The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2033-16

Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation

11 - 15 May 2009

Calibration of KAP Meters and CT Chambers

Costas Hourdakis
Greek Atomic Energy Agency
Athens
Greece

Strada Costiera 11, 34014 Trieste, Italy - Tel. +39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it, www.ictp.it

Joint ICTP-IAEA Advanced School on Dosimetry in Diagnostic Radiology & its Clinical Implementation

Calibration of KAP meters and CT chambers

Costas J. Hourdakis

Greek Atomic Energy Commission

Greece

11 – 15 May 2009

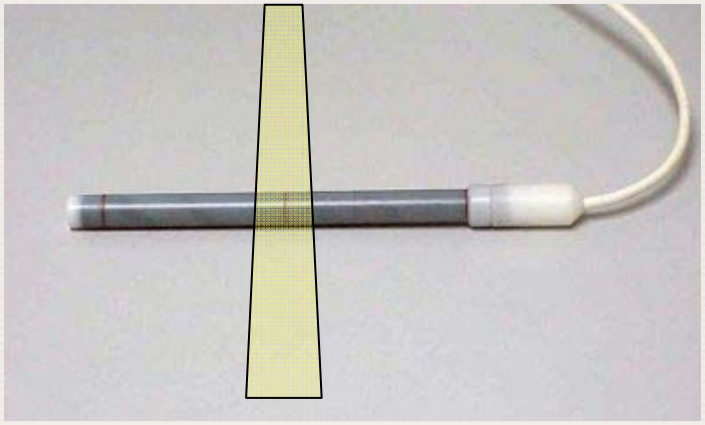
Miramare, Trieste, Italy

IAEA

International Atomic Energy Agency

CT chamber calibration

CT chamber is often called a **pencil chamber** because its active volume is a thin cylinder 100 mm in length or sometimes longer

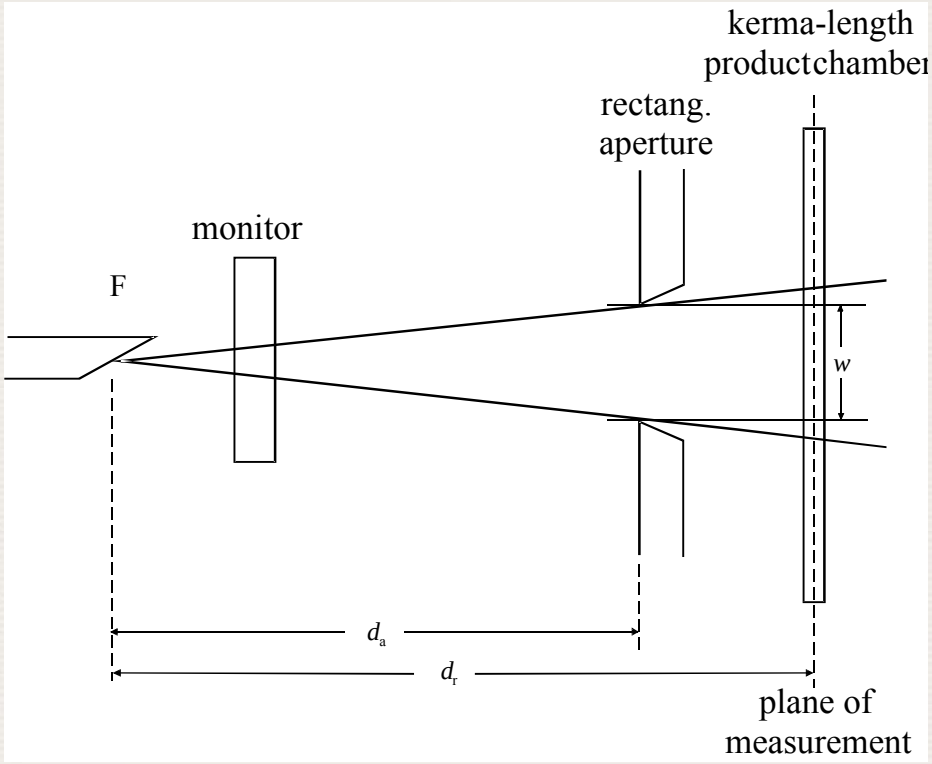


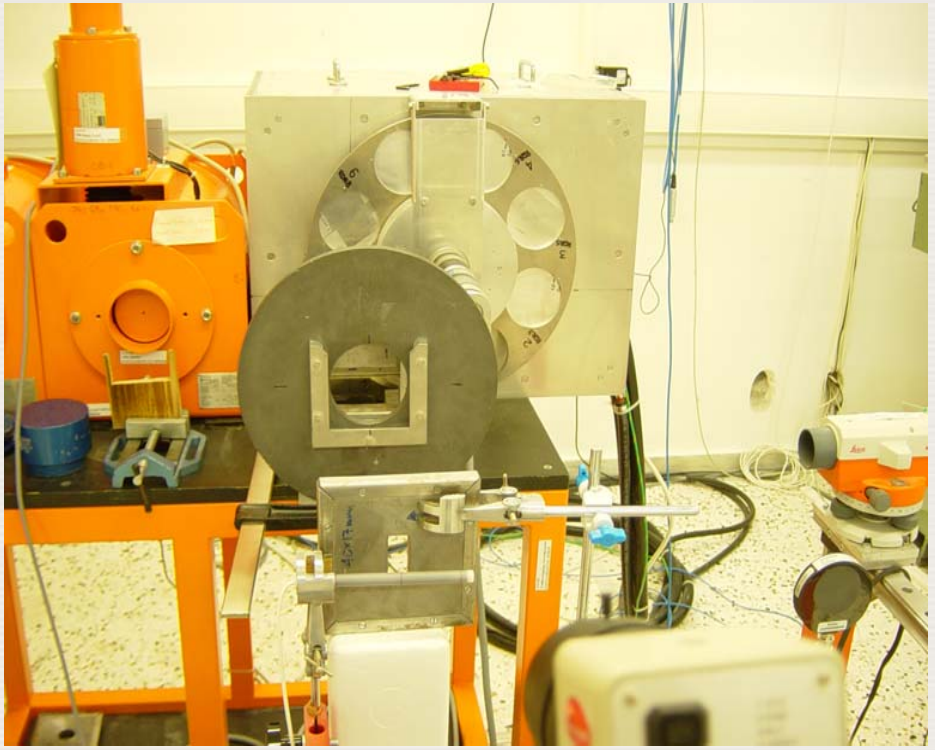
Partially irradiated (10% of its acive volume)
Air kerma-length product, P_{KL}

!!!

- The response of the active volume be uniform along its entire axial length
- Calibration procedures

CT chamber calibration

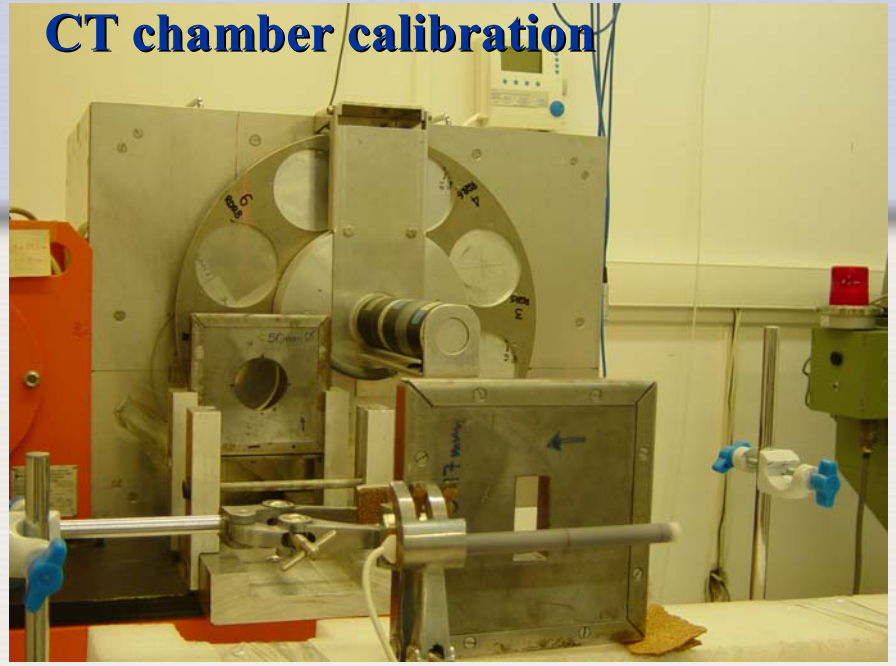




Use of an aperture (SLIT) to simulate the CT slice

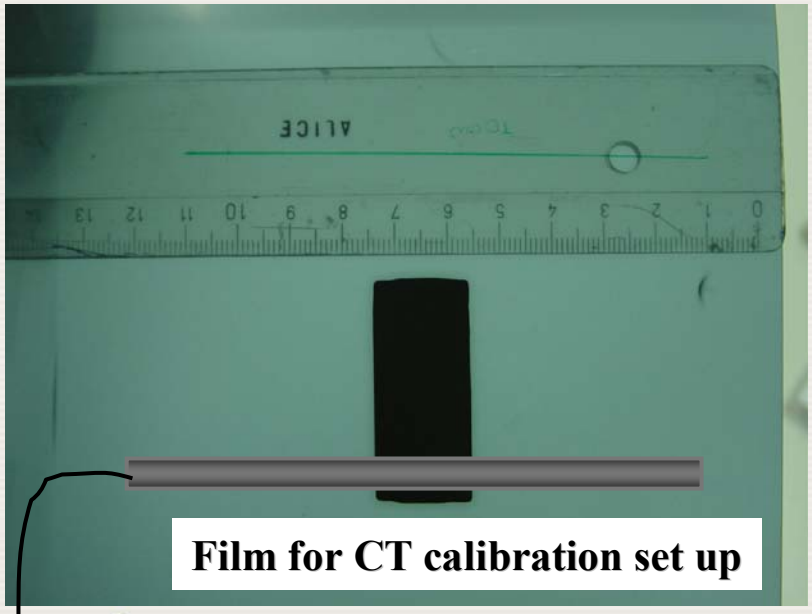
IAEA

CT chamber calibration

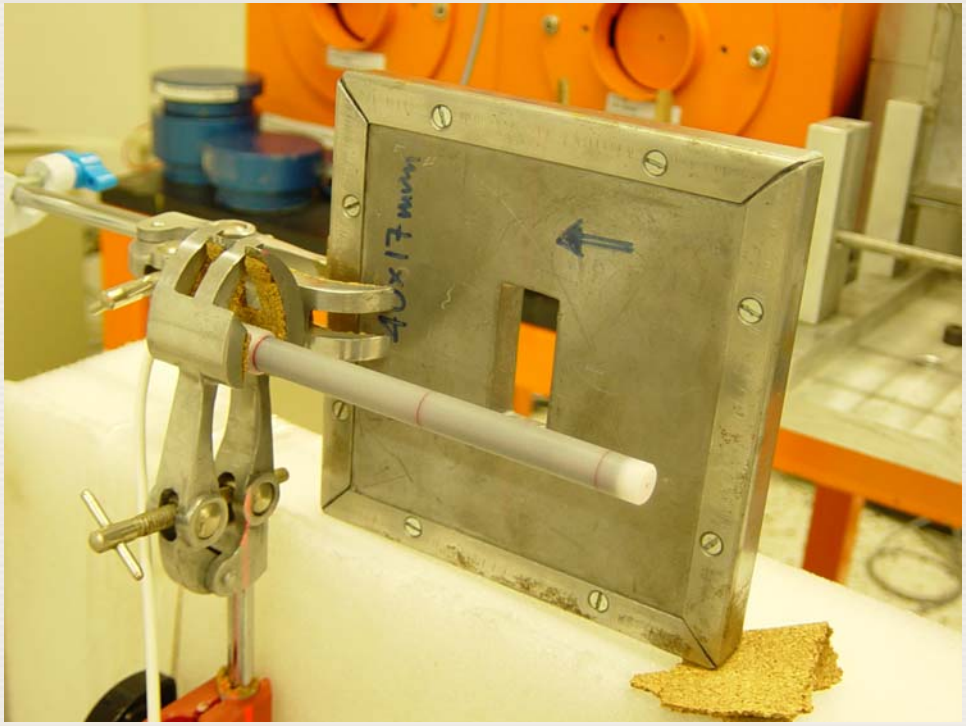


CT chambers are calibrated in the lab

NOT in a CT scanner

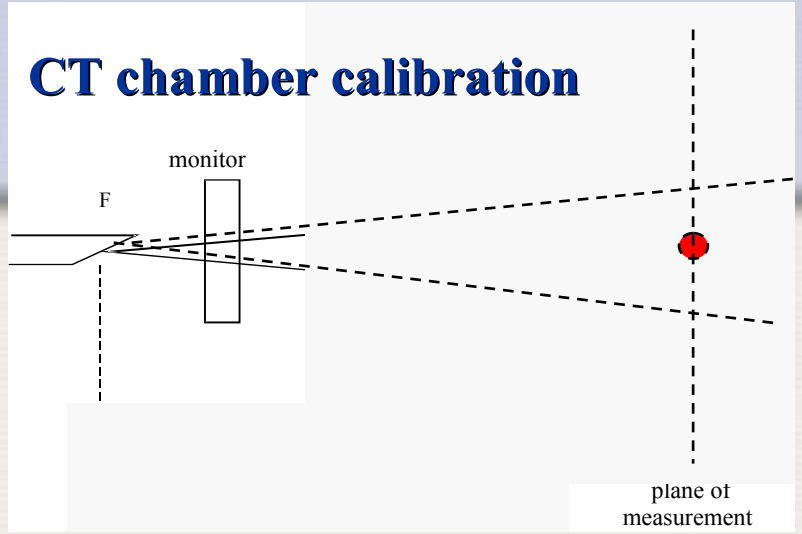


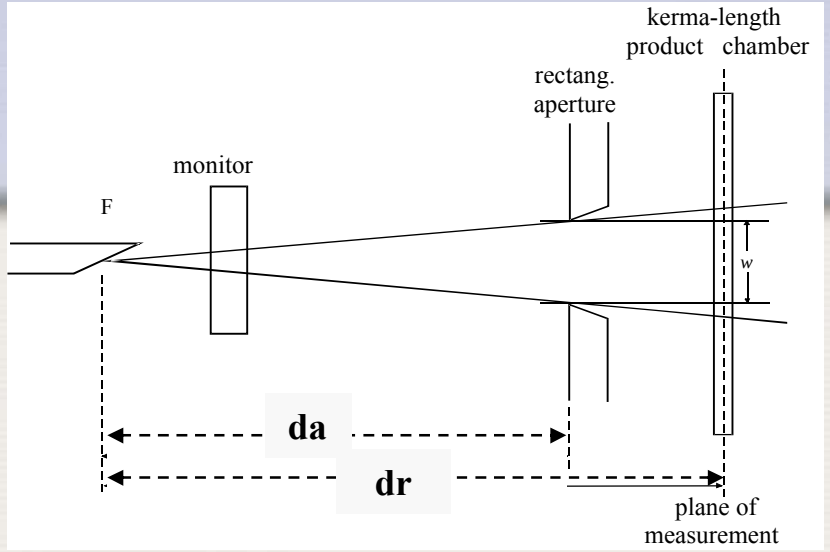
Film for CT calibration set up



IAEA

CT chamber calibration



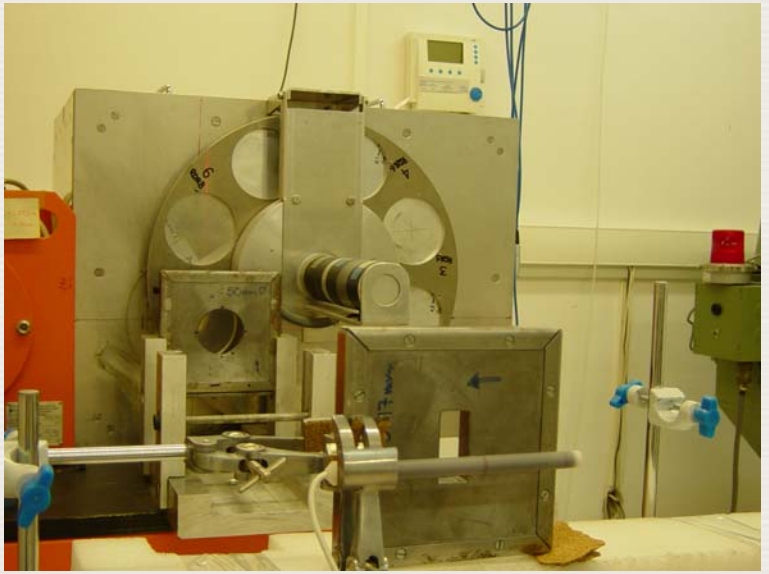


The air kerma is first determined with the reference ionization chamber in the plane of measurement for the RQT radiation qualities.

Then the lead rectangular aperture is positioned in front of the users' chamber behind the transmission monitor chamber.

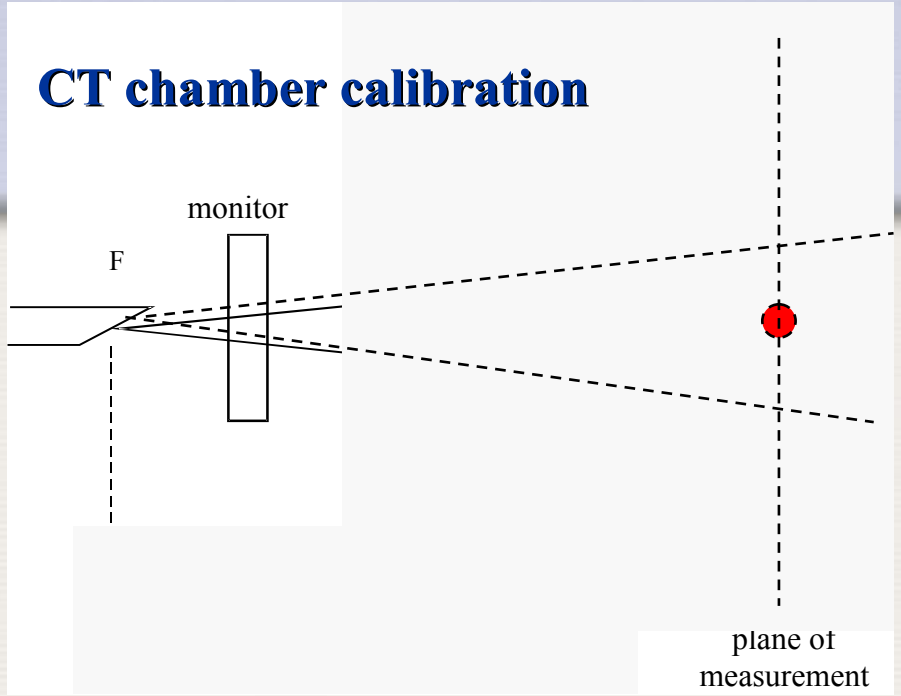
The outer dimensions of the aperture assembly shall be large enough to shield the whole of the chamber.

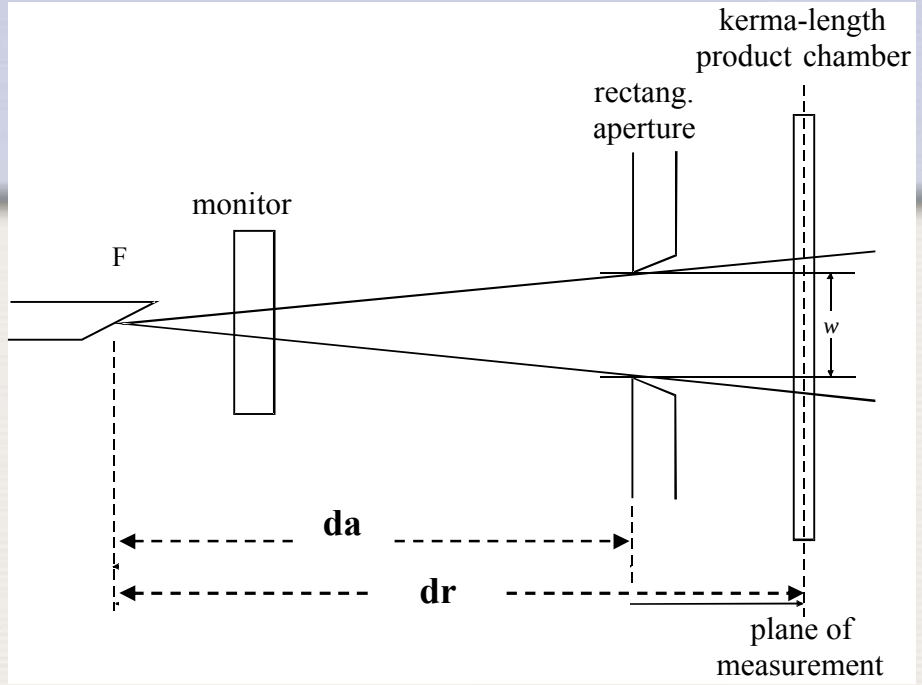
The separation of the lead aperture from the point of test must be precisely known.



IAEA

CT chamber calibration





The width, w, of the aperture should be between 20 mm and 50 mm and be known to within 0.01 mm.

In the plane of measurement the width of the field is : w·*dr* / *da*

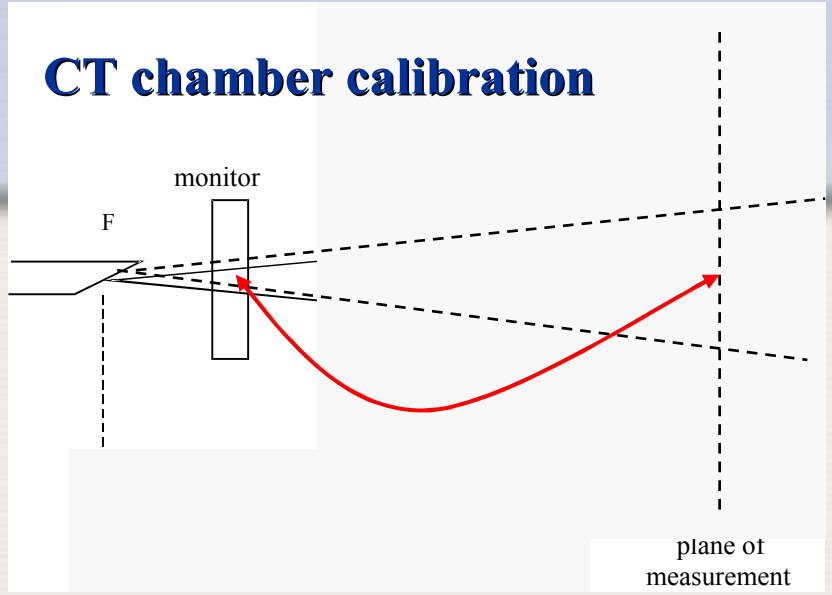
$$N_{P_{KL}} = \frac{K_i \cdot L}{M} \qquad N_{P_{KL,Q}} = \frac{K_i^{ref}}{M^{CT} \cdot k_{TP}^{CT}} \cdot \left(\frac{w \cdot d_r}{d_a} \right)$$

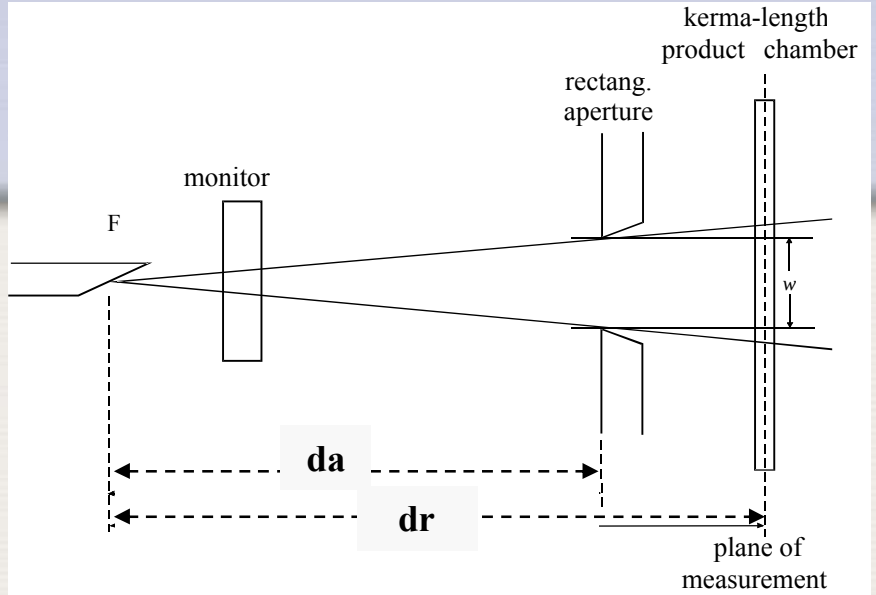
$N_{PKL,Q}$ calibration coefficient it terms of kerma-length product P_{KL}

M : dosimeter reading

IAEA

CT chamber calibration





$$N_{P_{KL,Q}} = \frac{K_i^{ref}}{M^{CT} \cdot k_{TP}^{CT}} \cdot \left(\frac{w \cdot d_r}{d_a} \right)$$

When a **monitor chamber** is used :

$$\overline{N}_{P_{KL,Q}} = \left(\frac{m^m \cdot k_{\mathrm{TP}}^m \cdot N_Q^m}{M^{CT} \cdot k_{\mathrm{TP}}^{CT}} \right) \cdot \left(\frac{w \cdot d_r}{d_a} \right)$$

where :

N_Q^m , is the calibration coefficient of the monitor chamber in terms of air kerma for radiation quality Q **in the plane of measurement**

m^m is the reading of the monitor chamber

M^{CT} , is the reading of the CT chamber

IAEA

CT chamber calibration

Radiation quality	X ray tube voltage kV	Added filtration	Nominal first half-value layer mm Al
RQT 8	100	RQR 8 + 0.2 mm Cu	6.9
RQT 9*	**120**	**RQR 9 + 0.25** mm Cu	**8.4**
RQT 10	150	RQR 10 + 0.3 mm Cu	10.1

IAEA

CT chamber calibration

$$N_{P_{KL,Q}} = \frac{K\ w\ d_r}{M \cdot k_{TP} \cdot d_a}$$

mGy mm / digit (reading)

Then in a CT at clinics :

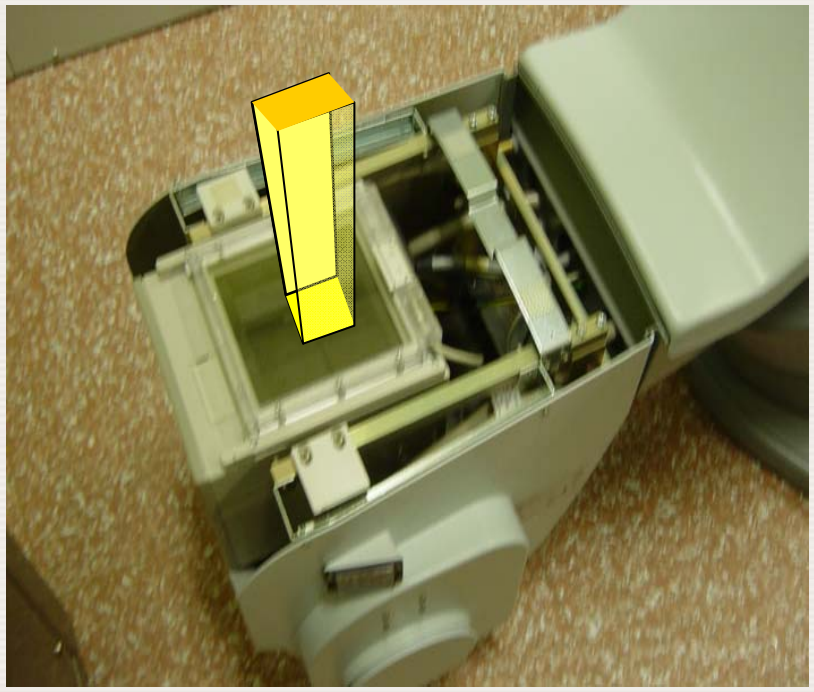
$$C_{\mathrm{a},100} = \frac{1}{NT}\,\overline{M}\,N_{P_{\mathrm{KL}},Q_0}\,k_Q\,k_{\mathrm{TP}}$$

$$C_{\mathrm{PMMA},100,\mathrm{c}} = \frac{1}{NT}\,\overline{M}_{\mathrm{c}}\,N_{P_{\mathrm{KL}},Q_0}\,k_Q\,k_{\mathrm{TP}}$$

IAEA

KAP meter calibration

the detector mounted on the tube housing is “transparent” to X rays



Partially irradiated

Air kerma-area product, P_{KA}

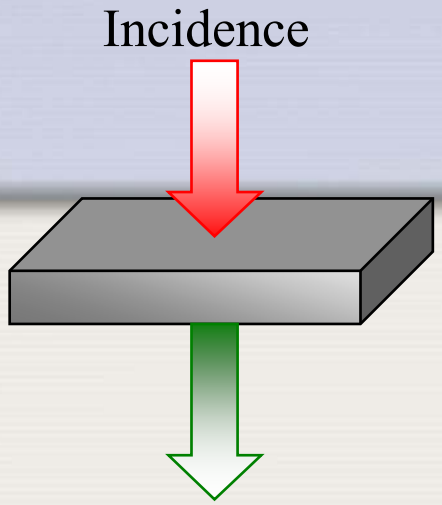
P_{KA} is the same at any distance from focus

KAP meters use :

- fluoroscopy,
- general radiography
- dental radiography equipment

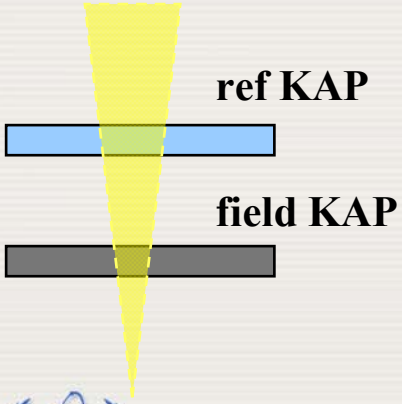
Provide useful information about patient doses in relation to examination procedures

IAEA



Depending on the application
the **INCIDENCE** or the **TRANSMITTED** radiation
is of interest

in patient dosimetry the
TRANSMITTED radiation
interests



in calibration of a field KAP
meter with a REFERENCE KAP
meter

the INCIDENCE radiation to the
reference KAP meter

interests

IAEA

KAP meter calibration

N = True quantity / reading

$N = P_{KA}^{ref}$ / reading

Two methods of KAP meter calibration :

1. Determination of the air kerma K_i and the irradiation area, A

$$P_{KA}^{ref} = K_i \cdot A$$

"kerma-area product" method

(or "beam area" (BA) method)

2. Use of a reference KAP meter, which measures directly the P_{KA}^{ref}

P_{KA}^{ref}

"KAP" method

IAEA

KAP meter calibration

KAP meter calibration at a laboratory → INCIDENCE radiation

KAP meter calibration at a laboratory → TRANSMITTED radiation

"kerma-area product" method

KAP meter calibration in situ → TRANSMITTED radiation

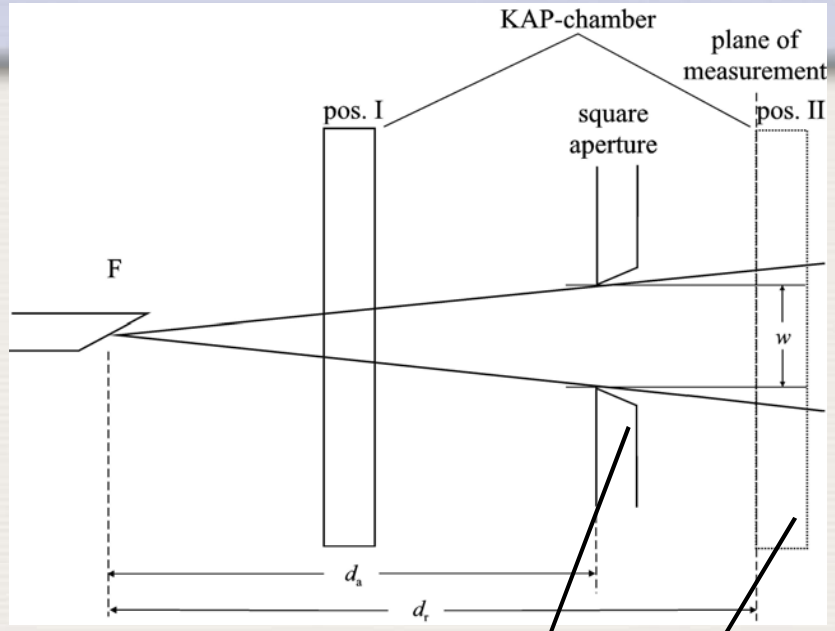
"kerma-area product" method

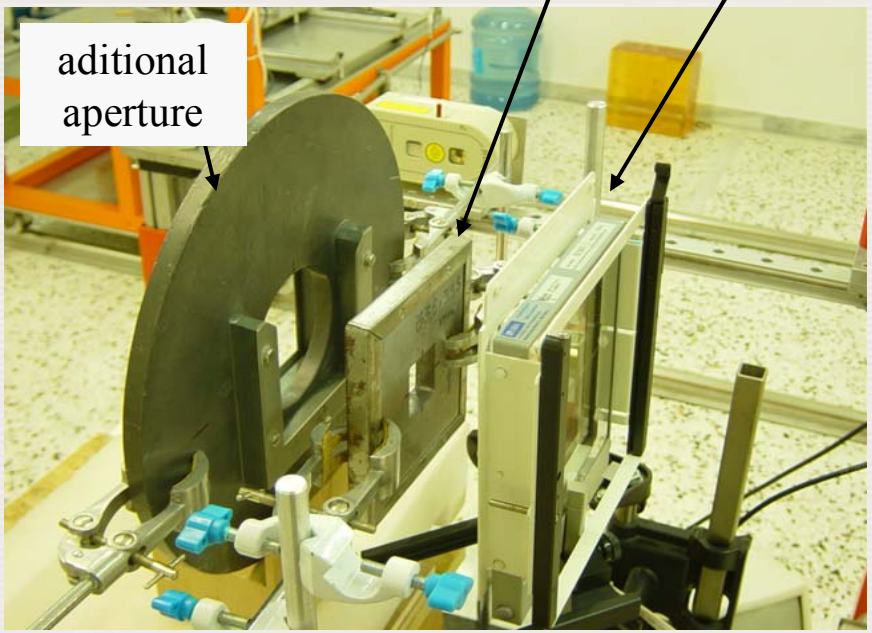
OR

"KAP" method

IAEA

KAP meter calibration : Calibration at the laboratory



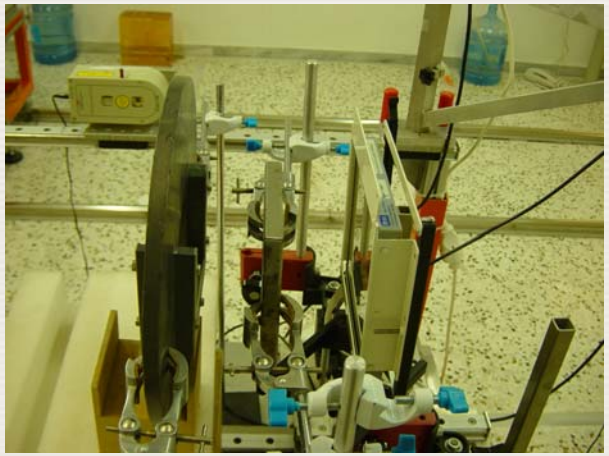


A circular or square lead aperture of 40 - 60 mm

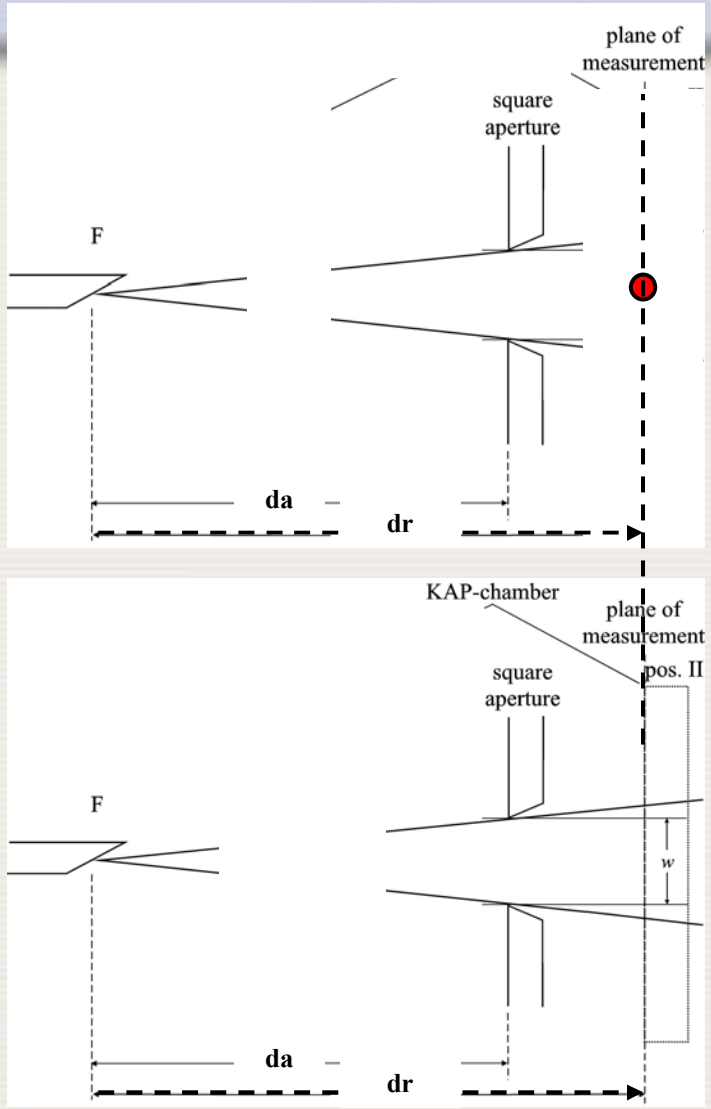
Known of exact aperture dimension, w

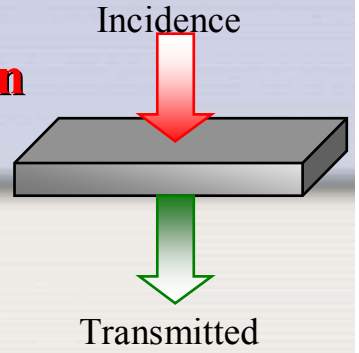
Aperture and plane of measurement (KAP) ~ 50 mm

Pos 1 : KAP for beam attenuation
Pos 2 : reference point of measurement



KAP calibration at lab : “kerma-area” method, Incidence radiation





K_i is measured behind the aperture

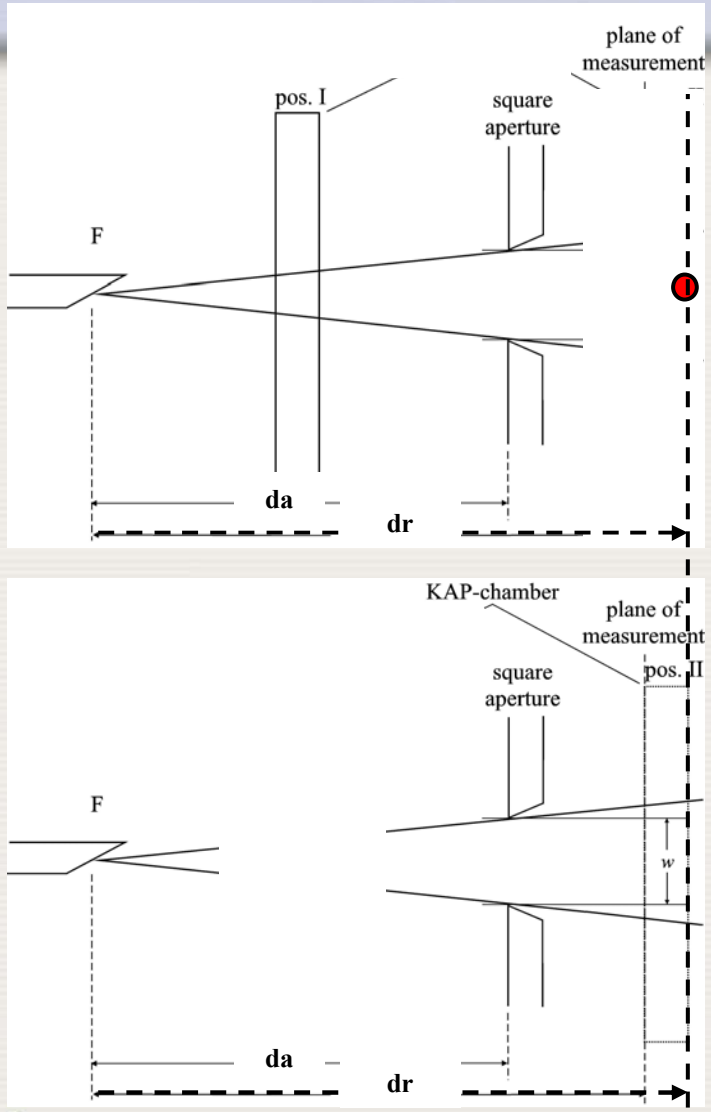
$$N_{P_{KA},Q} = \frac{K_i^{ref} \cdot A \cdot (d_r / d_a)^2}{M_{KAP} \cdot k_{TP}^{KAP}}$$

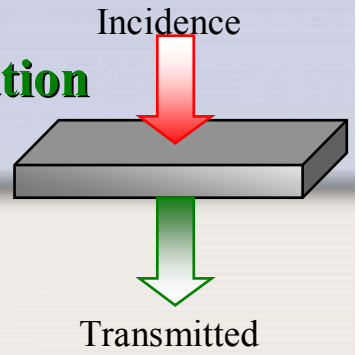
A is the cross section area of aperture
i.e. : $(w_1 \times w_2)$ or $\pi(w/2)^2$

KAP reference point of measurement
front surface or middle line

IAEA

KAP calibration at lab : “kerma-area” method, Transmitted radiation





K_i is measured behind the aperture

KAP in pos.I attenuates the beam,

so detector measures the attenuated beam (exit of KAP)

$$N_{P_{KA},Q} = \frac{K_i^{ref} \cdot A \cdot (d_r / d_a)^2}{M_{KAP} \cdot k_{TP}^{KAP}}$$

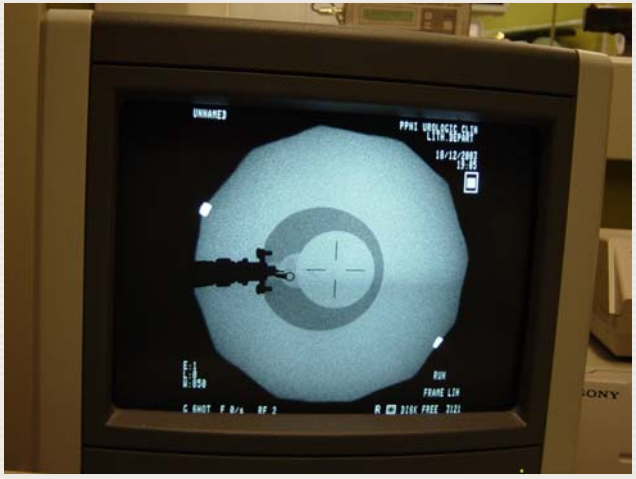
A is the cross section area of aperture
i.e. : $(w_1 \times w_2)$ or $\pi(w/2)^2$

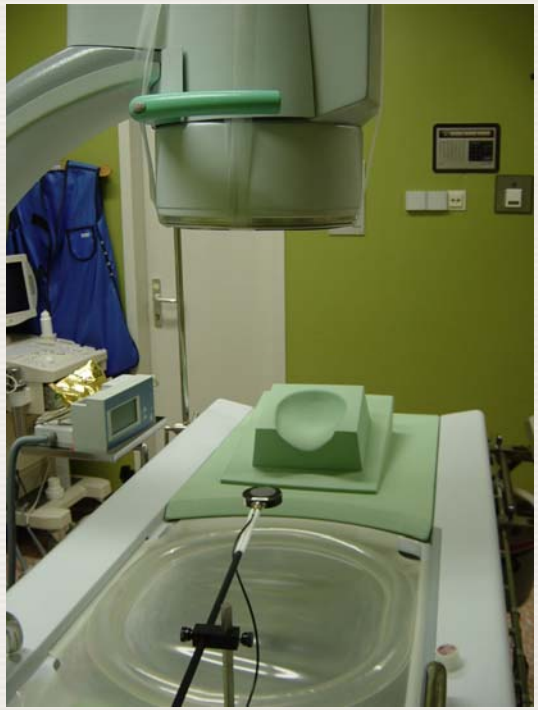
KAP reference point of measurement
back surface or middle line

IAEA

KAP calibration in situ : “kerma-area” method, Transmitted radiation

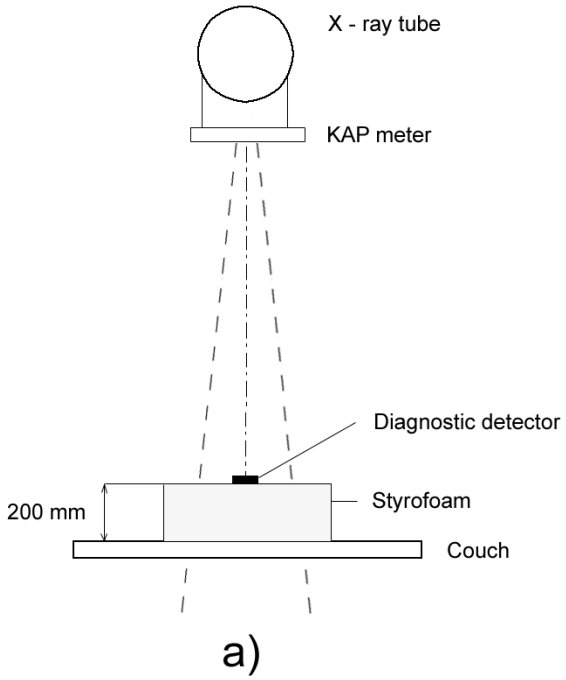
All X rays, both focal and extra focal, pass through KAP’s sensitive volume.





IAEA

KAP calibration in situ : “kerma-area” method, Transmitted radiation



a)

$$N_{P_{KA},Q} = \frac{M_Q^{ref}}{M_Q^{KAP}} N_{K,Q_0}^{ref} \; k_Q \; A_{nom}$$

Over-couch installation

1. Reference detector on the central axis at 200 mm above the couch (table top)
2. Collimate the X ray beam to 100 mm x 100 mm.
3. Expose the detector and the KAP meter using all combinations of tube voltage and total filtration occurring in the clinical applications (beam quality *Q*).
4. Register signals from the KAP meter, and the reference dosimeter.
5. Remove the reference chamber and position a film-screen cassette (or a direct film) CR cassette perpendicularly to the central axis at the position of the reference detector.
6. Expose the film-screen cassette or the film. The maximum optical density must not exceed 0.5 optical density units (OD).
7. Develop the film and determine the nominal beam area, *A*, as the area contained within 50% of the maximum optical density.

IAEA

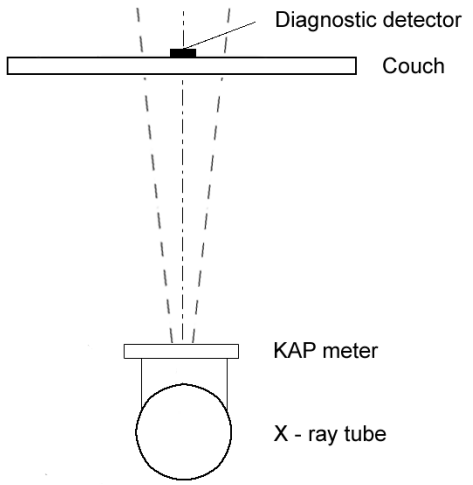
KAP calibration in situ : "kerma-area" method, Transmitted radiation

Under-couch installation

The detector should be positioned on the table top to reflect the beam attenuation and scattering by the table.

The air kerma-area product value should be representative of that in the beam incident on the patient and thus take into account the attenuation in the couch as well as the scatter from the couch that may reach the patient.

The couch may reduce by about 15%–30 % compared to the over-couch situation.

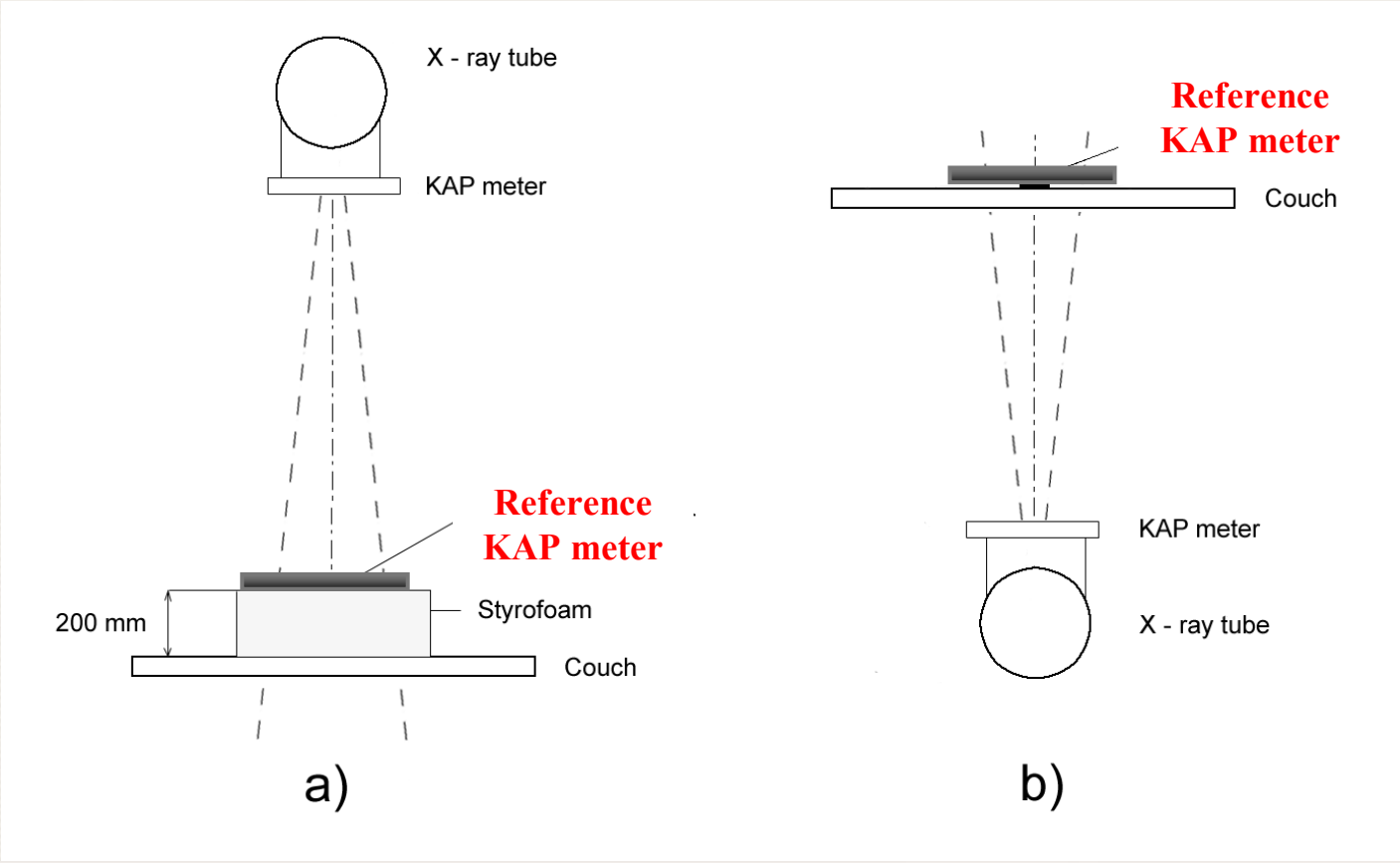


b)

$$N_{P_{KA},Q} = \frac{M_Q^{ref}}{M_Q^{KAP}} N_{K,Q_0}^{ref} \; k_Q \; A_{nom}$$

IAEA

Calibration using reference KAP meter, KAP METHOD : Transmitted radiation



$$N_{P_{KA},Q}^{KAP} = \frac{M_Q^{KAP_{ref}}}{M_Q^{KAP}} N_{P_{KA},Q_0}^{ref} \cdot k_Q^{KAP_{ref}}$$

IAEA

KAP calibration “kerma-area” method

Calibration using diagnostic dosimeter

- This method is usually more useful in clinics because proper dosimeter is easily available and its energy dependence is typically small. ↑
- Position of focal spot is not always marked clearly. ↓
- In some cases the determination of irradiation area and measurement distance was also difficult and uncertain. ↓
- More and more digital systems are available and estimating field size from softcopy adds an additional uncertainty in the measurement. ↓
- In this method an approximation of KAP quantity is used as a reference value and errors arising from in homogeneity in the field will increase the uncertainty of the calibration (Larsson et al) ↓

IAEA

From Toroi et al, STUK, 2008

Calibration using reference KAP meter : TANDEM method

Advantages

- The reference KAP value is measured according to the definition.
- Problems arising from the nonuniformities of the x-ray field is avoided.
- Independent of the measurement of distance and the field size.
- Calibration is easy to do.
- No uncertainties from distance or area measurements.

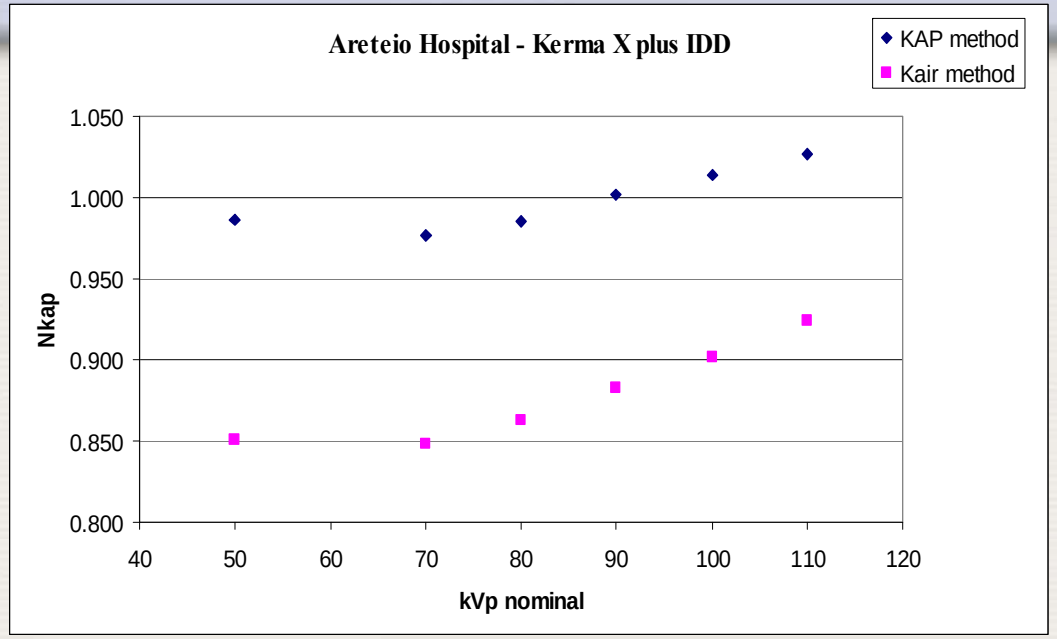
Disadvantages

- Extra KAP meter is needed.
- Ccomprehensive calibration for reference meter is needed.
- Inaccuracies if radiation quality is not well known
- Low values because of the small field

IAEA

From Toroi et al, STUK, 2008

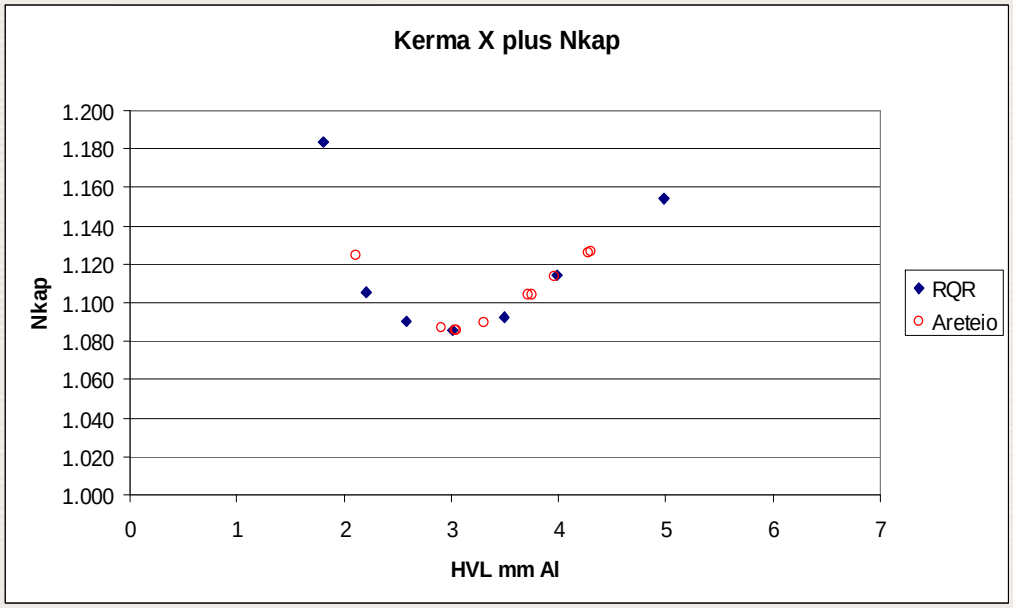
Method comparison



Under table tube

KAP method : the two KAP meters in contact

Kair method : on table top



IAEA

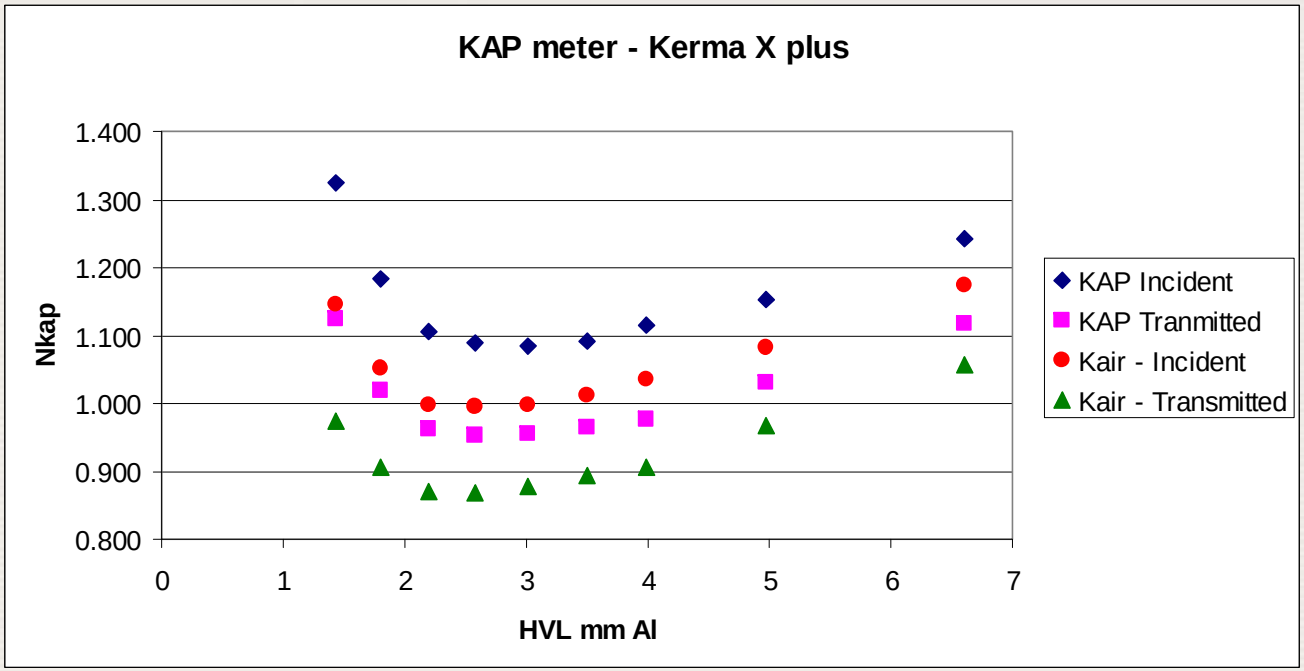
Radiation quality dependence of KAP meters

- KAP meters have large dependence on radiation quality.
- Adjusting the meter correctly with one radiation quality might achieve accuracy < 20%
- Half-value layer (HVL) can not describe alone radiation quality dependence.
- Radiation qualities used in clinical practice should be covered in calibration.
- Calibration should at least be done for all used filtrations and some chosen tube voltages.

IAEA

From Toroi et al, STUK, 2008

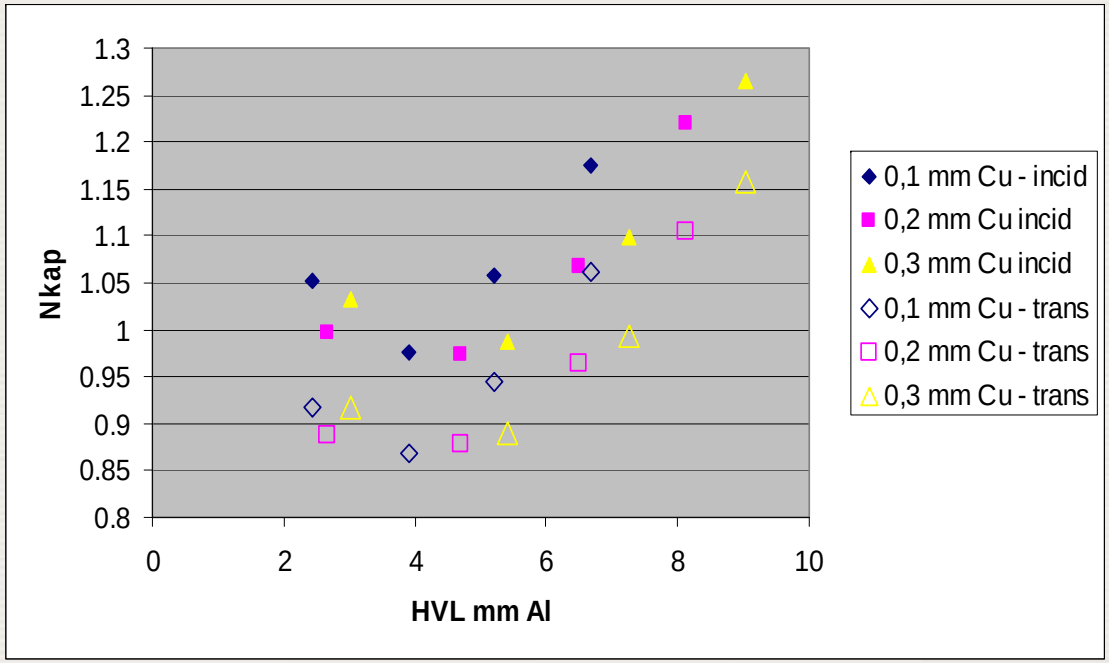
Radiation quality dependence of KAP meters



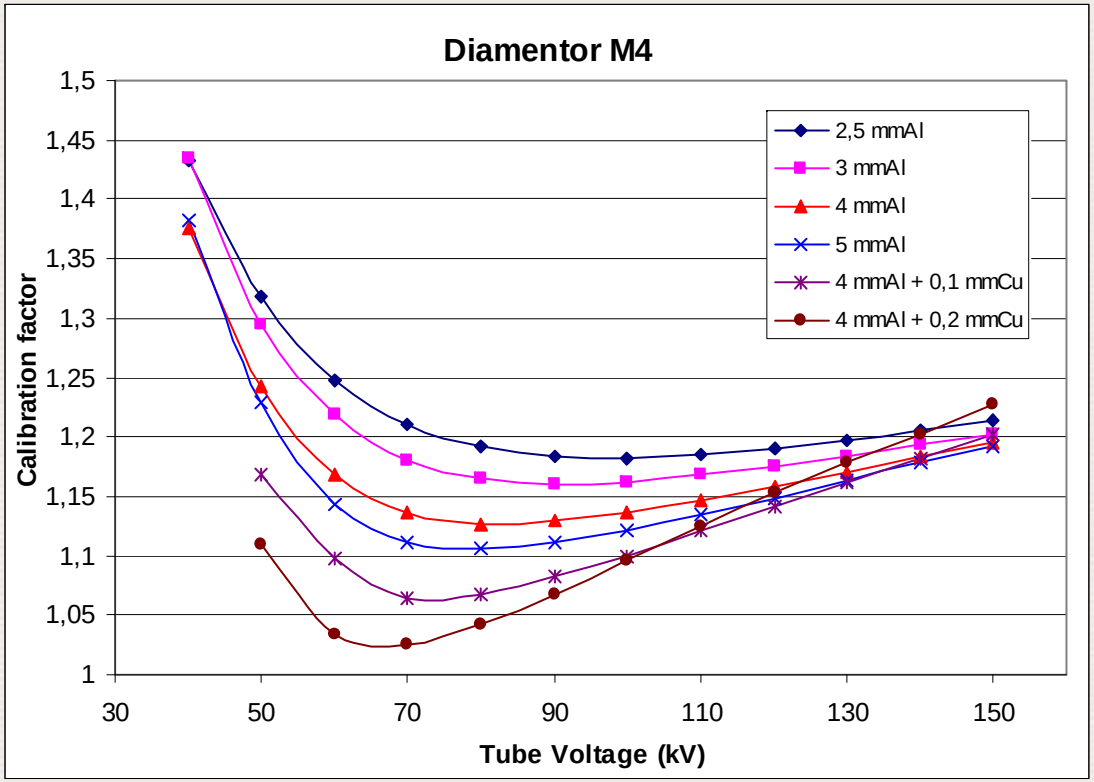
IAEA

Qualities for KAP calibration

Filtration	Tube voltage	HVL
inherent 3.5 mm Al plus	kVp	mm Al
0.1 mm Cu	**50**	2.45
0.1 mm Cu	**70**	3.92
0.1 mm Cu	**90**	5.22
0.1 mm Cu	**120**	6.68
0.2 mm Cu	**50**	2.68
0.2 mm Cu	**70**	4.68
0.2 mm Cu	**90**	6.50
0.2 mm Cu	**120**	8.11
0.3 mm Cu	**50**	3.02
0.3 mm Cu	**70**	5.42
0.3 mm Cu	**90**	7.27
0.3 mm Cu	**120**	9.04



Radiation quality dependence of KAP meters



From Toroi et al, STUK, 2008

IAEA