Committee Report
STAR Magnet Core
Final Design Review
September 12/13, 1994

Committee: J. Cullen (BNL/AGS), L. Dittert (consultant), A. Etkin (BNL/STAR, Safety), A. Pendzick (BNL/AGS), Ross Schlueter (LBL/ALS) W. R. Edwards (LBL/STAR, Committee Chair)

Introduction:

On the 12th of September, 1994 at BNL, members of the STAR Magnet design team made presentations to a Final Design Review Committee, on the core detail drawings, analysis results, specifications and the status of elements which interface with the Magnet Return Steel. The committee charge, review agenda, presentation materials and action items may be found in the Core FDR binder in the STAR Project Office. This review represented the last formal technical review of the magnet core prior to the release of the Request for Proposal (RFP) package to potential steel fabricators.

The information presented by the magnet design team was very good, enabling the committee to conduct an effective Final Design Review of this major technical procurement. The committee would like to express its thanks to the presenters and the Magnet design team for making its job a little easier.

Executive Summary:

The committee found that the design presented addressed the significant issues necessary for a steel vendor to produce the STAR Magnet Core. It was felt that the core design, as specified, will comfortably meet the STAR Detector's technical requirements.

It is recommended that some of the specifications be tightened up and some points in the statement of work (SOW) be further clarified. These specific instances are discussed in the section titled "Specifications, Statement of Work & RFP Process", below.

Except for some suggested refinement in the support structure's analysis and assembly procedures, the magnet and main magnet support design appear to be complete. The committee does recommend that at the end ring to backleg joint, the bolt pre-tension be increased to 40 percent of yield.

The committee commends the magnet team for paying attention to the TPC field quality throughout the design process, and for incorporating features that enhance or maintain field quality, as appropriate. Problems and scenarios have been anticipated to make sure magnetic forces and eddy currents cause neither catastrophic failures nor dimensional changes. Several magnetics-related action items largely address the issue of future magnet steel changes, both intentional and unintentional. These action items should complete the analysis of the already well-designed magnet steel and ensure reliable long-term operation.

It is suggested that STAR maintain a document that tracks the addition of magnetic materials within the magnetic volume, and verifies that none of these materials significantly alters the TPC field. This effort should be coordinated by the magnet subsystem manager.

The committee recommends that the magnet group establish, with the survey group, an overall magnet and detector survey plan. The plan should identify target reference points and specify whether or not they need to be part of the steel machining process.

The magnet group should specify the positioning sensitivity and load capacity of the hall cranes needed for assembly. A crane load readout would also be a valuable tool in assembling these heavy components.

The coil bumper analysis for the nine given operational perturbations was thorough. This analysis does point out the importance of keeping the STAR magnet within its operating envelope, especially coil cooling water temperature and current. A single document listing the coil operating envelope, sequential turn-on/turn-off procedures and the reasoning behind these would be helpful in the future.

In summary, the committee has some recommendations for follow-on effort, but found no outstanding critical technical issues that need to be addressed prior to releasing the RFP to potential bidders. The rest of this report will present several areas in which the committee believes the magnet core, support structure and specifications for these items might be improved.

Critical Issues/Findings:

In general, all significant issues have been addressed in the design as presented. There are no critical issues or findings. If built, the drawings and specifications as they now exist, would result in a magnet core which would comfortably meet the physics requirements of the STAR Magnet System.

One issue that the committee feels should be addressed soon is the design of the pole tip support carriage. The design of the carriage has not advanced appreciably since the PDR one year ago. This may provide an opportunity to redefine the carriage's design parameters to better take into account magnetic effects, rotational alignments and interference with the external TPC. Because the pole tip carriage design and analysis are still in the conceptual/preliminary design phase, the final design of the pole tip support carriage should be subjected to its own independent final design review.

Safety:

Although the assembly of the magnet is approximately 18 months away, it is a good time to start setting up the procedures required for assembly and movement of the magnet and pole pieces. The committee suggests that a preliminary plan be made for the development of procedures (formal and informal) and training. This should be done in consultation with STAR Management and RHIC safety personnel. Considerations for assembly include the need for formal checklists, required personnel, sequence of operations, lifting rig set-ups, use of special tooling, set-up of work platforms and scheduling of specific operations. For moving the magnet, consideration should be given to Lock-Out Tag-Out (LOTO), the need for formal checklists, required personnel, sequence of operations, use of special tooling and scheduling of specific operations.

Specifications, Statement of Work & RFP Process:

Magnet Core Specification (STAR Note 182)

The Committee makes the following observations with respect to the steel specification:

1. Section 3.4.1 requires the AISI 1008 steel to be fully annealed. It may be desirable to specify which anneal cycle will be used and at what point during processing the anneal(s) will be done.

2. Sections 3.4.2-3.4.5 define physical properties of the core steel. Number and location (where applicable) of inspection points should be specified for each type of inspection. For example, a ladle chemical analysis should be completed at least once for each heat.

3. In section 3.4.6, a better understanding of the abilities and limitations of non-destructive testing is needed. It may be desirable to request the seller's recommendation as to specification of test limits on these large pieces. Acceptable methods of repair for pole tip discrepancies should be well defined before an occurrence to minimize cost impact. What the

vendor perceives as an acceptable fix, and allows for in its price quotation, may not be acceptable to the buyer.

4. It is suggested that section 3.6 regarding surface finishes be expanded to call out a specific minimum requirement for painted surfaces.

5. Source inspection of parts is recommended to reduce the likelihood of increased transportation costs in the event of significant discrepancies.

6. The magnet core specifications should be expanded to include a specific definition of responsibility for the supply of bolts, inserts, off loading of steel at BNL, and repair of damages to these parts that may occur during transport from the buyer's last point of inspection to BNL.

SOW for STAR Magnet Core Fabrication (STAR Note 181)

The Committee makes the following observations with respect to the Statement of Work:

1. In Section 1.2, who, vendor or buyer, is responsible for damages in transit and for off-loading at the destination? This should be specified in the procurement documents.

2. Section 3.3 requires detailed production reporting on a biweekly basis. Production reporting every two weeks may be excessive; perhaps a monthly report is more reasonable.

3. Section 3.4 should detail minimum protection requirements with respect to rain, dust, and physical damage during transport. A protective coating for machined surfaces should be considered.

4. If multiple vendors are involved in the procurement it may be cost-effective to share "permit" information.

RFP Process

The Committee makes the following observations with respect to the RFP Process:

1. It is understood that many holes required for the attachment of undefined details to the core steel have been omitted from the core drawings. Placement of a generic hole pattern on drawings with their location and the number of holes estimated would allow for a more accurate price

estimate for the finished parts. Drawings could be modified for actual hole quantities and sizes after the contract is awarded.

2. The core design relies heavily upon Superbolt technology. Due to the critical nature of this application, care must be taken to assure the use of authentic hardware or its equal. Unless Superbolt brand hardware is required, a material specification may be needed.

3. Another area of concern is that of the low bidder. A means to evaluate bids needs to be devised so that a low bidder with no track record or of questionable ability to perform can be reasonably eliminated from the competition.

Structural Analysis of Core and Pole Tips:

Since the PDR of September, 1993, there has been considerable progress made in the design and structural analysis of the magnet steel, and in establishing assembly procedures. Comments of the PDR have been considered, and for the most part, incorporated in the final design. Except for some refinement in the support structure's analysis and assembly procedures, the magnet and main magnet support designs appear to be complete.

The design, analysis and drawings for the magnet core, including the connections, tip brackets, etc., look complete and are in sufficient detail to ensure the structural integrity of the magnet. The assembly procedures could be refined to consider the effect of the length (z direction) tolerance of the back legs on the longitudinal stiffness of the magnet as described in Action Item 26. The committee also recommend that the bolt pre-tension be increased to 40 percent of yield to this end.

Main Magnet & Pole Tip Support System Design and Analysis:

The Main Magnet Support Structure design and drawings are nearly complete and look very good. The one recommended refinement is that, to better simulate the actual support conditions, and to assess the effect the support structure and magnet distortions have on the rollers, the "fixed" supports of the saddle should be replaced with "spring" supports as described in Action Item 27.

The pole tip carriage design and drawings are in a preliminary state. Based on the estimated loadings the connection to the back of the pole tip could be simplified. This could decrease the time required to move the pole tip back for detector maintenance. Provisions should be made for rotating the pole tip to align the four bracket holes with the outer ring bolts in the tangential, and to align the holes in the x-x direction. Because the pole tip carriage design and analysis are still in the preliminary design phase, and in some respect in the conceptual design stage, this element should be subjected to its own "mini-FDR".

Magnetic Field Analysis:

The STAR steel group has incorporated features that enhance and maintain TPC field quality as appropriate (sufficient high-quality soft iron to avoid saturation-induced field quality degradation; maintaining symmetries; providing robust, broad-peaked operating points, etc.). Problems and scenarios have been anticipated to make sure that magnetic forces and eddy currents cause neither catastrophic failures nor dimensional changes that could subsequently alter the TPC field.

Several magnetics-related action items largely address the issue of future magnet steel changes, both intentional (moving end carriages and end caps, adding magnetic materials, etc.) and unintentional (dimensional changes upon reassembly or upon climate changes, etc.), that could have a negative effect on the field stability. These action items should bring to completion the analyses of the already well-designed magnet steel and furthermore, ensure reliable long-term operation.

Following are the recommendations of the committee regarding the magnetics and resulting field quality aspects:

1. A final TPC field quality optimization with POISSON for the "final" steel design, incorporating new spaces, dimension changes, etc. should be performed. Verify and document that some new set of coil current settings will give good field in this final steel version. Also do a final TOSCA recheck for field components in the azimuthal direction.

2. Modify the end rings such that the axial space between inner rings and 30 return bars is the same (0.25 inch) at both ends. Check the sensitivity of the field in the TPC volume to this dimension. Also check the field sensitivity to (a) random radial spaces between the inner rings and return bars, and (b) random axial spaces between outer rings and return bars.

3. Verify that none of the holes incorporated into the final steel design (a) cause saturation which alters the TPC field, or (b) cause a surface field perturbation that alters the field. Include holes in 30 return bars and holes in endcaps in analyses.

4. Maintain a document that tracks the addition of magnetic materials and verify that none of these materials alters significantly the TPC fields. Include pole tip carriage, bolts for detectors and electronics, etc. on the list.

5. Will the pole tip carriage structural steel affect the TPC field significantly? How about its effect on the external TPC? No specifications have been given for the field in the external TPC. If this is an issue, it needs to be addressed.

6. The wording in the specifications regarding magnetic properties and allowable variations needs more work. Be specific about heat treatment as well as the grade of iron desired.

Magnet Assembly Procedure:

At this phase of the project, it is important to establish, that the magnet can be assembled efficiently and meet the overall design tolerances. Required fixtures must be identified and sufficient attention must be given to the handling of each piece. In general, this has been demonstrated, and the committee suggests that the next level of detailed planning proceed and include the following:

1. Identify areas where tolerance buildup could be a problem.

2. Establish, with the survey group, an overall magnet and detector survey plan. Identify target reference points and specify if they should be part of the steel machining process.

3. Ensure detector support plans are sufficiently advanced so they do not affect the steel design or assembly sequence.

4. Identify special handling needs such as “tilt-up” fixtures or fixtures for rotational tolerances.

5. Review the assembly sequence and tolerances of the lower nine backlegs, because they set many of the overall tolerances.

6. Identify the positioning sensitivity and load capacity of the cranes needed for assembly. Various motor drives, such as variable frequency motor control, give very good positioning sensitivity over a wide range of speeds. Crane load readout would also be a valuable tool in assembling heavy components.

Coil "Bumper" Design:

The coil bumper analysis was thorough for the nine given operational perturbations. While it is difficult to anticipate all possibilities, the chosen perturbations give good insight into how coil forces vary with a given perturbation. This analysis does point out the importance of keeping the STAR magnet within its operating envelope, especially coil cooling water temperature and current. There is some evidence that these perturbations, along with age, eventually produce stress cracks in the coil, especially in epoxy-rich areas. A single document listing the coil operating envelope, sequential turn-on/turn-off procedures and the reasoning behind these would be extremely helpful in the future. This document should also include the original Pancake Test data, voltage tap and temperature information.