

## INSTALLATION AND TESTING OF SNS MAGNET POWER SUPPLIES\*

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### Abstract

This paper describes the types and quantities of dc and pulsed magnet power supplies required for the Spallation Neutron Source (SNS) Linear Accelerator: High-Energy Beam Transport (HEBT), Ring and the Ring-to-Target Beam Transfer (RTBT). There are over 600 magnets and more than 550 magnet power supplies. These magnet power supplies range in size from the bipolar corrector supplies rated at 35 volts, 20 amps to the main-ring dipole supply that is rated at 440 volts, 6000 amps. The Linac power supplies have a ripple/stability specification of 1000 parts per million while the ring supplies have a specification of 100 parts per million. There are also pulsed-power supplies for beam injection and beam extraction. The paper will show acceptance test results from the manufacturers as well as test results performed by the SNS magnet power supply group.

### INTRODUCTION

The SNS Accelerator is comprised of four main sections: the Linac, High-Energy Beam Transport (HEBT), Ring and Ring-to-Target Beam Transfer (RTBT). The Linac consists of subsystems: the Ion Source, Radio Frequency Quadrupole (RFQ), Low-Energy Beam Transport (LEBT), Drift-Tube Linac (DTL), Coupled-Cavity Linac (CCL) and the Super-Conducting Linac (SCL). Other areas of the accelerator are the HEBT, Ring and RTBT, which have DC quadrupole, steering and dipole magnet supplies. The Ring Service Building houses the injection and extraction pulsed magnet supplies.

### BIPOLAR MAGNET SUPPLIES

Danfysik manufactured 355 bipolar corrector magnet power supplies (Model 896), which were the first supplies to arrive at Oak Ridge. The supplies underwent extensive testing at the factory as well as testing at SNS. Testing included verifying the digital interlocks and running each unit for eight hours at varied current levels. The supplies are capable of a voltage output of +/- 35 or 75-volts with a current of +/- 20 amps. These supplies have a frequency response of 1 kHz. The voltage is selectable by transformer terminal jumpers. Most of the supplies only require the 35-volt level so the tests were

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performed at this setting. Where cable lengths are very long, the 75-volt output will be used. The corrector units are utilized in the DTL Section of the Linac in a Master-Slave configuration. They can be Master-Slaved up to seven units for an output of +/- 140 amps. When wired as Master-Slave units, the Master is the only unit which has active readouts and interlock indicators. The DTL has eighty-four units which make up 24 individual power supplies for the DTL dipole magnets. These corrector power supplies are used throughout the accelerator. The DTL supplies have been installed and operational since June, 2004.



Figure 1: Four of the DTL dipole magnet corrector power supplies, Master-Slaved to +/- 100 amps.

Innovative additions to the magnet power supply remote-control area are the power supply controller (PSC) and the power supply interface (PSI) [1] units developed by BNL engineers and Apogee Labs of North Wales, PA. It has always been time consuming and arduous, when using an assortment of manufacturers' power supplies,

endeavoring to interface to a central remote-control system. The SNS magnet power supplies were specified to have one type of interface, which would connect and interface directly to the PSI. The PSI and PSC are fiber-optically isolated so there is minimum noise interference from the power-supply circuits. LabView programs were written to test each supply. The program records the current, voltage, error and current set-point from the PSI. Another external DCCT was used to calibrate the central computer remote set-points and read-backs to the Central Control Room (CCR).

### COUPLED CAVITY LINAC (CCL)

IE Power, Inc., Toronto, Canada, is the supplier of the CCL magnet power supplies. Two models of supplies are used in the CCL. One is rated at 400-amps and 20-volts. This supply is used where there is a need to control the current of only one magnet. Seven units of this type are



Figure 2: CCL power supplies and current shunts.

utilized. The other supply is rated at 375-amps, 80-volts. This unit supplies eight magnets wired in series. Each magnet has an electronically-adjustable current shunt of 0-30 amps, manufactured by Alpha Scientific of Hayward, CA. The shunts allow the current in each magnet to be decreased from 0-30 amps from the magnets supplies' output current. Utilizing the shunts minimizes the number of power supplies required in the CCL Section of the Linac. There are a total of five power supplies with forty current shunts. Both ripple and stability are specified to be less than 1000 ppm (.1%). These supplies have been installed and operational since August, 2004.

### SUPER-CONDUCTING LINAC (SCL)

Alpha Scientific of Hayward, CA, is the vendor of the SCL magnet power supplies. There are a total of thirty-nine of these supplies in the SCL Section of the accelerator. Most of the supplies provide current to a doublet magnet, i.e., a horizontal and vertical quadrupole located on the same platform, one after the other. They are located in the warm sections between the Super-

Conducting Linac cavities. Eleven out of the thirty-nine power supplies provide current to only one magnet, while the rest are to doublets (two magnets).

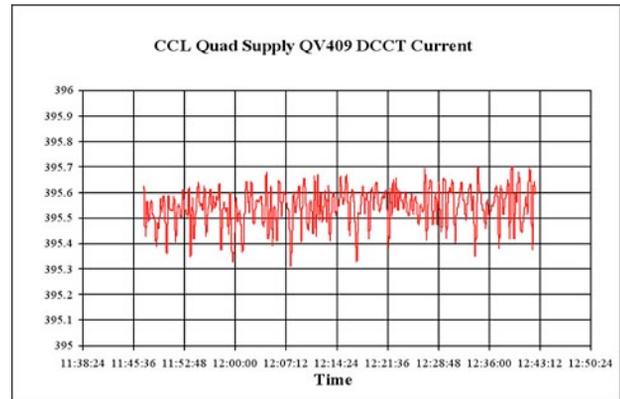


Figure 3: Current of CCL supply, 400A20V.

These supplies were specified to have a ripple and stability of less than 1000 ppm. All have been installed, tested and are ready for beam.

### HIGH-ENERGY BEAM TRANSPORT

The HEBT begins at the end of the SCL Linac and stops at the ring injection area. This section has larger magnets, which are needed to focus the higher-energy beam. The Linac beam dump and the larger dipoles that bend the beam to the injection area are located in this area. The HEBT Service Building houses twenty-two medium size power supplies, which provide current to the



Figure 4: HEBT Quadrupole and Dipole power supplies.

HEBT magnets, as far as the ground break. The remaining HEBT supplies are located in the Ring Service Building. There are several models of magnet power supplies used in this section as well as in the Ring and RTBT. IE Power, Inc., Toronto, Canada, is the supplier of seventy-seven medium-power magnet supplies. There are twelve different models used. (Refer to Table 1.) Each magnet's current and voltage requirements were compared to these

Table 1: Medium-power dc magnet supplies

MODEL	QUANTITY BY SERVICE BUILDING				TOTAL UNITS
	HEBT LDMP	Ring IDMP	RTBT EDMP	SPARES	
UD185A27V		4		1	5
UD390A24V	12	3		1	16
UD700A18V	6	3	4		13
UD700A25V		1		1	2
UD900A51V	3	2	4		9
UD900A80V			3	1	4
UD1300A95V		4	4		8
UD1300A125V		1		1	2
UD1405A390V	1	6		1	8
UD2500A50V		1	1	1	3
UD4000A18V		6			6
UD5040A18V				1	1

models in order to minimize the number of sizes required. All of the supplies in the HEBT service building (22) have been installed and fully tested. All supplies were specified, tested and have a ripple/stability of less than 100 ppm (.01%).

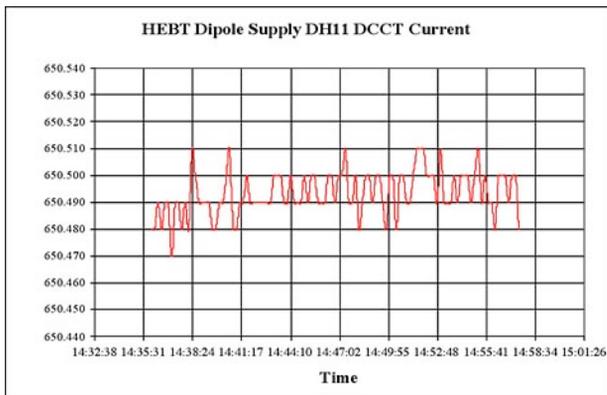


Figure 5: HEBT power supply 900A51V.

### RING PULSED POWER SUPPLIES

A unique injection bump power supply [2] was designed for the injection bump system. Eight individual magnets, driven by eight pulsed supplies, produce eight pulses, which must track [3] each other within .5%. The current pulses have a rise time of 2 ms with a flat top of 1ms and a fall time of .25 ms operating at a rep-rate of 60 Hz. These supplies have a specification of 1400 amps and +/- 800 volts.

The extraction kicker [4] system is comprised of fourteen Blumlein pulse-forming networks, which are thyatron switched to generate fourteen high-voltage (40kV), high-current (2500 amps) pulses, which have a rise time of 200 ns and a flat top of 700 ns and pulsing at 60 times a second. The kickers deflect the beam into the extraction septum's dc magnetic field. The field bends the beam into the RTBT line and then to the target, where upon collision produces the spallation of neutrons.

The Ring Service Building houses thirty-one medium-power dc magnet power supplies as well as the main ring dipole supply (6000A, 440V) and pulsed-power supplies: ring injection, extraction kickers. The medium-power, injector and the main ring dipole supplies were supplied

by IE Power, Inc., Toronto, Canada. The extraction kicker supplies were designed by BNL engineers and contracted, build-to-print, to Applied Power Systems, Inc., NY. All of the Ring and RTBT supplies have been installed with commissioning to begin in June, 2005.

### SUMMARY

All of the tested magnet power supplies, delivered to the SNS Project, have met or exceeded the ripple/stability specifications. There have been a few problems (less than 5%) during testing at Oak Ridge. These supplies were returned to the manufacturers for repairs. As of this writing, all supplies have been delivered and installed with over 50% tested. The remainder of the supplies will be tested by December, 2005.

### ACKNOWLEDGEMENTS

The HEBT, Ring and RTBT magnet power supplies were specified and contracted by BNL. I would like to express my gratitude to Bob Lambiase and Jon Sandberg of BNL for their long hours, dedication to writing power supply specifications and making sure that the SNS Project received quality and reliable magnet power supplies. Without their expertise and years of experience, SNS would not have the supplies we have today.

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