National Scientific Centre "Institute of Metrology"

NATIONAL SCIENTIFIC CENTRE "INSTITUTE OF METROLOGY" (NSC "Institute of Metrology")

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Report of NSC "Institute of Metrology" for the CCM

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Content:

Introduction

The National Scientific Centre "Institute of Metrology" (NSC IM) is a Head center for ensuring the unity of measurements in Ukraine. NSC "Institute of Metrology" passed more than a century of development from the first verification chamber of measures and weighs to the National Scientific Centre "Institute of Metrology".

NSC “Institute of Metrology”:

- creates, improves, stores and applies national measurement standards of units of values in 7 types of measurements;
- performs fundamental scientific research in the field of metrology, and also performs work related to the development and implementation of state programs on metrology and the concept of the development of the metrological system of Ukraine;
- provides scientific and applied research, performs scientific and research works related to the creation, improvement, storage, comparison, application of national measurement standards, creating systems for transferring the size of units of measurements;
- takes part in the development of projects for technical regulations, other regulatory acts, as well as regulatory documents in the field of metrology and metrological activities;
- carries out coordination and scientific and methodological support of work to ensure the unity of measurements for the relevant fields of activity;
- performs conformity assessment of measuring equipment;
- carries out calibration of measuring instruments;
- performs verification, on a voluntary basis, measuring instruments that are not applied in the field of legally regulated metrology and are in operation;
- performs verification of legally regulated measuring instruments that are in operation;
- performs measurements in the field of legally regulated metrology;
- maintains an information fund for the directions of its activities;
- performs international cooperation on issues that belong to its competence;
- stores 54 national primary measurement standards and 15 secondary measurement standards, which reproduce, maintain and transfer the units to state enterprises of the Department of Technical Regulation of the Ministry of Economy of Ukraine, enterprises and organizations of Ukraine and other CIS countries;
- performs international comparisons of National primary standards with national standards of other countries;
- prepares human resources of higher qualifications in the field of metrology and metrological activity;
- performs training at courses on raising proficiency of specialists-metrologists;
- organizes and performs workshops, international and national scientific and technical conferences on metrology and metrological assurance;
- publishes “Ukrainian Metrological Journal”, “Bulletin for International Metrology”.

1 Structure of the institute

General structure of the institute is given in Annex 1.
Basic data on the staff of the institute

Number of human resources in 2021	pers.
among which:	
basic staff	224
where on contract basis	17
Doctors of Science	6
Candidates of Science	11
laureates of State Prize	1
part-time basis	16

Quality System
NSC IM has the confirmed quality system: QSF-R44 certificate of recognition of quality management system according to ISO/IEC 17025 issued 10.05.2016.

2 Technical capabilities in the field of mass and related quantities

The reference measurement standards of Ukraine in the field of mass and related quantities were created in the late 90s of the 20th century after Ukraine became independent. NSC IM maintains the national primary standards in the field of mass, pressure, hardness, flowmetry and gravimetry. NSC IM provides transfer and uniformity of measurements in these fields.

Mass
NSC IM maintained the national primary mass standard.
The national primary mass standard includes the 1 kg reference mass standard made of stainless steel, two 1 kg copies, sets of weights and set of mass comparators.
Dissemination of the unit of mass is carried out in the range from 1 mg to 50 kg with accuracy E_1.
In 2019, after Ukraine became a full member of the Metre Convention, the first calibration of the original kilogram standard in the BIPM was performed.
NSC IM has a hydrostatic installation for determining the volumes of weights.
NSC IM participates in international comparisons and acts as a pilot laboratory (COOMET.M.M-S8).

Pressure

The reference measurement standards of the NSC "Institute of Metrology" for pressure include four national primary standards – DETU 04-03-01, NDETU M-01-2018, NDETU M-03-2019, DETU 04-01-96, covering the range of absolute pressures from 0.001 Pa up to 7 MPa and gauge pressures from minus 0.1 MPa to 400 MPa.

In the design of the standards DETU 04-03-01, NDETU M-01-2018, NDETU M-03-2019, the principle of an unsealed piston is used to measure medium and high pressures. The standards include deadweight testers with piston-cylinder-unit (PSU) with appropriate measuring ranges and sets of special weights for them.

The standard DETU 04-01-96 for measuring low absolute pressures is implemented on the basis of special compression vacuum gauges, the principle of which is based on the change in the height of the liquid column depending on the pressure during its preliminary compression.

At present NSC "Institute of Metrology" participates in international comparisons of COOMET "Supplementary comparison of national standards of gauge pressure in the range from 1 MPa to 10 MPa" (COOMET.M.P-S1), where it is a pilot laboratory. In future – participation in international comparisons for other pressure and vacuum ranges. The national standards created by the NSC "Institute of Metrology" contribute to metrological traceability and the development of technologies in different fields, such as the fuel and energy complex, mechanical engineering, metallurgy, food and chemical industries, aircraft construction. In plans – increasing the amount of the existing reference measurement standards for the expanding the measurement range, as well as creating a national standard for differential pressures.

Gravity

The National primary measurement standard of the gravity acceleration unit, which includes a ballistic stationary gravimeter and a ballistic transportable gravimeter, a fundamental gravimetric point was created by NSC IM in 1996.

The measurement standard maintains and transfers the unit of gravity to working measurement standards, as well as to working measuring instruments.

Ballistic stationary and transportable, components of the measurement standard, are the measuring instruments of gravity acceleration.

The range of values of gravity acceleration is from 9.77 m/s^2 to 9.85 m/s^2.

The expanded uncertainty of measurements $U = 11 \cdot 10^{-8}$ m/s^2 with a coverage factor $k = 2$ and confidential probability P=0.95.

The measurement standard participated in the comparisons of absolute gravimeters COOMET.M.G-S1 (COOMET Project 634/UA/14).

Prospective areas planned in the field of gravimetry:

Since 2012 scientific and research works are being performed: "Development and research of a ballistic laser gravimeter based on precision mobile devices using linear pulsed electromechanical transducers to measure the absolute value of gravity acceleration".

(Patent № 96904, Ukraine; Patent № 111307, Ukraine; Patent № 2011128560, Russia).

In 2018 there was started an initiative scientific and research work: "Development and research of an absolute gravimeter based on precision atomic interferometry of ultracold atoms with laser cooled atoms and their spatial localization".

Fields of application

- Metrology: ensuring reproduction of physical quantities: mass, force, pressure;
- Geodesy: creation of planned high-altitude geodetic and gravimetric networks;
- Geophysics: mineral exploration, geodynamic processes research;
- Space engineering: for calibrating satellite measurement systems.

Hardness

Scientific Centre of the Mechanical Measurements provides the standard measurements in the fields of hardness. NSC IM has two National measurement standards: National Primary Standard of Hardness Units on Rockwell and Superficial-Rockwell scales and National Primary Standard of Hardness Units on Brinell and Vickers scales.

National Primary Standard of Hardness Units on Rockwell and Superficial-Rockwell scales has five hardness levels 80-86 HRA, 80-100 HRBW, 20-30 HRC, 40-50 HRC, 60-70 HRC and six hardness levels 90-94 HR15N, 40-50 HR30N, 76-84 HR30N, 43-54 HR45N, 47–53 HR30TW, 70-82 HR30TW.

National Primary Standard of Hardness Units on Brinell and Vickers scales has six blocks of the Brinell scales with hardness levels 100 HBW 5/250/15, 200 HBW 5/750/15, 400 HBW 5/750/15,

100 HBW 10/1000/15, 200 HBW 10/3000/15, 400 HBW 10/3000/15 and six hardness levels 450 HV1, 750 HV1, 450 HV5, 750 HV5, 450 HV30, 750 HV30.
NSC IM participates in international comparisons in the field of hardness measurements and acts as a pilot laboratory (COOMET.M.H-S8).

Liquid flow

Liquid flowmeters are used in almost all sectors of the Ukrainian economy. For metrological assurance of reference and working flowmeters, the national primary standard of the unit of volume liquid flow in the range from $2.8 \cdot 10^{-4}$ m^3/s to $2.8 \cdot 10^{-2}$ m^3/s, mass liquid flow in the range from $2.8 \cdot 10^{-1}$ to 28 kg/s, liquid volume in the range from 0.1 m^3 to 3.0 m^3, and liquid mass in the range from 100.0 kg to 3000 kg running through the pipeline, DETU 03-04-04 (hereinafter – the measurement standard), is used. The measurement standard realises the weight principle of operation, for which a tank with water is weighed on the scales that has passed through the flow meter.
Metrological characteristics of the measurement standard:
- measuring range from 0.1 m^3/h to 100 m^3/h
- maximum permissible error ± 0.04%.

The measurement standard takes part in the international comparisons using the Coriolis flowmeters as the transfer standards.

NSC IM maintains the primary measurement standard of the unit of liquid volume.
Measuring instruments for measuring the volume of liquid is used in almost all sectors of the economy of Ukraine. One of the main methods of measuring the volume of liquid is the static method using capacity measures. For metrological assurance of liquid volume measurements, working standards of the 1st and 2nd classes are used, which receive the size of the unit of liquid volume from the national primary standard of the unit of liquid volume, DETU 03-03-13 (hereinafter – the measurement standard). Calibration of working standards of the 1st class (measuring tanks) on the measuring standard is performed by the weight method using distilled water.

Metrological characteristics of the standard:

Range	from $1 \cdot 10^{-3}$ m^3 to $1 \cdot 10^{-1}$ m^3 and from $5 \cdot 10^{-1}$ m^3 to 1 m^3	from $1 \cdot 10^{-1}$ m^3 (included) from $5 \cdot 10^{-1}$ m^3 (included)
Expanded uncertainty *U*	$8 \cdot 10^{-5}$	$5 \cdot 10^{-5}$

The measurement standard takes part in international comparisons, in which NSC "Institute of Metrology" is a pilot. The reference measuring tanks of the 1st class are used as the transfer standards.

3 International Comparisons

NSC IM participates in international comparisons and acts as a pilot laboratory. List of the comparisons is showed below.

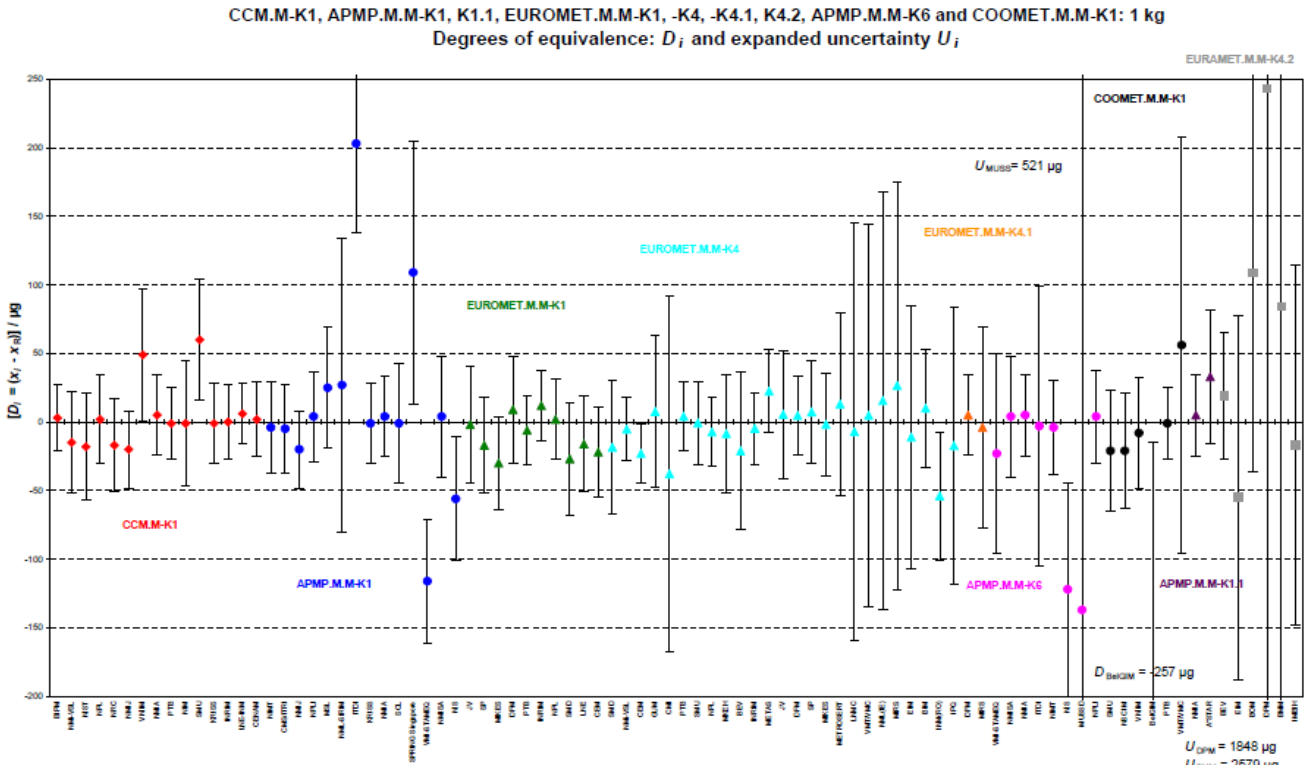
Indentifier	Description	Status	Role
COOMET.M.M-K1	Comparison of mass standards Stainless steel kilogram standards	Approved for equivalence	Participant

COOMET.M.M-K5	Comparison of mass standards Mass: 200 mg, 1 g, 50 g, 200 g and 2 kg	Approved for equivalence	Participant
COOMET.M.M-S2	Supplementary bilateral comparison in the field of mass measurements Mass of 200 mg, 1g, 50 g, 200 g and 1 kg	Report in progress, draft A	Pilot
COOMET.M.M-S5	Comparison of mass standards Mass: 50 mg, 50 g, 1 kg and 2 kg	Measurements completed	Pilot
EURAMET.M.M-S9	Sub-milligram mass comparison Mass: 0.5 mg, 0.2 mg, 0.2D mg, 0.1 mg and 0.05 mg	Approved	Participant
COOMET.M.P-S1	Comparison of standards of gauge pressure Gauge pressure: 1 MPa to 10 MPa	Report in progress, draft A	Pilot
COOMET.M.H-K1	Hardness (Vickers HV1, HV5, HV30) Hardness levels: 450 HV, 750 HV	Approved for equivalence	Participant
COOMET.M.H-S3	Comparison of national hardness standards of Superficial-Rockwell scales Hardness: Superficial-Rockwell 90-94 HR15N, 40-50 HR30N, 76-84 HR30N, 43-54 HR45N, 45-55 HR30TW, 70-82 HR30TW	Measurements completed	Pilot
COOMET.M.H-S4	Brinell Hardness Hardness levels: 100 HBW, 200 HBW, 400 HBW	Approved	Participant
COOMET.M.H-S5	Key comparison of national hardness standards of Rockwell scales Hardness: Rockwell A: 80 - 86 HRA; Rockwell B: 80 - 100HRBW; Rockwell C: 20 - 30 HRC, 40 - 50 HRC, 60 - 70 HRC. 25 HRC, 45 HRC, 65 HRC	Approved	Participant

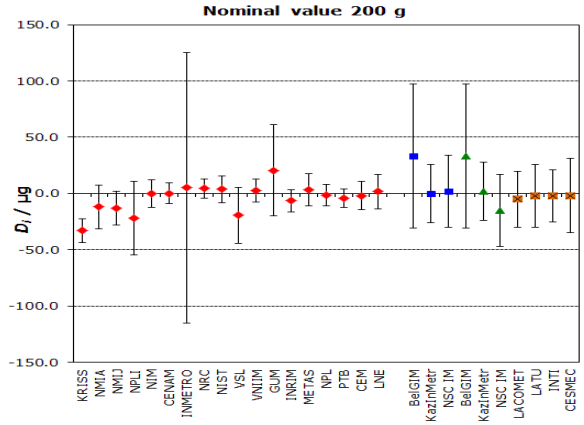
COOMET.M.G-S1	Gravitational acceleration Free-fall acceleration at a nominal value of 9.81 m/s2	Approved	Pilot
COOMET.M.FF-S6	Comparison of the determination of static volume of reference metallic tanks Volume of liquid: 5 L, 10 L and 20 L	Measurements in progress	Pilot
COOMET.M.FF-S7	Liquid volume Volume at 10 µL and 1000 µL	Measurements in progress	Participant
COOMET.M.FF-S10	Water flow and mass rate Flow rate From 0.1 t/h to 45 t/h	Measurements in progress	Participant

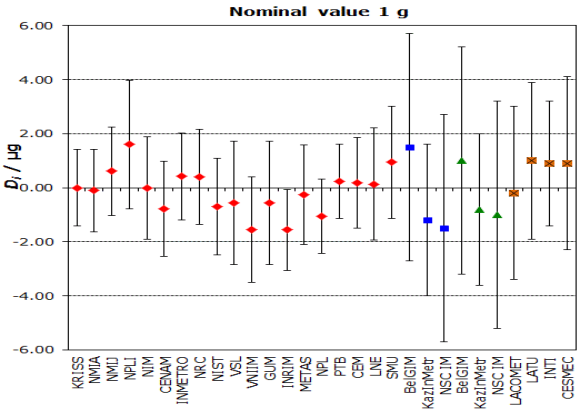
Degrees of equivalence of NSC IM national standards are showed below.

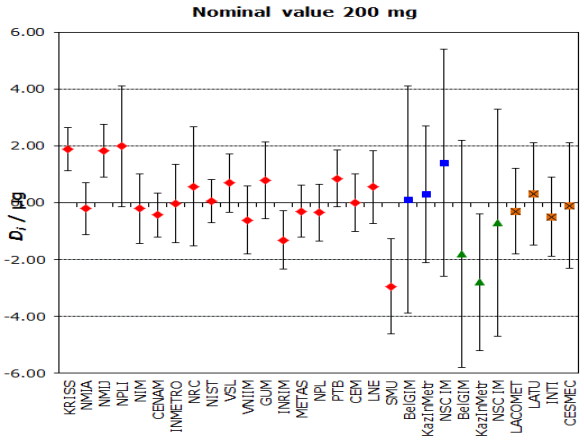
COOMET.M.M-K1



COOMET.M.M-K5

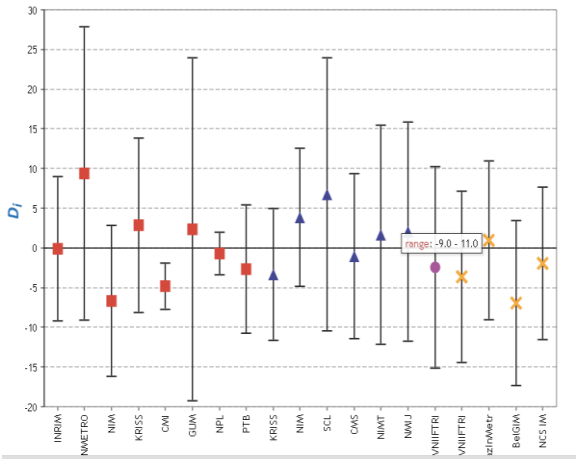




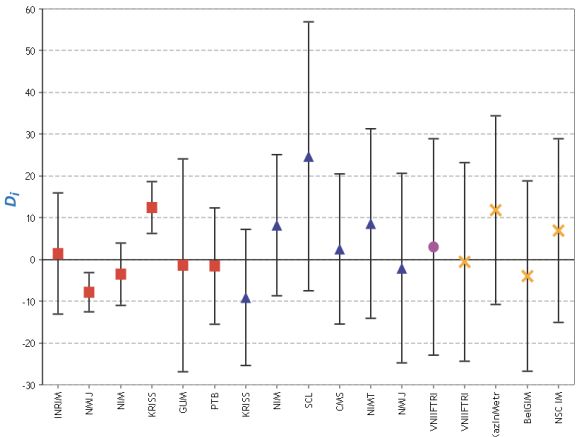


COOMET.M.H-K1

540 HV1



840 HV1



4 Published calibration and measurement capabilities of the institute

NSC IM has published CMCs in the field of mass and related quantities (mass – 5, gravity – 1, hardness – 1).

5 Research projects

NSC IM participates in EMPIR Project 19RPT02, "Improvement of the realisation of the mass scale".
The aim of the project is developing of EURAMET calibration guidance for mass scale realization and creation of software tools.

Research of additional factors in the measurement equation and the uncertainty budget of the results of hardness measurements.

Development and research of a ballistic laser gravimeter based on precision mobile devices using linear pulse electromechanical transducers to measure the absolute value of gravitational acceleration.

NSC IM planed researched that concerned
Development and advancement of an absolute gravimeter based on precision atomic interferometry of ultracold atoms with laser cooling of atoms and space localization

6 Publications of NSC "Institute of Metrology" for 2020–2012 in the field of Mass and related quantities

[1] Z. Zelenka, S. Alisic, B. Stoilkovska, R. Hanrahan, I.Kolozinska, G.Popa, D. Pantić, V.Dikov, J.Zůda, M.Coenegrachts, A.Malengo. Improvement of the Realisation of the Mass Scale. ACTA IMEKO. December 2020. Vol. 9. No. 5. P. 4–6.

[2] G. Narodnytskyi, P. Neyezhmakov. Measures to ensure the necessary accuracy of accounting petroleum products in the tanks. Ukrainian Metrological Journal. 2020. No. 4. P. 16–21. DOI: https://doi.org/10.24027/2306-7039.4.2020.224266.

[3] A. Aslanyan, E. Aslanyan, E. Obozniy, E. Galat, Ya. Dovzhenko, M. Zhamanbalin. RMO Brinell suplementary comparison COOMET M.H.-S4. Metrologia 2020 57 Tech. Suppl. 07003.

[4] V. Skliarov, Ya. Dovshenko, F. Menelao, J. Borovský, N. Kamkova, E. Obozny, M. Zhamanbalin. Final Report of COOMET.M.H-S5. Metrologia 2020 57 Tech. Suppl. 07025.

[5] O. Botsiura, O. Patsenko, I. Zakharov. Accounting for the kurtoses of input quantities in the procedure of evaluating measurement uncertainty using the example of weight calibration. Ukrainian Metrological Journal. 2020. No. 3. P. 36–41. DOI: https://doi.org/10.24027/2306-7039.3.2020.216839.

[6] V. Bolyukh, P. Neyezhmakov, A. Omelchenko, O. Vinnichenko. Reduction of auto seismic oscillations of the ballistic laser gravimeter on account of the excitation of the induction-dynamic catapult by a pulse packet. Ukrainian Metrological Journal. 2020. No. 3. P. 3–11. DOI: https://doi.org/10.24027/2306-7039.3.2020.216765.

[7] M. Kuz M, L. Zamikhovskyi, V. Skliarov, H. Kuz. Methodology and software for measuring the specific differences of the calculated volumes of natural gas. Ukrainian

Metrological Journal. 2020. No. 1. P. 62–67. DOI: https://doi.org/10.24027/2306-7039.1.2020.204232

[8] V.F. Boliukh, O.V. Fedorov, P.I. Neyezhmakov, A.V. Omelchenko, O.I. Vinnichenko. Analysis of the effect of seismic interference on the measurement results of gravitational acceleration by ballistic laser gravimeters. Ukrainian Metrological Journal. 2020. No. 1. P. 51–61. DOI: https://doi.org/10.24027/2306-7039.1.2020.204228.

[9] V. Skliarov, Ya. Dovzhenko, O. Patsenko. Research of vibration effect during the measurements of hardness on Rockwell scale. Metrology, information and measurement technologies and systems (MIMTS-2020). February 18–19, 2020: Abstracts. P. 136.

[10] Yu.Yu. Bunyayeva, H.A.Kharchenko, P.I. Neyezhmakov. The results of Ukraine's participation in CIPM activity. Ukrainian Metrological Journal. 2019. No. 4. P. 3–14. DOI: https://doi.org/10.24027/2306-7039.4.2019.195951.

[11] Yu.Yu. Bunyayeva, P.I. Neyezhmakov, Yu.F. Pavlenko. Why have international metrology Heads called the New SI "fundamentally better" and could it be even better? Ukrainian Metrological Journal. 2019. No. 3. P. 3–13. DOI: https://doi.org/10.24027/2306-7039.3.2019.182187.

[12] D.A. Brega. Ya.S. Dovzhenko, V. Skliarov, M.Yu. Zalohin. Experimental Determination and Comparative Analysis of the PPH030GP, ABS and PLA Polymer Strength Characteristics at Different Strain Rates. Science and Technique. 2019. V. 18, No. 3. P. 233–239. https://doi.org/10.21122/2227-1031-2019-18-3-233-239.

[13] G. Narodnytskyi, P. Neyezhmakov. New approaches to accounting petroleum and petroleum products in Ukraine. Ukrainian Metrological Journal. 2019. No. 2. P. 64–68. DOI: https://doi.org/10.24027/2306-7039.2.2019.174248.

[14] Yu. Bunyayeva, P. Neyezhmakov. Main achievements of Ukraine in international metrological activity. Ukrainian Metrological Journal. 2019. No. 1. P. 4–11. DOI: https://doi.org/10.24027/2306-7039.1.2019.164306.

[15] V. Bolyukh, V. Kupko, A. Omelchenko, A. Vinnichenko. Noise-resistant signal processing in a ballistic laser gravimeter with a symmetrical way of measuring the gravitational acceleration. Ukrainian Metrological Journal. 2019. No. 1. P. 54–62. DOI:10.24027/2306-7039.1.2019.164717.

[16] G.Yu. Narodnytskyi. About the size of measuring instruments sample in the conformity assessment of them with technical regulations on the module F. Ukrainian Metrological Journal. 2018. No. 3. P. 24–27. DOI: 10.24027/2306-7039.3.2018.152945.

[17] A.M. Negriyko, P.I. Neyezhmakov, O.I. Vinnichenko, L.P. Yatsenko. The design of modern absolute gravimeters based on atomic interferometers with cold atoms and prospects of their development in Ukraine. Ukrainian Metrological Journal. 2018. No. 3. P. 35–41. DOI: 10.24027/2306-7039.3.2018.152952.

[18] V.F. Bolyukh, P.I. Neyezhmakov, A.I. Vinnichenko. Stray magnetic fields of an electromechanical catapult of an electromagnetic and induction-dynamic type of a ballistic laser gravimeter. Ukrainian Metrological Journal. 2018. No. 3. P. 42–48. DOI: 10.24027/2306-7039.3.2018.152956.

[19] S. Davidson, A. Valcu, N. Medina, Ja. Zuda, L. Snopko, I. Kolozinska. Supplementary comparison of 500 microgram, 200 microgram, 100 microgram and 50 microgram weights – EURAMET.M.M-S9. Metrologia, 2017, 54, Tech. Suppl., 07023.

[20] A. Vinnichenko, A. Germak. Comparisons of absolute gravimeters (COOMET.M.G-S1). Metrologia, 2017, 54, Tech. Suppl., 07010

[21] S.G. Lyubetskiy, O.V. Moshenska, O.V. Zuyev. The features of use of the deadweight piston gauges. Ukrainian Metrological Journal. 2017. No. 4. P. 29–33.

[22] V. Bolyukh, A. Omelchenko, P. Neyezhmakov, A. Vinnichenko. Estimating the Accuracy of the Installation of the Induction Dynamic Catapult Anchor on the Performance of a Ballistic Laser Gravimeter with a Symmetrical Method of Measuring the Acceleration Due to Gravity. Metrology and Instruments. 2017. No. 6. P. 45–50.

[23] V.V. Skliarov. Application of the software package of engineering analysis for improving the metrological assurance of hardness measurement. Ukrainian Metrological Journal. 2017. No. 3. P. 50–60. DOI: 10.24027/2306-7039.3.2017.114721.

[24] G.Yu. Narodnitsky. On the measurement uncertainty of measuring instruments according to the results of their calibration. Ukrainian Metrological Journal. 2017. No. 2. P. 40–41.

[25] V. Boluh, V. Kupko, A. Omelchenko, A. Vinnichenko. Conception of Ballistic Laser Gravimeter with the Inductive-Dynamic Catapult and Protection Against Auto-Seismic Vibration. Metrology and Instruments. 2017. No. 2. P. 40–48.

[26] P. Gyrya, M. Loboichenko, G. Narodnytskyi, Ye. Vorontsov. Recommendations for Work with Standard Metal Measuring Tank. Metrology and Instruments. 2017. No. 3. P. 22–24.

[27] Ya. Dovzhenko, V. Skliarov, M. Zalohin. Application of the FEM for modeling and prediction of the relationship between the hardness and stress of the deformed body. Proceeding of Smart Structures NDE, 25-28 March 2017, Portland, Oregon, USA Proc. Volume SPIE 10165, Behavior and Mechanics of Multifunctional Materials and Composites 2017, 8 p. DOI: 10.1117/12.2258370.

[28] Ya. Dovzhenko, V. Skliarov, M. Zalohin. FEM simulation and experimental measurement of hardness by the Superficial Rockwell HRT scale using the steel and tungsten carbide spherical indenters. Proceeding of Smart Structures NDE, 25-28 March 2017, Portland, Oregon, USA Proc. Volume SPIE 10165, Behavior and Mechanics of Multifunctional Materials and Composites 2017, 8 p. DOI: 10.1117/12.2257352.

[29] Yu.Yu. Bunyayeva, P.I. Neyezhmakov, Yu.F. Pavlenko. What is the direction of the world metrology? (based on the analysis of the European Programmes and documents). Ukrainian Metrological Journal. 2017. No. 1. P. 23–29. DOI: 10.24027/2306-7039.1.2017.101918.

[30] B.F. Bolyukh, V.S. Kupko, A.V. Omelchenko, O.I. Vinnichenko. Reduction of the influence of the auto-seismic effect in a ballistic gravimeter with the induction and dynamic catapult and with a symmetrical way of measuring. Ukrainian Metrological Journal. 2016. No. 4. P. 14–17.

[31] V.A. Naumenko, S.D. Nedzelskiy, V.V. Skliarov. Testing ultrasonic gas meters GUVR-011 in compliance with international Recommendations OIML R 137-1 & 2-2014. Ukrainian Metrological Journal. 2016. No. 4. P. 23–24.

[32] G.Yu. Narodnytskiy. About the possibility of verification of residential water meters without their demounting by using the capacity measures. Ukrainian Metrological Journal. 2016. No. 4. P. 29–31.

[33] Ya. Dovzhenko, V. Skliarov. Investigation of the influence of duration of preliminary and total forces for measurement of hardness. Information Processing Systems. 2016. No. 6 (143). P. 147–150.

[34] G. Narodnytskyi. Concerning the limiting accuracy of liquid volume measurements by static volume measures. Metrology and Instruments. 2016. No. 4. P. 24-27.

[35] P. Neyezhmakov. The Method of the Quantitative Assessment of the Economic Feasibility of Creating the Primary (Reference) Measurement Standard. Measurement accuracy and the impact on society: NCSL International Workshop & Symposium (24–28 July, 2016, Saint Paul RiverCentre, St. Paul, Minnesota): Conference Proceedings. 2016. P. 1–5.

[36] V.F. Bolyuch, V.S. Kupko, A.V. Omelchenko, A.I. Vinnichenko. The concept of ballistic laser gravimeter with induction-dynamic catapult and reduced influence of auto-seismic effect. Ukrainian Metrological Journal. 2016. No. 2. P. 15–20.

[37] G.Yu. Narodnitskiy, E.F. Suhomlinov, S.Yu. Tyupa. Modernization of national primary standard of the unit of length for the liquid level. Ukrainian Metrological Journal. 2016. No. 2. P. 29–33.

[38] Ya.S. Dovzhenko, V.V. Skliarov. Investigation of the influence of action time of preliminary and main loads when measuring hardness. Proceedings. XIII International Scientific Seminar "Measurement Uncertainty: Scientific, Legislative, Methodological and Applied Aspects" UM 2016, Minsk, 2016. P. 119–122.

[39] V. Skliarov, M. Zalohin. Comparison and analysis of steel and tungsten carbide Rockwell B hardness ball indenters utilizing a general purpose finite element approach. Recent Advances in Systems, Control and Information Technology. Proceedings of the International Conference SCIT 2016, May 20–21, 2016 Warsaw, Poland. P. 664–673. DOI: 10.1007/978-3-319-48923-0_71.

[40] V. Bolyukh, A. Omelchenko, A. Vinnichenko. A ballistic laser gravimeter for a symmetrical measurement method with the inductive-dynamic catapult and auto-seismic vibration preventing. 4th IAG Symposium on Terrestrial Gravimetry: Static and Mobile Measurements, TG-SMM 2016. Proceedings. 2016. P. 113–118.

[41] V. Skliarov. Interlaboratory comparisons of the Regional Metrological Organization in the field of Rockwell's scales (progress and perspectives). Proceeding of 17th International Congress of Metrology CIM-2015, France, Paris, 21–24 September, 4 pp. DOI: org/10.1051/metrology/20150004003.

[42] V. Bolyukh, A. Omelchenko, A. Vinnichenko. A Effect of self-seismic oscillations of the foundation on the readout of a ballistic gravimeter with an induction-dynamic catapult. Measurement Techniques. 2015. 58(2). P. 137–142, A004.

[43] V.F. Bolyukh, S.V. Oleksenko, A.I. Vinnichenko. The effect of initial deviations of armature on indicators of induction-dynamic catapult of ballistic laser gravimeter. Ukrainian Metrological Journal. 2015. No. 3. P. 31–36.

[44] M.N. Loboychenko, G.Yu. Narodnitskiy. Specialities of liquid volume measurements by multisection tank trucks for petroleumproducts. Ukrainian Metrological Journal. 2015. No. 3. P. 43–47.

[45] V.V. Sklyarov, Ya.S. Dovzhenko, R.S. Proskurnya. Preparation of hardness testing blocks of the first class for carrying out of international comparisons for Rockwell scale. Ukrainian Metrological Journal. 2015. No. 2. P. 40–42.

[46] V. Skliarov. Regional Metrological organization Key Comparison in the field of Rockwell hardness scales (progress and perspectives). Information Processing Systems. 2015, No. 2 (127). P. 57–60.

[47] V. Bolyukh, A. Vinnichenko. Concept of an Induction-Dynamic Catapult for a Ballistic Laser Gravimeter. Measurement Techniques. 2014. 56(10). P. 1098–1104.

[48] A.V. Omelchenko, V.F. Boluch, A.I. Vinnichenko, Yu.A. Koroltkiy. Modelling of vertical auto-seismic oscillations of the basement of the ballistic gravimeter. Ukrainian Metrological Journal. 2014. No. 4. P. 50–54.

[49] Final report on COOMET.M.M-K5: Key comparison in the field of multiples and submultiples of the kilogram. Metrologia, 2014, 51, Tech. Suppl., 07003.

[50] A.V. Omelchenko, Y.M. Zanimonskiy, A.I. Vinnichenko, V.S. Kupko. Development of Methods for Data Processing in a Rise-and-Fall Gravimeter on the Basis of Polynomial Models. Static and mobile measurements. Proceedings of IAG Symposium on Terrestrial Gravimetry (17–20 September 2013, Saint Petersburg, Russia). 2013. P. 143–147.

[51] V. Skliarov, Ya. Dovzhenko, V. Moshchenok, S. Demchenko. The analysis of accuracy characteristics of the national primary standard of hardness units of Ukraine. Ukrainian Metrological Journal. 2013. No. 3. P. 19–24.

[52] V. Bolyukh, A. Vinnichenko. Temperature field in the vacuum chamber of a ballistic gravimeter. Measurement Techniques. 2012. 55(3). P. 229–235.

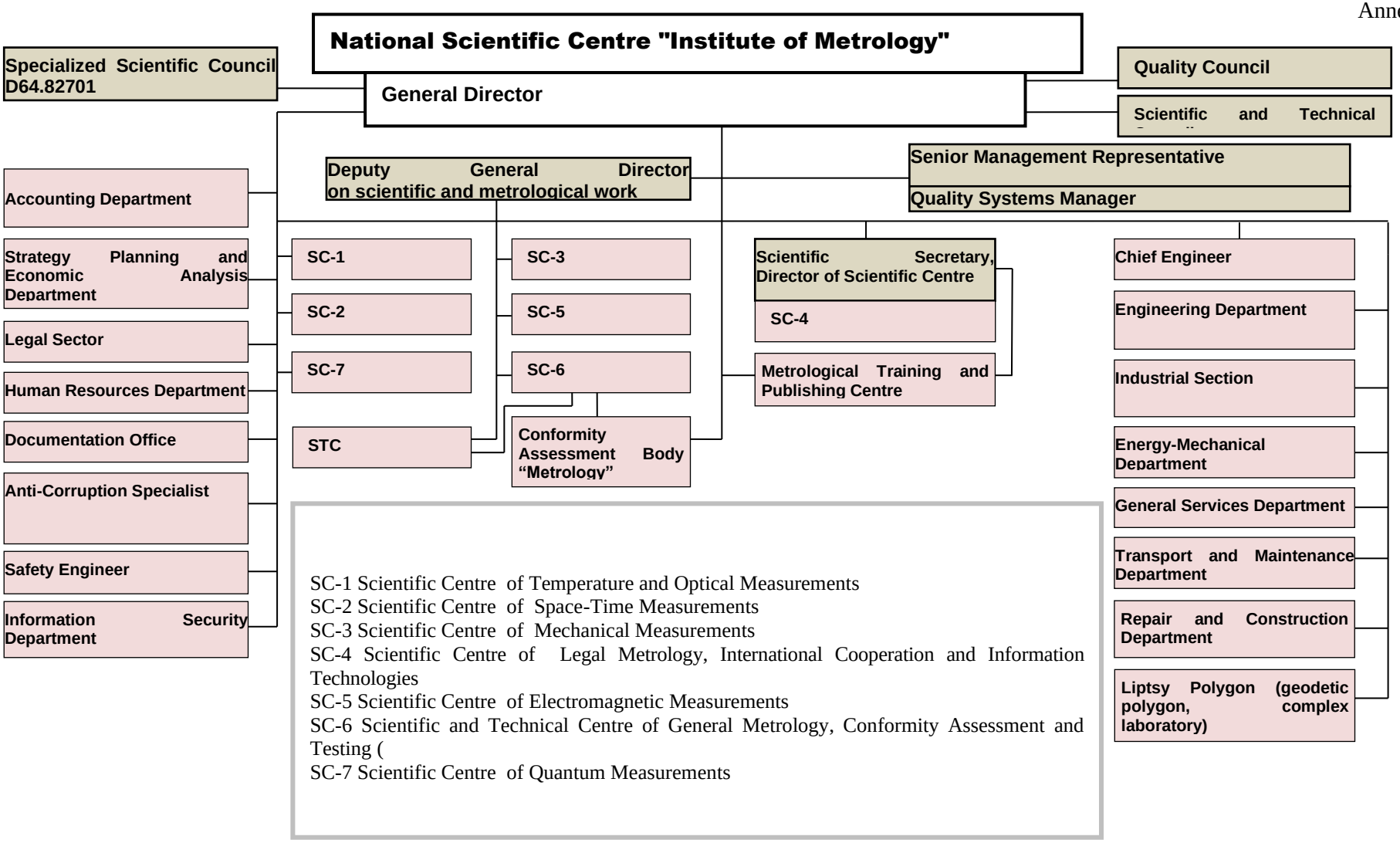
[53] Ya. Dovzhenko, K. Neyezhmakov, V. Skliarov. Experimental research of influence of indentor geometry when measuring hardness. Ukrainian Metrological Journal. 2012. No. 3. P. 43–47.

Patents of NSC "Institute of Metrology" in the field of Mass and related quantities

[1] Patent 118620 Ukraine, IPC GO1V/14 Ballistic gravimeter for symmetric and asymmetric methods of measuring the gravitational acceleration. Bolyukh V.F., Vinnichenko O.I. No. a201706239, application 19.06.2017; publication 26.12.2018, Bulletin No. 3. (In Ukrainian).

[2] Patent 111307 Ukraine, IPC G01V7/14 Ballistic laser gravimeter with induction-dynamic catapult for symmetric method of measuring the gravitational acceleration. Bolyukh V.F., Omelchenko A.V., Vinnichenko O.I., Korotkyi Yu.O. No. a201505402, application 02.06.2015; publication 11.04.2016, Bulletin No. 7. (In Ukrainian).

Annex 1



SC-1 Scientific Centre of Temperature and Optical Measurements
SC-2 Scientific Centre of Space-Time Measurements
SC-3 Scientific Centre of Mechanical Measurements
SC-4 Scientific Centre of Legal Metrology, International Cooperation and Information Technologies
SC-5 Scientific Centre of Electromagnetic Measurements
SC-6 Scientific and Technical Centre of General Metrology, Conformity Assessment and Testing (
SC-7 Scientific Centre of Quantum Measurements