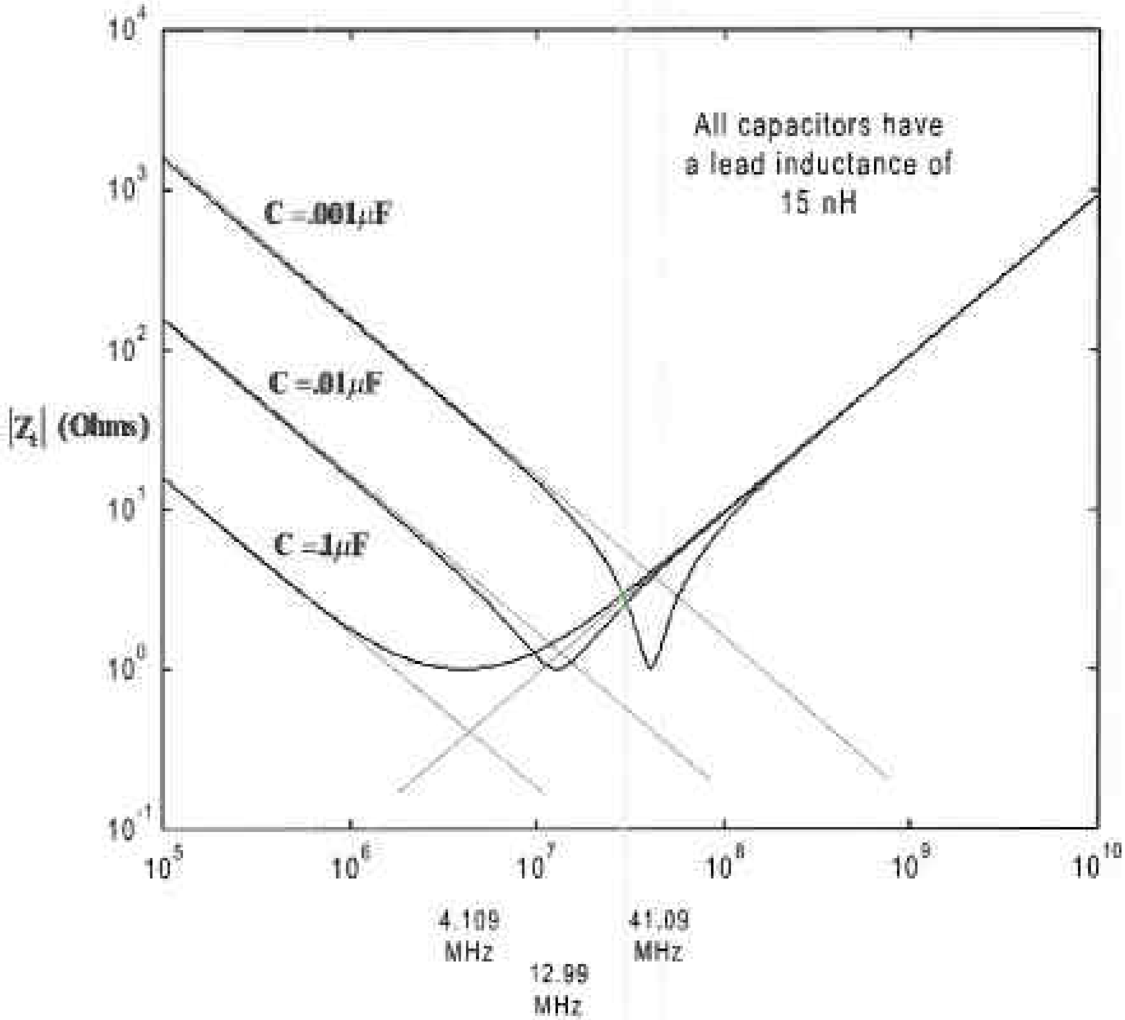


Figure 16: Plot of frequency dependent behavior of equivalent circuit for various capacitors.

A plot of the responses of the equivalent circuits for various capacitors is shown in Figure 16. The response of 0.001 μF, 0.01 μF, and 0.1 μF capacitors is shown. Here the lead inductances are all 15 nH, and the plate resistances are 1Ω. The resonant frequencies are seen to occur at 4.109 MHz, 12.99 MHz, and 41.09 MHz.

- **inductors**

Although all inductors consist of a coil of wire, many variations on the actual method of device construction exist. Inductors may be wound on cores made of non-magnetic material, or, more commonly, on materials with magnetic properties such as ferrite.

Due to their physical geometry, inductors, more than any other type of common circuit element, tend be sources of stray magnetic fields. Likewise, inductors are also more susceptible to effects due to external magnetic fields than other basic circuit elements. The type of inductor has a great deal to do with how susceptible it is to external fields. Air core and open magnetic core inductors tend to be the most susceptible to external fields, and also tend to generate fields which may interfere with other devices. It is often desirable to shield inductors in order to insure proper operation.

– equivalent circuit of inductor

As with the other circuit elements, an equivalent circuit for a generalized inductor may be constructed.

- The wire leads of the inductor introduce a series inductance L_{lead}, and a capacitance C_{lead} that is in parallel with the ideal inductance.
- Because a relatively large amount of wire is contained in the inductor coil, a parasitic resistance is modeled in series with the ideal inductance.
- Finally, a parasitic capacitance exists in parallel with the series combination of the parasitic resistance, and the ideal inductance. This capacitance is due mainly to the individual windings of the coil being in such close proximity to one another.

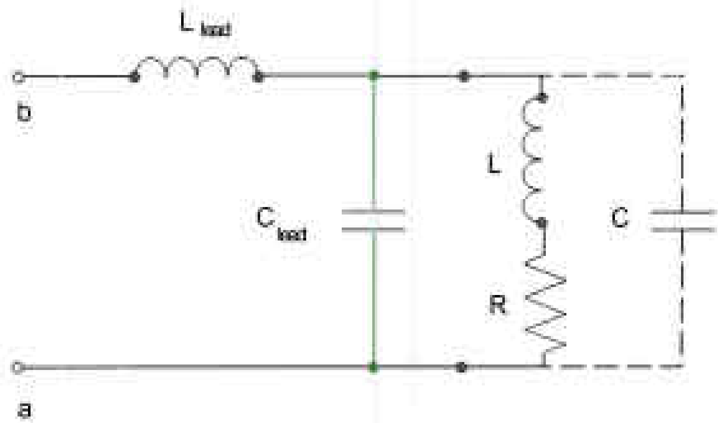


Figure 17. Equivalent circuit for inductor.

As with the devices examined previously, the generalized equivalent circuit for the inductor shown above may be simplified.

- The lead inductance L_{lead} is typically much smaller than the ideal inductance L, and may therefore be neglected.

- Additionally, the lead capacitance C_{lead} is typically much smaller than the parasitic capacitance $C_{parasitic}$.

Thus the simplified equivalent circuit for the inductor consists of a series combination of $R_{parasitic}$ and L in parallel with $C_{parasitic}$.

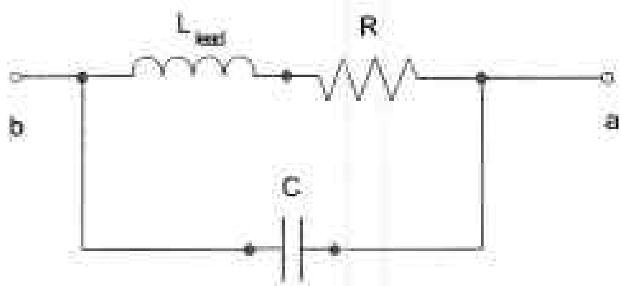


Figure 18. Simplified equivalent circuit for inductor.

The impedance of this simplified circuit is given by

$$\frac{1}{Z_{total}} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

where

$$Z_1 = j\omega L + R_{parasitic}$$

and

$$Z_2 = \frac{1}{j\omega C_{parasitic}}$$

This leads to

$$\frac{1}{Z_{total}} = \frac{j\omega C_{par.}\left(j\omega L + R_{par.}\right) + 1}{j\omega L + R_{par.}}$$

or

$$Z_{total} = \frac{j\omega L + R_{par.}}{1 - \omega^2 L C_{par.} + j\omega C_{par.} R_{par.}} .$$

As before, the behavior of the impedance of the equivalent circuit for the inductor is examined over a wide range of frequencies:

- At low frequencies, the parasitic resistance term dominates and the impedance is approximately equal to $R_{parasitic}$.

- As the frequency of operation increases, the ideal inductance L begins to dominate the impedance of the equivalent circuit near the frequency

$$\omega = \frac{R_{parasitic}}{L} .$$

- As the frequency increases further, the impedance of the parasitic capacitance decreases until it's magnitude is equal to that of the ideal inductance. This occurs at the self resonant frequency

$$\omega_o = \frac{1}{\sqrt{LC_{par.}}} .$$

The impedance of the equivalent circuit is a maximum at this frequency.

- Above the self-resonant frequency, the parasitic capacitance begins to dominate the behavior of the equivalent circuit. In this range of operation the impedance decreases with increasing frequency.

A plot of the responses of the equivalent circuits for various inductors is shown in Figure 19. The responses of 0.1 mH, 10 μH, and 1 μH inductors are shown. Here the parasitic capacitances are all 1 pF, and the parasitic resistances are 1Ω. The resonant frequencies are seen to occur at 15.92 MHz, 50.33 MHz, and 159.2 MHz.

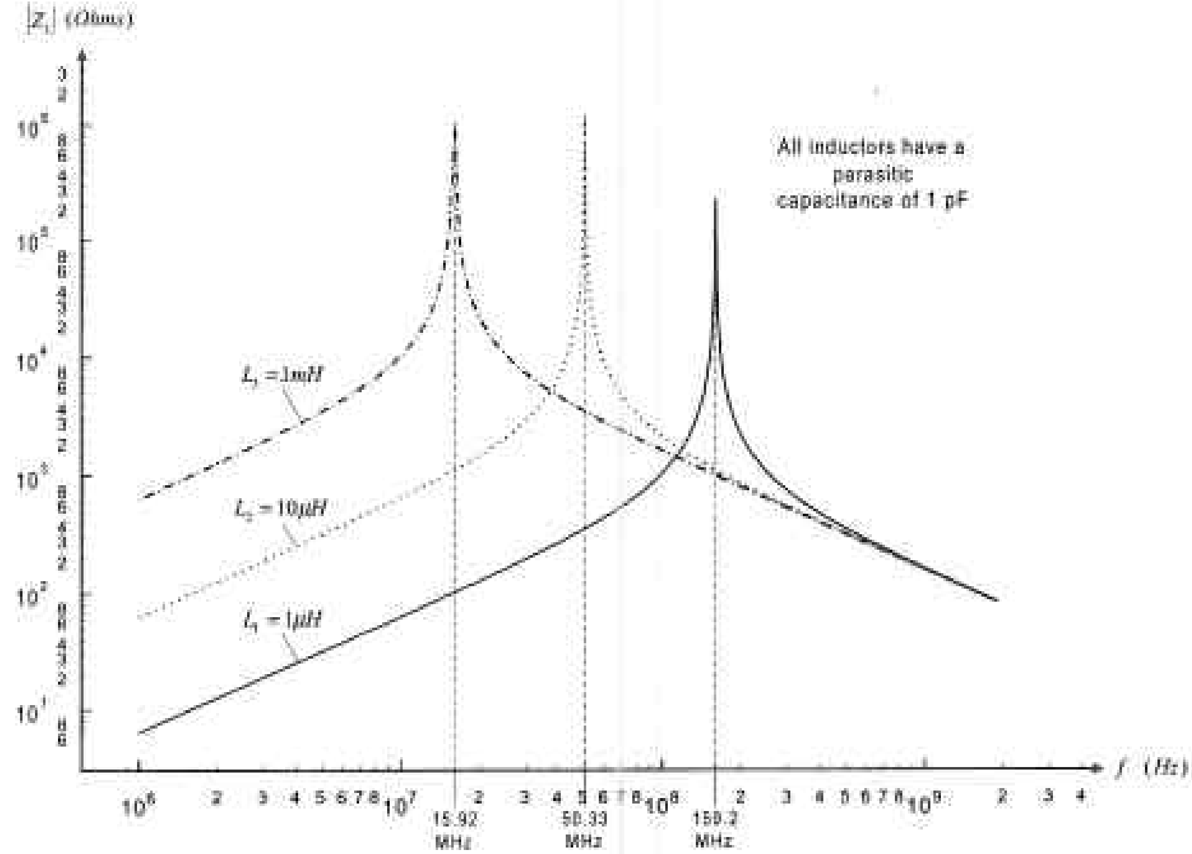


Figure 19. Plot of frequency dependent behavior of equivalent circuits for various inductors.

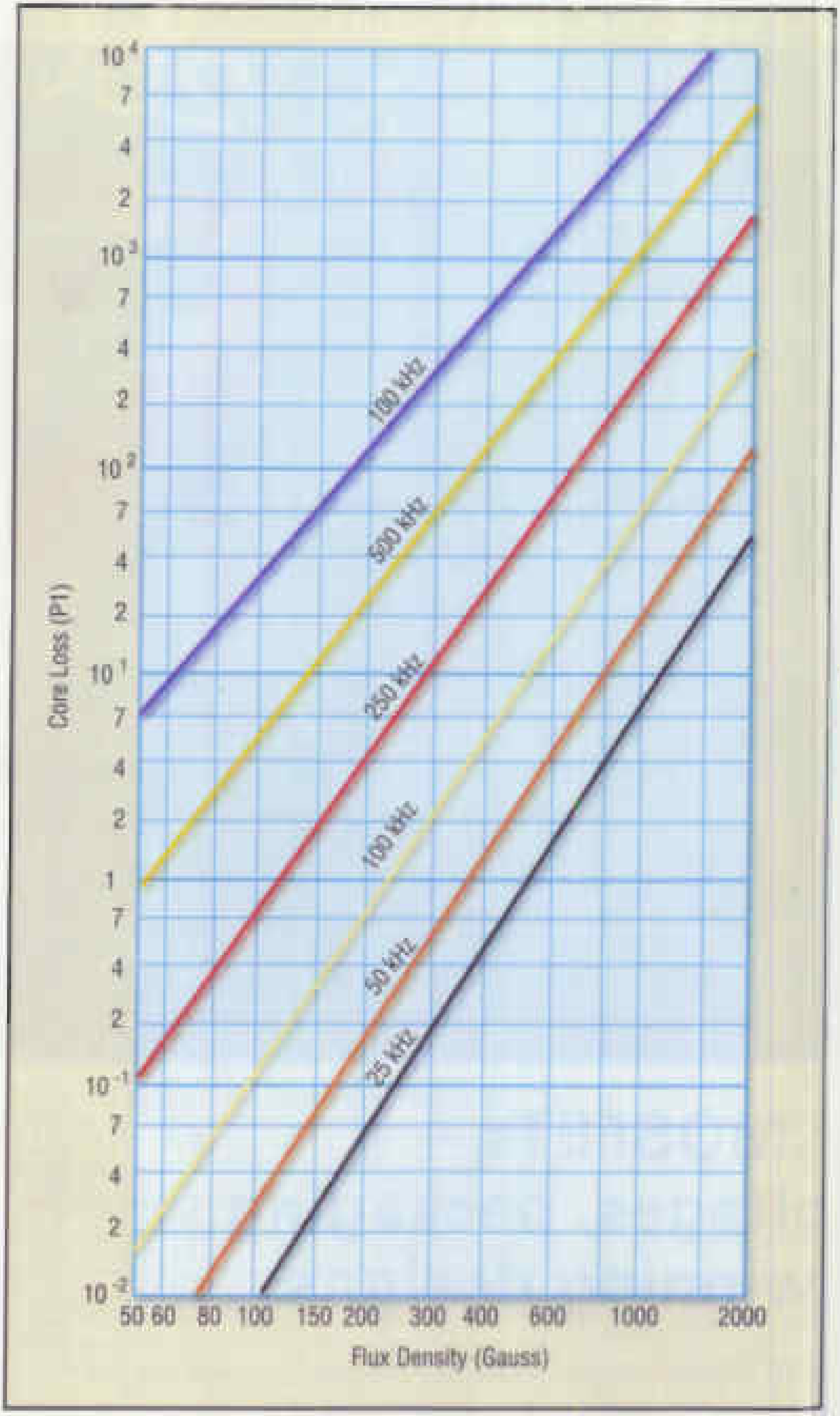
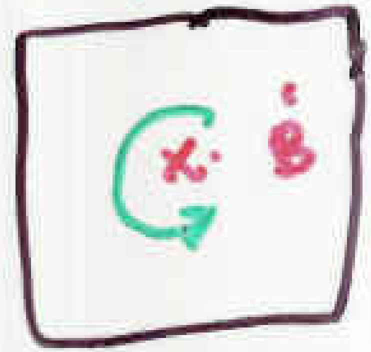


Fig. 3. *AC core loss for a particular ferrite material is plotted as a function of flux density at different frequencies. (Data courtesy of Spang and Co.)*

eddy current



$i_{ec} \approx V / R_{core}$

$V = \omega B$

$P^{ec}_{loss} = i^2 R_{core}$

$= \dfrac{V^2}{R_{core}}$

$P^{ec}_{loss} \sim \omega^2$

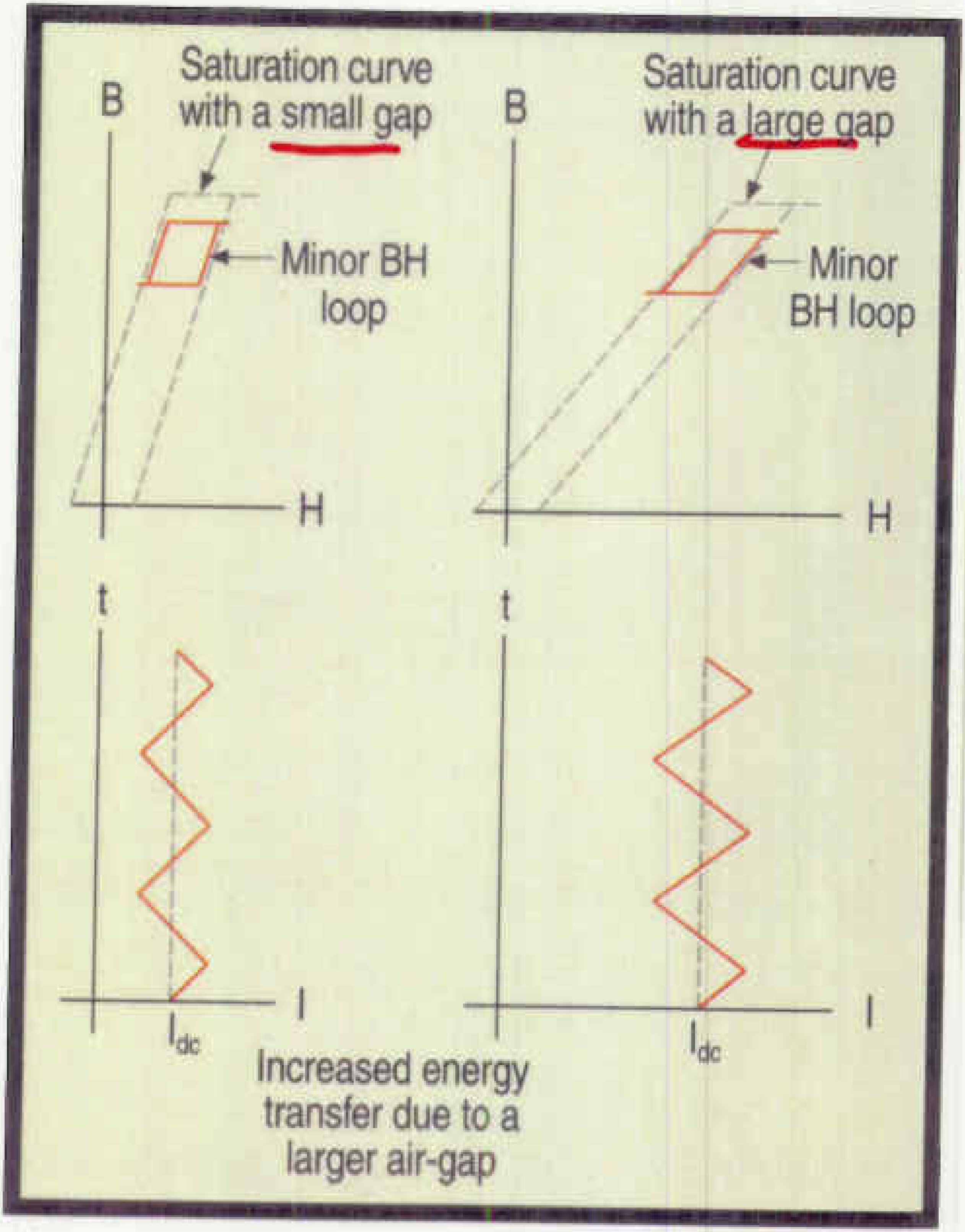


Fig.2. *Impact of a gap in magnetic core material.*