NCSX Cryogenics Systems
WBS-62

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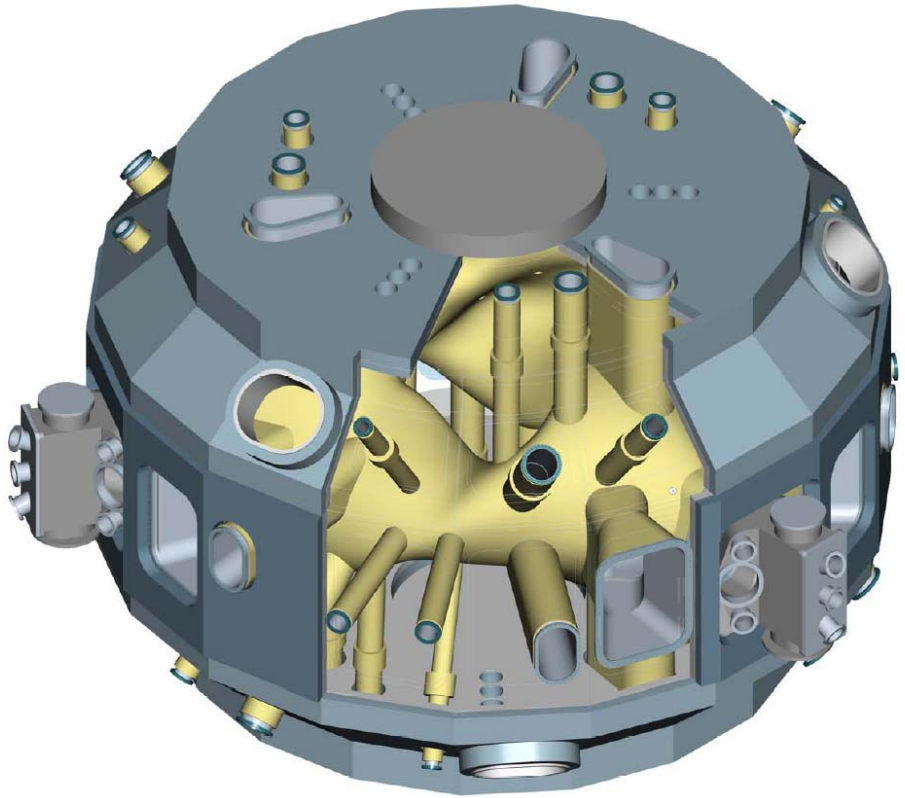
Overview

The stellarator core is supported by three cryogenic facility systems:

- **WBS 621** delivers LN_2 to the machine area.
- **WBS 622** performs heat removal from the field coils
- **WBS 623** Cools and maintains structure(s) within the cryostat at desired operating temperatures (~80K).



Requirements

- WBS621
  - Provide LN2 for distribution to:
    - LN2 Coil Cooling system
    - LN2/GN2 Structure Cooling
- WBS622
  - Provide LN2 (~210gpm @150 psig) to coil distribution manifold (WBS16) for extracting heat from PF, TF and Modular Coils.
  - Maintain single phase flow.
- WBS623
  - Cool structures without introducing thermal stresses
  - Maintain cold N2 atmosphere within Cryostat.

Interfaces

- WBS621
  - C-Site 9200-gallon LN2 tank
  - WBS-622 Coil LN2 circulation pump skid
  - WBS-623 LN2 supply to Cryostat
  - Test Cell Air monitoring system
- WBS622
  - Coil LN2 distribution manifold
  - HVAC exhaust
- WBS623
  - Cryostat (WBS-171)
  - HVAC exhaust
  - All structures within Cryostat

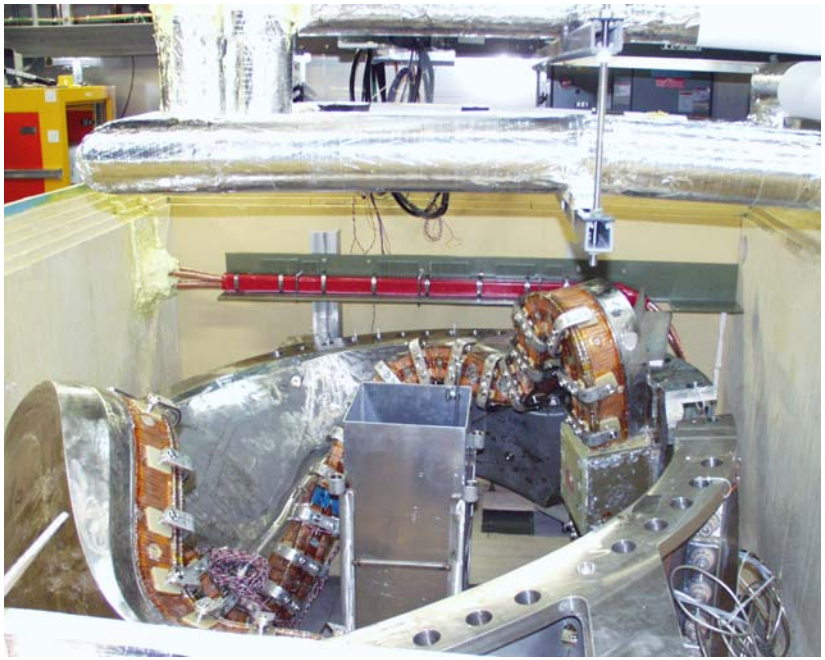
Design Plans (WBS-621 LN2 supply)

- This is very straightforward.
- Flow rates, heat loads and pressure drops are already reasonably well known. This gives us confidence that the current estimate is reasonably accurate.
- Design will incorporate flow diagrams, and isometric piping drawings. Detailed component drawings will be minimal. This will allow many elements of the design of the system to proceed without requiring the "final" parameters.
- When final requirements for flow rates, heat loads and pressure drops are available, the components shall be procured, assembled and installed.

Design Plans (WBS-622 Coil Cooling)

- A pressurized, LN_2 heat removal loop is required for the field coils.
- The prototype for this loop was operated for the coil testing.
- A scaled up version of the Coil Test Facility's pump skid is required to support these requirements.
- WBS-622 scope provides system capable of supporting full power operation. Heat removal requirements are ~50 MJ in a 15 minute recovery interval (about 56 kW avg.)

Design Plans (WBS-622 Coil Cooling)



- The C1 coil was cooled to the point that single phase liquid flow was established in the winding pack's coolant channels
  - A success!
  - The single phase flow approach is validated
  - Technical risk is low

Design Plans WBS-623

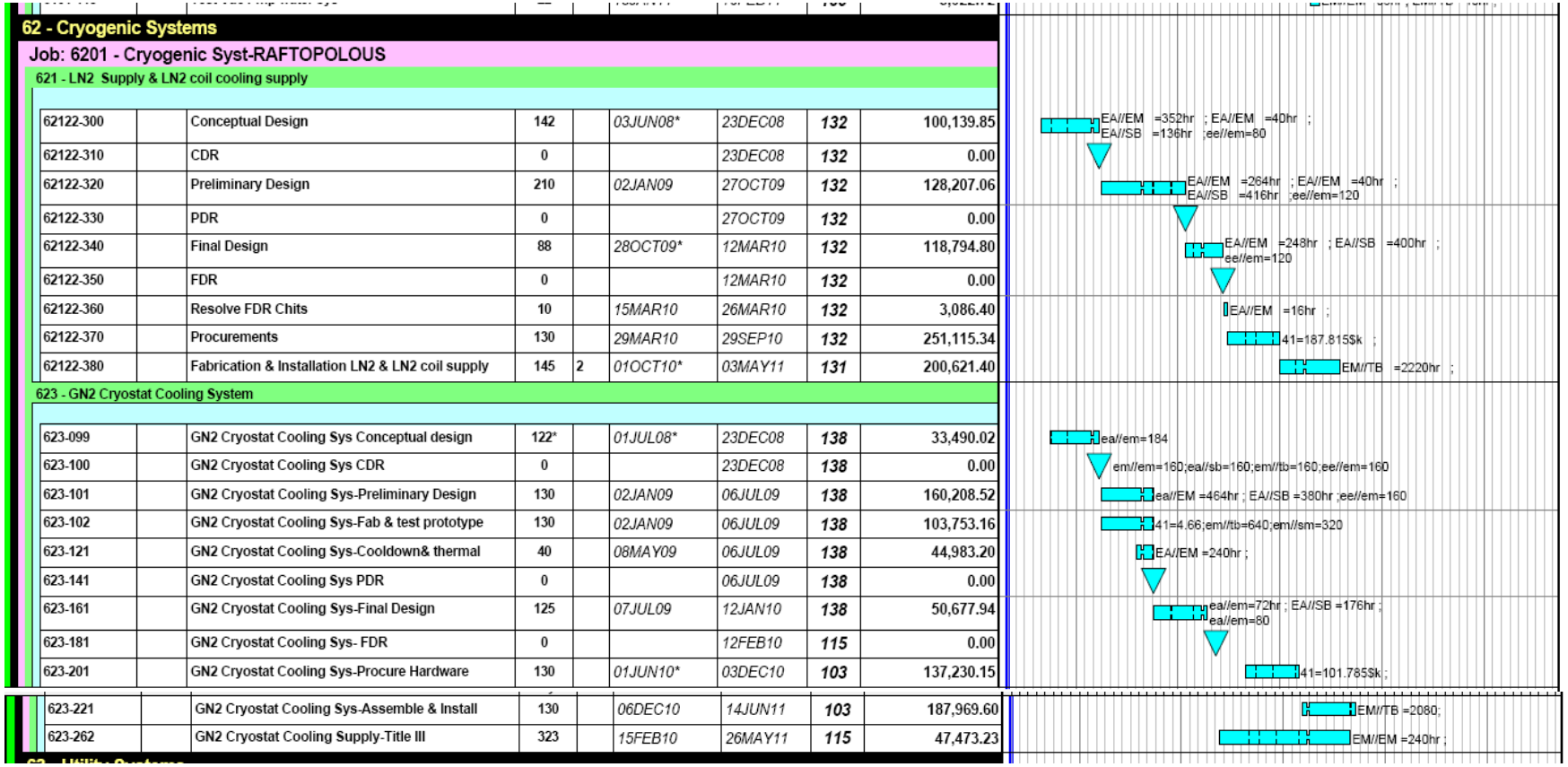
- Develop system to deliver LN2/GN2 for heat extraction from structures.
- Currently considering a system that evaporates LN2 to remove the heat.
- R&D - Have included funding in budget to prototype the cooling strategy
  - Develop better mixing of cold gas for improved convective heat transfer.
  - Electric and/or air motors are candidate drivers.
- Design Opportunities
  - Conduction cooling via plates or tubing will be considered (Alcator C-MOD recommendation).

Procurement Plans

- WBS 621 & 622
  - Components for these WBS elements are either common “off the shelf” items, or can be specified to order and delivered by vendors (i.e. the LN2 circulating pump)

- WBS 623
  - TBD: R&D efforts will drive design and procurements.

Costs and Schedule



62 - Cryogenic Systems

Job: 6201 - Cryogenic Syst-RAFTOPOLOUS

621 - LN2 Supply & LN2 coil cooling supply

62122-300		Conceptual Design	142		03JUN08*	23DEC08	132	100,139.85
62122-310		CDR	0			23DEC08	132	0.00
62122-320		Preliminary Design	210		02JAN09	27OCT09	132	128,207.06
62122-330		PDR	0			27OCT09	132	0.00
62122-340		Final Design	88		28OCT09*	12MAR10	132	118,794.80
62122-350		FDR	0			12MAR10	132	0.00
62122-360		Resolve FDR Chits	10		15MAR10	26MAR10	132	3,086.40
62122-370		Procurements	130		29MAR10	29SEP10	132	251,115.34
62122-380		Fabrication & Installation LN2 & LN2 coil supply	145	2	01OCT10*	03MAY11	131	200,621.40

623 - GN2 Cryostat Cooling System

623-099		GN2 Cryostat Cooling Sys Conceptual design	122*		01JUL08*	23DEC08	138	33,490.02
623-100		GN2 Cryostat Cooling Sys CDR	0			23DEC08	138	0.00
623-101		GN2 Cryostat Cooling Sys-Preliminary Design	130		02JAN09	06JUL09	138	160,208.52
623-102		GN2 Cryostat Cooling Sys-Fab & test prototype	130		02JAN09	06JUL09	138	103,753.16
623-121		GN2 Cryostat Cooling Sys-Cooldown& thermal	40		08MAY09	06JUL09	138	44,983.20
623-141		GN2 Cryostat Cooling Sys PDR	0			06JUL09	138	0.00
623-161		GN2 Cryostat Cooling Sys-Final Design	125		07JUL09	12JAN10	138	50,677.94
623-181		GN2 Cryostat Cooling Sys- FDR	0			12FEB10	115	0.00
623-201		GN2 Cryostat Cooling Sys-Procure Hardware	130		01JUN10*	03DEC10	103	137,230.15
623-221		GN2 Cryostat Cooling Sys-Assemble & Install	130		06DEC10	14JUN11	103	187,969.60
623-262		GN2 Cryostat Cooling Supply-Title III	323		15FEB10	26MAY11	115	47,473.23

Staffing

- WBS manager/Technical Expert – 1800 man-hours budgeted
- Cryogenics Consultant – 1200 man-hours budgeted
- Electrical/Controls Engineer – 1300 man-hours budgeted
- Thermal Analysis – 400 man-hours budgeted
- Designer/Draftsman – 1500 man-hours budgeted.
- Fabrication/Installation – Performed by PPPL technical staff ~ 6000 man-hours budgeted for mechanical, electrical and controls.

Risk Assessment

- WBS-621 LN2 supply – Low Design Maturity, Low Complexity
  - Sizing of piping is straight forward
  - Based on identified (calculated) heat loads, the capacity of existing C-site LN2 tank 9200 (gallon) is adequate.
  - Off-the-shelf components are used.
  - Providing a bit of reserve capacity should guaranty success.

- WBS-622 Pressurized LN2 cooling for coils – Low Design Maturity, Low Complexity
  - Coil testing cooling loop validates design.
  - Full power coil heat loads have been calculated.
  - Required flow rates and pressure drops have been calculated.
  - LN2 delivery system can be sized to accommodate requirements
  - Standard industrial products make up the system.
  - Providing a bit of reserve capacity should guaranty success.

Risk Assessment –cont.

- WBS-623 Cooling of structures – Low Design Maturity, High Complexity
  - Risks
    - Heat loads (from hot vessel and conduction thru insulation) can be calculated, but imperfections in installation *and* the modular nature of the cryostat may negatively affect performance and reliability.
    - Condensation of liquid at bottom of cryostat may cause sealing issues resulting in LN2 and cold gas leaks.
    - Stratification of GN2 temperatures may result in uneven cooling of the structures.
  - Mitigation
    - Seeking experience of other facilities that employ cryostats.
    - Cooling structures via conduction (as opposed to liquid spray & evaporation)
    - Prototyping the LN2/GN2 cooling concepts will quantify risk and will lead to solutions.