NEUTRON DOSIMETRY WITH PANASONIC TLD

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BACKGROUND INFORMATION

Panasonic neutron sensitive phosphor = $Li_2B_4O_7$

- responds to thermal neutrons
- responds to photons and betas
- has a very different photon energy response characteristics than $CaSO_4$

MORE BACKGROUND
- PHOSPHOR CHARACTERISTICS

Phosphor	Responds to	Used for
$^{n}Li_2{}^{n}B_4O_7$	Photons, betas, neutrons	Depends on filtration
$^{7}Li_2{}^{11}B_4O_7$	Photons, betas	Non-neutron response (betas and photons, depending on filtration)
$^{6}Li_2{}^{10}B_4O_7$	Photons, betas, neutrons	Neutron response. Either incident thermal or albedo, depends on filtration.
$CaSO_4$	Photons, betas	Photon response

$LI_2B_4O_7$ RESPONSE CHARACTERISTICS

E2 ($^{N}LI_2{}^{N}B_4O_7$ UNDER ABOUT 300 MG/CM² PLASTIC)

Radiation type	Field	Response to dose correction factor (DDE)
Gamma	662 keV (^{137}Cs)	Dose = E2 * 1.0
X-ray	73 keV (M150)	Dose = E2 * 1.3
Beta	$^{90}Sr/^{90}Y$	Dose = E2 * 2.4 (SDE)
Neutron	D_2O mod ^{252}Cf	Dose = E2 * 0.5
Neutron	bare ^{252}Cf	Dose = E2 * 3.8

➡ Correction factor (response to dose) depends on the radiation type and energy.

GOALS AND REQUIREMENTS

- What field combinations?
  - Known photon and known neutron
  - Unknown photon and known neutron
  - Unknown photon and unknown neutron
  - Unknown photon, unknown neutron, unknown beta

OPTIONS:
MORE COMPLEXITY PROVIDES MORE CAPABILITY

Dosimeter *(example)*	Calculation	Neutron Field	Photon Field	Beta Field	Comments
2 Elements	Basic	Known	Known	None	
4 Elements *(802)*	Simple	Known	Known	Possible	Beta or neutron not both
4 Elements *(802)*	Function style	Known	Unknown	Possible	Beta or neutron not both
8 Elements *(802&809)* *(812&809)*	Function style	Unknown	Unknown	Unknown	Beta and neutron. Provides information on neutron field

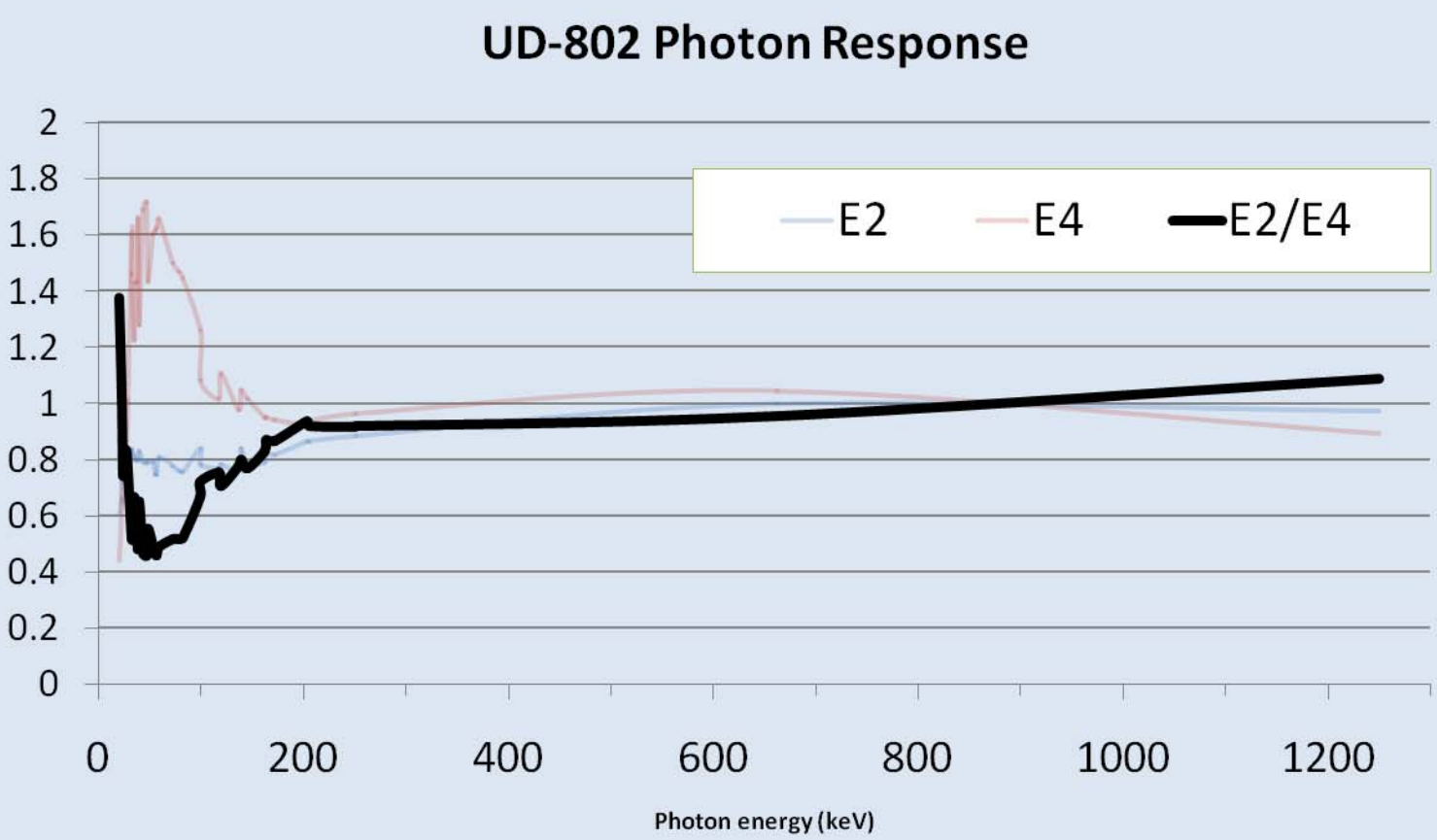
TWO ELEMENT BASIC DESIGN

Design	**Two elements** **- same filtration** **- one sensitive to photons and neutrons (^{n}Li), one sensitive to photons only (^{7}Li)**
Method	1. Calculate neutron signal = (neutron sensitive – neutron insensitive) = ^{n}Li - ^{7}Li 2. Calculate neutron dose = neutron signal *NCF
Issues	• Useful for simple photon plus neutron field • No photon characterization • No neutron characterization

FOUR ELEMENT SIMPLE DESIGN

Design	**Four element badge (eg UD-802)** **-Neutron sensitive element: $^{n}Li_2{}^{n}B_4O_7$ or $^{6}Li_2{}^{10}B_4O_7$** **-Neutron insensitive element(s): $CaSO_4$**
Method	1. Calculate neutron signal = (neutron sensitive – neutron insensitive) 2. Calculate neutron dose = neutron signal *NCF UD-802 example: neutron dose = (E2-E4)*NCF
Issues	• No neutron characterization, single NCF • Inaccurate for lower energy photons (< 300 keV), because E4 and E2 have different photon energy response characteristics • If not filtered, neutron sensitive element response will include beta

DIFFERENT PHOTON RESPONSE OF E2 AND E4 (UD-802, UD-812)



FOUR ELEMENT FUNCTION DESIGN

Design	Four element badge (eg UD-802) -Neutron sensitive element: $^{n}Li_2{}^{n}B_4O_7$ or $^{6}Li_2{}^{10}B_4O_7$ -Neutron insensitive element(s): $CaSO_4$
Method	1. Calculate photon response on E2 using E4 response, adjusted using function. 2. Calculate neutron (really non-photon) response of E2 3. Calculate neutron dose
Issues	• No neutron characterization, single NCF • Use of function for estimating photon response on E2 allows full range of photon energies • If not filtered, neutron sensitive element response will include beta

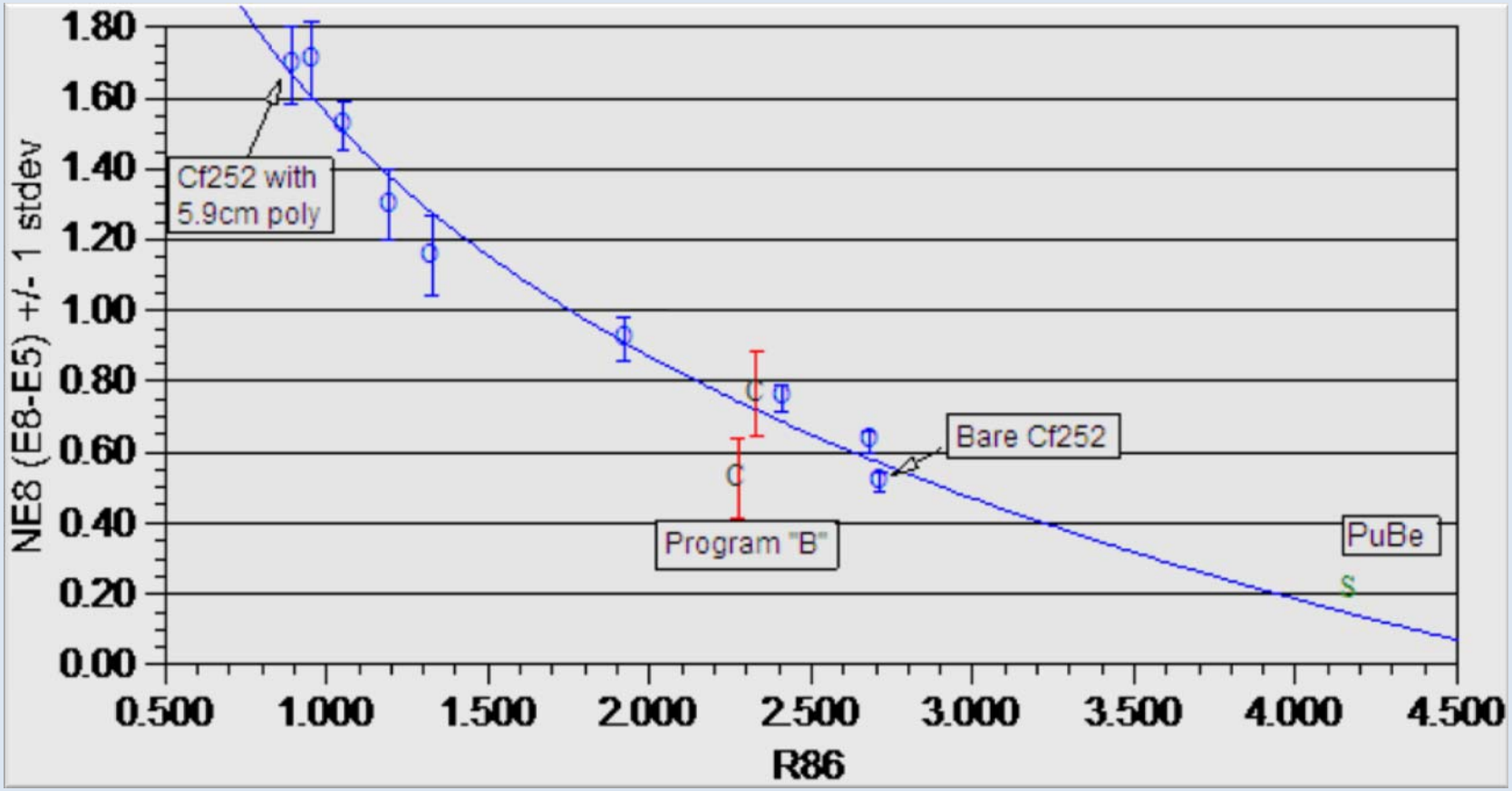
UD-809 DESIGN AND RESPONSE CHARACTERISTICS

	E1 (E5)	E2 (E6)	E3 (E7)	E4 (E8)
Phosphor	$^{7}Li_2{}^{11}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$
Front filter	Cd	Sn	Cd	Cd
Back filter	Cd	Cd	Cd	Sn
Used for	Photon response	Incident thermal		Albedo thermal

EIGHT ELEMENT FUNCTION DESIGN

Design	**Two four element badges (eg UD-802 & UD-809 or UD-812 & UD-809)** **-Neutron sensitive elements : $^{n}Li_2{}^{n}B_4O_7$ or $^{6}Li_2{}^{10}B_4O_7$** **-Neutron insensitive element(s): $CaSO_4$ and $^{7}Li_2{}^{11}B_4O_7$**
Method	1. Calculate photon response on neutron sensitive elements using neutron insensitive $CaSO_4$ elements E3, E4 and $^{7}Li_2{}^{11}B_4O_7$ E5 2. Calculate neutron (really neutron) response of E6 and E8 3. Characterize neutron field using albedo and anti-albedo neutron response 4. Calculate neutron dose with neutron response and selected NCF
Issues	• Use of function for estimating photon responses allows full range of photon energies • Can arrive at net beta response on UD-802 using neutron response and characterization • Neutron characterization allows selection of appropriate NCF

NEUTRON CORRECTION FACTOR USING UD-809



UD-802 VS UD-812 WITH UD-809

- UD-802
  - Uses $^{n}Li_2{}^{n}B_4O_7$
  - Non-photon response may include beta
- UD-812
  - Uses $^{7}Li_2{}^{11}B_4O_7$
  - Non-photon response is essentially all neutron

SOME PRACTICAL CHOICES

Dosimeter	Comments
UD-802	•Photon +beta or photon + neutron •Fine for NVLAP and DOELAP, no beta + neutron •For real world, issue different dosimeters for different jobs
Two UD-802	•#1 = standard filtration •#2 = with filter to eliminate beta response •Neutron response from #2 •Beta response from #1 - #2
UD-802 + UD-809	•Can provide neutron characterization •Beta response requires subtraction of neutron response
UD-812 + UD-809	•Neutron characterization •No need to subtract neutron to get beta response •Excellent for completely unknown mixed fields

OTHER ISSUES

- Filtration is designed for perpendicular radiation
  - Scattered neutrons that make it behind the filters will confound any difference in responses
  - Use a Cd fence around the badge to stop unfiltered thermal neutrons from getting to the elements

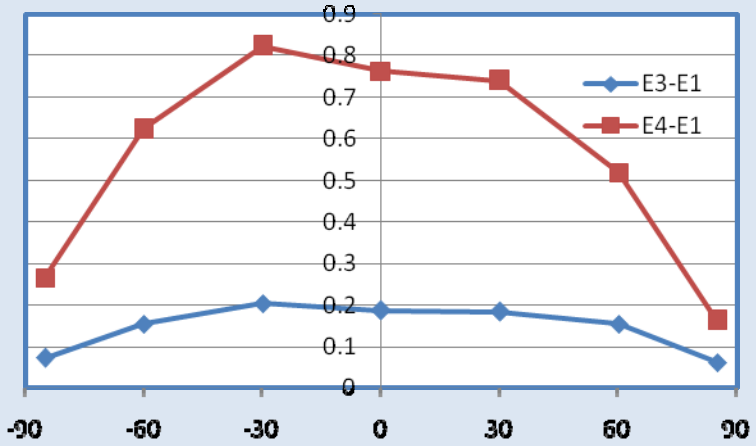
ANGULAR TESTING OF UD-809

DATA COURTESY OF R. CADOGAN, ANL

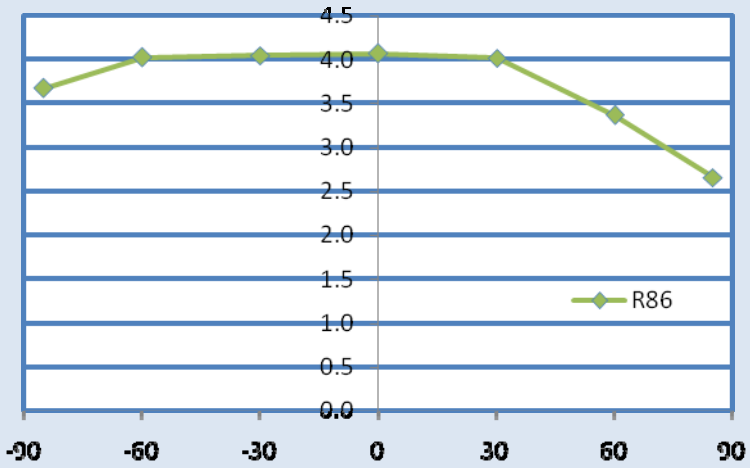
- UD-802/UD-809 dosimeters irradiated at PNNL. Rotating phantom
- Response/dose
- Albedo response is decreased
- Response looks more moderated

UD-809 ANGULAR RESPONSE BARE ^{252}CF HORIZONTAL AXIS

Net neutron response (relative to dose) of incident thermal (E3) and albedo (E4) elements



Ratio albedo:thermal



REFERENCES AND MORE INFORMATION

- A TLD Dose Algorithm for Mixed Fields at a Nuclear Weapons Facility, Stanford Dosimetry, Presented at the Radiation Protection Dosimetry Conference, 1994
- Back to Basics - Algorithms (3 MB pdf) Stanford Dosimetry, Presented at 2007 Dosimetry and Records Conference

THE END

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