State Enterprise “All-Ukrainian state research and production center of standardization, metrology, certification consumers’ right protection”
(SE “Ukrmetertеststandard”)

TECHNICAL PROTOCOL
on GULFMET.EM-S5
Supplementary Comparison
of AC Energy at 50/53 Hz

(Edition 1)

O. Velychko, S. Karpenko, H. Çayci, J. Bartholomew

Pilot laboratory: SE “Ukrmetertеststandard”
4, Metrologichna Str., 03143, Kyiv, Ukraine
E-mail: velychko@ukrcsm.kiev.ua
Coordinator of comparison: Oleh Velychko

January 2019
Kyiv, Ukraine

Table of Content

1 Introduction

To support the Calibration and Measurement Capabilities (CMCs) of AC Energy declared by members of COOMET, EURAMET and GULFMET in the framework of the CIPM-MRA, SE "Ukrmetrteststandard" (UMTS) is going to organize in 2019 GULFMET Supplementary Comparison of AC Energy for electric energy standards of low-frequency. Electric energy standard of low-frequency will be compared at 3 National Metrology Institutes (NMIs) from COOMET, EURAMET and GULFMET to establish the relationship between the electrical units of AC Energy at these NMIs.

Reliable measurements of electric energy are the cornerstone of electric restructuring schemes in economies worldwide. Any opportunity of testing the reliability of measuring methods and reference standards at an international level is very valuable to national metrology institutes. Supplementary comparisons in electric energy measurements are strongly fostered by RMOs. The goal of this comparison project is to compare the energy calibration systems of the participating NMIs.

Participating NMIs will be responsible for conducting the tests in their respective laboratories and submitting their test data in the format prepared for this comparison.

UMTS is proposed to be the pilot laboratory, which would be responsible for providing the travelling standard, coordinating the schedule, collecting and analyzing the comparison data, and preparing the draft report. Relevance of the comparison results are expected at the level of better than 0.05 %.

The results of this Supplementary Comparison will be described in Draft A and Draft B. The differences between almost all NMI's values and the reference values will be within the expanded measurement uncertainties at a coverage factor $k = 2$.

This protocol has been prepared following the CIPM MRA-D-05 [1]. For this energy comparison, the test frequencies of 50 Hz and 53 Hz, power factors 1.0, 0.5 Lag, 0.5 Lead and reactive power factors 1.0, 0.5 Lag, 0.5 Lead are proposed. This proposal differs from that early in energy comparisons, where some participants made measurements either at 50 Hz or 53 Hz.

2 Participants and time schedule of the comparison

Each participant is given 2 weeks to perform the measurements of electrical energy standard of low-frequency (50 Hz and 53 Hz) and 1 week to transfer to the pilot laboratory. The participants and the time schedule of the Supplementary Comparison are given in Table 1 and Table 2. There are 3 participants in this Supplementary Comparison.

Participants should have the travelling standard delivered to the address of the participant scheduled to perform measurements after themselves according to the schedule.

Table 1 List of participants of the supplementary comparison

№	NMI	Abbreviation of NMI	Address	Contact person	e-mail, phone, fax
1	State Enterprise "All-Ukrainian state research and production center of standardization, metrology, certification consumers' right protection" (SE "Ukrmetrteststandard")	UMTS	4, Metrolo-gichna Str., 03143, Kyiv, Ukraine	O. Velychko	velychko@ukrcsm.kiev.ua Tel./Fax: +38 044 526 0335
2	TÜBITAK Ulusal Metroloji Enstitüsü	UME	TÜBİTAK Gebze Yerleskesi Baris Mah., Dr. Zeki Acar Cad. No. 1 41470, Gebze Kocaeli, Turkey	H. Çayci	huseyin.cayci@tubitak.gov.tr Tel.: +90 262 679 5000
3	Abu Dhabi Quality and Conformity Council Emirates Metrology Institute	QCC EMI	Emirates Metrology Institute Abu Dhabi Quality and Conformity Council (QCC) CERT Sultan Bin Zayed the First Street Abu Dhabi, UAE	J. Bartholo-mew	Jon.Bartholomew@qcc.abudhabi.ae phone: +971 503862676 Fax: +971 24066677

Table 2 List of measurement dates

Abbreviation of NMI	Dates of measurements	Dates of delivery
UMTS	18.02–03.03.2019	04.03.2019
QCC EMI	11–24.03.2019	25.03.2019
UMTS	01–14.04.2019	15.04.2019
UME	22.04–05.05.2019	06.05.2019
UMTS	13–26.05.2019	Finish

3. Financial aspects and insurance

Each laboratory participating in the comparisons should be at their own expense to perform all the measurements and send travelling standard back to the pilot laboratory (including transportation costs, insurance costs and customs).
In addition, each laboratory participating in the comparisons should be at their own expense to cover all costs from the moment of arrival travelling standard in the country, up to the moment of sending back to the pilot laboratory.
Expenses may include (but are not limited to): charges at check travelling standard (customs fees, brokerage services, transportation within the country) and the costs of returning the standard pilot laboratory. The appraised cost of selected travelling standard is Radian Research RD-33-332 (serial number 301308) is 20,000 Euro.
IMPORTANT: In order to have the final time schedule of the comparison, all the participants should inform the pilot laboratory whether they agree to send the travelling standard by a customs agency, or may want to be responsible of a different way to transport the traveling standard.

4. Travelling standard and measurement instruction

4.1. Description of the travelling standard

Selected travelling standard is Radian Research RD-33-332 serial number 301308 (RD-33-332). The RD-33-332 has a guaranteed accuracy of 0.01% and was successfully used as a travelling standard in Key Comparison of Power (COOMET.EM-K5) [2]. UMTS was proposed to be the pilot laboratory in COOMET.EM-K5, which would be responsible for providing the travelling standard, coordinating the schedule, collecting and analyzing the comparison data, and preparing the draft report.
The measure process of measuring AC Energy is fully automatically with the help of connector output count number of pulses which is directly proportional to the measured active power. The output frequency of RD-33-332 is 20833.3333 Hz. More information of the RD-33-332 is available at www.radianresearch.com. Appearance of RD-33-332 is shown on Figure 1.

Figure 1 Appearance of travelling standard RD-33-332

Travelling standard RD-33-332 is three-phase electric power meter, works on principles of digital processing of electrical current and voltage signals.
Main characteristics of travelling standard RD-33-332:
– input voltage: 30…525 V (RMS);
– input current: 0,2…120 A (RMS);
– frequency of the input voltage and current signals: 45…65 Hz;
– constant of the frequency output: 125 000 pulse/Wh;
– supply voltage: 60…525 V (RMS);
– working range of the temperature: minus 20 °C…40 °C;
– keeping range of the temperature: minus 25 °C...80 °C;
– working range of the humidity: 0...95%;
– dimensions: 444.5×172×131 mm;
– weight: 6.21 kg.
Terminal block of the RD-33-332 is shown on Figure 2.

Figure 2 Terminal block of travelling standard RD-33-332

User manual for RD-33-332 is attached. All participants of the comparison should have learned the documentation before comparison conducting. Specification of equipment that will be sent to participants on Supplementary Comparison of AC Energy GULFMET.EM-S5 is shown in Table 3.

Table 3 The specification of equipment that will be sent to participants on Supplementary Comparison of AC Energy

No.	Name of equipment	Quantity
1	Selected travelling standard RD-33-332 (serial number 301308) (Figure 1)	1 piece
2	Power cable (Figure 3)	1 piece
3	Current cable (Figure 4)	2 pieces
4	Voltage cable (Figure 5)	2 pieces
5	Pulse cable (Figure 6)	1 piece
6	Clamping nuts for connection current cables of travelling standard RD-33-332 (Figure 7)	6 pieces
7	Container of travelling standard RD-33-332 (Figure 8)	1 piece

Figure 3 Power cable of travelling standard RD-33-332

Figure 4 Current cables for connection travelling standard RD-33-332

Figure 5 Voltage cables for connection travelling standard RD-33-332

Figure 6 Pulse cable for connection travelling standard RD-33-332

Figure 7 Clamping nuts for connection current cables of travelling standard RD-33-332

Also to each of partisipant will be send “Operations Manual RD-33 Portatable Three-phase Electricity Standard” and CONTRACT for participation.

4.2 Unpacking and packing

Travelling standard will be transported in a container, which is designed for safe transportation of the standard Figure 8. Upon arrival, participants should check the container and make sure that all parts are present according to the list. After the measurement model should be carefully packed back into the container, in which it has arrived. Linear dimensions of container: 600 mm x 450 mm x 290 mm. The weight of container (with the content) is about 15 kg.

Figure 8 Container of travelling standard RD-33-332

If the damage of the container is detected, travelling standard should be packed in new containers, which will provide the necessary protection during transportation.
Upon receipt of travelling standard it is necessary to check the container for external damage and verify the completeness of travelling standard in accordance with the attached list.
The copy of the technical description of RD-33-332 is attached. It is necessary to familiarize with the features of travelling standard before starting the measurement. It must be carefully removed from the container.
Opening the corpus of RD-33-332 is strictly prohibited. If some defects of travelling standard are found, the participating laboratory should have immediately informed the pilot laboratory by fax or e-mail. If the repair of travelling standard is needed, the participant of comparisons should send travelling standard in a pilot laboratory.
Participants must inform the pilot laboratory by fax or e-mail about the arrival of travelling standard by using the form shown on Figure 9.

Confirmation note for receipt		
Date of arrival		
NMI		
Name of responsible person		
The travelling standard	□ Damaged	□ Not Damaged
Additional notes:		

Figure 9 Sample form for the information of arrival of travelling standard RD-33-332

The participating laboratory should inform the pilot laboratory about departure of RD-33-332 by using the form shown on Figure 10.

Confirmation note for dispatch	
Date of shipment	
NMI	
Name of responsible person	
Shipment information (company name etc.)	
Additional notes:	

Figure 10 Sample form for the information of departure of travelling standard RD-33-332

After the measurements, each participant of comparison must send the travelling standard to the pilot laboratory. The laboratories participating in the comparison are responsible for arranging shipment of travelling standard to the pilot laboratory.

5. Description of the method of measurement
5.1 Operations before measurements

Before the measurements of active power in the RD-33-332 by measuring the output pulses it must be warmed up for 24 hours (connected to the main power supply). Current and voltage signals must be connected for 4 hours before measurement. Following these procedures, short-term shutdown signal current or voltage from travelling standard will not lead to loss of the standard's characteristics. But if the power supply of travelling standard will be turned off, then the procedure of warming up must be made over again.

The result to be reported is the calibration error of the travelling standard, defined as the difference between the measured quantity indicated by the traveling standard and the quantity applied to it, and divided by the applied VAh. The calibration error should be expressed in ± μWh/VAh. The error is positive if the travelling standard's indication is more positive than the applied quantity.

The RD-33-332 measurement principle is based upon the fundamentals of a high-speed charge-balance integrating analog to digital signal converter. RD-33-332 Dytronic utilizes two separate A/D converters. One accepts a current signal and is linked with two current references. The other accepts a voltage signal and is linked with two voltage references. These of course are for the analog voltage and current inputs of the RD-33-332. Both operate independently to provide the digital signal processor with signals accurate enough to meet the requirements of a true portable electricity standard. Gain error, charge timer resolution, signal to noise ratio and signal distortion were major areas dealt with and improved in development

Also before the measurements, it is necessary to familiarize design features and work principles of travelling standard by using technical description (user manual) of RD-33-332. Connection travelling standard in accordance with the scheme is shown on Figure 11.

To carry out measurements on Supplementary Comparison of AC Energy at 50/53 Hz (GULFMET.EM-S5) all the participants need to use a single-phase switching circuit. And as the reference of output signal is used frequency output. This is programmed to issue pulses used for phase A.

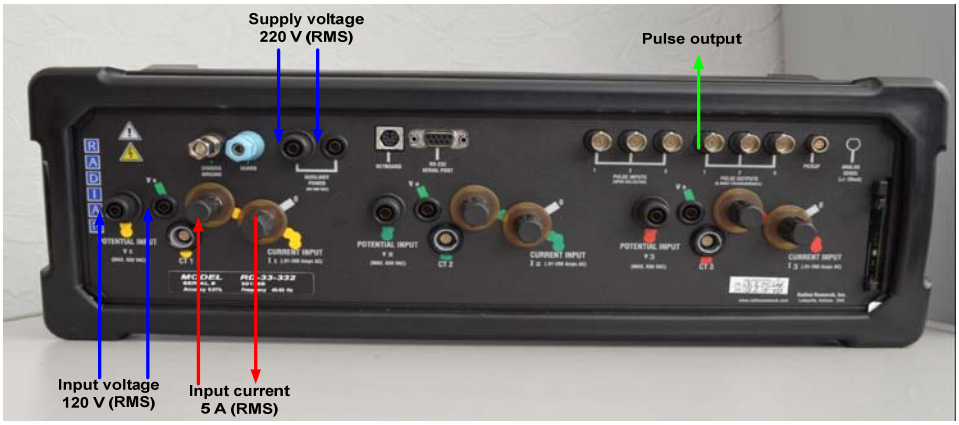

Figure 12 Connection scheme for travelling standard RD-33-332

5.2 Measurements

The travelling standard RD-33-332 is an energy meter of the energy-to-pulse converting type. The energy constant, K_H, of this standard is equal to 125 000 pulses/Wh. At 120 V, 5 A and power factor equal to unit, RD-33-332 are able to generate a train of pulses with a frequency equal to 20833.3333 pulses per second.

Recommended method: The comparison of electric pulses

At 120 V, 5 A and power factor equal to unit, RD-33-332 is able to generate a train of pulses with a frequency equal to 20833.3333 pulses per second. That is:

$$Frequency = \frac{Power \cdot K_H}{3600} \left[pulse / s \right]$$

RD-33-332 is provided with a built-in comparator. As shown in Figure 3, BNC port allows access to the built-in comparator. If the participation NMI wants to use the in-built pulse comparator on the RD-33-332, it should input the K_H of its energy reference standard at RD-33-332. Use the scroll down menu to input the constant. The K_H value of the participant's laboratory should be given in terms of pulses per Wh or pulses per kWh. The measurement method is not specified. Make sure that voltage and current are within at least 0.2 % of the values shown in Table 4:
for the voltage and current sources, make sure that their frequency is set at 50 Hz and 53 Hz, according to the testing points shown in Table 4;
at every testing point shown in Table 4, make as many independent measurements of the calibration error of the travelling standard as stated on the calibration procedures of the laboratory;

complete the calibration of the travelling standard by obtaining the mean value of its calibration error obtained at the testing points shown in Table 4. The calibration error is defined as the difference between the measured quantity indicated by the travelling standard and the quantity applied to it, and divided by the applied quantity. The calibration error of the travelling standard should be expressed in μWh/Vah;
the number of pulses on the RD-33-332 should be set to 1 000 000 (one Million);
for 1 million pulses, the integration time T_{int} for energy measurements will be approximately equal to:
a) T_{int} = 60 seconds, at 120 V / 5A / PF = 1.0 / RPF = 1.0;
b) T_{int} = 120 seconds, at 120 V / 5 A / PF = 0.5 Lag, 0.5 Lead / RPF = 0.5 Lag, 0.5 Lead;
the average of at least 10 sets of measurements should be reported;
the travelling standard should be de-energized between each set of measurements for at least one hour, followed by at least one hour warm-up period.
Main measurements should be performed with the input signals and environmental conditions such as in Table 4.

Table 4 The measurement points and condition of measurements

Unit	Value of the unit
Voltage	120 V ± 0.2 %
Current	5 A ± 0.2 %
Power factor	1.0, 0.5 Lag, 0.5 Lead deviation from the nominal value not exceeding ± 0.1%
Reactive power factor	1.0, 0.5 Lag, 0.5 Lead deviation from the nominal value not exceeding ± 0.1%
Frequency	50 Hz ± 0.05 Hz and 53 Hz ± 0.05 Hz
Temperature	23 °C ± 1 °C
Humidity	20 % – 70 %
Supply voltage	220 V ± 5 %
Frequency of the supply voltage	50 Hz ± 0.1 Hz

5.3 Uncertainty of the measurements

Uncertainty of the measurements should be calculated according to the GUM – Guide to the expression of uncertainty in measurement JCGM 100:2008 [3] (GUM 1995 with minor corrections). With the results of measurements should be given a model that describes how the measurement result was obtained considering all influencing quantities (voltages, currents, etc.). For each of the influencing quantities should be given the description of the source of uncertainty and an assessment of this uncertainty. All influencing quantities, their uncertainties, influencing coefficients, degrees of freedom and levels of confidence should be given in the budget of the uncertainty.
The budget of the uncertainty (Table 5) should include such number of influencing quantities and their uncertainties, which ensures the highest level measurements of electric energy for each of the laboratories.

Table 5 A suggestion format of the uncertainty budget

i	Quantity (unit)	Distribution	x_i	$u(x_i)$	v_i	c_i	$u_i(y)$ (μWh/VAh)
1							
2							
y	Std uncertainty of measurement						
		Coef. level = 95 %				$k = 2$	
		Expanded uncertainty (μWh/VAh) =					

6. The measurement report

Each participating NMI of the comparisons shall provide a report within 6 weeks from the date of departure travelling standard to the next participant.
The report shall be sent to the coordinator of comparisons by e-mail: velychko@ukrcsm.kiev.ua
The report shall include:
description of measurement methods;
description of the measurement circuit and used the standard possibilities of electricity;
confirmation of the traceability of the measurements (if participating laboratories has its own electric power units playback system, or must provide proof of traceability from another lab);
temperature and humidity in the laboratory during the measurement;
measurement results: certain amendments travelling standard values (6 values) for frequencies 50 Hz and 53 Hz, Power factor: 1.0, 0.5 Lead, 0.5 Lag and Reactive power factor: 1.0, 0.5 Lead, 0.5 Lag;
values of the respective standard uncertainties, the effective values of the degrees of freedom and expanded uncertainty;
detailed budget of uncertainty, which will be included in a report on the comparisons.
If between the measurements of any member, provided the pilot laboratory and preliminary comparisons reference value is detected a significant difference, it will be reported to the appropriate party. No other information on the measurement results will not be reported.

7. Report on comparisons

7.1 The reference value and the degrees of equivalence

This protocol has been prepared following the guidelines of the CCEM as given in [1]. The principles of the method of computation of the reference value are as follows [4]:
1. For the calculation of the reference value (RV), the weighted mean over the participating laboratories will be used. If the uncertainty contribution of a participant due to the traceability to another NMI participating in this comparison amounts to a substantial part of the overall uncertainty value, the result will not be taken into account in the calculation of the RV.
2. The degree of equivalence among the participating laboratories shall be expressed quantitatively by two terms:

the difference of the participating laboratory from the RV;
the uncertainty of this difference at a 95.45 % level of confidence.
4. In order to compare the results of the different participants, including the pilot laboratory, each of the participants should report a single measurement result for each of the testing points shown in Table 4.
5. The bilateral degrees of equivalence. As requested per the CCEM, the bilateral degrees of equivalence among the participating laboratories in a supplementary comparison will not be explicitly shown, but the formula for obtaining them will be included, thus allowing the participating laboratories to calculate their bilateral degree of equivalence from the data resulting from the difference between the participating laboratories and the RV.

7.2 Reports

Preliminary and final reports on the results of comparisons will be prepared by the pilot laboratory. The report will be prepared by the pilot laboratory within 4 months after the end of the measurement, and sent to the participants. The report is only for the participants of comparisons and is confidential. The report should be directed to the pilot laboratory for 2 months from the date of distribution of the Draft A. Comments will be considered in the Draft B. Draft B will be completed within 6 months after the end of the measurement. The final report will be prepared within 1 month from the receipt of the comments on the Draft B.

References

[1] CIPM MRA-D-05. Measurement comparisons in the CIPM MRA. p.28 https://www.bipm.org/utils/common/documents/CIPM-MRA/CIPM-MRA-D-05.pdf

[2] Velychko, O. and Karpenko, S., Final report on COOMET Key Comparison of Power (COOMET.EM-K5), SE “Ukrmetertеststandard”, December 2018, p.136.

[3] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement.

[4] Recommendation COOMET R/GM/19: 2008 Guidelines for evaluating data Additional comparisons COOMET.