Technical Protocol APMP.EM.BIPM-K11.4

Bilateral comparison of DC Voltage between KRISS and VMI

CONTENTS

1. INTRODUCTION

This bilateral key comparison between KRISS, Korea (South) and VMI, Vietnam has been organized by KRISS (pilot) in response to VMI's request for RMO comparison in DC voltage of 1.018 V and 10 V by transporting Zener voltage standards. An RMO KC for this APMP.EM.BIPM-K11.3 (pilot: KRISS) started in 2009. Circulation of the traveling standards is finished and the comparison is now in Draft A report preparation stage. This bilateral comparison is, therefore, a separate RMO KC. The protocol of this KC, K11.4 follows the protocol of the K11.3 with two minor differences: 1) The traveling standards, 2) Post evaluation of pressure coefficient of the traveling standard. The corresponding CCEM KC's are BIPM.EM-K11.a (1.018 V) and BIPM.EM-K11.b (10 V). The link of VMI result to the KCRV will be based on the KRISS result in BIPM.EM-K11.a & b, 2008.

2. TRAVELING STANDARDS

2.1 General requirements

The traveling standard should have good stability of its output voltages during transportation. To reduce the consequences of any unexpected behavior of the traveling standards,[1] two Zener standards (Fluke 732B) are used; one provided from KRISS, the other provided from VMI. Although the environmental conditions between the two labs are similar, appropriate uncertainty evaluation for temperature, humidity and pressure effect is necessary. This makes it necessary for us to prepare a set of traveling standards with data on their environmental coefficients.

Temperature correction

Temperature coefficients of the traveling Zener standards has been characterized at KRISS and shown in Table 1.

Pressure correction

Considering the atmospheric pressure conditions are almost same between the two labs and to save time from protocol approval and to carrying out measurements, the pressure coefficient will be evaluated right after all comparison measurements are finished at KRISS. Then the blank in the last column in the Table 1 will be filled out and included in the final report.

Humidity correction

Humidity effect of the Zener standards is known to have very slow time response [2]. In view of time schedule of comparison, the humidity effect will be treated as a drift effect when reference value is calculated by interpolation between two reference measurements as in the earlier EUROMET KC [3].

2.2 Description of standards

The traveling standards, two Fluke 732B electronic DC reference standards, have identification as follows:

TZS-K s/n 6270008

TZS-V s/n 7135019

The Fluke 732 B electronic DC reference standard has two output voltages, nominally 1.018 V and 10 V, respectively. The traveling standard should be handled carefully and be stored in a stabilized environment where relative humidity is between 40 % and 55 % R.H.

Characteristics of the standard standards

In Table 1 an overview is given of the temperature and pressure coefficients of the output voltages $U_{measured}$ of the traveling standards as determined by KRISS. The temperature effect is expressed in terms of the environmental temperature (α_T) and in terms of the oven thermistor resistance (α_R). The coefficient α_R will be used to make corrections for temperature effects (see measurement procedure).

Table 1: Temperature, humidity and pressure coefficients of 10 V and 1.018 V outputs. (The uncertainties are stated in terms of combined standard uncertainty, 1 sigma)

Standard	Output	Reference thermistor resistance at R_0 (kΩ)	Temperature coefficient α_R (nV Ω^{-1})	Reference pressure (hPa)	Pressure coefficient α_p (nV hPa^{-1})*
TZS-K	10 V	38.650	1.4 ± 0.2	998.00	30 ± 11
TZS-V	10 V	38.650	3.1 ± 0.2	998.00	37 ± 8
TZS-K	1.018 V	38.650	-0.27 ± 0.03	998.00	-7.4 ± 1.3
TZS-V	1.018 V	38.650	0.29 ± 0.02	998.00	0.7 ± 0.6

* As for the blank if this column, see 2.1.

The resistance of the oven thermistor will be used as an indicator for the temperature of the Zener standards.

2.3 Quantities to be measured

DC voltage outputs 1.018 V and 10 V for the two standards.

3. ORGANIZATION

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3.3 Time schedule

The comparison will be organized as Table 2.

Table 2: Time schedule

Year	Date of Measurement	Laboratory	Country or Economy
2012	22 June – 6 July	KRISS, Pilot laboratory	Korea (South)
	12 July – 27 July	VMI	Vietnam
	3 August – 17 August	KRISS, Pilot laboratory	Korea (South)

3.4 Transportation

Travelling standard should be hand-carried carefully during the transportations between 2 laboratories to avoid internal battery discharge during a prolonged customs clearance time and to avoid abrupt change of environmental condition (temperature, humidity, pressure). It is because the traveling standard has not been fully evaluated of its temperature, humidity and pressure coefficient.

Two or three weeks will be allowed for each participant to keep the standards in his (her) laboratory. This period includes recharging of the operation batteries, stabilization to the laboratory environment, the measurements and reporting the result to the pilot lab.

Because the standards should always be in the "IN CAL" state, during transit as well as measurement, quick and safe transport is essential.

3.5 Unpacking, handling, packing

The traveling standards should be handled carefully. Extreme temperature, humidity or pressure changes as well as violent mechanical shocks must be always avoided.

Powering of the standard

As soon as the standards arrive at the laboratory, each Fluke 732B must be supplied from the AC power line so that the internal batteries are fully charged with the self-contained automatic charger. **Be sure to check each AC line voltage selector** at the rear of the Fluke 732B before connecting the AC power cable. Be careful not to supply higher than rated voltage to the Fluke 732B! The full recharge will take about half of the transport time.

After measurements on each working day, the standards must continuously receive uninterrupted voltage from the AC line power overnight or on weekend to fully recharge the standards for next day measurements. At least half of total battery operation time is required to recharge the Fluke 732B. The front panel **AC PWR** indicator lights when the standard is connected to the AC line power.

During measurements, the Fluke 732B should be disconnected from the AC line power. If the internal battery voltage drops low, the front panel **LOW BAT** indicator will start blinking. Then the standard must be plugged into the AC line power immediately to allow the battery to be recharged.

The **IN CAL** indicator must be lit "on" during the whole comparison and transportation. **Be sure to fully recharge the standards before packing them.** In any case that the indicator is found to be "off", the laboratory should report immediately to the pilot laboratory, which will give specific instructions.

Front panel indicators

- **AC PWR**

  The AC PWR indicator lights whenever the standard is connected to AC line power (e.g. 220 V, 60 Hz). **Be sure to check each AC line voltage selector** at the rear of the Fluke 732B before connecting the AC power cable. Be careful not to supply higher than rated voltage to the Fluke 732B!

- **IN CAL**

  The IN CAL indicator goes out after excessive drops in battery operating voltage or gross changes in oven temperature. **If the IN CAL indicator doesn't light, you must immediately contact the pilot laboratory, which will give specific instructions how to proceed.**

- **CHARGE**

  The CHARGE indicator lights on when the standard is connected to the AC line power and the internal battery is in the charging mode. When the battery is near full charge, the CHARGE indicator goes off.

- **LOW BAT**

  The LOW BAT indicator blinks when approximately 5 hours of battery operation time remains. **When LOW BAT blinks, plug the Fluke 732B into the AC line power immediately to avoid extinguishing the IN CAL indicator.** The battery is recharged in about half of the used time with the self-contained automatic battery charger.

4. MEASUREMENT INSTRUCTIONS

4.1 Tests before measurements

Precautions

- Do not short the outputs.

- Make sure not to disconnect the standard from the AC line power for too long.

- Avoid extreme temperature, humidity or pressure changes as well as violent impacts.

Stabilization of the standards

After arrival in the participant's laboratory, the standards should be allowed to stabilize in a temperature and humidity controlled room for at least two days before the measurements can begin.

Powering of the standard during the measurements

When not carrying out measurements, the standards must be connected continuously to the AC line power. Measurement can be carried out after full charge, i.e., after charge indicator turns off. Measurements should be carried out with the standard disconnected from the AC line power. To allow the standard to stabilize, measurements should not begin any sooner than 2 hours after disconnecting the standard from the AC line power. Connect the AC line after finishing the measurements to recharge the standards. (See **„LOW BAT' in Clause 3.5)**

In addition to the battery-operated measurements, measurements can be made (and submitted to the pilot laboratory) with the standards connected to the AC line power. Notice that connection to the AC line power during measurement will probably have consequences for the connection of guard and/or ground.

4.2 Measurement Performance

Guarding

Assuming that you carry out the voltage measurements with the Fluke 732B's disconnected from the AC line power. The standards are kept floating. To reduce external noise, the GUARD of the Fluke 732B should be connected to ground potential of the measurement system, CHASIS GROUND of the Fluke 732B should be kept in no connection.

Measuring the internal thermistor resistance

The internal thermistor resistance must be reported so that temperature correction can be made. The thermistor resistances of the standards have nominal values between 38 kΩ and 40 kΩ (see Table 1). To avoid heating of the thermistor, the test current should **not exceed 10 μ A**. This implies that most

DMMs can not be used in their 100 kΩ range or auto-range setting.

Environmental conditions

The ambient temperature, humidity and pressure must be measured. Corrections must be made for temperature and pressure effects (see next section). Recommended measurement conditions are 23 ℃ and 45 %RH.

4.3 Method of measurement

Making corrections for temperature and pressure effects

The measured voltages $U_{measured}$ should be corrected for temperature and pressure effects. The temperature effect is taken into account through the thermistor resistance *R*. The following formula should be used to calculate the corrected voltages $U_{corrected}$:

$$U_{corrected} = U_{measured} - \alpha_R \cdot (R - R_0) - \alpha_p \cdot (p - p_0),$$

where α_R and α_p are the temperature and pressure coefficients as given in Table 1, *p* is the ambient air pressure, p_0 = 1010.00 hPa is the reference air pressure, and R_0 = 38.650 kΩ is the reference thermistor resistance.

Obviously, the uncertainties of both the thermistor resistance measurement and the air pressure measurement contribute to the total uncertainty of measurement.

5. UNCERTAINTY OF MEASUREMENT

5.1 Main uncertainty components, including sources and typical values

The uncertainty calculations must comply with the requirements of the 'Guide to the Expression of Uncertainty in Measurement' (issued by the International Organization for Standardization, JCGM 100 :2008). Foreseen sources of uncertainty:

- Type A
- DVM or null-detector gain-error uncertainty
- Uncertainty due to irreversibility of scanner or switch
- Leakage-error uncertainty

- Uncertainty due to uncompensated offset voltages
- Microwave-frequency uncertainty
- Uncertainty due to EMI
- Calibration uncertainty of measurement equipment (e.g., for measuring the thermistor resistance, pressure, etc.)

This is not a complete list and should be extended with uncertainty contributions that are specific for the participant's measurement system.

5.2 Scheme to report the uncertainty budget

See Appendix A and Chapter 6

6. MEASUREMENT REPORT

VMI's report must be sent to both the pilot laboratory and the TCEM chair within two days from the completion of measurements and before transporting to the next lab (KRISS).

6.1 Software

Reports should be submitted electronically, using the following software:

- Word 2003 or later version for the report including VMI's results
- Excel 2003 or later version for the raw data and detailed uncertainty budget

6.2 Contents of report

The report must contain:

- **The results of the measurement**

  For each reported value the following information must be provided using the form attached in Appendix:

  - identification of standard

- method of measurement
- date and time of measurement
- waiting time before starting measurement after disconnect AC line from the Fluke 732B
- measured voltage
- thermistor resistance
- ambient temperature, humidity, and pressure
- values of correction for temperature and pressure effects
- measured voltage corrected for temperature and pressure effects
- the Type A standard uncertainty
- the Type B standard uncertainty
- combined standard uncertainty
- the expanded uncertainty of measurement (confidence level of appr. 95 %)
- effective degrees of freedom

▪ **<u>Uncertainty budget and calculation</u>**

The uncertainty analysis should include a list of all sources of Type B uncertainty, together with the associated standard uncertainties as well as their evaluation method. For clarity, it is recommended to present the uncertainty budget in the form of a table (see, e.g., chapter 4 of the EA-4/02 document "Expression of the Uncertainty of Measurement in Calibration").

For each reported value, the expanded uncertainty of measurement and the coverage factor *k* must be given for confidence level of approximate 95 %.

▪ **<u>Description of the method of measurement</u>**

This includes information on:

- the method applied for correction of offset voltages

(manual or automatic switching, reversal of null-detector or not, etc.)

- the method applied for guarding and shielding, and connection to earth
- method applied for biasing the Josephson array*

  (bias on or off during measurement)
- method for Josephson step number adjustment and maximum value of null voltage*
- "bandwidth" of the voltage measurement (null-detector analog or digital filtering, number of samples, averaging, etc.)*

** Standard used is Josephson Voltage standard system*

7. REPORT OF THE COMPARISON

The draft version of the final report will be issued within one month after completion of the comparison. The draft report will be sent to the VMI and will be discussed. The whole procedure will be based on the CCEM Guidelines document WGLF/2007-12.

REFERENCES

[1] Thomas J. Witt, "Key Comparisons in Electricity: Case Studies from the BIPM," APMP TCEM MEETING, 5 September 2005.

[2] L.X. Liu et al, "APMP Comparison of DC voltage," Report APMP-IC-6-95, 2001.

[3] F. Liefrink et al, "Comparison of 10 V Electronic Voltage Standards," Final Report: EUROMET project no. 429, September 2002.

[4] J.W. Mueller, “Possible Advantages of a Robust Evaluation of Comparisons,” J. Res. Natl. Inst. Stand. Technol. **105**, 551, 2000.

[5] EA-4/02 “Expression of the Uncertainty of Measurement in Calibration”.

APPENDIX A: Forms for Summary Report

10 V:

Identification of standard	TZS-K	TZS-V
Method of measurement		
Date and time of measurement (from to)		
Measured voltage (V)		
Thermistor resistance (ohm)/ Ambient temperature (^{o}C)		
Humidity (% R.H.)/ Pressure (hPa)		
Corrected voltage at R_0 and p_0 (V)		
Number of measurements		
Type A standard uncertainty (nV)		
Type B standard uncertainty (nV)		
Combined standard uncertainty (nV)		
Expanded uncertainty (nV)		
Coverage factor *k*		
Effective degrees of freedom		

1.018 V:

Identification of standard	TZS-K	TZS-V
Method of measurement		
Date and time of measurement (from to)		
Measured voltage (V)		
Thermistor resistance (ohm)/ Ambient temperature (^{o}C)		
Humidity (% R.H.)/ Pressure (hPa)		
Corrected voltage at R_0 and p_0 (V)		
Number of measurements		
Type A standard uncertainty (nV)		
Type B standard uncertainty (nV)		
Combined standard uncertainty (nV)		
Expanded uncertainty (nV)		
Coverage factor *k*		
Effective degrees of freedom		