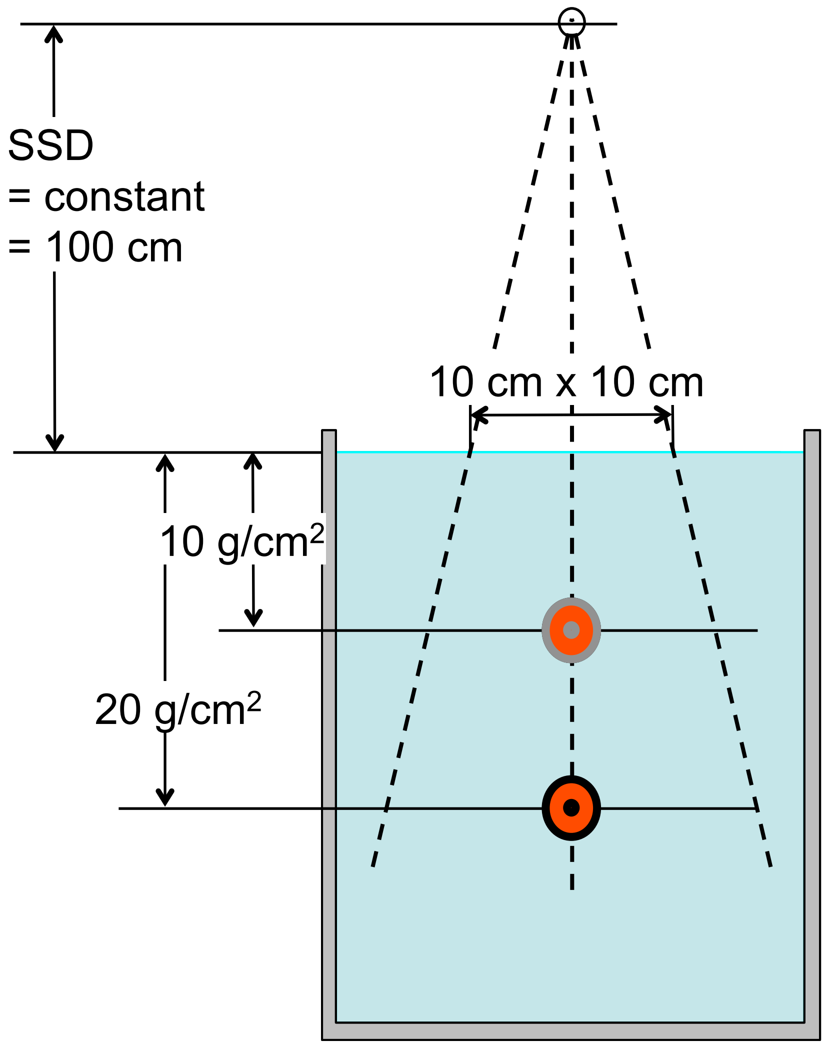
Results can be copied and paste into an EXCEL fle

Example of a depth dose measurement at central ray

Water Temperature:	20.60 °C
Air Pressure:	98.18 kPa



Step 4: Determination of the quality index for HE photons the depth dose method:



$$\Rightarrow M_{10} = 7.745 \text{ nC}$$

$$\Rightarrow M_{20} = 5.002 \text{ nC}$$

$$PDD_{20,10} = \frac{M_{20}}{M_{10}} = 0.652$$

Determination of the quality index for HE photons:

$$PDD_{20,10} = 0.65$$

$$\mathrm{TPR}_{20,10} = 1.2661 \cdot PDD_{20,10} - 0.0595$$

$$\mathrm{TPR}_{20,10} = 0.767$$

Step 5: Determination of k_Q

- reference beam quality Co-60

  used beam quality?? (15 MV)

Requires input of the beam quality index Q

Step 5: Determination of 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 *$TPR_{20,10}$***

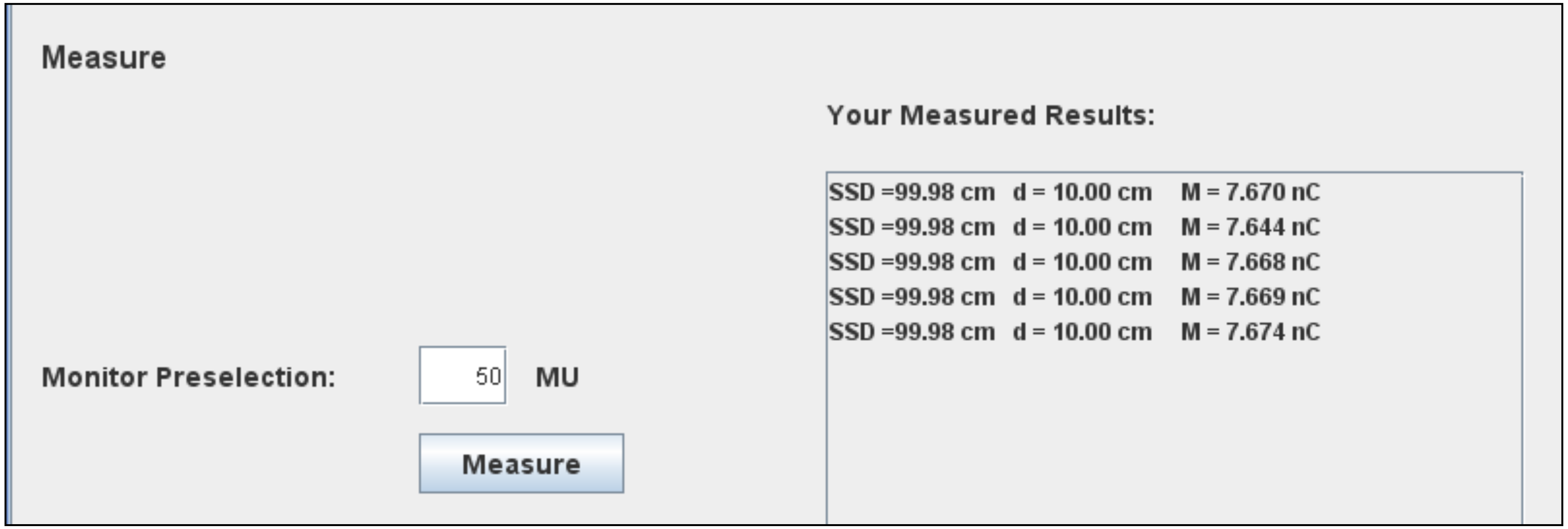
Quality index	0.74	0.76	0.767	0.78	0.80
PTW 30006/30013	0.98	0.975		0.968	0.960

by linear interpolation: 0.973

Charge measurement under **reference conditions** for 15 MV photons

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

Example of Measurement at a depth of 10 cm:



depth in cm	Mean charge in nC
10.0	7.674

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 :	$5\ g \cdot cm^{-2}$
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 :	400 V
Dose rate :	$1.0\ Gy \cdot min^{-1}$

Recombination correction has not been applied

Date of calibration	Head of the Dosimetry Laboratory	Calibration performed by
28.04.2006		

Measurement under **reference conditions**

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

measured water temperature: T = 20.6 °C

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

air density correction:

multiply measured M with:

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

Measurement under **reference conditions**

- reference saturation 100%

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	7.674
100.0	7.587

Measurement under reference conditions

- reference saturation 100%

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

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

Measurement under **reference conditions**

- reference saturation 100%

correction for the ion recombination effect:

multiply measured M with:

$$a_o + a_1\left(\frac{M_1}{M_2}\right) + a_2\left(\frac{M_1}{M_2}\right)^2 = 1.004$$

Measurement under reference conditions

- reference polarity ????

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

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%.

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Measurement under **reference conditions**

- 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!

Step 6: Determination of corrected charge M_Q

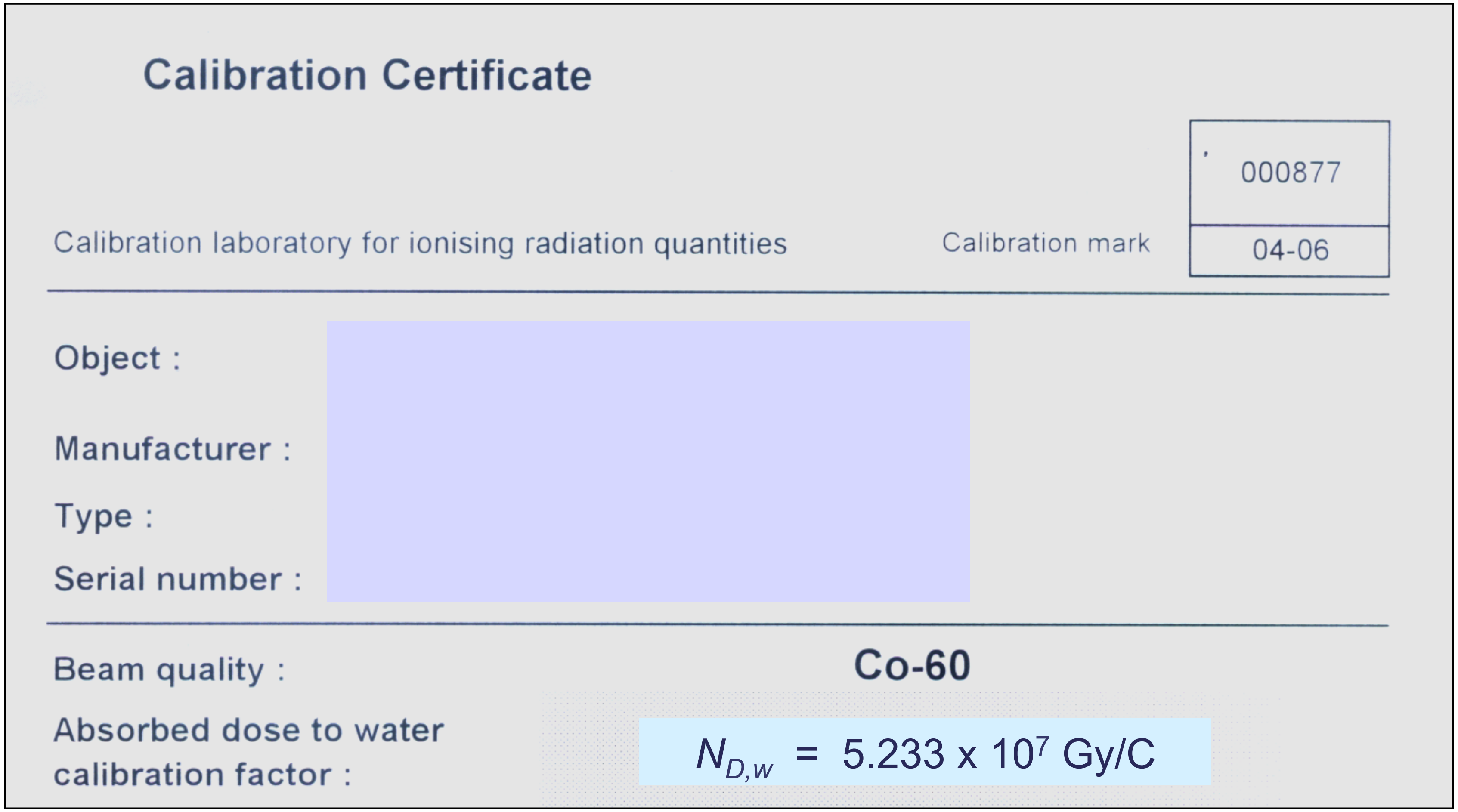
chamber reading in beam of quality *Q*
corrected for influence quantities to the reference conditions

$$M_Q = 7.674 \cdot 1.034 \cdot 1.004 = 7.967 \text{ [nC/50 MU]}$$

k_{TP}

k_s

Determination of N_{D,w,Q_o}



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

Using the formalism

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

$$M_Q = 7.967 \text{ nC/50 MU}$$

$$N_{D,w,Q_o} = 5.233 \times 10^7 \text{ Gy/C}$$

$$k_{Q,Q_o} = 0.973$$

$$D_{w,15MV} = 0.812 \text{ Gy/100 MU}$$