Report of the MICE Spectrometer Solenoid Review held on December 3 and 4, 2015 @FNAL

Reporting days:

- Closeout report delivered on 4 December 2015
- Final report delivered on 11 January 2016.

Review Committee:

- Herman ten Kate - CERN (chair)
- Jim Kerby – ANL
- Mike Anerella – BNL
- Peter Wanderer – BNL
- Tom Taylor – CERN
- Cesar Luongo – JLAB
- Peter McIntyre – TAMU
- Luigi Muzzi – ENEA.

Observers:

- Bruce Strauss – DOE
- Josef Boehm – RAL
- Oleg Kiricheck – ISIS.

Client:

- Review requested by Mark Palmer, Director, US Muon Accelerator Program.

1. Overview

The review committee met with the MICE Spectrometer Project team on December 3 and 4, 2015 at FNAL on request of Mark Palmer following the electrical breakdown of the M1 and M2 internal electrical circuitry in the so-called SSD magnet system, and attempting to move forward with an approach for repair and/or replacement of the magnets.

- The agenda is copied in Annex to this document.
- The agenda and presentations are stored on the following indico site: https://indico.fnal.gov/conferenceDisplay.py?confId=10652
- Agenda and all presentations are also collected in a portfolio in pdf format attached to electronic version of this document.

The committee would like to commend the MICE-SSU&D team for the professional set of presentations. The presentations provided, as far as known, a clear status of the magnet damage, concerns, and thoughts about options for the projected repairs and move-forward plans for the magnet system. The committee is impressed with the high level of commitment displayed by the US Muon Accelerator Program to fully support the science objectives of the collaboration, and its willingness to diligently work towards a satisfactory repair or replacements of the damaged MICE solenoid magnet.

The review committee expresses its assessment of status, observations, concerns, and recommendations immediately below and under the specific charge in each case.

Provided the resulting issues are suitably addressed, the review committee endorses acceptance of the talks as the basis for continuing the work for repair or replacement of the solenoid.

The project's Review Committee charges and their responses follow, enriched with additional observations, concerns and recommendations.

2. Response to the Charge to Review Committee

1.1. Evaluate the existing SS magnet power supply and quench protection scheme in light of the failure event.

The existing QP system based on cold diodes and resistors is not sufficiently robust. The margins are so small that operation of the system in a different way, without M2 for instance, causes the system to break down.

1.2. Examine modifications to the power and quench protection systems being proposed by the SS magnet group and assess the ability of the MICE experiment to safely operate the magnets in the Step IV configuration as well as the Cooling Demonstration configuration.

The plans for adaptations of the QP systems are generally endorsed though the designs need to be further detailed, and are contingent on the final decision to either repair or replace the magnet.

The proposed new QP for both the SSU and the SSD with added external dump is well conceived as the best plan to deal with the present system in step IV.

If building a new cold mass for SSD, the QP shall be based on using quench heaters and proper voltage taps in the approximate midpoint of conductor length of each coil section.

The resistors in series with the diodes in the SSD shall be eliminated. When charging/discharging time/voltage is a problem, a better solution is to add diodes to the stack.

Also the dimensioning of all internal leads and busses has to be reviewed and made more robust, i.e. have a larger cross section, properly insulated and fixed by locking bolts throughout the entire system.

It is recommended to position the internal QP leads in the lower part of the cryostat and the diodes geometrically above them, all to warrant that the parts are properly operating in liquid helium under all circumstances and to minimize the probability of arcing through helium gas.

2.1. Evaluate the technical details of the magnet recovery plan as presented by the SS magnet team.

The level of details is not the same for all options presented. Regarding the most likely options, opening/repair and new cold mass, the following can be said. If the option of a new cold mass is chosen, it is recommended to first conduct a make/buy analysis considering technical and schedule risk, as well as overall cost to the project; where make implies fabrication at Fermi, and buy implies an external vendor, be it a company or another laboratory.

For the option of a new cold mass, and if procured outside Fermi, it is considered essential to find an engineering and construction team (vendor) with experience in fabricating large bore solenoids, the tooling necessary to carry out the job, and ability to deliver within the required schedule constraints.

The design of the previous cold mass should be followed as closely as possible, though it is recommended to increase the operational margins of the coils.

Minor changes may also be considered which would reduce retraining as seen on the existing magnets, if implementing such changes introduces no significant risk. One such suggested change is to ensure that slip planes are provided between coils and the aluminum bobbin to reduce friction during excitation. However, the choice of the minor changes chosen could depend strongly on the experience of the ‘vendor’ who will ultimately do the work.

Some coils, in particular E2, are at about 60% of critical current, which does not provide sufficient margin. Typically such solenoids can run at about 30% of critical current. More NbTi in the present SS design would greatly help. It is recommended, as proposed, to increase the margins by resizing the coils, resulting in significantly lower peak fields, and allow up to 30% more turns, which looks feasible.

In the opening and repair option the problems with training and its consequences will remain. In that option it would be important to explore ways to add quench heaters attached to coil entries or outer surfaces.

Unlike for the previous repair where a large window was cut in the external cylinder to access the resistor and diode packs, for this repair it would be essential to remove the entire external cylinder.

It is noted that the problems with low margins are mitigated if the user field is reduced to 3 T which seems sufficient for spectrometer requirements, though quench protection consequences have to be checked. The effect of reducing the field on the optics has to be verified as well.

2.2. In particular, please address the robustness of each of the presented modifications and repair steps.

The committee only considers the open & repair and the new cold mass options.

A new cold mass with heater driven quench protection system will have to be tested and fully qualified for operation in the SS, and the entire cold mass can then be considered a robust core for integration into the magnet system.

The same level of robustness can probably not be achieved for the open & repair option.

2.3. Also consider the degree of operational safety that will be provided by executing the recovery option as presented.

Considering operational safety of the existing apparatus while the repair is prepared, a new cold mass construction in parallel with Step IV provides the best chance that Step IV can be performed undisturbed by repair work. This assumes that the improved quench protection equipment is operational for both SS systems.

3.1. Evaluate the balance of costs, schedule impact and risks associated with the recovery option based on the initial cost, schedule and risk analysis provided by the SS magnet team.

The risk table presented was developed by the MICE management and is consistent with their assumptions of severity and probability of occurrence. In particular, in the evaluation of the risk for the open/repair scenario the team has considered partial opening as performed in the previous repair which would entail greater risk than the full opening envisaged by the review committee.

The manufacturing time for a new cold mass shown to start in December 2015 and lasting 9 months, and only including a 40% margin is not credible in view of the foreseen design, analysis, engineering and model coil work proposed by the team. Even for a full industrial supply starting tomorrow this time is too short.

To come close to meeting the schedule, it is recommended, as said before, to stay as close as possible to the existing design, quickly find an outside vendor with experience in construction of such solenoids, and be creative in shortening the placement of the contract. For the in-house option (make) similar considerations apply, minimizing the design iterations and corresponding development time.

The cost table provided shows full overhead and includes 40% contingency, still leading to an overrun of some 250 k$ that will have to be covered.

The cost model presented is based on in-house manufacturing which is not necessarily the best way to go. A cost model based on industrial production should also be looked into as this may lead to a lower integrated cost.

3.2. Identify any elements of the plan that require further attention by the SS magnet group before finalizing the proposed recovery option.

See comments already made above.

4.1. Based on the overview and analysis presented by the SS magnet team, confirm whether the recovery option presented will provide a viable path forward for the MICE Experiment.

Make sure Step IV can be executed. The importance of running Step IV program to get physics output is greatly acknowledged and has to be respected. It is a strong argument in favor of making a new cold mass even though this may not be the most cost and time efficient solution.

The option to recommend also depends on the experience of the team as well as schedule and cost constraints. Given this, the committee recommends to proceed with the new cold mass option in full speed, but also plan for the repair option if when opening the cryostat it is deemed to be the fastest way to complete the cooling experiment, or if the effort to engage an outside vendor (or the lab.-based alternative) runs into unexpected delays. The components required for a repair should be prepared well ahead of opening.

As said before, the new cold mass has to be made according the present design but eliminating some production flaws and including adjustments for increasing operational margins of the coils.

A full development program at the lab should be avoided if more qualified outside vendors can be identified as part of the make/buy analysis.

Starting the detailed make/buy analysis as soon as possible is highly recommended. Thus the next step is a thorough survey of feasible manufacturing partners.

No matter where the new solenoid is ultimately made, as the construction will be on a best effort basis MICE will have to retain the technical risk associated with the production of a new cold mass.

4.2. Also, please identify any other magnet recovery options that should be evaluated prior to presenting the magnet recovery proposal to the MICE Collaboration and the funding agencies.

None.

3. Committee Observations, Comments and Concerns

The committee addressed replacing/repairing the SSD cold mass, but not the work involved in opening the cryostat, taking out the present cold mass and replacing it with the new one, or repairing it, and reinstalling it in the cryostat. The team will have to decide where and how this work is to be done and make appropriate plans well in advance.

4. Committee Recommendations

1. Finalize the improved quench protection systems for SSU and SSD, install and commission as soon as possible so that run IV can restart data-taking.
2. Finalize design of an upgraded coil with improved margin but with minimal changes to the original design. Ensure compatibility with optics requirements. Identify where to get the magnet built and launch the manufacture.
3. Prepare a repair kit for SSD to have ready in case the new cold mass is not ready on time.
4. Prepare a scenario for the timely removal of the SSD cold mass from its cryostat, the replacement or repair of the cold mass and the recommissioning of the magnet.
5. Evaluate the cost & schedule impact for discussion with the funding agencies on how best to proceed.

End Of File.

MICE Spectrometer Solenoid Recovery Review

Thursday 03 December 2015 - Friday 04 December 2015

Fermilab

Programme

Thursday 03 December 2015

Executive Session - Comitium (WH2SE) (09:00-09:30)

Introduction - Comitium (WH2SE) (09:30-09:45)

- **Presenters: Dr. PALMER, Mark**

SSD Failure and Diagnosis - Comitium (WH2SE) (09:45-10:30)

- **Presenters: Prof. BROSS, Alan**

Coffee Break - Comitium (WH2SE) (10:30-10:45)

MICE Goals and Optics Options - Comitium (WH2SE) (10:45-11:20)

- **Presenters: Dr. ROGERS, Chris**

Magnet Recovery Options - Comitium (WH2SE) (11:20-12:00)

- **Presenters: Dr. PALMER, Mark**

Lunch - Comitium (WH2SE) (12:00-13:00)

Present Design Construction Summary - Comitium (WH2SE) (13:00-13:40)

- **Presenters: VIROSTEK, Steve**

Present Design Electrical Analysis - Comitium (WH2SE) (13:40-14:15)

- **Presenters: Dr. PRESTEMON, Soren**

Step IV Operational Proposal - Comitium (WH2SE) (14:15-14:55)

- **Presenters: Dr. FEHER, Sandor**

Coffee Break - Comitium (WH2SE) (14:55-15:10)

Requirements for Cooling Demonstration - Comitium (WH2SE) (15:10-15:35)

- **Presenters: Prof. BROSS, Alan**

SSD Proposed Modifications - Comitium (WH2SE) (15:35-16:15)

- **Presenters: KASHIKHIN, Vladimir**

SSD Repair Plan - Comitium (WH2SE) (16:15-16:50)

- **Presenters: Dr. VELEV, Gueorgui**

Preliminary Schedule and Cost Summary - Comitium (WH2SE) (16:50-17:20)

- **Presenters: GARBINCIUS, Peter**

Executive Session - Comitium (WH2SE) (17:20-18:30)

Pre-Dinner - Comitium (WH2SE) (18:30-19:00)

Dinner at Chez Leon - Comitium (WH2SE) (19:00-21:00)

Friday 04 December 2015

Executive Session - Comitium (WH2SE) (09:00-09:30)

Q Period - Comitium (WH2SE) (09:30-10:30)

Coffee Break - Comitium (WH2SE) (10:30-10:45)

Discussion of Alternatives for Exploration - Comitium (WH2SE) (10:45-11:30)

Report Writing and Committee Lunch - Comitium (WH2SE) (11:30-13:30)

Closeout - Comitium (WH2SE) (13:30-14:00)