TO: **M. Cole**
FROM: **J. H. Harris**

SUBJECT: **NCSX Coil Protection Closeout Summary**

15 September 2008

Scope
This effort covers all R&D, Title I, II, and III for systems to protect the NCSX coil sets against improper configuration and electrical, mechanical, and thermal faults.

Work includes engineering design, procurement, and fabrication of leads, terminations, thermal transition boxes (TTB), and associated support hardware. Work in this WBS ends with delivery of components to machine assembly operations.

Additional technical details are in attachment of material presented at April, 2008 Lehman review.

Status
Thermocouples and strain gages had been added to drawings for the Modular Coils, SE140-101,102, &103.

Investigations were underway to add strain gages to the modular coil flange clamping bolts to determine if the bolts would lose clamping force during operation. Conventional and fiber optic gages were being investigated.

Operating limits for the thermocouples and strain gages had not been set at the time of the closeout.

Just prior to NCSX Project Termination, a Coil Protection Planning Meeting was held on May 29th to provide a path forward. The notes from this meeting are attached.

Interfaces
TF (WBS 131)
PF (WBS 132)
Trim Coils (WBS 133)
Modular (WBS 14)
Cryostat (WBS 17)

Specifications
No work had begun on a system requirements document

A formal FMECA would have been necessary as part of the engineering process.

Schematics
None

Models Completed
Models are sufficient for a PDR stage.

Drawings
None, but models are sufficient for a PDR. Some preliminary drawings would be ready at the time of the review.

Analyses
None completed by ORNL Engineering. Lead attachment field error calculations were performed by A Brooks at PPPL.

Testing
None

Costs
Cost estimates were updated on the latest WAF and were included in the 08 Lehmann review presentation (attached).

Remaining Work
- R&D to build and test lead spiders and mount brackets.
- The routing path for the leads.
- Location of TTB boxes.
- Analyses to confirm lead sizes.

The R&D was not required for the PDR.

Preliminary work (models) of two configurations of routing of leads and locating of TTB boxes were complete. Work would progress quickly (~2 weeks) once a choice was made.
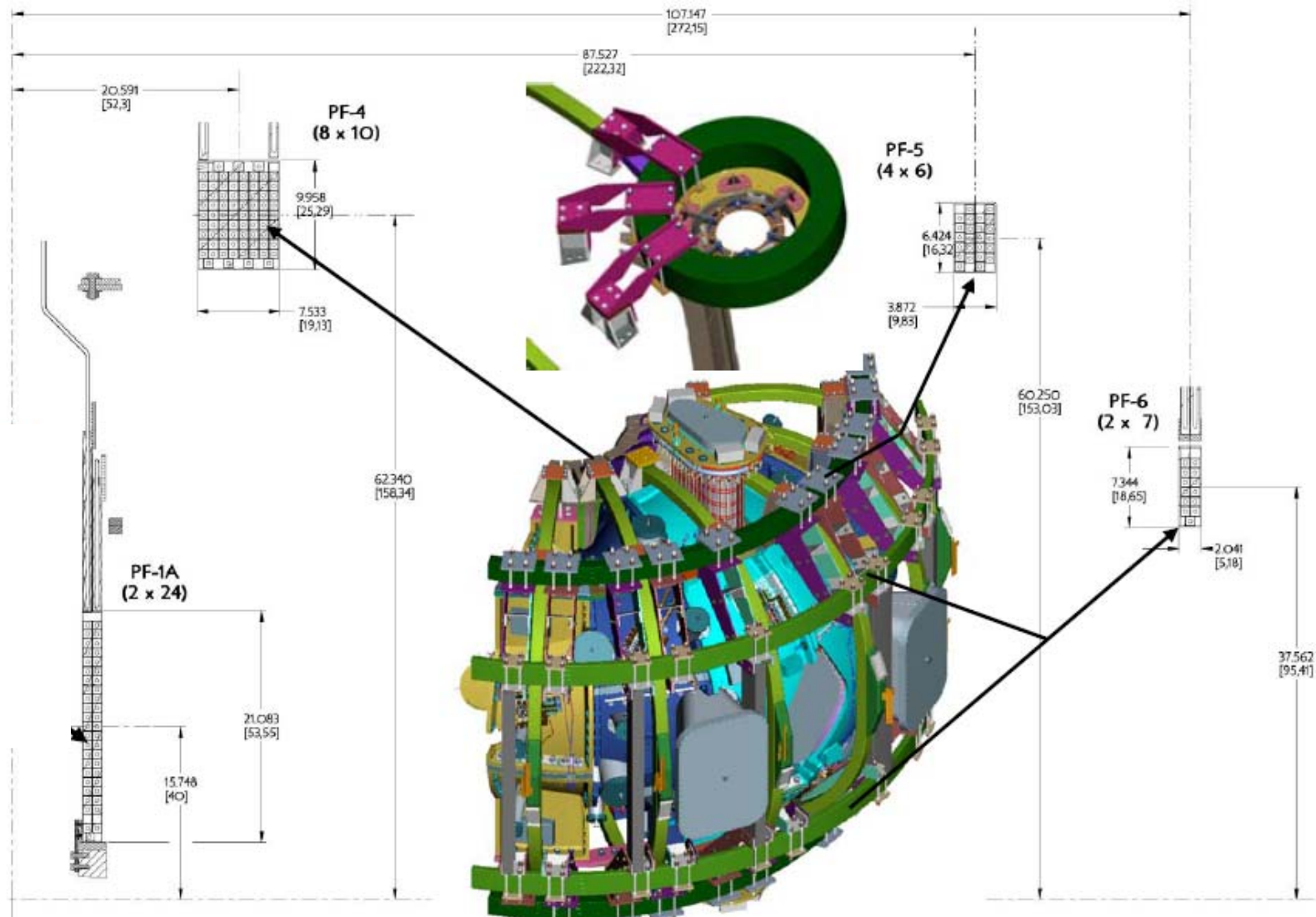Hand calculations of lead sizes were made, simply not formalized yet.

Conclusion
The work was in a preliminary phase, but was on schedule to meet the PDR schedule.
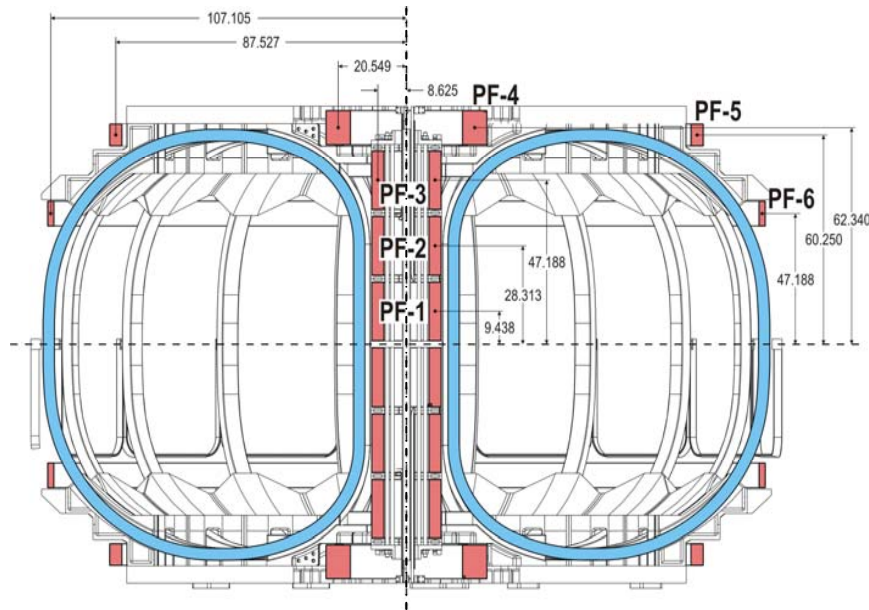
NCSX Coil Protection System

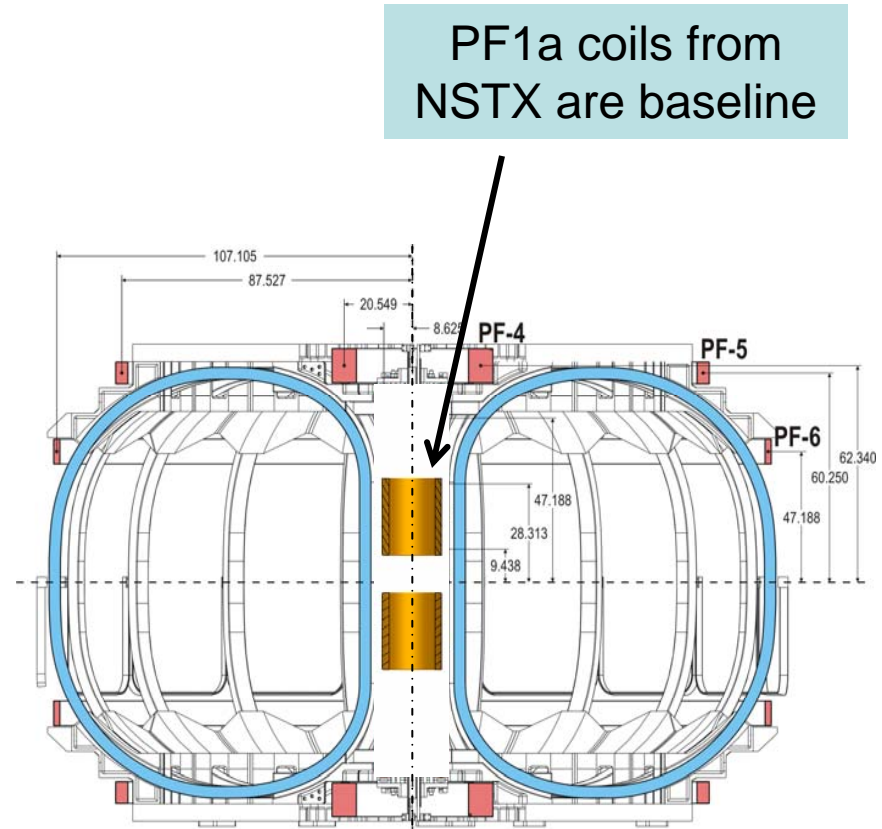## (Excepts from Lehman Review April 2008)

P.L. Goranson

Work Package 163

NCSX Coils

Central Solenoid, TF, and PF Configurations

Upgrade Configuration

Baseline Configuration

PF1a coils from NSTX are baseline

- Baseline is PF1a, PF4, PF5, and PF6 (2 each, upper and lower).
- Device can be upgraded if desired, where PF1a is replaced by PF1, PF2, PF3.

WBS 163 Coil Protection System

Description

This element covers the specification of coil protection requirements for the coil protection system.

Scope

Work covers Title I, II, and III Engineering support for development of the system, including any drawings, electrical and I&C schematics, or analyses. There is no design, fabrication, or hardware included under this package.

The results of thermal, electrical and mechanical analysis will be used to define allowable operating limits for the coils for commissioning, normal research operations, and fault conditions. Appropriate diagnostics and permissive, alarm, and failsafe signals to the power supply controllers and I&C systems will be defined.

Cost

Description:

This effort covers all Title I, II, and III engineering for the Coil Protection System. No hardware is anticipated for this job, only design interface with WBS 4 and 5.

| Task ID	Multiplier	Unit	Number of Units	Hours	ORNL EM	ORNL DSN
Title I an II Design						
Pro-E models (avg)	8	hrs/model	0	0	0	
assy dwgs	24	hrs/dwg	120 0	0	0	
Detail drawings	16	hrs/dwg	0	0	0	
installation dwg	16	hrs/dwg	0	0	0	
cooling schematic	0	hrs/dwg	0	0	0	
electrical schematic	8	hrs/dwg	0	0	0	
I&C schematic	20	hrs/dwg	120 4	80	0	120
stress analysis	0	hrs/calc	0	0	0	
thermal analysis	24	hrs/calc	0	0	0	
special analysis (electromagnetics)	40	hrs/calc	2	80	40	
Procurement Specifications	16	hrs/spec	0	0	0	
preliminary and final design reviews	40	hrs/rev	1	40	40	
meetings/reporting/presentations	10%	% of tot hrs		20	20	
Subtotal Title I & II Design				*220*	*100*	*120*

Schedule & Staffing

Schedule

Activity ID	MILE-STONE LEVEL	Activity Description	Duration (work days)	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete	FY08	FY09	FY10
163.001		Design Coil protection(input to WBS 4 & 5)	65		01OCT08*	12JAN09	435	31,576.20		ORNLEM =100hr ;ornldm=80;ea//em=40	

Staffing

Jeff Harris – 270 hours in 2009
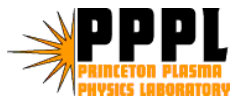
Cost Estimate Risks

Coil Protection Requirements (WBS 163)

Maturity – low

Job is at conceptual design stage. It interacts simultaneously with a several other WBS and relies on ongoing analysis. Number of documents is not established.

Complexity – low

Specifications may be replaced with data sheets where procured items are available as stock items.

Many parameters are supplied from other WBS areas and are already available.

Protocols and systems must be compatible with both initial commissioning and full research operations.

Coil Protection Planning
Hutch Neilson, May 29, 2008

The purpose of this document is to provide a strawman plans for coil protection. The coil protection peer review of 2/22/08 identified some possible gaps in the planning, which were documented in chits, specifically Nos. 1, 5, 6, 8, 13, 14. Issues are:

- Establishing coil operating limits and protection responses.
- Identifying failure modes and mitigation measures.
- Establishing sensor requirements (thermocouples, voltage leads, etc.)
- Establishing local I&C signal conditioning / signal processing requirements & responsibilities.

For all of the above, how far should we go beyond minimum Day 1 requirements? It may be wise to do the analysis needed to establish outer limits of the operating envelope now while the information and models are still fresh, even if the hardware implementation is postponed to upgrades.

This subject was addressed by Wayne Reiersen in a memo, "Coil Protection," (Feb. 22, 2007), which provides a good planning foundation, especially for Day 1 protection needs.

Proposed Plan

Chit 1.   Document Coil Protection Requirements
Chit 6.   Combination of measurements recommended for overheating protection
Chit 8.   Provide voltage sensor leads to support pre-shot resistance measurements

- Instantaneous overcurrent protection limits
  - WBS 14/13 to specify for Day 1 and upgrade

  WBS 163 will compile this information (Harris). Mike Kalish will support for WBS 13 scope. Harris for WBS 14.

  Needs a recommended level that can't be exceeded.

  Strawman (Phil): 110% peak current, subject to WBS 13/14 confirmation that it is safe w.r.t. struct. allowables.? Use the 2T scenario. Raki's accuracy has to be kept in mind.

  Wayne: assumption was that operators would proceed cautiously. Real operation will deviate from reference scenarios. Ramifications unknown, e.g. different ratios in A:B:C coils.

  WBS 4 to implement in hardware
- Pre-shot temperature permissive
  - Resistance method
    - WBS 14/13 to specify maximum acceptable pre-shot resistance.
    - WBS 14/13 to provide voltage sensor leads on coil terminals.
    - What is the maximum LN2 temperature? Cole: Will do.
    - What temperature accuracy is needed? Needed from coil designers:

- Maximum pre-shot temperature, -→ Really, maximum resistance
- Document design assumptions regarding voltage leads, connection, termination, location, etc. Phil will get details from C-Mod.
  - Mike Cole: voltage taps are not currently in the design. Raki: recommendation was made at a peer review.
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  - WBS 4 to implement in hardware
  o Temperature method
  - WBS 14 to define permissive based on suitable combination of outlet temperature, inlet-outlet temperature difference, shell temperature.
  - WBS 13 to define permissive based on suitable combination of outlet temperature, inlet-outlet temperature difference, coil/structure temperature.
  - Coil protection: document safe inlet-outlet temperature difference, and expected time-dependent trends after a pulse.
  - Trim coils: t.b.d
  - Provide concept design for TF coil local I&C (Kalish). Document in coil protection plan.
  - WBS TBD (14/13 or 5?) to implement in hardware.
- Coil overheating / Timed overcurrent protection limits
  o WBS 14 / 13 specify for Day 1 and upgrade
  o WBS 4 to implement in hardware (simple algorithm may be OK for Day 1)
    Coil protection will document the I2t limit of the coils.
    Time constant for cooldown needs to be documented
    Coils are inertially cooled. Not relying on flow to prevent overheating. LN2 is designed not to flash if it goes to the temperature of the coil.
    Fred is worried about protecting the fittings, etc. in the LN system- needs pressure relief.
- Instantaneous structural protection limits.
  o WBS 14 / 82 to specify safe current operating limits based on stresses (and other considerations if applicable). Information to be used by WBS 4 in designing a coil protection calculator, which would be an upgrade.
    Raki would like the equations needed for a coil protection calculator. **But this is too big a job to do now.**
  o Coil protection document should include a list of caveats and future analysis needed.
- Other coil protection conditions
  o Cryostat temperature or pressure: inhibit / trip?
  o Cryosystem operating parameters: flows, pressures, temperatures: inhibit / trip?

Chit 5. Document Coil Structural Protection Requirements
- Instantaneous structural protection limits.

- WBS 14 / 82 to specify safe current operating limits based on stresses (and other considerations if applicable). Information to be used by WBS 4 in designing a coil protection calculator, which would be an upgrade.
- Confirm that current levels permitted by temperature do not violate structural limits, and vice versa.

Chis 13 & 14. Coil FMECA's required
- Identify all single-point failures and effects.
- Identify all mitigation measures, including those involving the coil protection system.
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