A NEW FACILITY TO TEST SUPERCONDUCTING ACCELERATOR MAGNETS[*]

M.J. Lamm, J. DiMarco, E. Desavouret, S. Feher, J.D. Garvey, C. Hess, P.J. Limon, J.M. Nogiec,
D.F. Orris, J. Pachnik, T. Peterson, S. Sharonov, J. B. Strait, C. Sylvester, J.W. Sim, M. Tartaglia,
J.C. Tompkins, A.V. Zlobin
Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500

Abstract

Future high energy accelerators such as the Large Hadron Collider require accelerator magnets with the highest possible fields. For NbTi conductor magnets, this means operating at superfluid helium temperatures in the range of 1.8-1.9K. As part of Fermilab's superconducting magnet R&D program, we have built a facility to test magnets in a vertical dewar of superfluid liquid helium. The dewar is designed for magnets up to 4 m length and 620 mm diameter, with a temperature range of 1.8 K to 4.4 K and 1 atmosphere helium. The power system consists of 10 kA and 8.8 kA power supplies operating in parallel, with bus work and an extraction circuit that can accommodate up a 18kA excitation current. A description of the facility as well as operational experience from the first magnet tests are presented.

1 INTRODUCTION

Testing superconducting accelerator magnets in a vertical dewar can be time and cost effective since it eliminates the need for the construction and installation of a magnet-specific cryostat. Thus the development of a new facility to accommodate large diameter, high current magnets in a vertical dewar was an early consideration for Fermilab's participation in the LHC high gradient quadrupole (HGQ) program [1].

There are three major components to this new vertical magnet test facility (VMTF): 1) a dewar capable of efficient operation over a wide range of temperatures, 2) a high current power system with an energy extraction circuit and protection heater firing units and 3) hardware and software for control and monitor of the dewar, power supply and magnet instrumentation.

In preparation for the first HGQ magnet, VMTF has been commissioned through the tests of Tevatron Low beta quadrupoles (LBQ) [2].

2 VERTICAL DEWAR

Figure 1 shows a cross section of the vertical dewar [3]. The top of the dewar is recessed 1 meter from the VMTF floor to achieve the crane hook height required for manipulating 4 meter long magnets. The helium shell is separated from the outer vessel by a vacuum space and superinsulation, and an 80K shield. The helium volume is divided into two chambers, a 4.2K, 1 atm helium space for the vapor cooled leads and helium reservoir for the heat exchanger, and the lower space for the magnet at 1 atm and 1.8K-4.4K.

The lambda plate which separates these chambers consists of a G-10 plate bonded with epoxy to a tapered stainless steel ring. This ring is matched to a corresponding tapered surface on the dewar inner wall. Imperfections in the lambda plate-dewar seal have been improved by bonding a layer of stycast to the lambda plate between the stainless steel surfaces.

There are several penetrations through the lambda plate, for instrumentation, superconducting power leads and pressure relief valves. The lambda plate supports the weight of the magnet. The maximum length (diameter) of a magnet that can be tested is 4 m (620 mm). For small magnets, the helium volume can be significantly reduced by using a closed-cell foam displacer [4].

The temperature of the volume below the lambda plate is controlled through a built-in heat exchanger. This heat exchanger consists of 4 m long OFHC copper tubes in direct contact with the 1 atm helium in the lower chamber. The temperature of the liquid helium in the heat exchanger is controlled by a vacuum pump system, which is capable of removing 30 W of heat at 1.8K.

3 HIGH CURRENT POWER SYSTEM

Power system as shown schematically in figure 2 consists of two high current power supplies, an energy extraction circuit and water cooled copper bus. The power supplies

---

[*] Work supported by the U.S. Departement of Energy.

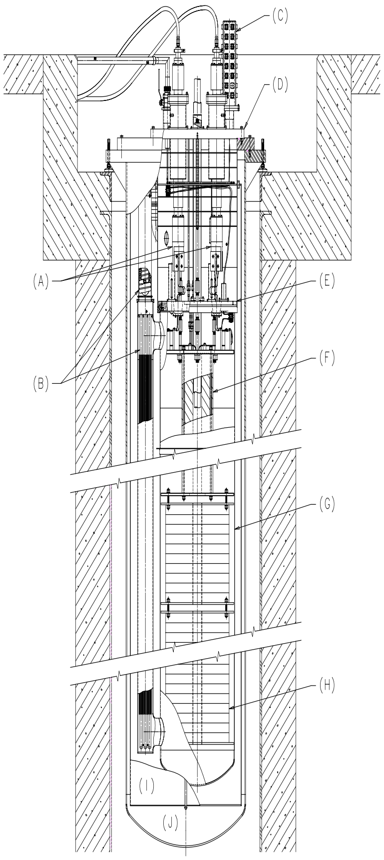

Figure: 1 Vertical dewar is located in a fiberglass lined concrete pit which is recessed 1 meter from the floor: (A) Vapor cooled leads (B) Heat exchanger, (C) Instrumentation tree, (D) Top Plate, (F) Magnet, (G) Helium Shell, (H) Displacer, (I) 80K Shield, (J) Vacuum shell

are Dynapower[5] 12 phase 40 V supplies. For these first commissioning tests, only one supply 10kA was required as the quench current for LBQ magnets is approximately 7kA at 1.9K. The power supply is controlled through a Fermilab built interface board [6].

The extraction circuit consists of a dump switch, a dump resistor and a personnel protection interlock system (shown in figure 3). The dump resistor consists of 12 90 mΩ stainless steel coils that are configured through parallel and series connections. A typical setting of 60 mΩ has a maximum energy deposition limit of 3 MJ/extraction. The dump switch[7] contains 10 parallel 1800 A SCR's in parallel with the dump resistor. Current is diverted from the SCR's to the dump resistor by removing the SCR gate and discharging the negatively biased 9000 μF capacitor bank across the SCR's.

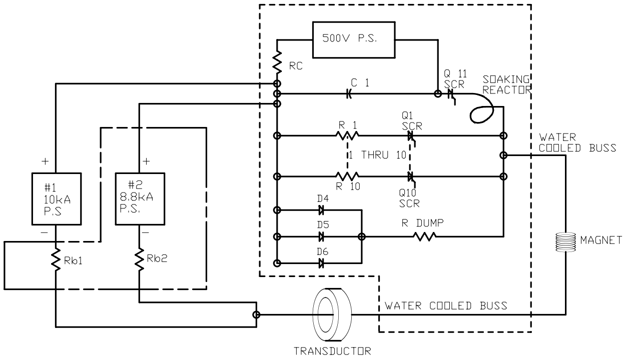

Figure: 2 High Current Power System Dashed line represents 18kA energy extraction circuit. Phantom lines represent upgrade to 18.8kA (Summer 1997).

4 INSTRUMENTATION AND SOFTWARE

Instrumentation is used to monitor cryogenic status and mechanical strain transducers, detect and characterize quench propagation in the superconducting magnet, and control power supply and cryogenic operation. Magnetic measurements are not yet fully implemented and will not be discussed.

Like tasks were group together into VME crates controlled by Motorola MVE167 processors. For example, thermometry and strain gauge control and monitoring is performed through programmable current sources, and read out through a FET based MUX.

Figure 3 shows the flow diagram for the quench detection and characterization electronics. The system includes 100kHz data loggers for recording quench voltages[8], a Change of State Module (COS) which records the time of various TTL level changes and relay contact closures[9] , a combined function digital IO,DAC and ADC board for heater power supply control [10] and a Fermilab built Quench Logic Module (QLM). The QLM performs the following tasks:

1) Checks the status of the extraction and power supply interlocks to give permission for power supply turn on.
2) Scans for change of states in the quench detection circuits for indications of a quench or otherwise fault condition and
3) Issues the commands subject to programmable time delays to phase off the power supply, fire the dump switch capacitor bank, fire the quench protection heaters and trigger the quench characterization data loggers.

The software monitoring and control system is described in another contributed paper [11]. The system includes graphical user interfaces, archivers, a data acquisition subsystem and direct control components.

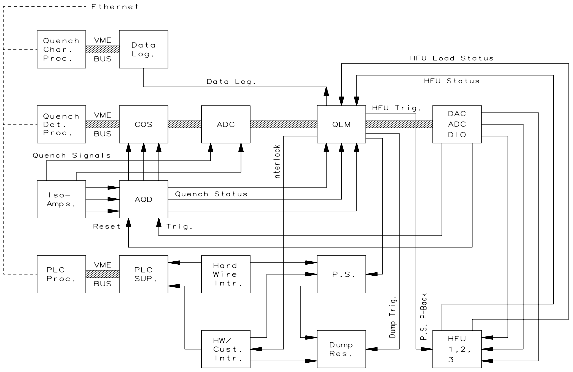

Figure: 3 Block diagram of quench detection-quench characterization circuit

5 COMMISSIONING WITH THE TEVATRON LBQ

Two commissioning runs were performed. For these runs, helium was supplied through portable 500L Helium dewars. In the near future we plan to connect the VMTF helium supply to the magnet test facility liquifier. During December 1996, the cryogenic operation of VMTF was commissioned. A 1.4m Tevatron Low Beta Quadrupole was successfully cooled to 1.9K. As a result of this study, improvements to the facility were made including a larger diameter helium transfer line and a better lambda plate seal.

In the April-May 1997 run, a newly constructed 1.4m Tevatron Low Beta Quadrupole was tested in VMTF. The cryogenic part of the program included determining heat loads as well as gaining operational experience in Helium I and Helium II. The magnet evaluation part of the program includes quench studies, splice resistance measurements, strain gauge transducer studies and quench protection heater studies.

Figure 4 shows the cool down from 4.2 K to 1.8K. Note that the thermometer below the lambda plate is above the heat exchanger and thus does not benefit from convection cooling. At the lambda point, all thermometers converge to the superfluid temperature.

6 CONCLUSIONS

We have successfully tested a Fermilab Tevatron Low Beta quadrupole in our new magnet test facility. The dewar operates well in both normal and superfluid helium. In this test with approximately 800 L of helium underneath the lambda plate, we reached a temperature of 1.9K from 4.2 K in about 4 hours; A bath temperature of 1.7K has also been achieved. For 3.7K operation, a vertical gradient of 10 mK or less over a 4 meter dewar length was possible due to the convection flow through the dewar heat exchanger. The VMTF instrumentation, a combination of commercially available and in-house designed and built, was successfully operated through graphical user interfaces on UNIX work stations.

.

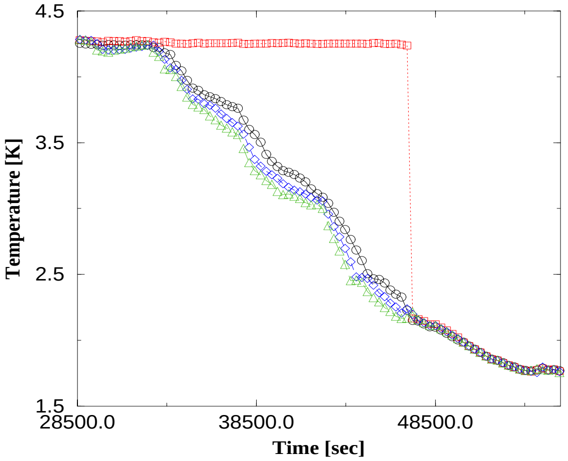

Figure: 4 Cooldown from 4.2K to 1.8K as measured by thermometers at different vertical positions under the lambda plate. The top thermometer (squares) is located directly below the lambda plate. Time scale is arbitrary.

7 ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Magnet Test Facility staff, in particular Clark Reid, Al Rusy, Bill Mumper, Steve Helis and Ed Schmidt, and the Fermilab Beams and Particle Physics Power Systems Groups.

REFERENCES

[1] R. Bossert et al., “Development of a High Gradient Quadrupole for the LHC Interaction Regions”, ASC 1996, Pittsburgh (1996)
[2] A. D. McInturff et al., “The Fermilab Collider D0 Low-β System”, EPAC, Rome, Italy, Vol. 2. p. 1264, June 1988.
[3] Manufactured and co-designed with Fermilab by Meyer Tooling and Manufacturing, Oaklawn IL
[4] Rohacell, Rohm Gmbh, Darmstadt
[5] The Dynapower Corp. Burlington, VT.
[6] S. Sharonov et al. “An Embedded Power Supply Controller”, presented at this conference.
[7] A. Visser, “Design Note of a 10,000V, 1,000Vdc Solid State Dump Switch for the Magnet Test Facity, Fermilab TM-1692.
[8] Pentek 4201A-004 MIX baseboard with 4275 ADC’s
[9] VMIVME-1160A VME Microsystems International Corp, Huntsville, AL
[10] MD-DAADIO, Matrix Corp, Raleigh, NC
[11] J.D. Nogiec et al., “A Distrubuted Monitoring and Control System” presented at this conference.