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Results on the effective area of a DHI piston-cylinder unit with the nominal area of 196 mm^2

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Mittatekniikan keskus

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Abstract

The pressure laboratory of the Centre for Metrology and Accreditation (MIKES) purchased in 2004 a new piston cylinder unit with the nominal effective area of 196 mm² to be used as a working standard in absolute and gauge pressure ranges from 25 kPa to 1,75 MPa. A series of measurements on the effective area of the new unit was carried on in MIKES, in Swedish National Testing and Research Institute (SP) and in Metrosert, the leading pressure laboratory in Estonia.

The results from MIKES, SP and Metrosert were in a good agreement with each other and with the value given by the manufacturer, DH Instruments, Inc., USA. There seems to be no significant difference in effective areas obtained in gauge and absolute modes.

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1 Introduction

The pressure laboratory of the Centre for Metrology and Accreditation (MIKES) purchased in 2004 a new piston cylinder unit with the nominal effective area of 196 mm² to be used as a working standard in absolute and gauge pressure ranges from 25 kPa to 1,75 MPa. The manufacturer of this unit is DH Instruments, Inc., Phoenix, USA and the operating fluid nitrogen or air.

MIKES is using since 1996 a DH Instruments PG7601 pressure balance equipped with a larger piston cylinder unit (nominal effective area 980 mm²) for the range from 5 kPa to 350 kPa gauge and absolute. The new piston-cylinder unit is used in the same balance body.

For the characterisation of the new instrument its effective area was measured with several pressure standards in MIKES, Swedish National Testing and Research Institute (SP) and in Metrosert, the Estonian institute responsible for their national standards.

2 Manufacturer's result

DH Instruments, Inc. is today perhaps the leading manufacturer of pressure balances used in national metrology institutes. Their calibration laboratory is accredited by the American Association for Laboratory Accreditation (A2LA). The best uncertainty in calibrating the effective area of a piston cylinder is as low as 7 ppm in the range from 5 kPa to 1,75 MPa [1].

The effective area for our piston-cylinder unit is given in the calibration report No. 33786 dated 13th January 2004 as

$$A(20,0) = 196,12116 \text{ mm}^2$$

at 20°C and null pressure. The pressure distortion coefficient λ is given as

$$\lambda = -1,67 \cdot 10^{-6} \text{ 1/MPa}$$

The uncertainty of the effective area corrected to the operating temperature and pressure is given as 11 ppm (coverage factor $k = 2$).

3 First measurement in MIKES

The first calibration in MIKES was carried out on 2nd and 3rd of February 2004. The standard used was a Desgranges & Huot 5203 pressure balance with the piston-cylinder unit No. 4012 with the nominal effective area of 98 mm² for the gauge pressure range from 0,1 MPa to 5 MPa. The effective areas of the MIKES pressure balances are traceable to BNM-LNE, France. The latest calibration for the unit No. 4012 was from November 2001, certificate No. B101167/1.

The piston cylinder unit DHI No. 620 was mounted in the DHI PG7601 balance body No. 149. The measurements were made on five nominal pressures ranging from 0,5 MPa to 1,75 MPa. The value obtained for the effective area $A(20)$ was

$$A(20) = 196,1202 \text{ mm}^2 \pm 0,0039 \text{ mm}^2 \text{ (k = 2)}$$

The pressure dependence of the effective area was found to be negligible.

4 Measurements in SP

The measurements in the pressure laboratory of the Swedish National Testing and Research Institute (SP) were made on 8th and 9th of March 2004 by Jukka IsoPahkala of SP and Markku Rantanen of MIKES:

The first measurements in SP were made in gauge mode. The SP standard was a Ruska 2465 pressure balance No. 53593. Two piston cylinder units were used, the first No. C-510 with the nominal effective area of 84 mm² and the second No. V-1194 with the nominal effective area of 8,4 mm².

The piston cylinder unit DHI No. 620 was again mounted in the DHI PG7601 balance body No. 149, and the measurements were made on six nominal pressures ranging from 0,2 MPa to 1,75 MPa. The value obtained for the effective area $A(20)$ was

$$A(20) = 196,1194 \text{ mm}^2 \pm 0,0042 \text{ mm}^2 \text{ (k = 2)}$$

The pressure dependence of the effective area was found to be negligible.

The measurements in the absolute mode were made in the range from 0,8 MPa to 1.75 MPa using only one piston cylinder unit (No. V-1194) in the Ruska balance. In both pressure balances the weights were under the bell jars evacuated with vacuum pumps. Instead of the traditional cross-floating the two pressure balances were put to equilibrium adjusting the residual pressures in the bell jars. The pressures in the bell jars were typically below 40 Pa.

The effective area $A(20)$ obtained for the piston-cylinder No 620 was now

$$A(20) = 196,1185 \text{ mm}^2 \pm 0,0046 \text{ mm}^2 \text{ (k = 2)}$$

Again, the effective area was practically independent of pressure.

Like in MIKES, the effective areas of pressure balances of SP are traceable to BNM-LNE, France.

5 Second measurement in MIKES

The second measurement in MIKES was made on 29th of March in absolute mode.

The piston cylinder unit DHI No. 620 was under the evacuated bell jar in the DHI PG7601 balance body No. 149. The pressures were generated by a gauge pressure balance and they were converted to absolute pressures adding the values of atmospheric pressures during measurements.

The gauge pressure standard was the same Desgranges & Huot 5203 with the piston cylinder unit 4012. The barometer used was a Vaisala PTB200AD No. 533521, one of the working standards in MIKES pressure laboratory since 1993.

The value obtained for the effective area $A(20)$ of our piston cylinder unit No. 620 was now

$$A(20) = 196,1199 \text{ mm}^2 \pm 0,0048 \text{ mm}^2 \text{ (k = 2)}$$

The measurements were made on four nominal pressures in the range from 0,8 MPa to 1,75 MPa. The effective area was found to be practically independent of pressure.

6 Third measurement in MIKES

The third measurement in MIKES was made between 17th of May and 2nd of June 2004 in gauge mode.

Now the standard used was a Desgranges & Huot 5111 pressure balance with the piston-cylinder unit No. 6687 with the nominal effective area of 980 mm² for the range from 20 kPa to 1 MPa. The latest calibration for this unit was from July 2003, certificate No. D060708/1.

The value obtained for the effective area $A(20)$ of our piston cylinder unit No. 620 was now

$$A(20) = 196,1184 \text{ mm}^2 \pm 0,0040 \text{ mm}^2 \text{ (k = 2)}$$

The measurements were made on five nominal pressures in the range from 0,1 MPa to 0,95 MPa. Again, the pressure dependency of the effective area was negligible.

7 Measurements in Metrosert

MIKES and Metrosert participated in 2003 - 2004 in an EuropeAid project called Development of Conformity Assessment Infrastructure in the Field of Metrology. In the framework of this project the pressure laboratory of Metrosert purchased new pressure standards to replace some of the old and worn-out ones, and MIKES arranged a one week local training session on the work with the new equipment. Measurements on the DHI piston cylinder unit No. 620 were a part of the training program, and they were carried out on 28th and 29th of September 2004.

The standard of Metrosert in this measurement was a Pressurements T1400 gas pressure balance No. 59128 equipped with a piston cylinder assembly No. X0228 with the nominal effective area 80,6 mm² for the pressure range 0,02 MPa to 3 MPa. The effective area and the masses of the weights were determined in the UKAS accredited calibration laboratory of Druck Ltd., certificates No. 08852 and No. 08862, both dated 2nd June 2004.

The piston cylinder unit No. 620 was again mounted in the balance body PG7601 No. 149. The measurements were made in the gauge mode on five nominal pressures ranging from 0,5 MPa to 1,75 MPa by Guliko Peterson of Metrosert and Markku Rantanen of MIKES. The results were reported in references [4] and [5].

The effective area $A(20)$ obtained was

$$A(20) = 196,1156 \text{ mm}^2 \pm 0,0089 \text{ mm}^2 \text{ (k = 2)}$$

Here, too, the pressure dependency of the effective area was found to be insignificant.

8 Fourth measurement in MIKES

The fourth measurement in MIKES on 1st of January 2005 in the gauge pressure range from 0,5 MPa to 1,75 MPa was a repetition of the first measurement in MIKES. Now, however, the piston-cylinder unit of the standard, Desgranges & Huot No. 4012, had been re-calibrated in BNM-LNE in November 2004 (certificate E090858/1). Now the effective area $A(20)$ obtained for the unit No. 620 was

$$A(20) = 196,1202 \text{ mm}^2 \pm 0,0039 \text{ mm}^2 (k = 2)$$

A slight decrease in the effective area with increasing pressure was found, but the change is insignificant compared to the total expanded uncertainty.

9 Summary of results

All the results, measurement modes and pressure ranges have been collected in Table 1. Further, the results and the uncertainties are illustrated in Fig. 1. The manufacturer's result consisting of the effective area value $A(20,0)$ for temperature 20°C and null pressure and the pressure distortion coefficient λ was converted to the average value $A(20)$ for the range from 0,05 MPa to 1,75 MPa. This conversion had only negligible effect on the expanded uncertainty.

Table 1. Summary of results on the effective area of DHI piston-cylinder unit No. 620

Laboratory	Date	Mode	Range of measurements MPa	Effective area mm ²	Uncertainty (k=2)	
					mm ²	ppm
DHI	Jan 2004	Gauge	Full coverage	196,1208	0,00216	11
MIKES	Feb 2004	Gauge	0,5 - 1,75	196,1202	0,00392	20
SP	Mar 2004	Gauge	0,2 - 1,75	196,1194	0,00416	21,2
SP	Mar 2004	Absolute	0,8 - 1,75	196,1185	0,00467	23,8
MIKES	Mar 2004	Absolute	0,8 - 1,75	196,1199	0,00490	25
MIKES	Jun 2004	Gauge	0,1 - 0,95	196,1184	0,00396	20,2
Metrosert	Sep 2004	Gauge	0,5 - 1,75	196,1156	0,0089	45
MIKES	Feb 2005	Gauge	0,5 - 1,75	196,1202	0,00392	20

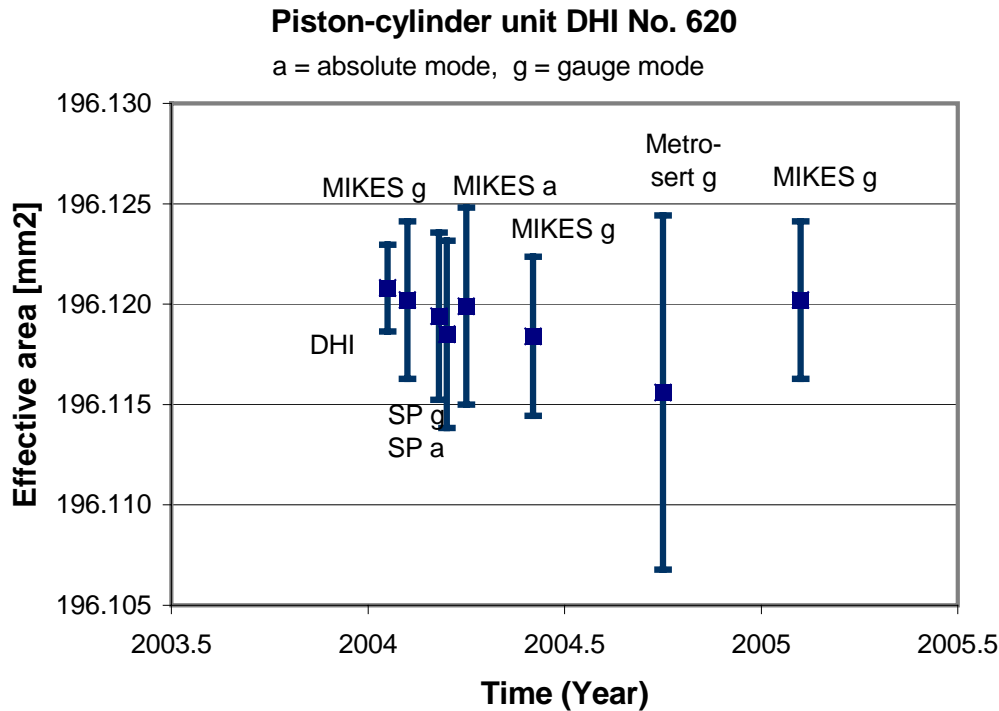


Figure 1. Summary of results on the effective area of DHI piston-cylinder unit No. 620

10 Conclusions

The conclusions are rather obvious, no considerations based on normalised errors are needed. The effective area value

$$A(20) = 196,1200 \text{ mm}^2 \pm 0,0039 \text{ mm}^2 (k = 2)$$

for the piston cylinder unit No. 620 offers a good consistency with the two other pressure standards of MIKES for the same pressure range, and in a very good agreement with the result of the manufacturer DH Instruments, Inc.

There seems to be no significant difference in effective areas in gauge and absolute modes when operating in the uncertainty level mentioned above.

The results from SP and Metrosert are in a good agreement with the results of MIKES.

11 Acknowledgments

The authors wish to thank Guliko Peterson of Metrosert and Jukka IsoPahkala and Fredrik Arrhén of SP for their contribution to the measurements.

12 References

- [1] Certificate Number 1599.01, dated 27th of March 2003. The American Association for Laboratory Accreditation.
- [2] Calibration report No. 33786. DH Instruments, Inc. 2004
- [3] Certificates of calibration M-04P006, M-04P048, M-04P134 and M-05P012. MIKES 2004 and 2005
- [4] Calibration Certificate K001-02-04/790K. Metrosert 2004
- [5] Rantanen, Markku & Peterson, Guliko: Pressure comparisons between MIKES and Metrosert: Ranges 95 kPa to 105 kPa absolute and 0,5 MPa to 1,75 MPa gauge. MIKES Publication J2/2005.

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