Report from Booster Corrector Review

October 30, 2006

Proton Plan
Booster Corrector Review

Committee Members Present:
M. Syphers (chair), T. Nicol, H. Pfeffer, B. Oshinowo

A short review of the Booster Corrector Magnet System was held on October 10, 2006. An overview of the project was presented by Eric Prebys, followed by talks on the magnet system by Dave Harding, recent prototype magnet measurements by Phil Schlabach, the power supply system by George Krafczyk, and installation and safety issues by Craig Drennan. The talks ran over their allotted time, and the meeting was ended without additional discussion. The Committee members met separately for discussion, which has generated this report.

The purpose of the review was to look into issues regarding beam physics, magnet and power supply design, production, installation, and alignment relevant to the production of the magnets and power supplies, with emphasis on the correctors scheduled for installation in the summer of 2007.

A highly innovative magnet design has been adopted, which has 12 iron poles surrounded a configuration of 6 separately powered coils wrapped in two different coil packages in order to produce dipole, quadrupole, and sextupole fields, normal and skew, and any combination, at each corrector. The laminations have been chosen to allow for the required ramp rates for correcting the orbit and adjusting tunes and chromaticities through the entire Booster cycle.

Magnets and Power Supplies

The magnet design is impressive. The coils shown at the meeting were solidly built, and the prototype data looks generally good, though some specs were not exactly met. This brings up questions such as, "should the specs be changed?" "are the magnets good enough?" "are beam physicists looking at the implications of the specs not being met?" The results of the prototype measurements do not seem to be driving any changes, so either everything is OK or no one has looked at their impact on Booster performance.

Prototype data show that the field at 1" has dB/B (relative to the desired strength) of ~ 15 units (e-4) with all coils powered full strength. Statements as to (a) whether this was expected from the magnet design, and (b) whether this is acceptable for accelerator performance would be appropriate. Differences in field strengths for positive and negative coil currents were also cited, but are unexplained. Again, the implications on Booster performance should be quantified.

The magnets appear to fail to meet specs in a few instances. For example, the sextupole field varies by more than 1% across the 3" aperture, and perhaps more importantly, the rise time of the field is about 2 to 3 ms, which is slower than desired.

With regard to the field rise time, the source of the slow rise does not seem to be understood. It would be a good idea to at least track down the source of the limitation and make sure that no feasible design change could correct it. More AC measurements are expected to be performed, but whether there is time to affect the magnet design afterward is not clear to the committee.

The total cooling path in the magnet is a long tube with a smallish opening and a low flow. To minimize clogging problems, we encourage the following measures:

a. Make sure the cooling paths are braised so as to minimize induced voltages and hence electroplating problems. The two cooling windings in a coil package should be braised in anti-series, so that their induced voltages immediately cancel. (The magnet designers are likely aware of this.)

b. Carefully filter the water going to the correctors.

c. Determine, through measurements, what a proper set of carefully placed thermal switches would be to help to detect a clogged path.

There does not appear to have been any attempt at detailed thermal testing of the magnet (or, at least, no report of such was presented). With the complicated set of coils and cooling channel, this needs to be done. For instance, it was noted that "we can probably even run with one water circuit blocked." It would be nice if this could be verified and quantified through testing.

The magnet presentation mentioned that the coils were hi-potted to ensure they are not shorted to each other or ground. It would be good to find out what the hipot level is to make sure it seems adequate. In addition, the AD EE Support group should conduct a corona benchmark test to further ensure that the insulation scheme is robust.

The committee would feel much more comfortable if 2 or 3 prototypes were produced, especially if one were installed and tested in the tunnel, before committing to the final installation during the long shutdown.

Is the BPM a new device, or recycled from the existing BPM system? How does this device fit in with the magnet installation? The committee heard no details on this, as was the plan according to the Charge letter, however the incorporation of the BPM into the magnet assembly, its intereferences (if any) with the field quality, alignment issues, stand, etc., need to be understood.

In the power supply presentation it was mentioned that the types of ramps that the Booster Group wanted to see were not known. This seemed peculiar, as the ramping of these magnets is the main driver of the upgrade. This has implications for the specification of the bulk supply for the correctors. The bulk supply is not a big cost factor, however, so designing to peak out all the correctors can be done, as long as it can all fit in the rack, etc. This issue needs to be resolved.

It was mentioned in the talk, after questioning, that there is a new function generator card being built for use in controlling the power supplies. The progress of this card, the ability to run the supplies with or without this card, and the start-up, commissioning, and routine operation of the magnet system needs to be discussed. What applications software is being written for setting the tunes, for example?

Installation and Alignment

The alignment group does not have an alignment tolerance specification yet for the magnet assembly. Alignment fixture and magnet stand designs depend on the alignment tolerance specification. This should be generated very soon. There was also no presentation on the magnet stand or any details of how the magnet is assembled or aligned in the tunnel.

New racks and cables are required for the magnet power supply system, while existing tunnel penetrations are OK for the project. A heat-test of cables through penetrations will be performed to measure temperature rise. Hazard Analysis, ALARA, walk throughs, and Quality Monitoring associated with the installation are being addressed.

Atypical locations in the tunnel have been thought through and solutions exist to fit in the new correctors (which are slightly longer than existing magnets). A detailed schedule exists (though still rough) of the installation process, though this was not presented or discussed. While the installation of this system should be straightforward, this was not demonstrated.

Schedule and Budget

The Committee is most worried about contingency in the schedule, not only in the production of the magnets, but also in regards to start-up and commissioning of the system -- magnets, power supplies, controls, applications software, etc. Any problem along the way keeps the entire complex down beyond the scheduled shutdown period. The Booster will be a new machine and start-up may be difficult.

Installation of 24 magnets during an 8 week shutdown period seems reasonable, if everything is ready to go. The risk materializes if the vendor has trouble during production, or runs out of time, etc. There needs to be time built in to the schedule to allow the contractor to build 1-2 magnets and have them tested at FNAL before proceeding. This should be put into the contract. If anything is learned during the production which suggests a change to the magnet design, there does not appear to be any time to react. Does a "Plan B" exist?

With only half of the correctors installed, the full benefits (any?) of the system cannot be realized until the second shutdown period in FY08. On the other hand, adjustments, vertical and horizontal, can be made with each corrector. The committee would have liked to have heard how the first half of the system will be used (alone, or in conjunction with the remaining original correctors) to perform adjustments to the synchrotron. If the FY07 installation will provide only partial benefits, is it possible to generate some smaller number of magnets and install them for "testing only" during the FY07 shutdown, gain experience with the magnets, their supplies, the software, etc., and then finish the entire installation during FY08? Perhaps the case for the existing scenario was made in earlier reviews and discussions, but it was not made here.

The magnet design and cost estimate is sound, the magnet production and QA plans are well thought out and in good hands. The risks involved are with the soon-to-be chosen contractor and issues that might arise during their "ramp-up." The power supply design is also in good hands, but again the schedule is tight. The installation schedule needs to be firmed up further, incorporating magnet stand development and alignment requirements.

Overall conclusions

An upgraded correction element package for the Booster has long been awaited, and the present plans, if carried out successfully, will provide a modern, robust system which is a necessary step for higher intensity operations. The system chosen incorporates a very innovative correction magnet design with much promise. As the first of its kind, to our knowledge, this system also brings with it some risk. While the mechanical and electrical specifications are challenging, they have straightforward solutions, and the risk involved is not in making the system work -- it is in making it work by the end of the June 2007 shutdown.

The half-day review of October 10 seemed too short for a complete investigation of this $2.4M project. This is one of the major pieces of the Proton Plan, and needs to be scrutinized in a more serious manner. The committee went away with the feeling that there was an interesting magnet program underway, but that some of the "specs" were not being met, and there was no general feeling from the presentations as to whether or not this presented any problem. Questions related to how to commission the system with beam, how to use the system operationally, what happens if the slew rate requirement cannot be met, and so forth, were not addressed in this review and should be. Likewise, much has been learned about how to construct the complicated corrector magnet. However, a complete magnet with restraining end caps, magnet stand, and alignment features has not been made. Thermal properties have been computed, but not completely measured. Getting from this stage to 24 complete systems within the next 8 months seems very challenging, indeed.

The committee would recommend a more comprehensive review of this project in the near future to ensure proper measures continue to be taken in this very important upgrade. In the interest of meeting the already-aggressive schedule, procurement plans that are already in place should move forward.

Mike Syphers
Tom Nicol
O'Sheg Oshimowo
Howie Pfeffer
October 17, 2006

Appendix:
- Charge
- Agenda

Charge to Booster Corrector Review Committee

Committee Members:

You are being asked to evaluate the new corrector system being built for the Booster. This system is a very significant part of our campaign to increase Booster efficiency over the next several years to the point where it deliver beam at a full 15 Hz, while keeping total beam loss in the tunnel at more or less the current level.

The project is on an extremely aggressive schedule to install half of the correctors in the Booster long straight sections in the 2007 summer shutdown, and the remaining correctors in the short straight sections the following year. Therefore, it's vital that we identify any issues that might jeopardize the success of this project while we still have time to address them. In reviewing the project, please consider the following questions:

1. Are the magnetic specifications for the corrector packages well suited to the goals of controlling beam position and maximizing Booster efficiency?
2. Is the corrector design well matched to the magnetic specifications in terms of multipole strength, slew rate, field quality, and repetition rate (heat load)?
3. Have the magnetic measurements adequately demonstrated the acceptability of the corrector design and are the proposed production measurements adequate for quality assurance?
4. Are the power supplies and associated control hardware and control hardware appropriate for the requirements of the system?
5. Is the mechanical for the installation optimal?
6. Is the installation plan for the long straight correctors reasonable, given the eight week length of the 2007 shutdown? This should address all aspects of installation, including the corrector and power supply installation, cabling, cooling water, alignment, and quality control.
7. What are the biggest risks, in terms of procurement, remaining design, fabrication, and installation?

Note that while the first four questions relate to the corrector system as a whole, the remaining questions are primarily focused on the correctors which will go in during the 2007 shutdown.

We understand that the controls software for this system will be vital to its success, but it will not be discussed at this time beyond a generic description necessary to evaluate the power supplies. In addition, we will not be discussion the integrated BPM, except to the extent that it might affect the magnetic field.

Sincerely,
Eric Prebys
Proton Plan Manager

"Booster Corrector Review"

Tuesday 10 October 2006
from **08:45** to **14:00**
at Industrial Central Building (***TD HQ Conf. Rm. (2nd floor)***)

Description: Review of the Booster Corrector System

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08:45	Executive Session (15') (document)	
09:00	Introduction and Magnet Requirements (20') (Slides)	Eric Prebys (*Fermilab*)
09:20	Magnet Design and Production Plan (40') (Slides)	David Harding (*FNAL*)
10:00	Magnet Measurements (35') (Slides)	Philip Schlabach (*FNAL*) , George Valev (*FNAL*)
10:35	break	
10:50	Power Supplies (20') (Slides)	George Krafczyk (*FNAL*)
11:10	Safety and Installation (30') (Slides)	Craig Drennan (*Fermilab*)
11:40	Conclusion and Discussion (20')	
12:00	Lunch/Executive Session	
13:30	Closeout (30')	Mike Syphers (*FNAL*)

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