Final Report

TC for Mass and Related Quantities (M)

1. Project Title

Bilateral comparison to determine the effective area of the piston cylinder unit by cross-floating

2. Coordinator

Richard Högström, MIKES (Finland)

3. EURAMET Registration Number

1207

4. KCDB Identifier

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Mass and Related Quantities

FINAL REPORT

Project no	EURAMET 1207
Participant(s)	MIKES (FI), MCCAA (MT)
Transfer standard	Gas piston cylinder unit - Manufacturer: DHI - Model: 50 kPa/kg
Type of comparison	Determination of the effective area by cross-floating method
Range of the comparison	Nominal area 196 mm^2 with nominal operational range 0.025 MPa to 1.75 MPa
Date of measurements	23. September 2009 (MIKES) 12. - 15. February 2012 (MCCAA)
Completion date of the comparison	21.3.2013
Coordinator's signature	

Richard Högström
Head of Pressure
VTT MIKES

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Appendices	A: Calibration results reported by the laboratories

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Participants

Name	Acronym	Address
Centre for Metrology and Accreditation (nowadays VTT MIKES)	MIKES	Tekniikantie 1 02151 Espoo, Finland
Malta Competition and Consumer's Affairs Authority	MCCAA	Kordin Business Incubation Centre, Corradino Industrial Estate, Kordin,PLA 3000, Malta

Nominal measurement points

In this comparison, laboratories determined the effective area of the piston cylinder unit using the cross-floating method. The nominal effective area is 196 mm^2. MIKES performed measurements at nominal pressures 0.025 MPa, 0.070 MPa, 0.100 MPa, 1.120 MPa and 1.150 MPa. MCCA measurements were performed at nominal pressures 0.5 MPa, 0.75 MPa, 1.0 MPa, 1.25 MPa, 1.5 MPa and 1.75 MPa. Four measurements were performed at each nominal pressure both in ascending and descending pressures. Detailed results are given in the calibration certificates in Appendix A.

Note. MIKES measurements cover only the lowest part of the operating range of the transfer standard. However, the results are in good agreement with the results from a calibration at MIKES in August 2009 performed in the range from 0.5 MPa to 1.75 MPa.

Reference equipment used in the comparison

Laboratory	Equipment id.	Description
MIKES	PG7607 p/c 451	Pressure balance DHI PG7607 no. 397: - Piston cylinder unit no. 451 - Mass set DHI no. 2229 - Mass carrier DHI no. 626 Traceability to the international system of units (SI) is provided as follows: - The piston cylinder effective area and the masses are traceable to Finnish national standards Uncertainty: - Effective area uncertainty is 34 ppm - Mass uncertainty is 3 ppm Measurement uncertainties are estimated according to GUM using the coverage factor $k = 2$, which for a normal distribution corresponds to a probability of approximately 95 %.
MCCAA	PG7202 p/c 1371	Pressure balance DHI PG7202 no. 825: - Piston cylinder unit no. 1371 Traceability to the international system of units (SI) is provided via calibration at

		pressure balance manufacturer FLUKE (calibration certificate FLUKE DHI 1284544524).

Transfer standard

Model	Serial number
Gas piston cylinder unit	620

Comparison scheme

	Laboratory	Date
1.	MIKES	23. September 2009
2.	MCCAA	12. - 15. February 2012

Both laboratories performed the measurements in the gauge mode using cross-floating method, where the equilibrium state of the two piston cylinder units are found with the help of the trim masses.

During the measurements at MIKES, the transfer standard PCU was mounted to a pressure balance basement DHI PG7601 no. 149 (owned by MIKES). During the measurements at MCCAA, the transfer standard PCU was mounted to a pressure balance basement DHI PG7601 no. 806 (owned by MCCAA).

Stability of the transfer standard

The stability of the transfer standard was estimated from MIKES calibration results. The transfer standard is owned by MIKES since 2006 and it is calibrated three times using cross-floating methods. The value used for uncertainty due to instability of the effective area is ±4 ppm.

Method for analyzing the results

Comparison of the laboratories

The analysis was carried out in the following way:

Laboratories determined the effective areas of the piston cylinder units according to their own calculation procedures.

The difference between the laboratories (D_{lab}) was then determined as follows:

$$D_{\mathrm{lab}} = A_{\mathrm{eff\,MCCAA}} - A_{\mathrm{eff\,MIKES}} \quad (1)$$

The uncertainty of the difference was taken as the combined uncertainty of the both laboratories and the estimated stability of the transfer standard:

$$u(D_{\mathrm{lab}}) = \sqrt{u^2(A_{\mathrm{eff\,MCCAA}}) + u^2(A_{\mathrm{eff\,MIKES}}) + u_{\mathrm{stab}}^2} \quad (2)$$

The standard uncertainty due to instability of the transfer standard (u_{stab}) during the comparison was taken into account as type B uncertainty component, rectangular distribution.

Significance of the observed differences

To analyse the significance of the differences calculated with equation (1), normalized error values (E_n) were calculated by dividing the difference with its expanded uncertainty ($k = 2$)

$$E_{n,lab} = \frac{D_{lab}}{U(D_{lab})} = \frac{D_{lab}}{2u(D_{lab})} \quad (3)$$

If -1 < E_n < 1, the estimate for the difference is smaller than its expanded uncertainty. In this case, there is no statistically significant difference between the results obtained by the laboratories.

Results of the comparison

Final results obtained with the transfer standard are presented in Table 1 and Figure 1.

Table 1. Results obtained with the transfer standard. The uncertainty includes the estimated instability of the transfer standard.

Nominal effective area A_{eff} (mm²)	MCCAA - MIKES D_{LabX} (ppm)	$U(D_{LabX})$ [1] (ppm)	Normalized error E_n
196	-0,5	41,7	-0,01

[1] Expanded uncertainty with the coverage factor of 2.

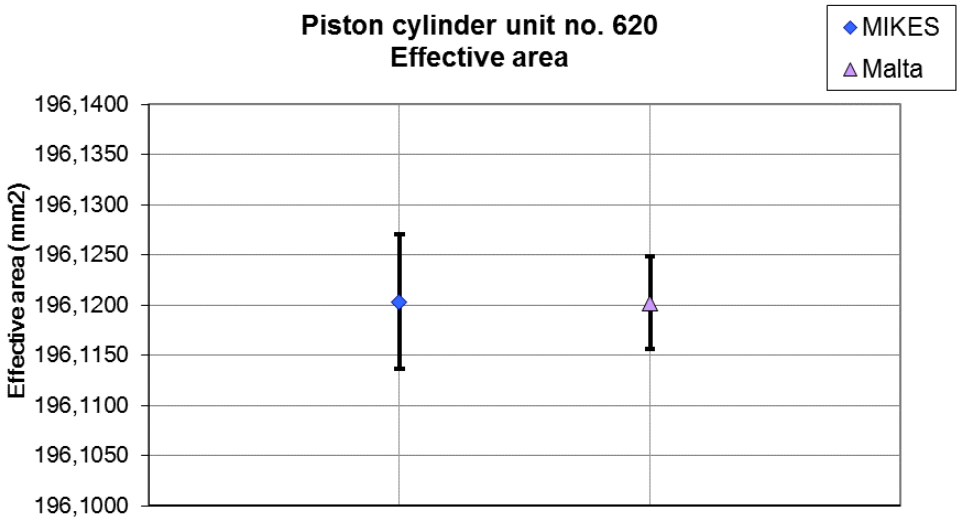

Figure 1. Results of the comparison. Error bars show the estimated expanded uncertainty (k = 2).

All the calculated En values are -1 < En < 1, which means there are no statistically significant differences between the results obtained by the laboratories.

Conclusions and discussion

All results agreed within the stated expanded uncertainties.

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APPENDIX A: Calibration results reported by the laboratories

KALIBROINTITODISTUS
KALIBRERINGSBEVIS
CERTIFICATE OF CALIBRATION

Nro nr • no.	M-09P115 *Calibration in the range from 0,025 MPa to 0,15 MPa*
Tilaaja Uppdragsgivare • Customer	Centre for Metrology and Accreditation (MIKES) P.O. Box 9 (Tekniikantie 1) FI-02151 Espoo
Kalibroitu laite Kalibrerat instrument • Calibrated instrument	Piston cylinder unit of a gas pressure balance
Valmistaja Tillverkare • Manufactured by	DH Instruments, Inc.
Tyyppi Typ • Model	0,05 MPa/kg, range from 0,025 MPa to 1,75 MPa
Sarjanumero Serienummer • Serial number	620
Kalibrointipäivä Kalibreringsdatum • Date of calibration	23.9.2009 (MR)
Päiväys Datum • Date	5.10.2009
Allekirjoitukset Underskrifter • Signatures	Markku Rantanen, Senior research scientist Sari Saxholm, Research scientist
Sivu Sida • Page	1/5
Liitteitä Bilagor • Appendices	4

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CIPM MRA

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Kalibroidun laitteen kunto
Kondition av kalibrerat instrument • Condition of calibrated instrument

The following information about the piston cylinder unit was available:

Manufacturer:	DH Instruments
Piston cylinder assembly:	s/n 620 (nominal pressure range 25kPa ... 1,75 MPa)
Thermal expansion coefficient for the effective area:	0,000009 1/°C (value given by the manufacturer)
Mass of the piston:	0,199998 kg, cal. 22.11.2007 MIKES, cert. M-07M070
Value used for the density of the piston:	6910 kg/m^3

The piston cylinder unit was mounted to a balance body DH Instruments PG7601 nro 149 of MIKES, and a weight carrier and a weight set of MIKES were used for the measurements.

Reference level:	Marked on the balance body
Weight set:	639411, masses cal. 12.5.2009 MIKES, tod. M-09M013
Weight carrier:	249, mass cal. 18.3.2008 MIKES, tod. M-08M018
Density of weights:	8000 kg/m^3
Density of carrier:	4970 kg/m^3

The calibrated piston cylinder assembly and the pressure balance body were in good working order.

Kalibrointimenetelmä
Kalibreringsmetod • Calibration method

Measurements

The piston cylinder unit and the pressure balance were allowed to stabilise in the laboratory room for more than 16 hours before starting the measurements. The piston cylinder unit was cleaned and mounted to the balance body. The pressure balance was placed on a table close to the measurement standard. The levelling was checked with a libel. The reference level of the object pressure balance was 4,2 cm lower than that of the standard.

Measurements were made on five nominal pressures. The weight combinations are given in Appendices 3 and 4. At each of the nominal pressures the object and the standard were cross-floated and trimmed with adjustment weights until the equilibrium was reached.

Measurements were made both in increasing and decreasing direction of pressure. Both pistons were rotated clockwise by hand.

The temperature of both piston-cylinder units were measured using a Pt-100 element installed in the balance body.

Calculation of results

Pressure p_{obj} generated by the object piston-cylinder unit can be calculated using the formula

$$p_{obj} = \frac{m\,g\,(1 - \rho_a/\rho_m) + \Sigma M\,g\,(1 - \rho_a/\rho_M)}{S_{(20,p)}\,[1 + 2\alpha\,(t - 20^\circ C)]}, \qquad (1)$$

where

m	is the mass of the piston ;
ρ_m	is the density of the piston;
ΣM	is the mass of the weights on the piston;
g	is the local gravity;

ρ_a is the density of the ambient air;
ρ_M is the density of weights;
$S_{(20,p)}$ is the effective area of the piston cylinder unit at 20°C at pressure p;
2α is the thermal expansion coefficient of the piston cylinder unit; and
t is the temperature of the piston cylinder unit.

When the object balance and the standard are interconnected

$$p_{obj} = p_{stand} - (\rho_f - \rho_a)\, g\, \Delta h,$$

where p_{obj} is the pressure at the reference level of the object and p_{std} is the pressure at the reference level of the standard.

Factor $(\rho_f - \rho_a)g\Delta h$ is the hydrostatic pressure due to the difference of the reference levels, where

ρf is the density of the pressurised medium
ρ_a is the density of surrounding air
g is the local gravity
Δh is the height difference of the reference levels (positive if the object is higher)

The effective area of the piston-cylinder unit $S_{(20,p)}$ at 20 °C can be calculated for each equilibrium pressure using the formula (1) if the masses of the weights, piston-cylinder temperature and the measurement conditions are known.

$$S_{(20,p)i} = \frac{m\, g\, (1 - \rho_a/\rho_m) + \Sigma M_i\, g\, (1 - \rho_a/\rho_M)}{p_{obj,i}[1 + 2\alpha\, (t_i - 20°C)]}.$$

As the uncertainty of the pressure generated by the standard increases as pressure decreases the results $S_{(20,p),i}$ may be weighted with factors w_i:

$$w_i = u_{pmax} / u_{pi}$$

Generally, the result of the calibration of a piston cylinder unit is given as the effective area $S_{(20,0)}$ (at 20 °C and at p = 0) and the linear pressure distortion coefficient λ. Values $S_{(20,0)}$ and λ are determined by plotting the area values $S_{(20,p)i}$ against pressure values and finding the best fitting straight line.

The results and the calculated effective area values are shown in Appendices 1 and 2.

The effective area at temperature t and pressure p is calculated as

$$S_{(t,p)} = S_{(20,0)}[1 + 2\alpha\,(t - 20\ °C)](1 + \lambda p).$$

Kalibroinnissa käytetyt mittanormaalit ja jäljitettävyys
Mätnormalerna som använts i kalibrering och spårbarhet • Measurement standards used in calibration and traceability

Pressure balance DHI PG7607 gas pressure balance s/n 397 equipped with
Piston cylinder unit nro 451 for the gauge or absolute pressure range 5 kPa to 190 kPa, calibrated at MIKES 21.8.2009 (certificate M-09P098)
Weight set nro 2229, calibrated at MIKES 11.5.2009 (certificate M-09M014).
Weight carrier nro 626, calibrated at MIKES 18.3.2008 (certificate M-08M018)

The best measurement capability of the standard is 1 Pa + 0,0022 % of measured pressure (k = 2).

Kalibrointiolosuhteet
Kalibreringsförhållanden • Calibration conditions

The measurements were made in the pressure laboratory of the Centre for Metrology and Accreditation (MIKES) 22.-23.8.2009 by Markku Rantanen and the pressure training team from the Malta Standards Authority.

Ambient temperature:	20,5°C ± 1 °C
Atmospheric pressure:	22.9.2009: 1008 hPa ± 2 hPa
	23.9.2009: 996 hPa ± 2 hPa
Relative humidity:	47% ± 10 %
Local gravity:	9,81907 m/s^2
Pressure transfer medium:	Nitrogen

Kalibrointitulokset ja mittausepävarmuus
Kalibreringsresultat och mätosäkerhet • Calibration results and measurement uncertainty

The effective area corresponding to the temperature 20 °C is

$$S_{(20,p)} = 196{,}1203\ \text{mm}^2 \pm 0{,}0067\ \text{mm}^2 \quad (k = 2)$$

The effective area can be taken as independent of pressure ($\lambda = 0$, measurement in the gauge pressure range 0,025 MPa ... 0,15 MPa).

The uncertainty of the effective area was calculated according to the document EA-4/02 using coverage factor k=2. For a normal distribution this corresponds to a coverage probability of 95%.

The dominating sources of uncertainty are presented in the following table:

	Relative uncertainty in parts per million ppm (1 s) Uncertainty factor
Standard deviation of the results	11
Uncertainty of the standard	12
Uncertainty of the weights	3
Uncertainty of the PCU temperature (± 0,2 °C)	3
Uncertainty in levelling-	3
Combined uncertainty	17
Expanded uncertainty (k = 2)	34 ppm

Huomautukset
Anmärkningar • Remarks

The result and the uncertainty calculation refer to the condition of the instrument during calibration. No allowance for future changes is included in the figures.

The calibration covers only the lowest part of the operating range of the object instrument. However, the result is in a good agreement with the result from a calibration at MIKES in August 2009 in the range from 0,5 MPa to 1,75 MPa (certificate M-09P092, dated 10.8.2009).

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Tämä todistus on kansainvälisen paino- ja mittakomitean (CIPM) laatiman vastavuoroisen tunnustamissopimuksen (MRA) liitteeseen C sisällytettyjen kalibrointi- ja mittauskykyjen (CMC) mukainen. Kaikki MRA:ssa mukana olevat laitokset tunnustavat toistensa kalibrointi- ja mittaustodistusten kelpoisuuden niille suureille, mittausalueille ja mittausepävarmuuksille, jotka on määritelty liitteessä C (katso yksityiskohdat http://www.bipm.org).

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This certificate is consistent with Calibration and Measurement Capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee for Weights and Measures (CIPM). Under the MRA, all participating institutes recognise the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see http://www.bipm.org).

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EFFECTIVE AREA IN A GAS PRESSURE BALANCE M-09P115
0Mgbal1v5 9.11.06 APP 1
File: 90923A

OBJECT: Pressure balance DHI PG7601, nro 149
Piston/cylinder unit 620, 0,025 ... 1,75 MPa
Piston mass 0,199998 kg Density 6910 kg/m3
Carrier mass 0,299996 kg Density 4970 kg/m3
Weight set 639411 Density 8000 kg/m3
Cal. 12.5.2009, cert. M-09M013
Temperature coefficient for eff. area: 0,000009 1/C
Reference level compared to standard: -4,2 cm +/- 0.2 cm

STANDARD: Pressure balance DHI PG7607 nro 397
Piston/cylinder unit nro 451, KN = 0,005 MPa/kg (gas)
Cal. 21.8.2009, cert. M-09P098, MIKES
Floating cylinder mass 0,700085 kg Density 9703 kg/m3
Mass cal 22.11.2007, cert. M-07M070
Carrier 626
Carrier mass 0,299999 kg Density 5013 kg/m3 Cal. 18.3.2008, cert. M-08M018
Weight set 2229 Density 8000 kg/m3 Cal. 11.5.2009, cert. M-09M014

CONDITIONS: Location: MIKES pressure lab.
Date: 22.-23.9.2009 Operators: Malta team, MR
Temperature: 20,5 C +/-1 C Rel.humidity: 45%+/-10%
Atm.pressure: 22.9.2009 1008 hPa+/-2 hPa Value used for air
23.9.2009 density: 1,192 kg/m3 22.9.2009
Gravity. g: 9,819073 m/s2 1,177 kg/m3 23.9.2009
Medium: Nitrogen

RESULTS:

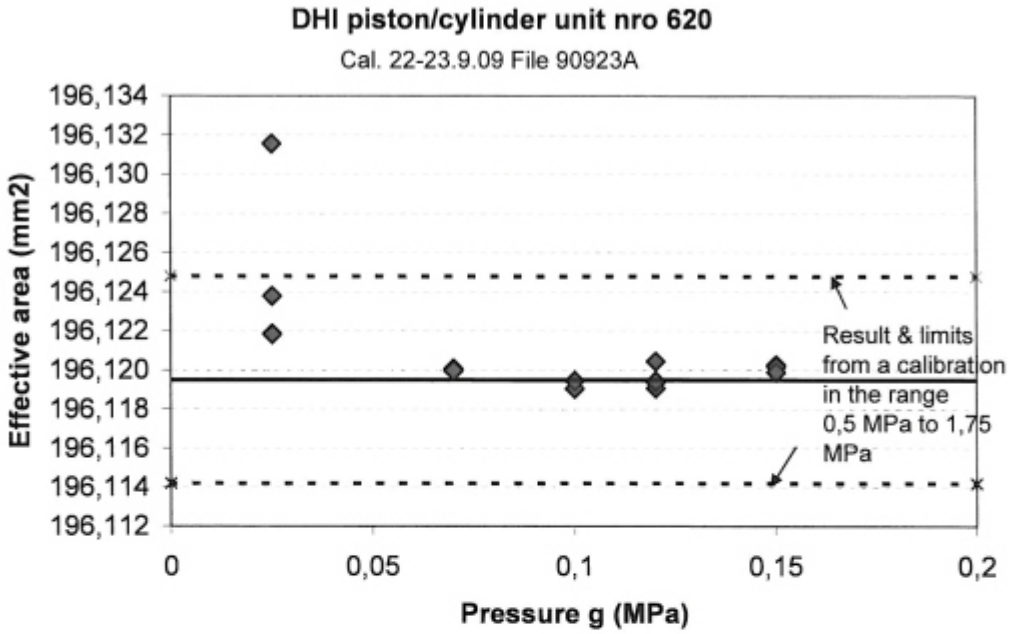
STANDARD:				OBJECT INSTRUMENT:					
Nominal pressure MPa	Masses kg	Trim weights kg	Tempe-rature C	Masses kg	Trim weights kg	Tempe-rature C	Pressure to object MPa	Calculated eff.area mm2	Result weight
0,025	5,000121	0,000000	22,4	0,499994	0,000120	21,7	0,025032	196,1316	0,50
0,025	5,000121	0,000000	22,4	0,499994	0,000095	21,8	0,025032	196,1219	0,50
0,025	5,000121	0,000000	22,5	0,499994	0,000100	21,9	0,025032	196,1238	0,50
0,025	5,000121	0,000000	22,5	0,499994	0,000095	21,9	0,025032	196,1218	0,50
0,070	14,000198	0,000000	22,3	1,400022	0,000145	21,7	0,070089	196,1200	0,88
0,070	14,000198	0,000000	22,5	1,400022	0,000145	21,8	0,070089	196,1201	0,88
0,070	14,000198	0,000000	22,5	1,400022	0,000145	21,8	0,070089	196,1200	0,88
0,070	14,000198	0,000000	22,5	1,400022	0,000145	21,9	0,070089	196,1200	0,88
0,100	20,000228	0,000000	22,3	2,000025	0,000185	21,6	0,100126	196,1190	0,95
0,100	20,000228	0,000000	22,5	2,000025	0,000185	21,8	0,100126	196,1191	0,95
0,100	20,000228	0,000000	22,5	2,000025	0,000190	21,8	0,100126	196,1195	0,95
0,100	20,000228	0,000000	22,5	2,000025	0,000190	21,9	0,100126	196,1194	0,95
0,120	24,000261	0,000000	22,3	2,400010	0,000260	22,1	0,120151	196,1204	0,98
0,120	24,000261	0,000000	22,5	2,400010	0,000235	21,8	0,120152	196,1191	0,98
0,120	24,000261	0,000000	22,4	2,400010	0,000240	21,9	0,120152	196,1194	0,98
0,120	24,000261	0,000000	22,6	2,400010	0,000240	21,9	0,120151	196,1194	0,98
0,150	30,000293	0,000000	22,3	3,000013	0,000310	22,0	0,150189	196,1203	1,00
0,150	30,000293	0,000000	22,5	3,000013	0,000300	21,8	0,150189	196,1202	1,00
0,150	30,000293	0,000000	22,5	3,000013	0,000300	21,8	0,150189	196,1202	1,00
0,150	30,000293	0,000000	22,6	3,000013	0,000295	21,9	0,150189	196,1199	1,00

Weighted average 196,1203 mm2
Weighted std.deviation 0,0022 mm2
Relative weighted std.deviation 11,0 ppm

Best fitting straight line

Effective area S(20,0) 196,1241 mm2
Pressure dependency -0,03615 mm2/MPa
Press.ditortion coeff. lambda -1,8E-04 1/MPa
Relative std. deviation 12,0 ppm

M-09P115
Appendix 2



Punnuslistaus-toiminto, ver 1: 1.4.2004 SS
Päivitetty, ver 7: 11.9.2008 SS

0,1

Piston/cylinder unit, carrier and weight set:

451 | 626 | 2229

Floating cylinder:	451	Cal. 21.8.2009, cert. M-09P098,
Kn [MPa/kg] =	0,005	Mass cal 22.11.2007, cert. M-07M070
Carrier	626	Cal. 18.3.2008, cert. M-08M018
Weight set 1:	2229	Cal. 11.5.2009, cert. M-09M014
Weight set 2:	-	-

Weight Id	Mass [kg]	Nom. pressure	press. 250,0	[kg] 5,000121	press. 700,0	[kg] 14,000198	press. 1000,0	[kg] 20,000228	press. 1200,0	[kg] 24,000261	press. 1500,0	[kg] 30,000293	press. 1500,0	[kg] 30,000293	press. 10,0	[kg] 0,200001	press. 0.0	[kg] 0,000000
		hPa																
451 floating cyl.	0,700085	35,0	35,0	0,700085	35,0	0,700085	35,0	0,700085	35,0	0,700085	35,0	0,700085	35,0	0,700085				
626 carrier	0,299999	15,0	15,0	0,299999	15,0	0,299999	15,0	0,299999	15,0	0,299999	15,0	0,299999	15,0	0,299999				
2229 100 g	0,100000	5,0																
2229 200 g 1	0,199999	10,0																
2229 200 g 2	0,200001	10,0													10,0	0,200001		
2229 500g	0,500002	25,0																
2229 1 kg	1,000015	50,0			50,0	1,000015			50,0	1,000015								
2229 2 kg 1	2,000019	100,0	100,0	2,000019	100,0	2,000019	100,0	2,000019	100,0	2,000019	100,0	2,000019	100,0	2,000019				
2229 2 kg 2	2,000018	100,0	100,0	2,000018			100,0	2,000018			100,0	2,000018	100,0	2,000018				
2229 4,5 kg	4,500003	225,0																
2229 5 kg 1	5,000045	250,0			250,0	5,000045	250,0	5,000045	250,0	5,000045	250,0	5,000045	250,0	5,000045				
2229 5 kg 2	5,000035	250,0			250,0	5,000035	250,0	5,000035	250,0	5,000035	250,0	5,000035	250,0	5,000035				
2229 5 kg 3	5,000027	250,0					250,0	5,000027	250,0	5,000027	250,0	5,000027	250,0	5,000027				
2229 5 kg 4	5,000036	250,0							250,0	5,000036	250,0	5,000036	250,0	5,000036				
2229 5 kg 5	5,000029	250,0									250,0	5,000029	250,0	5,000029				

Appendix 3

M-09P115

M-09P115
Appendix 4

Punnustenvalinta-taulukko, ver 1, 16.6.2005, SS
Päivitetty 16.6.2005, SS

Piston/cylinder unit, weight carrier and weight set:

Piston:	620	
Kn [MPa/kg] =	0,05	Mass cal. 22.11.2007, cert. M-07M070
Carrier:	249	Cal. 18.3.2008, cert. M-08M018
Weight set:	639411	Cal. 12.5.2009, cert. M-09M013
	-	-

Weight id.	Mass [kg]	Nom. pressure kPa	press. 250,00	[kg] 0,499994	press. 700,0	[kg] 1,400022	press. 1000,0	[kg] 2,000025	press 1200,0	[kg] 2,400010	press. 1500,0	[kg] 3,000013	press. 0,0	[kg] 0,000000	press. 0,0	[kg] 0,000000	press. 0,0	[kg] 0,000000
620 piston	0,199998	100,00	☑ 100,00	0,199998	☑ 100,00	0,199998	☑ 100,00	0,199998	☑ 100,00	0,199998	☑ 100,00	0,199998	☐		☐		☐	
249 carrier	0,299996	150,00	☑ 150,00	0,299996	☑ 150,00	0,299996	☑ 150,00	0,299996	☑ 150,00	0,299996	☑ 150,00	0,299996	☐		☐		☐	
639411 100 g 13	0,100007	50,00	☐		☑ 50,0	0,100007	☐		☑ 50,0	0,100007	☐		☐		☐		☐	
639411 200 g 11	0,200005	100,00	☐		☐		☑ 100,0	0,200005	☐		☑ 100,0	0,200005	☐		☐		☐	
639411 200 g 12	0,200009	100,00	☐		☐		☐		☐		☐		☐		☐		☐	
639411 500 g 10	0,500005	250,00	☐		☐		☑ 250,0	0,500005	☐		☑ 250,0	0,500005	☐		☐		☐	
639411 800 g 9	0,800021	400,01	☐		☑ 400,0	0,800021	☑ 400,0	0,800021	☐		☐		☐		☐		☐	
639411 1,8 kg 7	1,800009	900,00	☐		☐		☐		☑ 900,0	1,800009	☑ 900,0	1,800009	☐		☐		☐	
639411 1,8 kg 8	1,799994	900,00	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4 kg 6A	3,999996	2000,00	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 1	4,500011	2250,01	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 2	4,500002	2250,00	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 3	4,499883	2249,94	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 4	4,500001	2250,00	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 5	4,500013	2250,01	☐		☐		☐		☐		☐		☐		☐		☐	
639411 4,5 kg 6B	4,500008	2250,0	☐		☐		☐		☐		☐		☐		☐		☐	

Malta Competition and Consumer's Affairs Authority

STANDARD AND METROLOGY INSTITUTE

Metrology Directorate

EURAMET 1207

Determination of the Effective Area of a Piston–Cylinder Assembly

1. DUT

1.1 Piston–Cylinder Module

Model	
Manufacturer	DHI
Serial no.	620
KN nominal	50 kPa/kg
Nominal area	196 mm^2

1.2 Platform

Model	PG-7601-CE
Manufacturer	DHI
Serial no.	806

2. REF

2.1 Piston-Cylinder Module

Model	PC-7200-200
Manufacturer	DHI
Serial no.	1371
KN nominal	200 kPa/kg
Nominal area	49 mm^2
Calibration certificate no.	FLUKE DHI 1284544524
Last Calibration date	October 2010

2.2 Platform

Model	PG-7202-CE
Manufacturer	DHI
Serial no.	825

3. MEASUREMENT PROCEDURE

3.1 Cross–Floating

3.2 Gauge Mode

3.3 Nitrogen

1

3.4 Nominal Pressure Range: 0.5 MPa – 1.75 MPa, increments of 0.25 MPa

3.5 (4) cycles; each cycles up and down

3.6 Date Measurements: 12–15/02/2012

4. EVALUATION AND UNCERTAINTY

4.1 Based on EURAMET Guide no. cg–3 v 1.0

5. RESULTS

5.1

Nominal Pressure (g) [/10^6 Pa]	Mean Effective Area (20°C) [/10^{-6} m^2]	Repeatability of Effective Area (20°C) [/10^{-6} m^2]	Standard Uncertainty of Effective Area (20°C) [/10^{-6} m^2]
0.5	196.1206	0.0009	0.0023
0.75	196.1206	0.0007	0.0021
1	196.1202	0.0007	0.0020
1.25	196.1202	0.0006	0.0020
1.5	196.1197	0.0005	0.0019
1.75	196.1201	0.0005	0.0019

5.2 No dependence of the Effective Area on Pressure. Effective Area evaluated as arithmetic mean of values at different pressures:

Effective Area [20°C; (0.5 – 1.75) × 10^6 Pa (g)] = (196.1202 ± 0.0046) × 10^{-6} m^2 (k = 2)

Summary of participant's results in terms of effective areas and corresponding uncertainties.

MIKES

Effective area	Uncertainty $k = 2$	
(mm^2)	(mm^2)	(ppm)
196,1203	0,0067	34

MCCAA

Effective area	Uncertainty $k = 2$	
(mm^2)	(mm^2)	(ppm)
196,1202	0,0046	23