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JAPANESE INDUSTRIAL STANDARD

**Measuring methods for
characteristics of materials of
ferrite cores**

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Measuring methods for characteristics
of materials of ferrite cores

C 2561-1992

1. Scope This Japanese Industrial Standard specifies measuring methods for the characteristics of materials of ferrite cores mainly used in electronic components with inductance.

Remarks: The following Standards are cited in the Standard:

JIS B 0601 Definitions and designation of surface roughness

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

JIS B 7502 Micrometer callipers for external measurement

JIS B 7507 Vernier callipers

JIS C 2560 General rules for ferrite cores

JIS R 1602 Testing methods for elastic modulus of high performance ceramics

JIS R 1610 Testing method for vickers hardness of high performance ceramics

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 8704 Electrical methods of temperature measurements

2. Definitions For the purpose of this Standard, the principal definitions and symbols specified in JIS C 2560 shall apply.

3. Test conditions

3.1 Standard conditions Unless otherwise specified in the detail specification, the test shall be carried out under the standard conditions shown in Table 1. If any doubt arises on the decision based on the measured values under the standard conditions or if requested especially the test shall be made under the conditions of 3.2.

Table 1. Standard conditions

Item	Condition
Temperature	15°C to 35°C
Relative humidity	25 % to 85 %
Air pressure	86 kPa to 106 kPa

3.2 Referee conditions The referee conditions shall be either of the grades given in Table 2. If the grade is not specified in the detail specification the conditions of grade 2 in Table 2 shall be employed.

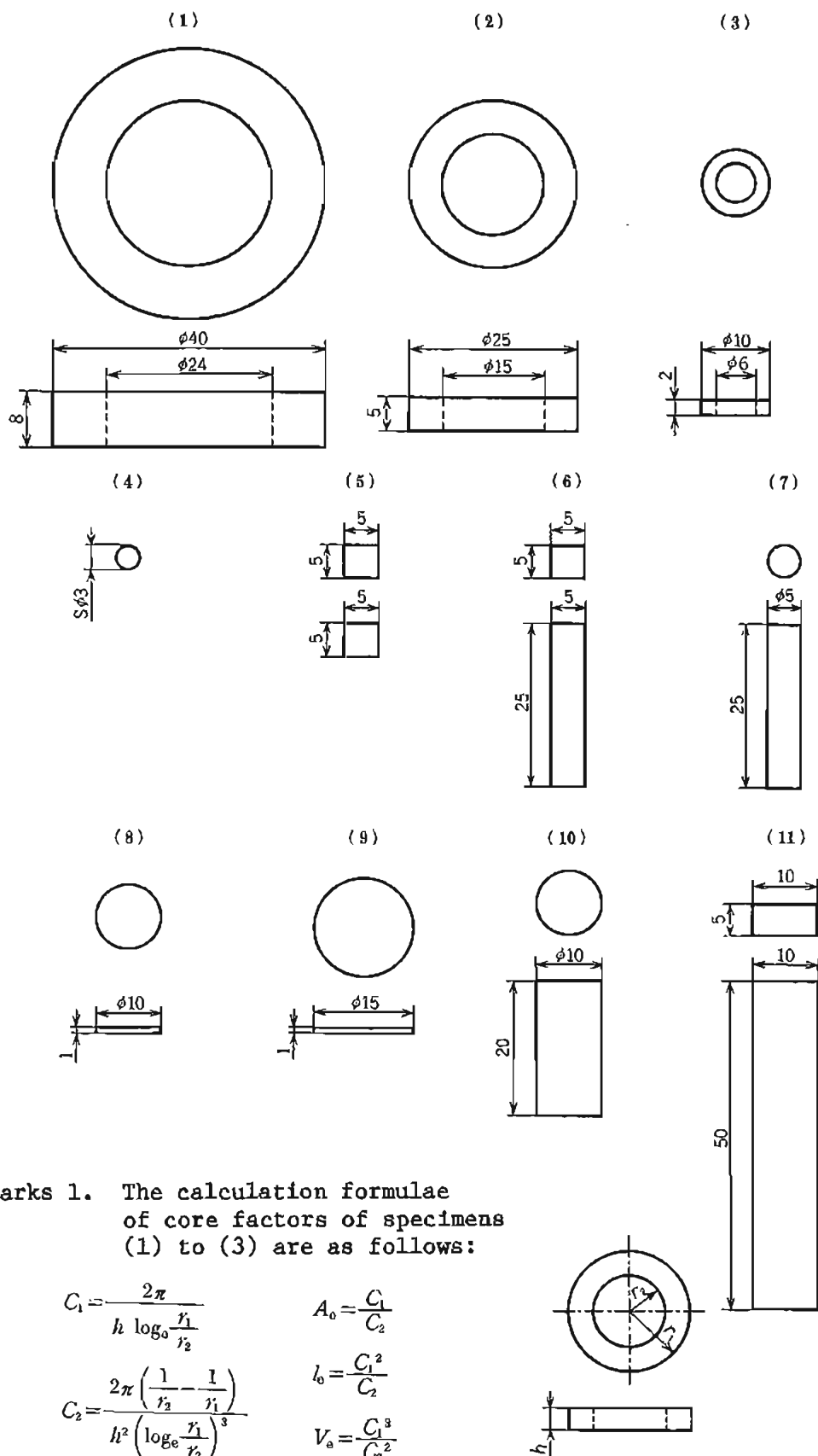
Table 2. Reference conditions

Item	Conditions	
	Grade 1	Grade 2
Temperature	23°C $\pm$ 1°C	23°C $\pm$ 2°C
Relative humidity	48 % to 52 %	45 % to 55 %
Air pressure	86 kPa to 106 kPa	

4. Specimens The shapes and dimensions (nominal values) of specimens used for test are shown in Fig. 1.

Fig. 1. Specimens

Unit: mm



2. The core factors of specimens (1) to (3) are shown below.

	$C_1 (\text{mm}^{-1})$	$C_2 (\text{mm}^{-2})$	$A_0 (\text{mm}^2)$	$l_e (\text{mm})$	$V_0 (\text{mm}^3)$
Specimen (1):	1.538	2.455×10^{-2}	62.63	96.29	6 030
Specimen (2):	2.460	1.006×10^{-1}	24.46	60.18	1 472
Specimen (3):	6.150	1.571	3.914	24.07	94.22

5. Electrical, magnetic and physical characteristic tests

Remarks: Unless otherwise stated, the voltage applied to the specimen shall be sinusoidal in electrical and magnetic tests.

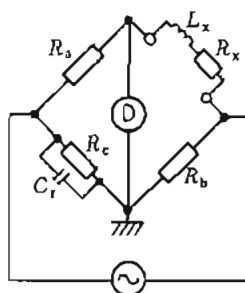
5.1 Permeability

Remarks: Various permeabilities except permeability of vacuum shall be expressed in relative permeability.

5.1.1 Initial permeability

- (1) Device and apparatus The testing device and apparatus used for the measurement shall be calibrated previously, shall have sufficient accuracy and the circuits shall be as given in Fig. 2 to Fig. 5.

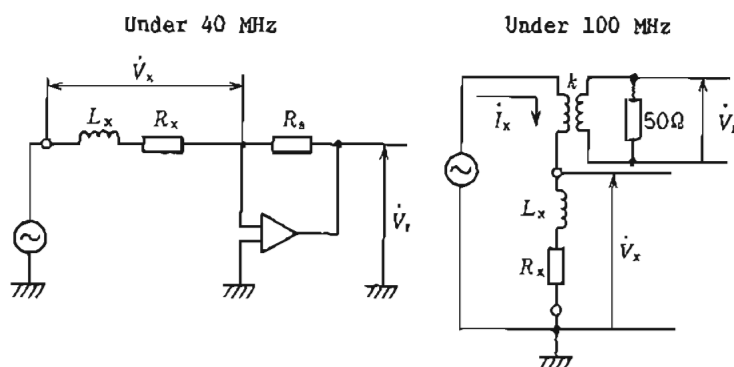
Fig. 2. Maxwell bridge



$$L_x = C_x \cdot R_a \cdot R_b$$

$$R_x = \frac{R_a \cdot R_b}{R_c}$$

Fig. 3. LCR meter



$$\begin{aligned} Z_x &= \frac{\dot{V}_x}{\dot{I}_x} \\ &= R_x + j\omega L_x \\ &= |\dot{Z}_x| e^{j\theta} \\ L_x &= \frac{|\dot{Z}_x| \sin \theta}{\omega} \\ R_x &= |\dot{Z}_x| \cos \theta \end{aligned}$$

$$\begin{aligned} \dot{V}_r &= 50 \cdot \dot{I}_x \\ \dot{Z}_x &= \frac{\dot{V}_x}{\dot{I}_x} \cdot 50 \\ &= R_x + j\omega L_x \\ &= |\dot{Z}_x| e^{j\theta} \\ L_x &= \frac{|\dot{Z}_x| \sin \theta}{\omega} \\ R_x &= |\dot{Z}_x| \cos \theta \end{aligned}$$

Fig. 4. Q meter

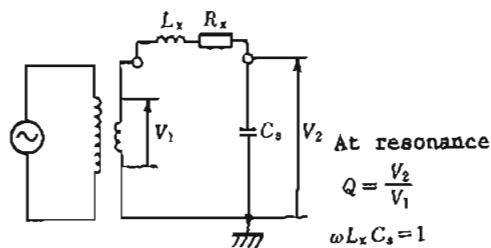
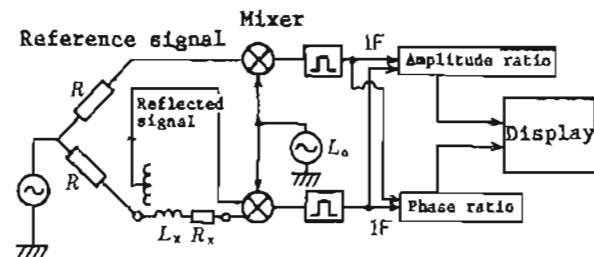


Fig. 5. Network analyzer

(2) Measurement specimen

- (a) Winding type measuring method Choose the specimens from those given in Fig. 1. (1) to (3) and uniformly wind an insulated wire over all the periphery of specimen. Select the pitch adequately so that the effect of distributed capacity is avoided.

When the measurement is made at a high temperature, use a heat resistant insulated wire, or apply a heat resistant insulating tape to the specimen.

- (b) Short-circuit coaxial method The specimen shall be that of Fig. 1 (3).

- (3) Preconditioning Neutralize the specimen before electro-magnetic measurements. Use a.c. neutralization or thermal neutralization as the neutralizing method. If there is no possibility of influence on the measured values, the neutralization may be omitted.

(4) Test methods and calculation

- (a) Winding type measuring method Measure the self inductance of specimen with the Maxwell bridge or LCR meter shown in Fig. 2 or Fig. 3, and calculate the initial permeability μ_i from the formula below.

The strength of measuring magnetic field shall be as given in Table 3.

Record the measuring frequency on the measurement record additionally.

$$\mu_i = \frac{l_c L}{\mu_0 A_c N^2}$$

where, l_c : effective magnetic path length of specimen actually measured (m)

L : self inductance of specimen (H)

μ_0 : permeability of vacuum $4\pi \times 10^{-7}$ (H/m)

A_c : effective cross-sectional area of specimen actually measured (m²)

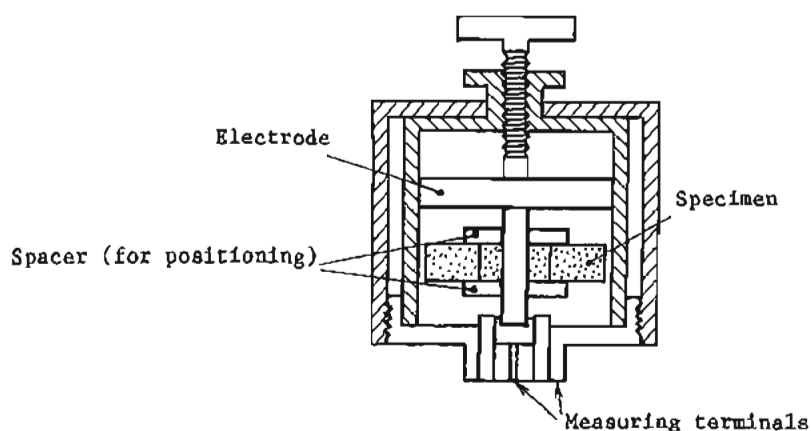
N : number of turns of specimen coil

- (b) Short-circuit coaxial type measuring method Measure the self inductance of short-circuit coaxial tube shown in Fig. 6 before insertion of specimen and that after insertion of specimen, by means of the LCR meter or network analyzer shown in Fig. 3 or Fig. 5, obtain the difference in the inductances so measured and calculate the initial permeability μ_i , from the formula given below.

The strength of measuring magnetic field shall be as given in Table 3.

Record the measuring frequency on the measurement record additionally.

Fig. 6. Example of short-circuit coaxial tube



$$\mu_i = 1 + \frac{(\Delta L) l_e}{\mu_0 A_e}$$

where, ΔL : difference in self inductances before and after insertion of specimen (H)

l_e : effective magnetic path length of specimen actually measured (m)

μ_0 : permeability of vacuum $4 \pi \times 10^{-7} (\text{H/m})$

A_e : effective cross-sectional area of specimen actually measured (m^2)

Table 3. Magnetic field for measuring initial permeability

Classification	Measuring magnetic field A/m
Material with general μ ($\mu_i < 4000$)	0.4
Material with high μ ($\mu_i \geq 4000$)	0.005

5.1.2 Complex permeability

- (1) Device and apparatus The testing device and apparatus used for the measurement shall be calibrated previously, shall have sufficient accuracy and the circuits shall consist of the Maxwell bridge, LCR meter or network analyzer shown in Fig. 2, Fig. 3 or Fig. 5, respectively.
- (2) Measurement specimen As specified in 5.1.1 (2).
- (3) Preconditioning As specified in 5.1.1 (3).
- (4) Testing method and calculation
 - (a) Winding type measuring method Measure the self inductance and resistance of specimen with the Maxwell bridge or LCR meter shown in Fig. 2 or Fig. 3, and calculate the complex permeability μ from the formulae given below.

The strength of measuring magnetic field shall be as given in Table 3.

Record the measuring frequency on the measurement record additionally.

$$\begin{aligned}\mu &= \mu' - j\mu'' \\ \mu' &= \frac{l_e L}{\mu_0 A_e N^2} \\ \mu'' &= \frac{l_e (R_{eff} - R_w)}{\mu_0 A_e \omega N^2} \\ \tan \delta &= \frac{\mu''}{\mu'}\end{aligned}$$

where, μ' : real component of complex permeability

μ'' : imaginary component of complex permeability

l_e : effective magnetic path length of specimen actually measured (m)

L : self inductance of specimen (H)

μ_0 : permeability of vacuum $4\pi \times 10^{-7}$ (H/m)

A_e : effective cross-sectional area of specimen actually measured (m²)

N : number of turns of specimen coil

R_{eff} : loss resistance of coil including specimen (Ω)

R_w : loss resistance of coil only (Ω)

ω : angular frequency (rad/s)

$\tan \delta$: loss factor

Note (1) Calculate angular frequency ω from the following formula:

$$\omega = 2\pi f \text{ (rad/s)}$$

where, π : ratio of circumference to its diameter

f : measuring frequency (Hz)

- (b) Short-circuit coaxial measuring method Measure the self inductance and resistance of the short-circuit coaxial tube shown in Fig. 6 before insertion of the specimen and those after insertion of the specimen, by means of the LCR meter or network analyzer shown in Fig. 3 or Fig. 5 respectively, obtain the differences in the inductances and resistances, and calculate the complex permeability μ from the formulae given below.

The strength of measuring magnetic field shall be as given in Table 3.

Record the measuring frequency on the measurement record additionally.

$$\mu = \mu' - j\mu''$$

$$\mu' = 1 + \frac{(\Delta L) l_e}{\mu_0 A_e}$$

$$\mu'' = \frac{(\Delta R) l_e}{\mu_0 A_e \omega}$$

$$\tan \delta = \frac{\mu''}{\mu'}$$

where, μ' : real component of complex permeability

μ'' : imaginary component of complex permeability

ΔL : difference in self inductances before and after insertion of specimen (H)

l_e : effective magnetic path length of specimen actually measured (m)

μ_0 : permeability of vacuum $4\pi \times 10^{-7}$ (H/m)

A_e : effective cross-sectional area of specimen actually measured (m²)

ΔR : difference in resistances before and after insertion of specimen (Ω)

ω (1) : angular frequency (rad/s)

$\tan \delta$: loss factor

5.1.3 Temperature coefficient and temperature factor of initial permeability

- (1) Device and apparatus The testing device and apparatus used for the measurement shall be calibrated previously, shall have sufficient accuracy and the circuits shall consist of the Maxwell bridge or LCR meter shown in Fig. 2 or Fig. 3, respectively. A thermostatic chamber shall be used as a device.
- (2) Measurement specimen As specified in 5.1.1 (2).
- (3) Preconditioning As specified in 5.1.1 (3).
- (4) Test method and calculation Place the specimen in the thermostatic chamber, measure each of the initial permeability at reference temperature T_1 (μ_{i1}) and the initial permeability at T_2 (μ_{i2}) in accordance with 5.1.1 (4), then calculate temperature coefficient of initial permeability $\alpha_{\mu i}$ and temperature factor of initial permeability $\alpha_{\mu tr}$ from the formulae given below.

Record T_1 , T_2 and the measuring frequency on the measurement record additionally.

- (a) Temperature coefficient of initial permeability $\alpha_{\mu i}$

$$\alpha_{\mu i} = \frac{\mu_{i2} - \mu_{i1}}{\mu_{i1}} \cdot \frac{1}{T_2 - T_1}$$

where, μ_{i1} : initial permeability at reference temperature T_1 (°C)

μ_{i2} : initial permeability at temperature T_2 (°C)

- (b) Temperature factor of initial permeability $\alpha_{\mu tr}$

$$\alpha_{\mu tr} = \frac{\mu_{i2} - \mu_{i1}}{\mu_{i1}^2} \cdot \frac{1}{T_2 - T_1}$$

Carry out the measurement of initial permeability after the specimen has reached the intended temperature, and apply the current only at the time of measurement.

The strength of measuring magnetic field shall be as given in Table 3.

5.1.4 Amplitude permeability

- (1) Device and apparatus The testing device and apparatus used for the measurement shall be calibrated previously, shall have sufficient accuracy and the measuring circuit shall be as shown in Fig. 7 or Fig. 8.