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PERFORMANCE OF HARSHAW TLD-100H TWO-ELEMENT DOSEMETER

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One of the advantages of LiF based thermoluminescent (TL) materials is its tissue-equivalent property. The Harshaw TLD-100H (LiF:Mg,Cu,P) material has demonstrated that it has a near-flat photon energy response and high sensitivity. With the optimized dosemeter filters built into the holder, the Harshaw TLD-100H two-element dosemeter can be used as a whole body personnel dosemeter for gamma, X ray and beta monitoring without the use of an algorithm or correction factor. This paper presents the dose performance of the Harshaw TLD-100H two-element dosemeter against the ANSI N13.11-2001 standard and the results of tests that are required in IEC 1066 International Standard.

INTRODUCTION

Recently, the American National Standards Institute (ANSI) updated the performance standards for personnel dosimetry monitoring (ANSI N13.11-2001) titled '*Personnel Dosimetry Performance—Criteria for Testing*'[1]. During the review of the algorithms and systems used to meet the modified requirements of this standard, it was decided to also evaluate the performance of the system without the use of a dose calculation algorithm. In addition, it was decided to evaluate the performance of the system using only two elements of LiF:Mg,Cu,P (TLD-100H) to report doses of $H_p(10)$ and $H_p(0.07)$. This is feasible due to the fact that, unlike other materials such as Al_2O_3:C, $CaSO_4$ or MgB_4O_7[2], the TLD-100H material has a near tissue-equivalent property and a very flat energy response. Other benefits of this material are the ability to use the material in a normal non-darkroom laboratory environment, negligible fade over extended periods of time, and no supralinearity in the accident dosimetry range[3]. While the dosemeter holder was capable of carrying a dosemeter card with 4 active elements, only the elements behind the $H_p(10)$ and $H_p(0.07)$ filters were used.

MATERIALS AND METHODS

The first part of this study was to use irradiation data from dosemeter testing at Battelle Pacific Northwest National Laboratory (PNNL). The dosemeters were irradiated to various energies of photons and betas. Neutrons were excluded from this study since only the photon and beta environments were being tested. The dosemeter holder was the Harshaw TLD Model 8840 shown in Figure 1. This holder was designed in collaboration with the U.S. Navy and is based on MCNP modeling and more severe environmental design requirements[4]. Since the study was to use only two elements, the responses of the TLD elements behind Position i (the copper filtered element), and Position iv (the tin filtered element) were not considered. The irradiations from PNNL were ISO Narrow Spectrum, as well as NIST (US) monoenergetic beam techniques. Shown in Figure 2 are the photons and betas used in this study. They are ISO beams: NS30, NS40, NS60, NS80, NS100, NS120, NS150, NS200, NS250 and NS300, NIST beams: M30, M60, M100, M150, M200, M250, H50, H60, H100, H150, H200, H250, H300, ^{137}Cs, ^{60}Co, ^{204}Tl, ^{85}Kr and ^{90}Sr/^{90}Y, and X rays: K17, K25, K31, K40, K49 and K59. Figure 2 also shows all of the specified ISO and NIST beam techniques in ANSI N13.11-2001. The overlaps are from the techniques used in the present study. These were the available techniques at the time of the test.

The system was then characterized with respect to photon energy. Figure 3 shows its photon energy response relative to ^{137}Cs for TL response per

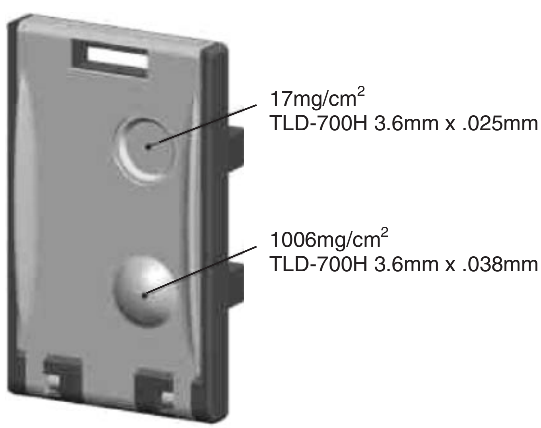

Figure 1. Harshaw TLD Model 8840 dosemeter holder.

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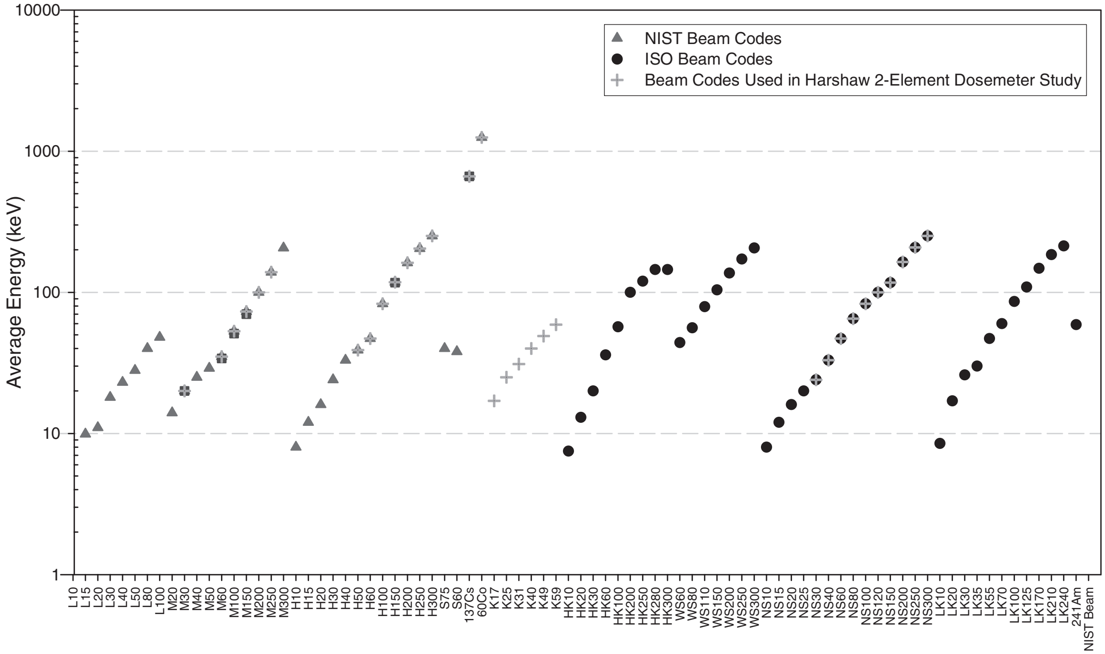

Figure 2. ISO and NIST (USA) beam techniques displayed in average photon energy, and techniques used in Harshaw TLD-100H two-element dosemeter.

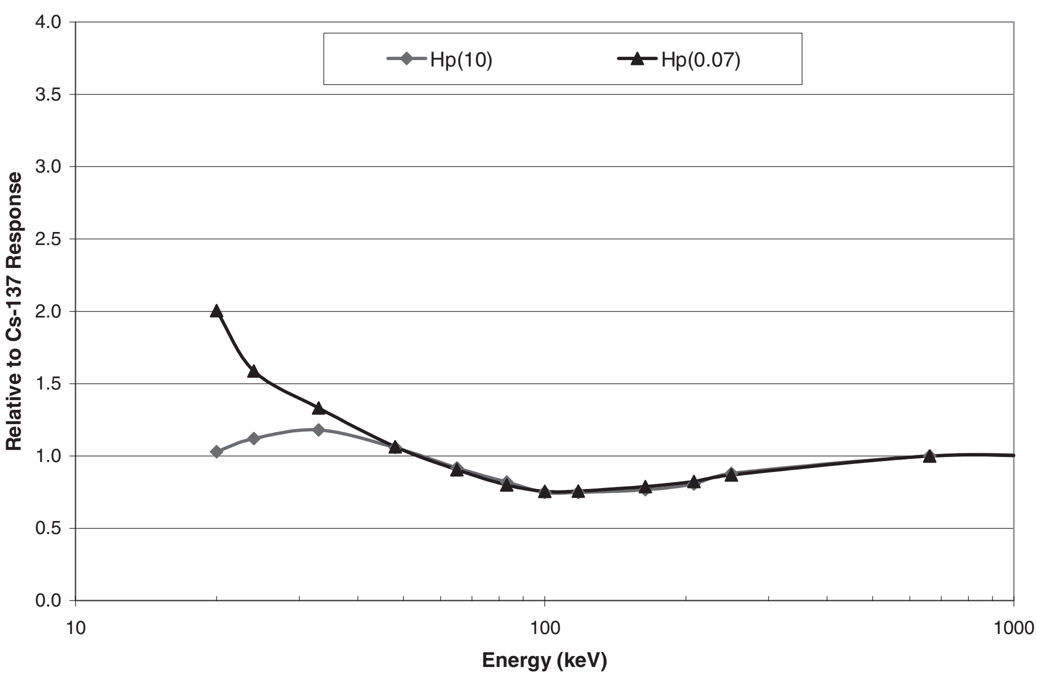

Figure 3. Personnel dose photon energy responses for Harshaw TLD-100H two-element dosemeter.

absorbed dose. It was then analyzed by studying the simulated responses for photons, betas and their mixtures. This simulation was achieved by artificially mixing different energy photons, and photons plus betas, in a ratio of 1:1, 1:3 and 3:1. There were >1000 mixed fields simulated in the study. The performance was analyzed by using the performance quotient, the percentage of difference between the irradiated and the reported dose.

A dosemeter type test was also performed as a part of this evaluation. The testing was detailed in a separate paper (Velbeck, K. J., Luo, L. Z. and Streetz, K. L. in press).

RESULTS AND DISCUSSION

Evaluation of the data was performed and the results were calculated using the ANSI requirement of ($|B|+S$), where B is the bias and S is the standard deviation of the series of measurements. The $|B|+S$ is defined in the ANSI N13.11-2001 document[1]. Each category shown below relates to the individual test requirements specified in the ANSI standard.

Category I general: accident category

Figure 4 shows the performance for Category I, accident photons. Based on the test criteria, both the X ray and ^{137}Cs fall well within the performance requirements. This is the general test category where there is no *a priori* knowledge given to the system on the expected exposure. In this test, many other dosimetry materials show supralinearity due to the high dose. Since the Harshaw TLD LiF:Mg,Cu,P material is linear within this test range, there is no need for the user to be concerned with the high dose levels. In addition, the Harshaw TLD readers support seven decades of linear readout range. The bias of ~10% is due to the small overresponse of the LiF:Mg,Cu,P to the 72 keV photons, while the almost zero bias is the result of the ^{137}Cs irradiation.

Category II: general photons

The general photons category relates to occupational exposure levels of photon doses. Based on the test results shown in Figure 5, both the results for $H_p(10)$ and $H_p(0.07)$ are within the required limits. This graph also shows the expected over and under response of the LiF:Mg,Cu,P material in the bias term of ~25%. From this graph we can also see that there is no systemic bias or large standard deviation in response, indicating that the calibration is correct and that all of the dosemeters performed nominally with no abnormal variations in element response. Figure 6 shows the performance quotient in a test sequence (various photons) for both $H_p(10)$ and $H_p(0.07)$ along with the 3σ limits. All of the test points fall well within the test performance requirements.

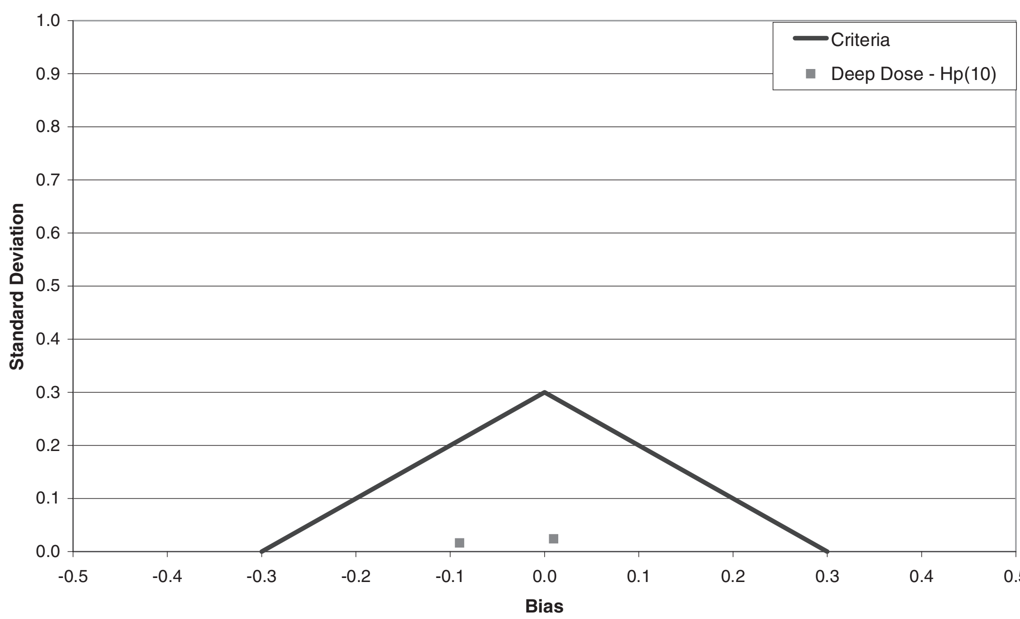

Figure 4. Harshaw TLD-100H two-element dosemeter performance in Category I (accident) of ANSI N13.11-2001.

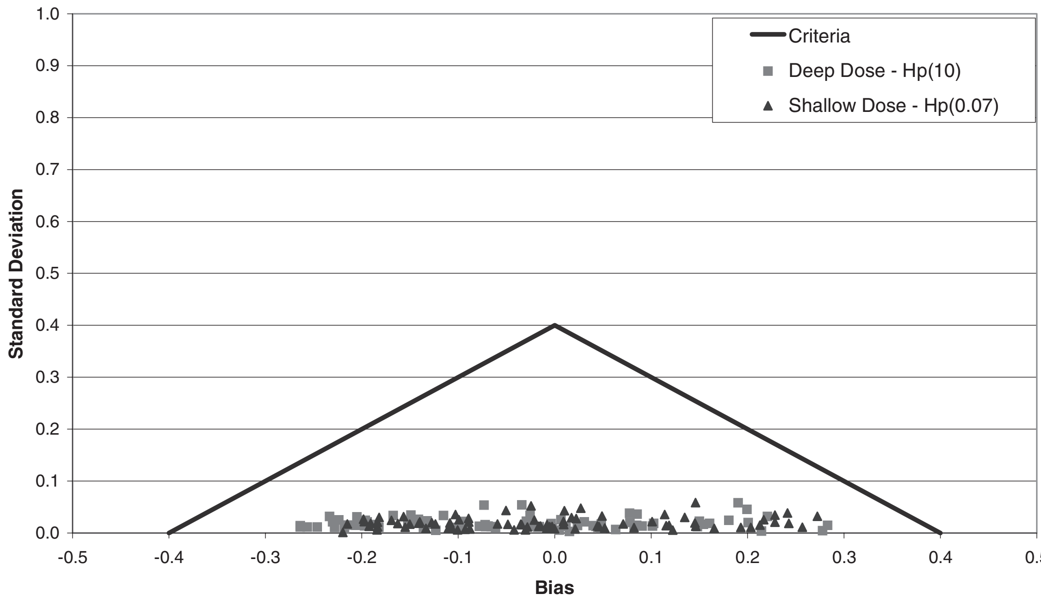

Figure 5. Harshaw TLD-100H two-element dosemeter performance in Category II (general photons) of ANSI 13.11-2001.

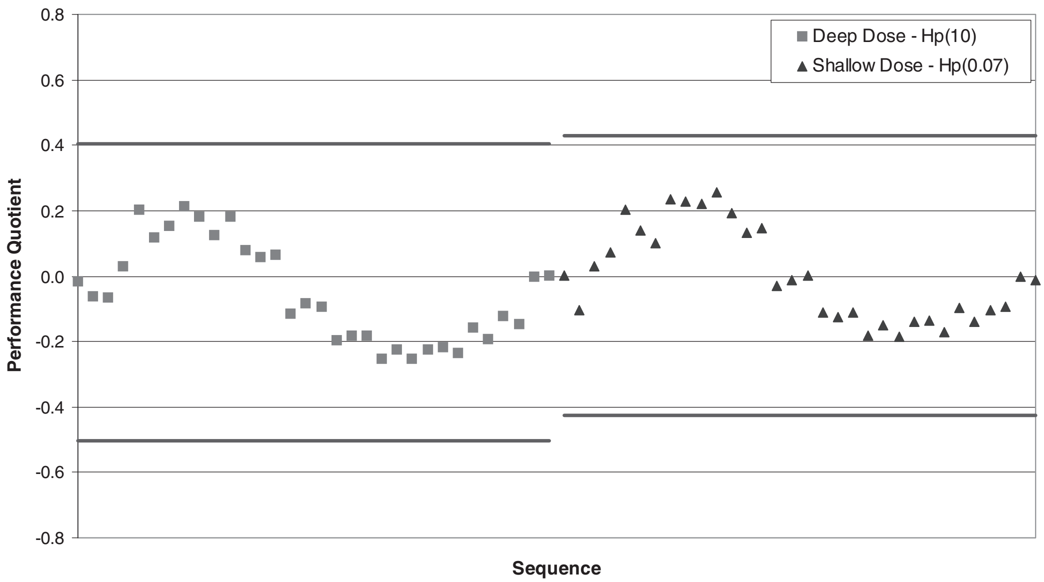

Figure 6. Harshaw TLD-100H two-element dosemeter performance quotient vs. different energy photons in Category II of ANSI 13.11-2001. The upper and lower lines are 3σ limits.

Category IIIB: high energy betas

The results of the beta tests show that there is up to a 30% bias (Figure 7). This is due to the calibration based on ^{137}Cs, the relatively thick TL chip (0.010 inches, 0.25 mm), and the response of the LiF:Mg,Cu,P to betas. While this is more bias than desirable, the dosemeter still passes the requirements.

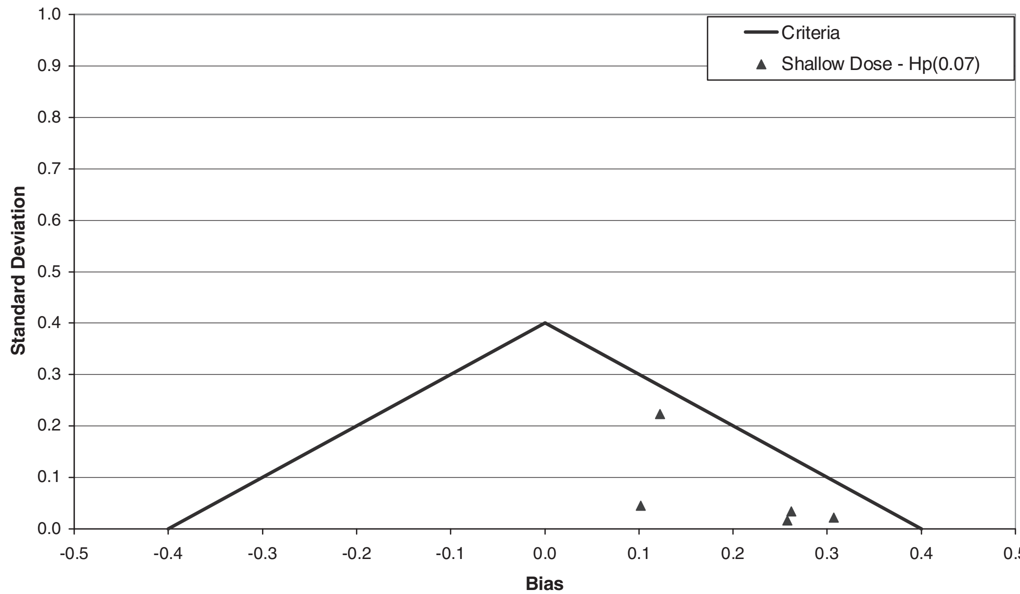

Figure 7. Harshaw TLD-100H two-element dosemeter performance in Category IIIB (high energy betas) of ANSI 13.11-2001.

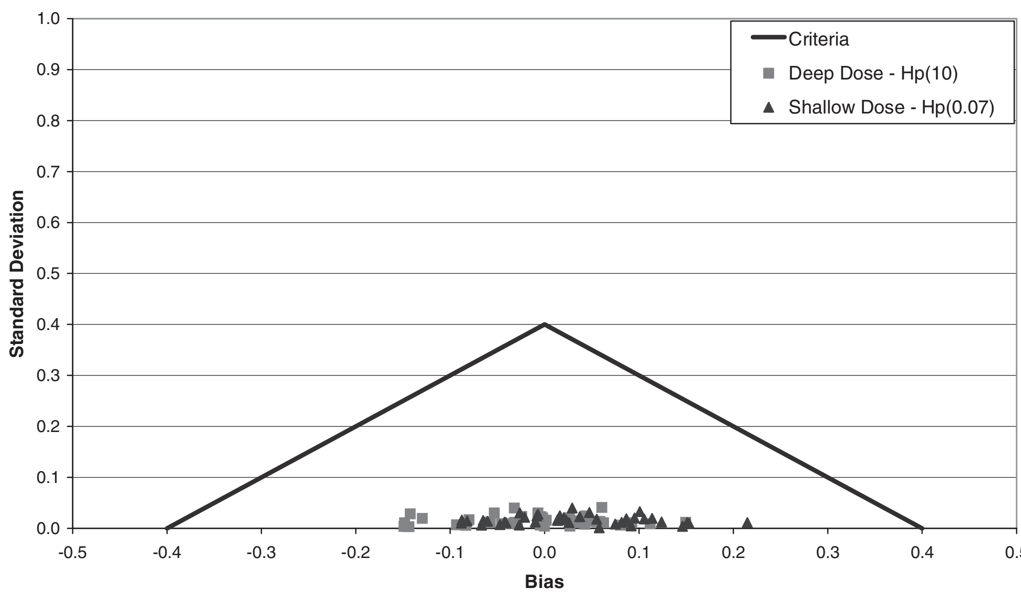

Figure 8. Harshaw TLD-100H two-element dosemeter performance in Category IV (photon mixtures) of ANSI 13.11-2001.

Category IV: photon mixtures

Figure 8 shows the results of the photon mixtures. These mixtures are combinations of low and high energy photons. Based on the results of this test, the dosemeter passes with a very low bias of <15%, except for one outlier at 22%. The similar graph (Figure 9) shows the performance quotient in this category. The results are again well grouped with low standard deviation and no major outliers.

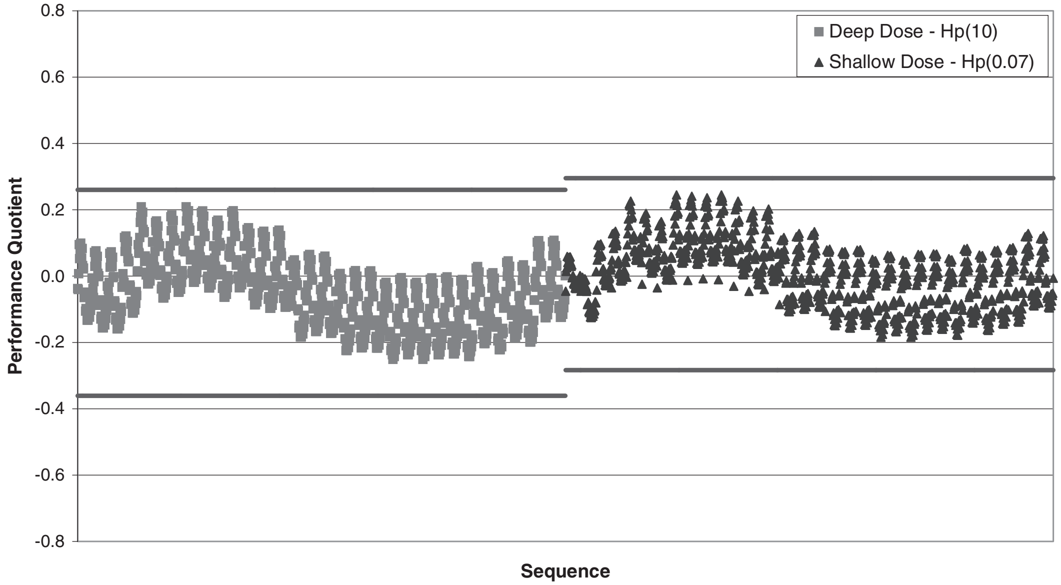

Figure 9. Harshaw TLD-100H two-element dosemeter performance quotient vs. different photon mixtures in Category IV of ANSI 13.11-2001. The upper and lower lines are 3σ limits.

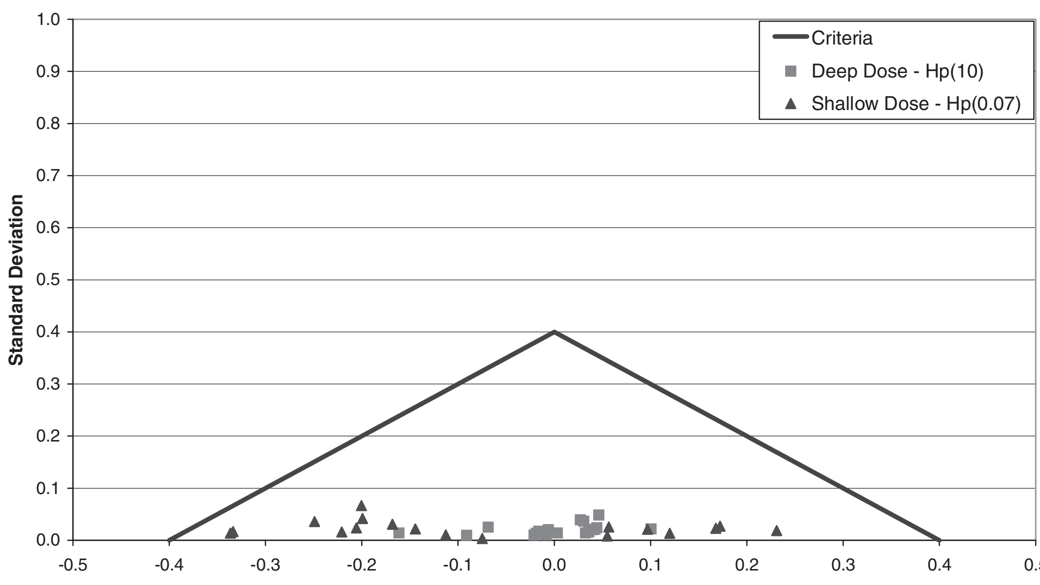

Figure 10. Harshaw TLD-100H two-element dosemeter performance in Category V (beta and photon mixtures) of ANSI 13.11-2001.

Category V: beta and photon mixtures

The beta and photon mixtures are the most extreme test on a two-element dosemeter. Based on the test results shown in Figure 10, the dosemeter passed the test. There are a few shallow dose results that have a slightly high bias but are within the performance criteria. Figure 11 shows the performance

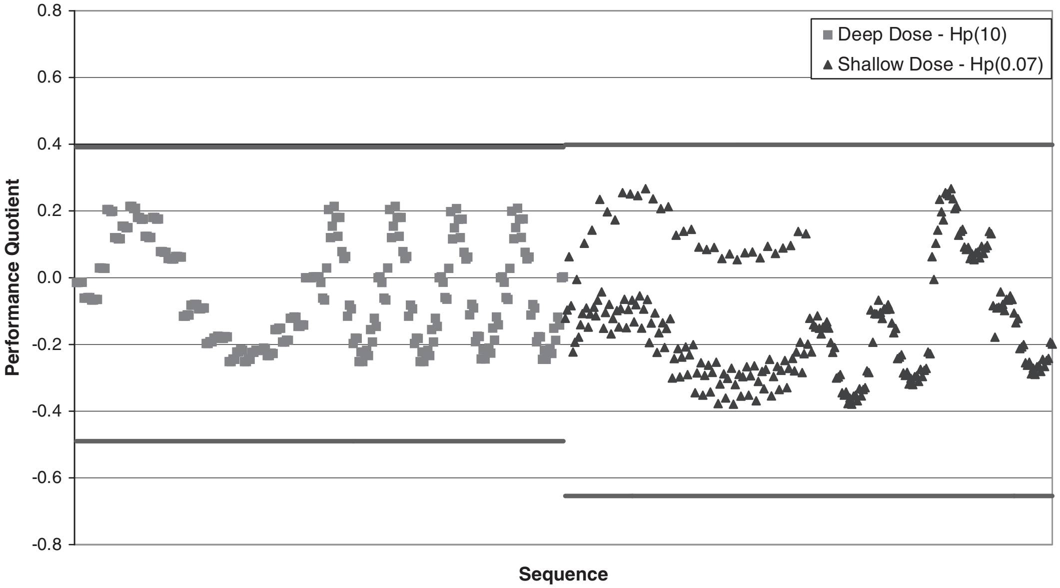

Figure 11. Harshaw TLD-100H two-element dosemeter performance quotient vs. different beta and photon mixtures in Category V of ANSI 13.11-2001. The upper and lower lines are 3σ limits.

quotient in a test sequence (various energy photon/beta mixtures) for both $H_p(10)$ and $H_p(0.07)$, along with the 3σ performance limits. This is for a 1 to 1 ratio of betas and photons. All of the test points fall within the test performance requirements.

CONCLUSION

The testing conducted during this evaluation verifies that the performance of a two element LiF:Mg,Cu,P dosemeter meets the performance required in ANSI N13.11-2001. The excellent energy response of the material makes it ideally suited for personnel, extremity and environmental dosimetry when the expected exposures are not from complex mixtures. In addition, the creation of algorithms for more complicated fields is simplified with the use of modern algorithm development techniques.

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