OPERATIONAL AVAILABILITY OF THE SNS DURING BEAM COMMISSIONING*

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Abstract

The Spallation Neutron Source accelerator systems will deliver a 1 GeV, 1.44 MW proton beam to a mercury target for neutron production. The beam commissioning of the accelerator systems is taking place in modules, as components are installed and tested. To date there have been four beam commissioning runs, the H- injector, Drift Tube Linac Tank 1, Drift Tube Linac Tanks 1-3 and Drift Tube Linac Tanks 4-6 plus CCL modules 1-3. Among the critical performance goals have been achieved are, demonstration of design 38 mA beam peak current, 1 msec long beam pulse, and 1 mA average beam. Results of accelerator availability during beam commissioning program are presented.

INTRODUCTION

The Spallation Neutron Source accelerator systems [1] will provide a 1 GeV, 1.44 MW proton beam to a mercury target for neutron production. SNS accelerator systems include:

- H- injector [2] capable of producing 38 mA peak current,
- 1 GeV Linear Accelerator [3],
- Accumulator Ring
- Associated Beam Transport lines [4].

The linear accelerator consists of a Drift Tube Linac(DTL), a Coupled-Cavity Linac (CCL) and a Superconducting Linac (SCL). The baseline linac beam has a 1 msec pulse length, 38 mA peak current and a repetition rate of 60 Hz. The beam is chopped for head-to-head injection into the Ring with a 68% duty cycle which results in a 1.6 mA average current. The SNS approach to beam commissioning of accelerator systems is to commission in modules, following the installation and testing of subsystems. To date there have been four beam commissioning runs, the H- injector, Drift Tube Linac tank 1, Drift Tube Linac tanks 1-3 and CCL modules 1-3. The availability of accelerator systems in each of these commissioning modules will be shown. A proactive "lessons learned" program using input from the commissioning runs, and R&D on marginal systems has resulted in increased availability in each successive module, despite the increasing number and complexity of systems being commissioned.

FRONT- END COMMISSIONING

The Front-End Systems were designed and built by Lawrence Berkeley National Laboratory (LBNL). The Front-End consists of an H- ion source followed by a low-energy beam transport (LEBT) section with electrostatic steering and choppers. This is followed by a 2.5 MeV RFQ which operates at , 402.5 MHz and a Medium Energy Beam Transport (MEBT) line which is used to sharpen the temporal profile of the chopped beam and to match the transverse and longitudinal of the beam to the DTL.

The overall downtime associated with equipment breakdown was 45.3% of planned machine available time. The largest contributors were:

- RF Systems: Infant mortality and design issues associated with the high voltage converter modulators. These systems have since been moved to the Power Supplies Group.
- Ion Source: Antenna lifetime and Source Vacuum
- Controls: EPICS Input-Output Controller
- Facilities: Chilled Water Systems

Lessons learned discussions led to a large number of improvements implemented on these systems.

- RF: Redesign and rework of marginal systems improved converter modulator availability on subsequent runs
- Ion Source: Began an R&D program on the ion-source hot spare test stand. Antenna lifetime was significantly increased to the point where it is not a significant contributor to accelerator downtime.

DRIFT TUBE LINAC TANK 1 and TANKS 1-3

The Drift Tube Linac consists of six accelerating tanks operating at 402.5 MHz with final output energy of 87 MeV. The transverse focusing is arranged in a FFODDO lattice utilizing permanent magnet quadrupoles. Some empty drift tubes contain beam position monitors and dipole correctors. The intertank sections contain BCMs, wire scanners and energy degrader/faraday cups (ED/FC). The first three of six DTL tanks were commissioned with beam in two separate runs. In the first run, DTL tank 1 (with output energy 7.5 MeV) was commissioned into a dedicated diagnostics package which was equipped with energy degrader/faraday cups, wire scanners, beam position monitors, a slit/harp emittance system, and a Bunch-Shape Monitor (BSM), which provided a detailed characterization of the output beam parameters.

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Additionally there was a full-power beamstop for a test of high-power operation. This was the last test of full power operation possible until the beam is delivered to the mercury neutron production target.

The goals of all commissioning runs have included a demonstration of complete system functionality. This includes accelerated beam with the design parameters up to the limits of the available beamstops and full functionality of the beam diagnostics. The runs are also used to use and further develop beam commissioning algorithms essential to future commissioning.

DRIFT TUBE LINAC TANKS 4-6 and CCL MODULES 1-3

The Coupled Cavity Linac consists of four accelerating Modules operating at 805 MHz with final output energy of 186 MeV. The transverse focusing is arranged in a FODO lattice utilizing electromagnet quadrupoles. The beam diagnostics include beam position/phase monitors, BCMs, BSMs wire scanners and an energy degrader/faraday cup (ED/FC).

The beam was drifted through CCL Module 4 so that it could be used as a portion of the delta-phi energy measurement technique. There was insufficient room between the end of Module 4 and the beamstop for a delta phi measurement. The final output beam energy in this beam commissioning phase was 157 MeV.

OPERABILITY RUN

Following the commissioning run for CCL Modules 1-3 we ran for a period of about one month as an operability test. During this run, all systems were operated but no beam was accelerated. For this to occur, the Ion Source was run out of time with respect to the accelerating RF. Operating statistics were taken as if a commissioning run were taking place.

OPERABILITY DURING COMMISSIONING

Beam operability accounting was done on a shift-by shift basis. The operating statistics were compiled weekly and at the end of the run. Beam time was divides into Planned Uptime and Planned Shutdown. Under Planned Uptime the time was broken down into:

- Machine On
- Machine Start Up/Shut Down
- Radiation Monitoring/Sweep
- Equipment Breakdown

Equipment Breakdown was divided by System, Sub System and Sub Sub System. The System category included:

- RF
- Controls
- Power Supplies
- Vacuum
- Water
- Ion Source
- Facilities
- Electrical
- Diagnostics
- Protection Systems
- Controls

Following each commissioning period, a series of Lessons Learned meetings was held. The major contributors to Equipment Breakdown were prioritized and addressed by the system owners and lead engineers usually in the form of a system upgrade. These upgrades were also applied to systems that had not yet been commissioned and to similar systems throughout the accelerator. In some cases R&D was needed on marginally available systems. An example of this was the Ion Source RF Antenna. Initially the lifetime of the antenna was quite short due to the aggressive nature of the hydrogen plasma in the ion source chamber. A program of R&D resulted in significantly longer lifetimes to the point where in the operability run following the last commissioning period, there was no down time associated with the Ion Source.

The application of the Lessons Learned meetings, resulting in prioritized system upgrades and R&D projects has been a powerful tool for improving the overall operational availability of SNS accelerator systems. This is shown in Table 1 which contains operational

Table 1. Operating Statistics for commissioning the Front End, DTL Tank 1 and DTL Tanks 1-3.

Commissioning Run	Front End	DTL1	DTL 1-3
	Percent	Percent	Percent
Total			
Planned Shutdown	1.6%	0.5%	3.6%
Planned Uptime			
Machine On Time	53.6%	62.5%	75.0%
Machine Start_Up	0.8%	0.9%	0.0%
Rad Monitoring/Tunnel Sweep/PPS	0.0%	0.4%	2.6%
Equipment Breakdown	45.3%	35.7%	18.8%
Breakdown			
RF	33.6%	27.9%	15.4%
Electrostatics			
Power Supplies	4.2%	22.3%	0.0%
Ion Source	31.7%	21.0%	5.6%
Facilities	9.7%	2.7%	0.0%
Electrical			
Cryogenics			
Diagnostics	6.9%	5.8%	0.0%
Protection Systems	0.0%	0.0%	0.9%
Controls	12.0%	17.2%	3.7%
Vacuum	2.0%	2.9%	0.0%
Water	0.0%	0.0%	74.4%

availability statistics for the first 3 SNS accelerator commissioning runs.

Table 1. Operating Statistics for commissioning DTL Tanks 4-6 and CCL Modules 1-3 plus the Operability Run.

DTL 4-6 thru CCL 3	Aug 6, 2004 thu Oct 17, 2004	Oct 18, 2004 thru Dec 15, 2004		Dec 15, 2004 thru Jan 18, 2005	
	Commissioning	Commissioning		Operability	
	Aug 6, 2004 thu Oct 17, 2004	Oct 18, 2004 thru Dec 15, 2004		Dec 15, 2004 thru Jan 18, 2005	
	Percent	Hours	Percent	Hours	Percent
Total		1382.0	100%	852.0	100%
Planned Shutdown	6.6%	554.5	40.1%	367.0	43.1%
Planned Uptime	93.4%	827.5	59.9%	485.0	56.9%
Machine On Time	57.5%	680.4	82.2%	408.4	84.2%
Machine Start_Up	7.1%	12.0	1.5%	10.9	2.2%
Rad Monitoring/Tunnel Sweep/PPS	0.2%	3.0	0.4%	8.5	1.8%
Equipment Breakdown	35.3%	132.1	16.0%	57.3	11.8%
Breakdown					
RF	43.9%	82.4	62.4%	39.0	68.1%
Electrostatics	0.2%				
Power Supplies	2.3%	5.7	4.3%	6.8	11.8%
Ion Source	15.4%	4.9	3.7%	0.0	0.0%
Facilities	0.3%	10.2	7.7%	0.0	0.0%
Electrical	0.3%				
Cryogenics	19.4%	1.3	0.9%	0.0	0.0%
Diagnostics	0.0%	0.0	0.0%	0.0	0.0%
Protection Systems	2.5%	9.0	6.8%	2.0	3.5%
Controls	10.2%	18.7	14.2%	2.5	4.4%
Vacuum	5.2%	0.0	0.0%	7.0	12.2%
Water	0.0%	0.0	0.0%	0.0	0.0%

The Equipment Breakdown as a fraction of Planned Uptime decreased in every commissioning run despite the increasing complexity as additional systems are commissioned. The Equipment Breakdown decreased from 45.3% during Front End Commissioning to 11.8% in the Operability run following DTL4-6 and CCL 1-3 commissioning.

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