THE SNS INSULATING VACUUM DESIGN FOR THE SUPERCONDUCTING LINAC*

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Abstract

The superconducting linac of the Spallation Neutron Source (SNS) has 23 cryomodules each of which incorporate either 3 or 4 niobium cavities. These cavities are submerged in a bath of liquid helium and maintained at an operating temperature of ~ 2K. This bath is surrounded by heat shields and a multilayer blanket within the cryomodule shell. The pressure in this area needs to be maintained at <5e-5 torr to limit heat leak due to gas convection. Some cryomodules have developed helium leaks into this vacuum cavity and now need to be actively pumped. This paper provides an overview of the Insulating Vacuum System (IVS) that has been installed for this purpose.

INTRODUCTION

The initial design of the SNS cryomodules did not require any active pumping around the multilayer blanket area or insulating vacuum area. The insulating vacuum is monitored using a cold cathode gauges (CCG) and thermal couple gauges (TC) that connect to a MKS Instrument Series 937A controller [4]. During the commissioning and startup phase of the SNS accelerator some cryo cavities developed helium leaks. Portable turbo pump carts were used to actively pump on these leaking cavities to maintain pressure <1e-4 torr. These portable pump carts are stand alone and do not have any control or monitoring interface with the SNS Control System. If one of these turbo pump carts has a failure, beam operation must be stopped to make a tunnel entry to allow a cryo operator to replace the cart or attempt to restart the turbo manually.

SNS rapidly designed and developed a new insulating vacuum pumping station that is fully controlled and monitored through EPICS. This integrated pump station now allows the cryo operator to monitor and control all components from the control room without interrupting beam operation and has increased machine reliability.

CONTROL HARDWARE DESIGN

The IVS will require four vacuum racks (see figure 1) to service all 23 cryomodules. Each vacuum rack uses an Allen-Bradley ControlLogix5000 Programmable Logic Controller (PLC) [5] to control two pumping stations. Each pump station provides pumping to 4 cryomodules for a total of 8 cryomodules per rack. The PLC provides all interlocks and control for turbo pump stations and gate valves. The PLC uses EtherNet/IP [2] to communicate to the EPICS Input/Output Controller (IOC) and Linux workstation provides the operator's interface.

CONTROL SOFTWARE IMPLEMENATION

Two "SOFT" IOCs are in service. Soft IOC runs with the EPICS IOC shell on a Linux server [8]. A process manager, ProcServ, developed at SNS to manage the soft IOC. Engineers can easily connect, control, monitor and restart the soft IOC. The IOC health information, like heartbeat, reboot time, etc., can be monitored as well.

Serial to Network Solution

To reduce the number of PLC I/O connections, a Digi PortServer [6] is used to interface with the MKS Series 937A controller's serial communication card. The Digi provides a RS-232 serial to Ethernet connectivity to allow full read and write capability for the vacuum gauges. Commands to turn CCGs high voltage on/off, change setpoints and to monitor pressures are accomplished through the Digi PortServer using asyn/StreamDevice solution [9][1].

Figure 1 - IVS Control Rack

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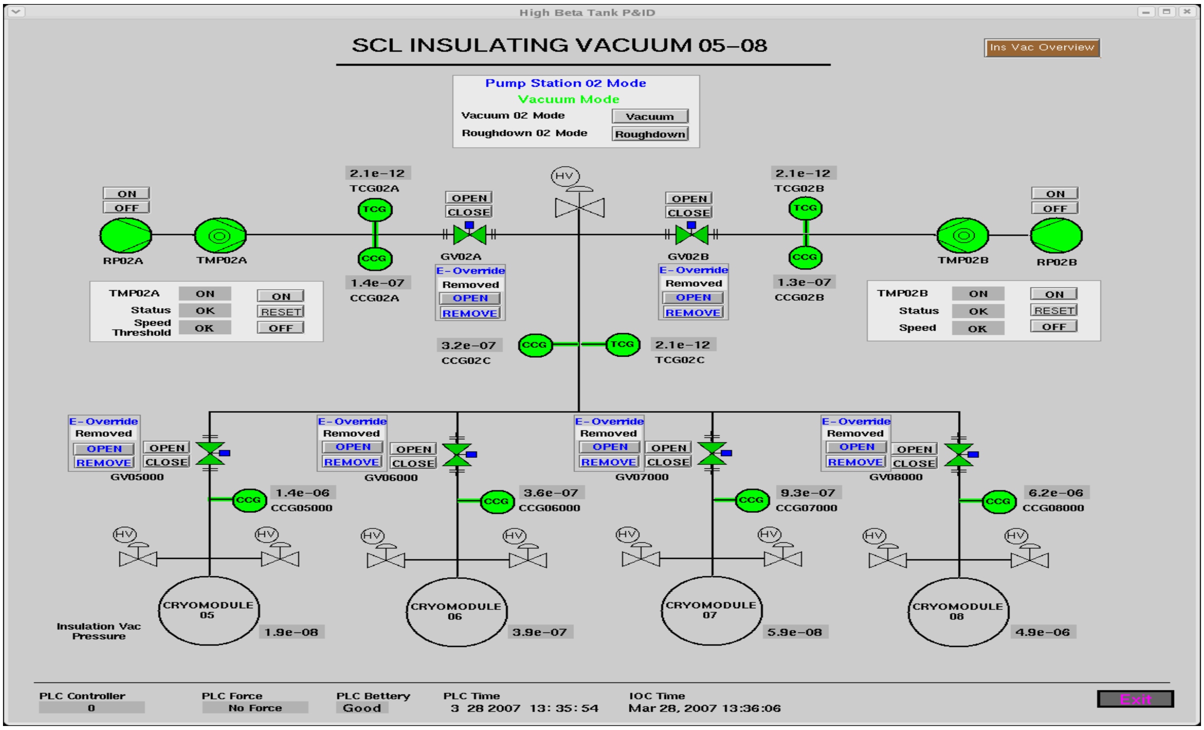

Figure 2 - IVS Control Screen for Cryomodules 5-8

CONTROL LOGIC

The EPICS control screen for each pump station is designed to allow an operator to monitor status and control every component from one location (see figure 2). This gives the operator a better view of the overall performance of the vacuum system and allows quicker response to change pumping configuration, than using multiple screens.

Modes of Operation

The IVS has two modes of operations, roughdown mode and vacuum mode. The roughdown mode is used to initially pump down the main manifold and gives the operator more flexibility over interlocks to open main manifold valves. The cryo isolation gate valves are disabled in roughdown mode to prevent an operator from inadvertently opening under poor vacuum conditions.

The once the main manifold has achieved < 1e-5 torr, the operator changes to vacuum mode. Vacuum mode will allow the opening of cryo isolation valves to modules that would require active pumping if the manifold pressure is lower than the cryo insulating vacuum. If multiple cryo modules are being actively pumped and one module develops a leak > 5e-5 torr, then all open cryo inlet valves will automatically close. The operator then can choose to reopen the valve to the troubled cryo module to provide maximum pumping until the module can be taken off-line.

Redundant Turbo Pumping Control

Two turbomolelecular pumps (TMP) can be use together or independently. Each TMP has a Pfeiffer TCP 350 Electronic Drive Unit [7] that is monitor and controlled by the PLC. If both pumps are being used and a fault occurs with a TMP then its isolation valve will interlock close and not interrupt the pumping of cryo modules. In single pump operation if a fault occurs the operator would have to start the secondary pump and wait a short time for the inlet pressure to be lower than the main manifold pressure before opening the TMP valve.

VACUUM DESIGN AND CONFIGURATION

The leak rate was measured on 4 of the leaking cryomodules to establish a reasonable basis for the design, the record values ranging from 1.9E-6 to 4.0E-5 torr-l/s. On one cryomodule the leak rate was also measured at both 2K and 4K where it was found that the difference in leak rate at these temperatures < 1%. A simplified analysis of the multi-layer blanket thermal system indicated that a pressure of < 1.0E-4 torr would be required to limit heat gain of the cryomodules due to gas conduction < 10% of that due to thermal radiation.

The insulating vacuum space of the cryomodule can be considered as a cryopump since it contains the cryo-cooled superconducting cavities which operate at a temperature of ~ 2K to 4K at which temperature the saturated vapor pressure for helium > 10 torr. The gas load to be pumped by will be essentially helium although for the purposes of the design analysis a mixture of 90% helium with the remaining 10% made up of residual gases was assumed.

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Mechanical Configuration

Various mechanical configurations of the IVS were evaluated ranging from pumping each cryomodule being pumped individually to all cryomodules being pumped from a common manifold which would extended the over 700’ of the cold linac. Design trade-off studies were conducted to determine the most effective configuration the outcome of which was a configuration that serviced 4 cryomodules from a centrally located pumping system. A compact design was desirable due to the physical constraints and as a result advantage was taken of the ability to operate the system at a relatively high pressure of 1.0E-4 torr when pumping the design level leak of 1.0E-4 torr-l/s from each of the 4 modules. This allowed the diameters of the manifolds and the size of components to be minimized.

A further trade-off study was conducted to compare the use of a diffusion pumped (DP) system, which have been previously used in a number of other facilities to pump the leaks in the insulating vacuum of cryomodules, with that of a turbomolelecular pumping system. The results of this trade-off indicated that the overall capital costs would be about 30% lower and the steady state power consumption would be reduced by over 50% for a TMP based system. In addition, being dry further reinforced the selection of a TMP based system over that of the DP system which would have the attended problematic issues of using oil especially in a radiation environment.

Equipment Layout

The pump support frame, which is suspended from the roof of the tunnel, supports two horizontally opposed TMP pumping stations (see Figure 3). Each station consists of an air cooled TMP rated at 50 l/sec helium backed by a diaphragm roughing pump rated 15 l/min. Each TMP is mounted vertically and has a 4.50” CF inlet flange which is mounted to a pneumatically operated angle valve. These two angled valves are connected by a 2.50” diameter horizontal teed manifold which connects to the main 3.00” diameter manifold which interconnects the 4 cryomodules and extend about 35’ in each direction. This manifold is supported from the roof of the tunnel.

The connection between the main manifold and the local manifold of each cryomodule is a vertical line, 2.00” diameter line about 5’ in length and uses viton sealed KF flanges to allow ready removal of this section for cryomodule removal in the event that this would be required. Pneumatically operated angled valves connect the vertical line from the main manifold to the local manifold of the cryomodule which are connected to the cryomodule via a manually operated gate valve. An additional manual valve is provide to allow connection of a temporary pump cart for pumping down the cryomodule insulating vacuum if ever required. Both the diaphragm roughing pump and fan for cooling the TMP are relay controlled and the TMP is powered and controlled from the electron drive unit located remotely in electronic racks located in the klystron gallery. Vacuum gauging is strategically located to monitor and allow the control of the IVS. TCs and CCGs are located at the inlet of each pump and in the main manifold connecting the individual cryomodules. A CCG is located on each of the 4 cryomodules to monitor insulating vacuum pressure. [3]

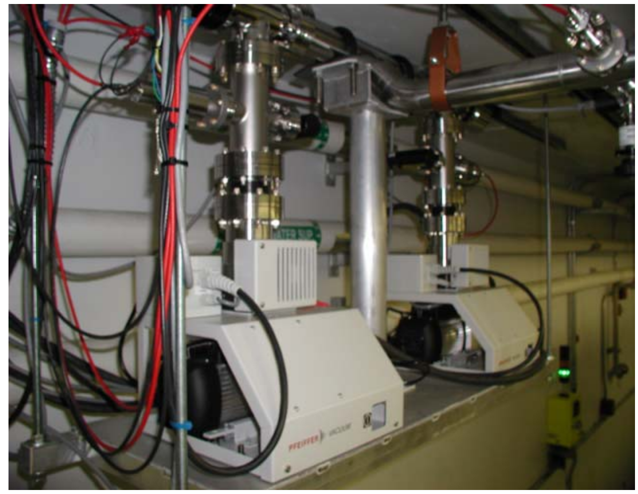

Figure 3 - Duel TMP Station

INSTALLATION STATUS

Currently the mechanical and control installation is complete for cryomodules 5-8. This group has been commission and running for three months. The installation for cryomodules 9-16 will begin in the next maintenance shutdown in late 2007. The controls and cable infrastructure for cryomodules 1-4 are installed, but these modules do not indicate any leaks. A decision was made to postpone the vacuum hardware installation and to concentrate on the modules that have leaks.

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