TEMPLATE FOR CLOSE OUT NOTE

TO: **Phil Heitzenroeder**
FROM: **Michael Kalish**

SUBJECT: **TF Coils Close out Notes, WBS 1361**

Date: 10/24/08

Scope

This job includes the design and manufacture of the TF Coils

Status

The Final Design of the TF Coils was completed in August of 2005. The contract for the fabrication of the TF Coils was subsequently awarded to Everson-Tesla. As part of the fabrication contract Everson-Tesla subcontracted the casting of the forward wedge assemblies to Osterby Inc. in Sweden and the final machining of the wedge castings after assembly to the coils to Atlas Machine in Pa. Everson-Tesla completed the fabrication of all 18 Coils with the delivery of Coil assembly #18 to PPPL in September of 2008. As a requirement of the contract Everson-Tesla also delivered manufacturing fixtures which remain in storage at PPPL. These include the VPI mold, winding fixtures, modified taping machine, and the fixture for locating and machining the wedge castings on the coil.

Interfaces

Diagnostic loop wires are incorporated into the TF Coil fabrication and coiled into a protective box ready for future instrumentation. TF Coil design to this point did not include the final I/O interface requirements. Final I/O interface requirements may include the requirement that the TF assemblies have thermocouples added to the coil cooling inlet and or outlet connections. Assembly fixture design was on going at the time of the projects cancellation and final fit checks of TF Coil three packs was considered as a possible step before final assembly.

Specifications

All final specifications including those for the coil conductor and wedge castings as well as the final assembly are posted on the NCSX web site.

Schematics and PIDs

N/A

Models

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All models are complete and posted in INTRALINK

Drawings

All TF Coil drawings including wedge, subassembly, conductor, and top level assembly drawings are complete and posted on the Engineering View Drawing Web Site

Analyses

All analysis are complete, checked and posted on the NCSX web site

Testing

All coils underwent a serious of electrical tests both at Everson-Tesla and at PPPL after delivery. Everson-Tesla testing was documented in their signed off manufacturing test plan documentation that was delivered with each coil. PPPL testing was documented by Tom Meighan in a summary spread sheet. All of this documentation will be stored in the Operations Center in fire proof filing cabinets. Other testing such as hydraulic testing of the cooling paths and cryogenic testing is also documented in the Everson-Tesla inspection test plan. The manufacturing test plan should be interrogated for a full accounting of the vendor testing.

Costs

No pending costs. Project completed by Everson-Tesla.

Remaining Work

No remaining work in the TF Coil Fabrication job. Early inspection and trial fit ups of the TF Coil are recommended to forestall any potential assembly problems. I/O requirements must be determined to choose any instrumentation such as thermocouples that may be added to the coils prior to assembly.

TF Coil Stress analysis results pointed to the importance of never cooling a TF Coil down so quickly that the NCSX modular coil and support structure are still warm. This creates high thermal stresses in the coil due to the ridged support structure and the relative expansion of the coil. Further system analysis is required to determine maximum delta T allowables. System operation procedures and instrumentation design should be driven by these requirements.

Lessons Learned:

Everson underestimated the R&D and development required to wind the first coil resulting in the delivery of the first coil months behind schedule. After the first six coils were completed Everson's schedule estimates were accurate and delivery was on time.

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Important to emphasis and reemphasis complexity of design to vendors so that they are not overly optimistic.

Winding D shaped TF Coils would have been easier for Everson with softer copper conductor. Specify the copper hardness to meet your requirement with margin but also try to minimize the required hardness and specify no greater than that to ease manufacturability.

Manage carefully a vendors selection of second tier subcontractors. While Everson was responsive in our requests to make up schedule they often were at the mercy of their subcontractor Osterby in Sweden who was manufacturing the wedge castings. Determine up front the risk to schedule in a vendors proposal due to the # of subcontracts and take steps to limit subcontracts or pad the schedule to account for the higher risk of delays.

Pay very close attention to fitting connections and leak checking prior to VPI. Recheck fittings after overnight coil preheating

Reinforce over and over the importance of cleanliness to the technicians. Bringing Everson personal to PPPL to see our Modular Coil Fabrication in progress created "buy-in" which helped foster a good attitude and good working relationship.

TF Coil Stress analysis indicated early on that the tensile strength of the glass epoxy bond to the copper conductor was insufficient to resist the tensile stresses resulting from the cryogenic cool down of the coil. This result was born out in testing at CTD. The design was adjusted to provide a Kapton layer of glass directly to the conductor for which the dielectric standoff capability provides great margin whether or not the Kapton adheres to the conductor. The design was subsequently tested successfully at cryogenic temperatures at Oak Ridge on a prototype bar at stress cycles equivalent to 20X life at stress and 2X stress at life.

The robust TF Coil insulation design was advantageous in mitigating the possibility of failure due to the infiltration of contamination during the winding of the coil. The available space allowed the TF coil design to include very high factors of safety with respect to the voltage standoff. All electrical testing exceeded requirements substantially.

The design of the cryostat for the TF Coil by Everson required the addition of a "stirrer" and heaters to agitate the liquid nitrogen bath and create enough convective cooling to bring the coil down to temperature in a reasonable time frame.

High stresses in the lead area of the coil were designed out by fabricating lead blocks as opposed to bending the lead out directly. This moved the high stress area from bending to tension and from a small cross section to a large cross section. Lead area forces were reacted through solid blocks of G11 from one side to the other instead of less reliable potted glass epoxy.

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Conclusion:

Overall contract was completed successfully. Everson-Tesla was responsive to our oversight and quality was maintained with our vigilance. Schedule slip never was significant enough to place the TF Coils near the critical path along for the luxury of pushing quality without impacting the critical path if the TF Coil schedule slipped.