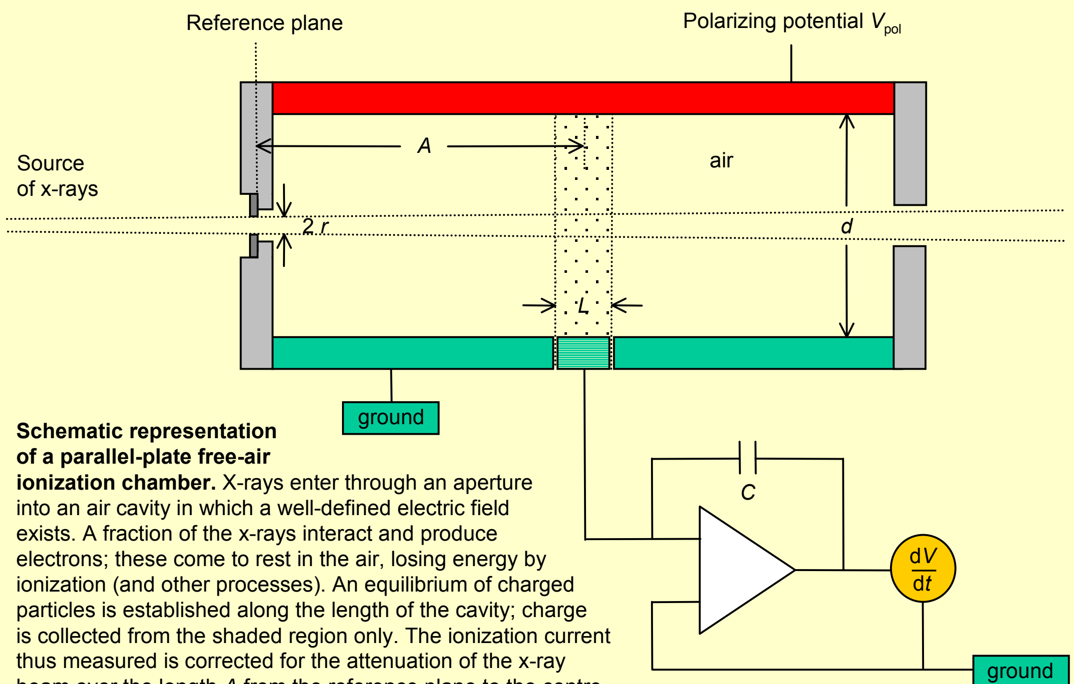
X-ray Dosimetry

The measurement of air kerma rate using a free-air ionization chamber standard



Schematic representation of a parallel-plate free-air ionization chamber. X-rays enter through an aperture into an air cavity in which a well-defined electric field exists. A fraction of the x-rays interact and produce electrons; these come to rest in the air, losing energy by ionization (and other processes). An equilibrium of charged particles is established along the length of the cavity; charge is collected from the shaded region only. The ionization current thus measured is corrected for the attenuation of the x-ray beam over the length *A* from the reference plane to the centre of the measuring volume.

Derivation of air kerma rate from measured rate of change of voltage

Derive ionization current as:

$$I = C\, dV/dt$$

(typical values: $C \sim 1$ nF, $dV/dt \sim 50$ mV s^{-1}, i.e. $I \sim 50$ pA).
Standard uncertainty typically 0.04 %.

Rate at which ions (of a given sign) are collected: $dN/dt = I/e$.

Mean energy expended per ion pair created is W_{air}. Then, assuming no losses, rate at which energy is released is:

$$dE/dt = W_{air}\, dN/dt = I\, W_{air}/e$$

(W_{air}/e) has dry air value 33.97 J C^{-1}, standard uncertainty 0.15 %.

Effective mass of air $m = \pi r^2 L \rho_{air}$, standard uncertainty 0.05 %.

Kerma is Kinetic Energy Released per unit MAss. Thus air kerma rate is

$$dK/dt = (dE/dt)/m = I\,(W_{air}/e)/(\pi r^2 L \rho_{air})$$

multiplied by a number of correction factors k_i.

Dimension of BIPM standard	10 kV to 50 kV (low-energy) standard / cm	100 kV to 250 kV (medium-energy) standard / cm
Aperture radius *r*	0.2500	0.4970
Attenuation length *A*	10.000	28.15
Collecting length *L*	1.5466	6.0004
Electrode separation *d*	7.0	18.0
Electrode width *w*	7.1	20.0
Polarizing potential V_{pol}	1 500 V	4 000 V

Correction factor k_i	Value for worst case	Standard uncertainty
air attenuation k_a	1.1921 at 10 kV	0.0003
scattered photons k_{sc}	0.9944 at 10 kV	0.0007
electron loss k_e	1.0078 at 250 kV	0.0010
ion collection efficiency k_s	1.0007 at 30 kV	0.0002
electric field distortion k_d	1.0000 at all qualities	0.0007
aperture edge transmission k_l	0.9996 at 250 kV	0.0001
front wall transmission k_p	0.9988 at 250 kV	0.0001
air humidity k_h	0.9980 at all qualities	0.0003
bremsstrahlung loss $(1-g)^{-1}$	1.0003 at 250 kV	0.0001