

TO: M. Cole
FROM: P. L. Goranson

SUBJECT: NCSX Liquid Nitrogen System (LN2) Closeout Summary

20June-08-PG

Scope

This element covers the distribution of Liquid nitrogen coolant within the Cryostat. The system serves all the actively cooled coils:

- TF (WBS 131)
- PF (WBS 132)
- Modular (WBS 14)

Work includes engineering design, procurement, and fabrication of ring manifolds, cooling hoses, valves, pressure gauges, and associated supports. Work in this WBS ends with delivery of components to machine assembly operations.

Status

At the time of closeout Preliminary Design of the LN2 system was complete (PDR on 6/05/08) and Title II Design was ready to begin. See PDR presentation & CHITs from this PDR.

Interfaces

The interface with Cryogenics Systems WBS 62 ended at the ring manifold supply and return flange within the Cryostat. A change was anticipated which would have moved the interface outside the Cryostat to the control valve and pressure gauge connections. This would have moved design of the supply headers to WBS 161 and would constitute an increase in the scope.

Specifications

Requirements are defined in the system requirements document NCSX-BSPEC-161-001, a preliminary copy (dA) of which is posted on the web.

A formal FMECA was not anticipated but a failure mode and mitigation plan was included in the PDR.

Schematics

A Flow Diagram and description of the system, as approved, is included in the FDR Presentation and is posted.

Models Completed

Pro E models of the following were completed and posted:

- Ring manifold configurations.
- Coolant line routing to the PF, TF, and MC coils.
- Coolant line termination design at each of the coil types and manifolds.
- G10 electrical break design.
- Manifold mounts.
- Manifold isolation.

Drawings

Drawings of the ring manifolds (SE100-021) and braided hoses (SE100-030) were started but not complete. They are posted.

Analyses

A summary of the coolant Thermo-Hydraulics are incorporated into the draft DAC NCSX-CALC-161-001-dA, which is posted on the web. They include hose sizing, flow rates, heat transfer coefficients, pressure drops, and anticipated hose lengths. The DAC had a preliminary check but not a formal one and is unsigned.

Testing

Prototypes of the G10 electrical break, based on designs tested in the C1 coil at PPPL, were fabricated and plunge tested in LN2 to confirm survivability. Leak tests were planned but never performed.

Costs

Cost estimates were updated to reflect the latest manifold design and increased hose lengths.

Remaining Work

- Pressure drop in the corrugated hosing was based on Manufacturer's estimates but remain un-collaborated; it may well be much higher than the estimates. An R&D program to measure the actual pressure drops in the hoses using both water and LN2 was planned to benchmark the calculations. Changes in pressure drop would not significantly affect the design.
- The G10 breaks were to be pressure tested under actual operating conditions, i.e. LN2 at 10 atmospheres.
- The control valves and pressure gauges had not been chosen. Suggestions for possible choices were made by participants in the PDR.
- Thermal analysis of the MC Lead Blocks was to be performed to determine whether they required cooling. The coolant would be supplied by one or more of the spare bibs included on the PF ring manifolds.

Conclusion

There were tasks (e.g., resolution of PDR CHITs) requiring completion at the time work was terminated, but none which would affect the design or delay continuation of the Title II design phase.

NCSX Coil Services

P.L. Goranson

Work Package 161

(Excerpts from the April 2008 Lehman Review)

Coil Services System Description

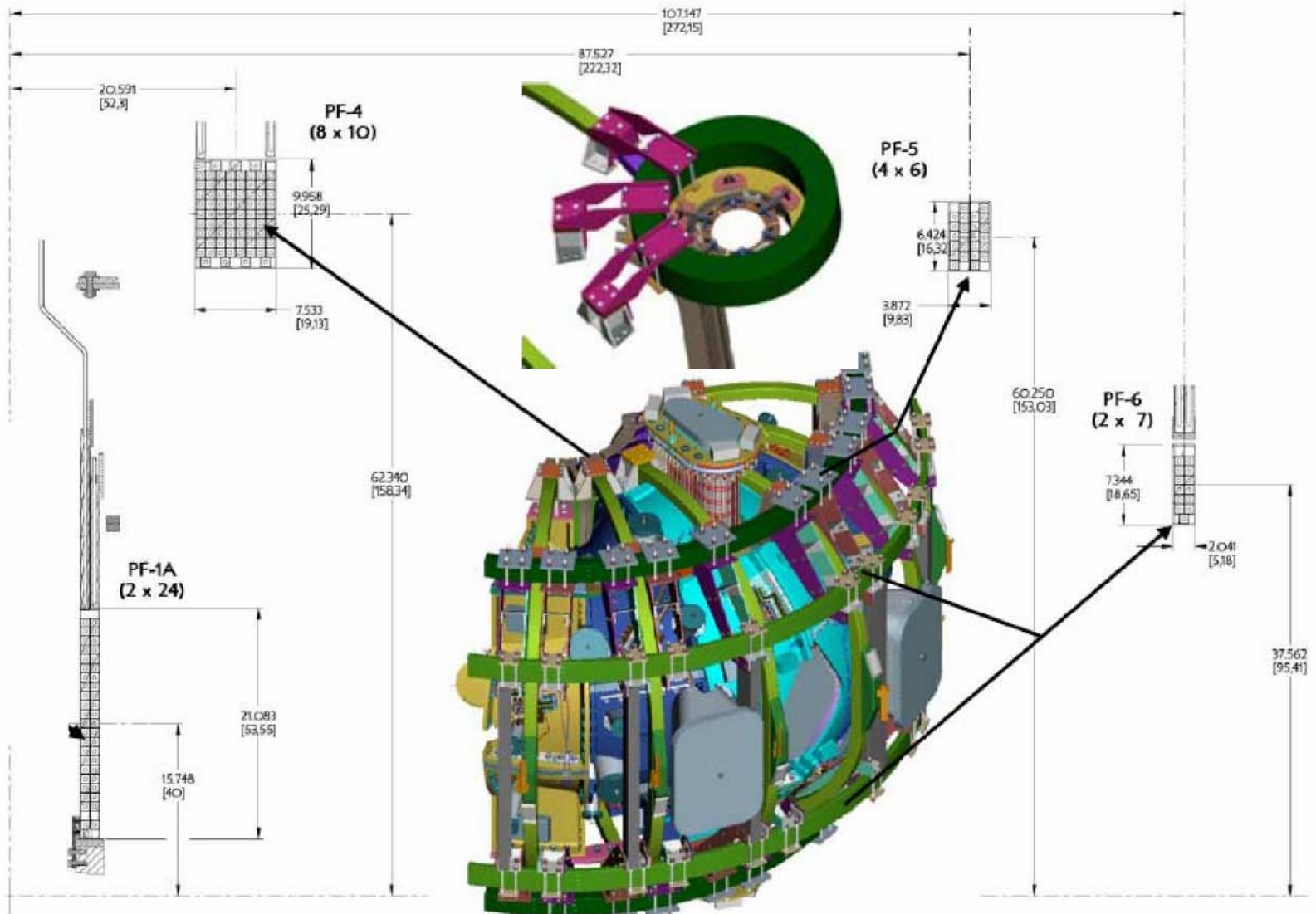


The coil services consist of the **cryogenic feeds** and **electrical leads** inside the cryostat, serving all of the coils, including conventional. It includes the specification of requirements for the coil protection system.

Lower-level elements include:

LN2 Distribution System (WBS 161);
Coil Electrical Leads (WBS 162); and
Coil Protection Requirements (WBS 163)

NCSX Coils



SC Project Review of NCSX, April 8-10, 2008



WBS 161 LN2 Distribution System



Description

This element covers the distribution of liquid nitrogen (LN2) coolant within the cryostat. The system serves all the actively cooled coils:

TF (WBS 131)

PF (WBS 132)

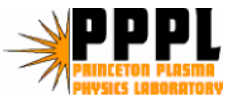
Modular (WBS 14)

Scope

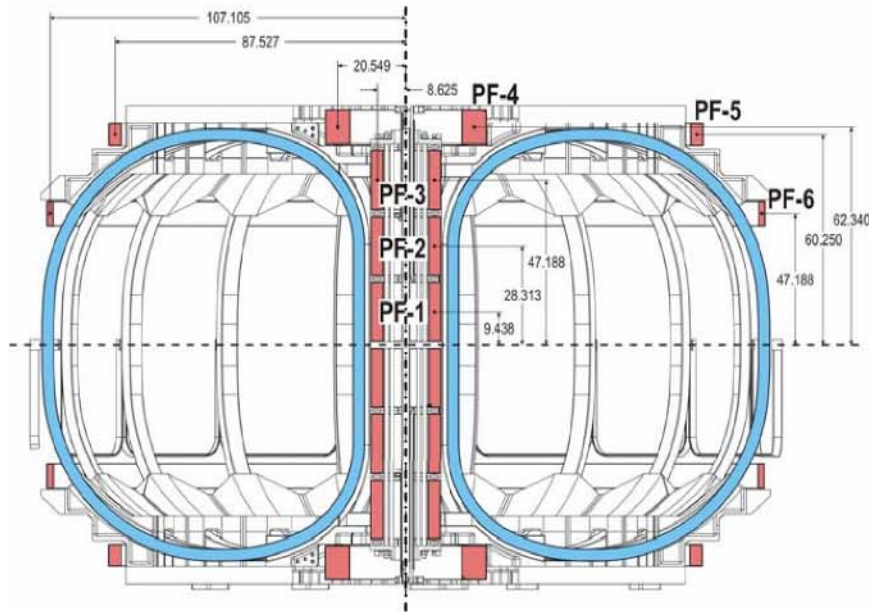
Work includes engineering design, procurement, and fabrication of manifolds, cooling hoses, jumper hosing, valving, and associated supports. Work in this WBS ends with delivery of components to machine assembly operations.

Interfaces

I&C is procured in 1408. WBS161 includes routing and distribution of coolant between coil input/output terminations and the supply/return manifolds. WBS17 provides supply/return headers and hook up interfaces in the Cryostat. Valves are included in WBS1 61.



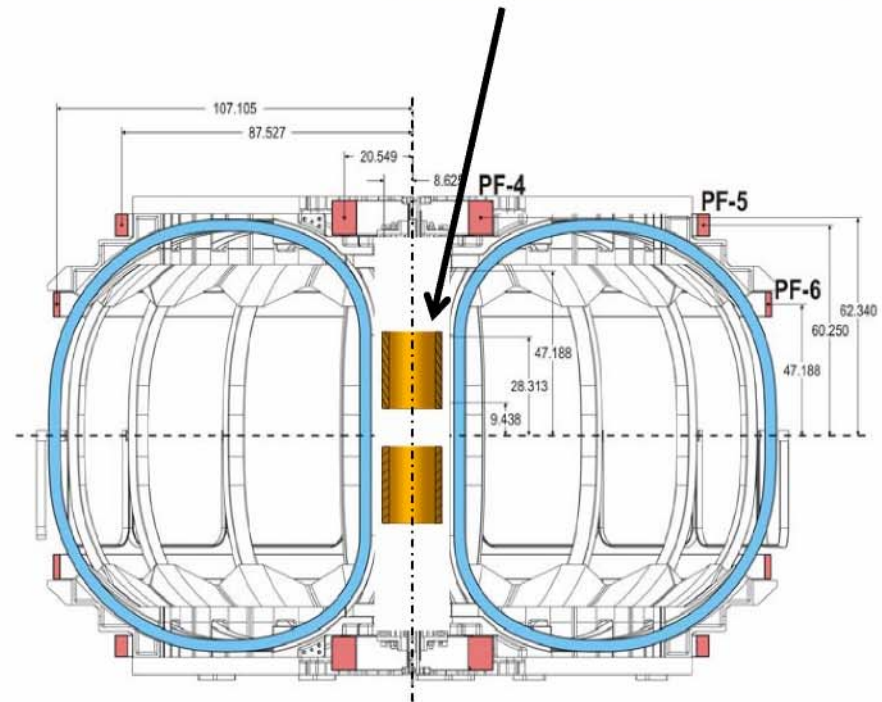
Central Solenoid, TF, and PF Configurations



Upgrade Configuration

- 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.

PF1a coils from NSTX are baseline



Baseline Configuration

Modular Coil and Conventional Coil Cooling



Requirements

- Operate at 77 K with LN₂.
- Operating pressure minimum 5 atmospheres absolute.
- Electric breaks in MC coil coolant lines poloidally.
- Electrical current limitation between cooling components. (bypass resistors isolate hoses to ground)
 - TF and PF hoses electrically isolated at coil terminations as well as headers
- Provide flow balance between systems.

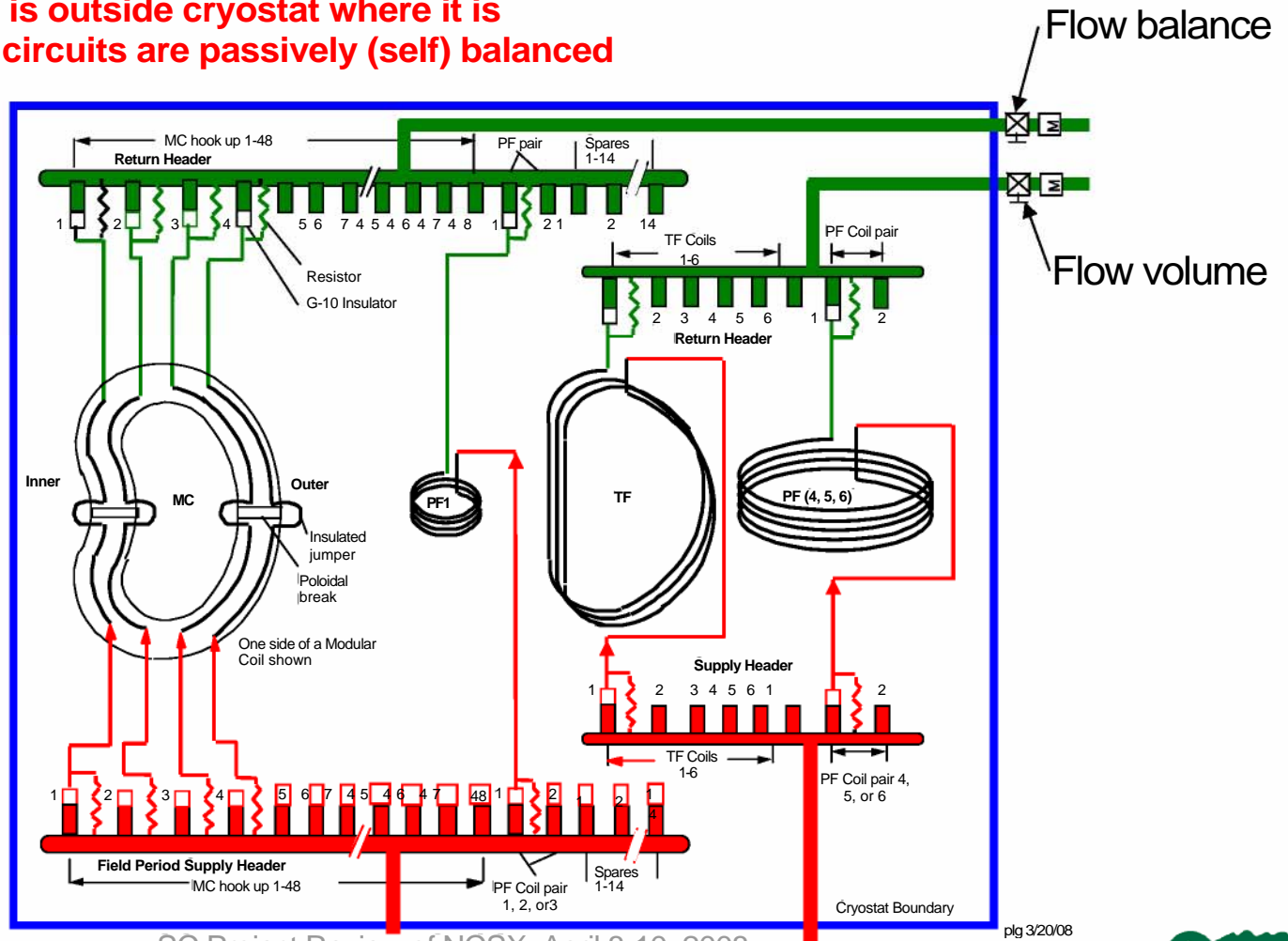


Costs reflect design in Cooling System Diagram shown below



Dual supply and return manifolds

- Individual controls are not required, a single valve in MC return balances both manifolds
- Valve and monitoring is outside cryostat where it is accessible
- Individual circuits are passively (self) balanced



SC Project Review of NCSX, April 8-10, 2008

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Flow distribution



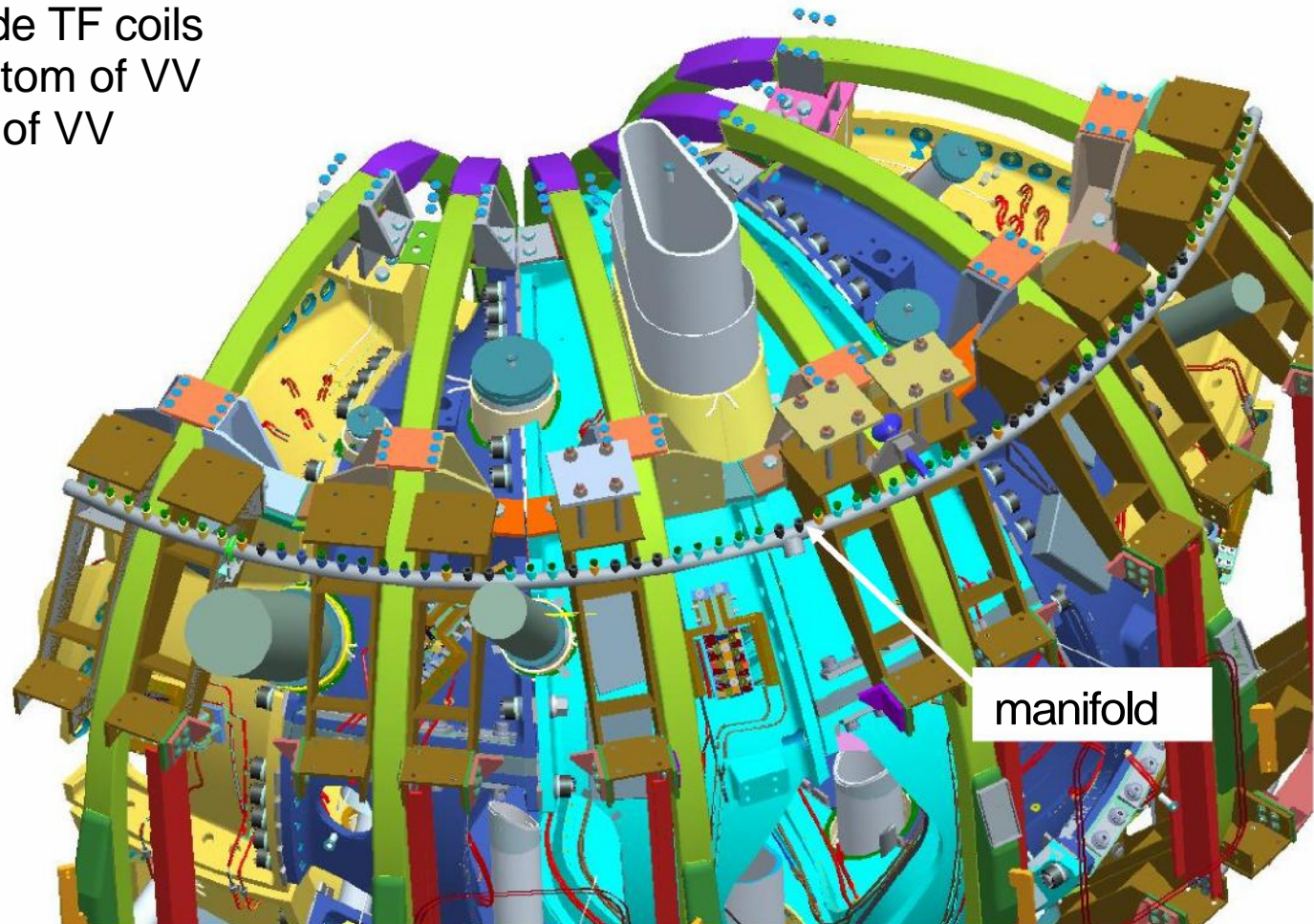
PF1A is used in CD4, replace by PF1, PF2, and PF3 in future operation.
 Pressure drops fall in two well defined groups.

	ID (in)	Length of tracing (ft)	Length of hose (ft)	Minimum flow required (gpm)	Actual flow (gpm)	Pressure drop (atmos)
MC	0.18	4	18	1.1	1.2	2.42
PF1	0.354	304	24	1.1	1.1	2.42
PF2	0.354	304	24	1.1	1.1	2.42
PF3	0.354	304	24	1.1	1.1	2.42
PF1A	0.354	178	24	1.1	1.2	2.42
spares				0.5	0.5	2.42
PF4	0.354	861	21	1.1	1.4	4.51
PF5	0.354	1100	21	1.1	1.2	4.51
PF6	0.354	786	18	1.1	1.4	4.51
TF	0.312	355	18	1.6	1.6	4.51

Typical manifold



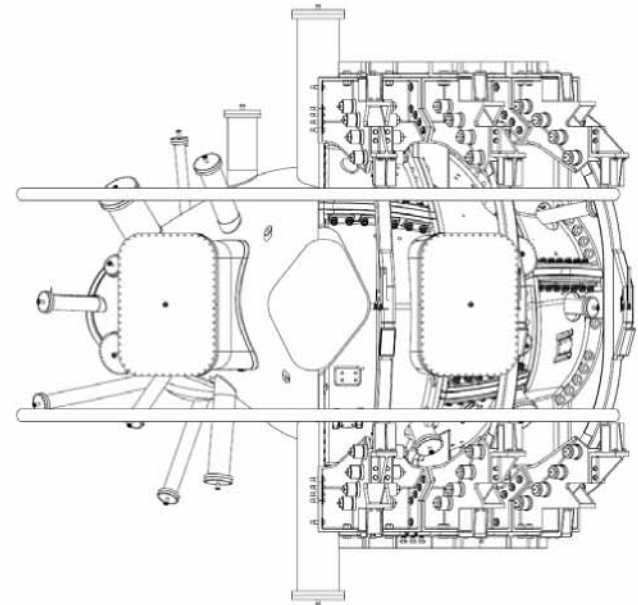
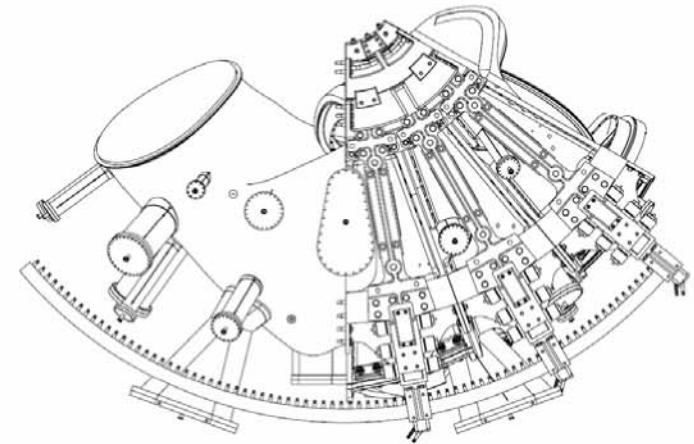
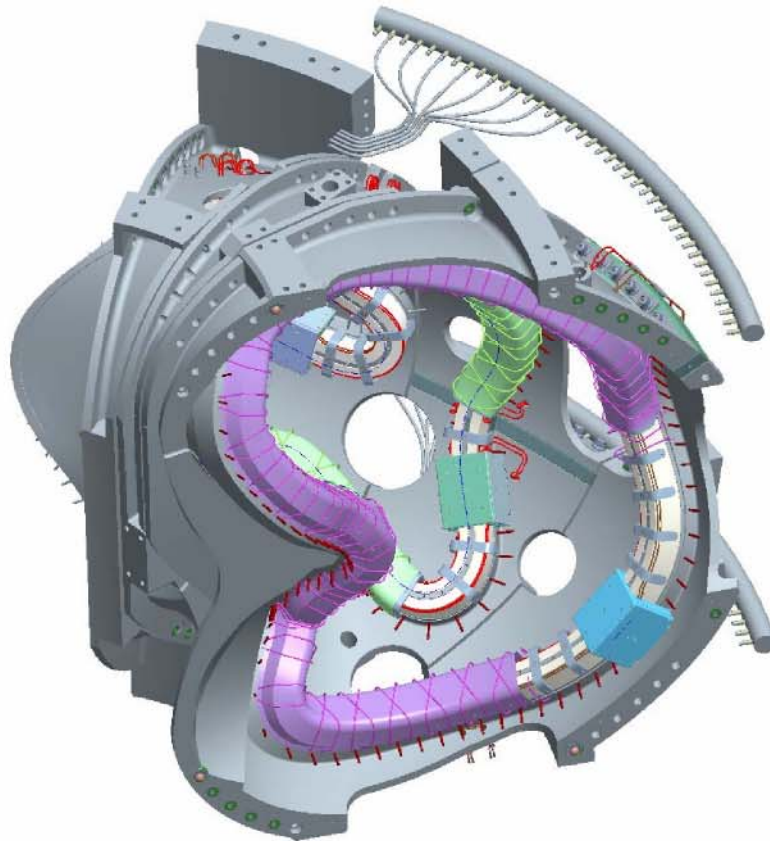
- Manifolds lie outside TF coils
 - supply near bottom of VV
 - return near top of VV



Manifold Jumpers



Transition to flex hosing at the winding form



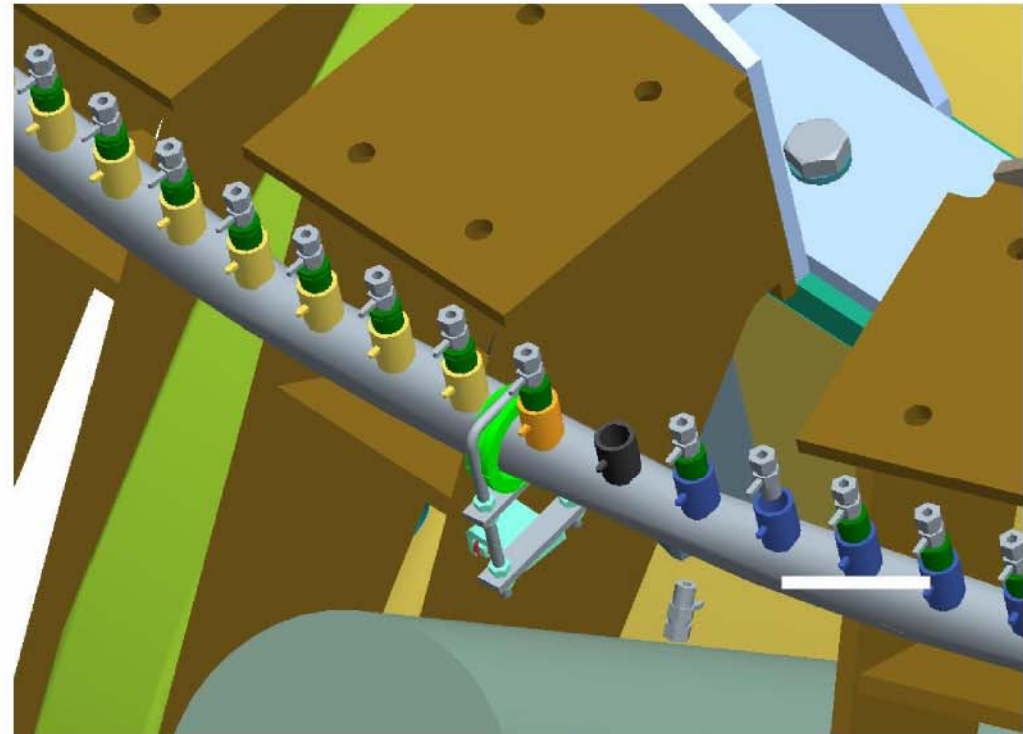
Manifold hose insulators



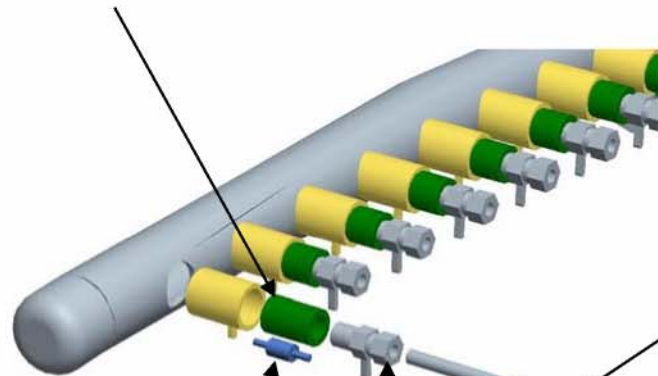
Hoses are isolated from the manifolds by G10 plugs

- prototype will be tested at 77K

-orientation of individual connections is TBD



G10 CR Male / Female coupling



Resistor

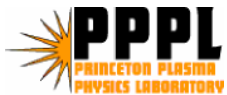
316 SS braided hose with 5/16 OD straight tube coupling at both ends

316 SS Yor-Lok 5/16 OD tube one end and 1/4J NPT on other end

Cost Estimate Basis



- **LN2 hoses are catalog items.**
 - Lengths are based on ProE models.
- **Manifold designs and prices are based on a similar design used on the VV.**
 - Sizing is based on thermo hydraulics performed by Engineering.
- **Material cost is estimated on a \$ per lb at current market.**
- **Supports are based on a \$/length of hose.**
- **Engineering time is based on number and type of drawings for each element, specifications, and the analyses anticipated.**



Labor



This effort covers all R&D, Title I, II, and III engineering for the LN2 distribution system inside the cryostat, which includes all the necessary manifolding and connections to interface with the ex-cryostat LN2 supply system. This system will be fabricated in-house by PPPL. All Title III engr associated with installation is included in WBS 7

Task ID	Multiplier	Unit	Number of Units	Hours	HOURS										
					EM ORNL	EM ORNL	RM ORNL	Dsn ORNL	MEM EMEM	PL EMEM	MSB EMSB	MEM EMEM	MSM EMSM	MSB EMSB	MTB EMTB
Title I & II Design															
Title I - Model Design															
Plan Model (avg)	8	hrs/model	21	168		168									
Assy Dwgs	16	hrs/dwg	24	384		384									
Detail Dwgs	8	hrs/dwg	13	104		104									
Installation Dwg	16	hrs/dwg	14	224		224									
Cooling Schematic	20	hrs/dwg	1	20		20									
Electrical Schematic	0	hrs/dwg	1	0		0									
I&C Schematic	20	hrs/dwg	1	20		20									
Stress Analysis	40	hrs/calc	1	40		40									
Thermal Analysis	40	hrs/calc	1	40		40									
Special Analysis (Electromagnets)	160	hrs/calc	0	0		0									
Fab Specifications	160	hrs/spec	2	320		320									
PDR/FDR Reviews	80	hrs/review	2	160		160									
Resolve PDR Comments	40	hrs/PDR	1	40		40									
Meetings/Reporting/Presentations	10%	% Total Hrs		152		152									
Subtotal Title I & II Design				1672	1672										
R&D Activities															
R&D - Pressure drop simulation w/ pressurized LN2 & valve															40
Subtotal R&D Activities															40
Title III Activities															
Disposition of RFDs & NCRs					1	hrs/	38	38							38
As Built Drawings					2	# dwgs	52	104	104						
Procurement Support								80						40	40

Description:

This effort covers procurement of materials for the LN2 distribution system by fixed price subcontract.

Assumptions:

outside engr rate =	120\$ per hour
outside fab rate =	60\$ per hour
outside inspection/technician rate =	80 \$ per hour
MDL labor	80\$per hour

Purchased parts:

coolant line pigtails from coils to manifolds	\$19,800 see notes below
Insulating Jumper hoses	\$4,320
Manifolds for cooling lines	\$9,085
valves	\$9,000 see notes below
orifices & other hardware	\$10,000
Thermocouples	\$0 included in job 1408 for
R&D material and labor from below	\$18,000 the modular coil
	<i>subtotal, purchased parts \$70,205 fabrication</i>

Fabrication and Assembly



Description:

This effort covers all the fabrication of the LN2 system inside the cryostat including headers.

Worksheets

coolant line pigtailed from coils to manifolds

Average length of pigtail

No. of coils	Total	3 ft								
		TF	Modular	PF1	PF2	PF3	PF4	PF5	PF6	Trim
circuits per coil at header	60	18	18	2	2	2	2	2	2	12
total circuits		1	8	0.5	0.5	0.5	0.5	0.5	0.5	0
Total number of pigtailed	168	18	144	1	1	1	1	1	1	0
	336	supply and return per circuit								

Manifolds for cooling lines

Assume 2 pairs of 1.5 inch manifolds for each field period, one above and one below the midplane inside the PF5 coil

Each set of manifolds will have 1/3 of the required cooling connections plus 25% spare

The manifolds will connect via vertical pipes to the supply system below the cryostat

avg toroidal perimeter of field period	16 ft
avg vertical height of connection lines	9 ft
no of headers/FP	4
cost of tubing	\$15 per foot, 316 SSt
cost per field period	\$1,488
total number of coolant connections, all headers	840
hours to weld each connection	0.5 hr per connection
shifts to form manifold tube	0.5 per manifold pair
crew size for forming	2
hours to cut vertical pipes	2 hrs per pipe
hours to weld vertical pipes to header	2 hrs per pipe
total shifts for manifolds	71
tech hours for manifolds	564 hours
technical oversight, inspection	141 hrs
total hours for manifolds	705 hrs



Schedule & Staffing

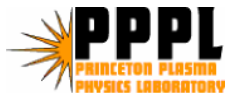


Schedule

Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days)	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete	FY		
									FY08	FY09	FY10
161 - LN2 Distribution											
191-001		Title I design WBS 161 LN2 manifolds&pipng	166*		01OCT07A	02JUN08	197	48,937.50			
191-002	3	LN2 manifolds&pipng- PDR	1		03JUN08	03JUN08	197	1,208.00			
161-003	3	Resolve PDR comments	5		04JUN08	10JUN08	197	6,040.00			
161-011A		R&D build mounts & lead terminations	60		11JUN08	04SEP08	197	24,040.00			
191-011		Title II design WBS 161 LN2 manifolds&pipng	60		11JUN08	04SEP08	197	65,250.00			
191-012		LN2 manifolds&pipng - FDR	1		05SEP08	05SEP08	197	1,208.00			
191-037		Prep Req,Bid,Award-manifolds,hoses,valves etc	25		08SEP08*	10OCT08	197	0.00			
191-038		Fab and deliver-manifold assy,hoses,valves etc	90		13OCT08*	26FEB09	197	136,453.09			
191-031		Title III engr WBS 161	118		08SEP08	03MAR09	1,420	24,040.53			

Staff

Jobs	start	end	days	weeks	Paul	Sorin	Scott	total	Total
					Goranson	Homescu	Dixon		
					40%	100%	100%	work hours	WAF
					hrs	hrs	hrs	available	hours
leads(162)	14-Mar	1-Feb-09	324	46.3	692.6	1351.4		2044	2044
headers(161)	1-Jan	1-Oct-08	274	39.1	522.3	500	1565.7	2088	1934



Cost Estimate Risks



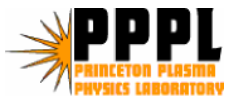
- LN2 Distribution System (WBS 161)

Design is straight forward and procured items are by and large commercially stocked. Manifolding is similar to gas system on VV, which is complete and costs are well documented.

Maturity – medium

Routing and interfaces are in early design phase and design is pre PDR. R&D required.

Complexity – low



Risk Mitigation

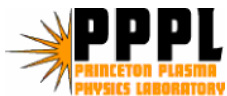


Schedule Milestones

- **An extra full time designer was assigned to Coil Services to assure schedule is met.**
- **Hoses will be 100% leak checked at delivery to prevent delays after installation. (lesson learned from VV)**

Design Integrity

- **R&D at MDL will confirm functionality of G10 insulators and flow rate in corrugated hoses.**



SC Project Review of NCSX, April 8-10, 2008
P. L. Goranson - page 18



SC Project Review of NCSX, April 8-10, 2008