# IEC 60740-1

Edition 1.0 2005-08

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Laminations for transformers and inductors –
## Part 1: Mechanical and electrical characteristics

## Tôles découpées pour transformateurs et inductances –
## Partie 1: Caractéristiques électriques et mécaniques



IEC 60740-1:2005

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# LAMINATIONS FOR TRANSFORMERS AND INDUCTORS –

## Part 1: Mechanical and electrical characteristics

## FOREWORD

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International Standard IEC 60740-1 has been prepared by IEC technical committee 51: Magnetic components and ferrite materials.

IEC 60740-1 cancels and replaces IEC 60740 published in 1982 and its amendment 1 (1991). The main changes are listed below:

a) ranges with lamination strips YS, YSUI 1, YSUI 2 and laminations YEE 2-..L added;
b) range YEI 1 extended at the above end;
c) ranges YED 2, YEF 2, YEL 2, YES 2, Type YM 1-5a and YM 1-7a cancelled;
d) national designations cancelled;
e) electrical characteristics for the laminations specified;
f) mechanical characteristics for laminations added;
g) holes added for lamination types YEI 1, YUI 1, YUI 2, YM 1;
h) in Annex A, a conversion of the polarisation $\hat{J}$ and the field strength $\hat{H}$ in a specific total apparent power is defined. For the characteristics of the reactive power and the power loss, equations and constants are specified.

This bilingual version (2011-11) corresponds to the monolingual English version, published in 2005-08.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 51/823/FDIS | 51/836/RVD |

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 60740 consists of the following parts under the general title *Laminations for transformers and inductors:*

Part 1: Mechanical and electrical characteristics

Part 2: Specification for the minimum permeabilities of laminations made of soft magnetic metallic materials.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be



- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

# LAMINATIONS FOR TRANSFORMERS AND INDUCTORS –

## Part 1: Mechanical and electrical characteristics

## 1 Scope

This part of IEC 60740 specifies the characteristics of laminations. Their preferred use is cores for transformers and inductors. The laminations are made of sheets and strips of magnetic materials, specified in IEC 60404-8-4 and IEC 60404-8-7.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-221, *International Electrotechnical Vocabulary (IEV) – Chapter 221: Magnetic materials and components*

IEC 60404-1:2000, *Magnetic materials – Part 1: Classification*



IEC 60404-8-4:1998, *Magnetic materials – Part 8-4: Specifications for individual materials – Cold-rolled non-oriented electrical steel sheet and strip delivered in the fully-processed state*



IEC 60404-8-7:1998, *Magnetic materials – Part 8-7: Specifications for individual materials – Cold-rolled grain-oriented electrical steel sheet and strip delivered in the fully-processed state*

IEC 60404-11:1999, *Magnetic materials – Part 11: Method of test for the determination of surface insulation resistance of magnetic sheet and strip*

IEC 61021-1:1990, *Laminated core packages for transformers and inductors used in telecommunication and electronic equipment – Part 1: Dimensions*

IEC 61021-2:1995, *Laminated core packages for transformers and inductors used in telecommunication and electronic equipment – Part 2: Electrical characteristics for cores using YEE 2 laminations*

ISO 286-1:1988, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*

## 3 Terms, definitions and symbols

For the purposes of this document, the definitions of IEC 60050-221 and the following apply.

**3.1**
**lamination**
produced from a magnetic alloy sheet, usually consisting of one piece or several joined pieces, forming one complete layer of a laminated core

**3.2**
**lamination strip**
produced from a magnetic alloy sheet, which can be composed to a layer of laminations or stacks for limbs or yokes

**3.3**
**square stack**
results, if the height of the package $h_p$ is equal to the limb width $d$.

**3.4**
**specific power loss**
loss of the core in an alternating field with specified frequency and sinusoidal waveform, generating a specified flux density divided by the core mass:



$$p_{Fe} = \frac{P_{Fe}}{m_{Fe}} \quad (1)$$

where



$p_{Fe}$ is the specific power loss, in W/kg;

$P_{Fe}$ is the power loss, in W;

$m_{Fe}$ is the core mass, in kg.

NOTE 1 In the power loss both the hysteresis loss and eddy current loss are included.

NOTE 2 This is valid for cores with and without an air gap in the magnetic path.

**3.5**
**specific reactive power**
reactive power of the core in an alternating field by specified frequency and sinusoidal, specified flux density divided by the core mass:

$$p_{BFe} = \frac{P_{BFe}}{m_{Fe}} \quad (2)$$

where

$p_{BFe}$ is the specific reactive power, in VA/kg;

$P_{BFe}$ is the reactive power, in VA;

$m_{Fe}$ is the core mass, in kg.

**3.6**
**specific reactive power of the air gap**
in an alternating field and sinusoidal, specified flux density is the r.m.s. reactive power in the air gap, divided by the core mass:

$$p_{\mathrm{BL}} = 0{,}25 \cdot \frac{l_{\mathrm{L}} \cdot f \cdot \hat{B}^2}{l_{\mathrm{Fe}} \cdot \rho} \quad (3)$$

where

$p_{\mathrm{BL}}$ is the specific reactive power of the air gap, in VA/kg;

$\hat{B}$ is the peak flux density, in T;

$f$ is the frequency, in Hz;

$\rho$ is the density of the core, in kg/dm$^3$;

$l_{\mathrm{L}}$ Is the length of the air gap, in µm;

$l_{\mathrm{Fe}}$ is the path length, in cm.

**3.7**
**specific total apparent power of cores without air gap**
in the mean flux path, the specific total apparent power consists of the specific reactive power and the specific power loss of the core and is the product of sinusoidal voltage and r.m.s. current divided by the core mass:



$$p_S = \sqrt{p_{\mathrm{BFe}}^2 + p_{\mathrm{Fe}}^2} \quad (4)$$



$$p_S = \frac{U \cdot I}{m_{\mathrm{Fe}}} = \frac{P_S}{m_{\mathrm{Fe}}} \quad (5)$$

where

$P_{\mathrm{S}}$ is the total apparent power, in VA;

$p_{\mathrm{S}}$ is the specific total apparent power, in VA/kg;

$p_{\mathrm{BFe}}$ is the specific reactive power, in VA/kg;

$p_{\mathrm{Fe}}$ is the specific power loss, in W/kg;

$U$ is the voltage, in V;

$I$ is the r.m.s. current, in A;

$m_{\mathrm{Fe}}$ is the core mass, in kg.

**3.8**
**specific total apparent power of cores with air gap**
in the mean flux path, the specific total apparent power consists of the specific reactive power of the core, the specific reactive power of the air gap and the specific power loss:

$$p_S = \sqrt{(p_{\mathrm{BFe}} + p_{\mathrm{BL}})^2 + p_{\mathrm{Fe}}^2} \quad (6)$$

where

$p_S$ is the specific total apparent power, in VA/kg;

$p_{BFe}$ is the specific reactive power of the core, in VA/kg;

$p_{BL}$ is the specific reactive power of the air gap, in VA/kg;

$p_{Fe}$ is the specific power loss, in W/kg.

**3.9**
**magnetic path length**
arithmetic mean of the longest and the shortest path length of the core neglecting radii.

NOTE For details of the calculation for each core, see 13.3 to 13.10.

### 3.10 Symbols

| | |
|---|---|
| $A_{Fe}$ | core cross-section, in mm$^2$; |
| $\hat{B}$ | peak flux density, in T; |
| $\hat{B}_n$ | nominal peak flux density, in T; |
| $\hat{B}_0$ | peak flux density for the characteristic of the specific reactive power, in dT; |
| $C_1$ | core constant 1, in mm$^{-1}$; |
| $C_2$ | core constant 2, in mm$^{-3}$; |
| $c_1$ , $c_2$ | constants for the characteristic of the specific reactive power; |
| $c_3$ , $c_4$ | constants for the characteristic of the specific power loss; |
| $d$ | limb width, in mm; |
| $f$ | frequency, in Hz; |
| $\hat{H}$ | peak field strength, in A/m; |
| $h_p$ | stack height, in mm; |
| $I$ | current, in A; |
| $I_1$ , $I_2$ , $I_3$ | currents in the phases of three-phase cores, in A; |
| $\hat{J}$ | peak polarisation, in T; |
| $l$ | magnetic path length, in mm; |
| $l_{Fe}$ | magnetic path length, in mm; |
| $l_{Fe1}$, $l_{Fe2}$ | magnetic path lengths for three-phase cores, in mm; |
| $l_L$ | path length of the air gap, in µm; |
| $l_q$ | magnetic path length cross to the rolling direction, in mm; |
| $l_w$ | magnetic path length in rolling direction, in mm; |
| $m_{Fe}$ | core mass, in kg; |
| $N$ | number of turns; |
| $N_1$ | number of turns of winding N$_1$; |
| $N_2$ | number of turns of winding N$_2$; |
| $P_1$ , $P_2$ , $P_3$ | power loss in the phases of three-phase cores, in W; |
| $P_{BFe}$ | reactive power of the core, in VA; |
| $P_{BL}$ | reactive power of the air gap, in VA; |
| $P_{Fe}$ | power loss, in W; |

| | |
|---|---|
| $P_m$ | test value of the power loss, in W; |
| $P_S$ | total apparent power, in VA; |
| $p_B$ | specific reactive power, in VA/kg; |
| $p_{BFe}$ | specific reactive power of the core, in VA/kg; |
| $p_{BL}$ | specific reactive power of the air gap, in VA/kg; |
| $p_{Fe}$ | specific power loss; in W/kg; |
| $p_{Fe0}$ | cardinal value for the specific power loss, in W/kg; |
| $p_S$ | specific total apparent power, in VA/kg; |
| $p_{S0}$ | cardinal value of the total apparent power, in VA/kg; |
| $p_{S,\ sin}$ | specific total apparent power at sinusoidal current; in VA/kg; |
| $R_1$ | resistance of winding $N_1$, in Ω; |
| $R_2$ | resistance of winding $N_2$, in Ω; |
| $R_n$ | precision resistor, in Ω; |
| $R_V$ | resistance of the voltmeter, in Ω; |
| $R_W$ | resistance of the voltage path of the wattmeter, in Ω; |
| $U$ | voltage, in V; |
| $U_1$ | voltage of the source, in V; |
| $U_{2\ r.m.s}$ | voltage of the winding $N_2$, in V; |
| $U_{2\ avg}$ | voltage of the winding $N_2$, in V; |
| $\hat{U}_n$ | peak value of the voltage across $R_n$, in V; |
| $V_{Fe}$ | core volume, in $mm^3$; |
| $x$ | tolerance factor; |
| $y$ | auxiliary value for the characteristics of the specific reactive power; |
| $y_1$ , $y_2$ | constants for the characteristics of the specific reactive power; |
| $y_3$ | constant for the characteristics of the specific power loss; |
| $\eta$ | stacking factor; |
| $\mu_0$ | magnetic constant, in H/cm ($4 \cdot \pi \cdot 10^{-9}$ H/cm); |
| $\mu_a$ | amplitude permeability; |
| $\mu_i$ | initial permeability; |
| $\pi$ | in this standard = 3,1416; |
| $\rho$ | the density of the core alloy, in $kg/dm^3$. |

# 4 Materials and lamination thicknesses

## 4.1 Materials

Laminations are made from one of the materials specified in Table 1.

**Table 1 – Preferred magnetic steel and alloys used for laminations**

| Material | Approximate composition in addition to iron | Density kg/dm³ | Designation IEC 60404-1 | Designation IEC 60404-8-4 IEC 60404-8-7 |
|---|---|---|---|---|
| Non-oriented silicon steel | 1 % to 3 % silicon | 7,65 | C 21 | M 270-35A 5<br>M 330-35A 5<br>M 330-50A 5 |
| | | 7,7 | | M 400-50A 5<br>M 530-50A 5 |
| | | 7,8 | | M 800-50A 5 |
| Grain-oriented silicon steel | 3,2 % silicon | 7,65 | C 22 | M 165-35S 5 |
| Nickel-iron alloys | 72 % to 83 % nickel | 8,7 | E 1 | ―― |
| | 45 % to 50 % nickel (both oriented and non-oriented) | 8,25 | E 3 | |
| | 35 % to 40 % nickel | 8,15 | E 4 | |
| Cobalt-iron alloys | 47 % to 50 % cobalt (isotropic) | | F 1 | |



## 4.2 Nominal lamination thickness

Lamination thickness shall be selected from one of the values specified in Table 2, according to the material in use.

**Table 2 – Material and lamination thickness**

| Material designation | Thickness mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0,5 | 0,38 | 0,35 | 0,3 | 0,2 | 0,1 | 0,05 |
| C 21 | o | - | o | - | - | - | - |
| C 22 | - | - | o | - | - | - | - |
| E 1 | - | x | x | o | o | o | x |
| E 3 non-oriented | - | x | x | o | o | o | x |
| E 3 grain-oriented | - | - | - | - | - | o | x |
| E 4 | - | x | x | o | o | o | x |
| F 1 | - | - | x | o | o | o | x |
| NOTE o: preferred value, x: usual, -: not usual. | | | | | | | |