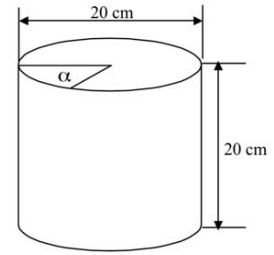
Dosimeter for Measuring Lens of Eye Dose

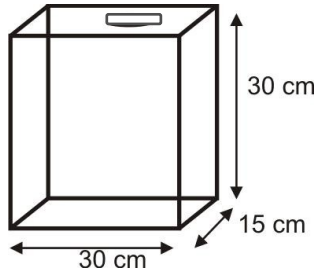
Chris Passmore, CHP

Mirela Kirr

C_k Debate

- C_k factors dependent on phantoms
  - ORAMED project (Optimization of RAdiation protection for MEDical) for eye lens dosimetry
    - ORAMED: Optimization of Radiation Protection of Medical Staff, F. Vanhavere, 2011
    - 20 cm high x 20 cm diameter cylinder
    - Water filled
    - Work started in 2008
  - Physikalisch-Technische Bundesanstalt (PTB) 2011
    - 30 cm x 30 cm x 15 cm slab
    - Water filled
    - Work started in 2012
  - PTB 2015
    - 20 cm high x 20 cm diameter cylinder
    - Water filled
- Which C_k factors to use?
  - ISO 4037-3 has both but cylindrical phantom preferred
  - IEC 62387 adopted cylindrical phantom due to issues noted with slab phantom at large angles





International Electrotechnical Commission (IEC) Type Testing

- IEC TC45/SC45B/WG14
- No agreed upon *H*p(3) C_k conversion factors internationally until IEC 62387:2012
  - Technically no agreed upon method to calculate the lens dose
  - C_k factors based on Physikalisch-Technische Bundesanstalt (PTB) data [6]
  - Dose conversion factors defined on slab phantom for *H*p(3) in disagreement with ORAMED findings
  - Slab phantom is widely used and available in many calibration laboratories
- IEC 62387:2017 used for type testing dosimeters
  - ORAMED cylindrical phantom and associated C_k factors adopted in this version


IEC 62387

Edition 1.0 2012-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation

Instrumentation pour la radioprotection – Systèmes dosimétriques intégrés passifs pour la surveillance de l'individu et de l'environnement des rayonnements photoniques et bêta

INTERNATIONAL ELECTROTECHNICAL COMMISSION

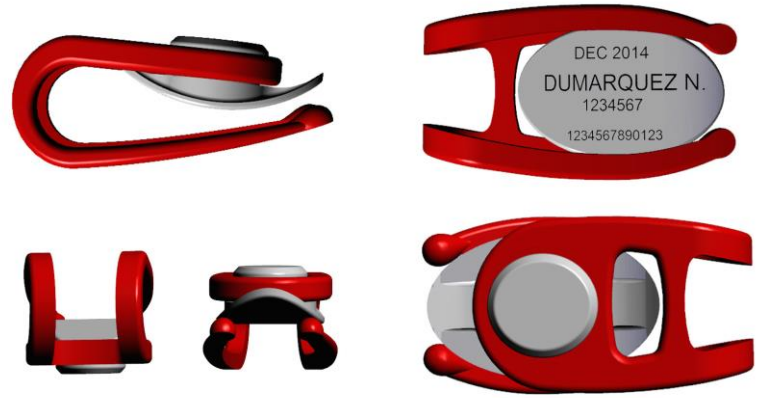
COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE XC

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

LANDAUER VISION Dosimeter for Measuring Lens of Eye

- Dosimeter designed to assess personnel Lens of Eye dose, *Hp*(3) due to exposure to ionizing radiation using thermoluminescent dosimetry (TLD) technology.
- Does not interfere with the field of view
- Can be worn on front or behind protective equipment
- TLD detector placed in the holder cavity and ultrasonically welded
- Laser engraved unique identifier for maintaining chain of custody
- Mounts on safety glasses, shields, face masks or surgical caps
- Easy cleaning



Performance Testing

- Dosimeters analysed using CO_2 Laser Heated TLD Readers
- *Hp*(3) calculated in accordance with current practices for Approved Dosimetry Services for both irradiated groups and background dosimeters
- Dose calculation algorithm for lens of eye developed with the reader calibrated to Hp(0.07) and dosimeters irradiated to a delivered dose of *Hp*(3)
- Background subtracted out of all dosimeters as per current processing procedures

Type Testing Results (I)

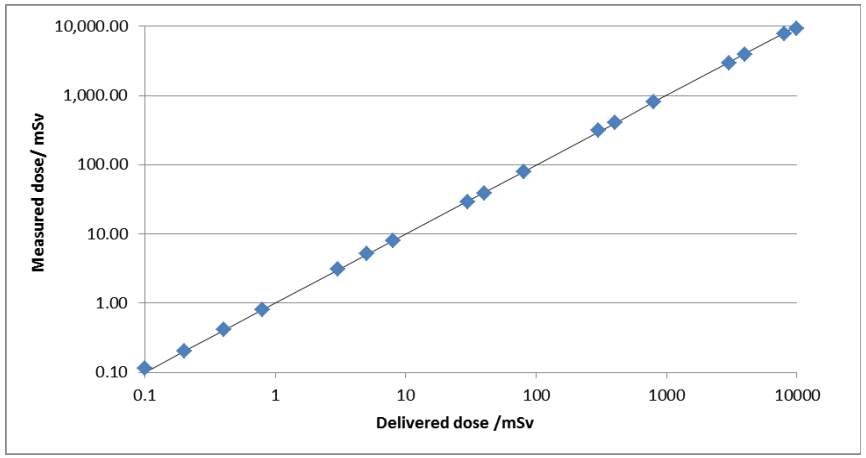
- Meets IEC 62387:2017 verified by 3rd party
  - Irradiations conducted at Laboratoire National Henri Becquerel (LNHB)
- Test Results
  - Coefficient of Variation
    - Test performed 18 dose equivalent values using Cs-137
    - Dose equivalent values between 0.05mSv and 10,000mSv
    - Ten dosimeters irradiated between 0.05mSv (5mrem) and 4mSv (400mrem)
    - Pass for *Hp*(3) between 0.05mSv and 10,000mSv

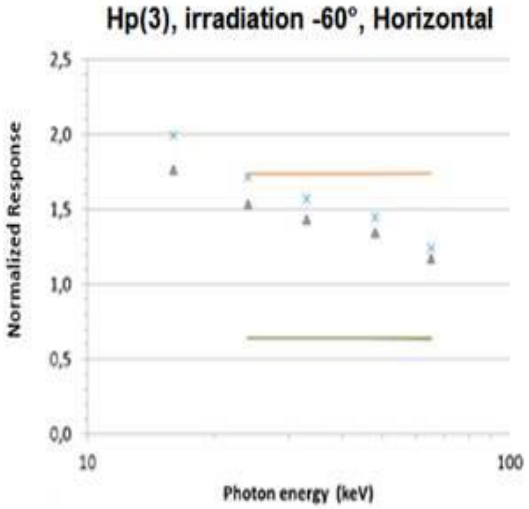
Criteria						
conv. True value (mSv)	0.050	0.100	0.201	0.40	0.80	3.00
H < 0.3 mSv ; 15% x c1	0.193	0.186	0.186			
H < 0.3 mSv ; 15% x c2	0.261	0.244	0.244			
coef of variation, v	0.113	0.087	0.058			
18.75-(H/0.08 mSv) % x c1				0.170	0.108	
18.75-(H/0.08 mSv) % x c2				0.294	0.294	
coef of variation, v				0.057	0.050	
H >= 1.1 mSv ; 5% x c1						0.062
H >= 1.1 mSv ; 5% x c1						0.081
coef of variation, v						0.025

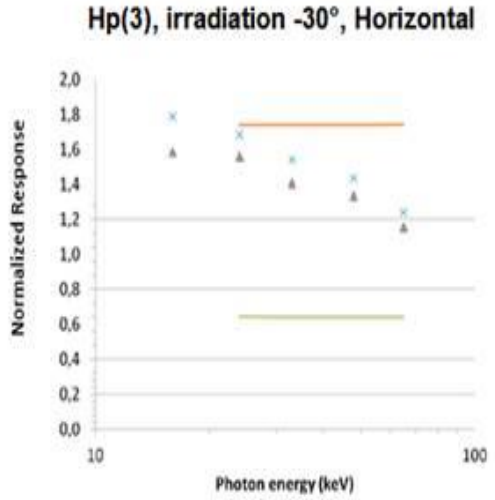
Criteria						
conv. True value (mSv)	400	801	3001	4001	8001	10000
H >= 1.1 mSv ; 5% x c1	0.064	0.064	0.064	0.069	0.064	0.064
H >= 1.1 mSv ; 5% x c1	0.087	0.087	0.087	0.099	0.087	0.087
coef of variation, v	0.037	0.036	0.038	0.034	0.042	0.033

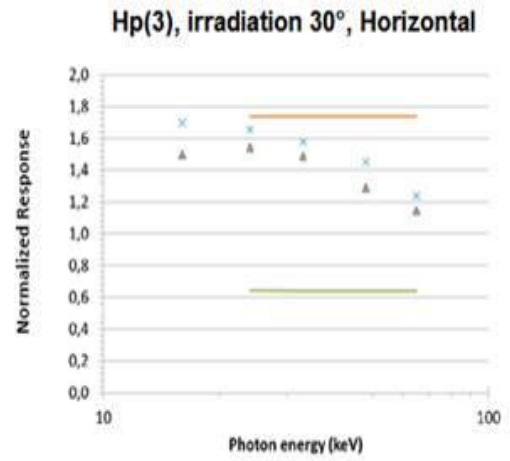
Type Testing Results (II)

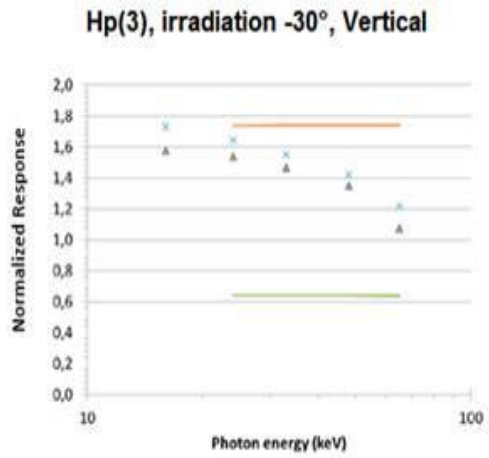
- Test Results
  - Linearity
    - Pass for *Hp*(3) between 0.05mSv (5mrem) and 10000mSv (1000mrad)
  - Energy and Angular Response
    - Pass for *Hp*(3) all energy range from NS30 (24keV) to Cs 137 (662keV), +/- 60°











Type Testing Results (III)

- Fade, Build up, Self Irradiation
  - 6 dosimeters groups used (3 groups irradiated to 0.7mSv using Cs-137 and 3 groups used for background monitoring)
  - Group 1 and 4 read 24 hr after irradiation
  - Group 2 and 5 read after one week
  - Group 3 and 6 read after 3 months
  - Fade less than 10% over 3 months

+24h	G1
((Gi - G2) - U_{com})	0.022
((Gi - G2) + U_{com})	0.060
Criteria	0.711

+3 months	G3
((Gi - G2) - U_{com})	0.051
((Gi - G2) + U_{com})	0.001
Criteria	0.701

0.91	0.910
((G2 / G1) - U_{com})	1.004
((G2 / G1) + U_{com})	1.082
1.11	1.110

Inter-comparison Studies (I)

- Test 1 organized by Personal Radiation Monitoring Group (PRMG) in United Kingdom
  - Five personal Dosimetry Services participated
  - The irradiations of dosimeters occurred on cylindrical water phantom, recommended by the ORAMED project and defined in the ISO 4037-3.
  - The irradiation techniques--RQR6 (80kV, ~ 40keV)
- Results
  - Two groups of doses 0.69mSv (69mrem) and 10.46mSv (1046mrem)
  - Performance analysed based on HSE testing criteria for extremity dosimeters
  - Passed band A and band B with bias of -24% for low doses and -8% for higher doses
  - Dosimeter performance analysed against the ISO 14146, all results pass

PRMG Eye Dosemeter Intercomparison - X-ray Irradiations

Exercise no.	**48**
Issuing Centre	**LANDAUER**
Date of Reading Dosimeters	
TLD type/formulation:	
Irradiating Centre:	**RRPPS**
Dosemeters irradiated	25/07/2017
Order number	APP/0123/UK

Dosemeter number	Reported dose (mSv)	Applied dose (mSv)	Reported / Applied	
1001139	0.49	0.69	0.71	
1001140	0.56	0.69	0.82	
1001141	0.51	0.69	0.74	
1001142	0.55	0.69	0.80	
1001143	0.49	0.69	0.72	
1001144	9.22	10.46	0.88	
1001145	9.69	10.46	0.93	
1001146	8.80	10.46	0.84	
1001147	9.50	10.46	0.91	
1001148	10.49	10.46	1.00	Background subtracted
1001152	0.00	0.00		0
1001154	0.00	0.00		

Applied dose Hp(10) (mSv)	Ratios	Applied dose Hp(10) (mSv)	Ratios
0.69		**10.46**	
	0.71		0.88
	0.82		0.93
	0.74		0.84
	0.80		0.91
	0.72		1.00
mean	0.76	mean	0.91
RSD(n-1)%	6.7	RSD(n-1)%	6.6
Bias%	-24.2	Bias%	-8.8
HSE Banding	**B**	**HSE Banding**	**A**

Intercomparison Studies (II)

- **Test organized by EURADOS (Session 2016)**
  - Dosimeters from 22 Dosimetry Services around the world
  - Dosimeters were irradiated to a variety of photon and beta sources and X Ray techniques at different angles
  - Landauer's results demonstrates acceptable performance for use in occupational fields requiring lens of eye monitoring.
  - Additional investigation was performed to optimize the dosimeter design
    - Landauer barely outside the trumpet curve for RQR6, 75°
    - 32% of participants showed results outside of Trumpet curve for RQR6, 75°

EURADOS European Radiation Dosimetry Group

PARTICIPANT AAO - Reference quantity $H_p(3)$ - Photon qualities

Radiation Quality	Dosimeter id	Conventional true value ± uncertainty (k=2) $H_p(3)_c$ (mSv)	Reported by participant H_r * (mSv)	Reported by participant H_s ** (mSv)	Response R= $\frac{H_s}{H_p(3)_c}$	Response ISO 14146 Criteria	Mean results per set-up $\overline{H_s}$ (mSv)	Mean results per set-up $\overline{R}$	Mean results per set-up CV (R) (%)
S-Cs, 0°	AAO_9	2.900 ± 0.088	2.616	2.616	0.90	YES	2.618	0.90	0.0
	AAO_10	2.900 ± 0.088	2.620	2.620	0.90	YES			
S-Cs, 60°	AAO_11	2.800 ± 0.084	2.320	2.320	0.83	YES	2.361	0.85	2.5
	AAO_12	2.800 ± 0.084	2.402	2.402	0.86	YES			
RQR 6, 0°	AAO_17	2.600 ± 0.130	3.652	3.652	1.40	YES	3.514	1.35	5.2
	AAO_18	2.600 ± 0.130	3.376	3.376	1.30	YES			
RQR 6, 45°	AAO_19	2.500 ± 0.126	3.423	3.423	1.37	YES	3.410	1.37	0.5
	AAO_20	2.500 ± 0.126	3.396	3.396	1.36	YES			
RQR 6, 75°	AAO_21	2.400 ± 0.120	4.016	4.016	1.67	NO	3.906	1.63	3.9
	AAO_22	2.400 ± 0.120	3.796	3.796	1.58	NO			
N-100, 0°	AAO_23	2.700 ± 0.136	2.825	2.825	1.05	YES	2.832	1.05	0.0
	AAO_24	2.700 ± 0.136	2.838	2.838	1.05	YES			

* H_r Participant reported value (corrected for background according to the routine protocol of the participant)

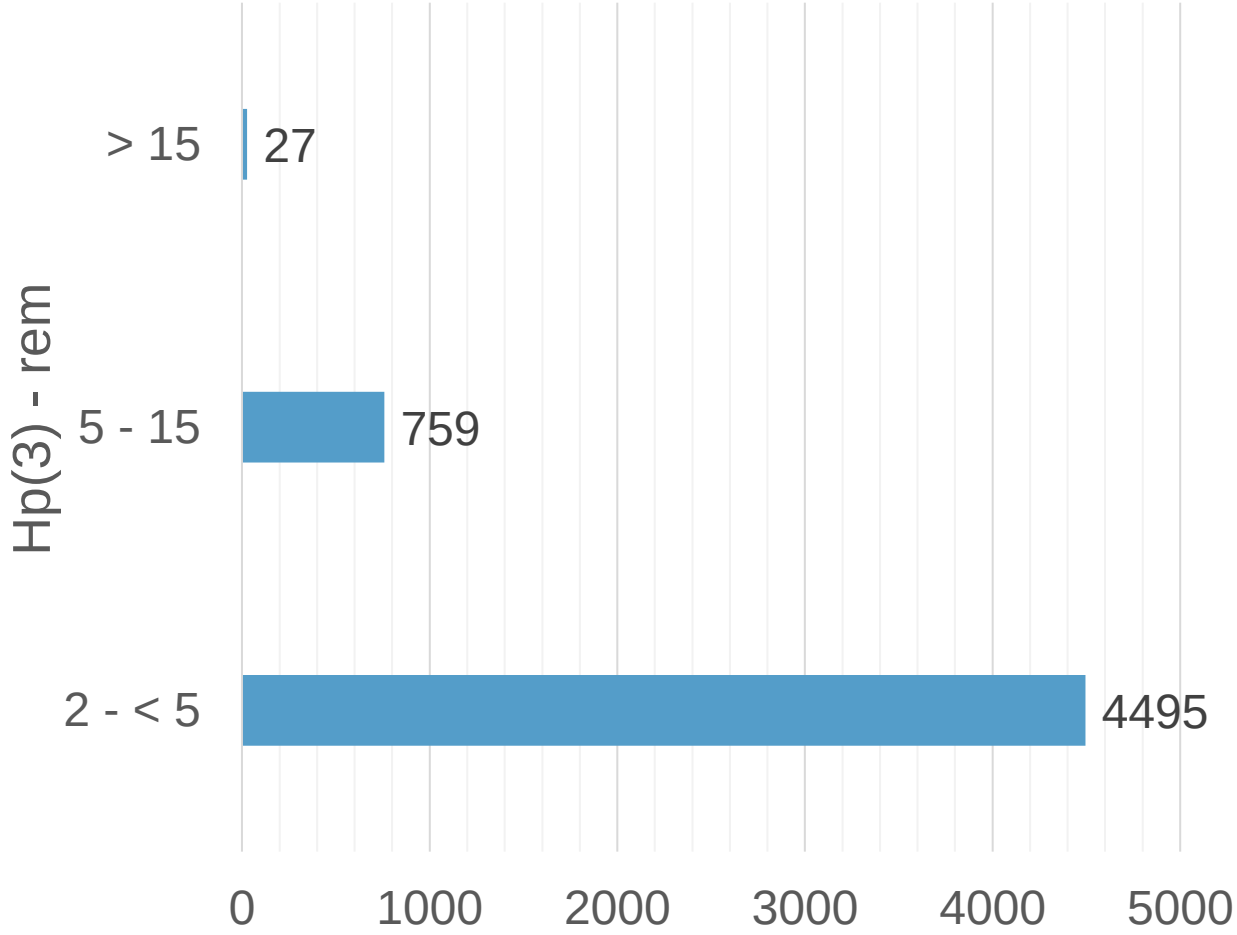
** H_s Participant reported value corrected for transit: $H_s = H_r - H_t$

Correction for transit for S-Cs: $H_t = 0.000$ mSv

Correction for transit for other photon qualities: $H_t = 0.000$ mSv

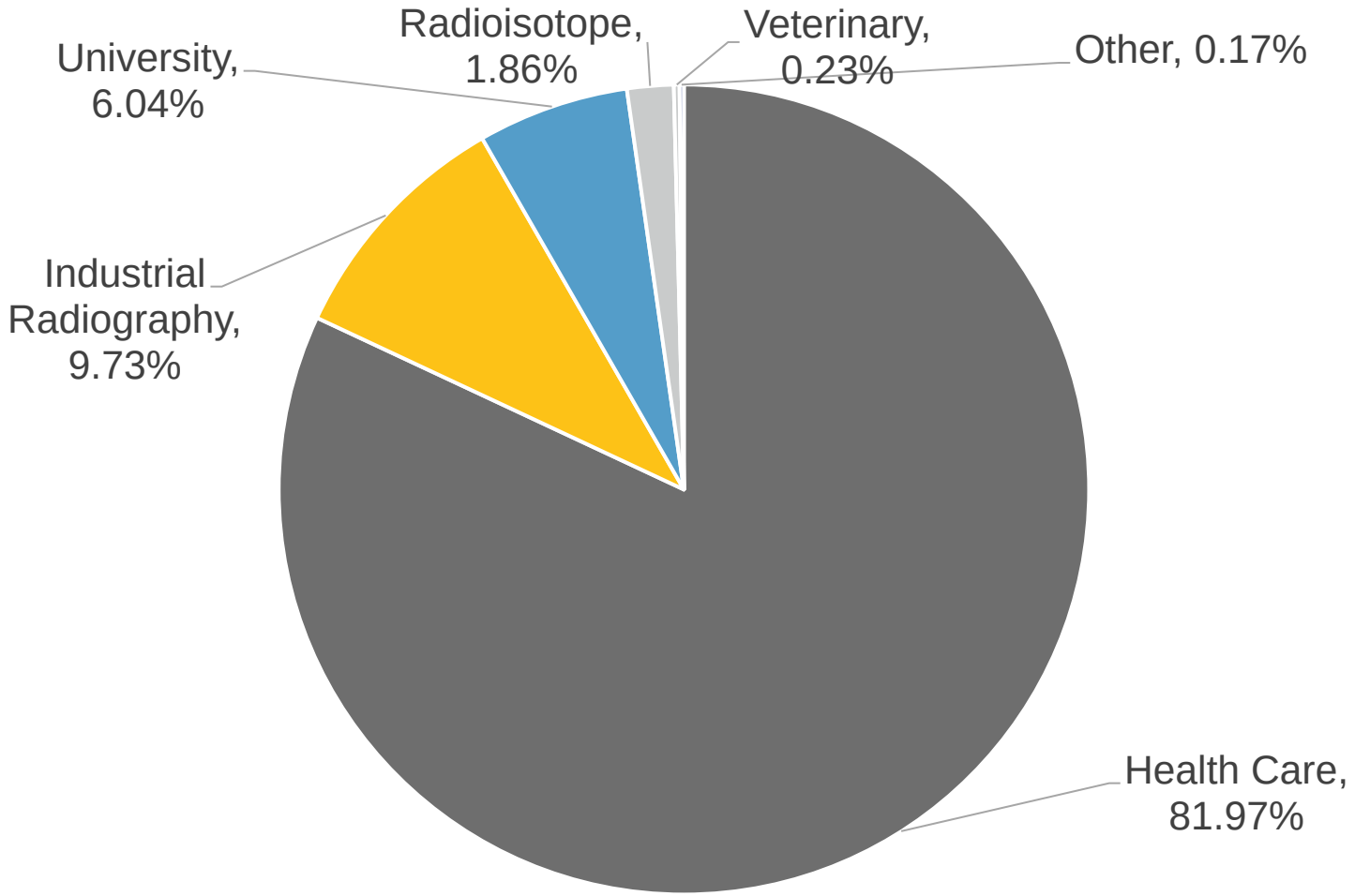
2017 *Hp*(3) Data from Landauer Repository

- 5281 workers exceeded 2 rem (20 mSv) in 2017
  - ICRP 103 lens dose limit of 2 rem (20 mSv) per year averaged over 5 years and currently in effect in Europe [12]
- 786 workers exceeded 5 rem (50 mSv) in 2017
  - NRC proposed to reduced lens of eye dose limit from 15 rem (150 mSv) to 5 rem (50 mSv) per year [13]
- 27 workers exceeded 15 rem (150 mSv) in 2017
  - Current 10CFR20 lens dose limit of 15 rem (150 mSv) [14]



Industry Segments with *Hp*(3) > 2 rem (20 mSv)

- Health Care, Industrial Radiography, University, Radioisotope, Veterinary, and Other (Transportation, Dental, and Research) are Industry Segments with doses greater than 2 rem (20 mSv)
  - University data might be closely associated with Health Care which would make it 88% of the total.



27 Participants >15 rem (150 mSv) by Occupation

Occupation	% of the Total >15 rem
Industrial Radiography	14.8%
Pain Management - Rehab	14.8%
Radiology - diagnostic radiology	14.8%
Vascular Surgery	14.8%
Interventional Radiology	7.4%
Cardiologist	3.7%
Clinical Psychologist	3.7%
Obstetrics & Gynecology	3.7%
PET Research Pediatrics and Tuberculosis	3.7%
Psychiatry & Neurology	3.7%
Radioisotope	3.7%
Security Threat Detection Research	3.7%
Speech-Language Pathologist	3.7%
Dental Implants	3.7%

- Categorized workers into disciplines using series codes and internet search
- Top 5 Occupations >15 rem (150 mSv)
  - Industrial Radiography (4)
  - Pain Management – Rehab (4)
  - Diagnostic Radiology (4)
  - Vascular Surgery (4)
  - Interventional Radiology (2)
- The remaining contained some interesting occupations
  - Researcher using 18F-FDG positron emission tomography (PET) scans to determine if tuberculosis treatment is working or drug resistant.
  - Psychiatrist specializing in cancer patients
  - Speech Pathologist using video-assisted fluoroscopy of swallowing (VFSS)
  - Dental implants

Conclusions

- Contradictions in ISO and IEC standards have been resolved.
  - C_k factors exits now to enable calculation of Hp(3) but ANSI N13.11 has not addressed Hp(3).
- Landauer could provide an ergonomical dosimeter suitable for measuring lens of eye
- Landauer data shows 5281 workers exceeded Hp(3) of 2 rem in 2017
  - 27 of which exceeded the federal limit of 15 rem for Hp(3)
- Landauer data shows health care industry leads the way with the number of workers with Hp(3) dose > 2 rem.
  - 82% and could be as high as 88% when considering universities.
  - This can be even more troubling considering non-uniform fields and complication of dosimeter placement.
- Health care industry will see significant impact if dose limits are reduced with key medical staff members exceeding lens of eye dose threshold regardless if 2 or 5 rem is adopted.
  - Credit for PPE and shielding similar to Webster effective dose equivalent calculations may be needed going forward.
- Health care industry will see significant impact if dose limits are reduced with key medical staff members exceeding limits if additional PPE or engineering controls are not implemented.
- 67% reduction noticed in the number of people exceeding Hp(3) annual limit as compared to the average that exceed in 2014, 2015, and 2016. Data from 2017 NRC Regulatory Information Conference

References

1. Federal Radiation Council, Staff Report No. 1, FRC60b, *Background Material for the Development of Radiation Standards*, May 13, 1960.
2. Landauer's Technical Basis for Lens-of-Eye Dose Calculation Method, C. Passmore, September 30, 2011
3. Soares CG, Martin PR. A consistent set of conversion coefficients for personnel and environmental dosimetry. Proceedings of the Panasonic User's Group Meeting, Somerset, PA; 5-9 June 1995.
4. ORAMED: Optimization of Radiation Protection of Medical Staff, F. Vanhavere, 2011
5. Radiat Prot Dosimetry, 2012 Jan;148(2):139-42. doi: 10.1093/rpd/ncr028. Epub 2011 Mar 9. *H*p(0.07) photon dosimeters for eye lens dosimetry: calibration on a rod vs. a slab phantom. Behrens R
6. NUREG/CR-1595, Radiological Assessment of Steam Generator Removal and Replacement: Update and Revision Table 2, December 1980
7. IAEA - New Dose Limits for the Lens of the Eye Implications and Implementation, E. Vano, *Practical issues for implementing the dose limit to the lens of the eye (medical),* October 2012
8. Type Test of the Lens of Eye Dosemeter of Landauer, LNHB 2015/37