Calibration of Barometers

(Theory and Practice)

Japan Meteorological Agency

Feb. 21, 2013

JMA/WMO Training Workshop on Calibration and Maintenance of Meteorological Instruments in RA II

Contents

§ 1 Calibration of barometers (theory)

JMA/WMO Training Workshop on
Calibration and Maintenance of
Meteological Instruments in RA II

1)Traceability of pressure (JMA's traceability)

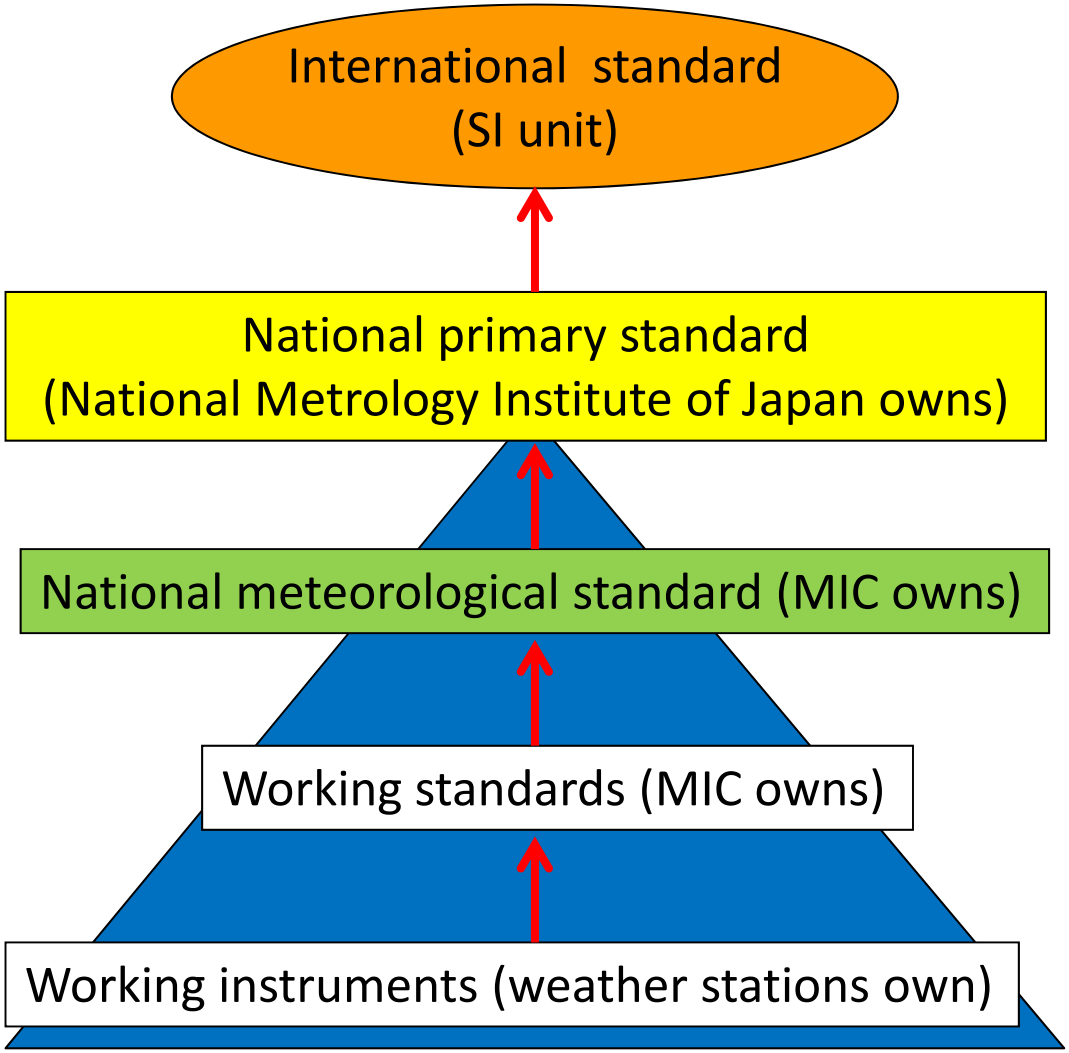


Fig.1 traceability of pressure

metrological traceability is defined by VIM ※ as

"property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty"

※ International vocabulary of metrology - Basic and general concepts and associated terms(VIM), (ISO/IEC Guide 99:2007)

Traceability of Pressure (JMA)

National Primary Standard	JMA Standard	Working Standard	Traveling Standard	Working Instruments
National Metrology Institute of Japan	Meteorological Instruments Center (JMA)			Observatories (JMA)
Mercury U-tube barometer using interferometer	Air piston gauge Air piston gauge AV-02 (Futaba Sokki, Japan) Weights (Futaba Sokki, Japan)	Digital barometer resonator barometer PTB220(Vaisala, Finland) RPM4(DHI, USA) F-452 (Yokogawa, Japan)	Digital barometer PTB330, PTB220 (Vaisala,Finland)	Digital barometer PTB330, PTB220 (Vaisala,Finland)

Calibration interval : every 3 years

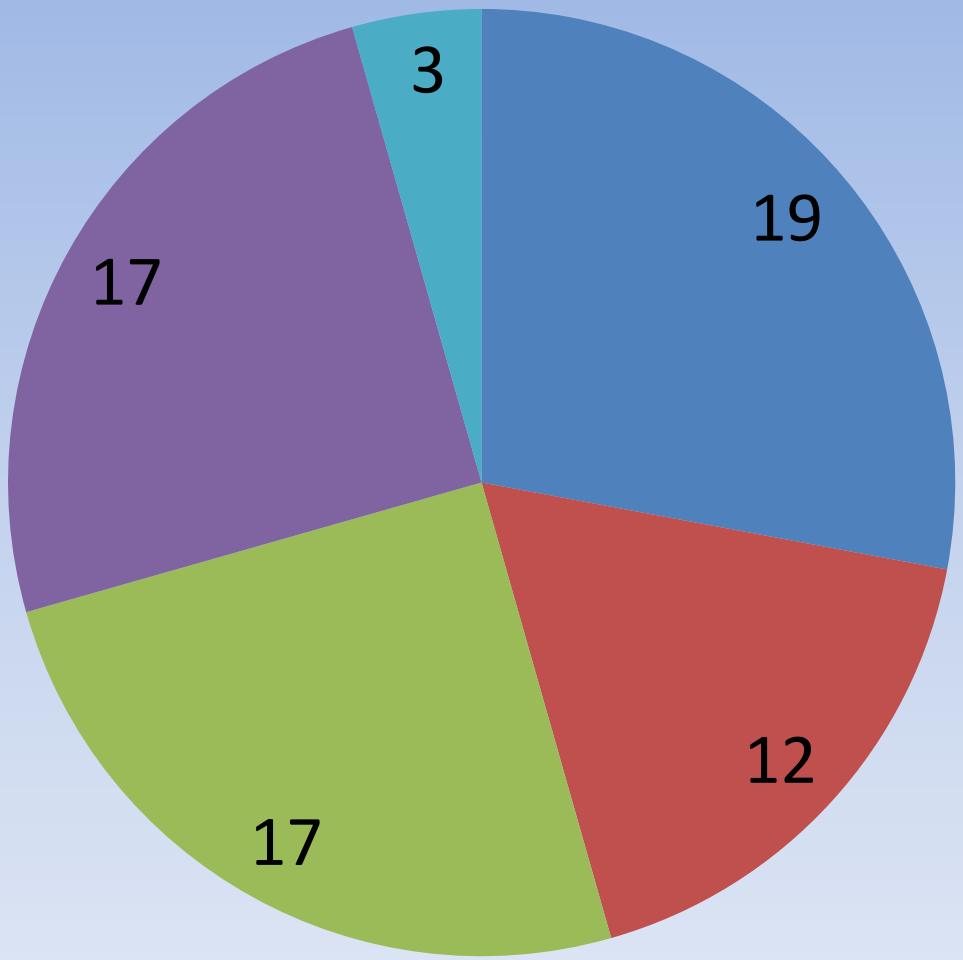
Calibration interval : every year

Calibration interval : every year

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

Replies to the questionnaire※ on barometers

What kind of barometers are you using for observations？



mercury barometer

aneroid barometer

barograph

electronic barometer

others

※ 24 countries of RA Ⅱ replied in 2011, multiple answers allowed

2) a. Mercury barometer

principle

atmospheric pressure is balanced against the weight of a column of mercury. For normal meteorological purposes, the length of the mercury column is measured against a scale graduated in units of pressure.

characteristics

- very delicate and difficult to transport;
- it is difficult to maintain the instrument and to clean the mercury;
- the instrument must be read and corrections applied manually;
- mercury vapor is highly toxic; → there is an increasing move away from the use of mercury barometers ;

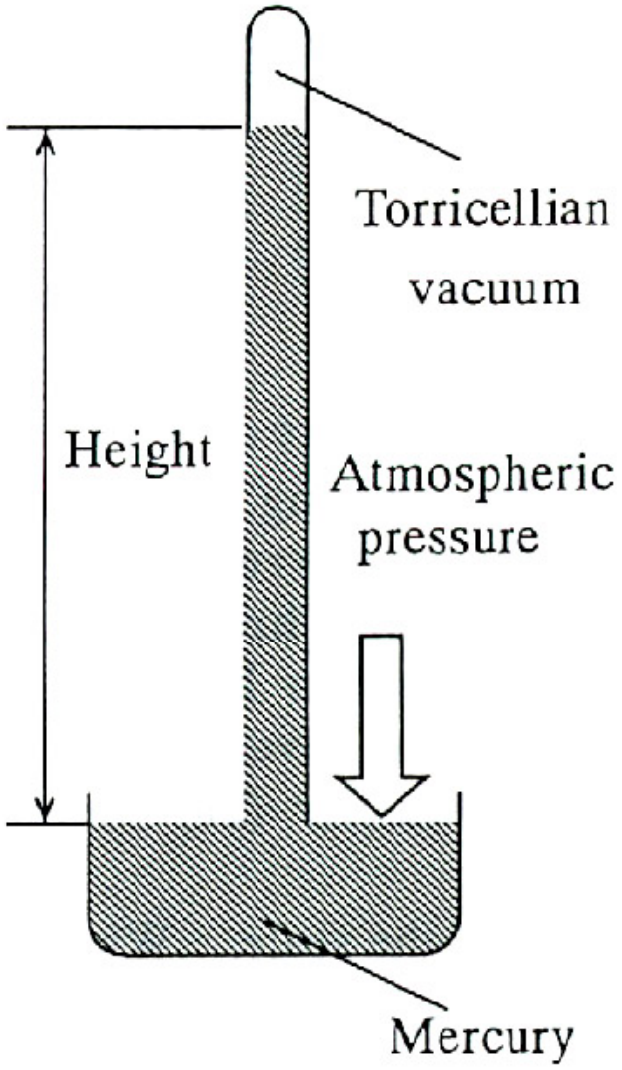


Fig.2 principle of mercury barometer

Mercury barometer (parts)

Fig.3 mercury barometer

2)b. Aneroid barometer

Characteristics

- compactness and portability
- easier to handle and use
- lower accuracy than mercury barometers

Fig.4 aneroid barometer

Principle (mechanism of aneroid barometer)

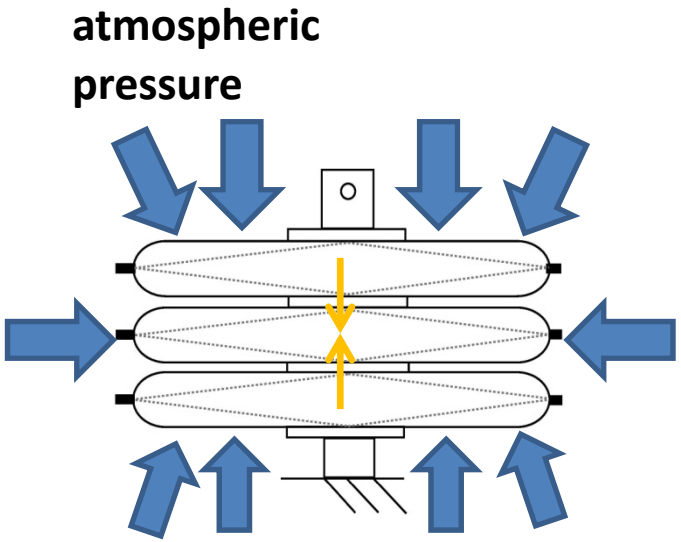


Fig.5 barometer capsule

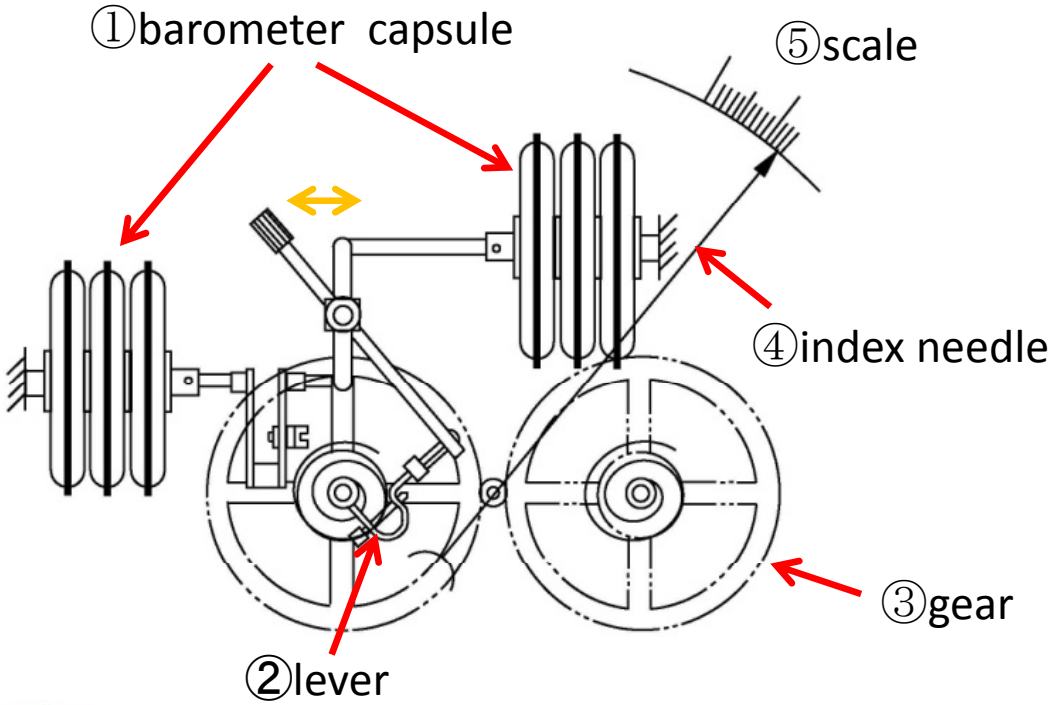


Fig.6 mechanism of aneroid barometer

Fig.7 aneroid barometer

Barograph (aneroid)

principle

The principle of the aneroid barograph is similar to that of the aneroid barometer, except that a recording pen is used instead of an index needle.

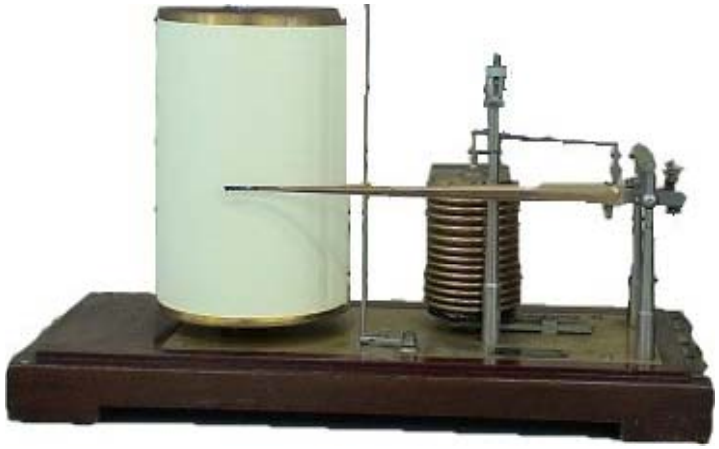


Fig.12 aneroid barograph

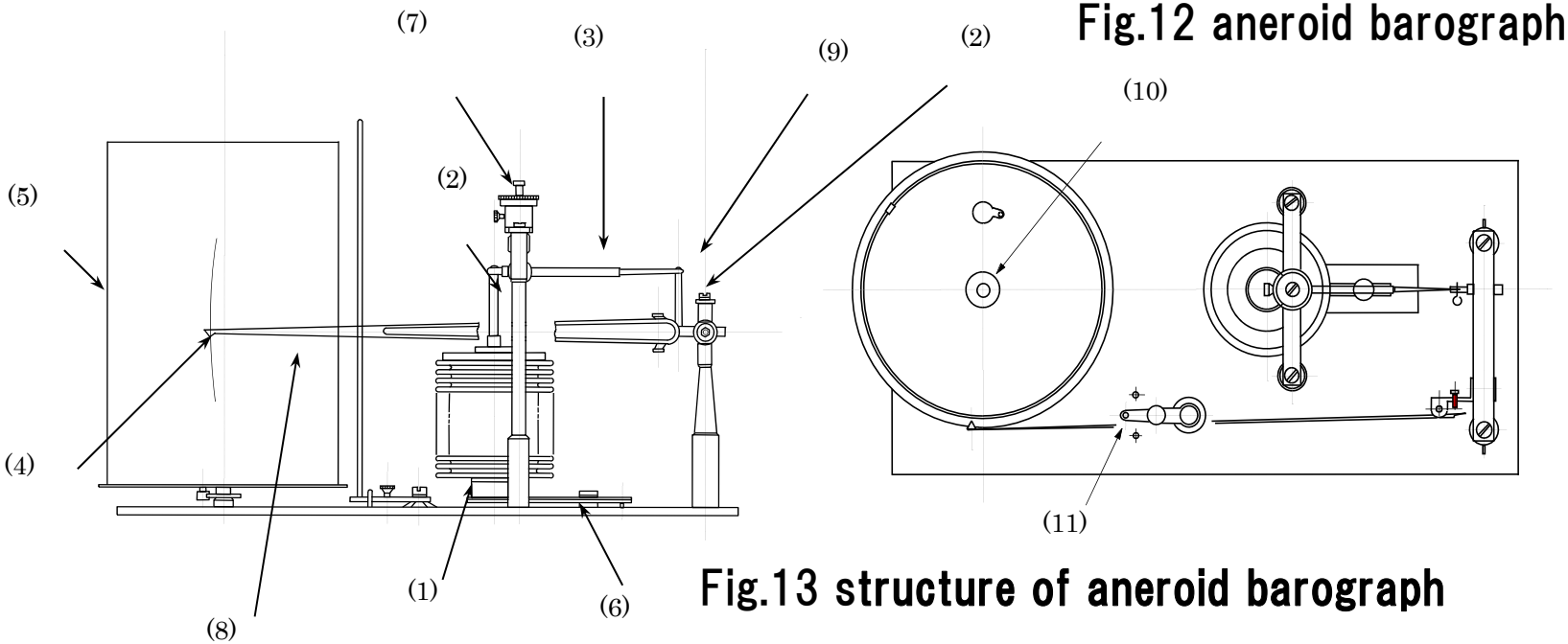


Fig.13 structure of aneroid barograph

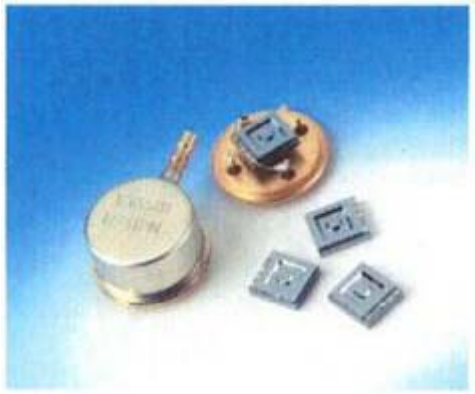
(1) Barometer capsule (2) Reed (3) Lever (4) Recording pen (5) Clock-driven drum (6) Bimetallic compensator(7) Indicator adjusting knob (8) Pen arm (9) Pin with ring (10) Holding screw of the clock-driven drum (11) Gate suspension arm.

2) c. Electronic barometer

principle

Most barometers make use of transducers which transform the sensor response into a pressure-related electrical quantity in the form of either analogue signals or digital signals. Monitors and data-acquisition systems, such as those used in automatic weather stations, are frequently used to display digital outputs or digitized analogue outputs.

Fig.8 electronic barometer



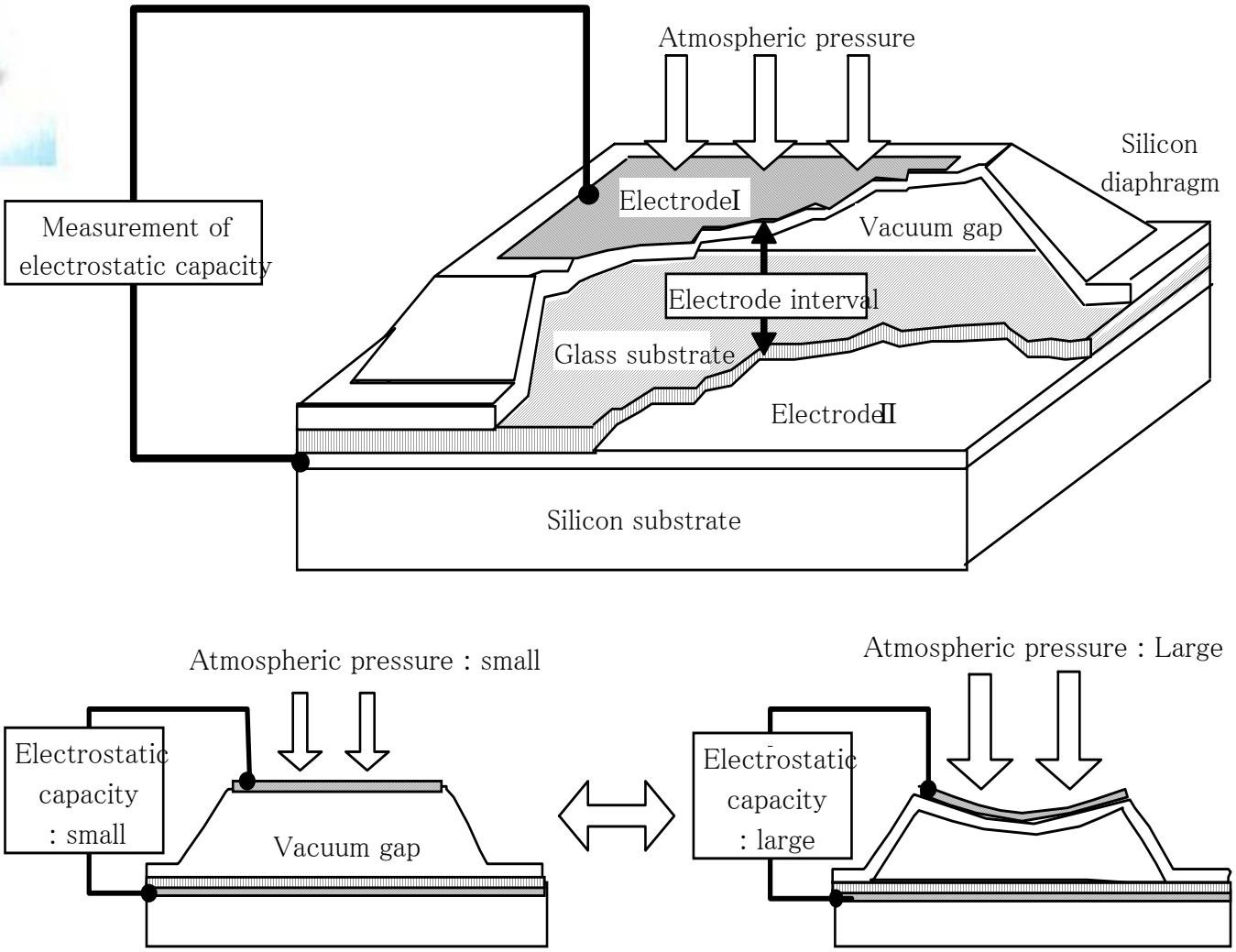
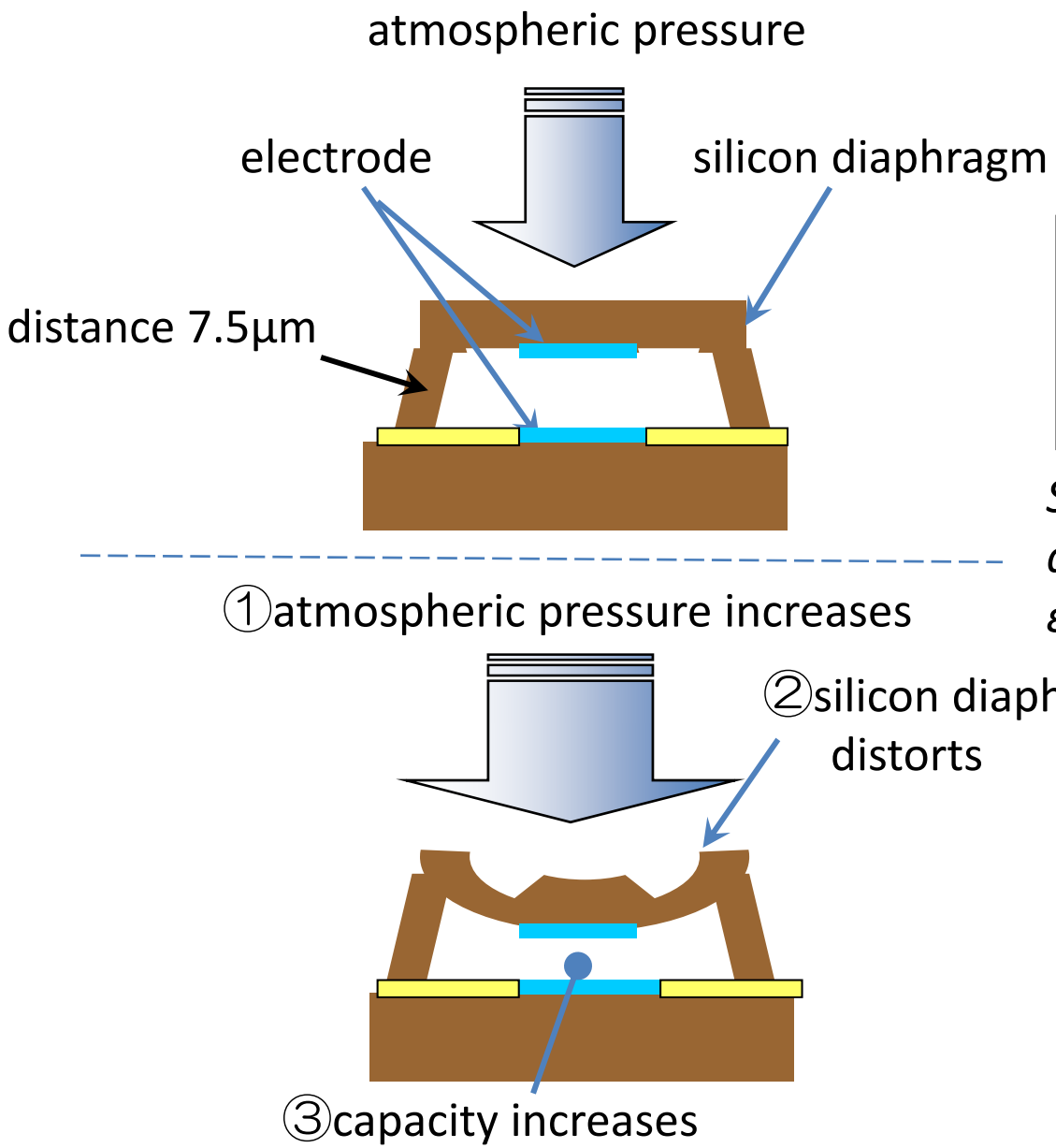


Fig.9 mechanism of electronic barometer's sensor



$$Capacity = \varepsilon_0 \frac{S}{d}$$

S = area of electrode

d= distance between electrodes

ε_0 = dielectric constant of vacuum

Fig.10 mechanism of electronic barometer's sensor

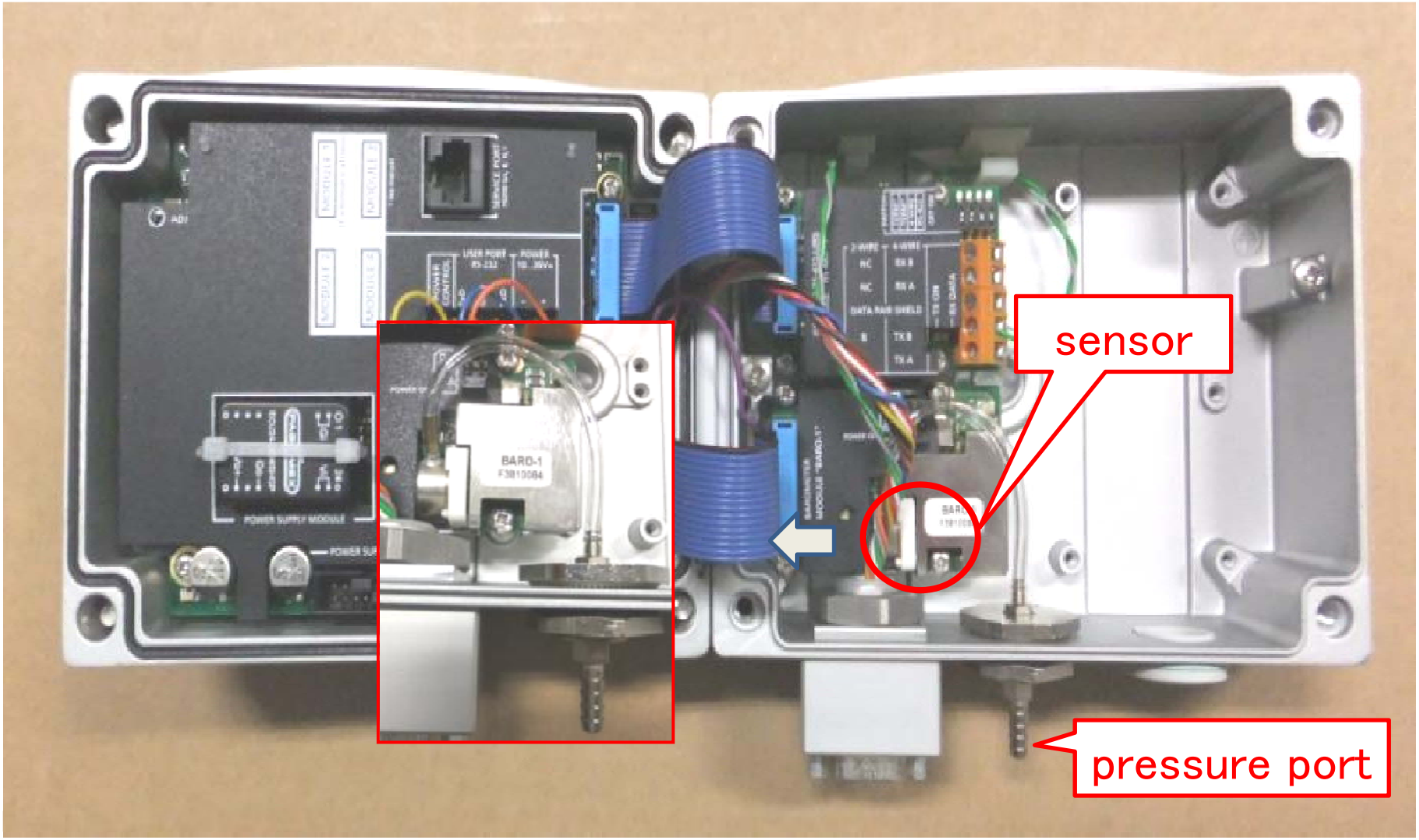


Fig11. PTB330, Vaisala

Sensors measuring pressures

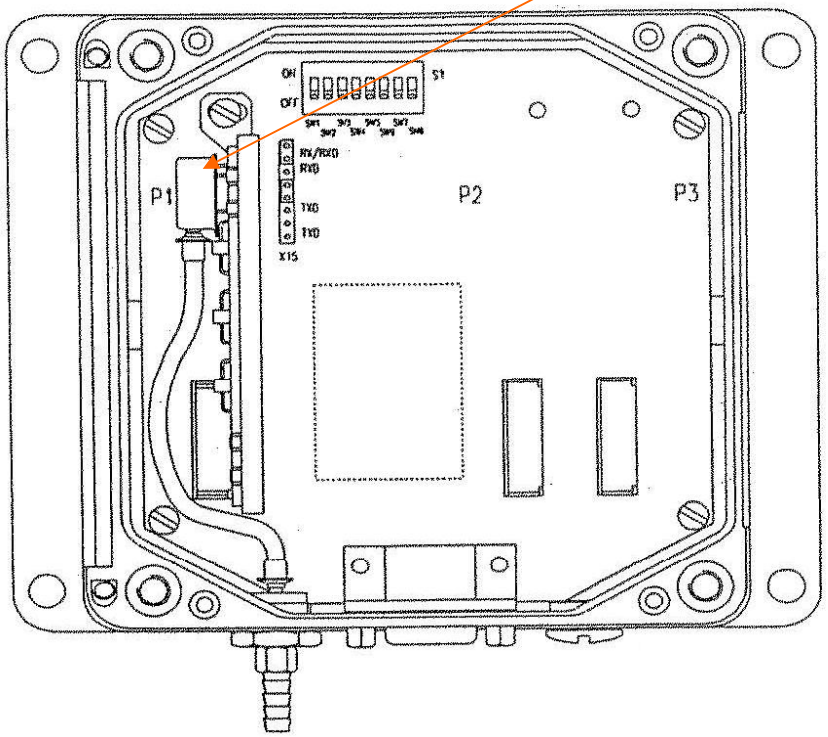


Fig.12 one-sensor type

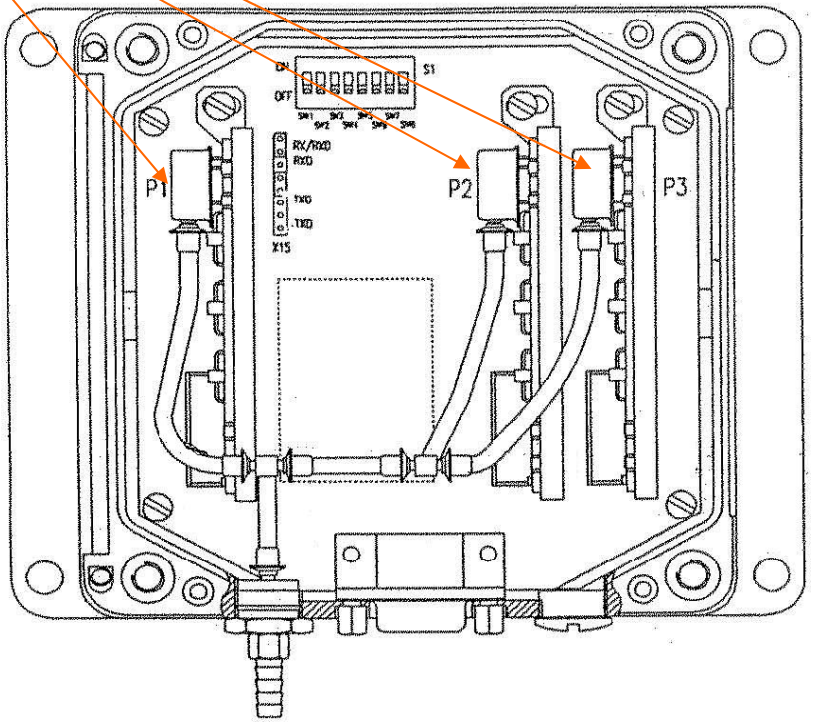


Fig.13 three-sensor type

2) d. Air piston gauge

WMO-CIMO requires 0.1 hPa as the desirable accuracy of field barometers, and ±0.3 hPa in the practical operation.

Thus, standard instruments are required to be more accurate. This **air piston gauge** satisfies these requirements.

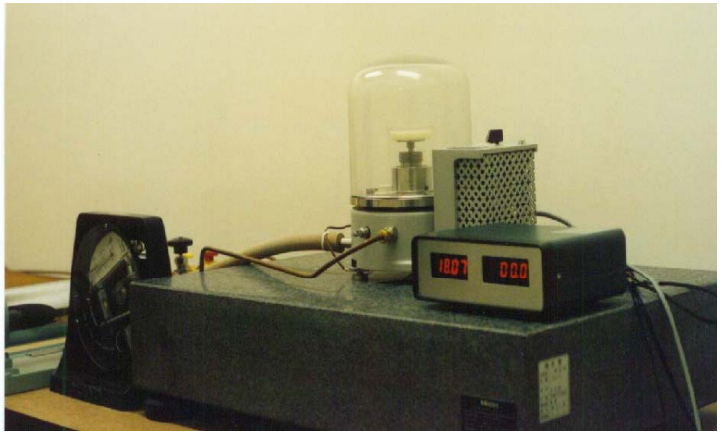


Fig.14 air piston gauge

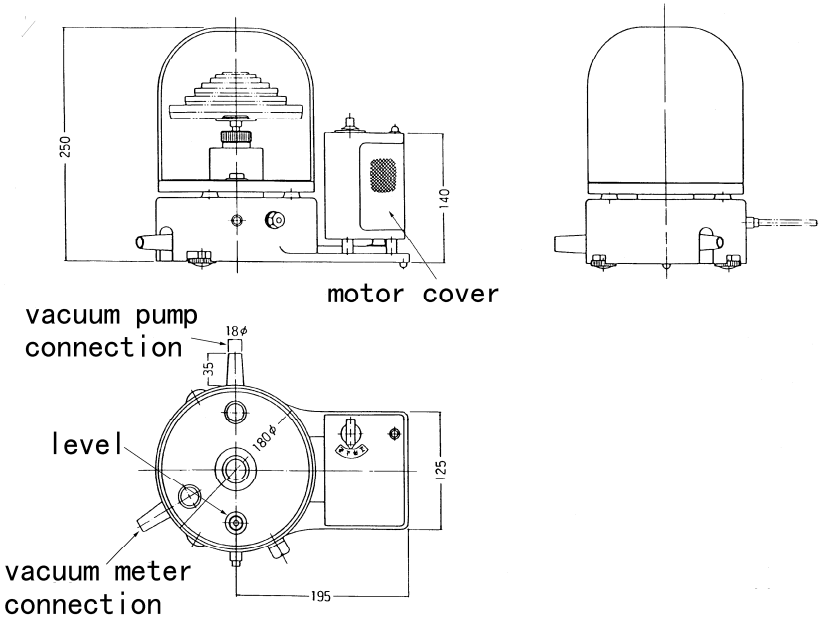


Fig.15 air piston gauge
(front view & top view)

Air piston gauge

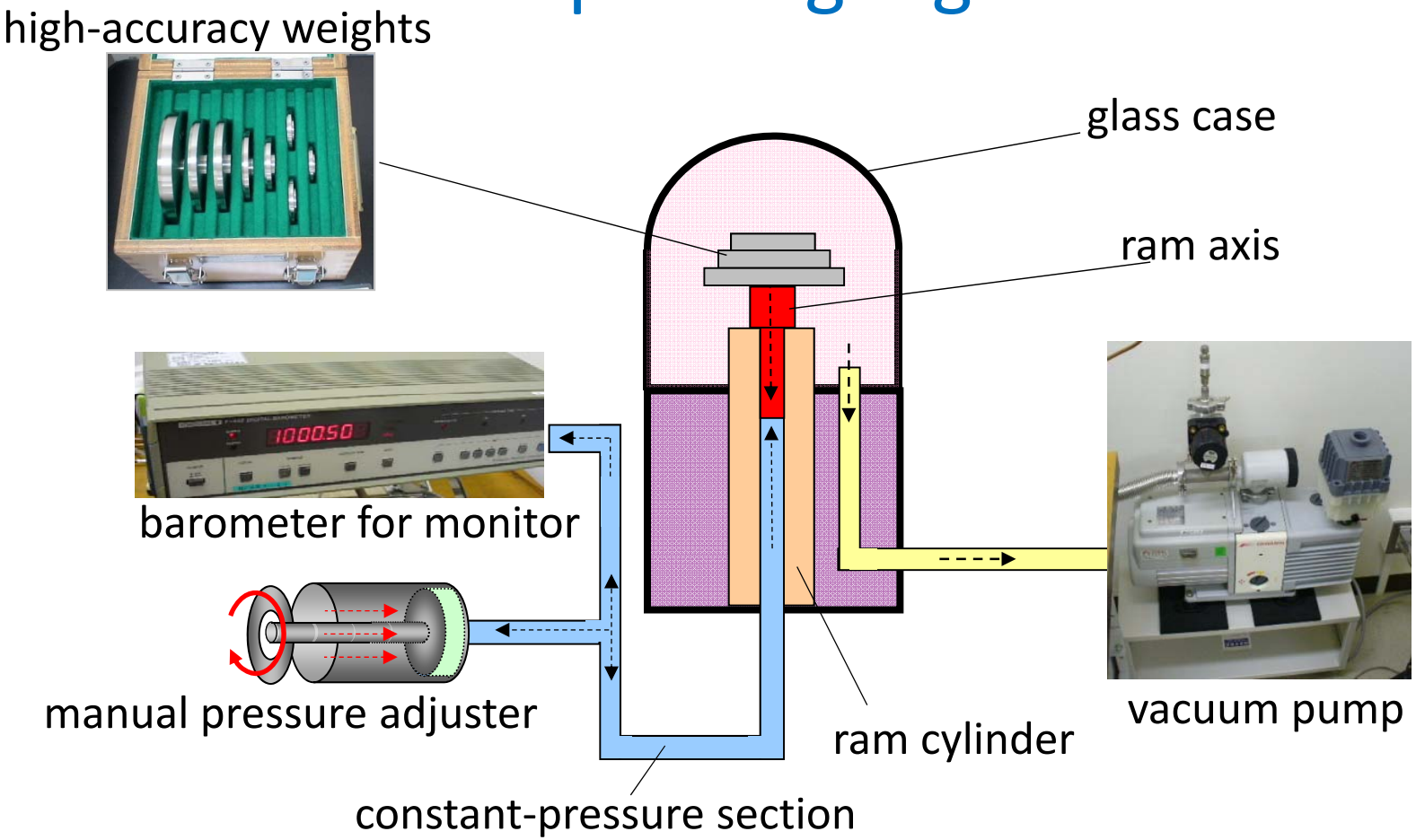


Fig.16 principle of air piston gauge

Principle

The air piston gauge produces an accurate pressure by balancing the vacuum section (the upper part) and the constant-pressure section (the lower part). Pressure in the lower part is determined by placing an approved high-accuracy weight on the upper part.

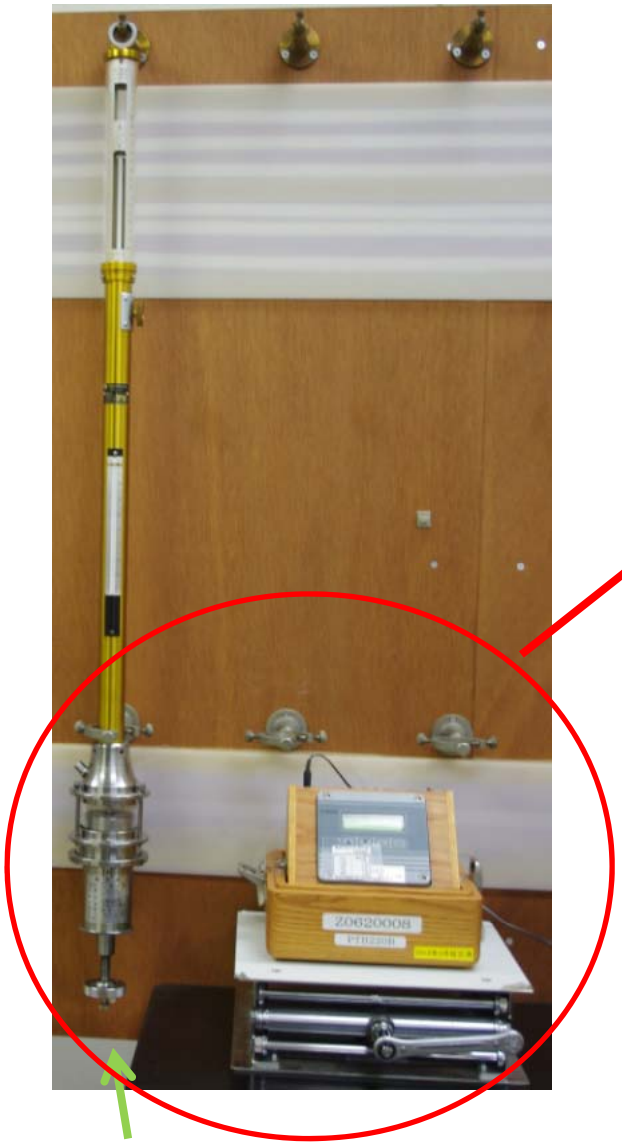
Calibration 1 (mercury barometer)

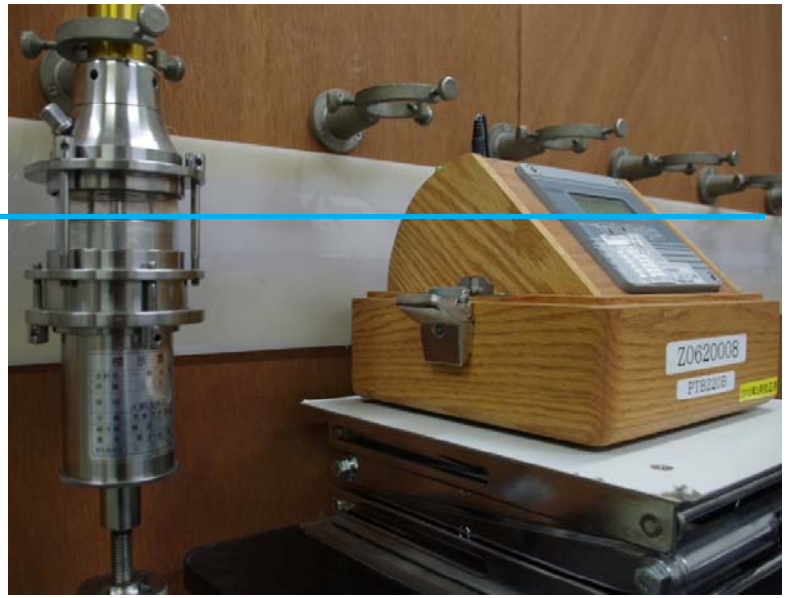
Conditions for calibration

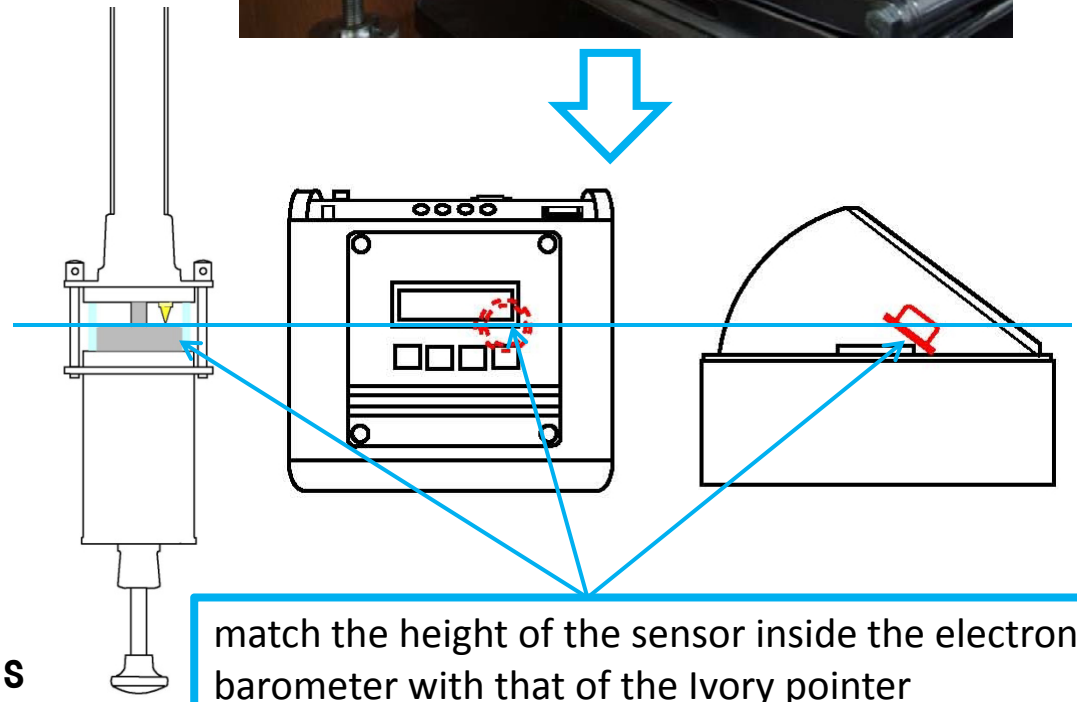
- pressure change of 1 hPa/h or less
- wind velocity of 3 m/s or less

Important points

- 20 atmospheric pressure readings should be taken.
- numbers of readings of atmospheric pressure showing a tendency of increase and a tendency of decrease should be approximately identical.
- the same person must take all measurements to prevent reading errors.
- temperature correction and gravity correction must be applied to mercury barometer readings.







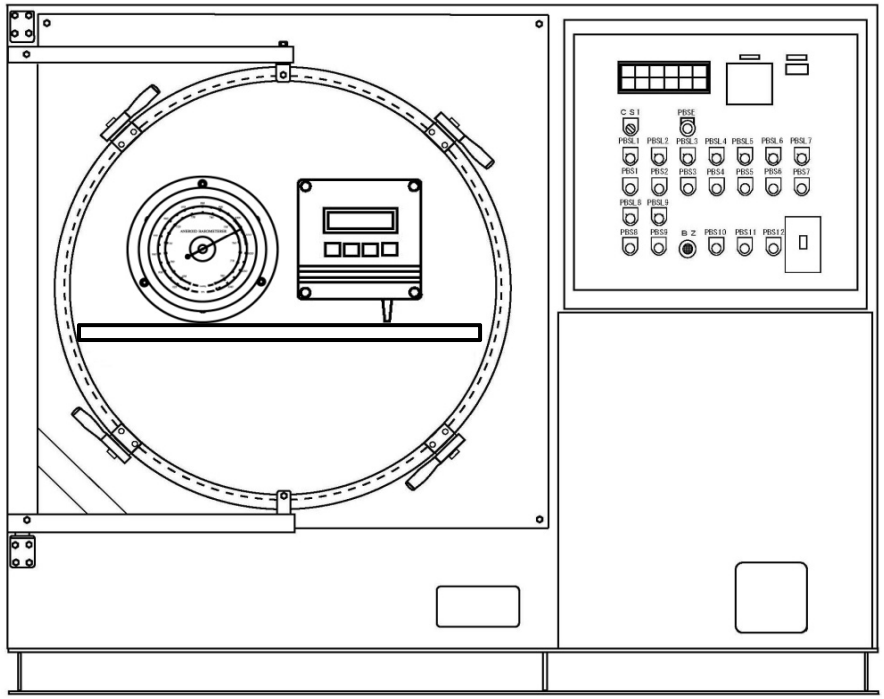
match the height of the sensor inside the electronic barometer with that of the Ivory pointer

Fig.17 installing barometers

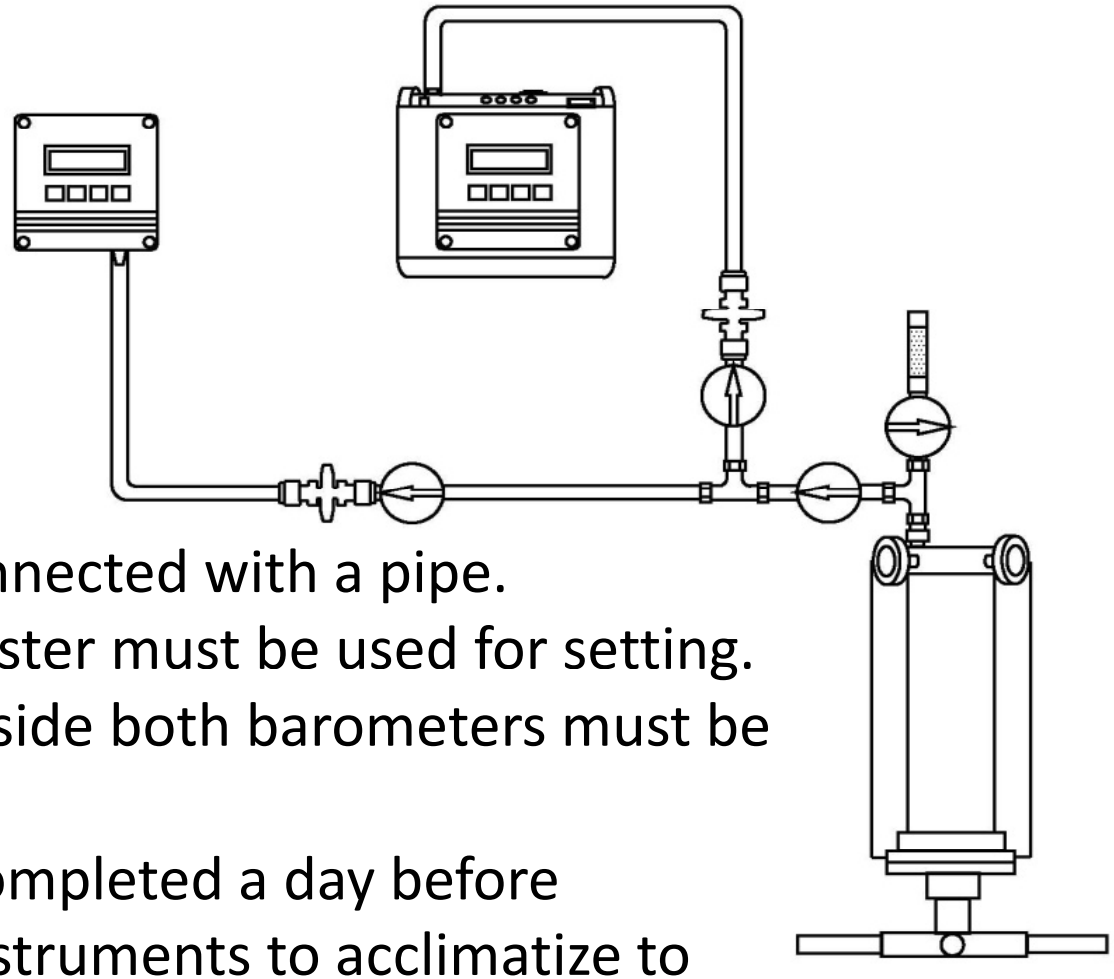
Calibration 2 (aneroid barometer)

Important points

- If aneroid barometer readings differ from those of the standard electrical barometer by ±0.3 hPa or more, the index knob should be adjusted.
- pressure sensors inside both barometers must be at the same height.



Calibration 3 (electronic barometer)



Important points

・barometers must be connected with a pipe.

・ a manual pressure adjuster must be used for setting.

・ the pressure sensors inside both barometers must be at the same height.

・installation should be completed a day before calibration to allow the instruments to acclimatize to room temperature.

§ 2 Calibration of barometers (practice)

JMA/WMO Training Workshop on
Calibration and Maintenance of
Meteological Instruments in RA II

1) today's practice

Purpose: Learn how to calibrate barometers.
Target : Being able to calibrate barometers with a traveling standard barometer in your country.

Outline ※:

① Calibrating **a mercury barometer** with a traveling standard barometer

② Calibrating **an electronic barometer** with a traveling standard barometer and a manual pressure adjuster

③ Calibrating **an aneroid barometer** with a traveling standard barometer in the chamber for pressure

④ Inspecting temperature effects of an **aneroid barometer** in a chamber for temperature

※ ①&② are set to be carried out in the barometer inspection room on the basement floor, ③&④ in the inspection room on the first floor.

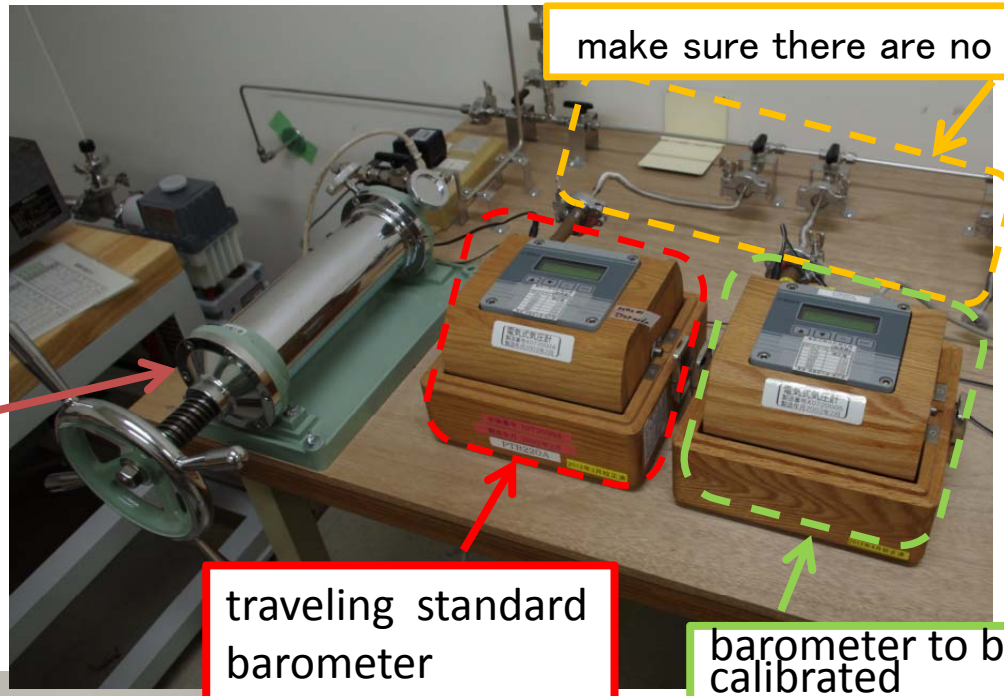
1. Calibrate a mercury barometer with a traveling standard barometer

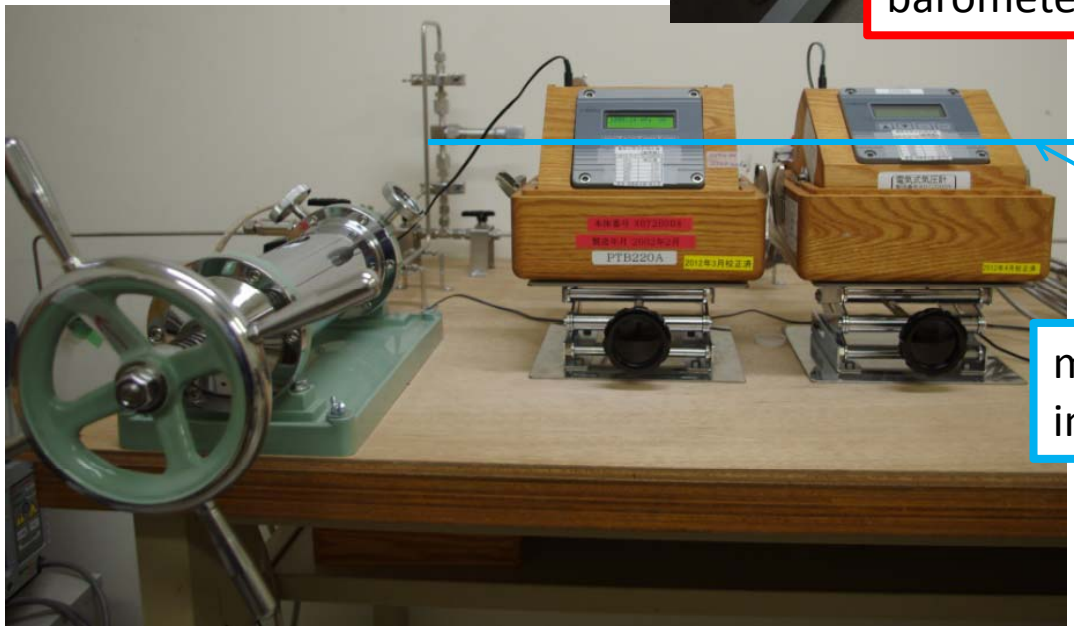
traveling standard barometer

ivory point

mercury barometer

2.Calibrate an electronic barometer with a traveling standard barometer with a manual pressure adjuster





3.Calibrate an aneroid barometer with a traveling standard barometer in the chamber for pressure

chamber for pressure
（4 ～1150hPa）

old fashioned type (not used today)

4.Inspect temperature effects of an aneroid barometer in a chamber for temperature with a traveling standard barometer

aneroid barometer

traveling standard barometer

chamber for temperature

The calibration sheet of Mercury Barometer

Number of times	Month Day	Hour, minute	Temperature reading of thermometer	Tendency of atmospheric pressure	standard barometer			Barometer to be calibrated (Mercury barometer)				Index errer
					Reading	Correction value	Pressure value	Reading	Temperature correction value	Gravity correction value	Pressure value	
1							0.00		0.00	0.00	0.00	0.00
2							0.00		0.00	0.00	0.00	0.00
3							0.00		0.00	0.00	0.00	0.00
4							0.00		0.00	0.00	0.00	0.00
5							0.00		0.00	0.00	0.00	0.00
6							0.00		0.00	0.00	0.00	0.00
7							0.00		0.00	0.00	0.00	0.00
8							0.00		0.00	0.00	0.00	0.00
9							0.00		0.00	0.00	0.00	0.00
10							0.00		0.00	0.00	0.00	0.00
11							0.00		0.00	0.00	0.00	0.00
12							0.00		0.00	0.00	0.00	0.00
13							0.00		0.00	0.00	0.00	0.00
14							0.00		0.00	0.00	0.00	0.00
15							0.00		0.00	0.00	0.00	0.00
16							0.00		0.00	0.00	0.00	0.00
17							0.00		0.00	0.00	0.00	0.00
18							0.00		0.00	0.00	0.00	0.00
19							0.00		0.00	0.00	0.00	0.00
20							0.00		0.00	0.00	0.00	0.00
										Average		0.00
										Standard deviation		0.00
	Correction value			0.00 hPa						Maximum value		0.00
										Minimum value		0.00
										Very difference		0.00

The calibration sheet of Aneroid Barometer

Calibration point	Standard barometer			Reading of barometer to be calibrated	Difference between standard barometer and calibrated barometer at each calibration point	Average of difference between standard barometer and calibrated barometer at each calibration point	Differnce Between adjacent calibration	Index errer	Hysteresis error
	Reading	Correction value	Pressure value						
			(A)	(B)	(C)=(B)−(A)	(C)/3		(D)	
1040	1039.42	0.00	1039.42	1039.7	0.28	①		(①＋⑧)/2	0.05
	1039.45	0.00	1039.45	1039.7	0.25	0.24		0.2	
	1039.52	0.00	1039.52	1039.7	0.18		0.05		
1000	999.41	0.00	999.41	999.6	0.19	②		(②＋⑦)/2	−0.03
	999.39	0.00	999.39	999.6	0.21	0.19		0.2	
	999.43	0.00	999.43	999.6	0.17		0.06		
960	960.33	−0.01	960.32	960.5	0.18	③		(③＋⑥)/2	−0.02
	960.40	−0.01	960.39	960.5	0.11	0.13		0.1	
	960.40	−0.01	960.39	960.5	0.11		0.10		
920	920.08	−0.02	920.06	920.3	0.24	④		(④＋⑤)/2	0.05
	920.10	−0.02	920.08	920.3	0.22	0.23		0.2	
	920.08	−0.02	920.06	920.3	0.24		0.05		
920	919.92	−0.02	919.90	920.1	0.20	⑤			
	919.94	−0.02	919.92	920.1	0.18	0.18			
	919.96	−0.02	919.94	920.1	0.16		0.03		
960	959.95	−0.01	959.94	960.1	0.16	⑥			
	959.97	−0.01	959.96	960.1	0.14	0.15			
	959.95	−0.01	959.94	960.1	0.16		0.07		
1000	999.95	0.00	999.95	1000.2	0.25	⑦			
	1000.01	0.00	1000.01	1000.2	0.19	0.22			
	999.97	0.00	999.97	1000.2	0.23		0.03		
1040	1040.06	0.00	1040.06	1040.2	0.14	⑧			
	1039.96	0.00	1039.96	1040.2	0.24	0.19			
	1040.02	0.00	1040.02	1040.2	0.18				

Inspection of the temperature coefficient

Inspection Point(℃)	30℃		0℃	
Standard barometer Reading	1022.10	1022.01	1021.09	1020.90
Correction value	0.00	0.00	0.00	0.00
Pressure value	1022.10	1022.01	1021.09	1020.90
Reading of barometer to be calibrated	1022.30	1022.20	1020.20	1020.80
Index error(hPa)	0.20	0.19	-0.89	-0.10
Average Index	0.20		-0.49	
Temperature in chamber (℃)	29.63	29.74	0.67	0.61
Mean temperature the chamber	29.69		0.64	
Temperature coefficient (hPa/℃)	{(0.20)-(-0.49)}/{(29.69)-(0.64)}=			
	0.023752151			

Correction value	
920	-0.2
960	-0.1
1000	-0.2
1040	-0.2

Temperature coefficient	hPa/℃
	0.0238

Thank you