COMMISSIONING PLANS FOR THE SNS DTL AND CCL*

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Abstract

The Front End (FE) of the Spallation Neutron Source (SNS) will be commissioned at ORNL during the autumn of 2002. The Drift Tube Linac (DTL) and Cavity Coupled Linac (CCL) will be commissioned next. The delivery of beam to the Super Conducting Linac (SCL), is planned for August 2004. This paper describes the commissioning plans for the DTL and CCL parts of the linac. Techniques for finding the RF set-point, matching and steering are touched upon, as well as the order in which these will be used. Typical beam parameters, as proposed for commissioning purposes, are discussed as well as how commissioning fits together with ongoing installation work in the tunnel.

1 INSTALLATION, TESTING AND COMMISSIONING SEQUENCE

The FE of the SNS [1][2], consisting of an H- source, a Low Energy Beam Transport (LEBT), an RFQ and a Medium Energy Beam Transport (MEBT), has been commissioned at LBNL [3] and will be re-commissioned at ORNL during the autumn of 2002, after which DTL commissioning commences. In parallel with FE installation and re-commissioning, installation of DTL related equipment is and will be ongoing.

The SNS DTL operates at 402.5 MHz and consists of 6 tanks (DTL1 to DTL6). During FE commissioning there will be diagnostics downstream of the MEBT and therefore DTL1 must be installed later. Similarly, during DTL1 commissioning there will be diagnostics downstream of the DTL1 tank, therefore DTL2 cannot be installed at that time. For this reason DTL3 was the first tank to have been produced and will be used to prove the integration tests of all DTL3 systems.

All DTL tanks and CCL modules will be tested, prior to commissioning, in a similar way: Once equipment or sub-systems like RF, vacuum, diagnostics, controls, cooling etc. have been installed, this equipment will be tested and integrated (without beam) before the actual commissioning (i.e. with beam) will start. Testing will firstly consist of a "vertical" part (each sub-system will be fully tested individually) and subsequently of a "horizontal" part (all sub-systems are tested simultaneously). One will then proceed with the conditioning of the tanks at high RF power level (both manual and computerized control are foreseen). For some sub-systems, like diagnostics, beam will be needed to fully demonstrate their functionality. For this purpose dedicated time is foreseen at the start of commissioning.

The SNS DTL will be commissioned in 2 phases. During the first phase, DTL1 will be commissioned, using a dedicated set of diagnostics installed on a so-called diagnostics- or D-plate (see Fig. 1) [4]. During DTL1 commissioning, installation and testing of the other DTL tanks will continue. Once DTL1 commissioning has finished, the D-plate will be replaced by DTL2 and DTL installation and testing will be completed. Note that by this time the first CCL module will also have been installed in the tunnel.

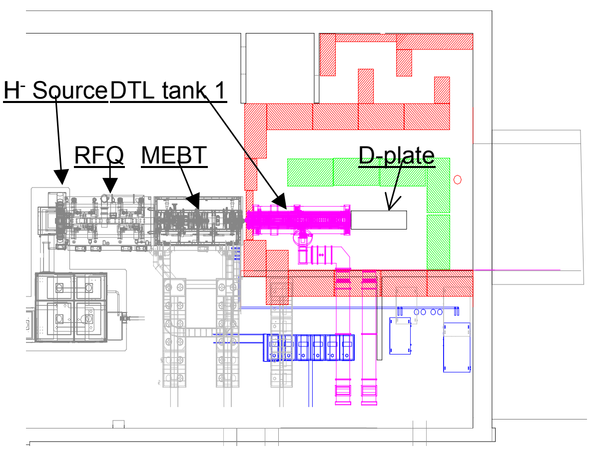

Figure 1: DTL tank 1 and its dedicated D-plate are surrounded by shielding walls. The H- source, RFQ and MEBT are also shown.

During the second phase, DTL2 to DTL6 will be commissioned one after the other with the same in-line diagnostics that will be used during operation. For DTL6 much of the diagnostics is in fact housed in the first CCL module.

Once the DTL is commissioned, the 4 modules that make up the CCL will be commissioned in sequence, again using in-line diagnostics, starting in May 2004.

2 COMMISSIONING GOALS

The initial requirement on the beam for the SNS project is to deliver $1*10^{13}$ ppp (particles per pulse) on target for commissioning. The primary goal set out for DTL-CCL commissioning is to deliver $2*10^{13}$ ppp at the correct energy to the SCL.

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The average power of the beam during commissioning is limited by the “beam stop” used (see Table 1). As a consequence, production beam parameters will need to be independently demonstrated. For comparison, parameters for the production beam out of the SCL are also given.

Table 1: Typical beam powers during commissioning

	W_{out} (MeV)	I_{peak} (mA)	τ (μsec)	PRF (Hz)	P_{ave} (kW)
DTL 1	7.5	10-38*	0.3-1000	1-60	11.7
DTL 2-6	23-87	10-38	0.3-50	1-10	0.165
CCL 1-4	107-186	10-38	0.3-50	1	0.24
SCL(prod.)	1000	38	1000	60	1400

*chopped to 26 mA

Other commissioning goals are achieving the design beam quality, measuring the pulse to pulse jitter in beam parameters (e.g. beam centre), quantifying beam loss and achieving the maximum peak current possible. Table 2 lists some of the diagnostics that will be used for these purposes: BPM (beam position monitor), BCM (beam current monitor), WS (wire scanner) and BLM (beam loss monitor).

Table 2: Typical requirements for diagnostics; the BPM phase precision is in degrees of the processing frequency

Diagnostic	Range	Precision	Beam	τ_{beam}
BPM phase	0-360°	±2°	≥10 mA	≥50 μsec
Position (DTL)	±6.5 mm	±0.4 mm	≥10 mA	≥300 nsec
Position (CCL)	±7.5 mm	±0.4 mm	≥10 mA	≥300 nsec
BCM	1-50 mA	50μA		≥300 nsec
WS position	±15 mm	±0.2mm	≥10 mA	50 μsec
FWHM		10%		
BLM	-	0.1 W/m	≥50 MeV	≥50 μsec

The next paragraphs give an overview of the commissioning plans for the DTL and CCL. Detailed simulation results for some of the techniques used for commissioning can be found an accompanying papers [5], [6].

3 DTL TANK 1 COMMISSIONING

By the end of FE commissioning, the 2.5 MeV MEBT beam will have been characterized and tuning, steering and matching algorithms will have been validated for the FE. DTL1 commissioning can then proceed with the measurements as listed in Table 3.

Table 3: DTL1 measurements with D-plate

Measurement	Technique	Diagnostic
rf ϕ & amp.	ϕ_{out} vs. ϕ_{rf} ϕ acceptance vs. amp.	1 BPM Faraday cup/degrader
Acceptance (transverse)	transmission vs. steering	CM & Faraday cup
$\varepsilon_{x\&y}$		D-plate slit & collector
Profile (transverse)	calibrate permanent WS	Wire scanner
steering	validate algorithm	D-plate slit & collector
MEBT matching (transverse)	validate algorithm	D-plate slit & collector
MEBT matching (longitudinal)	ϕ separatrix scan	Faraday cup/degrader
production beam demo	26 mA (chopped) @ 6%	D-plate dump

The RF set point will need to be determined first; this is done by means of a phase scan: one observes the beam induced phase difference between BPMs (Beam Position Monitor), placed 6βλ (one period) apart, as a function of RF phase and repeats this scan for different RF amplitudes.

For longitudinal matching, typically the last two of the 4 MEBT bunchers will be used. Their effect may be observed with the BPMs on the D-plate (Fig. 2).

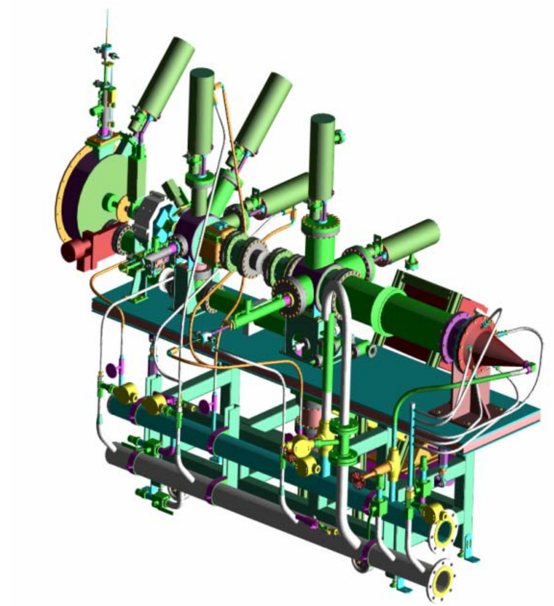

Figure 2: A schematic layout of the D-plate, which will be used during DTL1 commissioning.

For transverse matching, mainly the last four quadrupoles in the MEBT will be used (the transverse focusing within the DTL consists of permanent magnet quadrupoles) for adjustment, and the slit and collector emittance measurement device on the D-plate will be the primary diagnostic. The emittance measurement results will subsequently be analyzed with a computer program developed for this purpose [7]. This program, which has already been used during FE commissioning, takes specific care of estimating realistic emittance values for measurements, which contain bias and noise.

In order to control beam loss, initially BCMs will be used. Currently BLMs are being developed for the DTL. These will be low energy neutron detectors, consisting of a photo multiplier, scintillator and amplifier with a remotely controlled gain coefficient.

4 DTL TANK 1-6 COMMISSIONING

Once DTL1 has been commissioned and the D-plate has been replaced by DTL2, DTL commissioning will proceed, using in-line diagnostics only [8]. It will include re-commissioning of DTL1. The commissioning will be an iterative process, consisting of measurements as listed in Table 4.

Table 4: DTL measurements with in-line diagnostics

Measurement	Technique	Diagnostic
rf ϕ & amp.	ϕ_{out} vs. ϕ_{rf}	1 BPM
	$\Delta\phi_{out}$ vs. ϕ_{rf}	2 BPMs
	ϕ acceptance vs. amp.	Faraday cup/degrader
Profile (transverse)	wire scanner	permanent WS
steering	validate algorithms	BPMs & BLMs

The RF set point for most of the DTL tanks can be determined by means of phase scans. Absorber-collector arrangements are located behind each DTL tank and will serve to confirm the RF set-point found with the phase scans. For DTL6 only acceptance scans will be used.

For steering purposes, 2 individually powered steering correctors per plane and per tank are housed inside drift tubes that do not contain quadrupoles. For each tank their action on the beam will be observed with 2 dual plane BPMs.

5 CCL COMMISSIONING

The CCL, consisting of 4 modules with 12 segments each (see Fig. 3), will operate at double the DTL frequency (i.e. 805 MHz).

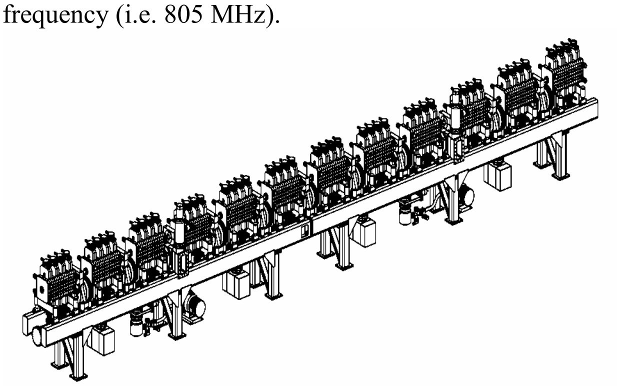

Figure 3: 12 segments of a CCL module

As with the DTL, the commissioning of the CCL will be an iterative process of measurements (see Table 5).

Table 5: CCL measurements with in-line diagnostics

Measurement	Technique	Diagnostic
rf ϕ & amp.	$\Delta\phi_{out}$ vs. ϕ_{rf}	BPMs
	ΔT	BPMs
	beamloading scan	RF Fw/Rv
transverse matching	minimize envelope breathing	WSs
steering	minimum steering	BPMs & BLMs

A coarse setting for the RF set-point can easily be obtained by means of phase scan matching [9]. The fine tuning of this set-point is subsequently obtained using the delta-t method [10].

With the diagnostics discussed so far, one depends solely on the model for the longitudinal matching from DTL to CCL. Bunch Shape Monitors (BSM) can provide a unique opportunity to verify the longitudinal matching and RF set-point experimentally, and will therefore be used [11].

In the CCL, beam loss will be controlled with fast ionization chambers.

6 CONCLUSION

The commissioning plans and goals for the SNS DTL and CCL have been established. Currently installation work for DTL equipment is well underway to allow for DTL commissioning to start in early spring 2003, which will be followed by CCL commissioning in spring 2004.

7 ACKNOWLEDGEMENTS

Many more people than those in the author list have contributed to these commissioning plans; we are grateful to all of them.

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