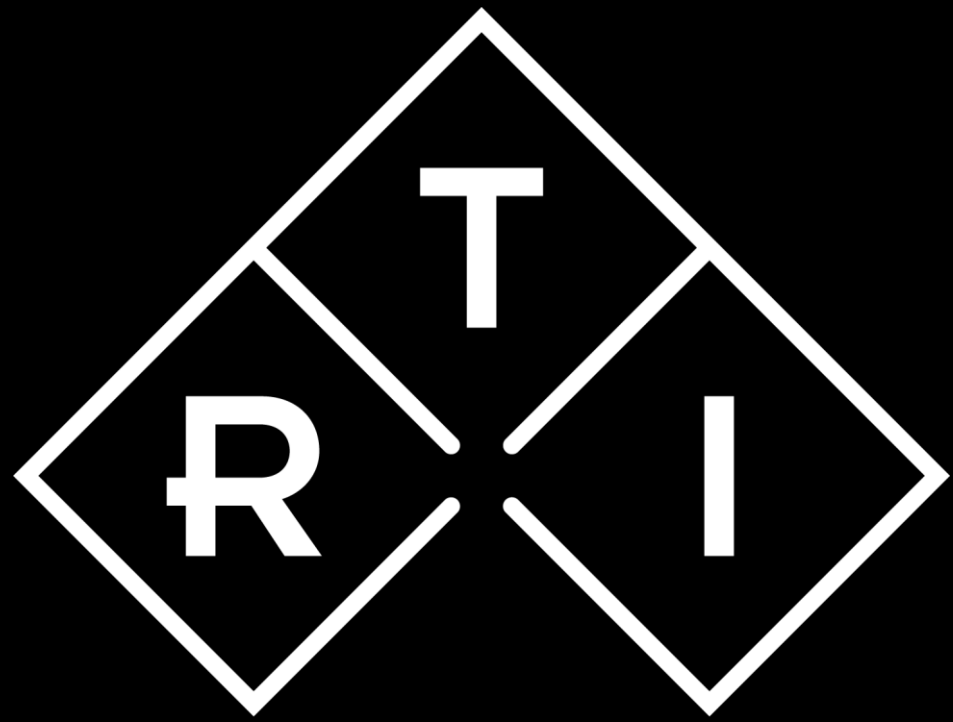

INDEPENDENT X-RAY
QUALITY ASSURANCE

Bridges in Traceability from Primary Laboratories to the Use of X-ray Multimeters in Clinical Practice

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Abstract

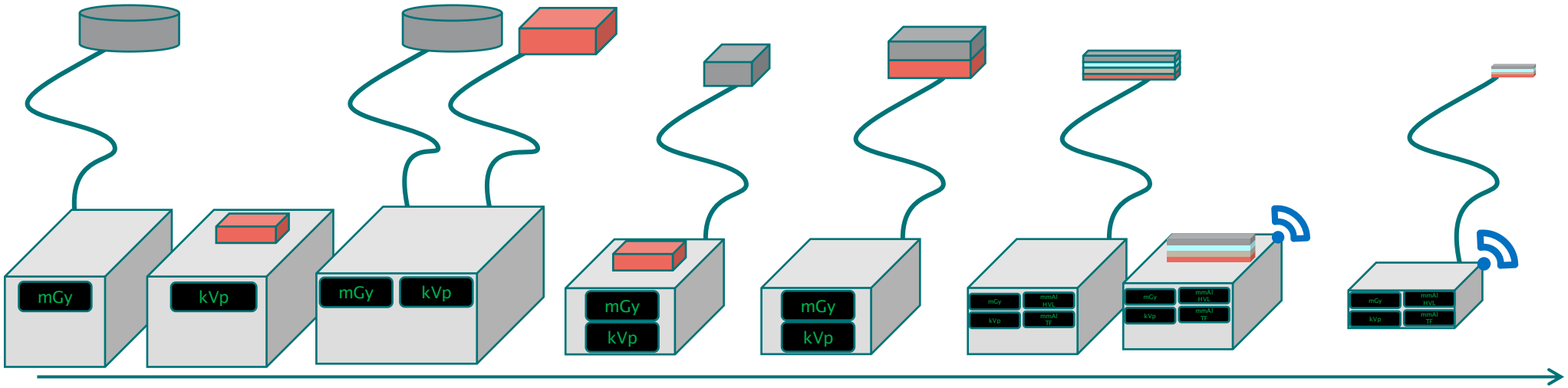
Non-invasive x-ray multimeters (XMMs) have been used for x-ray quality control for over 40 years. In the 80's and 90's the meters were designed with separate detectors for measurement of air kerma (or exposure), and tube potential respectively. Since then, the XMMs have developed to measure several parameters simultaneously. Today there are a range of different brands that measure tube potential, air kerma, HVL, and total filtration equivalent (TF) in one single exposure. The meters are designed to meet the demands on measurement on the broad range of x-ray units used in clinical practices. The spectral variation between various models of clinical units is big. To that one can also add the complexity of dynamic variations, such as pulse variations in energy, amplitude, width, and frequency.

Bridge the traceability from standards in primary laboratories to the clinical practice is many times a challenge. For tube potential and air kerma the variation in x-ray spectra is the main challenge. We do have well-established standards to rely on. But interpolation as well as extrapolation are used to cover the broad range of spectral variations.

What to expect when no primary reference is available? E.g. HVL
There is yet no primary laboratory that offers calibration of HVL. There are a few laboratories that offers accredited calibration of HVL based on own defined methodologies. The spread in CMC is quite wide (and maybe a bit too narrow in some cases). An international harmonized definition of HVL, and methods for calibration would help calibration laboratories establishing their methods, aiming for trustable HVL calibration.

Summary
For reliability in use of XMM's in the daily quality control it starts with reliable calibration of the basic quantities. User of XMM's must be aware that of influencing parameters which may have major impact on the measurement uncertainty in the daily use.

History of XMM's – X-ray MultiMeters



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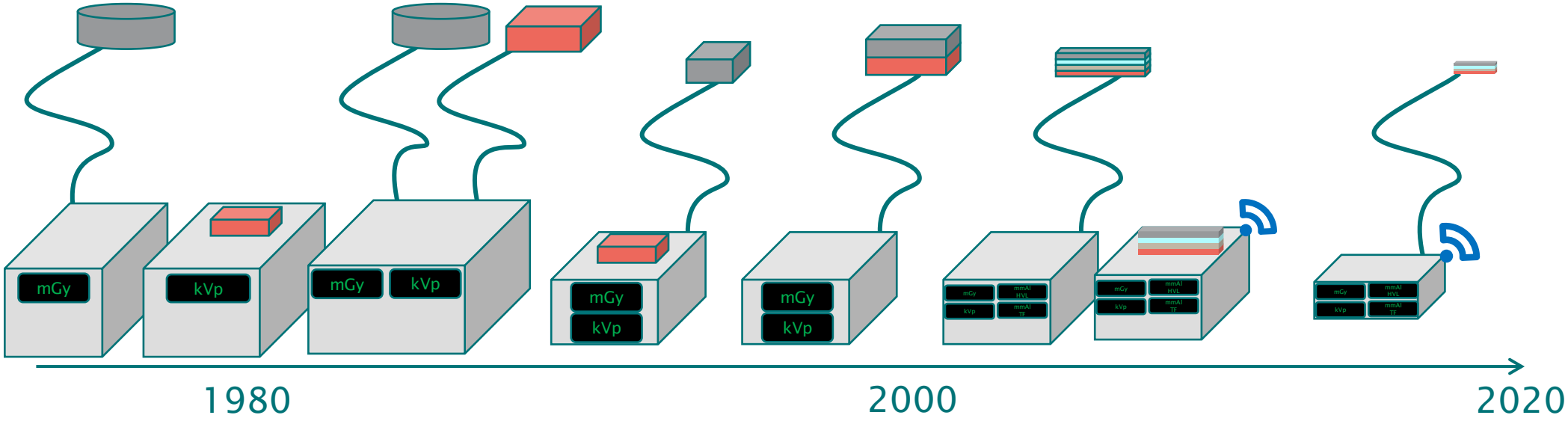
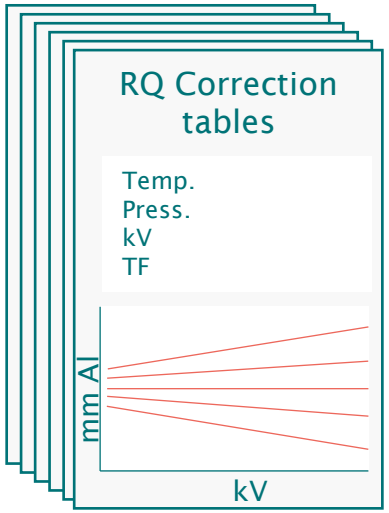
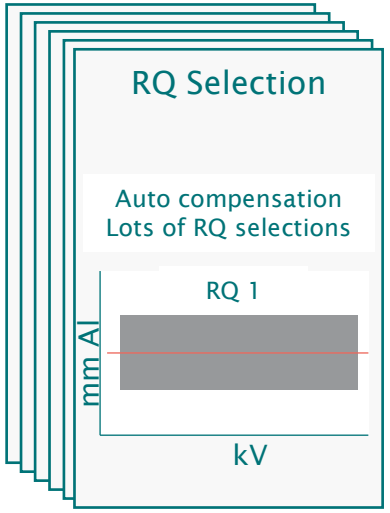
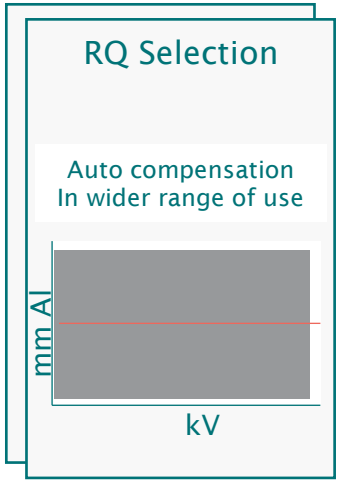








Clinically used Radiation Qualities

1980

Modality	Target	Filter alternatives		
R/F	W	2-4 mm Al		
CT	W	3 mm Al	+0.25 mm Cu	
Dent	W	1-2.5 mm Al		
Mam	Mo	30 µm Mo	25 µm Rh	1 mm Al
	Rh		25 µm Rh	1 mm Al

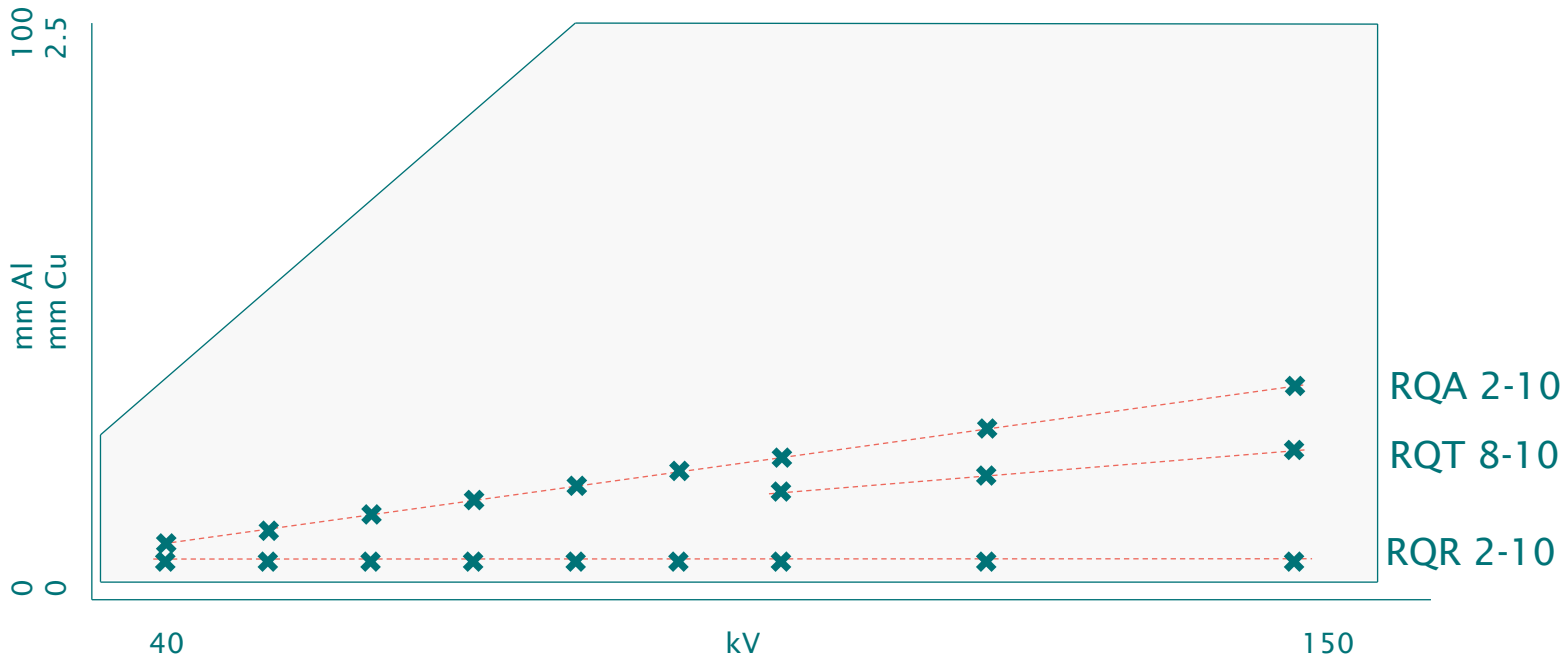
2024

Modality	Target	Filter alternatives					
R/F	W	2-4 mm Al	0-1.5 mm Cu				
CT	W	2-5 mm Al	+Cu	+Sn	+unknown		
Dent	W	1-2.5 mm Al					
Mam	Mo	30 µm Mo	25 µm Rh	1 mm Al		0.25 mm Cu	
	Rh		25 µm Rh	1 mm Al	30 µm Ag	0.25 mm Cu	
	W		40-60 µm Rh	0.5-1 mm Al	40-75 µm Ag	0.25-0.3 mm Cu	1.0-1.3 mm Ti

Air Kerma

Clinical conditions vs Available Traceable Radiation Qualities

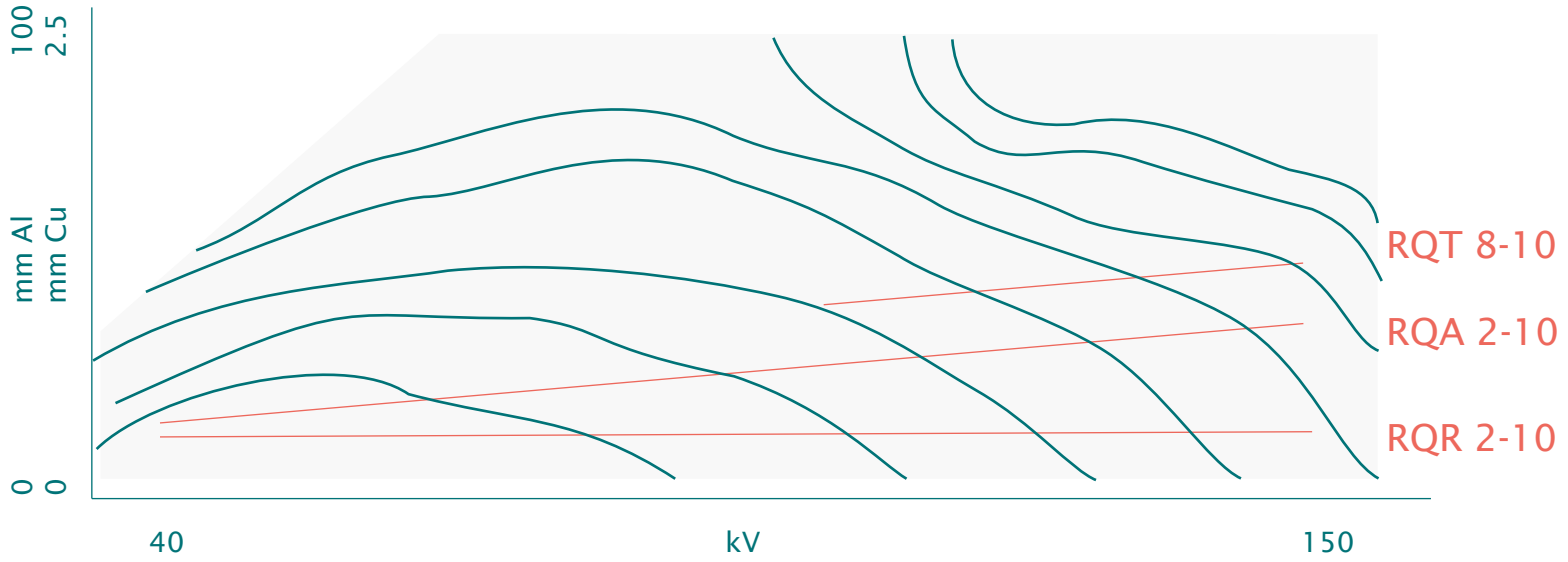
R/F - 40–150 kV



Air Kerma Radiation Qualities in the R/F range of energies

RQR, RQA, RQT - IEC 61267;Ed.2, 2005

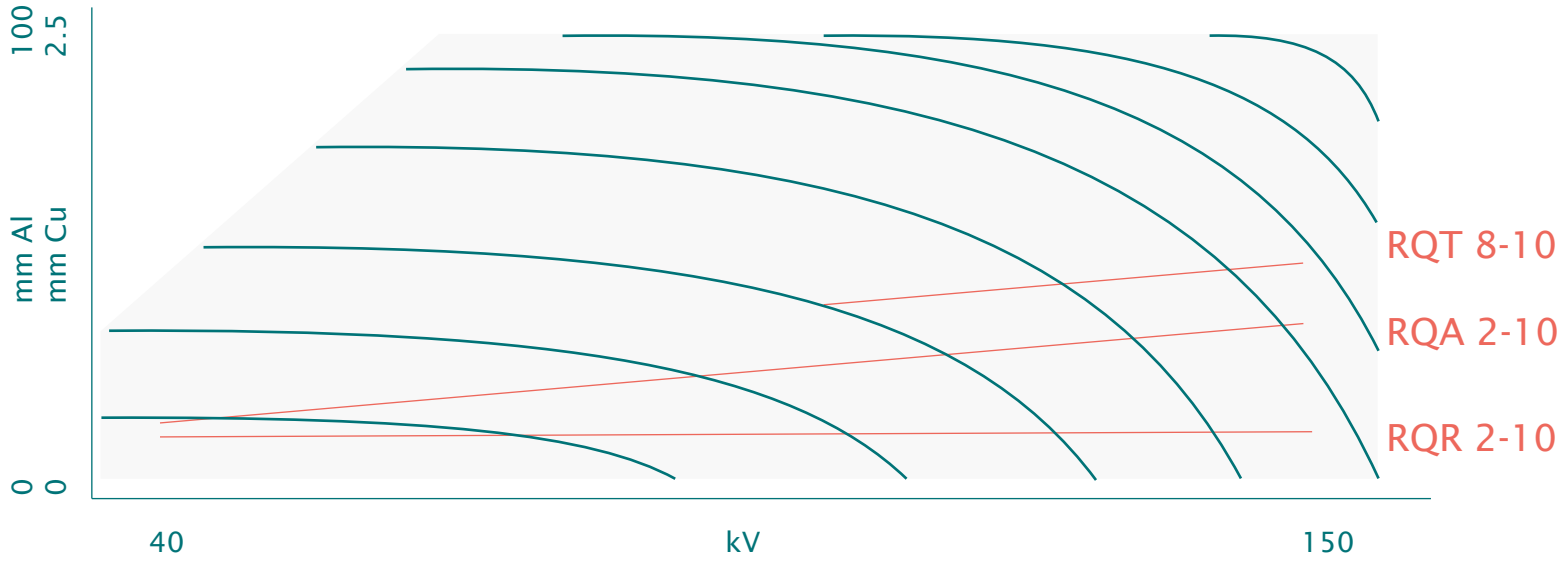
How do XMM's handle this?



Like this?

Quite un-predictable

How do XMM's handle this?



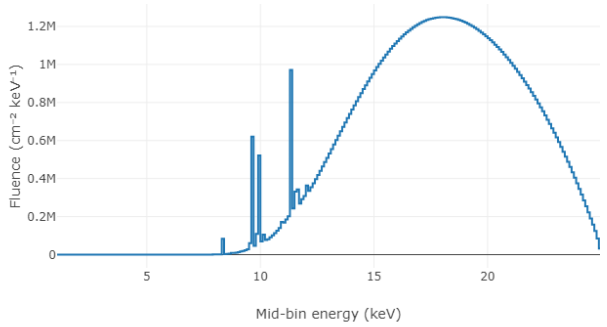
Or like this? Smooth, nice and relatively predictable

Mammography

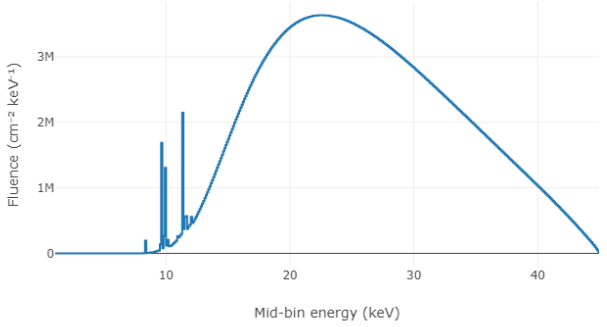
Basically the same applies to mammography range of radiation qualities

Challenge with large variations in X-ray spectra due to k-edges and kV range from 20 to 50 kV

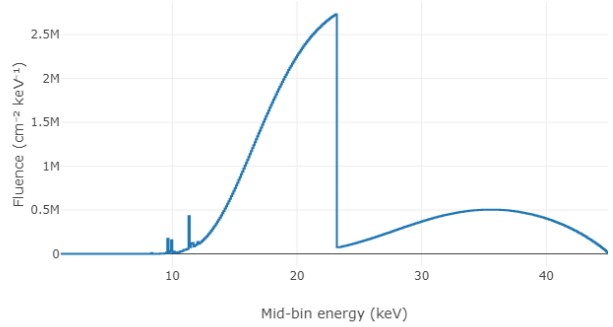
W/0.7mmAl, 25 kV



W/0.7mmAl, 45 kV



W/50µmRh, 45 kV



Simulations with SpekPy Web
ver. 2.0.8
https://spekpy.smile.ki.se/

Half Value Layer (HVL)

HVL is used to define radiation qualities. It's also used clinically to assure that unnecessary low energy radiation is not present.

definition of HVL?

The quick answer is that HVL is a simplified description of a radiation spectra, and that it is defined by the amount of a material (Al) that reduces the Air Kerma (or photon fluence?) to 50%.

What uncertainties can be expected when taking into account the various influencing parameters?

Key uncertainty contributions

Filter Purity
Filter Thickness
non-ideal narrow beam geometry
Energy linearity for Air Kerma detector
Measure Repeatability

What is a realistic "Best measuring ability" (CMC)?

Ionizing radiation

Technology area	*M*	*Parameter*	*Material*	*Measure*	*Best measuring ability (CMC) +/-*
Air kerma	Ir e	Half value layer (HVL)	Test device	18 - 40 kV, 0,2-4,0 mm Al	2,7%
		Half value layer (HVL)	Test device	40 - 155 kV, 1,4-15 mm Al	2,0 %

Tube Potential

- **kVp vs PPV**

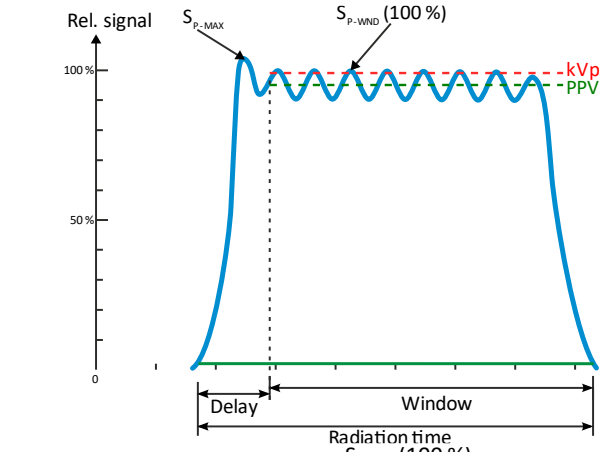
  Generators are in general adjusted to kVp – but is there a common definition? And how does it comparison to expectation?

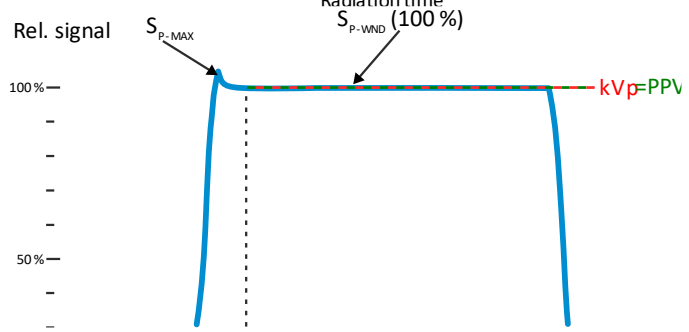
  The defined term by IEC, Practical Peak Voltage (PPV) is not clinically used.

  However - PPV has a more direct relevance to image quality in clinical use.

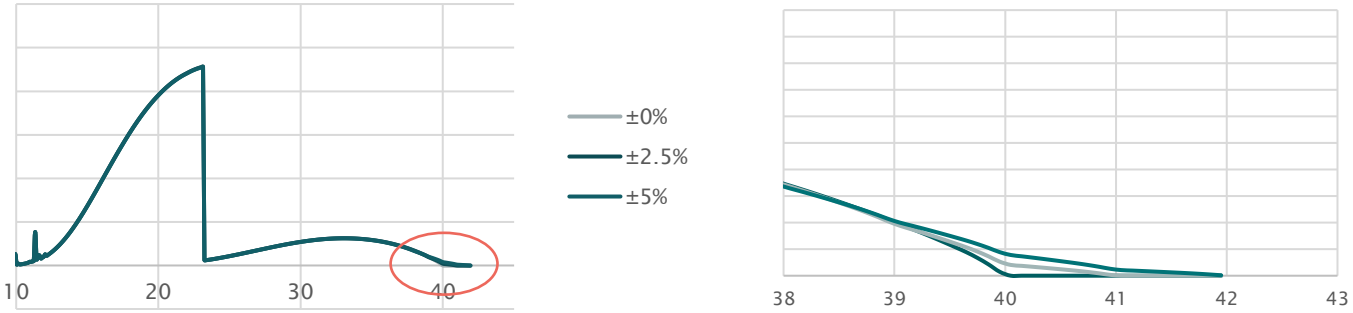
- **What will a spectrometer tell? And how to evaluate result?**

  Simulating ripple at 40 ±2 kV, W/50 µm Rh





W/50 µm Rh, 40 kV (SpekPy Web ver. 2.0.8)

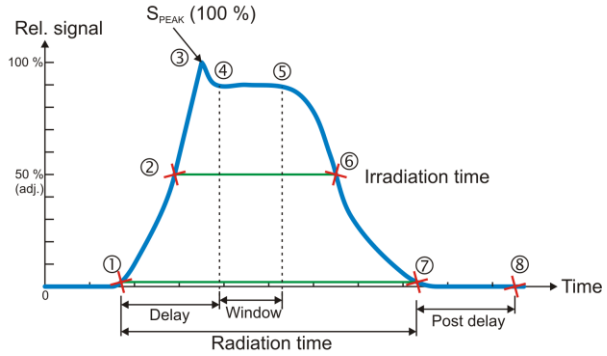


Time

◇ Irradiation Time, Radiation Time and/or Exposure Time

Generator standards refer to loading state in the generator. How does that compare to the time that irradiation is present?

IEC 60601-2-63, IEC 60601-2-65



IRRADIATION TIME
IRRADIATION TIME is measured as the time interval between the instant when the AIR KERMA RATE has risen for the first time to a value of 50 % of the peak value, and the instant when it finally drops below the same value.
NOTE 1 see also definition 3.32 of IEC 60601-1-3:2008

Citating IEC 60601-2-65
“LOADING TIME (the time during which the X-RAY MONOBLOCK ASSEMBLY is powered) and the IRRADIATION TIME (the time during which the AIR KERMA RATE exceeds a given percentage of the maximum and steady-state value - or in other words the time during which there is significant emission of X-ray)”

Total Filtration

What is common standard? Is there a need?

Some safety standards refer to minimum total filtration equivalent.

It is also clinically handsome since the Total Filtration is constant and do not vary with change of other parameters.

Factors that have more or less influence on measurement uncertainty for XMM's in Clinical use

Everything that has influence on the X-ray spectra will have effect on the measurement uncertainty with the XMM

How much it will influence depends on the XMM design

Major influencing parameters are:

- Tube Potential and it's ripple
- Additional filtration
- Anode angle (and anode surface)
- Back scatter
- Scatter from phantom, compression paddle or other material nearby the device

Conclusion

International standards and definitions

together with

Primary and Secondary laboratories who offers relevant calibration

sets a baseline

Usability

The XMM design must cover the range of intended use.

The user of the XMM must be aware of what has influence on measurement uncertainty

40 years of X-ray safety & quality