Comparison of primary pressure standards of METAS and CMI in the range 50 - 600 kPa

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Abstract
We present the results of a supplementary comparison between the pressure laboratories from CMI and METAS in gauge pressure from 50 kPa up to 600 kPa. The transfer standard is a piston-cylinder of 10 cm^2 area. The results show the equivalence of the pressure realised by the two laboratories.

1. Introduction

The pressure laboratory of Metas (Switzerland) has made a strong effort in order to become a primary laboratory. This implied numerous changes in the laboratory like new equipment, new method of work and the characterisation of all the piston-cylinders of the laboratory.
The pressure laboratory of the CMI in Brno (Czech Republic) has a good tradition of internal traceability and already took part to some international comparisons.
This comparison allowed the participants to assess their methods of measurement as well as their calculation of the effective area of the piston-cylinder units.

2. Aim of the comparison

The goal of the comparison is the measurement of the effective area of a transfer standard from 50 kPa up to 600 kPa in gauge pressure. All the piston-cylinder units used in this comparison have been fully characterised dimensionally and are primary standards.

3. Primary standard of the Metas

The primary standard of Metas used in this comparison is a pressure balance 5111 from Degranges & Huot equipped with the piston cylinder Nr 7393. The piston cylinder is made of tungsten carbide with an area of about 10 cm^2. The piston cylinder has been characterised by the length laboratory of Metas for diameter at different height as well as circularity and verticality.

4. Primary standard of the CMI

The primary pressure standard of the CMI is a pressure balance DHI 7601 equipped with the piston cylinder 368. The piston is made of ceramic and the cylinder is made of tungsten carbide with an effective area of about 10 cm^2. The piston cylinder has been characterised by the length laboratory of the CMI.

5. Transfer standard.

The transfer standard is a piston cylinder made of tungsten carbide of 35 mm diameter that is made for the DHI 7601 pressure balance. The transfer standard had been characterised by DHI beforehand as well as by the length laboratory of Metas. The transfer standard belongs to Metas and is normally used for calibrations performed at Metas. The transfer standard has been chosen because each participating laboratory had a base adapted to it.

6. Measurements by the length laboratory of Metas

The diameter of the piston has been measured at four different heights at orthogonal angles. The difference between the largest and the smallest diameter is 0.08 µm while the uncertainty of the measurement is 0.10 µm (k = 2). The difference from circularity of the piston has been characterised at 10 different heights and is always smaller than 0.08 µm.

The diameter of the cylinder has been measured at eight different heights at orthogonal angles. The measurements have shown that the diameters at both ends of the cylinder are larger than in its middle height. The difference can be as high as 1.0 µm , however it is possible to find a central part, 20 mm long, where the diameters measured have their values within 0.10 µm. It is the part that has been used for the effective area calculation. The difference from circularity is also better than 0.10 µm for the eight different locations. The verticality measurement clearly shows the increase of the diameter at the two ends of the cylinder.
On the basis of the dimensional measurements, an effective area at null pressure of 9.805525 cm^2 at 20 °C has been calculated. The deformation coefficient factor has been determined using the formula of Legras [1] and is $4.20 \cdot 10^{-12}\ Pa^{-1}$.

7. Measurements by the pressure laboratory of Metas.

Measurement by cross-floating with the D&H 5111 have been conducted in May 2004 before shipping the piston-cylinder to CMI as well as in July 2004 once it came back. The two series of measurements did not show any significant change in the effective area of the piston-cylinder. The effective area measured by cross-floating is roughly 7 ppm smaller than the value determined by length measurement. The deformation coefficient is $7.1 \cdot 10^{-12}\ Pa^{-1}$ with an uncertainty of $4.0 \cdot 10^{-12}\ Pa^{-1}$.

8. Measurements by the pressure laboratory of the CMI.

Measurements at the CMI have been made in June 2004. The results of CMI are higher by 9 ppm to the dimensional measurement at low pressure but this difference decreases when the pressure is increased. The unusual behaviour of the effective area determined by the CMI seems to be due to a deformation of the reference piston-cylinder with the applied pressure.

9. References

[1] J.-C. Legras, “La mesure des pressions statiques“, Editions Chiron, Monographies du BNM, 1986

	Metas	CMI	Transfer
Serial Number	7393	368	608
Producer	Desgranges - Huot	DHI	DHI
Measurement range	20 kPa - 1 MPa	5 kPa - 350 kPa	8 kPa - 1 MPa
Material of piston	tungsten carbide	ceramic	tungsten carbide
Material of cylinder	tungsten carbide	tungsten carbide	tungsten carbide
A_0, effective area at 20 °C without pressure (m^2)	$9.804805 \cdot 10^{-4}$	$9.805079 \cdot 10^{-4}$	$9.805525 \cdot 10^{-4}$
Relative uncertainty of A_0 (k = 1)	$4.50 \cdot 10^{-6}$	$4.00 \cdot 10^{-6}$	$4.50 \cdot 10^{-6}$
Pressure distortion coefficient (Pa^{-1})	$3.70 \cdot 10^{-12}$	$5.50 \cdot 10^{-12}$	$4.20 \cdot 10^{-12}$
Uncertainty of the distortion coefficient (k = 1) (Pa^{-1})	$5.00 \cdot 10^{-13}$	$1.00 \cdot 10^{-13}$	$5.00 \cdot 10^{-13}$
Linear expansion coefficient of piston ($°C^{-1}$)	$4.50 \cdot 10^{-6}$	$5.50 \cdot 10^{-6}$	$4.50 \cdot 10^{-6}$
Linear expansion coeff. of cylinder ($°C^{-1}$)	$4.50 \cdot 10^{-6}$	$4.50 \cdot 10^{-6}$	$4.50 \cdot 10^{-6}$

Table 1: Characteristics of the piston-cylinders used in this comparison. The areas have been determined by dimensional measurements.

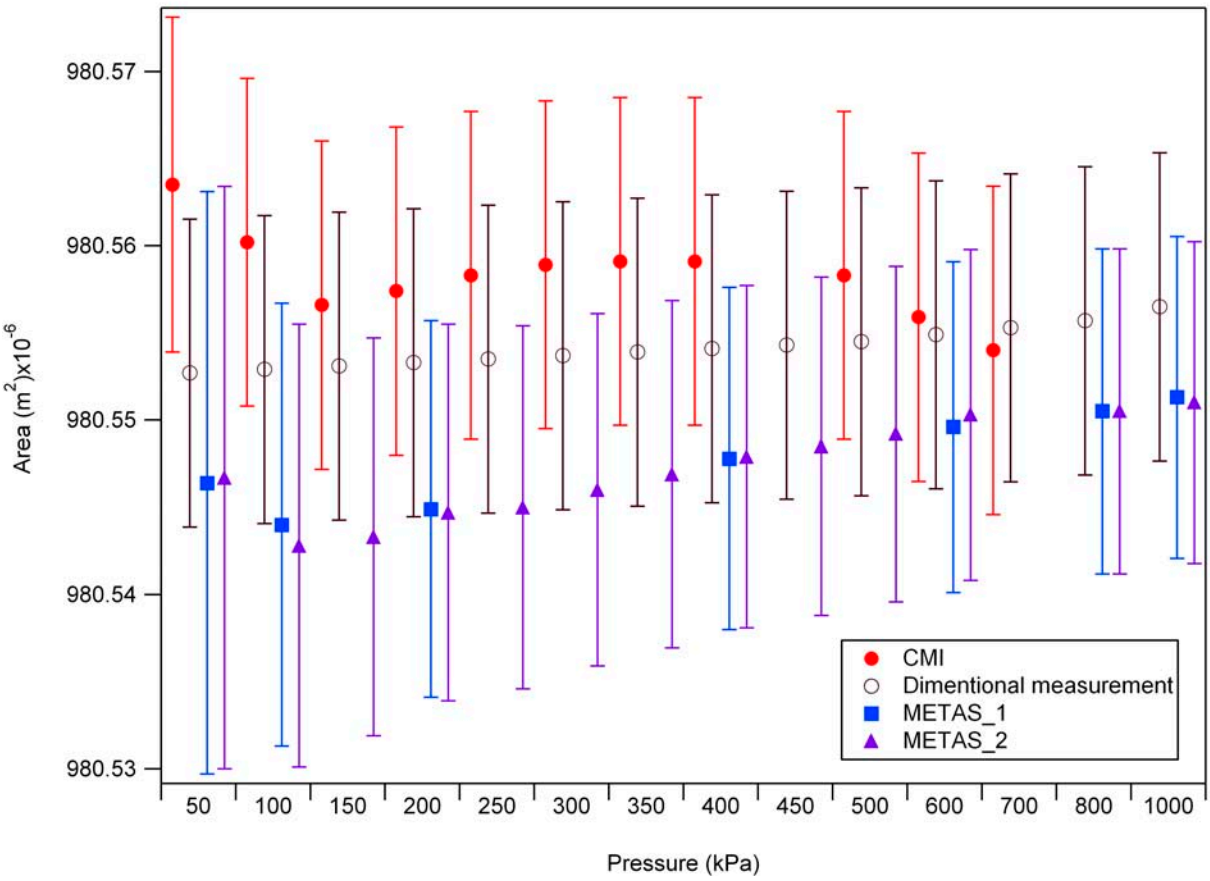

Figure 1: Effective area of the transfer standard determined by flotation by CMI and METAS and by dimensional measurement by the length laboratory from METAS. The bars indicate the expanded uncertainty (k = 2).

Appendix 1

Values of the effective area of the transfer standard determined by flotation by CMI and by METAS.

	Metas		CMI			
Nominal pressure	Area(20 °C)	U(k = 2)	Area(20 °C)	U(k = 2)	Difference	En factor
(kPa)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	
50	9.8054629E-04	1.7E-08	9.8056266E-04	9.6E-09	1.6366E-08	0.85
100	9.8054337E-04	1.3E-08	9.8056004E-04	9.4E-09	1.6671E-08	1.05
150	9.8054445E-04	1.1E-08	9.8055639E-04	9.4E-09	1.1935E-08	0.81
200	9.8054493E-04	1.1E-08	9.8055757E-04	9.4E-09	1.2643E-08	0.88
250	9.8054527E-04	1.0E-08	9.8055834E-04	9.4E-09	1.3077E-08	0.93
300	9.8054604E-04	1.0E-08	9.8055927E-04	9.4E-09	1.3229E-08	0.96
400	9.8054760E-04	9.9E-09	9.8055941E-04	9.4E-09	1.1807E-08	0.86
500	9.8054837E-04	9.8E-09	9.8055936E-04	9.4E-09	1.0995E-08	0.81
600	9.8054927E-04	9.6E-09	9.8055834E-04	9.4E-09	9.0641E-09	0.67
600	9.8055064E-04	9.5E-09	9.8055600E-04	9.4E-09	5.3605E-09	0.40
500	9.8054990E-04	9.5E-09	9.8055581E-04	9.4E-09	5.9115E-09	0.44
400	9.8054911E-04	9.6E-09	9.8055826E-04	9.4E-09	9.1469E-09	0.68
300	9.8054750E-04	9.8E-09	9.8055886E-04	9.4E-09	1.1360E-08	0.84
250	9.8054588E-04	1.0E-08	9.8055877E-04	9.4E-09	1.2896E-08	0.93
200	9.8054465E-04	1.0E-08	9.8055855E-04	9.4E-09	1.3901E-08	0.99
150	9.8054457E-04	1.1E-08	9.8055823E-04	9.4E-09	1.3657E-08	0.95
100	9.8054217E-04	1.1E-08	9.8055730E-04	9.4E-09	1.5125E-08	1.02
50	9.8054222E-04	1.3E-08	9.8055685E-04	9.4E-09	1.4627E-08	0.92