Debunking Myths and Urban Legends in Ionizing Radiation Dosimetry

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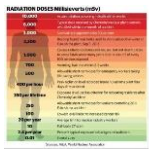
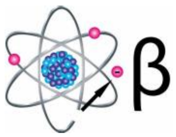
Chief Technology Officer
Radiation Detection Company

NVLAP Performance Testing Categories

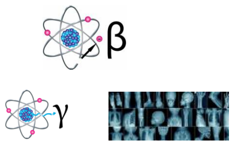


Accident Photons — I

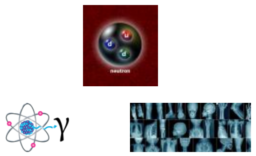
Photons/Photon Mixtures — II



Beta — III

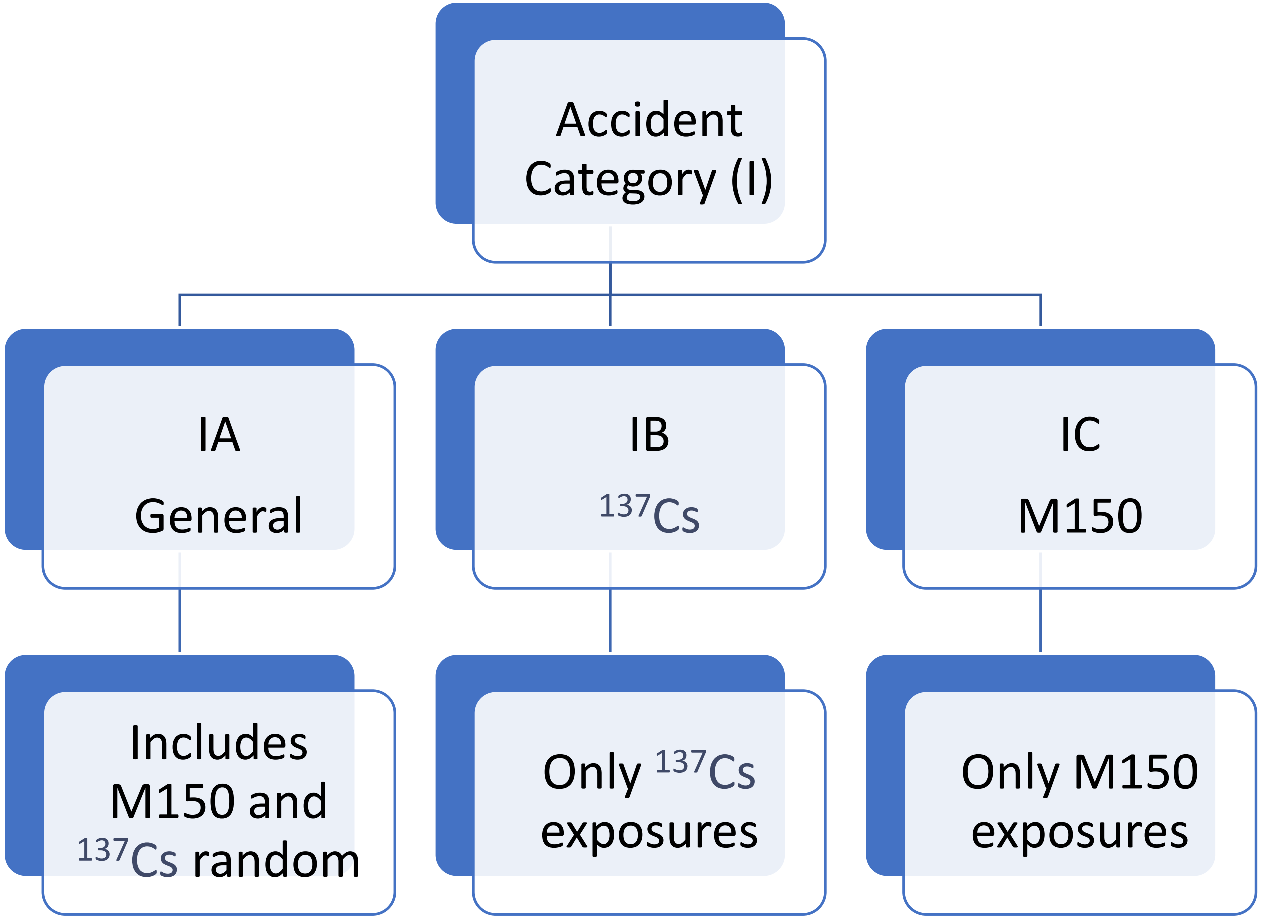


Beta/Photon Mixtures — IV



Neutrons/Photons — V

NVLAP Category I - Accident



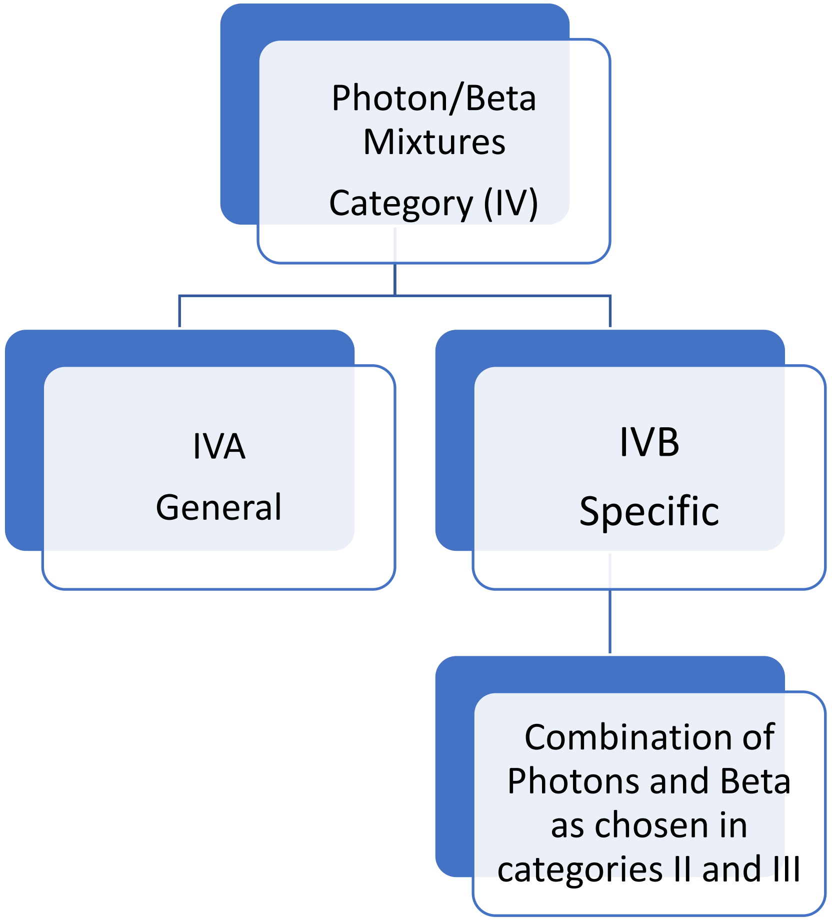
NVLAP Category II – Pure Photon & Photon Mixtures

- Photon/Photon Mixtures Category (II)
  - IIA General
    - Photon energy >20keV, angles
  - IIB High Energy
    - Only ^{137}Cs and ^{60}Co exposures; angles
  - IIC Medium Energy
    - Photons of energy >70keV; angles
  - II D Plutonium Specific

NVLAP Category III - Betas

- Beta Category (III)
  - IIIA General
    - IIIB and IIIC Random
  - IIIB High Energy
    - ^{90}Sr
  - IIIC Low Energy
    - ^{85}Kr
  - III D Uranium Slab

NVLAP Category IV – Photon & Beta Mixtures



NVLAP Category V – Neutron & Photon Mixtures

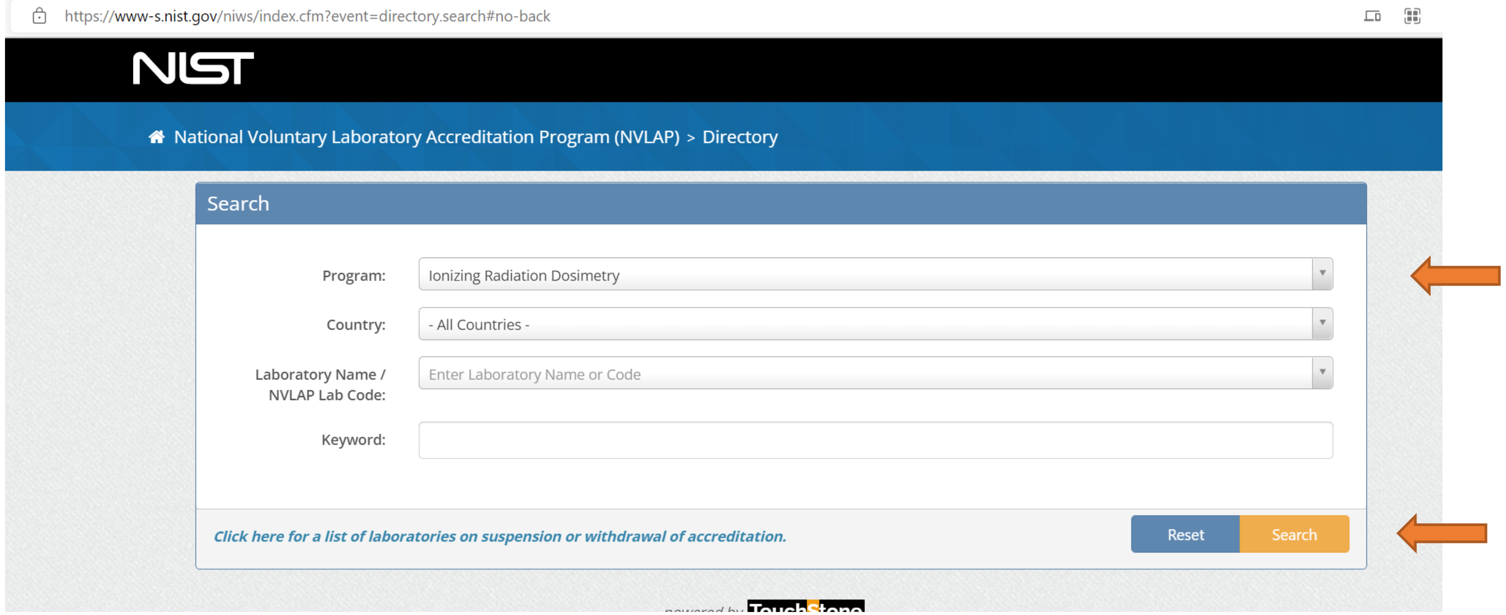
- Neutron/Photon Mixtures
  Category (V)
  - VAA
    General
    - Combination of Moderated or bare ^{252}Cf and Photons in Category IIA
  - VBA
    Specific
    - Combination of Bare ^{252}Cf and Photons chosen in Category IIA
  - VCA
    Specific
    - Combination of Moderated ^{252}Cf and Photons chosen in Category IIA

Note

1. **NVLAP is only offering moderated ^{252}Cf.**
2. **Only Photon General Fields shown and used by other labs at this time.**

NVLAP Scope of Accreditation Listing on NIST Website

- NVLAP Scope of Accreditation for Ionizing Radiation Dosimetry
  - http://www-s.nist.gov/niws/index.cfm?event=directory.search#no-back



List of Accredited Labs

https://www-s.nist.gov/niws/index.cfm?event=directory.results

NIST

National Voluntary Laboratory Accreditation Program (NVLAP) > Directory > Search Results

Search Criteria

Program: Ionizing Radiation Dosimetry
Area of Accreditation: All
Country: All Countries

Search Results

Show All entries

Search:

Lab Code	Lab Name	City	State	Country
100504-0	Naval Dosimetry Center	Bethesda	MD	US
100505-0	Duke Energy Dosimetry Laboratory	Huntersville	NC	US
100512-0	Radiation Detection Company	Georgetown	TX	US
100518-0	Landauer, Inc.	Glenwood	IL	US
100536-0	Arizona Public Service Co., Palo Verde Nuclear Generating Station	Tonopah	AZ	US
100539-0	U.S. Army Dosimetry Center	Redstone Arsenal	AL	US

Specific Dosimetry Laboratory

NIST

National Voluntary Laboratory Accreditation Program (NVLAP) > Directory > Lab Accreditation > Naval Dosimetry Center (100504-0)

Lab Information

Lab Name:	**Naval Dosimetry Center**	Lab Code:	100504-0
Lab Type:	Not Available for Commercial Testing	Website:	
Address:	4975 North Palmer Road, Bldg 84T Bethesda, MD 20889-5629 United States	Contact:	**Jeffrey Delzer** email: *jeffrey.a.delzer.mil@mail.mil* phone: *301-295-5410* fax:

Accreditation:

Ionizing Radiation Dosimetry

Expiration Date: **Dec 31, 2022**

Download Documents:

- Accreditation Scope ISO/IEC 17025:2017
- Accreditation Certificate ISO/IEC 17025:2017

Dosimetry Laboratory Scope

National Voluntary
Laboratory Accreditation Program

NVLAP® ilac-MRA

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

Naval Dosimetry Center
National Naval Medical Center
4975 North Palmer Road, Bldg. 84T
Bethesda, MD 20889-5614
Jeffrey Delzer
Phone: 301-295-5410 Fax: 301-295-5981
E-Mail: jeffrey.a.delzer.mil@mail.mil

IONIZING RADIATION DOSIMETRY **NVLAP LAB CODE 100504-0**

Scope of Accreditation:
This facility had been evaluated and deemed competent to process the radiation dosimeters listed below through employing the Harshaw/Bicron automatic reader models 8800PC.

WHOLE BODY

This facility is accredited to process the following dosimeters by demonstration of compliance with ANSI HPS N13.11 through testing.

Harshaw 8841 (DT702/PD) (4 chip MVP Copper doped Integrated Dosimetry System) in a Harshaw/Bicron model 8840 holder for ANSI/HPS N13.11-2009 categories IA, IIA, IIIA, IVAB, and VCB.

EXTREMITY

This facility is accredited to process the following dosimeters by demonstration of compliance with ANSI HPS N13.32 through testing.

Bicron DXTRAD-707H finger ring for ANSI/HPS N13.32-2008 categories IA, IIA, IIIA, and IVAA.

2022-07-25 through 2022-12-31
Effective dates

For the National Voluntary Laboratory Accreditation Program

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Commercial Dosimetry Laboratories

RADIATION DETECTION CO.

LANDAUER®

MIRION TECHNOLOGIES

pl medical

Best™ Dosimetry Services

ThermoFisher SCIENTIFIC

Summary of Commercial Labs NVLAP Scope of Accreditation
(Yellow Indicates Limitations in Dosimeter as of September 2022)

Laboratory	Whole-Body Dosimeter Model	Dosimetry Technology	Accident		Photons			Betas		Mixture (Photon + Beta)			Mixture (Neutron + Photon)		
			IA	IB	IIA	IIB	IIC	IIIA	IIIB	IVAA	IVAB	IVAC	VAA	VBA	VCA
RDC	Code 82 TLD Model XBGN	$^{n}Li_2B_4O_7$ / $CaSO_4$	x		x			x		x					
RDC	Code 82H TLD XBGN	^{7}LiF:Mg,Cu,P / ^{6}LiF:Mg,Cu,P	x		x			x		x					x
Landauer	Luxel+ Pa (A4)	Al_2O_3:C	x		x			x		x					
Landauer	Luxel+ Ta (A5)	Al_2O_3:C / CR-39	x		x			x		x					x
Landauer	Luxel+ Ja (B3)	Al_2O_3:C / CR-39	x		x			x		x					x
Landauer	Luxel+ Pa Escort Card (B6)	Al_2O_3:C	x												
Landauer	InLight LDR Model 2 - L02N (A7)	Al_2O_3:C	x		x			x		x					
Landauer	InLight LDR Model 2 - L02N (A9)	Al_2O_3:C / CR-39	x		x			x		x					x
Landauer	InLight LDR Model 2 OSLN - L11N (C1)	Al_2O_3:C / Al_2O_3:C + $^{6}Li_2CO_3$	x		x			x		x					x
Landauer	InLight LDR Model 2T OSLN - L02N (C1)	Al_2O_3:C / Al_2O_3:C + $^{6}Li_2CO_3$ / CR-39	x		x			x		x					x
Landauer	RadWatch Model 1	Al_2O_3:C Mipox	x				x								
Mirion	RemTrak Wallet Card (100555-G)	^{n}LiF:Mg,Ti		x		x									
Mirion	Apex (100555-B6)	BeO	x		x				x		x				
Mirion	TLD 760 -PB (100555-H)	^{7}LiF:Mg,Ti / ^{6}LiF:Mg,Ti	x		x			x		x					x
Mirion	Genesis TLD-760-DB (100555-Z)	^{7}LiF:Mg,Ti / ^{6}LiF:Mg,Ti	x		x			x		x					x
Mirion	Genesis Ultra TLD-MCP-BP (100555-B9)	^{7}LiF:Mg,Cu,P / ^{6}LiF:Mg,Cu,P	x		x			x		x					x
Mirion	Genesis Ultra TLD-MCP-DB (100555-A1)	^{7}LiF:Mg,Cu,P / ^{6}LiF:Mg,Cu,P	x		x			x		x					x
Mirion	Genesis Ultra-CR39 TLD-MCP-DB-CR-39 (100555-Y)	^{7}LiF:Mg,Cu,P / ^{6}LiF:Mg,Cu,P / CR-39	x		x			x		x					x
Mirion	Instadose ID-1.6 (100555-A7)	DIS	x		x										
Mirion	Instadose ID-1.7 (100555-B4)	DIS	x		x										
Mirion	Instadose 1+ (100555-B7)	DIS	x		x										
Mirion	Instadose 2 (100555-B8)	DIS	x		x				x						
PL Medical	Panasonic TLD UD802AT/874AICM	$^{n}Li_2B_4O_7$ / $CaSO_4$	x		x			x		x					
PL Medical	Landauer OSL InLight Model 2	Al_2O_3:C	x		x			x		x					
Best Dosimetry	Harshaw Type 8840 TLD Model 0806000220 Holder	^{7}LiF:Mg,Cu,P / ^{6}LiF:Mg,Cu,P	x		x			x							x
ThermoFisher	NetDose Gamma (600295-A1)	SiPM	x		x										

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Buyer Beware

- NVLAP is a license to hunt for processor, but buyer beware
  - If a dosimetry provider selects specific photon or beta performance testing categories B or C then they need specific information about the radiation field to accurately assess dose.
  - If a category is not tested then the dosimeter is not accredited for that radiation environment.
  - If the dosimetry processor select only category A, General, the dosimeter does not require a priori knowledge of the radiation environment to accurately assess the dose
- NRC noticed that licenses were not using appropriate dosimeters for their radiation fields.
  - Nuclear Regulatory Commission (NRC) issued NRC Information Notice 2014-05, *Verifying Appropriate Dosimetry Evaluation*
- If the dosimeter is not tested in category A then the dosimeter has a limitation and the RSO must be vigilant!

Real World Example – ^{99m}Tc Generator

- Tc-99m Generators
  - Radiation field = photons 141, 740, and 778 keV mixed with beta E_{max} of 436, 548, and 1214 keV
  - Dosimeter must be accredited at a minimum for IIB, IIC, IIIA, IVBA, and IVCA.
  - Instadose 1, Instadose+, Instadose 2, NetDose, Apex BeOSL, Luxel+ Pa Escort Card, RemTrak, RadWatch, and Best's Harshaw Type 8840 dosimeters should not be used in this field.

Real World Example – $^{106}Ru/^{106}Rh$ Brachytherapy

- $^{106}Ru/^{106}Rh$ Brachytherapy for ocular melanoma
  - Radiation field = photons 512, 622, and 1050 keV mixed with beta E_{max} of 39, 2407, and 3541 keV
    - Note a beta energy less than 70 keV cannot penetrate the dead layer of skin of 0.07 mm and will not contribute to the total shallow dose.
  - Dosimeter must be accredited to cover high energy photons, high energy betas, and mixtures of high energy photon / high energy betas.
    - Dosimeters not accredited in IIA, IIIA, and IVAA would at a minimum need to be accredited to IIC, IIIB, and IVCB.
  - Instadose 1, Instadose+, NetDose, Luxel+ Pa Escort Card, RemTrak, RadWatch, and Best's Harshaw Type 8840 dosimeters should not be used in this field.

Real World Example – Boron-Neutron Capture Therapy

- Boron-Neutron Capture Therapy is a process where ^{10}B is delivered to a tumor and then irradiated with thermal neutrons which yields ^{7}Li and alpha particles to kill the tumor.
  - Workers must wear dosimeters with neutron monitoring capabilities.
  - The following dosimeters are not tested in the neutron category and should not be used.
    - RDC XBGN Panasonic, Luxel Pa, InLight LDR Model 2, Luxel+ Pa Escort, RadWatch, RemTrak, Apex BeOSL, Instadose 1, Instadose 1+, Instadose 2, PL Medical Panasonic, PL Medical InLight, Best Medical Harshaw, and NetDose.

Technologies Used in US Market

SiO_2

ThermoFisher

OSL

BeO
Mirion
Dosimetric

TLD

$Li_2B_4O_7$
$CaSO_4$
Panasonic

DIS

Direct Ion
Storage
Mirion

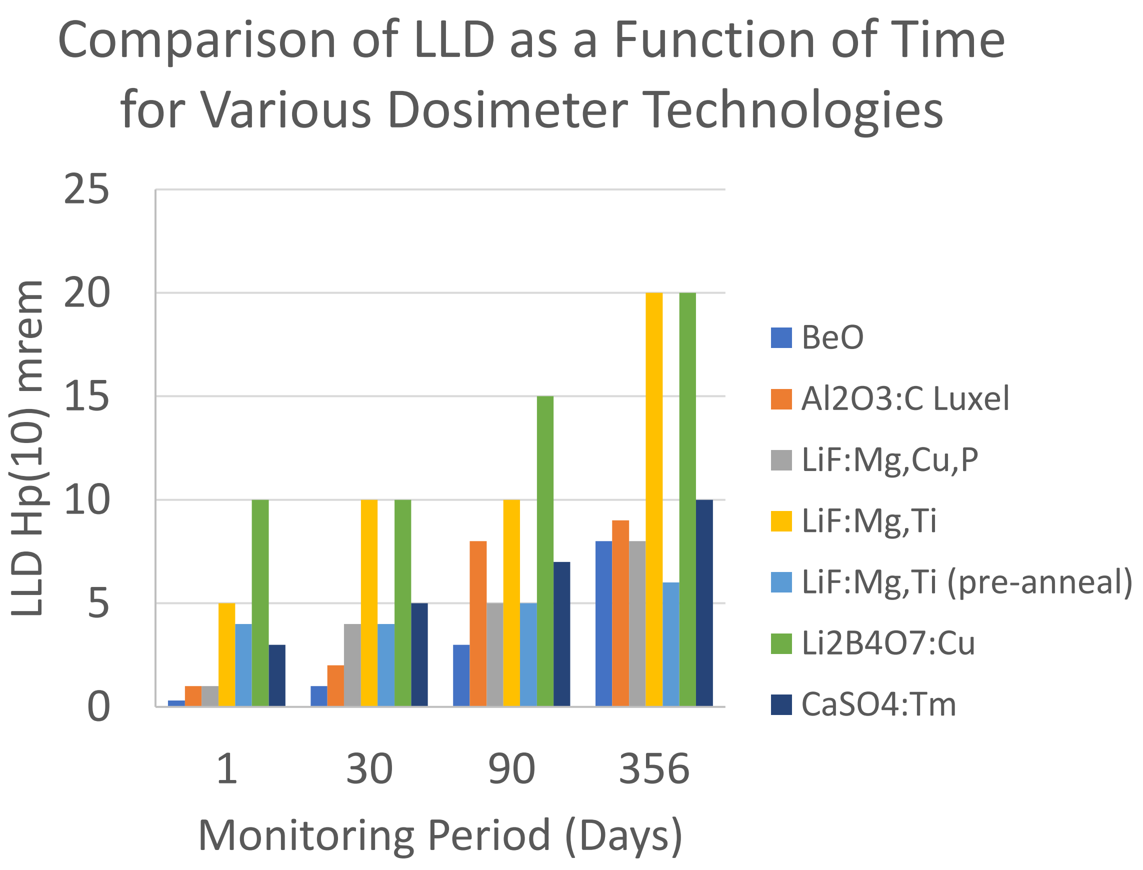
TLD

LiF
ThermoFisher

OSL

Al_2O_3:C
Landauer

LLD Misconceptions



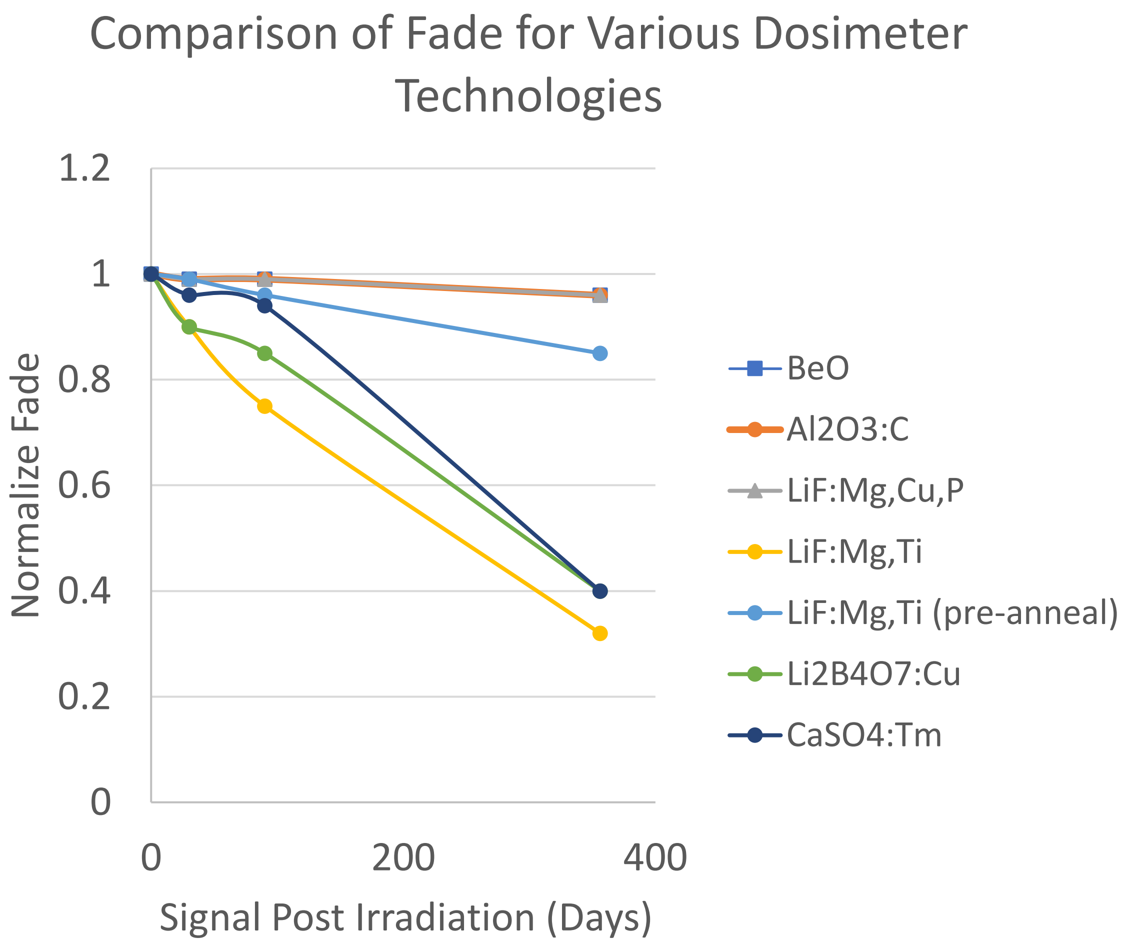
- Lower Limit of Detection (LLD) varies as a function of monitoring frequency.
  - LLD varies due to the standard deviation of the background dosimeters, Equation 1.
- Using an LLD of 1 mrem for all monitoring frequencies will lead to inaccurate reporting of dose.

Equation 1. Lower Limit of Detection

$$LLD = \frac{2[t_p S_o + (t_p S_1/H_1)^2 H'_o}{[\ 1 - (t_p S_1/H_1)^2\ ]}$$

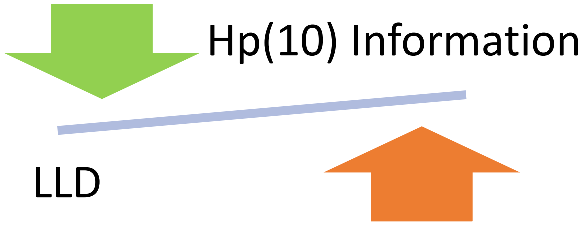
t_p = t distribution for n-1 degree of freedom and a p value of 0.95
S_o = standard deviation of the unirradiated dosimeter results
S_i = standard deviation of the irradiated dosimeter results
H_1 = average of the irradiated dosimeter results
H'_o = average of the unirradiated dosimeter results without subtracting background

Fade - Urban Legends



- Fade is the loss of signal induced in a detector over time post irradiation.
  - BeO, Al_2O_3:C, and LiF:Mg,Cu,P have similar fade of ~4% per year.
  - Even though LiF:Mg,Cu,P has been around since 1994 its fade is mistakenly assumed to be the same as LiF:Mg,Ti.
  - LiF:Mg,Ti TLD systems can be optimized to significantly improve fade using a pre-anneal process.

Balancing Dosimetry Technology and Compliance Surveillance



- Excessive Monitoring

- LLD might not be reached.
- Masking the number of workers exceeding 1 mSv (100 mrem) per year.
- Consequence missed dose
  - Moving from a Monthly monitoring frequency to Quarterly reduces the potential missed dose by a factor of 2.

- Insufficient Monitoring

- Risk of compliance issue.
- Slow reaction time to detect and correct unusual exposure situations.
- Consequences would be Compliance issue or ALARA Level exceeded.

<u>Conclusion</u>

Extending monitoring frequencies results in more accurate dose result for dosimeters recording "M" or <1 mSv (100 mrem) and does not jeopardize compliance.

- **Monthly to Quarterly gives worker an additional 2 months to exceed the LLD.**
- **Quarterly to annual give worker an additional 9 months to exceed LLD.**

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Conclusion

- The RSO needs to be aware of the following aspects when selecting a dosimeter:
  1. Is the dosimeter suitable for the radiation field?
     - Compare the radiation field with the scope of accreditation to assess proper coverage.
  2. Monitoring frequency needs to be selected based on your need for information and the worker's probability to exceed the LLD for the wear period.
  3. Lower limit of detection gives the RSO a scientific approach to compare dosimeters.
     - Do you really care about a 1-day LLD of 1 mrem? The RSO really needs to know if the dosimeter will be worn long enough for the worker to reach the LLD for the wear period.
  4. Fade is an important characteristic of a dosimetry system. The loss in signal can result in underestimating the occupational exposure.