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THE WAYS TO REALISE NATIONAL MASS STANDARD OF SMALL COUNTRY IN 3RD MILLENIUM

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Abstract. The metrological requirements for the mass determination in regard to balances, weights and weighting are discussed, and achievable uncertainties in weightings in the laboratory and in actual practice given. The presentation describes a present situation in mass measurements in Lithuania and provides a technical specification for the establishment of Lithuanian state measurement standard of the mass unit.

Keywords: mass national standard.

1. INTRODUCTION

The necessity to establish Lithuanian national standard of mass unit is based on the need of the Lithuanian industry, development of the research and the intention to be recognized on the basis of the Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes [1]. The research on establishment of Lithuanian system of the national mass standard traceable to international mass unit realization infrastructure was based on systematization of the experiences and was hedged around with the limited resources from one side and with strict international recognition requirements from another. It was needed to establish the calibration measurement capability level suitable for national industry and science development and accepted by the multilateral agreement on the recognition of the national standards acceptance.

2. ORGANIZATION OF THE METROLOGY IN LITHUANIA

After the Lithuanian's independency have been restored the Lithuanian standardization and quality department was established, commissioned with the task to supervise metrology issues. On the 1 January 1998, Government of the republic of Lithuania has reorganized the Lithuanian Standard Board into three independent institutions: State Metrology Service (VMT), National Accreditation Bureau and Lithuanian Standards Board. VMT performs functions of the national metrology institute with the decentralized system. Since the in the proprietary aspect the national standards for various quantities belongs to the VMT the practical work of the establishment and maintenance is carried out by the three another institutions: Semiconductor Physics institute (VMT/PFI) – national standards for temperature, time and frequency, electrical voltage, resistance and current, Lithuanian Energy institute (VMT/LEI) – national standards for the gas, water and oil products flow and rate; Vilnius Metrology Center (VMT/VMC)- the national standards for gauge blocks, electrical capacitance, inductance and the complex of the national standards for the mass and related quantities.

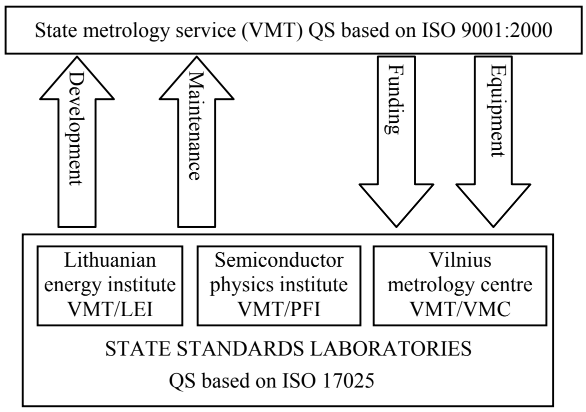


Fig. 1 Organization of Lithuanian national metrology institute

State Enterprise "Vilnius Metrology Center" (further called "Vilnius Metrology Center" or VMC) is juridical body, which constitutor is State Metrology Service (VMT). The modern history of VMC starts on 1991 12 02 when by the decision of Lithuanian Republic Government the self-supporting subdivisions of Lithuanian state standardization and metrology center were reorganized to Vilnius State Metrology Center. By the same decision Vilnius State Metrology Center was attributed to Lithuanian State Standardization Office (now – Lithuanian Standardization Board) regulation field. After the Lithuanian State and Municipality Enterprises law (1994 12 21 N^{o} I-722) have been adopted Vilnius State Metrology Center was reregistered into State Enterprise "Vilnius Metrology Center".The main document regulating VMC activities is State Enterprise's "Vilnius Metrology Center" laws, what are approved and changed by the constitutor.

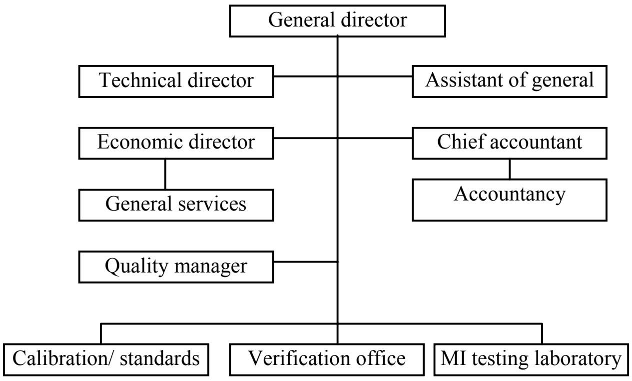


Fig. 2 Organisation structure of VMT/VMC

The national standards are maintained in the VMC calibration laboratory what is separate VMC subdivision and was established according to the order of General Director (Fig.2). VMC in its activity follows Lithuanian Republic constitution, Lithuanian Republic State and municipality enterprises and other laws, Government resolutions and VMC regulations. The state standards are created in the VMT/VMC calibration laboratory according to special documented procedure.

3. THE STRUCTURE OF THE LITHUANIAN NATIONAL MASS UNIT STANDARD

During the national program for the Metrological procurement the number of the mass measurements performed in the Lithuanian industrial and scientific areas in various ranges was determined. The mass measurements practically are performed in each company in the ranges varying from 10^{-7}kg to $1{,}5\times10^{5}$ kg with the related uncertainty from 10^{-8} to 0,05. Most frequently the measurements are performed in the range from 100 mg to 20 kg.

There is not the recognized national standard of mass in Lithuania yet. Practically the functions of the temporally national standards are performed by the reference standards of the Vilnius metrology center. This means that the traceability in the mass field depends on the capability of the concrete enterprise to maintain it. Today this is possible only thank to the PHARE fund or thank to support of another countries.

The calibration laboratory of the VMC is accredited by the Netherlands accreditation body RvA in mass measurement range from 1 mg to 10kg and can calibrate weights with uncertainty suitable for E_2 class weights. The quality system of the VMC calibration laboratory fulfils the requirements of the standard LST EN ISO/IEC 17025. VMC has E_1 class (according to OIML R 111) weights in the range from 1 *mg* to 1 *kg* and E_2 class weights in the range 1 kg to 10 kg. These weights have been calibrated in the Poland, Sweden, Denmark, and Germany. The current level of the Lithuanian calibration measurement capabilities comparing them to another countries in 1 kg range is about several times less and this impose obligation to continue investments and development until the level foreseen will be reached.

The importance of the high accuracy mass measurement to the industry of Lithuania can be seen from the fact that in the register of measurement instruments of Lithuania it is above than 170 types of weighting instruments, and total amount of the measurement instruments in the mass and related quantities is 408. This is second number after the number of the flow measurement instruments. VMC performs more that 15 000 weights calibration per year. The total amount of the measurement instruments of the mass and related quantities calibrated per year is above 68 600 and this is 56% of total measurement instruments calibrated at VMC per year.

The analysis shows that enterprises not having possibility to calibrate mass measurement instruments have to look for this possibility abroad, what is in most cases is to complicate and the traceability is not ensured properly. This is the reason for the necessity to establish calibration of the E_1 class weights.

After evaluation of the different possible structures of the existing mass unit realization schemes the several different models of mass unit realization can be determined. The choice of the concrete model depends on the industrial scientific potential of the country.

First model. Several Pt-Ir standards, active participation in CCM activities, research on new definition of kg unit, leading role in regional metrology organizations, key laboratories during interlaboratory comparisons. The best calibration capabilities declared in 1 kg level from 28 µg to 32 µg;

Second model. Pt-Ir standard as a top-level national standard, participation in regional metrology organizations, mass scale unit realization. Best calibration capabilities declared in 1 kg level 35 to 100 µg;

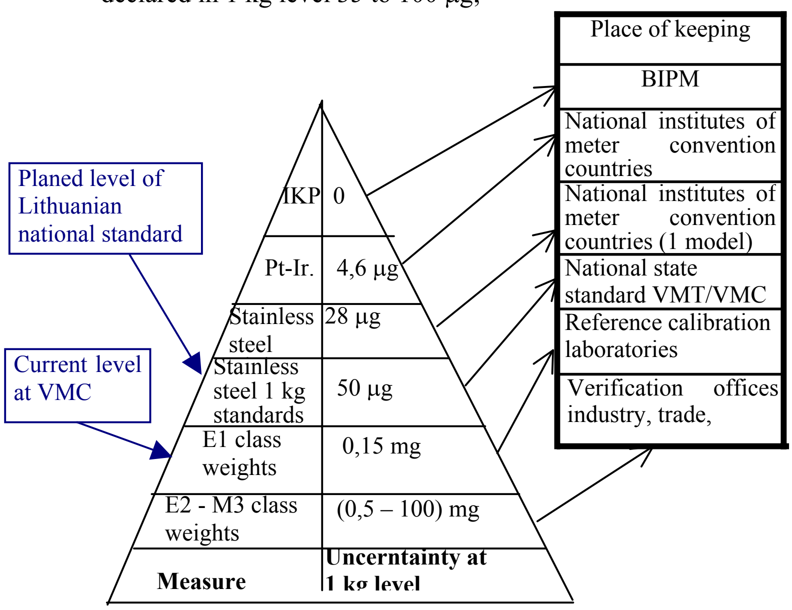


Fig. 3. Traceability of Lithuanian national mass standards to the international prototype of the kilogram The uncertainties mentioned corresponds to the 95 % probability level.

Third model. Stainless steel cylinder form standard 1 kg national standards, mass scale realization, participation in regional metrology organizations. The best calibration capabilities achieved from 70 to 150 µg;

Forth model. For the mass scale realization mass sets are used. All set is calibrated in another countries. Due to limited capabilities – restricted participation in regional metrology organization activities. Calibration capabilities achieved from 150 µg;

Analysis shows that not only equipment possessed define the calibration capabilities. It can be found situations when even with Pt-Ir international kilogram prototypes available due to lack of the maintenance and non-participation in intercomparisons the calibration capabilities are either from 150 µg to 0,5 mg, or not declared and not recognized at all. Another not follow able situation is when country is not a signatory of multilateral agreement on recognition of national standards and calibration certificates. In such cases the system is not recognized and not published even with active participation in regional metrology organization activities.

The decision taken is that Lithuania must establish the national mass standard consisting from the stainless steel non- magnetic weights of the 1 *kg* nominal mass. The national mass standards have to be cylindrical in form with diameter equal to the height. (*h*=*d*). In the case when as the national standard the Pt-Ir weights are considered the uncertainty due to the buoyancy in air is match higher as the repeatability of balances available and influence of all another uncertainty components. This case requires exceptionally accurate air density measurement what can be achieved only with very high investments. In the case when two stainless steel weights are compared the air density can be known with the accuracy of 0,1 %.

For the possibility to participate in the international intercomparisons the national mass standards laboratory must be equipped with the E_1 class weights in the range from 1 mg to 20 kg. The structure of the national mass standard laboratory must achieve the level of the international mass standard hierarchy scheme related to the national metrology institutes.

The structure of the Lithuanian national mass standards system and traceability charts hierarchy was proposed basing on the investigations on the mass unit realization systems in another countries, equipment available on the market, the needs of the Lithuanian industry and quality assessment system and economical calculations. The following structure of the national mass standard laboratory is proposed: Reference weights (Three cylindrical stainless steel 1 kg weights; The set of the reference weights (OIML shape) 1kg, 500g, 200g, 200gA, 100g, 50g, 20g, 20gA, 10g, 5g, 2g, 2gA, 1g, 1gA. etc. to 1 mg; the set of the cylindrical weights H500g, H500gA, H200g, H200gA, H100g, H100gA, H50g, H50gA); automatic mass comparators; Volume measurement comparator; the system for the registration of the environmental conditions; the special software. The mass unit maintenance scheme is in Fig. 4.

4.CALIBRATION AND MEASUREMENT CAPABILITIES OF LITHUANIAN NATIONAL MASS STANDARD LABORATORY

The participation in the international key comparisons is main condition to achieve of the international recognition of the mass measurements performed. The acceptable results of the participation in such intercomparisons can be achieved not only when the mass unit will be realized in whole range of the mass measurements but as well when the this realization will the constant in time and independent from the influencing factors.

Seeking for the highest accuracies in the mass measurements the substitution method shall be used. Using this method the reference and weight under calibration are substituted on the weighting pan and the mathematical model of the unknown mass is as follows:

$$m_T = m_R + \rho_a(V_T - V_R) + \Delta m'_W;$$

Here:

m_T – unknown mass;

m_R – reference mass;

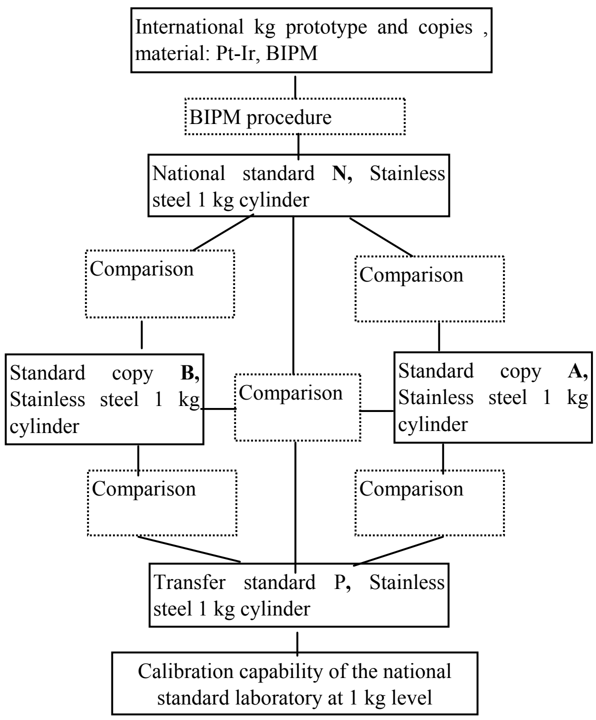
ρ_a – air density;

V_T – volume of calibrated standard;

V_R – volume of the reference standard;

$\Delta m'_W$ – difference measured.

The investigations seeking to establish most effective ways to reduce uncertainty components having most influence to the mathematical model of the mass measurement must be established and controlled. The three most influencing uncertainty components are – reference value uncertainty, air buoyancy correction and influence of the balance (weighting process). The required level of air buoyancy correction is achieved when the required levels for the accuracy of the air and weights density measurements



4 fig. Mass unit maintenance scheme.

are used. The influence of the weighting process is reduced by proper weighting scheme usage. The reference value uncertainty can be reduced using right traceability source ensuring necessary level of uncertainty. The second important point in the reference value uncertainty reduction is proper evaluation of the drift of the reference standard. Taking into account all mentioned influencing factors the mass unit value establishment can achieve 50 µg measurement capability (Table 1).

The proper consideration establishing the national mass standard laboratory should be designated to the to the investigation for the proper mass scale realization method and for achieving uncertainty levels required for mass scale. The mass scale realization matrix suitable for the automatic mass comparator should be used. The most commonly the mass scale equitation's are solved using least squares method with Lagrange multiplier.

After the investment will be completed and the equipment will be installed the last part of the validation process shall be processed including the experimental investigation seeking to found if the results of the mass measurements performed in Lithuania corresponds to the results achieved in the countries participating in the BIPM key comparisons, in such way making the basis for the entrance of Lithuanian measurement capabilities to the annex C of the agreement on Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes. By this theoretically and practically is shown that if the proposed structure of the Lithuanian national mass standard will be implemented the requirements of Lithuanian industry and quality assurance systems will be satisfied fully, and all mass measurements performed in the country will be traceable to international mass prototype through the unbreakable chain of mass comparisons.

Table 1. Calibration capability of VMT/VMC

Quantity X_i	Standard uncertaity $u(x_i)$		Distribu-tion	Influence	$u_i(y_i)^2$, mg^2
Δm_w	$u(\Delta m_w)$	0,002 mg	normal	1	0,000004
Refence value m_R	$u(m_R)$=	0,015 mg	normal	1	0,000225
Drift δm_R	$u(\delta m_R)$=	0,015 mg	square	1	0,000075
Air density ρa	$u(\rho_a)$=	0,005 mg/cm^3	normal	V_T-V_R =-1,57 cm^3	$6{,}2\cdot10^{-5}$
Volume of calibrated VT	$u(V_T)$=	0,005 cm^3	normal	ρ_a = 1,2 mg/cm^3	$3{,}5\cdot10^{-5}$
Volume of reference VR	$u(V_R)$=	0,005 cm^3	normal	ρ_a = 1,2 mg/cm^3	$3{,}5\cdot10^{-5}$
Resolution of balance		0,01 mg	square	0,707	$1{,}7\cdot10^{-5}$
Weight exchange mechanism influence		0,01 mg	square	1	3,3·10-5
				$u(m_T)$=	0,025
				k=	2
				U=	0,050 mg

CONCLUSIONS

1. The model for the realization of the mass unit was created and evaluated. It was determined that the national mass standard have to be calibrated with the 30 µg uncertainty.
2. It was determined that the stainless steel national mass standards can ensure calibration measurement capability 50 µg in the range of 1 kg what fulfils all Lithuanian industry demands and creates possibilities to successfully participate in the international comparisons organized by the International Bureau for the Weights and Measures BIPM and the regional metrology organizations.

REFERENCES

[1] "Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes. Paris, 14 October 1999." www.bipm.org.

[2] Kochsiek M., Glaser M. Comprehensive mass metrology. – Berlin: Wiley-VCH Verlag, 2000. 562 S.

[3] Смирнова Н. А. и др. Сличения эталонов-копий с государственным первичным эталоном единицы массы // Труды ВНИИМ. Ленинград: Энергия, 1978. Выпуск 224(284). c. 3-8.

[4] Ueki M., Nezu Y. and Ooiwa A. New facility for weight calibration service at NRLM. // Proceedings of the 14th IMEKO World Congress (Tampere, Finland). - Helsinki: Finnish Automation Support, 1997. Topic 3..

[5] Havard D.C., Lewis S. L. Initial stages in disseminating the UK Mass Scale: From the National Prototype Kilogram to the Stainless Steel Reference Kilograms. NPL Report MOM98. – Teddington: NPL, 1995. 54 p.

[6] Zarządsenia Nr 43 Prezesa Głównego Urzędu miar z dnia 18 października 1999r. W sprawie ustanowienia państwowego wzorca jednostki miary masy // Dziernik urzędowy miiar I probiernictwa. Warszawa: GUM, 1999. Nr. 6.

[7] Lietuvos metrologinio aprūpinimo problemų analizė. Nacionalinės metrologinio aprūpinimo programos ataskaita – Kaunas: Technologija, 1997. P. 134.

[8] V. Dalidėnas, R. P. Žilinskas. Valstybinių etalonų įrengimo Lietuvoje problemos ir strategija. // Matavimai. Kaunas: Technologija, 1997. Nr. 2(5). P. 21-25.

[9] Gläser M. Cycles of comparison measurements, uncertainties and efficiencies. // Meas. Sci. Technol. Bristol: Institute of Physics Publishing, 2000. Vol. 11 N. 1. P. 20-24.

[10] Prowse D.B. and Anderson A.R. Calibration of a Set of Masses in Terms of One Mass standards. // Metrologia. Sevres: BIPM, 1974. Vol. 10. N.2. P. 123-128.

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