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**Test methods for density and relative
density of chemical products**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Chemical Industry Association (JCIA)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS K 0061** : 2001), which has been technically revised.

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Test methods for density and relative density of chemical products

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 758** : 1976, Edition 1. This Standard has incorporated the parts of **ISO** that corresponds to **JIS**, namely the specification of the Gay-Lussac pycnometer in **6.3** “Pycnometer method”, with some changes in technical contents, and also added **JIS**’s own test methods based on unique needs of the Japanese market, including the hydrometer method, the pycnometer methods using other pycnometers than the Gay-Lussac pycnometer, the vibration density meter method and the in-liquid weighing method (balance method) for liquid products, as well as the density and specific gravity measuring method for solid and gaseous products. In Clause 1, Clause 2, Clause 3, **6.3.1**, **6.3.2**, **6.3.4**, **6.3.5**, **6.3.6** and Clause 9, which contain requirements given in the corresponding International Standard, the vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JC.

1 Scope

This Standard specifies general methods for measuring the density and specific gravity of chemical products.

NOTE 1 For the purpose of this Standard, chemical products mean all products prepared through chemical reaction.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 758 : 1976 *Liquid chemical products for industrial use — Determination of density at 20 °C* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

WARNING Chemical products may be volatile, explosive or radioactive. It is the responsibility of anyone who conducts measurements in accordance with this Standard to establish appropriate safety, health and environmental practices with reference to Safety Data Sheet (SDS) or other documents.

2 Normative references

Part or all of the provisions of the following standards, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (in-

cluding amendments) indicated below shall be applied.

JIS B 7410 *Liquid-in-glass thermometers for testing of petroleum product*

JIS B 7525-1 *Hydrometers — Part 1 : Density hydrometers*

JIS B 7525-3 *Hydrometers — Part 3 : Specific gravity meters*

JIS K 0050 *General rules for chemical analysis*

JIS K 0211 *Technical terms for analytical chemistry (General part)*

JIS K 0557 *Water used for industrial water and wastewater analysis*

JIS R 3503 *Glass apparatus for chemical analysis*

JIS Z 8401 *Rounding of numbers*

JIS Z 8703 *Standard atmospheric conditions for testing*

JIS Z 8704 *Temperature measurement — Electrical methods*

JIS Z 8705 *Method of temperature measurement by liquid-in-glass thermometers*

JIS Z 8710 *Temperature measurement — General requirement*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions, and those given in **JIS K 0211** apply.

3.1

density

mass per unit volume of a sample

Note 1 to entry It is expressed in g/cm³.

3.2

specific gravity

ratio of the density of a sample to that of water in the case of a solid or liquid sample, and ratio of the density of a sample to that of dry air in the case of a gaseous sample

Note 1 to entry It is also referred to as relative density.

Note 2 to entry Because specific gravity is non-dimensional, it has an advantage that the same value can be obtained regardless of the unit system.

3.3

mass

physical quantity, expressed in kilogrammes (kg), defined by the Planck's constant

Note 1 to entry The mass value is obtained by correcting the apparent mass value for the influence of air buoyancy.

3.4

apparent mass

mass of an object determined by weighing it in air by means of a balance

Note 1 to entry The value is smaller than the mass by the amount influenced by air buoyancy.

Note 2 to entry For the purpose of this Standard, “weigh the mass” means to obtain a mass value by weighing the apparent mass and then correcting it for air buoyancy. The procedure for weighing the mass is described in **5.6 b**).

3.5

metrological traceability

characteristic of a measurement result to be relatable to a metrological reference through a seamless chain of written calibrations, each of which contributes to the uncertainty of the result

Note 1 to entry “Calibration” means a series of operations for determining the relationship under specific conditions between a value indicated by a measuring device or measuring system, or a value given by a material measure or a reference material, and a corresponding value realized by a standard.

(SOURCE: **JIS Z 8804** : 2012, **3.3** and **JIS Z 8807** : 2012, **3.3**)

3.6

JCSS (Japan Calibration Service System)

system for supplying measurement standards based on the Measurement Act

Note 1 to entry “Calibration” under this system means the act of proving the linkage (see **3.5** “metrological traceability”) to the measurement device concerned through a series of comparisons with relevant national or international standards.

(SOURCE : **JIS Z 8804** : 2012, **3.4** and **JIS Z 8807** : 2012, **3.4**)

4 Measuring methods

4.1 General

The measuring method shall be selected according to the sample property (liquid, solid or gas) and the amount of sample from the methods given in **4.2**, **4.3** or **4.4**.

4.2 Measuring methods for density and specific gravity of liquid and their outlines

The measuring methods for density and specific gravity of liquid and their outlines are given in Table 1.

Table 1 Measuring methods for density and specific gravity of liquid and their outlines

Measuring method	Relevant subclause	Outline
Hydrometer method	6.2	A hydrometer is used. With the hydrometer floated in the sample, the density or specific gravity of the sample is directly read on the scale on the stem of the hydrometer.
Pycnometer method	6.3	A pycnometer is used. After the volume of the pycnometer is calibrated, the mass of the sample placed in the pycnometer is weighed, and the density of the sample obtained. The following pycnometers are used. 1) Wardon pycnometer, [6.3.2 a) 1)], preferably of 50 ml capacity. 2) Gay-Lussac pycnometer [6.3.2 a) 2)], preferably of 25 ml or 50 ml capacity, and with or without a thermometer. 3) Hubbard pycnometer [6.3.2 a) 3)], applicable to highly viscous liquids, and preferably of 25 ml capacity. 4) Graduated pycnometer [6.3.2 a) 4)], preferably of 5 ml capacity, capable of small volume measurements, but not suitable for use with highly viscous liquids. 5) Ostwald pycnometer [6.3.2 a) 5)], preferably of 2 ml capacity, capable of small volume measurements, but not suitable for use with highly viscous liquids.
Vibration density meter method	6.4	A vibration density meter is used. Because the intrinsic vibration period of a U-tube sample cell correlates with the density of fluid in the cell, the density of the sample is calculated after determining the cell constant from the above correlation by using the reference materials.
In-liquid weighing method (balance method)	6.5	The density of a sample is obtained by measuring the buoyancy on a solid of known density when it is immersed in the sample liquid.

4.3 Measuring methods for density and specific gravity of solid and their outlines

The measuring methods for density and specific gravity of solid and their outlines are given in Table 2.

Table 2 Measuring methods for density and specific gravity of solid and their outlines

Measuring method	Relevant subclause	Outline
In-liquid weighing method (balance method)	7.2	The density of the sample is obtained from its mass and buoyancy measured in air and in a liquid of known density using a balance.
Pycnometer method	7.3	A pycnometer is used. This method requires special attention to complete de-aeration and selection of liquid. The following pycnometers are used. 1) Le Chatelier's pycnometer (7.3.1), having a volume scale of specified precision so that the volume of a sample placed in the pycnometer can be directly read. It is easy in operation and applicable to granular or powdery samples with a grain size of several millimetres or less. It requires about 30 ml to 40 ml of sample volume for measurement. Among the pycnometers for measurement of liquids, the following can also be used for measurement of solids. 2) Wardon pycnometer [7.3.2 b) 1.1], preferably of 50 ml capacity, and applicable to granular or powdery samples with a grain size of several millimetres or less. 3) Gay-Lussac pycnometer [7.3.2 b) 1.2], preferably of 25 ml, 50 ml and 100 ml capacity, applicable to granular or powdery samples with a grain size of several millimetres or less, and with or without a thermometer. 4) Hubbard pycnometer, [7.3.2 b) 1.3], preferably of 25 ml capacity, and with a big opening suitable for samples with large grain size.
Density gradient tube method	7.4	A density gradient tube, which is a graduated glass tube with a liquid column, the density of which increases continuously and linearly in the direction from top to bottom, is used. The sample is floated in the density gradient tube, and the density of the sample is read at the position of the scale at which the sample has come to a standstill and from the calibration curve prepared by standard floats.

4.4 Measuring methods for density and specific gravity of gas and their outlines

The measuring methods for density and specific gravity of gas and their outlines are given in Table 3.

Table 3 Measuring methods for density and specific gravity of gas and their outlines

Measuring method	Relevant subclause	Outline
Pycnometer method (Dumas' method)	JB.2	A glass bulb with a cock is used as a pycnometer. After the capacity of the pycnometer is calibrated, the mass of the sample placed in the pycnometer is weighed, and the density of the sample obtained.
Effusion method (Bunsen-Schilling method)	JB.3	The specific gravity of a sample is determined by defining the specific gravity of air as 1 at the given same temperature and given same pressure, i.e. without specifying the temperature and pressure conditions during measurement.

5 Common requirements

5.1 General

The units used for mass, volume, temperature and pressure shall be gramme (g) [or kilogramme (kg)], cubic centimetre (cm³) [or millilitre (ml), litre (L) and cubic metre (m³)], degrees Celsius (°C) and kilopascal (kPa), respectively. The units of density shall be grammes per cubic centimetre (g/cm³) [or grammes per millilitre (g/ml), kilogrammes per litre (kg/L) and kilogrammes per cubic metre (kg/m³)].

The density and specific gravity values in this Standard shall be determined by multiple measurements, and should normally be obtained to the third decimal place or higher precision; if otherwise specified in the “Expression of measurement results” subclause of each measuring method, that specification shall apply.

Further, if other requirements than above are specified in the specific product standard or agreed between the interested parties, those requirements shall apply.

5.2 Expression of density

The density shall be expressed with symbols denoting the temperature and pressure during measurement as follows.

- Density (20 °C)** Density of a sample at 20 °C, when no pressure condition is specified.
- Density (t °C, p kPa)** Density of a sample at t °C and pressure p kPa.
- Density (t °C)** Density of a sample at t °C, when no pressure condition is specified.

For liquid and solid samples, the specification of pressure condition may be omitted by assuming the atmospheric pressure to be 101.325 kPa because the influence of pressure within the normal variations of atmospheric pressure is negligible. For gaseous samples, the specification of pressure condition may be omitted when the test pressure is 101.325 kPa or converted to 101.325 kPa.

5.3 Expression of specific gravity

In this Standard, the specific gravity of chemical products is measured by means of a

specific gravity hydrometer. The specific gravity can also be calculated from density. The specific gravity of a liquid or solid sample is expressed with symbols denoting the temperatures of sample and water. The specific gravity of a gaseous sample shall be specified with symbols denoting the temperatures and pressures of sample and air as follows.

- a) **Specific gravity (20/20 °C)** Ratio between the density of liquid or solid sample at 20 °C and that of water at 20 °C; or ratio, when no pressure condition is specified, between the density of gaseous sample at 20 °C and that of dry air at 20 °C.
- b) **Specific gravity (t_1/t_2 °C, p_1/p_2 kPa)** Ratio between the density of gaseous sample at temperature t_1 °C and pressure p_1 kPa and the density of dry air at temperature t_2 °C and pressure p_2 kPa.
- c) **Specific gravity (t_1/t_2 °C)** Ratio between the density of liquid or solid sample at temperature t_1 °C and that of water at temperature t_2 °C; or ratio, when no pressure condition is specified, between the density of gaseous sample at t_1 °C and that of dry air at t_2 °C.

For liquid and solid samples, the specification of pressure condition may be omitted by assuming the atmospheric pressure to be 101.325 kPa because the influence of pressure within the normal variations of atmospheric pressure is negligible. For gaseous samples, the specification of pressure condition may be omitted when the test pressure is 101.325 kPa or converted to 101.325 kPa.

5.4 Condition of measuring site

The measuring site should be maintained at the atmospheric pressure of 86 kPa to 106 kPa, temperature of 20 °C $\pm$ 5 °C and humidity of (65 $\pm$ 20) % as specified in the standard atmosphere given in JIS Z 8703.

The measuring site should be a laboratory equipped with air conditioning equipment that can keep the temperature and humidity constant within the specified tolerance, or a laboratory with minimum temperature and humidity fluctuations.

5.5 Standard temperature

The standard temperature for density measurements of the chemical products in this Standard is 20 °C, and that for specific gravity measurements, 20/20 °C. This temperature specification assumes that measurements will be conducted under the atmospheric pressure of the measuring site. Where, due to the properties and characteristics of the specific chemical product, other temperature than 20 °C (hereafter referred to as the measurement temperature) is specified in the specific product standard or the series of product standards, or agreed between the interested parties, that temperature may apply. In this case, the density of water and air required for calculation of density and specific gravity shall be as given in Annex JA.

When measuring mixtures with different boiling or melting points and when the measurement temperature is changed from the ordinary temperature, it shall be verified that no change in composition due to volatilization or solidification occurs.

5.6 Apparatus and procedures commonly used for measurements

The general requirements of apparatus and procedures used for measurements specified in this Standard shall be in accordance with the following and **JIS K 0050**.

a) **Balance**, chemical or electronic force.

A chemical balance is a symmetrical beam balance or direct-reading balance with constant sensitivity, the maximum measurable mass of which is 100 g to 200 g and by which the difference of 0.1 mg can be read.

The chemical or electronic force balance shall be calibrated by weights having undergone calibration by a JCSS-certified laboratory.

b) **Weighing of mass** Weigh the apparent mass of an object in air using a balance specified in a), and obtain the mass by the following formula.

Samples, containers used for measurement, etc. shall be stored in clean atmosphere and handled with clean forceps or gloved hands in order to avoid contamination that may cause an error in measurement.

The correction of air buoyancy shall be performed when a highly accurate mass value is required and therefore the error resulting from the density difference between the object and the weight cannot be ignored.

$$w_0 = w + w\rho(1/d_1 - 1/d_2)$$

where, w_0 : mass of object (g)
 w : apparent mass of object (g)
 ρ : density of air during measurement (g/cm³)
 d_1 : density of object (g/cm³)
 d_2 : density of weight used in chemical balance (g/cm³) or density of weight used in calibration of electronic force balance (g/cm³)

Notes for measurement are as follows.

- 1) Generally, $\rho = 0.001\ 2\ \text{g/cm}^3$ shall be used as the density of air during measurement. Where a more precise value is required, Annex JA shall be referred to.
- 2) Generally, the density of an object d_1 shall be rounded off to two significant figures, and in the case of multiple objects, it shall be the average of all the objects. When the object is or contains the object of density measurement, the density value should be calculated without correction of air buoyancy.
- 3) The density of weights d_2 depends on the material and structure of the weights. The standard weights based on the Measurement Act are made from a material 8.0 g/cm³ in density.

In general measurement of density or specific gravity, if the measured value is required down to the decimal place of 0.001, the correction of air buoyancy is not necessary. In other words, though the density of air being 0.001 2 g/cm³ affects the decimal place of 0.001 of density and specific gravity of the sample, when water is used as a reference for measurement and the density of sample is between 0.6

g/cm³ to 1.3 g/cm³ in various pycnometer methods, the error resulting from using apparent masses for the masses of apparatus, sample and material used references for measurement will be within 0.000 4 g/cm³ because the influence of air buoyancy on each will considerably be offset in the density and specific gravity calculation. In this case, therefore, using apparent masses as mass values for calculation is not considered problematic. This decision shall be made by the analyst after verification or made for each specific product standard.

- c) **Thermometer** A glass thermometer specified in **JIS B 7410**, selected according to the measurement temperature and the precision.

NOTE For example, a thermometer verified in accordance with the Measurement Act, or any glass thermometer, resistance thermometer or thermoelectric thermometer having an equivalent performance to this that has been calibrated by a JCSS-certified laboratory.

- d) **Temperature measuring method** Temperatures shall be measured according to **JIS Z 8704**, **JIS Z 8705** and **JIS Z 8710** using a thermometer specified in c).

5.7 Materials used as references for measurement

For materials used as references in measurements specified in this Standard, the following air and dry air are recommended.

- a) **Water**, distilled or ion-exchanged, de-aerated by boiling, application of a vacuum or ultrasonic irradiation, and having a density as given in Table JA.1.
- b) **Dry air** The air in the measuring site dried with the use of desiccant, having a density of 0.001 20 g/cm³ if used for calibration. For a more precise value of density, see Annex JA.

5.8 Rounding of numbers

The values shall be rounded according to Rule A or Rule B specified in **JIS Z 8401**.

5.9 Notes for handling of chemical products

Any chemical substance handled shall be first checked for its name and safety. If confirmation of safety is not possible due to the lack of available information regarding the properties of the substance, a prior investigation into this matter shall be made so that the substance can be handled with adequate safety measures in place.

If the substance is regulated by laws and regulations due to its hazardousness, toxicity, radioactivity, etc., it shall be handled in accordance with the relevant laws and regulations after sufficient preparation and provision of safety measures.

6 Measuring methods for density and specific gravity of liquid

6.1 General

The density and specific gravity of a liquid shall be measured by one of the following methods according to the amount, properties, etc. of the sample.

- Hydrometer method (6.2)

- Pycnometer method (6.3)
- Vibration density meter method (6.4)
- In-liquid weighing method (balance method) (6.5)

6.2 Hydrometer method

6.2.1 Principle

With the hydrometer floated in the sample, the density or specific gravity of the sample is directly read on the scale (density or specific gravity) on the stem of the hydrometer. This method enables direct reading of the density or specific gravity value and therefore is simple in procedure. Some hydrometer series are capable of measuring to the fourth decimal place. This method is applicable to virtually all liquids.

6.2.2 Equipment and apparatus

The equipment and apparatus used for the measurement shall be as follows.

- a) **Hydrometer**, with known instrumental error: either a density hydrometer specified in **JIS B 7525-1** having a measuring range of 0.600 g/cm³ to 2.000 g/cm³ or a specific gravity hydrometer specified in **JIS B 7525-3** having a measuring range of 0.700 to 1.850.

NOTE 1 For example, a hydrometer verified in accordance with the Measurement Act, or a hydrometer calibrated by a JCSS-certified laboratory. For measurements performed for the purposes of transaction or certification, a hydrometer verified in accordance with the Measurement Act shall be used.

Figure 1 shows an example of hydrometer. See **JIS B 7525-1** and **JIS B 7525-3** for detailed construction of hydrometer.

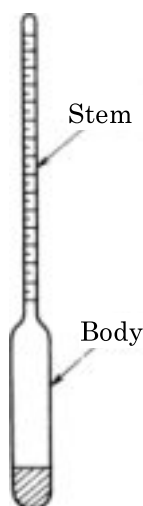


Figure 1 Example of hydrometer

- b) **Thermometer**, in accordance with 5.6 c).

NOTE 2 For example, a thermometer of No. 42(SG) or 44(SG) specified in **JIS B 7410**.

- c) **Cylinder**, made of glass or transparent plastic that does not affect the properties of the sample, having an inner diameter larger by 25 mm or more than the maximum diameter of the hydrometer and such a height that, when the hydrometer is put in the cylinder, the bottom of the hydrometer is 25 mm or more above the bottom of the cylinder.
- d) **Thermostat bath**, capable of keeping the temperature of the sample in a cylinder at $20.0\text{ }^{\circ}\text{C} \pm 0.1\text{ }^{\circ}\text{C}$.
- e) **Stirring rod**, made of a material which will not be corroded or deteriorated by the sample, and suitable for thorough agitation of the sample in the cylinder to make the density or specific gravity of the sample uniform.

6.2.3 Procedure

The procedure shall be as follows.

- a) Put the sample into a cylinder with care not to include bubbles and set the cylinder in a thermostat bath. After stirring the sample by vertical motions of a stirring rod, dip a thermometer fully into the sample, i.e. so that the entirety of its enclosed liquid is immersed in sample from the bottom of the bulb to the top of the column (temperature indicator), and measure the temperature of the sample.
- b) When the temperature of the sample has reached $20.0\text{ }^{\circ}\text{C} \pm 0.1\text{ }^{\circ}\text{C}$, gently float a clean hydrometer previously kept at approximately $20\text{ }^{\circ}\text{C}$ in the sample, and when it has come to a standstill, sink it by two scales into the sample by hand and then let go. Giving the hydrometer a little twist when letting it go will prevent it from touching the cylinder wall before coming to a standstill.
- c) When the hydrometer has come to a standstill, read the scale to the nearest $1/5$ of the smallest graduation at the upper edge (top) of the meniscus in the case of a hydrometer of meniscus top reading and to the nearest $1/5$ of the smallest graduation at the lower edge of the meniscus in the case of a hydrometer of horizontal surface reading, and record the reading. Reading of the hydrometer scale shall be as illustrated in Figure 2 and as follows.
 - 1) **Meniscus top reading** When using a hydrometer of meniscus top reading to measure the density or specific gravity of an opaque sample, read the scale at the upper edge (top) of the meniscus of the sample, and convert this value to the value at the lower edge using a correction factor previously determined.
 - 2) **Horizontal surface reading** When using a hydrometer of horizontal surface reading to measure the density or specific gravity of a transparent sample, raise the eye level gradually from a height little lower than the sample liquid level, and at the first moment the initially oval sample liquid surface appears to be a straight line (horizontal liquid level), read the scale.

Note that if the stem of the hydrometer is contaminated, the readings will be affected by the surface tension. The hydrometer shall be picked up by holding the top of the

stem with care not to touch the graduated part. To clean the hydrometer, a cleaning agent suitable for the properties of the sample shall be used; normally, a cloth or paper moistened with neutral detergent or ethanol is used to wipe the stem.

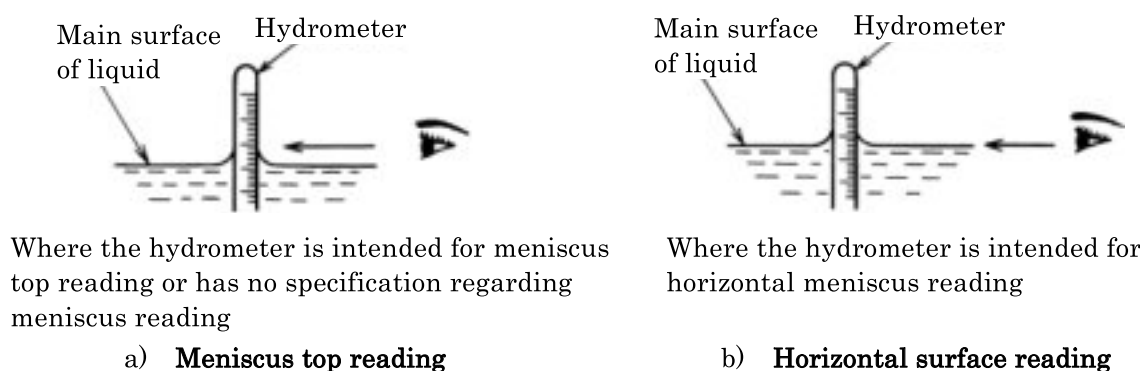


Figure 2 Reading of hydrometer scale

6.2.4 Calculation

Calculate the density (20 °C) and specific gravity (20/20 °C) according to the following.

If the reference temperature used for the scale of the hydrometer is different from the measurement temperature, perform the temperature correction in accordance with **JIS B 7525-1** and **JIS B 7525-3**. For instrumental error correction, subtract the instrumental error from the hydrometer reading.

To determine the instrumental error by comparison with a calibrated density hydrometer or specific gravity hydrometer, use the following formula. When the value is not required down to the decimal place of 0.001 for measurement, the correction of instrumental error may be omitted.

$$E = R - (R_s - e)$$

where, E : instrumental error
 R : reading of hydrometer to be used for measurement
 R_s : reading of calibrated hydrometer
 e : instrumental error of calibrated hydrometer

The influence of air buoyancy on the values of density (20 °C) (g/cm³) and specific gravity (20/20 °C) obtained by hydrometer method is only that caused by the mass of air equal to the volume of the stem extending beyond the liquid surface and therefore is usually negligible.

a) When density (20 °C) is obtained using a hydrometer with a density scale (20 °C), use the following formula.

$$D = D_{20} - E$$

where, D : density (20 °C) (g/cm³)

D_{20} : reading of hydrometer with a density scale (20 °C) (g/cm³)
 E : instrumental error

- b) When density (20 °C) is obtained using a hydrometer with a density scale (15 °C), use the following formula.

$$D = 0.999\ 88 (D_{15} - E)$$

where, D : density (20 °C) (g/cm³)
 D_{15} : reading of hydrometer with a density scale (15 °C) (g/cm³)
 E : instrumental error

- c) When density (20 °C) is obtained using a hydrometer with a specific gravity scale (15/4 °C), use the following formula.

$$D = 0.999\ 85 (S_{15} - E)$$

where, D : density (20 °C) (g/cm³)
 S_{15} : reading of hydrometer with a specific gravity scale (15/4 °C)
 E : instrumental error

- d) When specific gravity (20/20 °C) is obtained from density (20 °C), use the following formula.

$$S = D/0.998\ 21$$

where, S : specific gravity (20/20 °C)
 D : density (20 °C) (g/cm³)

6.2.5 Expression of measurement results

Density and specific gravity values shall be rounded off to the third decimal place. However, the precision with which the density and specific gravity values can be determined depends on the scale interval and maximum permissible error of the series of hydrometer used.

Example In the case of the L50 series density hydrometer, determination of density to the fourth decimal place is possible.

6.3 Pycnometer method

6.3.1 Principle

A pycnometer is filled with the sample and after it is adjusted to the volume at the measurement temperature in a thermostat bath, the mass of the sample in the pycnometer is weighed, and then the mass of water under the same temperature and the same volume is weighed using the same pycnometer. The mass of the sample divided by the mass of water is multiplied by the density of water, and taken as the density of the sample at measurement temperature.

This method is based on the fundamental principle of density measurement, and provides high precision results to the fourth decimal place, but its operation is somewhat complicated.

6.3.2 Equipment and apparatus

The equipment and apparatus used shall be as follows.

a) **Pycnometer**

- 1) **Wardon pycnometer**, with a cap for preventing evaporation of overflowed liquid, preferably of 50 ml capacity. See **JIS R 3503** for detailed construction. Figure 3 shows an example.

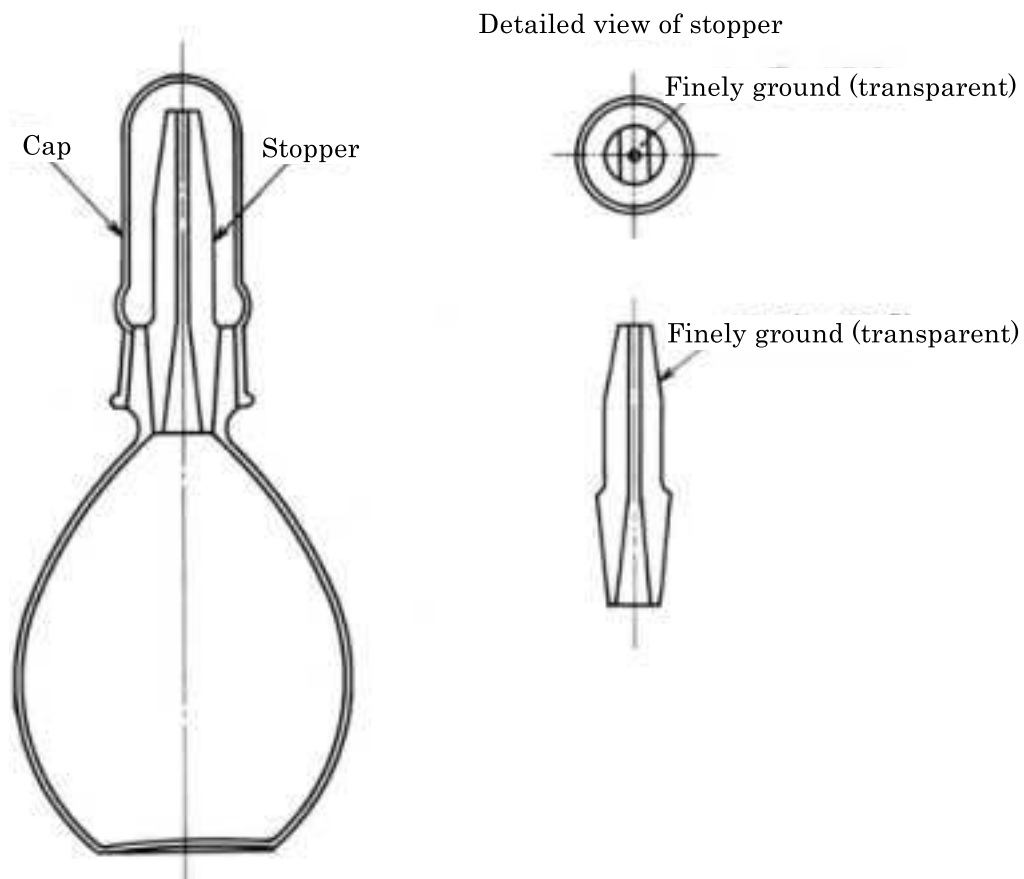
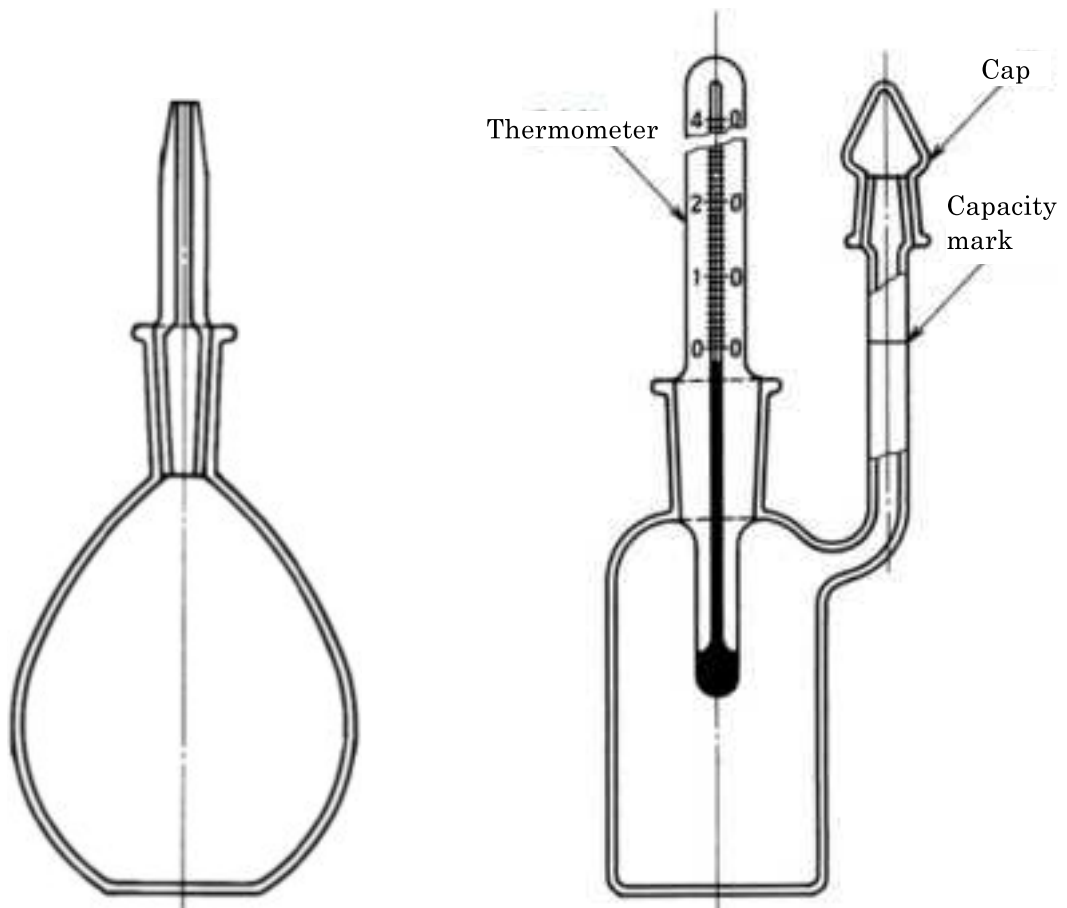


Figure 3 Example of Wardon pycnometer

- 2) **Gay-Lussac pycnometer**, having a capacity mark on the side tube for adjustment of liquid level, overflow resistant, preferably of 25 ml or 50 ml capacity, and with or without a thermometer. See **JIS R 3503** for detailed construction. Figure 4 shows examples.



a) Example of Gay-Lussac pycnometer b) Example of Gay-Lussac pycnometer with thermometer

Figure 4 Examples of Gay-Lussac pycnometer