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JAPANESE INDUSTRIAL STANDARD

Testing methods of ceramic insulators for electrical and electronic applications

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Testing methods of ceramic insulators for
electrical and electronic applications

C 2141-1992

1. Scope

This Japanese Industrial Standard specifies testing methods of ceramic insulators used for electrical equipment and electronic equipment (hereafter referred to as "ceramics").

Remarks 1. The following Standards are cited in this Standard:

JIS B 0601-Definitions and Designation of Surface Roughness

JIS B 0651-Instruments for the Measurement of Surface
Roughness by the Stylus Method

JIS B 7410-Liquid-in-Glass Thermometers for Testing of
Petroleum Products

JIS B 7502-Micrometer Callipers for External Measurement

JIS B 7503-Dial Gauges Reading in 0.01 mm

JIS B 7507-Vernier Callipers

JIS B 7734-Micro Hardness Testing Machines for Vickers and
Knoop Hardness

JIS C 1303-High Insulation Resistance Meters

JIS C 2320-Electrical Insulating Oils

JIS R 1611-Testing Methods of Thermal Diffusivity,
Specific Heat Capacity, and Thermal Conductivity
for High Performance Ceramics by Laser Flash
Method

JIS R 3503-Glass Apparatus for Chemical Analysis

JIS Z 8401-Rules for Rounding off of Numerical Values

JIS Z 8704-Electrical Methods of Temperature Measurements

2. The International Corresponding Standards to this Standard
are given below.

IEC 672-2 (1980) Specification for ceramic and glass
insulating materials. Part 2: Methods of test

2. Definitions

For the purpose of this Standard the following principal definitions apply:

- (1) bulk volume Total volume of ceramics including closed pores and open pores in addition to the solid part.
- (2) apparent volume The volume equal to the remainder obtained by subtracting the volume of open pores from the bulk volume.
- (3) apparent porosity The ratio of the volume of open pores only excluding closed pores, in percentage, to the bulk volume.
- (4) bulk density The quotient obtained by dividing the mass of the ceramics by the bulk volume.
- (5) apparent density The quotient obtained by dividing the mass of the ceramics by the apparent volume.

3. Classification of tests

Tests are classified as given in Table 1.

Table 1. Classification of tests

Classification	Applicable clause
Water absorption	5.
Apparent porosity	
Bulk density	
Apparent density	
Surface roughness	6.
Flexural strength	7.
Modulus of elasticity	8.
Hardness	9.
Mean coefficient of linear expansion	10.
Resistance to thermal shock	11.
Specific heat capacity	12.
Thermal diffusivity and thermal conductivity	13.
Volume resistivity and surface resistivity	14.
Dielectric breakdown strength	15.
Relative permittivity and dissipation factor	16.

4. Rounding-off of numerical values

Measured values or mean values obtained by each test shall be rounded off to the number or place of figures shown in Table 2, according to JIS Z 8401.

Table 2. Rounding-off of numerical values

Classification	Number or place of figures for rounding-off
Water absorption	One place of decimal
Apparent porosity	
Bulk density	Three significant figures
Apparent density	
Surface roughness	Two significant figures
Flexural strength	Three significant figures
Modulus of elasticity	
Hardness	
Mean coefficient of liner expansion 10^{-6}	One place of decimal
Resistance to thermal shock	In terms of 10
Specific heat capacity	Three significant figures
Thermal diffusivity	
Thermal conductivity	
Volume resistivity	Two significant figures
Surface resistivity	
Dielectric breakdown strength	
Relative permittivity	
Dissipation factor 10^{-4}	In terms of one

5. Water absorption test, apparent porosity test, bulk density test and apparent density test

5.1 Equipment and apparatus The equipment and apparatus shall be as follows:

- (1) Thermostatic chamber A thermostatic chamber which can regulate the inside temperature to 105°C to 120°C.

- (2) Balance A balance with reciprocal sensitivity of 1 mg or better.
- (3) Beaker The beaker of at least 200 mg specified in JIS R 3503.
- (4) Bell jar with vacuum pump A vacuum container which can maintain a reduce pressure condition of at least 2×10^3 Pa.
- (5) Thermometer The alcohol thermometer with minimum scale of 1°C specified in JIS B 7410.
- (6) Wire netting A wire netting made of stainless steel.

5.2 Test specimen The test specimen shall have a mass not less than 5 g, and chippings shall be eliminated before the measurement.

5.3 Method of test

5.3.1 Dry mass Dry the test specimen in a thermostatic chamber regulated at 105°C to 120°C , take it out of the chamber when it reaches a constant mass, cool it to room temperature in a desiccator, measure the mass with the balance and take the value as the dry mass m_1 .

5.3.2 Soaking method Employ either one of the soaking methods of test specimen (with water) given below.

- (1) Method 1 Bring the dried test specimen to a constant mass, in a dried beaker, and place the beaker in the vacuum container. Maintain the vacuum at 2 to 3×10^3 Pa for 5 min. Then pour distilled water or demineralized water (hereafter referred to as "water") in the beaker located in the vacuum container. Introduce a sufficient amount of water to immerse the test specimen.

After complete immersion of test specimen into water, evacuate the container for a further 5 min and then return the container to the atmospheric pressure by introducing air.

- (2) Method 2 Place the dried test specimen to a constant mass in a beaker containing water and boil it. In this procedure the volume of water shall be enough to immerse the test specimen.

Provide a wire netting about 1 cm above the bottom of the beaker.

Place the test specimen on this wire netting so that the water circulates sufficiently. The duration of boiling shall be 30 min.

5.3.3 Mass in water of soaked test specimen Measure the mass of soaked test specimen in water and denote it as the mass in water m_2 . Record the temperature at this measurement.

5.3.4 Mass of soaked test specimen (in air) Take the soaked test specimen out of water, quickly wipe off water drops on the surface with wet gauge⁽¹⁾, measure the mass and denote it as the mass of soaked test specimen m_3 .

Note ⁽¹⁾ Soak the gauge sufficiently with water, then wring it to such an extent that it is enough to remove water drops on surface of test specimen only.

5.4 Calculation

5.4.1 Water absorption Calculate water absorption A_w from the following formula:

$$A_w (\%) = \frac{m_3 - m_1}{m_1} \times 100$$

5.4.2 Apparent porosity Calculate apparent porosity P_A from the following formula:

$$P_A (\%) = \frac{m_3 - m_1}{m_3 - m_2} \times 100$$

5.4.3 Bulk density Calculate bulk density ρ_B from the following formula:

$$\rho_B (g/cm^3) = \frac{m_1}{m_3 - m_2} \times \rho_w$$

where, ρ_w : density of water at test (g/cm^3)

5.4.4 Apparent density Calculate apparent density ρ_A from the following formula:

$$\rho_A (g/cm^3) = \frac{m_1}{m_1 - m_2} \times \rho_w$$

where, ρ_w : density of water at test (g/cm^3)

6. Surface roughness test

6.1 Equipment and apparatus The equipment and apparatus shall be as follows:

- (1) Instrument The instrument specified in JIS B 0651.
- (2) Stylus A stylus of cone shape with an apex angle of 90° having a radius of curvature $5 \mu m$ at its spherical tip.

6.2 Test specimen The test specimen is the sample of an optional size which can be mounted to the instrument.

6.3 Method of test Obtain any or all of the center-line mean roughness (R_a), maximum height (R_{max}) and ten-point mean roughness (R_z) in accordance with JIS B 0601.

6.4 Expression of results Express the results as follows:

- (1) Express the center line mean roughness (R_a) in $\mu\text{m } R_a$.
- (2) Express the maximum height (R_{max}) in $\mu\text{m } R_{max}$.
- (3) Express the ten-point mean roughness (R_z) in $\mu\text{m } R_z$.

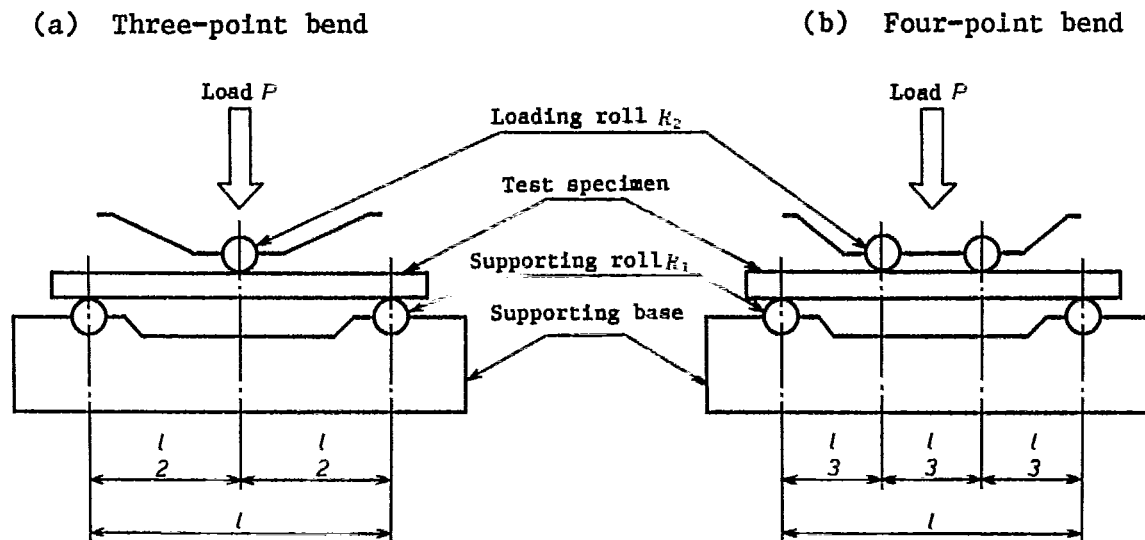
7. Flexural strength test

7.1 Equipment and apparatus The equipment and apparatus shall be as follows:

- (1) Flexural testing machine A suitable material testing machine capable of maintaining its crosshead at a prescribed constant moving speed. The accuracy of load indication of the material testing machine shall be such that the measurement to $\pm 1\%$ of the true load is possible.
- (2) Supports The supports shall consist of rolls as illustrated in Fig. 1, their modulus of elasticity shall be not less than $14.7 \times 10^4 \text{ N/mm}^2$ and their material shall not cause plastic deformation or break during the test. The radii of these rolls R_1 , R_2 shall have the appropriate values given in Fig. 1, and the roughness of both surfaces shall be 1.6 S specified in JIS B 0601.

Use the supports of the same shape for the right and left positions and their length shall be exceeding the width of the test specimen.

Fig. 1. Supports



$$R_1 : 2.0 \text{ mm to } 5.0 \text{ mm} \quad R_2 : 0.5 \text{ mm to } 5.0 \text{ mm} \quad l : 30.0 \pm 0.5 \text{ mm}$$

- (3) Micrometers The micrometer calliper for external measurement specified in JIS B 7502 or a micrometer at least equivalent in accuracy.

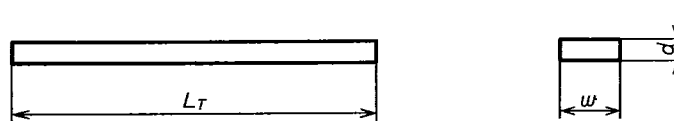
- (4) Dial gauge The dial gauge reading in 0.01 mm specified in JIS B 7503 or a dial gauge at least equivalent in accuracy.
- (5) Vernier calliper The vernier calliper with a minimum reading length 0.05 mm specified in JIS B 7507 or a vernier calliper at least equivalent in accuracy.

7.2 Test specimen The shape of test specimen shall be rectangular sheet or square bar and the dimensions shall be as shown in Fig. 2.

The test specimen shall be free from such defects as burr and chippings.

Fig. 2. Shapes and dimensions of test specimen

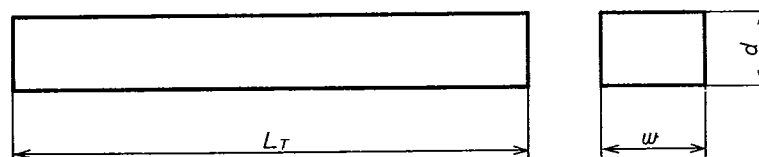
(a) Rectangular sheet test specimen



L_T : 36 mm min. w : 12.0 ± 0.1 mm d : 1.00 ± 0.05 mm

The rectangular sheet test specimen shall have the surface as calcined.

(b) Square bar test specimen

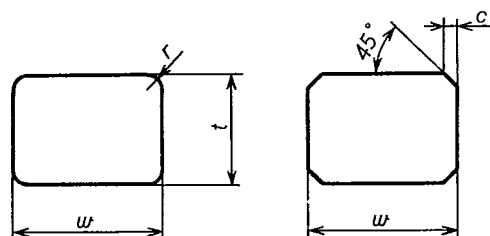


L_T : 36 mm min. w : 4.0 ± 0.1 mm d : 3.0 ± 0.1 mm

The parallelism between upper and lower surfaces shall be not more than 0.02 mm.

Manufacture the square bar test specimen by grinding work. The upper and lower surfaces shall have the surface roughness of 0.8 S specified in JIS B 0601. If other than 0.8 S state the fact in the report. Round or chamfer the ridges as illustrated in Fig. 3.

Fig. 3. Rounding or chamfering of ridges of test specimen



r or c : 0.1 to 0.3 mm

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7.3 Method of test The method of test shall be as follows:

- (1) Carry out the measurements of the width and thickness of test specimen previously by using the micrometer or dial gauge.
- (2) Make the distance between supports and the distance between loading points as shown in Fig. 1 and measure them previously using the vernier calliper.
- (3) Apply the load to the loading points of test specimen at a moving speed of crosshead 0.5 mm/min, and measure the maximum load at fracture of the test specimen.

7.4 Calculation Calculate the flexural strength from the measured values on individual test specimen according to the following formula:

$$\sigma_{b3} = \frac{3Pl}{2wd^2}$$

$$\sigma_{b4} = \frac{Pl}{wd^2}$$

where, σ_{b3} : flexural strength at three-point bend (N/mm²)

σ_{b4} : flexural strength at four-point bend (N/mm²)

P : load at rupture of test specimen (N)

l : distance between lower supports (mm)

w : Width of test specimen (mm)

d : thickness of test specimen (mm)

8. Modulus of elasticity test

8.1 Static test method

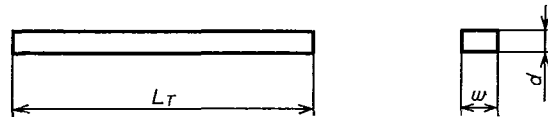
8.1.1 Equipment and apparatus The equipment and apparatus shall be as follows:

- (1) Testing machine A material testing machine of mechanical system or oil hydraulic system, or a static loading device. The accuracy of load indication shall be + 1 % of the true load. It shall provide a mean to indicate the strain at an accuracy of + 1 %, and shall have the supports for three-point bend or four-point bend shown in Fig. 1 as the accessory. The strain may be measured by the method employing wire strain gauge or by the measurement of displacement of loading point.
- (2) Supports The supports shall be as specified in 7.1 (2). However, the distance between supporting rolls l shall be 30 mm to 80 mm.
- (3) Micrometer The micrometer calliper for external measurement specified in JIS B 7502 or a micrometer at least equivalent in accuracy.

- (4) Dial gauge The dial gauge of grade 1 specified in JIS B 7503 or a dial gauge at least equivalent in accuracy.

8.1.2 Test specimen The shape of test specimen shall be a rectangular cross-section bar and the dimension shall be as given in Fig. 4. The roughness of upper and lower surfaces of test specimen shall be the 1.6 S specified in JIS B 0601.

Fig. 4. Shape and dimensions of test specimen



L_T : $l + 6 \text{ mm min.}$ w : 4 mm min.

d : (a) When wire strain gauge is used: $1.0 \text{ mm} \leq d \leq 0.050 l$

(b) Other cases Three-point bend: $1.0 \text{ mm} \leq d \leq 0.052 l$

Four-point bend: $1.0 \text{ mm} \leq d \leq 0.034 l$

The parallelism between upper and lower surfaces shall be not more than 0.02 mm.

8.1.3 Method of test The method of test shall be as follows:

- (1) Dimensions of test specimen Carry out the measurements of the width and thickness of test specimen previously by using the micrometer or dial gauge.
- (2) Loading method In general the load shall be not less than 70 % of the expected value of flexural strength of the test specimen in question. When a material testing machine is used, make the moving speed of cross-head not more than 0.5 mm/min, and apply the load in a region where the stress-strain curve shows a straight line.

Prior to the test apply the load once under such conditions so that the supports and test specimen get good fit.

(3) Measurement of strain

- (a) Measurement by wire strain gauge The length of wire strain gauge shall be not more than 1 mm for three-point bend, and not more than 8 mm for four-point bend. Paste the gauge to the lower surface of test specimen at the middle of supporting rolls in longitudinal direction and measure the strain.

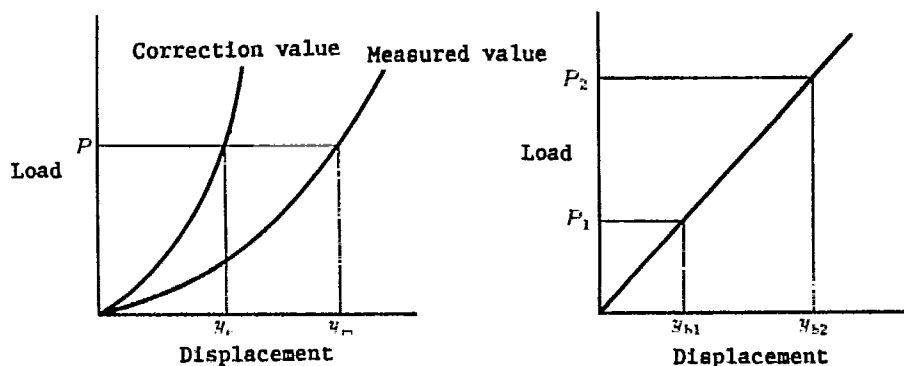
- (b) Measurements of displacement at loading point and at middle of test specimen Measure the displacement of loading point from the moved distance of crosshead of material testing machine.

Measure the displacement of the middle of test specimen by means of a displacement detector of differential transformer system or the like.

Prepare a correction specimen previously using the same material as that of test specimen or a material having a higher modulus of elasticity than test specimen. When the same material as the test specimen is used, the correction specimen shall be a rectangular cross-section bar with the same length and width as those of test specimen, and a thickness not less than 4.6 times the thickness of test specimen. Measure the displacement in the same loading area as that for measurement on the test specimen using this correction specimen, and obtain the correction value curve shown in Fig. 5 (a). Obtain the amount of displacement of test specimen at each load (y_b) as the difference between measured value (y_m) and prepare the load-displacement diagram after correction shown in Fig. 5 (b).

Fig. 5. Load-displacement diagram and its correction method

- (a) Correction method of measured values (b) Load-displacement diagram after correction



8.1.4 Calculation

- (1) Three-point bend Obtain the modulus of elasticity by three-point bend as stated below.
- (a) Case of strain gauge Calculate the modulus of elasticity by using the diagram as shown in Fig. 6 which is obtained as stated in 8.1.3 (3)(a) from the formula given below.