Fermi National Accelerator Laboratory

FERMILAB-Conf-92/93

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April 1992

Presented at the *CEC/ICMC Conference*, Huntsville, Alabama, June 11-14, 1991.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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TEVATRON LOW-BETA QUADRUPOLE TRIPLET INTERCONNECTS

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ABSTRACT

Installation of cold iron quadrupole magnets in the Low Beta (Superconducting High-Luminosity) upgrade at Fermilab required a newly designed magnet interconnect. The interconnect design and construction experience is presented. Considered are the connections carrying cryogenic fluids, beam vacuum, insulating vacuum, superconducting bus leads, their insulation and mechanical support. Details of the assembly and assembly experience are presented.

INTRODUCTION

The use of cold iron magnets to replace existing warm iron magnets at B0 Collider Detector Facility (CDF) and to add a new Triplet Set at D0 resulted in a series of magnets known as Cold Iron Low Beta Quadrupoles. The upgrades at B0 and the new installation at D0 use five pairs of high-current quadrupoles and four high-gradient correctors on either side of the interaction point. The longest quadrupole lattice designated Q3, has a 5893 mm (232 in) magnetic length. The three pairs of quadrupoles bracketing the detector form asymmetric triplet lenses. See Figure 1. Perhaps the most complicated and challenging mechanical design aspect of the Low Beta insertion is the interconnect (the junction of cryogenic, vacuum and electrical systems).

BRIEF HISTORY

Initial interconnect design concepts followed the early design "B" SSC dipole magnet interconnect design.[1] Using SSC design criteria, all cryogenic connections were to be automatic welded and automatic cut off in the field. The single phase helium interconnect was a 273 mm (10.75 in) ID tube/bellows assembly which was axially stored on the lead end 273 mm (10.75 in) OD cold mass. This allowed the beam tube bellows connection to be made and to complete the electrical bus work powering the magnets in series. Following these connections the tube bellows assembly would be slid across to the adjacent cold mass and welded. R&D work with automatic welding and

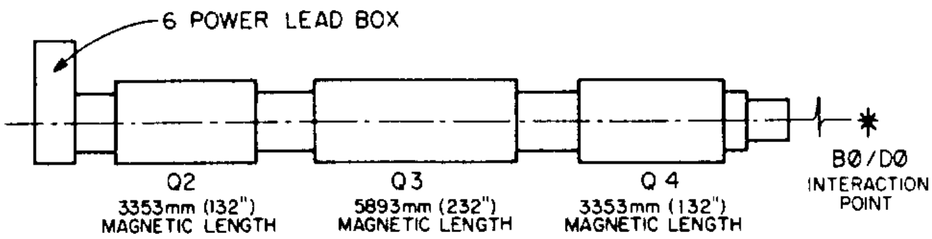

Fig. 1. Low Beta Quad Triplet Latice

cutting equipment was reasonably successful, but the physical bulk of these devices would become incompatible with installing these magnets.

SECOND GENERATION DESIGN

The triplet magnets were located as close to the interaction region as possible, thereby placing the final magnet into the end of the detector itself. To avoid interference with the Torid and Forward Hadron Calorimeter physical constraints were imposed by the B0 (CDF) detector that Low Beta magnets must fit within a 508 x 508 mm (20 in x 20 in) cross section envelope. This precluded the use of automatic cut off/welding equipment under development for the SSC. In order to meet schedule all welded connections for the cryogenic piping, with the exception of the single phase helium were changed to a flange/metal seal connection identical to those used in the Tevatron at Fermilab.

THIRD GENERATION DESIGN

An SSC dipole magnet number DD0011 developed instability under internal pressurization during a quench condition. The failure of this bellows caused project engineers to seek an alternate to large diameter bellows assemblies.[2] This led to the use of ASME-Elliptical Heads as closures for the Cold Mass Assembly. Dual single phase outlets 76.2 mm (3 in) OD tubing with welded bellows and flanges using metal seals similar to those used on Tevatron were chosen. Vacuum closure became a large 457 mm (18 in) diameter retractable bellows with a Marmon type flange and "O" ring elastomer seal.

CRYOGENIC FLUIDS

The cryogenic interconnect consists of seven pipes, two for liquid nitrogen supply/return, two for single phase helium supply, two for two phase helium supply/return and one for single phase helium return with bellows to accommodate axial cooldown and warmup. All pipes are ASTM A-269 304L stainless steel. See Figure 2. The flow path is in series with a turnaround system built into the last magnet in the triplet string. The tight envelope for the triplet precluded the use of external return lines, thereby requiring fully internal return flow path design. The use of a seal type interface allows for easy leak checking at assembly, facilitates the mounting and dismounting at Magnet Test Facility (MTF) and negates the effects of grinding and its associated chips and dust on the supporting cryogenic and vacuum systems.

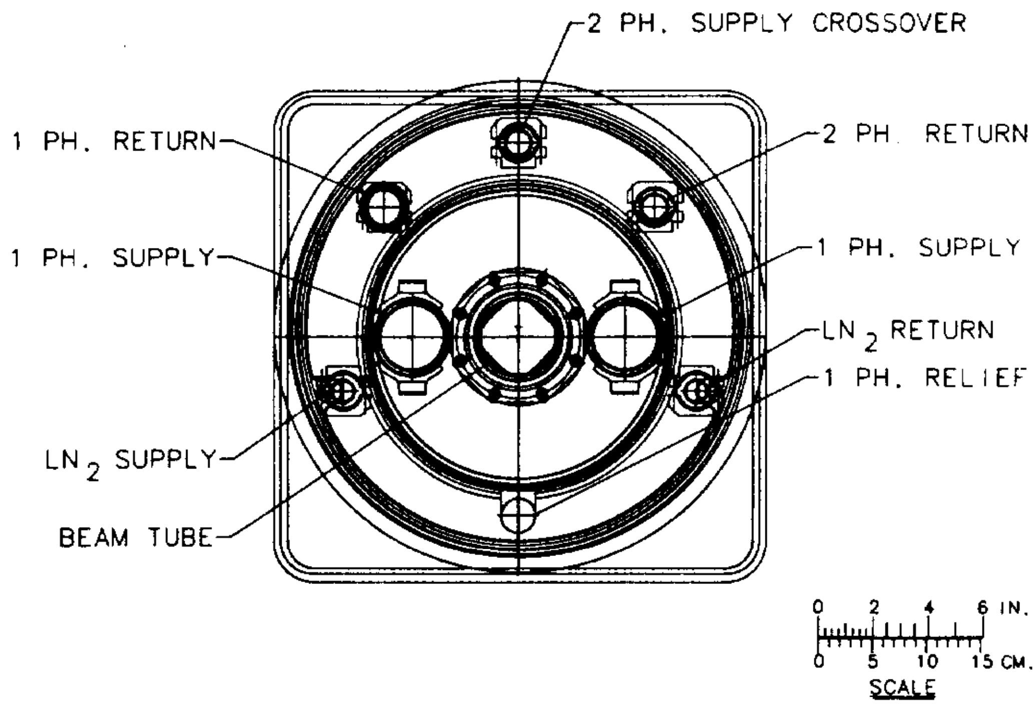

Fig. 2. Interconnect Cross Section

BEAM TUBE

To avoid any diminishing of beam luminosity at the interaction regions, and to provide necessary cooling to the coil the beam tube was fabricated from standard Tevatron dipole beam tube material ASTM A-276 304N STN STL in a 73.9 mm (2.908 in) square geometry with rounded corners. The beam tube is under external pressure during normal operating conditions and quench. Tests and calculations determined the point of inelastic buckling to be 524 k Pa (76 psi). This became the critical component in determining maximum allowable internal pressure for the triplet cold masses. The interconnect consists of a welded ASTM A-276 316L stainless steel bellows with a male metal seal Conflat style flange on the lead end of the magnet and a mating flange on the return end of the adjacent magnet. The bellows is retracked by mechanical means prior to installation as a protective measure and to facilitate installation.

INSULATING VACUUM

The outer vacuum shell interconnect consists of a 457 mm (18 in) diameter hydro-formed ASTM A-276 316L stainless steel bellows with a male 'O' ring flange on the lead end of the magnet and a 457 mm (18 in) dia ASTM A-312 stainless steel pipe section with a female flat flange on the return end of the adjacent magnet. The bellows is retracked by mechanical means prior to installation as a protective measure and to facilitate installation.

SUPERCONDUCTING BUS LEADS

The triplet interconnect requires the splicing of 3 doubled superconducting lead pairs at the interface of the 6 power lead box to the Q2 magnet (see fig. 3). The power bus, for the adjacent Q3 and Q4 magnets, is carried thru insulated channels in the cold iron assembly.

The leads are doubled up during assembly of the coil. The leads are further insulated prior to installation of the lead block holders. The insulation system consists of wrapping each single lead pair with .001 x .375 wide Kapton tape two thirds overlap. In addition to the above, a layer of .005 x .375 wide DMD (Dacron Mylar Dacron) one half overlap is added. The double lead pair is then insulated with a layer of .005 x .375 wide DMD. Shrink Mylar is then applied to the doubled lead pair. The double lead pairs are mechanically fastened at two inch intervals using Kevlar thread which is tied off, knotted and bonded using a cyanoacrylate adhesive.

The leads, upon exiting the magnet end plate are guided and mechanically held against the magnet end plate using a split G-10 block. The insulated leads are routed to the G-10 lead holder which guides and separates the leads, provides mechanical support and electrical insulation (see fig. 4).

CONCLUSIONS

A number of mechanical and cryogenic subsystems were successfully designed and made operational. The Triplet sets have been installed and cooled down at B0. The interconnect design has proven to be reliable and straight forward to install.

The experience gained in this program is being used to guide designers working on the current generation of SSC dipole magnet interconnects.

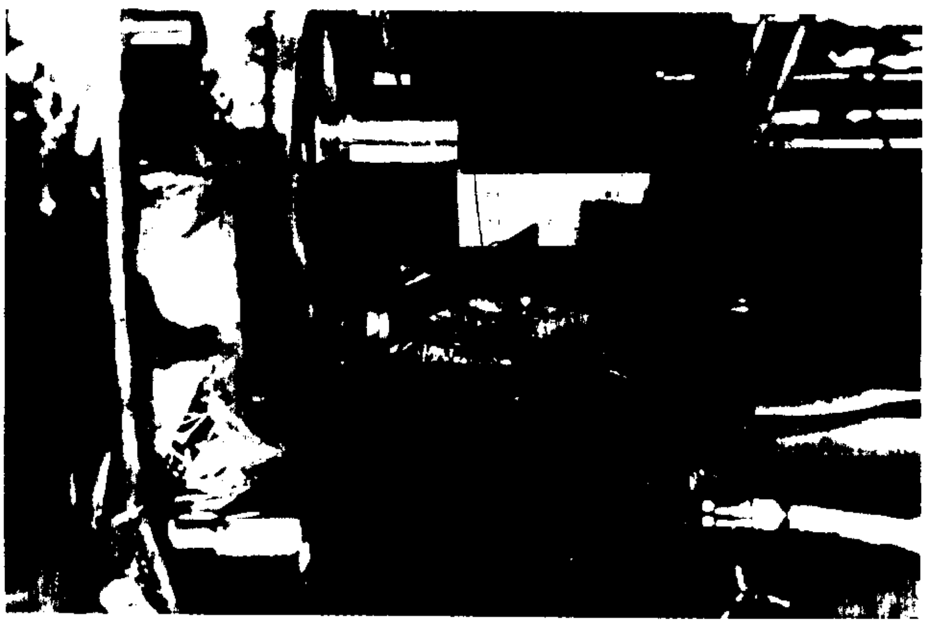

Fig. 3. Splicing of Leads at Q2 Interface

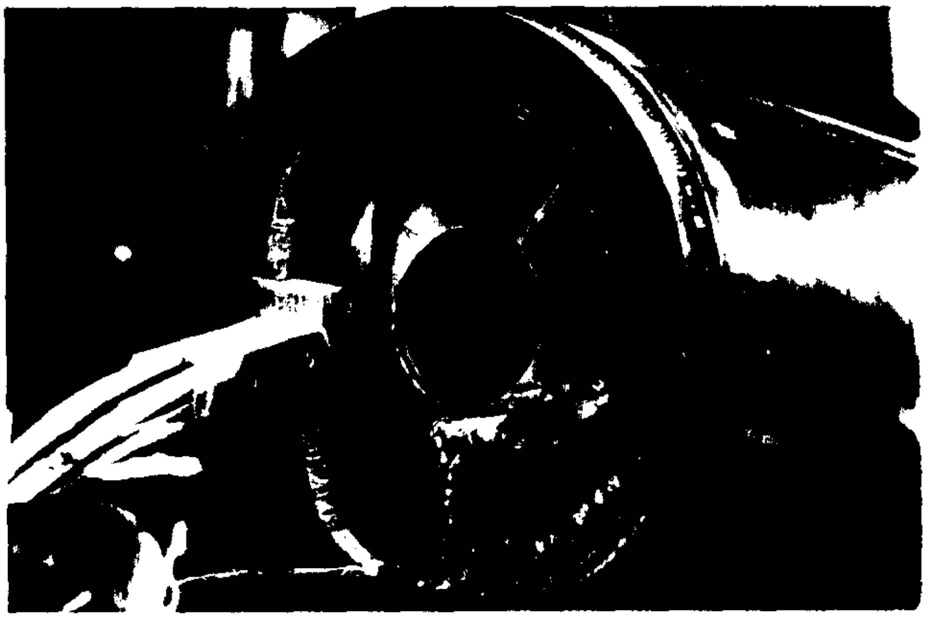

Fig. 4. Lead Route and Lead Holder

ACKNOWLEDGEMENTS

The authors wish to acknowledge the sincere interest, the contribution and cooperation of the Fermilab design, production, procurement, quality assurance groups and the assembly team at Lab 5. A note of praise and admiration also goes to Mrs. K. Swanson for her excellent manuscript typing.

The work as presented was performed at Fermi National Accelerator Laboratory, which is operated by Universities Research Association, Inc., under contract with the U.S. Department of Energy.

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