Type Test a New Personnel Dosimeter System to IEC 62387:2012

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Abstract

Thermo Fisher Scientific has introduced a new personnel dosimeter, model 8850. This new dosimeter consists of a standard Thermo Scientific™ Harshaw™ TLD LiF: Mg,Cu,P card, with a new holder design. The reusable holder is small and lightweight, and contains filtration optimized for personnel dosimetry. This new dosimeter was type tested to IEC 62387:2012 along with the Thermo Scientific Harshaw Model 8800PLUS TLD Reader. Extensive testing of the radiological, environmental and mechanical performance of the system was performed according to the standard. The dosimeter is sensitive to a wide photon energy range from 16 keV and dose range from 0.01 mSv. It is also sensitive to beta from 85Kr. Comprehensive angular and side effect tests for photon and beta were also completed. This paper presents the high achieving type test results and uncertainty analysis of each test.

Introduction

A dosimetry system is expected to be type tested against a relevant IEC international standard. The technical content of IEC standard is kept under constant review to ensure that it reflects the current technology. The standard for the thermoluminescent dosimeter (TLD), a passive dosimeter, has evolved from IEC 1066:1991 to IEC 62387:2012, from applicable to a TLD specific system to a broader based standard which applies to an integrated passive dosimetry system. In its evolution, it harmonized with relevant ISO standards (ISO 4037, 6980, and 8529) on reference radiation and calibration; it extended photon and beta energy ranges and involved more complicated mixture radiations and higher angles for testing; it integrated Hp(3) requirement; it incorporated the concept of a measurement consisting of a value and an associated uncertainty; and it aligned the performance requirements of a dosimetry system with the recommendations on accuracy in ICRP Publication 75.

In this test, majority of irradiations for radiological testing were carried out at PTB and PNNL, national laboratories of Germany and US. The associated uncertainties of the radiations ranged 3 – 5%. Irradiations for Environmental testing were performed using in-house sources, which were traceable to NIST or PTB with uncertainties of 5%.

Multiple dosimeters were irradiated at a single test point to have n measurement. The uncertainty U with 95% confidence level was then determined by

$$U = \frac{t_{n-1}}{\sqrt{n}} \cdot s$$

The combined uncertainty of each testing point was calculated according to

$$U_{com} \approx \frac{\overline{G}}{\overline{G}_{r,0}} \sqrt{\left(\frac{U}{\overline{G}}\right)^2 + \left(\frac{U_{r,0}}{\overline{G}_{r,0}}\right)^2} \quad \text{for} \quad \overline{x} = \frac{\overline{G}}{\overline{G}_{r,0}}$$

$$U_{com} \approx \sqrt{U^2 + U_{r,0}^{\ 2}} \quad \text{for} \quad \overline{x} = \overline{G} \pm \overline{G}_{r,0}$$

$$U_{C,com} = \sqrt{U^2_{C,rel;r,0} + U^2_{C,rel;i}}$$

Where,

U_{com} is the expanded uncertainty of a combined quantity, i.e. testing radiation field and reference radiation field (^{137}Cs, $C_{r,0}$ = 3 mSv).

G is indicated (measured) value.
$G_{r,0}$ is indicated value under reference conditions.

$U_{c,com}$ is the expanded uncertainty of reference radiation source at conventional true values $C_{r,0}$ and C_i

Dosimetry System

TLD Reader:

Thermo Scientific Harshaw Model 8800 Plus

Software:

WinREMS
WinAlg8850

Heating Profile:

Preheat: 10s @ 165°C
Acquisition: 13s (16s) w/heating rate 15°C/s to max temperature 260°C
Anneal: 10s @ 260°C

Dosimeter:

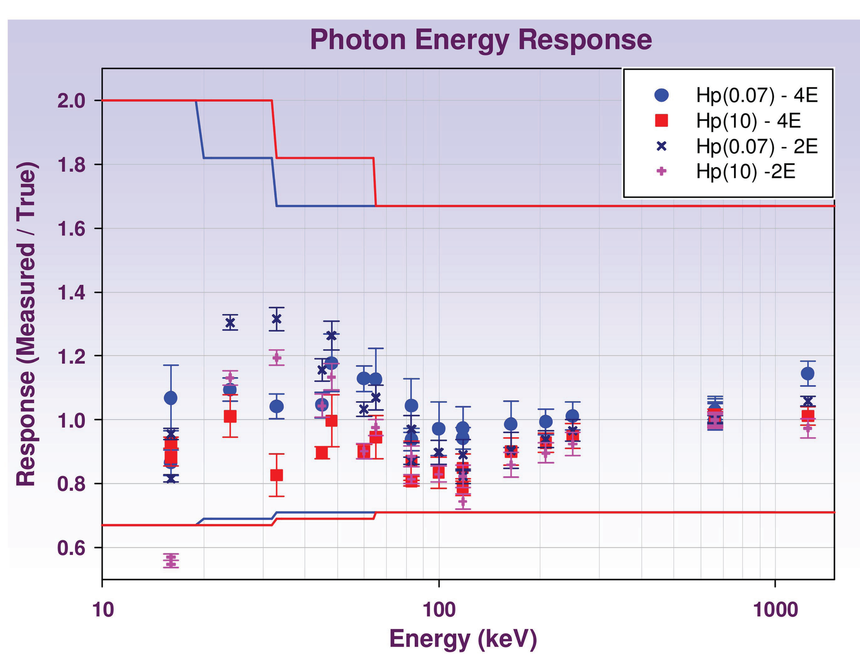
Thermo Scientific Harshaw 8850 Holder
TLD LiF:Mg,Cu,P Card:
7H7H7H6H
0.38 x 0.38 x 0.25 x 0.38 mm
07H7H0
0 x 0.38 x 0.25 x 0 mm

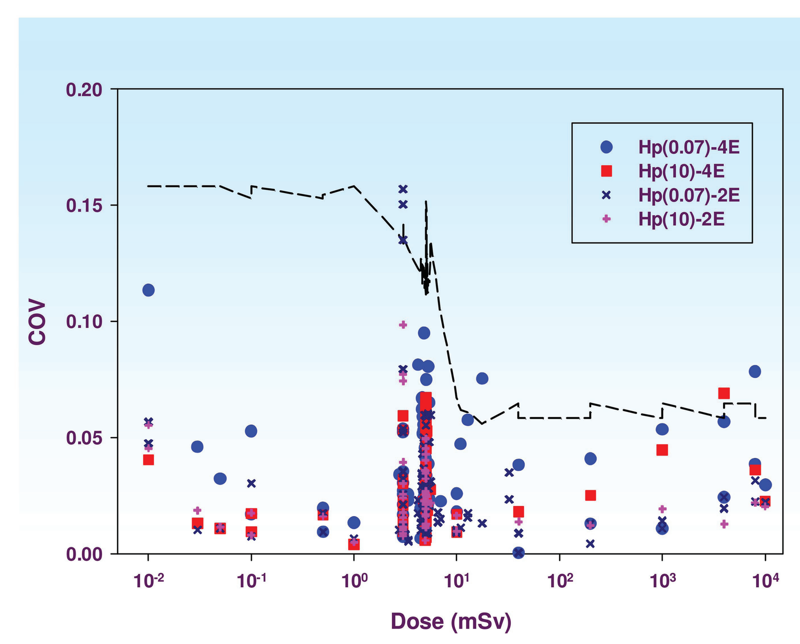
Two configurations were tested:
- 4 element card + dose algorithm
- 2 element card, direct readout*

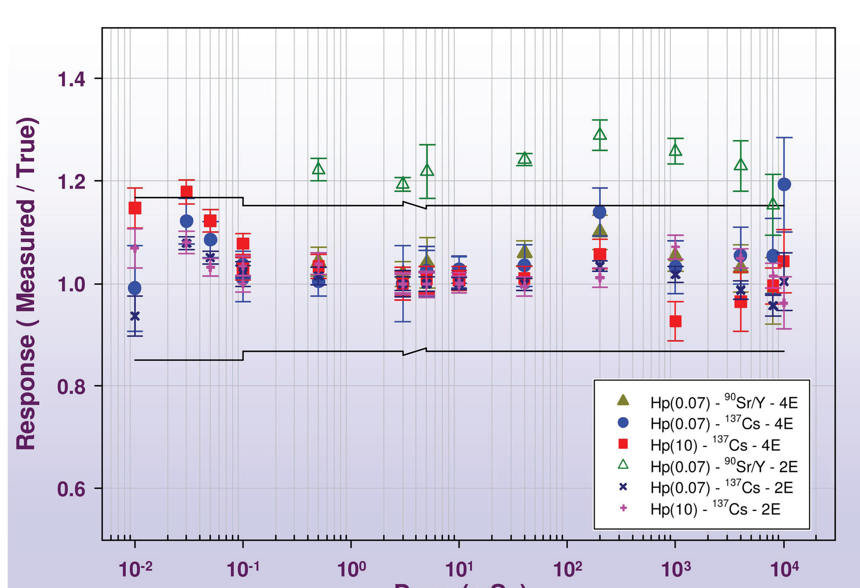
* LiF is near tissue equivalent and has flat energy response

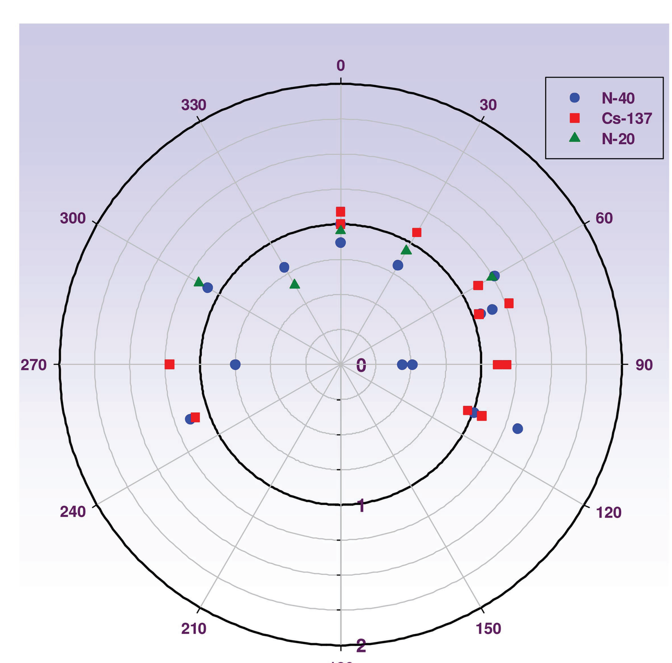
Results

More than 100 testing points include wide ranges of radiation, 16 keV to 1250 keV photon, 0.2 MeV to 0.8 MeV (mean energy) beta, and neutrons, in dose extends from 10 µSv to 10 Sv and angles to 90°. Mixed field A:B ratio spans from 1:9 to 9:1. Environmental test is from -20°C to 50°C and RH 20% to 75% (achievable from the test setup). Light exposure testing is12% greater than the IEC specified sunlight. Some results are shown below, a complete report will be available in full article.









Summary

Category	Sub-category	Requirement	Result – Four Element	Result – Two Element
Radiation Performance Requirements And Tests (Dosimetry System)	Coefficient of Variation	Statistical doses fluctuations are within specified ranges	Fulfilled	Fulfilled
	Non-Linear Response	$0.91 - U_{C,com} \le \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com}\right) \cdot \frac{C_{r,0}}{C_i} \le 1.11 + U_{C,com}$	Fulfilled	Fulfilled
	Overload, After-effects and Reusability	$0.91 - U_{C,com} \le \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com}\right) \cdot \frac{C_{r,0}}{C_i} \le 1.11 + U_{C,com}$ and Each COV within range	Fulfilled over-resp at 0.01 mSv afterward	Fulfilled over-resp at 0.01 mSv aftereffect
	Responses – Photon, Beta, and Neutron, Energy and Angular	$r_{min} - U_{C,com} \le \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com}\right) \cdot \frac{C_{r,0}}{C_i} \le r_{max} + U_{C,com}$ for wide ranges of photon, beta, and neutron, and radiation energy and angle	Fulfilled for wide ranges radiation	Fulfilled to wide ranges radiation
Response to Mixed Irradiations (Dosimetry System)		$r_{min,w} \le r = \frac{G_{K+L}}{C_{K+L}} \cdot \frac{C_{r,0}}{G_{r,0}} \le r_{max,w}$ $r_{min,w} = \frac{r_{min,K} \cdot C_K + r_{min,L} \cdot C_L}{C_K + C_L}$, $r_{max,w} = \frac{r_{max,K} \cdot C_K + r_{max,L} \cdot C_L}{C_K + C_L}$	Fulfilled 1:9 to 9:1 ratio for Photon Lower ratio for Beta and neutron	Fulfilled 1:9 to 9:1 ratio for Photon

Category	Sub-category	Requirement	Result – Four Element	Result – Two Element
Environmental Performance Requirements and Tests	Ambient Temperature **(Dosimeter)**	$0.91 \le \frac{\overline{G}_2}{\overline{G}_1} \pm U_{com} \le 1.11$ and $\lvert\overline{G}_2 - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv	Fulfilled	Fulfilled
	Light Exposure **(Dosimeter)**	$0.91 \le \left(\frac{\overline{G}'_i}{\overline{G}'_2} \pm U_{com}\right) \le 1.11$ and $\lvert\overline{G}'_i - \overline{G}'_2 \pm U_{com}\rvert \le 0.07$ mSv	Yel and Grn Fulfilled in 112% intense light	Yel and Grn Fulfilled in 112% intense light
	Long Term susceptibility **(Dosimeter)**	$0.91 \le \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{com}\right) \le 1.11$ and $\lvert\overline{G}_i - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv in a month	Fulfilled	Fulfilled
	Reader Stability **(Reader)**	$0.91 \le \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{com}\right) \le 1.11$ and $\lvert\overline{G}_i - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv	Fulfilled	Fulfilled
	Ambient Temperature **(Reader)**	$0.91 \le \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{com}\right) \le 1.11$ and $\lvert\overline{G}_i - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv	Fulfilled	Fulfilled
	Light Exposure **(Reader)**	$0.91 \le \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{com}\right) \le 1.11$ and $\lvert\overline{G}_i - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv	Fulfilled under sunlight	Fulfilled under sunlight
	Primary Power Supply **(Reader)**	$0.91 \le \frac{\overline{G}_2}{\overline{G}_1} \pm U_{com} \le 1.11$ and $\lvert\overline{G}_2 - \overline{G}_1 \pm U_{com}\rvert \le 0.07$ mSv	Fulfilled	Fulfilled

Conclusion

Thermo Fisher Scientific personnel dosimeter 8850 and Model 8800Plus Reader is type tested. The 4-element card option fulfills IEC 62387:2012 requirement for photon, beta, and neutron monitoring. The 2-element option is also an excellent gamma dosimeter.

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