Review Panel Report

from

MICE – MuCool Coupling Coil Engineering Design Review

held at

Institute for Cryogenics and Superconductivity Technology

(ICST)

Harbin Institute of Technology

(HIT)

Harbin, China

December 6-8, 2008

Contents

Appendices

1. Members of Review Panel

Alan Bross (Chair)	Fermi National Accelerator Laboratory (FNAL)
Mike Green	Lawrence Berkeley National Laboratory (LBNL)
Vladimir Kashikhin	Fermi National Accelerator Laboratory (FNAL)
Wing Lau	University of Oxford
Derun Li	Lawrence Berkeley National Laboratory (LBNL)
Steve Virostek	Lawrence Berkeley National Laboratory (LBNL)
Zian Zhu	Institute of High Energy Physics, Beijing (IHEP)
Mike Zisman	Lawrence Berkeley National Laboratory (LBNL)

2. Background

The MICE channel will require two superconducting coupling coils which are integrated with 4 201MHz RF cells to form the RFCC module.

The Coupling Coil (CC) is a relatively large, (1.5m diameter), superconducting solenoid mounted in a self-contained cryostat and cooled by 2 cryo-cooler units. The cryostat is self-contained but the CC units are mounted at the centre of the 201 MHz RF cavity modules. For this reason integration of the two modules is a key element of the design.

The performance of RF modules in the presence of background magnetic fields is of prime interest to MICE and MuCool. The first step is to test the performance of an RF cavity in the presence of a CC at the Fermilab MTA facility. There is, therefore, a requirement for three Coupling Coil modules, one for MuCool and two for MICE. Under a MOU with LBNL, ICST will undertake to design, manufacture and test the Coupling Coils for MICE – MuCool.

In December 2006 the Institute for Cryogenics and Superconductivity Technology (ICST), Harbin commenced the Engineering Design Study of the Coupling Coils for the MICE experiment and MuCool Test Area under the general supervision of LBNL staff. The Engineering Design Report was submitted to MICE – MuCool in May 2007. The first Engineering Design Review was convened and executed at ICST from 16th – 19th May 2007. This review focussed on details of the thermal performance of the CC with cryo-coolers, on manufacturing specifics, testing, schedule and manpower.

3. Review Objectives and Scope

3.1 Primary Objectives

The primary objectives were to evaluate the following elements of the ICST Proposal:

- Engineering Design

    - To assess the mechanical and cryogenic design of the coupling coil and its suitability in terms of thermal performance with cryo-coolers. In particular, evaluate overall robustness of the cryo-cooler liquid-helium circuit design and point out any areas for concern.

    - Where possible to make this evaluation against standard codes of practice or established principles of superconducting magnet manufacture.

    - To assess the compatibility and matching of the magnet design to the MICE and MuCool specifications

- Manufacturing Proposals

    - To evaluate the test coil winding approaches and their suitability for winding the actual coupling coils.

    - To access the manufacturing concepts and proposed procedures.

- Development, Prototyping and Test

    - To evaluate the plans and schedule for testing the two test coils.

- System Integration

    - To evaluate the proposals for integration of basic magnet components to form a complete CC module

    - To assess the integration of the CC module into a complete RFCC module and final integration with MICE – MuCool Planning and Schedule

- Planning and Schedule
    - To evaluate the production schedule for the coupling coils, in particular the proposed delivery date for the first (MuCool) coil
    - To evaluate The ability of the group to carry out the planned activities, i.e., are the available resources adequate to the task

3.2 Key Elements of the review

1) To review and confirm the Engineering Design against MICE – MuCool
    a) Specifications
    b) Parameters
    c) Interfaces
2) Assess the manpower requirements and resources for the project

3.3 Review Outputs

- The Review Committee should formulate a list of actions relating to any unresolved design, production or manpower issues.
- These actions should identify a person/institute responsible and set a date for completion
- To give preliminary feedback to ICST through a closeout presentation
- To prepare a review report to be presented to the MICE Collaboration for approval

4. Overview

The Review was conducted through a series of presentations (see Appendix 1) by ICST Design Team members. The updated Engineering Design Report (dated 2008-12-03) provided more detailed reference for Review Panel members. The review presentations and Design Report addressed all aspects of design, manufacture, system integration and test, manpower and schedule. The committee felt that the engineering design, analysis and prototyping are now at an advanced stage. The ICST team has demonstrated a solid, well thought out effort with regard to the magnet system design and preparation for fabrication.

Since this was the second detailed design review of the CC, the charge given to the committee was more directed as indicated in section 3.1 and enumerated explicitly here:

The committee should review and comment on:

1. The mechanical and cryogenic design of the coupling coil and its suitability in terms of thermal performance with cryo-coolers. In particular, evaluate overall robustness of the cryo-cooler liquid-helium circuit design and point out any areas for concern.

2. The test coil winding approaches and their suitability for winding the actual coupling coils.

3. The plans and schedule for testing the two test coils.

4. The production schedule for the coupling coils, in particular the proposed delivery date for the first (MuCool) coil.

5. The ability of the group to carry out the planned activities, i.e., are the available resources adequate to the task.

5. Detailed Findings, Comments and Recommendations/Analysis

This section presents the committee's findings, comments and recommendations.

5.1 Mechanical and Cryogenic Design

A. Findings

The mechanical design is now well advanced and has been supported by detailed simulation and calculation. Considerable detailed design work has been done since the previous CC review which has resulted in an improved design which was presented in detail and looked very solid There are a number of major changes, but adequate justification was presented for all proposed changes. The major changes include:

- A more robust design for the cold mass supports
- Increased coil ID and thickness which is accompanied by the necessary changes in the vacuum vessel dimensions
- A modified epoxy catalyst selection
- The use of dry unglued Kapton as a slip plane in the middle of the G-10 insulation
- A decision to use two cryo-coolers to maintain temperature

The cold mass stress analysis did not include the magnetic force as a load input. While the added stress is likely small, there could be locally higher stresses at the cold mass support connection points. Since the stress model presented was axi-symmetric, a different (likely 3D) model is needed to assess the local stresses. In addition an assessment of acceleration loads on the magnets during shipping and handling was not complete. Although several stress results were presented based on slip vs. no slip planes and aluminum banding (not stainless), an analysis based on the final cold mass design has not yet been done.

B. Comments

The HIT/ICST group has now performed a detailed design which includes study/simulation of all mechanical, cryogenic, thermal and electrical aspects of the system and the design is supported by detailed calculation and simulation. A number of potential unresolved issues are listed below:

- The insulation between the quench protection leads and ground may not be adequate.
- The insulation between the banding and the outer layer of the coil may not be adequate
- The heater between the coupling coil mandrel and the coil is unwise. There are other ways of inducing a quench in the magnet that don't involve the danger of voltage breakdowns in the ground plane insulation between the coil and the mandrel
- Shipping loads transverse to the magnet axis still appear problematic. A shipping container design that addresses this issue will be needed.
- A number of fabrication issues were raised that require additional evaluation:
    - Possibility of air bubbles under G-10 plates
    - Possible need for kapton insulation for leads in quench protection system
    - Relocation of heater outside of mandrel
    - Consideration of unbalanced loads on cold mass supports
    - Avoiding teflon in temperature sensor
    - Checking resonant frequency of thermal shield assembly
    - Finalizing cryocooler specs to permit ordering
    - Assessing need for 304L stainless steel *vs.* 304
    - Assessing need for strain gauges on cold-mass supports
    - Method to integrate cooling pipes into cover plate needs better definition
- Several structures in the magnet assembly require bimetal tubing, which should be ordered earlier and checked before assembly.

C. Recommendations

- Updated drawings should be sent to Virostek and Lau to confirm all interface dimensions.
- Revisit the boundary conditions for gussets.

- In collaboration with MICE staff, define maximum pressure in vacuum vessel from He leakage and include a vent line with relief valve and/or burst disk to accommodate it.
- A decision regarding the use of slip planes should be finalized.
- Improve the insulation between quench protection leads and ground.
- Improve the insulation between outer layer of coil and banding.
- The use of a corona test in place of the straight high-pot at 6.4 kV should be considered.
- Double check to see what the ultimate and yield stress of the 5356-Al banding material is at 77 K and 4 K.
- One should allow for a 0.2 to 0.25 W extra heat load on the cooler second stage due to the cooler sleeve when a drop in cooler is used.
- The pipe from the bottom of the condenser to the bottom tank should not be in contact with the cold mass.
- The 12 mm thick flexible strap should be replaced by three 4 mm flexible straps welded together at the ends.
- Regarding the machined groove for the external pipe, a procedure is needed to make sure that the welding or soldering of the cooling pipe to the groove to improve the thermal contact can be "quantified", i.e. we need to make sure that there is sufficient fusion at the contact areas as it would be difficult to tell if adequate fusion is achieved. Failure to achieve good fusion could mean that there might not be sufficient contact areas for thermal conduction.
- Check if 304L should be used for the cryostat as 304SS can be magnetized.
- Perform a frequency check on the thermal shield to make sure that it does not resonate with the driving frequency of whatever transportation mode we use for the shipping of the coil by road.
- For shipping a transportation support and frame needs to be designed to absorb any load in the in-plane direction of the coil during shipping. The mechanical analysis during shipping should consider peak accelerations as great as 6G.
- Since the full scale magnets will require large quantities of material to be procured and shipped from the US, the types and quantities of materials needed must be conveyed as soon as possible (at least 3 months before needed).
- The fiberglass bands for the cold mass supports will require a considerable amount of time to procure. If these are to be purchased in the US, several vendors will have to be contacted to provide quotes prior to placing an order through LBNL procurement. If the bands can be made in China, some prototype samples will be needed to allow for a check and test of the quality before ordering the full quantity (at least 48 of each length are needed. The design drawings must be completed as soon as possible so that this process can begin.

- The MuCool/MICE coupling coils will require a total of six PT-415 cryocoolers for normal operation plus any spares that are desired. Three standard configuration coolers have been ordered by U. Miss. The configuration of the additional coolers to be ordered should be established soon due to the long lead time. Possible added options include magnetic shielding of the valve housing and incorporation of ports for direct temperature measurement of the cold head stages.

5.2 MTA Interface Issues

A. Findings
Overall, the MTA interface issues do not appear to be a problem. Sufficient vertical clearance is available to allow for a LHe transfer line and stinger needed for the pre-cool.

B. Comments
A revised design for the support stand for the MuCool coupling coil is needed since the magnet will now be mounted to the floor. The support stand design must take into consideration interference with the platform stand for the 201 MHz RF cavity.

C. Recommendations
- The HIT/ICST team should interface with Fermilab via A. Bross to finalize the support design.
- The HIT/ICST team should interface with Fermilab via A. Bross in order to finalize the design for the LHe transfer line and LN_2 pre-cool line and hook-up to the CC.

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5.3 MICE Interface Issues

A. Findings
The key dimensions of the coupling coil pertaining to integration with the RFCC vacuum vessel were presented. However, the fabrication tolerances will be needed in order to ensure compatibility. Interface points that must be carefully evaluated/studied include: 1. the coupling coil vessel ID, OD and length and 2. The RF coupler cut-outs, and cold mass support interface gussets. The increased OD of the coupling coil vessel could cause the RF coupler mounting tubes on the RFCC vacuum vessel to be extended outward and the impact of this change on the length of the couplers needs to be assessed by LBNL RF design group.

B. Comments
None.

C. Recommendations

- The cold mass support interface gussets will require a weld prep to allow LBNL to make the connection to the RFCC vacuum vessel. ICST must work out the details of this weld prep with Allan DeMello of LBNL.
- The latest 3D CAD model of the MICE coil should be sent to Allan DeMello at LBNL so it can be integrated in the overall RFCC module CAD model.
- The latest 3D CAD model of the MuCool coil should be sent to Alan Bross so it can be incorporated in the overall MTA CAD model. The relevant portions of the MTA CAD model should be sent to ICST to facilitate the design of the MuCool coupling coil support stand.
- ICST should add lifting points to the coupling coil to allow lifting while the magnet is in the horizontal or vertical orientation.

5.4 Coil Winding Approaches

A. Findings
The actual techniques used for the test coils will not be the exact procedures that will be used for the final coils, but explored a number of different approaches to some of the steps. In addition, the procedures for the large coil were modified part way through the winding.

B. Comments
Although the large winding did not follow a consistent set of procedures throughout the wind, the final procedure that came out of this exercise looks to be appropriate for the final coil windings if the following recommendations are adhered to.

C. Recommendations
- The procedures should be finalized to reflect (as closely as possible) the procedures used in the large test coil winding.
- A corona test during winding should be considered. This has been shown to be more sensitive to shorts than a HV test.

5.5 Testing of the Test Coils

A. Findings
The small test coil is complete and will soon be ready for test. The large test coil needs a bit more work, but should be ready for testing to begin soon. Its test cryostat is ready at this time. Two alternative plans are under consideration with regard to coil testing:

- Test the small coil first, followed by large coil, or
- Test large coil first, possibly followed by a small coil test.

Neither plan has a resource-loaded schedule that makes it credible at present and, in addition, the manpower needed to accomplish either plan is not fully identified. Furthermore, there is no written test plan specifying what is to be measured, how it will be measured, and what constitutes a successful outcome.

B. Comments

The large coil test is critical to release the MuCool coil for winding. In order to minimize any schedule delays, this test must be the priority for the group. It will be useful for the group to explore various test methodologies, a corona test for example and the final test plan should be agreed on with LBNL and MICE Tech Board. The group should realize that evaluation and approval of the test results may take some time and these need to be considered when developing their final schedule.

C. Recommendation

- Develop a fully resource-loaded test schedule, giving preference to large test coil. The plan should be aggressive but must be realistic and needs to account in schedule for time to evaluate and approve test results before winding of MuCool coil starts.
- Develop a written test plan for review by LBNL and MICE.
- The committee feels that the HIT/ICST team should proceed as rapidly as possible with the test of the large coil. The testing of the small coil is of secondary importance and should be postponed if it delays test of the large coil.

5.6 Production Schedule

A. Findings

An updated schedule was presented, but did not include enough detail for the committee to be able to evaluate its realism. The new schedule shows considerable delays compared with earlier versions and these are not likely to be made up. The committee notes, however, that based on the large test coil results, the current schedule is more credible than past versions.

B. Comments

The resources needed to carry out the required tasks look marginal, although considerably improved from situation 6 months ago. The plans for where to do fabrication are sketchy and certainly need refinement. The current delivery date for the MuCool coil is October or November 2009 (with caveat above). This is late compared with desired date and likely still optimistic. Finally, the committee remains strongly in favor of HIT finishing fabrication.

C. Recommendations

- Create an updated, resource-loaded fabrication plan for MuCool and MICE coils and update LBNL-HIT MOU addendum in order to get a commitment to meet the desired schedule.
- Proceed with the material order for cold-mass supports before December 20, 2008.
- The committee strongly prefers continuing the present construction approach with HIT/ICST responsible for cold mass fabrication. We feel that assigning the fabrication task elsewhere would generally result in diffuse responsibilities, cost penalties, and schedule delay.
- Address the ICST project management situation as soon as possible. The committee feels that the management team must include Li Wang in a strong management team at HIT and proceeding with Coupling Coil fabrication project as planned is our recommended approach.The ICST team will also need to augment its technical manpower in order to maintain the desired schedule.

5.7 Manpower and the Capabilities of the ICST Group

A. Findings

The ICST group is competent and hardworking and progress since the last review has been significant. The committee wants to point out our extremely positive impression of the work of the ICST students who have uniformly done an impressive job on the project. The level of documentation is exemplary as was quality of presentations. Manpower resources remain an issue, however, where the committee sees a short-fall in the technicians, welders, project management resources needed to complete the project successfully. Nonetheless, progress since the last review was very noticeable.

B. Comments

HIT needs to find a way to solve the resource limitations particularly with respect to project management. The committee urges the LBNL team and MICE management to try to help with this issue.

6. Conclusions

The Review Committee would like to congratulate the entire HIT/ICST Team for the excellent progress that they have made since the last review, even during this somewhat difficult time. The quality of the analytical and technical work that has been done by the group is exemplary. It was especially rewarding to see such high-quality work from the junior members of the team.

The engineering design, analysis and prototyping are now at an advanced stage and we are confident that the Coupling Coil project can be carried out successfully given the availability of proper resources.

Addendum

Agenda for MICE Coupling Magnet Review
December 6–8, 2008

Location: Small conference room, ICST building, HIT, Harbin, China

Attendees:

ICST: MICE group

Committee: M. S. Zisman, Derun Li, Steve P. Virostek, M. A.Green (LBNL/USA)
Alan Bross, Vladimir Kashikhin (Fermilab/USA), Wing Lau (Oxford/UK), ZiAn Zhu (IHEP/CHN)

Agenda:

Date	Time	Content	Lecture
December 6	9:00-9:30	Executive Session	Committee
Review on MICE/MuCool Coupling Magnet Updated Design	9:30-9:45	Welcome address	ICST Directors
	9:45-10:15	Introduction to Contents to be reviewed	L.Wang
	10:15-10:25	Coffee break	
	10:25-11:00	Basic design parameters and overall design	L.Wang
	11:00-12:00	Coil assembly design	H.Pan/F.Y.Xu/X.K.Liu
	12:00-13:30	Lunch at HIT cafeteria	
	13:30-14:15	Quench protection system design	X.L.Guo/F.Y.Xu
	14:15-15:15	Cooling design for coupling coil	L.Wang/H.Pan/ H.Wu
	15:15-15:30	Coffee break	
	15:30-16:00	Cooling design for coupling coil (continued)	L.Wang/ H.Pan/ H.Wu
	16:00-16:45	Cold mass support assembly design	H.Wu
	16:45-17:30	Vacuum Chamber and interface design	X.L.Guo/ X.K.Liu
	17:30-18:30	Executive Session	Committee
	18:30-19:30	Dinner	
December 7	9:00-9:30	Test coils' design	X.L.Guo
Review on Test Coils	9:30-10:15	Test coils' winding technique and cold mass assembly	F.Y.Xu
	10:15-10:30	Coffee break	
	10:30-11:00	Test coils' winding technique and cold mass assembly (continued)	F.Y.Xu
	11:00-11:45	Some tests (SC joints, bending radius, etc.)	H.Pan/H.Wu
	12:00-13:00	Lunch at HIT cafeteria	
	13:30-14:30	Construction of cryo-test system	X.K.Liu/A.B.Chen
	14:30-15:15	Other topics related to MuCool/MICE coupling magnet design	MICE group
	15:15-15:30	Coffee break	
	15:30-17:00	Executive Session	Committee
	17:30-19:00	Dinner	

December 8	9:00-10:15	Executive Session (Report Preparation)	Committee
	10:15-10:30	Coffee break	
	10:30-11:30	Close out	All
	11:30-12:30	Lunch at HIT cafeteria	