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REPORT ON CCEM-K2 COMPARISON OF 10 MΩ AND 1 GΩ RESISTANCE STANDARDS

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Abstract

An international comparison of dc resistance at 10 MΩ and 1 GΩ was organized under the auspices of the Comité Consultatif d'Électricité et Magnétisme (CCEM) and piloted by the National Institute of Standards and Technology (NIST) with 14 other national metrology institutes (NMIs) participating. Results from the comparison are reported.

Introduction

In the past, key comparisons of resistance standards have been carried out at the 1 Ω and 10 kΩ levels. In 1995, the CCEM (formerly CCE) decided to extend the scope of some key comparisons to demonstrate equivalence of NMI's standards more effectively, and identified dc resistance $\geq 10^9$ Ω (1 GΩ) as one of the critical measurement areas. NIST volunteered to be the pilot for this key comparison and recommended using wirewound 10 MΩ and film-type 1 GΩ standards as the traveling resistors. 1 GΩ wirewound resistors were not at the disposal of the pilot laboratory, although, in general, wirewound resistors are more stable than film types. Thus, it was decided to include wirewound 10 MΩ standards in the comparison in the event that problems arose with the traveling 1 GΩ standards. Also, the comparison at two different resistance levels would be a check on a NMI's resistance scaling process [1].

Measurements

The traveling standards were measured by the participating NMIs during a three-and-a-half year period beginning in August of 1996 and concluding in March of 2000. Table 1 shows the participating NMIs in chronological order by mean date of measurement. During the comparison, the pilot laboratory measured the traveling standards over seven distinct periods of time. The pilot lab measurements were made using two measurement systems, a guarded Wheatstone bridge system [2] and a guarded dual-voltage-source bridge system [3]. The pilot lab did not specify to the participants what method to use to measure the traveling standards. It was assumed that each NMI would use its normal measurement method thus providing a more realistic assessment of the quality of the NMI's measurement process. Among the fifteen NMIs, five different methods were used to measure the traveling standards.

Table 1. Participant list.

National Research Council, Canada, **(NRC)**
Bureau National de Métrologie- Laboratorie Central des Industries Électriques, France, **(BNM-LCIE)**
National Physical Laboratory, U. K., **(NPL)**
Physikalisch-Technische Bundesanstalt, Germany, **(PTB)**
Commonwealth Scientific and Industrial Research Organization- National Measurement Laboratory, Australia, **(CSIRO-NML)**
Measurements Standards Laboratory, New Zealand, **(MSL)**
Council for Scientific and Industrial Research- National Measurement Laboratory, South Africa, **(CSIR-NML)**
National Institute of Standards and Technology (Pilot), U. S. A., **(NIST)**
Swedish National Testing and Research Institute, Sweden, **(SP)**
Office Fédéral de Métrologie, Switzerland, **(OFMET)**
Istituto Elettrotecnico Nazionale, Italy, **(IEN)**
Nederlands Meetinstituut- Van Swinden Laboratorium, The Netherlands, **(NMi-VSL)**
Korea Reasearch Institude of Standards and Science, The Republic of Korea, **(KRISS)**
National Institute of Metrology, China, **(NIM)**
D. I. Mendeleyev Institute for Metrology, Russia, **(VNIIM)**

Data Analysis

For each traveling standard at the 10 MΩ and 1 GΩ resistance levels, a time-dependent reference value (x_{iP}) is calculated based on a least-squares linear regression of the pilot laboratory values. For each NMI measurement of each traveling standard (x_i), a difference from the time-dependent reference value ($D_i = x_i - x_{iP}$) is determined and combined as a weighted average ($D_{i\text{COMB}}$) for 10 MΩ and 1 GΩ, respectfully. The $D_{i\text{COMB}}$s and the expanded relative uncertainty ($k = 2$) for each NMI, $U_{i\text{COMB}}$, are used to determine a key comparison reference value, X_{KCRV}, and an uncertainty of the key comparison

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reference value, U_{KCRV}, for the 10 MΩ and 1 GΩ resistance levels. The statistical analysis and formulas are described in detail in a separate paper submitted to the conference [4]. For the 10 MΩ resistance level, the $X_{KCRV} = 0.346 \times 10^{-6}$ and $U_{KCRV} = 0.859 \times 10^{-6}$, and for the 1 GΩ resistance level, the $X_{KCRV} = 0.099 \times 10^{-6}$ and $U_{KCRV} = 3.19 \times 10^{-6}$.

Results

Figure 1 shows for each NMI the difference from the key comparison reference value (D_{iKCRV}) at 10 MΩ and 1 GΩ. For each NMI, the difference from the X_{KCRV} is less than the NMI's expanded relative uncertainty (k = 2). For many of the NMIs, their difference from the X_{KCRV} is quite small compared to their expanded relative uncertainty. The data reported in figure 1 has been corrected to a nominal temperature of 23 °C. The participating NMIs were requested to measure the traveling standards at both 10 V and 100 V, although this was not always possible. The 100 V data are used when available due to the improvement in the signal-to-noise ratio at the higher voltage.

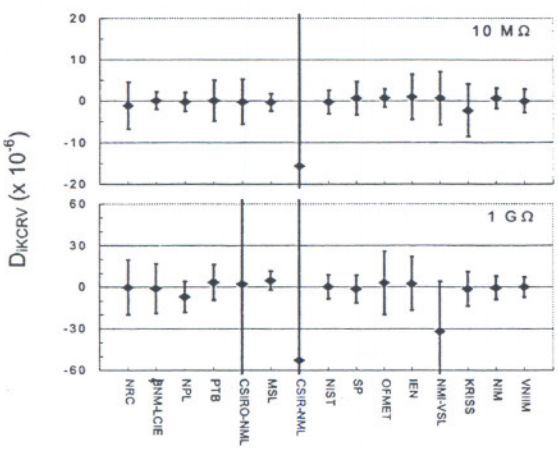

Figure 1. Differences from key comparison reference value at 10 MΩ and 1 GΩ. Error bars denote expanded relative uncertainty for the individual NMIs using $k = 2$.

Conclusions

The results of this key comparison have demonstrated good agreement among the participating NMIs at 10 MΩ and 1 GΩ. All of the participating NMIs agree within the 95 % confidence level and most agree within the 99 % confidence level. The results have also shown that the scaling processes at participating NMIs are effective up to 1 GΩ, and that the five measurement methods used all give reasonable agreement in the results. The traveling standards appeared to have functioned satisfactorily during the 43-month period of this comparison.

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