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SSC DIPOLE MAGNET MODEL CONSTRUCTION EXPERIENCE

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ABSTRACT

A program to assemble full scale SSC dipole magnet models has been implemented. Details of the assembly program, assembly experience, and the comparison of the final magnet assembly to the design parameters are presented. Potential design improvements as well as magnet assembly techniques are discussed.

INTRODUCTION

The SSC dipole magnet development program includes the assembly of a premanufactured coil and cold mass subassembly built at Brookhaven National Laboratory into a cryostat system that was manufactured at Fermilab.[1]

The concept of different manufacturers each building a major component of the magnet which could be assembled at any site is one of the goals of the program.

A full scale dipole magnet thermal model was manufactured and assembled prior to the assembly of the first SSC dipole magnet model. [2]

The complete magnet contains all of the magnet support systems, thermal isolation shields, insulation, expansion joints, vacuum vessel, magnet interconnection devices, and a complete alignment system.

COMPLETE MAGNET

The complete magnet has been previously described in detail[3] and only its major features are presented herein. The magnet general arrangement is as shown by Fig. 1. and 2.

Cold Mass Assembly

The cold mass assembly consists of the beam tube, correction elements, collared coils, laminated iron yoke, and outer helium containment shell. The cold mass components are joined together forming a leak tight and structurally rigid assembly.

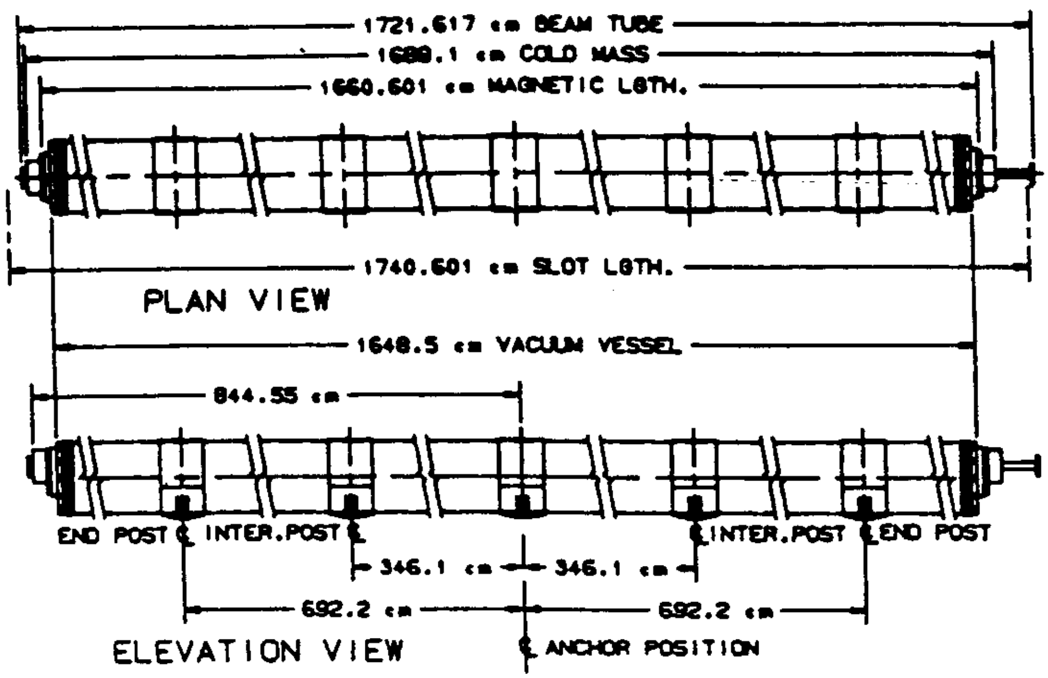

Fig. 1 Cryostat plan and elevation views.

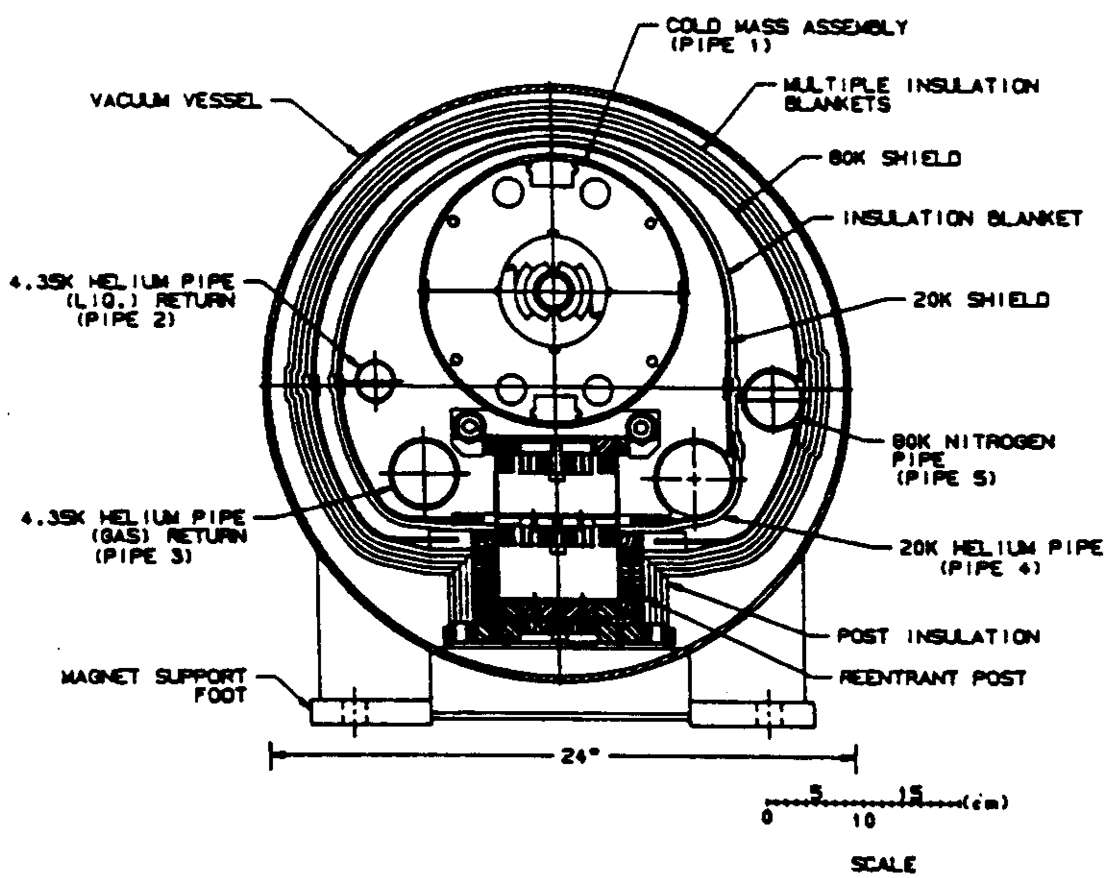

Fig. 2. Cross section through a support point.

Cryogenic Piping

The cryostat assembly contains all piping that interconnects the magnet refrigeration system throughout the circumference of the accelerator rings. A five pipe system is employed for cryogenic and safety reasons.

Thermal Shields

Thermal shields maintained independently at 20 K and 80 K surround the cold mass assembly. The shields absorb the radiant heat flux and provide heat sink stations for the suspension system. The shields are supported by and thermally connected to the cold mass assembly supports.

Insulation

Insulation is installed on the inner and outer shield external surfaces. The insulation consists of blankets of flat, reflective radiation shields with mat spacers.[4] One blanket is installed on the inner shield and four are installed on the outer shield.

Suspension System

The cold mass and shields are supported relative to the vacuum vessel at five points by the suspension system.[5] The system incorporates a reentrant type support post. The support's insulating sections are fiber reinforced plastic tubing with attached metallic end connections and heat intercepts.

Vacuum Vessel

The vacuum vessel provides containment for insulating vacuum and the cold mass connection to ground. The magnet assembly procedure incorporates insertion of the complete internal subassembly into the vacuum vessel. The support post - vacuum vessel connection provides the alignment of the cold mass assembly relative to the vacuum vessel.

Interconnections

Mechanical and electrical interconnections between adjacent magnets are required at the magnet ends. It is essential that the connections be straight forward to assemble and disassemble, compact, and reliable. The design facilitates assembly and disassembly operations in the SSC tunnel.

ASSEMBLY

The major components of the dipole cryostat, i.e., the magnet proper in its helium containment vessel (cold mass), cryogenic piping, heat shields, insulation, and alignment fiducials, are located and supported by reentrant post supports connected to the tow plate. This major subassembly, complete with the anchor system and heat intercepts, is inserted into an outer vacuum vessel.

Cold Mass Subassembly

As a first step in final magnet assembly, the premanufactured magnet cold mass is located on an assembly station, and slide cradles with their supporting subassembly, and alignment fiducial targets, are installed. The cold mass passes to another assembly station, where the axial anchor subassembly, as well as helium return lines, are attached. Next, the five assembled support posts are installed on a locating fixture. The support post heat intercepts are attached, and the 20 K and 80 K heat shields are installed quadrant by quandrant, and attached to the support post intercepts. Thermal insulation blankets come next (one blanket on the 20 K heat shield, four on the 80 K shield), followed by heat conduction straps also connected to the intercepts. These steps complete the preparation of the entire cold mass subassembly for insertion into the vacuum vessel. The arrangement is shown in Fig. 3

Vacuum Vessel

The vacuum vessel is fabricated from cylindrical sections of welded steel pipe, with precision machined mounting feet attached. The machined surfaces of the feet are perpendicular and parallel to related surfaces of the support posts. This arrangement assures alignment of the center of the beam tube in the cold mass with respect to the outside of the vacuum vessel. End rings to hold shipping restraints and reinforcing segments to the support points are attached, and all welding is completed using automated equipment. The inspected assembly is then transferred to the final assembly station where the alignment and support tray (used for the final assembly operation) is installed. A cross section through a support point is shown in Fig. 4.

Final Assembly

The cold mass subassembly and vacuum vessel are lined up, and a slide and pulley system draws the cold mass into the vacuum vessel Fig. 5. Precision fixture points, together with the positive location of the support post feet, allow the cold mass to be located properly relative to the vacuum vessel. A system of optical fiducials is checked to assure the correct alignment. The assembly is clamped and welded together. All external vacuum vessel alignment fiducials are set. The magnet is then inspected, given a final leak check, painted, and the post and vessel shipping restraints are installed. It is now ready for final testing and measurements.

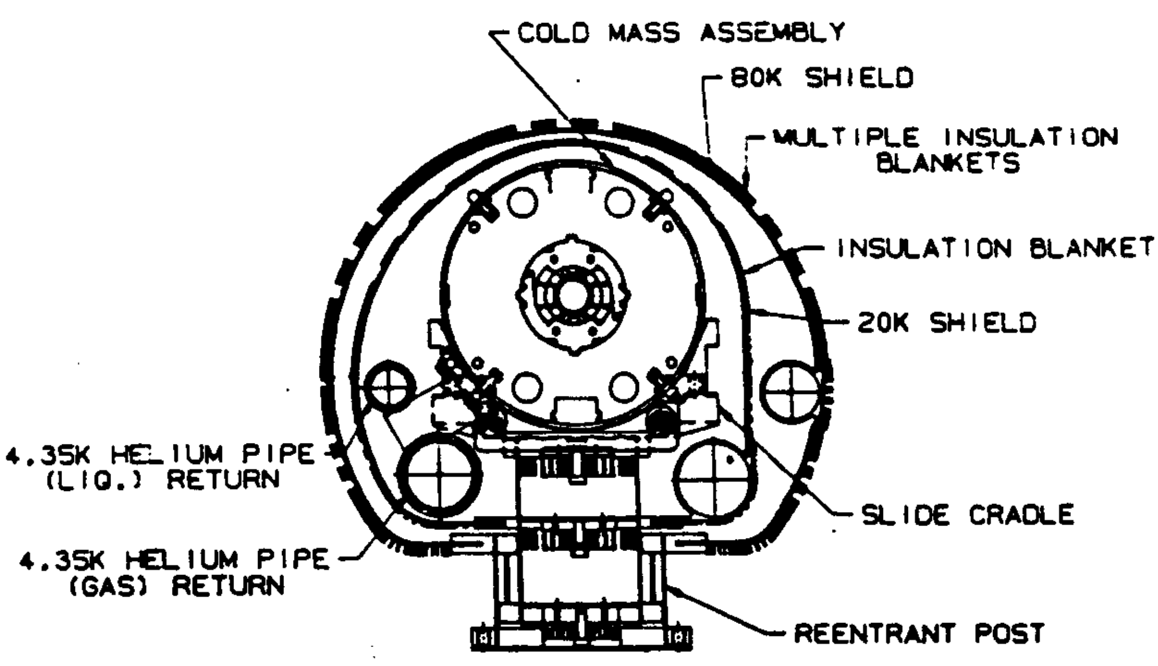

Fig. 3. Cold mass subassembly.

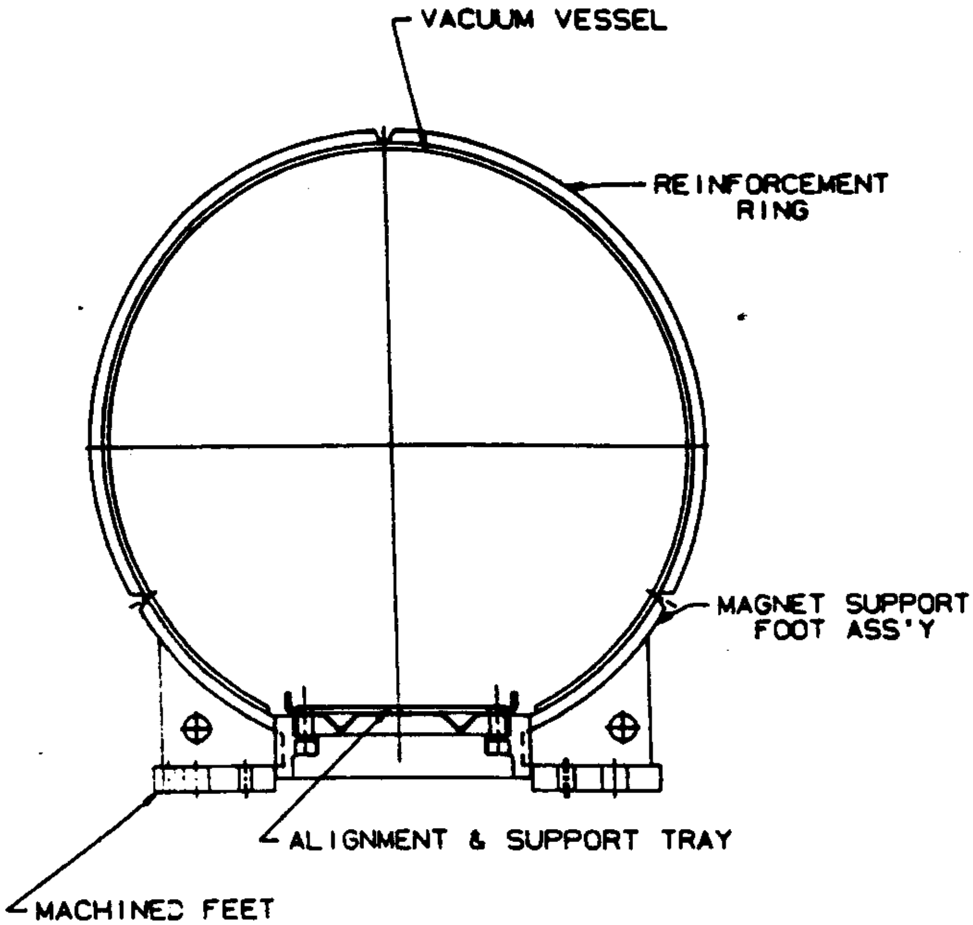

Fig. 4. Vacuum vessel subassembly.

Cryostat Alignment Reference

The alignment of the magnetic centerline of the magnets depends on the transfer from the iron yoke to reference marks on the outside of the cryostat. Optical tooling techniques are normally used for these transfers.

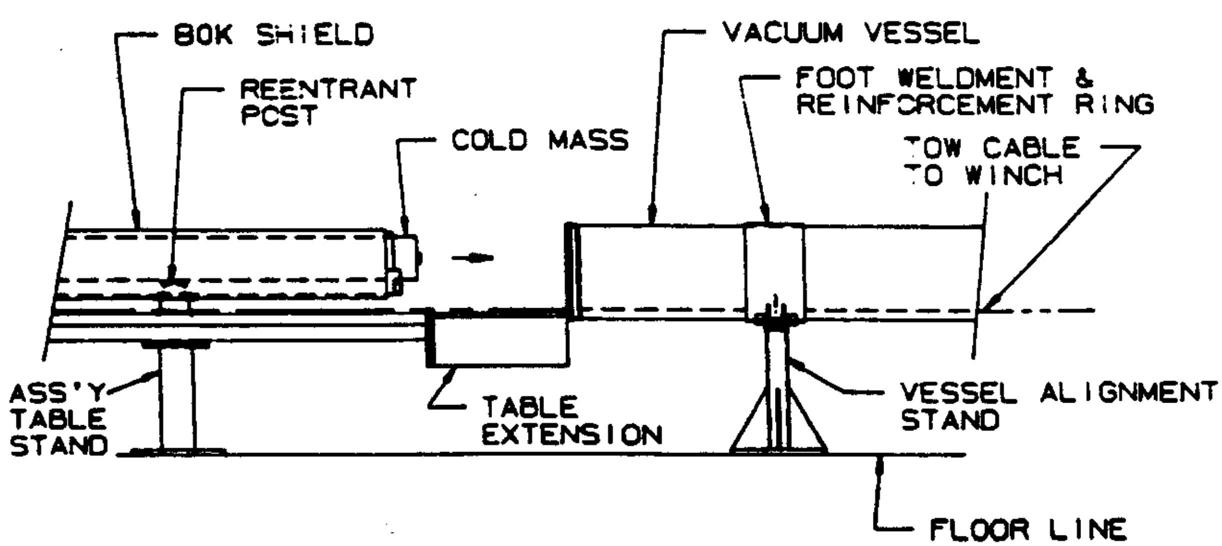

Fig. 5. Magnet final assembly fixture.

Factory Certification Tests

The tests required to certify each dipole for SSC acceptance, before it leaves the factory or factories, include several types and are performed at various stages of the fabrication and assembly process. These tests, conducted at room temperature, are summarized.

(a) Electrical Measurements and Tests
1. Resistance, inductance, and of each of the four windings and of the complete magnet.
2. Hi-pot between windings, between windings and collars, and between coil and bore tubes to 2-3 kV.

(b) Magnetic Measurements
All magnets will have field measurements made at room temperature. The current will be limited to $\pm$15 A, and the following quantities will be measured:
B_0, a_n, and b_n, n = 1 to 6.

The field at 15 A is about 150 G.

RESULTS

The assembly of the first SSC dipole magnet using parts that were manufactured without production tooling, and working toward an ambitious assembly schedule was an exciting experience.

The close cooperation of the various laboratories, and the in house support of the concerned Fermilab groups, assured the successful completion of the first dipole magnet assembly.

The following areas of assembly difficulties were noted, and changes in design and procedures have been incorporated into later dipole magnet assemblies.

Cold Mass Subassembly

The initial full scale cold mass that was received had reference fiducial locations that were not to specification. This required a change in our method to attach the support and anchor systems to the cold mass.

After setting the cold mass on a special fixture, the average mechanical fiducial points were located relative to the fixed center line of the coil location at the center anchor position of the cold mass. The support slides were reworked, aligned, and attached to the cold mass to assure proper operation. The supports were all individually measured for length and diameter, and shims were added to assure equal dimensions to the cold mass center.

The anchor was assembled, and one end was welded to the cold mass outer shell.

The piping system was installed and mechanical tests indicated that additional supports were required. The pipe anchors as originally designed failed initial tests, and were reworked satisfactorally.

The 20 K and 80 K heat shields were manufacutured in short sections to assure delivery to meet our production schedules and welded together to make the required design dimensions. Distortion caused by welding forced the shields to come in contact with other parts of the cold mass assembly.

This caused a considerable amount of rework and modification to assure a proper fit.

The insulation blankets were modified to fit the reworked shields, and an assembly scheme was implemented and completed.

The final rework required was the modification of the subassembly tow plate. This was completed, and the subassembly received its final inspection.

Vacuum Vessel

The vacuum vessel was ordered without penetrations for supports, and with extra length to allow for design modifications. Special tooling was purchased to allow the actual machining of the vessel on the assembly floor, and these operations worked out satisfactorally. Rework of the magnet supports required the modification of the support mounting feet. In addition, engineering studies indicated the need to add circumferential reinforcement at the five support positions to the vacuum vessel. The development of a proper welding technique to keep welding stresses from causing vessel distortion was a major goal and highlight of this operation.

The mounting feet, vacuum vessel body, and structural additions were mounted on a special fixture, aligned, welded, and assembled into a successfull vacuum vessel subassembly.

A reworked slide plate, and special machined vessel end rings were attached to complete this major component.

Final Assembly

With the careful rework and inspections of major subassemblies, the technique of sliding the cold mass into the vacuum vessel was accomplished. The special fixtures together with a cable pulling device worked without a flaw.

The final measurements and quality inspections were completed without a problem, and the magnet was prepared for transport.

Cryostat Alignment Reference

The designed alignment verification scheme which utilized fiducial points on the cold mass that were transferred to tooling balls on the supports proved to be impractical to use as a production technique. The system required the use of survey scopes on both ends of the magnet, and lights to see the targets in magnet interiors that were difficult to see.

IMPROVEMENTS

All of the systems will benefit from ongoing tooling and fixture upgrades. These upgrades will assure consistent dimension and fit of magnet parts. Redesign of parts for increased operating clearances will result in an improved assembly process.

CONCLUSIONS

- The magnet design is functional, and a satisfactory SSC dipole assembly was produced.

- Fully designed components must be available to assure efficient assembly.
- Design improvements should be initiated for the support system attachment scheme.
- Alignment verification must be reevaluated to assure an automatic measurement system during assembly.

Acknowledgements

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These efforts resulted in an assembled SSC dipole magnet that proved many new principles of design and assembly techniques. The work was completed on schedule, and delivered to the Fermilab Magnet Test Facility for further evaluation.

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