The Future Direction of Passive Dosimetry

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Presentation Outline

History of Passive Dosimetry

Dosimetry Technology

Commercial Aspects

Standards

Origins of Thermoluminescence

Born: January 25, 1627, Ireland
Died: December 30, 1691, London
Education: University College, Oxford, Eton College

On October 27, 1663, Robert Boyle borrowed a diamond from his acquaintance, Mr. Clayton. And had some interesting times with it.

"Eleventhly, I also brought it to some kind of Glimmering Light, by taking it into bed with me, and holding it a good while upon a warm part of my naked body.

Twelfthly, to satisfy my self, whether the motion introduce'd into the stone did generate the light upon the account of its producing heat there, I held it near the flame of a candle, Till it was qualify'd to shine pretty well in the dark"

Robert Boyle (1663) report on a study he conducted to discover the cause of the luminescence behavior of a diamond which belonged to Mr. Clayton

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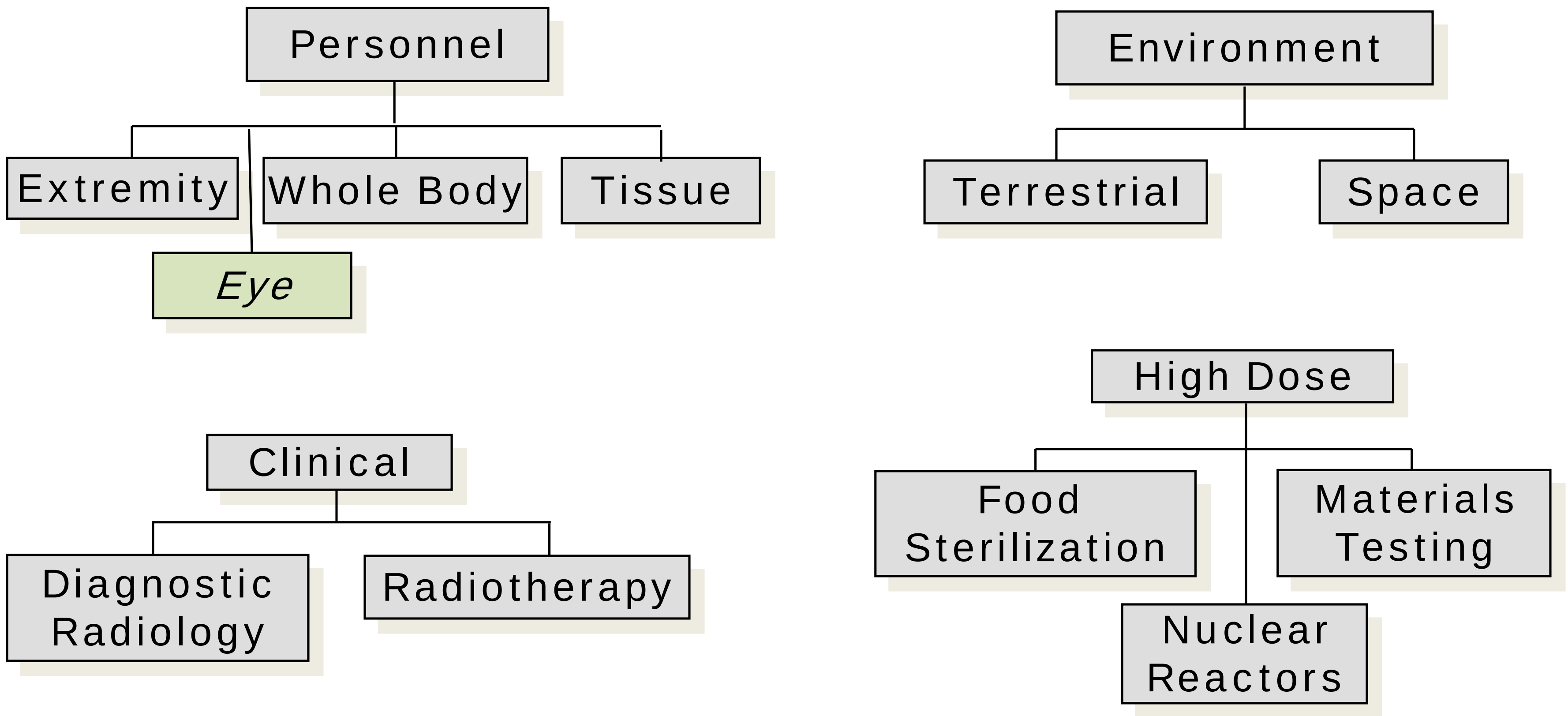
Thermoluminescence History

- 1663 – Robert Boyle discovered the TL phenomena (Diamond)
- 1920s – Marie Curie investigated the effects of radiation (radium) on calcium materials (CaF_2)
- 1950s – Farrington Daniels (UW) first suggested the use of thermoluminescence as a technique in radiation dosimetry (~TLD-100 LiF)
- 1960s – Harshaw Chemical company formulates TLD-100 (LiF:Mg,Ti)
- Many other TL, OSL & RPL materials have been studied and some commercialized to date

Applications of Passive Dosimetry



Source: McKeever S.W.S., Moscovitch M., and Townsend P.D., "Thermoluminescence dosimetry materials – properties and uses", Nuclear Technology Publishing, Kent, England. ISBN 1 870965 19 1, (1995).

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Traditional Passive Dosimetry Technologies

TLD	OSL	RPL
Thermo Fisher	Landauer	Chiyoda / Toshiba
Panasonic	Dosimetrics	
RADOS (Mirion)	Freiberg / Nutech	
TLD Poland		
Freiberg / Nutech		

Many other country specific systems and materials with limited commercial extent

Fringe Passive Dosimetry Systems

Combined OSL & TLD

- High Resolution 3D Imaging
- Sample Automation
- Research Focus

Electron Spin Resonance (ESR)

- Alanine Dosimetry plus Tissue, Blood, Nails & Bone
- Detection Beginning to Encroach on Personal Monitoring

Passive-Active & Active Dosimetry

Passive-Active Dosimetry


Mirion Dosime

Active Dosimetry

Active & Passive Dosimetry

- Camera Provides Active Dosimetry
- Passive Dosimetry
  - Screen
  - Electronic Components
- Potentially Useful for Unexpected Radiological Events
- Cellular Provides Radiological Network

Ideal Personal Dosimetry Characteristics

Material

- Tissue Equivalent
- Energy Independent
- Cover Wide Dose Range
  - Environmental to Accident
  - Doserate Independent
  - No Supra / Sub Linearity
- No Fade
- Stable and Long Life
- Light Sensitivity Manageable
- Ability to Clear the Dosimetry Material Without Special Processing
- Complete Chain of Custody
- Able to Meet Current and Potential Future Requirements
- Linear or No Dose Algorithm

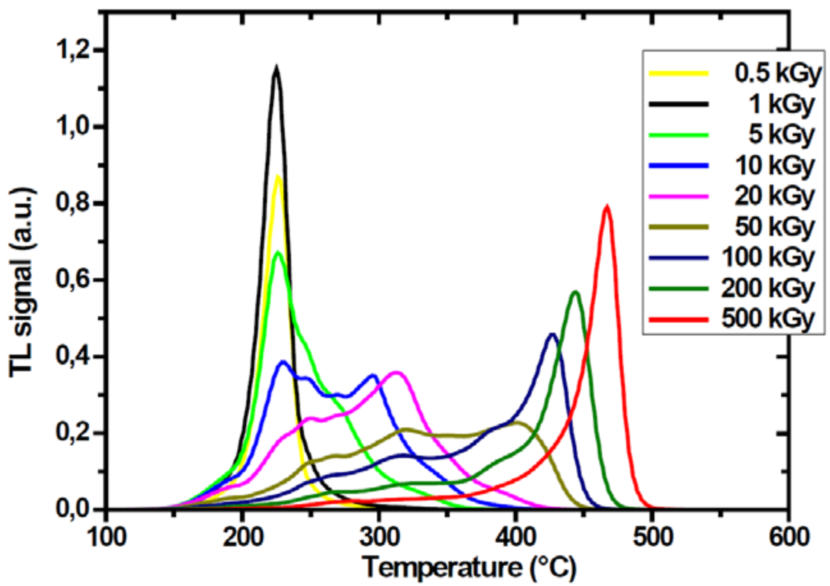
Instrument

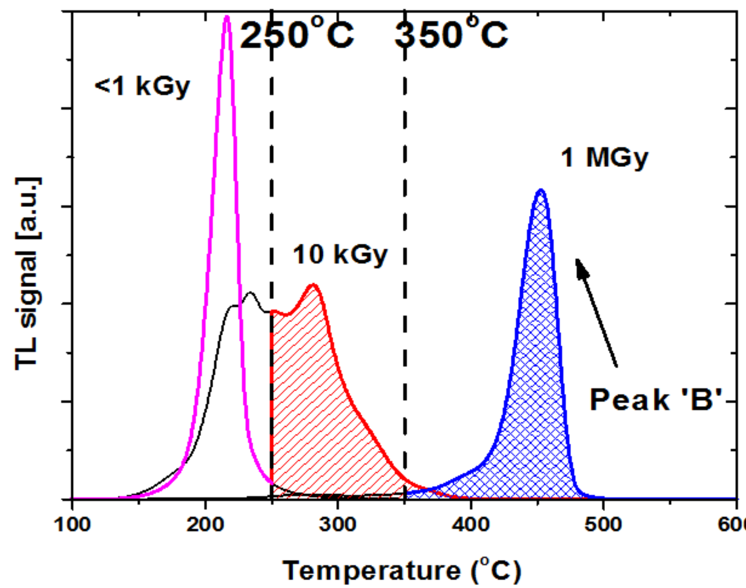
- Cover Wide Dose Range
- Capable of Reading Various Material Types
- Accurate Reproducible Readout
- Optimized Light Collection of Emitted TL
- Built In QA / QC Capability
- Reliability
- Easy to Maintain & Support
- Adequate Capacity Suited for Dosimetry Requirements
- Modularity & Scalability

High Level Dosimetry w/LiF:Mg,Cu,P TLDs

QUALITIES, ENERGIES AND DOSE RANGES OF RADIATION USED FOR TESTS OF HIGH-DOSE HIGH-TEMPERATURE EMISSION OF LIF DETECTORS

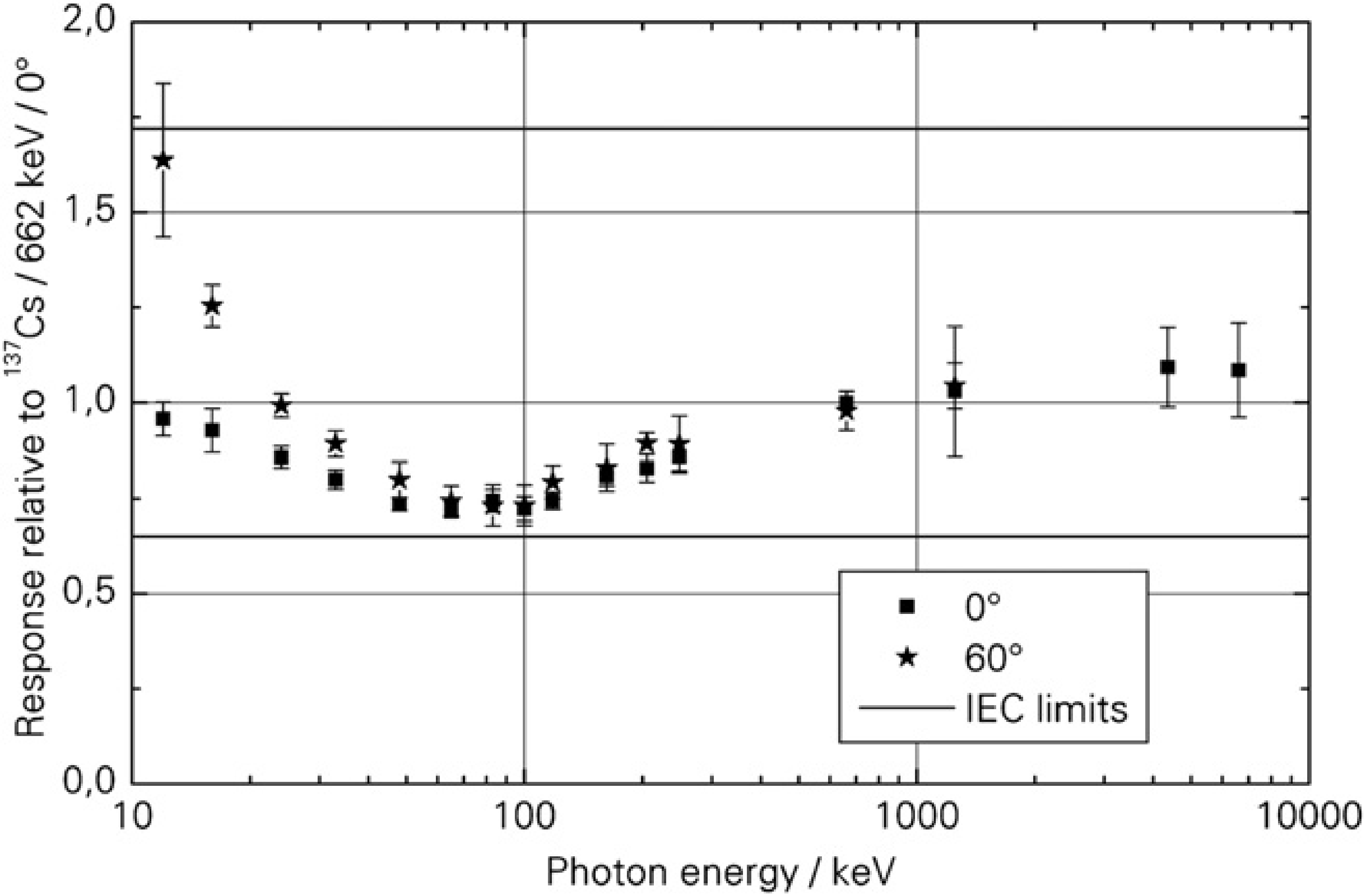
Radiation type	Radiation energy	Dose/Fluence range	References
Gamma	1.25 MeV	1 Gy - 1 MGy	[12], [13, [14], [15], [16]
Electron	6 MeV, 10 MeV	5 kGy - 1 MGy	[17], unpublished results
Proton	25 MeV, 23 GeV	1 Gy - 1 MGy	[15], [18],
Neutron	Thermal & epithermal; 180 MeV	$1x10^4$ - $3x10^{15}$ n/cm^2	[19], [20], [21], [22], [33]
Alpha-particle	5.5 MeV	$1x10^7$ - $1x10^{11}$ α/cm^2	[23]
Mixed field	>20 MeV, HEH	Up to 10^{15} HEH/cm^2	[24], [25], unpublished results



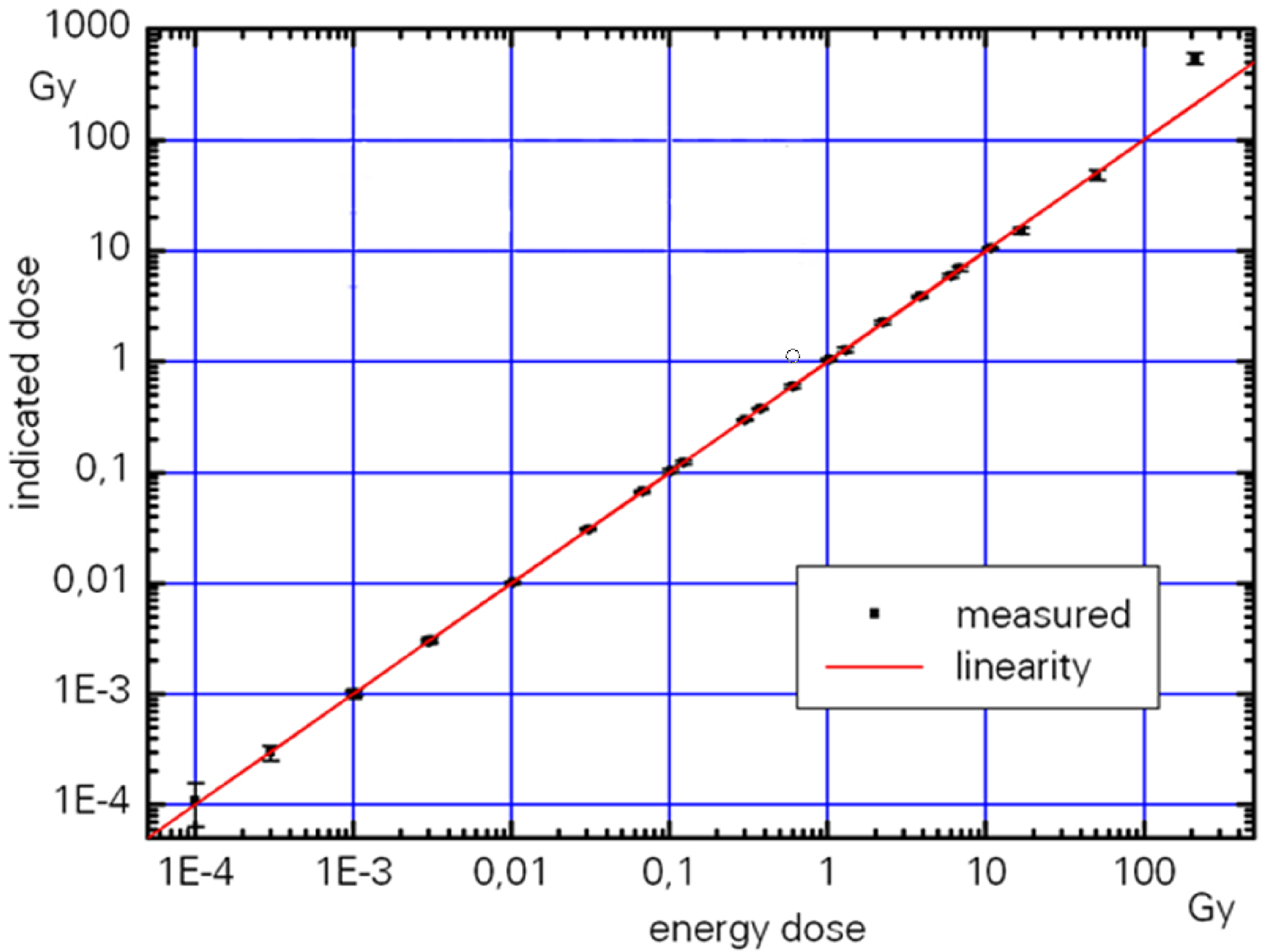


Source: Barbara Obryk - Radiation Physics and Dosimetry Department, Institute of Nuclear Physics Polish Academy of Sciences Radzikowskiego 152, 31-342 Kraków, Poland

Hp(10) Energy Independence - BeO



High Dose Linearity - BeO



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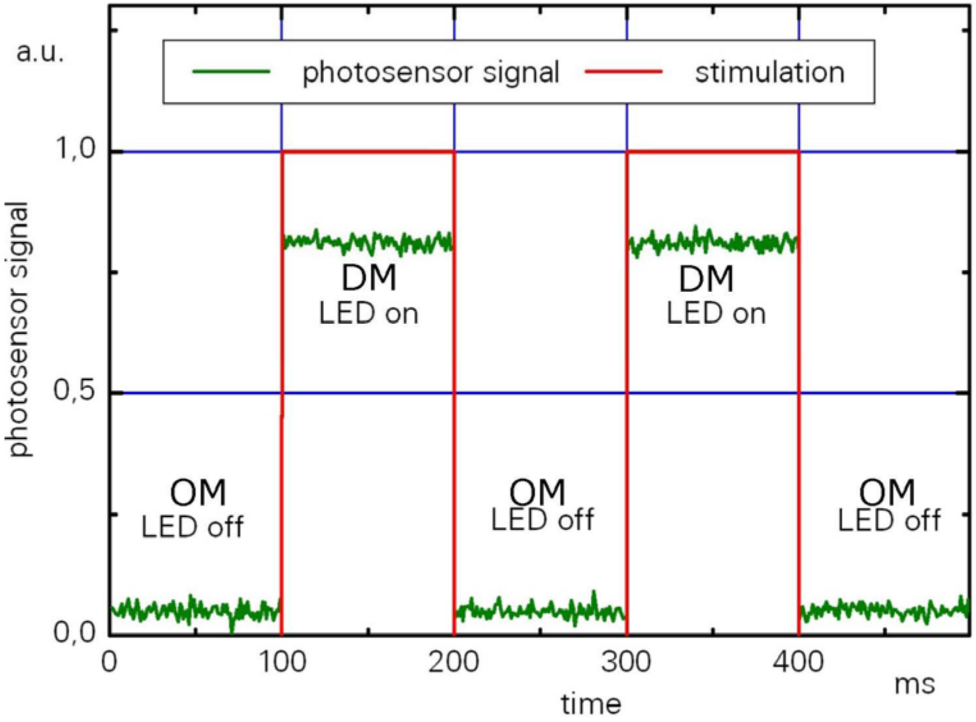
Collecting the Raw Data



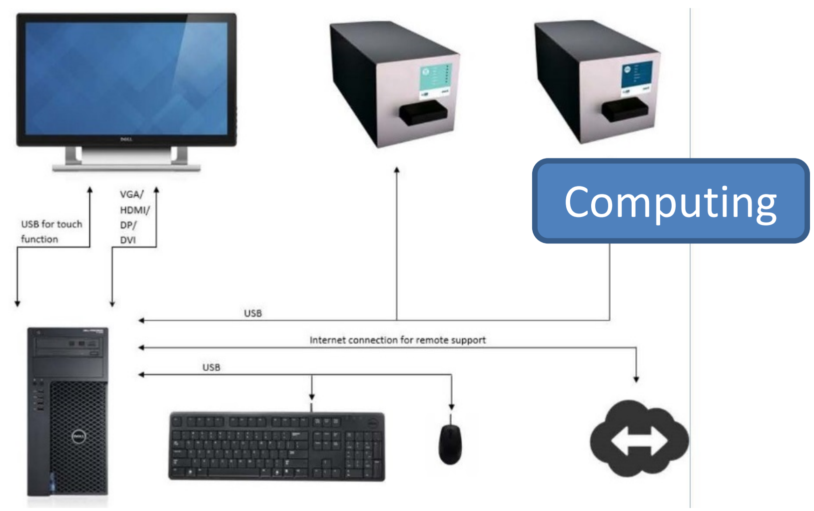
- Alternately Collect
  - OM1…OM5
  - DM1…DM5
- Also Collect
  - Dosimeter ID
  - Time stamp of the readout
  - Reader ID
  - Reader temperature T during readout

During Initial LED Stimulation the OSL Material is Evaluated to Determine Dose & LED Power Adjusted

Source: Dosimetrics BeO Dosimetry System

Traditional Fixed Capacity Systems

Modularity – Manual to Automatic



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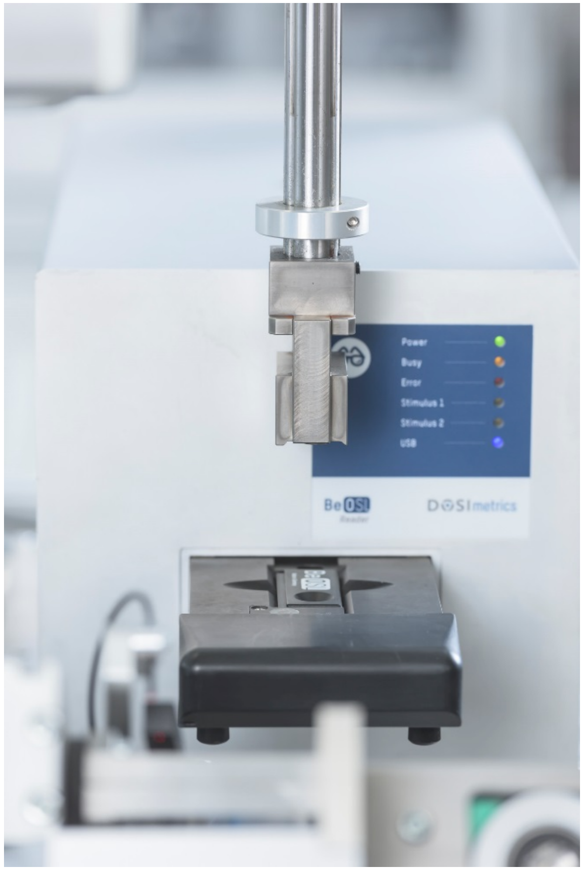
Scalability



Robotics Augment Manual Systems To Provide Automation & Scalability

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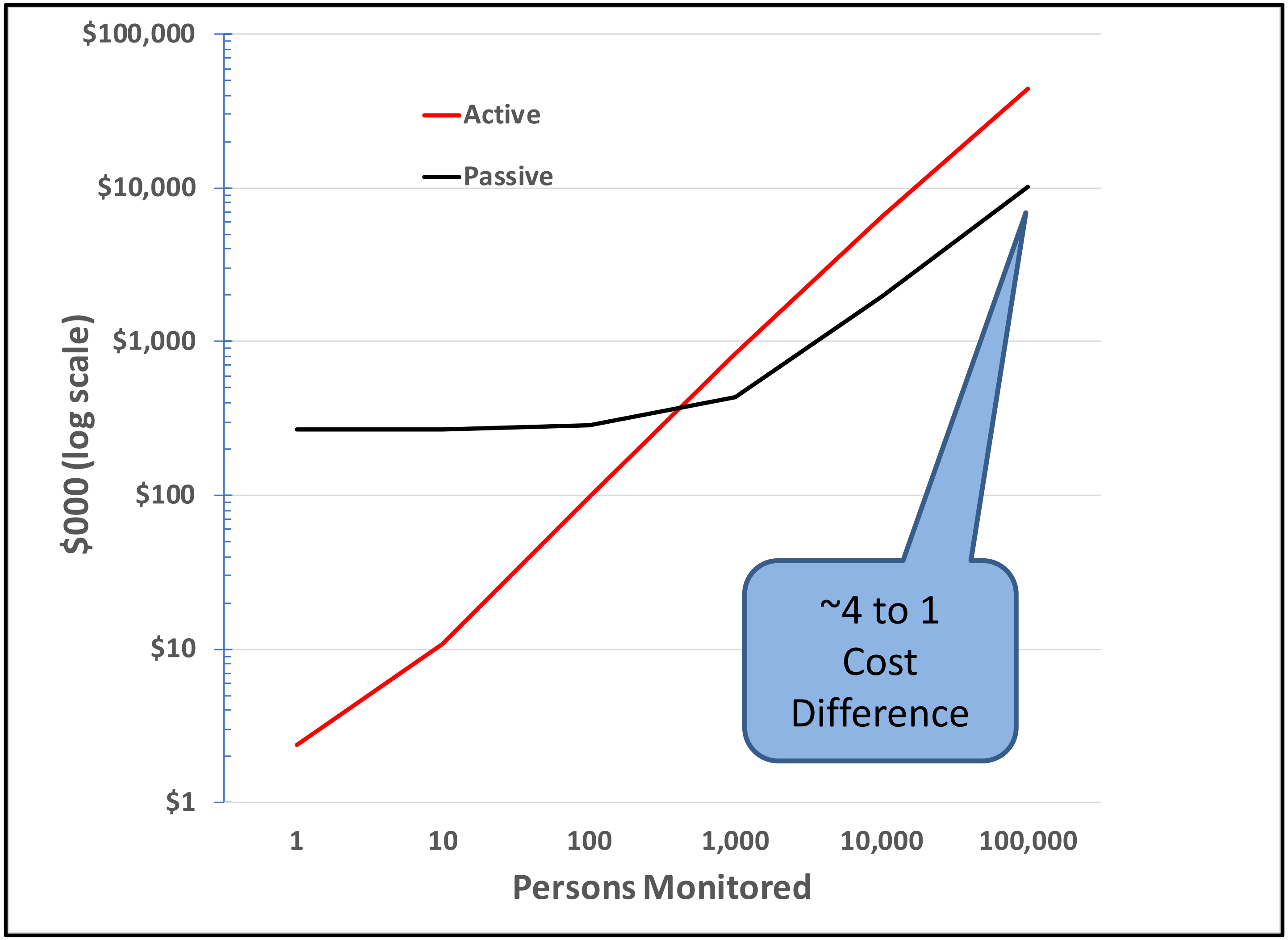
- Dosimetry Technology
- Commercial Aspects
- Standards

Active vs Passive Cost Comparison



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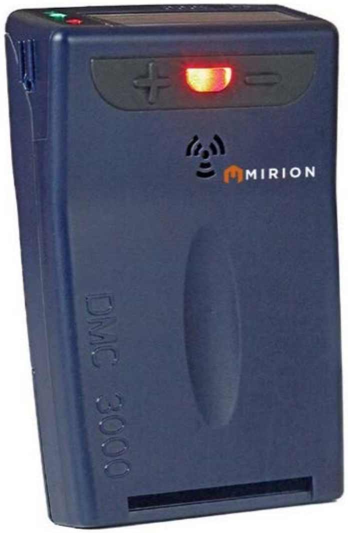
Active vs Passive Other Cost Considerations

- Annual Calibrations
  - Active Individually
  - Passive in Bulk
- Batteries
- Electronics Repair
- Replacement
- Shipping Costs
- Users / Management May Not Want To Perform Readouts



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USA Dosimetry Accreditation Programs

Department of Energy Labs
Department of Energy Laboratory
Accreditation Program (DOELAP)

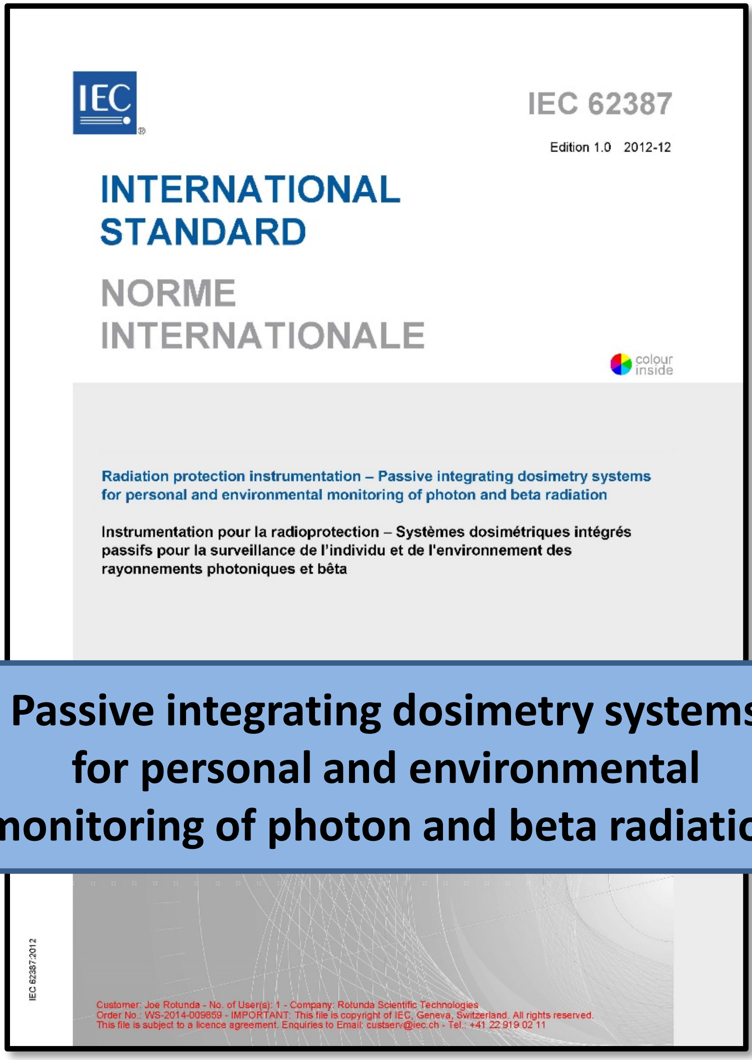
Nuclear Regulatory Commission
National Voluntary Laboratory
Accreditation Program (NVLAP)

Different Methods of Testing

- Accreditation
  - DOELAP
  - NVLAP
- Type Testing
  - IEC 62387
  - ISO 12794

ISO 17025 - General requirements for the competence of testing and calibration laboratories

IEC 62387 & ISO 12794 Passive Dosimetry Standards



IEC 62387

Edition 1.0 2012-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

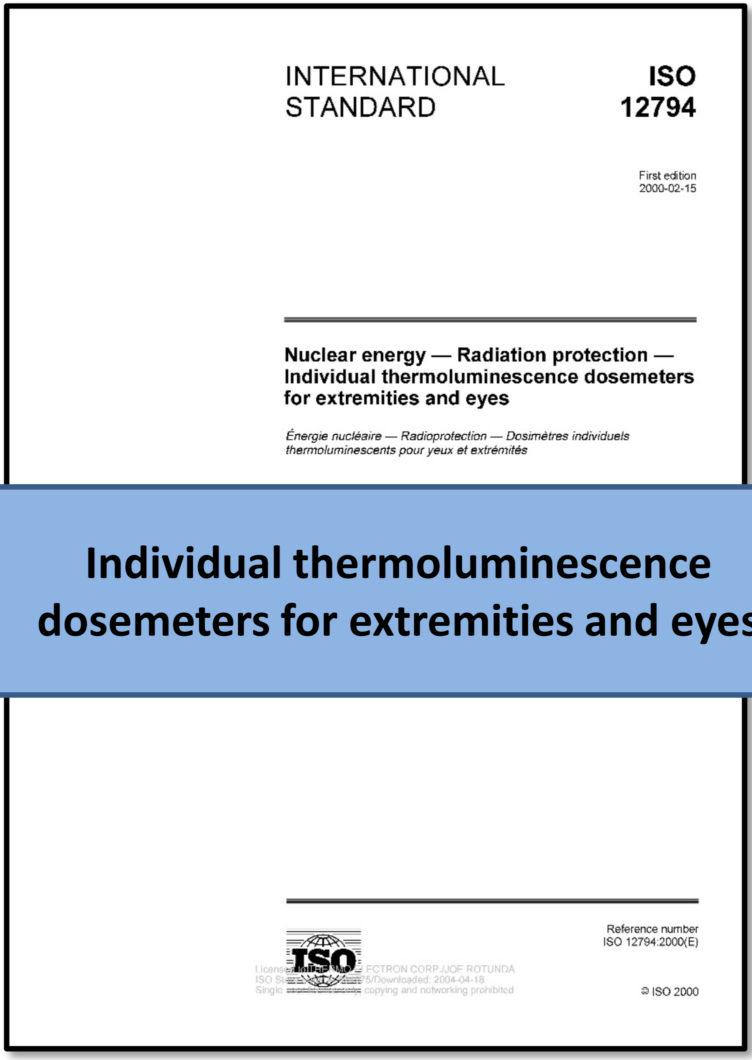
colour inside

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

IEC 62387:2012

Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation



INTERNATIONAL STANDARD

ISO 12794

First edition
2000-02-15

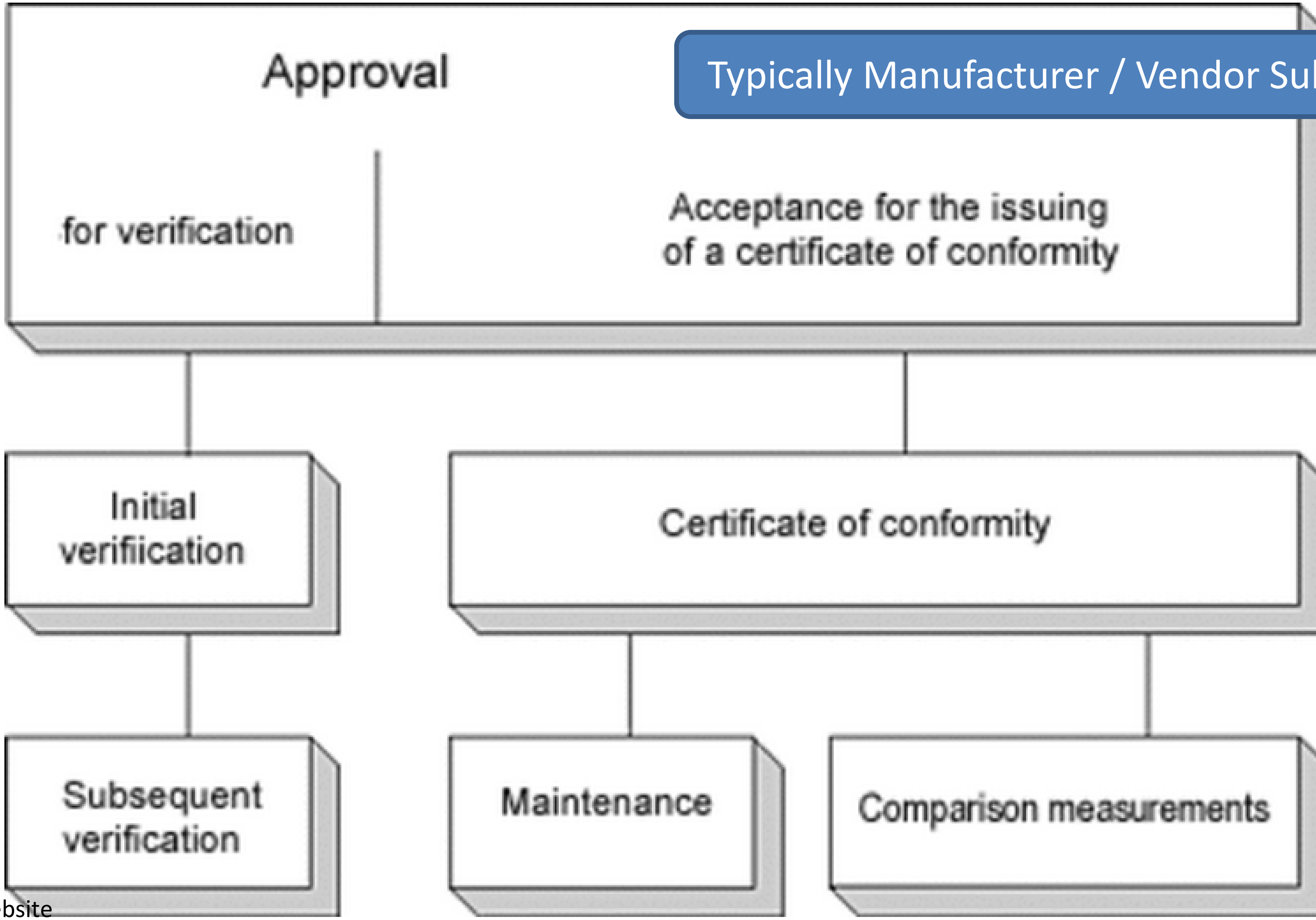
Nuclear energy — Radiation protection — Individual thermoluminescence dosemeters for extremities and eyes

Énergie nucléaire — Radioprotection — Dosimètres individuels thermoluminescents pour yeux et extrémités

Reference number
ISO 12794:2000(E)

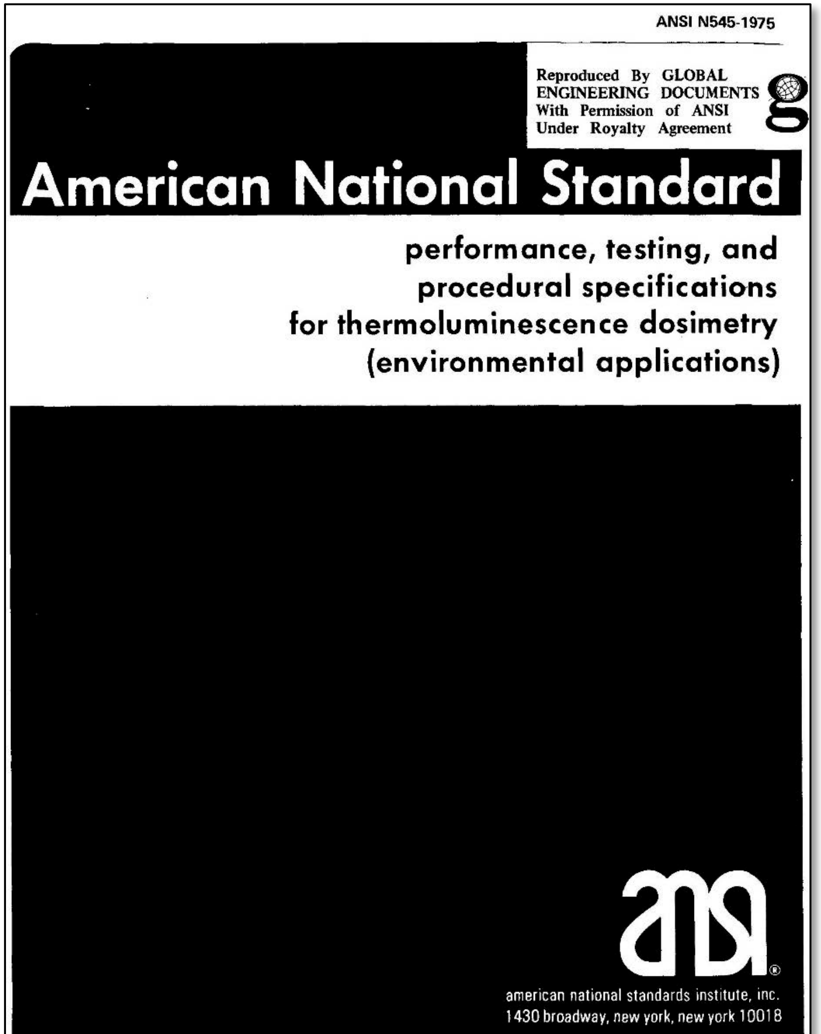
Individual thermoluminescence dosemeters for extremities and eyes

PTB Type Test Process



Source: PTB Website

ANSI Performance Testing N545-1975 & N13.37-2014



ANSI N545-1975

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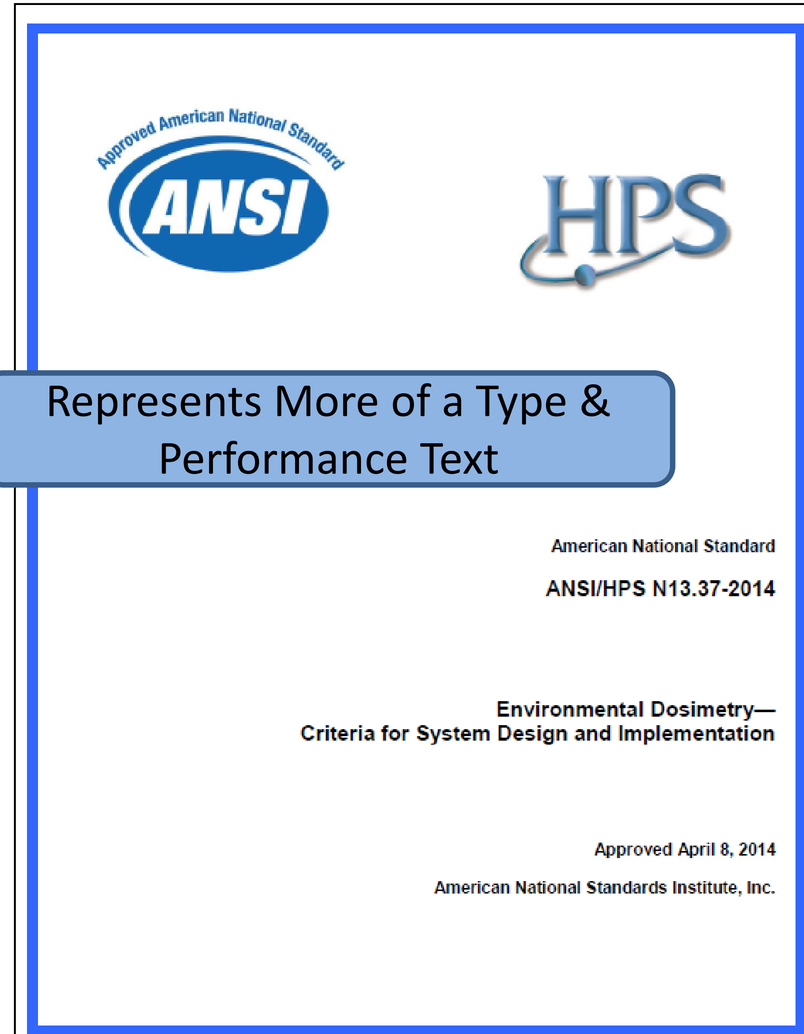
American National Standard

performance, testing, and procedural specifications for thermoluminescence dosimetry (environmental applications)

american national standards institute, inc.
1430 broadway, new york, new york 10018



American National Standard

ANSI/HPS N13.37-2014

Environmental Dosimetry—
Criteria for System Design and Implementation

Approved April 8, 2014

American National Standards Institute, Inc.

Represents More of a Type & Performance Text

The Future of Passive Dosimetry

Technology Developments

- Dosimetry Material Refinement to Create Near Perfect Characteristics
- Enhanced Neutron Dosimetry (OSL)
- Modular & Scalable Hardware
- Extremity & Eye Dosimetry (OSL)
- Linear Algorithms or No Algorithm

Disruptive Technology

- Many New and Innovative Technologies
  - Could Displace Current Technologies
  - Many Never Escape the Lab / Region
  - Some Unable to Scale-Up
  - Costs per Dose Possibly Higher
- Solutions to Pulsed Fields – Active Dos.
- Technology Fusion

Commercial

- Competition Forces Prices Down
- New Vendors Entering the Market
- Some Vendors Exit The Market
- Requirements & Standards Drive Solutions
- Active & Active-Passive Dosimetry Could Replace Passive If Overall Costs & Regulations Change

Final Thoughts

- OSL & TLD Will Be The Workhorses for the Foreseeable Future
- Active-Passive Technology Will Serve Specific Segments
- Active Dosimetry Complimentary To Passive Dosimetry
- Cost Will Prevail With All Else Being Equal