INSTALLATION OF THE SPALLATION NEUTRON SOURCE (SNS) SUPERCONDUCTING LINAC*

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Abstract

The Spallation Neutron Source (SNS) superconducting linac (SCL) consists of 11 medium beta (0.61) and 12 high beta (0.81) superconducting RF cryomodules, 32 intersegment quadrupole magnet/diagnostics stations, 9 spool beampipes for future upgrade cryomodules, and two differential pumping stations on either end of the SCL. The cryomodules and spool beampipes were designed and manufactured by Jefferson Laboratory, and the quadrupole magnets and beam position monitors were designed and furnished by Los Alamos National Laboratory. Remaining items were designed by Oak Ridge National Laboratory. At present the SCL is being installed and tested. This paper discusses the experience gained during installation and the performance in terms of mechanical and cryogenic systems.

CRYOMODULE TRANSPORTATION

Shipping cryomodules from Jefferson Laboratory to Oak Ridge was investigated thoroughly [1]. The cryomodule acceleration design criteria were 4g vertically, 5g longitudinally (along the beam axis), and 0.5g transversely. A damped shipping fixture and an air ride trailer (Fig. 1) were used to minimize acceleration. Typical vibration frequencies were ~10 Hz or less.

Figure 1: Final cryomodule delivery on March 16, 2005.

Shipments were monitored with a Shockwatch® *Shocklog*® mounted on top of each cryomodule. The most severe shock observed (Fig. 2) of 2.25g vertically was caused by the crane used to offload Cryomodule High Beta 12. Maximum accelerations measured during transit were typically 1 to 1.5g vertically, and 0.5 to 0.75g axially and transversely.

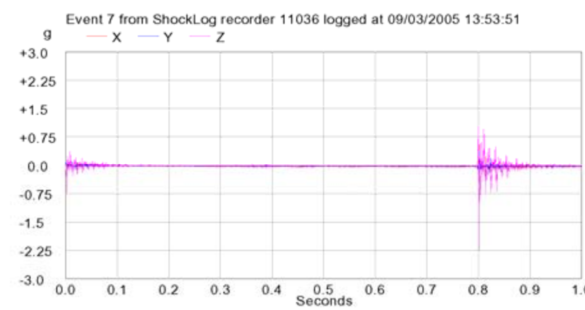

Figure 2: Most severe transportation shock – experienced during cryomodule offloading.

Cavity passband measurements were made before and after shipping of each cryomodule. No significant frequency changes were observed, indicating that there was no mechanical movement or deformation of the cavities.

CRYOMODULE INSTALLATION

The general sequence of installation was driven by progress in the klystron gallery. Significant activity in the tunnel could proceed only after the installation of water systems, cable trays, and equipment racks in the gallery, since only after that could cables be pulled to the tunnel.

Installation

Cryomodule infrastructure was installed by construction crafts. This included water systems, compressed air lines, stands and grout, and cabling and terminations. The most time-consuming activity was the installation of the beam line electrical interface, shown in Fig. 3. This consisted of routing and terminating hundreds of power/signal wires to overhead terminal blocks, and then connecting these to the cryomodule. Wiring each cryomodule took approximately three weeks for a two-electrician crew.

Once the electrical work was completed for a specific slot, the cryomodule was moved into position using a battery powered trailer "tugger". At this point subsequent work was performed by SNS engineers and technicians. The cryomodule was aligned, and the outer conductor coupler extenders and associated water cooling lines, thermocouples (for water and coupler ceramic window),

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and flow switch were installed. The insulating vacuum and helium circuits were leak checked, and Joule-Thomson (JT) valve actuators installed.

Figure 3: Installation of the electrical beamline interface.

System Checkout and Cooldown

Once mechanical installation was completed, extensive system checkouts were performed. Vacuum system, RF systems, and cryogenic controls required calibration and complete signal/interlock verification from the cryomodule, to the equipment racks and control system.

The cryogenics group tested the tuner motors and at the same time made cavity passband measurements. Personnel also pumped and purged helium circuits to prevent contamination of the Central Helium Liquifier. Because it is possible that the JT valves may leak, U-tubes connecting the cryomodule to the helium transfer lines were installed only after all systems had been checked and signed off as ready for cooldown.

Cryomodule cooldown was performed at the rate of 100-150K per hour in order to avoid excessive mechanical stress while still progressing rapidly through the “Q disease” region (although SNS cavities have been baked to avoid this problem). After cooldown, RF measurements were taken, and then the final waveguide connection made. At this point, the cryomodule was ready for RF testing [2]. Figure 4 shows a number of medium beta cryomodules cooled down and ready for testing.

Three of the cryomodules cooled down so far developed significant leaks to the insulating vacuum, necessitating warm-up and repair. This problem was also observed at JLab, and was due to instrumentation feedthroughs on the end can helium circuits. The repair involved removing the end can cover (a “skill” saw with carborundum blade worked well), insulation and copper shield, and isolating the leaking feedthrough. The feedthrough was removed and a plug was welded onto the helium piping. Surface mount silicon diodes were attached to the piping.

Figure 4: Medium beta cryomodules installed and ready for RF testing.

WARM SECTION ASSEMBLY AND INSTALLATION

The intercryomodule region, or warm section, consists of a quadrupole magnet/diagnostic assembly. Much of the assembly and installation of these is detailed elsewhere in these proceedings [3].

The warm sections were designed by Oak Ridge National Laboratory and fabricated by Energy Beams Inc., New Jersey. Assembly was originally planned to be performed at JLab. In order to develop the expertise and facilities for particulate-free assembly, warm section cleaning and assembly was moved to Oak Ridge. This necessitated the rapid installation of Class10/100 cleanroom facilities (Fig. 5), ultrasonic cleaning tanks, and an ultra-pure water system.

Figure 5: SNS cleanroom with cleaning system in foreground and Class 10 assembly area in background.

Liquid particle counters were installed and used to control the ultrasonic cleaning process (Fig. 6). Ultra-pure water flowed into each end of the pipe and was sampled at

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the middle. This method, suggested by an external review committee, provided a high level of quality assurance.

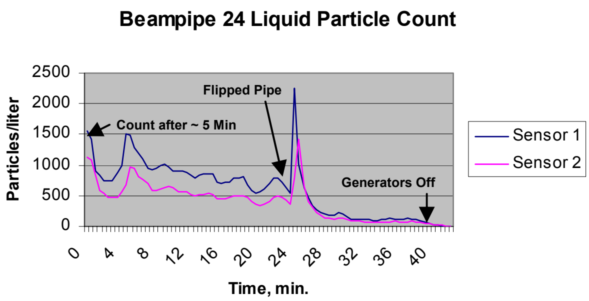

Figure 6: Liquid particle sampling of warm section ultrasonic cleaning.

DIFFERENTIAL PUMPING STATIONS

Differential pumping stations at both ends of the SCL provide a vacuum transition to the higher pressure coupled cavity linac and high energy beam transport. The low energy station, shown in Fig 7, contains a wire scanner, current monitor, two beam position monitors, an insertable beam stop, and quadrupole magnets, as well as ion pumps and a fast valve. The high energy station contains only vacuum components. These stations will be installed in May and June of 2005.

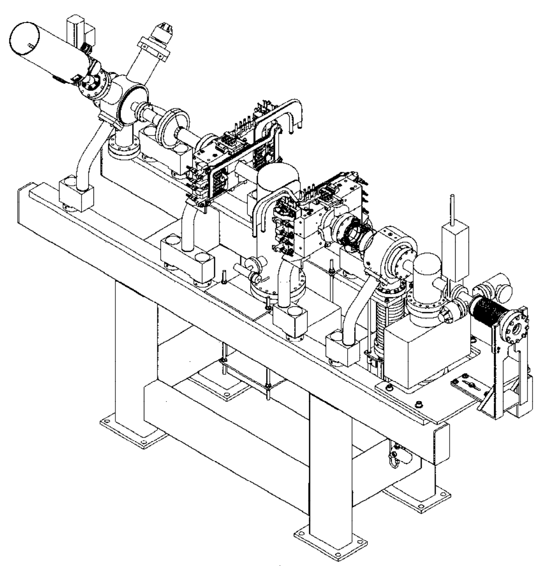

Figure 7: Low Energy Differential Pumping Station.

INTEGRATION AND SCHEDULING

Initial SCL integration was accomplished with the use of cross section drawings to identify equipment locations. An important consideration was a "stay-out" zone for U-tube insertion/removal. Mock-ups and prototypes were also constructed. The beamline electrical interface needed several iterations to ensure functionality for all users.

The first cold cryomodule was tested in September 2004. By January 2005, four cryomodules had been cooled down and two warm sections installed. Cryomodule installation/cooldown has proceeded at the pace of nearly one per week (Fig. 8). This rapid pace has been facilitated by daily 8:00 a.m. planning meetings to coordinate activities. Plans also have shifted quickly. For example, the repair of cryomodules constrained warm section installation, as we elected to connect warm sections only after a cryomodule had been cooled down. This limited the rate of warm section installation considerably. Downstream installation in the tunnel area of the nine spool beampipes (dummy cryomodules) was accelerated to keep vacuum connections on schedule.

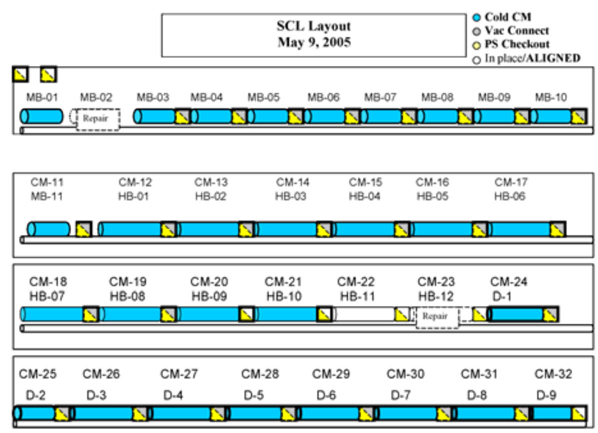

Figure 8: Installation Progress Chart.

CONCLUSIONS

SNS SCL installation is nearly complete. As part of this effort, personnel have gained expertise and facilities for particle-free cleaning and assembly – essential items for future maintenance. Final system checks must be performed. Overall integration with protection systems and vacuum valve checkouts must be done carefully and cautiously.

REFERENCES

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[3] R. Kersevan et al. "Status Report on the Installation of the Warm Sections for the Superconducting Linac at the SNS", this conference, RPPT070