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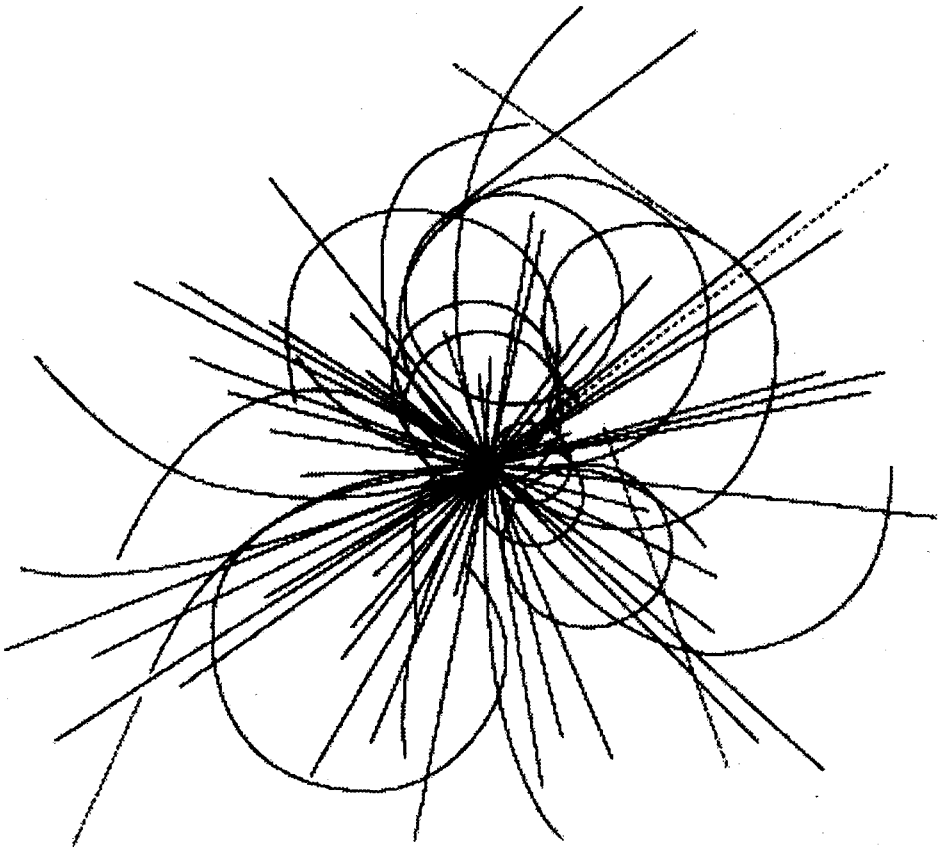

Superconducting Super Collider Laboratory

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DESIGN AND ANALYSIS OF THE CRYOSTAT SYSTEM FOR A 15 m LONG PROTOTYPE QUADRUPOLE MAGNET

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INTRODUCTION

Quadrupole magnets with a gradient of 190 T/m are required in several sections of the interaction region of the SSC collider ring. These magnets have an aperture of 50-mm and greater and they are expected to operate at 4.3 K. They vary in length from approximately 6 m to about 15 m. Superconducting magnets with a 50-mm aperture and 15-m length have never been built before. It is necessary to develop and prove out the design and technology for long quadrupole magnets before embarking on the design of tunnel magnets of similar design. A research and development program was initiated in January 1992 in the Magnet Systems Division of the SSC Laboratory to develop such a magnet. The goal of this R&D program was to develop a producible and cost effective magnet design and fabrication process that can satisfy performance needs.

The baseline design is the 50-mm Dipole Cryostat developed at Fermi National Accelerator Laboratory.[1] Attempts were made to improve upon baseline design wherever this was feasible. This paper presents the design that was developed for the cryostat system of the prototype quadrupole magnet. A cross-section view of the magnet, showing the cryostat system components is shown in Figure 1.

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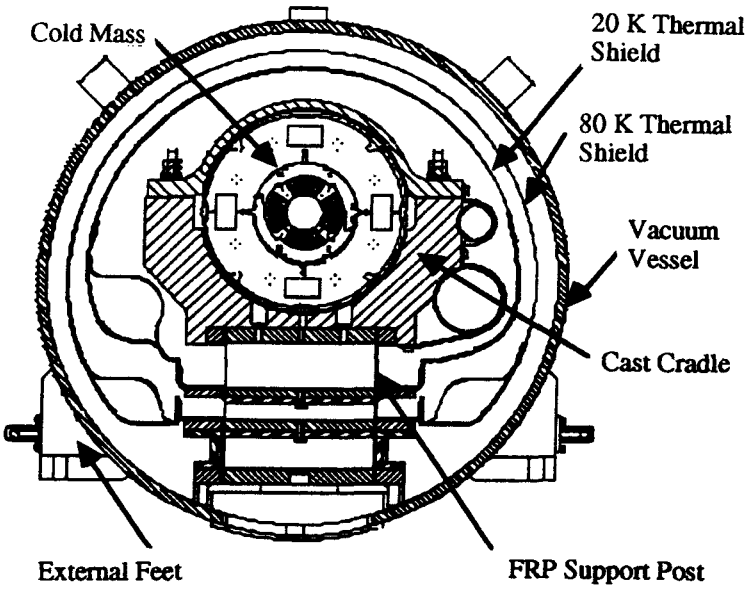

Figure 1. QCE Magnet cross-section.

DESIGN REQUIREMENTS

The design requirements for the quadrupole magnets in the interaction region had not been developed at the inception of the program. As such, the cryostat system design requirements were derived from available requirements for magnets with similar functions or physical characteristics. or physical characteristics. Individual interaction region quadrupole magnets will probably have requirements that are different from these derived requirements. However, this serves as a reasonable starting point. The structural requirements were derived from collider magnet specifications. The collider dipole static heat leak budget was the specification used since both magnets have approximately the same physical length. The alignment requirement was derived from the collider quadrupole specifications. The following is a summary of the requirements:

Structural Loads:		0.5 G lateral 0.5 G axial 3 G vertical
Static Heat Leak Budget		0.363 watts at 4 K 5.055 watts at 20 K 37 watts at 80 K
Alignment:	Cold Mass Sag:	< 0.06 mm

In addition to these requirements, the magnet was also required to satisfy ASME pressure vessel and piping code requirements (Section VIII and B31.3). The magnet will be tested in the Magnet Test Laboratory and as such its external supports and interfaces must be compatible with the test stands.

CURRENT CONFIGURATION

The physical characteristics of the magnet are summarized below. The cold mass parameters were derived from the 40 mm collider dipole magnet design.

Cold Mass OD	=	276.78 mm (Maximum)
Cold Mass Length	=	15123.7 mm (end plate to end plate)
Shell Thickness	=	4.93 mm (nominal)
Weight Intensity	=	3650 N/m
Cold Mass Stiffness	=	4.7×10^7 mm^4 (125% skin stiffness – theory)
(second moment of area)	=	6.25×10^7 mm^4 (measured from 40 mm collider dipole magnet cold mass DD0018)

VACUUM VESSEL

The vacuum vessel design is simpler than the Accelerator System String Test (ASST) dipole design. The present design has a wall thickness of 12.7 mm, compared to the 8.3 mm wall thickness of the ASST design. The added wall thickness provides enough structural strength to eliminate the reinforcing rings at the support post locations. The vessel wall is uniform throughout. The length of the vacuum vessel is 14 960 mm. It has four circumferential welds and three longitudinal welds. The outside diameter of the vessel is 711.2 mm. The vacuum vessel is 74% stiffer than the ASST vessel. The fundamental frequency of the entire magnet assembly increases about 20% as a result of this increased stiffness and will therefore improve dynamic response to ground motion and therefore stability. The material is structural steel ASTM A516 Grade 70, consistent with the material selected for the collider dipole and quadrupole magnets.

One of the design requirements is that the magnet has to interface with the test facilities in the SSCL Magnet Test Laboratory. To accomplish this, the ASST dipole feet and end rings are integrated into the design. The end rings are modified on the faces that mate with the vacuum vessel since the inner and outer diameters of the vacuum vessel are greater than those of the ASST vacuum vessel. The side that mates with the test facility is not modified.

SUSPENSION SYSTEM

The suspension system is comprised of the cold mass support posts and the sliding cradles. The magnet has seven posts compared with five for the ASST Design. The number of posts was driven by the cold mass sag requirements. The support posts are of single tube design. Figure 2 shows the support post with the rings and disks. The material used is fiber reinforced plastic (FRP), the same material used in the outer tube of the re-entrant posts of the ASST design. Extensive development of both the FRP material and shrink fit concepts are documented in the literature.[2,3] The 4 K and 300 K disks and rings, fastened by shrink fits, are stainless steel while the 20K and 80K disks and rings are aluminum 6061-T6. The outer dimensions of the rings were modified to match the corresponding dimensions of the support post being designed by Genaral Dynamics for collider dipole

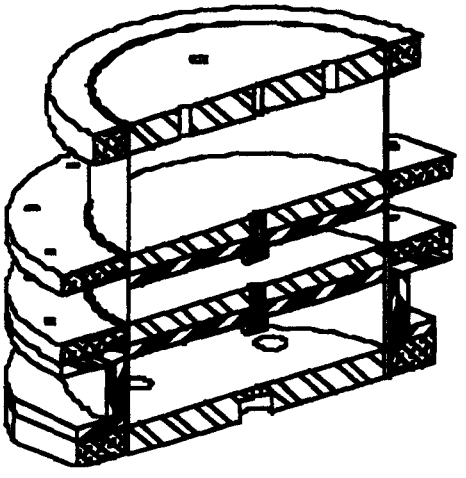

Figure 2. Fiber Reinforced Plastic Single Tube Support Post.

magnets. This was done to assure compatibility between the two post designs if the need came up to use the CDM support post in the magnet. The post design is much simpler than the re-entrant post design and it has far fewer components than the re-entrant post. The seven posts meet the static heat leak budget of the five re-entrant posts, the structural design loads for the collider magnets of 0.5 G axially, 0.5 G laterally and 3 G vertically. There is a factor of safety of 2 on buckling loads.

The cast cradle is a modification of the ASST design. It is made up of two parts, a lower section and an upper steel strap. The lower section is made of cast steel and machined. It is dimensioned to accommodate the support post which is about 25 mm longer than the re-entrant post.

The bolted split ring that holds the cradle in place was eliminated for ease of assembly. The center cradle is attached to the cold mass by welding eight 1-inch gussets to the cradle on one side and the cold mass on the other side. This technique eliminates ASME qualifications of the cast cradle but does not compromise structural integrity.

INSULATION SYSTEM

The insulation system for this magnet consists of thermal shields at the 80 K and 20 K levels, two multi layer insulation blankets wrapped around the 80K shield and cryogenic pipes to carry the cryogens. The 4 K and 20 K blankets of the baseline ASST design were eliminated.[4] The major requirement for the shields was that they had to conform to ASST interface requirements at the ends of the magnet. The QCE shield design eliminated the transition joints and used extruded 304 L stainless steel pipes to improve reliability. The design provided more room to adjust the shields during assembly. The thermal shields are connected thermally to the cryogenic pipes by thermal straps. They are restrained in troughs in the shields with structural aluminum straps.

SUMMARY

The cryostat system for a 15-m long quadrupole magnet with a 50-mm aperture has been designed. The magnet has a uniform walled vacuum vessel with dipole external feet and ASST end rings to ensure compatibility with Magnet Test Laboratory test facilities. The port is a low profile platform that is welded onto the inside of the vacuum vessel. The support post is a fiberglass reinforced plastic single tube post with shrink fit rings and disks at 4 K, 20 K, 80 K and 300 K.

REFERENCES

1. T. H. Nicol, "Design Development for The 50 mm Superconducting Super Collider Dipole Cryostat," Supercollider 3, Edited by J. Nonte, Plenum Press, New York, 1991, pp. 1029–1036.
2. T. H. Nicol, "SSC 50 mm Collider Dipole Cryostat Single Tube Support Post Conceptual Design and Analysis," Supercollider 4, Edited by J. Nonte, Plenum Press, New York, 1992, pp. 747–755.
3. T. H. Nicol, J. D. Gonczy, R. C. Niemann, "Design and Analysis of the SSC Dipole Magnet Suspension System," Supercollider 1, Edited by M. McAshan, Plenum Press, New York, 1989, pp. 637–649.
4. R. Pletzer, "Results of Preliminary Analysis of 50 mm Dipole Magnet Without 4 K and 20 K MLI Blanket," MSD Memorandum, 1991.