

JIS

JAPANESE INDUSTRIAL STANDARD

Testing Methods for Low Frequency Transformers and Inductors

JIS C 6435—1989

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J I S

Testing Methods for Low Frequency Transformers
and Inductors

C 6435-1989

1. Scope

This Japanese Industrial Standard specifies the testing methods for transformers and inductors to transmit the signals of the rated output⁽¹⁾ under 100 W and rated frequency under 150 kHz that are mainly used for switchboards, carrier devices, radio and television receivers, audio and video apparatus, broadcasting studio equipment and portable radio transmitters/receivers (hereafter referred to as "transformers and coils", respectively).

Note (1) The rated output means the power of sinusoidal waveform.

2. Definitions

For the main terms used in this Standard the definitions in JIS C 0010, JIS C 5301 and JIS C 5602 apply, and the rest of the terms shall be as follows:

- (1) self inductance The value obtained by dividing the value of electromotive force which is produced by the change of current flowing through a coil to disturb the change, as the dividend, by the rate of current change. In this Standard, it is expressed by the effective resistance and the series inductance.
- (2) effective resistance The electrical resistance of a winding under a.c. current.
- (3) 16-Hz attenuation The operating attenuation of a transformer at 16 Hz.
- (4) reference frequency The frequency determined as a reference for measurement.

3. Test Conditions

3.1 Standard Conditions The test and measurements shall be carried out at a temperature of 15 to 35°C, relative humidity of 25 to 85 % (may be ignored if there is no influence on the test and measurement results) and an air pressure of 86 to 106 kPa (860 to 1060 mbar). However, if doubt arises on the decision based on the measured values under these standard conditions or if especially required, the conditions of 3.3 shall be employed.

If conversion is necessary the conditions of 3.2 shall be employed.

If it is difficult to carry out the test and measurement, the test and measurement may be carried out under the conditions other than the standard conditions unless there is any dispute (see 5.3 of JIS C 0010).

3.2 Reference Conditions The reference conditions shall be the reference conditions specified in 5.1 of JIS C 0010 [temperature 20°C, air pressure 101.3 kPa (1013 mbar)]. However, only the temperature may be employed as the reference condition.

3.3 Referee Conditions The referee conditions shall be as given in Table 1.

Unless otherwise specified, the conditions of symbol I grade 2 shall be employed (see 5.2 of JIS C 0010).

Table 1. Referee Conditions

Symbol	Temperature °C			Relative humidity %		Air pressure kPa (mbar)
	Nominal value	Grade 1	Grade 2	Grade 1	Grade 2	
I	20	± 1	± 2	63 to 67	60 to 70	86 to 106 (860 to 1060)
II	23			48 to 52	45 to 55	
III	25			48 to 52	45 to 55	
IV	27			63 to 67	60 to 70	

3.4 Grounding The measurement shall be carried out while the specimen is grounded, if the specimen is so constructed.

4. Construction and Dimensions Tests

4.1 Construction The construction shall be examined visually.

4.2 Dimensions Unless otherwise specified, the dimensions shall be measured by vernier caliper specified in JIS B 7507 or the external micrometer specified in JIS B 7502.

5. Electrical Performance Tests

5.1 Insulation Resistance

5.1.1 Testing Method All terminations or lead wires attached to a transformer or an inductor winding shall be short-circuited in general. The test shall be carried out by applying the specified d.c. voltage for 1 min between windings or winding and iron core to be tested, using the insulation resistance tester of JIS C 1302 or a super insulation meter and then the indicated value shall be read.

5.1.2 Precautions for Test

- (1) If no doubt arises on the judgement, the charging duration may be within 1 min.
- (2) The test voltage shall not exceed the value specified in the dielectric withstand voltage test.
- (3) To prevent overcurrent and/or overvoltage and to protect test equipment and the transformer or inductor to be tested (specimens) in case of a short circuit, protective devices should preferably be equipped.
- (4) As a rule, an electrostatic shielding shall be connected to the iron core, case or mounting metal fittings.

5.2 Dielectric Withstand Voltage

5.2.1 Testing Method All terminations or lead wires pertaining to a transformer or inductor winding shall be short-circuited generally, and the specified voltage shall be applied between windings or winding and iron core for the specified duration. Then the check shall be carried out to see if there is any abnormality. The test voltage shall be increased from 0 V to the specified voltage at a rate of 500 V (effective values or d.c.) or less per second and, after the specified duration, the voltage shall be gradually decreased to 0 V.,

5.2.2 Precautions for Test

- (1) When test voltage is d.c., the ripple voltage shall be small enough compared with the test voltage. When the test voltage is a.c., the waveform shall be substantially sinusoidal.
- (2) To protect test equipment and specimens in case of flashover, a protective device should preferably be equipped.
- (3) As a rule, an electrostatic shielding shall be connected to the iron core, case or mounting metal fittings.

5.3 Layer Withstand Voltage

5.3.1 Testing Method All windings (except the specified one) of the transformer or inductor shall be open. As a rule, terminations to be grounded in use shall be connected to the iron core, case or mounting metal fittings and then grounded. The specified frequency and voltage shall be applied to the specified winding for the specified duration. Then the check shall be carried out to see if there is any abnormality. The test voltage shall be increased from 0 V to the specified voltage at a rate of 500 V (effective values) or less per second and, after the specified duration, the voltage shall be gradually decreased to 0 V.

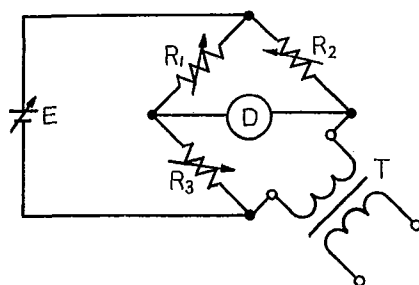
5.3.2 Precautions for Test

- (1) For this test the measuring instrument capable of measuring voltage and current at the specified frequency or the method by which their changes can be easily measured shall be employed.
- (2) The waveform of the applied voltage shall be substantially sinusoidal.
- (3) The specified frequency shall be well separated from the natural resonance frequency of the specimen.
- (4) Protective devices should be preferably equipped to protect test equipment and specimen in case of a short circuit.

5.4 D.C. Resistance

5.4.1 Measuring Circuit Example of the circuit for measuring d.c. resistance of a transformer or inductor is shown in Fig. 1.

Fig. 1. Measuring Circuit of D.C. Resistance



R_1, R_2 : ratio arm resistor

R_3 : standard variable resistor

T: specimen

E: d.c. power source

D: detector

5.4.2 Measuring Method and Calculation Formula The ratio arm resistors R_1, R_2 and the standard variable resistor R_3 shall be adjusted to balance the bridge. Then the d.c. resistance R_x of the transformer or inductor shall be calculated from the following formula:

$$R_x = \frac{R_2}{R_1} R_3$$

5.4.3 Precautions for Measurement

- (1) Care shall be taken so that the temperature of the specimen is equal to the ambient temperature.
- (2) The current to be passed through the specimen shall be in an appropriate range so that the resistance does not change remarkably.
- (3) A double bridge should be preferably used especially when low resistance values are measured.

5.5 D.C. Resistance Unbalance

5.5.1 Measuring Circuit As specified in 5.4.1

5.5.2 Measuring Method and Formula The d.c. resistance shall be measured on neutral point of the specimen. Each side of the direct current resistance to the neutral point of the test sample of transformer or the coil shall be measured respectively. These values are assumed as R_1 and R_2 , and then the d.c. resistance unbalance R_s shall be calculated from the following formula:

$$R_s (\%) = \frac{|R_1 - R_2|}{R_1 + R_2} \times 100$$

If the ambient temperature is other than 20°C, the conversion shall be made by the following formula.

$$R_0 = \frac{R_t}{1 + \frac{1}{K} (t - 20)}$$

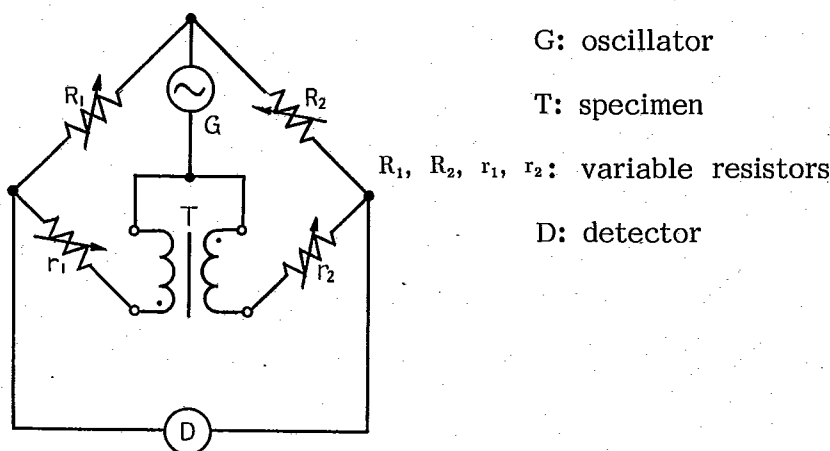
where, R_0 : d.c. resistance converted to 20°C
 R_t : d.c. resistance at $t^\circ\text{C}$
 K : constant, $K=234$ for copper

5.5.3 Precautions for Measurement As specified in 5.4.3.

5.6 Transformation Ratio

5.6.1 Measuring Circuit An example of the circuit for measuring transformation ratio of transformer is shown in Fig. 2.

Fig. 2. Measuring Circuit of Transformation Ratio



5.6.2 Measuring Method and Calculation Formula The primary winding and the secondary winding shall be connected differentially to the power supply current. Then the variable resistors R_1 , R_2 , r_1 , and r_2 shall be adjusted to balance the bridge. The transformation ratio n of the windings w_1 and w_2 shall be calculated from the following formula:

As a rule, the measuring frequency shall be 1 kHz.

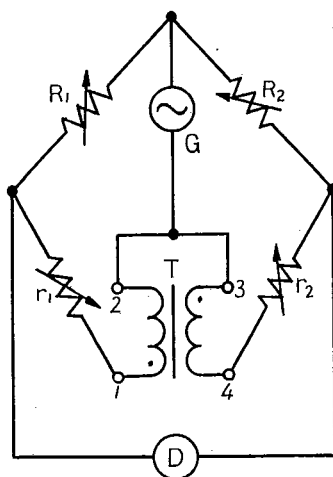
$$n = \frac{n_1}{n_2} = \frac{R_1}{R_2}$$

where, n_1 : number of turns of primary winding
 n_2 : number of turns of secondary winding

5.7 Polarity

5.7.1 Test Circuit An example of the test circuit for polarity of transformer is shown in Fig. 3.

Fig. 3. Polarity Test Circuit



G: oscillator

T: specimen (An example of termination numbers is shown)

 R_1, R_2, r_1, r_2 : variable resistors

D: detector

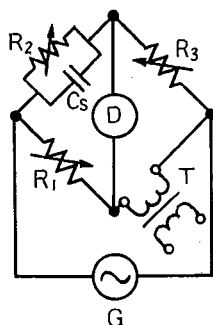
5.7.2 Testing Method Each winding of the specimen shall be connected to the circuit shown in Fig. 3. Then the test shall be carried out to see whether the bridge can be balanced or not by regulating the variable resistors R_1, R_2, r_1 and r_2 . When the terminations 1 and 3 are in the same polarity, the bridge is balanced and if they are in the different polarity, it is not balanced.

5.8 Self-inductance

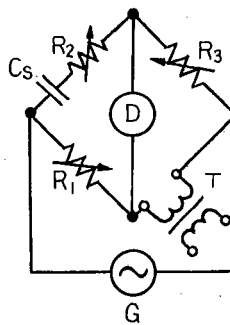
5.8.1 Measuring Circuit Examples of the circuit for measuring self-inductance of transformer or inductor are shown in Figs. 4, 5, 6 and 7.

Fig. 4. Measuring Circuit of Self-inductance

(a) Series Method



(b) Parallel Method



G: oscillator

 R_1, R_2, R_3 : variable resistors

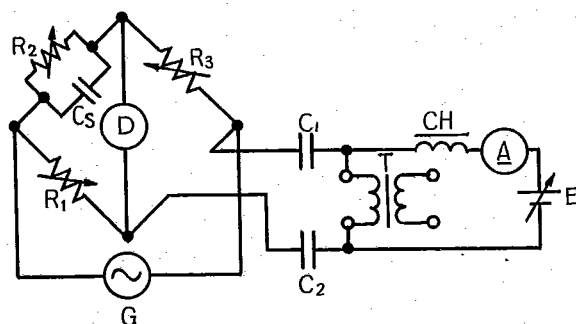
D: detector

T: specimen

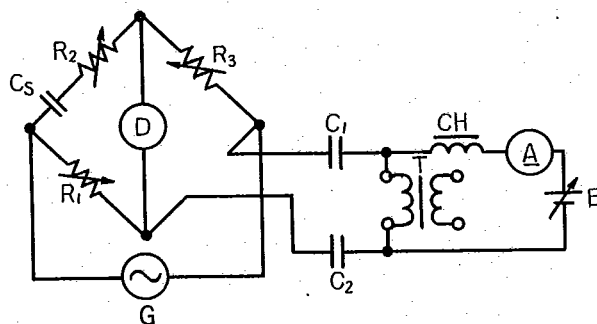
 C_s : standard capacitor

Fig. 5. Measuring Circuit of Self-inductance
(When d.c. is superposed)

(a) Series Method



(b) Parallel Method



G: oscillator

D: detector

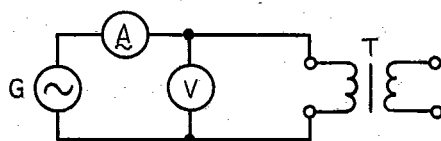
 C_s : standard capacitor R_1, R_2, R_3 : variable resistors C_1, C_2 : capacitors

CH: choke coil

E: d.c. power source

 $\underline{A}$: d.c. ammeter

T: specimen

Fig. 6. Measuring Circuit of Self-inductance
(When frequency is 50 or 60 Hz)

G: oscillator

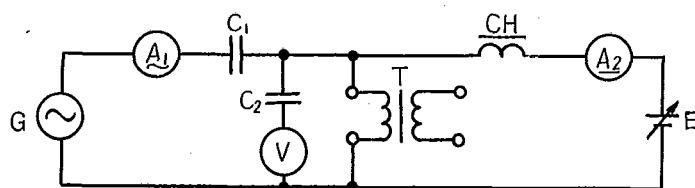
 $\underline{A}$: a.c. ammeter

V: voltmeter

T: specimen

Fig. 7. Measuring Circuit of Self-inductance

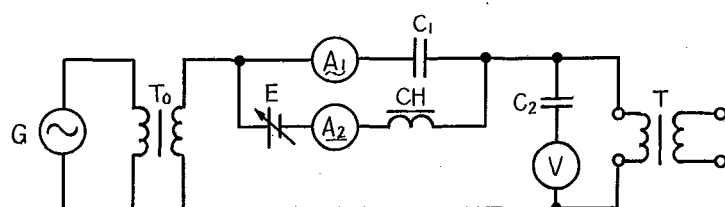
(a) When d.c. is superposed



G: oscillator

 T_0 : transformer A_1 : a.c. ammeter A_2 : d.c. ammeter

(b) When frequency is 50 Hz or 60 Hz V: voltmeter

 C_1, C_2 : capacitors

CH: choke coil

E: d.c. power source

T: specimen

5.8.2 Measuring Method and Calculation Formula

- (1) In the Cases of Figs. 4 and 5 The test shall be carried out at the specified frequency, termination voltage or current. The variable resistors R_1 , R_2 and R_3 shall be adjusted to balance the bridge. Then the self-inductance L_x (H) of the specimen shall be calculated from the following formula:

For (a)
$$L_x \text{ (H)} = C_s \cdot R_1 \cdot R_3 \times 10^{-6}$$

where, C_s : capacitance value of standard capacitor (μF)

R_1, R_3 : indicated value of each variable resistor (Ω)

For (b)

$$L_x \text{ (H)}^{(2)} = L \cdot \frac{1}{1 + \left(\frac{2\pi f L}{R}\right)^2}$$

where, $L = C_s \cdot R_1 \cdot R_3 \times 10^{-6}$ (H)

$R = R_1 \cdot R_3 / R_2$ (Ω)

f : measuring frequency (Hz)

C_s : capacitance value of standard capacitor (μF)

R_1, R_2, R_3 : indicated value of each variable resistor (Ω)

Note (2) The value converted to series method

- (2) In the Cases of Figs. 6 and 7 The test shall be carried out at the specified a.c. voltage or current. The self-inductance L_x (H) shall be calculated from the following formula:

$$L_x \text{ (H)} = \frac{\sqrt{\left(\frac{V}{A}\right)^2 - R_{dc}^2}}{2\pi f}$$

where, V : indicated value on voltmeter (V)

I : indicated value on ammeter (A)

R_{dc} : d.c. resistance value of winding to be measured (Ω)

f : measuring frequency (50 Hz or 60 Hz)

5.8.3 Precautions for Measurement

- (1) The superposed d.c. current and a.c. voltage shall not exceed the specified values.
- (2) The voltmeter shall be of an effective value type or a mean value type. The input impedance shall be large enough compared with that of the winding to be measured.
- (3) The impedance of choke coil CH in Fig. 5 shall be large enough compared with that of the winding to be measured. The impedances of capacitors C_1 and C_2 shall be small enough compared with that of the winding to be measured.
- (4) The impedance of choke coil CH in Fig. 7 (a) shall be large enough compared with that of the winding to be measured. The impedance of the capacitor C_2 shall be small enough compared with the input impedance of a.c. voltmeter V.
- (5) The impedance of choke coil CH in Fig. 7 (b) shall be large enough compared with that of capacitor C_1 . The impedance of C_2 shall be small enough compared with the input impedance of voltmeter V.
- (6) Unless otherwise specified, the case shall not be grounded.

5.9 Effective Resistance

5.9.1 Measuring Circuit Examples of the circuit for measuring effective resistance of the transformer or inductor are shown in Fig. 4 and Fig. 5.

5.9.2 Measuring Method and Calculation Formula The test shall be carried out at the specified frequency, termination voltage or current. The bridge shall be balanced by controlling variable resistors R_1 , R_2 and R_3 . Then the effective resistance R_x (Ω) of the specimen shall be calculated from the following formula:

- (1) For Fig. 4 (a) and Fig. 5 (a)

$$R_x \text{ (}\Omega\text{)} = \frac{R_1}{R_2} R_3$$

where R_1 , R_2 , R_3 : indicated value on each variable resistor (Ω)

(2) For Fig. 4 (b) and Fig. 5 (b)

$$R_x (\Omega) ^{(3)} = R \cdot \frac{1}{1 + \left(\frac{R}{2 \pi f L} \right)^2}$$

where, $L = C_s \cdot R_1 \cdot R_3 \times 10^{-6}$ (H)

$$R = R_1 \cdot R_3 / R_2 (\Omega)$$

 f : measuring frequency (Hz) C_s : capacitance of standard capacitor (μ F) R_1, R_2, R_3 : indicated value on each variable resistor (Ω)Note ⁽³⁾ The value converted to series method.

5.9.3 Precautions for Measurement

- (1) The superposed d.c. current and the a.c. voltage shall not exceed the relevant specified value.
- (2) The voltmeter shall be of an effective value type or a mean value type. The input impedance shall be large enough compared with that of the winding to be measured.
- (3) The impedance of choke coil CH in Fig. 5 shall be large enough compared with that of the winding to be measured. The impedance of capacitors C_1 and C_2 shall be small enough compared with that of the winding to be measured.

5.10 Leakage Inductance

5.10.1 Measuring Circuit An example of the circuit for measuring leakage inductance of a transformer is shown in Fig. 4. The winding on the load side of the specimen shall be short-circuited during the measurement.

5.10.2 Measuring Method and Calculation Formula The test shall be carried out at the specified frequency, termination voltage and current. The variable resistors R_1, R_2 and R_3 shall be adjusted to balance the bridge. Then leakage inductance L_x (H) of the specimen shall be calculated from the following formula:

For Fig. 4 (a) $L_x \text{ (H)} = C_s \cdot R_1 \cdot R_3 \times 10^{-6}$

where, C_s : capacitance of standard capacitor (μ F) R_1, R_3 : indicated value on each variable resistor (Ω)

For Fig. 4 (b)

$$L_x \text{ (H)} = L \cdot \frac{1}{1 + \left(\frac{2 \pi f L}{R} \right)^2}$$

where,

$$L = C_s \cdot R_1 \cdot R_3 \times 10^{-6} \text{ (H)}$$

$$R = R_1 \cdot R_3 / R_2 (\Omega)$$

f : measuring frequency (Hz)

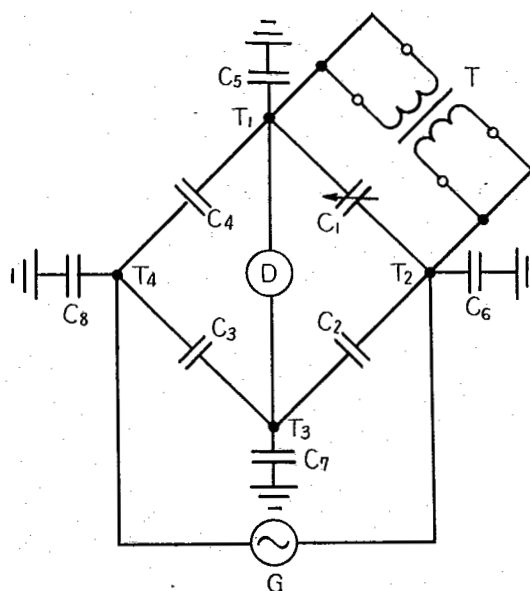
C_s : capacitance of standard capacitor (μF)

R_1, R_2, R_3 : indicated value on each variable resistor (Ω)

5.11 Direct Capacitance between Windings

5.11.1 Measuring Circuit An example of the circuit for measuring direct capacitance between windings of transformer is shown in Fig. 8.

Fig. 8. Measuring Circuit of Direct Capacitance between Windings



G: oscillator

D: detector

C_1 : variable capacitor

C_2, C_3, C_4 : fixed capacitors (approx. 200 pF)

C_5, C_6, C_7, C_8 : fixed capacitors (approx. 10000 pF)

5.11.2 Measuring Method and Calculation Formula The bridge shall be balanced at the specified frequency in the states i.e. when W_1 and W_2 are connected to the vertexes T_1 and T_2 of the bridge and when they are disconnected. If the values of capacitor C_1 are referred to as C'_1 and C''_1 respectively, the direct capacitance between windings C_D shall be calculated from the following formula:

$$C_D = C'_1 - C''_1$$