TRACEABILITY OF AIR PRESSURE CALIBRATIONS AT EARS WMO REGIONAL INSTRUMENT CENTRE

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1. Introduction

Calibration Laboratory of Environmental Agency of the Republic of Slovenia is an important subject in an integral QA system in terms of periodical calibrations of field measuring instruments. CL performs accredited calibrations of measuring instruments in the field of temperature, relative humidity, air pressure and air quality quantities: carbon monoxide, sulphur dioxide, ozone, nitrogen monoxide and nitrogen dioxide.

Accredited laboratory has to establish and maintain traceability to the national or international level. Recognition and analysis of uncertainty sources is most important subject in calibration procedure development and uncertainty evaluation. Traceability schemes and calibration procedures are further presented in the area of air pressure calibrations.

2. Traceability scheme

Traceability of air pressure calibrations is maintained in the range from 500 hPa to 1200 hPa. Calibration laboratory uses dead weight gauge DH 24610 as a reference standard. The basic principle of the dead weight gauge consists of a vertical piston freely rotating within a cylinder. The two elements of good quality define a surface called ‘effective area’. The downward force, generated by the air pressure, is in equilibrium with an upward force generated by dynamometer. The performance of dynamometer is checked by removing the piston and its housing and using set of masses to verify linearity and full scale prior and after calibration. The metrological elements which contribute to overall accuracy of the system are:

- the piston/cylinder assembly refers directly to standards of length,
- the dynamometer is adjusted using master weights,
- the vacuum gauge,
- the temperature of the piston.

Both elements, piston/cylinder and masses, are the subject of calibration certificates showing traceability to national/international standards.
The reference standard is strictly used for working standard comparison calibrations. Calibration laboratory uses Vaisala PTB220AD in the measuring range from 600 hPa to 1100 hPa and Setra M370 from 0 to 1400 hPa. Highly pure nitrogen (N5) combined with pressure regulator (DH PPC1) is used as a pressure media. For barographs and mechanical barometers calibration the Theodore Friedrichs pressure chamber is commonly used. List of Calibration laboratory standards is shown in table 1.

Standard	Type	Range	Status	Recal. Period
Dead weight gauge	DH 24610	0 ÷ 1200 hPa	Reference standard	2 years
Digital barometer	Vaisala PTB 220	600 ÷ 1100 hPa	Working standard	1 year
Digital barometer	Setra M 370	0 ÷ 1400 hPa	Working standard	1 year
Digital multimeter	Keithley 2000	0 ÷ 1000 VDC 0 ÷ 10 MΩ	Working standard	1 year

Barometric chamber	Lambrecht 8700.0000	40 ÷ 1100 hPa	Medium generator	-
Pressure regulator	DH PPC1	0 ÷ 7000 hPa	Medium generator	-
Vacuum pump	Leybold	-	-	-

Table 1: List of Calibration laboratory standards

The elements of reference standard, piston/cylinder assembly, masses and piston’s temperature, are recalibrated in Slovenian national accredited laboratories: Institute of metals and technology, Metrology institute of the Republic of Slovenia and Calibration laboratory itself for temperature sensor. Recalibration period is two years. Working standard are recalibrated annually by comparison with dead weight gauge.

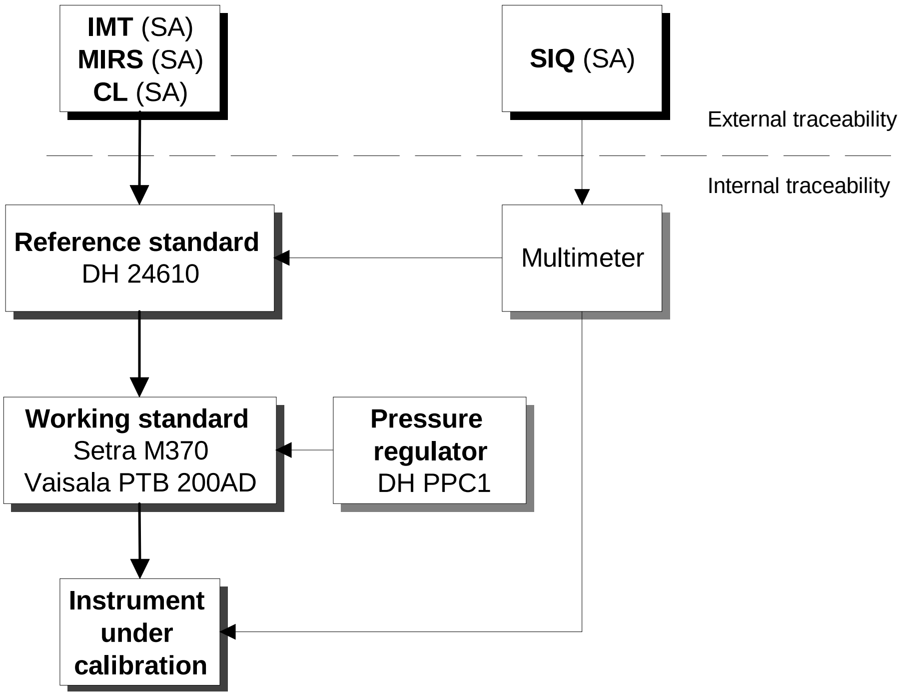

Figure 1: Air pressure calibrations traceability scheme

The equation for calculation of pressure using dead weight gauge is derived from equation of pressure of pressure balance:

$$p = (1 - L \cdot p) \cdot k_n \cdot \frac{g_l}{g_n} \cdot \frac{N}{N_K} \cdot \frac{\rho_m - \rho_a}{\rho_m - 1{,}2} \left[1 - (\alpha_p + \alpha_c) \cdot (t - 20)\right] + \mu + \rho_a \cdot g_l \cdot h$$

Parameter	Description
L	Pressure deformation coefficient [0,000 Pa^{-1}]
p	Measured pressure [Pa]
kn	Measured pressure to mass conversion coefficient of the piston/cylinder assembly at 20°C (calibration certificate) [20,00270 kPa/kg]
gl	Local gravity [9,80615880 m/s^2]
gn	Standard gravity [9.80665 m/s^2]
N	Readout at the DPG [dig]
Nk	Dynamometer readout at 1 kg weight [100 000 dig]
ρ_m	Volumic mass of the weight's metal– stainless steel AISI 304 L [7920 kg/m^3]
ρ_a	Volumic mass of the air at calibration place [kg/m^3]

1,2	Standard air density - agreed value [1,2 kg/m^3]
α_p	Linear thermal expansion coefficient of the material of piston [0,45.10^{-5} /°C]
α_c	Linear thermal expansion coefficient of the material of cylinder [0,45.10^{-5} /°C]
t	Temperature of piston/cylinder assembly [1/°C]
μ	Residual pressure [Pa]
h	Difference in heights between reference and working standard [m]

The major contributions in uncertainty budget of reference standard is uncertainty of pressure to mass conversion coefficient, reproduceability and linearity of dynamometer. Expanded uncertainty of our reference standard in the range from 500 hPa to 1100 hPa is $5.5 \cdot 10^{-5} \cdot p$ +5 Pa.

3. Working standard

Working standards are used for dissemination of unit of pressure by comparison calibrations of field measuring instruments. Calibration laboratory uses Vaisala PTB220AD in the measuring range from 600 hPa to 1100 hPa and Setra M370 from 0 to 1400 hPa. The calibration system is shown on figure 2:

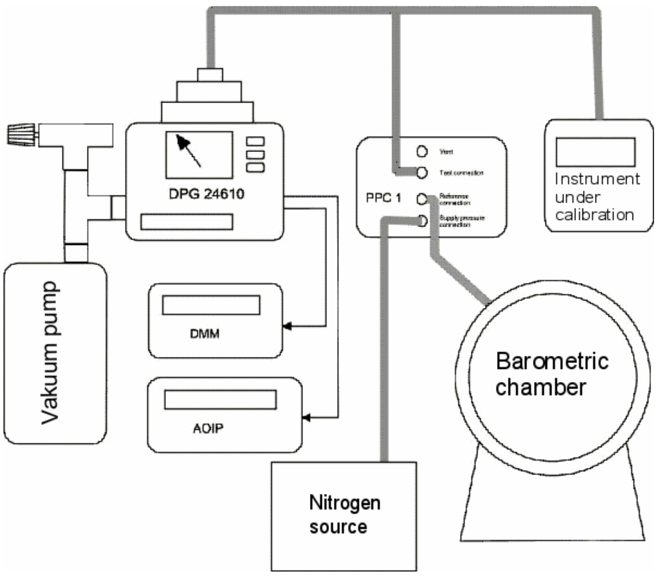

Figure 2: Working standard calibration system

Calibration procedure consists of 7 steps:

1. Warm up of completely assembled system. During warm up all components reach temperature equilibrium. This is particularly important for the piston cylinder assembly (PCA) and the dynamometer which operates in the vacuum. This step lasts at least 16 hours.
2. Calibration of the dynamometer. In this step the PCA is removed and 4 kg weights are placed on the dynamometer and removed from it to enter the gain. Finally the whole range of the dynamometer is checked using six 1 kg weights.
3. Warm up of completely assembled system. Since during the calibration of the dynamometer it was exposed to the atmosphere it is necessary to reach temperature equilibrium in the vacuum again. This step lasts at least 4 hours.
4. Zeroing of the dynamometer by applying vacuum above the PCA too.
5. Calibration of instrument being calibrated itself. It is carried out in three cycles of increasing and decreasing pressure from minimum to maximum value in 10% steps.
6. Check of offset of the dynamometer by applying vacuum above the PCA too.
7. Check of linearity of the dynamometer as in step 2.

Expanded uncertainty of working standard is 12 Pa. The relative contributions of uncertainty components in working standard calibration is shown in chart 1:

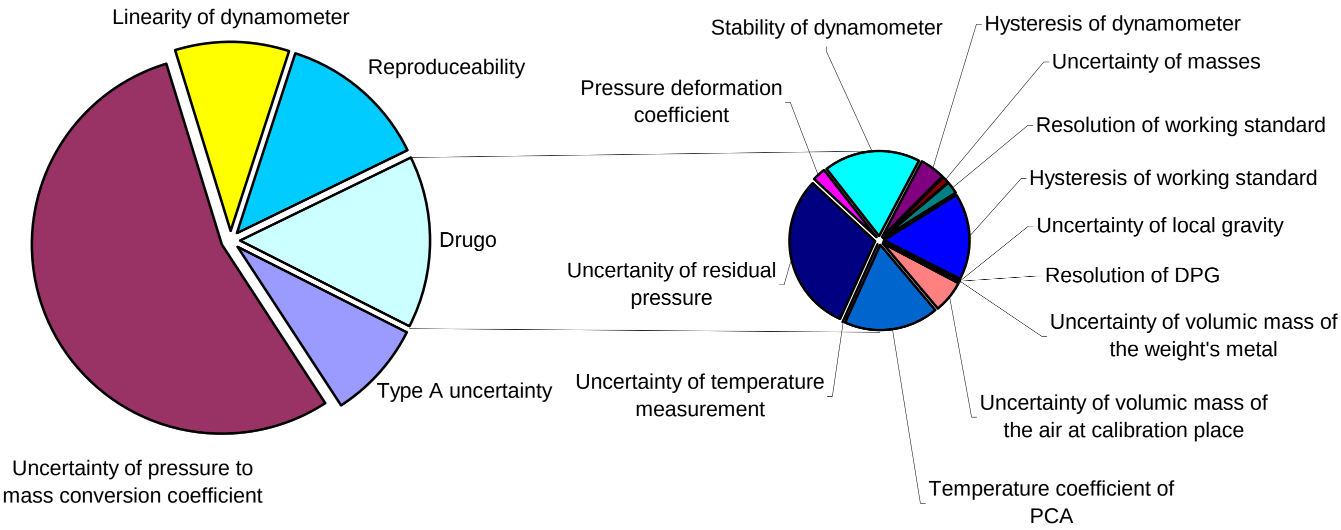

Chart 1: Relative contributions of uncertainty components

4. Analysis of influence quantities for on-site air pressure measurements

The most important influencing quantity of electronic barometers is constantly changing environmental temperature. Calibration laboratory analyzed the influence of temperature to different types of electronic barometers. As a reference instrument the Vaisala PTB 220AD was used for air pressure measurement in the laboratory environment. Two Setra M270 and one Vaisala PTB220 were placed in climatic chamber. The influence of air fluctuations inside the chamber was avoided using small tubes to introduce the air pressure. The test conditions in the climatic chamber were: relative humidity 50%± 5% and the temperature was changed from -20°C to 40°C in 10°C intervals. The results of the test are shown in chart 2.

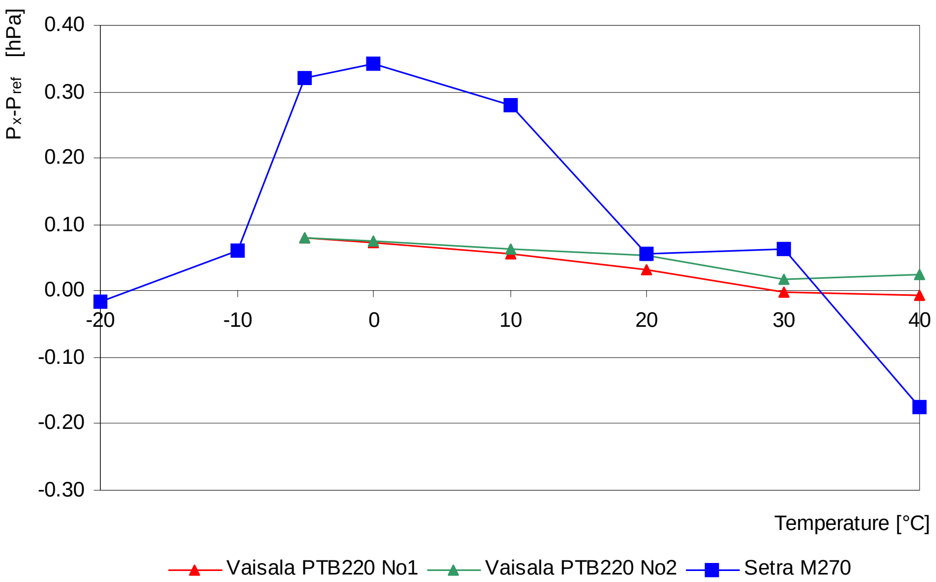

Chart 2: Temperature influence

As shown on chart 1 Vaisala PTB220 barometers have good built-in temperature compensation. The deviations did not exceed manufacturer's specification 0.1 hPa in temperature range form 0°C to 40°C. Setra M270 showed slightly stronger temperature dependency. Maximum difference compared to a reference instrument was 0.35 hPa.
Calibration laboratory also tested the response of electronic barometers on a temperature change. We decided the 10°C change in 20 minutes (from 0°C to 10°C) which represent extreme conditions. The maximum difference in case of Vaisala barometers did not exceed 0.1 hPa. The results are shown in chart 3:

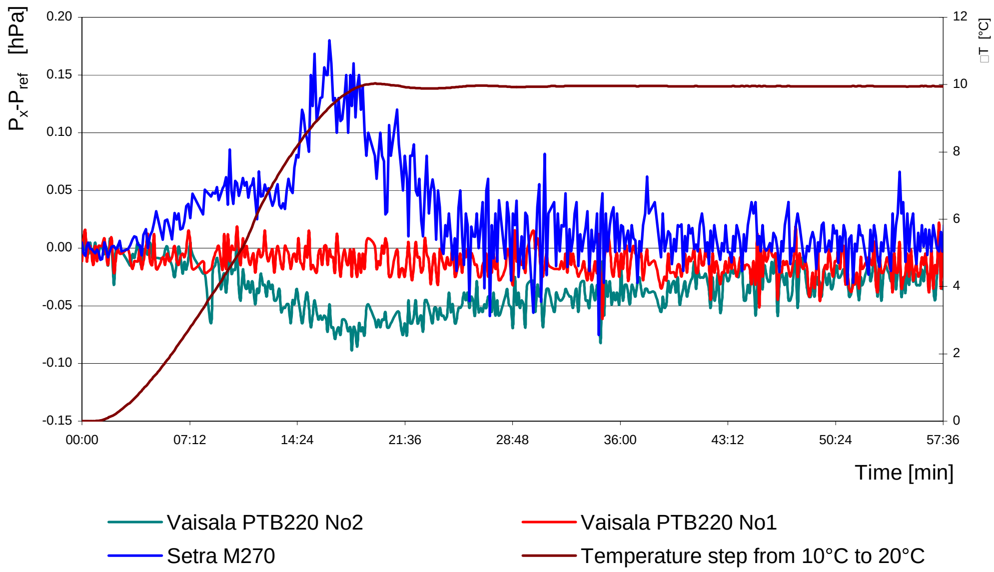

Chart 3: Barometers response on temperature change

Calibration laboratory also tested influence of relative humidity on electronic barometers. The climatic chamber test conditions were following: relative humidity at 20%, 50% and 90% were introduced at 0°C, 23°C and 40°C. The results are shown in chart 4:

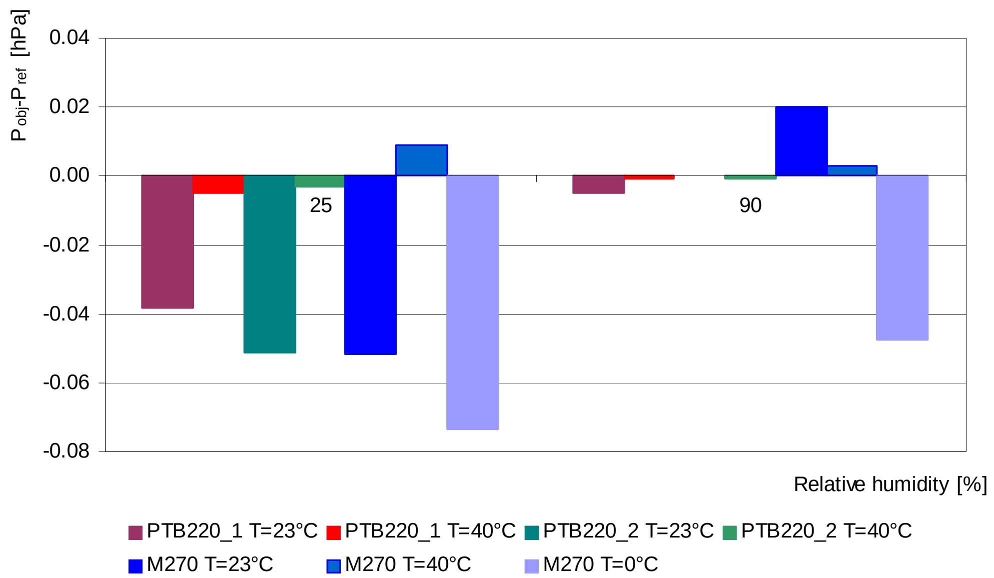

Chart 4: Relative humidity infulence

5. Conclusion

The expanded uncertainty of electronic barometers used in our meteorological network in laboratory conditions is 17 Pa. When barometers are installed at a measuring site the measuring uncertainty increases due to environmental conditions: temperature influence, a/d converter of automatic station, drift of barometer, etc. An estimation of expanded uncertainty for *in-vivo* measurements is 30 Pa.
Relative uncertainty contributions of influenced quantities in air pressure measurements in meteorological network are shown on chart 5:

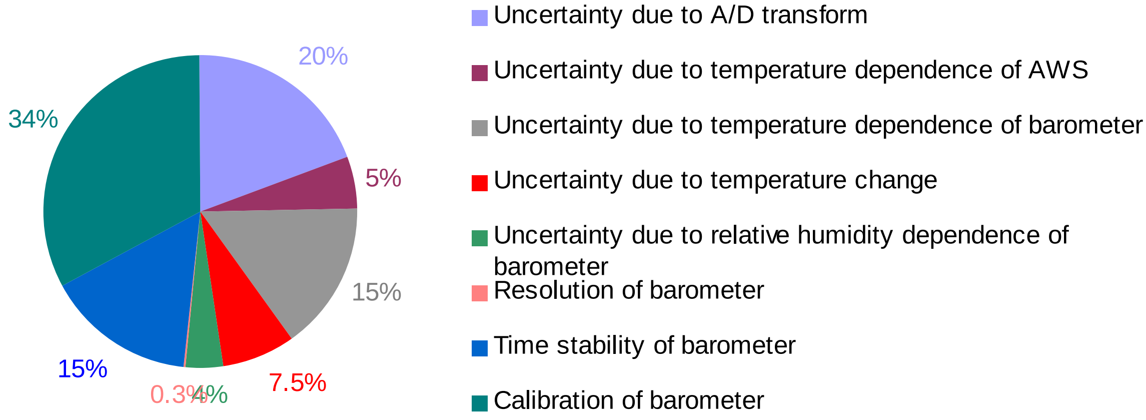

Chart 5: Relative uncertainty contributions of influenced quantities in air pressure measurements in meteorological network

6. Reference

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