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Power Dissipated in Doubler Type Cryostat and Heat Shield

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Summary

The power dissipated in the bore tube, cryostat and heat shield is calculated for magnetic field distributions generated by sheet currents simulating the doubler excitation windings. Results are given for the doubler dipole.

Method

When the power dissipation is acceptably low (less than .1 watt per magnet), the effect of eddy currents on the field distribution is small (less than .01 percent). Hence, the power losses will be calculated using fields generated only by the excitation currents. Thus

$$P = \frac{1}{2} \text{ Real} \int E \cdot J^{*} \, dv \, . \tag{1}$$

Using the thin sheet approximation

$$P = \frac{1}{2} \, \ell \, s\omega^{2} \oint_{C} (\text{Real } W)^{2} \, d\ell, \tag{2}$$

where $W = A_z + iV$ is the complex potential previously calculated[1]. The magnet length is ℓ, s is the surface conductivity, ω the angular frequency, C is the curve representing the bore tube, cryostat, or heat shield.

Results

The results are presented in Tables 1 - 3 for various temperatures and materials. These results may be scaled for any variable except those specifying the shape and location of the component according to

$$P \,\alpha\, \frac{\ell f^2 \delta I^2}{\rho} \,, \tag{3}$$

where f is the frequency, δ the component thickness, I the excitation current, and ρ the resistivity. Values of resistivity[2] are given in Table 1.

It appears that stainless steel must be used for all the components in order to keep the power loss sufficiently low.

References

1. S.C. Snowdon,"Eddy Currents in Superconducting Dipole Banding", NAL Technical Note TM-464 (Dec. 28, 1973)
2. H. Brechna,"Superconducting Magnet Systems", Ch. 1, p. 15, Springer-Verlag (1973).

Table 1. Design Data for Doubler

Conductor Current	2815 A
Number of Turns	140
Current Sheet Radius	1.1325 in
Inner Radius of Iron	3.0625 in
Current Sheet Offset	.375 in
Magnet Length	240.577 in
Frequency	.0167 Hz
Bore Tube Radius	.670 in
Bore Tube Offset	.375 in
Bore Tube Thickness	.030 in
Inner Cryostat Radius	2.000 in
Inner Cryostat Thickness	.018 in
Outer Cryostat Radius	2.125 in
Outer Cryostat Thickness	.018 in
Heat Shield Radius	2.6875 in
Heat Shield Thickness	.03125 in

Table 2. Resistivities of Cryogenic Temperatures

	4.2°K	21°K	78°K
Stainless Steel (304)	50.	50.	52.
Copper (OFHC)	.016	.018	.26
Aluminum (Comm.)	.101	.110	.40

Resistivities are expressed in μΩ - cm units.

Table 3. Power Loss in Doubler

Material	Bore Tube	Inner Cryostat	Outer Cryostat	Heat Shield	Heat Shield
	4.2°	4.2°K	4.2°	21°K	78°K
Stainless Steel (304)	.052 W	.036 W	.036 W	.070 W	.067 W
Copper (OFHC)	162. W	113. W	114. W	194 W	13.5 W
Aluminum (Comm.)	25.7 W	18. W	18. W	31.8 W	8.7 W