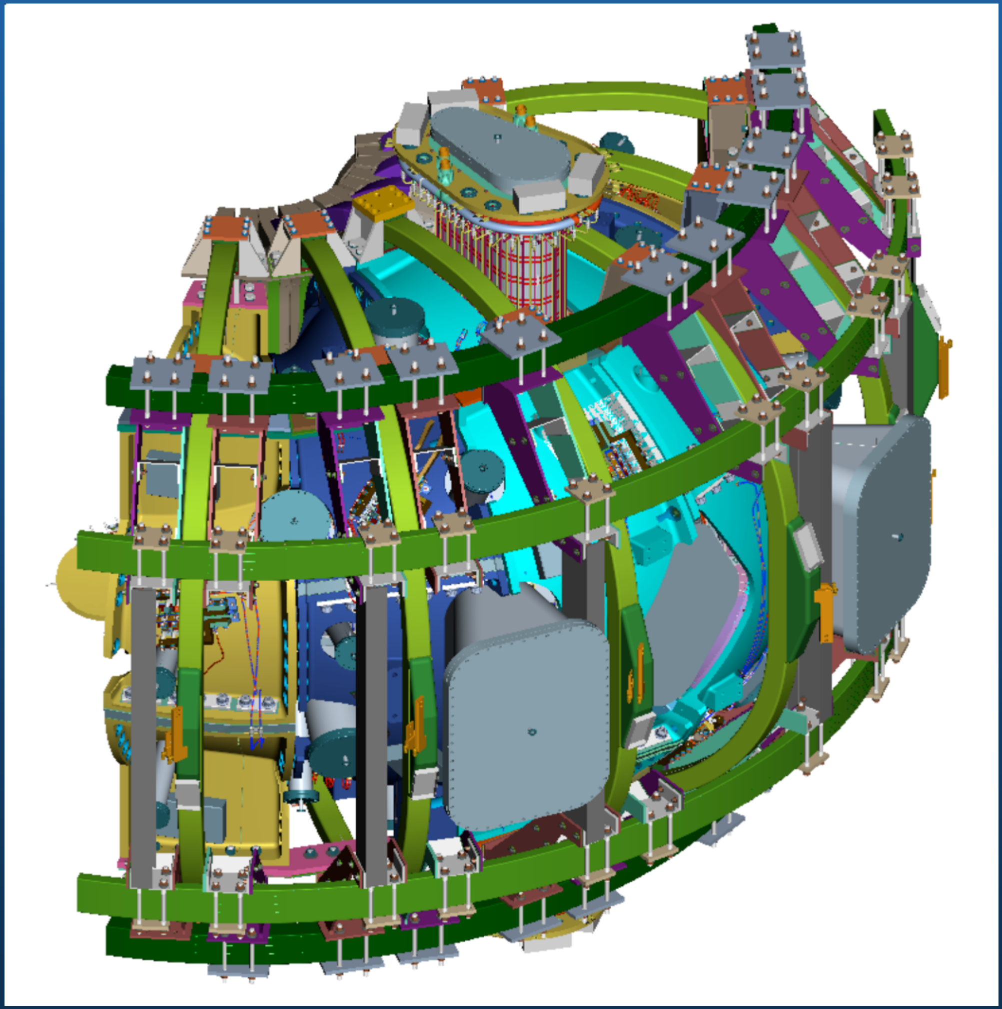
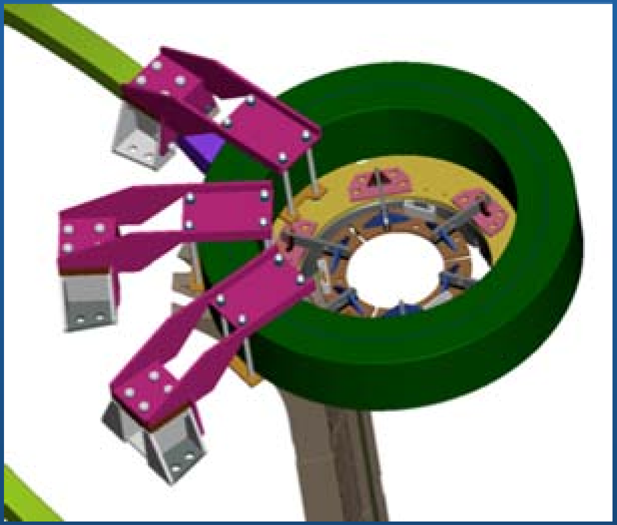
NCSX Poloidal Field Coil Final Design Review





James H. Chrzanowski

Michael Kalish

Bruce Paul

Joseph Rushinski

Fred Dahlgren

Len Myatt

Outline

- ***Charge for Review Committee***
- ***Requirements***
- ***Analysis***
- ***Design***
  - *Documentation and Drawings*
- ***Chits from Previous Reviews***
- ***Procurement Plan, Cost and Schedule***

Charge to Review Committee

- Are the requirements defined? What is the proposed design?
- Is the analysis consistent with the proposed design?
- Are fabrication documents (drawings, specifications) complete?
- Are there satisfactory fabrication plans?
- Have prior design review chits been addressed?
- Have all technical, cost/schedule, and safety risks been addressed?

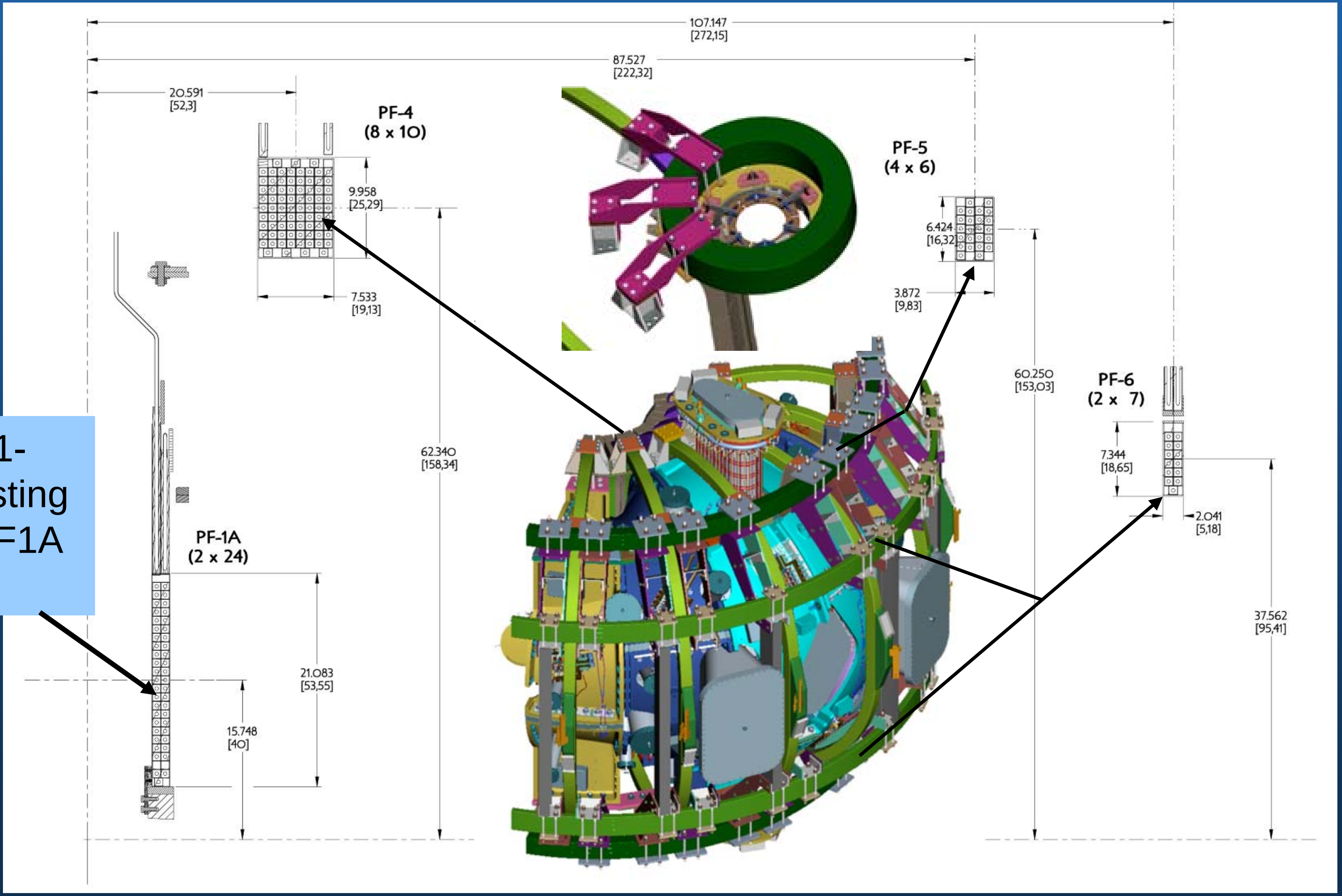
Requirements

- The PF coils will be designed to meet the requirements of all the reference scenarios. **[Ref. GRD Section 3.2.1.5.3.3.2]**
  - **1.7 T Ohmic Scenario**
  - **1.7 T High Beta Scenario**
  - **2 T High Beta Scenario**
  - **1.2 T Long Pulse**
  - **320 kA Ohmic Scenario**
- Electrical **[Refer. GRD Appendix A.2.3.4]**
  - **Voltage standoff to resist maximum operating voltage of 2 KV for PF4 and PF6 in series**
  - **Voltage standoff to resist maximum operating voltage of 2KV for PF5 upper and lower [capability to be powered separately]**
  - **Define Maintenance Test, Manufacturing Test, and Design Standoff values for the PF coils**

Requirements

- Tolerance / Location
  - Global requirement is that toroidal flux in island regions shall not exceed 10%
  - In plane installed perturbations less than +/- 3mm
  - Out of plane installed perturbations less than +/- 3mm
  - Leads and Transitions must have a less than 1% effect on toroidal flux in island regions
- Cooling
  - Pre-Pulse Temp of 80 K
  - Pulse repetition rate recovery shall not exceed 15 minutes
- Design Life
  - 13,000 cycles per year
  - 130,000 cycles per lifetime

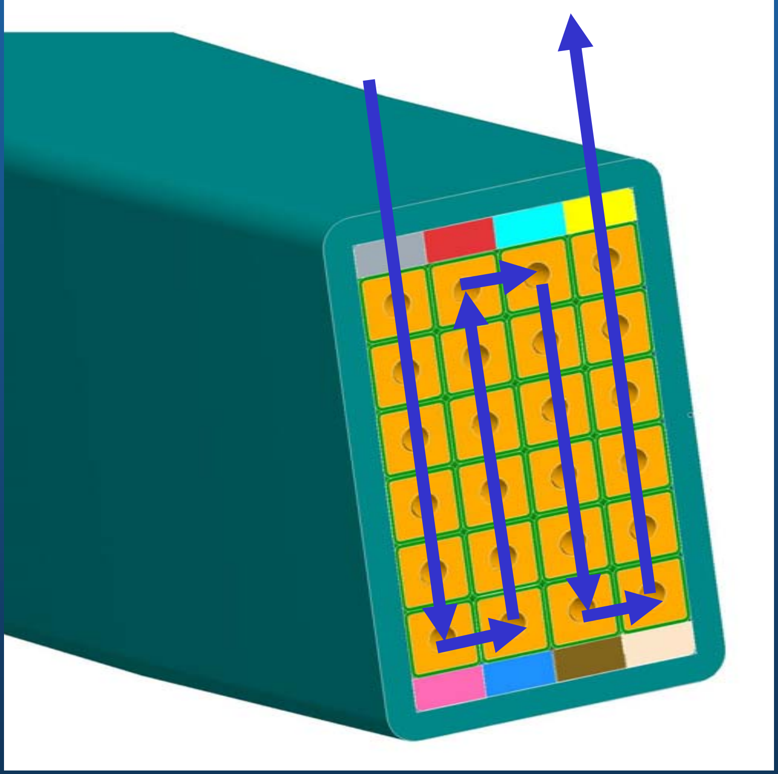
PF Coil Locations



Day #1-
Use existing
NSTX PF1A
coils

PF Coil Construction

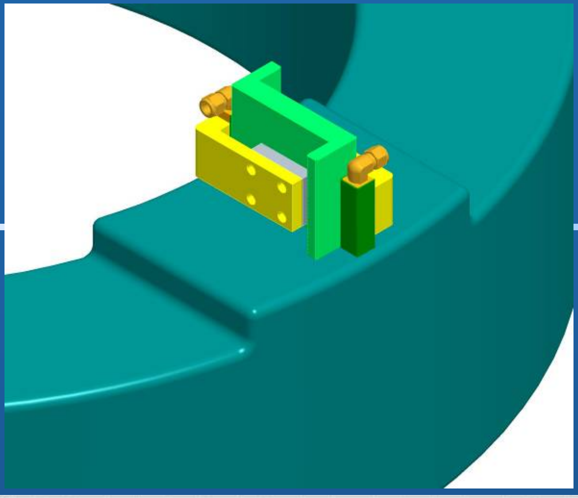
- Conventional design and construction
- Round Geometry
- Extruded copper conductor
- Induction braze joints
- Glass and Kapton turn insulation
- Glass groundwall insulation
- VPI coil using CTD-101 K epoxy system [used on Modular and TF coils]

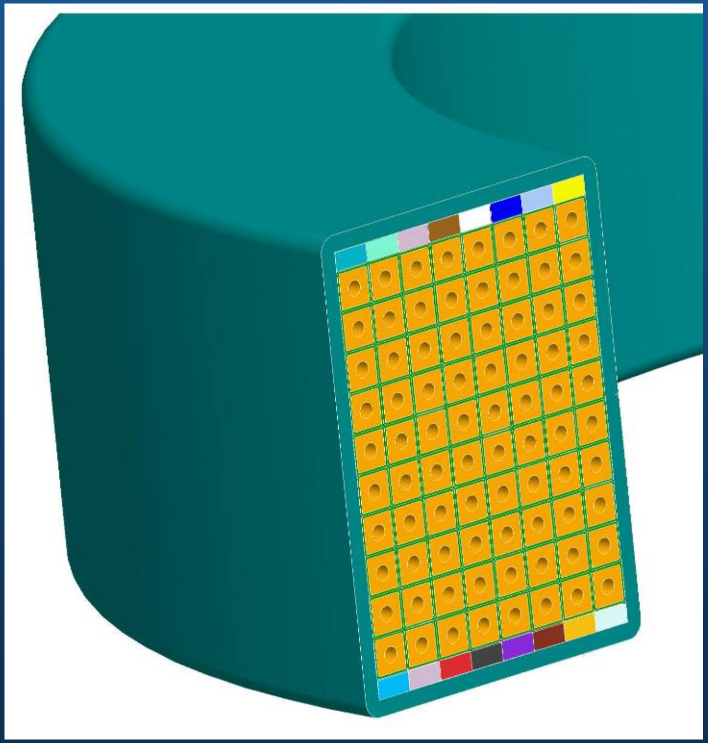


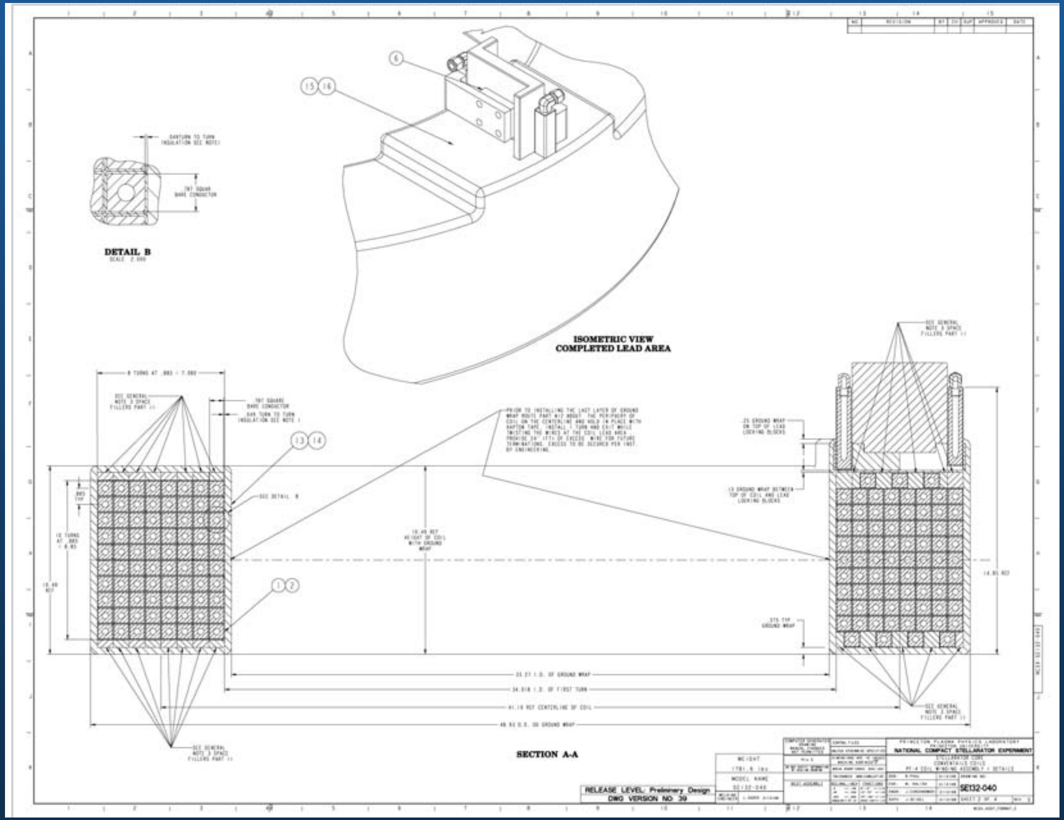
PF4 Coil

NCSX

- Turns = 80 [8 x 10]
- Outer Diameter = 49 inches
- Cross Section = 10.5 x 7.8 inches
- Conductor Length= 861 ft



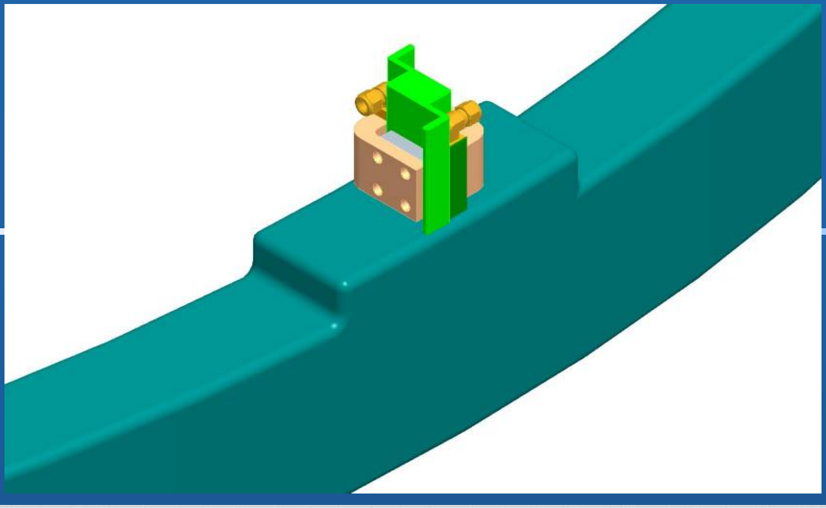


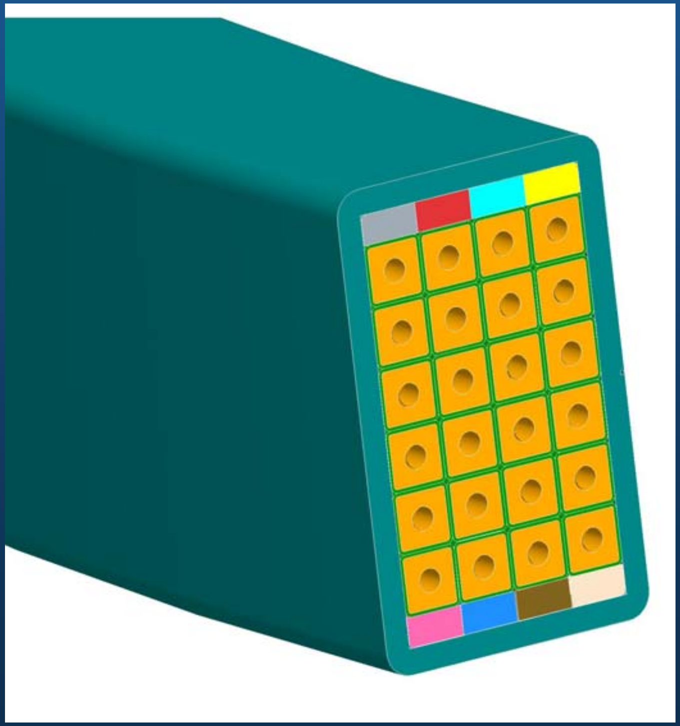


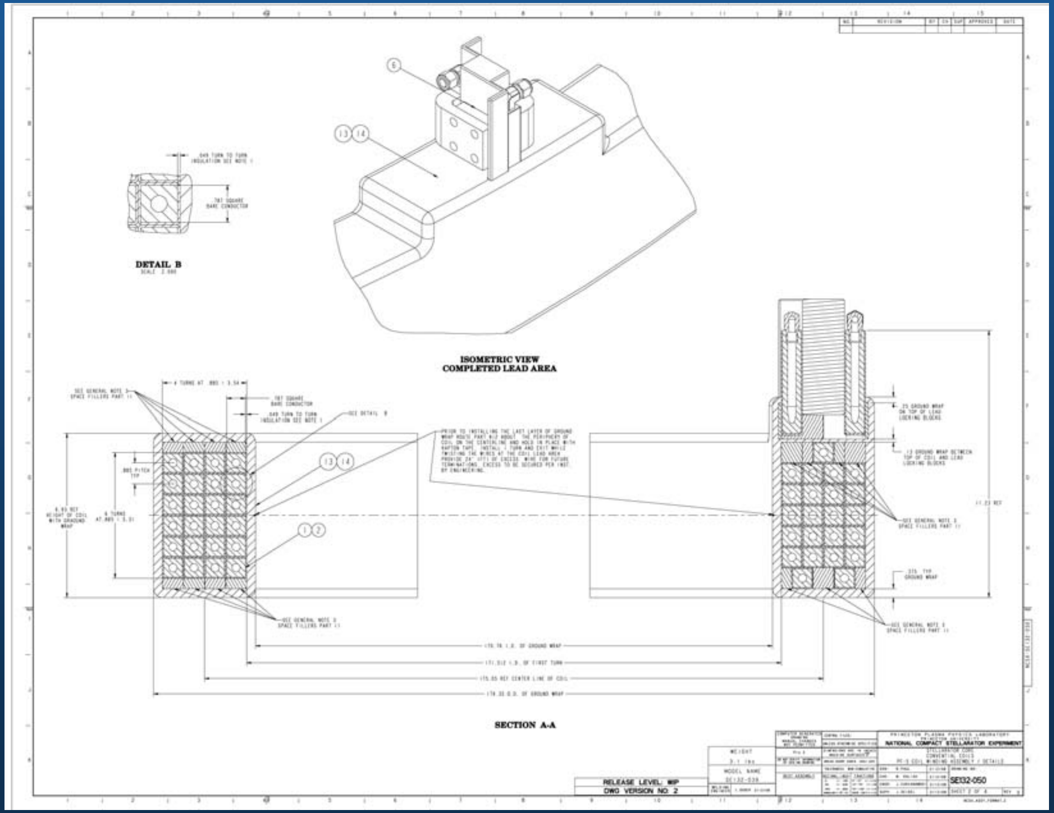
PF5 Coil

NCSX

- Turns = 24 [4 x 6]
- Outer Diameter = 179 inches
- Cross Section = 6.9 x 4.3 inches
- Conductor Length = 1100 ft



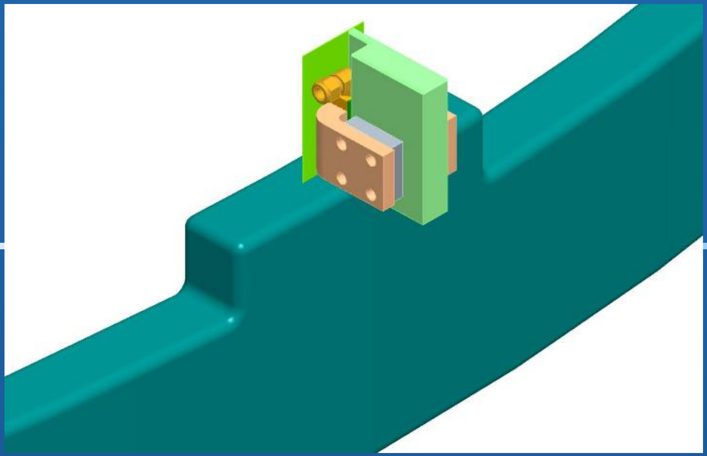


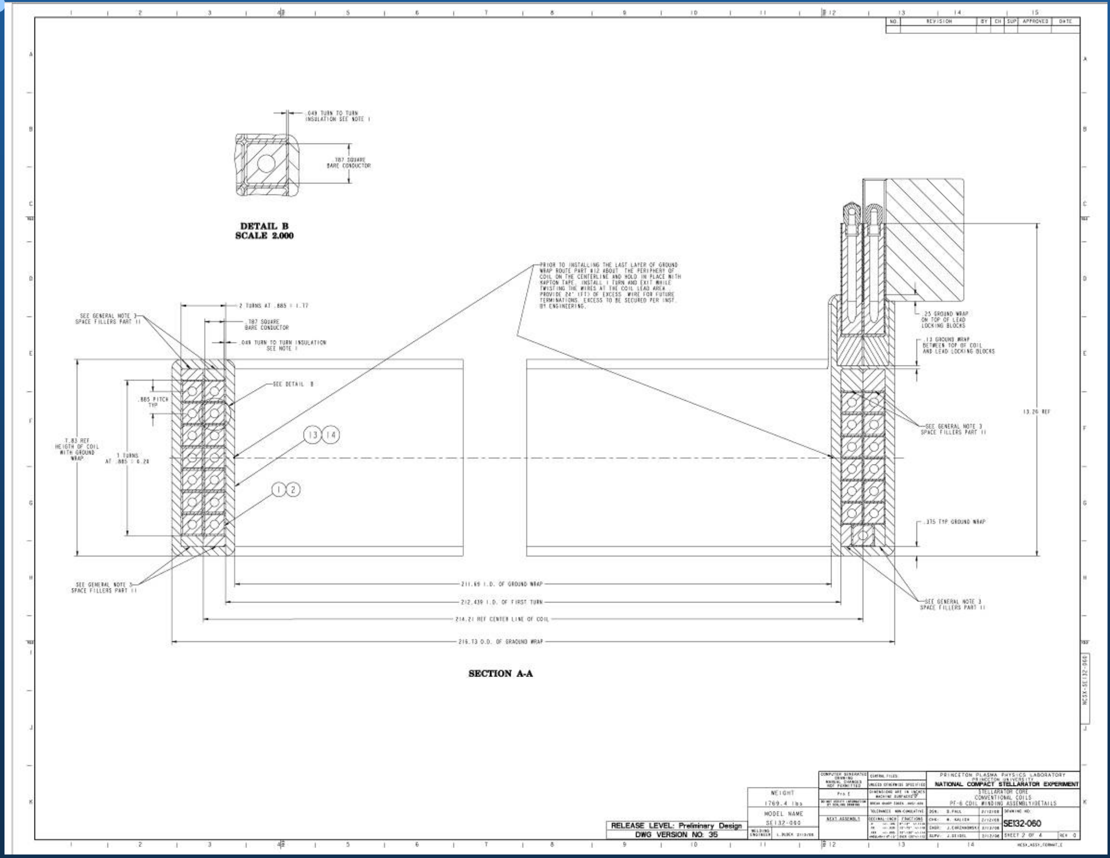


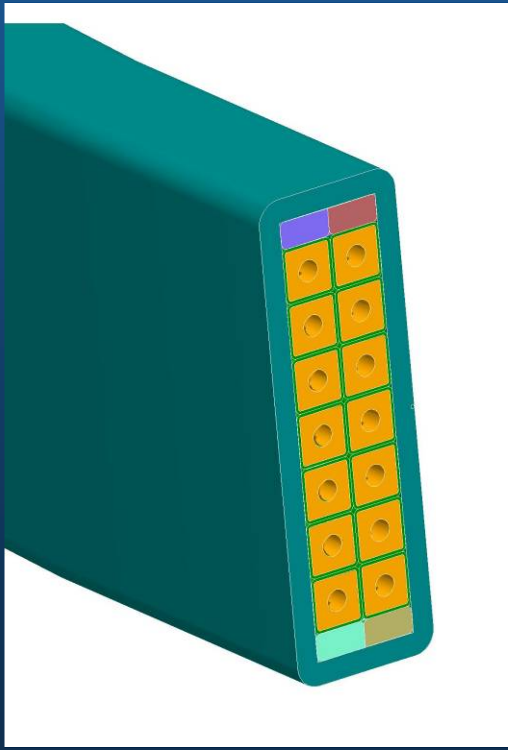
PF6 Coil

NCSX

- Turns = 14 [2 x 7]
- Outer Diameter = 216 inches
- Cross Section = 7.8 x 2.5 inches
- Conductor Length = 786 ft

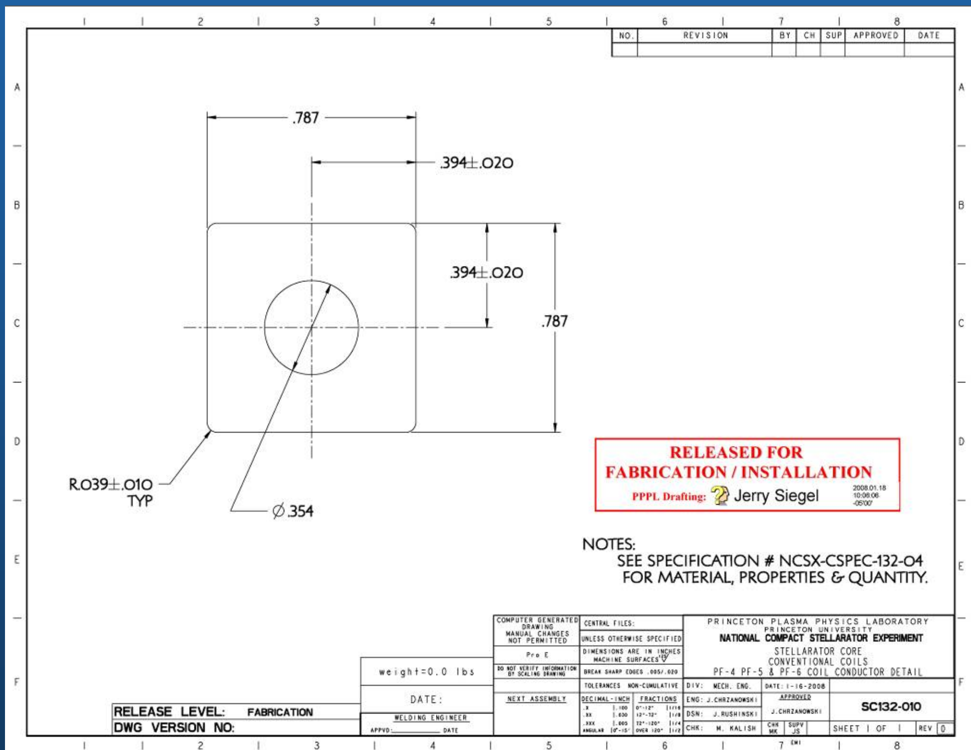






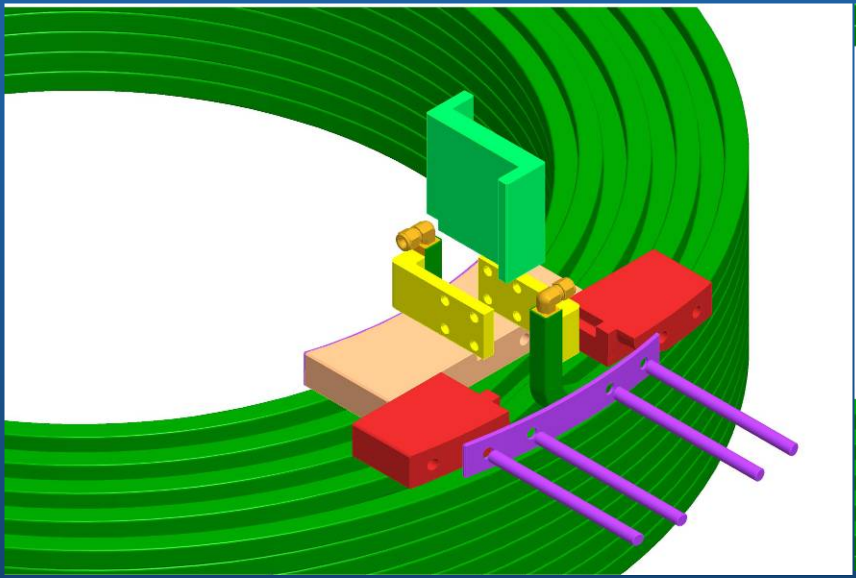
Conductor for PF Coils

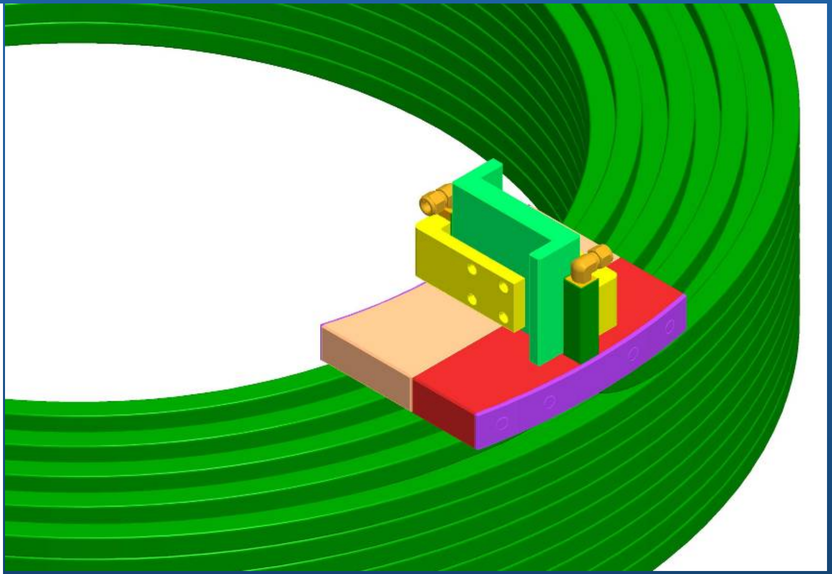
NCSX



- A single extruded copper conductor size will be used for all three types of PF coils.
- Conductor specification & SOW has been generated and approved
  - •NCSX-CSPEC-132-04
  - •NCSX-SOW-132-01
- Conductor Details:
  - 0.787 x 0.787 inch
  - 0.354 inch dia. Hole
  - Silver-bearing OFC grade CDA 104, 105 or 107
- Requisition no. 405978 has been submitted and bids are due this work

PF Lead Blocks

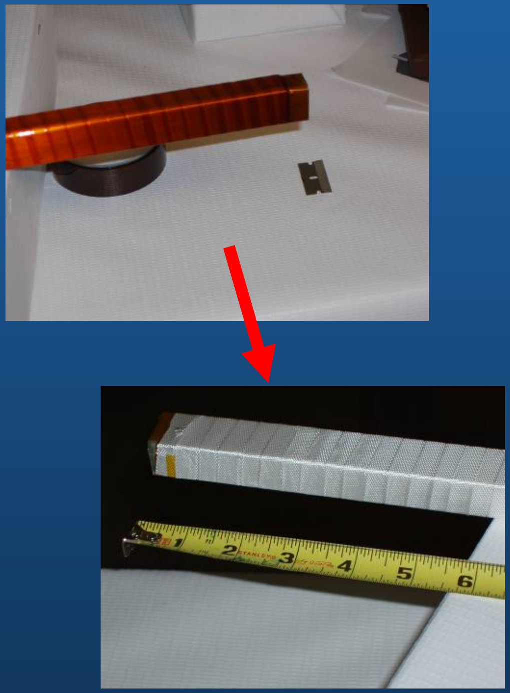




- Leads locked together using G11 Blocks and pins
- Forces on leads very low on the order of 10 lbs excluding exterior fields
- Fiberglass overwrap applied over G-11 blocks

PF Coil T/T Insulation Scheme

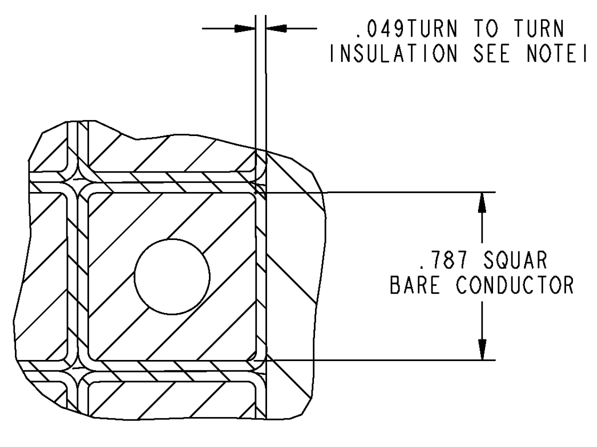
- ½ Lap Layer of Kapton to provide primary dielectric strength
- Releasing Kapton layer resolves thermal stress issue.
- Analysis verifies that coil stiffness is adequate after releasing insulation from conductors
- Prototype testing proved out insulation winding pack approach



PF Turn to Turn Insulation

NCSX

PF Turn Insulation		Thickness		Dielectric Strength	
1/2 Lap Layer of Kapton	Kapton	0.002		12.20	
	Adhesive	0.0015		0.00	
	Kapton	0.002		0.00	
	Adhesive	0.0015		0.00	
1/2 Lap Layer Dry Glass	Glass	0.007		2.10	
	Glass	0.007		2.10	
1/2 Lap Layer Dry Glass	Glass	0.007		2.10	
	Glass	0.007		2.10	
1/2 Lap Layer Dry Glass	Glass	0.007		2.10	
	Glass	0.007		2.10	
		0.049	**Inches**	**24.80**	**KV**



CTD Test Data: Glass/Epoxy
S-2 fiberglass and CTD-101K resin system
@76 degrees K~ 76.3 KV/mm = 3 KV/mil ~ **assume 300 V/ mil**

DuPont Data: Kapton HN
2 mil thick insulation:
6100 volts per mil = 12,200 volts

- Turn Insulation is comprised of [1] half-lapped layer of Kapton Tape [0.0035 in.] plus [3] half-lapped layers of S-2 fiberglass tape [0.007 in.]
- Turn to turn dielectric strength ~ 24.8 x 2 = 49.6 KV
- Kapton allows for decoupling of insulation from conductor during cool down.

PF Groundwall Insulation

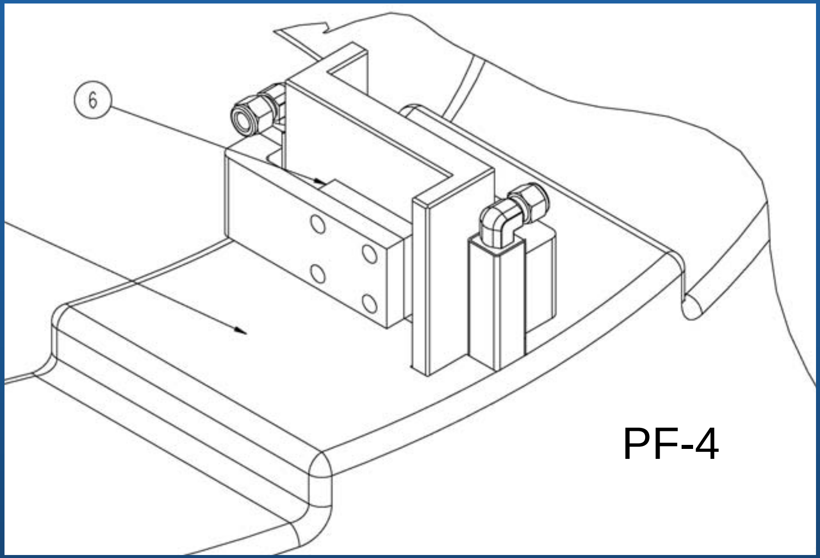
NCSX

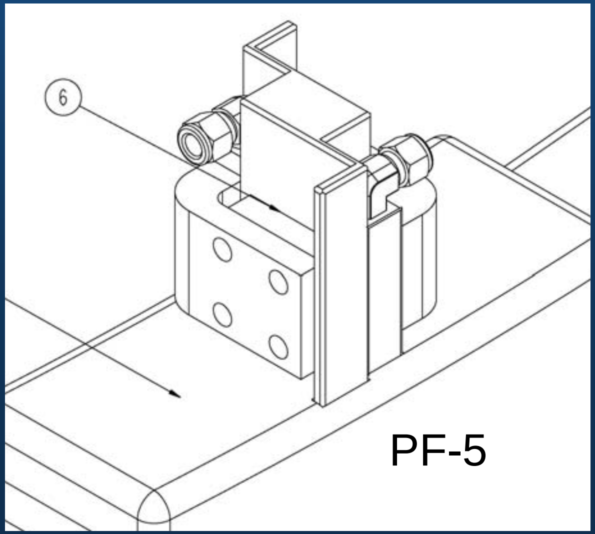
PF- Ground Wrap Insulation		Thickness		Dielectric Strength	
1/2 Lap Layer Dry Glass	Glass	0.165		49.50	
[11] layers x 0.015 in.	Glass	0.165		49.50	
1/2 Lap Layer Dry Glass	Glass	0.024		7.20	
[2] layers x 0.012 in.	Glass	0.024		7.20	
		0.378	**Inches**	**113.40**	**KV**

- **Ground wall has been increased to 3/8 inch thick of S-2 glass and epoxy [CTD-101K]**
- **Provides electrical standoff, mechanical structure and exterior toughness**
- **Groundwall dielectric strength= 113.4 + 24.8 [turn] = 138.2 KV**

CTD Test Data: Glass/Epoxy
S-2 fiberglass and CTD-101K resin system
@76 degrees K~ 76.3 KV/mm = 3 KV/mil ~ **assume 10% of test value = 300 V/ mil**

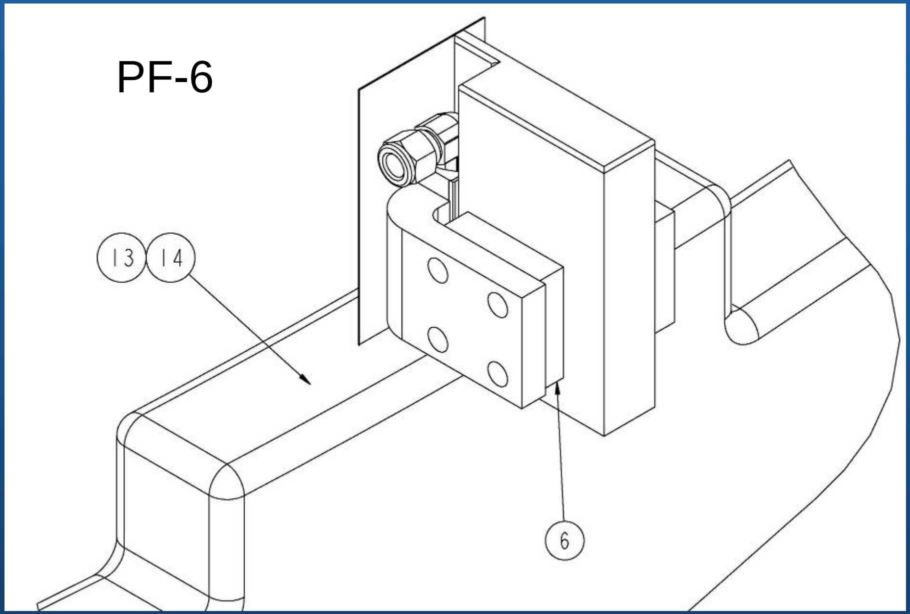
PF Leads Tracking Distance

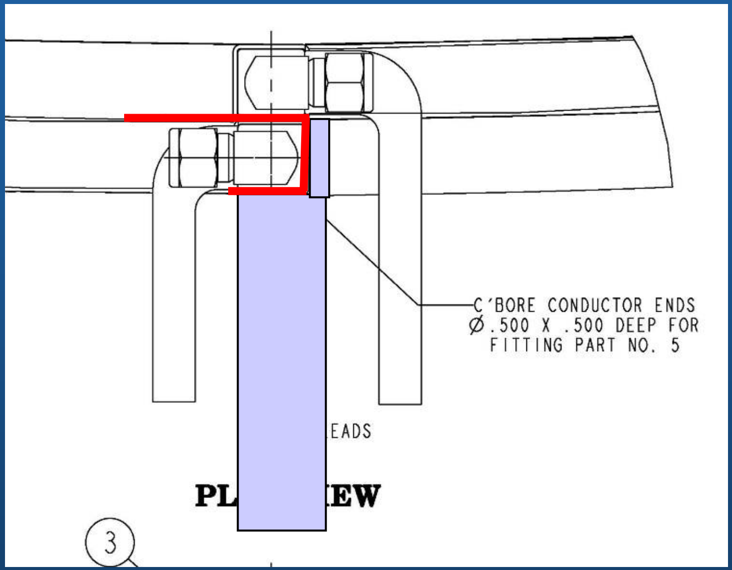




- **Tracking distance "Rule of Thumb": 1 inch for 20 kV [based upon testing]**
- **The leads for the PF-4 and PF-5 coils provides adequate space for G-11 shields and distance**
- **A minimum of 60 KV tracking distance can be achieved**
- **PF-6 will requires additional care in achieving our goal**

PF Leads and Tracking Distance





- Due to the close proximity of the cooling fittings on PF-6, an additional Kapton cuff will be required after the VPI operations
- I recommend that this work be completed by PPPL after the coils have been delivered

Turn To Turn Voltage Standoff Requirement

NCSX

NCSX Coil Voltage Standoff Requirements Turn to Turn

		PF4 Upper & Lower	PF5 Upper	PF5 Lower	PF6 Upper & Lower
Operating Voltage (KV) across coil		2.00	2.00	2.00	2.00
Turn to Turn (KV) per coil		0.25	1	1	1
Maintenance Field Test Voltage (KV)	(Operating Voltage x 2) + 1	1.50	3.00	3.00	3.00
Manufacturing Test Voltage (KV)	Maintenance Test Voltage x 1.5	2.25	4.50	4.50	4.50
Design Voltage Standoff (KV)	Manufacturing Test Voltage x 1.5	**3.38**	**6.75**	**6.75**	**6.75**
Coil Turn to Turn Break Down		**49.60**	**49.60**	**49.60**	**49.60**
Safety Factor		**14.7**	**7.3**	**7.3**	**7.3**

- **Substantial Margins in Turn to Turn Dielectric Standoff**
- **Design for 49 KV**
- **Coils nominally see 1 KV or less Turn to Turn**
- **Upper and Lower PF5 not in series [independently powered]**

Ground Plane Voltage Standoff Requirement

NCSX

NCSX Coil Voltage Standoff Requirements to Ground

		PF4 Upper & Lower	PF5 Upper	PF5 Lower	PF6 Upper & Lower
Operating Voltage (KV)		2.00	2.00	2.00	2.00
Maintenance Field Test Voltage (KV)	(Operating Voltage x 2) + 1	5.00	5.00	5.00	5.00
Manufacturing Test Voltage (KV)	Maintenance Test Voltage x 1.5	7.50	7.50	7.50	7.50
Design Voltage Standoff (KV)	Manufacturing Test Voltage x 1.5	**11.25**	**11.25**	**11.25**	**11.25**
Groundwrap Breakdown (KV)	Groundwrap plus Turn to turn	**138.20**	**138.20**	**138.20**	**138.20**
Safety Factor		**12.3**	**12.3**	**12.3**	**12.3**

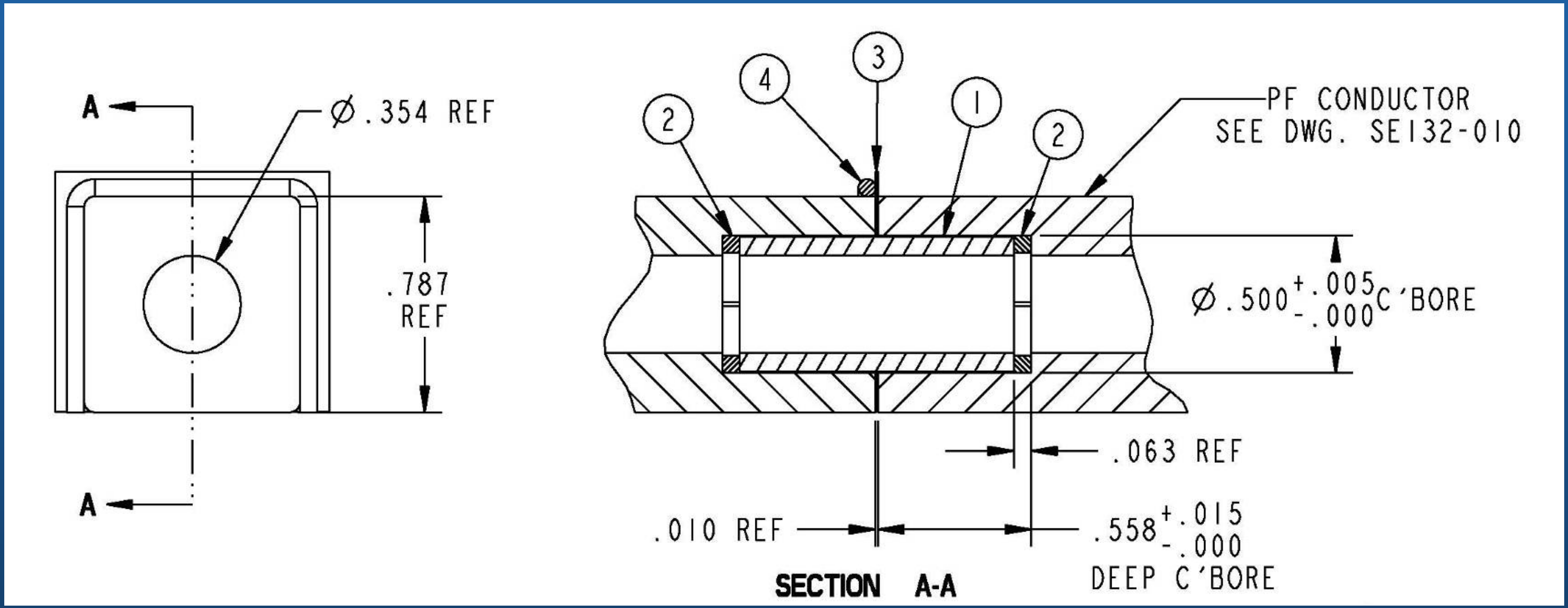
- **Voltage standoff to resist maximum operating voltage of 2 KV**
- **Maintenance Test, Manufacturing Test, and Design Standoff formulas defined**
- **Design Voltage Standoff to ground is 138 KV for all three coils**
- **Ground Wrap dielectric standoff requirement meets system requirement**

Manufacturability - Manufacturing Tolerances

- Requirement = In plane and out of plane installed perturbations shall be less than +/- 3 mm
- Coil specification will require +/- 1.5 mm using half of the allowable installed tolerance budget
- D Shaped NCSX TF Coils have been manufactured to about a +/- 1.5mm tolerance in their free state but a guarantee of that over the larger diameters for the PF Coils is not guaranteed
- Coil as it is removed from the VPI mold will be within

  +/- 1mm but coil is likely to distort in it's free state
- Support structure must be capable of re-shaping coil as required
- Coils can be positioned during installation to average out of tolerance conditions

Manufacturability- TF Brazed Joint



- **Example of a Typical Brazed Joint**
  - OFHC copper sleeve is used with "Sil-Fos" Wafer and 1.5 mm diameter ring to ensure full coverage and no voids
  - Induction brazing will be required for quality repeatability of braze joints. Potential vendors will have to possess, rent or procure unit for the PF coils

Sensor Loop Placement

- Co-wound diagnostic sensor Loops will be applied to ID of each PF coil
- These will be provided by PPPL to the coil vendor along with details on the proper installation.
- The diagnostic loops will be similar to the ones used on the TF coils
- Applied under last layer of ground wrap insulation
- The diagnostic leads will be twisted and brought out near the coil leads
- PPPL will provide a plastic box that will be attached to the coil for protecting the diagnostic leads

Thermal / Hydraulic Analysis Requirements

- Peak temperature and recovery time calculated for maximum required pulse (highest I^2T Operating Scenario) for each coil per the GRD
- Pulse Repetition not to exceed 15 minutes

	PF 4	PF5	PF6
Operating Scenario	320 kA Ohmic	1.7T High Beta	1.7T Ohmic
Equivalent Square Wave	.65 Seconds	.54 Seconds	.73 Seconds
Max Current	15155 Amps	7728 Amps	8195 Amps

Thermal / Hydraulic Analysis Results

- The pressure differential requirement is 60 psi for PF4 (same as the TF Coils).
- PF4 Peak temperature rise is 5 deg C
- PF4 base temperature increases by 3 deg C and then cycles 2 deg per each 15 minute pulse.
- PF5 and PF6 experience total temperature excursions of less than 2 deg C
- LN2 system Flow requirement is between 1 and 1.2 GPM per coil
- Total flow requirement for all six coils is less than 7 GPM

Stress Analysis Inputs

NCSX

- Time points analyzed for all scenarios
- Highest Loads not necessarily at maximum currents
- Coils analyzed with fixed and flexible supports
- Coils analyzed with and without thermal stress for worst case (highest force) operating conditions

Table 2.0-1 Magnetic Forces from Max Current Time Points

Time Point	PF4U [kN] Vertical/Radial	PF5U [kN] Vertical/Radial	PF6U [kN] Vertical/Radial
1.7 T Ohmic, t=0.0 s (PF6 I_{min})	**-222/+725**	**+85/+22**	**-82/+53**
2.0 T High-β, t=0.197 s (PF6 I_{max})	-87/+820	-11/+46	+10/+36
320 kA Ohmic, t=0.206 s (PF4 I_{min})	**-201/+1984**	**-10/+82**	**+18/+19**
1.7 T High-β, t=0.0 s (PF5 I_{max})	-46/+118	+68/+23	-72/+51
Gravity (from 3D ANSYS model)	-9.8/0	-14/0	-9.6/0

Stress Analysis Thermal vs EM Hoop Deflections

- Initial calculation demonstrates thermal deflections due to cool down predominate
- EM Hoop stress and deflection is insignificant
- **Analysis indicates overall stresses are low if cool down is homogeneous**

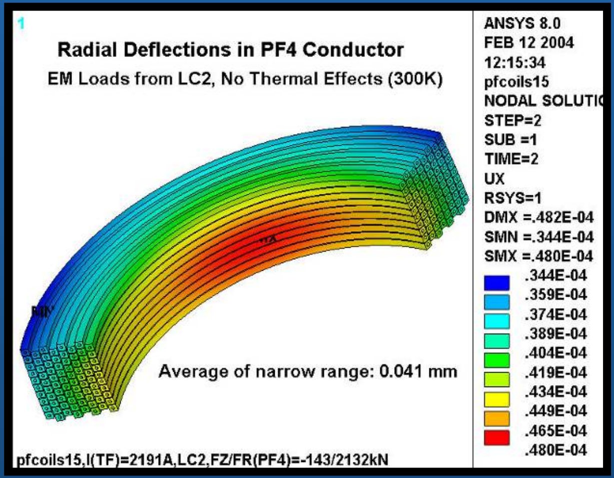


Table 2.0-2 Nominal Coil Hoop Stress and Radial Deflection

PF	Radial Force, F_r [kN]	Coil Dimensions [m]			Ave. Hoop Stress, σ_h $F_r/(2\pi dr dz)$ [MPa]	Ave. Hoop Modulus[1] E [GPa]	Deflection [mm]	
		r	dr	dz			Magnetic $(\sigma_h/E)r$	Thermal $(\alpha\Delta T)r$
4	1984	0.522	0.1852	0.2473	7	93	0.04	1.5
5	82	2.223	0.0922	0.1574	1		0.02	6.2
6	53	2.720	0.0457	0.1798	1		0.03	7.6

Stress Analysis – Copper Conductor

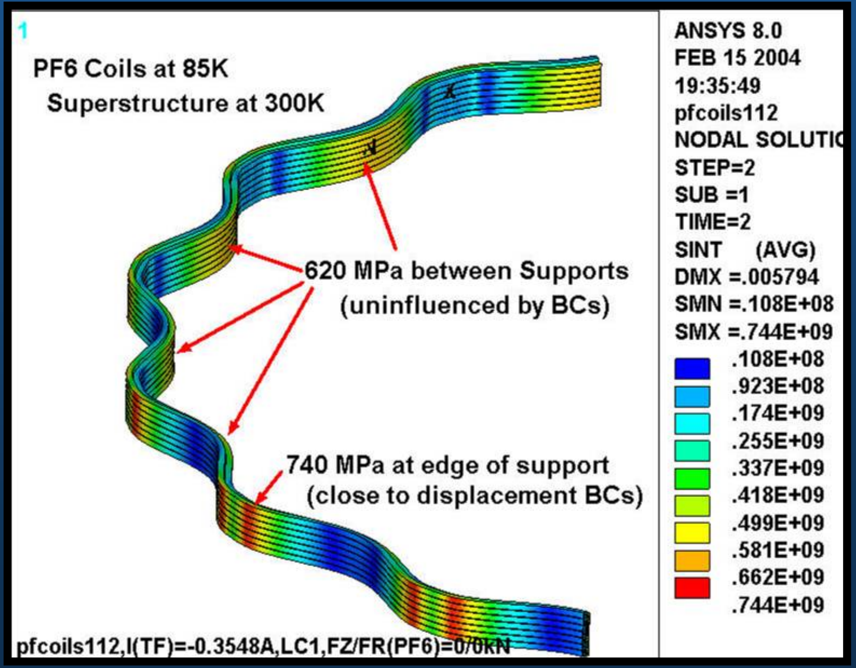
- Allowable copper stress Sm is 110 MPa
- With coils and structure at the same temperature there remains a factor of safety of at least two
- Present structure design utilizes a clamped configuration

Run	PF	Radial Constraint	Temp Coil/Structure [K]	LC	Conductor Stress Intensity [MPa]
10	4	free	85/85	0	46.6
15		free	300/300	2	19.2
12		free	85/85	2	49.1
13		clamped	85/85	2	48.0
114		clamped	85/300	0	**731**
16	5	free	85/85	1	49.2
14		free	85/85	2	46.1
19		free	85/85	0	46.1
111		clamped	85/85	0	53.1
113		clamped	85/300	0	**588**
18	6	free	85/85	0	48.1
17		free	85/85	1	51.0
110		clamped	85/85	0	54.6
112		clamped	85/300	0	**744**

Stress Analysis - Copper / Structure Results were checked

- Analysis performed for Structure confirms low stresses [19 MPa] when coil and structure are at same temperatures
- This analysis was performed by Fred Dahlgren who verified the calculations made by Len Myatt

- However, if the coils temperature between the coils and structure are not matched, unacceptable high stresses result.
- PF6 Cu Stresses approach 620 MPa midway between coil supports with coil at 85K and coil supports at 300K
- PF4 and PF5 stresses are as high
- **Operational control of the cool down process will be critical**



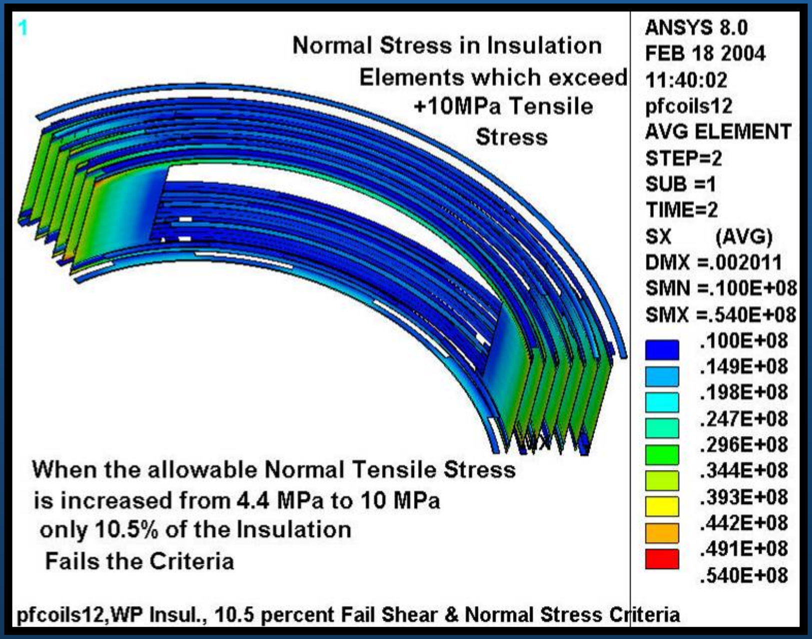
Stress Analysis Insulation - In Plane & Compression

- Stress allowable in plane limited to 165 MPA
- Stress allowable compression limited to 460 MPa
- Insulation Stress "In-Plane" and "Compression" has large margin
- Component of stress due to EM loads is very small

Run	PF	Radial Constraint	Temp Coil/Structure [K]	LC	In-Plane Compression/Tension [MPa]	Flat-Wise Compression [MPa]
10	4	free	85/85	0	-42.9/+9.6	-6.3
15		free	300/300	2	-0.6/+3.4	-3.0
12		free	85/85	2	-42.5/+10.1	-8.3
13		clamped	85/85	2	-41.4/+10.8	-8.3
114		clamped	85/300	0	-93.9/+81.3	-177
16	5	free	85/85	1	-40.9/+10.6	-7.4
14		free	85/85	2	-41.1/+10.4	-7.1
19		free	85/85	0	-40.7/+10.3	-7.1
111		clamped	85/85	0	-39.0/+12.9	-7.2
113		clamped	85/300	0	-49.5/+103	-81.8
18	6	free	85/85	0	-39.6/+10.2	-6.4
17		free	85/85	1	-40.7/+10.5	-6.6
110		clamped	85/85	0	-36.6/+13.0	-7.5
112		clamped	85/300	0	-110/+140	-99.5

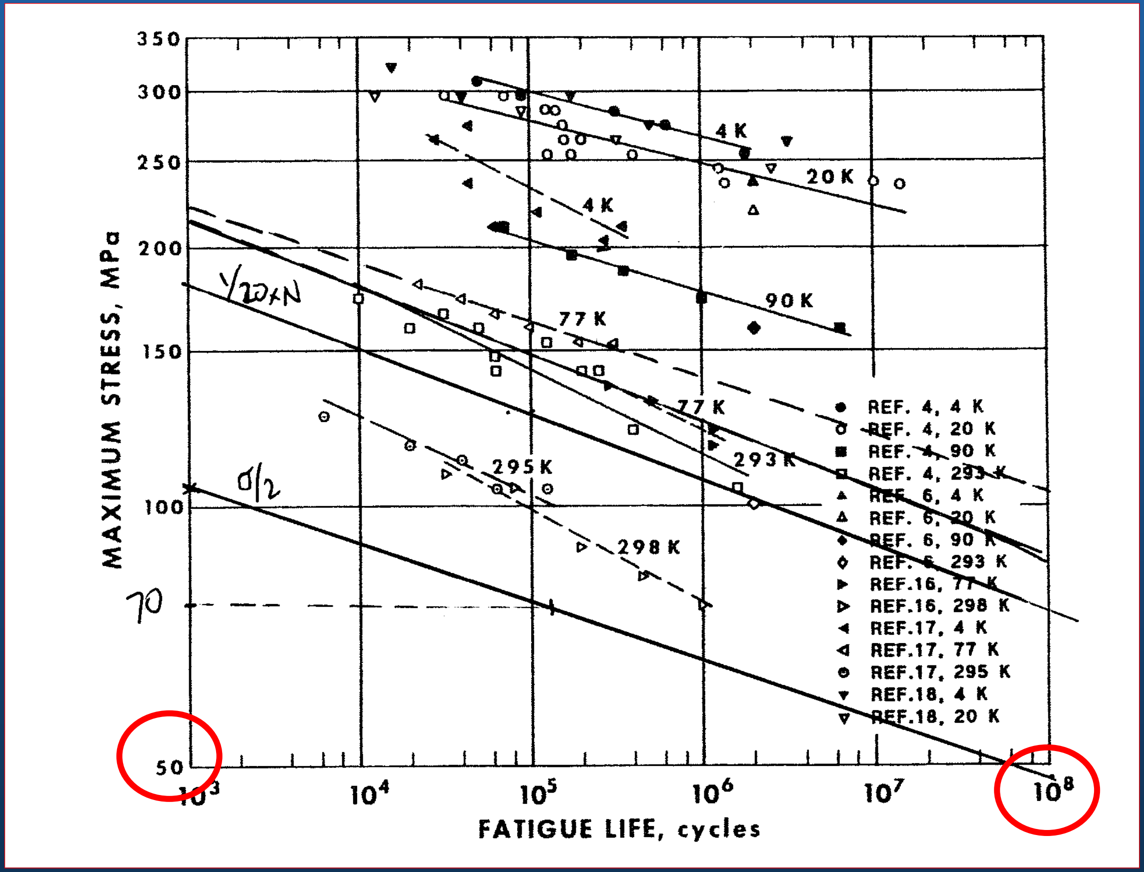
Stress Analysis Insulation Tensile

- EM loads contribute insignificantly to the tensile insulation stress
- Analysis of local tensile loads indicates failure of the bond to the cooper conductor
- Testing pursued to determine if higher allowable tensile value could be used
- Testing indicates that tensile allowable is between "0" and 4.4 MPa



Projected Fatigue Life for Conductor

- Allowable number of cycles (N) based on 20 MPa alternating stress is greater than 100,000,000 (~infinite)
- Actual number of required cycles is 130,000



Fatigue Curve

Analysis and Testing Summary

- Analysis completed for operating scenarios / requirements as specified in the GRD
- Coils meet 15 minute rep rate with a maximum 5 deg C rise
- Conductor meets stress requirements with margin
- Insulation satisfies all relevant stress requirements with margin for in plane and compressive stress
- Cryogenic fatigue tests verify validity of Kapton to conductor insulation scheme at required fatigue life to satisfy tensile stress requirement
- Testing verifies analysis assumptions for composite beam properties
- Testing verifies dielectric standoff for turn to turn and turn to ground requirements

Requirements Addressed

- **The PF coils are designed to meet the requirements of all the reference scenarios. [Ref. GRD Section 3.2.1.5.3.3.2]**
  - *Stress analysis acceptable for all operating scenarios*
- **Electrical**
  - *Design meets electrical voltage standoff requirements [verified by testing]*
- **Tolerance / Location**
  - *Procurement specification will address tolerances*
  - *May require structure to compensate*
- **Cooling**
  - *Analysis confirms acceptable temperature rise and rep rate*
- **Design Life**
  - *Testing and analysis confirms fatigue life*

PDR Chit Disposition- sheet 1

Design Review/QA Audit [Cog Engr./RLM/Chair]	Review Date	#	Chit / Audit Finding [Originator]	Review Board Recommend.	Project Disposition
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	1	Verify configuration preserves stellarator symmetry i.e. bottom coils are installed rotated about machine "X" exit 180° [Brooks]	Concur	Coils are identical. Positioning of the coils in proper configuration for stellarator symmetry will have to be identified on final assembly drawings
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	2	Calculations establishing the voltage and number of turns and current requirements have to be referenced [Ramakrishnan]	Concur	All voltage and coil turns, current are based on the GRD
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	3	Consider using a ground plane [Neumeyer]	Concur	Ground planes are usually used for systems >5 Kv Availability of cryogenic compatible ground plane is not known
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	4	Sensor loop may have noise problem unless there is a shield via ground plane in coil or around sensor loops. Proper designer would place sensor outside of ground plane [Neumeyer]		Similar arrangement was used for both modular and TF coils Diagnostic group should determine whether this will be a problem in any of the coil systems
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	5	Check calculations of turn-to-turn voltage. [Neumeyer]	Concur	Turn to turn voltages were re-examined by J. Chrzanowski & presented in this FDR
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	6	Max turn to turn voltage to the specifies. [Ramakrishnan]	Concur [See chit 5]	See chit #5

PDR Chit Disposition- sheet 2

NCSX

Design Review/QA Audit [Cog Engr./RLM/Chair]	Review Date	#	Chit / Audit Finding [Originator]	Review Board Recomm	Project Disposition
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	7	Need to establish minimum lead to lead and lead to ground creeping distances for lead's to ensure safety margin on leads. [Neumeyer]	Concur	Concur- Presented in FDR
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	8	Need to plan to measure coil copper temperature to prevent flow of LN2 into warm coil. T/C's in copper not recommended. Consider fiber optic probe or resistance measured scheme [Neumeyer]	Concur	Thermocouples will be included on supply and return points later by I&C group No TC's are being installed on coil as part of PF fabrication
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	9	Who is responsible for coil protection due to thermal shock? Will this be covered as part of WBS 5 (I&L) with interlocks to the cryogenic system? [Strykowsky]	Other [See Chit 8]	See chit #8
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	10	The number of thermal cycles consideration for the design to be documented [Ramakrishnan]	Concur [If not already given in GRD]	Number of thermal cycles does not effect design of PF coils- No stress issues
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	11	The time at test voltage should be 1 min to allow for charging current to the level off and not influence the true leakage current. [Meighan]	Concur	This will be specified in coil specification

PDR Chit Disposition- sheet 3

Design Review/QA Audit [Cog Engr./RLM/Chair]	Review Date	#	Chit / Audit Finding [Originator]	Review Board Recomm	Project Disposition
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	12	Coil shape should be maintained with bracing from time of VPI completed until coils are installed in machine this will minimize reshaping (PF-5 and PF-6 only) [Chrzanowski]	Concur	SOW will include requirement for shipping structure to maintain coil shape
Kalish/Neumeyer/ Heitzenroeder PF Coil PDR	12/14/07	13	Special stripping instructions are required. [Ramakrishnan]	Other [See Chit 12]	See chit #12

Procurement Plan / Issues

- **Expedite delivery by pre-ordering copper conductor and supplying to vendor / vendors [Requisition has been submitted award by 2/25/08]**
- **RFQ will include three options:**
  - PF-4, PF-5 and PF-6 as one procurement
  - PF-5 and PF-6 together
  - PF-4 separately
- **A list of potential bidders has been compiled**
- **Schedule and Cost estimates are based on budgetary information received from Everson as well as PPPL derived estimates**
- **Critical need dates driven by the installation of the lower PF5 and PF6 Coils. Vendors will be asked to stage deliveries so that these coils are received first. [Lower PF-5 & 6 first]**
- **Have already begun early start of procurement. [SPEB has already been formed and have met]**

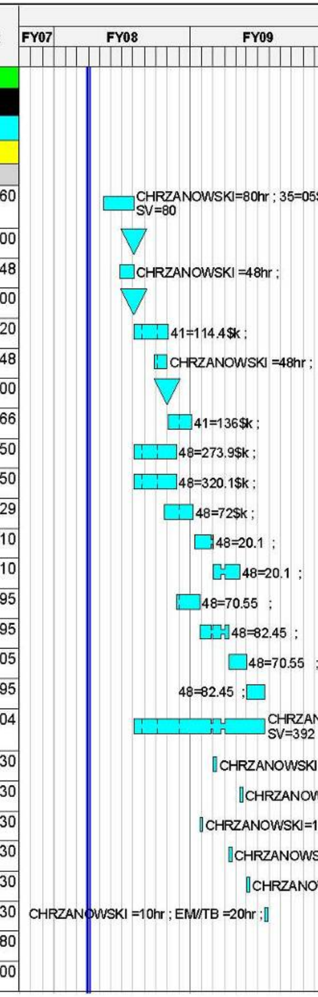
PF Coil Procurement Schedule

Task #	Description	Respon-sible	Duration	Planned Start	Planned Finish	Actual Start	Actual Finish
1.	Issue Sources Sought FedBizOpps Notice	LLS		12/11/07	12/11/07		12/11/07
2.	Receive Statements of Interest	LLS		12/11/07	1/04/08		
3.	Requisition issued	JHC		1/09/08	1/09/08		
4a.	SPEB Members Nominated	JHC		1/4/08	1/04/08		1/03/08
4.	SPEB Appointed	RJH		1/11/08	1/11/08		1/03/08
5.	Source Selection Plan drafted	LLS	3 days	1/15/08	1/17/08		1/18/08
6.	PF Coil FDR	JHC			2/20/08	FDR	
7.	Specification/Drawings Finalized	JHC	14 days	2/12/08	2/25/08		
8.	RFP issued	LLS	3 days	2/25/08	2/28/08		
9.	PPPL Provided Material On Order	JHC			2/25/08		
10.	Pre-Proposal Conference	LLS/JHC			3/07/08		
11.	Proposals due	LLS	28 days	2/29/08	3/27/08		
12.	Proposal Evaluation Completed	SPEB	14 days	3/28/08	4/10/08		
13.	SPEB Recommendation Completed	SPEB	5 days	4/11/08	4/15/08		
14.	SSO Decision	RJH	3 days	4/16/08	4/18/08		
15.	Subcontract Negotiation – DOE Approval[1]	LLS	14 days	4/19/08	5/02/08		
16.	Subcontract Awarded	LLS	4 days	5/03/08	5/06/08	AWARD	
17.	Subcontractor receive PPPL Material	JHC		6/02/08	6/02/08		
18.	Delivery of Lower PF Coils #5 and #6	Contractor	293 days	5/06/08	2/23/09		
19.	Delivery of Lower PF4 and Upper #4,5,6	Contractor	512 days	5/06/08	9/30/09		

[1] DOE PSO approval of Subcontract required if the price exceeds $1 million.

PF Coil Fabrication/Delivery Schedule

Activity ID	MILE	Activity Description	Duration (work days)	Forecast Start	Forecast Finish	Baseline Finish	Total Float	%	Earned value cost (BCWP)	Budget	Target 2 Budgeted Cost
cc 9450 - NCSX Fabrication (MIE)											
13 - Conventional Coils											
Job: 1352 - PF Coil Procurement-CHRZANOWSKI											
PF Coil Fabrication											
141-035		Bid & Award PF Coil Fabrication	58	12FEB08	01MAY08	27MAY08	32		0.00	35,811.60	35,811.60
141-036	2	PF Coils Awarded	0		01MAY08	27MAY08	32		0.00	0.00	0.00
141-037		Bid & Award Conductor	25	28MAR08	01MAY08	27MAY08	102		0.00	8,916.48	8,916.48
141-038	3	PF Conductor Awarded	0		01MAY08*	27MAY08*	102		0.00	0.00	0.00
141-038.1		PF Conductor Delivery	65	02MAY08	04AUG08	27AUG08	102		0.00	149,635.20	149,635.20
141-039		Bid & Award Materials	25	27JUN08	01AUG08	01AUG08	58		0.00	8,916.48	8,916.48
141-040		PF Materials Awarded	0		01AUG08*	01AUG08*	58		0.00	0.00	0.00
1352-100		Materials Delivery PF 4,5,6	45	04AUG08	06OCT08	06OCT08	58		0.00	178,529.66	178,529.66
1352-121		Design/Fab Tooling for PF 5	80	02MAY08	25AUG08	18SEP08	32		0.00	280,747.50	280,747.50
1352-122		Design/Fab Tooling for PF 6	80	02MAY08	25AUG08	17NOV08	77		0.00	328,102.50	328,102.50
1352-120		Tooling for PF 4	55	25JUL08*	10OCT08	10OCT08	54		0.00	74,072.29	74,072.29
1352-150		Fabricate/Dlvr PF 4 lower	35	13OCT08	02DEC08	02DEC08	54		0.00	21,125.10	21,125.10
1352-151		Fabricate/Dlvr PF 4 upper	45	03DEC08	12FEB09	12FEB09	405		0.00	21,125.10	21,125.10
1352-165		Fabricate/Dlvr PF 5 Lower	45	26AUG08	28OCT08	20NOV08	32		0.00	73,128.99	72,965.95
1352-145		Fabricate/Dlvr PF 6 Lower	45	29OCT08	12JAN09	04FEB09	32		0.00	86,654.95	86,654.95
1352-166		Fabricate/Dlvr PF 5 Upper	35	13JAN09	02MAR09	25MAR09	358		0.00	74,148.05	74,148.05
1352-146		Fabricate/Dlvr PF 6 Upper	35	03MAR09	20APR09	13MAY09	358		0.00	86,654.95	86,654.95
141-031		Title III engr WBS 132	241	02MAY08	21APR09	14MAY09	863	LOE	0.00	148,047.04	148,047.04
141-900		PF4 Lower Inspection & Test	5	03DEC08	09DEC08	09DEC08	54		0.00	3,561.30	3,561.30
141-900A		PF4 Upper Inspection & Test	5	13FEB09	19FEB09	19FEB09	405		0.00	3,561.30	3,561.30
141-901		PF5 Lower Inspection & Test	5	29OCT08	04NOV08	01DEC08	77		0.00	3,561.30	3,561.30
141-902		PF6 Lower Inspection & Test	5	13JAN09	19JAN09	11FEB09	32		0.00	3,561.30	3,561.30
141-905		PF5 Upper Inspection & Test	5	03MAR09	09MAR09	01APR09	393		0.00	3,561.30	3,561.30
141-906		PF6 Upper Inspection & Test	5	21APR09	27APR09	20MAY09	358		0.00	3,561.30	3,561.30
141-903		Refurbish PF 1a	20	18FEB10*	17MAR10	17MAR10	101		0.00	6,820.80	6,820.80
141-904		Assemble PF1a and CS structure	30	18MAR10	28APR10	28APR10	101		0.00	21,550.00	21,550.00



PF Coil Baseline Cost Estimate

- Current Baseline Cost Estimate Remains Unchanged
- Estimate driven by vendor budgetary estimates
- Baseline materials estimate generated based on insulation and copper conductor cost as of May 07
- Copper prices have risen and may cause slight increase in material estimate
- Alternative in house fabrication estimate did not compare favorably to vendor estimates
- Baseline estimate includes $$$ to by enough copper for one spare coil of any type to reduce risk

Summary

- **Critical-** Operational Differential Temperature between Support Structure and coils needs to be addressed- Cool Down requirements
- Conductor requisition has been submitted to procurement
- Calculations have been checked by Fred Dahlgren
- Completed Detailed Drawings- being approved
- CSPEC nearly complete will be sent out for review this week
- SPEB has been established to begin the coil vendor selection
- SRD is also ready for review and approval [awaiting information from Mike Z.]