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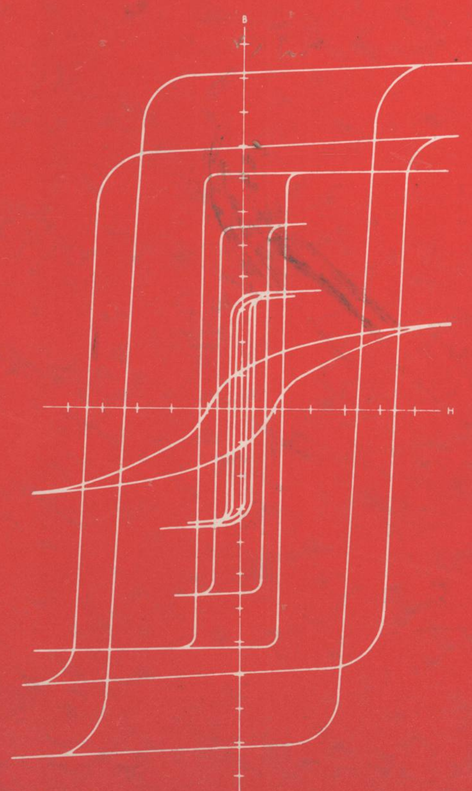
# Magnetic Core Selection for Transformers and Inductors

## A User's Guide to Practice and Specification



Colonel Wm. T. McLyman

# MAGNETIC CORE SELECTION FOR TRANSFORMERS AND INDUCTORS

## A User's Guide to Practice and Specification

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# MAGNETIC CORE SELECTION FOR TRANSFORMERS AND INDUCTORS

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# PREFACE

This book was written as a supplement to the Transformer and Inductor Design Handbook. The idea was to bring the majority of the cores available in industry in line with standard units of measurement so the engineer could pick the configuration best suited for his design.

The aforementioned handbook has new equations and procedures that simplify the design of magnetic components. The equations used in the handbook are in (cgs) units while magnetic core manufacturers supply data in mixed units and in no standard format. Most of the material in this book is in tabular form to assist the designer in making the trade-offs best suited for his particular application in a minimum amount of time. Approximately twenty core manufacturers are represented, with core types such as:

1. Laminations
   (a) EI and EE
   (b) L and DU
   (c) UI
   (d) 3 phase
2. C cores, 1, 2, 4 and 12 mil
   (a) EE cores, 4 and 12 mil
3. Tape toroidal core
   (a) Caseless, 1, 2, 4 and 12 mil
4. Ferrites
   (a) Toroids
   (b) EE, EI and U
   (c) Pot cores
5. Powder cores

When the designer has established the area product $A_p$ or the core geometry coefficient $K_g$, he can then look in this book for that particular core to obtain the following data:

C core

1. Strip width (cm)
2. Build Up (cm)
3. Window width (cm)
4. Window length (cm)

5. Magnetic path length (cm)
6. Finished Transformer Height (cm)
7. Finished Transformer Width (cm)
8. Finished Transformer Length (cm)
9. Iron weight (grams)
10. Copper weight (grams)
11. Mean Length Turn (cm)
12. Iron area $A_c$ $(cm)^2$
13. Window area $W_a$ $(cm)^2$
14. Area product $A_p$ $(cm)^4$
15. Core geometry $K_g$ $(cm)^5$
16. Transformer surface area $(cm)^2$

Over 12,000 cores have been tabulated for the engineer. The engineer will find that some cores will have the same area product $A_p$ or core geometry $K_g$ coefficient, but will have different size configurations. With this data the engineer can tell at a glance if that particular design or core configuration will work, or what changes will have to be made.

Possibly for the first time, 57 manufacturers core loss data curves have been organized with the same units for all core losses. The data was digitized right from the manufacturers data sheets. Then the data was modified to put it in metric units, gauss to tesla and watts per pound to watts per kilogram. This data was then put into the computer to develop a new first order approximation in the form of:

$$w = k f^m B^n$$

where w is the calculated core loss density in watts/kilogram, f is the frequency in hertz, B is the flux density in tesla, and k, m, n are coefficients derived using a three-dimensional least square fit law from the digitized data. These curves include silicon, nickel-iron, ferrites, powdered iron and metglas. This book can now be used as a new tool to simplify and standardize the process of transformer design.

Also listed in this book are manufacturer cross reference, brackets for C cores, laminations and toroidal core retainers.

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# SYMBOLS

| | |
|---|---|
| $\alpha$ | regulation, % |
| $A_c$ | effective iron area, $cm^2$ |
| $A_p$ | area product, $W_a \times A_c$, $cm^4$ |
| $A_t$ | surface area of a transformer, $cm^2$ |
| $A_w$ | wire area, $cm^2$ |
| $A_{w(B)}$ | bare wire area, $cm^2$ |
| AWG | American Wire Gauge |
| $B_{ac}$ | alternating current flux density, teslas |
| $B_{dc}$ | direct current flux density, teslas |
| $B_m$ | flux density, teslas |
| $B_r$ | residual flux density, teslas |
| $B_s$ | flux density to saturate, teslas |
| cir-mil | area of a circle whose diameter = 0.001 inches |
| D | lamination tongue width, cm |
| E | voltage |
| Eng | energy, watt seconds |
| $\eta$ | efficiency |
| f | frequency, Hz |
| F | fringing flux factor |
| G | window height, cm |
| H | magnetizing force ampturns/cm |
| $H_s$ | magnetizing force to saturate |
| I | current, amps |
| $I_{in}$ | input current, amps |

| | |
|---|---|
| $I_m$ | excitation current, amps |
| $I_o$ | load current, amps |
| $I_p$ | primary current, amps |
| $I_s$ | secondary current, amps |
| $J$ | current density, amps/cm$^2$ |
| $K$ | constant |
| $K_e$ | electrical coefficient |
| $K_f$ | wave form coefficient |
| $K_g$ | geometry coefficient |
| $K_i$ | gap loss coefficient |
| $K_j$ | current density coefficient |
| $K_s$ | surface area coefficient |
| $K_u$ | window utilization factor |
| $K_v$ | volume coefficient |
| $K_w$ | weight coefficient |
| $L$ | inductance, henry |
| $l_g$ | gap, cm |
| $l_m$ | magnetic path, cm |
| $\ell$ | linear dimension, cm |
| MLT | mean length turn, cm |
| MPL | magnetic path, cm |
| $\mu_\Delta$ | effective permeability |
| $\mu_m$ | core material permeability |
| $\mu_o$ | absolute permeability |
| $\mu_r$ | relative permeability |
| $n$ | turns ratio |
| $N$ | turns |

| | |
|---|---|
| $N_p$ | primary turns |
| $N_s$ | secondary turns |
| $P$ | power, watts |
| $\phi$ | flux webers |
| $P_{cu}$ | copper loss, watts |
| $P_{fe}$ | core loss, watts |
| $P_{in}$ | input power, watts |
| $P_g$ | gap loss, watts |
| $P_o$ | output power, watts |
| $\psi$ | heat flux density, watts/$cm^2$ |
| $P_p$ | primary loss, watts |
| $P_s$ | secondary loss, watts |
| $P_{\Sigma}$ | total loss (core and copper), watts |
| $P_t$ | apparent power, watts |
| $R$ | resistance, ohms |
| $R_{cu}$ | copper resistance, ohms |
| $R_o$ | load resistance, ohms |
| $R_p$ | primary resistance, ohms |
| $R_s$ | secondary resistance, ohms |
| $R_t$ | total resistance, ohms |
| $S_1$ | conductor area/wire area |
| $S_2$ | wound area/usable window |
| $S_3$ | usable window area/window area |
| $S_4$ | usable window area/usable window area + insulation area |
| SF | stacking factor |
| T | flux density, teslas |

| | |
|---|---|
| VA | volt-amps |
| $V_d$ | diode voltage drop |
| $V_{in}$ | input voltage, volts |
| $V_o$ | load voltage, volts |
| $V_p$ | primary voltage, volts |
| $V_s$ | secondary voltage, volts |
| Vol | volume, $cm^3$ |
| W | watts |
| $W_a$ | window area, $cm^2$ |
| $W_t$ | weight, grams |
| $W_{tcu}$ | copper weight, grams |
| $W_{tfe}$ | iron weight, grams |
| $\zeta$ | zeta resistance correction factor for temperature |