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DEVELOPMENT OF THE NATIONAL LABORATORY FOR PRESSURE IN MONTENEGRO

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Abstract:
This paper focuses on the process of establishing the Laboratory for Pressure at the Montenegrin Bureau of Metrology (MBM), the National Metrology Institute of Montenegro, which disseminates the unit of pressure in the field of calibration and conformity assessment in a small, centralized metrology system. Establishment of a traceability chain, development and the continual improvement of measurement methods, participation in interlaboratory comparisons and PT schemes, accreditation according to ISO/IEC 17025, registration of calibration and measurement capabilities (CMC) in BIPM KCDB for pressure, are stages in the development of the Laboratory for Pressure and also in proving its competencies at the international level.

Keywords: national standard for pressure; traceability; interlaboratory comparisons

1. INTRODUCTION

The MBM is responsible for the field of scientific, legal and industrial metrology in Montenegro, as well as for the control of precious metals. Since its establishment in 2006, the MBM has been focused on a centralized way of organizing metrological activities, in which state standards are concentrated in national calibration laboratories that provide traceability for the needs of: calibration of standards used in legal metrology, measurements in the trading of goods and services, industry, health, consumer protection, etc. Dissemination of metrological traceability from the SI to stakeholders in Montenegro is performed through nine national calibration laboratories, which were accredited step by step during the period 2013–2019 according to the standard ISO/IEC 17025. Up until now, the MBM has published 32 CMCs in BIPM KCDB in the field of measurement: temperature, volume, length, pressure, frequency and relative humidity. The Laboratory for Pressure published two CMCs in 2021. All the declared CMC values of the MBM laboratories are at the same time covered by the scope of the accreditation. Also, all the MBM laboratories have implemented a Quality Management System which has been successfully validated through peer review evaluation by a EURAMET quality expert [1].

The Laboratory for Pressure provides reliability and traceability of measuring and calibration results for customers of lower hierarchical levels in Montenegro to the International System of Units (SI).

Activities performed at the Laboratory for Pressure are related to:

- The realization, conservation, maintenance and improvement of the national standard for pressure in Montenegro;
- Ensuring metrological traceability in the field of pressure in Montenegro through the transfer of the unit of pressure from the national standard to secondary and working pressure standards;
- Development of measuring methods for transferring the unit of pressure;
- Calibration of pressure-measuring instruments:
  - Electromechanical manometers in the range from −95 kPa to 120 MPa;
  - Electromechanical absolute pressure-measuring instruments in the range from 10 kPa to 200 kPa;
- Interlaboratory comparisons;
- Type approval examination for pressure measuring instruments;
- Verification of pressure-measuring instruments in the area of legal metrology.

2. IMPORTANCE OF PRESSURE MEASUREMENT

Pressure measurement is an integral part of daily activities in numerous areas of work and life.

In meteorology, measuring atmospheric pressure is the basis for weather forecasting. In medicine, measuring blood and eye pressure are an integral

part of procedures for determining the health status of individual organs, as well as the overall condition of the organism [2].

Underestimation by 5 mmHg of systolic blood pressure without therapy in 25% of cases contributes to an increase in the current rate of fatal strokes and fatal myocardial infarction [3].

On the other hand, overestimating true blood pressure by 5 mmHg would lead to the introduction of inappropriate hypertensive drug therapy for almost 10% of the population, with exposure to drug side effects, the psychological effects of misdiagnosis, and unnecessary cost [3].

Driving with incorrect tire pressure can affect vehicle behavior and seriously endanger the safety of drivers and passengers, and even cause accidents in which lives may be endangered.

In industry, it is mandatory to measure pressure in the management of technological processes, as well as the preservation of the environment and general safety.

The accuracy of pressure measurements, in addition to the above, is important for many other activities where the failure of a pressure gauge leads to an increase in material costs, environmental incidents and various types of accidents. In practice, pressure measurement is performed in a very wide range, which is the reason for the development of numerous measuring methods, as well as the existence of different types of measuring devices.

There are two basic categories of pressure measurement which are covered in the MBM: absolute pressure measurement including measurement of atmospheric (barometric) pressure, and gauge pressure measurement (negative and positive).

3. NATIONAL NEED AND CAPACITY DEVELOPMENT IN PRESSURE

The development of the Laboratory for Pressure began in 2007 on the basis of the equipment of the former military laboratory which existed within the Technical Experimental Center of the Yugoslav Army at the "Sava Kovacevic" Technical Repair Institute in Tivat.

Following the halting of the work of the Technical Repair Institute, the Government of Montenegro reallocated equipment from the metrology laboratories to the MBM. With the relocation of equipment to Podgorica and the employment of new staff, activities that represent the essence of the work of the metrology laboratory began [4].

Traceability of standards and equipment was achieved in 2008 by calibrating standards in the MIRS/IMT/LMT – Laboratory of Pressure Metrology, DI in Slovenia.

In order to overcome problems of the competencies of metrologists, staff training was conducted at the National Pressure Calibration Laboratory of Croatia in 2009.

The priority activities in the MBM were the development of services in legal and industrial pressure metrology, while scientific metrology at that moment was not focused on. The main metrological equipment for assuring traceability owned by the laboratory during that period is shown in Table 1.

Table 1: Pressure standards that were in use from 2008 to 2010

Models of devices	**Measurand range**
Pneumatic-Hydraulic Deadweight Tester, USSR, MVP-2.5	–86.66 kPa to –6.67 kPa
	4.9 kPa to 245 kPa
Hydraulic Deadweight Tester, USSR, MP-6	50 kPa to 600 kPa
Hydraulic Deadweight Tester, Poland, MTU-60	0.245 MPa to 5.88 MPa
Hydraulic Deadweight Tester, USSR, MP-600	2.45 MPa to 58.8 MPa

The existing, passed-down equipment was very modest, outdated and of inadequate metrological quality for the national standard, and the requirements of the users on a continuous basis. Montenegro needed a laboratory that would simultaneously perform calibration and verification for Montenegrin stakeholders and meet the requirements arising from international metrological organizations. The MBM immediately began the process of procuring new standards that would meet the needs at the national level.

Support came from the European Union, through the Pre-accession Assistance program "Development of Quality Infrastructure in Montenegro" (IPA 2007) where, in addition to equipment, the MBM received technical assistance, as well as the opportunity to participate in the first interlaboratory comparisons and projects within the European Association of National Metrology Institutes (EURAMET).

The Laboratory for Pressure officially opened on 20 May 2011 as part of the celebration of World Metrology Day in Montenegro. Intensive development led to the MBM becoming a full member of EURAMET in 2011. Also, the laboratory is continuing to make progress and is improving the skills of its staff through the Pre-accession Assistance program "Development of Quality Infrastructure and Metrology in Montenegro" (IPA 2011).

The new equipment (shown in Table 2) and its application in everyday work have enabled the Laboratory for Pressure to develop a wide network of service users in the field of pressure (calibration, verification and type approval for pressure-measuring instruments).

Table 2: Pressure standards of Montenegro

Models of devices	**Measurand range**
Pneumatic Deadweight Tester, DH Budenberg, 554 A	20 kPa to 4 MPa
Hydraulic Deadweight Tester, DH Budenberg, 580 HXA	0.1 MPa to 120 MPa
Electromechanical manometer, Druck PACE1000	−95 kPa to 100 kPa
Barometer, Druck PACE1000	750 hPa to 1150 hPa

In order to better cover the area of absolute pressure up to 200 kPa, negative gauge pressure and positive gauge pressure up to 100 kPa, in 2013 the MBM procured a PACE1000 Precision Pressure Indicator (PPI).

Currently, the national standards are the Pneumatic Deadweight Tester, the Hydraulic Deadweight Tester, as well as the PACE1000 PPI that has one sensor for small negative and positive gauge pressure in the range from −95 kPa to 100 kPa and another sensor for the barometric pressure range from 750 hPa to 1150 hPa. The gauge mode pressure with the addition of barometric pressure is used for absolute pressure calibrations.

The development of awareness of the importance of the calibration of measuring instruments has contributed to an increase in the number of stakeholders and requests for calibrations at the Laboratory for Pressure.

The number of calibrations performed in the Laboratory for Pressure during period 2008–2021 is shown in Figure 1.

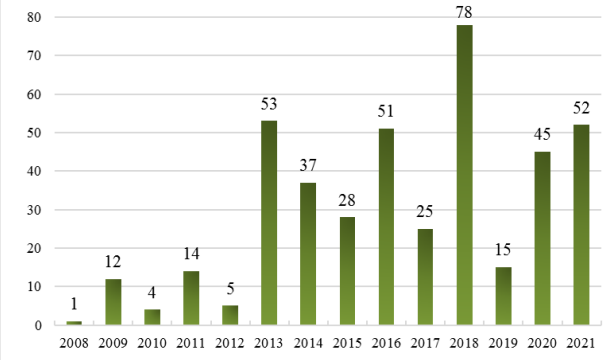

Figure 1: Number of calibrations performed in the Laboratory for Pressure from 2008 to 2021

Also, there was a significant increase in the number of manometers verified in the Laboratory for Pressure in the period 2008–2021, which is the result of changes in legislation (Figure 2).

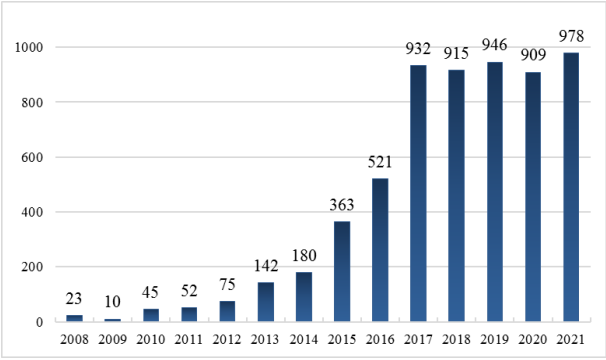

Figure 2: Number of manometers verified in the Laboratory for Pressure from 2008 to 2021

Another important activity of the Laboratory for Pressure is to check compliance with the prescribed technical and metrological requirements in order to issue a Type Approval Certificate of manometers for measuring pressure in pneumatics and blood pressure manometers. In this regard, the Laboratory for Pressure, supported by the National Laboratory for Temperature of the MBM, conducted for the first time a procedure of verification and type approval examination for blood pressure manometers for a public health institution.

4. QUALITY MANAGEMENT & ACCREDITATION BY ISO/IEC 17025

Implementation of a Quality Management System based on the ISO/IEC 17025 standard is a requirement of the CIPM Mutual Recognition Agreement (CIPM MRA), which the MBM signed in 2011. The international obligations of NMIs arising from the CIPM MRA require continuous participation in interlaboratory comparisons and competency assessments, which is under review of EURAMET.

The Laboratory for Pressure met this requirement in November 2015 when a certificate of conformity of the Quality Management System with the standard requirements of ISO/IEC 17025 was received from the Accreditation Body of Montenegro (ATCG) and the Croatian Accreditation Agency (HAA), a signatory of the EA MLA agreement.

The Laboratory for Pressure has documented measuring methods through four technical procedures: QMP 7.2/01-LP: Technical procedure for calibration of manometers with the Pneumatic Deadweight Tester, QMP 7.2/02-LP: Technical procedure for calibration of manometers with the Hydraulic Deadweight Tester, QMP 7.2/03-LP:

Technical procedure for calibration of manometers using the PACE1000 PPI (Precision Pressure Indicator), and QMP 7.2/04-LP: Technical procedure for calibration of manometers on pressure calibrators.

The traceability of the effective area of the Deadweight Testers and the PACE1000 PPI is currently confirmed through the Calibration Certificates of MIRS/IMT/LMT – Slovenia.

The traceability scheme for the Laboratory for Pressure is shown in Figure 3.

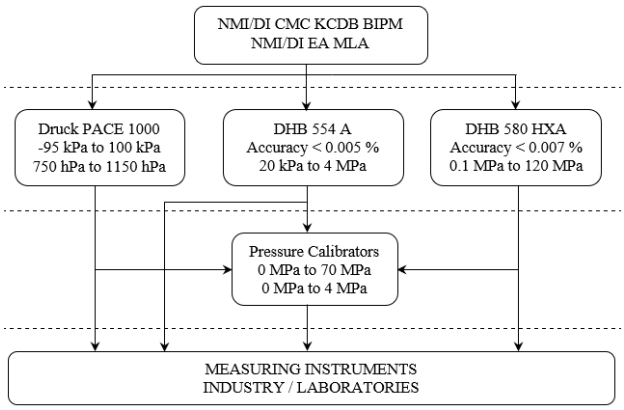

Figure 3: Traceability scheme for the Laboratory for Pressure

Since 2015, the Laboratory for Pressure has successfully passed the regular control visits of technical and lead assessors of the ATCG and HAA, and current scope of accreditation of the Laboratory for Pressure is shown in Table 3.

Table 3: Scope of accreditation of the Laboratory for Pressure

Measurand/ Calibration item	**Measurand range**	**Expanded uncertainty**
Gauge pressure/ Electromechanical manometers working medium: gas	−95 kPa to 100 kPa	$1{\cdot}10^{-4}\ {\cdot}p$ + 10 Pa
	100 kPa to 4 MPa	$1{\cdot}10^{-4}\ {\cdot}p$, but not < 25 Pa
Gauge pressure/ Electromechanical manometers working medium: oil	100 kPa to 6 MPa	$8{\cdot}10^{-5}\ {\cdot}p$, but not < 100 Pa
	6 MPa to 120 MPa	$1{\cdot}10^{-4}\ {\cdot}p$, but not < 500 Pa
Absolute pressure/ Electromechanical manometers	100 hPa to 750 hPa	$1{\cdot}10^{-4}\ {\cdot}p$ + 15 Pa
	750 hPa to 1150 hPa	15 Pa
	1150 hPa to 2000 hPa	$1{\cdot}10^{-4}\ {\cdot}p$ + 15 Pa

5. INTERNATIONAL RECOGNITION OF COMPETENCIES

From the very beginning, the Laboratory for Pressure has focused on the interests of Montenegrin users, because its main goal is to create a metrological system that supports business processes and provides confidence in the measurement result, which is important for both domestic users and their foreign partners [4].

In order to prove its calibration and measurement capabilities, the Laboratory for Pressure participated in the EURAMET.M.P-S13 interlaboratory comparison [5] in hydraulic media from 10 MPa to 100 MPa in gauge mode. Some of the results of this comparison (10 MPa and 100 MPa increasing pressure) are shown in Figure 4 and Figure 5, respectively.

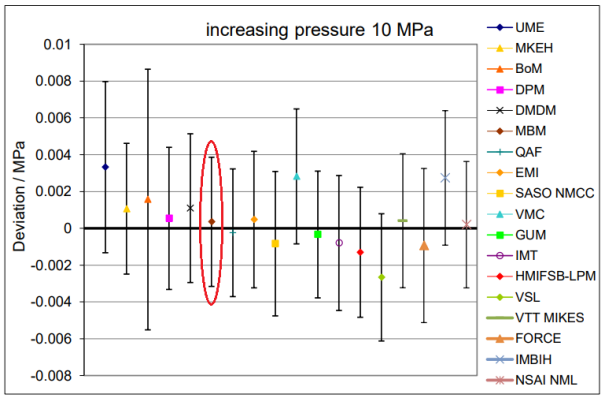

Figure 4: Deviations from the reference value with uncertainties at 10 MPa in the EURAMET.M.P-S13 interlaboratory comparison [5]

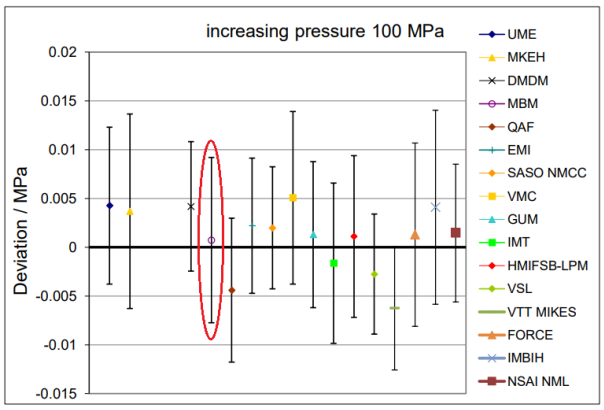

Figure 5: Deviations from the reference value with uncertainties at 100 MPa in the EURAMET.M.P-S13 interlaboratory comparison [5]

Gravity is very important in the accurate determination of pressure on Deadweight Testers. Using interpolation formulas to determine g has been shown to not be accurate enough.

Since the values obtained from multiple sources differed significantly, the Laboratory for Pressure got interested in Bundesamt für Eich-und

Vermessungswesen's (BEV) project for determining *g*.

In December 2015, BEV published the report "Absolute Gravity Measurements Albania–Kosovo–Montenegro 2015" [6], which states the value for *g* as 9.80279147 m/s^2 on the floor of the Laboratory for Pressure in Podgorica.

The benefit of participating in the EURAMET.M.P-S13 interlaboratory comparison, in addition to determining the value of *g*, is the publication of the CMCs of the Laboratory for Pressure in the BIPM KCDB, that are shown in Table 4.

Table 4: CMCs of the MBM Laboratory for Pressure in the BIPM KCDB

Quantity	Method of Measurement	Measurand	Uncertainty Equation
Gauge pressure	Oil medium	0.3 MPa to 6 MPa	$7 \cdot 10^{-5} \cdot p$ + 50 Pa
Gauge pressure	Oil medium	6 MPa to 120 MPa	$1 \cdot 10^{-4} \cdot p$ + 500 Pa

Recently the laboratory started two bilateral EURAMET comparisons [7] between the national standards for pressure of Slovenia and Montenegro:

- EURAMET Project 1549 is in gas media (absolute mode) from 10 kPa to 200 kPa;
- EURAMET Project 1550 is in gas media (gauge mode) from 0.1 MPa to 3.5 MPa.

The goal is to determine the degree of equivalence between the two countries and to support Montenegro's new applications for CMCs in the BIPM KCDB.

6. SUMMARY

In general, the quality of production, control processes, protection of public health and the environment, as well as general safety, depend on the reliability of measurement results [4]. In the metrological system of Montenegro, the capacities of the Laboratory for Pressure are projected primarily to fulfill the needs of legal and industrial metrology.

The Laboratory for Pressure delivers services to a wide range of customers, such as laboratories, in order to meet the requirements of the standards for which they are accredited, customers using legal measuring instruments for which verification is mandatory according to the Law on Metrology, healthcare institutions, customers using pressure-measuring instruments in traffic safety and industries whose internal quality system regulations require pressure measurement.

Acting in the spirit of the Montenegrin Bureau of Metrology's Mission, which emphasizes the achievement of high-quality services, right from the beginning the Laboratory for Pressure has been improving its methods and procedures, analyzing what has been done and trying to improve its work process through systematic and gradual improvement at every step.

Although traceability in the field of pressure measurement in Montenegro is generally established and competencies achieved at the highest level, the constant improvement of metrological abilities through interlaboratory comparisons is required. Also, in order to improve the economic potential of Montenegro, it is necessary to exchange knowledge with scientific institutions and the academic community in the country as well as to connect with the metrological systems in the region.

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