**The MICE Coupling Coil at FNAL**

V. Kashikhin, January 12, 2011

The situation with the MICE Coupling Coil project in China was reviewed in December, 2010. The magnet mechanical design is finished, but the SINAP team continues incorporation of some changes mostly related to the magnet cooling. The Qi Huan firm finished the superconducting coil winding and the outer Al bandage ring and is ready to send the coil to HIT to have the cover plate (with cooling tubes) welded to the coil bobbin. The HIT team is in the process of preparing the test stand and fabricating the tooling for welding the cover plate.

**The base line scenario for this project is:**

* *Commission the test stand at HIT.*
* *Test the 1/8th scale model of the coil.*
* *Qi Huan manufactures the magnet cold mass.*
* *Test this cold mass at HIT and return to Qi Huan.*
* *Final assembly of the cold mass with the cryostat at Qi Huan.*
* *Full test the magnet with cryo-coolers at Qi Huan.*
* *Ship the magnet to FNAL for the test in the MuCool area.*

The main concern related to this approach is that we did not see much progress in the test stand construction or in the tooling for the cover-plate welding. It seems, that there are very limited resources and people with experience in the area of superconducting magnets fabrication and test available at HIT or even at Qi Huan. So, from this point of view the project is under the risk that during test, the coil will be damaged. This magnet has very high inductance ~ 600 H, huge magnetic field energy ~ 13 MJ, 7 T field, and 80 km of single strand conductor wound in series on the 1.5 m diameter Al mandrel. Because of the chosen passive quench protection system, all the energy dissipated into the coil and magnet will have a long recovery time. The coil is subdivided into 8 sections and each section is protected by shunt resistors with cold diodes. There is some uncertainty in the quench scenarios because they rely on the “quench back” effect (heating of Al mandrel by induced currents with corresponding coil heating). Even for a very experienced team at FNAL, it will be difficult to **safely** test this magnet.

Possible scenarios for FNAL to help the project:

**Scenario 1**

* Provide the HIT, SINAP, Qi Huan teams support with information.
* Delegate experts to help with magnet tests, test stand commissioning.
* Participate in the HIT tests.

**Scenario 2**

* Ship the cold mass and cryostat parts with cryocoolers to FNAL.
* Assemble the magnet at FNAL.
* Test the magnet at FNAL.

This second scenario requires a relatively large effort.

Tasks:

**1. Final Coupling Solenoid assembly at FNAL:**   
*- Design and fabrication the assembly tooling for the cold mass mounting, applying superinsulation, cryostat welding, cold mass position tuning.   
- Fabrication electrical tests, resistances, inductances, Hi-pot, etc..   
- Vacuum leaks check.*

*- Write the final assembly production report.***2. Preparation of sub-systems for magnet tests, field measurements, quench diagnostics, sensors monitoring (supposed to use an existing DAQ cart):**   
*- Design and fabrication interfaces between magnet and DAQ cart.   
- Design and fabrication additional electronics if needed.   
- ~~Purchasing the high quality regulated power supply.~~ ?*

*- Design and fabrication Hall probe positioning fixture.*

*- Write the sub-system descriptions.*

**3. Magnet tests:**

*- Writing the test and magnet commissioning plan.*

*- Room temperature magnetic field measurements, defining the magnetic center position, tuning the cold mass position.*

*- Cryogenic and cooling system tests with monitoring all thermal and stress sensors with the following analysis of obtained data.*

*- Magnet tests at low currents with the tuning the DAQ system, quench detection.*

*- Magnet training with the parallel analysis of monitored data.*

*- Write the test report.*

**4. Fabrication and test support:**

*- Superconductor sample tests, single bare strands, thermally insulated strands, copper stabilized buses.*

*-Shunt resistor and diodes assembly test to measure the peak temperatures, diodes opening voltages at cryogenic temperatures.*

*- HTS leads test in the perpendicular magnetic field 1-2 T*

*- Quench simulations and test results analysis.*

*- Write the support section report.*

**5. Magnet commissioning:**

*- Safety tests. High air pressure test?*

*- Preparation of documentation for the safety panel review and approval.*

*(Note: In any event, this has to be done since the magnet will be used in the MTA)*

*- Write the recommendation report on the base of test result for the magnet operation at FNAL and RAL.*

It is difficult to accurately estimate the needed labor to support this activity because this only be made after careful analysis of the existing equipment, experience, fabrication and technological constraints. Also, there is some uncertainty regarding the amount of required final assembly work.

Below is shown a table with a very preliminary look at the effort. Roughly ½ this manpower could be supplied from MICE (LBL, SINAP, HIT, Qi Huan)

Table 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | Task description | Tech.,  FTE | Drafter,  FTE | Eng./Sci. FTE |
| 1 | Final assembly | 3 | 0.5 | 2 |
| 2 | Sub-systems | 1 | 0.5 | 2 |
| 3 | Magnet tests | 1 | 0.15 | 3 |
| 4 | Fabrication and test support | 0.4 | 0.2 | 0.5 |
| 5 | Magnet commissioning | 0.1 | 0.15 | 0.5 |
|  | Total | 5.5 | 1.5 | 8 |

This estimate does not include contingency for possible magnet repair, and if some parts require a redesign. There is also the risk that the delivered magnet parts and magnet design do not meet the specified parameters. The designed magnet has a very low quench margin; even a small degradation of only 1 cm of wire out of 80 km will reduce the quench current. The number of quenches for the magnet training is strongly limited by the long recovery time.

Nevertheless, from the professional point of view this magnet is a large step with respect to state-of-the-art magnet technology (low current, large number of turns, cryocoolers, passive protection, compact, economic, etc..). The obtained experience will be useful for other FNAL projects.