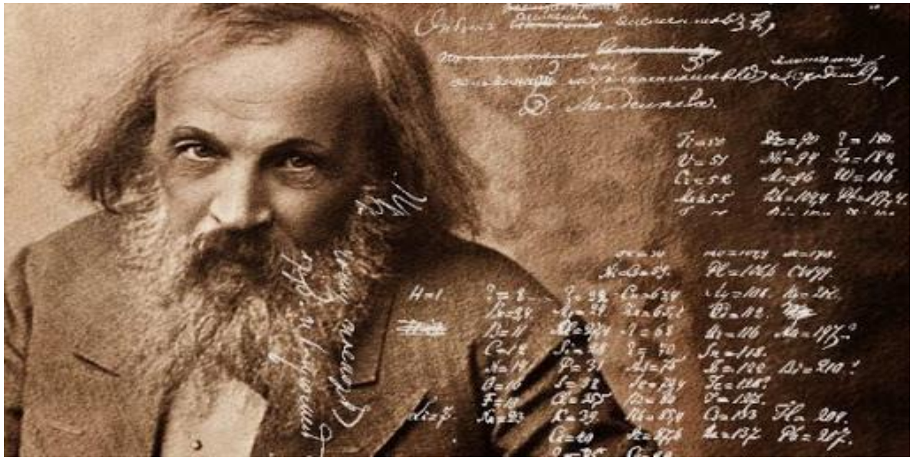
About
National Scientific Centre “Institute of Metrology”, Kharkiv, Ukraine,
Mass and related quantities
for 18th meeting of CCM

Senior Researcher Irena Kolozinska



The history of **National Scientific Centre "Institute of Metrology"** began on **8 October 1901**, when at the initiative of an outstanding scientist Dmitry Ivanovich Mendeleyev the first Ukrainian verification chamber was established in Kharkiv with the functions of verification and stamping the trade weights and measures.

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The 1973 Least-Squares Adjustment of the Fundamental Constants*

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This paper is a summary of the 1973 least-squares adjustment of the fundamental physical constants carried out by the authors under the auspices of the CODATA Task Group on Fundamental Constants. The salient features of both the input data used and its detailed analysis by least-squares are given. Also included is the resulting set of best values of the constants which is to be recommended for international adoption by CODATA, a comparison of several of these values with those resulting from recent past adjustments, and a discussion of current problem areas in the fundamental constants field requiring additional research.

Key words: Data analysis; fundamental constants; least-squares adjustments; quantum electrodynamics.

Contents

*Work partially supported by the U.S. National Bureau of Standards Office of Standard Reference Data.

TABLE 14.1. Summary of γ'_p determinations

Publication date, laboratory[a], and author	γ'_p	γ'_p	γ'_p	Uncertainty (ppm)	Eq. No.
Low Field					
	$10^8\ s^{-1}\cdot T^{-1}_{LAB}$	$10^8\ s^{-1}\cdot T^{-1}_{BIPM}$	$10^8\ s^{-1}\cdot T^{-1}_{BI69}$		
1968, ETL Hara et al.[b]	2.6751384(107)	2.6751449(107)	2.6751156(107)	4.0	(14.1)
1972, NBS Olsen and Driscoll[c]	2.6751344(54)		2.6751370(54)	2.0	(14.2)
1965, NPL Vigoureux[d]	2.6751707(107)	2.651480(107)	2.6751187(107)	4.0	(14.3)
1971, VNIIM Malyarevskaya, Studentsov, and Shifrin[e]	See text.		2.6751100(161)	6.0	(14.4)
High Field					
	$10^8\ A_{LAB}\cdot s\cdot kg^{-1}$	$10^8\ A_{BIPM}\cdot s\cdot kg^{-1}$	$10^8\ A_{BI69}\cdot s\cdot kg^{-1}$		
1966, KhGNIIM Yagola, Zingerman, and Sepetyi[f]	2.675079(20)[h]	2.675101(20)	2.675130(20)	7.4	(14.5)
1971, NPL Kibble and Hunt[g]	2.675075(43)		2.675075(43)	16	(14.6)

[a] ETL = Electrotechnical Laboratory, Japan; KhGNIIM = Kharkov State Scientific Research Institute of Metrology, U.S.S.R.
[b] Refs. [0.1, 14.2]. [c] Ref. [14.3]. [d] Refs. [0.1, 14.4]. [e] Refs. [14.5, 14.6]. [f] Refs. [0.1, 14.7, 14.8].
[g] Refs. [14.9, 14.10]. [h] This result is in terms of A_{BIH}, the ampere as maintained at VNIIM.

High Field

	$10^8\ A_{LAB}\cdot s\cdot kg^{-1}$	$10^8\ A_{BIPM}\cdot s\cdot kg^{-1}$	$10^8\ A_{BI69}\cdot s\cdot kg^{-1}$		
1966, KhGNIIM Yagola, Zingerman, and Sepetyi[f]	2.675079(20)[h]	2.675101(20)	2.675130(20)	7.4	(14.5)
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REVIEWS OF
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Determination of e/h, Using Macroscopic Quantum Phase Coherence in Superconductors: Implications for Quantum Electrodynamics and the Fundamental Physical Constants

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The implications of the new determination of e/h using the ac Josephson effect in superconductors for both quantum electrodynamics (QED) and our knowledge of the fundamental physical constants are analyzed in detail. The implications for QED are investigated by first deriving a value of the fine structure constant α from experimental input data which do not require the use of QED theory for their analysis. These include the Josephson-effect value of e/h, the Faraday constant, the gyromagnetic ratio of the proton, the magnetic moment of the proton in units of the nuclear magneton, the ratio of the ampere as maintained by the United States National Bureau of Standards to the absolute ampere, and certain accurately known auxiliary constants. This is done by critically reevaluating all of the experimental data presently available on these quantities and applying the standard techniques of a least squares adjustment, including tests for incompatibility. The value of α so obtained is then used to evaluate the theoretical expressions for the Lamb shift and fine structure splitting in hydrogen, deuterium, and ionized helium, the hyperfine splitting in hydrogen, muonium, and positronium, and the anomalous magnetic moment of the electron and muon. These theoretical values are compared with critically reexamined experimental values, thus providing a test of QED in which *a priori* information from QED itself is not essential. The consequences of the new measurement of e/h for our present knowledge of the fundamental physical constants are demonstrated by deriving new "best" values for the fundamental constants from a critically selected subset of all the available data. In addition to providing a consistent set of constants, this analysis focuses attention on areas in which there remain important questions which require clarification. The experimental and theoretical work necessary for the resolution of these questions is discussed, with emphasis on ways in which the study of quantum phase coherence effects in low temperature superfluid systems can make significant contributions.

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TABLE IV. Summary of some velocity-of-light measurements made since 1948 (MWI, microwave interferometer; IRRS, infrared rotational spectrum; FLRC, fixed-length resonant cavity; VLRC, variable-length resonant cavity). (Probable errors have been converted to standard deviations by multiplying by 1.48.) The errors quoted for the Kolibayev and Grosse geodimeter measurements are statistical only.

Year of publication	Author	Method	c (km/sec)
1967	Simkin, Lukin, Sikora, and Strelenskii	MWI	299 792.56±0.11
1967	Grosse	Geodimeter	299 792.5±0.05
1965	Kolibayev	Geodimeter	299 792.6±0.06
1950–1962	McNish (1962) summary of data of Bergstrand, USCGS, and others	Geodimeter	299 792.6±0.25
1958	Froome	MWI	299 792.50±0.10
1955	Florman[a]	RWI	299 795.1±1.5
1955	Plyler, Blaine, and Connor[b]	IRRS	299 792±6
1954	Froome [revised, Froome (1958)]	MWI	299 792.75±0.30
1952	Froome	MWI (first instrument)	299 792.6±0.7
1951	Aslakson[c]	Shoran	299 794.2±2.8
1950	Bol[d]	FLRC	299 789.3±1.0
1950	Essen[e]	VLRC	299 792.5±1.5
1949	Aslakson[c]	Shoran	299 792.4±3.6
1948	Essen and Gordon-Smith[f]	FLRC	299 792±4.5

[a] E. F. Florman, J. Res. Natl. Bur. Std. **54**, 335 (1955).
[b] E. K. Plyler, L. R. Blaine, and W. S. Connor, J. Opt. Soc. Am. **45**, 102 (1955).
[c] C. I. Aslakson, Trans. Am. Geophys. Union **32**, 813 (1951); **30**, 475 (1949); Nature **168**, 505 (1951); **164**, 711 (1949).
[d] K. Bol, Phys. Rev. **80**, 298 (1950).
[e] L. Essen, Proc. Roy. Soc. (London) **A204**, 260 (1950).
[f] L. Essen and A. C. Gordon-Smith, Proc. Roy. Soc. (London) **A194**, 348 (1948).

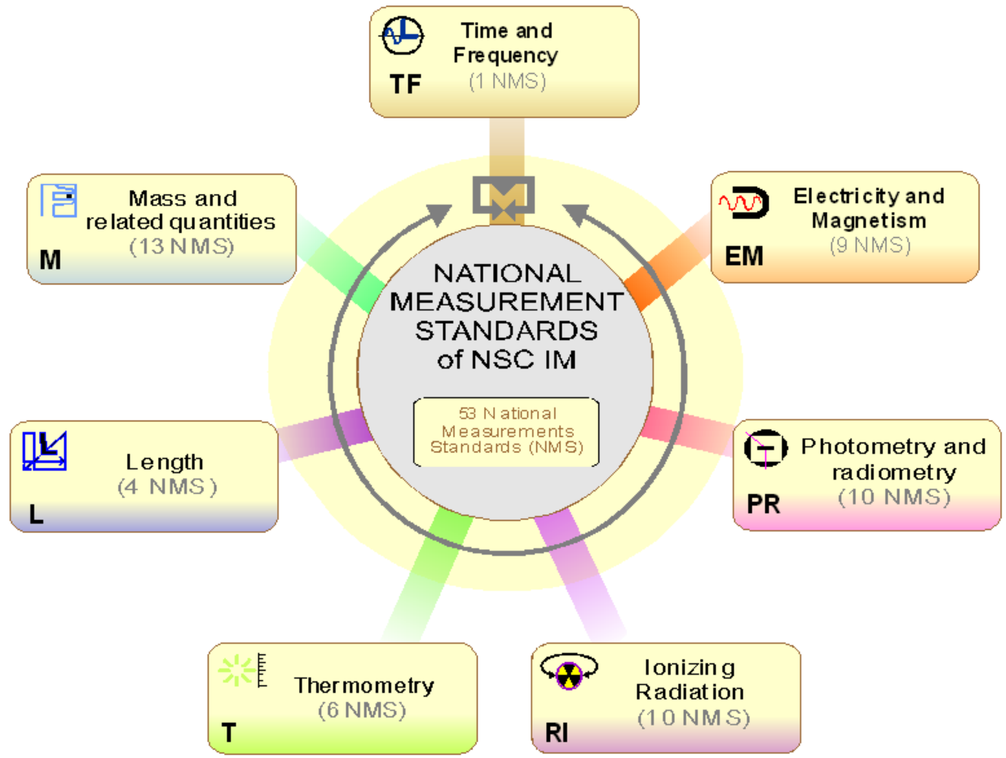
Year of publication	Author	Method	c (km/sec)
1967	Simkin, Lukin, Sikora, and Strelenskii	MWI	299 792.56±0.11

National Scientific Centre "Institute of Metrology"

53 National Measurement Standards in NSC "IM"

M Mass and related quantities (13 NMS)

- **MASS**
- **PRESSURE**
- **HARDNESS**
- **GRAVITY**
- **FLUID FLOW**



NETU M-07-2020 (created in 1997)

Range: from 1 mg to 50 kg


BUREAU INTERNATIONAL DES POIDS ET MESURES
Pavillon de Breteuil, F - 92312 Sèvres Cedex

No. 48 | 23 July 2019

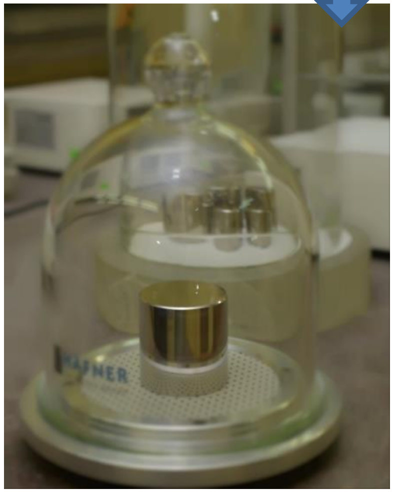
CERTIFICATE

for a 1 kg mass standard, designated

“DSTU 02-01-09/1kg”

belonging to the
National Scientific Centre “Institute of Metrology”
(NSC)
Kharkiv, Ukraine

(First BIPM calibration)

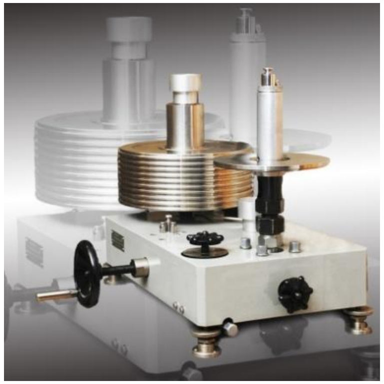


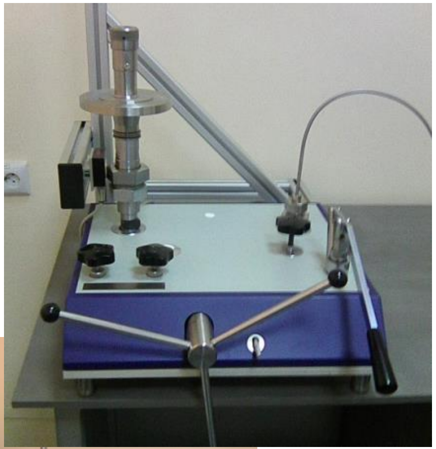
Mass comparators from 1 mg to 50 kg

Mass comparator for mg range

Installation of hydrostatic weighing
for determining the volume of weights

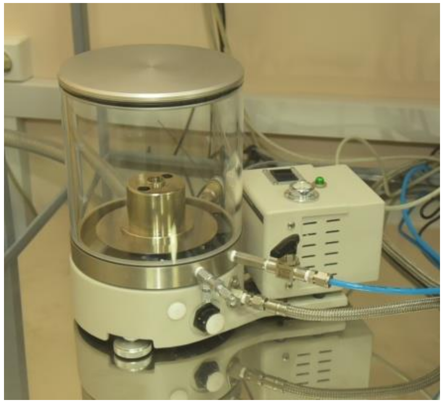
PRESSURE





DETU 04-03-01 (established in 2001)
Gauge pressure: 50 kPa – 10 MPa
Uncertainty: 10 ppm
Pressure transmitting medium: aviation kerosene
Principle: Pressure balance

NETU M-01-2018 (created in 2017)
Gauge pressure: 10 MPa – 400 MPa
Uncertainty: (22 – 72) ppm
Pressure transmitting medium: oil
Principle: Pressure balance



NETU M-03-2019 (created in 1997, improved in 2018)
Gauge pressure: minus 0,1 MPa – 7 MPa
Absolute pressure: 270 Pa – 7 MPa
Uncertainty: (14 – 26) ppm
Pressure transmitting medium: gas
Principle: Pressure balance

National Scientific Centre “Institute of Metrology”

NETU M-10-2021 Rockwell, Super Rockwell

Metrological characteristics

Range	(70-93) HRA, (25-100) HRBW, (20-67) HRC	(70-94) HR15N, (40-86) HR30N, (20-78) HR45N, (62-93) HR15TW (15-82) HR30TW, (10-72) HR45TW
u_A	0,08 HR	0,16 HR
u_B	0,11 HR	0,21 HR
U	0,26 HR	0,52 HR

DETU 02-03-99 Brinell, Vickers

Metrological characteristics

Range	from 8 HB to 450 HB from 95 HBW to 650 HBW	from 8 HV to 2000 HV from 9,8 H to 19,6 H	 from 49,0 H to 980,7 H
u_A	$1\cdot10^{-3}$	$2\cdot10^{-3}$	$1\cdot10^{-3}$
u_B	$1{,}25\cdot10^{-3}$	$2{,}5\cdot10^{-3}$	$1{,}25\cdot10^{-3}$
U	$3{,}2\cdot10^{-3}$	$6{,}4\cdot10^{-3}$	$3{,}2\cdot10^{-3}$







Metrological characteristics

Range	From 9,77 m/s^2 to 9,85 m/s^2
u_A	$5 \cdot 10^{-8}$ m/s^2
u_B	$2 \cdot 10^{-8}$ m/s^2
U	$11 \cdot 10^{-8}$ m/s^2

Since 2012, research has been carried out: "Development and research of a ballistic laser gravimeter based on precision mobile devices using linear pulse electromechanical transducers to measure the absolute value of free fall acceleration", (Patent № 96904, Ukraine; Patent № 111307, Ukraine; № 2011128560, Russia).

In 2018, a new research work was started: "Development and research of absolute gravimeter based on precision atomic interferometry of ultracold atoms with laser cooling of atoms and their spatial localization."

DETU 03-04-04

State primary standard unit of volume flow rate in the range from $2.8 \cdot 10^{-4}$ to $2.8 \cdot 10^{-2}$ m^3/s, mass flow rate in the range from $2.8 \cdot 10^{-1}$ to 28 kg/s, the volume of liquid in the range from 0.1 to 3.0 m^3 and the mass of liquid in the range from 100.0 to 3000 kg.

Metrological characteristics

Range	from $2,8 \cdot 10^{-4}$ m^3/s to $2,8 \cdot 10^{-2}$ m^3/s from $2,8 \cdot 10^{-1}$ kg/s to 28 kg/s	from 0,1 m^3 to 3,0 m^3 from 100,0 kg to 3000 kg
u_A	$2 \cdot 10^{-5}$	$2 \cdot 10^{-5}$
u_B	$3,7 \cdot 10^{-5}$	$1,2 \cdot 10^{-4}$
U	$8,4 \cdot 10^{-5}$	$24,2 \cdot 10^{-5}$

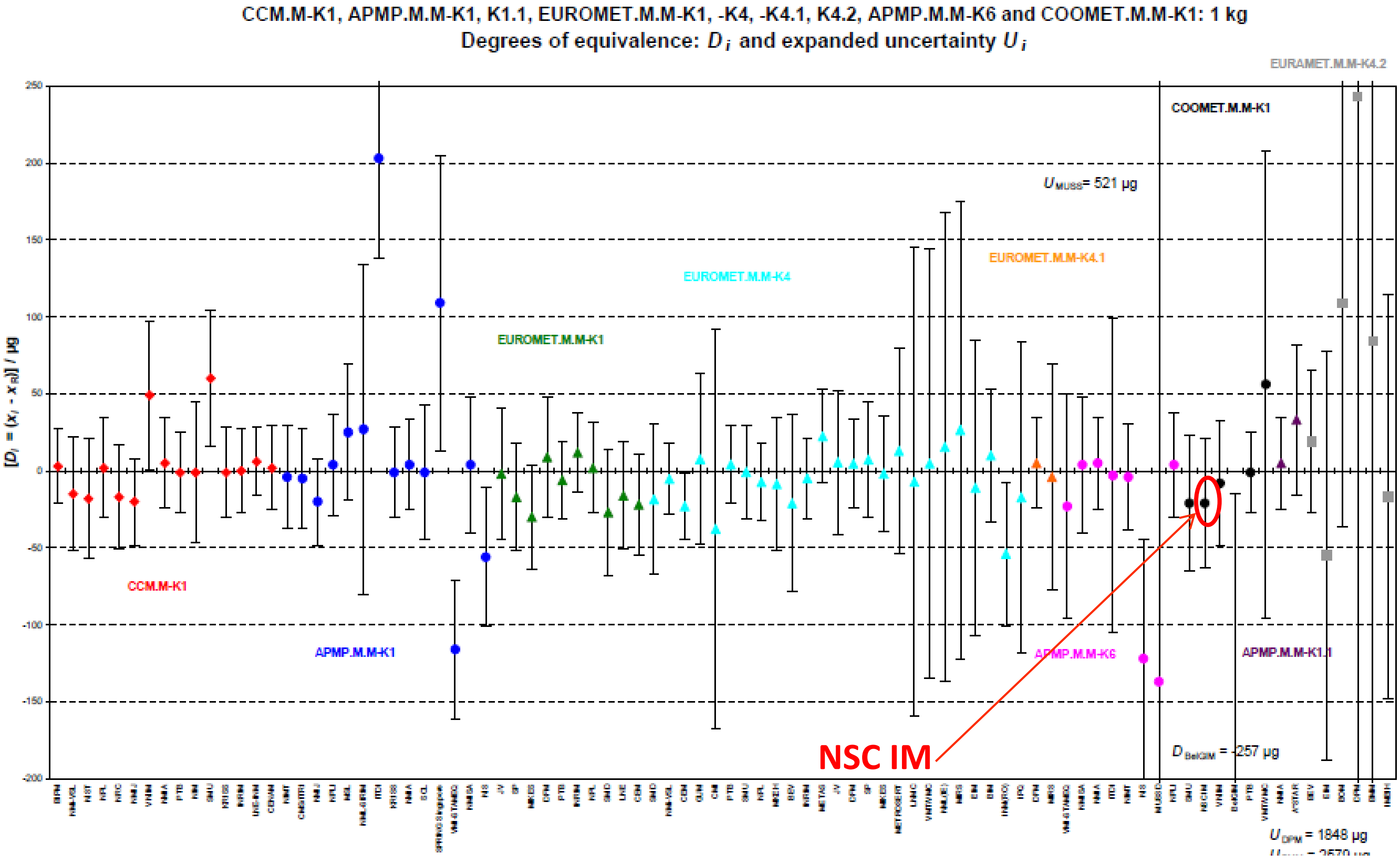
DETU 03-03-13

State primary standard of unit volume of liquid

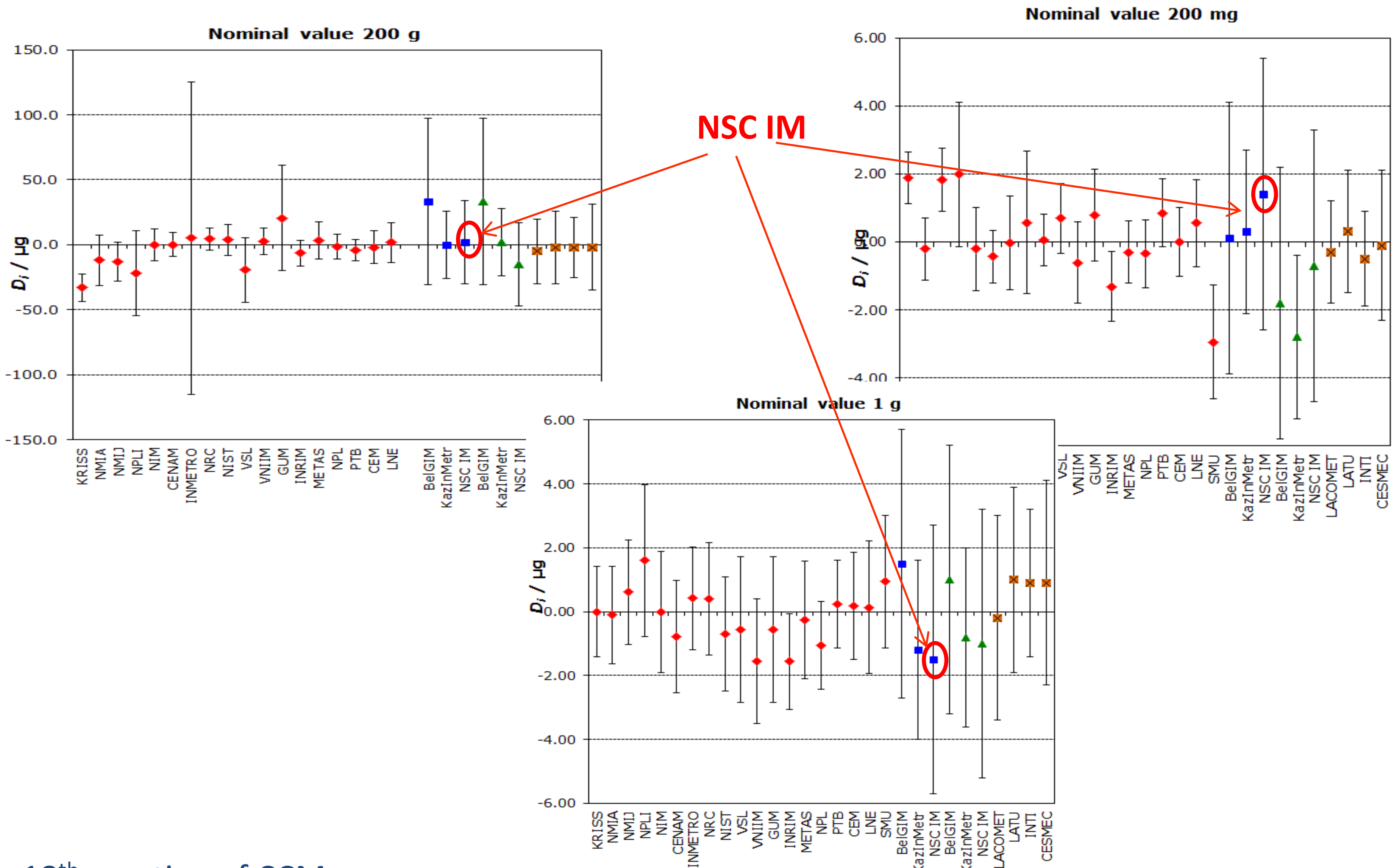
Metrological characteristics

Range	from $1 \cdot 10^{-3}$ m^3 to $1 \cdot 10^{-1}$ m^3 from $5 \cdot 10^{-1}$ m^3 to 1 m^3	from $1 \cdot 10^{-1}$ m^3 (including) to $5 \cdot 10^{-1}$ m^3 (including)
u_A	$3 \cdot 10^{-5}$	$1,5 \cdot 10^{-5}$
u_B	$2,5 \cdot 10^{-5}$	$1,9 \cdot 10^{-5}$
U	$8 \cdot 10^{-5}$	$5 \cdot 10^{-5}$

Degrees of equivalence



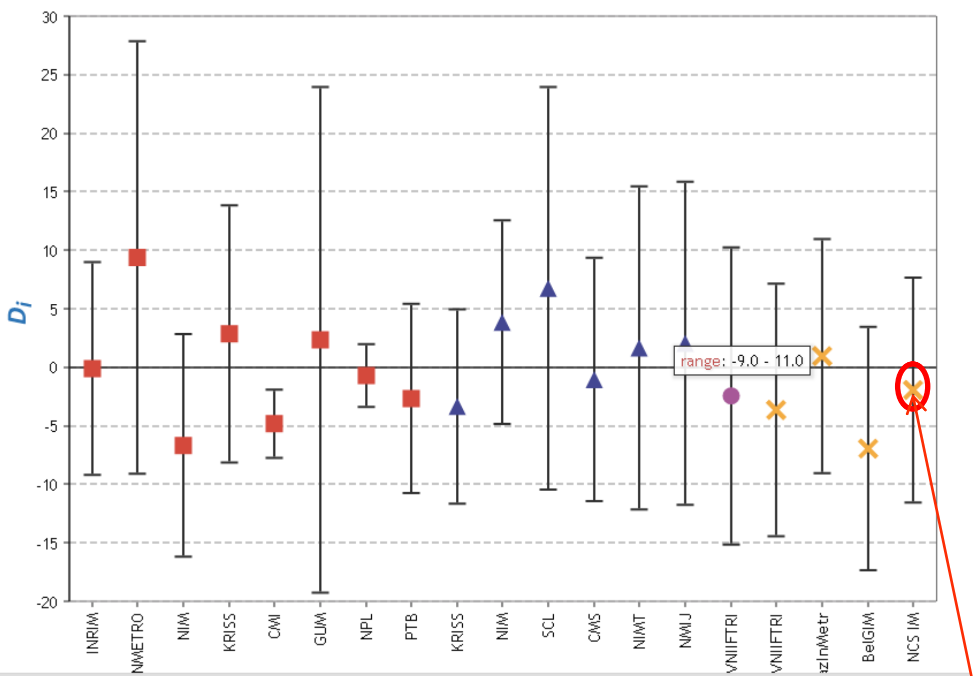
Degrees of equivalence
COOMET.M.M-K5



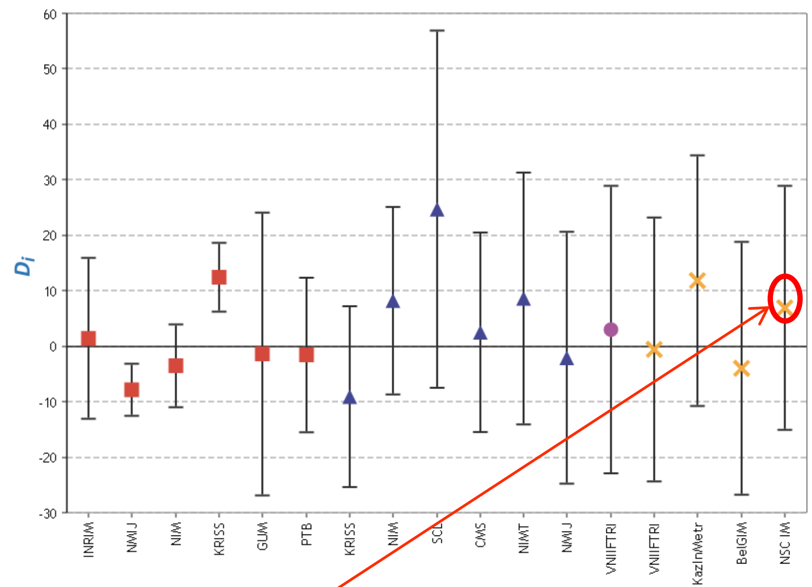
Degrees of equivalence

COOMET.M.H-K1

540 HV1



840 HV1



NSC IM

COMPARISONS

Number	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

COMPARISONS

Number	Description	Status	Role
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

COMPARISONS

Number	Description	Status	Role
COOMET.M.G-S1	Gravitational acceleration Free-fall acceleration at a nominal value of 9.81 m/s^2	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

COMPARISONS

Number	Description	Status	Role
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

CMCs in KCDB

MASS

Quantity	Instrument or Artifact	Measurement method	Measurand Minimum value	Measurand Maximum value	Unit	Expanded uncertainty Minimum value	Expanded uncertainty Maximum value	Unit
Mass	Mass standard	Subdivision method	1.0	100.0	mg	2.0	4.0	µg
Mass	Mass standard	Subdivision method	0.1	1.0	g	4.0	4.2	µg
Mass	Mass standard	Direct comparison in air	1.0	10.0	g	4.2	6.5	µg
Mass	Mass standard	Direct comparison in air	10.0	100.0	g	6.5	31.0	µg
Mass	Mass standard	Direct comparison in air	0.1	1.0	kg	31.0	45.0	µg

GRAVITY

Quantity	Instrument or Artifact	Measurement method	Measurand Minimum value	Measurand Maximum value	Unit	Expanded uncertainty	Unit
Gravity (free fall) acceleration	On (stable) site	Absolute measurement	9.77	9.85	m/s^2	2.08E-7	m/s^2

HARDNESS

Quantity	Instrument or Artifact	Measurement method	Parameters	Unit	Expanded uncertainty	Unit
Hardness	Primary hardness standard block	Vickers	Total force : for 49.03 N to 294.2 N	(dimensionless)	1.5	%

RESEARCH PROJECTS

- EMPIR EURAMET
  The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

  Project 19RPT02, "Improvement of the realisation of the mass scale" (EMPIR [1] Call 2019 –Research Potential)

  The project will facilitate cooperation leading to improved calibration capabilities at participating, less-developed, NMIs. It will also produce draft EURAMET calibration guidance applicable to the new definition of the kilogram, backed by software, training tools and maintenance methods. This will provide opportunities for upgraded research activities for which mass measurement accuracy is critical

- 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

- **Prospective works**:
  Development and advancement of an absolute gravimeter based on precision atomic interferometry of ultracold atoms with laser cooling of atoms and space localization

SOME PUBLICATIONS

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

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.

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.

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.

National Scientific Centre
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