

---

# **Ferrites - "The Most Important Properties"**

## **1994 Soft Ferrite Users Conference**

**By : George Orenchak**  
**Ferrite International Company**

Inductance - Electrical property that opposes any change in current because of a magnetic field.

$L = (.004) (\mu) (N^2) (Ae) (10^6) / L_e$  (in Henries)

- Material Permeability, core dimensions & number of turns all affect inductance and therefore affect component size

$A_e$  = effective cross sectional area

$L_e$  = effective magnetic path length

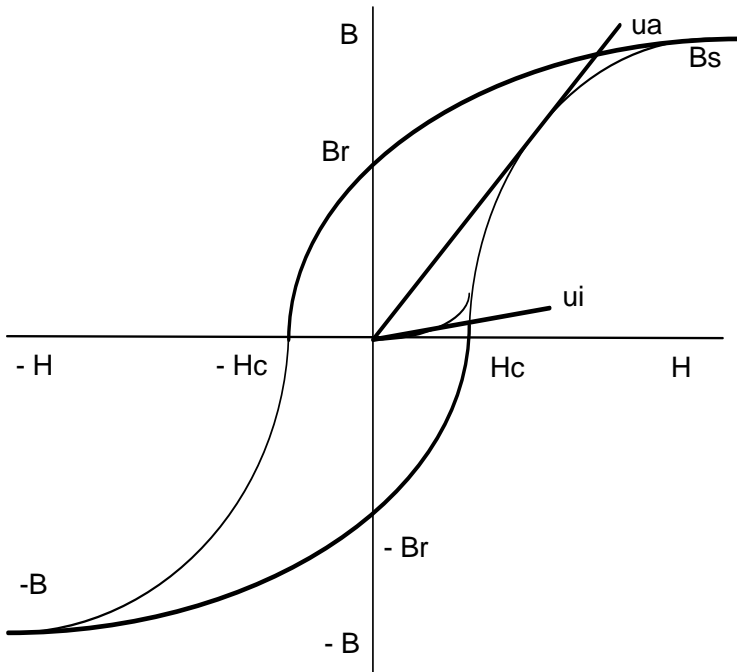
$N$  = turns on coil.

Inductance Index  $AI$  is the Inductance per unit turn in  $nH/N^2$

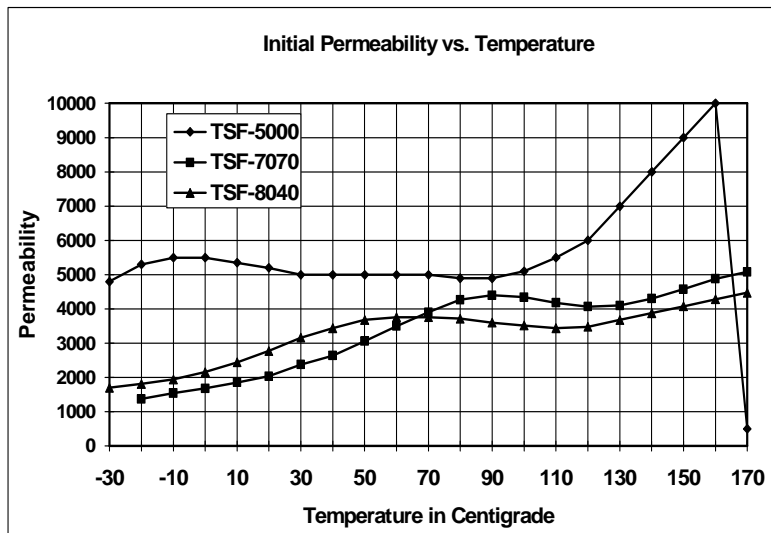
---

Ferrites - "The Most Important Properties"

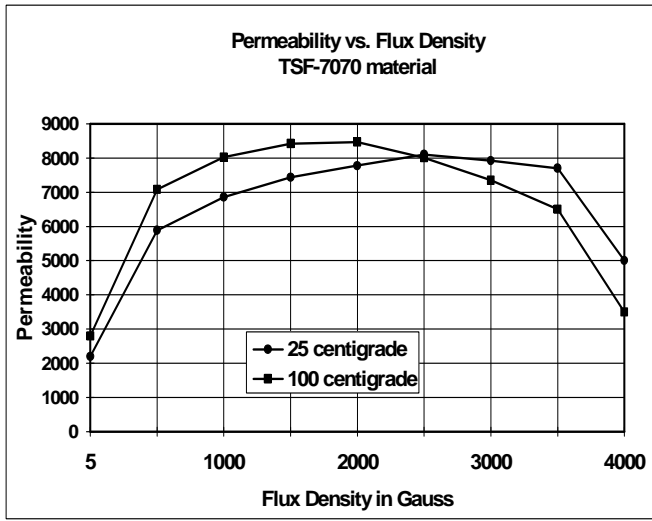
Slide 1



**Hysteresis Curve**  
**B = Magnetic Flux Density**  
 Flux per unit area induced by a field  $\epsilon$   
**H = Magnetizing Force**  
 The externally applied force that indu  
 flux in a magnetic material  
 $u = B / H = \text{Permeability}$   
 Initial Permeability at low amplitudes  
 Amplitude Permeability at high amplit  
**Bsat = Saturation Flux Density**  
 The value of magnetic flux density at  
**Br = Residual Induction**  
 The magnetic Induction remaining in  
 material after the magnetizing force ( removed



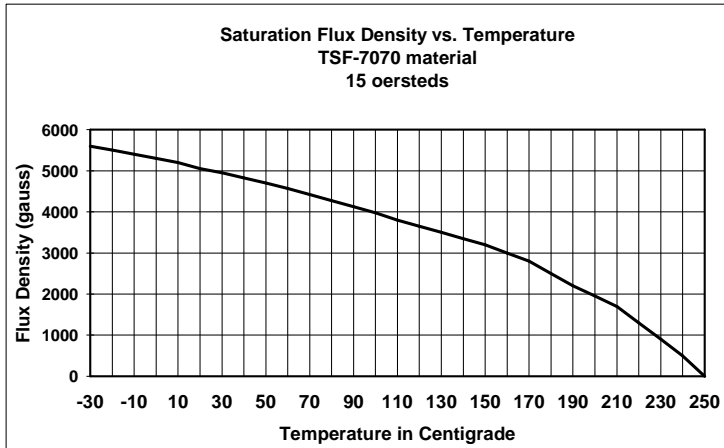
- Permeability varies with temperature and drops to unity above the curie temperature.



- Permeability varies with Flux Density and drops to unity when saturated. Soft Ferrite materials saturate sooner at elevated temperatures.

Saturation Flux Density - The value of magnetic flux density at saturation. A materials maximum magnetic induction.

$$B = (E_{rms})(10^8) / (4.44)(f)(N)(A_e)$$



- Saturation Flux Density decreases with increasing temperature. Often a material's Saturation Flux Density is a constraint on the minimum core size.

f = frequency

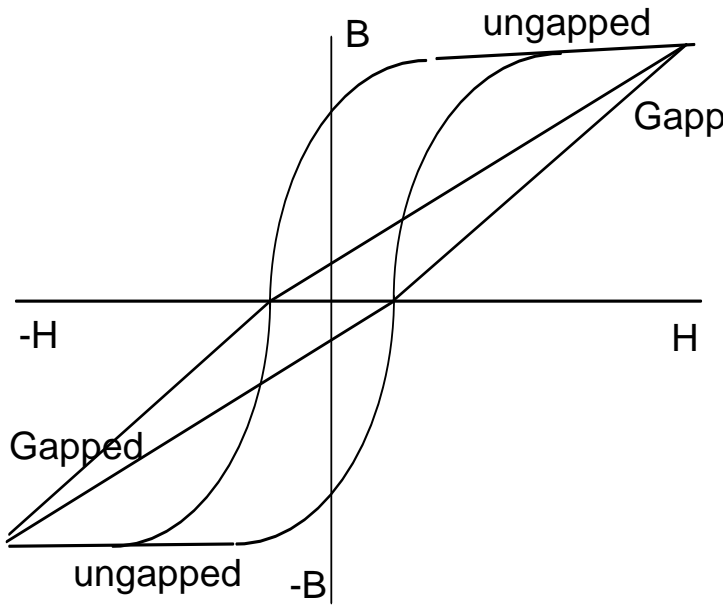
N= turns

A<sub>e</sub> = effective core area

---

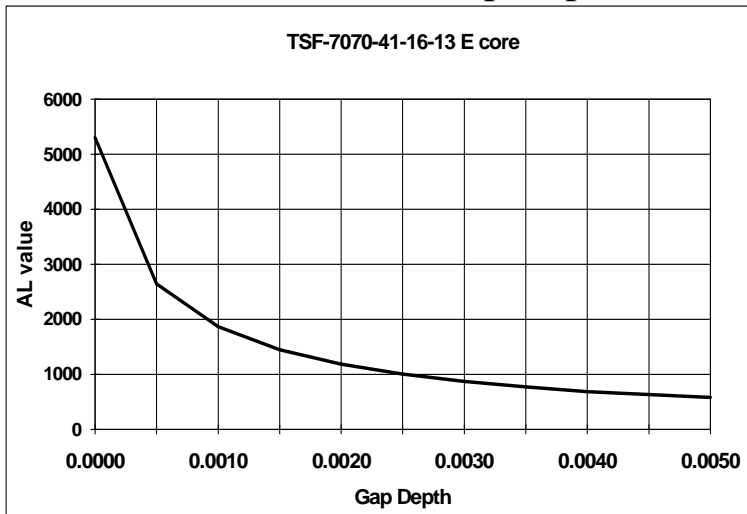
Ferrites - "The Most Important Properties"

Slide 5



- The hysteresis loop shears over with increasing gap depths. The gapped structure results in lower effective permeabilities but requires more magnetizing force to saturate the core.

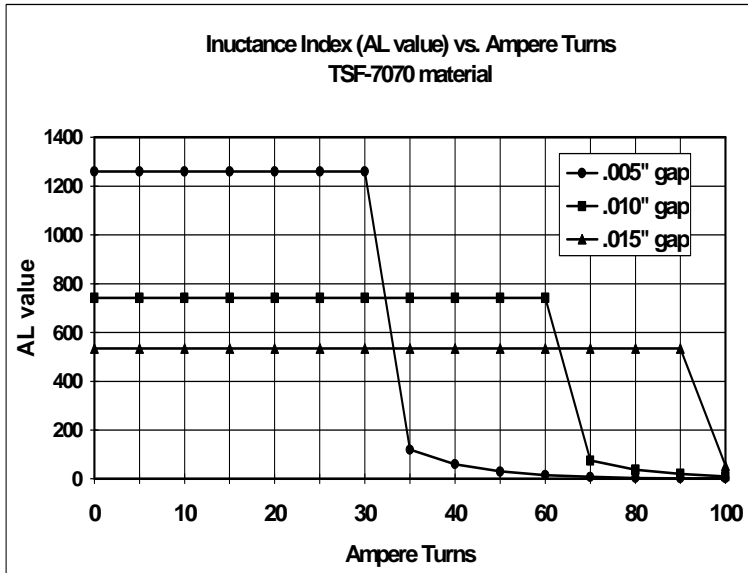
## Inductance Index AL vs. Gap Depth



- Inductance decays exponentially as the air gap increases. The slope is steep for small gaps which have large AL values. For this reason larger tolerances are needed compared to the AL tolerances for deep gaps that have shallow slopes and small AL values.

$AL = (4\pi\mu AeAg) / (\mu AeLe) + Ag(Lc - LG)$   
times  $(1 + Lg / \text{Square root } Ae \ln(2G/Lg))$   
to account for fringing flux





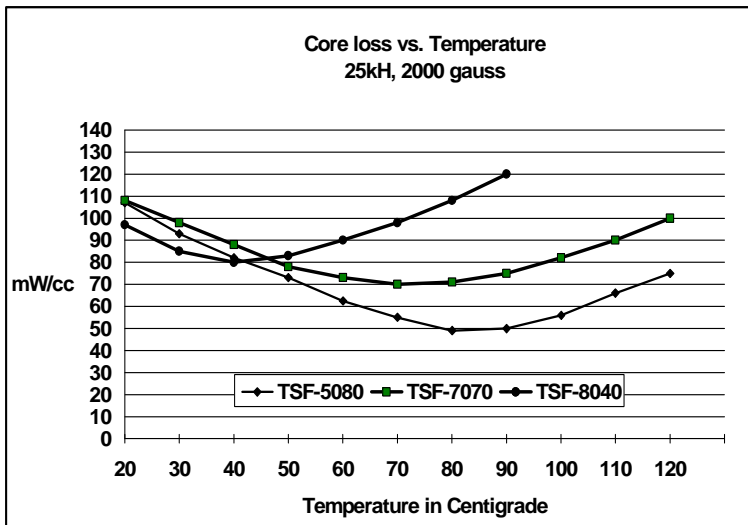
- Inductance rolls-off as the material saturates. Small gaps (Large AL values) saturate sooner than large gaps (small AL values)

## Losses

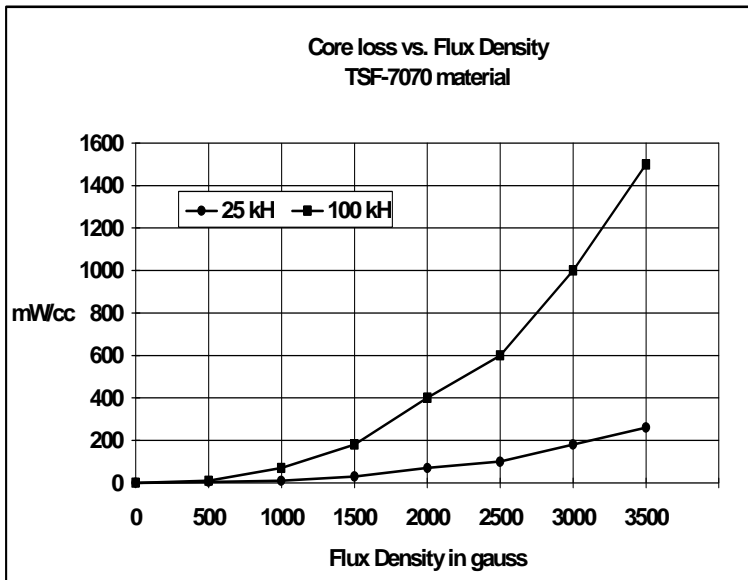
Loss Factor - Figure of merit of a material at low levels of magnetizing force (  $\tan \delta / \mu Q = 1 / \mu Q$  )

Core Loss - A measure of the efficiency of a material at high levels of magnetizing force. Dissipated energy in the form of heat.

- Often a materials core loss characteristics is a constraint on the minimum core size.



- A number of material grades have been designed so that their minimum core loss occurs at specific temperatures.

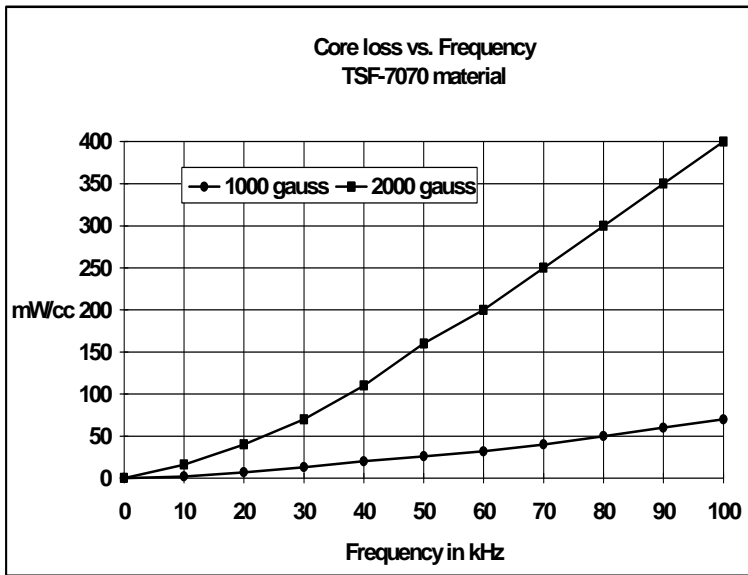


- Core Loss increases exponentially with increasing Flux Density.

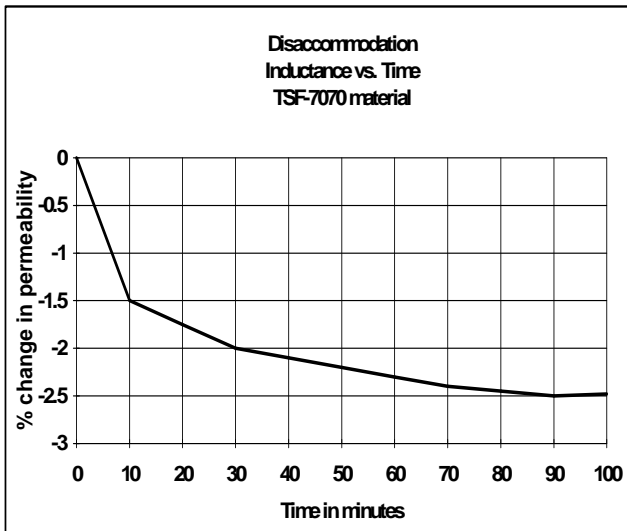
---

Ferrites - "The Most Important Properties"

Slide 11



- Core Loss increases exponentially with increasing frequency.



- Disaccommodation is the variation of permeability with time. Mechanical, magnetic or thermal disturbances cause the initial permeability to be raised to an unstable value from which it returns as a function of time. This process is indefinitely repeatable.

Ferrite Material Constants	
Specific Heat	0.25 cal / g / °c
Thermal Conductivity	10 x 10 <sup>-3</sup> cal / sec / cm / °c
Coefficient of Linear Expansion	8 to 10 x 10 <sup>-6</sup> / °c
Compressive Strength	60 x 10 <sup>3</sup> lbs / in <sup>2</sup>
Young's Modulus	18 x 10 <sup>3</sup> lbs / in <sup>2</sup>
Hardness (Knoop)	650
Density	4.6 to 4.8 gm / cm <sup>3</sup>