

**NCSX Heater Control System**

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

**P. L. Goranson**

**Work package 1270**

**Outline**

**Updated 10/25/07 R. Gernhardt**

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* 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**

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**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**

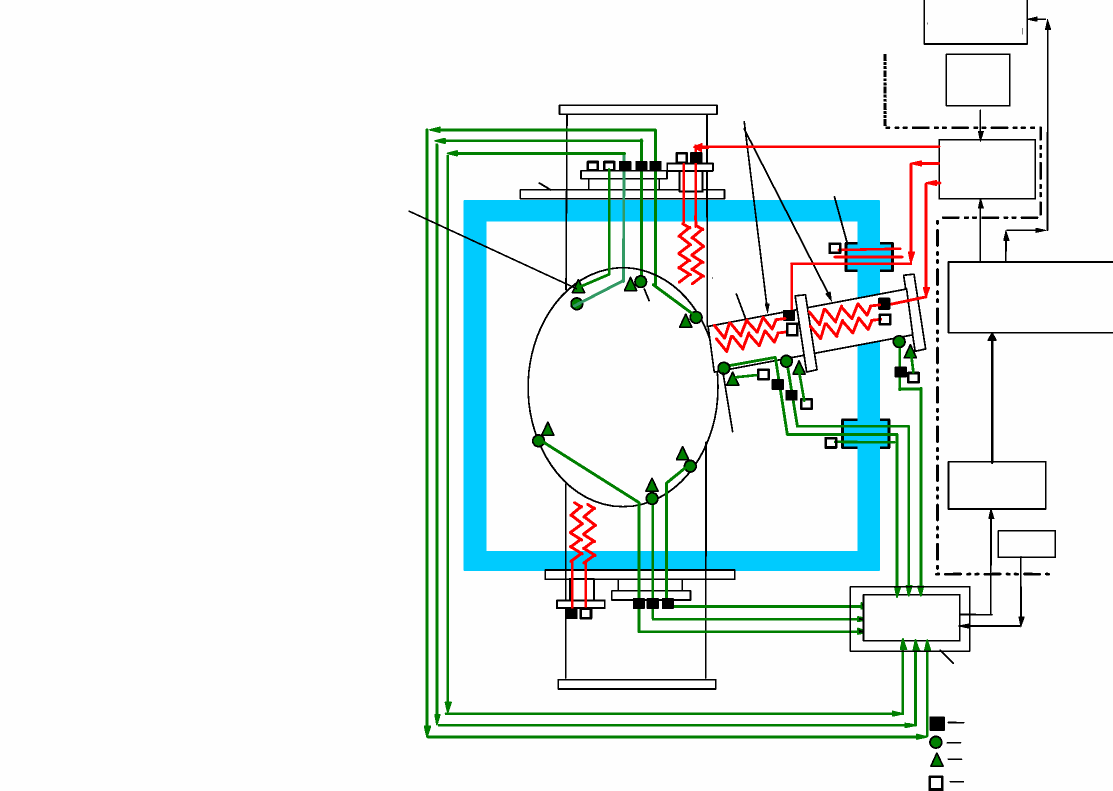
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* **Monitor the VV temperature during standby and bake out operation.**
* **Operation range - room temperature to 375 C**
* **The leads must be insulated from all structure including VV and Cryostat.**
* **The signal conditioners must be the isolated 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**





Coolant

Tube System

**VERTICAL PORT**

WBS 12
  
Interface

Heater Current Controllers

Heater Tape

Port Thermocouple

Power

CRYOSTAT BOUNDARY

Signal Conditioner

Electrical Isolation

Connectors Thermocouples

Connector not hooked up

**Interface Block Diagram:**

Diagnostic Flange (WBS 12)

CRYOSTAT BOUNDARY

VV Body Thermocouple

**VACUUM VESSEL**

**Typical Inner and Outer Port Extension**

Feedthrough (WBS 7)

WBS 12 Interface

Temperature
  
Monitor

Process/Temperature Programmable Controller

Heater
  
Power
  
Supply

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| **VACUUM VESSEL TEMPERATURE CONTROL** | **plg 4/08/05** |
|  |  |

* **Provides for:**

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– **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.**

* **PLC based temperature control of heaters:**

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– 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.

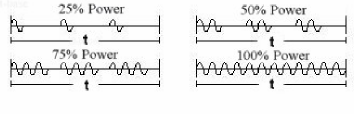


* **Heater 120VAC control:**

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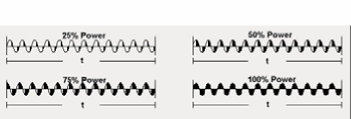
– Zero crossing Time Pulsed Output (TPO) solid state relay supplies variable 120VAC pulse train to heater.

– 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:**

|  |  |  |
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– **Ref: NCSX-PRL-1 2-003-00**

* **Type-E, Isolated, electrically floating junction Type-E, Isolated, electrically floating junction.**

– **Similar to type Omega XCIB-E-4-3-1 0.**

* **Heaters:** – **Manufacture: BriskHeat**
* **BIH series tapes are constant resistance type.**

– ***Custom BIH Style Heating Tape:* 1/2” 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:* 1/2” 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**



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| **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 editi | 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**

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Wire: #2 awg $600

#4 awg $180

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

#10 awg $1000

2/0 $250

#6 & #8 awg $140

Multi-conductor shielded (1 000ft.), 1 05c 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

**Instrumentation and Control- Labor Estimate**

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| **FABRICATION** | | | eng | dsn | sr lab |  | tech |  |
| **Prototype** R Gern hardt | | |  |  |  |  |  |  |
| 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  5 |  |  |  |  |
| Commission I&C interface, test ----R.Gernhardt/ J.Dong | | |  | 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 |

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| **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 |  | 5  1  5 |  |  |  |  |  |
| 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 | | |  | 10 |  |  |
| Select/Evaluate Control software packages | | |  | 1 |  |  |
| CI&C interface development | | |  | 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 |
|  |  |  |  |  |  |  |  |  |  |



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



**NCSX RESISTANCE HEATING TEMPERATURE CONTROL SYSTEM**

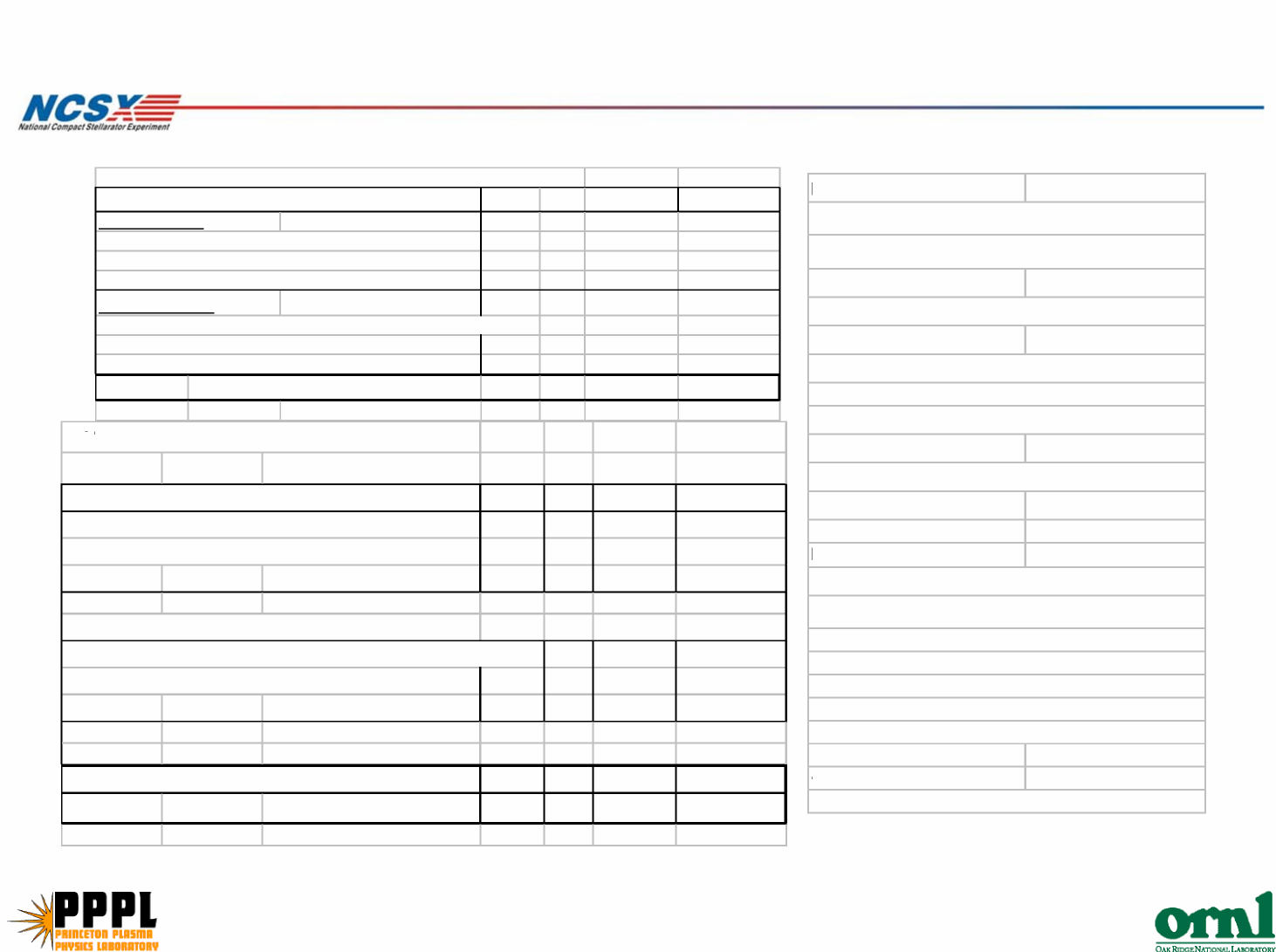
**AC Power, Field/Rack/Tray Wire- F.Jones--- 10/24/07**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Task Man days | | | | | | |  | |  |
| **DESIGN** | | | eng |  | dsn | sr lab |  | tech |  |
| **Design/drafting & supervision- F.Jones** | | |  |  | 4  4  3 1 1 1  1  3  4  4  3  3  2 |  |  |  |  |
| Machine elevation & tray details | |  |  |  |  |  |
| Tray support fabrication detail | |  |  |  |  |  |
| Rack internal layout details | |  |  |  |  |  |  |  |
| Existing Panel draw rev. | |  |  |  |  |  |
| New panel schedule dwg. | |  |  |  |  |  |
| Shutdown dwg | |  |  |  |  |  |  |  |
| AC power CWD for panel/xfmr | |  |  |  |  |  |
| 5 rack ac power CWDs | |  |  |  |  |  |
| Heater power from rack to connector | | |  |  |  |  |  |  |
| Wiring diagrams & termination details | | |  |  |  |  |
| Thermocouple wiring from rack to | | |  |  |  |  |
| Machine and termination details | |  |  |  |  |  |  |  |
| Tray test cell plan drawing | |  |  |  |  |  |
| JHA, procedure, ECN, work order | | |  |  |  |  |
| Package issue and field walk down | | |  |  |  |  |
|  | | |  |  |  |  |
|  |  | **Design Man Days** |  | **0** | **34** |  | **0** |  | **0** |
|  |  |  |  |  |  |  |  |  |  |
| **PROCUREMENT** eng | | | |  | dsn | sr lab |  | tech |  |
| **AC Power** F.Jones/tech shop | | |  |  | 1  1  1 |  |  |  |  |
| Order Breakers, Panels, Pwr cable, field cables, x-formers | | |  |  |  |  |
| **Tray/Conduit** | | F.Jones/tech shop |  |  |  |  |
| Order tray/ conduit | |  |  |  |  |  |
| **Material research** | | F.Jones |  |  |  |  |  |  |
|  | |  |  |  |  |  |
|  |  | **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** | | | |  | 5 |  |  |  |  |
| 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 tray12 | | |  |  |  |  |  | 12 |
| Install/terminate thermocouple extension | | |  |  |  |  |  |  |
| Wire from rack to machine | | |  |  |  |  |  | 24 |
| Revision/Construction Supervision | | |  |  |  |  |  |  |
|  |  |  |  | **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 |



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power in central I&C.

**ESTIMATE INCLUDES:**

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**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** | | | | |
|  |  | | |  |
| **TAL LABOR ESTIMATE** |  |  |  | |
|  |  |  |  | |

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

**TO**

**ESTIMATE BASED ON:**

1. PLC feedback control system to

maintain port temperatures during stanby

and bakeout operations.

1. 120 zones of ACTIVE heater

temperature control.

1. 282 thermocouple channels available for

monitoring and feedback control of

vacuum vessel and port extension

temperatures.

1. Archival of TC temperatures and heater
2. AC power labor and M&S costs.
3. PLC programming and M&S costs
4. Rack installations and wiring cost
5. Includes TC/Htr Field cabling and

terminination costs from control racks

to feedthru ports at vessel.

1. Test and commissioning costs.

**COSTS NOT INCLUDED:**

1) Control room PCs (2?) computer division

**Schedule**



**Staffing – Resources to be assigned by PPPL**

|  |  |  |
| --- | --- | --- |
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**Cost Estimate Risks**

**Uncertainty of the Estimate Design Maturity Medium Design Complexity Low**

|  |  |  |
| --- | --- | --- |
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**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.**