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SPECIFICATION FOR NON-ORIENTED ELECTRICAL STEEL SHEETS FOR MAGNETIC CIRCUITS

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BUREAU OF CEYLON STANDARDS

SPECIFICATION FOR NON-ORIENTED ELECTRICAL STEEL SHEETS FOR MAGNETIC CIRCUITS

S. L. S. 383 : 1976

Gr. 8

BUREAU OF CEYLON STANDARDS
53, Dharmapala Mawatha,
COLOMBO 3.

Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.

This Standard does not purport to include all the necessary provisions of a contract.

BUREAU OF CEYLON STANDARDS
53, DHARMAPALA MAWATHA,
COLOMBO 3.

Telephone : 26055
26054
26051

Telegrams : " **PRAMIKA** "

SRI LANKA STANDARD SPECIFICATION FOR NON-ORIENTED ELECTRICAL STEEL SHEETS FOR MAGNETIC CIRCUITS

FOREWORD

This Sri Lanka Standard Specification has been prepared by the Drafting Committee on Electrical Steel Sheets. It was approved by the Electrical Engineering Divisional Committee of the Bureau of Ceylon Standards, and was authorised for adoption and publication by the Council of the Bureau on 7th July, 1976.

One of the purposes of formulating this standard is to facilitate cross-reference to electrical steel sheets in Sri Lanka standards covering electrical apparatus and appliances.

With a view to facilitating the supply of magnetic steel sheets of the exact requirements to the consumers, detailed information necessary along with each enquiry and order is given in Appendix A and may be treated as a guideline.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or observation shall be rounded off in accordance with CS 102 : 1971*. The number of figures to be retained in the rounded off values shall be the same as that of the specified value in this standard.

All standard values given in this specification are in SI units.

The publications of the Indian Standards Institution and the British Standard Institution were consulted in the preparation of this Standard, and the assistance gained therefrom is acknowledged.

1. SCOPE

This standard covers non-oriented magnetic steel sheet and strip primarily for machines and transformers operating at power frequencies.

2. TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

*CS 102 : 1971 - Presentation of Numerical Values.

2.1 Magnetic Steel Sheet — Magnetic steel sheet is a material used in the form of stampings and strips as a core for rotating electric machines and static apparatus, such as transformers and reactors. In practice, this material is referred to as " electrical steel sheet " or " silicon steel sheet ". For the purpose of this standard, the term " magnetic steel sheet " shall be used.

2.2 Non-Oriented Magnetic Steel Sheet — Steel sheet having substantially the same magnetic and electrical characteristics in all directions in the plane of the sheet.

2.3 Hot-Rolled Magnetic Steel Sheet — Magnetic steel sheet which is reduced to final gauge entirely by hot-rolling.

2.4 Cold-Rolled Magnetic Steel Sheet and Strip — Magnetic steel and strip which is reduced to final gauge by cold-rolling.

2.5 Batch — A single charge of the product of one or more casts heat-treated together with similar quality grading up to a maximum weight of 5 tonnes.

2.6 Stacking Factor — The ratio of the calculated volume of a stack of laminations (based on density) to the measured solid volume of the stack under testing load.

2.7 Magnetic Field Strength (H) — The force experienced by a unit pole when placed at the given point in a magnetic field, it being assumed that the introduction of the pole does not disturb the field.

The unit of magnetic field strength in the SI system is amperes per metre (A/m).

2.8 Magnetic Induction / (Magnetic Flux Density) (B) — The flux per unit area through an element or area at right angles to the flux. The flux density in the SI system is tesla (T) (weber per square metre).

2.9 Specific Core Loss — The total power in watts expended per kilogram of magnetic material in which there is a symmetrical harmonically varying induction of a specified maximum value B (in tesla) at a specified frequency.

2.10 Permeability — The magnetic flux density divided by the magnetic field strength (B/H). The unit in SI system is henry per metre (H/m).

3. DESIGNATION OF GRADE

3.1 Magnetic steel sheet and strip shall be designated by 100 × (guaranteed maximum loss in W/kg) (see Table 1), where guaranteed maximum loss is the total loss which shall not be exceeded by any sample of the same batch when tested under conditions specified in Clause 10.1 at a flux density of 1.0 T.

3.2 The purchaser shall supply the information as per Appendix A along with the enquiry and order.

4. PREFERRED THICKNESS

4.1 The preferred nominal thicknesses for each grade are given in Table 1.

4.1.1 If sheets are required in thicknesses other than those specified in Table 1, these may be supplied subject to prior agreement between the purchaser and the manufacturer.

Table 1 — Standard Grades and Preferred Thickness
(Clauses 3.1, 3.2, 4.1 and 4.1.1)

Group	*Grade*	*Nominal Thickness* mm
A	360	0·40
	300	0·50
	260	0·63
	230	1·00
	180	
B	140	0·35
	130	0·40
		0·45
		0·50
C	120	0·35
	108	0·50
	99	
	92	

5. BATCH IDENTIFICATION

The manufacturers shall assign, for identification, a serial number to each batch.

6. SIZES

6.1 The sizes of coils and sheets shall be subject to mutual agreement between the purchaser and the manufacturer.

6.2 The following sizes of sheets shall be considered as preferred sizes for all the grades specified in this standard :

Length mm	*Width* mm
3 000	1 000
2 500	1 000
2 000	1 000
1 500	750

7. TOLERANCES

7.1 Length and Width — The permissible tolerances on the sizes specified under Clause 6 shall be as follows :

Tolerance on width, $^{+\ 10 \cdot 0\ \text{mm}}_{-\ 0}$

Tolerance on length, $^{+\ 20 \cdot 0\ \text{mm}}_{-\ 0}$

7.1.1 Tolerance on sizes other than those covered under Clause 6.2 shall be subject to agreement between the purchaser and the manufacturer.

7.2 Tolerance on Shape — If the edges are curved, the curvature shall be such as to permit a rectangle of the specified size being out from the sheet.

7.3 Thickness

7.3.1 Subject to mutual agreement between the purchaser and the manufacturer the tolerance on thickness shall be based on :

(*a*) Actual thickness measurement in accordance with Clauses 7.3.2, 7.3.3 and 7.3.4 ; or

(*b*) mass in accordance with Clause 7.3.5.

7.3.2 The tolerance on the thickness at any point on any sheet measured by micrometer at a point not less than 15 mm from any edge for sheets cut from cold-rolled sheet and strip ; and not less than 30 mm from any edge or less than 100 mm from any corner for hot mill pack rolled sheet and strip, shall conform to the requirements specified in Table 2.

Table 2 — Tolerance on Thickness
(Clause 7.3.2)

Nominal Thickness mm	Tolerance mm
0·45, 0·40 and 0·35	± 0·05
0·50 and 0·63	± 0·08
1·00	± 0·10

7.3.3 Hot-Rolled Sheets — Thickness of 95 percent of the sheets in any batch, measured as in Clause 7.3.2, shall be within a range of thickness variation for an individual sheet as specified in Table 3.

7.3.4 Cold-Rolled Sheets — The maximum range of thickness variation for an individual sheet in general shall be less than those given in Table 3.

Table 3 — Range of Thickness Variation for any one Sheet
(Clauses 7.3.3 & 7.3.4)

Nominal Thickness mm	Range mm
0·45, 0·40 and 0·35	0·08
0·50 and 0·63	0·10
1·00	0·15

7.3.5 Unless agreed otherwise, in the case of hot-rolled sheet and strip the variation in thickness shall be determined on the basis of variation in average mass in kg/m². For this purpose, two samples shall be cut from one sheet chosen at random, the length of each sample being equal to the full width of the sheet and its area being equal to 0·2 m². The variation in the average mass of these two samples shall be not more than 10 per cent of the nominal mass per square metre given in Table 4. The mass shall be calculated by assuming that the material in each grade has the density given in Table 4 and using the formula :

$$W = D \times t$$

where

W = mass in kg/m²
D = density in gm/cm³ and,
t = nominal thickness in m.

Table 4 — Assumed Density and Calculated Mass in kg/m² on Magnetic Steel Sheets (Clause 7.3.5)

Grade	Density	Mass in kg/m² of Nominal Thickness					
(1)	(2) g/cm³	0·35 (3) mm	0·40 (4) mm	0·45 (5) mm	0·50 (6) mm	0·63 (7) mm	1·00 (8) mm
360	7·80	2·73	3·12	3·51	3·90	4·91	7·80
300	7·75	2·71	3·10	3·49	3·88	4·88	7·75
260	7·70	2·70	3·08	3·46	3·85	4·85	7·70
230	7·65	2·68	3·06	3·44	3·82	4·82	7·65
180	7·60	2·66	3·04	3·42	3·80	4·79	7·60
140 and 130	7·55	2·64	3·02	3·40	3·78	4·76	7·55
120 and 108	7·55	2·64	3·02	3·40	3·78	4·76	7·55
99 and 92	7·55	2·64	3·02	3·40	3·78	4·76	7·55

7.4 Tolerances on sheet and strip supplied for specific purposes shall be subject to agreement between the purchaser and the manufacturer.

8. FREEDOM FROM DEFECTS

8.1 The sheets shall be free from loose scale, rust and any residues resulting from pickling or neutralizing liquor. The residual scale, if present, should be adherent and should not be detachable in subsequent processing by shearing or stamping. The sheets shall be reasonably free from waviness, cracks and as free from internal stresses as is commercially practicable.

9. TEMPERATURE OF TESTS

9.1 The tests shall be carried out at 27 ± 5°C.

10. ACCEPTANCE TESTS

10.1 Guaranteed Maximum Losses — Test samples shall be cut from annealed sheets selected at random and shall be tested as described in Appendix B at a flux density of either 1 T or 1·3 T at 50 Hz as required by the purchaser while placing the order. The total loss in watts per kilogramme shall be not greater than that specified in Table 5.

10.1.1 Retests— Should a test sample fail and two further samples indicate that the core loss is greater than the maximum loss specified for the respective grade, the batch represented by these samples shall be taken as not complying with the requirements of that grade.

10.1.2 Subject to agreement between the purchaser and the manufacturer the results of this test may be used as a guide for accepting the material against any other grade not specified in this standard.

10.2 Stacking Factor — The surface quality of the sheets, when measured in terms of stacking factor as specified in Appendix C, shall comply with the minimum values given in Table 6.

10.3 Brittleness Test — The brittleness test shall be carried out as specified in Appendix D. The number of bends which the test pieces of different grades shall withstand and the radius of jaw is given in Table 7.

11. PERMEABILITY AND AGEING TESTS (Optional Tests)

11.1 If required by the purchaser, the permeability test shall be carried out as specified in Appendix E.

11.1.1 Typical values of **B** in tesla corresponding to values of **H** in ampere per metre in test specimens are given in Table 8. The values of **H** shall not exceed the maximum values specified in Table 8.

11.2 Ageing Test — If required by the purchaser, the ageing test shall be carried out as specified in Appendix F. The deterioration in specific core loss shall not exceed the values given in Table 9. This is applicable at both 1·0 T and 1·3 T flux densities.

12. PACKING

The sheets or coils shall be suitably packed to avoid any damage in transit and the packing details shall be subject to the approval by the purchaser before despatch from the manufacturer's works.

13. MARKING

13.1 Every bundle of sheets shall be legibly marked with the following:

(*a*) Manufacturer's name or trade mark, if any ;

(*b*) Group and thickness ; and

(*c*) Cast number or identification mark by which the sheets can be traced to the cast from which they were made.

13.2 Each batch of Group A, Group B and Group C sheets be marked with its thickness, grade number and with its batch identification serial number in a manner acceptable to both the purchaser and the manufacturer.

Table 5 — Maximum Core Losses for Electrical Steel Sheets
(Clause 10.1)

Group	Grade	Maximum Total Loss in W/kg of Nominal Thickness											
		0·35 mm		0·40 mm		0·45 mm		0·50 mm		0·63 mm		1·00 mm	
		1 T	1·3 T	1 T	1·3 T	1 T	1·3 T	1 T	1·3 T	1 T	1·3 T	1 T	1·3 T
A	360	—	—	—	4·92	—	—	3·60	5·58	4·30	6·50	5·50	—
	300	—	—	—	4·12	—	—	3·00	4·76	3·59	5·64	4·62	—
	260	—	—	—	3·70	—	—	2·60	4·12	2·84	4·70	3·94	—
	230	—	—	—	3·40	—	—	2·30	3·75	2·51	4·21	3·08	—
	180	—	—	—	2·93	—	—	1·80	3·22	2·13	3·64	—	—
B	140	1·40	2·36	—	2·51	—	2·67	—	2·82	—	—	—	—
	130	1·30	2·20	—	2·36	—	2·51	—	2·67	—	—	—	—
C	120	1·20	2·03	—	—	—	—	1·54	2·51	—	—	—	—
	108	1·08	1·90	—	—	—	—	—	—	—	—	—	—
	99	0·99	1·76	—	—	—	—	—	—	—	—	—	—
	92	0·92	1·63	—	—	—	—	—	—	—	—	—	—

NOTE : If required by the purchaser, maximum core losses at flux densities other than those specified may be guaranteed in accordance with the agreement between the purchaser and the manufacturer.

Table 6 — Stacking Factor (Minimum)
(Clause 10.2)

Nominal Thickness mm	Hot Rolled Pickled Sheets per cent	Hot Rolled Unpickled Sheets per cent	Cold Rolled per cent
0·35	93	92	97
0·40	94	93	97
0·45	95	94	97
0·50	95	94	98
0·63	96	95	98

Table 7 — Number of Bends
(Clause 10.3)

Grade	Radius of Jaw (R) mm	Number of Bends Min
360 to 230	5·0	6
180	5·0	4*
140	5·0	2*
130	5·0	1*
120 to 92	9·5	—

* Unless agreed otherwise, the number of bends normally apply to material which will subsequently be incorporated in rotating electrical machinery or will be used for special applications. The end use shall be specified in the enquiry and order.

Table 8 — Values of B to Produce Corresponding Values of H
(Clause 11.1.1)

Group	Grade	Values of B in tesla for H in A/m					
		400	800	1 600	4 000	8 000	24 000
A	360	1·31	1·46	1·54	1·67	1·78	1·98
	300	1·27	1·38	1·50	1·64	1·76	1·96
	260	1·30	1·38	1·48	1·60	1·72	1·94
	230	1·30	1·38	1·48	1·60	1·72	1·92
	180	1·28	1·37	1·46	1·58	1·70	1·90
B	140	1·28	1·36	1·44	1·56	1·67	—
	130	1·28	1·36	1·44	1·56	1·67	—
C	120	1·30	1·41	1·49	1·59	1·70	1·90
	108	1·26	1·35	1·43	1·55	—	—
	99	1·26	1·35	1·47	1·55	—	—
	92	—	—	—	—	—	—

Table 9 — Permissible Deterioration in Specific Core Loss in Ageing
(Clause 11.2)

Group	Deterioration in Specific Core Loss After Ageing
	Max per cent
A	5
B	2
C	1

APPENDIX - A

(Clause 3.2)

INFORMATION TO BE SUPPLIED ALONGWITH EACH ENQUIRY AND ORDER

A - 1 Grade of magnetic steel sheet or strip required (see Table 1).

A - 2 Whether the sheet or strip is to be supplied hot-rolled or cold-rolled.

A - 3 Whether it is required for use on rotating machines or for any special application, in which case the end use should be stated.

A - 4 Length, width and thickness of sheet and strip required (see Table 1 and Clause 6.2).

A - 5 Whether the sheet is to be tested at flux density of 1.0 T or 1.3 T at 50 Hz for determining specific core loss.

A - 6 Any optional tests required (see Clause 11).

A - 7 Any special requirements (see Clauses 4.1.1, 6.1, 7.1.1, 7.4, 11 and foot-note under Table 7).

APPENDIX - B

(Clause 10.1)

DETERMINATION OF SPECIFIC CORE LOSS

B - 1 **Test Method** — When magnetic properties of the basic magnetic material are desired the test specimens shall, whenever possible, consist of strips arranged in Epstein square test apparatus so as to constitute a square magnetic circuit with the strips completely overlapped (double-lapped) at the corners. Flat-rolled magnetic materials supplied as sheets or coils shall preferably be tested in this form of the specimen, whenever dimensions permit.

B - 2 Selection of Test Specimens

B - 2.1 Sample sheets shall be selected at the rate of three sheets per batch. For material rolled as continuous coil, two more samples shall be taken per batch, one each from outer and inner rings of the coil, subject to mutual agreement between the supplier and the purchaser. Test specimens measuring 3 cm wide and not less than 28 cm long (30·5 cm being found convenient) shall be cut from the sheets thus selected for tests carried out under Epstein square test methods. The minimum number of test pieces to be cut in the case of the standard thickness of sheets shall be as under :

Thickness of Sheets mm	*No. of Test Pieces* Min
0·50 0·45 0·40	16
0·35	20

B - 2.2 However, the total weight of the sheets shall be not less than 400 g and its weight should be determined within ± 1g. Wherever the density of the material is not known, the value should be taken as given under Clause C – 4.1 of Appendix C.

B - 3 Preparation of Test Specimens

B - 3.1 Half of the test specimens required shall be cut parallel to and the other half perpendicular to the direction of rolling. They shall be cut with sharp shears according to pattern shown in Fig. 1 and shall be free from shearing defects such as burrs, bent edges, etc. Where the material has been produced as continuous coils, sufficient length should be discarded from the end of the coil to ensure uniform properties in the test strips.

B - 3.2 Material shall be tested without any heat-treatment.

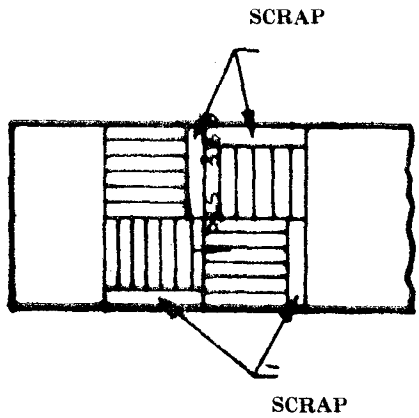

Fig. 1 – Suggested Distribution of Strip to be Cut from Sheets.

B - 4 Assembly of Test Specimens

B - 4.1 The test specimens selected in accordance with Clause B - 2 of Appendix B and prepared as specified under Appendix B shall be divided into four groups containing equal number of strips and nearly of the same weight, for testing. The strips (always a multiple of four in number) shall be inserted into the test frame solenoids one at a time starting with one strip in each of two opposite solenoids and then inserting a strip into each of the other two solenoids so that these latter strips completely overlap the former two at the four corners. This completes one layer of strips constituting a complete flux path with double-lap joints. Successive layers are built up in the same fashion until the specimen is completely assembled.

B - 4.2 Half the specimens cut perpendicular to the direction of rolling shall be in two opposite solenoids whereas the other half of specimens cut parallel to the direction of rolling shall be in the other two opposite solenoids.

B - 4.3 No insulation is normally required between the strips. However, the test specimens may be insulated by means of press spahn or cardboard separators with approximately the same thickness as that of the sheets under test.

B - 4.4 If the specimen strips are reasonably flat and have reasonable area of contact at the corners a sufficiently low reluctance is usually obtained without resorting to pressure on the joints. When the joints are unavoidably poor, the use of light pressure on the joints or non-magnetic corner weights is permissible.

B - 5 Testing Apparatus

B - 5.1 **Scope** — This apparatus provides a test for core loss measurement of flat-rolled magnetic materials at moderate and high inductions (up to 1·5 T when tested at power frequency of 50 Hz). The method also provides a test for AC permeability from measured peak values of exciting current at magnetizing forces from 80 to about 8 000 A/m for the same frequency.

B - 5.2 **Basic Circuit** — Figure 2 shows the essential apparatus and circuit connections for this test. Terminals 1 and 2 are connected to a source of adjustable AC voltage of sinusoidal wave form and sufficient power rating to energise the primary circuit without appreciable voltage drop in the source impedence. Voltage adjustment should not be made by inserting series impedence in the magnetizing circuit.

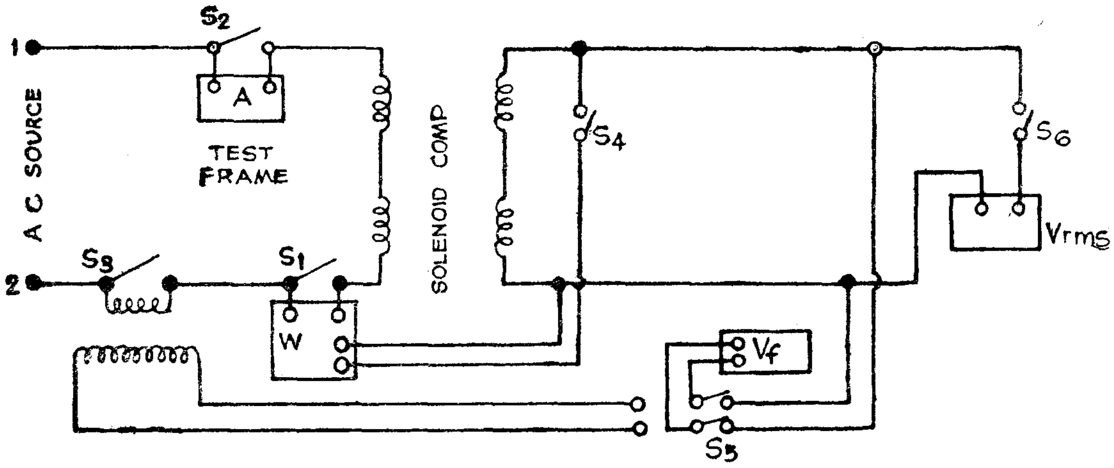

Fig. 2. Schematic Circuit for Specific Core Loss Determination

B - 5.3 Apparatus — The apparatus shall consist of the following parts :

(*a*) Epstein test frame,
(*b*) Flux voltmeter,
(*c*) RMS voltmeter,
(*d*) Wattmeter,
(*e*) RMS ammeter, and
(*f*) Power supply

The components shall be in conformity with the following :

(*a*) **Epstein Frame**—The test frame shall consist of four solenoids (each having two windings of sufficient cross-section to accommodate the specimen strips) surrounding the sides of the square magnetic circuit and a mutual inductor to compensate for air-flux within solenoids. The solenoids are mounted so as to be accurately in the same horizontal plane, and with the centre line of solenoids on opposite sides of the square exactly 25·0 cm apart. The winding of the test frame should extend over at least 19 cm of the length of each side of the square.

(*b*) **Flux Voltmeter** — A true average-type voltmeter, with scale readings in average volts multiplied by 1·11, so that its indications will be identical with those or the true RMS meter on a pure sinusoidal voltage, shall be provided for evaluating the peak value of the test induction. The full-scale error of the instrument shall not exceed 0·30 per cent at 50 Hz although 0·20 per cent accuracy is desired. The resistance of the flux voltmeter shall be not less than 1 000 ohms per volt of full-scale indication.

(*c*) **RMS Voltmeter** — A true RMS - indicating voltmeter shall be provided for evaluating the form-factor of the voltage induced in the secondary winding and for evaluating the instrument losses. The accuracy of the RMS voltmeter shall be the same as that specified for the flux voltmeter. The resistance of the RMS voltmeter shall be not less than 500 ohms per volt of full-scale indication.

(*d*) **Wattmeter** — The wattmeter should be of low-power-factor type with a number of ranges for both voltage and current. It should be of adequate sensitivity and should be accurate to $\pm$ 0·5 per cent (preferably to $\pm$ 0·3 per cent) of full scale. It should have a voltage coil circuit which does not absorb more than 5 per cent of the power to be measured.

(*e*) **RMS Ammeter** — A true RMS - indicating ammeter is needed if measurement of exciting current are to be made. A nominal accuracy of 1·0 per cent of full scale is permissible for this instrument.

(*f*) **Power Supply** — A source of sinusoidal test power of low internal impedance and excellent voltage and frequency stability is required for this test. Voltage stability within 0·5 per cent is necessary for precise work. The frequency of the source should be accurately controlled within 0·2 per cent of the nominal value.

B - 5.4 Procedure Testing

(*a*) Prior to testing the specimen, strips shall be checked for length and be measured to within $\pm$ 0·5 mm. The specimen shall be weighed on a scale and weight determined within $\pm$ 1g. The main cross-sectional area in square centimetres of the specimen is calculated from the relation :

$$A = \frac{m}{4 \rho . l} \qquad \ldots\ldots (1)$$

where m = total mass of specimen in grams; ρ = density of material in grams per cubic centimetres ; and l = actual mean length of individual strips in centimetres.

(*b*) Specimen shall be equally divided into 4 sets and inserted into the solenoids one by one. With specimens cut half parallel and half across the direction of rolling, strips cut parallel shall be in two opposite solenoids and all the cross strips in the other two opposite solenoids.

(*c*) If the specimen strips are reasonably flat and have a reasonable area of contact at the corners a sufficiently low reluctance is usually obtained without resorting to pressure on the joints. When the joints are unavoidably poor, the use of light pressure on the joints, or non-magnetic former weights is permissible.

(*d*) The required apparatus is connected as in Fig. 2 and terminals 1 and 2 connected to the power source and the supply frequency adjusted to 50 Hz. The voltage applied to the magnetizing winding is adjusted until the induced emf corresponding to the required flux density in the specimen is indicated on the flux voltmeter, and the reading of the wattmeter is taken.

(*e*) The specific core loss of the specimen in watts per unit weight is obtained by dividing the net watts by that portion of the weight of the specimen constituting the active magnetic flux path in the specimen. Equations and instructions for computing the active weight of the specimen and the specific core loss are given in Clause B - 5.5 of Appendix B.

B - 5.5 Calculation

(*a*) The value of the flux voltage, Ef, at the desired test induction in the specimen is calculated in accordance with the equation :

$$\text{Ef, volts} = 4 \cdot 44\ B_{Max}\ ANf \qquad \ldots\ldots (2)$$

where B_{Max} = maximum intrinsic flux density in tesla : A = mean cross sectional area in square metres, as given in equation (1) ; N = number of turns in secondary winding ; and f = frequency in cycles per second.

No correction is made in these expressions for the air-flux enclosed by the secondary winding :

$$\frac{A_1 - A}{A} \times H \qquad \ldots\ldots (3)$$

where A_1 = mean cross-sectional area of the secondary winding connected to the mean voltmeter in square metres ; and H = magnetizing force corresponding to $B_{Max.}$

Normally this correction is negligible if it does not exceed 0·2 pre cent B_{Max} but it is desirable to eliminate it entirely by balancing the linkage of air-flux with the secondary winding connected to the voltmeter by means of an air-cored mutual inductor. For this purpose the mutual inductor is connected with its primary in series with the magnetizing winding of the test square and its secondary in series opposition with the secondary in series opposition with the secondary winding on the test square connected to the voltmeter.

Let wattmeter reading be W_1, and W_2 be the total iron loss. Then,

$$W_2 = \frac{N_1}{N_3}\, W_1 - \frac{V_W^2}{R_W} - \frac{V^2}{R_V} \qquad \ldots\ldots (4)$$

where N_1, N_3 are the number of turns in magnetizing winding and in secondary winding connected to the wattmeter, respectively ; V_W, V are the RMS voltages applied to wattmeter voltage circuit and voltmetres, respectively ; and R_W, R_V are the resistances of wattmeter voltage circuit and voltmeter circuits, respectively.

The conditions of the test shall be such that the form-factor, $\frac{V_{rms}}{V_{mean}}$ is $1 \cdot 11 \pm 0 \cdot 03$. In case this value falls outside this range a suitable corrections is to be applied. This may be determined by taking **3** or **4** tests with different values of form factor f_1 and plotting a curve connecting total losses and f_1^2. This curve should be linear and the total losses corresponding to $f_1 = 1 \cdot 11$ may be read off by extrapolating to $f_1^2 = 1 \cdot 232$. Alternations of form-factor are most conveniently produced by inserting a resistor or an air-cored inductor in series with the magnetizing circuit.

(*b*) **Core Loss** — In the 25cm Epstein frame it is assumed that 94 cm is the effective magnetic path with specimen strips 28 cm or longer. Thus, active weight

$$m_1 = \frac{ml_1}{4l} \qquad \ldots\ldots (5)$$

where m is the total specimen weight in grams. l is the actual strip length in cm. and $l_1 = 94$ cm.

$$\text{Then } m_1 = \frac{0 \cdot 0235\ m}{l}\ \text{kg}$$

where m is in grams and l is in centimetres.

Let W_2 = total losses in watts corrected, if necessary, to $f_1 = 1 \cdot 11$. Specific core loss is given in terms of watts per kilogram by the following formula :

$$\text{Specific core loss} = \frac{W_2 \times l}{0 \cdot 0235\ m} = \frac{42 \cdot 5\ W_2 l}{m}$$

B - 5.6 Repeatability — Repeated measurements on the same samples should not differ by more than 0·5 per cent.

APPENDIX - C

(Clause 10.2)

DETERMINATION OF STACKING FACTOR

C - 1 Apparatus — A compression testing machine or any other device capable of gradually exerting the specified pressure may be used for this test.

C - 1.1 Measuring Device — The measuring device shall be capable of measuring the height of the stack placed symmetrically with respect to the compression head on either side of the stack. The use of dial gauges capable of measuring with an accuracy of one-hundredth of a millimetre is recommended. Vernier callipers may also be used.

C - 2 Test Specimens — The test shall be carried out on the test samples prepared for determining specific core loss consisting of not less than 16 pieces. Shearing burrs or loose particles shall be carefully removed from the pieces before the test.

C - 3 Test Procedure — The test specimens are carefully weighed with an accuracy of $\pm$ 1 g and loaded in the machine between plates that are suitably supported or backed so as to ensure uniform distribution of the pressure. The required pressure of 3·5 kg/cm^2 is gradually applied to an area of not less than 25 mm $\times$ 13 mm at approximately the centre of the stack. The average thickness of the test specimens at the specified pressure is calculated from measurements of the plate separations.

C - 4 Calculation — Percentage stacking factor is calculated from the following :

$$\text{Stacking factor, per cent} = \frac{m}{wl\,\rho\,t} \times 100$$

where m = weight of test specimens in grams, w = width of test specimens in centimetres, l = length of test specimen in centimetres, ρ = density of test specimens in grams per cubic centimetre, and t = measured average separation plate faces in centimetres.

C - 4.1 Density — Unless otherwise specified by the manufacturer, the following densities may be assumed for calculation purposes :

Silicon Content Percent	*Assumed Density* g/cm³
0 to 0·5	7·85
Over 0·5 to 2·0	7·75
Over 2·0 to 3·5	7·65
Over 3·5 to 5·0	7·55

APPENDIX - D

(Clause 10.3)

DETERMINATION OF BRITTLENESS

D - 1 Brittleness is evaluated by determining the number of bends which a test piece can be subjected to in a fixture or some other suitable device under specified conditions, without showing signs of fracture.

D - 2 The test shall be carried out on the test samples prepared for determining specific core loss. Only the test samples cut parallel to the direction of rolling shall be used. A suitable length (50 to 60 mm) and width (10 to 15 mm) shall be cut from the test specimens and used for bend test. The essential features of the bend testing machine are illustrated in Fig. 3.

D - 3 Procedure

D - 3.1 First bend the test piece through 90°, this bend not being counted. Then bend the test piece backwards and forwards through 180° until fracture occurs. One bend is taken as one movement through 180°. The bend during which fracture occurs is not counted.

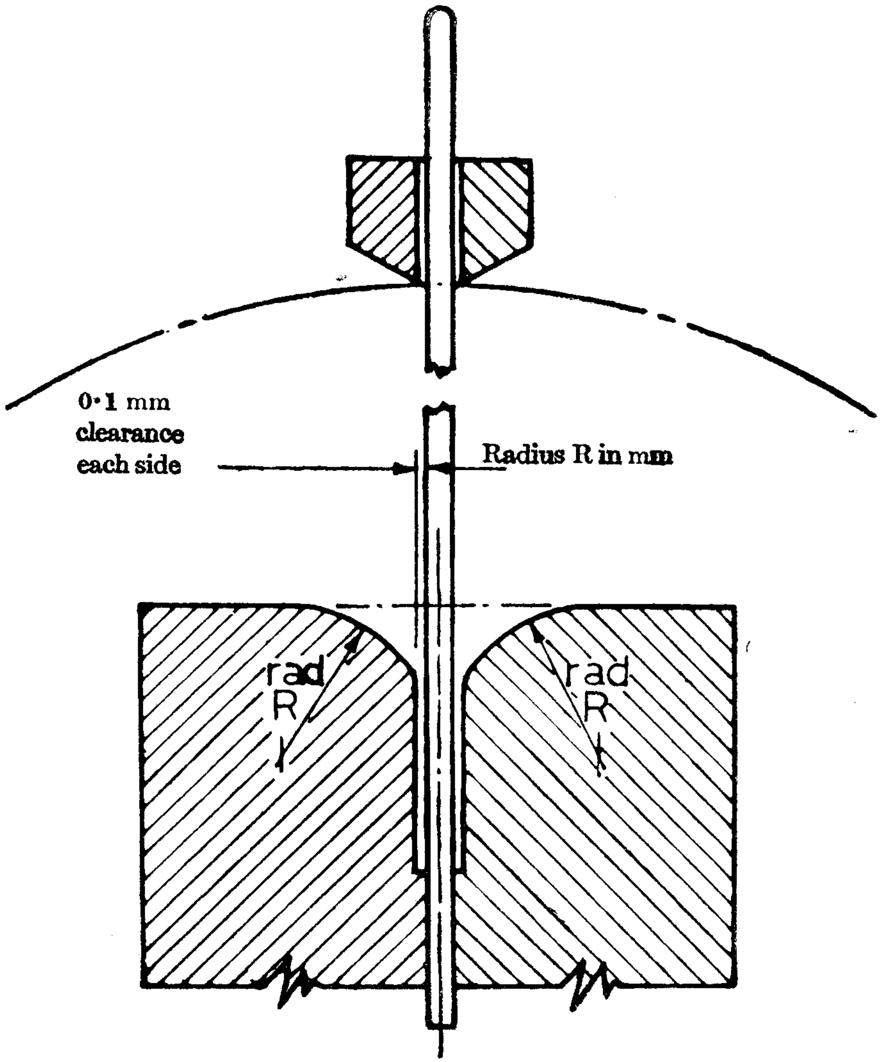

Fig. 3 - Essential Elements of Bend Testing Machine

APPENDIX - E

(Clause 11.1)

DETERMINATION OF PERMEABILITY

E - 1 Permeability test is made by the ballistic method using a ballistic galvanometer of periodic time of not less than 7 seconds. The ballistic method shall be considered as a standard method. For routine testing either any permeameter or bridge method with Epstein square frame may be employed.

E - 2 Sampling, Preparation and Assembly of test Specimens

E - 2.1 The test specimen shall be cut from a sheet selected at random from a batch of 5 metric tonnes or part thereof to be tested. The specimen shall have the same width as the Epstein test specimen. One-half of the test pieces shall be cut parallel to and the other half perpendicular to the direction of rolling as given in Fig. 1. The total number of test pieces taken for this test shall not exceed 12.

E -2.2 All the strips shall be cut from a single sheet and shall be distributed symmetrically over the entire area of the sheet as far as practicable.

E - 2.3 The strips shall be weighed accurately before assembling and their mean cross-section calculated from the formula :

$$A = \frac{m}{\rho l}$$

where A = mean cross-section in square centimetres of the test strips, m = total mass in grams of the strips, ρ = density in grams per cubic centimetre of the material, and l = mean length in centimetres of the test strips.

E - 3 Procedure

E - 3.1 The test may be carried out in a permeameter employing either of the methods given under Clauses E-3.1.1 and E-3.1.2 of Appendix E for measuring the magnetizing force H.

E - 3.1.1 **Measure magnetizing** force H directly employing a search coil wound on a non-magnetic core and placed adjacent to a length of the test specimen within which magnetization is approximately uniform. Determine both B and H by noting the ballistic galvanometer deflections when the magnetizing current is reversed.

E - 3.1.2 Alternatively, calculate H from the known values of the magnetizing current and the number of turns per centimetre length in the main magnetizing winding. After the application of emf to compensate for the reluctance of the joints etc., and to provide for a high degree of uniformity of magnetization along the length of specimen under test, determine B as under Clause E-3.1.1 of Appendix E. Calibrate the instrument by reversing a measured current in a standard mutual inductance unit.

E - 3.2 Precautions

E - 3.2.1 Avoid the application of excessive stress to the specimens while clamping them or while placing winding or search coils on them.

E - 3.2.2 Before testing, carefully demagnetize the specimen from a maximum magnetizing force H of not less than 4000 A/m. If subsequently inadvertently applied; demagnetize the specimen again from the higher magnetizing force.

E - 3.3 Correction for Air-Flux — Correct the measured value of flux density to allow for the air-flux enclosed by the search coil. The correction (which is negative) is given by :

$$\frac{A^1 - A}{A} \times H$$

where A^1 = cross-sectional area of the search coil, and
A = mean cross-section of the test strips.

APPENDIX - F

(Clause 11.2)

AGEING TEST

F - 1 The ageing test shall be carried out on test pieces prepared for the determination of specific core loss under Appendix B.

F - 2 Re-determine the change in specific core loss after subjecting a certain specimen to an ageing treatment at 100°C for not less than 600 hours and express the result as the percentage increase in loss.

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