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Estimate of eddy current power loss in the dipole vacuum chamber

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ESTIMATE OF EDDY CURRENT POWER LOSS IN THE DIPOLE VACUUM CHAMBER

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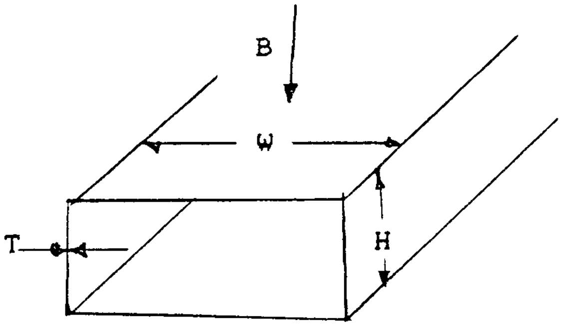
Recently there was some concern about the heating of the vacuum chamber in the booster dipoles due to the eddy current. A crude estimate of the eddy current power loss in the vacuum chamber of the dipole magnet is done. Suppose we can approximate the vacuum chamber cross section as a rectangle of width W height H and thickness T. The voltage generated at the side wall can be expressed by



$$V = \dot{B}\ W/2\ L$$

where $\dot{B}$; rate of magnetic field rise

L; length of the chamber

The power in the side wall can be expressed

$$P_{side} = 2V^2 / (72\ 10^{-8}\ L/H/T)$$

where 72×10^{-8} is resistivity of the vacuum chamber material.

$$P_{side} = 6.94\ 10^5\ \dot{B}^2 W^2\ L\ H\ T$$

The voltage at distance X from the center on the top and bottom plate can be expressed

$$V = \dot{B}\ X\ L$$

and power can be expressed

$$P_{T \text{ and } B} = 2\int_{-W/2}^{W/2} V2\ T/(72\ 10^{-8}\ L)\ dX$$

$$= 2.78\ 10^6\ T\ L\ \dot{B}^2 \int_{-W/2}^{W/2} X^2\ dX$$

$$= 2.78\ 10^6\ T\ L\ \dot{B}^2 W^3/12$$

and the total power is

$$P_{total} = 6.94\ 10^5\ \dot{B}^2 W^2 LT(H + W^3/3)$$

for example, if we assume

$\dot{B}$; 6.5 Tesla/sec

W; .15 m (6 inches)

T; 2 mm

H; 3.8 cm (1.5 inches)

P_{side} = 50 watts/m

$P_{T \text{ and } B}$ = 1.5 watts/m

P_{total} = 51.5 watts/m

The power losses are significant. However, compared to the estimated power requirement of 400 watts/m in order to bake the vacuum chamber at the temperature of 200°C, temperature rise expected, due to continued pulsing, does not seem too excessive.