Spallation Neutron Source Interface Control Document

1.5.5 Ring Vacuum System and 1.9.5 Ring Controls

105000000-IC003-R00A

Approval Page

	1.5.5 Ring Vacuum System	1.9.5 Ring Control System
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Spallation Neutron Source
Interface Control Document

Ring and Transport Line Vacuum System
To
Integrated Control System.

Prepared for the
U.S. Department of Energy
Office of Science

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managing
Spallation Neutron Source activities at
Argonne National Laboratory
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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 as follows:

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

3 Vacuum System Devices

All Vacuum System devices shall be operable in a manual mode via their own 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 Vacuum System shall also provide remote serial communication protocols when available.

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 Table1. Each valve shall have the Vacuum Control connections listed in Table 2.

Table 1. Valve ICS Controls.

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

Table 2. 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. Remote serial communication may be used to read pump current, pressure, and voltage. The Allen-Bradley 1756- MVC or VME 485 modules have been approved for use.

The IPs shall be used for vacuum systems monitoring and shall have the ICS controls listed in Table 3. Each ion pump controller shall have the Vacuum Control connections shown in Table 4.

Table 3. Ion Pump Controller ICS Controls.

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

Table 4. 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 Thermal Conductivity Gauges

The low vacuum levels within the accelerator, 1000 to 10^{-4} Torr, shall be measured using a 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 5.

Table 5. TCG ICS Controls.

TCG Parameter	ICS Control
Set Trip Point Level	Output
Pressure Reading	Input
Set Point Level Reading	Input
Set Point Status	Input

3.4 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 6.

Table 6. CCG ICS Controls.

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

The same gauge controller shall control CCGs and TCGs. Remote serial communication using RS-485 or DeviceNet standards may be used to read gauge pressures.

Each gauge controller shall have the Vacuum Control connections listed in Table 7.

Table 7. 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

3.5 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 8. The interface between the RGAs and Vacuum Control system is to be determined.

Table 8. RGA ICS Controls.

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

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

3.6 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 9.

Table 9. 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	Input
Turbo TCG Pressure Reading	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 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 10 and 11. 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 10. Distribution of PLC Inputs

PLC	SGV Inputs	CCG Inputs	TCG Inputs	IP Inputs	Other Inputs	Total Inputs
HEBT_Vac:PLC	8	8	8	12	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 11. 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. Vacuum device controllers may have either serial RS-485 interfaces or DeviceNet interfaces. If the vacuum device controller interface is DeviceNet, the PLC may host the DeviceNet network. If the interface is RS-485, the IOC shall host the serial networks. The function of IOC is described in System Architecture section.

4.1 Valve Interlocks

A vote-to-close scheme shall be implemented in the PLC ladder logic. A sector gate valve shall close if any combination of two (2) out of a possible three (3) adjacent vacuum interlock signals indicate that the vacuum is above the acceptable operating limits. Each valve shall have vote-to-close inputs from upstream (U/S) devices and downstream (D/S) devices. The vacuum interlock signals shall be generated from TCGs, CCGs, and IPs, and shall be 24 Vdc positive voltage applied to the PLC input through relay contacts residing in the gauge and ion pump controllers. The relay contacts shall close, conducting the 24 Vdc to the PLC inputs, when the vacuum system pressure is below a threshold to be determined for each vacuum subsystem. The relay contacts shall open if the pressure is above the threshold and if the controller or 24 Vdc power supply lose input power. The valve will not close if only one relay contact opens. The PLC code shall prevent a sector gate valve from being opened if the threshold of a TCG on either side of the valve is exceeded. This prevents the valve from being opened if the vacuum system on either side of the valve is at atmospheric pressure. The preliminary sector valve interlocks for the HEBT, Ring, and RTBT lines are shown in Appendix C.

The sector gate valve Ring_Vac:SGV_C9 shall not open unless the D/S Ring_Vac:TCG_8 and U/S Ring_Vac:TCG_10 pressure thresholds are satisfied (24 Vdc must be present at the PLC inputs for both devices).

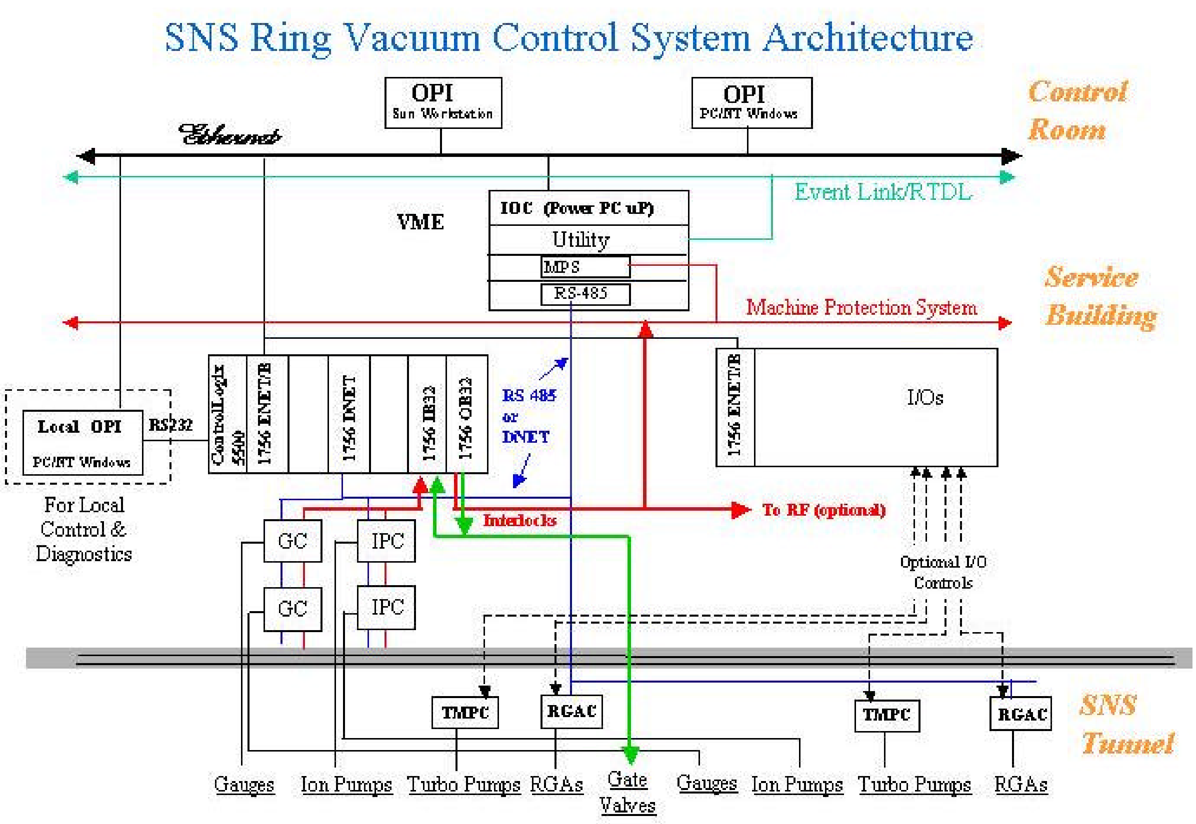
SGV_C9 shall close if: (Ring_Vac:IP_C6 AND Ring_Vac:CCG_C8) OR (Ring_Vac:CCG_C8 AND Ring_Vac:CCG_C2) OR (Ring_Vac:CCG_2C AND Ring_Vac:IP_C6) U/S thresholds are not satisfied. SGV_C9 shall also close if: (Ring_Vac:CCG_C10 AND Ring_Vac:CCG_C11) OR (Ring_Vac:CCG_C11 AND Ring_Vac:IP_C10C) OR (Ring_Vac:IP_C10C AND Ring_Vac:CCG_C10) D/S thresholds are not satisfied.

The valve interlock voting scheme pseudocode may be expressed as:

4.2 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.

Figure 1. Vacuum Systems Control Architecture



Three IOCs are planned, one each for HEBT, RING and RTBT vacuum systems. The IOC software and operator screens shall be developed by the ICS. The IOC shall reside in a VME chassis located in the same support building as the PLC.

The PLC may communicate with the IOC through an EtherNet/IP or ControlNet interface. The IOC may interface directly with vacuum device controllers if the vacuum device controllers use RS-485 serial communication.

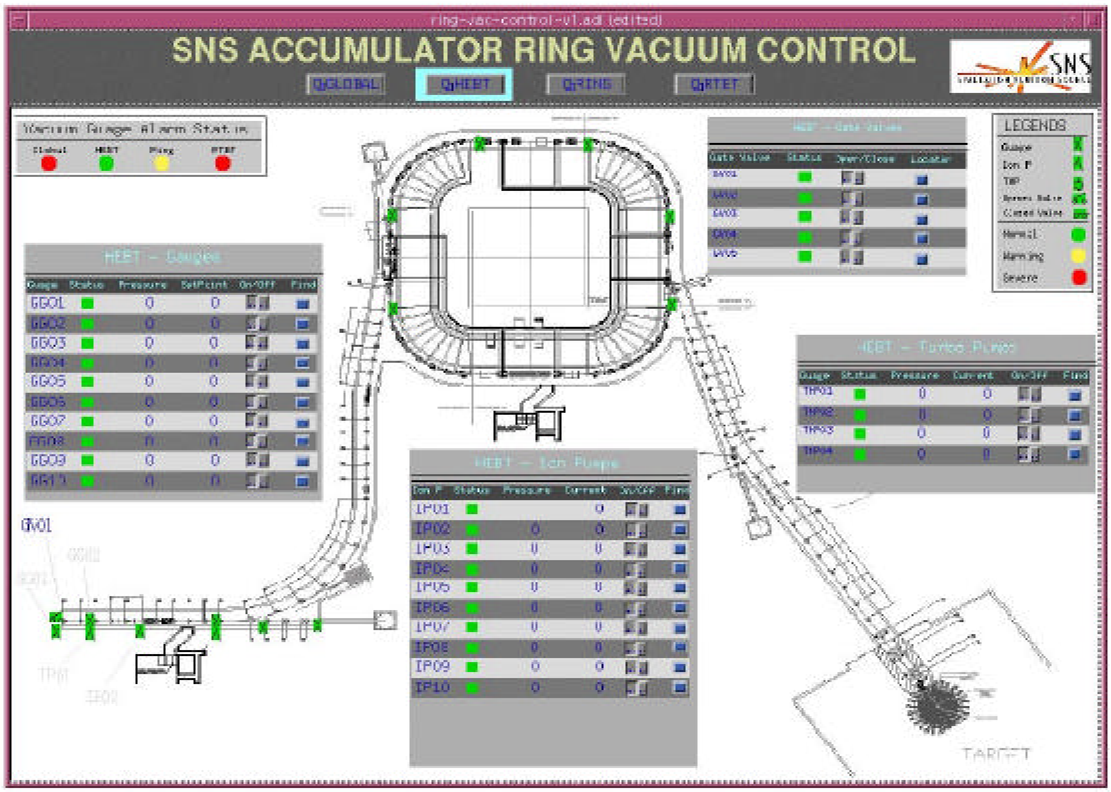
The ICS shall specify, purchase, install, and terminate the Ethernet network or ControlNet network cables. The ICS shall specify, purchase, and install the VME serial interface modules.

4.3 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.

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

Figure 2. Graphical User Interface Screen for Ring Vacuum Control



The Vacuum System display shall be updated in five (5) to 30 (thirty) seconds. The refresh 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.

4.4 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.

5 Schedule

Dates	Activities
03/31/01	Preliminary Ring Vacuum ICD
02/01/01 – 03/31/02	PLC programming standardization and programming
04/01/02 – 03/31/04	Ring Vacuum Control System Design and Implementation
04/01/04 – 06/30/05	Ring Vacuum System Commissioning
09/30/05	Testing Complete, System Operational

6 Appendix A. References

The following documents are referenced:

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.

7 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).

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

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

	U/S TCG Signal	U/S Signal			Gate Valve	D/S Signal			D/S TCG Signal
	HEBT_Vac:TCG_12	HEBT_Vac:IP_12	HEBT_Vac:CCG_12	HEBT_Vac:CCG-16	LDmp_Vac:SGV_1	LDmp_Vac:CCG_2	LDmp_Vac:CCG_4	LDmp_Vac:IP_4	LDmp_Vac:TCG_2
HEBT	HEBT_Vac:TCG_1			HEBT_Vac:CCG_1	HEBT_Vac:SGV_1	HEBT_Vac:CCG_2	HEBT_Vac:CCG_10	HEBT_Vac:IP_5	HEBT_Vac:TCG_2
PLC	HEBT_Vac:TCG_10	HEBT_Vac:IP_10	HEBT_Vac:CCG_2	HEBT_Vac:CCG_10	HBET_Vac:SGV_10	HEBT_Vac:CCG_12	HEBT_Vac:CCG-16	HEBT_Vac:IP_12	HEBT_Vac:TCG_12
	HEBT_Vac:TCG_16	HEBT_Vac:IP_18	HEBT_Vac:CCG_12	HEBT_Vac:CCG-16	HEBT_Vac:SGV_19	HEBT_Vac:CCG_20	HEBT_Vac:IP_20	HEBT_Vac:IP_22	HEBT_Vac:TCG_20
					---------between Q24 & Q25----------------				
	HEBT_Vac:TCG_31	HEBT_Vac:IP_25	HEBT_Vac:IP_32	HEBT_Vac:CCG_31	HEBT_Vac:SGV_32	Ring_Vac:CCG_A10	IDmp_Vac:CCG_1	Ring_Vac:IP_A10A	Ring_Vac:TCG_A10
					IDmp_Vac:FV_xx				
	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	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
PLC1	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
					--------------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
					----------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	HEBT_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						

Each PLC shall have spare channels of 4 Is and 8 Os