A SUMMARY AND STATUS OF THE SNS RING VACUUM SYSTEMS *

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Abstract

The Spallation Neutron Source (SNS) ring is designed to accumulate high intensity protons. Ultrahigh vacuum of 10^{-9} Torr is required in the accumulator ring to minimize beam-residual gas ionization. To reduce the secondary electron yield (SEY) and the associated electron cloud instability, the ring vacuum chambers are coated with titanium nitride (TiN). This paper describes the design, fabrication, assembly and vacuum processing of the ring and beam transport line vacuum chambers as well as the associated instrumentation

INTRODUCTION

The SNS ring vacuum system consists of the High Energy Beam Transport (HEBT) line, the Accumulator Ring and the Ring to Target Beam Transport (RTBT) line. The Accumulator ring has a circumference of 248m with 4 arcs and 4 straight sections while the RTBT and HEBT have a total length of 450m of beam transport lines.

The goal of SNS [1] is to provide a short pulse (~ 0.7 μs) of proton beam at 60 Hz with an average beam power of 1 MW to a neutron-generating target. To improve reliability and to allow hands-on maintenance, the uncontrolled particle loss in the ring during a one msec period must be less than 10^{-4} per pulse or less than 1 nA/m. In the design phase of the vacuum system beam losses due to H^- stripping, nuclear scattering, multi-Coulomb scattering and residual gas ionization were evaluated. The vacuum requirements to minimize beam losses for HEBT, the Accumulator Ring and RTBT are $5x10^{-8}$ Torr, $1x10^{-9}$ Torr and 10^{-7} Torr respectively.

The inner surfaces of the 248 m Spallation Neutron Source (SNS) accumulator ring vacuum chambers are coated with ~100nm of TiN to reduce the SEY of the chamber walls.

SYTEM DESCRIPTION

HEBT Vacuum

The HEBT line is divided into three sections, the LINAC matching section, the achromat bend section and the injection section. The LINAC matching section has a 12cm beam aperture and consists of two HEBT collimators, foil strippers and other beam diagnostic equipment. The vacuum chambers were fabricated using 12cm diameter stainless steel tubes. An alignment fixture similar to the one shown in figure 2 was used during welding of the chambers. The acromat bend section has eight 21cm quadrupoles/chambers and 8 long dipole magnets/chambers of 6m in length. Three of the dipole chambers have extraction ports to accommodate the linac dump line, the momentum dump line and the Beam In Gap monitoring line. The injection section chambers are fabricated from 12cm diameter stainless steel tubes, similar to those of the linac matching section.

The vacuum windows of the three dump lines in HEBT vary in design depending on the power rating of the dumps. The 7.5 kW linac dump window is edge-cooled with water. The flight tube downstream of this window to the dump will be filled with helium. The 2 kW momentum dump window is fabricated with stainless steel with a small air gap between the window and the dump. Both windows will be located in the HEBT tunnel. The injection dump, located in the injection dump building will handle up to 200 kW power and is water-cooled.

Accumulator Ring

The accumulator ring, with a circumference of 248 m, has four arc sections and four long straight sections (a four-fold symmetry) [2]. The vacuum system is divided into eight vacuum sectors, four arc vacuum sectors and four straight vacuum sectors, isolated with all-metal pneumatic gate valves. The arc vacuum sectors are ~ 34 m long, consisting of eight half-cell vacuum chambers, which are 4 meters long and a quarter-cell chamber. A typical half-cell assembly is shown in figure 1. The straight vacuum sectors are ~ 28 m long, consisting of two quadrupole doublet chambers as well as chambers for injection, collimation, RF, instrumentation and extraction.

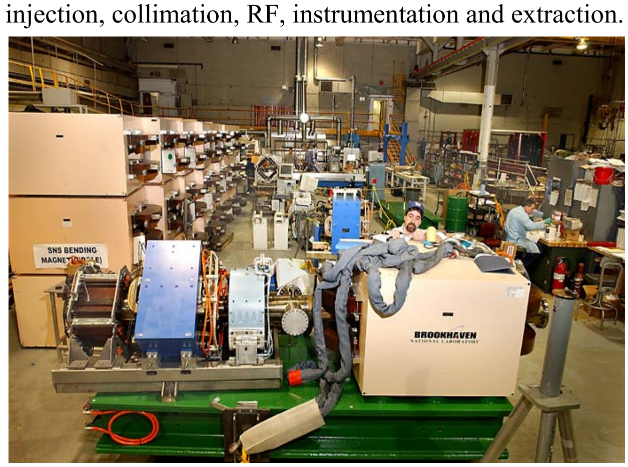

Figure 1: Typical Half-cell assembly with vacuum chamber.

All half-cell and quarter-cell chambers were fabricated from 316L stainless steel, which has excellent mechanical/vacuum properties. Conflat-type flanges and

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seals are used to join the chambers together. In several locations with potentially high background radiation, such as the injection, extraction and collimator regions, quick-disconnect type flanges and seals are used, which will minimize the radiation exposure during machine maintenance periods. All chambers were chemically cleaned and vacuum fired at 450oC for 48 hours.

A welding fixture as shown in figure 2 was used align and clamp the parts together during the welding of all the half-cell, quarter-cell and straight section chambers. The fixture was precision surveyed and ensured all the BPM's, pump tees, dipole chambers and tubes were aligned with respect to the quadrupole magnet pole tips. The alignment was of particular importance for long chambers such as the quad doublets and half-cell chambers.

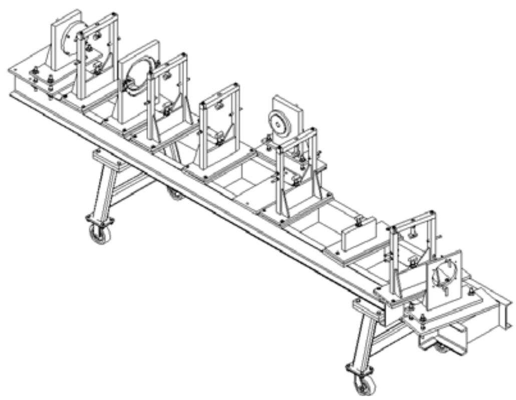

Figure 2: Fixture used to align chambers during welding.

Fig. 3 shows a standard arc half-cell chamber. The two-meter long dipole chamber has an elliptical inside cross section of 23cm (H) by 16cm (V), providing ample aperture for a future upgrade to 2 MW. The chamber is curved with a bending angle of 11.25 degrees. The top and bottom halves of the dipole chambers were formed by bending each half of the chamber on a bending brake. The two halves were then TIG welded together along the mid plane. The chamber was then filled with steel shot and had end caps welded on to contain the shot. The chambers were bent to the proper radius with rollers machined to match the chamber cross section in a bending brake. To minimize the deflection and to assure the structural stability of the chamber under vacuum load, the dipole chambers were fabricated from 5 mm sheet metal.

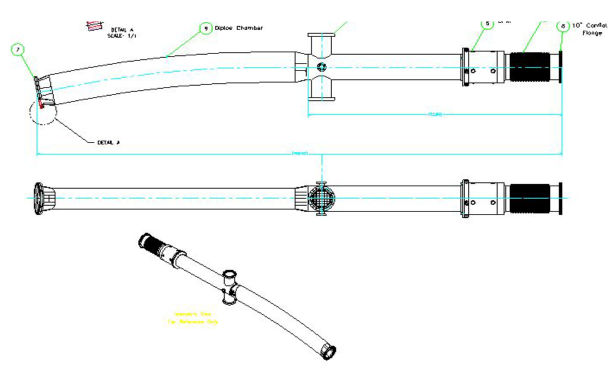

Figure 3: Typical half-cell vacuum chamber assembly.

To reduce wall impedance, there is a tapered transition from the dipole chamber to the round quadrupole pipe. The quadrupole pipe has an I.D. of 19 cm to 25 cm. The remainder of the half-cell chamber consists of a beam position monitor (BPM), a pump port and a bellows. To minimize the radiation induced stress corrosion, the thin wall bellows were fabricated from Inconnel 625. The pump port has a 203mm Conflat flange with an RF screen installed with >80% transparency for evacuation. The pump section and the end Conflat flanges were TIG welded to the dipole/quadrupole chamber.

Special chambers such as doublet chambers (Fig 4 and 5), collimators, RF cavities and injection and extraction equipment are all located in the straight sections. The doublet chambers consist of a quadrupole pipe, BPM, pump port, bellows and flanges. Tapered transitions were also used to adapt to different pipes sizes and reduce the wall impedance. Quick disconnect chain clamps [3] are used with copper CFX seals on flanges up to 250 mm in diameter. On flanges with larger diameters than 250mm, Helicoflex Delta seals were used with chain clamps and were found to be faster and more reliable than CFX seals.

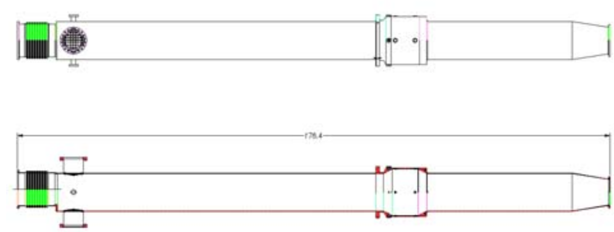

Figure 4: Injection quad doublet chamber assembly.

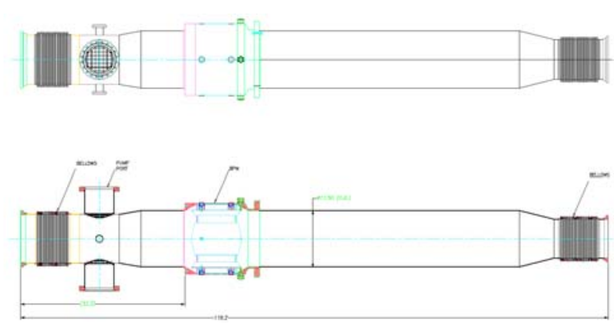

Figure 5: Extraction quad doublet chamber assembly.

RTBT Vacuum

A pressure of $\sim 10^{-7}$ Torr is required for the RTBT section adjacent to ring extraction and $\sim 10^{-6}$ Torr near the target area. The RTBT vacuum chambers have a 21cm aperture except for the last 30m of RTBT inside the Target building which has a 36cm aperture. No vacuum pumps are installed near the Target due to the intense radiation and the lack of access. Remote-operable quick-disconnect type flange assemblies are designed and employed for the quadrupole doublet chambers adjacent to the Target. A Fast valve will installed to protect the

RTBT vacuum from catastrophic failure of target or dump windows.

Vacuum Pumps

Two types of vacuum pumps will be used throughout the vacuum systems. Turbopump/dry pump carts will be used for the initial pump down and to supplement the high vacuum sputter ion pumps. One turbopump cart will be installed at each vacuum section preferably near high outgassing sources and potential leaks but away from high radiation areas. A number of sputter ion pumps will be installed in each vacuum section as the main high vacuum pumps for their cleanliness, reliability and cost. No linearly distributed pumps are needed due to the large aperture and the large conductance of vacuum chambers.

TIN COATING OF RING VACUUM CHAMBERS

The inner surface of the ring vacuum chambers are coated with ~100nm of TiN [4] to reduce the secondary electron yield (SEY) and to avoid the electron cloud and the e-p instability caused by electron multi-pacting as observed in a few high-intensity proton storage rings. The extraction kicker ferrite surfaces facing the beam are also coated with TiN. The injection kicker ceramic chambers are initially coated with a layer of copper, to carry the image current, then with 100nm of TiN. DC magnetron sputtering is the method used to deposit the coating to the chambers walls. This method has about a 10 times higher deposition rate than that of pure DC sputtering allowing chambers to be coated in several hours. The TiN coating on stainless steel reduces the SEY by approximate 30% as shown in figure 6.

VACUUM INSTRUMENTATION AND CONTROL

The vacuum system instrumentation includes gauges and controls for valves, ion pumps, and turbomolecular pumps. The ion pump power supplies are located in the service building. Remote serial communication will be used to turn on/off the pump high voltage and to read pump current, pressure, and voltage. The sputter ion pump current, which is proportional to pressure, will give a detailed pressure profile around the ring. Two sets of Pirani and cold cathode gauges are installed at each vacuum sector as primary vacuum gauges. Allen-Bradley ControlLogix programmable logic controllers (PLCs) are used to monitor gauge and pump setpoint outputs and control valves. The principal function of the PLC is to provide logic to control the sector gate valves that isolate one vacuum sector from another in the event of an interlock. Turbomolecular pumps used to rough down can be operated remotely. A schematic of the I&C system is shown in figure 7.

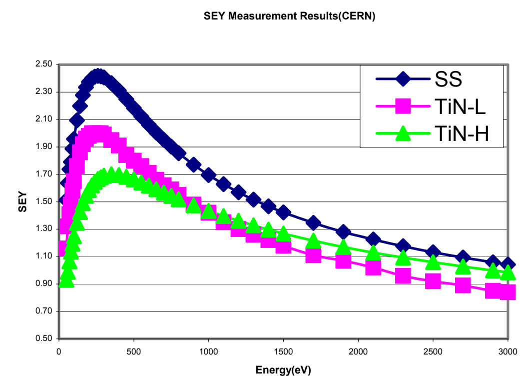

Figure 6: SEY as a function of incidence electron energy for bare and TiN coated stainless steel coated at high and low pressure.

Data exchange between PLCs is accomplished through a real-time, redundant-media ControlNet network [5]. The PLCs in each service building will also generate machine protection system (MPS) beam permit signals and up to the minute vacuum status appropriate for the various machine operation modes.

The PLC may communicate with the input-output controller (IOC) through an EtherNet/IP or ControlNet interface. The IOC can interface directly with vacuum device controllers through RS-485 serial communication [6].

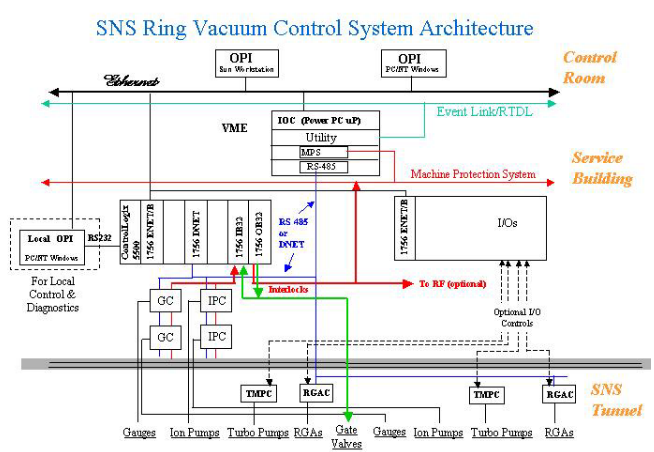

Figure 7: I&C Vacuum system schematic.

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