Spallation Neutron Source
Interface Control Document

1.5.5 Ring Vacuum System
and
1.9.5 Ring Controls

105000000-IC0003-R00
February 2002

Approvals

	1.5.5 Ring Vacuum System	1.9.5 Ring Control System
Originators:	Loralie Smart, Engineer	Johnny Tang, Application Architect
Group Leaders:	H.C. Hseuh	John Smith

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Ring and Transport Line Vacuum System
and
Integrated Control System.

Prepared by
L. A. Smart, J. Y. Tang
Brookhaven National Laboratory
SNS Project

UT-Battelle, LLC
managing
Spallation Neutron Source activities at

Argonne National Laboratory
Thomas Jefferson National Accelerator Facility
Los Alamos National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley National Laboratory
Oak Ridge National Laboratory

under contract DE-AC05-00OR22725
for the
U.S. Department of Energy

CONTENTS

1. Scope

This document provides the interface requirements between the Vacuum System devices and the Integrated Control System (ICS) for the SNS Ring and Transport lines.

This document is intended to be a guideline for the design of SNS Ring and Transport line vacuum control systems.

This document may be modified as a change request to the control system. Proposed changes require Vacuum System and ICS review and approval.

2. Vacuum Requirements

The successful operation of SNS is dependent upon the reliable operation of the accelerator Vacuum System in the high and ultra-high vacuum range under high-intensity beam operating conditions.

Associated with the vacuum pressure levels are the availability and reliability requirements of the vacuum subsystems and their components. The required vacuum levels are summarized in Table 1.

Table 1. Vacuum System Pressures.

Subsystem	Pressure
HEBT	$\leq 5 \times 10^{-8}$ Torr
Ring	$\leq 1 \times 10^{-8}$ Torr
RTBT	$\leq 1 \times 10^{-7}$ Torr

3. Vacuum System Devices

All Vacuum System devices shall be operated via intelligent controllers where applicable. Vacuum devices include valves, gauges, ion pumps, turbomolecular pumps, and residual gas analyzers.

The Vacuum System shall provide ICS with the manufacturer and model number of each vacuum device, as they are determined. The manufacturer, model number, and part numbers for defined vacuum system device hardware can be found in Appendix A. The Vacuum System shall also provide remote serial communication protocols when available. Refer to the manufacturer’s operation manuals for specific protocol information.

The Vacuum System devices shall be named in accordance with the SNS SRD for Equipment, Device, and Signal Naming. Name examples are given in Appendix B.

The Vacuum System shall be responsible for specifying, purchasing, installing, and terminating all wiring from the vacuum devices to the device controllers, and the wiring from the device controllers to the lowest-level ICS interface(s).

ICS and Vacuum Control inputs and outputs are listed for each vacuum device. The ICS Controls are inputs and outputs of the high-level software applications written by the ICS used to remotely monitor the vacuum systems. The Vacuum Controls are inputs and outputs of the low-level vacuum software written by the Vacuum system.

3.1. Valves

There are two principle types of valves, sector gate valves (SGVs) and pump isolation valves (PIVs). All valves shall have +24 Vdc solenoids, and have both open and closed limit switch-type indicators. Each valve shall have the ICS controls listed in Table2. Each valve shall have the Vacuum Control connections listed in Table 3.

Table 2. Valve ICS Controls.

Valve Parameter	ICS Control
Open/Close Valve	Output
Reset Latched Fault	Output
Valve Open Indicator	Input
Valve Closed Indicator	Input

Table 3. Valve Vacuum Controls.

Valve Parameter	Vacuum Control
Open Limit Switch	Input
Closed Limit Switch	Input
Valve Solenoid	Output

3.2. Ion Pumps

Ion pumps (IPs) maintain high vacuum in the accumulator ring and transport lines. Typical ion pump controllers operate two ion pumps simultaneously and independently. RS-485 remote serial communication shall be used to obtain status, pump current, pressure, and voltage readings. Refer to the ion pump controller manual for RS-485 protocol information. The VME 485 interface shall be used.

The IPs shall be used for vacuum systems monitoring and shall have the ICS controls listed in Table 4. Each ion pump controller (IPC) shall have the Vacuum Control connections shown in Table 5. The allowable IPC set point lower limit shall be 1×10^{-8} Torr. The upper limit shall be 1×10^{-5} Torr.

Table 4. Ion Pump Controller ICS Controls.

Ion Pump Controller Parameter	ICS Control	Units
HV On/Off	Output	
HV On/Off Status	Input	
Start/Protect Mode Status	Input	
Set-point On/Off Status	Input	Torr
Set-point Level Reading	Input	Torr
Pump Pressure Reading	Input	Torr
Pump Current Reading	Input	Amperes
Pump Voltage Reading	Input	Volts

Table 5. Ion Pump Controller Vacuum Controls.

Ion Pump Controller Parameter	Vacuum Control
Serial Data	Serial Network
HV1 Set Point 1 Status	Input
HV1 Set Point 2 Status	Input

3.3. Gauges

3.3.1. Thermal Conductivity Gauges

The low vacuum levels within the accelerator, 1000 to 10^{-4} Torr, shall be measured using a convection-enhanced Pirani-type thermal conductivity gauge (TCG). The TCGs shall be used for vacuum system monitoring and interlocks. Each TCG shall have the controls listed in Table 6.

Table 6. TCG ICS Controls.

TCG Parameter	ICS Control	Units
Set Trip Point Level	Output	Torr
Pressure Reading	Input	Torr
Set Point Level Reading	Input	Torr
Set Point On/Off Status	Input	

3.3.2. Cold Cathode Gauges

The high vacuum levels within the accelerator, 10^{-3} to 10^{-10} Torr, shall be measured using a cold cathode gauge (CCG). The CCGs shall be used for vacuum system monitoring and interlocks. Each CCG shall have the controls listed in Table 7.

Table 7. CCG ICS Controls.

CCG Parameter	ICS Control	Units
High Voltage On/Off	Output	
Set Trip Point Level	Output	Torr
Pressure Reading	Input	Torr
Set Point Level Reading	Input	Torr
Set Point On/Off Status	Input	

3.3.3. Gauge Controllers

The same gauge controller shall control CCGs and TCGs. Remote serial communication using RS-485 shall be used to read gauge pressures. Refer to the gauge controller manual for RS-485 protocol information. Each gauge controller shall have the Vacuum Control connections listed in Table 8. The upper and lower set point limits for the gauges shall be the maximum range allowed by the gauge controller until limits have been determined by operations. The allowable limits are shown in Table 9.

Table 8. Gauge Controller Vacuum Controls.

Gauge Controller Parameter	Vacuum Control
Serial Data	Serial Network
CCG1 Set Point	Input
CCG2 Set Point	Input
TCG1 Set Point	Input
TCG2 Set Point	Input

Table 9. Gauge Controller Relay Set Point Limits.

Gauge Set Point	Lower Limit	Upper Limit
CCG1	2.0×10^{-10}	9.5×10^{-3}
CCG2	2.0×10^{-10}	9.5×10^{-3}
TCG1	2.0×10^{-3}	$9.5 \times 10^{+2}$
TCG2	2.0×10^{-3}	$9.5 \times 10^{+2}$

3.4. Residual Gas Analyzer

Partial pressure levels within the accelerator shall be measured using a Residual Gas Analyzer (RGA). The RGA shall be used to characterize the residual gases in the vacuum to aid in determining the gas source such as a water leak or component outgassing. The Faraday cup type RGA shall be capable of measuring partial pressures between 10^{-4} and 10^{-11} Torr. The controls for RGAs may include the parameters shown in Table 10. An RS-485 interface is planned for the RGAs.

Table 10. RGA ICS Controls.

RGA Parameter	ICS Control	Units
RGA OnLine/OffLine	Output	On/Off
Emission On/Off	Output	On/Off
Scan Mode Select	Output	Analog/Table/Leak
Start/Stop Scan	Output	Start/Stop
Partial Pressure Readings*	Input	Torr
Total Pressure Reading	Input	Torr

*The number of partial pressure readings depends on the Scan Mode.

3.5. Turbomolecular Pump Station

The turbomolecular pump station (TMPS) is used to pump the beam line from atmospheric pressure to high vacuum, or to maintain vacuum in case of a leak. Remote operation of the TMPS shall be accomplished through PLC control of analog inputs and discrete inputs and outputs. Detailed interface requirements have not been determined. Potential TMPS controlled parameters are listed in Table 11.

Table 11. TMPS ICS Controls.

TMPS Parameter	ICS Control
TMPS OnLine/OffLine	Output
Mechanical Pump On/Off	Output
Mechanical Pump Status	Input
Turbo Pump On/Off	Output
Turbo Pump Status	Input
Foreline Valve Open/Close	Output
Foreline Valve Status	Input
PIV Open/Close	Output
PIV Status	Input
Turbo CCG HV On/Off	Output
Turbo CCG Pressure Reading - Analog	Input
Turbo TCG Pressure Reading - Analog	Input
Auxiliary CCG Pressure Reading	Input

4. Vacuum Controls

A programmable logic controller (PLC) shall be used to monitor gauge and pump interlocks and control valves. The primary function of the PLC is to provide control of the sector gate valves (SGVs) that sectionalize the vacuum systems. The valve control logic shall be designed to be fail-safe. A sector valve will close in case of a) vacuum conditions deteriorating to a specified limit, b) power loss, and c) operator input from the support building or remote terminal. The vacuum PLCs shall provide interlock outputs to subsystems (e.g., RF System) and receive interlock inputs from subsystems such as Target System. The preliminary sector valve interlocks for the HEBT, Ring, and RTBT lines are shown in Appendix C.

The control of the HEBT, Ring, and RTBT vacuum systems shall be implemented using a network of PLCs. Four PLCs are planned, based on the vacuum device distribution: one each for the HEBT and RTBT subsystems, and two for the Ring subsystem. All vacuum system interlocks shall use 24 Vdc control power. The approximate number of vacuum devices to be controlled and the associated PLC input and output (I/O) points for SNS HEBT, RING and RTBT are summarized in Tables 12 and 13. TMPS inputs and outputs are not included at this time. Each PLC shall monitor up to six (6) 16-point input modules and control at least one 16-point output module.

Table 12. Distribution of PLC Inputs

PLC	SGV Inputs	CCG Inputs	TCG Inputs	IP Inputs	Other Inputs	Total Inputs
HEBT_Vac:PLC	8	12	8	8	8	44
Ring_Vac:PLC_a	16	16	16	32	8	88
Ring_Vac:PLC_b	12	12	12	24	8	68
RTBT_Vac:PLC	8	12	12	10	8	50

Table 13. Distribution of PLC Outputs

PLC	SGV Outputs	Other Outputs	Total Outputs
HEBT_Vac:PLC	4	4	8
Ring_Vac:PLC_a	8	4	12
Ring_Vac:PLC_b	6	4	10
RTBT_Vac:PLC	4	4	8

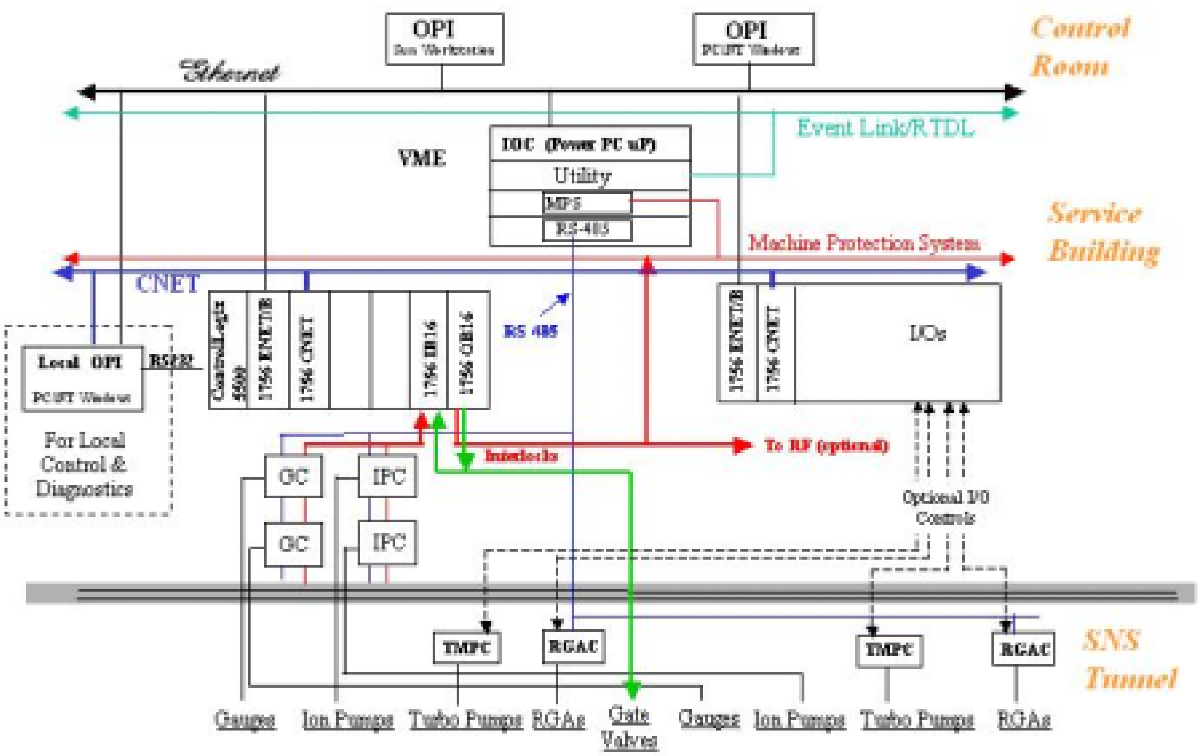
The PLC shall be an Allen-Bradley ControlLogix 5500 or equivalent. The input signals shall be 24 Vdc. The PLC input module shall have isolated inputs rated for 24 Vdc rated at 50 mA minimum. The PLC chassis shall have ten (10) slots. The output signals to the valve solenoids shall be 24 Vdc. The PLC output modules shall have isolated output contacts rated at 200 mA minimum. The PLC ladder logic programs shall be developed by the Vacuum System. The Vacuum System shall be responsible for specifying, purchasing, installing, and terminating all wiring between the PLC and vacuum devices and controllers.

5. Global Control Interfaces

The vacuum system controls architecture is illustrated in Figure 1. The Input/Output Controller (IOC) provides the gateway between the global control system and vacuum instrumentation system. All information for machine operators shall be provided by the IOCs. The IOC shall host the RS-485 serial communication networks

Four IOCs are planned, one each for HEBT and RTBT, and two for Ring vacuum systems. There shall be one IOC and VME chassis per PLC installed. The IOC shall reside in a VME chassis installed in the same rack as the PLC. See Appendix D for the HEBT PLC rack layout. The PLC shall communicate with the IOC through an EtherNet/IP or ControlNet interface. The IOC software and operator screens shall be developed by the ICS. The ICS shall specify, purchase, install, and terminate the Ethernet network or ControlNet network cables. The ICS shall specify, purchase, and install the VME serial interface modules.

Figure 1. Vacuum Systems Control Architecture

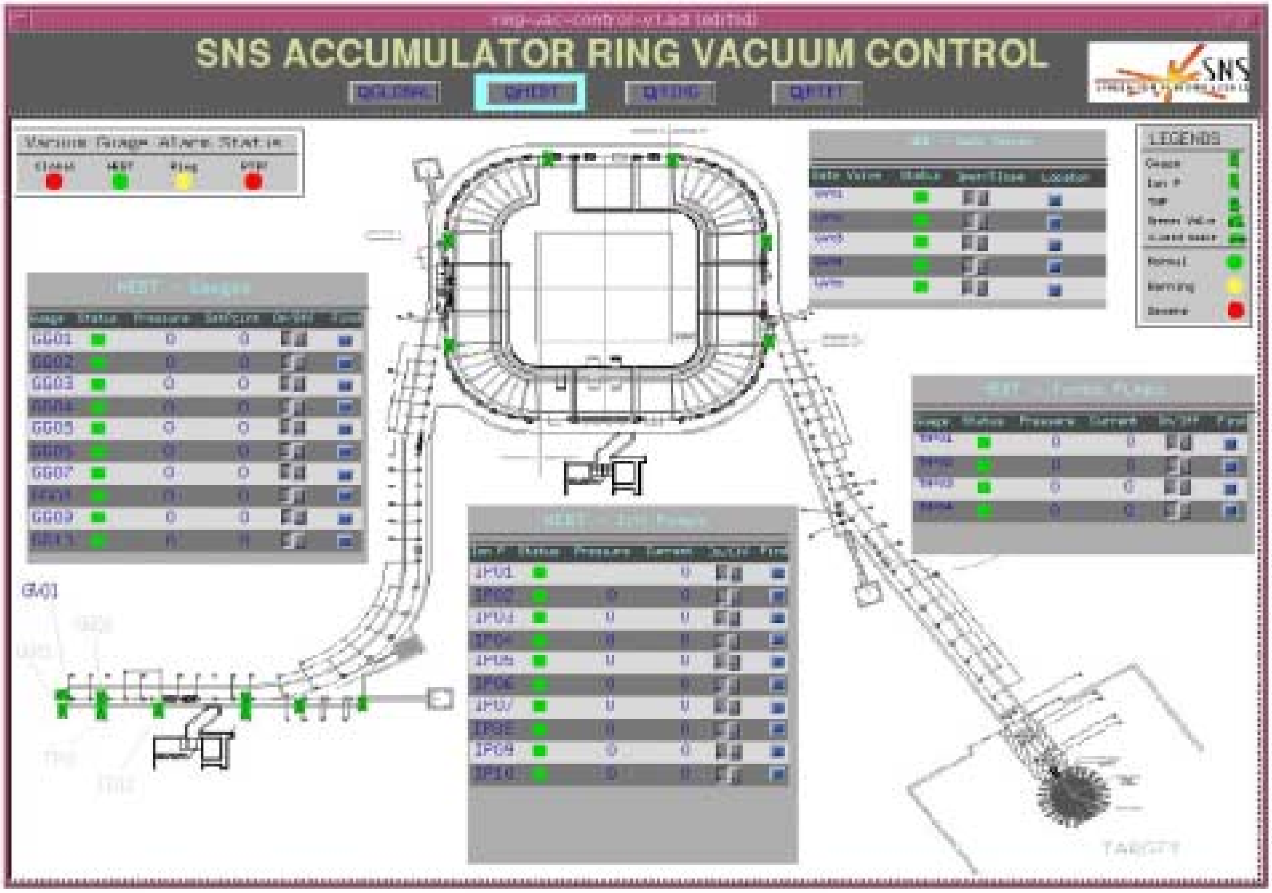


5.1. Operator Interfaces

The Experimental Physics and Industrial Control System (EPICS) shall be used to provide the graphical user interface for operation of the vacuum systems via the IOC. Colors in the graphical user interface shall be used in accordance with the SNS Global Control System EPICS Color Usage Standard.

An EPICS display manager shall be used for monitoring and controlling vacuum devices. A typical graphic operator interface (OPI) screen for SNS vacuum controls is shown in Figure 2. The display manager shall be able to run on Unix and NT platforms.

Figure 2. Graphical Operator Interface Screen



The Vacuum System display shall be updated in five (5) to thirty (30) seconds. The update rate will depend upon device response time and subsystem requirements. Beam vacuum gauge readings may be updated more frequently than ion pump readings.

The ICS shall provide data logging applications. Readings from collections of vacuum devices will be logged at intervals ranging from ten (10) seconds to one (1) hour. The ICS shall provide tools to create, edit, and save logging files. The ICS shall provide applications to view archived and current logged data.

5.2. Machine Protection System interface

The Vacuum Systems PLC shall generate the Machine Protection System (MPS) Beam Permit signals for the defined Machine modes. The MPS Vacuum Interface Requirements are specified in {Document Number}. Details of the MPS to Vacuum System interface are to be determined.

Appendix A. Vacuum System Device Hardware

Device	Manufacturer	Model	Part Number
Sector Valve - HEBT	VAT		10844CE44, 10846CE44, 48144CE74, 77144CE44
Sector Valve - Ring	VAT		48146-CE74
Sector Valve - RTBT	VAT		48146-CE74, 10844CE44, 77144-CE44
Gauge Controller	MKS Instruments, HPS Division	Series 937	937A-120V60TR-CCCCCT48509
Ion Pump Controller	Varian Vacuum Products	DUAL	929-7011-S004
Residual Gas Analyzer	TBD	TBD	TBD
Turbomolecular Pump Cart	TBD	TBD	TBD

Appendix B. Ring and Transport Line Vacuum Device Name Examples

The examples below follow the naming convention specified in the SRD for Equipment, Device, and Signal Naming (SNS 102000000-SR0001-R00).

Subsystem	Instance Numbering	Descriptive Device Location
HEBT	HEBT_Vac:SGV_10	Sector valve nearest quadrupole QH10.
HEBT	HEBT_Vac:IP_10	Ion Pump nearest quadrupole QH10.
Ring	RING_Vac:CCG_A4	Cold Cathode Gauge nearest quadrupole QHA4, in superperiod A.
Ring	RING_Vac:IP_C11b	Second Ion Pump nearest quadrupole QVC11 in superperiod C.
RTBT	RTBT_Vac:TCG_02	Thermal Conductivity Gauge nearest quadrupole QH2.

Appendix C. SNS HEBT, Ring and RTBT Gate Valve Interlock Assignments

	U/S TCG Signal	U/S Signal			Gate Valve	D/S Signal			D/S TCG Signal
	HEBT_Vac:TCG_13	HEBT_Vac:IP_13	HEBT_Vac:CCG_13	HEBT_Vac:CCG_18	LDmp_Vac:SGV_1	LDmp_Vac:CCG_1	LDmp_Vac:CCG_4	LDmp_Vac:IP_4	LDmp_Vac:TCG_1
HEBT	HEBT_Vac:TCG_1			HEBT_Vac:CCG_1	HEBT_Vac:SGV_1	HEBT_Vac:CCG_2	HEBT_Vac:CCG_8	HEBT_Vac:IP_4	HEBT_Vac:TCG_2
PLC	HEBT_Vac:TCG_8	HEBT_Vac:IP_8	HEBT_Vac:CCG_2	HEBT_Vac:CCG_8	HEBT_Vac:SGV_10	HEBT_Vac:CCG_13	HEBT_Vac:CCG_18	HEBT_Vac:IP_13	HEBT_Vac:TCG_13
	HEBT_Vac:TCG_18	HEBT_Vac:IP_18	HEBT_Vac:CCG_13	HEBT_Vac:CCG_18	HEBT_Vac:SGV_19	HBET_Vac:CCG_20	HEBT_Vac:IP_20	HEBT_Vac:IP_22	HEBT_Vac:TCG_20
	---------ground break between Q24 & Q25-----------------								
	HEBT_Vac:TCG_27	HEBT_Vac:IP_25	HEBT_Vac:IP_32	HEBT_Vac:CCG_27	HEBT_Vac:SGV_32	Ring_Vac:CCG_A10	IDmp_Vac:CCG_1	Ring_Vac:IP_A10A	Ring_Vac:TCG_A10
Ring					IDmp_Vac:FV_xx				
PLC1	IDmp_Vac:TCG_1	IDmp_Vac:IP_1	IDmp_Vac:CCG_1	Ring_Vac:CCG_A10	IDmp_Vac:SGV_1	IDmp_Vac:CCG_2		IDmp_Vac:IP_2	IDmp_Vac:TCG_2
	Ring_Vac:TCG_D13	Ring_Vac:IP_D12	Ring_Vac:CCG_D13	Ring_Vac:CCG_D11	Ring_Vac:SGV_A1	Ring_Vac:CCG_A2	Ring_Vac:CCG_A8	Ring_Vac:IP_A3	Ring_Vac:TCG_A2
	Ring_Vac:TCG_A8	Ring_Vac:IP_A6	Ring_Vac:CCG_A8	Ring_Vac:CCG_A2	Ring_Vac:SGV_A9	Ring_Vac:CCG_A10	Ring_Vac:CCG_A11A	Ring_Vac:IP_A10A	Ring_Vac:TCG_A10
	Ring_Vac:TCG_A13	Ring_Vac:IP_A13A	Ring_Vac:CCG_A12	Ring_Vac:CCG_A13	Ring_Vac:SGV_B1	Ring_Vac:CCG_B2	Ring_Vac:CCG_B8	Ring_Vac:IP_B3	Ring_Vac:TCG_B2
	Ring_Vac:TCG_B8	Ring_Vac:IP_B6	Ring_Vac:CCG_B8	Ring_Vac:CCG_B2	Ring_Vac:SGV_B9	Ring_Vac:CCG_B10	Ring_Vac:CCG_B12B	Ring_Vac:IP_B11	Ring_Vac:TCG_B10
	--------------ground break between BQ9 & BQ10-----------								
	Ring_Vac:TCG_B12B	Ring_Vac:IP_B13	Ring_Vac:CCG_B12B	Ring_Vac:CCG_B10	Ring_Vac:SGV_C1	Ring_Vac:CCG_C2	Ring_Vac:CCG_C8	Ring_Vac:IP_C3	Ring_Vac:TCG_C2
Ring	Ring_Vac:TCG_C8	Ring_Vac:IP_C6	Ring_Vac:CCG_C8	Ring_Vac:CCG_C2	Ring_Vac:SGV_C9	Ring_Vac:CCG_C10	Ring_Vac:CCG_C11	Ring_Vac:IP_C10C	Ring_Vac:TCG_C10
PLC2	Ring_Vac:TCG_C11	Ring_Vac:IP_C11C	Ring_Vac:CCG_C11	Ring_Vac:CCG_C10	Ring_Vac:SGV_C11	Ring_Vac:CCG_C12	Ring_Vac:CCG_C13	Ring_Vac:IP_C12	Ring_Vac:TCG_C12
	Ring_Vac:TCG_C13	Ring_Vac:IP_C13	Ring_Vac:CCG_C13	Ring_Vac:CCG_C12	Ring_Vac:SGV_D1	Ring_Vac:CCG_D2	Ring_Vac:CCG_D8	Ring_Vac:IP_D3	Ring_Vac:TCG_D2
	Ring_Vac:TCG_D8	Ring_Vac:IP_D6	Ring_Vac:CCG_D8	Ring_Vac:CCG_D2	Ring_Vac:SGV_D9	Ring_Vac:CCG_D11	Ring_Vac:CCG_D13	Ring_Vac:IP_D10A	Ring_Vac:TCG_D11
	RTBT_Vac:TCG_2	RTBT_Vac:IP_2	RTBT_Vac:CCG_2		RTBT_Vac:SGV_3	RTBT_Vac:CCG_4	RTBT_Vac:IP_4	RTBT_Vac:IP_8	RTBT_Vac:TCG_4
	----------ground break between Q11 & Q12---------------------								
	RTBT_Vac:TCG_12	RTBT_Vac:IP_12	RTBT_Vac:CCG_12		RTBT_Vac:SGV_12	RTBT_Vac:CCG_14	RTBT_Vac:CCG_17	RTBT_Vac:IP_14	RTBT_Vac:TCG_14
RTBT	RTBT_Vac:TCG_17	RTBT_Vac:IP_17	RTBT_Vac:CCG_14	RTBT_Vac:CCG_17	RTBT_Vac:SGV_19	RTBT_Vac:CCG_19	RTBT_Vac:CCG_23	RTBT_Vac:IP_21	RTBT_Vac:TCG_19
PLC	RTBT_Vac:TCG_23	RTBT_Vac:IP_23	RTBT_Vac:CCG_19	RTBT_Vac:CCG_23	RTBT_Vac:SGV_24	RTBT_Vac:CCG_25	RTBT_Vac:CCG_27**	RTBT_Vac:IP_25	RTBT_Vac:TCG_25
					RTBT_Vac:FV_24				

Additional Interlock Signals

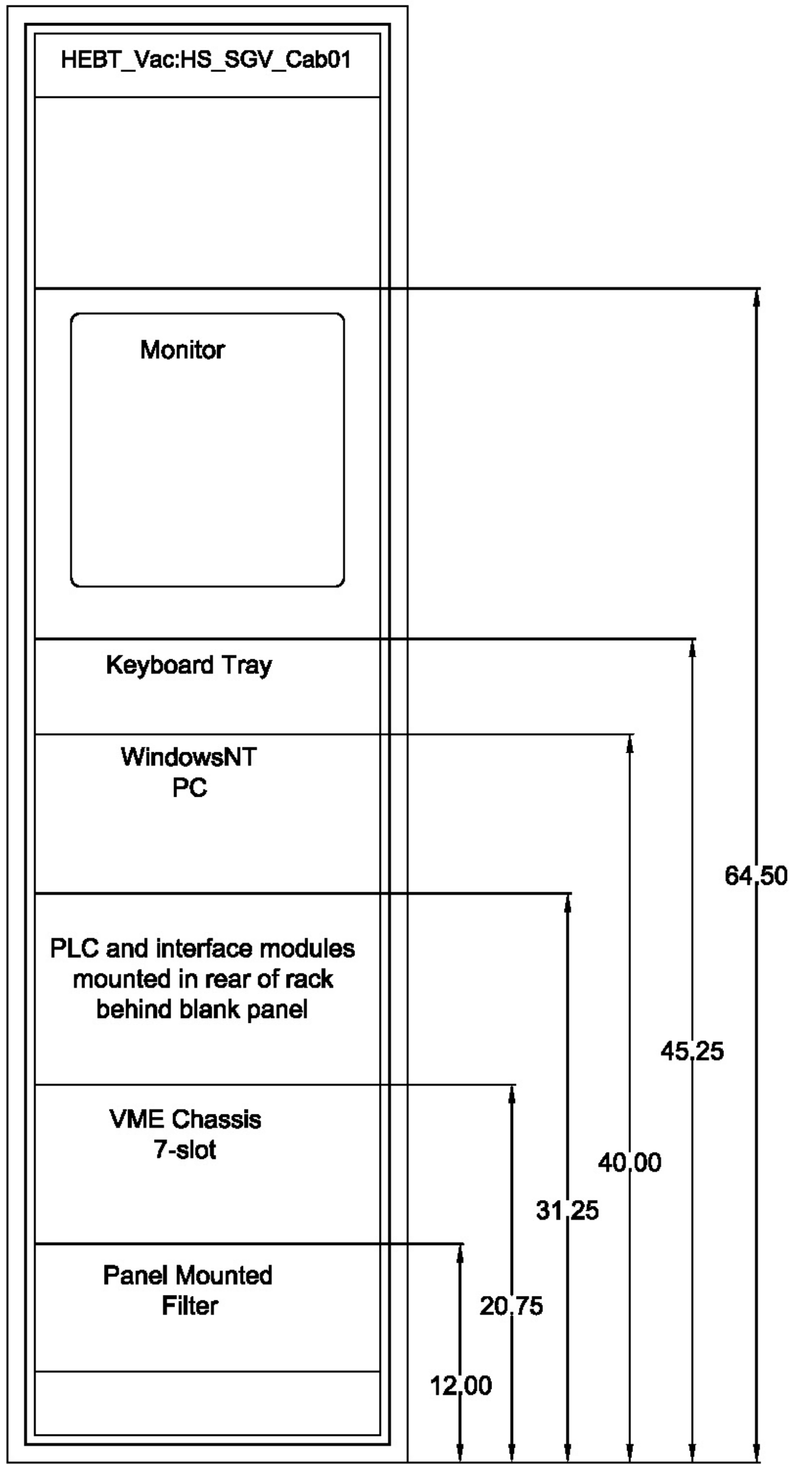
HEBT Vac PLC		**Ring Vac PLC 1**		**Ring Vac PLC 2**		**RTBT Vac PLC**	
To:	From:	To:	From:	To:	From:	To:	From:
SCL_Vac:SGV_?	IDmp_Vac:FV_xx	Ring A&B valves	IDmp_Vac:CCG_2	Ring RF Cavities	Ring_Vac:CCG_D11	Ext. Dump Harp	Edmp_Vac:CCG_1
HEBT_RF:ECC	HEBT_Vac:CCG_10	Ring A&B valves	IDmp_Vac:FV_xx	Ring RF Cavities	Ring_Vac:CCG_D13	All RTBT Valves	RTBT_Vac:FV_24
HEBT_RF:ESC	HBET_Vac:CCG_20	Ring Inj. Kicker_A10	Ring_Vac:CCG_A10	Ring IPM	Ring_Vac:CCG_D11	All RTBT Valves	RTBT_Vac:CCG_25
Inj. dump Harp	IDmp_Vac:CCG_2	Ring Inj. Kicker_A12	Ring_Vac:CCG_A12	Ring Ext. Kicker	Ring_Vac:CCG_C10		
Linac dump Harp	LDmp_Vac:CCG_4			Ring Ext. Kicker	Ring_Vac:CCG_C11		
All HEBT Valves	IDmp_Vac:FV_xx						
All HEBT Valves	IDmp_Vac:CCG_2						

HEBT devices were updated on 1/23/02

Each PLC shall have spare channels of 4 inputs and 8 outputs

HEBT_Vac:SGV_1 to be provided by SCL and may be controllered by SCL PLC

Appendix D. HEBT PLC Rack Layout



Front View

Appendix E. Hardware and Software Item List for SNS Ring Vacuum Control System

ITEM	QTY	NOTES
VME Crate	5	One each for HEBT and RTBT; 2 for Ring and one for development/backup
Ethernet Hub	5	
PPC (IOC)	5	
VIPC616 VME IP carrier	4	
IP-OctalPlus-485	4	One per VME crate
Logix5550 controller	5	One each for HEBT and RTBT; two for Ring; one for development/backup
1756-A10 chassis	5+	If there are more than 8 analog or digital I/O modules, another chassis, power supply and 1756-ENET are needed.
1756-PA72 power supply	5+	One per PLC chassis
1756-ENET	5+	One per PLC chassis
1756-IF16 analog input module	TBD	Each analog input module can be configured for 8 differential inputs
1756-OB16I	TBD	Each module has 16 isolated digital outputs
1756-IB16I	TBD	
IFM for 1756 digital I/O modules	TBD	
Pre-wired cables for digital I/O modules	TBD	
Programming Cable	2	
Ion Pump Controller	40	
Gauge Controller	24+	
PC Workstation	4	One PC workstation each for HEBT, Ring and RTBT; one portable laptop for development; Each should have VMware workstation software installed to support Linux (EPICS client software) and Windows 2000 (PLC ladder logic programming)
RSLogix 5000 programming software	1	
RSView32 software	1	
Redhat Linux		
Windows 2000		

Appendix F. Schedule

Dates	Activities
03/31/01	Preliminary Ring Vacuum ICD.
02/10/02	HEBT/Ring/RTBT Vacuum Controls ICD.
10/30/02	HEBT PLC Vacuum Control System Prototype.
10/30/03	HEBT/Ring PLC Vacuum Control System.
03/31/04	HEBT/Ring/RTBT PLC Vacuum Control System.
06/30/05	Ring Vacuum System Commissioning.
09/30/05	Testing Complete, System Operational.

References

1. SNS 102000000-SR0001-R00 (SRD for Equipment, Device, and Signal Naming).
2. SNS MPS Vacuum Interface Document.
3. SNS Global Control System EPICS Color Usage Standard.