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A WARM BORE CRYOSTAT FOR THE TESTING OF A POTENTIAL ILC SUPERCONDUCTING QUADRUPOLE MAGNET AT SLAC

Weber T. B., Adolphsen C., Nicol T.H.*, Racine M., Rogers, R., Spencer C. M., Thompson, E., Weisend II, J.G.

Stanford Linear Accelerator Center, 2575 Sand Hill Rd, Menlo Park, CA 94025,USA
*Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510, USA

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This paper will present the design and status of the cryostat system.

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DESIGN

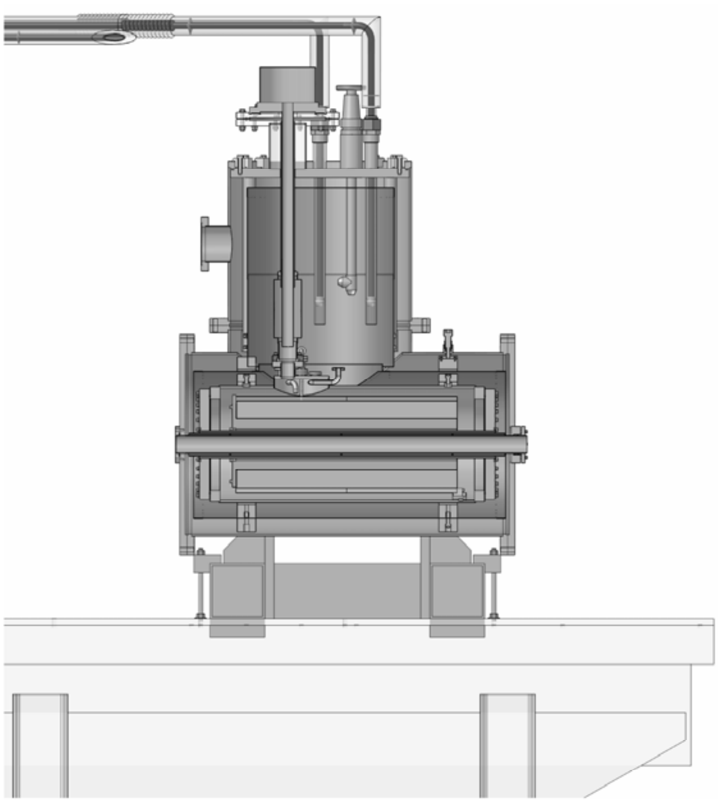
System Overview

The requirement that the magnet be constrained and have a warm bore presented a unique problem to the design of the cryostat. Additionally, the quadrupole when used in the ILC cryomodule is cooled by forced convection, while the available cryogenic system for the test stand required the use of bath cooling. The resulting design has the magnet mounted in a small helium vessel surrounded in turn by a LN_2 cooled 80 K shield and a room temperature vacuum vessel.

The experiment will take place at the SLAC Magnetic Measurements Facility. Liquid helium for the magnet will be supplied from a 500 l Dewar which in turn will be filled by a 2000 l liquid helium trailer. Liquid helium for the test will be made at one of the large liquefier/refrigerators at SLAC and transferred to the trailer. The estimated heat load to 4.2 K results in the trailer requiring refilling roughly every 7 days. More than one 2000 l trailer exists, so that experiments can continue while a trailer is being refilled.

There are 3 paths for the helium from the 500 l liter Dewar to take once it enters the cryostat. One path is for cool down and enters from the bottom of the helium vessel. A second enters the top hat on the Dewar and will be used to fill the magnet once it is cold and maintain the helium level during operations. A third line can be used to force liquid helium into the space between the magnet coils and the warm bore in case there is evidence of helium gas bubbles developing in this space and affecting magnet performance..

LN_2 will be supplied by a separate 2000 l trailer. Both the nitrogen and helium boil off from the system will be vented to atmosphere. Figure 1 shows a cut away view of the magnet cryostat. Figure 2 shows its connection to the cryogenic supply.



. Figure 1 Longitudinal cross section of the quadrupole magnet test cryostat

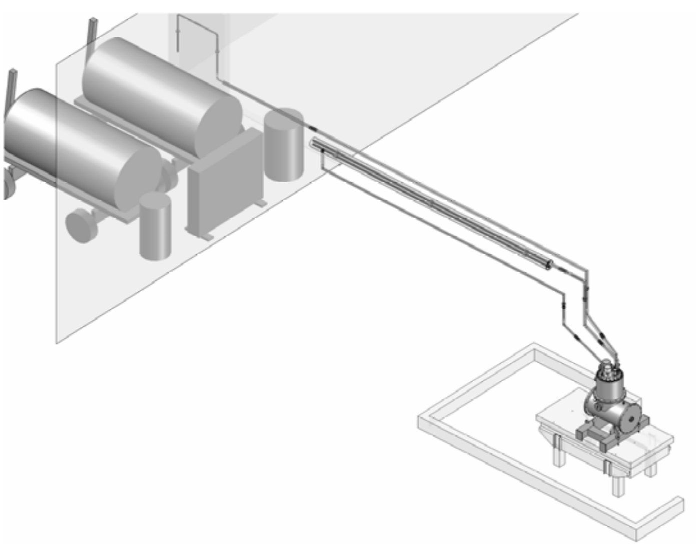


Figure 2 Connection of magnet cryostat to the cryogenic supply. Trailers for LHe and LN_2 located outside the test lab are shown.

Helium Vessel

Fixing the provided magnet within the helium vessel was challenging due to the competing requirements of very low vibration and minimal heat leak. Several designs were rejected when the motion levels were analyzed. When all elements of the requirements were factored in it was decided G-10 rings would attach the magnet to the helium vessel with a calculated heat load of 1.5 W to 4.2 K and 7 W at 80 K. Limiting the heat flux from the outer vessel G-10 supports requires the supports to be made into 2 separate concentric rings with a copper liquid nitrogen cooled shield between the rings. The copper liquid nitrogen shield extends around enclosing all the helium space. The bolts from room temperature to liquid nitrogen temperature are made from titanium to reduce the heat flux into the G-10. The resulting resonant frequency of the helium vessel is calculated to be 53 Hz perpendicular to the axis of the magnet and 58 Hz along the axis of the magnet, significantly above the region of concern. A cross section of the attachment between the magnet and vacuum vessel is shown in Figure 3.

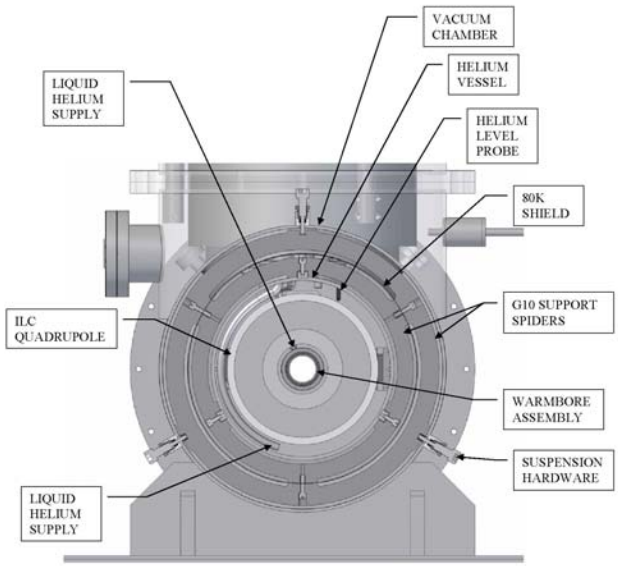


Figure 3 Cross section of ILC quadrupole cryostat

Warm Bore

The design of the warm bore was dictated by the construction of the magnet as it was already built before the cryostat was designed (see Figure 4). Space limitations on the bore coupled with the minimum diameter of the bore to provide for the test fixture limited the options available. A 76.2 mm bore tube was picked for the inner magnet vessel and a 50.8 mm bore tube was selected for the warm bore. Both tubes are electro polished internally to 0.2 micrometer finish while the exterior has been mechanically polished and then electro polished. A copper shield will be placed between the 2 tubes and it will be cooled by liquid nitrogen. Calculated heat flow from the warm bore to the copper shield is 4 W at 80 K with a further loss of 1 W to 4.2 K.

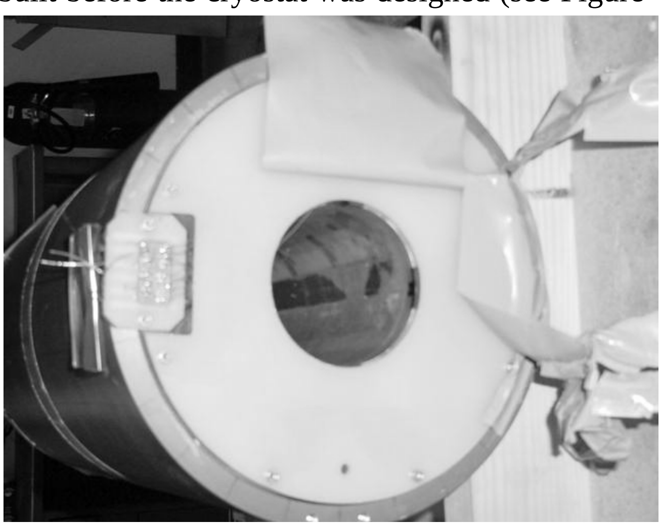


Figure 4 Completed superconducting quadrupole magnet produced by Ciemat.

The total heat leak to the 4.2 K and 80 K levels in the cryostat is estimated to be 5 W and 16 W respectively.

Power Leads and Controls

The power leads were designed and supplied by DESY and will be vapor cooled by cold gas from the magnet cryostat. A separate lead test has been carried out at SLAC in June 2006 and the required flow appears to be about 20 slm when operating the leads at 60 A. DESY reports the helium consumption for the leads at 100 mg/sec.

A National Instruments Compact FP unit will handle cryogenic control. The quench detection will be provided by a National Instruments Compact R10 unit.

STATUS

The design of all but a few ancillary parts is complete and construction of the cryostat components is underway. The magnet has arrived at SLAC and been machined to accept the mounting piece. The main vacuum vessel has been machined, welded and leak tested (see Figure 5). The development of the control and quench detection systems is well underway. Currently, it is expected that the first cold test of the cryostat will occur in September 2006 with the first magnetic measuring run shortly thereafter.

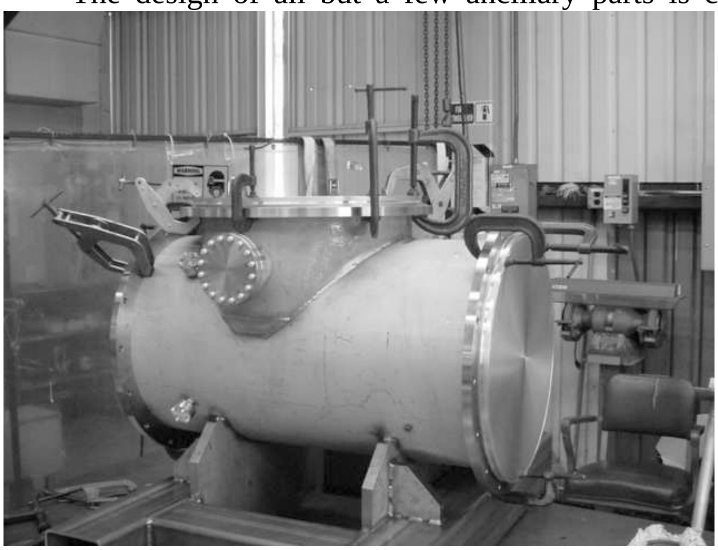


Figure 5 Vacuum vessel assembly for the quadrupole cryostat undergoing leak test at SLAC.

SUMMARY

A warm bore cryostat for testing prototype ILC quadrupole has been designed and is under construction. First experiments using this cryostat are expected later this year. With some effort, this cryostat may also be used to test other prototype ILC superconducting magnets.

ACKNOWLEDGEMENTS

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