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Reply

Reply to letter to the editor by R. B. Hayes

An attentive reading of the articles in question (Nagy and Desrosiers, 1996; Nagy et al., 2000; Sleptchonok et al., 2000) would have enabled Hayes to resolve his concerns using information provided directly in the text. A simple reproduction of portions of these articles is sufficient to address his criticisms. The two criticisms of our work are the 'possible' influence of transient signals from the binder and the range of applicability of our data.

1. The 'possible' influence of transients from the binder:

From the beginning of alanine dosimetry development at NIST nearly 10 years ago, we have paid very close attention to the attributes and quality of the binder contained in dosimeters used in our service (low-density polyethylene powder from Polysciences)[1]. A spectrum of the binder irradiated separately from alanine is compared with the spectrum of an alanine dosimeter irradiated to the same dose in Fig. 1. The contribution of the binder signal to the total signal of the dosimeter is about 0.0034%, which is more than an order of magnitude smaller than the uncertainty of our measurements. The essentially non-existent binder signal was undetectable in the time study described in the article cited by Hayes in his critique. This work focused specifically on the very small changes in the alanine signal intensity during the first hours and days after irradiation (Nagy and Desrosiers, 1996). That paper, reporting signal measurements with an uncertainty below 0.1%, refers to our search for any possible influence from the binder on p. 790:

> ... irradiation of samples of the pure alanine powder used in preparing the pellets has been performed under the same conditions. The described dependencies of the signal were observed both for pellets containing polyethylene as a binder and for pure alanine powders without additives.

Therefore, there is no measurable influence of EPR signals from the polymer binder on the time-, humidity- and temperature-dependent measurements described in these works.

The measurement procedure we use is commonly accepted worldwide. As the signals measured in our system are essentially pure alanine signals, the parameters are optimized for high-dose alanine dosimetry. There is no apparent reason why a different set of parameters (that comply with the general requirements of quantitative EPR methodology) would produce different results under our conditions. Except, of course, for those parameters (e.g., modulation amplitude) identified in our work (Sleptchonok et al., 2000).

2. The applicability of our data:

Hayes wrote: "That NIST has characterized their own and Bruker's dosimeters are not in question. In both works however (Nagy et al., 2000; Sleptchonok et al., 2000), the authors make a blanket statement that other practitioners should adopt NIST results over and above the already established ASTM standards or even worse, over and above the practitioners very own system/dosimeter specific measured values."

This is a clear misrepresentation of our stated recommendations. On p. 132 of Sleptchonok et al., 2000, on humidity effects,

> Fading characteristics of alanine dosimeters vary with the shape and possibly the composition of dosimeters. Therefore, verification of these effects is recommended for users when dosimeters are from different sources.

On p. 8 of Nagy et al., 2000, on temperature effects,

> In performing temperature corrections, a dosimetrist should take into consideration... applicability

[1] Mention of commercial products does not imply recommendation or endorsement by the NIST, nor does it imply that the products identified are the best for the purpose.

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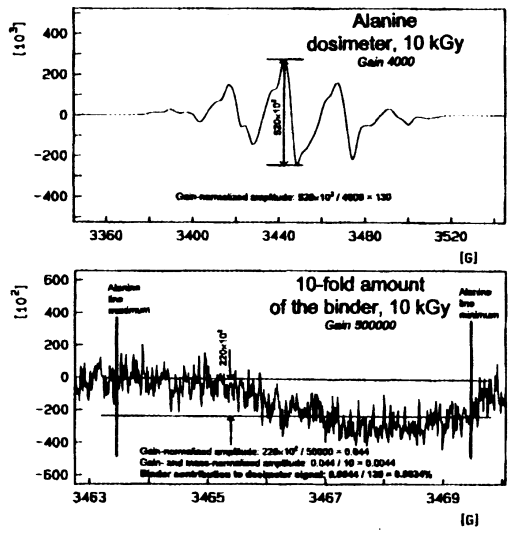

Fig. 1. EPR spectra of freshly-irradiated samples. The alanine dosimeter contained 10% of the polyethylene binder. To obtain a measurable signal, it was necessary to increase the mass of the pure polyethylene binder sample such that it was equivalent to that contained in 10 dosimeters. The following recording parameters were the same for both spectra: microwave power 0.25 mW, modulation amplitude 2.85 G, time constant 655 ms, sweep time 671 s. The positions of the maximum and minimum of the alanine central line shown in the bottom figure correspond to the frequency at which the binder spectrum was recorded. Note the differences of the two spectra in the receiver gains and in the orders of magnitude of vertical axis scales.

> of that value to a particular type of dosimeter (specific dosimeter shape, binder type and concentration).

On p. 9 of the temperature paper (the closing sentence for the article, in fact),

> Additional experiments may be necessary to verify the applicability of available values in specific cases.

Based on the experimental design of the humidity and temperature experiments, we stand behind these measurement procedures as the state-of-the-art. It is these *measurement practices* that we advocate:

> It is the recommendation of these authors that the measuring practices described here should be used in place of those described in the current ASTM standard on alanine dosimetry (Sleptchonok et al., 2000).

Note that, contrary to the claims of Hayes, the emphasis is on *measuring practices*, not the numerical values.

Our extensive tabulation of previously published humidity and temperature data was seen as a 'NIST criticism' by Hayes. In fact, our intentions were quite the opposite. The display of variation in published values was aimed at discouraging dosimetrists from blindly using any one particular published value. The current version of the ASTM alanine standard, as written, implies that certain values (e.g., temperature coefficient) can be applied universally. As the primary author and task group chair of the ASTM alanine standard since 1994, I (Desrosiers) was tasked with preparing a revision of the standard to address these shortcomings. This document was recently distributed worldwide to all major users of alanine dosimetry, including several prominent national metrology institutes; the support for these changes was unanimous.

Hayes wrote: "numerous alternate measurement procedures exist which have very dramatic benefits *in accuracy and precision* over and above the NIST system".

The accuracy of the NIST dosimetry service is world-class; it is verified on an annual basis through international comparisons with several national metrology institutes. Moreover, the precision of the NIST dosimetry service is clearly the best-in-the-world. Our alanine transfer dosimetry service carries an overall uncertainty of 1.3% at the 95% confidence level. There is no comparable service worldwide that operates below 2%.

However, it is apparent from the papers cited by Hayes on this subject that he is confusing accuracy and precision with sensitivity. The papers cited all focus on using alanine in the therapy range and below, and do not contain any accuracy/precision information useful in justifying his claims of superiority. A low dose detection limit does not necessarily translate to improvements in high-dose precision.

NIST alanine dosimetry only services users of ionizing radiation above the therapy range. NIST does provide calibration services to the medical therapy community. However, in the United States, the calibration service needs of dosimetry users at the therapy level and below are better served by other (non-alanine) dosimetry systems. NIST maintains a continuous dialogue with the ionizing radiation measurement community to keep abreast of their needs.

We are well aware of the techniques used in the therapy level papers (Hayes et al., 2000; Ruckerbauer et al., 1996; Sharpe et al., 1996). Though interesting, their potential improvements in precision are only useful to the extent that they contribute to an overall improvement of the alanine dosimetry calibration service. There are other factors (e.g., throughput, cost) that can outweigh precision. For example, NIST is currently developing a new alanine dosimetry system that

will be slightly *lower* in precision than its current service. It will be an on-demand, Internet-based service that will deliver results in real-time at drastically reduced costs. The user-friendliness and low cost of the service far outweigh small concessions in precision.

In summary, we believe our procedures are free of flaws and state-of-the-art. We performed these measurements on two alanine systems, one of which is commercially available. Lastly, our assessment of the transferability of our data and our recommendations were clearly stated.

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