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Third edition
2006-04

Calculation of the effective parameters of magnetic piece parts

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CALCULATION OF THE EFFECTIVE PARAMETERS OF MAGNETIC PIECE PARTS

FOREWORD

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International Standard IEC 60205 has been prepared by IEC technical committee 51: Magnetic components and ferrite materials.

This third edition cancels and replaces the second edition published in 2001, corrigendum 1 (2001). This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) unit of angles through the text are described by using "radian";
b) new words are added in 2.1 "All angles are in radians";
c) replacement, Clause 3.9, of the equation $\frac{l_2}{A_2} = \frac{\ln d_2 g / d_3}{D\pi(h_1 - h_2)}$ by $\frac{l_2}{A_2} = \frac{\ln d_2 g / d_3}{D\pi(h_1 - h_2)/2}$;
d) new cores "EL, ER, PQ, EFD and E planar" are added in this edition.

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

FDIS	Report on voting
51/848/FDIS	51/857/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.

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

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- withdrawn;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.

A bilingual version of this publication may be issued at a later date.

CALCULATION OF THE EFFECTIVE PARAMETERS OF MAGNETIC PIECE PARTS

1 Scope

This International Standard lays down uniform rules for the calculation of the effective parameters of closed circuits of ferromagnetic material.

2 Basic rules

The following basic rules are applicable to this standard.

2.1 All results shall be expressed in units based on the millimetre, shall be accurate to three significant figures, but to derive l_e , A_e , and V_e the values of C_1 and C_2 shall be calculated to five significant figures. All angles are in radians.

NOTE The purpose of specifying this degree of accuracy is only to ensure that parameters calculated at different establishments are identical and it is not intended to imply that the parameters are capable of being determined to this accuracy.

2.2 A_{min} is the nominal value of the smallest cross-section. All the dimensions used to calculate A_{min} shall be the mean values between the tolerance limits quoted on the appropriate piece part drawing.

2.3 Calculations are only applicable to the component parts of a closed magnetic circuit.

2.4 All dimensions used for the purpose of calculations shall be the mean value within the tolerance limits quoted on the appropriate piece part drawing.

2.5 All irregularities in the outline of the core, such as small cut-outs, notches, chamfers, etc. shall be ignored unless otherwise described.

2.6 When the calculation involves the sharp corner of a piece part, then the mean length of flux path for that corner shall be taken as the mean circular path joining the centres of area of the two adjacent uniform sections, and the cross-sectional area associated with that length shall be taken as the average area of the two adjacent uniform sections.

Calculation of effective parameters l_e , A_e and V_e.

The effective parameters can be defined as

$$l_e = C_1^2/C_2 \qquad A_e = C_1/C_2 \qquad V_e = l_e A_e = C_1^3/C_2^2$$

where

l_e is the effective magnetic length of the core (mm);

A_e is the effective cross-sectional area (mm^2);

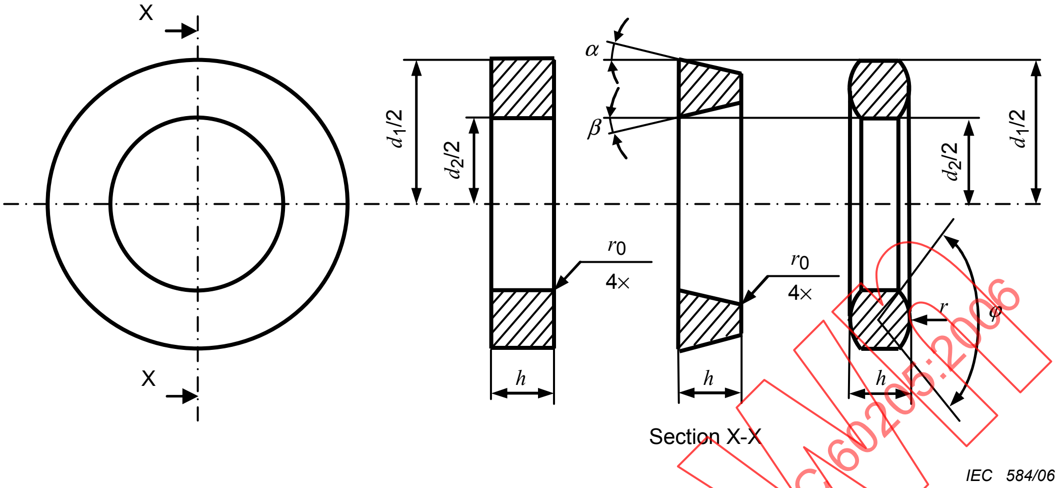
V_e is the effective volume (mm^3);

C_1 is the core constant (mm^{-1});

C_2 is the core constant (mm^{-3}).

3 Formulae for the various types of cores

3.1 Ring cores



$$C_1 = \frac{2\pi}{h_e \ln(d_1/d_2)}$$

$$C_2 = \frac{4\pi(1/d_2 - 1/d_1)}{h_e^{\,2} \ln^3(d_1/d_2)}$$

3.1.1 For ring cores of rectangular cross-section with sharp corners

$$h_e = h$$

3.1.2 For ring cores of rectangular cross-section with an appreciable average rounding radius r_0

$$h_e = h(1 - k_1) \quad k_1 = \frac{1{,}7168 r_0^{\,2}}{h(d_1 - d_2)}$$

3.1.3 For ring cores of trapezoidal cross-section with sharp corners

$$h_e = h(1 - k_2) \quad k_2 = \frac{h(\tan\alpha + \tan\beta)}{d_1 - d_2}$$

3.1.4 For ring cores of trapezoidal cross-section with an appreciable average rounding radius r_0

$$h_e = (1 - k_1 - k_2)$$

3.1.5 For ring cores of cross-section with circular arc frontal sides

$$h_e = h - \frac{d_1 - d_2}{4\sin^2(\varphi/2)}\left(2\sin\frac{\varphi}{2} - \frac{\sin\varphi}{2} - \frac{\varphi}{2}\right)$$

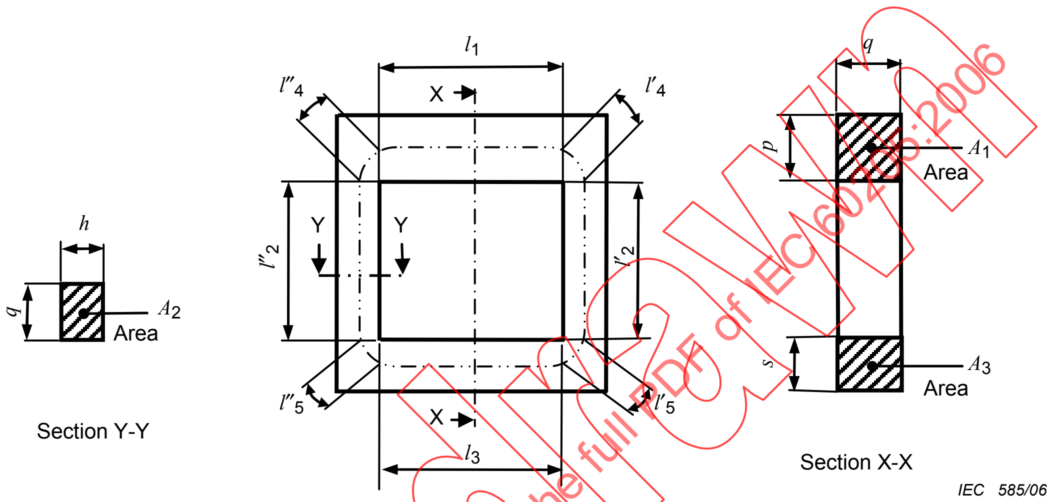
$$\varphi = 2\arcsin\frac{d_1 - d_2}{4r}.$$

NOTE When the winding is uniformly distributed over a ring core, it may be expected that, at all points inside the ring core, the flux lines will be parallel to its surface.

No leakage flux will therefore leave or enter the ring core. This justifies the use of a theoretically more correct derivation of the effective parameters which does not make use of the assumption that the flux is uniformly distributed over the cross-section.

3.2 Pair of U-cores of rectangular section

NOTE U + PLT (Plate)-cores use U core formulas



Length of flux path associated with area A_2:

$$l_2 = l_2' + l_2''$$

Mean length of flux paths at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(p + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(s + h)$$

Mean areas associated with l_4 and l_5:

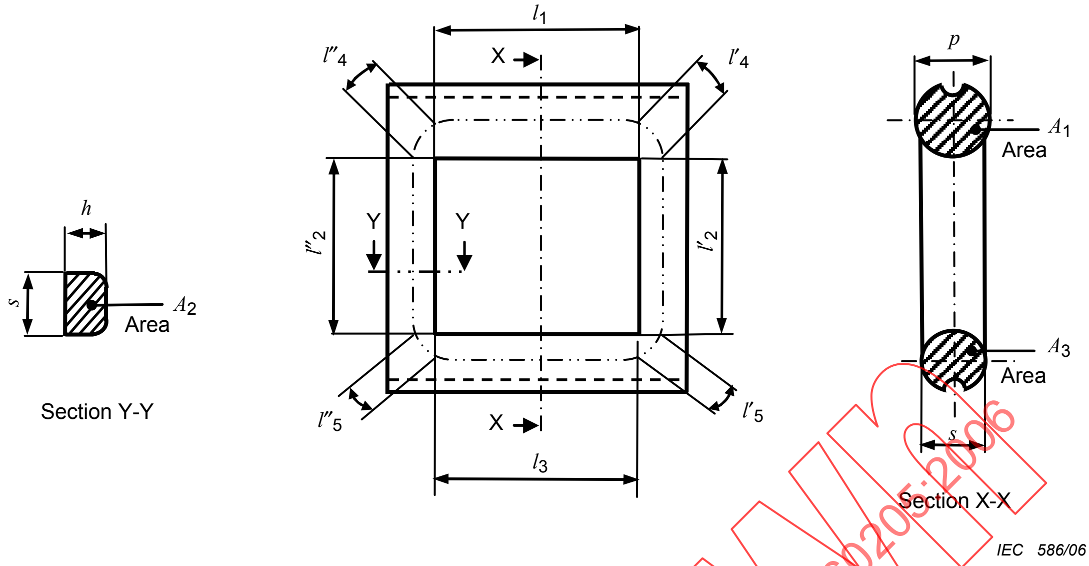
$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{A_i^2}$$

3.3 Pair of U-cores of rounded section

NOTE U + PLT (Plate)-cores use U core formulas.



In calculating A_2 ignore any ridges introduced for the purpose of facilitating manufacture.

Length of flux path associated with area A_2:

$$l_2 = l_2' + l_2''$$

Mean length of flux path at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(p + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(s + h)$$

Mean areas associated with l_4 and l_5:

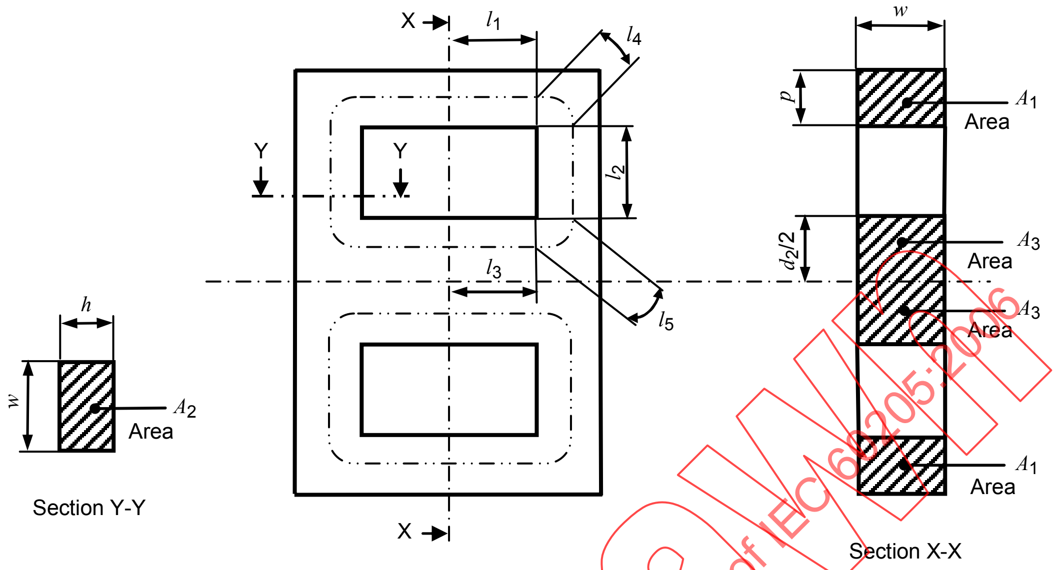
$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{A_i^2}$$

3.4 Pair of E-cores of rectangular section

NOTE E + I (Plate)-cores use E core formulas.



IEC 587/06

Area of half the centre limb: A_3

Mean length of flux paths at corners:

$$l_4 = \frac{\pi}{8}(p + h)$$

$$l_5 = \frac{\pi}{8}\left(\frac{d_2}{2} + h\right)$$

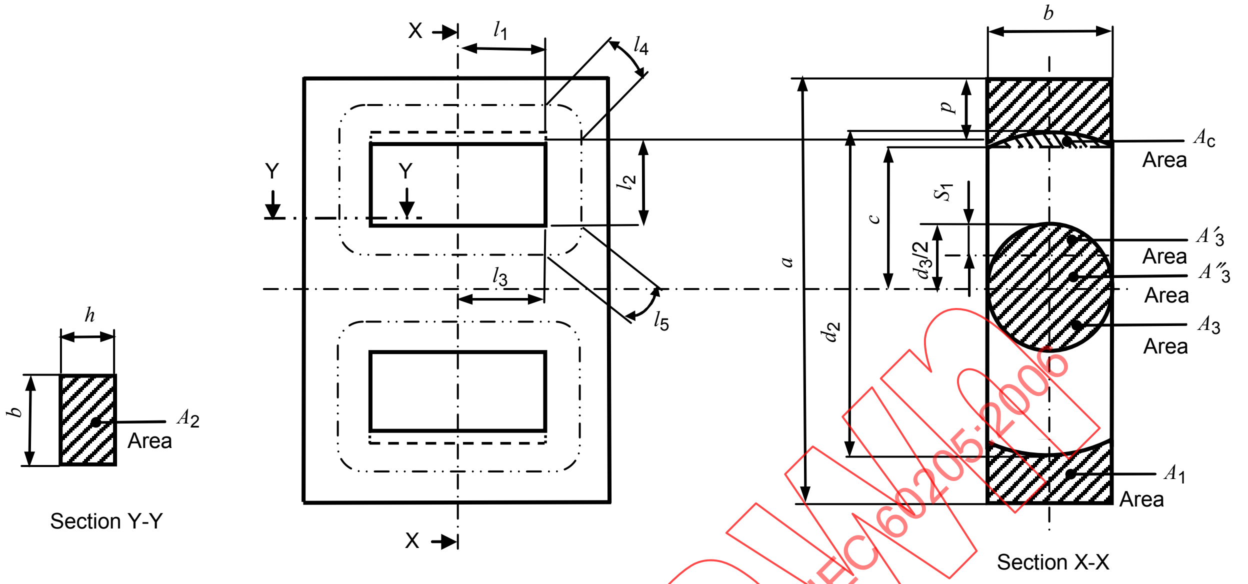
Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{2A_i^2}$$

3.5 Pair of ETD/EER-cores



IEC 588/06

A_1 is equal to the rectangle $b\left(\frac{1}{2}a-c\right)$ less the cap or segment A_c .

$$A_C = \frac{1}{4}d_2^{\,2}\arcsin\left(\frac{b}{d_2}\right) - \frac{1}{4}b\sqrt{d_2^{\,2}-b^2}$$

$$A_1 = \frac{1}{2}ab - \frac{1}{4}b\sqrt{d_2^{\,2}-b^2} - \frac{1}{4}d_2^{\,2}\arcsin\left(\frac{b}{d_2}\right)$$

Mean length of flux path at back walls:

$$l_2 = \frac{1}{4}\left(d_2+\sqrt{d_2^{\,2}-b^2}\right) - \frac{d_3}{2}$$

NOTE l_2 is taken from the mean value of $\frac{1}{2}(d_2-d_3)$ and $(c-d_3/2)$.

Area of half the centre limb:

$$A_3 = A_3' + A_3''$$

The condition to obtain $A_3' = A_3''$ is

$$S_1 = 0{,}2980 d_3$$

Mean length of flux path at corners:

$$l_4 = \frac{\pi}{8}(p+h)$$

where $p = \frac{a}{2} - l_2 - \frac{d_3}{2}$

$$l_5 = \frac{\pi}{8}(2S_1 + h)$$

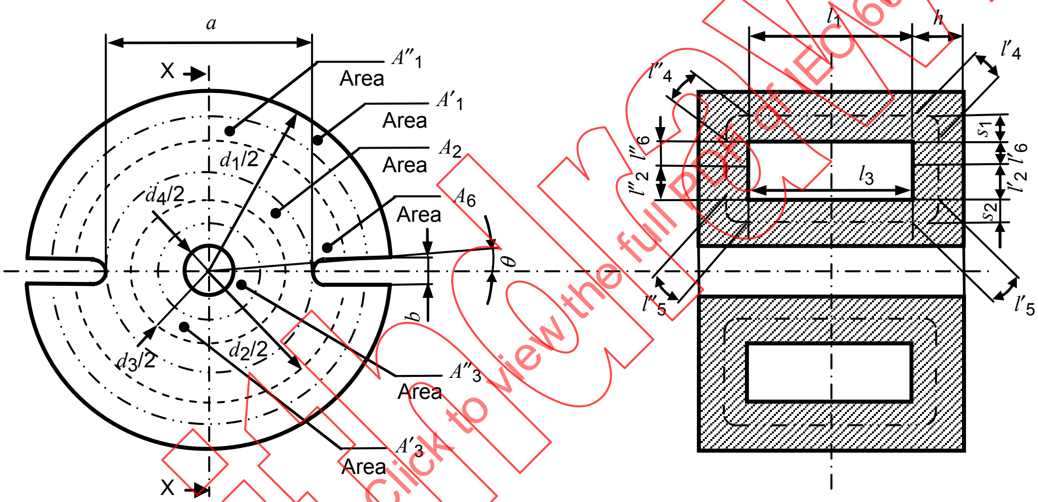
Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{2A_i^2}$$

3.6 Pair of pot-cores



Section X-X

IEC 589/06

Area of outer ring:

$$A_1 = A_1' + A_1''$$

The condition to obtain $A_1' = A_1''$ is

$$S_1 = -\frac{d_2}{2} + \sqrt{\frac{1}{8}\left(d_1^{\,2} + d_2^{\,2}\right)}$$

Area of centre limb:

$$A_3 = A_3' + A_3''$$

The condition to obtain $A_3' = A_3''$ is

$$S_2 = \frac{d_3}{2} - \sqrt{\frac{1}{8}\left(d_3^{\,2} + d_4^{\,2}\right)}$$

Area of ring:

$$A_1 = \frac{1}{4}(\pi - n\theta)\left(d_1^{\,2} - d_2^{\,2}\right)$$

$$\theta = \arcsin \frac{2b}{d_1 + d_2}$$

where

b : slot width

n : number of slots

Core factors associated with l_2:

$$\frac{l_2}{A_2} = \frac{1}{\pi h} \ln \frac{a}{d_3}$$

$$\frac{l_2}{A_2^{\,2}} = \frac{a - d_3}{\pi^2 a d_3 h^2}$$

Area of centre limb:

$$A_3 = \frac{\pi}{4}\left(d_3^{\,2} - d_4^{\,2}\right)$$

Mean length of flux paths at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(2S_1 + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(2S_2 + h)$$

Areas associated with l_4 and l_5:

$$A_4 = \frac{1}{8}(\pi - n\theta)\left(d_1^{\,2} - d_2^{\,2}\right) + \frac{\pi}{2} d_2 h$$

$$A_5 = \frac{\pi}{8}\left(d_3^{\,2} - d_4^{\,2} + 4 d_3 h\right)$$

Core factors associated with l_6:

$$\frac{l_6}{A_6} = \frac{1}{(\pi - n\theta)h} \ln \frac{d_2}{a}$$

$$\frac{l_6}{A_6^{\,2}} = \frac{d_2 - a}{a d_2 (\pi - n\theta)^2 h^2}$$

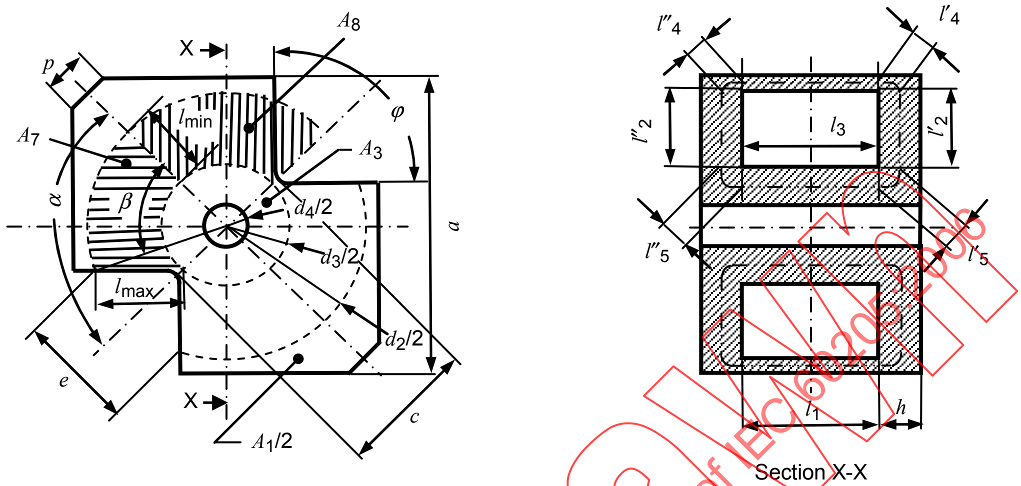
$$C_1 = \sum_{i=1}^{6} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{6} \frac{l_i}{A_i^2}$$

3.7 Pair of RM-cores

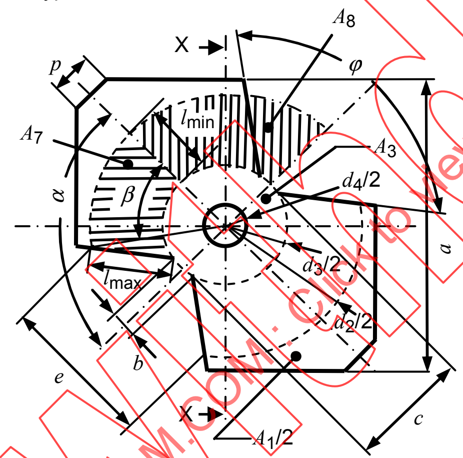
NOTE 1 This calculation is also applicable to the core type without hole.

NOTE 2 RM + I (Plate)-cores use RM core formulas.

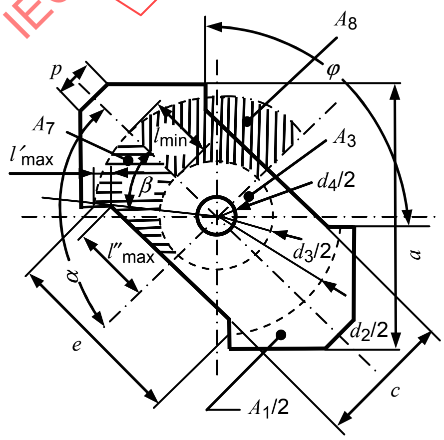
Type 1 – RM6–S, RM6–R



Type 2 – RM7



Type 3 – RM4, RM5, RM8, RM10, RM12, RM14



$l_{max} = l'_{max} + l''_{max}$

IEC 590/06

Total area of the outer leg:

$$A_1 = \frac{1}{2}a^2\left\{1+\tan\left(\beta-\frac{\pi}{4}\right)\right\}-\frac{\beta}{2}d_2^{\,2}-\frac{1}{2}p^2$$

where $\beta = \alpha - \arcsin\dfrac{e}{d_2}$

Core factors associated with l_2:

$$\frac{l_2}{A_2} = \frac{\ln\dfrac{d_2}{d_3}f}{D\pi h}$$

where $f = \dfrac{l\,\text{min} + l\,\text{max}}{2l\,\text{min}}$, $D = \dfrac{A_7}{A_8}$

$$l_2 = l_2' + l_2''$$

$$\frac{l_2}{A_2^{\,2}} = \frac{(1/d_3 - 1/d_2)f}{(D\pi h)^2}$$

Type 1:

$$l_{\text{max}} = \sqrt{\frac{1}{4}\left(d_2^{\,2}+d_3^{\,2}\right)-\frac{1}{2}d_2 d_3\cos(\alpha-\beta)}$$

Type 2:

$$l_{\text{max}} = \sqrt{\frac{1}{4}\left(d_2^{\,2}+d_3^{\,2}\right)-\frac{1}{2}d_2 d_3\cos(\alpha-\beta)}-\frac{b}{2\sin\dfrac{\varphi}{2}}$$

Type 3:

$$l_{\text{max}} = \frac{e}{2}+\frac{1}{2}\left(1-\sin\frac{\varphi}{2}\right)(d_2-c)$$

Type 1: RM 6-S:

$$A_7 = \frac{1}{4}\left\{\frac{\beta}{2}d_2^{\,2}+\frac{1}{2}e^2\tan\beta-\frac{1}{2}e^2\tan\left(\alpha-\frac{\varphi}{2}\right)-\frac{\pi}{4}d_3^{\,2}\right\}$$

Type 1: RM 6-R:

$$A_7 = \frac{1}{4}\left\{\frac{\beta}{2}d_2{}^2 + \frac{1}{2}d_2 d_3 \sin(\alpha-\beta) + \frac{1}{2}(c-d_3)^2 \tan\frac{\varphi}{2} - \frac{\pi}{4}d_3{}^2\right\}$$

Type 2:

$$A_7 = \frac{1}{4}\left\{\frac{\beta}{2}d_2{}^2 - \frac{\pi}{4}d_3{}^2 + \frac{1}{2}\left(b^2 - e^2\right)\tan\left(\alpha - \frac{\varphi}{2}\right) + \frac{1}{2}e^2 \tan\beta\right\}$$

Type 3:

$$A_7 = \frac{1}{4}\left\{\frac{\beta}{2}d_2{}^2 - \frac{\pi}{4}d_3{}^2 + \frac{1}{2}c^2 \tan(\alpha-\beta)\right\}$$

$$A_8 = \frac{\alpha}{8}\left(d_2{}^2 - d_3{}^2\right)$$

Area of centre pole:

$$A_3 = \frac{\pi}{4}\left(d_3{}^2 - d_4{}^2\right)$$

Mean length of flux paths at corners and mean areas associated with these:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}\left(h + \frac{1}{2}a - \frac{1}{2}d_2\right)$$

$$A_4 = \frac{1}{2}\left(A_1 + 2\beta d_2 h\right)$$

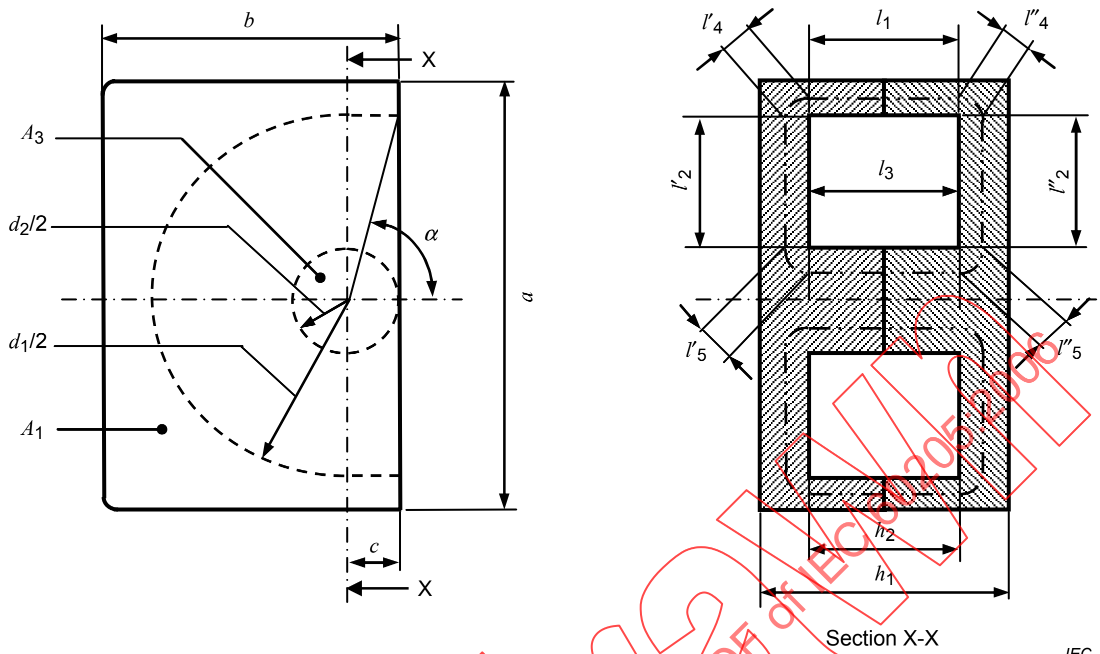
$$l_5 = l_5' + l_5'' = \frac{\pi}{4}\left\{d_3 + h - \sqrt{\frac{1}{2}\left(d_3{}^2 + d_4{}^2\right)}\right\}$$

$$A_5 = \frac{1}{2}\left\{\frac{\pi}{4}\left(d_3{}^2 - d_4{}^2\right) + 2\alpha d_3 h\right\}$$

$$C_1 = \sum_{\mathrm{i}=1}^{5}\frac{l_\mathrm{i}}{A_\mathrm{i}} \qquad C_2 = \sum_{\mathrm{i}=1}^{5}\frac{l_\mathrm{i}}{A_\mathrm{i}^2}$$

NOTE This calculation ignores the effect of spring recesses and stud recesses. These may have some influence on the outcome of the calculation, especially for smaller cores.

3.8 Pair of EP-cores



IEC 591/06

As a pair:

$$\frac{l_1}{A_1} = \frac{h_2}{ab - \pi d_1^{\,2}/8 - d_1 d_2/2}$$

$$\frac{l_1}{A_1^{\,2}} = \frac{h_2}{\left(ab - \pi d_1^{\,2}/8 - d_1 d_2/2\right)^2}$$

$$\frac{l_2}{A_2} = \frac{2}{(\pi - \alpha)(h_1 - h_2)} \ln \frac{d_1}{d_2}$$

$$\frac{l_2}{A_2^{\,2}} = \frac{4(d_1 - d_2)}{(\pi - \alpha)^2 (h_1 - h_2)^2 d_1 d_2}$$

$$\frac{l_3}{A_3} = \frac{h_2}{\pi\left(\frac{d_2}{2}\right)^2} = \frac{4h_2}{\pi d_2^{\,2}}$$

$$\frac{l_3}{A_3^{\,2}} = \frac{h_2}{\pi^2\left(\frac{d_2}{2}\right)^4} = \frac{16h_2}{\pi^2 d_2^{\,4}}$$

Areas associated with l_4 and l_5:

$$l_4 = l'_4 + l''_4 = \frac{\pi}{2}\left(\gamma - \frac{d_1}{2} + \frac{h_1 - h_2}{4}\right)$$

$$\gamma = \sqrt{\frac{(\pi-\alpha)d_1^{\,2} + 2\left(ab - \pi d_1^{\,2}/8 - d_1 d_2/2\right)}{4(\pi-\alpha)}}$$

where γ is a hypothetical radius bisecting the cross-sectional area of the ring.

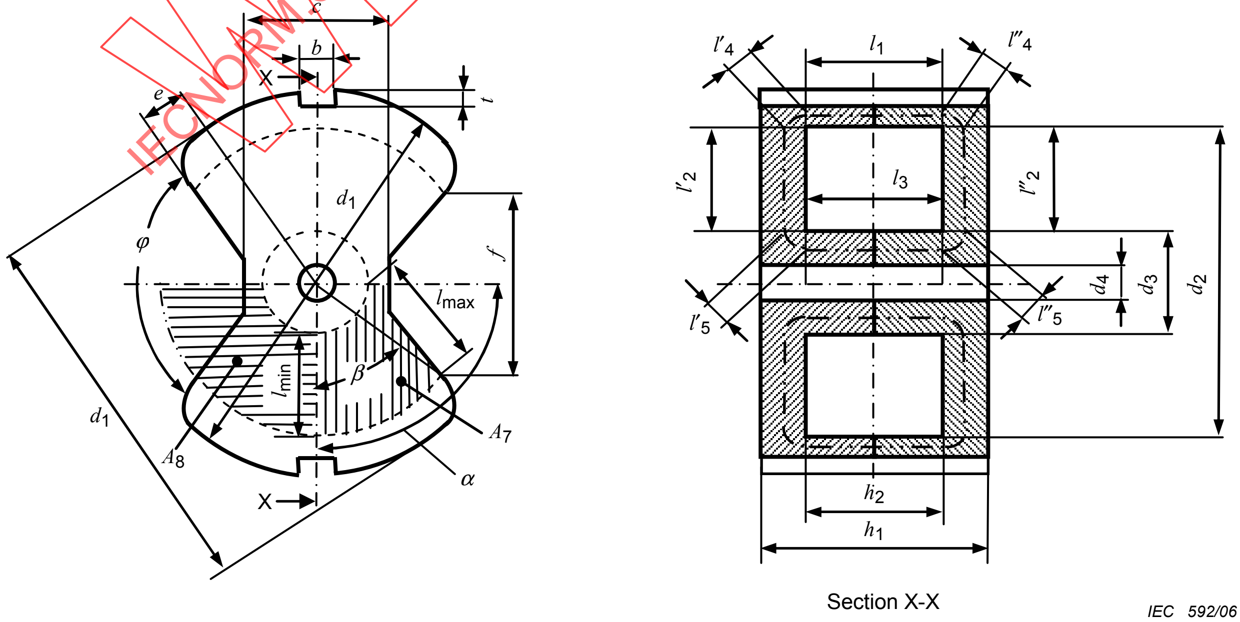
$$A_4 = \frac{1}{2}\left\{ab - \frac{\pi}{8}d_1^{\,2} - \frac{d_1 d_2}{2} + (\pi-\alpha)d_1\left(\frac{h_1}{2} - \frac{h_2}{2}\right)\right\}$$

$$l_5 = l'_5 + l''_5 = \frac{\pi}{2}\left(0{,}29289\frac{d_2}{2} + \frac{h_1 - h_2}{4}\right)$$

$$A_5 = \frac{\pi}{2}\left\{\frac{d_2^{\,2}}{4} + \frac{d_2}{2}(h_1 - h_2)\right\}$$

$$C_1 = \sum_{i=1}^{5}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5}\frac{l_i}{A_i^{\,2}}$$

3.9 Pair of PM-cores



Total area of the leg:

$$A_1 = \frac{\beta}{2}\left(d_1^2 - d_2^2\right) - 2bt$$

where $\beta = \alpha - \arcsin\frac{f}{d_2}$

Core factors associated with l_2:

$$l_2 = l_2' + l_2''$$

$$\frac{l_2}{A_2} = \frac{\ln\frac{d_2}{d_3}g}{D\pi(h_1 - h_2)/2}$$

where $g = \frac{l\,\text{min} + l\,\text{max}}{2l\,\text{min}}$, $D = \frac{A_7}{A_8}$

$$l_{\max} = \sqrt{\frac{1}{4}\left(d_2^{\,2} + d_3^{\,2}\right) - \frac{1}{2}d_2 d_3 \cos(\alpha - \beta)}$$

$$\frac{l_2}{A_2^{\,2}} = \frac{(1/d_3 - 1/d_2)g}{\{D\pi(h_1 - h_2)/2\}^2}$$

$$A_7 = \frac{\beta}{8}d_2^{\,2} + \frac{1}{8}f^2\tan\beta - \frac{1}{8}f^2\tan\left(\alpha - \frac{\varphi}{2}\right) - \frac{\pi}{16}d_3^{\,2}$$

$$A_8 = \frac{\alpha}{8}\left(d_2^{\,2} - d_3^{\,2}\right)$$

Area of centre limb:

$$A_3 = \frac{\pi}{4}\left(d_3^{\,2} - d_4^{\,2}\right)$$

Mean length of flux paths at corners and mean areas associated with these:

$$l_4 = l_4' + l_4'' = \frac{\pi}{8}\left(h_1 - h_2 + d_1 - d_2\right)$$

$$A_4 = \frac{1}{2}\left\{A_1 + 2\beta d_2\left(h_1 - h_2\right)\right\}$$

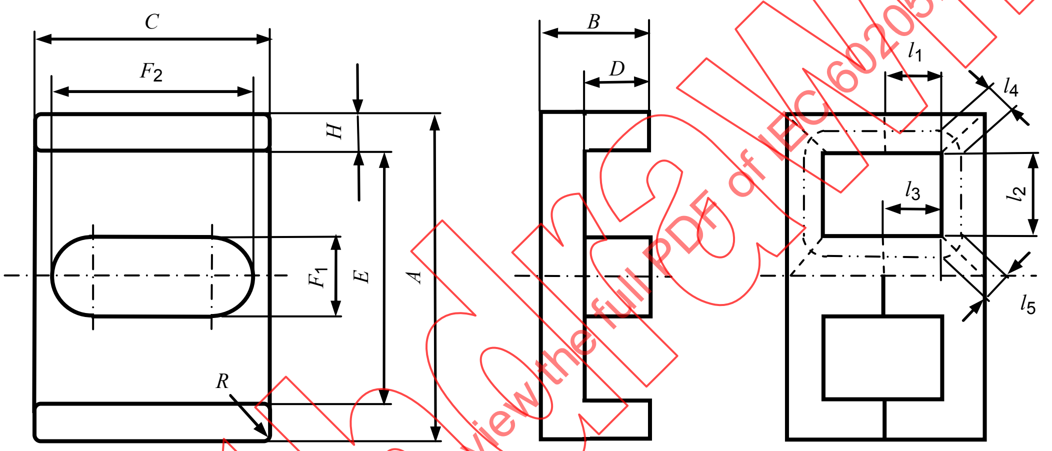
$$l_5 = l_5' + l_5'' = \frac{\pi}{4}\left\{d_3 + h_1 - h_2 - \sqrt{\frac{1}{2}\left(d_3^{\,2} + d_4^{\,2}\right)}\right\}$$

$$A_5 = \frac{\pi}{8}\left(d_3^{\,2} - d_4^{\,2}\right) + \alpha d_3\left(h_1 - h_2\right)$$

$$C_1 = \sum_{\mathrm{i}=1}^{5} \frac{l_\mathrm{i}}{A_\mathrm{i}} \qquad C_2 = \sum_{\mathrm{i}=1}^{5} \frac{l_\mathrm{i}}{A_\mathrm{i}^{\,2}}$$

3.10 Pair of EL-cores

NOTE EL + PLT (Plate)-cores use EL core formulas.



IEC 593/06

Area of outer leg:

$$A_1 = \frac{1}{2}(A - E)C - 4\left(R^2 - \frac{1}{4}\pi R^2\right)$$

Mean length of flux path at outer leg:

$$l_1 = D$$

Area of back wall:

$$A_2 = \frac{1}{2}\left(C + (F_2 - F_1) + \pi F_1/2\right)(B - D)$$

Mean length of flux at back wall:

$$l_2 = \left(\frac{E}{2} - \frac{F_1}{2}\right)$$

Area of centre limb:

$$A_3 = \frac{1}{2}\left\{\frac{1}{4}\pi F_1{}^2 + (F_2 - F_1)F_1\right\}$$

Mean length of flux path at centre limb:

$$l_3 = D$$

Area of out side corner:

$$A_4 = \frac{A_1 + A_{21}}{2}$$

where $A_{21} = (B - D)C$

Mean length of flux path at outside corner:

$$l_4 = \frac{\pi}{8}\left(\left(\frac{A}{2} - \frac{E}{2}\right) + (B - D)\right)$$

Area of inside corner:

$$A_5 = \frac{A_{23} + A_3}{2}$$

where $A_{23} = ((F_2 - F_1) + \pi F_1/2)(B - D)$

Mean length of flux path at inside corner:

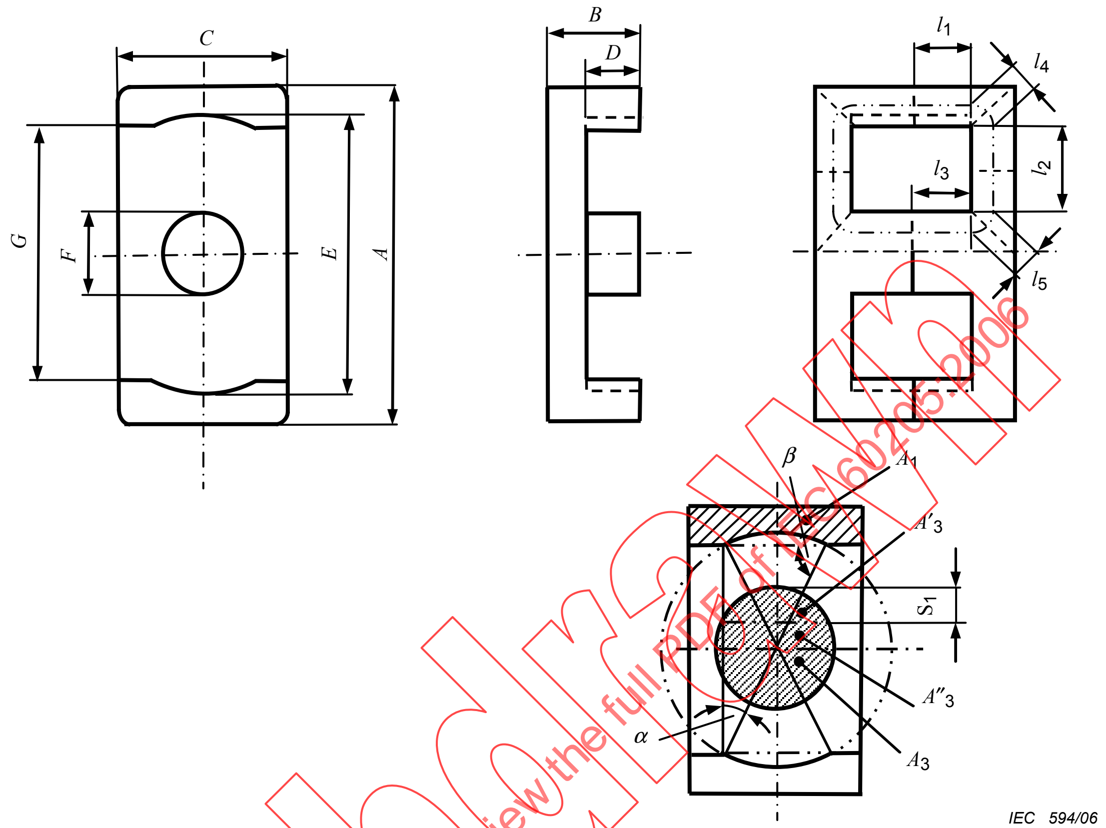
$$l_5 = \frac{\pi}{8}\left(\frac{A_3}{F_2} + (B - D)\right)$$

$$C_1 = \sum_{i=1}^{5}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5}\frac{l_i}{2A_i{}^2}$$

$$l_e = C_1{}^2/C_2 \qquad A_e = C_1/C_2 \qquad V_e = C_1^3/C_2^2$$

3.11 Pair of ER-cores (low profile)

NOTE ER + PLT (Plate)-cores use ER core formulas.



IEC 594/06

Area of outer leg:

$$A_1 = \frac{1}{2}C(A-G) - \left(\frac{\alpha E^2}{4} - \frac{EG}{4}\sin\alpha\right)$$

where α = arccos (G/E)

Mean length of flux path at outer leg:

$$l_1 = D$$

Area of back wall:

$$A_2 = C(B - D)$$

Mean length of flux path at back wall:

$$l_2 = \frac{1}{4}\left(E + \sqrt{G^2 + C^2} - 2F\right)$$

Area of centre limb:

$$A_3 = \frac{1}{2}\left(\frac{1}{4}\pi F^2\right)$$

Mean length of flux path at centre limb:

$$l_3 = D$$

Area of outside corner:

$$A_4 = \frac{A_1 + A_2}{2}$$

Mean length of flux path at outside corner:

$$l_4 = \frac{\pi}{8}(p + h)$$

where

$$h = B - D \qquad p = \frac{A}{2} - \frac{E}{2}$$

Area of inside corner:

$$A_5 = \frac{A_2 + A_3}{2}$$

Mean length of flux path at inside corner:

$$l_5 = \frac{\pi}{8}(2S_1 + h)$$

The condition to obtain $A'_3 = A''_3$ is

$$S_1 = \frac{1}{2}F(1 - \sin\alpha) = 0{,}2978F$$

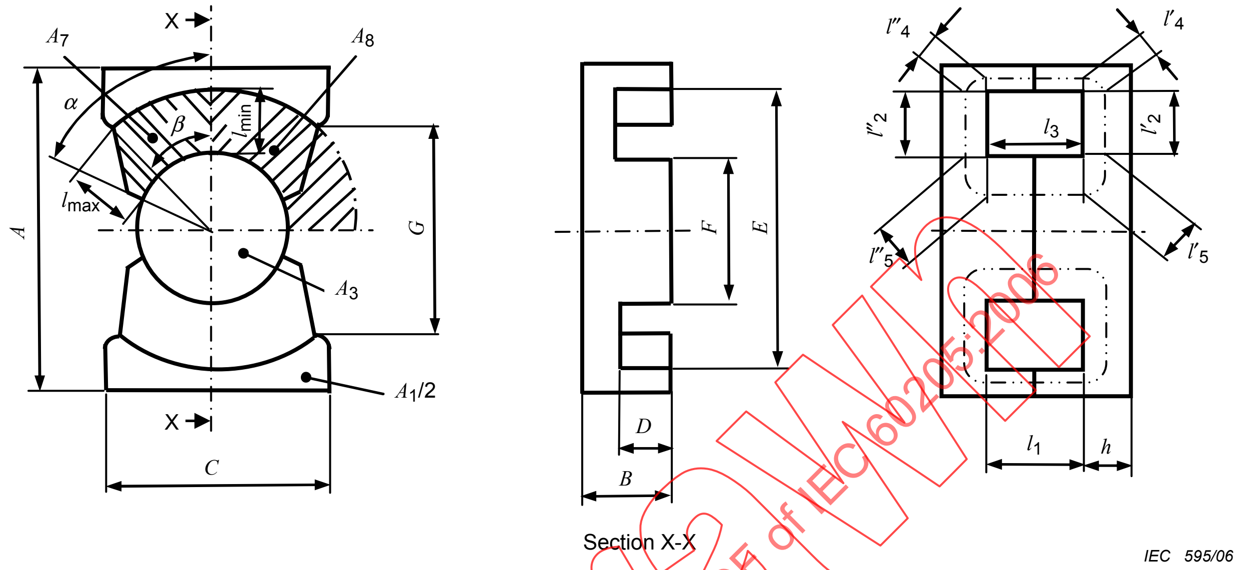
$$C_1 = \sum_{i=1}^{5}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5}\frac{l_i}{2A_i^2}$$

$$l_e = C_1^2/C_2 \qquad A_e = C_1/C_2 \qquad V_e = C_1^3/C_2^2$$

3.12 Pair of PQ-cores

NOTE 1 This calculation ignores the effect of spring recesses.

NOTE 2 PQ + PLT (Plate)-cores use PQ core formulas.



Area of outer leg:

$$A_1 = C\,(A - G) - \frac{\beta E^2}{2} + \frac{EG}{2}\sin\beta$$

where β = arccos (G/E)

Mean length of flux path at outer leg:

$$l_1 = 2D$$

Core factors associated with l_2:

$$\frac{l_2}{A_2} = f\,\frac{\ln(E/F)}{K\pi(B - D)}$$

$$\frac{l_2}{A_2^2} = f\,\frac{1/F - 1/E}{2K^2\pi^2(B - D)^2}$$

where

$$K = \frac{A_7}{A_8} = \frac{A_7}{\dfrac{\pi}{16}\left(E^2 - F^2\right)}$$

$$f = \frac{l_{min} + l_{max}}{2l_{min}}$$

NOTE l_{max} may be determined by measurement.