SSCL-N-797

1st Workshop on Testing of SSC Magnet Cryogenic Performance

Edited by
Quan-Shen Shu

Magnet System Division
Superconducting Super Collider Laboratory*
2550 Beckleymeade Ave.
Dallas, TX 75237

February 1992

*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

CONTENTS

Brief Report of The Workshop on Testing of SSC Magnet Cryogenic Performance

Quan-Sheng Shu, Scott Peck and Donald Franks

March 8,1992

A workshop on testing of the SSC magnet cryogenic performance was held at the SSC laboratory on 2/11/92, followed by a working group meeting the next morning (2/12/92). There were 41 participants from B & W, BNL, GD, FNAL, Martin Marietta, NIST, SSCL and WEC. This workshop had a total of 11 plenary presentations, which reviewed past calculations and measurements and discussed plans for future measurement and modeling analyses. The working group was divided into two subgroups. One group was assigned to review and plan cryogenic testing, instrumentation and test facilities. The other group focused on thermal models, process control and component testing.

A Brief Summary of The Workshop Presentations

As the opening talk, J. Tompkins (head, Test and Data Management Department, SSCL MSD) addressed the purposes of the workshop and the approaches to pursue the goals. He also described the outline of what the working groups should accomplish.

The collider requirements and the operational impact were introduced by M. McAshan (head, Cryogenic Department, SSCL ASD). The following static heat leak budget of Collider Dipole Magnet (CDM) and the collider sector were presented:

Temperature, K	CDM, W	Sector, W
4.2	0.363	306
20	5.055	2121
80	37	12810

He introduced the requirements of the CDM pressure drop of ΔP=70 Pa, required to drive He flow through the dipole; the CDM maximum ΔT is 50mK. He talked about the minimum cryogenic piping sizes, which were given from the CDM PID specification (9 Jan, 1992). Insulation vacuum and vacuum leakage were also discussed.

T. Nicol from FNAL presented the calculations and measurements of heat leaks in 40 mm and 50 mm dipole magnet cryostats. The post design, the suspension heat leak measurement dewar, and the MLI heat leak measurement facilities were discussed in detail. Also, the results from the cryostat thermal model with an open cycle measurement were reviewed. The performance of the cryostat met the heat leak budget.

The ER magnet string tests were summarized by J. Weisend (SSCL). The measurements are made on five SSC 40 mm dipoles in order to determine if the magnet is within its heat leak budget, not necessarily to determine the source of any problem. The 20 K heat leak is generally 2 times above budget and the 80 K heat leak is generally at or below budget. The data suggest an intersection, and thus thermal short between the two shields. The tests also show that the various methods of connecting the interconnect shield (rivet, weld and fasteners) are essentially equivalent.

M. Kuchnir (FNAL) gave a history of how people at Fermilab measured the heat leak in the Tevatron magnet. They used the same principles, however, one of their test arrangements is unique. They tilted the magnet string 25 degrees from horizontal and measured the boiloff as a function of the liquid level. This enabled them to estimate the heat leak in each section of the magnets.

BNL and FNAL are the two important contributors who tested all of the SSC dipoles. A. Prodell (BNL) described their cryogenic system and test stands. They have the capability of keeping a magnet cold with 150 g/s single phase He. The changes of temperature, pressure and flow rate during and after quench were presented. The cooling integral was compared with the magnet storage energy (87% at 6000A and 64% at 8413A). T. Peterson (FNAL) gave an evaluation of single magnet tests at Fermilab. The instrumentation in the cryogenic test stand was introduced in detail. The cryogenic parameter changes associated with quench were described also. The influence on quench due to warm bore heat leak were discussed

D. Frank and R. Pletzer (SSCL) introduced their dynamic thermal model. This modeling objectives include design issue trade studies for cryostat, mechanical stress analyses, cryogenic system sizing and design as well as cold mass thermal analyses and design. They discussed the difinition of magnet heat leak and the dipole heat leak budget. The magnet thermal test was also considered. They used the thermal model to analyze the thermal performance of the magnet and heat leak; the initial results were presented.

Q. S. Shu and I. Syromyatnikov (SSCL) introduced the MTL cryogenic test capabilities. They described several outstanding issues on heat leak measurement. These included the approaches to reduce the influences of the heat leak through the interconnect regions and of the temperature differences in a He stream. The results of temperature increase as functions of heat load and flow rate were presented both for static heat leaks and warm bore heat leaks through the beam tube using a dynamic thermal model. The specially designed thermometer system with differential transducer allows them to measure the temperature difference more precisely. Magnet cool down simulations were also presented.

J. Weisend gave the capability and plans of the ASST (the magnet string test). In phase 1, this string will have five 50 mm dipoles, an SPR spool, a quadrupole and 2 end spools. The experiments are planned to start in June of 1992 and the congressional milestone must be met by October, 1992. Heat leak measurements will be made on 20 K, 80 K and to the cold mass.

Scott Peck from GDSS, the CDM subcontractor, presented the status of GDSS cryostat design and thermal performance, and proposed an integrated test plan to validate cryogenic performance. Scott also discussed the technical constraints on testing, a prototype instrumentation list, and programmatic constraints on testing. Finally, he summarized the several options for the heat leak measurements.

Report on The Working Group Discussion

The Working Group meeting of the cryogenic performance testing was conducted following the plenary presentation. After a brief discussion of how we were to organize into the A and B Groups, and what was wanted for each to discuss, we then divided into the two working groups. As near term, we consider how to best use FNAL MTF data measurements and testing facilities, and as long term, we discussed how to use string test measurements at the ASST and at one of the MTL test stands with capable of testing three magnet string, as well as how to test for production magnets. Splinter A addressed the topics of single magnet and string testing, instrumentation, and facility constraints.

Splinter B addressed component testing, modeling/analysis, and process control. Process Control is felt needed for the production magnets. It considers design variables and, consequently, what can cause the heat leak to vary between magnets. Its results would be used to determine what should be considered as an acceptable variation.

At Group A, two purposes of testing were discussed: verifying the design and checking production. It seemed to be the consensus that verifying the design will be done primarily in the string test. The industrial people are concerned about defining tests which can be done to check production cryostat quality. They would like these to be done at the vendor's facility, and the test may be of a "go, no-go" nature, i. e. not to provide a heat leak number but just to say it is acceptable or not acceptable. Enclosed herewith are various possible test options in order to verify the design and long term production check.

For a single magnet test, the following ideas were discussed

(1) use of a cold stand with special designed Feed/End cans to reduce the end effects plus good instrumentation,
(2) lower inventory to make higher sensitivity,
(3) warm flow through cold mass and measurements of the heat load at 20 K,
(4) use of a warmer 20 K shield to amplify the heat leak,
(5) use of superfluid He,
(6) float 20K shield, watching the equilibrium temperature and the cold mass heat load,
(7) Watching the pressure increase in a magnet caused by heat leakage,
(8) the "gas bulb test",

Then, the magnet string as a test vehicle was considered :

(1) special string with three or five magnets, but only replacing the middle one to have consistent end effects. The one in the middle is the test magnet. This would minimize heat leak to the magnet "ends". If not controlled, this end heating can be substantial.
(2) use of regular string testing to obtain more heat leak information

The three other special issues were discussed

(1) how the dipole CDM 323 at FNAL MTF can be used as a vehicle with more sensors inside,
(2) verify design and not do cold production test, e.g. electric resistance check,
(3) better instrumentation, e. g. differential VPT group.

The Group B, first defined the mission of each element in the context of an overall plan to verify heat leak. The group determined that the role of analysis and modeling is primarily to do sensitivity studies on both a full cryostat and on components. These will drive out appropriate test conditions, e.g., the minimum shield flow rate that will provide maximum temperature rise sensitivity without affecting the heat leak. Sensitivity studies can also provide guidance for optimum instrumentation types and locations. They can be used to determine the feasibility or practicality of monitoring particular process control variables and to establish limits on those variables. In B Group meeting we also discussed the possibility of "sensitivity" studies to drive out test conditions. The possibility of operating the magnet thermal shields at higher temperatures was one such example. How sensitive is cold mass heat leak to a shield temperature higher than 20 K ? Also, Tom Nicol raised the question of how well known are the thermophysical properties used in the magnet? Support posts are an example. Do we need tests to determine the various material properties?

As regards the Process Control considerations of the multi-layer insulation (MLI) there were considered to be the possibilities of variations in layer density, seams and gas pressure. There were also the possibilities of changes in emittance of the material from batch to batch as well as changes in view (angle) factors inside the cryostat.

Similarly, as regards the support post heat conduction, variabilities were considered to be such as material properties, contact heat transfer coefficient and geometry. The other significant effect we discussed for Process Control implications was that of "thermal shorts" due to such as MLI blanket compression, shield contacts and straps. Test data would be needed here to assess their various effects.

Finally, modeling can be used to establish the viability of test procedures, i.e., the ability of and degree of accuracy to which a test can measure heat leak.

The role of component testing is to provide material properties data for the thermal models and for process control checks, to measure component heat leak contributions for verification against the design targets, and to provide heat fluxes and temperature distributions for calibration and validation of the models.

Recommendations and Follow Up Activities:

1. Thermal analyses should include parametric studies of performance based on realistic spreads in properties of materials and variation in production. We need to be able to understand an "average heat leak" and the expected variation around the average.

2. It was stated several times that most of the heat leak budget problems observed in the ER string test were traced to defects in assembly of components: MLI compaction, shields in incorrect position, etc. Novel test for fabrication integrity were suggested, including the possibility of vibration testing and/or electric tests. Up to now, cryostat inspection has been limited to piping positions at the end of the magnet.

3. There was general agreement that the 20 k and 80 K shields will have heat leaks of such a magnitude that measurement could be possible with single magnets, although it will not necessarily be done at the design flow condition. The cold mass heat load of about 0.3 W was a focus of the working group discussion. We should find a reliable way to resolve this problem.

4 The possibility of limited thermal testing on DCA 323 (at FNAL) using various sensors.

5 Al Prodell (BNL) said that the single phase He flow at BNL MTF could only be reduced to about 100 g/s. If they were to go lower than this it could damage gas bearings in the flow system. Unfortunately, this is much too high to get any cold mass heat leak data from on these magnets. However, he did mention the possibility of installing a "bypass" in the MTF single phase He line to the test CQM. He said he would try to call Franks to give a report on what he saw for the possibility of the bypass.

6. General Dynamics doing "sensitivity analyses" on variables in the magnet thermal design. See what variables have the most effect on heat leak.

7. Randy Pletzer conducting various transient thermal analyses with his magnet math thermal models.

8. The proposed NASA/Lewis Research Center test on measuring outgassing and resulting 80 K MLI performance during pump down.

9. The possibility of measuring emittance values of various cryostat materials at cryogenic temperatures by Lockheed Research.

10. The working groups should continue to evaluate and refine the various test approaches considered.

11. A follow up meeting will be scheduled at GDSS sometime in April. the agenda will be developed by the steering group based on the ongoing work.