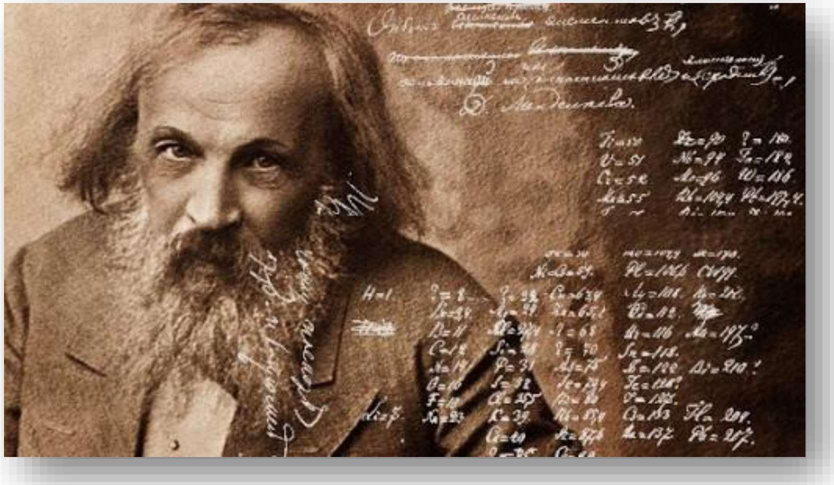
CCT/20-63

About National Scientific Centre “Institute of Metrology”

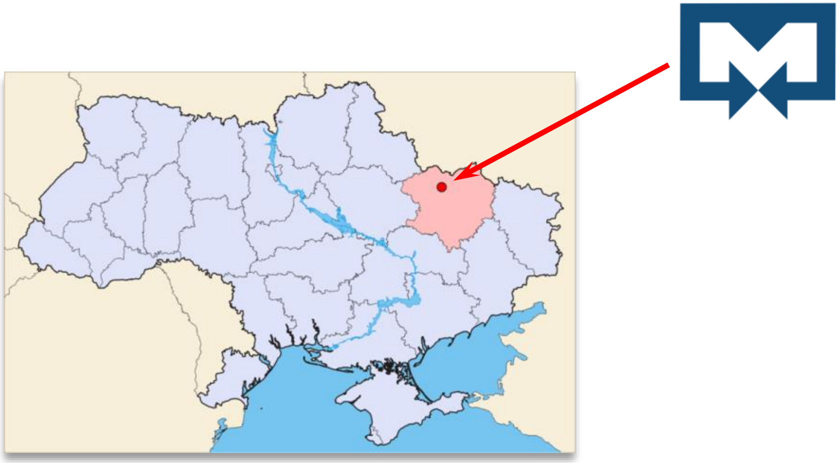
Thermometry

Researcher Svitlana FIL,
Secretary of TC 1.10 COOMET

HISTORY



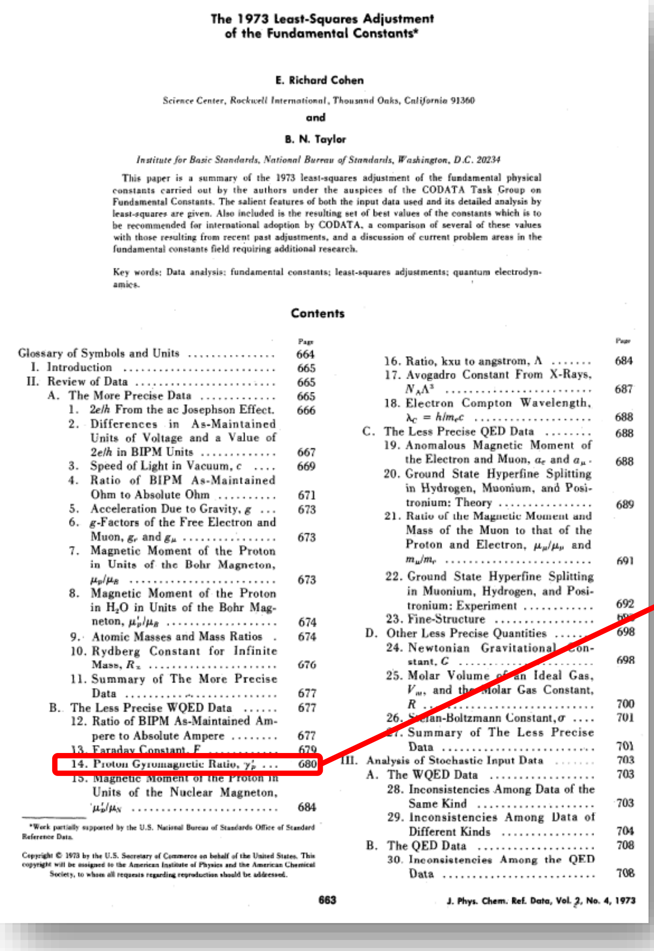
The history of **National Scientific Centre "Institute of Metrology"** began on **8 October 1901**, when at the initiative of an outstanding scientist Dmitry Ivanovich Mendeleyev the first Ukrainian verification chamber was established in Kharkiv with the functions of verification and stamping the trade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



National Scientific Centre “Institute of Metrology”
42 Myronosytska str., Kharkiv, 61002, Ukraine

Measurements of the proton gyromagnetic ratio

History



The 1973 Least-Squares Adjustment of the Fundamental Constants*

E. Richard Cohen

Science Center, Rockwell International, Thousand Oaks, California 91360

and

B. N. Taylor

Institute for Basic Standards, National Bureau of Standards, Washington, D.C. 20234

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

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

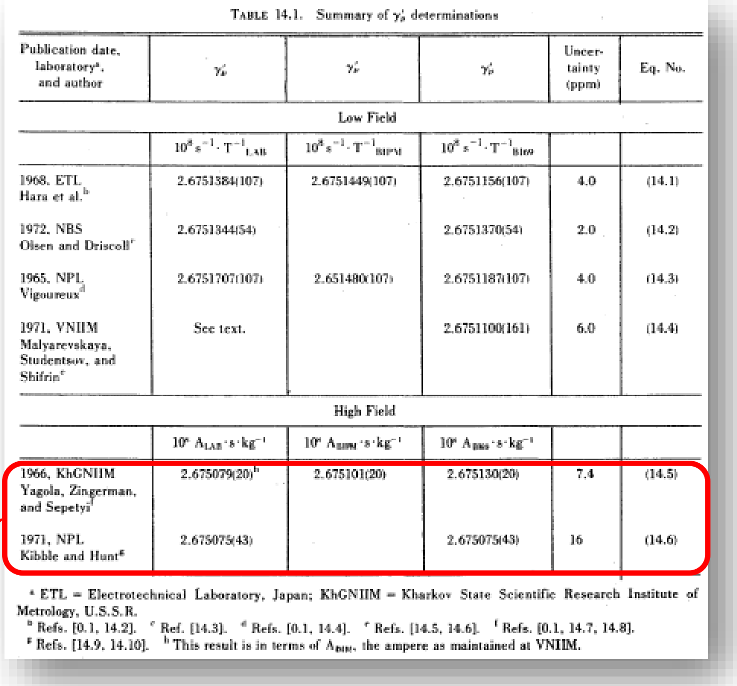
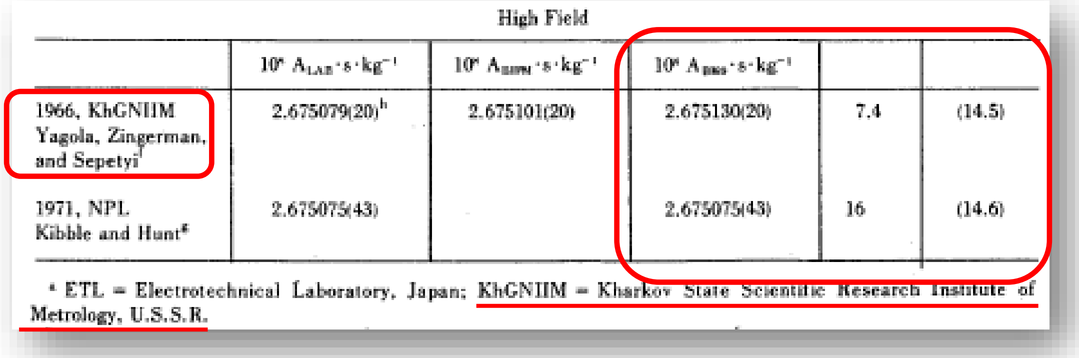


TABLE 14.1. Summary of γ'_p determinations

Publication date, laboratory[a], and author	γ'_p	γ'_p	γ'_p	Uncertainty (ppm)	Eq. No.
Low Field					
	$10^8\ s^{-1}\cdot T^{-1}{}_{LAB}$	$10^8\ s^{-1}\cdot T^{-1}{}_{BIPM}$	$10^8\ s^{-1}\cdot T^{-1}{}_{NBS69}$		
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					
	$10^8\ A_{LAB}\cdot s\cdot kg^{-1}$	$10^8\ A_{BIPM}\cdot s\cdot kg^{-1}$	$10^8\ A_{NBS}\cdot s\cdot kg^{-1}$		
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

	$10^8\ A_{LAB}\cdot s\cdot kg^{-1}$	$10^8\ A_{BIPM}\cdot s\cdot kg^{-1}$	$10^8\ A_{NBS}\cdot s\cdot kg^{-1}$		
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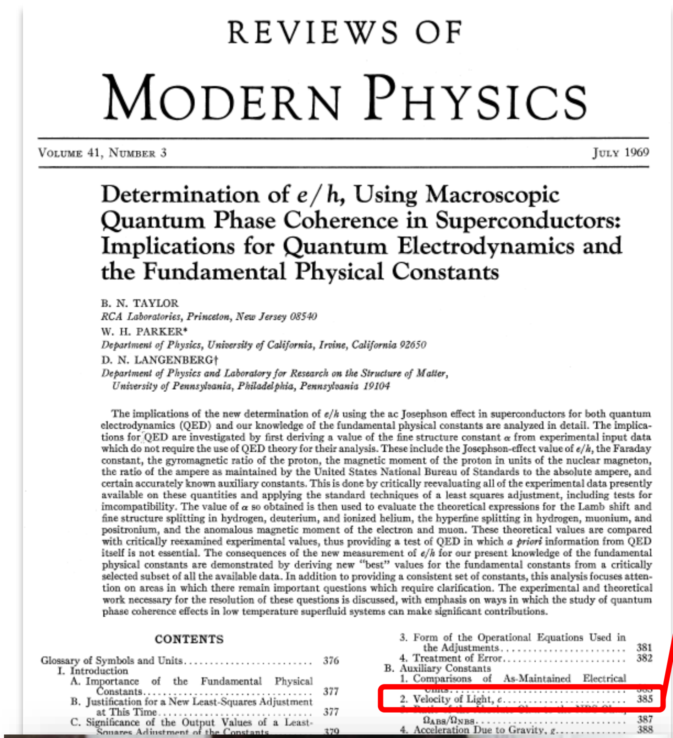
[a] ETL = Electrotechnical Laboratory, Japan; KhGNIIM = Kharkov State Scientific Research Institute of Metrology, U.S.S.R.

Measurements of the speed of light

These studies have formed the basis for laser range measurements



REVIEWS OF

MODERN PHYSICS

VOLUME 41, NUMBER 3 JULY 1969

Determination of e/h, Using Macroscopic Quantum Phase Coherence in Superconductors: Implications for Quantum Electrodynamics and the Fundamental Physical Constants

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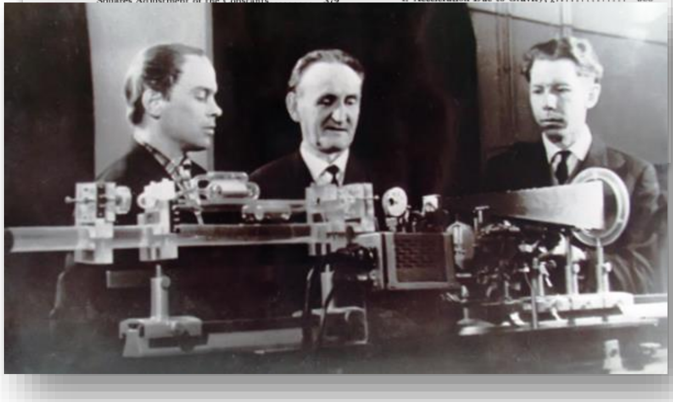
The implications of the new determination of e/h using the ac Josephson effect in superconductors for both quantum electrodynamics (QED) and our knowledge of the fundamental physical constants are analyzed in detail. The implications for QED are investigated by first deriving a value of the fine structure 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.

CONTENTS



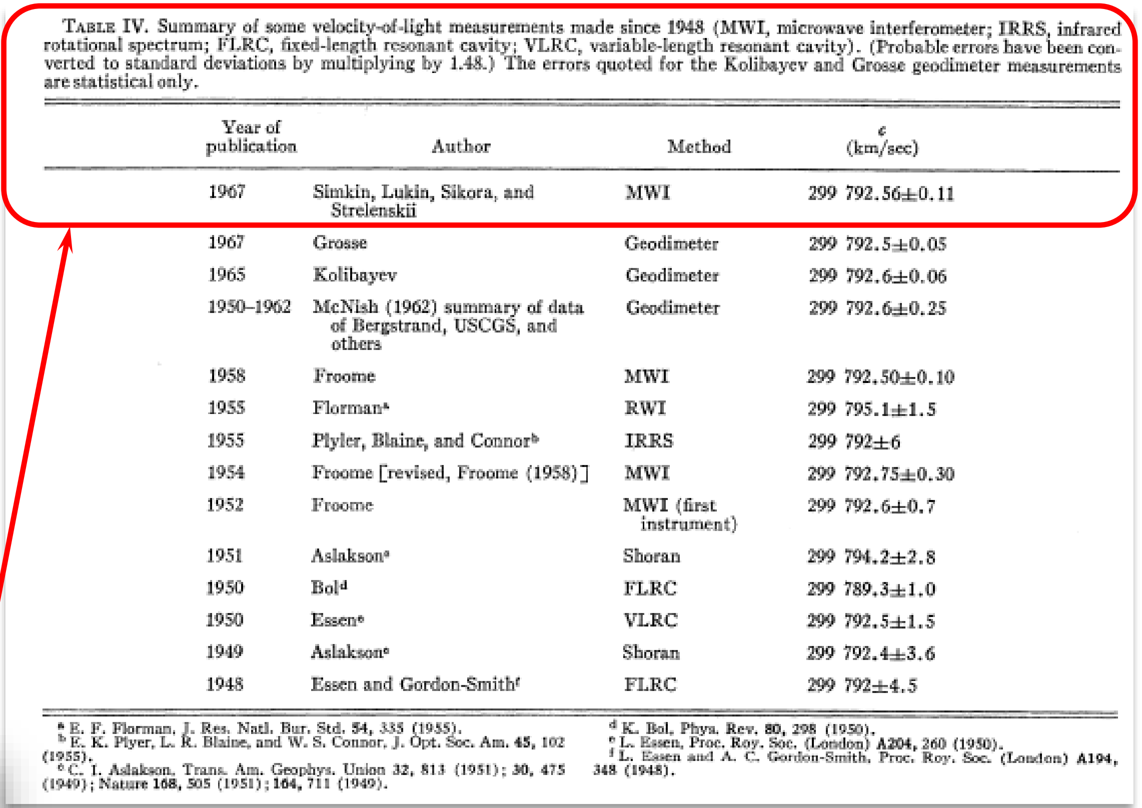
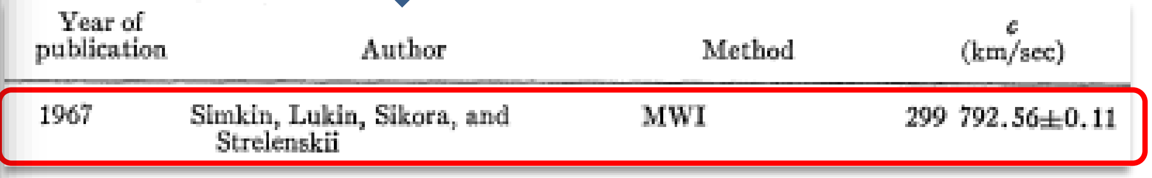


TABLE IV. Summary of some velocity-of-light measurements made since 1948 (MWI, microwave interferometer; IRRS, infrared rotational spectrum; FLRC, fixed-length resonant cavity; VLRC, variable-length resonant cavity). (Probable errors have been converted to standard deviations by multiplying by 1.48.) 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

STAGES OF EVOLUTION IN THE FIELD OF THERMOMETRY

1947 - creation of the first reference optical pyrometer in NSC “Institute of Metrology”

- methods of “luminance comparison" and “luminance addition" were developed

- development of a high-precision installation EOP-51, which made it possible to expand the temperature range up to 10,000 °C

- a high-speed pyrometer was developed, which provided temperature measurement in the range 1227 °C – 39727 °C with a time resolution of 10^{-5} s

- creation of equipment based on a cryogenic radiometer with electrical substitution

HISTORY OF THERMOMETRY

ИЗМЕРИТЕЛЬНАЯ ТЕХНИКА

5

1956

52 ИЗМЕРИТЕЛЬНАЯ ТЕХНИКА № 5

Пирометры ЭОП-51М и ОП-48М для измерения температуры до 6000°C

В. Е. ФИНКЕЛЬШТЕЙН, Е. С. ШПИГЕЛЬМАН и В. В. КАНДЫБА

В Харьковском государственном институте мер и измерительных приборов (ХГИМИП) в течение ряда лет проводилась работа по созданию точных оптических пирометров, в результате были созданы образцовый оптический пирометр 2-го разряда ОП-48 и эталонный оптический пирометр ЭОП-51

Pyrometers EOP-51M and OP-48M for temperature measurement up to 6000 °C

Ph.D. V. Finkelshtein

Pyrometer EOP-51

Класс 42i, 9₀₁ № 104412

СССР

ОПИСАНИЕ ИЗОБРЕТЕНИЯ

К АВТОРСКОМУ СВИДЕТЕЛЬСТВУ

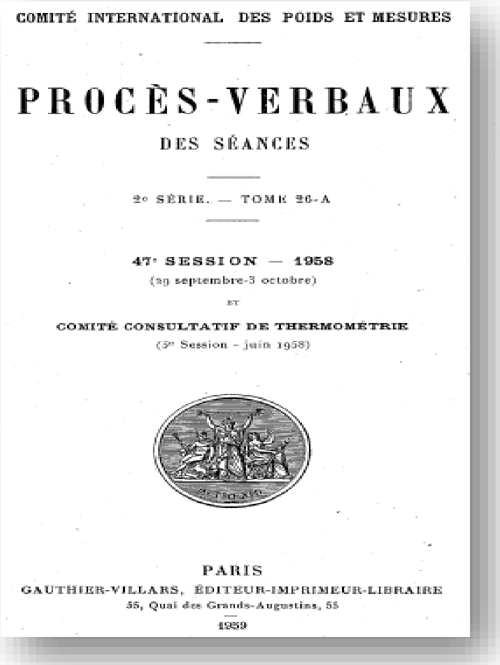
В. Е. Финкельштейн

СПОСОБ ГРАДУИРОВКИ И ПОВЕРКИ ОПТИЧЕСКИХ ПИРОМЕТРОВ ПРИ ТЕМПЕРАТУРЕ ВЫШЕ 2500°

Заявлено 29 февраля 1956 г. за № 9/604/453410 в Комитет стандартов, мер и измерительных приборов при Совете Министров СССР

Certificate of authorship

HISTORY OF THERMOMETRY



COMITÉ INTERNATIONAL DES POIDS ET MESURES

PROCÈS-VERBAUX
DES SÉANCES

2e SÉRIE. — TOME 26-A

47e SESSION — 1958
(29 septembre-3 octobre)
ET
COMITÉ CONSULTATIF DE THERMOMÉTRIE
(5e Session – juin 1958)

PARIS
GAUTHIER-VILLARS, ÉDITEUR-IMPRIMEUR-LIBRAIRE
55, Quai des Grands-Augustins, 55
1959

ANNEXE T 18

Institut de Métrologie D. I. Mendéléev (U. R. S. S.)

NOUVELLE MÉTHODE POUR L'ÉTALONNAGE DES PYROMÈTRES OPTIQUES. NOUVEAU PYROMÈTRE OPTIQUE DE PRÉCISION (1)

Par V. E. PHINKELSCHTEIN et V. V. KANDIBA

(Traduction)

On sait que l'étalonnage d'un pyromètre optique dans le domaine des hautes températures est effectué à l'aide d'un système de gradation qui permet de réaliser l'égalisation de la luminance d'un corps noir à la température T avec celle d'un corps noir à une température plus basse T_0 (2).

L'équation sur laquelle est basée l'extrapolation a la forme suivante

$$\int_0^\infty \lambda^{-5}\left(e^{\frac{C_2}{\lambda T}}-1\right)^{-1}\tau'_\lambda V_\lambda \tau_\lambda \, d\lambda = \int_0^\infty \lambda^{-5}\left(e^{\frac{C_2}{\lambda T_0}}-1\right)^{-1} V_\lambda \tau_\lambda \, d\lambda, \tag{1}$$

où τ'_λ, facteur de transmission du verre absorbant pour la lumière de longueur d'onde λ;
τ_λ, facteur de transmission du verre rouge du pyromètre;
V_λ, efficacité lumineuse relative de l'œil.

Comme systèmes de gradation on utilise ordinairement des verres absorbants, ce qui entraine une diminution sensible de la précision dans la reproduction de l'échelle de température, car l'erreur de la mesure du facteur de transmission pour le verre absorbant est très grande.

---

(1) *Trud. Inst. Metrol. D. I. Mendeleev*, no 36 (96), 1958, p. 16.

(2) Nous appellerons cette grandeur « température de luminance apparente ». Pratiquement, T_0 est toujours choisie inférieure à 2 000° K.

Institut de Métrologie D. I. Mendéléev (U. R. S. S.)

NOUVELLE MÉTHODE POUR L'ÉTALONNAGE DES PYROMÈTRES OPTIQUES. NOUVEAU PYROMÈTRE OPTIQUE DE PRÉCISION (1)

Par V. E. PHINKELSCHTEIN et V. V. KANDIBA

— T 149 —

l'œil de l'observateur. L'utilisation d'un tel diaphragme permet d'obtenir au cours des mesures la brillance la plus commode pour l'œil.

Le pyromètre est muni de quatre verres absorbants destinés à étendre le domaine de l'échelle. En outre, sa construction permet d'employer des secteurs tournants comme systèmes de gradation.

La combinaison des verres absorbants (pour les mesures des températures jusqu'à 3 000° C) est montée sur un support tournant situé entre l'objectif et la lampe pyrométrique.

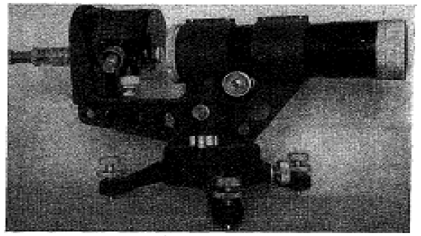


Fig. 3.

Le verre absorbant supplémentaire (п–6 000), destiné aux mesures dans l'intervalle 2 500-6 000° C, a un diamètre de 80 mm; il est placé devant le tube de l'objectif du pyromètre afin de diminuer son échauffement au cours des mesures aux hautes températures [5].

En introduisant simultanément les deux systèmes de verres absorbants — le verre п–6 000 et la combinaison de verres colorés, montés sur un support commun — on a la possibilité d'effectuer des mesures dans l'intervalle 2 000-10 000° C.

Les écarts moyens quadratiques du pyromètre ЭОП-51М sont donnés dans le tableau suivant.

Température.	Écart moyen quadratique.
1 400°C	0,1 %
2 000	0,2
6 000	1,0
10 000	1,5

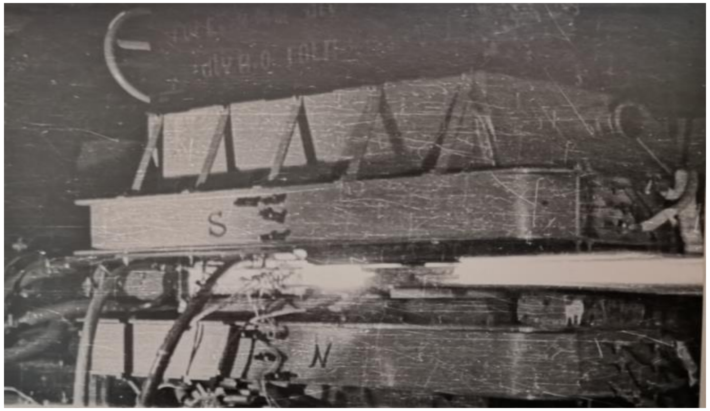
(Avril 1958)

Les écarts moyens quadratiques du pyromètre ЭОП-51М sont donnés dans le tableau suivant.

Température.	Écart moyen quadratique.
1 400°C	0,1 %
2 000	0,2
6 000	1,0
10 000	1,5

(Avril 1958)

A set of instruments for **measuring high plasma temperatures** and diagnostics in special conditions **range *from 1227 °C to 39727 °C;* error is 3%**



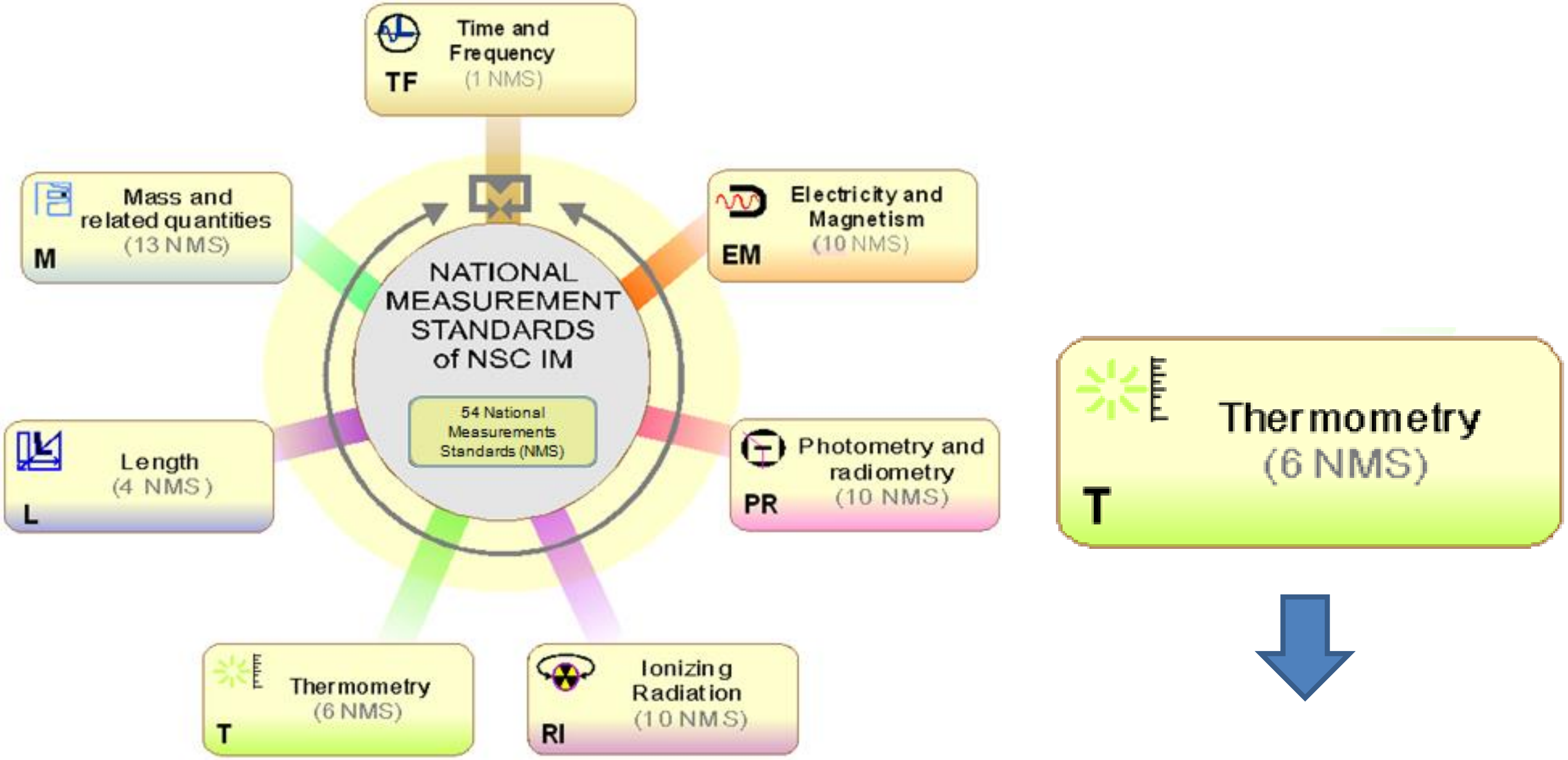
MHD Generator

Highly sensitive measuring complex for measuring plasma parameters

Application field for measuring plasma

TODAY

54 National Measurement Standards in NSC “IM”



NMS 06-06-98 National primary standard of the unit of temperature of Kelvin in the range from 13.8 K to 273.16 K;
NMS 06-05-98 National primary standard of the unit of temperature of Kelvin in the range from 273.16 K to 1357.77 K;
NMS 06-07-04 National primary standard of the unit for IR-radiation in the range from 962.67 K to 1234.93 K;
NMS 06-03-96 National primary standard of the unit of temperature for radiation in the range from 1357.77 K to 2800 K;
NMS 06-04-97 National primary standard of the unit of combustion energy;
NMS 06-02-96 National primary standard of the unit of specific heat of solids in the range from 1800 K to 3000 K.

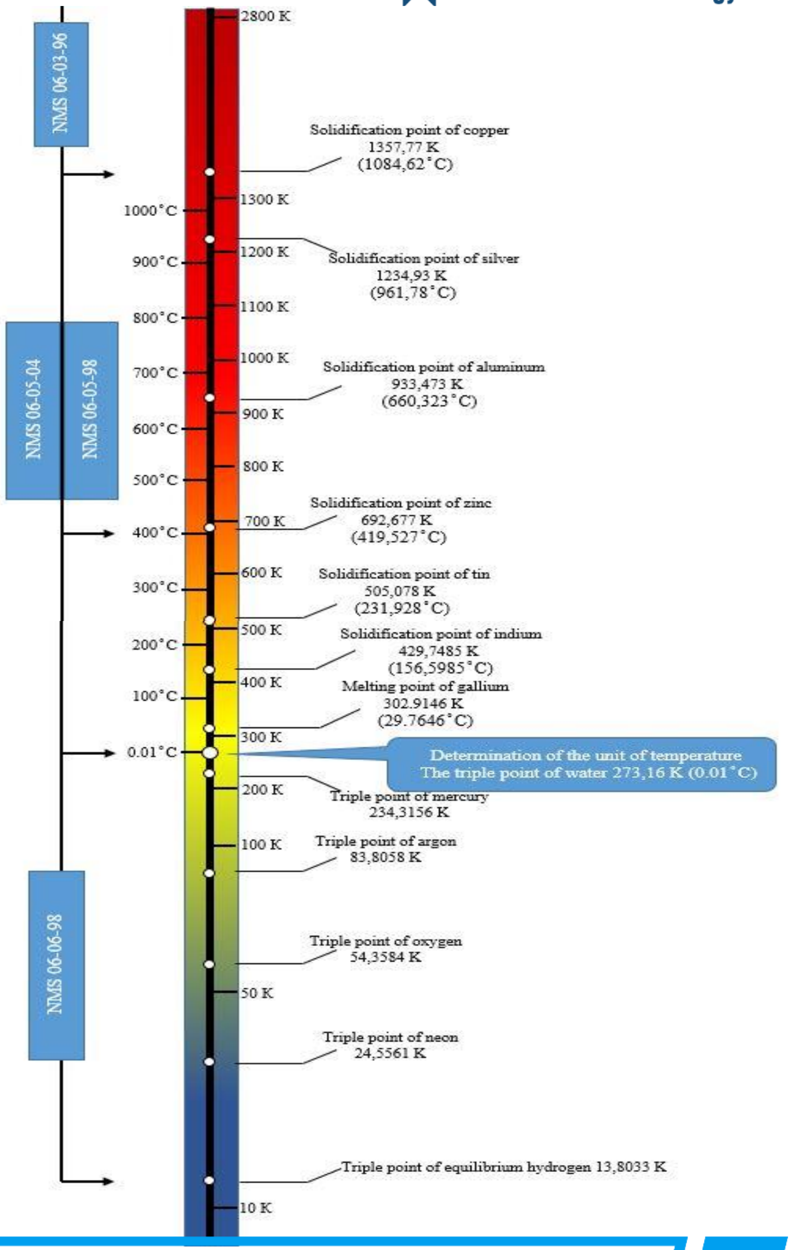
TODAY

NMS 06-03-96 National primary standard of the unit of temperature for radiation in the range from 1357.77 K to 2800 K

NMS 06-07-04 National primary standard of the unit for IR-radiation in the range from 962.67 K to 1234.93 K

NMS 06-05-98 National primary standard of the unit of temperature of Kelvin in the range from 273.16 K to 1357.77 K

NMS 06-06-98 National primary standard of the unit of temperature of Kelvin in the range from 13.8 K to 273.16 K



Contact thermometry

NMS 06-06-98 National primary standard of the unit of temperature of Kelvin in the range *from 13.8 K to 273.16 K*

⇩

NMS 06-05-98 National primary standard of the unit of temperature of Kelvin in the range *from 273.16 K to 1357.77 K*

expanded uncertainty (U)

from 2,3·10^{-4} К to 5,5·10^{-3} К

⇩

Radiation thermometry

NMS 06-07-04 National primary standard of the unit for IR-radiation in the range from
692.67 K to 1234.93 K
expanded uncertainty (U)
0.5 К (fixed point Zn blackbody)

NMS 06-03-96 National primary standard of the unit of temperature for radiation in the range from
1357.77 K to 2800 K
expanded uncertainty (U)
0.5 К (fixed point Cu blackbody)

Thermophysical measurements

NMS 06-02-96 National primary standard of the unit of specific heat of solids in the range *from 1800 K to 3000 K*

NMS 06-04-97 National primary standard of the unit of *combustion energy*

Our experience and capabilities in the field of thermometry

THE TOTAL NUMBER OF CMCs

INSTRUMENT OF ARTIFACT	CMC VALUE	CMC QUANTITY
Fixed point cell	0,01 - 419,527 °C	5
Long-stem standard platinum resistence therdmometers	0,01 - 660,323 °C	11
Industrial Platinum Resistance Thermometer,digital IPRT	0,01 - 660,323 °C	13
Thermocouple (type S and R)	29,7646 - 1084,62 °C	19
Thermocouple (type B)	660,323 - 1084,62 °C	
Thermocouple (type Pt/Pd)	231,928 - 1084,62 °C	
Thermocouple (type Au/Pt)	29,7646 - 660,323 °C	
Digital thermometer thermocouple	29,7646 - 419,527 °C	4
Liquid - in - glass thermometers	0,00 °C	4
Base metal type J	0,0 - 760,0 °C	1
Base metal type E, K, N	0,0 - 1100,0 °C	1
Variable temperature blackbody	0 - 419,527; 1085,0°C	5
Fixed-point blackbody	419,527; 1084,62°C	3
Radiation thermometer	0 - 419,527; 1085,0°C	5
Standard radiation thermometer	1085,0°C	1
Vacuum tungsten strip lamp	1084,62°C	1
	CMC amount	73

THANK YOU

For Your Attention

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