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**Test methods for electrical steel strip
and sheet — Part 3: Methods of
measurement of the magnetic properties
of electrical steel strip and sheet at
medium frequencies**

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Contents

Page

Introduction	1
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 General principle of a.c. measurements	4
4.1 General	4
4.2 Principle of the 25 cm Epstein frame method	4
4.3 Test specimen	4
4.4 The 25 cm Epstein frame	5
4.5 Air flux compensation	7
4.6 Power supply	8
4.7 Voltage measurement	8
4.8 Current measurement	9
4.9 Frequency measurement	9
4.10 Power measurement	9
5 Procedure for the determination of the specific total loss	9
5.1 General	9
5.2 Preparation for measurement	9
5.3 Adjustment of power supply	10
5.4 Measurements of power	11
5.5 Determination of the specific total loss	11
5.6 Reproducibility of the specific total loss measurement	12
6 Procedure for the determination of the peak value of magnetic polariza- tion, r.m.s. value of magnetic field strength, peak value of magnetic field strength and specific apparent power	12
6.1 General	12
6.2 Test specimen	13
6.3 Principle of measurement	13
6.4 Apparatus	15
6.5 Measuring procedure	16
6.6 Determination of the peak value of magnetic polarization $\hat{J}$	16
6.7 Determination of the r.m.s. value of magnetic field strength	17
6.8 Determination of the peak value of magnetic field strength	17
6.9 Determination of the specific apparent power	18
6.10 Reproducibility	19
7 Test report	19

Annex A (informative)	Epstein frame for use at medium frequencies	20
Annex B (informative)	Digital sampling method for the determination of the magnetic properties	21
Annex JA (informative)	Cutting method of test specimens and test instru- ment specifications	25
Annex JB (informative)	Comparison table between JIS and corresponding International Standard	28

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 The Japan Electrical Manufacturers' Association (JEMA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS C 2550-3:2011** is replaced with this Standard.

This **JIS** document is protected by the Copyright Law.

Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

JIS C 2550 series consists of the following 5 parts under the general title *Test methods for electrical steel strip and sheet*

Part 1 : Methods of measurement of the magnetic properties of electrical steel strip and sheet by means of an Epstein frame

Part 2 : Methods of determination of the geometrical characteristics of electrical steel strip and sheet

Part 3 : Methods of measurement of the magnetic properties of electrical steel strip and sheet at medium frequencies

Part 4 : Methods of test for the determination of surface insulation resistance of electrical strip and sheet

Part 5 : Methods of measurement of density, resistivity and stacking factor of electrical strip and sheet

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Test methods for electrical steel strip and sheet — Part 3 : Methods of measurement of the magnetic properties of electrical steel strip and sheet at medium frequencies

Introduction

This Japanese Industrial Standard has been prepared based on **IEC 60404-10:2016**, Edition 2, with some modifications of the technical contents to reflect the technology widely applied in Japan.

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 JB.

1 Scope

This part of **JIS C 2550** specifies the method of measurement of the a.c. magnetic properties of electrical steel strip and sheet in the medium frequency range 400 Hz to 10 kHz.

This part also specifies the method of measurement of the magnetic properties of electrical steel strip and sheet by means of an Epstein frame.

The Epstein frame is applicable to test specimens obtained from electrical steel strips and sheets of any grade. The a.c. magnetic properties are determined for sinusoidal induced voltages under excitation conditions (hereafter referred to as sinusoidal magnetic flux excitation conditions), for specified peak values of magnetic polarization and for a specified frequency. The measurements are to be made at an ambient temperature of $(23 \pm 5) ^\circ\text{C}$ on test specimens which have first been demagnetized.

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

IEC 60404-10 : 2016 *Magnetic materials — Part 10 : Methods of measurement of magnetic properties of electrical steel strip and sheet at medium frequencies* (MOD)

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 2550-5 *Test methods for electrical steel strip and sheet — Part 5 : Methods*

of measurement of density, resistivity and stacking factor of electrical strip and sheet

NOTE Corresponding International Standard : IEC 60404-13 *Magnetic materials — Part 13 : Methods of measurement of density, resistivity and stacking factor of electrical steel sheet and strip*

JIS C 2552 *Cold-rolled non-oriented electrical steel strip and sheet delivered in the fully-processed state*

NOTE Corresponding International Standard : IEC 60404-8-4 *Magnetic materials — Part 8-4 : Specifications for individual materials — Cold-rolled non-oriented electrical steel strip and sheet delivered in the fully-processed state*

JIS C 2553 *Cold-rolled grain-oriented electrical steel strip and sheet delivered in the fully-processed state*

NOTE Corresponding International Standard : IEC 60404-8-7 *Magnetic materials — Part 8-7 : Specifications for individual materials — Cold-rolled grain-oriented electrical steel strip and sheet delivered in the fully-processed state*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.1

magnetic field strength

strength of vector field, i.e. magnetic field, which magnetizes the specimen

The magnetic field strength H is generally calculated by Formula (1).

$$\int H dl = N_1 I_1 \dots\dots\dots (1)$$

where, H : magnetic field strength (A/m)
 l : magnetic length (m)
 N_1 : total number of turns of magnetizing winding wound in magnetic path
 I_1 : magnetizing current (A)

On the assumption that the magnetic field strength H is uniform throughout the magnetic path of the Epstein frame, the effective magnetic length l_m shall be set to its specified value. Accordingly, the magnetic field strength H is calculated by Formula (2).

$$H = \frac{N_1 I_1}{l_m} \dots\dots\dots (2)$$

where, l_m : effective magnetic length (m), $l_m = 0.94$

3.2

effective magnetic length

equivalent magnetic path length, expressed in metres (m), of a specific part assumed to

be uniform in magnetic field strength over the entire magnetic path, in the magnetic circuit in which magnetic field strength is not uniform

NOTE For the Epstein frame, the effective magnetic path length is assumed to be equal to 0.94 m.

3.3

magnetic flux density

amount of magnetic flux per unit cross-sectional area, expressed in teslas (T), of the test specimen uniformly magnetized

3.4

magnetic polarization

strength of magnetization per unit cross-sectional area, expressed in teslas (T), of the test specimen uniformly magnetized

NOTE For the Epstein frame, the value measured by using the secondary winding and the mutual inductor for air flux compensation is the magnetic polarization J . The relation between magnetic flux density B and magnetic polarization J is expressed by the formula $B = J + \mu_0 H$ where the magnetic constant is given as $\mu_0 [= 4\pi \times 10^{-7} \text{ (H/m)}]$. For a high permeability material, e.g. an electrical steel strip and sheet, magnetic flux density B and magnetic polarization J are almost equal. These two terms are generally interchangeable when used.

3.5

effective mass

equivalent mass, expressed in kilogrammes (kg), obtained on the assumption that, of the core constituting the magnetic circuit, the portion which has a length equivalent to the effective magnetic length contributes to the specific total loss (see 4.4).

3.6

air flux compensation

making the induced voltage of the secondary winding correspond to the differential value of the magnetic polarization J by subtracting the voltage induced in the secondary winding in the absence of test specimens inside the solenoids from the induced voltage of the secondary winding (see 4.5)

3.7

specific total loss

value obtained by dividing energy per unit time, which is consumed in a test specimen when the measurement is carried out under the sinusoidal magnetic flux excitation condition, by effective mass of the test specimen (see 5.5)

It is expressed in watts per kilogramme (W/kg).

3.8

specific apparent power

value obtained by dividing the product of the r.m.s. value of excitation voltage and the r.m.s value of magnetizing current, when the measurement is carried out under the sinusoidal magnetic flux excitation condition, by the effective mass of the test specimen (see 6.9)

It is expressed in volt-amperes per kilogramme (VA/kg).

4 General principle of a.c. measurements

4.1 General

Clause 4 specifies the general conditions for the determination of a.c. magnetic properties of electrical steel strip and sheet by means of the 25 cm Epstein frame.

4.2 Principle of the 25 cm Epstein frame method

The 25 cm Epstein frame, which comprises a primary winding, a secondary winding and the specimen to be tested as a core, forms an unloaded transformer whose characteristics are measured by the method described in the following subclauses 4.3 to 4.10.

At the higher end of the frequency range, a specially constructed Epstein frame (see Annex A) may be required in which the interwinding capacitances are low, so that the capacitive part of the impedance has a negligible impact on the loss results. The material of the winding formers supporting the windings has a low dielectric loss.

A separate measuring system (for example a commercially available digital bridge capable of measuring resistance, capacitance and inductance) is required to determine the interwinding capacitance of the Epstein frame.

4.3 Test specimen

The strips to be tested are assembled in a square, having double-overlapped corner joints (see Figure 1) thus forming four limbs of equal length and equal cross-sectional area.

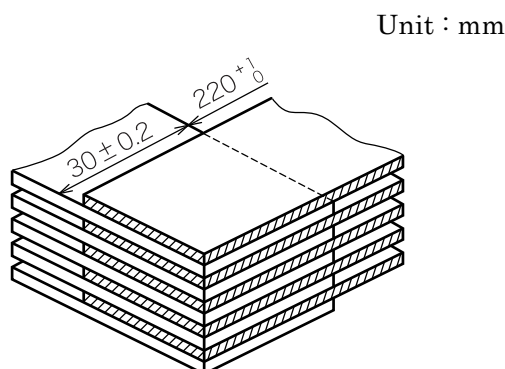


Figure 1 Double-lapped corner joints of test specimens having length 280 mm

The strips shall be sampled in accordance with the appropriate product standard of

either **JIS C 2552** or **JIS C 2553**.

NOTE For the cutting method of test specimen strips, see Annex JA.

The strips shall be cut by a method which will produce substantially burr-free edges and, if so specified, heat treated in accordance with the corresponding product standard. They shall have the following dimensions :

- width 30 mm $\pm$ 0.2 mm;
- length 280 mm to 320 mm.

The length of the strips shall be equal within a tolerance of ± 0.5 mm.

When the strips are cut parallel or normal to the direction of rolling, the edge of the parent sheet shall be taken as the reference direction.

The following tolerances shall apply for the angle between the specified and actual direction of cutting.

- $\pm 1^\circ$ for grain-oriented steel sheet;
- $\pm 5^\circ$ for non-oriented steel sheet.

Only flat strips shall be used. Measurements shall be made without adding other insulation than insulating films.

The number of test specimen strips comprising the core shall be not less than twelve and shall be a multiple of four. Recommended number of strips according to the thickness of a specimen is given in Table 0A.

A force of (1 ± 0.1) N shall be applied to each corner, normal to the plane of the overlapping strips.

Table 0A Number of strips

Thickness mm	Number of strips	Thickness mm	Number of strips
0.025	80	0.25	16
0.05	48	0.27	16
0.10	28	0.3	16
0.20	16	0.35	16
0.23	16	0.50 or over	12

4.4 The 25 cm Epstein frame

The 25 cm Epstein frame shall consist of four solenoids into which the test specimen strips are inserted in such a manner that a closed magnetic circuit is formed (see Figure 2).

Unit : mm

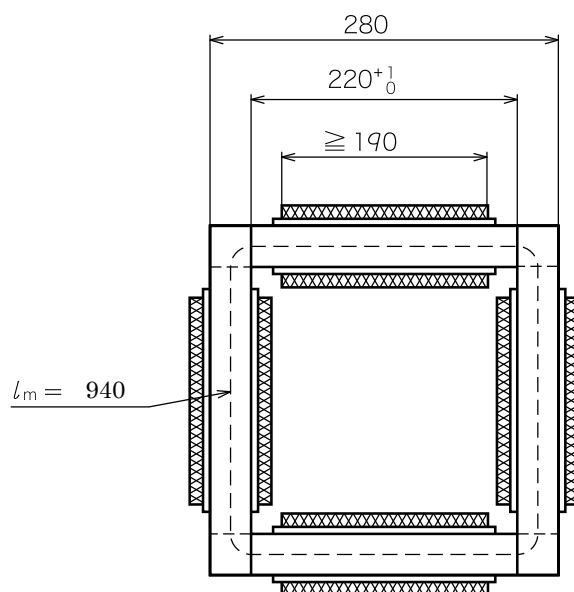


Figure 2 The 25 cm Epstein frame (test specimen strip length 280 mm)

If measurements are to be made under the conditions specified in 4.5, a mutual inductor for air flux compensation may be provided for the Epstein frame.

The winding formers supporting the windings shall be made of hard insulating material of low dielectric loss, such as polystyrene. They have a rectangular cross-section with 32 mm inner width. A height of approximately 5 mm is recommended.

The solenoids shall be fixed to an insulating and non-magnetic base in such a way to form a square (see Figure 2). The length of the sides of the square formed by the internal edges of the strips of the specimen to be tested as a core shall be 220^{+1}_0 mm (see Figures 1 and 2).

In order to avoid undue wear of the winding formers and especially of their inner surfaces, winding formers of larger cross-section can be used into which replaceable liners of appropriate dimensions may be inserted.

Each of the four solenoids shall have two windings :

- a primary winding, on the outside (magnetizing winding);
- a secondary winding, on the inside (voltage winding).

The primary and secondary windings shall be distributed uniformly over a minimum length of 190 mm, each solenoid having one quarter of the total number of turns.

The individual primary windings of the four solenoids shall be connected in series, and the individual secondary windings shall be connected in a similar fashion.

At the higher end of the frequency range, the loss contribution due to the capacitance between the primary and secondary windings and also the self-capacitance of the secondary winding could be significant. The windings shall be spaced to minimize this