

**NIST-Sponsored Comparison of Standards for Absorbed Dose to Water  
from  $^{60}\text{Co}$  Gamma Radiation at Radiation-Processing Levels**

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Introduction

As a precursor to the scheduled 2009 CCRI(I) comparison, the NIST conducted a comparison in 2008 of national standards for absorbed dose to water from  $^{60}\text{Co}$  gamma radiation at the dose levels used in radiation processing. The purpose of the comparison was to explore the influence of a newly discovered absorbed-dose-rate effect. The comparison covered the range from 1 kGy to 30 kGy and used NIST alanine dosimeters as the transfer dosimeters [1, 2].

The last comparison of the high-dose standards for absorbed dose to water from  $^{60}\text{Co}$  gamma radiation among the primary dosimetry laboratories offering standards and services was in the late 1990s. Organized by the Bureau International des Poids et Mesures (BIPM) and conducted by the National Institute of Standards and Technology (NIST, USA) and the National Physical Laboratory (NPL, UK), the previous comparison included also the Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti (ENEA-INMRI, Italy), the Physikalisch-Technische Bundesanstalt (PTB, Germany), the National Institute of Metrology (NIM, China), and the International Atomic Energy Agency (IAEA, Vienna). Because it does not offer a high-dose service, the BIPM took part at a single dose level (1 kGy) to provide a direct link to the international reference for absorbed dose to water in  $^{60}\text{Co}$  gamma-ray beams. The published comparison [3] reported a general level of agreement between the institutes at three dose levels: 5 kGy, 15 kGy, and 30 kGy. The agreement was well within the expanded uncertainty for each institute.

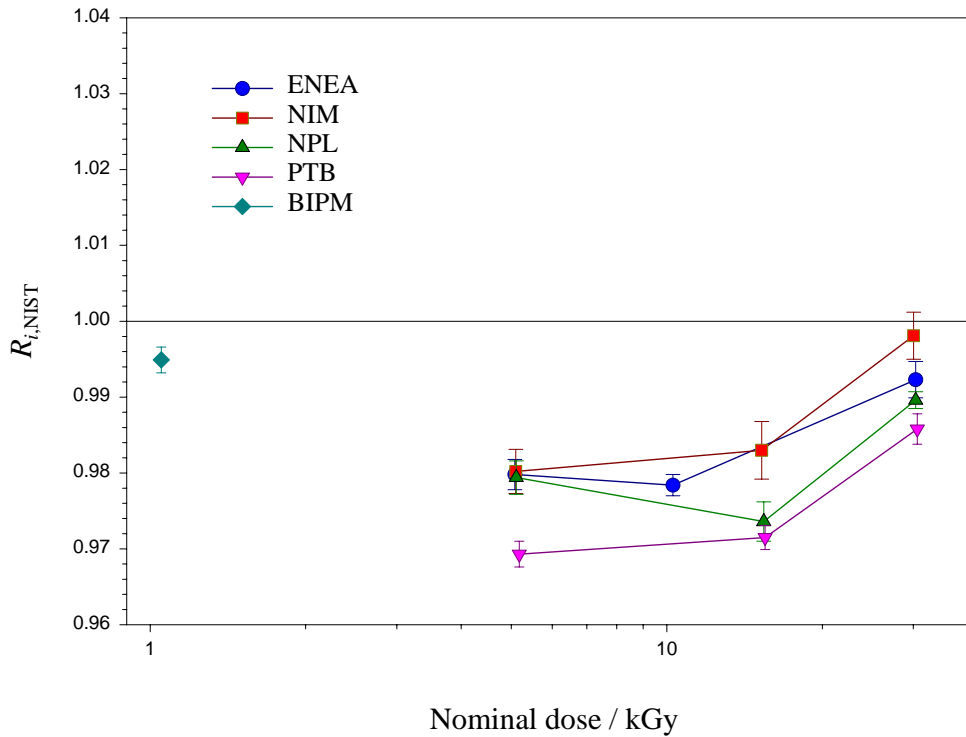


Figure 1. Previous results for the comparison ratios  $R_{i,NIST}$  using NIST alanine transfer dosimeters [3].

An examination of the level of agreement reveals suggestions of dose-dependent trends in the data. Although these trends were within the uncertainties, it was thought they might be related to dose-dependent trends historically found in NIST-NPL comparisons (unpublished data). For the past few years, NIST has conducted experiments to learn the root cause of these differences, which has culminated with new findings that could explain and reconcile the level of agreement among high-dose dosimetry laboratories. Evidence of an alanine dosimetry dose-rate dependence that is dependent on the absorbed dose has been documented (see, *e.g.*, Fig. 2), and a manuscript describing this work has been published [4].

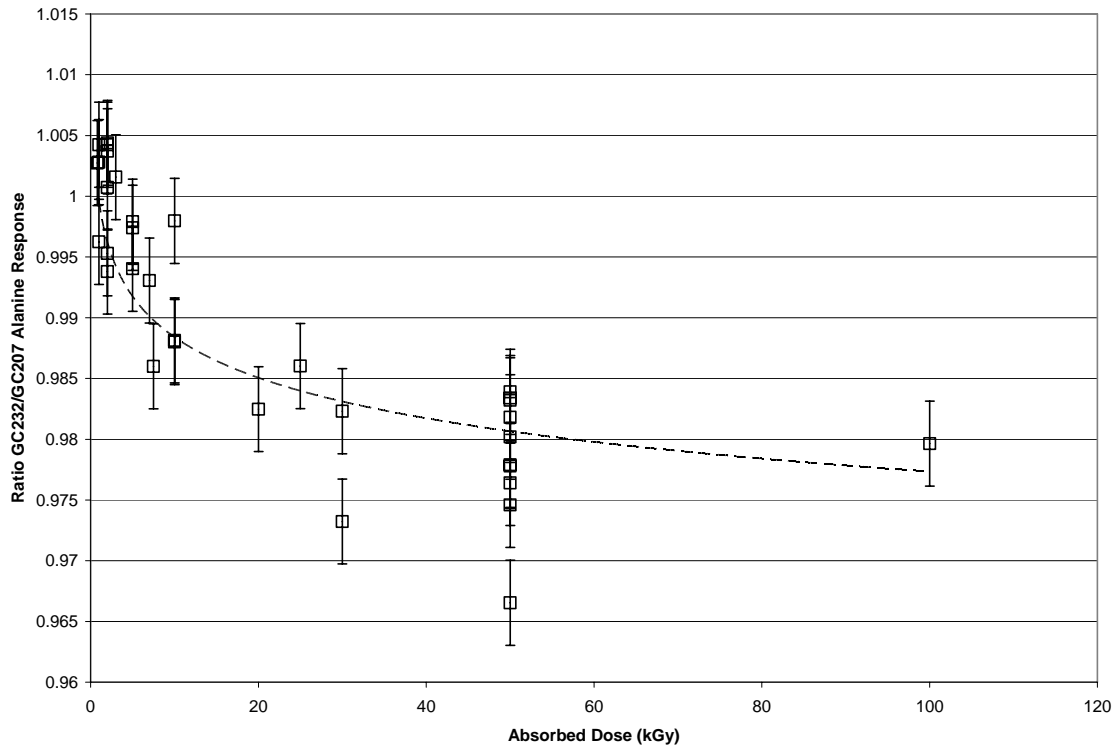


Figure 2. GC232-irradiated (low dose rate) alanine dosimeter measurements as a ratio to GC207-irradiated (high dose rate) dosimeter measurements for the same absorbed dose [4].

The 2008 NIST comparison aims to assess if this effect, unknown in the previous CCRI(I) comparison, can be observed in a comparison exercise. For the 2008 NIST comparison, the dose rates for  $^{60}\text{Co}$  sources within a laboratory's calibration scheme and/or the protocol for calibration of these sources were required from each participant so their dose rates could be considered in the data-analysis phase.

### Measurements

The NIST alanine dosimeters for use in the 2008 comparisons were supplied in watertight cylindrical holders nominally 12 mm in diameter and 29 mm in length; each vial contains four alanine pellets. The relative standard uncertainty of absorbed-dose estimates derived using the NIST dosimeters is 1.0 %. A detailed protocol for the comparison was issued in advance to the participating institutes. Each institute was sent ten alanine transfer dosimeter vials from the NIST. Of each ten, two remained unirradiated (as control dosimeters) and two were irradiated to each of four nominal dose levels; 1 kGy, 5 kGy, 15 kGy and 30 kGy. The irradiation geometry was not specified in detail in the protocol; each irradiating institute used their normal arrangement. This policy permitted the absorbed-dose estimates to be representative of those routinely disseminated by each institute, rather than modified for the purpose of the comparison. Irradiations by the participants occurred between 20 November 2008 and 6 December 2008. The dosimeters were returned to NIST with information on the average irradiation temperatures and the absorbed-dose estimates.

### Results

Dosimeters from the participating laboratories were measured at the NIST according to established procedures [2] and compared to the NIST calibration, as shown in Fig. 3..

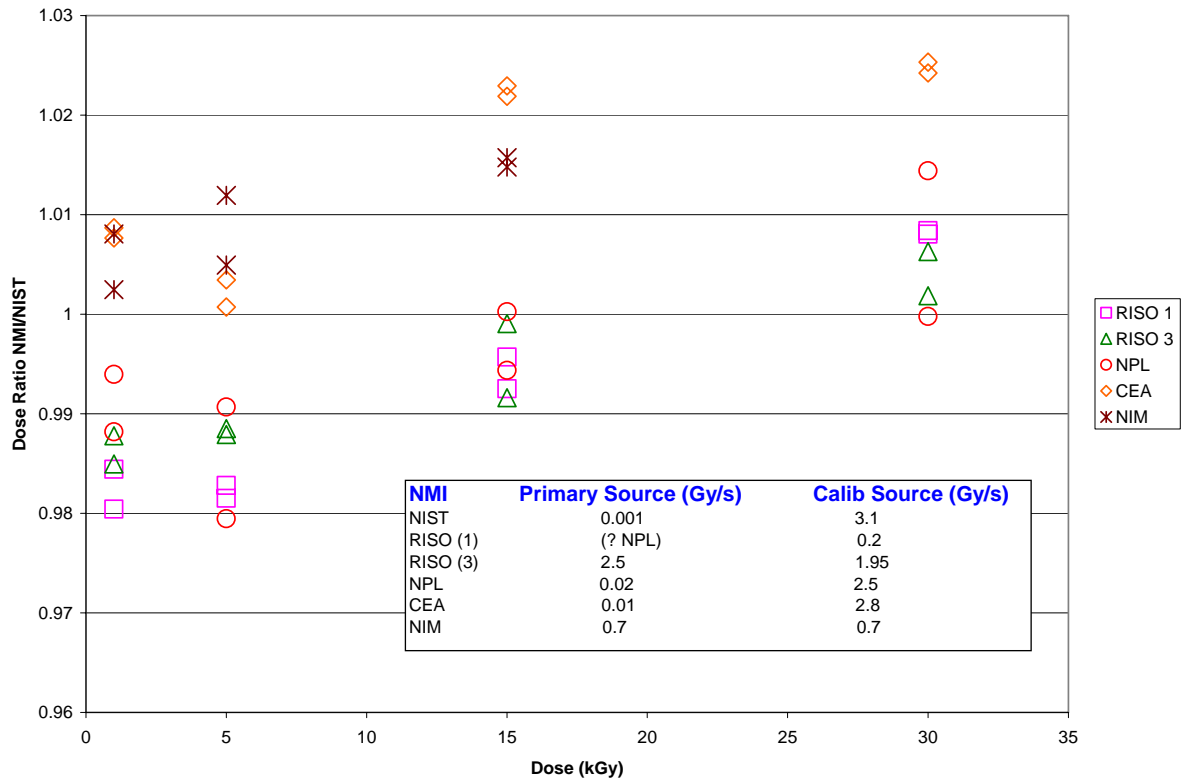


Figure 3. Results of 2008 NIST comparison: the ratio of absorbed dose reported by the NMI participant divided by the NIST measured absorbed dose versus the nominal dose in kGy.

### Conclusions

- Low doses (1 kGy and 5 kGy) show excellent agreement between all NMIs.
  - The recommendation by NIST to include 1 kGy in the 2009 CCRI comparison should be helpful to the analysis as it lends support to the equivalence found at 5 kGy.
- High doses (15 kGy and 30 kGy) from low-rate sources display the alanine-rate effect.
- Other high-dose trends that suggest a rate effect that might be related to the calibration method for the NMI source, but these differences are relatively minor (as they are within the NIST uncertainty).
- Overall, better agreement was found with the NIST than in the previous comparison from the 1990s.

### References

1. *Radiation Processing Dosimetry Calibration Services and Measurement Assurance Program*, J.C. Humphreys, J.M. Puhl, S.M. Seltzer, W.L. McLaughlin, M.F. Desrosiers, D.L. Bensen, M.L. Walker, NIST Special Publication 250-44, March 1998.
2. Ionizing Radiation Division Quality manual for Calibration Services, Procedure 12, <http://www.physics.nist.gov/Divisions/Div846/QualMan/index.html>

3. *CCRI supplementary comparison of standards for absorbed dose to water in  $^{60}\text{Co}$  gamma radiation at radiation processing dose levels*, D.T. Burns, P.J. Allisy-Roberts, M.F. Desrosiers, V. Yu. Nagy, P.H.G. Sharpe, R.F. Laitano, K. Mehta, M.K.H. Schneider, Y. Zhang, *Radiat. Phys. Chem.* **75** (2006) 1087-1092.
4. *Discovery of an Absorbed-Dose / Dose-Rate Dependence for the Alanine-EPR Dosimetry Systems and Its Implications in High-Dose Ionizing Radiation Metrology*, M.F. Desrosiers, J.M. Puhl, S.L. Cooper, *NIST J. of Res.* **113** (2008) 79-95.