NCSX Heater Control System

P. L. Goranson

Work package 1270

Outline

Updated 10/25/07 R. Gernhardt

- Scope
- Requirements
- System Proposed
- Configuration
- Component details
- M&S and Labor cost details
- Total Cost (M&S and Labor)
- Schedule
- Risk and Mitigation

Scope

- Provide resistance heating temperature control system to maintain the NCSX inner port extension wall temperatures during standby and bake out operation.
- Monitor temperatures of the vacuum vessel body and port extensions during standby and bake out operation.
- Send temperature data to Central I & C for archival and interface to other disciplines.

Requirements-1

Criteria

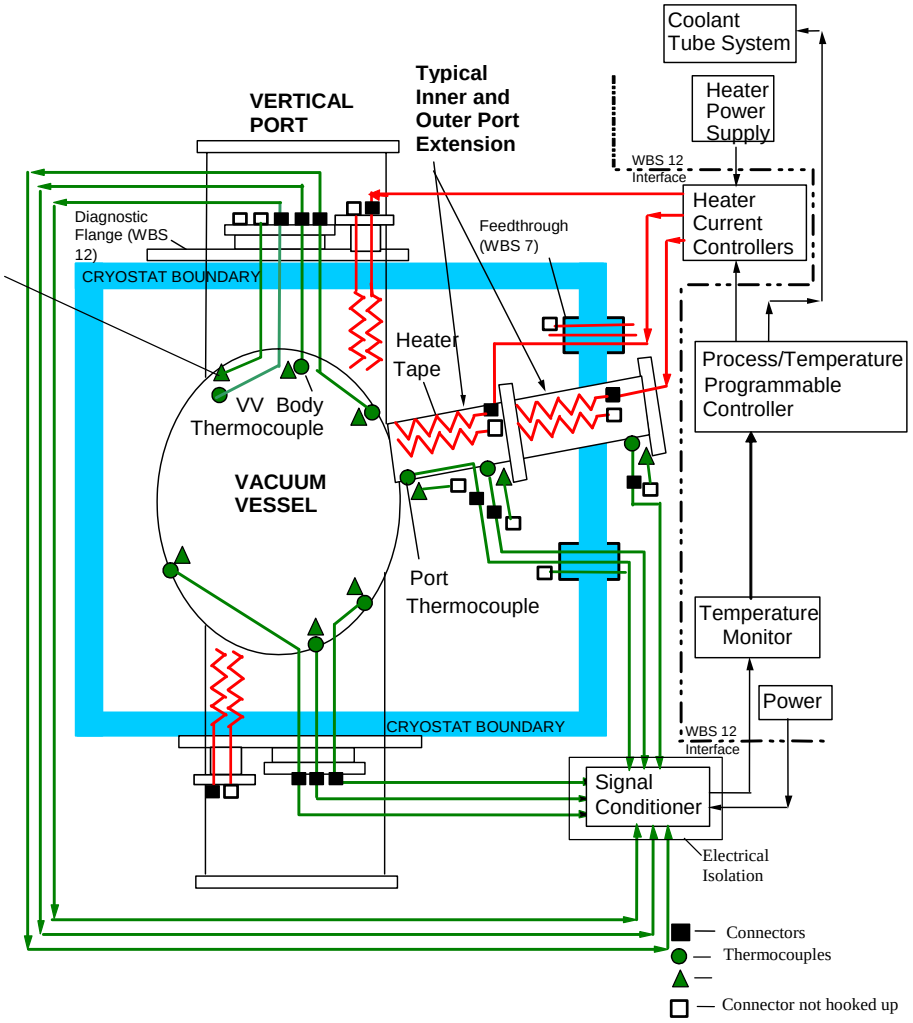
- **Monitor the VV temperature during standby and bake out operation.**
- **Operation range - room temperature to 375 C**
- **The leads must be insulated from all structure including VV and Cryostat.**
- **The signal conditioners must be the isolated type. Additionally, the instrument cabinet will be isolated from ground by insulation and isolation transformers.**
- **Each heater must be capable of continuous variable operation from 0 - 200 watts.**

Interfaces

- **Provisions must be provided by WBS 171 for future hookup of additional thermocouples when outer port extensions are added. The interfacing electrical system must be capable of upgrade to accommodate the upgrade.**
- **WBS 12 will be responsible for overall design of the system including choice and location of components, mounting provisions, lead routing, signal conditioning, and electrical isolation.**
- **WBS 12 will be responsible for coordination of the thermocouple design with the other interfacing disciplines (WBS 171 and WBS 5).**
- **For purpose of assigning interface responsibility, the WBS 4 responsibility shall end at the power panel.**

Requirements-2

Interface Block Diagram:



System Proposed, page 1

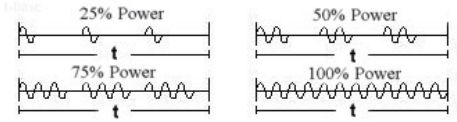
- **Provides for:**
  - **120 Channels of Active Heater Temperature Control Zones**
    - **114 heating control zones (channels) requested.**
  - **282 Channels of Thermocouple monitoring points**
    - **279 (expandable) temperature monitoring points requested.**

System Proposed, page 2

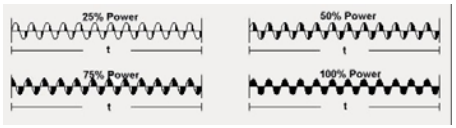
- **PLC based temperature control of heaters:**
  - Rockwell Control Logix Platform
  - Networking
    - Control Net for PLC I/O and Local Programming/Control
    - TCP/IP interface to Central I&C for data exchange. May use Rockwell software.TBD
    - Ethernet/IP network for Remote system control operator interfaces.
  - Software
    - RSLogix 5000 PLC programming software. PC platform
    - RSView32 or SE MMI software---TBD . PC operator interface.

System Proposed, page 3

- **Heater 120VAC control:**
  - Zero crossing Time Pulsed Output (TPO) solid state relay supplies variable 120VAC pulse train to heater.
    - TPO chosen to minimize RFI to diagnostics.



    - Phased output SSR's are noisy (i.e.. Standard lighting dimmers)



  - Heater power limited by Variac.
  - Secondary SSR protects for thermal runaway (shorted TPO control SSR).
  - One or more thermocouples provide feedback for each heating zone PID loop.
    - Failed TC sets alarm, notifies operator and removes TC for heating zone mix allowing conditional heater zone control.

Sensor Specifications

- **Thermocouples:**
  - **Ref: NCSX-PRL-12-003-00**
    - **Type-E, Isolated, electrically floating junction Type-E, Isolated, electrically floating junction.**
  - **Similar to type Omega XCIB-E-4-3-10.**

- **Heaters:**
  - **Manufacture: BriskHeat**
    - **BIH series tapes are constant resistance type.**
  - ***Custom BIH Style Heating Tape:*** **½" W X 10 Ft. L, non-magnetic.**
  - **Heavy Insulated Heating Tape, 520 Total Watts, 24" Leads Same End, Split Plug, 120 Volt.**
  - ***Custom BIH Style Heating Tape:*** **½" W X 6 Ft. L, non-magnetic.**
  - **Heavy Insulated Heating Tape, 310 Total Watts, 24" Leads Same End, Split Plug, 120 Volt**

Control I/O M & S Costs

I/O M&S Total = $211,262

NCSX Heater/TC Instrumentation and Control Component Parts List

Provides for 120 Heaters and 282 Thermocouples

Rev 1: 24 OCT 2007 R.Gernhardt

Item	Description	Mfgr	Model	unit cost	Qty	Item Cost	Comment	Source
	PLC							
1	Logix 5560 processor with 2 M memory. (Is 2M enough??	Allen-Bradley	1756-L61	$5,105.00	1	$5,105.00	memory size???	Rumsey Electric
2	Control Logix Chassis, 10 slot	Allen-Bradley	1756-A10	$542.00	8	$4,336.00	TBD	Rumsey Electric
3	Control Logix Power supply, 10 A	Allen-Bradley	1756-PA 72	$805.00	8	$6,440.00		Rumsey Electric
4	Controlnet interface module	Allen-Bradley	1756-CNB	$1,312.00	8	$10,496.00		Rumsey Electric
5	Control Logix Ethernet interface module	Allen-Bradley	1756-ENBT	$1,760.00	1	$1,760.00		Rumsey Electric
6	MODBUS-TCP/IP communications module for 1756 chassis	ProSoft	MV156-MNET	$2,228.00	1	$2,228.00		Rumsey Electric
7	Control Logix Enhanced Isolated TC module, 6 Channel	Allen-Bradley	1756-IT6I2	$1,915.00	47	$90,005.00		Rumsey Electric
8	Interface module for above 1756-IT6I2	Allen-Bradley	1492-AIFM 6TC-3	$154.00	47	$7,238.00		Rumsey Electric
9	Cable for above 1756-IT6I2	Allen-Bradley	1492-ACABLE 025-Y	$177.00	47	$8,319.00		Rumsey Electric
10	Control Logix Ethernet interface module	Allen-Bradley	1756-ENBT	$1,760.00	1	$1,760.00		Rumsey Electric
11	Control Logix Analog Output, 8 Channel	Allen-Bradley	1756-OFB	$1,787.00	15	$26,805.00		Rumsey Electric
12	Cable for above 1756-IOFB	Allen-Bradley	??????????			$0.00	TBD	Rumsey Electric
13	Control Logix Digital Output, 16 Channel	Allen-Bradley	1756-OB16D	$727.00	8	$5,816.00		Rumsey Electric
14	Controlnet PCI interface card for local PC	Allen-Bradley	1784-PCIC	$1,569.00	1	$1,569.00		Rumsey Electric
15						$0.00		Rumsey Electric
16								
17	**SOFTWARE**							
18	Logic Programming, RSLogix5000, standard, NetWorx edit	Rockwell	9324-RLT300NXENE	$3,350.00	1	$3,350.00	TBD	Rumsey Electric
19	PIDE_AUTOTUNE software for RSLogix5000	Rockwell	9323-ATUNEENE	$490.00	1	$490.00	TBD	Rumsey Electric
20		Rockwell			1			Rumsey Electric
21	RSView SE Server 25 Display w/RSLinx Enterprise	Rockwell	9701-VWSS025LENE	3,960.00	1	$3,960.00	Server-- local?????	Rumsey Electric
22	RSView SE Server 25 Display	Rockwell	9701-VWSS025AENE		1	$0.00	Client-- Remote???/?	Rumsey Electric
23								
24	**CONTROL DISPLAY PC'S**							
25	Test cell PC, display & keybord	TBD		$1,300.00	1	$1,300.00		
26	Control room pc - supplied by CI&C	TBD						
27								
28	**HEATER DRIVE**							
29	Solid State Relay, 4-20ma in, 25 A AC TPO output	Power I/O	DMA-6V25	$99.00	120	$11,880.00		Power I/O
30	Solid State Relay, 4-32 VDC control, 20 A	Crydom	CKRD2420	$31.00	120	$3,720.00		Allied
31	Variac, 120VAC, 5 A	Staco	511	$98.00	120	$11,760.00		Newark
32	Fuse & holder, TBD			$1.00	120	$120.00		
33	Bud Panels for Variac mounting, 5.25" x 19"	Bud	PS-1252	$18.94	30	$568.20		Allied
34	Bud Panels for PLC mounting, 7" x 19"	Bud	PS-1253	$19.06	10	$190.60		Allied
35	DIN Rails, 6' length to mount SSR's and TC interfaces	Various		$5.00	12	$60.00		
36								
37	**FIELD CABLE CONNECTORS**							
38	Heater cable connectors, 16 socket, crimp type MS	Amphenol	MS3126F20-16S	$61.62	16	$985.92		Allied
39	Crimp tool, positioner, Ins/Ext for MS3126F20-163	Amphenol	M22520/1-01	$500.00	1	$500.00		
40	TC cable connectors, socket crimp type - G.Labik to purchase						TBD	
41						$0.00		
42	Misc hardware	various		$500.00	1	$500.00		
					TOTAL:	**$211,261.72**	NOTE: List cost	

AC Power, Field/Rack/Tray Wire M & S Costs

NCSX Resistance heating system field installation by: Frank Jones

Materials total: $42,894

Wire: #2 awg	$600
#4 awg	$180
#10 awg	$1000
2/0	$250
#6 & #8 awg	$140
Multi-conductor shielded (1000ft.), 105c	
Power cable for heaters ($6/ft.)	$6000
Thermo-extension cable (2000ft.):……..	
Type-E shielded-8pr.($4/ft.)	$8000
2-“GE” breakers & enclosure	$2000
42 ckt. “GE” panelboard…….	
3 ph. 4 wire, 150A	$1500
480v, square-D 70a Breaker (250 af)	$700
G-10 sheets…….	
5-1/8” 24” x 36”	$260
2-1/8” 36” x 76”	$364
PVC shed. 40 conduit, 50 ft.	$75
5-2.5kva MGE isolation Transformers	$6000
5-20a plugmold strips	$550
5-emi/rfi filters	$1500
5 fan assemblies	$500
30-25amp 1 pole breakers	$1050
5-20amp 1 pole breakers	$175
Panduit 2” x 2” in rack	$250
4” x 18” fiberglass tray fittings For thermo-wire	$1700
4 x 12” fiberglass tray fittings For heater power	$1200
4” x 18” fiberglass straight tray For thermo-wire	$2000
4 x 12” fiberglass straight tray For heater power	$1200
Aluminum and fiberglass Strut	$200
Isolation transformer 45 kva, 480v to 208/120v…41kvdc iso.	$5500

Instrumentation and Control- Labor Estimate

NCSX RESISTANCE HEATING TEMPERATURE CONTROL SYSTEM						
Instrumentation and Control - R.Gernhardt- 10/24/07						
	Task		Man days			
DESIGN			eng	dsn	sr lab	tech
Documentaion		R.Gernhardt				
Rack layout (1 dwg)					1	
Internal PLC terminal layout drawings (6)					3	
Create Spreadsheet- End to End - Device to PLC wire list					5	
Intra rackCWD's, PLC to Drive components (10)					5	
Control		R Gernhardt, J.Dong, Sichta				
Define temp control algorithms, Associate TC W/Htr zones.					5	
Prepare I&C interface doc. & PLC tag assignment			5		10	
Select/Evaluate Control software packages			1		1	
CI&C interface development			5		2	
		Design Man Days	11	0	32	0
PROCUREMENT			eng	dsn	sr lab	tech
Connectors		R Gernhardt				
Order Heater Field cable connectors (MS type)					0.5	
Hardware						
Order PLC I/O hardware					1	
Order Heater Drive components					0.5	
Software						
Order Control display software					1	
		Procurement Man Days	0	0	3	0

FABRICATION			eng	dsn	sr lab	tech
Prototype		R Gernhardt				
Configure/Evaluate typical htr / TC control channel					5	
Rack		Tech shop				
Fabricate Variac and PLC mounting panels (40)						2
Mount Variacs (120) to panels						2
Mount Drive components (240- SSR's) on DIN rails						2
Control		R Gernhardt				
Configure & program PLC					20	
Program RSView control pages (heater ~6), (TC~6), (System~7)					20	
		Fabrication Man Hours	0	0	45	6
INSTALLATION			eng	dsn	sr lab	tech
Rack		R Gernhardt/ Tech shop				
Install and wire Drive components					1	10
Control		R Gernhardt/Tech shop				
Install / network PLC chassis (8), Wire PLC I/O,					3	3
Test- PLC & Control software					5	
Install / network test cell PC ---- J.Dong			1			
Commission I&C interface, test ----R.Gernhardt/ J.Dong			5		5	
Test Procedure					1	
		Installation Man Days	6	0	15	13
LABOR			**eng**	**dsn**	**sr lab**	**tech**
		TOTAL Man Days	**17**	**0**	**95**	**19**
		Man Hr	136		760	152
		Man Month	0.85		4.75	0.95

AC Power, Field/Rack/Tray Wire- Labor Estimate

NCSX RESISTANCE HEATING TEMPERATURE CONTROL SYSTEM					
AC Power, Field/Rack/Tray Wire- F.Jones--- 10/24/07					
Task		Man days			
DESIGN		eng	dsn	sr lab	tech
Design/drafting & supervision- F.Jones					
Machine elevation & tray details			4		
Tray support fabrication detail			4		
Rack internal layout details			3		
Existing Panel draw rev.			1		
New panel schedule dwg.			1		
Shutdown dwg			1		
AC power CWD for panel/xfmr			1		
5 rack ac power CWDs			3		
Heater power from rack to connector					
Wiring diagrams & termination details			4		
Thermocouple wiring from rack to					
Machine and termination details			4		
Tray test cell plan drawing			3		
JHA, procedure, ECN, work order			3		
Package issue and field walk down			2		
	Design Man Days	**0**	**34**	**0**	**0**
PROCUREMENT		eng	dsn	sr lab	tech
AC Power	F.Jones/tech shop				
Order Breakers, Panels, Pwr cable, field cables, x-formers			1		
Tray/Conduit	F.Jones/tech shop				
Order tray/ conduit			1		
Material research	F.Jones		1		
	Procurement Man Days	**0**	**3**	**0**	**0**
FABRICATION		eng	dsn	sr lab	tech
Tray Conduit prefab	Tech shop				4

INSTALLATION	eng	dsn	sr lab	tech
Construction/Electricians				
Install 70a, 3 pole 480v breaker				
(coordinate panel PP_141 shutdown)				2
Install conduit thru wall to test cell				2
Install 45 kva isolation transformer				
(handling and secure to floor)				4
Install primary & secondary breaker				2
Install new panelboard				
(assemble & install branch breakers)				2
Install conduit between xfmr and breaker Enclosures				2
Install ac power conductors & terminate				6
Install power and instrument dedicated trays				
around top and bottom of machine				16
Fabricate & Install tray support system				4
Install rack power conduit				4
Install 2-trays from machine to racks				8
Install 5 racks insulated to 5KV				8
Install 5 isolation xfmrs at racks				
(install 5 filters and plugmold strips)				7
Hi-pot racks to verify isolation				
(coordinate with TC work)				2
Install rack power wire 1/c #10				2
Install heater power from panel to rack				
(30-120v circuits-fan out at racks)				10
Install/terminate heater power from racks to				
Machine via tray 12				12
Install/terminate thermocouple extension				
Wire from rack to machine				24
Revision/Construction Supervision		5		
		5	**0**	**117**
	eng	**dsn**	**sr lab**	**tech**
TOTAL AC Pwr/Fld Man Days	**0**	**42**	**0**	**121**
Man Hr	0	336	0	968
Man Month	0	2.1	0	6.05

Total Costs- M&S and Labor

NCSX RESISTANCE HEATING TEMPERATURE CONTROL SYSTEM				
MATERIALS & SUPPLY	Quantity	units	unit cst	Total
Ray G estimate				
A-B PLC hardware,Software, I/O modules, term blks				
Control PC/Displays, Network modules,				
Heater Drive components and Field Cable connectors				$211,262
F.Jones estimate				
AC power, breakers, enclosures, panels, x-formers, wiring				
Cable tray, conduit, TC/Htr Field cables				
Rack filters, fans and installation materials				$42,894
TOTAL Materials cost (unloaded)				**$254,156**

TOTAL LABOR ESTIMATE				
Instrumentation & Control	eng	dsn	sr lab	tech
Computer Div. / R.Gernhardt / Electrical Tech				
Includes Design, Procurment, Fabrication and Installation				
Man Days	**17**	**0**	**95**	**19**
AC Power, Field/Rack/Tray Wire				
F.Jones- Design/Drafting / Electrical Tech (Tech Shop)				
Includes Design, Procurment, Fabrication and Installation				
Man Days	**0**	**42**	**0**	**121**
LABOR Totals (I&C + AC PWR)	**eng**	**dsn**	**sr lab**	**tech**
TOTAL Man Days	**17**	**42**	**95**	**140**

ESTIMATE BASED ON:

1) PLC feedback control system to maintain port temperatures during stanby and bakeout operations.
2) 120 zones of ACTIVE heater temperature control.
3) 282 thermocouple channels available for monitoring and feedback control of vacuum vessel and port extension temperatures.
4) Archival of TC temperatures and heater power in central I&C.

ESTIMATE INCLUDES:

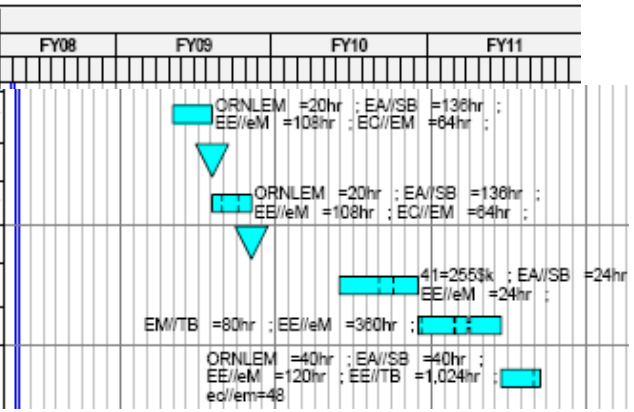
1) AC power labor and M&S costs.
2) PLC programming and M&S costs
3) Rack installations and wiring cost
4) Includes TC/Htr Field cabling and terminination costs from control racks to feedthru ports at vessel.
5) Test and commissioning costs.

COSTS NOT INCLUDED:

1) Control room PCs (2?) computer division

Schedule

Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete
1270-30		Preliminary design	65		*02FEB09**	*01MAY09*	***244***	46,618.64
1270-40		PDR	0			*01MAY09*	***244***	0.00
1270-50		Final Design	65		*04MAY09*	*04AUG09*	***244***	46,618.64
1270-60		FDR	0			*04AUG09*	***244***	0.00
1270-70		Procure Hardware	130		*01MAR10**	*31AUG10*	***107***	348,434.48
1270-80		Fabrication	130		*01SEP10*	*14MAR11*	***107***	72,225.29
1270-90		Installation	65	2	*15MAR11*	*14JUN11*	***107***	127,753.12



Staffing – Resources to be assigned by PPPL

Cost Estimate Risks

Uncertainty of the Estimate

Design Maturity **Medium**

Design Complexity **Low**

The design is straight forward, and uses industry standard components but is a conceptual design at this point.

Risk Mitigation

MDL built a prototype of the Heater and TC controller system (driver and feedback control) and installed it as a furnace controller, with good results.