IMPLEMENTING OF THE CIPM MRA OF THE NATIONAL METROLOGICAL INSTITUTE "UKRMETRTESTSTANDARD"

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Abstract – Results of CIPM, EURAMET and COOMET key and supplementary comparisons of national measurement standards and calibration and measurement capabilities (CMCs) of the Ukrainian national metrological institute "Ukrmetrteststandard" in 2000–2010 are considered.

Keywords: comparisons, national standards, national metrological institute, regional metrology organizations.

1. INTRODUCTION

The Mutual Recognition Arrangement (MRA) has been drawn up by the International Committee of Weights and Measures (CIPM), under the authority given to it in the Metre Convention, for signature by directors of the national metrology institutes (NMIs) of Member States of the Convention [1].

Maim objectives of MRA CIPM are: to establish the degree of equivalence of national measurement standards (NMS) maintained by NMIs; to provide for the mutual recognition of calibration and measurement certificates issued by NMIs; thereby to provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs [2].

NMI directors sign the MRA CIPM with the approval of the appropriate authorities in their own country and thereby: accept the process specified in the MRA CIPM for establishing the database; recognize the results of key and supplementary comparisons as stated in the database; recognize the calibration and measurement capabilities (CMCs) of other participating NMIs as stated in the database.

Multilateral agreements for national accreditation and regulatory bodies depend for their validity on the accuracy of NMSs and of calibration and measurement certificates issued by NMIs. This mutual recognition is founded on the efforts of each individual NMI to base its measurements and measurement uncertainties on SI units. This arrangement is in two parts: signatories recognize the degree of equivalence of NMSs of participating NMIs; the signatories recognize the validity of calibration and measurement certificates issued by participating NMIs.

Participation in the arrangement through their regional metrology organization (RMOs) is also open to the NMIs of States and Economies that are Associates of the General Conference of Weights and Measures (CGPM). Comparison of NMSs must be carried out periodically between NMIs from RMOs to establish the relationship between their practical units.

2. GENERAL PROVISIONS

The function of CIPM MRA is to extend and consolidate pre-existing worldwide confidence in measurements. The technical basis of CIPM MRA is the set of results obtained in the course of time through key comparisons (KCs) carried out by the Consultative Committees (CCs) of the CIPM, the International Bureau of Weights and Measures (BIPM) and RMOs, and published by the BIPM and maintained in the KCs database – KCDB [2].

RMO KCs must be linked to the corresponding CIPM KCs by means of joint participants. The degree of equivalence derived from an RMO KCs has the same status as that derived from a CC KCs. A Joint Committee of the RMOs and the BIPM (JCRB) is responsible for the coordination of data provided by the RMOs, and other actions undertaken by them to promote confidence in calibration and measurement certificates. Coordination of the KCs is effected through consultations between the CCs and the RMOs.

Scheme interactions NMIs, CCs CIPM, RMOs and BIPM performances on Figure 1.

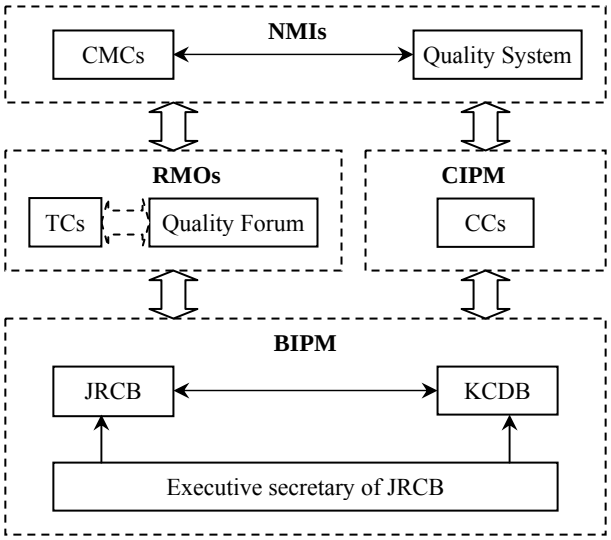

Fig. 1. Scheme interactions of NMIs, CCs CIPM, RMOs and BIPM

NMIs participating in CIPM MRA are expected to extend existing international confidence in their activities by publishing regular reports on the work of their laboratories and transmitting them to the BIPM, and by participation in relevant conferences. Demonstration of competence and capability may require visits and examination of procedures by an NMI and/or by peers selected by the local RMO [2].

3. COMPARISONS OF THE NATIONAL MEASUREMENT STANDARDS OF NMI "UKRMETRTESTSTANDARD"

The NMI "Ukrmetrteststandard" (UMTS) is among the largest centre of scientific, legal and practical metrology in Ukraine dealing with precise measurements and methods assuring their traceability to NMSs.

The UMTS conducts scientific applied investigations in the field of metrology and carries out scientific research work related with establishment, improvement, maintenance and application of primary and secondary standards. In NMI keeping twelve Ukrainian State (national) standards of units in fields: "Electrical and Magnetism" (6 standards), "Amount of Substance" (3 standards), "Length" (1 standard), and "Mass and related quantities" (2 standards), which was created in 1998–2010 [3–5].

The list of comparisons of NMSs of the UMTS for "Electrical and Magnetism" (EM) and "Amount of Substance" (QM) is shown on Table 1 [6–8]. In four comparisons for EM (COOMET.EM-K4, COOMET.EM-S4, COOMET.EM-S2, and COOMET.EM-S5) UMTS are pilot NMI.

The Figure 2 shows the data on the CCs and RMOs comparisons in the 2005–2010, respectively, and the Figure 3 relationship between the KCs and SCs comparisons for EM and QM is given.

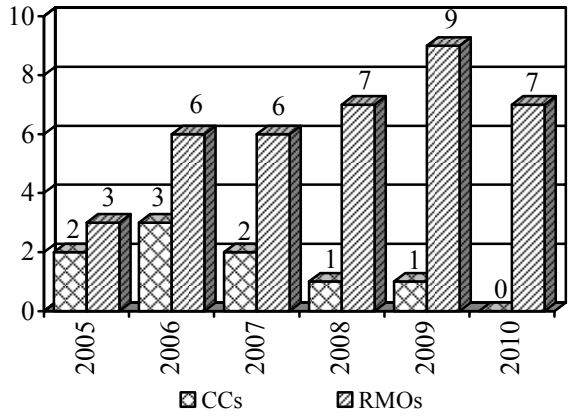

Fig. 2. CCs and RMOs comparisons for EM and QM in 2005–2010

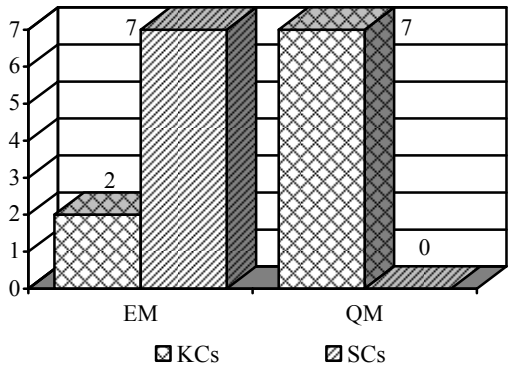

Fig. 3. Key and supplement comparisons for EM and QM

The results of KC COOMET.EM-K4 (Draft A [8]) will be linked to key comparison CCEM-K4 between the practical capacitance units (capacitance 10 pF) of ten NMIs from four RMOs (EUROMET – EUROMET.EM-K4, COOMET.EM-K4, APMP.EM-K4.1, SIM.EM-K4), and of the BIPM, which organized the Consultative Committee for Electricity and Magnetism (CCEM).

The KC COOMET.QM-K3 [9] on automobile gases were carried out by the Consultative Committee for Amount of Substance (CCQM) – CCQM-K3 and by regional metrological organizations EUROMET (EUROMET.QM-K3) and APMP (APMP.QM-K3). All laboratories find the gravimetric value within ± 0.7 % relative to the gravimetric value. This holds for all three components, CO, CO_2 and C_3H_8 in nitrogen.

In 2007 VNIIM offered to organize within COOMET a KC of natural gas linked to CCQM-K23b. There were five NMIs that decided to take part in COOMET.QM-K23b in order to claim new or improve present CMCs. Most of the NMIs (VNIIM, BAM, SMU, CMI) participated in CCQM-K23b; BelGIM and "Ukrmetrteststandard" participated in a KC of natural gas for the first time. The agreement of the results in COOMET.QM-K23b is very good. Most of the results agree with the KC Reference Value (KCRV) within 0.5% relative. BelGIM and "Ukrmetrteststandard" performed well in this KC [10].

The KC COOMET.QM-K1.a is the second KC in the field of gas analysis organized by the COOMET, and corresponds to measurements of carbon monoxide in nitrogen for nominal amount-of-substance fractions of 100 μmol/mol and 1000 μmol/mol. COOMET.QM-K1.a results could be linked to those of an earlier KC, CCQM-K1.a, carried out by the CCQM.

The aims of this COOMET exercise were the recognition of NMSs of Belarus and Ukraine in view of entering CMCs of BelGIM and "Ukrmetrteststandard" in the KCDB of the BIPM; and to improve the CMCs of those laboratories which previously participated in the KC CCQM-K1a. All the laboratory results stand within ± 0.6% relative to the gravimetric value obtained by the coordinating laboratory for the nominal value 100 μmol/mol, and within ± 0.3% relative to the gravimetric value for the nominal value 1000 μmol/mol. This represents a satisfying output [11].

Results of the KC CCQM-K36 "Electrolytic conductivity at 0,5 S/m and 5 mS/m" are reported in [12]. Two pilot comparisons have been organised by the CCQM in the field of electrolytic conductivity: the pilot study CCQM-P22 at the values 1,28 S/m and 0,1 S/m and the study CCQM-P47 at the values 50 mS/m and 5 mS/m. Good agreement is found between the majority of participants.

The KC CCQM-K18 [13] was started in order to evaluate the equivalence of NMIs as a follow-up of the previous study CCQM-P52. There were 13 NMIs participating in KC using a primary method for pH measurement. The fair agreement between the results reflects increased difficulty in measurement, where the buffer composition may slightly change during the measurement and extrapolation to the start time of measurement is usually necessary.

TABLE 1 Comparisons of Ukrainian national measurement standards of the NMI "Ukrmetrteststandard" for EM and QM

National measurement standard		**Key (K) and Supplement (S) Comparison**		
Name	Metrological parameters	Projects	NMIs	Parameters
Electrical and Magnetism – EM				
♦ The State Standard of the unit of AC electric voltage units from 0.1 to 1000 V, DETU 08-07-02	0.1–1000 V 10 Hz–1 MHz $U = 4 \cdot 10^{-6}$	♦ COOMET.EM-S1	**UMTS** and VNIIM (2)	1 V 20 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz
♦ The State Standard of the unit of DC electric voltage units in the range from 1–180 kV, DETU 08-04-99	1–180 kV $U = 12 \cdot 10^{-6}$	♦ COOMET.EM-S7	**UMTS**, VNIIMS, LCOE (3)	1, 100 kV, 5 mA
♦ The State Standard of the unit of AC electric voltage units from 1 to $1.2 \cdot 330/\sqrt{3}$ kV and conversion factor of voltage, DETU 08-05-99	$1–330/\sqrt{3}$ kV 50 Hz $U = (0.5–5) \cdot 10^{-4}$	♦ COOMET.EM-S5 ♦ COOMET.EM-S6	**UMTS (pilot)**, VNIIMS, BelGIM, GSM, CMI (5) **UMTS**, VNIIMS, CMI, SP, HUT, ICMET, LCOE (7)	6, 10 kV 50 Hz, 100 V $110/\sqrt{3}$, $220/\sqrt{3}$, $330/\sqrt{3}$ kV, 50 Hz
♦ The State Standard of the units of electrical capacitance and dissipation factor, DETU 08-06-01	10^{-3}–100 μF tg δ = $1 \cdot 10^{-5}$–1 1000 Hz $U = (1–40) \cdot 10^{-6}$	♦ COOMET.EM-K4, ♦ COOMET.EM-S4	**UMTS (pilots)**, VNIIM, PTB, BelGIM, BIM, NMIJ-AIST, KazInMetr (7)	10 and 100 pF, 1.0 and 1.592 kHz
♦ The State Standard of the units of inductance and dissipation factor, DETU 08-09-09	100 mH –10 H 1 kHz $U = 3 \cdot 10^{-5}$	♦ EURAMET.EM-S26	**UMTS**, PTB, VSL, NPL, METAS, INETI, NML, NMISA, GUM, OMH, INM, SMD, DANIAmet-DPLE, IAI SL, SIQ, UME (16)	100 mH, 1.0 kHz, 1 mA
♦ The State Standard of the units of electrical power and power factor , DETU 08-08-02	1–6000 W (single and three phases) 40–70 Hz 10–600 V 0.1–10 A $U = 50 \cdot 10^{-6}$	♦ EURAMET.EM-K5.1 ♦ COOMET.EM-S2	**UMTS**, PTB, UME, VSL, LNE, INM, BIM, NPLI, SMU, OMH, MIKES, ZMDM (12) **UMTS (pilot)**, BelGIM, BIM (3)	120 V, 5 A, 53 Hz cos φ = 1, 0.5, 0.01 120 V, 5 A, 50 Hz cos φ = 1, 0.5, 0.01
Amount of Substance – QM				
♦ The State Primary Standard of the mole fraction unit for the components in gaseous media, DETU 05-01-98	$5 \cdot 10^{-5}$–99,99 % $U = 0{,}6 \cdot 10^{-5}$–6,5 %	♦ COOMET.QM-K3 ♦ COOMET.QM-K23b ♦ COOMET.QM-K1a	**UMTS**, VNIIM, BelGIM, BAM (4) **UMTS**, VNIIM, BelGIM, SMU, CMI, BAM (6) **UMTS**, VNIIM, BelGIM, BAM (4)	CO (30 mmol/mol), CO_2 (135 mmol/mol) C_3H_8 (2 mmol/mol) $7\ 10^{-2}$ – N_2; $3\ 10^{-2}$ – CO_2; $95\ 10^{-3}$ – C_2H_6; $35\ 10^{-3}$ – C_3H_8; $8\ 10^{-3}$ – i-C_4H_{10}; $1\ 10^{-2}$ – C_4H_{10} CO in N_2: ~ 100, 1000 μmol/mol
♦ The State Primary Standard of the unit of electrolytic conductance of liquids, DETU 05-02-04	$1 \cdot 10^{-4}$–60 S/m $U = 5 \cdot 10^{-2}$ %	♦ CCQM-K36a ♦ CCQM-K36b	**UMTS**, CMI, DFM, GUM, NIST, IEN, PTB, INMETRO, INPL, SP, OMH, SMU, CENAM, VNIIFTRI (14)	0.5 mS/m (KCl) 5 mS/m (HCl) in water
♦ The State Primary Standard of pH, DETU 05-03-07	0–14 pH (0–95°C) $U = 0{,}0034$	♦ CCQM-K18 ♦ CCQM-K20	**UMTS**, SMU, NMIJ-AIST, PTB, NIST, INMETRO, GUM, CENAM, CMI, INPL, LNE, BIM, NIM (13) **UMTS**, DFM, SMU, NMIJ, NIST, CMI, BIM, GUM, INMETRO, INPL, CENAM, VNIIFTRI (12)	pH ~ 10.012, 25 °C pH ~ 1.68, 15, 25 and 37 °C

Notes: Overal **40** NMIs from COOMET, EURAMET, APMP, SIM, and AFRIMET participated in these comparisons;
U – expanded uncertainty.

Comparison CCQM-K20 [14] was performed to demonstrate the capability of the participating NMIs to measure the pH value of an unknown potassium tetroxalate buffer by the primary method. The buffer of nominal pH ~ 1.7 was measured at three temperatures: 15 °C, 25 °C, and 37 °C. The comparison was an activity of the Electrochemical Working Group (EAWG) of the CCQM. All participants applied the primary method for pH. The result for the unknown buffer solution is the acidity function at zero chloride modality. Good agreement of the results was observed for the majority of participants.

4. CMCs OF THE NMI "UKRMETRTESTSTANDARD"

The list of all CMCs of NMI "Ukrmetrteststandard" is shown on Table 2. This list includes now three fields: "Electricity and Magnetism" (capacitance, inductance, AC voltage, DC and AC high voltage, AC high current), "Amount of substance" (gases and electrolytic conductivity), and "Length" (gauge block, optical polygons, roughness standard).

The Figure 4 shows the data on the CMCs in the 2005–2010, respectively, and the Figure 5 relationship between the EM, QM and L is given.

The NMI "Ukrmetrteststandard" is a leading Ukrainian NMI in the field of EM and QM. From 2005 to 2010 CMCs for the this NMI increased from 4 to 47. In the near future is expected to increase CMCs for NMI "Ukrmetrteststandard" on the results of comparisons already completed (QM and EM).

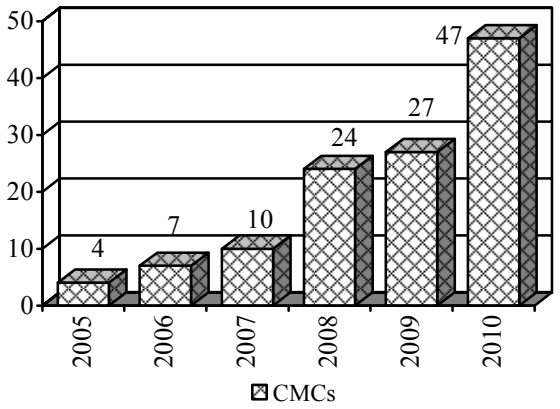

Fig. 4. CMCs of NMI "Ukrmetrteststandard" in 2005–2010

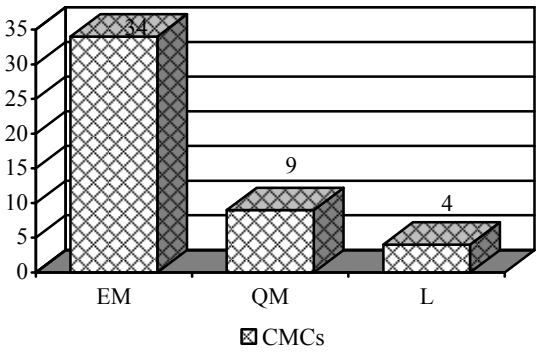

Fig. 5. CMCs for EM, QM, and L

TABLE 2 CMCs of NMI "Ukrmetrteststandard"

Calibration or Measurement Service	**CMCs** (lines/ matrix)		Categories	NMI services
	lines	matrix		
***Electrical and magnetism – EM* (34/4)**				
♦ Capacitance (capacitors, dissipation factor, meter)	7	0	4.2.1, 4.2.2, 4.2.4	15–21
♦ Inductance (self inductance, quality factor, meter)	5	0	4.3.2, 4.3.5, 4.3.6	22–26
♦ AC voltage (AC-DC transfer difference)	3	1	5.1.1, 5.1.2, 5.1.3	1–3
♦ AC voltage up to 1000 V (sources, meters)	2	1	5.2.1, 5.2.2	4, 5
♦ AC power (active and reactive power, single and three phase)	4	2	7.1.1, 7.1.3	27–30
♦ AC energy (active and reactive energy, single and three phase)	4	0	7.1.1, 7.1.3	31–24
♦ High DC voltage (sources, meters, ratio)	3	0	8.1.1, 8.1.2, 8.1.3	6–8
♦ High AC voltage (sources, meters, ratio)	4	0	8.3.1, 8.3.2, 8.1.4	9–12
♦ High AC current (ratio)	2	0	8.6.3	13, 14
***Amount of substance – QM* (9/0)**				
♦ Gases (environmental: carbon monoxide, carbon dioxide, propane)	3	0	4.2	4-08
♦ pH (aqueous buffer solution)	3	0	6	06/01, 02, 03
♦ Electrolytic conductivity (aqueous solution)	3	0	7	07.01, 02, 03
***Length – L* (4/0)**				
♦ Gauge block (central length)	1	0	2.2.1	4
♦ Optical polygons (face angle)	1	0	3.1.1	15
♦ Roughness standard (R_a, R_{max} – ISO parameters)	2	0	4.2	17–18

3. CONCLUSION

The NMI "Ukrmetrteststandard" carry out works on the comparisons of all national measurement standards, which organized the CCQM, EUROMET and COOMET. In COOMET KC of capacitance 10 pF (COOMET.EM-K4) and SC of capacitance 100 pF (COOMET.EM-S4) the NMI "Ukrmetrteststandard" is pilot. The results of this comparison will be linked to key comparisons CCEM-K4 and EUROMET.EM-K4**,** APMP.EM-K4.1, SIM.EM-K4.

The NMI "Ukrmetrteststandard" are pilot laboratories for supplementary comparisons COOMET.EM-S2 (electrical power) and COOMET.EM-S5 (AC high voltage).

The NMI "Ukrmetrteststandard" participated in key comparison, which organized the COOMET: COOMET.QM-K3 (automobile gases), COOMET.QM-K26b (natural gas), COOMET.QM-K1a (carbon monoxide in nitrogen), which results linked to key comparisons CCQM-K3, CCQM-K26b, and CCQM-K1a respectively, and have good results.

The NMI "Ukrmetrteststandard" participated in key comparisons, which organized the CCQM: CCQM-K36 (electrolytic conductivity), CCQM-K18, and CCQM-K20 (pH of tetroxalate buffer), and have good results.

From 2005 to 2010 CMCs for the this NMI "Ukrmetrteststandard" increased from 4 to 47, and in the near future is expected to increase CMCs on the results of comparisons already completed.

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