Calibration of barometers
(Lecture and Training)
Outline

1. How to maintain observation accuracy of atmospheric pressure in JMA
2. How to calibrate the mercury barometers
3. How to calibrate the electric barometers
How to maintain observation accuracy of atmospheric pressure in JMA
Traceability of pressure

National Primary Standard

Air piston gauge
Air piston gauge AV-02 (Futaba Sokki, Japan)
Weights (Futaba Sokki, Japan)

JMA Standard

Digital barometer resonator barometer
PTB220 (Vaisala, Finland)
RPM4 (DHI, USA)
F-452 (Yokogawa, Japan)

Working Standard

Digital barometer
PTB330, PTB220 (Vaisala, Finland)

Working Standard (Traveling Standard)

Digital barometer
PTB330, PTB220 (Vaisala, Finland)

Observatory (JMA)

Field Instruments

Mercury U-tube barometer using interferometer

Meteorological Instrument Center (JMA)

Calibration: every year

Calibration: every year (surface observatory)
: every 2 years (aviation observatory)

Calibration: every 3 years
How to calibrate the mercury barometers
The principle of mercury barometer

- Vernier
- Knob
- Attached thermometer
- Ivory needle
- Adjustable screw

Diagram:
- Torricellian vacuum
- Atmospheric pressure
- Height
- Mercury
How to calibrate the mercury barometers?

(a) Installation

(b) Calibration

Calibration of the mercury barometers against the electric barometer (standard barometer)
(a) Installation

Align the heights of the ivory needle and the sensor inside the electric barometer.
How to read a mercury barometer

(1) Read the value of the attached thermometer as quickly as possible

(2) Tap the vessel of mercury a couple of times gently and turn the adjustment screw slowly to raise mercury surface until it contacts the tip of an ivory pointer slightly.

(3) Tap the mercury barometer a couple of times gently and turn the vernier adjustment screw, and align the top of the mercury column with the zero line of the vernier. Never turn the adjustment screw any more.

(4) Check again whether the tip of the ivory pointer contacts a mercury surface slightly.

(5) Check again whether the top of mercury column is aligned with the zero line of the vernier, read the value of pressure.

(b) Calibration
Notes for (2)
Check the position of the tip of the ivory pointer carefully to avoid parallax errors.

Keep a pit being made onto the surface. In this case, turn an adjustment screw left and lower the mercury surface.

Notes for (5)
Keep an eye on the vernier coming into contact with the top of mercury column!!
Check the position of vernier carefully by making visual identification in a vertical direction.
How to read the electronic barometer

(1) Read the pressure value on the display and write it down in the calibration sheet.

(2) Write down a correction value corresponding for a calibration point nearest from the measured value in the calibration sheet.

Real pressure value = The pressure value on the display + the correction value
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<th>読み取り値</th>
<th>標準気圧計の読取り値</th>
<th>入力データの種類</th>
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補正値 = - (①)
How to calibrate the electric barometer
Principle of Atmospheric Pressure Measurement

Electronic Barometer

Measurement of electrostatic capacity

Atmospheric pressure

Silicon diaphragm

Glass substrate

Vacuum gap

Electrode I

Electrode II

Atmospheric pressure: small

Electrostatic capacity: small

Vacuum gap

Atmospheric pressure: large

Electrostatic capacity: large

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Japan Meteorological Agency
How to calibrate the electric barometers

(a) Installation

(b) Calibration

Calibration of the electric barometers against the electric barometer (standard barometer)
(a) Installation

Ensure there are no leaks.

Align the heights of both of the sensors inside electric barometers.
Standard barometer

Barometer to be calibrated

Pressure adjuster
decrease

Calibration (Pressure inspection)

Calibration points 880, 920, 960, 1000, 1040 (hPa)

3 times

increase
### The calibration sheet of Electric barometer

<table>
<thead>
<tr>
<th>Calibration point</th>
<th>Standard barometer</th>
<th>Reading</th>
<th>Correction value</th>
<th>Pressure value</th>
<th>Difference between reading of standard barometer and calibrator at each selected point</th>
<th>Difference between adjacent calibration points</th>
<th>Index error</th>
<th>Hysteresis error</th>
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**Correction value:**
- 880: $- (1)$
- 920: $- (2)$
- 980: $- (3)$
- 1000: $- (4)$
- 1040: $- (5)$
Appendix: mercury barometer
Corrections for temperature

The temperature correction means to correct a barometric reading, obtained at a certain temperature, to a value when mercury and graduation temperatures are 0 °C. The temperature of the attached thermometer is used for this purpose.

The height of the mercury column varies with temperature, even the atmospheric pressure is unchanged. The graduation of the barometer is engraved so that the correct pressure is indicated when temperature is 0 °C. In a case that when temperature is above 0 °C, the graduation expands and the measured value will be smaller than the true value. This effect of temperature must be corrected from these two aspects collectively. Correction for the expansion and contraction of mercury is much larger than that for the expansion and contraction of the graduation.

The correction value for temperature \( C_t \) is expressed as follows:

\[
C_t = \left( H - H_0 \right) \mu \left( t - t_0 \right) + \left( H_0 - H_0 \right) \lambda \left( t - t_0 \right)
\]

where:
- \( H \) is the barometric reading.
- \( t \) °C is the temperature indicated by the attached thermometer.
- \( \mu \) is the volume expansion coefficient of mercury. (18.18 \times 10^{-5} \text{ (°C)}^{-1})
- \( \lambda \) is the linear expansion coefficient of the tube. (1.84 \times 10^{-5} \text{ (°C)}^{-1})

There is a small difference in absolute values for correction between temperatures below and above 0 °C. The values for correction at temperatures above 0 °C are negative and those below 0 °C are positive.

Corrections for gravity

Gravity affects the height of the mercury column. After the corrections for temperature, the reading under the local acceleration of gravity has to be reduced to the one under the standard gravity acceleration. This is called corrections for gravity.

The gravity value for correction \( C_g \) is derived by:

\[
C_g = H_0 - H = H - \frac{g - g_0}{g_0}
\]

where:
- \( g_0 \) is the standard gravity acceleration. (980.665 cm/s^2)
- \( g \) is the gravity acceleration at a calibration point. (TSUKUBA: 979.949 cm/s^2)
- \( H_0 \) is the barometric reading after the temperature corrections.
- \( H \) is the value already corrected for gravitation.

The gravity acceleration used in corrections for gravity value is calculated to the fifth decimal place, in m/s^2. When the gravity acceleration at the observing point is larger than the standard gravity acceleration, the gravity value for correction is positive. Otherwise, the value for correction is negative.

To use a barometer for regular observations at a particular location, a synthesis correction table that summarizes values for correction for index error, temperature and gravity should be used.