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Second Workshop on the Testing of SSC Magnet Cryogenic Performance

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Report of the "Second Workshop on Testing of SSC Magnet Cryogenic Performance"

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A second workshop on testing of the SSC CDM cryogenic performance was held at General Dynamics in San Diego on 6/29/92. There were 12 participants from SSCL, FNAL, GD, and BNL. Attendees included Bill Boroski, Moises Kuchnir, and Peter Mazur (FNAL), Margareta Rehak (BNL), and Quan-Sheng Shu, Adnan Yucel, Igor Syromyatnikov, John Weisend, Bob Smellie, Jon Simmons, Phil Kraushaar and Don Franks (all from SSCL). Nine presentations were made to review relevant development plans and calculations related to the thermal performance of the CDM cryostats. Three other presentations on cross-flow cooling calculations were made. An open discussion of issues related to a string test of GD prototype magnets was held, followed by a working group meeting. The working group proposed that a string test be pursued, with a parallel effort to define a heat leak test facility that might emulate a string test. We also recommend that Accelerator cryogenics develop tolerance bands on magnet heat leaks as a first step towards quantifying an acceptable sample size of magnets tested for heat leak.

Review of the Purpose of the Workshop meeting

(1) Review the progress in plans, calculations and R&D test results of the magnet cryogenic performance and the cryogenic test instrumentation since the first workshop in Feb '92. (Our discussion all dealt with testing of the GD CDM Production design. We have not addressed any plan for CQM testing. This CQM testing may turn out to be quite different from that for the CDMs.)

(2) Discuss the status of ASST at SSCL and the GD Master Test Plan

(3) Discuss the work on magnet cross-flow cooling calculations and experiments and the issues related to possible String Tests of GD prototype magnets.

Brief Summary of the Workshop Presentations

Scott Peck of General Dynamics opened the meeting with a presentation of the GD approach to assuring the thermal performance of the CDM cryostats. The approach consists of a combination of analysis, test, and process control at the individual component level and at the cryostat assembly level. The point was made that thermal performance assurance consists both of design verification and "as built" performance verification.

Ted Hardy of GD then followed with a review of the development plans for the helium adsorber module, support post, and thermal shields. These components are key players in the thermal performance of the cryostat. The key point here was that testing will verify the thermal performance of these components at the component level.

Next was Don Franks of SSCL, who summarized the testing that will be done on the MLI in the cryostats installed in the ASST. Temperature profiles through the blankets will provide insight into how the blankets perform installed in a string compared to the sample tests done at FNAL.

Quan-Sheng Shu of SSCL then presented results of an analysis of cooldown of a single magnet on the MTL test stand with variaties of cooling procedures using the MTL cryogenic system. Peter Mazur made a comment concerning the history of the cooldown rate, mentioning that actual testing has alleviated early concerns over cryostat warpage and adverse affects on quench behavior and recommends that future cooldowns be done as fast as possible.

A status of the ASST test was then presented by John Weisend of SSCL. There appeared to be no problems with the test and it was proceeding as planned.

Bill Isaacs of GD (substituting for Bob Churchill) followed with a review of the GD test stand instrumentation and relevant portions of the master test plan. There were questions related to aspects of the magnet interface that differ on magnets that are cold tested.

The final presentation related to the thermal performance of the cryostats was made by Igor Syromyatnikov of SSCL, on the MTL Cold Test Stand Cryogenic instrumentation.

Three presentations on cross-flow cooling calculations were then made by Scott Peck (GDSS), Adnan Yucel (SSCL), and Margareta Rehak (BNL). All three presented similar models with similar results which indicate that cross flow cooling is effective in removing heat introduced at the beam tube before it raises the conductor temperature and reduces margin.

Key Thoughts Developed During the Meeting About Magnet Testing

Magnet Cryogenic Testing

(1) Are we going the right way to be sure the cryostats are doing what they should - as regards heat leak ?

(2) The need for testing is driven by the Collider Ring requirement that magnet heat leak to the 4 K Helium does not greatly exceed the budget allocation. This allocation is based on the refrigeration system limit which, in turn, is largely driven by the Synchrotron heating - which is a big heat load in comparison to that of the magnet by itself.

Thermal testing needs to be done of the GD Prototype magnets. This is to ensure the thermal design is acceptable. Such testing also needs to be done of an "on going" sample of the Production design magnets. This is to assure they are being built in keeping with the Prototype design.

Concern is that if thermal design / assembly problems develop in the Production magnets, that without sample testing, these magnets might very well get all the way

into Collider Ring installation First indication of heat leak problems would then be from measurements of the cryogen flows through them. This is a long way down stream on the process. Furthermore, a lot of magnets could have been built by then with inherent problems.

It was agreed that unless all magnet are tested then there will be some risk of thermal problem magnets slipping through and getting installed. Since this is not feasible, some risk must be expected on magnets with thermal problems getting installed in the Collider Ring. Possibly some visual inspection may catch the worst of these.

(3) A related question, then, is how bad does magnet heat leak have to be before it would have to be removed from the Collider Ring? This appears an Accelerator Cryogenics determination.

(4) Consensus on magnet thermal acceptance testing was that the Production magnets need to be tested for heat leak in either a String or something that "emulates" a String. This is for reasons of "end effects" heat leak.

The problem here is that the 4 K heat leak to be verified is very small. In comparison, in a test fixture, such as FNAL MTF or even the planned SSCL MTF, the end effects heating can be formidable. At the First Workshop (Feb '92), Tom Peterson reported that he measured some "3+" watts heating into the 4 K Helium through the CDMs at FNAL MTF. In comparison, their budget value is 0.36 watts.

(5) About using the ASST String for such magnet testing, John Weisend said it was his experience that it took a long time to install magnets into such a String, and is no easy thing. Also, there is a mechanical fit problem, too. The ASST magnets are 600 mm longer than the standard CDMs.

(6) What got discussed as an alternative to ASST was to develop a test fixture that "emulated" - for the test magnet - the adjacent magnets and their temperatures. This would eliminate end effects heating.

This fixture could be in a separate, "Heat Leak Test Facility". Desirability perceived for this is that incoming magnets could be tested in this facility for meeting the heat leak requirements. After passing this testing they would go to the magnetic testing.

Rationale here is that the requisite thermal testing can be done much faster and simpler than the magnetic testing. Also, no electrical connections would be involved here; these are a possible source of heat leak. Ideally, the thermal test could be structured to supply specified cryogenic flow rates and inlet temperatures to the test fixture. If so, the thermal test could then become a "Go / No Go " test, depending on heat leak measured from the test magnet.

Unresolved issues seen on the above measurement include:

A) How precisely can the heat leak into the test magnet be measured ?
It was reported (? by Peter Mazur) that FNAL MTF had problems on measuring the 3 watt heat load that went into the test magnet 4 K Helium, there. Also related to this are concerns about "stratification" in the single-phase he at low flow rates.

B) What is an allowable tolerance on the test magnet heat leak acceptability ? We need to develop a "tolerance band" - how much "over" the limit can the magnet go and still be OK ?

(7) About the test magnets, unresolved issues include :

A) How many magnets do we want to sample test ? GD said the production rate is 10 / day.

B) What amount of time is needed for test magnet thermal acceptance testing ? About this, GD (Bill Isaacs) said they had planned "60 hours" for the time for the magnet thermal testing. It seemed this time is roughly in keeping with what Peter Mazur cited for getting magnets into test at FNAL MTF, too. We need further sure whether the thermal equilibrium is reached in such a period of time.

C) Are special instrumentation / sensors needed on those magnets planned for testing?

(8) About the thermal testing (5.A), above, discussion developed on the possibility of trading the cost of the accuracy on the test magnet heat leak for some increase in the Collider Ring cryogen refrigeration system.

What is the cost for measurement accuracy ? Do we want to spend a lot of money and get the best possible accuracy ? or do we want to investigate the cost (and problems / control issues) involved in increasing the refrigeration capacity of the Collider Ring refrigeration system to accept the possibly somewhat higher heat associated with this magnet testing uncertainty ? Where is the money better spent ?

(9) An Interface Issue that got brought up, but not resolved, was that of the flanges to be used on the GD magnets. These flanges need to mate with SSC hardware for test purposes. It was agreed to defer this issue to Rich Bailey to work out with SSCL, separately. Maybe use flanges that remove for magnet installation into the Collider Ring.

ASST Status at SSCL and the GD Master Test Plan

In this part of the meeting John Weisend and Don Franks presented on their respective involvements with ASST. GD presented a little on their test schedule.

On ASST, John showed pictures of the String magnets and the building. Don presented on plans for RGA measurements of the Half Cell vacuum and also thermal test data reduction.

On the GD testing, they said they had contracted to build two more test stands at Hammond. This would increase their capacity to four stands. Don Franks told GD of his concerns for conducting thermal tests at these stands. The concerns being that they would experience "end effects" heating such as at FNAL MTF and the resulting impact would overwhelm whatever heating flowed through the magnet thermal insulation. Upshot being they would not get any detailed thermal data - just as there are none from the FNAL MTF tests.

Magnet Cross-Flow Cooling Calculations

Three people presented on this. Adnan Yucel presented on his recent modeling work. Also, Scott Peck and Margarita Rehak.

Models involved were all theoretical. There were no test data, yet, to substantiate anyone's models. GD had used some limited test data, though, to show, apparently, there was some change (Reynolds Number effect ?) to be expected on cross-flow 4 K Helium pressure drop versus flow rate through the magnet. Previously, they had not been sure such an effect existed - flow rates though the magnet being in the "turbulent" flow regime where friction factor depends primarily on surface roughness.

Margarita Rehak said BNL had been working on cross-flow cooling for several years, now. Ron Schutt had started the effort. She had now taken it over. She said they saw "mole heating" as the "driving need" for such. Said they saw problems on this cooling arrangement if there was internal leakage in the 1/4-inch laminations.

Management Decisions Required

The following are seen to be management decisions, per the above discussion;

(1) Whether to build a test fixture ("heat leak test facility") that emulates a String.
(2) If a test fixture is to be built, where? It needs to be in close proximity to the magnetic test area.
(3) Who's to build (pay for) and operate (people) such a test fixture ? Is this a GD task since they are responsible for guaranteeing performance ? If GD, only test GD magnets ?
(4) If it is decided to pursue such a facility, a realistic budget cost of such is needed. Who's to do this? Associated questions include : refrigeration system needed and its controls, vacuum pumps and controls, the fixture that the test magnet will mount into, flow system instrumentation, etc.
(5) Getting Accelerator Cryogenics to identify what the cost / problems are in increasing the Collider Ring 4 K Helium refrigeration system capacity.

Recommendations

Recommendations regarding magnet testing per the above include:

(1) Conduct "reduced flow rate" tests of 4 K Helium in ASST. See how low flow rates can go before an indication of stratification. This should give good data on magnet system level heating. This is a String. Consequently, no " end effects" heating.

(2) Make a decision to determine if a Thermal Test Facility is needed. If so, what testing is needed there and with what accuracy ? If a decision against such a facility is made, determine what the alternatives are.

Issues associated with such a facility include: Where do the cryogens come from, what controls and sensors are needed for the cryogen system, vacuum pumps and their controls, thermal sensors needed, etc.

(3) If a separate test facility (Thermal Test Facility) is to be built, where? Is this to be at the subcontractors or is it to be at SSCL. If at SSCL it could be used for testing magnets from the various magnet subcontractors. Also, it would permit testing magnets after they had been shipped.

(4) If a decision is made to build the test facility, a conceptual design needs to be developed. From this an assessment needs to be made of how much time is to be allotted to magnet testing, there. This would determine how many magnets can be tested during Production.

(5) Accelerator Cryogenics should determine heat leak limits on the Collider Ring refrigeration system. Also, assess of cost / work to increase system capacity (4 K Helium, in particular).