STATUS REPORT ON THE INSTALLATION OF THE WARM SECTIONS FOR THE SUPERCONDUCTING LINAC AT THE SNS*

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Abstract

The SNS superconducting linac (SCL) consists of 23 cryomodules (CMs), with possibly 9 additional CMs being added for future energy upgrade from 1 GeV to 1.3 GeV[1, 2]. A total of 32 warm sections separate the comparatively short CMs, and this allows a CM exchange within 48 hours, in order to meet demanding beam availability specifications. The 32 warm section chambers are installed between each pair of CMs, with each section containing a quadrupole doublet, beam diagnostics, and pumping [3]. The chambers are approximately 1.6 m long, have one bellows installed at each end for alignment, and are pumped by one ion-pump. The preparation and installation of these chambers must be made under stringent clean and particulate-free conditions, in order to ensure that the performance of the SCL CMs is not compromised. This paper discusses the development of the cleaning, preparation, and installation procedures that have been adopted for the warm sections, and the vacuum performance of the system.

SCL WARM SECTION CHAMBERS

One SCL warm section chamber is shown in fig.1. The chamber fits within two SCL CM gate valves.

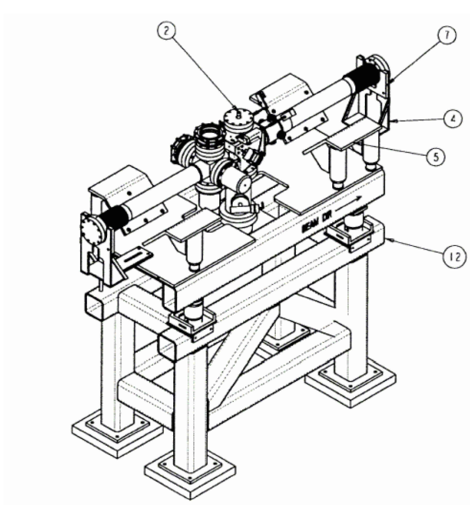

Figure 1: SCL warm section chamber on magnet stand (magnets are not shown).

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Each chamber is equipped with two bellows, four beam-position monitor (BPM) electrodes, four specially coated viewing ports, one electron pick-up electrode, one 60 l/s ion-pump, one Convectron gauge, one all-metal manual valve, and on gas purge/vent assembly.

CLEANING, ASSEMBLY, AND TESTING

All parts have been inspected, cleaned separately, and assembled in a class-10 clean-room facility. De-ionized water has been used for pre-cleaning all parts, and ultrasonic transducers have been used to break loose any contaminant particles on the surface of the chamber which could be detrimental to the RF operation of the SCL cavities, potentially leading to higher-than-normal X-ray generation. Liquid-phase particle counts have been carried out throughout the cleaning procedure. After drying with filtered nitrogen, the different parts have been assembled in a separate area, under a class-10 laminar-flow hood. Once completed, each assembly has gone through a preliminary leak-checking, a thorough bake-out at 150ºC (for at least 48 hours), and a final leak-check. Records of all cleaning and testing data are kept for each chamber, for future reference. A typical residual-gas analyzer (RGA) spectrum after bake-out shows the presence of hydrogen, water, carbon monoxide, and traces of methane and carbon dioxide, as expected from a clean ultra-high vacuum system. Few failures have been reported during this phase, mainly small leaks at flanges, or BPM feedthroughs which have been quickly fixed.

INSTALLATION IN THE SCL TUNNEL

After passing the final RGA and leak-test, each chamber was backfilled with filtered dry nitrogen, moved out of the clean-room area, lifted with a crane and installed on the magnet stand, inside the two quadrupoles. At this time, a selected number of these chambers was fitted with laser-wire boxes [4]. The final assembly was then moved to the SCL tunnel, pre-aligned, and finally moved to the assigned SCL slot. Once in place, it underwent a final alignment.

Vacuum Installation: Preparation

As stated above, the main issue concerning the warm-section chambers was to avoid particle contamination of the SCL RF cavities. An international committee of experts had been asked by the SNS to review and comment on our vacuum installation procedures. After several rounds of videoconferencing, a detailed procedure describing step by step the vacuum connection of a warm-section chamber to the two neighboring CMs has been

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approved. The first connection between CM-3 and CM-4 being successful, we adopted the same procedure for the remaining 31 chambers.

The 62" (~1.6m) longitudinal space between the gate valves (GVs) of two neighboring CMs represents a tight space, especially when a laser-wire box is installed on the warm-section chamber, as show schematically in fig.2. In addition to that, there is a limitation in height. It showed impossible to make the final connections between the warm-section chamber's end-flanges and the CMs' GV flanges using a single clean-room running across the whole area. We were therefore forced to devise a set of smaller, portable clean-rooms (CRs): two 2' by 4' CRs, placed across the areas where the connections had to be made, and one bigger CR connecting the previous two. The latter was used as a grey-area for storing tools and donning CR garments.

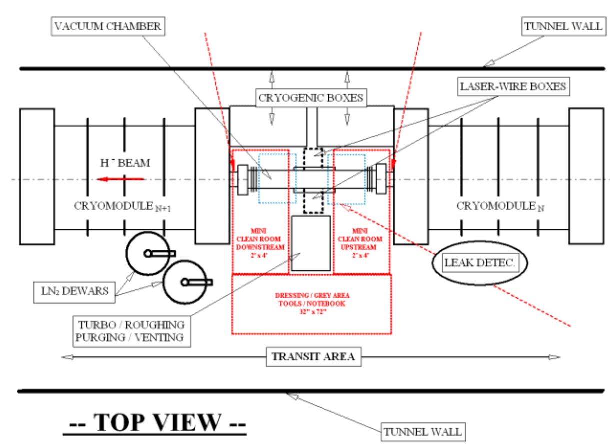

Figure 2: Schematics of the vacuum installation of one SCL warm-section chamber.

Each 2' by 4' CR was thoroughly cleaned using filtered (3 nm pore-size filters), ionized boil-off nitrogen from 200 liter dewars. This phase was carefully monitored by portable CR particle counters (PC), capable of measuring particle sizes in the range of 0.2 to 2.0 microns. Once the PC showed "zero" counts, the corresponding CR was considered "cleaned", and the connection to the CM GV flange made. Typically, it would take of the order of 1 to 2 days for each CR area to be cleaned. A team of two trained technicians would typically clean the CRs in parallel: in such a way an installation rate of 2 chambers per week has been achieved, although this pace has slowed down at times due to work on other impending vacuum issues on the CMs.

Vacuum Installation: Connection to the CMs

A team of two technicians would make the final connection between the warm-section chamber and the CMs. One technician would stay inside the tiny 2' by 4' CR, the other one staying in the grey-area CR, passing tools and components as needed (screws, copper gaskets, wrenches, etc…). During each connection, a portable PC would be placed under the flanges to be connected, at a small distance. A typical connection would take of the order of 30', with only 2'-5' during which the vacuum system of the warm-section and the body of the CM GV were opened. Constant purging with 1 psig positive, dry, filtered nitrogen was kept, in order to minimize the possibility of any residual CR dust falling inside the chambers. At the end of each connection, the PC data were downloaded to a notebook computer kept in the grey-area, and immediately analyzed. So far, no connection has ever been made with more than a few particles being counted by the PC, integrated over the time when the vacuum system was open. Fig.3 shows a typical spectrum of particles as recorded by a PC.

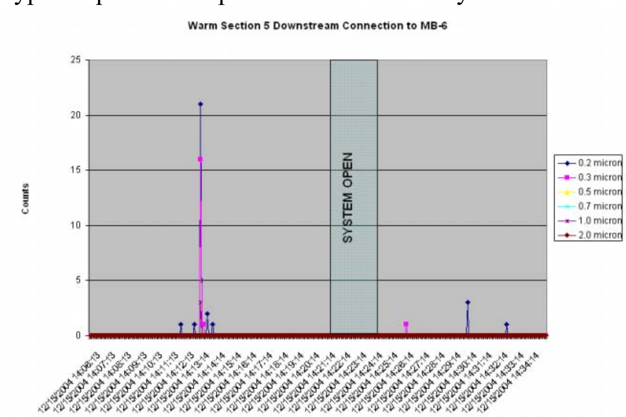

Figure 3: Particle counter data taken during vacuum connection of a SCL warm-section chamber.

Vacuum Installation: Connection to "Dummy Cryomodule" Chambers

As stated above, the last nine CM slots are, at this time, not being populated by CMs. This will happen at a later time, during a possible upgrade of the machine. The ~6.3 m length of a high-beta CM is therefore taken by a beam pipe spool piece, also called "dummy cryomodule" chamber, i.e. a 3" ID tube with one pump-out "tee" port equipped with a 30 l/s IP. Value-engineering arguments have led to removing one of the two GVs connected to each warm-section. As a consequence of the fact that the body of the GV on each dummy chamber had been found responsible for the generation of a very large number of particles, an additional pre-cleaning step for each GV has been carried out. Typical PC rates have gone from thousands of particles down to none. Eight out of the last 9 warm-section chambers have then been connected to the two neighboring dummy-CM chambers using the same procedure and hardware as for real CMs, as explained in the previous paragraph. The downstream flange of the last warm-section has been blanked-off, waiting for the so called high-energy differential pumping chamber to be installed.

VACUUM RESULTS

Static Vacuum

Table 1 shows the results obtained so far, in terms of pressure measured by the CM IPs (for reference) and by

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the warm-section chambers' IPs. All GVs were closed. It should be mentioned that all pressures listed below for the warm-section chambers are consistent with what expected from a vacuum system which was vented after baking, and had not been re-baked in situ. All pressures have been steadily improving over time, and we are confident that they will all fall below 1.0E-8 Torr.

Table 1: Typical SCL warm-section and CM pressures; "N/A": chamber/CM not installed or connected yet; "-": no pressure reading available; IP pressures are in Torr.

CM/SLOT #	CM IP	Warm Section IP
1	N/A	N/A
2	-	N/A
3	2.9E-8	4.7E-9
4	4.9E-10	1.9E-9
5	8.8E-9	2.3E-9
6	1.5E-9	5.0E-9
7	6.1E-10	4.5E-9
8	4.5E-10	6.2E-9
9	4.7E-10	3.6E-9
10	3.9E-10	3.1E-9
11	6.7E-10	3.2E-9
12	4.6E-10	2.5E-9
13	1.7E-8	1.9E-9
14	5.0E-10	1.9E-9
15	3.3E-10	2.0E-9
16	4.9E-10	1.8E-9
17	4.1E-9	3.0E-9
18	5.0E-10	3.5E-9
19	4.6E-10	-
20	-	N/A
21	-	N/A
22	-	N/A
23	N/A	N/A
24 Dummy	N/A	6.8E-9
25 "	5.9E-9	-
26 "	6.7E-9	1.7E-8
27 "	4.4E-8	1.5E-7
28 "	3.2E-8	4.1E-8
29 "	-	2.0E-8
30 "	1.6E-8	2.6E-8
31 "	3.1E-8	4.4E-8
32 "	1.8E-8	3.2E-8

Vacuum Behavior during RF Tests

A confirmation that the connection of two warm-section chambers to three consecutive CMs had been successful in terms of lack of particle contamination has come from a dedicated test [5]. The X-ray background generated by field-emission triggered by the presence of dust inside the superconducting cavities of each CM has been recorded before and after opening the GVs. The pressure, as measured by the IP on the warm-section chambers, dropped from ~1.0E-8 torr down to ~9.0E-10 torr, due to the high pumping speed of the cold surfaces inside the CM as compared to the nominal 60 l/s of the warm-section IP. This was done while RF power was being sent to the CM's cavities. No increase in the X-ray level has been observed, therefore confirming the cleanliness of the vacuum connection procedure.

CONCLUSIONS

The installation of 32 warm-section chambers in the SCL tunnel of the SNS is proceeding well. Few problems have been encountered so far, with no major impact on the overall schedule of the SNS.

Barring unexpected problems, the remaining SCL warm-section chambers will be installed in the incoming weeks. Once completed, the whole SCL vacuum system will be tested, with major attention being paid to the safe operation of the almost 60 GVs, especially concerning the protection of the sensitive vacuum environment of the superconducting cavities.

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