MECO Magnet Meeting, Columbia University, October 10-12, 2004

Report of the Magnet Oversight Group to the RSVP Project Director

Contents:

1. Introduction and general comments

First of all we wish to recognize all the good work put into this project both by the UCI MECO team and the MIT magnet design team. The experiment is extremely challenging, and its success will depend in large part on the provision of a reliable magnet system that satisfies the geometric and field profile requirements. This is a large and complicated superconducting magnet system, the design, construction, installation and commissioning of which is a complex project in its own right. In recognition of this, the MECO team took the good decision of entrusting the conceptual design of the magnet to the Plasma Science and Fusion Center at MIT, which has considerable experience in the design and construction of various superconducting magnets.

The Magnet Oversight Group (MOG) was formed at the request of the RSVP Project Director, and the purpose of this meeting was to report to him our evaluation of the status of the conceptual design of the magnet system, of the proposed approach to its purchase, and of the management of the project. The members of the MOG are given in Annex 1, and the Charge to the Committee and the Agenda of the Meeting are given in Annexes 2 and 3. A list of those present at the meeting is given in Annex 4.

In June 2002 the MIT team produced a 300-page conceptual design report on this magnet, and both before and after that date there have been a number of reviews. A presentation of the project to potential vendors took place at the 2003 Magnet Technology Conference (MT-18) in Morioka. A complete set of documentation is available via the excellent UCI MECO website. At this meeting an overview of the experiment and the conceptual design of the magnet, together with the present approach to its purchase, were explained in detail to this new standing committee. The quality of the presentations was exemplary, and we were impressed by the enthusiasm and dedication of all concerned, despite understandable frustration due to lack of funding to proceed with the work.

2. Technical points

Conductor

The availability of SSC surplus cable provides an attractive opportunity for cost saving, but also leads to some constraints in the design choices. Without going into the details, it would appear that the disadvantages of this do not outweigh the advantages. We presume that a cost/benefit analysis was done in the initial stages of the design. Likewise, the approach of stabilizing the keystoned cable by soldering it into a channel in a copper extrusion is classical, and a number of superconducting magnets using such a conductor have been successfully built.

Our only comments on this are that we would like to see fewer variants (two of the conductors are very similar in size), and we would suggest soldering using tin-silver eutectic (melting point ~ 225 deg C), so that the splices can be made using tin-lead solder. With regard to the splices, it should be relatively easy to achieve a resistance per splice of less than 0.5 nΩ, i.e. less than one tenth of that mentioned in the presentations, and a level at which it could be envisaged to include splices in the windings (see below).

MECO presently proposes to use insulation consisting of two layers of Kapton covered with two layers of fiberglass, the weak bond between the smooth Kapton and copper being regarded as a positive feature. We would, however, recommend a scheme ensuring a good bond of conductor to insulation and suggest considering the use of commercially bonded fiberglass and polyimide tape known as GUG or UG (Upilex/glass) available from Arisawa Ltd., Japan.

The chosen temperature margin of > 1.5K is appropriate. It could be that the real temperature margin is greater than this, due to a pessimistic interpretation of the load line.

For the record, if we were to be starting the exercise today all members of the Committee would consider far more seriously the use of much longer lengths of conductor made by co-extruding sc cable in a pure aluminum sheath, the additional cost of such an option probably being partially offset by simplifications elsewhere in the project. However, as mentioned above, the adopted classical solution is certainly viable and has the merit of being well-known to the MIT team.

Coil layout

We regard the large number of coils as a cause for concern. We would strongly suggest trying to reduce the segmentation. Longer units, e.g. length ~ diameter, would look more reasonable. For the DS one could consider even longer segments. By admitting splices within the coils this may be feasible and should lead to lower integration costs and reduced risk due to fewer electrical and cryogenic connections. In addition all winding-flange interfaces present a potential risk of bonding failure and resin cracking, so a substantial reduction in the number of interfaces will reduce the risk of training.

The committee was not convinced about the “stress during a quench” arguments that were used to justify the short coil winding length. The quench~stress arguments should be revisited, followed by an in-depth technical review.

The reasoning behind the force retention via the aluminum mandrels is unclear. The difference in contraction between the copper-based coil pack and the aluminum mandrels could be problematic - we would have preferred to see a choice of materials with a closer coefficient of contraction.

Coil winding

There is an increasing tendency in the magnet industry to take advantage of the newer epoxy resins with lower curing temperatures, to find ways to avoid full vacuum impregnation. We recommend considering the use of a wet winding technique or possibly a prepreg conductor insulation instead of VPI to provide some potential for reducing cost and relaxing time constraints.

Cooling

We strongly recommend that the use of conduction cooling be considered for the PS. The choice of bath cooling was made when the heat load on the coil was ~ 400 W. Now that with the improved shielding heating due to nuclear radiation is down to ~ 100 W this would be clearly possible. There would be four major advantages with such a choice:

- Use of a single cooling concept for the whole magnet system
- Large reduction in the liquid helium inventory
- Elimination of breakdown voltage problems in helium
- Elimination of safety problems associated with the helium pressure vessel

The piping layout could be simplified by adopting the thermal syphon approach successfully applied to the ALEPH, CMS and ATLAS CS magnets. We recommend minimizing the number of pipe-to-pipe joints. When possible, the interest of reliability, welding should be preferred to hard soldering. In order to reduce thermal gradients during cool-down and warm-up, as well as dT in operation, the copper sheets connecting the cooling circuits to the coil modules should be bonded to as large a surface as possible.

We understand the desire to use liquid nitrogen for cooling the heat shields and above all the intercepts on the stainless steel supports. However we feel that more attention should be given to the inconvenience of having to rely on a constant supply of fairly large quantities of LN2, as well as to safety issues, such as oxygen depletion in the vicinity in case of a massive leak, and explosion due to freezing of the liquid due to accidental contact with a liquid helium circuit. It was mentioned in the presentation that as the system will be provided with a new refrigerator, the use of helium gas at ~ 70 K could be considered as an alternative to LN2. We strongly advise that this option be followed up, together with a review of the supports in order to reduce the heat load, e.g. by using composite and/or titanium instead of stainless steel.

We recommend care in the evaluation of the cryogenic load of the control dewar and valve boxes. The heat load of these devices is often severely underestimated.

Power supply circuits

In the interest of simplification we suggest reducing the present six units to a minimum, based on a simple cost/benefit study.

Quench protection

Problems with the quench detection system are the largest single cause of faults during operation of superconducting magnets. .For operation we strongly recommend the use of a hard-wired analogue system based on bridge detection or comparison of voltages across large sections of the magnet system, with few channels and redundancy. It is important to distinguish safety from the diagnostics one may wish to have especially during commissioning. The present not-redundant 100-channel digital system may be applicable for commissioning diagnostics, but is unnecessarily complicated for operation.

For the external resistive partial energy dump in case of quench, we would advise to change from series to parallel, with double switch and diodes. This is to preclude the risk of coil isolation, with consequent high voltage, and burn-out in the event of a switch failure. For redundancy we also recommend the use of switches having multiple poles.

Controls

A close look at failure scenarios often reveals something new. It is therefore recommended to make an in-depth failure analysis of the entire magnet system and to adapt the design to take the result into account.

The cryogenic controls should be designed with the operation in view. It would be clearly an advantage for BNL to be strongly involved in this part of the work.

3. Design status

In view of the preceding comments and recommendations it is evident that the conceptual design will benefit from a further iteration. It is evident (and reasonable) that the coils are in a more advanced state than the integration, which is in turn more advanced than the knowledge of the installation and commissioning.

There is clearly insufficient input for single vendor bid package. In our opinion there needs to be model coil input for a final engineering design. This is required in order to qualify the technology adopted for winding and bonding, the indirect cooling and thermal performance, and in addition to perform the operations and thereby train the core team for following up the production.

The name of the game is RISK REDUCTION. There is only one chance to build the magnet system and it has to work. In short, significant work needs to be done before starting the final engineering design.

4. Schedule

The schedule is tight.

- More time should be allocated for the contract process
- Model coil work is not explicitly included
- The time allocated for installation and commissioning appears to be short

Our rough estimate is that the overall project might take about a year more than that presented. Preparatory work should be started as soon as possible, and an effort should be put into the search for timesaving assembly procedures.

5. Cost

A lot of work has obviously been put into assembling the detailed estimates that were presented. Our comments on cost are necessarily of a general nature, e.g.

- 10% profit appears optimistic – it may be 15%,
- Labor rates look low (in particular for qualified welders),
- Cost is based on ‘04 prices. Should escalate to ‘06 prices.

The most important comment is that we would expect the final price coming from a single vendor to be considerably higher than that quoted. This is primarily because certain features are either underestimated or omitted, e.g.

- 15% purchasing overhead appears low. Our experience is 20-25%,
- 0% risk included. Once again, our recent experience suggests 20-30%.

In total, the real cost may be ~ 25% higher when the single vendor option is chosen.

The estimate of cost of system integration at BNL requires further study.

Our proposal would be to get independent budget cost estimates based on the purchase of major components.

6. Management

Risk reduction should be attributed the highest priority. To this end all things, in all aspects, should be made as simple as possible.

We consider the risk involved in going to a single vendor to be too high. You may pay twice - now for risk, later for cost overruns (and have to do some of the work yourself anyway). Consequently we strongly advise to go for a “Buy-in-Parts” scenario. This may save ~ 25% in cost, as well as increase the likelihood of getting a working magnet on time. This cost saving will be more than sufficient to finance the core magnet team required for production follow-up, trouble-shooting and assembly.

The team at MIT should be reinforced to ensure design and procurement of the magnet proper: the technical management of that part of the project should remain there. The team should include a qualified manufacturing engineer and qualified inspectors should be engaged to follow closely the work in the companies.

The magnet will be installed, commissioned and operated at BNL. It is therefore essential that MIT and BNL work together, and that BNL involvement grows with time. As the requirements converge, it would be in the interest of satisfying the technical goals to attribute part of the specification work, and the procurement of the refrigerator, external cryogenics and cryogenic controls, and power supplies to BNL. BNL could also provide the equipment needed for quench detection and protection, as such equipment has already been developed for RHIC. It is also imperative to get BNL on board and co-responsible for integration, installation and commissioning.

Coming back to the magnet itself, it would be helpful to get feedback from industry in particular on coil winding, segmentation and impregnation. With this in mind it would be useful to make a draft RFI as soon as possible (within 3 months, say) for the magnet, to be followed by a draft RFP/SOW to get some answers on cost, schedule and technical feasibility from a few companies within the next 6 to 9 months. In addition, and most important, this process should be exploited in the short term to permit visits to potential suppliers for technical discussions that will hopefully lead to improvements in the final engineering design.

We advise that in order to reduce project risk the effort should now be concentrated on the magnet itself. The provision of immediate funding should enable the achievement of the following critical studies and preparatory work in the course of the next 6 months, which are essential in order to keep the magnet project on track:

- Re-design of cooling of the PS, replacing bath by conduction cooling,
- Simplification of the magnet by reducing the number of coil segments,
- Make test windings to validate conductor, winding and insulation technologies,
- Do the industrial studies through the RFI, and prepare the RFP,
- Strengthen the team at MIT to speed up design work,
- Design and start construction of tooling for a full scale model test coil.

7. Conclusions

- We are confident that the conceptual design which has been developed is a sound basis to move forward to an RFP for the magnet.

- The groups that have carried out this work should be supported and strengthened.

- To this end we recommend sufficient intermediate funding, following a cost estimate, for the high priority studies listed above.

- Equipment that will have to be operated and maintained by BNL should be specified with their collaboration, and procured through BNL.

- These recommendations are made with the objective of reducing technical, financial and schedule risk, and minimizing the overall cost of the magnet.

Annex 1

Members of the MECO Magnet Oversight Group (MOG)

Elwyn Baynham (RAL)
Gene Fisk (FNAL)
Thomas Taylor (CERN) (chairman)
Herman ten Kate (CERN and University of Twente)
Akira Yamamoto (KEK)

Annex 2

CHARGE to the MECO Magnet Oversight Group for this meeting:

[1] What are the functional requirements of the MECO magnet system?
- (a) Present magnet design and status
  - -- conductor/layout/tolerances/margins
- (b) Sensitivity of experiment to changes in magnet parameters
- (c) Technical risks and sensitivity to design choices/ justification of choices
- (d) Schedule
- (e) Costs

[2] What is the optimum scenario for achieving the required MECO magnet system in the appropriate time frame? Specifically, evaluate all plausible mechanisms for magnet procurement and include all technical, cost, schedule, and integration and management issues.

Annex 3

Agenda (outline)

Sunday 10 October:	Executive Session
	Overview of MECO and MECO magnet
	Presentations re functional requirements of magnet system
	Executive Session – first discussion and formulate questions
	Questions to MECO
Monday 11 October:	Executive Session
	Answers to yesterday's questions
	Presentations re procurement mechanisms
	Presentations re management, cost and schedule
	Executive Session – formulate questions
	Questions to MECO
Tuesday 12 October:	Executive Session
	Answers to yesterday's questions
	Executive Session – formulate conclusions and recommendations
	Closeout – Presentation of conclusions and recommendations to MECO

Detailed Agenda

Sunday, October 10

Topic	Presenter	Minutes	Cumulative Duration
Executive session		60	60
Welcome and introductions		15	75
Technical presentations on functional requirements and how we meet them			
Physics overview and requirements	Molzon/Hebert	30	105
Magnet overview	Smith	30	135
Field spec and tolerances	Molzon	45	180
Coffee break		15	195
Conductor, insulation and joints	Smith	45	240
Quench detection and protection	Smith	30	270
Lunch		45	315
Structural design	Titus	45	360
Cryogenic design	Smith	30	390
Explosion risk with using LN2	Molzon	20	410
Magnet assembly	Titus	30	440
Coffee break		15	455
Magnet installation	Titus	20	475
Startup and acceptance testing	Smith	15	490
Outcome of previous magnet reviews	Hebert	15	505
Executive session		60	565
Questions to MECO		60	625

Monday, October 11

Executive session		60	60
Answers to yesterday's questions	As needed	60	120
Coffee break		15	135
Procurement options and baseline plan	Smith	60	195
Lunch		45	240
Management	Smith	30	270
Schedule	Smith	30	300
Cost	Smith	30	330
Coffee break		15	345
Executive session		60	405
Questions to MECO		60	465

Tuesday

Executive session		60	60
Answers to yesterday's questions	As needed	60	120
Executive session-formulate conclusions and recommendations		120	240
Lunch		45	285
Closeout-presentations of conclusions and recommendations		60	345

Annex 4

Persons present:

MOG members (see Annex 1)

MIT

Brad Smith
Peter Titus
Alexi Radovinsky

University of California, Irvine

Michael Hebert
William Molzon

BNL

Praveen Chaudhari (BNL Director, at closeout)
Wuzheng Meng
David Phillips
Philip Pile
Peter Wanderer
Peter Yamin

BNL/Columbia

William WIllis
Jonathan Kotcher
Alexander Firestone (closeout)

Other MECO

Krishna Kumar (University of Massachusetts, Amherst)
Paul Souder (Syracuse University)
Ed Hungerford (University of Houston)

NSF

Pat Bautz
Marvin Goldberg
Jack Lightbody
James Whitmore