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Abstract—The superconducting solenoid magnet for the GEM detector poses unusual fabrication and handling challenges because of its extraordinary size. It will be more than 30% larger in diameter than the largest existing particle detector coils. Each of the two coil elements that compose the air-core solenoid, will be about 19 meters in diameter and 15 meters long. Major components weighing as much as 1500 Mg must be transported and manipulated at the Interaction Region 5 (IR5) fabrication site of the SSC Laboratory as the magnets are fabricated. Because of their large size, the magnets will be fabricated, assembled and tested at special purpose facilities at the IR5 site. The site-use plan must accommodate the fabrication of other detector components and the assembly of large flux shaping iron structures in a timely manner to allow subsequent testing and detector assembly. Each cold mass will be composed of twelve 45-Mg coil windings that are joined prior to assembly into the 19-m diam annular cryostat.

I. INTRODUCTION

Two very large detectors will be deployed for the startup of the Superconducting Super Collider [SSC]. One of these, the GEM Detector, has as a dominant feature, a large thin superconducting solenoid magnet. Two counter rotating proton beams will collide at the geometric center of the

detector and the GEM solenoid magnet will provide the 0.8 Tesla magnetic field necessary for high resolution tracking and identification of the charged particles generated by the collision. [1]

The GEM solenoid electromagnet is significantly larger than any particle detector magnets that have been built to date with a mean coil diameter of 19 m and a half coil length of about 15 m [2]-[3]. It will be constructed in two halves each weighing almost 1500 Mg. This size is much too large to transport by truck or railroad to the SSCL Interaction Region 5 (IR5) site. Assembly considerations have played an important part in the making of design decisions, mandating essentially all component assembly at SSCL. Details of the magnet design are given in [4]-[6].

Two large assembly buildings that dominate the IR5 site will be used for the assembly of the GEM magnet and other large detector components (Fig. 1). Module winding will occur in the South Assembly Building (SAB). Twelve modules will be stacked in the North Assembly Building (NAB) to become the cold mass. A large assembly area will also be located outside and adjacent to the NAB. This outside assembly area is called the hardstand area. This area will be surfaced with crushed rock only and compacted into a suitable working surface for heavy loading. The hardstand will be available for magnet vacuum shell fabrication, other large structure fabrication and general staging and storage.

Final field assembly of electromagnets has been successfully employed in experimental devices (such as MFTF, L3, g-2) when the size of the magnet precludes factory assembly. Our preliminary planning indicates that a

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Fig. 1. The IRS site surface facilities that will be employed during GEM detector assembly.

similar approach will also work well for assembly of the GEM magnet when the techniques are properly applied. The baseline magnet assembly plan is to do all of the assembly work with the axis of the magnet vertical followed by a magnet rotation to the uprighted operational orientation. Our concept design study, conducted in consultation with industry, indicates that this baseline is the minimum cost approach consistent with industry practices and acceptable handling risks.

Each magnet half will be given a final leak check with the cold mass at cryogenic temperatures prior to lowering the magnet half into the experimental hall.

OFF-SITE COMPONENT FABRICATION

Each magnet is assembled from a large number of special purpose components. Cold mass components include the bobbin, conductor, splices and specialized winding tooling. Cryostat components include cold mass supports, the annular vacuum vessel, thermal shields and the lead stack. Component sizes have been determined by shipping and efficient manufacturing considerations as well as magnet design constraints. In general, component configurations are chosen to minimize on-site assembly and verification. A description of component fabrication plans is given in [5].

COIL MODULE WINDING

The coil will employ cable-in-conduit-conductor (CICC). The conductor will be wound as a single layer onto the inside surface of an aluminum bobbin of each 1.2 m long coil module. Twelve identical modules will be bolted together during assembly to form each cold mass. The coil module longitudinal segment length was set by the maximum practical continuous length of conductor that industry can supply.

Each bobbin is divided into four equal segments in the hoop direction. These are a convenient size for truck transport. These segments are bolted together on the bobbin preparation station of the SAB. Two winding stations composed of ring turntables and supporting tooling will be set up in the highbay of the SAB. Twenty-four coil

modules will be wound at the rate of one a month [1]. A travel lift with a 50 Mg capacity will be used to transport coil modules from the SAB to the NAB for further assembly.

VACUUM SHELL FABRICATION

An industrial fabricator will supply transportable cryostat components from their fabrication facilities to SSCL for field assembly into the final annular vessel configuration. Shell welding will be done in two stages to allow complete leak detection and repair of the vessel prior to mating with the cold mass. The first stage will be to weld the shell segments together into two subassemblies with a split line between subassemblies. This first stage welding will occur in the hardstand area adjacent to the NAB using portable equipment only. All of the heavy welding will be done at this stage with no coil on the inside of the vacuum shell. When the vacuum shell subassembly welding is completed the vacuum shell will be split into two halves by separation at the parting line. The second stage welding is the final closure welding of the cryostat. The closure welding will be done with the cold mass inside. The closure welds are small seal welds only. This welding will be done inside the NAB as part of the final magnet assembly.

The vacuum shell design concept will accommodate leak checking of the vacuum shell and the thermal radiation shield at an early stage without the cold mass. The vacuum shell will be welded temporarily with a thin strip of steel which can be ground off after leak testing. The weld closure strip will be sized to carry atmospheric pressure loading only. The dominant structure loads will be carried by bolted flange joints. The closure welds are seal welds only. The thermal radiation shield will also be leak checked at this stage. The final leak test will be done with the shield at cryogenic temperature to verify that it is free of cold leaks.

THERMAL RADIATION SHIELD FABRICATION

A liquid nitrogen cooled thermal radiation shield will be used to minimize the radiation heat load transmitted to the cold mass. The basic building blocks for this system are aluminum panels which are approximately 4-m wide and 15 m long. The panels are curved and stiffened with reinforcement in both directions. Trace cooling tubes are welded onto the panels and leak checked by the contractor before the panels are transported to SSC. Superinsulation blankets are applied onto both sides of the shields prior to installation onto the vacuum shells. Two C-shaped end caps will shield the ends of the coil. Conduction cooling of the ends is adequate and cooling traces are not needed. A pin-in-slot design is used for the shield mounting hardware so that the shield is free to slide in both directions to accommodate thermal contraction of the shield.

MAGNET ASSEMBLY

The next stage is to assemble components into a half magnet. The approach was developed in collaboration with

vessel and magnet fabricators, qualified rigging specialists, and engineers with experience in the handling and assembly of large pieces of equipment. The baseline approach will mate large cylindrical components with longitudinal axes vertical. The components that are to be assembled vertically are easily picked up by the top rim of the cylinder or supported on the bottom rim by compression members. They are then nested together by lowering the inner item into the outer item. Such large structures need adequate clearance during mating. We have allowed 10-cm radial clearance.

A special purpose heavy lifting device, provided by a rigging specialist, will be used for the mating of major subassemblies. This operation will be conducted outside with the longitudinal axes of the cylinders vertical. Heavy duty transporters will be ganged together to move heavy items. These transporters are readily available from a number of U.S. rigging contractors.

ASSEMBLY SEQUENCE

The assembly sequence of each half coil consists of ten steps.

1-Assemble bobbins and wind coils in the SAB. After winding, remove the module from the winding station with the straddle lifter and transport the coil module to the NAB to be stacked up into a half coil (Fig. 2). Make electrical splice joints between coil modules as the modules are being stacked. Add cryogenic cooling manifolds and instrumentation to the cold mass. Test all components.

2-Simultaneously fabricate the vacuum shells outside on the hardstand. After subassembly welding and leak detection, split the shell into two parts and move both halves into the assembly building on the heavy duty transporter.

3-Mount the thermal radiation panels onto the vacuum shells and install the remainder of the plumbing.

Fig. 2. Assembly of the cold mass in the North Assembly Building.

4-Transport the vacuum shell subassemblies outside to the heavy lift device using the heavy transporter. Assemble the inner and outer vacuum shell subassemblies with the thermal radiation panels inside. Move the vacuum shell assembly back into the assembly building and closure weld the vacuum shell. Leak test the vacuum shell and thermal radiation shield.

5-Disassemble the vacuum vessel by grinding off the closure weld strips and separating the shell at the parting line.

6-Transport the cold mass assembly and inner vacuum shell with top ring subassembly outside to the heavy lift device using the heavy transporter. Insert inner vacuum shell into the cold mass. This assembly done outside and then moved back into the NAB to complete assembly.

7-Mate the inner vacuum shell/cold mass subassembly to the outer vacuum shell by lowering the combination down into the outer vacuum shell as shown in Fig. 3. This assembly is done outside and then moved back into the NAB.

8-Leak check the assembled magnet at room temperature.

9-Bring half magnet to the final orientation by uprighting the magnet in the heavy lift device (Fig. 4).

10-Carry out final surface verification tests.

INSTALLATION OVERVIEW

Once the magnet half is tested it will be lowered into the experimental hall using the same heavy lift equipment that was used for assembly. Details of installation and testing are given in [1]-[5].

Fig. 3. Mating of cold mass and outer vessel shell.

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