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Impact of ICRU Report 90 recommendations

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ICRU Report 90

Published in October 2016
(despite what it says on the front cover!)

First report of its type from ICRU for several decades

AAPM members – free access to all ICRU publications!

This presentation isn't about ICRU but….

- Originally known as the International X-Ray Unit Committee
- Then the International Committee for Radiological Units
- Conceived at the First International Congress of Radiology in London in 1925
- The primary objective was to propose a unit for measurement of radiation as applied in medicine.
- From 1950 the ICRU expanded its role significantly to embrace a wider field.
- Has published authoritative reports on a range of issues, from radiation therapy to the dose from air travel

Who asked for this report?

"This Report is the result of a specific request by the Consultative Committee on Ionizing Radiation (CCRI), established by the International Committee for Weights and Measures (CIPM), the body that supervises the work of the International Bureau of Weights and Measures (BIPM).

During its ongoing work, the CCRI has looked to ICRU as the authoritative source of internationally accepted values of key parameters needed in measurement standards for ionizing radiation."

Introduction to ICRU 90

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Introduction to ICRU 90

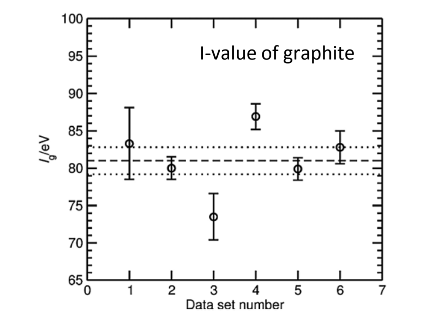
The CCRI represents National Measurement Institutes from around the world (such as NIST and NRC) and is therefore perhaps the foremost collection of measurement-obsessed radiation physicists! If anyone needs accurate data they do.

What does it say?

Quite a bit actually!

- ✓ Examines key data for stopping powers for charged particles ranging from electrons to carbon ions
- ✓ Assigns values and uncertainties to the mean excitation energies for air, graphite, and liquid water (I-values)
- ✓ Provides updated tables of stopping powers covering the energy range from 1 keV to 1 GeV
- ✓ Reviews photon cross sections for air, water, and graphite and compares them with relevant measurements to estimate their uncertainties
- ✓ Recommends values for the average energy to create an ion pair in air, W_{air}
- ✓ Summarizes the available data for important radiochemical reactions:
  - the chemical yield for Fricke dosimetry
  - the heat defects for graphite and liquid water
- ✓ Reviews the humidity correction factor for air-filled ionization chambers

Graphs are better than text – here are a few from the report!



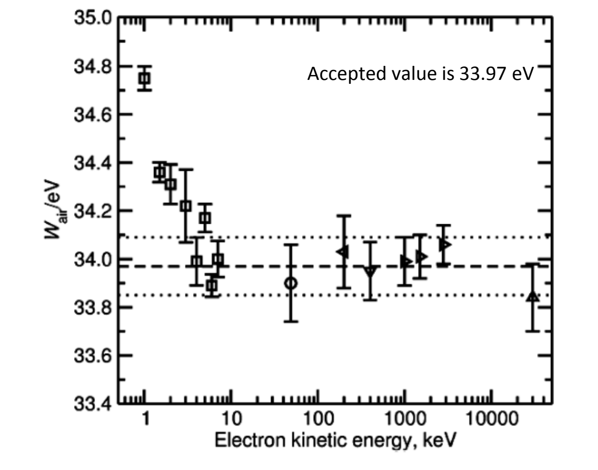
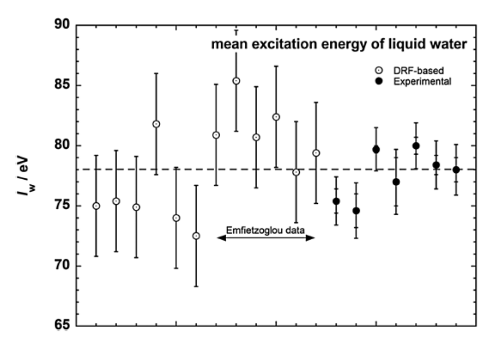


Figure 5.4. Values of W_{air} extracted from measured data. Symbols



I-value and W_{air} values

A lot of work to collate and analyze data from a wide range of sources

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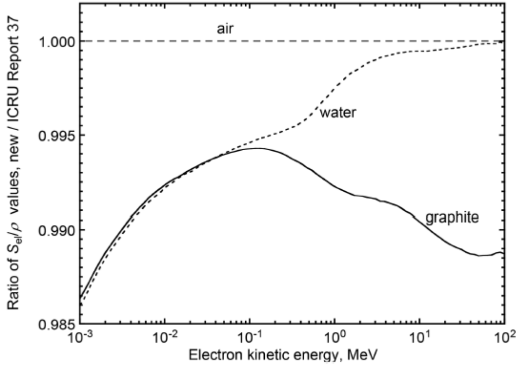

Figure 7.1. Ratios of the mass electronic stopping power for electrons recommended in this Report to those given in ICRU Report 37 (1984a), as a function of the electron energy, for graphite (solid line), liquid water (short dashes), and air (long dashes).

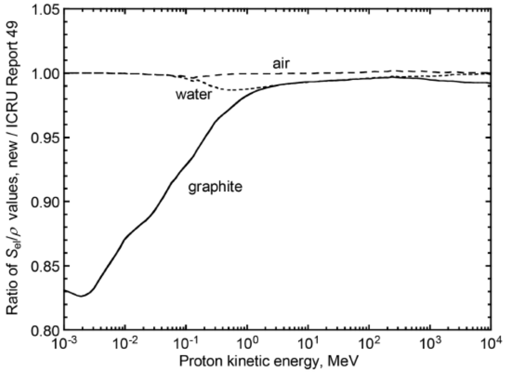

Figure 7.2. Ratios of the mass electronic stopping power for protons recommended in this Report to those given in ICRU Report 49 (1993), as a function of the proton kinetic energy, for graphite (solid line), liquid water (short dashes), and air (long dashes).

Changes in stopping powers

Some of the new data results in apparently very big changes

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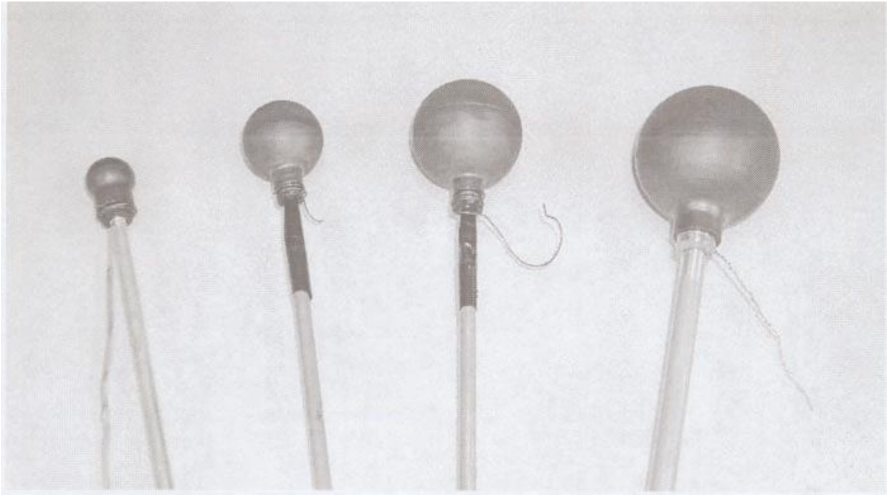
20 kV to 300 kV X Ray Air Kerma – Free-Air Ionization Chamber

$$K_{\text{air}} = \left(\frac{W_{\text{air}}}{e}\right)\frac{Q}{\rho_{\text{air}}V_{\text{eff}}}\left(\frac{1}{1-\bar{g}_{\text{air}}}\right)\prod_i k_i$$

^{60}Co, ^{137}Cs, ^{192}Ir Air Kerma – Graphite Cavity Ionization Chambers



$$K_{\text{air}} = \left(\frac{W_{\text{air}}}{\text{e}}\right)\frac{Q}{\rho_{\text{air}}V}\left(\frac{1}{1-\bar{g}_{\text{air}}}\right)\left[\frac{(S/\rho)_{\text{graphite}}}{(S/\rho)_{\text{air}}}\right]\left[\frac{(\mu_{\text{en}}/\rho)_{\text{air}}}{(\mu_{\text{en}}/\rho)_{\text{graphite}}}\right]\prod_i k_i$$

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What is the impact?

A. Key data

Quantity	Previous	This Report	Relative standard uncertainty (%)	Relative change (%)	Comments
W_{air} for electrons[a]	33.97 eV	33.97 eV	0.35	0	
W_{air} for protons[a]	34.23 eV	34.44 eV	0.4	0.6	See Section 5.4.4
W_{air} for carbon ions[a]	34.50 eV	34.71 eV	1.5	0.6	See Section 5.4.4
h_w (4°C)	0	0	0.15	0	Low-LET radiations
$G(Fe^{3+})$					See Table 5.8
I_{air}	85.7 eV	85.7 eV	1.40	0	
I_g	78 eV	81 eV	2.2	3.8	See footnote b, below
I_w	75 eV	78 eV	2.6	4.0	

[a]High-energy (assumed asymptotic) value.
[b]This Report recommends the use of $\rho = 2.265$ g cm^{-3} in the evaluation of the density-effect correction to the electronic stopping power of charged particles in graphite.

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Impacts kV air kerma standards: increased uncertainty

Impacts dose calculations

Has a surprisingly large effect for certain situations

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What is the impact?

B. Practical dosimetry measurements

Quantity	Relative change, %		Comments
D_w for photons			See Eqs. (7.2) and (7.3)
$N_{D,w,^{60}Co}$	0		
$(s_{w,air}p_{ch})_Q$	+0.5		For lower-energy beam qualities
	+0.2		For higher-energy beam qualities
$(s_{w,air}p_{ch})_{^{60}Co}$	+0.7		
Total change in D_w for photons		−0.2	For lower-energy beam qualities
		−0.5	For higher-energy beam qualities
D_w for electrons			See Eqs. (7.2) and (7.3)
$N_{D,w,^{60}Co}$	0		
$(s_{w,air}p_{ch})_Q$	+0.3		
$(s_{w,air}p_{ch})_{^{60}Co}$	+0.7		
Total change in D_w for electrons		−0.4	
W_{air} for protons and carbon ions			See Eq. (7.6).
$N_{D,air}-N_K$	−0.2		See text following Eq. (7.6)
$(s_{w,air}p_{ch})_Q$	−0.4		Protons and carbon ions
Total change in $(W_{air})_Q$		+0.6	Based on the assumption $p_{ch,Q} \approx 1$
D_w for protons and carbon ions			See Eqs. (7.2) and (7.3).
$N_{D,w,^{60}Co}$	0		
$(s_{w,air}p_{ch})_Q$	−0.4		
$(s_{w,air}p_{ch})_{^{60}Co}$	+0.7		
$(W_{air})_Q$	+0.6		
Total change in D_w for protons and carbon ions		−0.5	

Assumes high energy beams and a Co-60 $N_{D,w}$ calibration

Changes are on the order of 0.5 % for all beams

Nothing to worry about?

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What is the impact?

B. Practical dosimetry measurements

Quantity	Relative change, %
D_w for photons	
$N_{D,w,^{60}Co}$	0
$(s_{w,air}p_{ch})_Q$	+0.5
	+0.2
$(s_{w,air}p_{ch})_{^{60}Co}$	+0.7

This change impacts every Co-60 air kerma calibration worldwide:

- Radiation protection calibrations
- Air-kerma based dose protocols (IAEA TRS-277, AAPM TG-21)
- Likely similar changes for Cs-137 and Ir-192 air kerma measurements
- Perhaps not significant clinically but definitely measurable

You will see changes in your calibration certificates!

Summary

- ✓ ICRU Report 90 provides an up-to-date review of data that impact ionizing radiation measurements
- ✓ There are recommendations for changes in key parameters that will impact primary standard dosimetry laboratories – changes to primary standards, increases in measurement uncertainties
- ✓ Some of these changes trickle down to reference dosimetry in the clinic
- ✓ No change is larger than 0.7 %, so it's not clinically significant but will be measurable using reference-class instruments
- ✓ Changes are planned to be adopted by the international community from **1st January 2018**

More Information

- ICRU Report 90 on AAPM web site (Publications)
- AAPM Virtual Library Presentations

2016 Annual Meeting

Steve Seltzer - “Key Data for Ionizing-Radiation Dosimetry”

Malcolm McEwen - “Worldwide Radiation Metrology”

Thank You