MITTATEKNIIKAN KESKUS

CENTRE FOR METROLOGY AND ACCREDITATION

Julkaisu J7/2001

COMPARISONS IN THE PRESSURE RANGE FROM 50 kPa TO 350 kPa

Final Report on EUROMET Project 455

Markku Rantanen

Helsinki 2001

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1 INTRODUCTION

In 1997, the pressure laboratories of Czech Metrological Institute (CMI), Centre for Metrology and Accreditation (MIKES) and Nederlands Meetinstituut (NMi), all using the same type of pressure balances with 35 mm diameter ceramic piston for the pressure range 20 kPa to 350 kPa, started a project to compare their results of pressure measurements and the results of dimensional measurements for the effective areas of the piston cylinder units.

Later, the pressure comparisons between MIKES and Centro Espanol de Metrologia (CEM), MIKES and Swedish National Testing and Research Institute (SP) and MIKES and Norwegian Metrology and Accreditation Service (Justervesenet, JV) were included in the project.

Most of the results have already been reported elsewhere [1, 4, 5, 11]. The present paper is a summary report concentrating on results obtained on the MIKES equipment.

2 MEASUREMENTS ON MIKES PISTON CYLINDER UNIT N:O 277

Comparisons between the pressure balances of CMI, MIKES and NMi, two by two, were undertaken in 1997 - 1999. The results were presented by J. Verbeek in the 3rd CCM International Conference on Pressure Metrology in Torino, May 1999 [1], and will be published in Metrologia.

The pressure balances in the comparison are of the type PG7601, manufactured by DH Instruments, Inc. The pistons are made of ceramic material and the cylinder of tungsten-carbide. The ratios of the effective areas were determined from cross-floating experiments at gauge pressures in the range 50 to 350 kPa. The reproducibility of the measurements was within $2 \cdot 10^{-6}$, and the ratios within $6 \cdot 10^{-6}$.

Measurements at CMI

The effective area value determined by the Czech Metrological Institute (CMI) for the MIKES unit No. 277 in April 1999 was 980, 528 ± 0,012 mm^2 (k = 2).

At CMI the traceability of pressure in the range 50 to 350 kPa is based on the effective area value determined for their 35 mm diameter unit from dimensional measurements made by CMI. The value obtained for the effective area of the CMI reference standard was confirmed in comparisons with leading pressure laboratories in Europe, e.g. with PTB [2, 3].

Measurements at NMi

The effective area value determined in June 1997 by Nederlands Meetinstituut (NMi) for the MIKES unit No. 277 was 980, 541 ± 0,028 mm^2 .

At NMi the traceability of pressures in this range is based on the effective area determined for their 35 mm diameter unit from dimensional measurements.

Measurements at SP/FFA

In May 1998 a pressure comparison was arranged between MIKES and the Aeronautical Research Institute of Sweden (FFA) in the range 32 to 132 kPa [4]. In the comparison FFA used their reference standard for this range, a Ruska piston-cylinder unit with a nominal effective area of 335 mm^2.

The effective area value determined for the MIKES unit No. 277 was 980,520 ± 0,016 mm^2.

The Swedish national laboratory for pressure was maintained by FFA until the end of 1998 and since then by the Swedish National Testing and Research Institute (SP). At SP/FFA the effective areas of pressure balances are traceable to Laboratoire National d'Essais (BNM-LNE), France.

Measurements at JV

At Justervesenet (JV); Norway, a development project on the pressure laboratory was started in 1999. As a part of this project two pressure comparisons between Justervesenet and MIKES were arranged, and the results were presented in the Nordic Conference on Measurements and Calibration [5].

The effective area value determined by JV in June 1999 for the MIKES unit No. 277 was 980,532 ± 0,029 mm^2.

Like CMI, MIKES and NMi, even JV uses the same type of pressure balances with 35 mm diameter ceramic piston for the gauge and absolute pressure range 20 to 350 kPa. The effective area is traceable to BNM-LNE, but at the time of the measurements there was only one calibration result yet.

Measurements at MIKES

The effective areas of the MIKES pressure balances are traceable to BNM-LNE, France. For the range 50 kPa to 1 MPa the reference standard is a Desgranges & Huot 5111 pressure balance with a 980 mm^2 piston cylinder unit No. 6687. This unit has been calibrated at BNM-LNE three times, in 1995, in 1997 and in April 2000.

Some experiments on determining the effective area of this unit from dimensional

measurements were made in Finland in 1996. However, the result was not fully satisfactory, and the uncertainty was much higher than in BNM-LNE certificates.

The effective area of the piston cylinder unit No. 277 has been determined several times by cross-floating against the reference standard. The latest calibrations were made in January 1998, July 1998, May 1999 and in May 2000 [6], with the following results:

Jan. 1998	980, 529 ± 0,023 mm^2
July 1998	980, 527 ± 0,022 mm^2
May 1999	980, 526 ± 0,019 mm^2
May 2000	980, 522 ± 0,019 mm^2

Manufacturer's value for the effective area

The manufacturer of the MIKES piston cylinder unit No. 277, DH Instruments Inc., determined the effective area in September 1996 as 980,543 ± 0,015 mm^2 [7]. The effective area of the DH Instruments 35 mm diameter reference unit has been determined several times by dimensional measurements and direct comparisons with LNE and NIST [8].

3
COMPARISON OF RESULTS ON MIKES PISTON CYLINDER UNIT N:O 277

A summary of all the results on piston-cylinder unit No. 277 is shown in Fig. 1 and in Table1. All the laboratories gave their results with no dependence on pressure.

Table 1. Summary of results on piston cylinder unit No. 277

Laboratory	Date	Result mm^2	U (k=2) mm^2	Deviation from ref. mm^2	E_n
DH Instr.	Sep. 1996	980,543	0,015	0,015	0,58
NMi	July 1997	980,541	0,028	0,013	0,37
MIKES 1	Jan. 1998	980,529	0,023	0,023	0,03
FFA/SP	May 1998	980,520	0,016	-0,008	-0,30
MIKES 2	July 1998	980,527	0,022	-0,001	-0,34
CMI	Apr. 1999	980,528	0,012	0,000	0,00
MIKES 3	May 1999	980,526	0,019	-0,002	-0,07
JV	June 1999	980,532	0,029	0,004	0,11
MIKES 4	May 2000	980,522	0,019	-0,006	-0,21

The reference value for the comparison was taken as the median from the results of CMI, NMi and SP/FFA. As the pressures of SP/FFA, JV and MIKES are all traceable to BNM-LNE, only one result of this group was taken. Of these three, SP/FFA has the longest history and the lowest uncertainty.

The uncertainty of the median has been calculated using the method of Müller as described in the final report on EUROMET comparison 389 [9]:

1,858

$$s = \frac{}{\sqrt{(n-1)}} \text{-------} \; x\, MAD$$

where s is the uncertainty
n is the number of participants contributing to the reference value
MAD is the median of absolute deviations from the median.

Using coverage factor k = 2, the reference value is 980,528 ± 0,021 mm^2. It was assumed that there was no time dependent change in the piston cylinder unit No. 277 during the three years of the comparison.

Table 1. shows the deviation from the reference value and the normalised error value E_n for each result.

4
CEM MEASUREMENTS ON MIKES PISTON CYLINDER UNIT NO. 6687

The piston cylinder unit Desgranges & Huot 5111 No. 6687 with an effective area of 980 mm^2 is the reference standard of MIKES for the range 50 kPa to 1 MPa. This unit has been calibrated at BNM-LNE three times in 1995 to 2000 [10]:

BNM-LNE Oct. 1995: $A_{0,20C} = 980,4787 \pm 0,0065\ mm^2$, $\lambda = (4,0 \pm 0,4) \cdot 10^{-6}\ MPa^{-1}$
BNM-LNE June 1997: $A_{0,20C} = 980,4910 \pm 0,0076\ mm^2$, $\lambda = (4,0 \pm 0,4) \cdot 10^{-6}\ MPa^{-1}$
BNM-LNE April 2000: $A_{0,20C} = 980,4856 \pm 0,0087\ mm^2$, $\lambda = (4,0 \pm 0,4) \cdot 10^{-6}\ MPa^{-1}$,

where $A_{0,20C}$ is effective area at pressure $p = 0$ and temperature $t = 20^oC$
λ is the pressure distortion coefficient of the efficient area.

Some experiments were made in Finland in 1996 even on the unit No. 6687 for determining the effective area from dimensional measurements. The uncertainty, however, was higher than in the BNM-LNE certificates. Further, the results showed a minor straightness error in the piston.

In March 1999 the pressure laboratory of Centro Espanol de Metrologia (CEM) determined the effective area of the MIKES unit No. 6687 using the cross floating method as with the following results [11]:

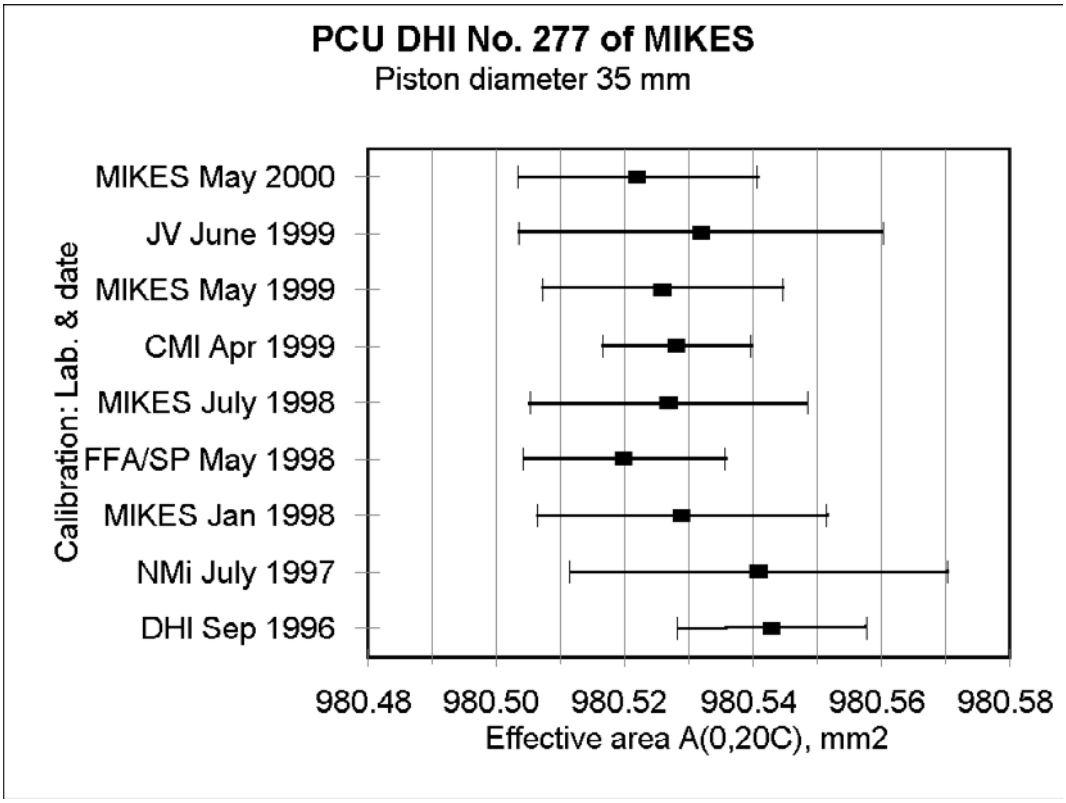
$A_{0,20C} = 980,488 \pm 0,009\ mm^2$, $\lambda = 5,57 \cdot 10^{-6}\ MPa^{-1}$

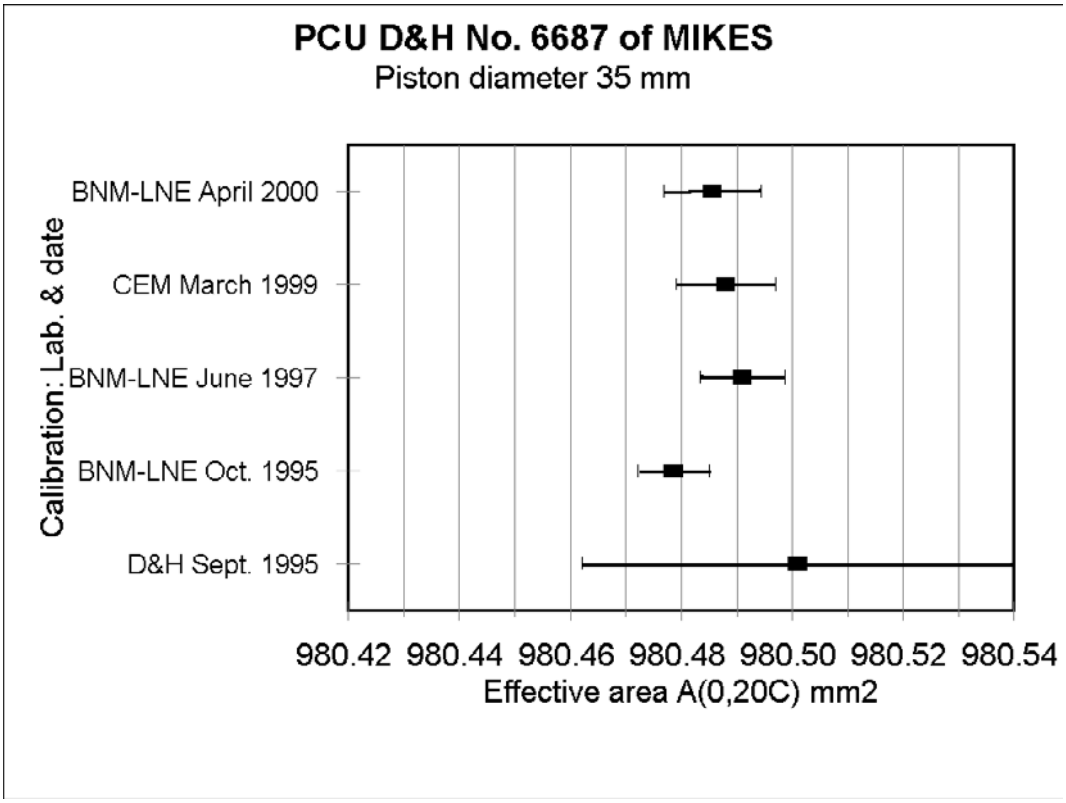
The CEM result is in a very good agreement with the results of BNM-LNE. Even at CEM, the effective areas of pressure balances are traceable to BNM-LNE. In the pressure range 20 kPa to 1 MPa the CEM standards are Desgranges & Huot 5111 pressure balances with a 980 mm^2 tungsten carbide piston cylinder units.

The manufacturer's original value for the unit No. 6687 from September 1995 had a relatively large uncertainty [12]:

$A_{0,20C} = 980,501 \pm 0,039\ mm^2$, $\lambda = 4 \cdot 10^{-6}\ MPa^{-1}$

A summary of the results on piston-cylinder unit No. 6687 is shown in Fig. 2.





Figures 1 and 2. Summary of results on piston cylinder units No. 277 and No. 6687.

5
CONCLUSIONS

The results obtained by CMI, NMi, MIKES, SP/FFA and JV on the piston cylinder unit No. 277 were in a very good agreement with each other.

The result of CEM on the piston cylinder unit No. 6687 was in a very good agreement with the results of BNM-LNE.

6
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Tilaukset toimistosihteeri Kirsi Tuomisto, puh. (09) 6167 457,
e-mail kirsi.tuomisto@mikes.fi.

MITTATEKNIIKAN KESKUS
CENTRE FOR METROLOGY AND ACCREDITATION
P.O. Box 239
FIN- 00181 HELSINKI
Tel. +358 9 616 761
Telefax +358 9 616 7467

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