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Bilateral comparisons on COOMET Project 684/MD/16 "Pilot comparisons of national standards in the field of gas flow"

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Abstract

The article describes the procedure for performing international bilateral comparisons of the national measurement standards of the units of gas volume and volume flow in Ukraine and Moldova. The comparisons were carried out within COOMET Project 684/MD/16 "Pilot comparisons of national standards in the field of gas flow". The list of reference standards that took part in comparisons is indicated. The range of gas volume flow, in which the comparisons were carried out, is from 0.5 m^3/h to 50 m^3/h. For the flow range from 0.5 m^3/h to 1 m^3/h, a drum-type meter was used, and for the range from 2 m^3/h to 50 m^3/h, comparisons were performed using a rotary gas meter. It is indicated that the national state primary and secondary standards of the gas volume and volume flow units took part in the comparisons from Ukraine, while from Moldova it was the national standard of the gas volume flow unit. A brief description of the national measurement standards and the principle of reproduction of the gas volume and volume flow units is presented. In particular, it was noted that the primary and secondary standards of Ukraine are built on the basis of bell-type prover, and the standard of Moldova combines a piston and bell-type prover. The method of calculating, calculation of expanded uncertainty and determining the degree of equivalence of the national standards of Ukraine and Moldova are demonstrated. The results of bilateral comparisons in the form of Table 1 are presented and shown in Fig. 4. The degree of equivalence of the national standards does not exceed 0.41, which indicates that the primary and secondary standards reproduce the gas volume and volume flow units with declared uncertainties, and transfer standards retain their metrological characteristics throughout the cycle of comparisons. General conclusions are drawn about the success of bilateral comparisons.

Keywords: comparison; national measurement standards; reference standards; flow; uncertainty; degree of equivalence.

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Introduction

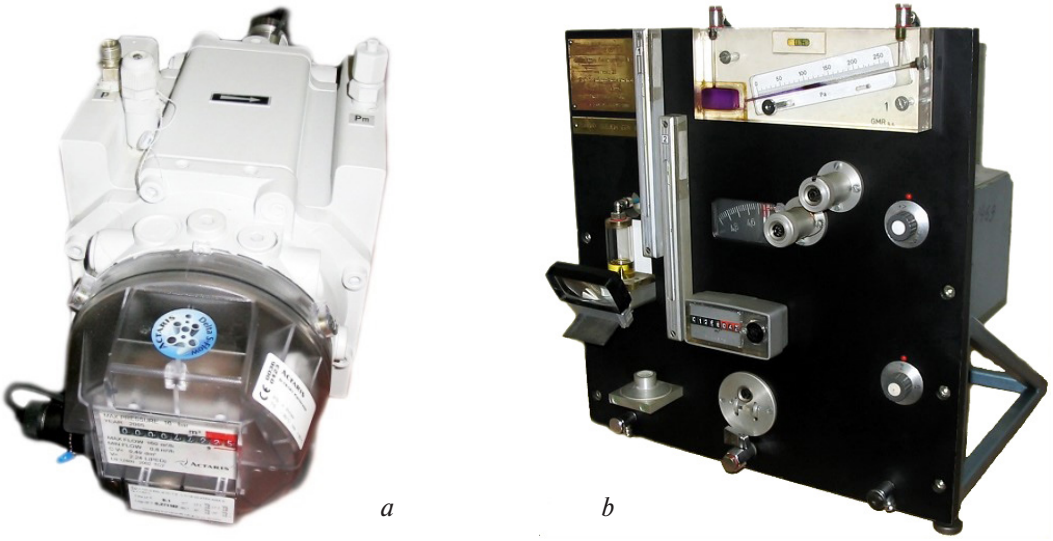
SE "Ivano-Frankivskstandartmetrology" as a scientific metrological center, the organization-custodian of the national primary and secondary standards of the gas volume and gas volume flow units, regularly participates in international comparisons within Technical Committee TC 1.4 "Flow Measurement" of Euro-Asian Cooperation of National Metrological Institutions COOMET.

In the period from 2019 to 2020, bilateral comparisons of the measurement standards of gas volume and gas volume flow units were carried out on COOMET Project 684/MD/16 "Pilot comparisons of national standards in the field of gas flow".

Two laboratories took part in the comparisons – SE "Ivano-Frankivskstandartmetrology", Ivano-Frankivsk, Ukraine (IFDCSMS, pilot laboratory) and the National Institute of Metrology, Chisinau, Republic of Moldova (NIM, coordinator of comparisons). Gas flow range – from 0.5 m^3/h to 50 m^3/h.

The main purpose of the comparisons was to establish the degree of equivalence of the national standards of gas consumption and assess the calibration and measurement capabilities of laboratories of scientific metrological centers in the field of flow measurement. In addition, the successful completion of international comparisons and confirmation of the declared value of expanded uncertainty is a prerequisite for the recognition of the measurement standards that ensure the reproduction and transfer of physical units and, accordingly, their metrological characteristics in the key comparison database (KCDB) of the International Bureau of Weights and Measures (BIPM). Also, for the standards that have been included into the KCDB and have CMCs, it is necessary to periodically participate in international comparisons to confirm their metrological characteristics.

SE "Ivano-Frankivskstandartmetrology" after the successful completion of comparisons on the Project COOMET.M.FF-S1 219/SK-a/00 (Level A, Level B)



a *b*

Fig. 1. Appearance of the Delta S-Flow G100 (*a*) and EP2 (*b*) reference standards

received 3 CMCs in gas volume flow in the range from 0.016 m^3/h up to 1600 m^3/h (UA1 – UA3). In addition, it successfully participated and confirmed the included CMCs in the following comparisons: COOMET.M.FF-S3 412/UA/07, CCM.FF.K6b.2011, COOMET.M.FF-S9 680/RU/16.

The purpose of this article is a detailed analysis of the results of bilateral comparisons of the national standards of gas volume flow of Ukraine and Moldova, in particular methods of calculating the degree of equivalence and technical base (standards) that participated in the comparisons.

Each participating laboratory used its own calibration procedure for the measurements. The comparisons were carried out in accordance with the recommendations of COOMET "Regulations on Comparisons of Measurement Standards of COOMET National Metrology Institutes and Designated Institutes" [1] and the directive of the BIPM on the implementation of key comparisons [2].

The principle of comparisons – direct transfer of the gas volume unit from the standard of the laboratory-participant to the reference standard.

The scheme of comparisons is circular, the comparison standards are consistently calibrated in the pilot laboratory (IFDCMS), in the NIM laboratory and again in IFDCMS. This is necessary to exclude the influence of possible changes in the characteristics of the comparison standards during transportation.

Reference standards

Delta S-Flow G100 №8785901001 meters manufactured by Actaris Gaszahlerbau Gmbh, Karlsruhe, Germany and EP2 №3155828 by GMR, Skutež, Czech Republic were used as reference standards.

Delta S-Flow is a rotary gas meter with two three-bladed rotors, each blade of which is placed at an angle of 120 degrees to each other and shifted by 60 degrees along the length. This design completely avoids the resonant phenomena characteristic of rotary meters with conventional octagonal rotors. The meter works in the flow range from 1 m^3/h to 160 m^3/h. The appearance of the meter is shown in Fig. 1*a*. An integral part of the measuring instrument is also the inlet and outlet pipes with the same diameter DN = =50 mm as the meter, which are sent to the participants of the tests together with the meter. A prerequisite for the normal operation of the meter is a strictly horizontal working position of the meter on the test equipment. The thermometer for measuring the gas temperature is installed in the sleeve built into the inlet pipe. The pressure transducer is connected to the "P" output of the meter. The tests are performed without lubricating the meter bearings with oil.

The EP2 meter is a drum meter equipped with high-frequency and low-frequency pulse removal sensors, it operates in the flow range from 0.016 m^3/h to 2 m^3/h. Appearance of the EP2 meter is shown in Fig. 1*b*. A prerequisite for the normal operation of the meter is the control of the correct level of oil in the meter and compliance with the temperature in the range from 18 to 22 °C.

Standards

From Ukraine, the National state primary standard of the gas volume and volume flow units DETU 03-01-15 (UA1) and the National secondary standard of the gas volume and volume flow units NDETU M-04-2019 (UA2) took part in the comparisons (Fig. 2). These standards are bell-type provers that reproduce gas volume and volume flow units by forcing out of the bell meter portion of air reduced to standard conditions, the volume of which is clearly defined by ensuring the stability of geometric parameters of the meter: diameter and height. Reproduction of the gas volume flow unit, in turn, is realized by moving the bell meter with different values of the set speed for a certain period of time.

a *b*

Fig. 2: *a* – appearance of the National state primary standard of the gas volume and volume flow units DETU 03-01-15 (UA1) with the mounted reference standard Delta S-Flow meter; *b* – appearance of the National secondary standard of the gas volume and volume flow units NDETU M-04-2019 (UA2)

In Moldova, the research was performed on the primary standard of the gas volume and volume flow of the Republic of Moldova Bell Piston Prover DN 400 (Fig. 3), which is a combination of a bell-type prover and prover with reference critical nozzles.

Results

The relative error of measurement e_r is the difference between the measurement results of the gas volume obtained from the comparison standard V_M and the value of the volume V_E reproduced by the standard of the participating laboratory, reduced to V_E, expressed as a percentage. That is:

$$e_r = \frac{V_M - V_E}{V_E} \times 100. \quad (1)$$

The basis for evaluating the successful result of the laboratory in comparisons for the *i*-th value of the flow rate is the parameter of the degree of equivalence E_i [3], which is calculated according to the following equation:

$$E_i = \left| \frac{d_i}{U(d_i)} \right|. \quad (2)$$

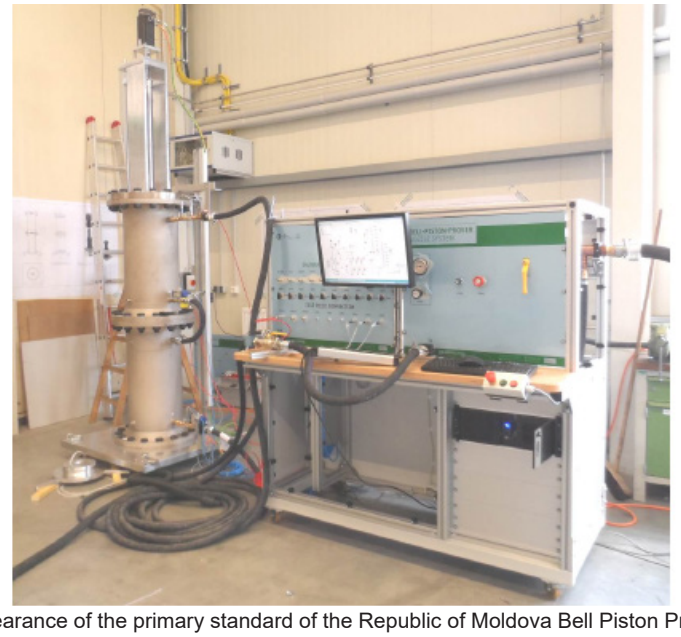


Fig. 3. Appearance of the primary standard of the Republic of Moldova Bell Piston Prover DN 400

Table 1

Results of measurements and calculations of the degree of equivalence

Flow	Deviations from K_{nom} Ukraine, e_{Uri}, %	Deviations from K_{nom} Moldova, e_{Uri}, %	The difference in results d_i, %	Expanded uncertainty of results $U(d_i)$, %	Degree of equivalence E_i, %
50	0.05	0.04	0.01	0.29	0.03
40	0.04	0.00	0.04	0.29	0.12
32	0.01	0.00	0.01	0.29	0.03
25	-0.01	-0.01	0.00	0.29	0.00
20	-0.02	-0.02	0.00	0.29	0.00
12	-0.06	-0.05	-0.01	0.29	0.03
10	-0.08	-0.12	0.04	0.29	0.14
8	-0.11	-0.19	0.08	0.29	0.27
4	-0.25	-0.31	0.06	0.29	0.21
2	-0.54	-0.45	-0.09	0.30	0.30
1*	0.15	0.06	0.09	0.29	0.31
0.5*	0.30	0.18	0.12	0.29	0.41

* – the results of comparisons using the reference standard EP2, the remaining results – obtained using the reference standard Delta S-Flow.

The difference d_i was calculated according to the following equation:

$$d_i = e_{Uri} - e_{Mri}, \quad (3)$$

where e_{Mri} – the relative value of the deviation of the conversion factor of the reference standard from the nominal value (relative error), measured on the primary standard of the Republic of Moldova; e_{Uri} – the relative value of the deviation of the conversion factor of the reference standard from the nominal value (relative error), measured on the primary standard of Ukraine.

The expanded uncertainty of the d_i result for independent laboratories is calculated according to the following equation:

$$U(d_i) = \sqrt{U_{Ui}^2 + U_{Mi}^2}, \quad (4)$$

where U_{Mi} – expanded uncertainty of the measurement result on the i-th value of the flow obtained at the primary standard of the Republic of Moldova; U_{Ui} – expanded uncertainty of the measurement result on the i-th value of the flow obtained at the primary standard of Ukraine.

The obtained values of the degree of equivalence E_i for each value of the gas volume flow should be within $E_i \leqslant 1$, which indicates the success of the comparisons. If the value of $E_i > 1.2$ is exceeded, it can be stated that the results of the comparisons are negative and the values obtained during the study on the standard of the laboratory – the participant of the comparisons need immediate correction. If the results are found in the interval $1 < E_i \leqslant 1.2$ it is considered that there are general non-critical deficiencies that need to be corrected.

Fig. 4 shows a graphical representation of the results obtained using the reference standard Delta S-Flow [4].

Conclusion

All values of the degree of equivalence for all flows $E_i < 1$, which indicates positive results of the comparison, namely:

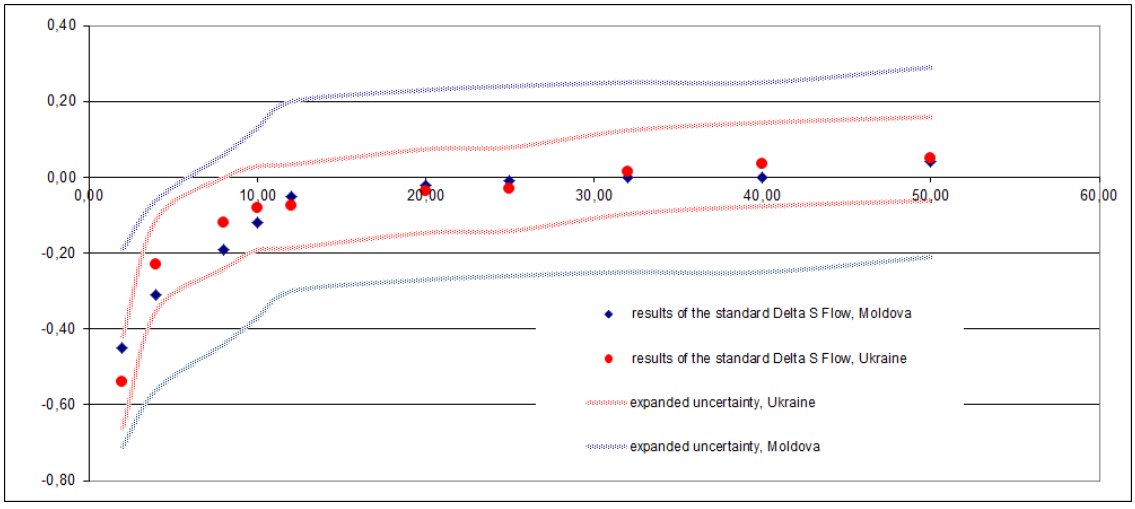


Fig. 4. Graphical representation of the results obtained using the Delta S-Flow reference standard

– reference standards have retained their metrological characteristics throughout the cycle of comparisons;

– the standards of the participating countries reproduce the size of the gas volume and volume flow units with the uncertainties declared by the relevant laboratories;

– measurements in laboratories are carried out under appropriate environmental conditions, in compliance with the procedures and requirements that are set to both standards and reference standards;

– calibration methods used by the laboratories of the participating countries allow to obtain reliable results with appropriate uncertainties.

Двосторонні звірення за темою KOOMET 684/MD/16 "Пілотні звірення національних еталонів витрати газу"

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Анотація

У статті описано процедуру проведення міжнародних двосторонніх звірень національних еталонів одиниць об'єму та об'ємної витрати газу України та Молдови. Звірення проводились у рамках теми KOOMET 684/MD/16 "Пілотні звірення національних еталонів одиниць об'єму та об'ємної витрати газу". Зазначено перелік еталонів порівняння, які брали участь у звіреннях. Діапазон об'ємної витрати газу, в якому проводились звірення, становить від 0,5 до 50 м^3/год. Для діапазону витрати від 0,5 до 1 м^3/год застосовано лічильник барабанного типу, а для діапазону від 2 до 50 м^3/год звірення проводились із застосуванням роторного лічильника газу. Вказано, що від України у звіреннях брали учать національний державний первинний та вторинний еталони одиниць об'єму та об'ємної витрати газу, в свою чергу, від Молдови брав участь національний еталон витрати газу. Подано короткий опис національних еталонів і принцип відтворення одиниць об'єму та об'ємної витрати газу. Зокрема, зазначено, що первинний та вторинний еталони України побудовані на базі установок дзвонового типу, а еталон Молдови об'єднує в собі установку поршневого та дзвонового типів. Продемонстровано методику проведення обчислень, розрахунку розширеної невизначеності та визначення ступеня еквівалентності національних еталонів України та Молдови, а також наведено результати двосторонніх звірень. Ступінь еквівалентності національних еталонів не перевищує 0,41, що свідчить про те, що первинні та вторинні еталони відтворюють одиниці об'єму та об'ємної витрати газу із задекларованими невизначеностями, а еталони передавання зберігають свої метрологічні характеристики протягом усього циклу звірень. Наведено загальні висновки, в яких зазначено про успішність двосторонніх звірень.

Ключові слова: звірення; національні еталони; еталони порівняння; витрата газу; невизначеність; ступінь еквівалентності.

Двухсторонние сличения по теме KOOMET 684/MD/16 "Пилотные сличения национальных эталонов расхода газа"

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Аннотация

В статье описана процедура проведения международных двусторонних сличений национальных эталонов единиц объема и объема расхода газа Украины и Молдовы. Сличения проводились в рамках темы KOOMET 684/MD/16 "Пилотные сличения национальных эталонов единиц объема и объемного расхода газа".

Представлен перечень эталонов сравнения, принимавших участие в сличениях. Указано, что от Украины в сличениях принимали участие национальный государственный первичный и вторичный эталоны единиц объема и объемного расхода газа, в свою очередь, от Молдовы принимал участие национальный эталон расхода газа. Представлено краткое описание национальных эталонов и принцип воспроизведения единиц объема и объемного расхода газа. Отмечено, что первичный и вторичный эталоны Украины построены на базе установок колокольного типа, а эталон Молдовы объединяет в себе установку поршневого и колокольного типов. Продемонстрирована методика проведения вычислений, расчета расширенной неопределенности и степени эквивалентности национальных эталонов Украины и Молдовы, а также приведены результаты двусторонних сличений. Степень эквивалентности национальных эталонов не превышает 0,41, что свидетельствует о том, что первичные и вторичные эталоны воспроизводят единицы объема и объемного расхода газа с задекларированными неопределенностями, а эталоны сравнения сохраняют свои метрологические характеристики на протяжении всего цикла сличений.

Ключевые слова: сличения; национальные эталоны; эталоны сравнения; расход газа; неопределенность; степень эквивалентности.

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