Experience with a new 1 GPa standard of the CMI

Zdeněk Krajíček*, Dominik Pražák, Richard Páviš, Martin Vičar, Václav Sedlák, Jiří Tesař

Czech Metrology Institute, Brno, Czech Republic, *zkrajicek@cmi.cz

Abstract: The expansion of the high-technology leads to the increasing demands for the calibration services in the extremal pressure ranges, both vacuum and high gauge pressure in liquid medium. The presentation will deal with the second one, focusing on the solution chosen by the Czech Metrology Institute (CMI) to improve its services in the range of gauge pressure from 0.5 GPa to 1 GPa. A new high-pressure standard will be described and its first evaluation outlined.

Introduction

The pressure range above 0.5 GPa is ensured by only 8 NMIs within the framework of the Key Comparison DataBase (KCDB) of the BIPM. Also, when searching the KCDB, we can find only 3 completed comparisons in a range above this limit while another has not been finished yet. The development of the primary metrology of the very high pressures has recently been revived in Europe which led to a novel inter-laboratory comparison in 1 GPa range (EURAMET.M.P-S14).

Original situation at CMI

CMI utilizes the Czech national standard of gauge pressure in oil medium up to 0.5 GPa which is based on a state-of-the-art pressure balance. However, CMI has had to rely on a very outdated pressure multiplier system Amsler from 0.5 GPa to 1 GPa, with an unsatisfactory uncertainty 0.2 % of measured value (for k = 2). It was also the reason for the participation of the CMI in EURAMET.M.P-S14 had to be limited only up to 0.5 GPa. Such a situation had to be solved.

A new high-pressure standard

We chose a novel instrument on the market – type BH5-10000B by French company Aréméca. It has a tungsten-carbide piston-cylinder of a simple free deformation design which represents a breakthrough, because until recently only the re-entrant and the controlled-clearance piston-cylinders have been utilised for the range above 0.5 GPa.

The new high-pressure standard

The piston-cylinder has a tiny nominal effective area equal 0.5 mm^2. A diameter of the piston equals cca 0.8 mm, an outer diameter of the cylinder cca 17.8 mm and a height of the cylinder cca 39.6 mm.

The piston with a carrier mounted on it (right) and the cylinder (left)

A nominal working range of the instrument is from 0.02 GPa to 1 GPa. The manufacturer states that it can be operated up to 1.09 GPa and remains safe up to 1.5 GPa. The manufacturer stated effective area A_0 = 5.03002 10^{-7} m^2 (for 20 °C) and λ = 9.4 10^{-7} MPa^{-1}. The reported accuracy class for the nominal range equals 25 kPa + 0.05 % of measured value. The instrument is operated using di(2)-ethyl-hexyl-sebacate oil. The weight of the piston with its carrier is cca 1 kg, the remaining set of 15 mass pieces has a total weight 50.5 kg.

Traceability and uncertainty

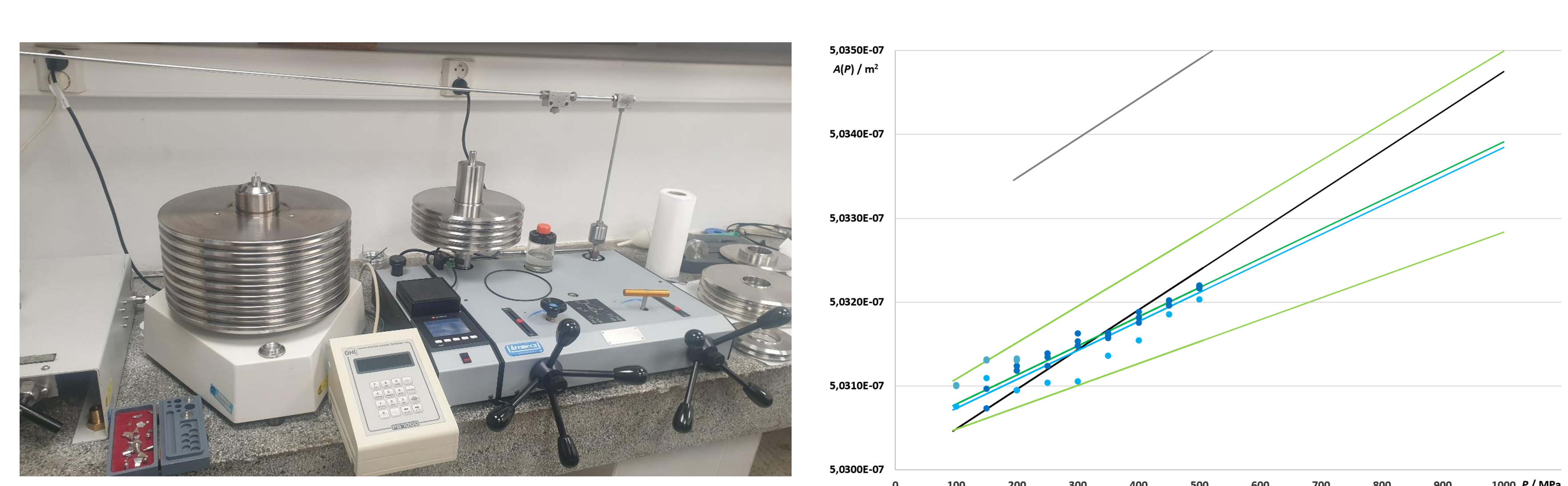
The new instrument was calibrated by the mentioned above Czech national standard. Firstly, piston-cylinder no. 1637 was used for the range 150 MPa to 500 MPa, with 50 MPa step, in two increasing series and one decreasing, dark blue dots. Secondly, piston-cylinder no. 109 was used for the range 100 MPa to 500 MPa, with 50 MPa step, in one increasing series, light blue dots. Finally, piston-cylinder no. 119 was used for the range 100 MPa to 200 MPa, with 50 MPa step, in two increasing series, teal dots. During these measurements we also monitored free rotation time and piston fall rate which were satisfactory.

We used the results of the measurements with the 500 MPa piston-cylinders for a linear regression procedure (blue line) which resulted in a value of the effective area A_0 = (5.03039 ± 0.00014)·10^{-7} m^2 and the pressure deformation coefficient λ = (6.9 ± 0.4)·10^{-7} MPa^{-1} (for 20 °C, only type-A uncertainty). Then we used this pressure deformation correction for all the measured points. From the resulting set of the zero-pressure effective areas we obtained the average A_0 = (5.03044 ± 0.00006)·10^{-7} m^2 (only type-A uncertainty).

We increased the uncertainty of A_0 by the uncertainty the national standard of gauge pressure in oil at 100 MPa (42 ppm) and put uncertainty of l to be 25 % for safe. This lead to the final values of A_0 = (5.03044 ± 0.00021)·10^{-7} m^2 and λ = (6.9 ± 1.7)·10^{-7} MPa^{-1} (for 20 °C, for k = 2). Our determination of A_0 and λ differs from the those of the manufacturer by more than our uncertainty. However, if we depict in a pressure dependence of our effective area (dark green line) together with its uncertainty limits (light green line), then, in the range from 0.1 to 1 GPa, the dependence of the manufacturer (black line) is totally in those limits and everything lies deeply in the conservative specification of the manufacturer (grey line).

We also used Lame's equation to determine λ. We used the effective area value to get piston radius and cylinder inner radius and a calliper measurement for cylinder outer radius. The tungsten-carbide mechanical properties were taken from a web database. Thus, we got λ = (6.6 ± 0.7)·10^{-7} MPa^{-1} (for k = 2). Although the method is rather coarse, it lead to a very good agreement with the experimental value.

Our first estimation of the best measurement capability of the new instrument is 0.025 % of measured value (from 0.15 GPa to 1 GPa, for k = 2) which would be a considerable improvement.



Traceability, uncertainty and manufacturer's specification

Conclusion and future plans

A novel instrument was made traceable to the Czech national standard and evaluated. The first results and experience are very promising. The new piston pressure gauge has been working at ČMI for more than a year without any problems. It is easily portable and working with this pressure gauge is very simple. However, a correctness of the described above traceability of our new standard must be still confirmed by an international comparison which is a task for the nearest future. We are looking for partners for international comparison.

Acknowledgements

The authors would like to thank to M. Chytil (SMU) for his collaboration and help.

IMEKO TC3|TC5|TC16|TC22 International Conference 2022
Dubrovnik, Croatia, 11th to 13th October, 2022