EMC Final Design Review
Report of the Committee
STAR Note #397

Introduction:

A Final Design Review (FDR) for the STAR EMC was held on February 24th and 25th, 1999. A committee, consisting of R. Brown, A. Pendzick, S. White, B. Christie, H. Matis, H. Wieman, Y. Makdisi and B. Edwards (chair) participated in this review which took place at Brookhaven National Lab.

The review covered design requirements, analyses, hardware design, optical system design, installation tooling, module assembly plans and installation schedule of the Barrel Tile Calorimeter and Shower Max. A secondary purpose of the review was to communicate the RHIC and STAR standards and requirements for drawings and documentation, procedures, safety review and operational readiness reviews.

The review agenda, presentation materials and action items can be found in the EMC FDR binder in the STAR Project Office. The action items from this review are considered an appendix to this report.

Summary & Conclusions:

The EMC Group has made good progress over the past year and is now ready to begin module component production. This statement can be made because, of the few action items (6) and few suggestions/recommendations that were made, none of them will delay the ordering of materials and the fabrication of parts. The major recommendations made will require the addition of instrumentation during the assembly process in one case and the design of a method of testing after module installation in another. In the case of the last recommendation, some epoxy shear tests and better analysis of the epoxy bond are required for the showermax. This last issue will hold up module assembly and so should be resolved quickly.

A design review of the EMC electronics should be planned for the coming months - well before the summer shutdown. The modules don’t add a lot of capability to STAR without electronics to read them out.

With respect to the module installation schedule - it is the committee's opinion that when all things are considered, there is a 50% probability of getting 6 or more modules installed this summer (1999). However, we'd assign a 90% probability to getting 2 or more modules in. The committee suggests that EMC Management plan two-shift operation for the two week module insertion window (approx. Aug. 12-25, 1999). Part of the reason for the low probability of a large number of modules being installed this summer is the last minute delivery of the installation tooling (2 weeks before it's needed).

The committee has 3 major recommendations:

1) apply strain gauges to the straps on the first 3 modules manufactured. This should be done to help understand the impact of manufacturing tolerances on the uniformity of module strap loading and to help ensure that there are no failures.

2) come up with a quick and easy method to test fibers for damage immediately after installation.

3) characterize both the shear strength of the epoxy and the shear stress that results during handling and shipping of the Shower Max Detector.

These recommendations along with the committees suggestions, comments and concerns are further described in the body of the report.

Module Mechanical Design:

The straps that hold the front and back plates together are a possible achilles heal (tendon?) for the EMC... The design principle is fine, but the stack up of manufacturing tolerances (strap length, slot depth, front/back plate flatness) could cause certain straps to pick up much more than their share of the load - perhaps pushing them close to failure.

The stated tolerance stack-up is 0.004 in. If two adjacent straps and slots were at opposite ends of the tolerance spectrum, this variation in length would be taken out in additional strain in the short strap. The straining of the short strap would continue until the adjacent strap began to take up load, This strain (0.004"/12"), taken by the short strap before the adjacent strap begins to take up load, is equivalent to 10 Ksi stress. Note that this stress is then additive to the subsequent module stack pre-load stress. This simple calculation assumes that the bending stiffness of the top and bottom plates are significantly higher than the tensile stiffness of the straps (not necessarily true).

The committee, however, is somewhat concerned that the stated max. tolerance stack-up has been underestimated. To settle this issue quickly and effectively, it was agreed that the first several modules manufactured would be outfitted with strain gauges on each strap. See the recommendation below.

Recommendation: apply strain gauges to straps on first 3 modules manufactured. Watch strain readings on straps during the loading process to ensure approximately equal loading. Check strain readings again after transportation to BNL to ensure things haven't changed. If strap loading isn't sufficiently uniform (any straps see

stresses that reduce FS yld to below 3 for example) shimming or sorting of straps may be necessary.

A weld specification is also required for the straps. The vendor selected for fabrication should provide a certification document that details all machine parameter settings, weld materials, parts fixturing, number of passes, and operator. In conjunction with this weld specification, a QA specification should be written outlining non-destructive and destructive testing that is to be performed. It is also suggested that WSU request a minimum of (6) six sample welded straps and perform, independent of the vendor, tensile testing until failure in their operating orientation. The QA documentation, with the inspectors signature, should follow each strap fabrication with individual identification serial numbers.

If at any time during the fabrication of either the module top plate, bottom plate, and/or straps there is a change in design, materials specification or supplier, parts manufacturer, strap weld specification/QA, Belleville spring washer specification, or pre-load procedure of the module during assembly - independent testing and verification should be performed to ensure the acceptability of the parts. At this time, it should be determined if the first module assembled, containing any of these parts, should be strain gauge instrumented and tested to re-confirm the uniform loading of each strap.

Optical System:

The design of the optical system has progressed considerably. Among the developments are: understanding of tolerances on scintillator plates, fibers and choice of vendors, adoption of optical connector transitions at side of modules, and at the PMT splitter box.

Fabrication methods for fiber assemblies, megatiles and QC tests have been developed. The QC steps currently planned cover as completely as possible all steps of the production. It may be that some steps which validate manufacturers' measurements could eventually be dropped.

The EMC group has also been careful to adopt wherever possible solutions that have already been shown to work in CDF, SDC & CMS.

The committees main concern is the criticality of the clear fiber cable run at fab and installation. With 120,000 fiber signals, what is an acceptable failure rate?. Perhaps more tests have been performed than were presented at the review. What was presented was that an older cable design was tried, found to have problems during installation and then improved upon. It is not clear what testing of this final design was performed. There was also not a definite commitment to test for failures immediately upon installation.

Recommendation: The group should come up with a quick and easy method to test fibers for damage post installation (before full readout system is connected).

Similarly, an earlier fabrication method for cables was tried and gave ~25% yield. The design was subsequently improved. However, what is known about the expected failure rate for this new method?

Fortunately, there doesn't seem to be a schedule problem in getting enough cables made for the assembly of 12 modules by the summer. Clear fiber installation during module insertion (the pulling process) is not yet optimized. A fiber pull test should be performed to establish an acceptable clear fiber cable and connector design, that when attached and bundled on the back of the module, can be pulled through the fiber guides during module installation. It is suggested that further studies and thought be given to this problem now in order to make this process easier and to reduce chances of breakage.

The EMC Group should produce a detail drawing for each of the 3 fiber types showing connectors and a table of the various lengths for each cable type.

Shower Max:

The Shower Max Detector (SMD) system design appears fine, The QC program is very complete. However, detail drawings need to be put into the STAR drawing format and added to the STAR Drawing database.

The shear strength of the FR-4/Cu to Alum extrusion glue joint is the most significant outstanding question. There were no joint strength data presented during the review. Nor was there any analytic justification of the present design. To remedy this, the committee recommends doing 2 things:

Recommendation: 1) Perform tests to determine the epoxy shear strength. Try different epoxy systems to attain sufficient strength. 2) Calculate the shear stress under various conditions - deflection during handling/shipping & for 75 degree F delta T. Compare this to the shear test results to ensure a satisfactory design factor of safety.

Schedule and Installation:

The module installation schedule presented at the review, which shows 8-12 modules being completed in time for this summers installation window, was stated to be conservative. It is the committee's opinion that it is not so conservative. All things considered, the committee would assign a probability of 50% to getting 6 or more modules installed in the 2 week module insertion window on the East side this summer (approx. Aug. 12-25). However, we'd assign a 90% probability to getting 2 modules in. The committee suggests that EMC Management plan 2 shift operation for the two week installation window (approx. Aug. 12-25). This requires finding appropriate manpower (both lead and support) and ensuring proper training.

The installation tooling design is solid - the committee has no issues with it. The last minute arrival (1-2 weeks before this summers installation window) of the tooling is cutting it too close for comfort. This doesn't allow for much assembly, test and check-out before it's first use and is partially responsible for the somewhat low (50%) probability of getting 6 or more modules installed. The committee suggests that EMC Management carefully monitor the progress of the installation tooling and take action to ensure on-time or early arrival of this hardware.

Integration:

The EMC group has worked closely with STAR Integration for many years. They have examined the integration drawings and they understand very well the space that has been allocated for them.

There was some concern that the EMC fibers will fit between the coils. It would be wise to check this on the actual magnet. The EMC group has selected their eta boundary so that it lines up in eta with CTB boundary.

The EMC barrel does not need water or airflow. However, the shower max does needs a source of non-flammable gas. The group should specify their requirements with respect to space, location of components and pipe runs for their gas system as soon as possible. Space in the Gas room is very tight and as the EMC is one of the last subsystems to be installed, the flexibility STAR has in locating equipment is minimal.

While this was not an electrical review, there are several mechanical decisions that will have major influence on the electrical performance. First, the signal from the photomultipliers is optically coupled to the readout phototubes. Therefore, there is no concern for grounding for this design. However, the showermax pre-amps are mounted in the EMC barrel. Unfortunately, because of the large size of the EMC Showermax there will be a large capacitive coupling. The EMC group might consider building a shield around the showermax that is isolated from the barrel. After installation, the shield could be grounded to the barrel to reduce noise. Putting in this capability now could make fixing a noise problem easier.

The RHIC safety committee will probably require a hard ground to the EMC barrel. Therefore, there should be a threaded lug or screw hole to accommodate this should it become necessary.

At sometime, someone may want to know precisely where the module boundaries are in the barrel. It is suggested that fiducial marks be added to the modules. These should be positioned so that they can be seen by the surveyors with the poletips retracted in the WAH.

Safety:

As only the mechanical and Optical components of the EMC Barrel were included in the review, the most significant safety issue is the potential fire hazard associated with the plastic. There is approximately 12 tons of plastic in the calorimeter module tile assemblies, and on the order of 450 km of fiber running from the tiles to the photomultiplier tubes. This fiber amounts to something on the order of 10 cubic feet of plastic. The material in the tiles and fibers, primarily polystyrene, should be presented for review to the BNL Fire Safety Engineer as soon as possible. It is also recommended that as much of the calorimeter system as possible be formally presented for review to the RHIC Experimental Safety Committee (RESC) no later than June, 1999.

The Shower Maximum Detector design was presented at the review, but there were no details presented on how the HV would be distributed within the detector. The presentation to the RESC should include this detail.