Calibration of Thermometers (Lecture and Training)

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Japan Meteorological Agency

8 Nov. 2016

Outline

1. [Theory] Temperature measurements and calibration of thermometer

   (Here in the lecture room)

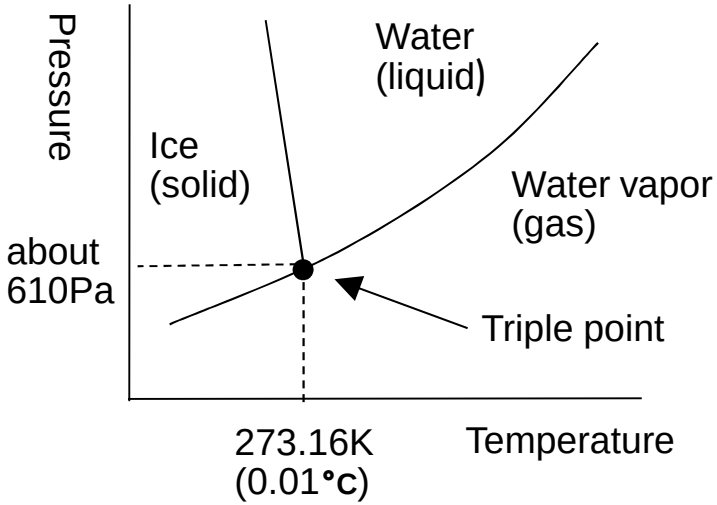
2. [Practice] Calibration of thermometers

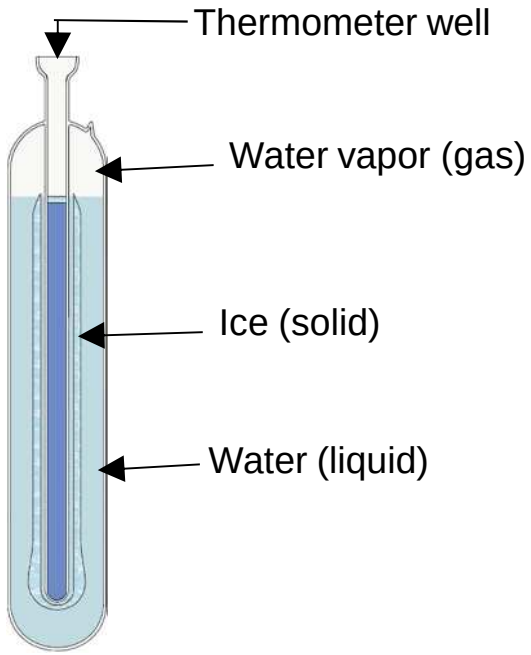
   (At the calibration room on the 1st floor)

1. Temperature measurements (theory)

Definition of the SI unit of thermodynamic temperature (kelvin)

"The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water."





Water triple point cell

The International Temperature Scale of 1990 (ITS-90)

- $t/°C = T/K - 273.15$

  T: thermodynamic temperature (unit: Kelvin)

  t: temperature in degrees Celsius (unit: °C)

- The range from 13.8033K(-259.3467°C) to 961.78°C is defined by means of platinum resistance thermometers calibrated at certain fixed points and applying specified interpolation procedures.

Defining fixed points of the ITS-90

Number	Temperature		Substance(*1)	State(*2)
	T90/K	t90/℃		
1	3 to 5	-270.15 to -268.15	He	V
2	13.8033	-259.3467	e-H_2	T
3	～17	～-276.15	e-H_2(or He)	V(or G)
4	～20.3	～-252.85	e-H_2(or He)	V(or G)
5	24.5561	-248.5939	Ne	T
6	54.3584	-218.7916	O_2	T
7	83.8058	-189.3442	Ar	T
8	234.3156	-38.8344	Hg	T
9	273.16	0.01	H_2O	T
10	302.9146	29.7646	Ga	M
11	429.7485	156.5985	In	F
12	505.078	231.928	Sn	F
13	692.677	419.527	Zn	F
14	933.473	660.323	Al	F
15	1234.93	961.78	Ag	F
16	1337.33	1064.18	Au	F
17	1357.77	1084.62	Cu	F

(*1)All substances except 3He are of natural isotopic composition;

e-H_2 is hydrogen at the equilibrium concentration of the ortho- and para-molecular forms.

(*2)V: vapour pressure pont;

T: triple point (temperature at which the solid, liquid, and vapour phases are in equilibrium);

G: gas thermometer point;

M ,F: melting point, freezing point

(temperature, at a pressure of 101325Pa, at which the solid and liquid phases are in equilibrium)

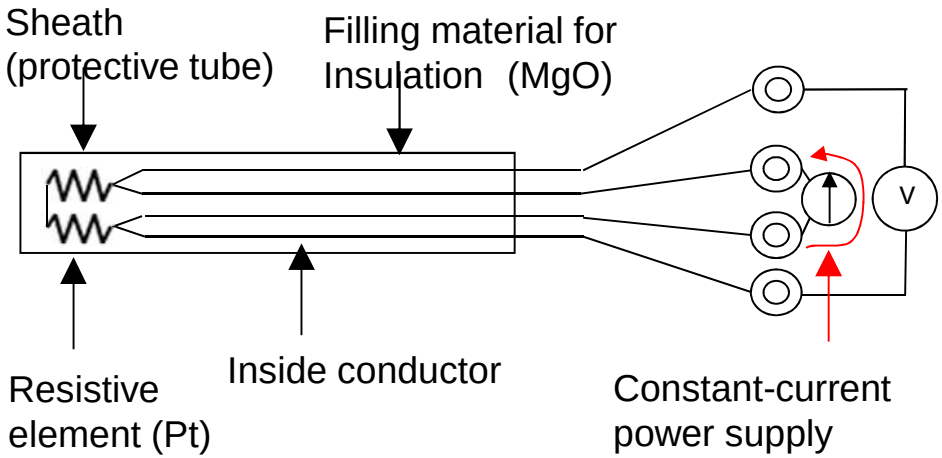
Types of thermometers

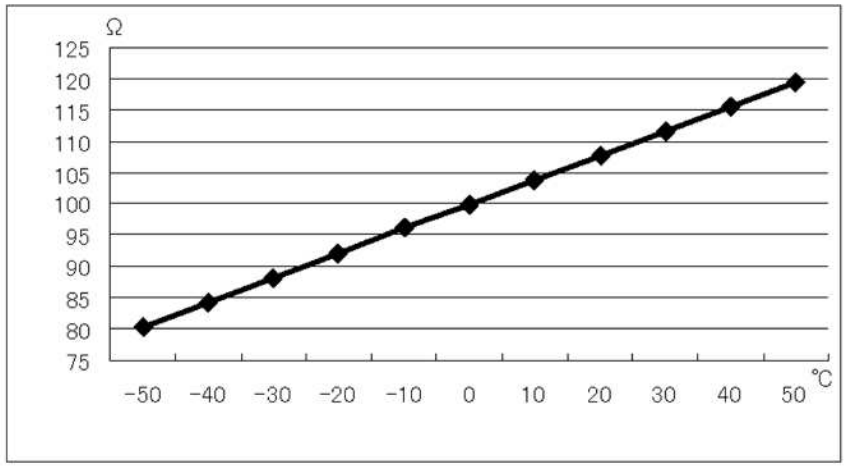
1. Contact-type thermometers
   - Platinum resistance thermometer
   - Liquid-in-glass thermometer
   - Thermocouple

   etc.

2. Radiation thermometers

Platinum resistance thermometer





Example of the relation between
temperature and resistance

Traceability of Temperature (JMA)

Jan. 2013 by JMA

Measurement standards traceable to national standards

National Metrology Institute of Japan

JMA Standard

Working Standard

Field Instruments

Meteorological Instruments Center (JMA)

Observatory (JMA)

Temperature fixed points

・Indium point (156.5985°C)
・Mercury point (-38.8344°C)
・Water triple point (0.01 °C)

Standard resistor (100Ω)

Calibration:
・every year
NSR-160
・every 2 years
Water triple-point cell
Standard resistor

Platinum resistance thermometer

NSR-160 (Netsushin, Japan)

Alternating current bridge F-600 (ASL, UK)

Water triple-point cell (0.01°C)

Standard resistor(100Ω)

Check: every 6 months
Using water triple-point cell

Calibration: every year

Platinum resistance thermometer

TS-81A (Chino, Japan)

Alternating current bridge F-250 (ASL, UK)

Calibration: every 5 years

Platinum resistance thermometer

Calibration: at the time of installation

Platinum resistance thermometer
TS-81A (Chino, Japan)

Alternating current bridge F-250 (ASL, UK)

Check:
・every 3 months (manned observatory)
・every year (automatic weather station)

Tolerable range: ±0.4°C

Mercury-in-glass thermometer (psychrometer)

気象庁

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Calibration:
- every year NSR-160
- every 2 years Water triple-point cell Standard resistor

Platinum resistance thermometer

NSR-160 (Netsushin, Japan)

Alternating current bridge F-600 (ASL, UK)

Water triple-point cell (0.01°C)

Standard resistor(100Ω)

Check: every 6 months Using water triple-point cell

Calibration: every year

Platinum resistance thermometer

TS-81A (Chino, Japan)

Alternating current bridge F-250 (ASL, UK)

Platinum resistance thermometer
TS-81A (Chino, Japan)

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Calibration: at the time of installation

Platinum resistance thermometer

Calibration: every 5 years

Check:
- every 3 months (manned observatory)
- every year (automatic weather station)

Tolerable range: ±0.4°C

Mercury-in-glass thermometer (psychrometer)

Certificate of Calibration (Platinum resistance thermometer)

ilac-MRA IAJapan JCSS
JCSS 0025

SERIAL No. 120674A

CERTIFICATE OF CALIBRATION

ACCREDETED LABORATORY
Tanaka Kikinzoku Kogyo K.K. Isehara Works Thermometer Calibration Laboratory

ADDRESS Suzukawa 26 Isehara-City Kanagawa Japan 259-1146

Customer : Meteorological Instruments Center JMA Address: 1-2 nagamine, tsukuba ibaraki

Item : Platinum Re... Therm... M...e : ...tsushi...

Type : NSR-160 SE...IAL N... : NS...160

Calibration Metho... Fixed ...oint A...bient : Temp. 25°... Hum. 60%

Description : Temperature

The Calibration Result.

Temperature (℃)	Resistance Ratio(Wt)
Triple Point of Mercury -38.8344	0.844216 ±0.000008
Freezing Point of Indium 156.5985	1.609468 ±0.000012

The uncertainties are for a confidence probability of not less than 95%

Note : All quoted resistances ratio has been extrapolated to a current of 0mA.
The resistance at triple pint of water has been 99.9289Ω.
The measurement has done by using Guild*line* 9975 current comparator resistance bridge.

Calibrated on 25 August 2012

Issued by Tanaka Kikinzoku Kogyo K.K.
Isehara Works Thermometer Calibration Laboratory

Date of issue 28 August 2012

Approved Signature T. Hamada

Tokio HAMADA

This certificate is issued in accordance with the conditions of accreditation granted by Japan Calibration Service System, which is based on ISO/IEC 17025 and also participates in the MRA not only APLAC but also ILAC.

The Calibration Result.

Temperature (℃)	Resistance Ratio(Wt)
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Standard resistor (100Ω)

Calibration:
- every year
  NSR-160
- every 2 years
  Water triple-point cell
  Standard resistor

Platinum resistance thermometer

NSR-160 (Netsushin, Japan)

Alternating current bridge F-600 (ASL, UK)

Water triple-point cell (0.01°C)

Standard resistor(100Ω)

Check: every 6 months
Using water triple-point cell

Calibration: every year

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TS-81A (Chino, Japan)

Alternating current bridge F-250 (ASL, UK)

Calibration: at the time of installation

Calibration: every 5 years

Alternating current bridge F-250 (ASL, UK)

Platinum resistance thermometer

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- every 3 months (manned observatory)
- every year (automatic weather station)

Tolerable range: ±0.4°C

Mercury-in-glass thermometer (psychrometer)

Alternating current bridge (Working standard)

Alternating current bridge (JMA standard)

100Ωstandard resistor

RS232C

PC

Stabilized power supply

AC100V powersupply

Platinum resistance thermometer (Working standard)

Platinum resistance thermometer (JMA standard)

Liquid bath chamber or Ice point inspection box (only for 0°C)

Liquid bath chamber

Ice point inspection box

JCSS 0295

Calibration Certificate

Client Name : **********
Client Address : **********
Calibration Site : Meteorological Instruments Center, Japan Meteorological Agency
Calibration Item : Thermometer
Type and Serial Number : **********
Manufacturer : **********
Calibration Method : As shown in page 2.
Calibration Conditions : Room Temperature 21.6 °C - 25.6 °C
Relative humidity 22 % - 34 %
Calibration Results : As shown in page 2.
Date of Application : 26 November 2012
Date of Performance of the Calibration : 27 - 29 November 2012

Date of issue : 10 January 2013

The issuing Authority

Mitsugi Katsuyama
Director,
Meteorological Instruments Center, JMA
1-2 Nagamine Tsukuba-shi Ibaraki Japan

This certificate is based on article 144 of the Measurement Law and indicates the result of calibration in accordance with measurement standards traceable to Primary Measurement Standards (National Standards) which realizes the physical units of measurement according to the International System of Units (SI). The accreditation symbol is attestation of which the result of calibration is traceable to Primary Measurement Standards (National Standards).
The certificate shall not be reproduced except in full, without the written approval of the issuing laboratory.
The calibration laboratory who issued this calibration certificate conforms to ISO/IEC 17025:2005.
This calibration certificate was issued by the calibration laboratory accredited by IAJapan who is a signatory to the Mutual Recognition Arrangement (MRA) of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC). This (These) calibration result(s) may be accepted internationally through ILAC/APLAC MRA.

Calibration method

- The calibration item was calibrated with the following reference standards and instruments:
  Platinum resistance thermometer : NSR-160, NS-05030 (Netsushin)
  Water triple point cell : 5901C-G, 2038 (FLUKE)
  Alternating current bridge : F600AC, 012705/09 (ASL)
  Standard resistor 100 Ω in temperature controlled enclosure :
  5685A, 14553/02 (Tinsley)
- The calibration item was compared with the above reference standards in the liquid chamber at the following calibration points over than 0 °C (in the ice point bath). The procedure used in this calibration was the standard operating procedure manual No.4 of Meteorological Instruments Center, JMA.

Calibration results

Nominal temperature (°C)	Reference temperature (A) (°C)	Calibrated indication temperature (B) (°C)	Deviation (B) - (A) (°C)	Expanded uncertainty (°C)
-10	-10.000	-9.980	0.020	0.045
0	0.000	0.020	0.020	0.013
10	10.000	10.019	0.019	0.036
20	20.000	20.019	0.019	0.036
30	30.000	30.018	0.018	0.036
40	40.000	40.019	0.019	0.036
50	50.000	50.020	0.020	0.036

Note

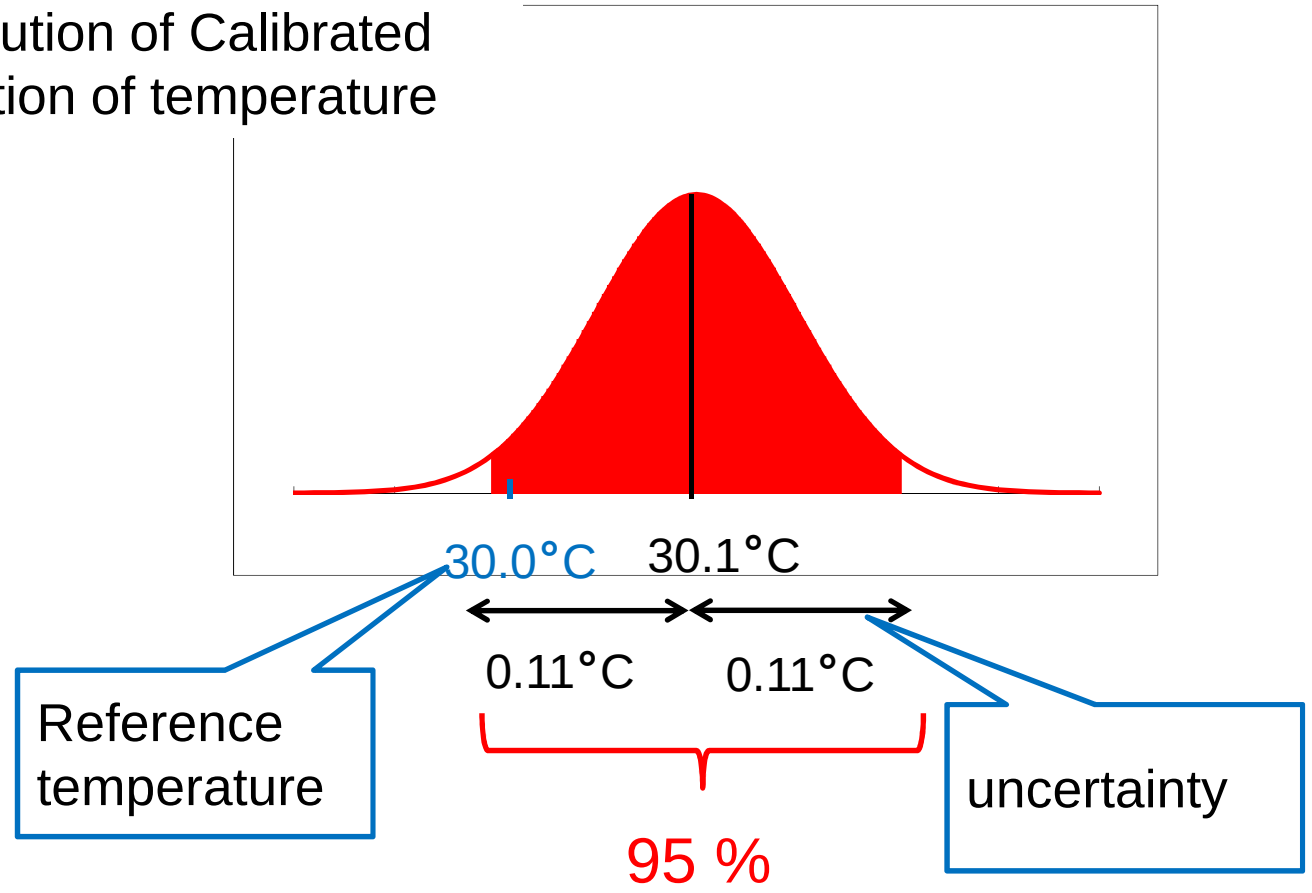
The reported expanded uncertainty is stated as the combined standard uncertainty multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95 %.
Characterization type is ITS-90 (R0 = 99.9963, A4 = -1.938829×10^{-2}, B4 = 1.068843×10^{-4}).

- End of Certificate -

Calibration result

Image

Distribution of Calibrated
Indication of temperature



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Jan. 2013 by JMA

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Using water triple-point cell

Calibration：every year

Platinum resistance thermometer

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Tolerable range：
±0.4°C

気象庁

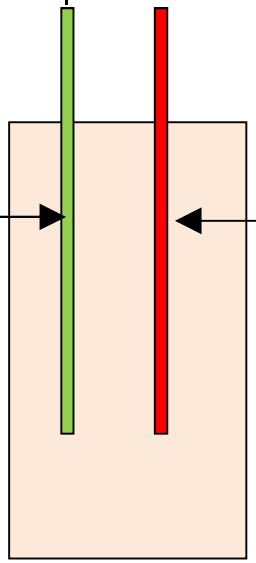
Meteorological Instrument Center

Japan Meteorological Agency

Alternating current bridge (Working standard)

<Not 0°C>

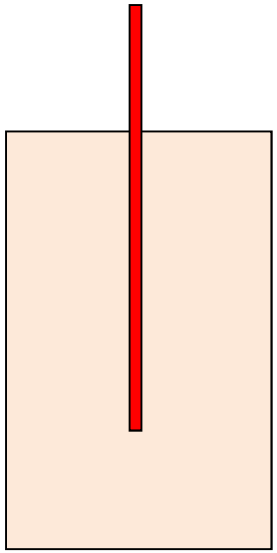
Platinum resistance thermometer (Working standard)



Platinum resistance thermometer or Mercury-in-glass thermometer (Field instruments)

Liquid bath chamber

<0°C>



Ice point inspection box

An example of Calibration result of Mercury-in-glass thermometer

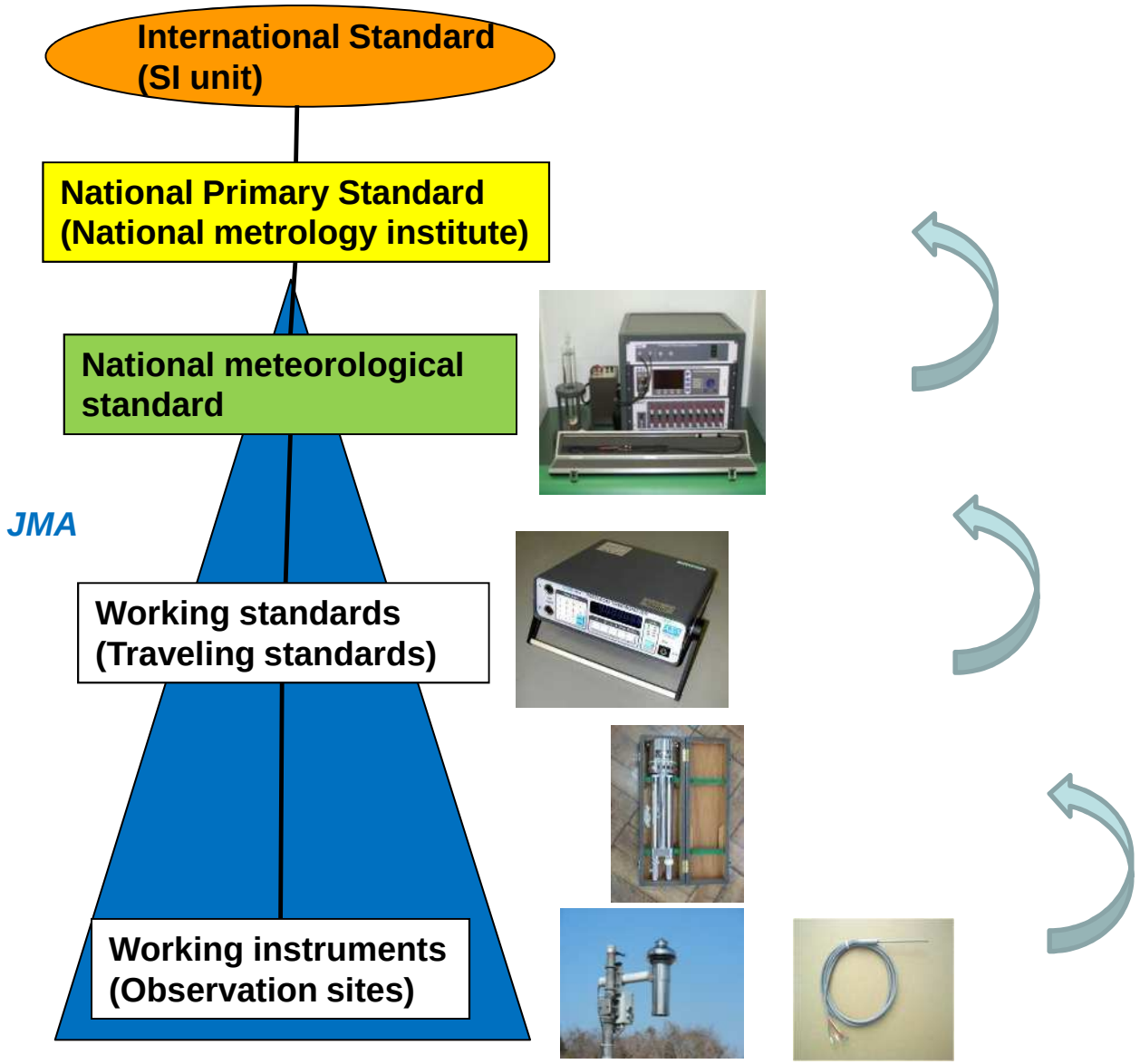
Instrument No.

Calibration point

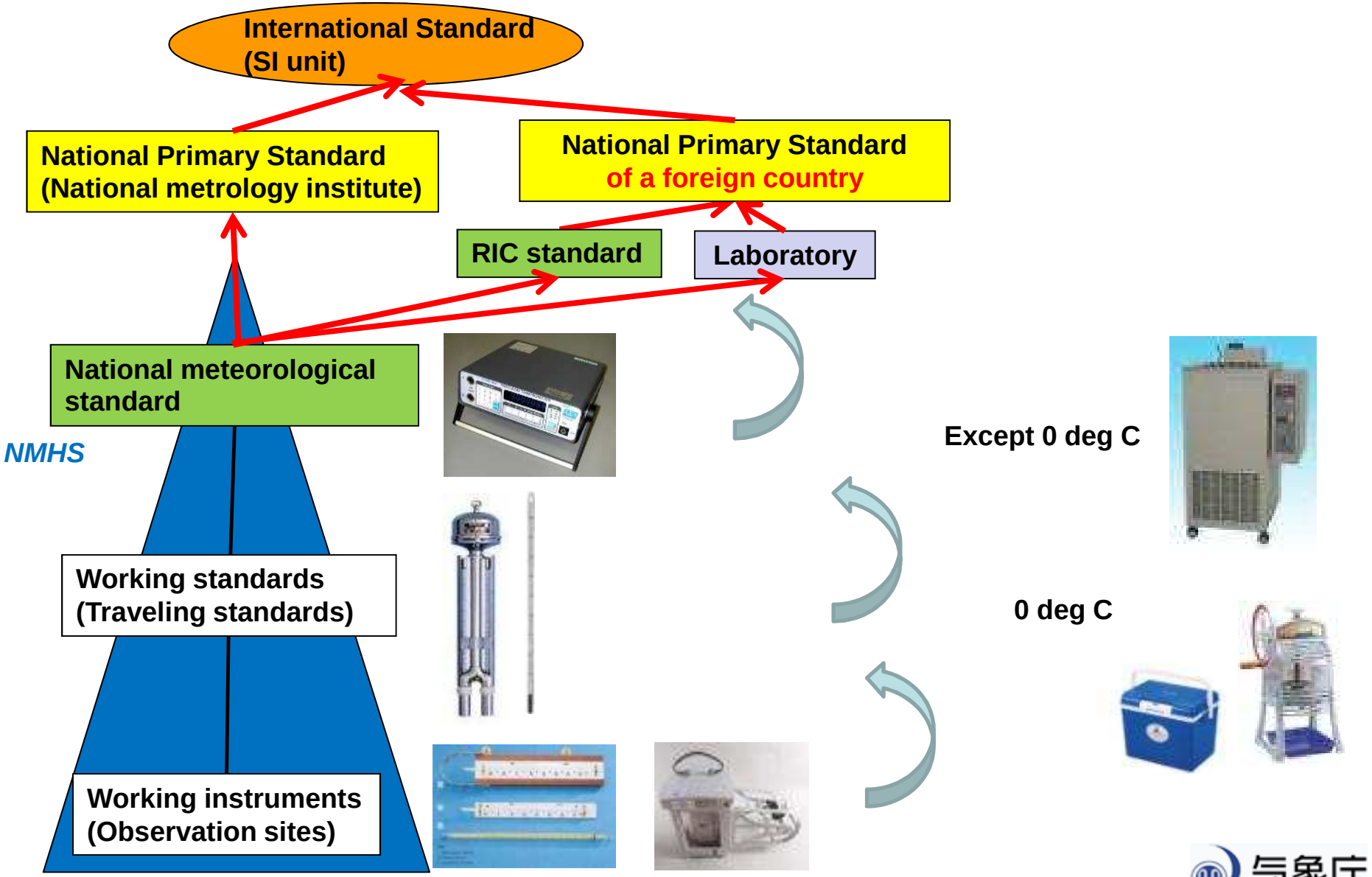
測器識別番号	41625-00215
検査点[℃]	補正値[℃]
40	−0.1
35	−0.1
30	−0.2
25	−0.2
20	−0.1
15	−0.1
10	−0.1
5	−0.1
0	−0.1
−5	−0.1
−10	−0.1
−15	−0.2
−20	−0.2
−25	−0.2
−30	−0.2

Instrument error

Traceability of Temperature as to JMA



An example chart of traceability (Temperature)



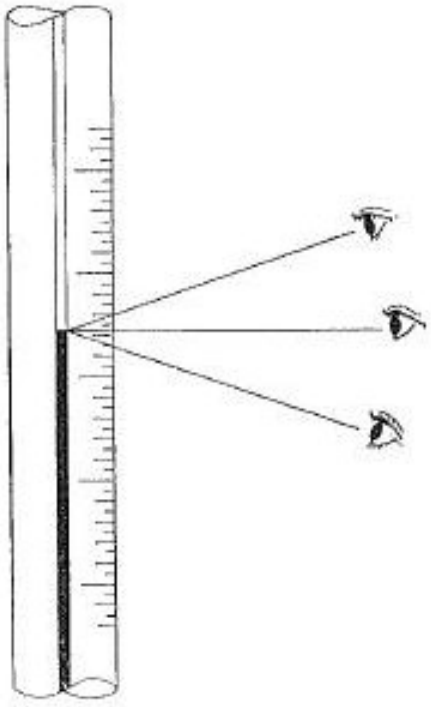
2. Calibration of thermometer (practice)

Today’s practice (planned…)

- Calibrated items:
  - Platinum resistance thermometer: 1 sets
  - Mercury-in-glass thermometer : 3 sets

- Calibration points:
  - 0°C （Ice point）
  - 30°C (with liquid bath chamber)

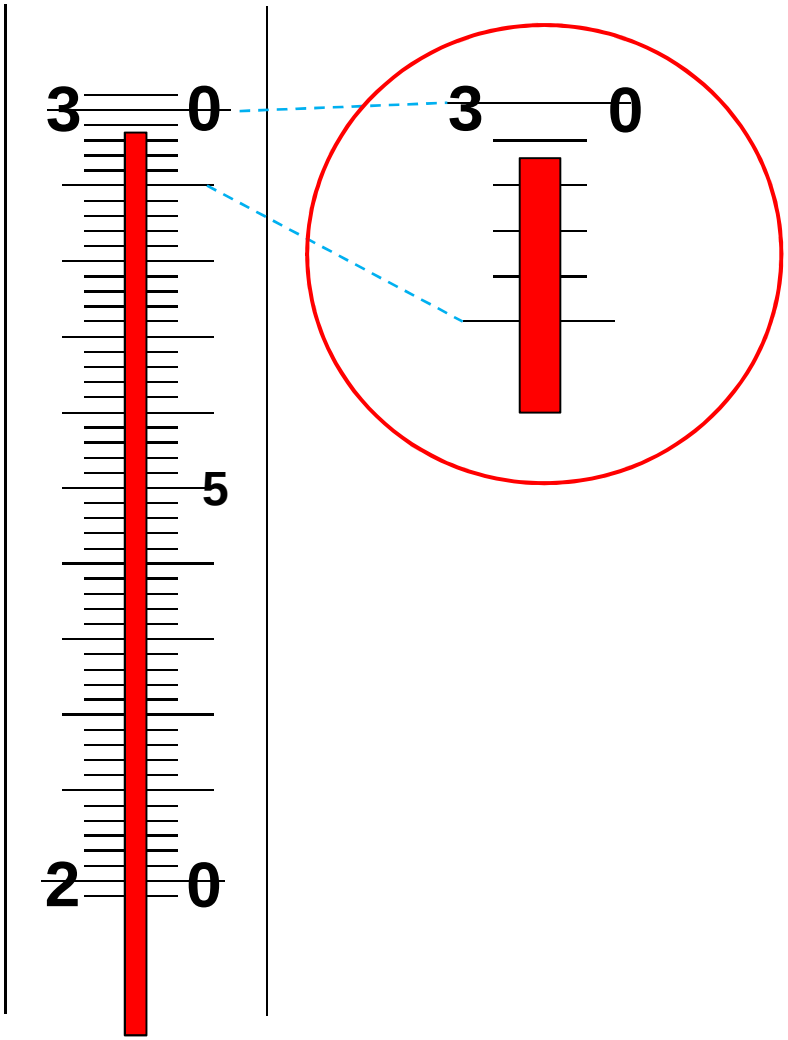
Liquid in glass thermometer



Caution for reading;

The observer ensures that the straight line from his/her eye to the meniscus, or index.

Liquid in glass thermometer



How to read the value;

- The interval of line: 0.2°C
- Read the value in units of 0.1°C.

The value of left example;

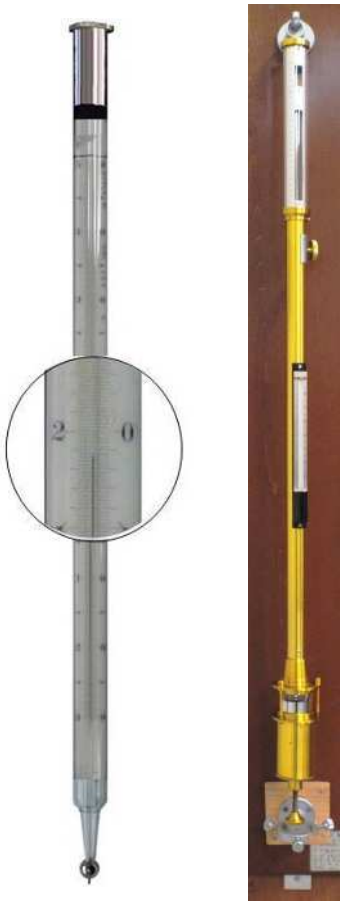
29.7°C

3. Minamata Convention on Mercury

Minamata Convention on Mercury

- **The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury, which was agreed in 2013.**

- **Under this Convention, imports and exports of mercury will no longer be allowed. In this context, production, importation and exportation of mercury-added products such as thermometers and barometers will be stopped by the year 2020.**



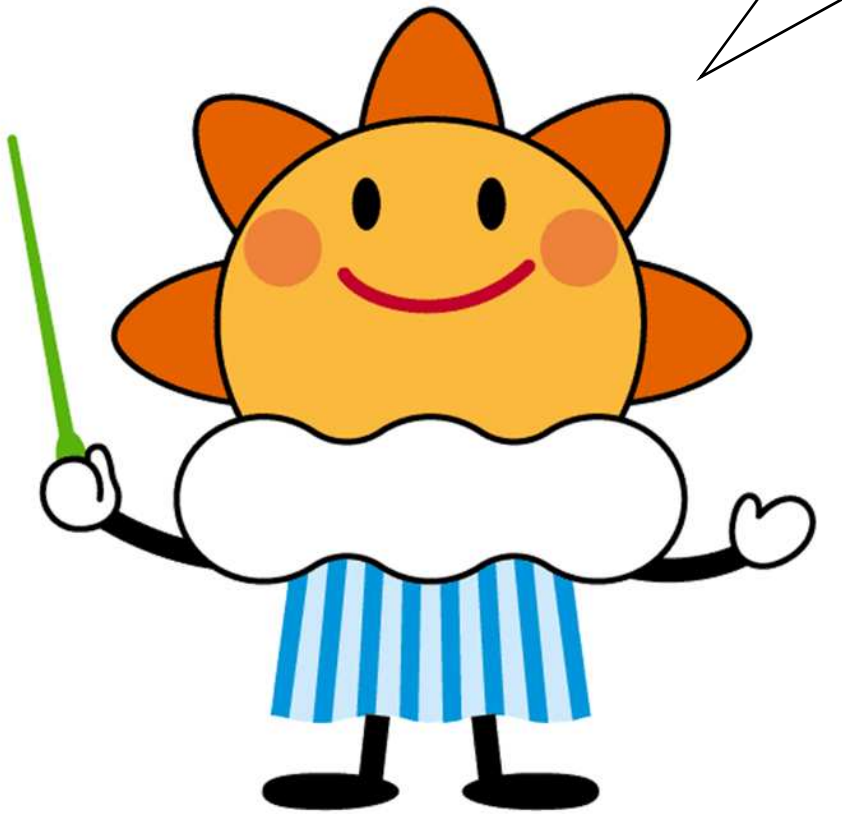
↓

NMHSs which use mercury-added instruments should prepare a transition to modern Alternatives.

UNEP MINAMATA CONVENTION ON MERCURY

http://www.mercuryconvention.org/

Thank You!



Mascot of JMA ”Harerun”