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High Field Dipole Magnet Design Concepts*

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ABSTRACT

High field dipole magnets will play a crucial role in the development of future accelerators whether at Fermilab or elsewhere. This paper presents conceptual designs for two such dipoles; 6.6 and 8.8 Tesla, with special focus on their suitability for upgrades to the Fermilab Tevatron. Descriptions and cross-sectional views will be presented as will preliminary estimates of heat loads and costs.

INTRODUCTION

Superconductor performance has steadily improved over the course of the past several years. These improvements, coupled with a better understanding of the mechanics of building superconducting coils, better analysis tools for studying the interactions of individual coil components, and improved refrigeration systems, make it possible to consider dipole magnets with fields as high as 10 Tesla.[1] This paper presents conceptual designs for two such magnets. Both may be considered for general accelerator applications, but are treated here as proposals for upgrades to the existing Tevatron at Fermilab.

6.6 TESLA DIPOLE

Figure 1 illustrates a conceptual view of a 6.6 Tesla dipole suitable for use in the 1.5 Tev pbar-p Tevatron upgrade proposal. This cross section is much like that of an SSC dipole, but with cryogenic piping compatible with existing Fermilab refrigerators. It consists of a 16.76 cm diameter collared coil assembly with a 7.62 cm aperture surrounded by cold iron. The cold iron assembly is 45.97 cm in diameter, truncated at the top and bottom to an overall height of 32.00 cm. An annular space of 0.64 cm between the outside of the collared coil and the inside of the cold iron serves as a flow passage for two-phase helium in counterflow heat exchange with the collared coil. The collared coil assembly operates at 4.5K. An 80K thermal radiation shield serves to intercept heat radiating from 300K. The shield is covered by 2-3 cm of multilayer insulation (MLI).

The cold assembly, consisting of the collared coil, cold iron, and 80K shield, is supported at three places along the length of the magnet by reentrant support post assemblies. The support tubes are filament wound glass in an epoxy matrix. The support posts are derived from work on SSC dipoles and constitute a structurally sound, thermally efficient support system.[2]

The entire cryostat internal assembly, consisting of the cold assembly and supports, is contained inside a 60.96 cm diameter vacuum vessel. The proposed length of the assembly is 8.5 m, but is not restricted to that length. The proposed length allows three 6.6 Tesla dipoles to replace four Tevatron dipoles, thus preserving the Tevatron lattice.

Estimated heat loads and magnet costs are summarized in Tables 1 and 2 respectively. Magnet costs are listed separately and may be considered generic estimates. Project costs are applicable only to the referenced upgrade proposals at Fermilab.

8.8 TESLA DIPOLE

Figure 2 illustrates a conceptual view of an 8.8 Tesla dipole suitable for use in the 1.8 Tev pbar-p Tevatron upgrade proposal. The collared coil assembly is identical to that in the 6.6 Tesla configuration described above. To achieve 8.8 Tesla, this coil must operate at 1.8K. Again, this is a cold iron assembly, but with added iron to prevent saturation at the higher field. The cold

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iron assembly is 56.00 cm in diameter truncated at top and bottom to a height of 40.64 cm. Because it operates at 1.8K, the 8.8 Tesla option does not use two-phase for heat exchange. Rather, two thermal radiation shield are used; operating at 5K and 80K respectively. Both shields are covered with multilayer insulation.

Support posts similar to those described for the 6.6 Tesla option serve as the suspension system, securing the entire cold assembly to the vacuum vessel. Due to the increased iron size and additional radiation shield, the vacuum vessel is 81.28 cm in diameter. Again, the proposed length is 8.5 m, but is not restricted to that length.

Although suitable for use in a 1.8 Tev upgrade operating in collider mode, the 8.8 T dipole described above is not suitable for use in fixed target experiments. Losses due to hysteresis and magnetization during ramping require more refrigeration at 1.8K than can be met by the current or planned liquifier upgrades at Fermilab.[3]

Estimated heat loads and magnet costs are summarized in Tables 1 and 2 respectively. Magnet costs are listed separately and may be considered generic estimates. Project costs are applicable only to the referenced upgrade proposals at Fermilab.

SUMMARY

Both of the high field dipoles designs described above and illustrated in the accompanying figures are built upon existing work, e.g. the Fermilab Tevatron and the SSC. They are far from the only solutions to the design problem. In some instances they may not even be viable candidates. For example, the 8.8T option is not suitable for use in fixed target experiments. New technologies and new materials may well play a role in future design ideas. It does seem clear, however, that we can build dipole magnets with fields approaching 10 Tesla using existing technology and design practices. What is required is a concentrated effort to that end.

REFERENCES

1) Mantsch, P.M., "Prospects for 6- and 10-Tesla Magnets For a Tevatron Upgrade," Hadron Collider Working Group Presentation, Snowmass 1988.

2) Nicol, T.H., Niemann, R.C. and Gonczy, J.D., "SSC Magnet Cryostat Suspension System Design," Advances in Cryogenic Engineering, Volume 33, 1987, pp. 227-234.

3) Theilacker, J. and Peterson, T., Hadron Collider Working Group Presentation, Snowmass 1988.

4) Conceptual Design Report, Proton-Proton Collider Upgrade (Main Injector, New Tevatron), Fermi National Accelerator Laboratory, May 1988.

Table 1. Heat Load Estimates (Per Magnet)[4]

1.5 Tev pbar-p	1.8K	4.5K	80K
6.6 T Dipole	na	2.6W	20.5W
Quad	na	1.3W	5.7W
Spool	na	7.0W	18.9W
1.8 Tev pbar-p			
8.8 T Dipole	0.1W	2.3W	31.2W
Quad	0.1W	1.3W	5.7W
Spool	0.1W	7.0W	18.9W

Quads and spools are assumed to be roughly equivalent in structural size for all options.

Table 2. Magnet Cost Summary
For 1.5 and 1.8 Tev Upgrade Proposals[4]

Dipole Cost Summary

	6.6 T 8.5 m	8.8 T 8.5 m
Coil Assembly Mat'l	71.8K	71.8K
Coil Assembly Labor	9.2K	9.2K
He Containment Mat'l	22.2K	30.0K
He Containment Labor	4.3K	4.3K
Cryostat Mat'l	7.5K	12.5K
Cryostat Labor	3.2K	3.2K
Total Per Magnet	118.2K	131.0K

Miscellaneous Component Costs

Standard Quad	38.5K
Special Quad (Avg)	41.3K
Spool (Avg)	65.7K

Project Costs (Magnets Only)

	1.5 Tev	1.8 Tev
Standard Dipoles	75.3M	83.5M
Standard Quads	6.8M	6.8M
Special Quads	1.0M	1.0M
Spools	13.4M	13.4M
Totals	96.5M	104.7M

Quads and spools are assumed to be roughly equivalent for all options.

All costs are in 1988 dollars.

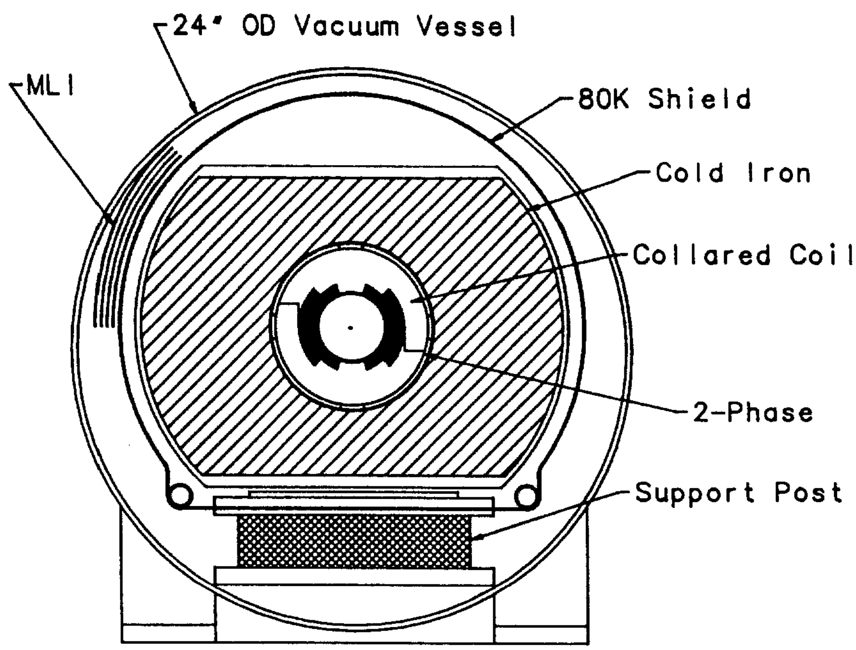

Figure 1. 6.6 Tesla Dipole Conceptual Design Cross Section

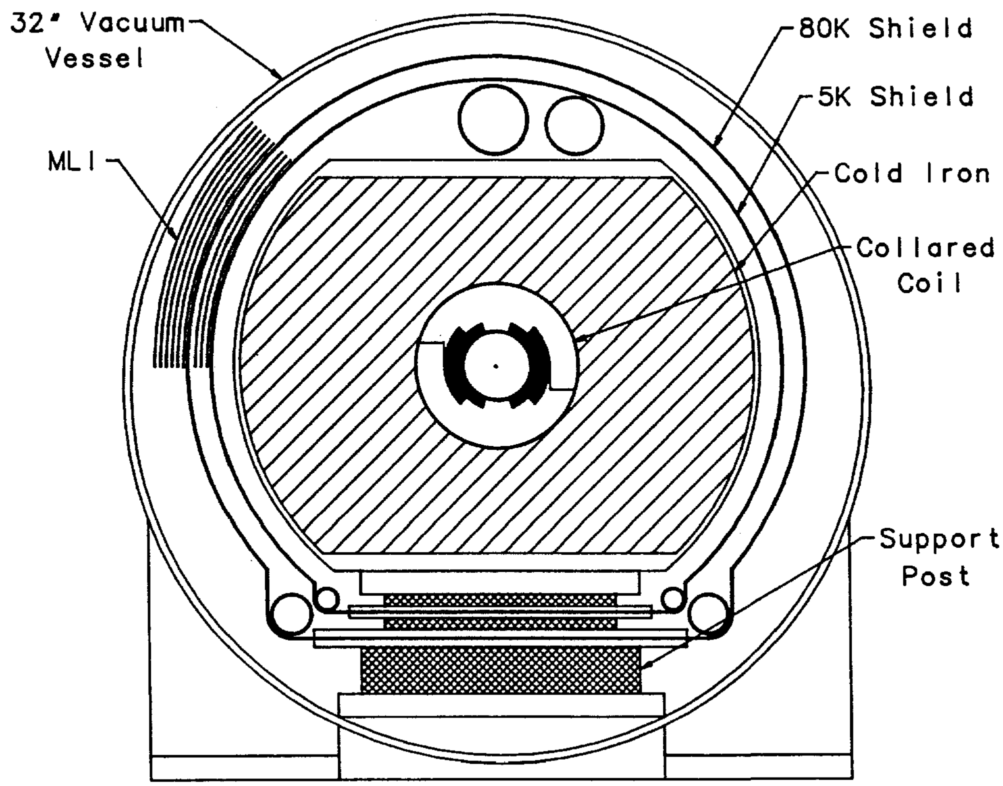

Figure 2. 8.8 Tesla Dipole Conceptual Design Cross Section