EURAMET Bilateral comparison in high gauge pressure 250 MPa (EURAMET.M.P-S16)

Technical Protocol

Pilot laboratory:

Central Office of Measures (GUM), Poland

1. Introduction

In October 2005 GUM established its CMC entry for high pressure (up to 250 MPa) equal to $2{,}0 \cdot 10^{-4} \cdot p$ based on the old piston cylinder unit of MP-2500 pressure balance. However this level of uncertainty was definitely unsatisfactory, so it was decided to replace aged standard with a new one. As a result new pressure balance was purchased and installed in GUM, in the end of 2013 year.

EURAMET.M.P-S16 comparison project is to give basis for CMC entry update.

2. Participants

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3. Transportation and costs

Transportation of the standard of GUM to and from CMI will be performed by GUM staff, using a company car. Therefore no instruction due to transportation process is needed. All transportation costs are covered by GUM.

Timetable:

Delivering GUM standard to CMI date	42nd week: 12-13.10.2015
Collecting GUM standard from CMI date	44th week: 26-27.10.2015

4. Standards used in comparison

	CMI	GUM
Type	Pressure balance	Pressure balance
Model	PG 7302	CPB6000
Material of piston/cylinder	tungsten carbide/tungsten carbide	tungsten carbide/stainless steel
A_0, effective area at 20 °C without pressure (m^2)	$1{,}961612 \cdot 10^{-6}$	$1{,}961574 \cdot 10^{-6}$
Pressure distortion coefficient (Pa^{-1})	$6{,}2 \cdot 10^{-13}$	$8{,}4 \cdot 10^{-12}$
Linear expansion coefficient of piston/cylinder ($°C^{-1}$)	$9{,}0 \cdot 10^{-6}$	$14{,}5 \cdot 10^{-6}$
Serial no.	PG 7302 / 200 (stand)/2077 (mass set) / 1637 (piston-cylinder)	13091/13088
Manufacturer	DHI	Desgranges et Huot
Measuring range	(5 ÷ 500) MPa	(5 ÷ 250) MPa
Pressure medium	Oil (sebacate)	Oil (sebacate)
Uncertainty	$1{,}9 \cdot 10^{-13} \cdot p^2 + 2{,}3 \cdot 10^{-5} \cdot p + 9$ Pa (p in Pa)	$3{,}9 \cdot 10^{-5} \cdot p + 340$ Pa (p in Pa)

5. Measurement procedures

Method used for measurements is direct comparison between GUM and CMI standards. Following gauge pressure points will be used: (50; 100; 150; 200; 250) MPa of increasing pressure (only in loading) in five measurement series.

The pressure transmitting medium shall be oil (sebacate), which will be provided by GUM. During connection performing the measuring system should be vented, so no gas is left inside tubes.

The height difference should be nullified if it is possible, otherwise the offset should be taken into account. Horizontality of both standards should be carefully checked with the built-in spirit levels and on the top level of the mass loading bells after a significant change of the loaded mass.

Both standards should have valid calibration of their internal sensors (temperature of the piston-cylinder and temperature, pressure and humidity of air). In case there is no internal sensor, external one should be used, with traceability requirement being kept.

Before the beginning of the measurements, it is necessary to provide a suitable check concerning the tightness of the system.

TS is recommended to be located close to the laboratory's reference standard to keep the pressure line between the two instruments as short as possible.

At each measuring point the nominal total mass is to be adjusted, so the equilibrium is kept. Trim masses can be added either on the side of GUM standard or CMI standard. Following data is noted at each point: sensitivity, pressure generated by CMI standard, piston-cylinder temperature of each pressure balance, environmental conditions (temperature, humidity, ambient pressure) and if applicable also the height difference. All this data (except sensitivities) must be accompanied with uncertainty estimation.

The measurements shall be performed at nominal temperature 20,0 ± 0,5 °C.

6. Report of results

A few comments on the type of the piston-cylinder of GUM, the way of determination of its effective area and its estimation of the uncertainty, as well as any usefull information, will be added.

For each standard the pressure will be calculated based on noted data, according to following equation:

$$p = \frac{m_t \cdot g \cdot (1 - \frac{\rho_a}{\rho_m}) + \sigma \cdot c}{A_p \cdot [1 + (\alpha_p + \alpha_c) \cdot (t - t_r)]}$$

where:

p – gauge pressure measured at the bottom of the piston,
m_t – total mass applied on the piston,
g – local gravity,
ρ_a – density of air,
ρ_m – density of weights,
A_p – effective area of the piston-cylinder unit (including pressure distortion coefficients: λ and λ'),
α – linear thermal expansion coefficient (respectively: piston and cylinder)
t – measured temperature of the piston-cylinder assembly during measurements,
t_r – reference temperature of the piston-cylinder assembly,
σ – surface tension of the oil,
c – circumference of the piston.

For each measurement point pressure will be calculated as the average value.
Uncertainty of the pressure measured by the standard shall be calculated according to ordinary laboratory procedures.

The comparison results will be evaluated due to following equation:

$$E_n = \frac{|p_{CMI} - p_{GUM}|}{\sqrt{U_{CMI}^2 + U_{GUM}^2}},$$

where:

p_{CMI}, p_{GUM} – pressure calculated for CMI and GUM standard,
U_{CMI}, U_{GUM} – combined uncertainty calculated for appropriate pressure (k=2).