Chapter 9　Standards for Meteorological Instruments

CONTENTS

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9.1　Definition of Standards for Meteorological Instruments

It is necessary to calibrate instruments prior to their deployment in order to ensure high-quality observational data. Comparison and calibration must also be performed periodically to track instrument performance and enable appropriate correction. This calibration and comparison requires a system of standard meteorological instruments. As detailed in Chapter 1, Section 1.1, there are various levels of standards, and the group of reference, transfer and working standard devices defined in the section constitutes the standard instrument system. The current chapter gives an outline of this system in Japan.

9.2　Procedures for Achieving Observation Accuracy

The accuracy of meteorological observations is evaluated comprehensively in consideration of errors caused by the performance of instruments, measurement methods and surrounding conditions.

Requirements for the accuracy of individual observations as provided in the CIMO Guide are described in Section 1.3.

To attain the required level of accuracy, it is necessary to use instruments whose performance exceeds the requirements. It is also necessary to keep instruments for comparison and calibration to enable adjustment of operational instruments for maximum performance.

9.3　System of Standard Meteorological Instruments

9.3.1　Outline of the System of Standard Meteorological Instruments

Figure 9.1 shows the concept of the system of standard meteorological instruments. National meteorological standards established by each national Meteorological Service serve as the basic standards for operational use. Some of these national standards have their own traceability to international or WMO standards, while others are established independently. National meteorological standards are regarded as references, as they are traceable to other higher standards including national ones. WMO strongly recommends periodic comparison and calibration of national meteorological standards with regional standards maintained by Regional Instrument Centers to ensure the international coherency of meteorological observations among Members.

Working standards at local calibration centers are kept traceable to national meteorological standards using transfer standards (also known as travelling standards).

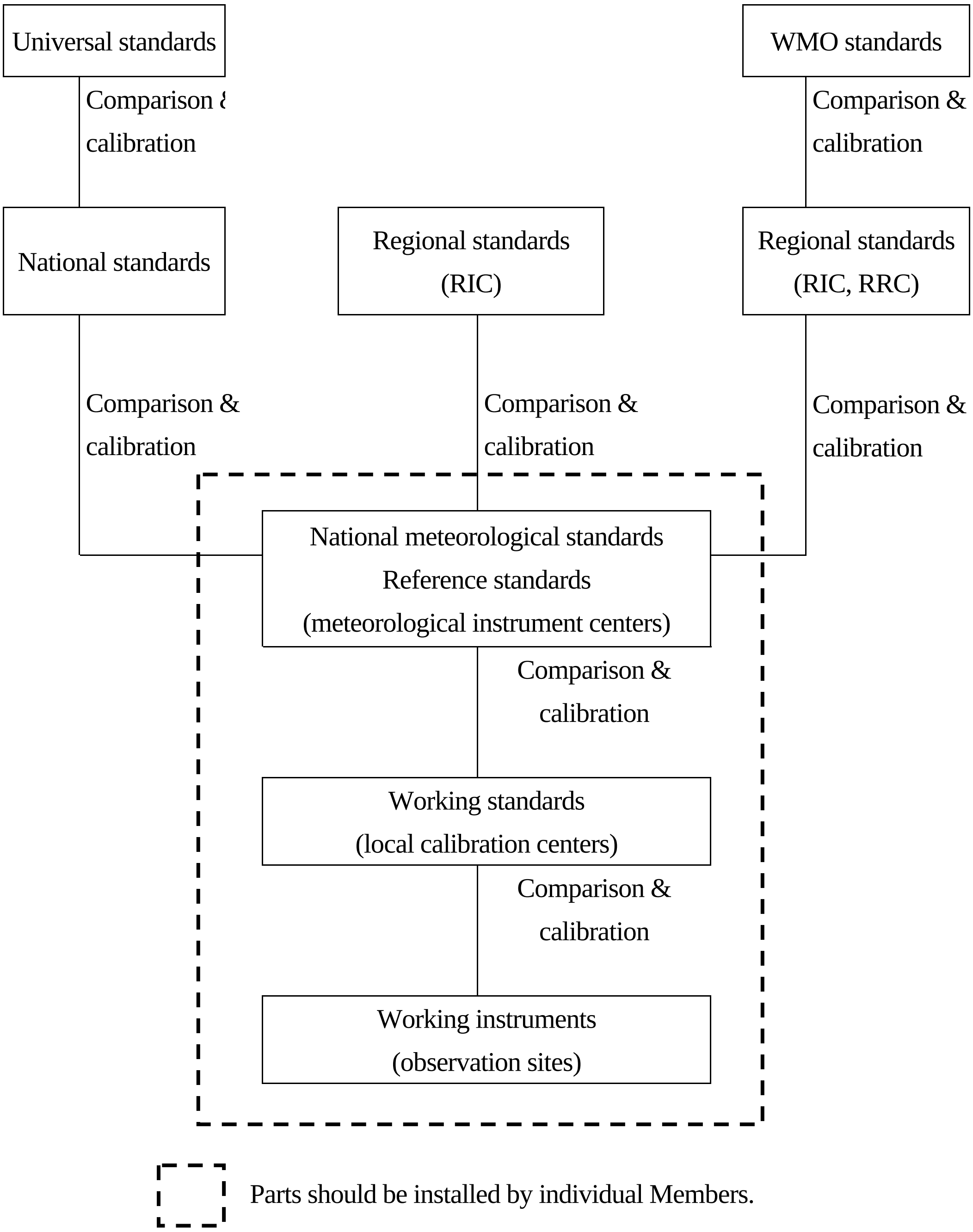


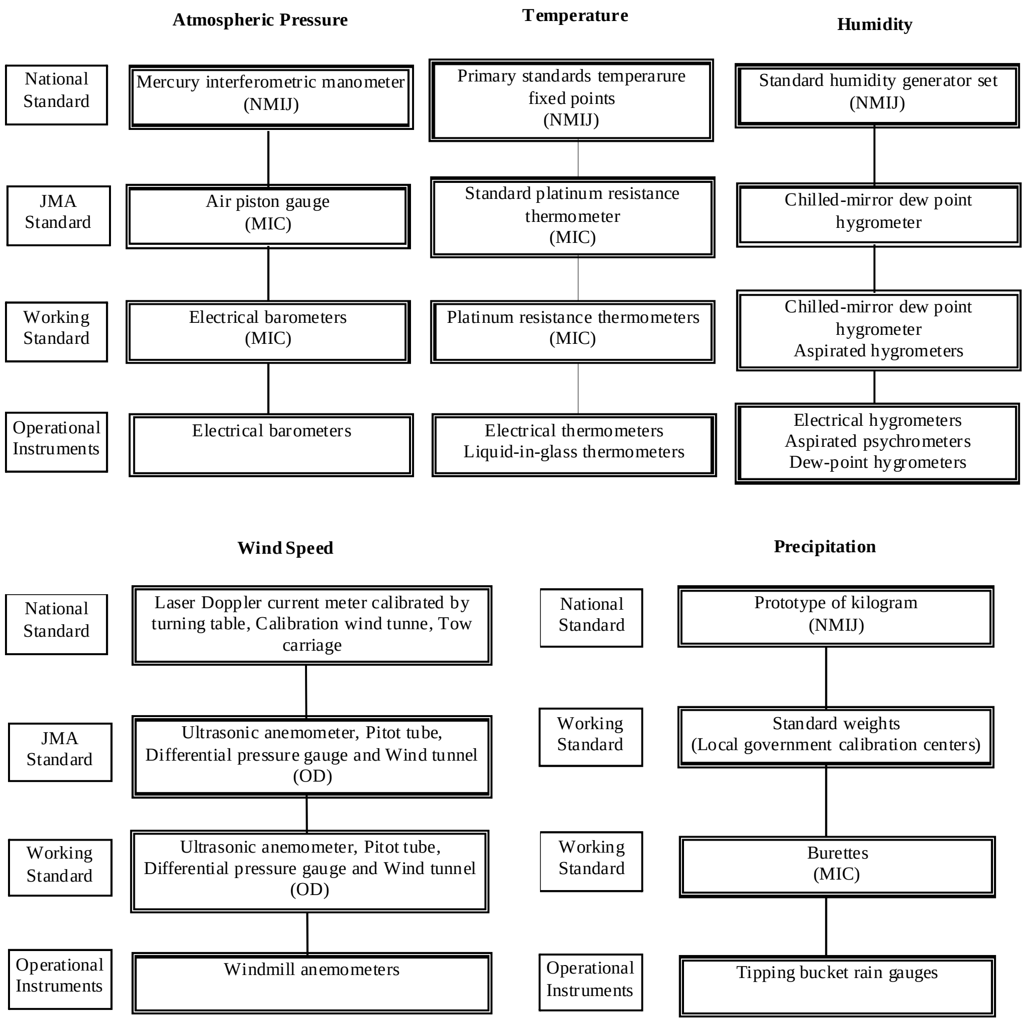
Figure 9.1 Outline of the system of standard meteorological instruments

9.3.2 Requirements for the Standard Meteorological Instrument Systems of Individual Members

Figure 9.1 shows the system of standard meteorological instruments that individual Members should establish.

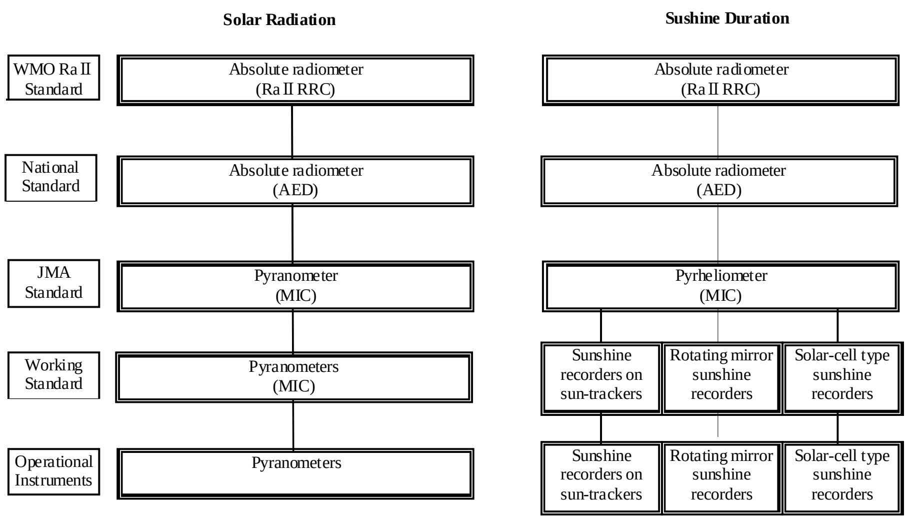
Each instrument in the system must meet the operational accuracy requirements laid down by CIMO as a minimum. Operational instruments should be corrected periodically with reference either to national meteorological standards or working standards at local calibration centers.

CIMO recommends that individual Members ask RICs for technical advice to establish their own standard instrument systems.



NMIJ: National Metrology Institute of Japan (Advanced Industrial Science and Technology)
MIC: Meteorological Instruments Center
OD: Observational Division of JMA

Figure 9.2 System of Standard Meteorological Instruments in Japan (part 1)



RRC: Regional Radiation Center
AED: Atmospheric Environment Division
MIC: Meteorological Instruyments Center

Figure 9.3 System of standard meteorological instruments in Japan (part 2)

9.3.3 The Standard Meteorological Instrument System of Japan

This section describes the standard meteorological instrument system of Japan.

Figure 9.2 and 9.3 outlines the standard system for pressure, temperature, humidity, wind speed, precipitation, solar radiation and sunshine.

JMA standards, or national meteorological standards, are maintained at the Meteorological Instruments Center (MIC), where RIC Tsukuba is also located. Working standard instruments are maintained at MIC for comparison and calibration to operational instruments.

9.3.3.1 Pressure

(1) The national standard instrument for ascertaining Japan's primary pressure standard is a mercury interferometric manometer maintained at the National Metrology Institute of Japan (NMIJ) of the National Institute of Advanced Industrial Science and Technology (AIST). The national meteorological standard of pressure is traceable to this national standard.

(2) The national meteorological standard instrument is an air piston gauge, which also serves as the JMA standard. This JMA standard is periodically compared and calibrated with the national standard.

(3) The working standard instrument is an electrical barometer. This working standard is periodically compared and calibrated with the JMA standard at observatories.

9.3.3.2 Temperature

(1) The national standard of temperature comes from primary standard temperature fixed points at NMIJ.

(2) The JMA standard instrument is a standard platinum resistance thermometer, and is periodically compared and calibrated with the national standard. Its resistance is checked occasionally at the triple point of water at MIC.

(3) The working standard instruments are platinum resistance thermometers. They are compared and calibrated with the JMA standard at MIC.

9.3.3.3 Humidity

(1) The national standard instrument for humidity is a standard humidity generator maintained at NMIJ.

(2) The JMA standard instrument is a chilled-mirror dewpoint hygrometer combined with an electrical thermometer. The hygrometer is traceable to the national standard through periodic comparison and calibration with it. The electrical thermometer is periodically compared and calibrated with the JMA temperature standard instrument (a standard platinum resistance thermometer).

(3) The working standard instruments are a chilled-mirror dewpoint hygrometer and an aspirated psychrometer, which are periodically compared and calibrated with the JMA standard at MIC.

9.3.3.4 Wind Speed

(1) The national standard instrument is a laser Doppler current meter calibrated by turning table, a calibration wind tunnel and a tow carriage at NMIJ.

(2) The JMA standard instrumentation consists of an ultrasonic anemometer, a pitot tube, a differential pressure gauge and a wind tunnel. The first three are periodically compared and calibrated with the national standards.

(3) Working standard instrumentation consists of an ultrasonic anemometer, a pitot tube, a differential pressure gauge and a wind tunnel. The first three are periodically compared and calibrated with the JMA standard in JMA's Observational Division.

9.3.3.5 Precipitation

(1) There is no national or JMA standard instrument for precipitation.

(2) Working standard instruments are burettes, which are periodically inspected with standard weights at local government calibration centers.

9.3.3.6 Solar Radiation

(1) Solar radiation requires traceability to the WMO standard.

(2) Regional standard instruments are maintained under WMO standards. The standard instrumentation for Region II is a group of absolute radiometers maintained at JMA's Atmospheric Environment Division (AED). The regional standards are periodically compared and calibrated with the WMO standards.

(3) The national standard instruments are absolute radiometers maintained at JMA’s AED. The national standards are periodically compared and calibrated with the regional standards.

(4) The JMA standard instrument is a pyranometer maintained at MIC. It is periodically compared and calibrated with the national standards.

(5) The working standard instruments are pyranometers maintained at MIC. They are periodically compared and calibrated with the JMA standard.

9.3.3.7 Sunshine

(1) Sunshine duration requires traceability to the WMO standard.

(2) Regional standard instruments are maintained under the WMO standards. The standard for Region II is a group of absolute radiometers maintained at JMA’s Atmospheric Environment Division (AED). The regional standards are periodically compared and calibrated with the WMO standards.

(3) The national standard instruments are absolute radiometers maintained at JMA’s AED. The national standards are periodically compared and calibrated with the regional standards.

(4) The JMA standard instrument is a pyrheliometer maintained at MIC. It is periodically compared and calibrated with the national standards.

(5) The working standard instruments are three pyrheliometer types: sunshine recorders on a sun-tracker, rotating-mirror sunshine recorders and solar-cell-type sunshine recorders maintained at MIC. They are periodically compared and calibrated with the JMA standard.

9.4 Maintenance of Standard Systems (Comparison, Calibration)

Instruments show secular changes in performance and correction requirements. To maintain accuracy, traceability to standards must always be kept.

9.4.1 Comparison and Calibration via Regional Instrument Centers

CIMO recommends periodic comparison and calibration between national standards and regional standards at RICs once every five years. These tasks can be performed using travelling standards.

9.4.2 Comparison and Calibration by Individual Members

CIMO recommends periodic comparison and calibration of operational instruments with national or working standards. The periodicity of such work should be determined by considering secular changes in the performance of instruments and working conditions. Instruments with significant changes over time require frequent calibration.

CIMO recommends that individual Members consult RICs for advice on the maintenance of their systems of standard instruments.

9.4.3 Instruments Used for Comparison and Calibration

The accuracy of national meteorological standards and working standards must be of an equivalent or higher level than that provided by CIMO.

As it is difficult to carry out comparison and calibration with high accuracy in the open air (where atmospheric conditions may change more quickly than instruments can respond to them), calibration chambers in which temperature, humidity and pressure can be stably maintained are used for these tasks. Calibration chambers maintained by JMA are described in Section 9.4.5.

CIMO also recommends the use of travelling standards for comparison between reference standards and working standards. Travelling standard equipment must be rigid enough to endure transportation, and be stable enough that its performance does not change after transportation.

9.4.4 Standard Instruments Used for Comparison and Calibration in Japan

This section introduces the reference standard instruments for pressure, temperature and humidity maintained at RIC Tsukuba.

9.4.4.1 Pressure

(1) Air piston gauge

This air piston gauge consists of a piston gauge, a vacuum gauge, a vacuum pump, a pressure adjuster and a pressure medium (dry air) (Figure 9.4 and Picture 9.1).

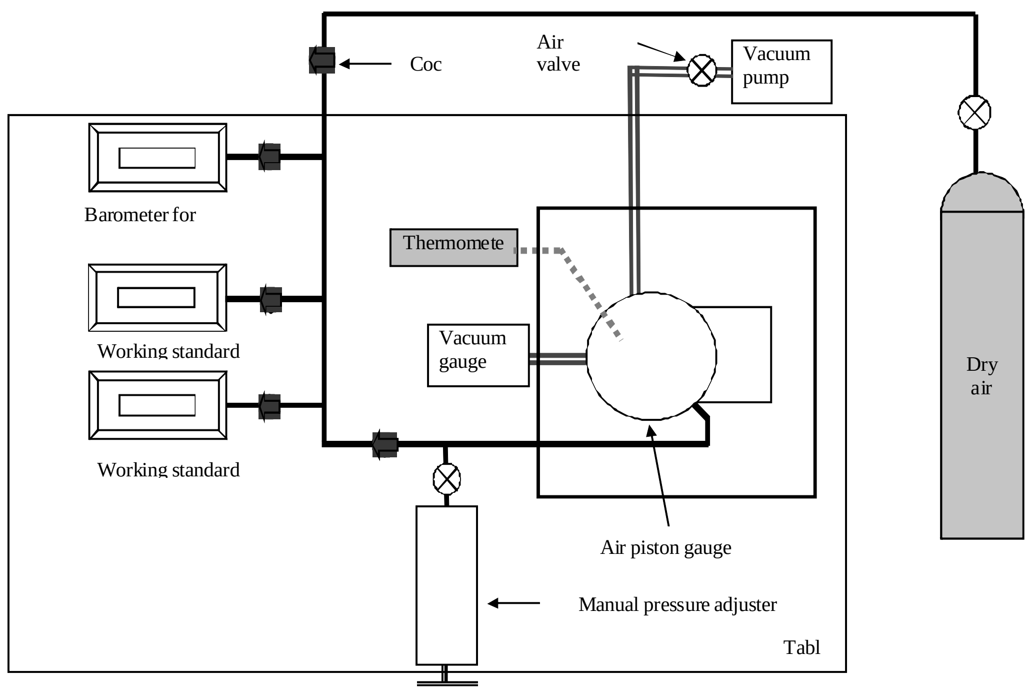


Figure 9.4 Air piston gauge system overview

Picture 9.1 Air piston gauge

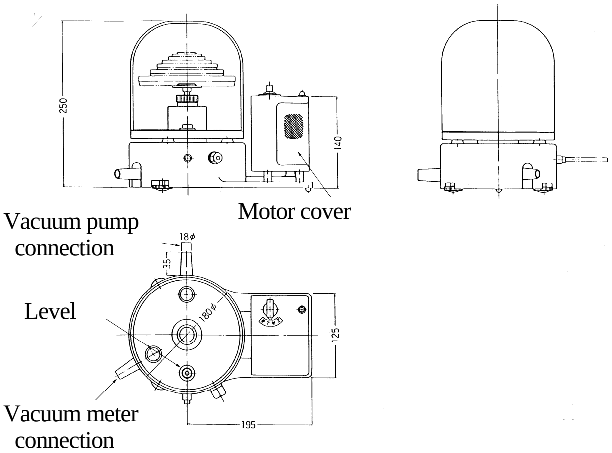


Figure 9.5 Air piston gauge

It produces an accurate level of pressure by balancing the vacuum section (the upper part) and the constant-pressure section (the lower part). Pressure in the lower section is determined by placing an approved high-accuracy weight on the upper section. By combining several weights, a wide range of pressures from 50 hPa to 1,150 hPa can be covered at intervals of 10 hPa.

Pressure in the lower section is adjusted with the vacuum pump and pressure adjuster so that it balances with the weight on the upper section.

The pressure in the lower section is led to the air inlet of the pressure gauge to be calibrated through the piping cock.

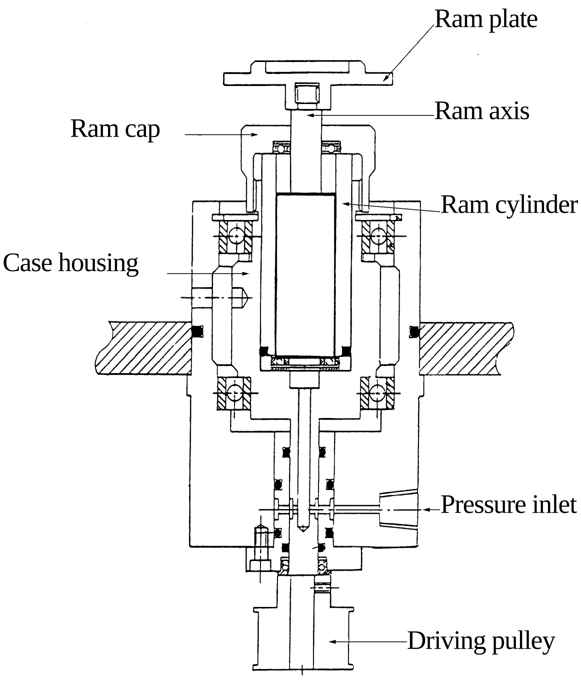


Figure 9.6 Ram cylinder

Figure 9.5 shows an overall view of the air piston gauge. Figure 9.6 is a sectional view of the rotary mechanism that produces the vacuum in the upper section and pressure in the lower section, both of which are in the ram cylinder. The two sections are separated and kept airtight by the smoothly rotating ram axis.

On top of the ram cylinder is a ram dish, on which high-accuracy weights are placed. Dry air (the pressure medium) is introduced into the lower section to create pressure, whose level can be controlled accurately by changing the weights.

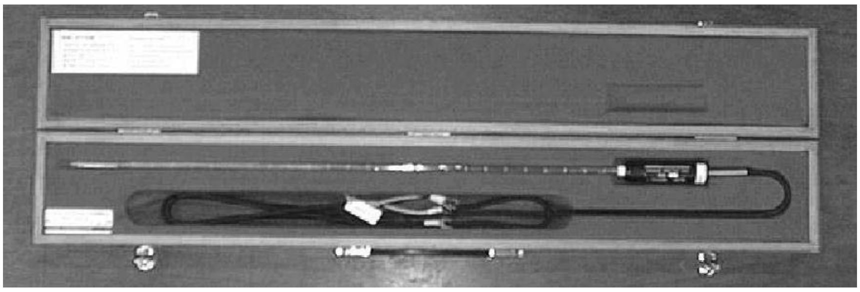
The weights are made of stainless steel and are approved by comparison with standard weights.

9.4.4.2 Temperature

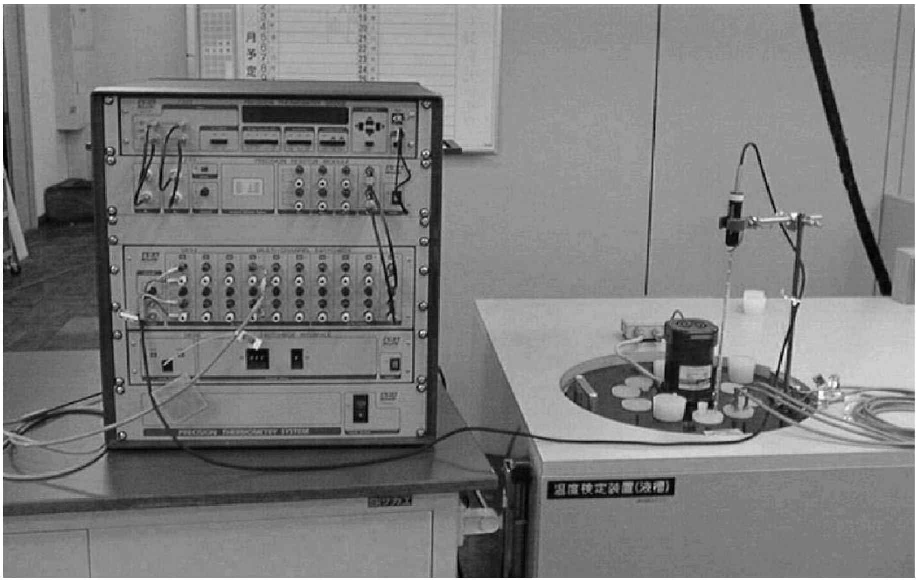
The national meteorological standard instrument for temperature is a standard platinum resistance thermometer. Its principles of measurement are described in Chapter 2 Measurement of Temperature.

This type is also used as a travelling standard.

Picture 9.2 shows the sensor of the standard platinum resistance thermometer, and Picture 9.3 shows calibration with this type of thermometer in a liquid-type calibration chamber. The sensor of the standard thermometer is placed at the center of the calibration chamber, and the thermometers to be calibrated are set around it. Each sensor is connected to an alternating-current bridge through a switch box to allow measurement of its electrical resistance. The resistance levels of each sensor are measured one by one for calibration of the temperature scale against the standard.



Picture 9.2 Standard platinum resistance thermometer sensor



Picture 9.3 Thermometer calibration system

9.4.4.3 Humidity

The humidity standard setup consists of a chilled-mirror dewpoint hygrometer and an electric thermometer. The electric thermometer is identical to that described in the previous section, and the chilled-mirror dewpoint hygrometer is described in this section. Figure 9.7 shows its configuration.

A chilled-mirror dewpoint hygrometer accurately determines the quantity of moisture in the air by directly measuring the dewpoint or frost-point temperature. Figure 9.8 shows the principle of its measurement. The sensor consists of a metal mirror, which is cooled until dew forms on its surface.

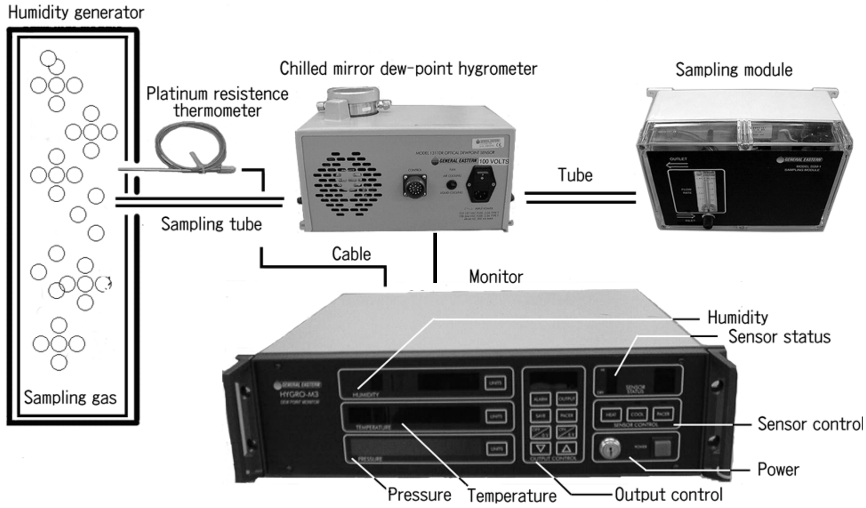


Figure 9.7 Chilled-mirror dewpoint hygrometer configuration

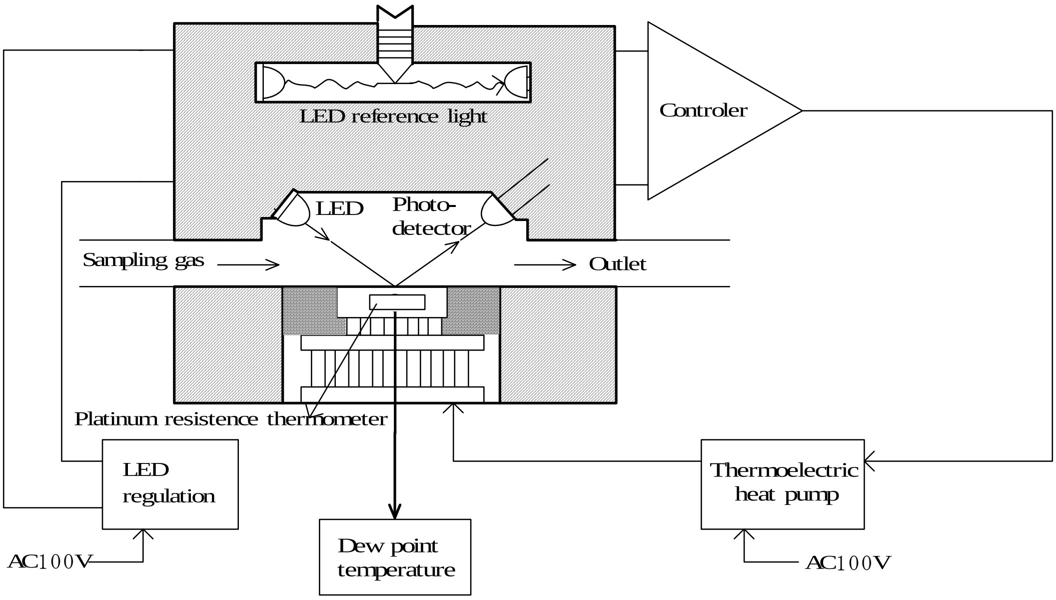


Figure 9.8 Principle of measurement of a chilled-mirror dewpoint hygrometer

Dew formation is determined optically; when it begins to appear, the temperature (known as the dewpoint temperature) of the mirror is measured with the electric thermometer.

The chilled-mirror dewpoint hygrometer shown in Figure 9.7 measures a range of humidity levels from 0.03% to 100% with a sensitivity of 0.03°C for dewpoint temperature.

9.4.5 Facilities Used for Comparison and Calibration

This section introduces the inspection facilities (calibration chambers) maintained at RIC Tsukuba. The calibration facilities consist of the six units described below.

(1) Temperature calibration chamber (air type)

This is an air chamber whose internal temperature can be set to a value between -40°C and +50°C with an accuracy of ±0.3°C and a stability of ±0.3°C/min. It is used to compare and calibrate thermometer equipment such as bimetal thermographs whose sensors and recorders are integrated and cannot be separated.

(2) Temperature calibration chamber (liquid type)

This is a liquid chamber whose internal temperature can be set to a value between -85°C and +50°C with an accuracy of ±0.1°C and a stability of ±0.1°C/min. It is used to compare and calibrate the sensors of thermometer equipment such as electrical thermometers whose sensors and recorders can be separated. The chamber is filled with a special inert liquid that makes it possible to achieve a temperature of -85°C.

(3) Thermal shock test chamber

The internal temperature in this type of chamber can be raised from -40°C to +50°C within 30 minutes with an accuracy of ±1.0°C, and change from high to low temperatures is also possible. It is used to test the durability of instruments against cyclic temperature changes.

(4) Pressure calibration chamber

The pressure in the chamber can be set to a value between 1,050 hPa and 4 hPa with an accuracy of ±1 hPa. It is used to compare and calibrate barographs and barometer probes.

(5) Two-pressure humidity generator

This chamber generates specific levels of humidity based on the principle that humidity (the quantity of water vapor in a particular volume of gas) is proportional to pressure when the temperature is constant. The pressure in the chamber can be reduced by adjusting the expansion valve to lower the level of humidity in proportion with pressure. Although the chamber cannot form a specific level of humidity in conditions of temperature change, it provides sufficient space for comparison and calibration of large integrated instruments whose sensors and recorders cannot be separated, such as hair hygrographs.

The generator can produce levels of relative humidity between 15% and 95% with an accuracy of ±1%.

(6) Thermo-hygro regulator (wet and dry air mixing type)

This regulator generates specific levels of humidity by mixing saturated air (i.e., that with a relative humidity of 100%) with dry air. The method allows temperature control and consequently the attainment of specific levels of humidity at specific temperatures. It can produce levels of relative humidity between 20% and 95% (accuracy: ±2%) with temperature control between -40°C and +50°C (accuracy: ±0.5°C), and can be used for purposes such as testing the temperature characteristics of hygrometers. As the space in the chamber is limited, it cannot be used to compare and calibrate large instruments whose sensors and recorders cannot be separated, such as hair hygrographs.