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THE LIQUID HELIUM THERMOSYPHON FOR THE GEM DETECTOR MAGNET

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INTRODUCTION

The GEM detector magnet, a horizontal solenoid 19.5 m in diameter and wound with a niobium-titanium cable in conduit, will be located with its axis 19.5 m below grade. The conductor is wound on the inside of an aluminum bobbin which is cooled by liquid helium which flows by natural convection in a thermosyphon loop from a large storage dewar located at the ground surface. The function of the thermosyphon system is to absorb the environmental heat load as well as any internally generated heat. In the first category is included that heat which is transferred to the magnet by way of the mechanical supports, the insulation and the current leads. The internally generated heat includes the resistive heating within the normally conducting conductor splices and the inductive heating of the bobbin during current transients. Though similar systems¹ have been employed elsewhere, there are some unique aspects to the present design. By taking advantage of the large vertical head available, the parallel heat exchanger passes within the magnet remain sub-cooled, thus insuring single phase coolant within the magnet. It is believed that this will be the first instance of such a large vertical head being used to this advantage in a helium system.

SYSTEM DESCRIPTION

A flow schematic for the entire helium system, of which the thermosyphon is part, is shown on Figure 1. The refrigeration of the current leads is shown on Figure 1 as being provided by a separate forced flow circuit which also provides supercritical coolant to the conductor conduit to enhance conductor stability. An option to provide the current lead refrigeration with the thermosyphon is presently under consideration.

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¹Lottin, J.T. and Duthil, R., Aleph Solenoid Cryogenic System, Proc. ICEC 12, Butterworth, 1988.

Because of the need for an extreme level of reliability, the system has been configured to minimize both the total number of actively controlled cold valves and the number of active control elements in the experimental hall.

HEAT LOADS

The steady heat loads are estimated on what we believe is a conservative basis at 0.8 kW. The inductive heating of the 7.6 cm thick bobbin wall has been analyzed by Radovinsky². The bobbin wall is segmented in both the axial and circumferential directions to reduce the heating during current transients, and as a result, the heat generation on charging which is done at a slow rate (eight hours) is low. The heating on emergency discharge which occurs exponentially with a time constant of 100 s is another matter, however. The bobbin is assembled from twenty four spools, each with a 1.2m axial dimension, which are electrically, and therefore, to some extent thermally isolated from each other. During emergency discharge, Radovinsky calculates a peak heating in the end spools of 1.8 kW at 9 s which is followed with an exponential decay.

THERMOSYPHON THERMODYNAMICS

There is a slight warming of the liquid helium as it descends from the storage reservoir at the surface³ and then a much more significant warming as it is heated in the bobbin heat exchanger and then finally some vaporization as the hydrostatic head is reduced at the upper end of the return leg. The heating on the return side of the thermosyphon gives rise to the bouyancy which drives the natural convection flow. For 1.3 atmospheres pressure in the surface reservoir, the pressure at the bottom of the thermosyphon is 2.1 atm. and 1.8 atm. at the top of the magnet. With a worst case storage temperature of 4.5 K at the surface (saturated at 1.3 atmospheres), the temperature at the bottom of the thermosyphon is 4.6 K and if we specify a maximum temperature of 4.75 K at the top of the magnet, for the assumed heat load, a flow of about 0.7 kg/s is needed. The 4.75 K is well below the current sharing temperature of 7.5 K. The quality of the return flow at the surface is about 7%.

PIPING

The supply side, or down comer, piping is liquid nitrogen shielded to minimize the inlet temperature to the magnet. The supply and return piping is sized based on a balance between the frictional head loss and the differential of the hydrostatic head between the two the two sides of the flow loop. On this basis, for a mass flow of about 700 g/s, 3.5 inch pipe is chosen for the supply side and 4 inch pipe on the return. For the bobbin heat exchanger, a single 3/4 inch tube on each bobbin segment looks about right when considering the frictional pressure drop, however, a somewhat larger size, or perhaps multiple tubes, would be desirable from the standpoint of increasing the bobbin heat capacity to stabilize the temperature during rapid turn down of the magnet current. The liquid helium contained within a one inch ID heat exchanger tube has twice the heat capacity of the 3 inch thick aluminum bobbin at 4.5 K. These sizes appear to be more than adequate for the cool down flow which is limited by compressor and nitrogen heat exchanger capacity.

²Radovinsky, A., Joule Heating of GEM Detector Bobbins, MIT-GEM-EM-014, 16Dec 93.

³ Because the energy equation requires the conservation of the sum of the enthalpy and elevation, a warming results from a decrease in elevation.

Fig. 1 GEM Magnet, Helium Flow Schematic

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