INSTALLATION OF THE SPALLATION NEUTRON SOURCE (SNS) WARM LINAC

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Abstract

The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built at Oak Ridge National Laboratory (ORNL). The SNS project design and construction is a partnership involving six Department of Energy (DOE) national laboratories including Argonne, Brookhaven National Laboratory (BNL), Thomas Jefferson National Laboratory (JLab), Lawrence Berkeley National Laboratory (LBNL), Los Alamos National Laboratory (LANL), and ORNL. At the present time the warm linac system, designed by LANL, is being installed and commissioned. Results have been very good. The warm linac is comprised of six Drift Tube Linac (DTL) tanks and four Coupled Cavity Linac (CCL) modules. These accept an incoming negative hydrogen ion beam from the Front End injector at 2.5 MeV, and accelerate it to 185 MeV. Currently DTL tanks 1-3 are installed and commissioned with beam and DTL tanks 4-6 and CCL modules 1-3 are installed and ready to condition. Installation experience will be presented and alignment, vacuum and field tuning performance will be described.

THE DTL

The DTL accepts a beam of H- from the Front End injector at 2.5 MeV and accelerates it through six RF structures to 87 MeV. Each structure houses a varying number of drift tubes (DTs) from 59 in DTL 1 to as few as 21 in DTL 6 for a total of 210. Of the 210 DT's, 140 hold permanent magnet quadrupoles for collimation, 24 hold electromagnetic dipoles for steering, and 10 have beam position monitors. Each structure is powered by a 2.5 MW klystron. Physically, the DTL system is 36.7 m long, 1.39 m wide, 2.3 m tall, and a beam center of 1.3 m.

The DTL was designed and procured by LANL for the SNS project. Fabrication and some initial component testing was contracted by and/or performed at LANL. Assembly, installation, tuning, and integration was performed by ORNL staff with assistance by LANL.

Assembly & Installation at the SNS Site

DTL tank segments arrived in a "just finished" state. After the steel machining process each segment was sent to GSI in Darmstadt, Germany for copper plating. From there, the segments came directly to ORNL. ORNL staff removed the masking from the copper plating process, polished all tank surfaces, retapped threaded holes, prepared all vacuum sealing surfaces, and in some cases copper brush plated sealing surfaces to prevent rusting. Upon completion, the segments were joined on a stand and the DTL assembly process began. Preparation of the first DTL tank was slow, however a great deal was learned during the process. Staff took time to develop techniques to accelerate future installations and many problems were identified and resolved. The first tank was prepared at an off-site building and then moved via crane and truck to the site. This was an unwieldy process and it posed a physical risk to the equipment and its alignment. Therefore, the remaining 5 structures were assembled in the SNS Front End Building and then moved into the linac tunnel using Hillman rollers. This turned out to be both efficient and safe and a completed structure could be moved and set in place in one day with minimal equipment risk (Fig. 1).

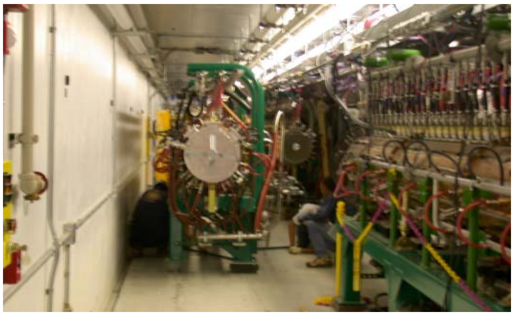


Figure 1: DTL 4 moving into place.

Alignment

Alignment of the DTL tanks was very time consuming. Since the system had never been assembled, only theoretical component sizes and locations were available so it was important to completely map the system during assembly. Nearly all of the alignment work was done using a LEICA laser tracker. Once the assembled main tank was on a stand it was levelled and fiducialized with respect to its frame and referenced to its ideal future position in the beamline. After which, all of the DT's, previously individually fiducialized and magnet mapped (Fig. 2), were loaded into the tank and aligned with respect to the tank and the assembly's beam center. Final positioning in the tunnel was done using only the external tank fiducials. Recently, the external alignment of all six structures was re-checked and, after minor adjustments, was within ~50 μm of optimal beam transport position.

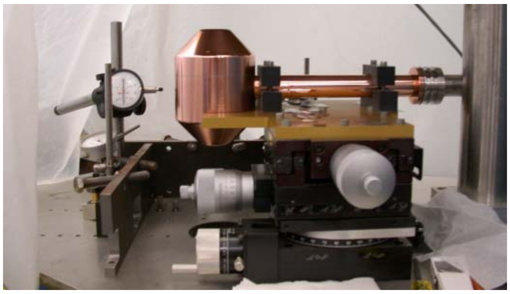


Figure 2: Fiducialization of a drift tube**.**

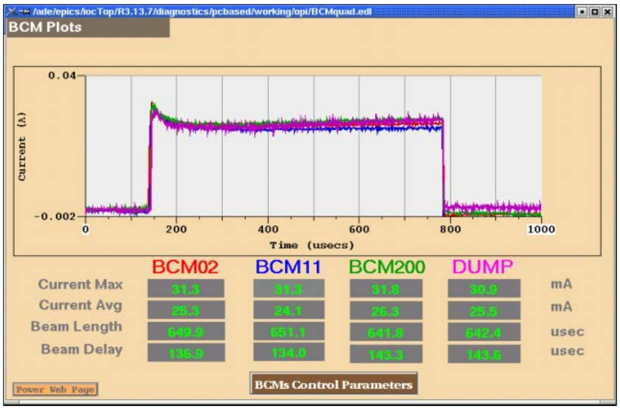
Tuning

The entire cavity is designed to be operated at 402.5 MHz. Before the post couplers are inserted, the fields are brought to design values through the use of the slug tuners. The entire set of slug tuners is then adjusted such that when the post couplers are inserted, the cavity will resonate at the design frequency. This step is essential so the post couplers are minimally excited for unperturbed operation. After the post couplers are inserted, the cavity is tuned to stabilize the fields. This is accomplished by pulling out and pushing in the post couplers. The post couplers were designed with a small bend which, by a rotation operation, fine tunes the field structure (Fig. 3). The final step in tuning the cavity includes the sizing of the coupling iris. This was performed initially with a nitrogen purge in the cavity to measure the physics of the coupler and then under vacuum for the final measurements and iris cuts.

Figure 3: Open end of DTL showing tuners and DTs.

DTL Commissioning

DTL operation is now fairly well understood. Three of the DTL's have been commissioned with beam having nearly 100% transmission through to the beamstop and the emittance data appears reasonable (Fig. 4). Vacuum goals were met with a specification of 2 x 10^{-7} torr and measured values in the high 10^{-8} torr range.



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BCM Plots

	BCM02	BCM11	BCM200	DUMP	
Current Max	31.3	31.3	31.8	30.9	mA
Current Avg	25.3	24.1	26.3	25.5	mA
Beam Length	649.9	651.1	641.8	642.4	usec
Beam Delay	136.9	134.0	143.3	143.6	usec

Figure 4: Beam current for DTL commissioning.

THE CCL

The CCL accelerates the H^- ions from 87 to 186 MeV. It consists of four RF structures, each consisting of 12 segments with 8 accelerating cavities per segment. Each structure is powered by a 5.0-MW klystron. Physically, the structure is 55.4 m long, 1.7 m high, and 0.6 m wide and located in a tunnel that is 4.3 m wide by 3.0 m tall. The major components of the CCL are the support frame, segments, bridge couplers (BC's), quadrupole magnets, vacuum system, cooling system, and diagnostics (Fig. 5).

Figure 5: CCL in the tunnel.

The CCL was designed and procured by LANL, fabrication and testing of the accelerator structure was performed by ACCEL in Bergisch Gladback, Germany, and installation and integration at the SNS site was performed by ORNL staff.

Assembly & Installation in the Tunnel

Installation of the CCL began with the delivery of the first CCL structure in November 2003. The original plan was to assemble and test each CCL structure in an assembly building and then break the structure into two halves (each up to 7.7 m long, weighing ~ 5600 kg) and move them into the tunnel for final installation. The advantages of this concept are (1) more space available for assembly and testing and (2) allowing the assembly to be done without impacting tunnel construction activities. The disadvantage of this concept was that the large and somewhat delicate structure must be lifted and moved several km and then reassembled in the tunnel. In the end, the tunnel was available when the first CCL structure arrived and the decision was made to assemble it there. In retrospect, this was the correct decision and saved considerable time. Most assembly activities could be comfortably performed on the aisle side of the beam line where there is 2.3 m of clearance to the wall. On the back side of the beam line, space is limited but adequate for assembly activities. We used two small gantry cranes in the tunnel for lifting heavy components (Fig. 6).

As with any complex device assembled in a tight space, the assembly sequence and deciding what activities can be done in parallel is critical. The critical installation path was the segment and BC installation. These had to be in place and leak tested before other activities could continue. After this, the critical path was magnet installation and testing. We put other activities in parallel with these when possible.

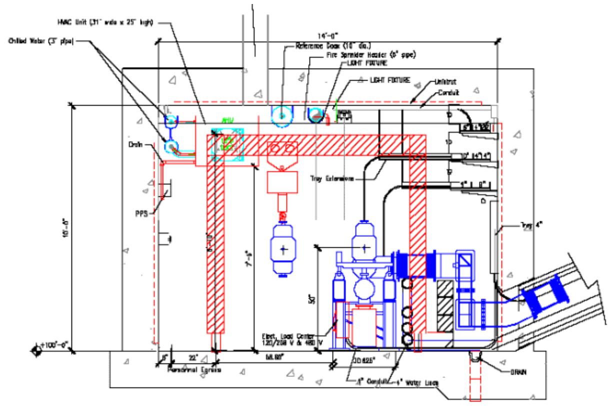

Figure 6: CCL tunnel cross-section with gantry.

The installation learning curve was very steep with the first module taking ~ 4 months to install. The remaining modules took only 2½ months each. This was attributed to the experience of the team and an improved sequence. For example, on CCL 1 the segments were installed on the frame and then the vacuum system installed. On later modules, much of the vacuum system was installed prior to the segments allowing much more access. This made reaching the hundreds of bolts much easier and the assembly went much faster.

The most critical step of the assembly sequence was the installation of the BC's (Fig. 7). Before the BC's could be installed it was vital that the segments were accurately aligned to within ~100 µm. A laser tracker was used for all alignment activities. Segment and BC alignment played a crucial part in creating a low stress and vacuum tight joint. The mating flanges at each end of the segment are parallel within ~125µm. An o-ring carrier with an integrated RF seal ring is installed at each end of the BC. (All other CCL joints are made with metal seals.) After leak testing of the BC was complete it was unlikely that the system would have to be disassembled so tuning and installation of vacuum, cooling, magnets, and RF systems could occur.

Figure 7: CCL bridge coupler installation preparation.

Magnets were aligned within 100µm which was driven by the SNS beam alignment requirements (Fig. 8).

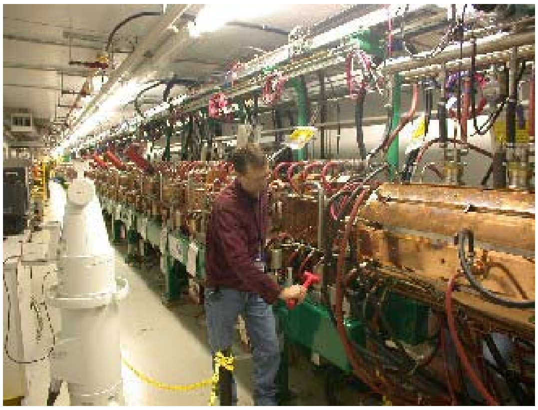

Figure 8: CCL magnet alignment.

CCL RF Conditioning Performance

RF conditioning is the first opportunity to bring all CCL systems together to see how they perform. 2.6 MW of RF power was applied to CCL module 1. Performance of all systems during the test was good. The vacuum system which consists of 10 ion pumps connected to a 15 cm diameter manifold in turn connected to the segments and BC's via a 7.6 cm bellows, achieved a pressure of 3 x 10^{-7} torr during conditioning. Pressure was continuing to decrease at the end of conditioning, so achieving the design value of 1.4 x 10^{-7} torr is assured.

WARM LINAC COOLING

The cooling system for both DTL and CCL cavities are nearly identical. They consist of a pumping skid (variable speed pump, heat exchanger, and control valves, etc) located in a gallery ~7 – 8 m from the tunnel. Pipes are routed into the tunnel to manifolds that distribute cooling to the RF cavities. The total cooling flow is ranges from 120 to 235 gpm, depending upon the cavity, at up to 90 psi and must control the cavity temperature to within +/- 0.2 C. Initial testing indicated control within +/- 0.6 C was achievable with the existing equipment but better control would require valve modifications which are now in progress.

CONCLUSIONS

The SNS Warm Linac installation has gone relatively smoothly and is all but complete. Conditioning of the first 3 DTL tanks and the first CCL module is complete and others will be conditioned in mid-July of 2004. Thus far, all systems meet the SNS operational requirements. Preparations are underway for commissioning with beam of DTL's 1 – 6 and CCL's 1 – 3 which will begin in early September 2004.