Laboratoire National
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LNE-LNHB

PROPOSAL FOR EYE-LENS DOSEMETER CALIBRATION AND TYPE TESTING

ORAMED WP2

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energie atomique • energies alternatives

WP2 of ORAMED :

"*Critically revising the theoretical fundamentals on which the eye lens operational quantity $H_p(3)$ is based and thereafter the way to calculate it*"

Why :

- $H_p(3)$ is defined (ICRU)
- No Conv. Coef in ICRP publication, ICRU report, (ISO standard !!)
- No dosemeter (only evaluation in most of cases)
- Cataract cases have been reported for doses lower than a reported "threshold" (2 Gy) in IR/IC …/…

Therefore it is needed :

- Calculation of Conversion coef $h_p(3)$ from air kerma to $H_p(3)$ (see G Gualdrini oral talk)
- Design of dosemeters (see P. Bilski oral talk)
- Specify the calibration and type test procedures for optimizing the radiation performance requirements

Type Test:

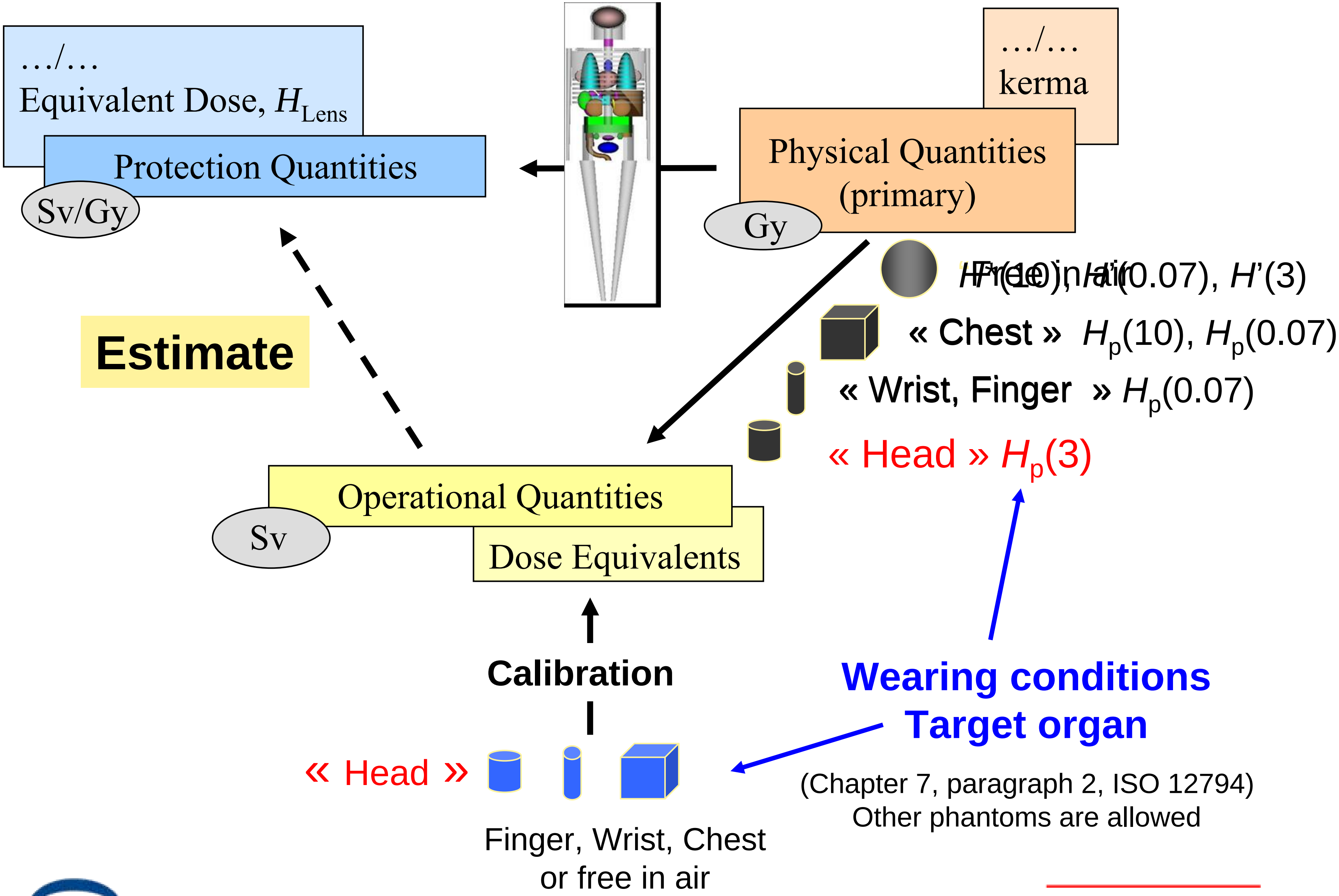
Before being available on the market, dosimetry systems are type tested according to the relevant IEC or ISO standard. Type tests are intended to demonstrate the basic performance of the type of the dosemeter.

To help the user in choosing his dosemeter depending on the workplace

Calibration:

When the dosimetry system is used by dosimetry services, it’s calibration **MUST** be traceable to the international system of units trough a national reference.

Radiation Protection



Type tests for dosimetry systems based on passive personal dosemeters, to monitor individuals occupationally exposed to external radiation

IEC 62387-1 “Radiation protection instrumentation – Passive integrating dosimetry systems for environmental and personal monitoring – Part 1: General characteristics and performance requirements” (2007)

ISO 12794 “Nuclear energy – Radiation protection – Individual thermo luminescence dosemeters for extremities and eyes” (2000)

IEC 62387-1 ; ISO 12794

Same goal but two slightly different approaches

ISO standard are based on the characteristic of the dosemeter as a whole

IEC standard studies a dosimetry system including requirements about (reader, ancillary equipments and procedures for converting the reading into dose).

✓Only the ISO standard takes into account the eye lens dosimetry

✓ISO standard is especially written for TLD based dosemeters while IEC standard include any type of dosemeters.

✓None of these standards takes into account the pulsed radiation fields !

Comparison of the main requirements of ISO and IEC standards for passive photon dosimetry.

(Influence) quantity	ISO 12794	IEC 62387-1
Type of detector and type of dosemeter	TLD, Extremity and eyes	all passive; whole body (EC 160 table 7.1)
Radiation energy	(15 keV to 3 MeV) 0,5 ≤ response ≤ 1.5	any energy (80 keV to 1.25 MeV) and angle: 0.71 ≤ response ≤ 1.67
Angle of incidence (0 to 60°)	at 60 +/-5 keV: 0.85 ≤response≤ 1.15	
Linearity	**1 mSv** to 1 Sv: 0.9 ≤ response ≤ 1.1	**0.1 mSv** to 1 Sv: 0.91 ≤ response ≤ 1.11
Coefficient of Variation	reproducibility: 10% batch homogeneity: 15%	from 15% (< 0.1 mSv) to 5% (> 1.1 mSv)
Environmental conditions and others	temperature up to +40°C and humidity up to 90%: 0.9 ≤ response ≤ 1.1 light exposure: 0.9 ≤ response ≤ 1.1	temp.:-10°C to +40°C, humidity 40% to 90% Fading, light, reader stability and power supply combined: 0.83 ≤ response≤ 1.25
Additivity	no requirement	0.91 ≤ response ≤ 1.11
Electromagnetic Compatibility		IEC 61000-6-2, deviation limited
Mechanics		IEC 60068-2-32, deviation limited
Software		WELMEC Guide 7.2

Comparison of the main requirements of ISO and IEC standards for passive ph[illegible] dosimetry.

(Influence) quantity	ISO 12794	I[illegible]
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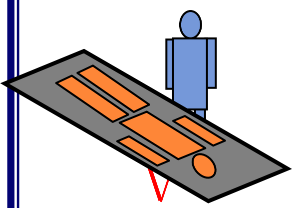
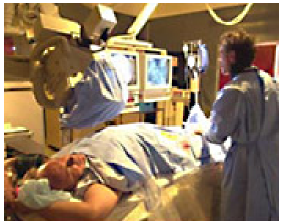
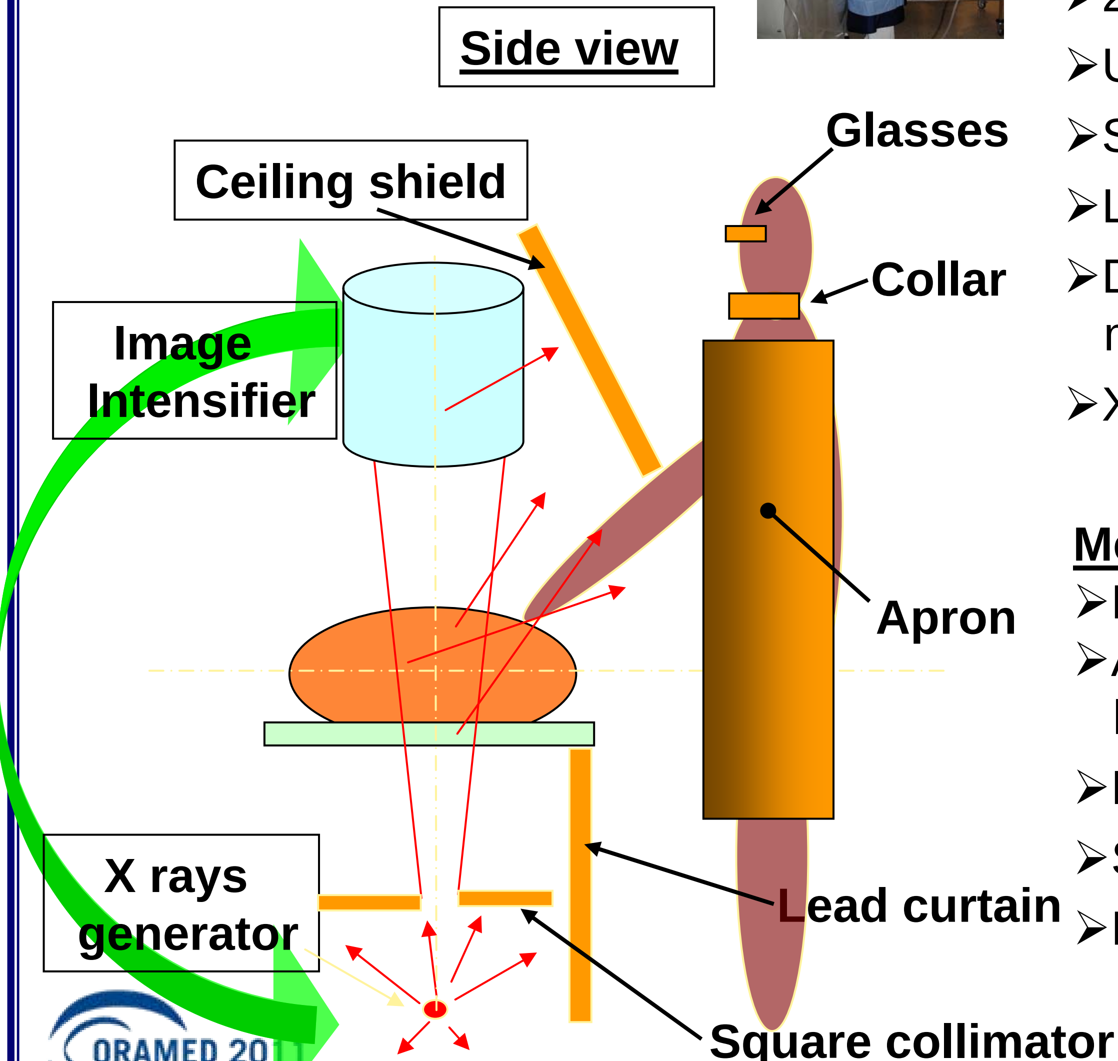
[illegible]		WELMEC Guide 7.2

Compromise solution between
What we would like, what is necessary,
and what is achievable

As standard are updated regularly
Performance can be improved in an iterated process







Workplace

- 20 -150 keV
- Use of protection 1/100
- Scattered radiations
- Low doses "behind protection"
- Do not move a lot "patient" and medical staff
- X rays generator can move

Measurement conditions

- Dosemeter in contact with the skin
- As close as possible to the eye lens to measure the real exposure.
- High sensitivity
- Strong angle dependency
- Reduced energy domain

Type test and quality control procedures:

Taken from ISO 12794

(Individual thermo luminescence dosemeters for extremity and eyes)

- Batch homogeneity
- Reproducibility
- **Linearity**
- Stability of the dosemeters under various climatic conditions
- **Detection threshold: Not exceed 1 mSv**
- **Self irradiation: after 60 days, zero points shall not exceed 2 mSv**
- Residue
- Effect of light exposure on the dosemeter
- **Isotropy: at (60 +/-5) keV ; 0° to 60° ; +/- 15%**
- **Energy response: 15 keV to 3 MeV ; +/- 50%**

Detection threshold

ISO - **1 mSv** IEC (**0.1 mSv**) lower limit of the "dose" range

Should be sufficient for measuring the X-rays shielded by the protective material !

Starting from the natural background, (Cosmic + Telluric about 0.8 mSv – France)
Per month 0.8 / 12 ~ 67 µSv;
Accounting for a factor of 3.3 (ISO 11929) 2, **0.220 mSv** (1 month).

Other attempt from experimantal data (Hirning) **~0.350 mSv** (1 month) (maximum)

Starting from the limit of exposure 150 mSv /year in terms of H_{lens} ,
For A workers and a 1 month period,150 x (3/10) / 12 = 3.75 mSv
Detection threshold at about one tenth of this maximum **0.375 mSv** (1 month).

Such a lower threshold has consequences on:

- The **sensitivity to self irradiation** should be reduced down to **0.2 to 0.4 mSv**.
- The **linearity range 200 µSv to 1 Sv (+/-10%)**

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0.2 mSv could be a good compromise solution.

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- The **sensitivity to self irradiation** should be reduced down to **0.2 to 0.4 mSv**.
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Performance requirements for energy response

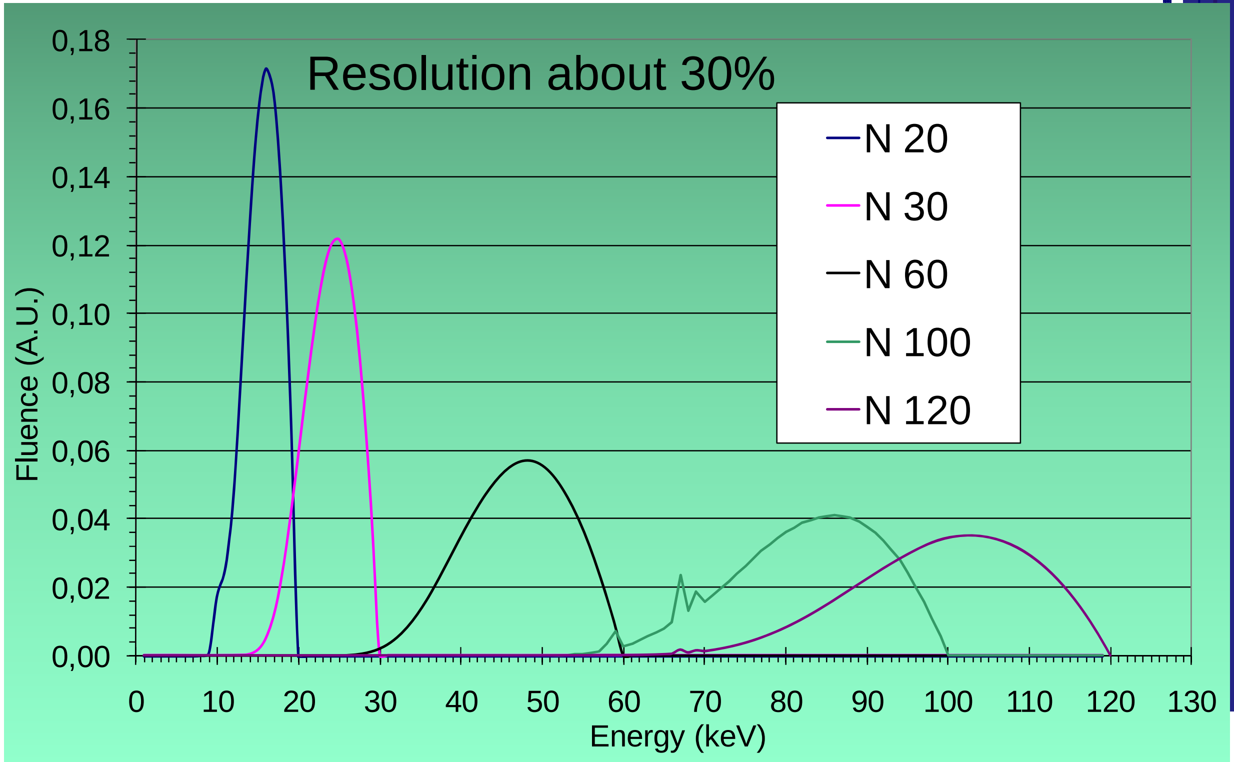
Existing for broad energy range (15 keV - 3 MeV) **± 50%**

Taking example on data of the "European Commission, Technical Recommendations for Monitoring Individuals Exposed to External Radiation, No 160" for the values of assessed annual dose values at or near the dose limit, the maximum variation could be **± 20%** or in a more general probabilistic approach the 95 % confidence interval should not exceed 0.67 to 1.5 , i.e. about **± 40%** (with a coverage factor of 2).

The energy domain can be restricted to 20-150 keV with a maximum variation of the energy response of **± 30%.** If the use of the dosemeter is restricted in IC/IR (E < 150 keV)

Remarks: Both IEC and ISO standard only rely on radiation qualities of ISO 4037. "**narrow" series** shall be used:

N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150.



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A stricter criterion could be used
+/- 30%

The energy domain … …0-150 keV with a maximum variation of the energy response of **± 30%.** … …e dosemeter is restricted in IC/IR (E < 150 keV)

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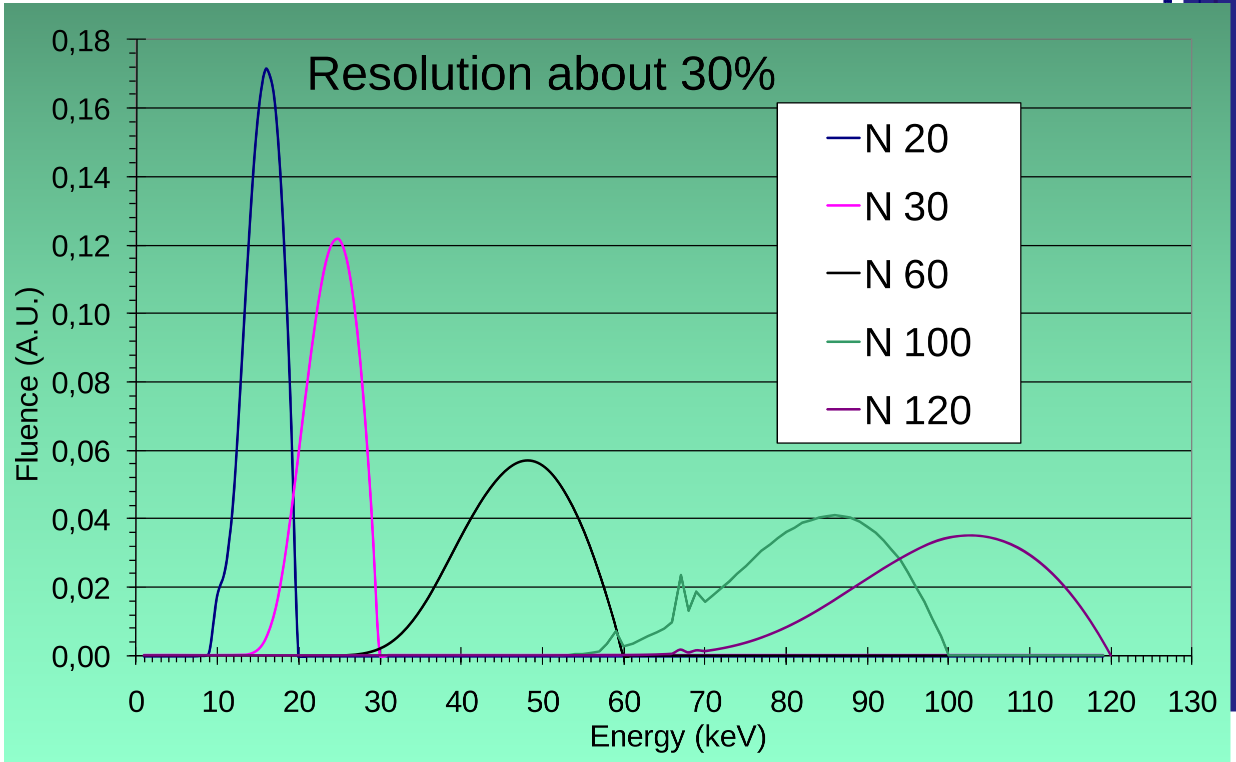

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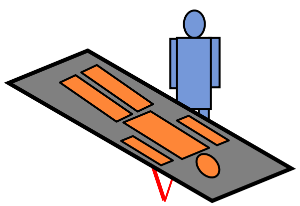
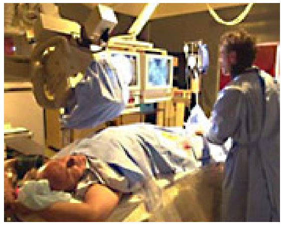
 

Performance requirements for angle response

Taking into account the particular case of IC/IR exposure (quite static position), a drastic requirement is necessary

The ISO standard states: “the mean value of the response at angle of incidence 0°, 20°, 40° and 60° from the normal shall not differ from the corresponding response for the normal incidence by more than **+/-15%** when irradiated with photons of 60 keV”.

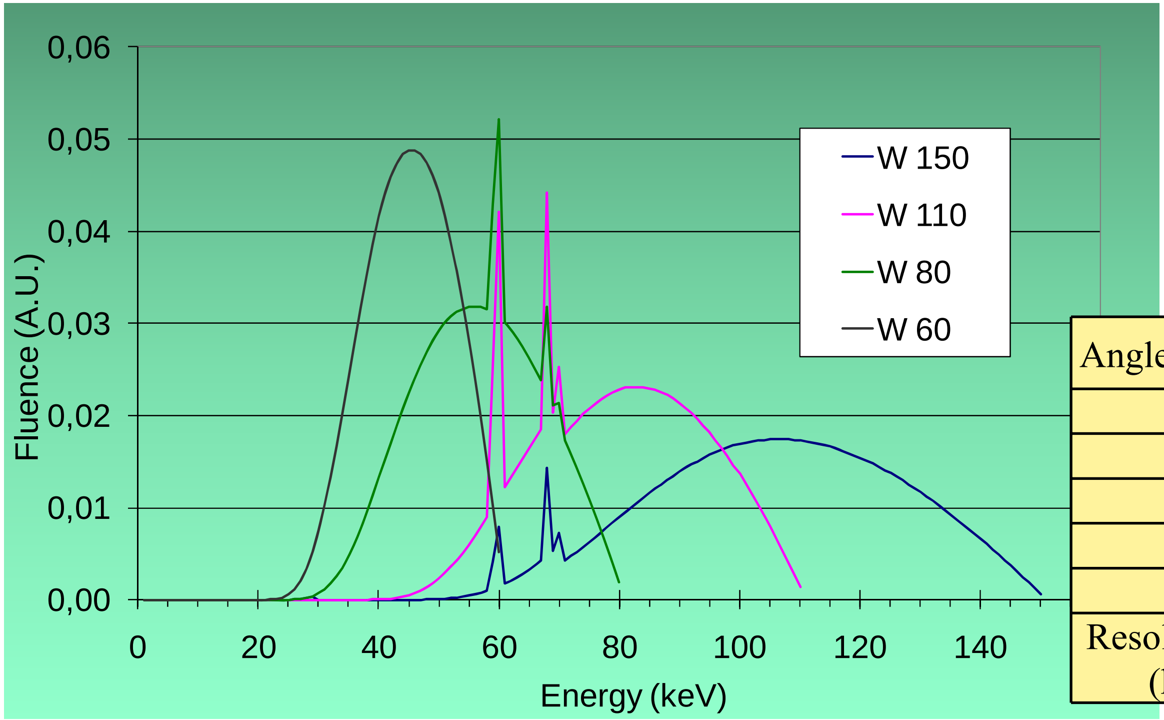
If the domain of angle is extended to 75°, taking into account the difficulty of the measurements at such an angle, the criterion can be relaxed to **+/-30%** without jeopardizing the quality of the measurements.

Calibration

^{137}Cs ? ^{60}Co ?

For IC/IR, if energy response failed, a specific calibration can be done using a beam with E < 150 keV.

In agreement between the calibration lab. And the end user, it is then useful to choose A quality close to the workplace radiation field.

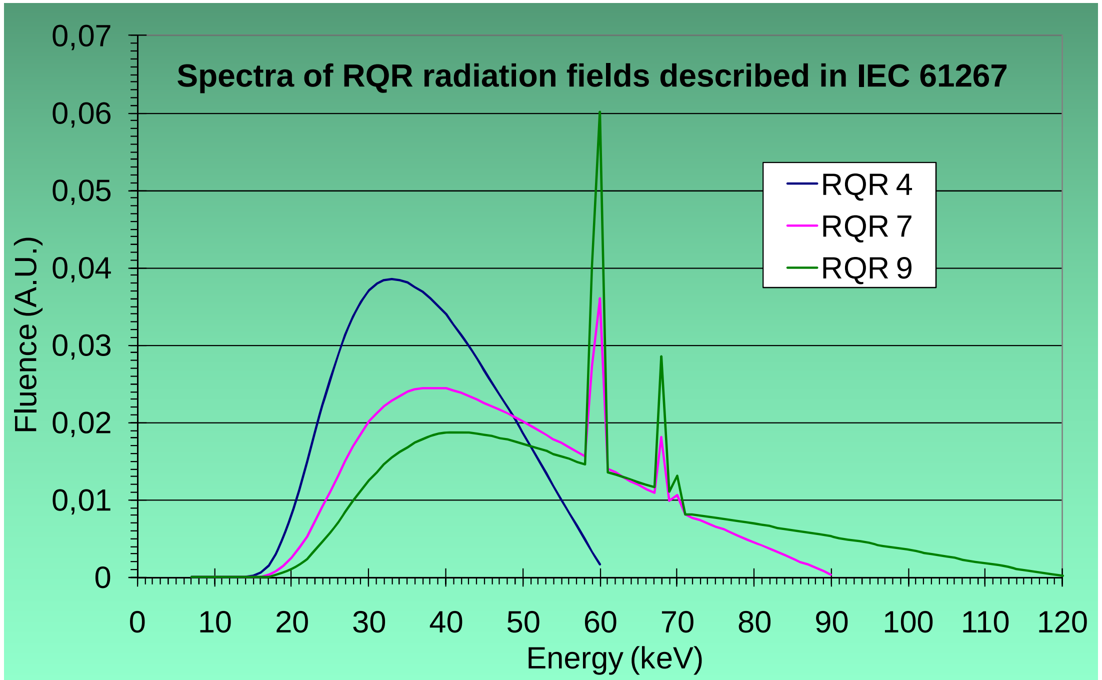


Monte Carlo calculations (PENELOPE Code), standard uncertainties better than 0.3%

$$h_{p,K}(3) = H_p(3)/K_{air} \quad \text{(Sv/Gy)}$$

Angle (degree)	W 60	W 80	W 110	W 150
0	1.47	1.58	1.65	1.57
20	1.46	1.58	1.63	1.54
45	1.42	1.53	1.60	1.54
60	1.34	1.47	1.54	1.50
75	1.20	1.34	1.45	1.40
Resolution % (keV)	48 (29)	55 (44)	51 (56)	56 (84)

The total filtration of the spectra is quite large and the energy distribution, characterized by the resolution, is smaller than the one of RQR spectra.



Conversion coefficient from air kerma to dose equivalent at 3 mm depth

$$h_{p,K}(3) = H_p(3)/K_{air} \qquad (Sv/Gy)$$

Monte Carlo calculations (PENELOPE Code), standard uncertainties better than 0.3%

Angle (degree)	IEC 61267			ISO 4037			CONRAD
	RQR4 (60 kV)	RQR7 (90 kV)	RQR9 (120 kV)	N30	N80	N120	70 kV
0	1.239	1.376	1.461	1.019	1.665	1.588	1.495
20	1.229	1.373	1.452	1.009	1.659	1.584	1.484
45	1.179	1.326	1.406	0.955	1.599	1.554	1.429
60	1.108	1.253	1.347	0.875	1.546	1.516	1.367
75	0.953	1.107	1.210	0.698	1.420	1.424	1.231
Resolution % (keV)	**73 (27)**	**67 (32)**	**77 (44)**	**32%**	**32%**	**27%**	**52 (22)**

(Influence) quantity	**This work (proposal)**	**ISO 12794**	**IEC 62387-1**
Type of detector type of dosemeter	All passive eyes	TLD, Extremity and eyes	all passive; whole body (EC 160)
Radiation energy	(15 keV to 3 MeV) 0,6 ≤ response ≤ 1.4 (20 keV to 100 keV) 0,7 ≤ response ≤ 1.3	(15 keV to 3 MeV) 0,5 ≤ response ≤ 1.5	any energy (80 keV to 1.25 MeV) And angle: 0.71 ≤ response ≤ 1.67
Angle of incidence at 60 +/-5 keV	0.85 ≤ response ≤ 1.15 (0° to 60°) 0.7 ≤ response ≤ 1.3 (0° to 75°)	0.85 ≤response≤ 1.15 (0° to 60°)	
Detection threshold	0.2 mSv	1 mSv	(0.1 mSv)
Linearity	0.2 mSv to 1 Sv 0.9 ≤ response ≤ 1.1	1 mSv to 1 Sv 0.9 ≤ response ≤ 1.1	0.1 mSv to 1 Sv 0.91 ≤ response ≤ 1.11
Coefficient of Variation	----	Reproducibility: 10% Batch homogeneity: 15%	from 15% (< 0.1 mSv) to 5% (> 1.1 mSv)
Environmental conditions and others	----	Temperature up to +40°C humidity up to 90%: 0.9 ≤ response ≤ 1.1 light exposure: 0.9 ≤ response ≤ 1.1	temperature: -10°C to +40°C, Humidity: 40% to 90% Fading, light, reader stability and power supply combined: 0.83 ≤ response≤ 1.25

Conclusions

These proposals are aimed at being the starting point for discussion when revising the existing standard.

This work was devoted to passive dosemeters.
In the future it is likely that some electronic dosemeter will be available, so the same work should be done for active dosemeter.
For these dosemeters pulsed radiation fields will have to be considered.

I thank you for your attention