RECENT DEVELOPMENTS IN BIPM VOLTAGE STANDARD COMPARISONS

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Abstract

The BIPM carries out a number of comparisons of DC voltage standards with national metrology institutes. These take the form of on-site comparisons of Josephson standards or bilateral comparisons using travelling standards based on Zener diodes. This paper describes some of the new procedures used in both types of comparisons and presents some results of five recent BIPM key comparisons.

Introduction

The Mutual Recognition Arrangement among National Metrology Institutes (NMIs) places particular importance on key comparisons to demonstrate a NMI's ability to measure certain critical quantities. The Consultative Committee on Electricity and Magnetism has identified comparisons of 1.018 V and 10 V standards, including Josephson array voltage standards (JAVS), as key comparisons. These standards, which are sometimes commercial systems, are used as primary voltage standards in an increasing number of NMIs. To take advantage of the high accuracy of JAVS, on-site direct comparisons have been carried out by the BIPM since 1991.

Another way that NMIs check the coherence of JAVS standards is to use Zener diode-based references (Zeners) as travelling standards in international comparisons. Such comparisons are most demanding of the performance of Zeners. Nevertheless, provided that corrections are made for the effects of pressure and temperature on the Zener outputs, it appears possible to reach the one part in 10^8 level of uncertainty.

The NMIs that do not posses JAVS often rely on Zeners as travelling standards to assure traceability to Josephson standards via calibrations and comparisons with other NMIs or with the BIPM. Over the years, some NMIs have participated in regular calibrations of their national voltage standard by the BIPM. Consequently, they have established accurate values and drift rates of their standards. They now participate regularly in bilateral comparisons of their voltage standard with the BIPM.

On-site JAVS Comparison

The most recent BIPM on-site comparison took place in May 1999 at the SMU. The BIPM JAVS [1] was shipped there, assembled and compared with the SMU JAVS [2]. The latter is a commercial 10 V system incorporating a wide-range DVM and operated with software that allows voltage differences of several millivolts between the JAVS output and the instrument being calibrated. The time over which an output voltage near 10 V can be maintained is of the order of a few tens of seconds. This, and the practical impossibility of biasing on one particular voltage step and no other, led to using, for the first time, an alternative procedure in BIPM on-site JAVS comparisons. The SMU JAVS measured the BIPM JAVS as if it were a standard to be calibrated. Although the final uncertainty was limited by the DVM in the SMU system, the results were satisfactory if compared with the limitations of the alternative, on-site comparisons of Zener calibrations that were also performed.

Travelling Zeners comparisons

With NMIs equipped with JAVS

The BIPM studied the dependence on ambient temperature [3] and pressure [4] of its Fluke 732B voltage standards and found that these effects, especially the latter, can lead to significant errors if not corrected. Temperature and pressure coefficients were determined so that corrections may be applied. These standards are now available to NMIs as part of the BIPM programme of bilateral comparisons. Three recent comparisons were carried out with NMIs equipped with JAVS. These can be viewed as comparisons of JAVS, limited by the Zeners' noise and stability, the uncertainties in their pressure and temperature coefficients, and uncertainties in their drift rates. Alternatively, assuming that the JAVS are in perfect agreement, the comparisons can serve to evaluate the uncertainties associated with the Zener travelling standards and check the veracity of the corrections.

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A. BIPM/NIST(Gaithersburg)/NIST (Boulder) comparison

The NIST (Boulder) agreed to a BIPM proposal to check the level of agreement obtainable in a 10 V comparison with a laboratory situated at a high altitude so that the pressure correction would approach three or four parts in 10^7. By including the NIST Gaithersburg facility, the stability of the travelling Zeners could be checked while at the same time assuring a strong tie with previous and future comparisons involving the SIM regional metrology organization (RMO). Three Zeners were shipped by air freight and measured for two-week periods according to the schedule BIPM - $NIST_G$ - $NIST_B$ - $NIST_G$ - BIPM carried out from October 1998 to January 1999 [5].

B. BIPM/VNIIM comparison

A 1.018 V comparison with the VNIIM was carried out between November 1998 and January 1999 for the purpose of comparing JAVS. Two Zeners were transported by air as hand baggage and measured at the VNIIM in a single week [6].

C. BIPM/OFMET comparison

A 10 V comparison with the OFMET was carried out between March 1999 and May 1999 for the purpose of comparing JAVS. Three Zeners were transported to the OFMET by automobile and measured there over a two-week period [7].

With NMIs that do not possess JAVS

D. BIPM/NML comparison

A 10 V comparison with the NML was carried out in June 1999. Two Zeners were shipped via air freight and measured at the NML for two weeks. The purpose of this comparison was to continue the link between our voltage standards that has operated on a regular basis since 1989. The values assigned by the NML to BIPM travelling Zener standards, based on the predicted behaviour of the NML voltage standard, are compared with those measured by the BIPM before and after the NML measurements [8].

Results

Final results, including uncertainty analyses, will be presented at CPEM 2000.

The provisional results expressed as the difference between the values that would be attributed to a standard by the two laboratories and the combined 1-σ uncertainties are given in Table I.

Conclusions

The main conclusion is that bilateral comparisons of Zeners can achieve relative uncertainties of the order of a few parts in 10^8 while on-site comparisons of Zeners can achieve uncertainties of a few parts in 10^9. The uncertainties achieved in on-site comparisons of 10 V JAVS [9] is a few parts in 10^{10}. The comparisons reported here link, via the BIPM, three RMOs: SIM, COOMET and EUROMET.

Table I. Provisional results expressed as the difference $\Delta U_{A/B} = (U_A - U_B)$ between the values that would be attributed to a standard by the two laboratories and the combined 1-σ uncertainties u_C.

Laboratories	$(\Delta U/U)/10^{-8}$	$(u_C/U)/10^{-8}$	Comparison
SMU/BIPM	0.14	0.11	JAVS
SMU/BIPM	0.62	0.36	on-site Zener
$NIST_G$/BIPM	2.6	1.4	Zeners
$NIST_B$/BIPM	2.2	1.7	Zeners
$NIST_G$/$NIST_B$	0.4	1.3	Zeners
VNIIM/BIPM	0	3	Zeners
OFMET/BIPM	−1.4	1.4	Zeners
NML/BIPM	2.9	23	Zeners

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