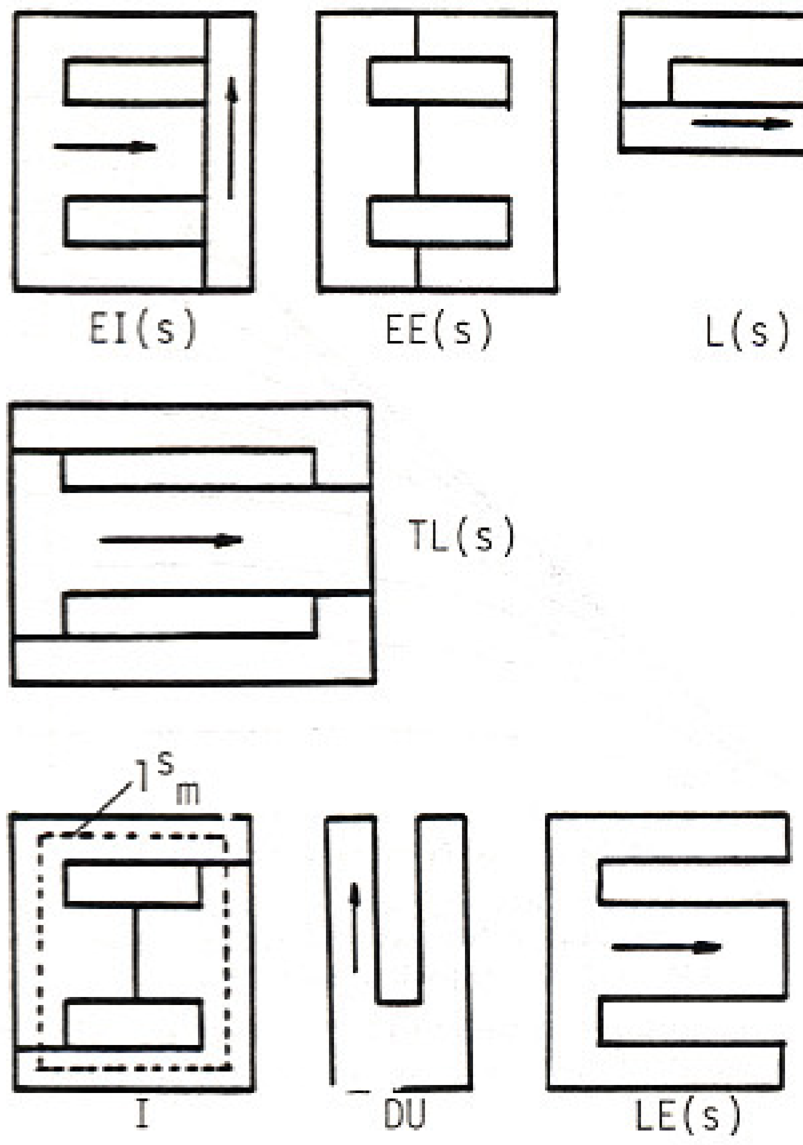
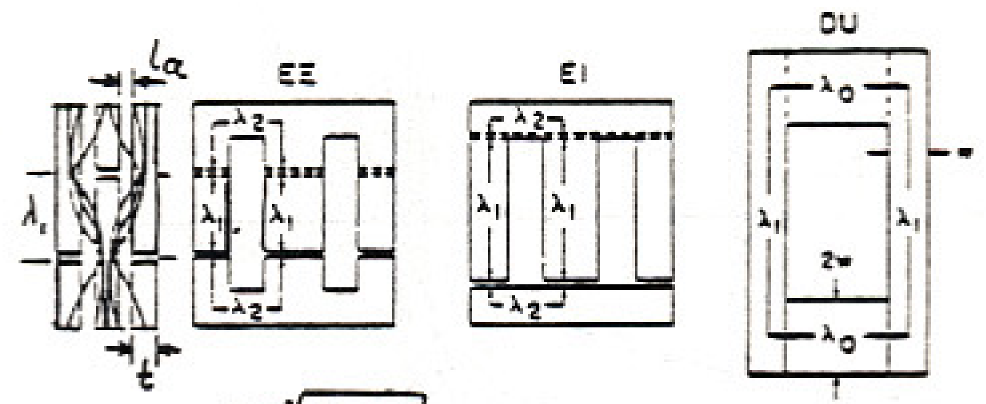


Fig. 8 Typical lamination shapes (s) scrapless configuration possible.

Core Structures

Some transformers, like current transformers, can be built with toroidal core structures and toroidal copper windings, to minimize fringing field losses. This is, however, expensive. Most power and electronic transformers use bobbin or stick wound copper coils into which laminations are inserted, often by automatic stacking machines. Figure 8 shows typical shapes of scrapless EI, EE, L and TL laminations which, in most cases, have geometric dimensions providing long flux paths in grain direction. Other non scrapless shapes, like F and EE laminations, are useful because they allow to adjust the air gap in the center of the coil by maintaining a self shielding flux path lm* around the coil, thus preventing cross talk in the electronic coils. Sometimes EE laminations with an air gap stamped in the center leg, often bonded into stacks, are used to minimize cross talk. E-core stacks are available with A_L values from 160 to 800. DU, DE and Long E laminations minimize effective air gaps when stacked 1 X 1 interleaved, so that the highest possible induction values can be obtained. In Figure 9 is shown how to calculate the stack permeability of EE, EI, DU laminations (per Pfeifer, Brenner) from its geometric configurations.



$a = \sqrt{la\ t\ \mu}$

$$\left.\begin{matrix}\text{EE}\\ \text{El}\end{matrix}\right\}\ \mu_s = \frac{\mu m\ lm}{lm + 2a\left(\coth\frac{\lambda_1}{a} + \tanh\frac{\lambda_2}{a}\right)}$$

$$\text{DU}\ \}\ \mu_s = \frac{\mu\ lm}{lm-w+a\,\dfrac{2 - \tanh\frac{\lambda 1}{a}\tanh\frac{w}{a} - \tanh^2\frac{w}{a}}{\tanh\frac{\lambda_1}{a} + \tanh\frac{w}{a} - 2\tanh\frac{\lambda_1}{a}\tanh^2\frac{w}{a}}}$$

Fig. 9 Stack permeability μ_s for 1 X 1 overlapped EI, EE, DU, DE laminations

t = thickness
la = air gap between lamination layer
a = $\sqrt{la\ t\ \mu m}$ effective shearing length
$\lambda 1$ = overlap length
$\lambda 2$ = shunt length
μm = permeability

The hysteresis loop can be sheared to improve the incremental permeability with superposed d.c. by stacking E laminations in groups of 2 X 2 or 3 X 3 or 4 X 4. Figure 10 shows the incremental permeability of .014" thick, 2425EE laminations made of 50% Ni-Fe, stacked 1 X 1, 2 X 2, 3 X 3 or 4 X 4 interleaved over and butt stacked with various gaps, the d.c. premagnetization. Such stacking methods allow to maximize the inductance for a.c. signals with superposed d.c. at a very low cost. To calculate the permeability for lamination stacks, stacked 2 X 2 or 3 X 3, the thickness t and the air gap la in Figure 8 have to be doubled.

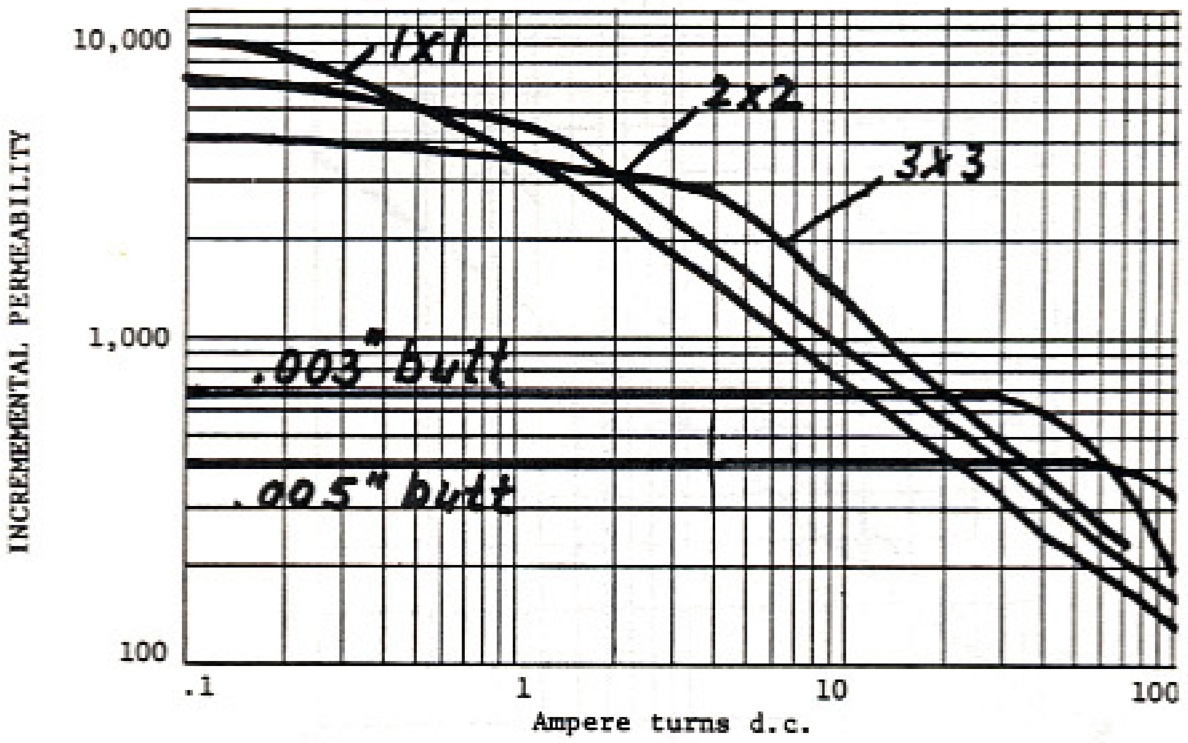


Fig. 10 Incremental a.c. permeability for .014" EE2425, 50% Ni-Fe over superposed d.c. field, stacked 1 X 1, 2 X 2, 3 X 3 and butt gapped.