SPALLATION NEUTRON SOURCE CRYOGENIC TEST FACILITY HORIZONTAL TEST APPARATUS (HTA) OPERATION*

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Abstract

The Spallation Neutron Source (SNS) has built Superconducting Radio Frequency (SRF) processing and testing facilities to support improvement programs and future upgrades. The Cryogenic Test Facility (CTF) system is capable of delivering liquid helium at 4.5K to different test apparatus in support of SRF testing. This paper describes the final stages of fabrication, commissioning and the initial operation of the Horizontal Test Apparatus (HTA). The HTA allows for cold testing of single jacketed medium-beta or high-beta SRF cavities. Heat loads, capacities, and other performance data collected during operation will be presented. Cavity testing lifecycle for plasma processing research and development will be discussed. System changes to allow for 2K helium operation in the HTA will also be addressed.

INTRODUCTION

The Spallation Neutron Source contains a superconducting linear accelerator which consists of eleven medium beta and twelve high beta cryomodules. The availability and reliability of the cryomodules has been high. However, the superconducting section of the linear accelerator has not met the energy specification of 1 GeV [1]. To increase the energy of the beam and meet the future upgrade requirements, the performance of multiple cryomodules must be improved. SNS is currently installing and developing superconducting radiofrequency (SRF) processing and test facilities to develop methodology in increasing beam energy and facilitating necessary repairs. Part of this recent development work was the commissioning of the Cryogenic Test Facility (CTF) standalone refrigeration system which is capable of providing helium at both 4.5 K and 2 K to the SRF test facilities [2].

One promising technique currently under development at SNS in the SRF facilities is the use of cold plasma to process impurities on the inner surface of SRF cavities [3]. Plasma cleaning utilizes the RF system of the cavities to cause ignition of small amounts of gas injected into the beam line vacuum space of the cavity. Extensive bench testing has been conducted on warm cavities to develop the correct gas mixture and RF techniques for plasma ignition. Earlier this year, cryogenic testing of a plasma processed cavity occurred in the Vertical Test Apparatus (VTA) connected to the CTF. This VTA test was conducted on an undressed high beta SNS cavity. One drawback to the VTA testing of plasma processed cavities is that the cavity has to be removed from the VTA for processing to occur. The motivation for using Horizontal Test Apparatus (HTA) as the primary vehicle for plasma R&D is that a dressed cavity could have cryogenic testing and plasma processing performed without the removal of the cavity from the HTA. The use of plasma to clean cryomodules in the SNS LINAC represents the final stage of the current R&D plan [4].

HTA DESCRIPTION

The purpose of the HTA is to allow for the cryogenic testing in liquid helium at either 4.5 K or 2K of dressed medium beta and high beta cavities and to support in-place plasma processing. The features of the HTA include: vacuum vessel with two large doors on either side to allow internal access, helium cooled copper thermal shields, cryogenic bayonet connections to the CTF, cryogenic helium control valves, an internal liquid helium dewar with level probe, diagnostic heaters, pressure and temperature instrumentation, a cavity beam line warm-to-cold (WTC) piping through the vacuum vessel, and a gas manifold for supplying plasma R&D gases.

The HTA was designed by SNS personnel and fabricated in 2005 by Alloy Fabrication. The vessel was originally fabricated as a vacuum vessel with thermal shields, but without any internal cryogenic piping or cavity support mechanism. In 2012, the HTA design was completed and Ability Engineering installed the cavity rail support mechanism and all cryogenic helium components. This Ability design allows for a cavity to be inserted and removed from the HTA through use of an electric lift. The rail system of the lift matches the rail system of the HTA allowing the cavity to be slid into the vessel. This cavity insertion is shown in Fig. 1.

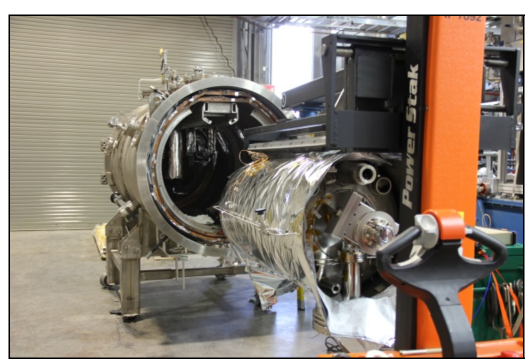

Figure 1: HTA cavity insertion.

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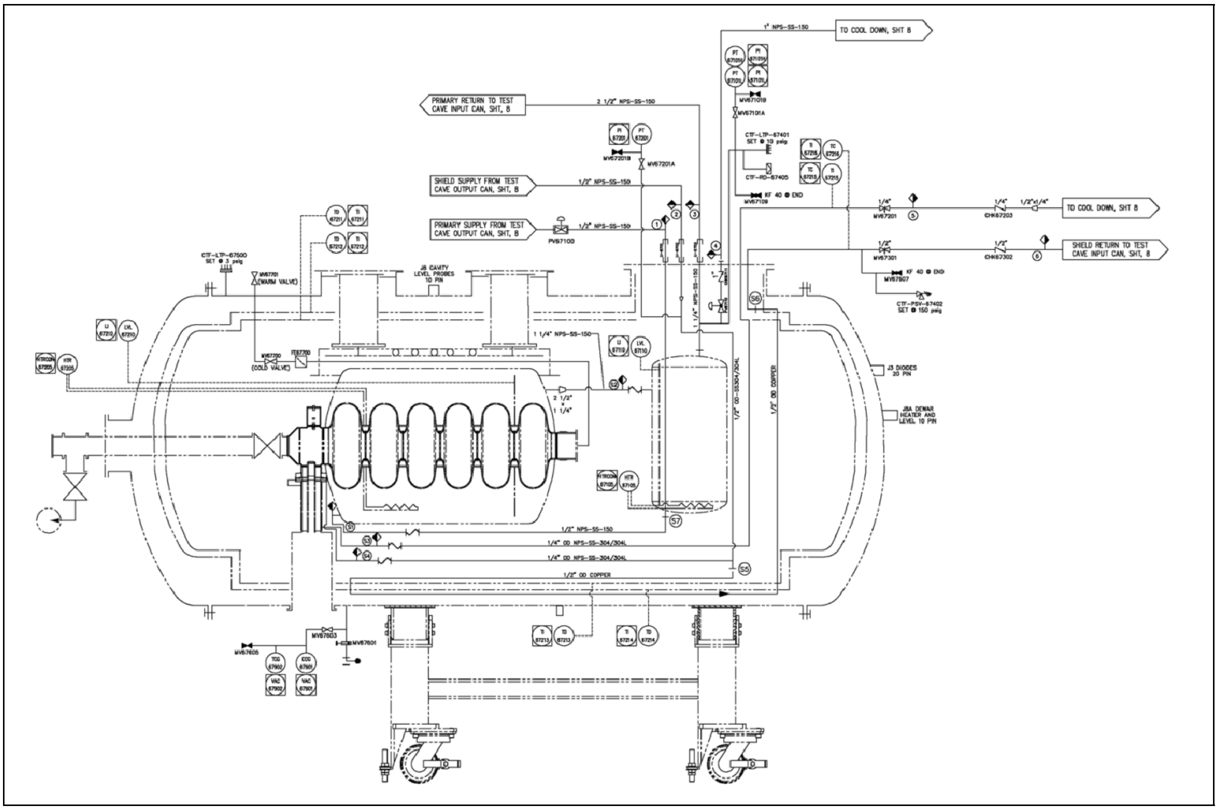

Figure 2: HTA Process and Instrumentation Drawing (P&ID).

The HTA is designed for helium to cool the primary cavity circuit, the thermal shields and the coupler. The process and instrumentation drawing is shown in Fig. 2. The HTA has different bayonet connections for the helium supplies to the shield and the primary cavity circuits. The primary circuit is responsible for supercritical helium supply at 5 K to the cavity and internal HTA dewar. The shield circuit supplies supercritical helium at 5 K for coupler cooling and shield cooling. Cryogenic valves control the flow of helium to the shield and regulate the exhaust temperature to approximately 60 K. A backpressure control valve on the shield circuit regulates the pressure in the shield above the cricital pressure of helium so that liquid helium accumulation within the shield is avoided.

The CTF system supplies supercritical helium at 3 atm to the Distribution Box (DB). Inside the distribution box is located a large aluminium heat exchanger to allow for cooling of the primary helium supply during 2 K operation.

The WTC design of the HTA serves several purposes. It is designed in two pieces fit through the vacuum vessel movable door. The WTC does not have any bends, which will allow a camera to monitor the plasma ignition through a sapphire window on the instrumentation cross. The WTC was cleaned inside the RFTF clean room and then installed on the HTA under portable cleanroom conditions to maintain the cleanliness standards while continuously pumping on the cavity beam line vacuum.

TESTING RESULTS

In June of 2014, the high beta cavity HB59 was installed in the HTA and the entire assembly was positioned inside the RF Test Facility (RFTF) test cave and connected to the CTF cryogenic transfer line as shown in Fig. 3.

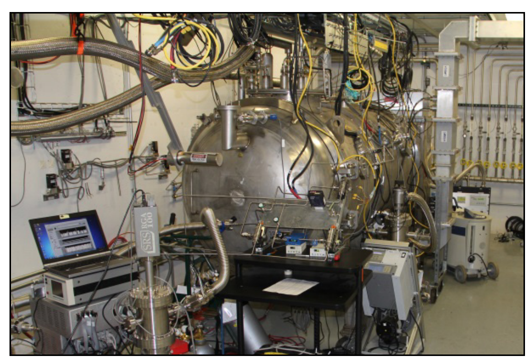

Figure 3: HTA inside RFTF test cave.

Due to the position of the 2 K heat exchanger inside the DB, the CTF coldbox, CTF dewar, transfer line and HTA needed to be cooled in parallel with close monitoring and regulation of the return temperature from the HTA. The purpose of this joined process is to protect the heat exchanger from excessive thermal stress. The maximum differential temperature allowed between the supply and return helium flows is 100 K. As a result of this constraint, the cool down of the primary circuit of the system was very slow. The rate achieved was about 10 K/hr with liquid accumulation observed in the HTA 27 hours after starting. This differs from previous cryomodule cool downs in the test cave which are regulated to 100 K/hr cool down rate for the cavities. The shield circuit of the HTA was cold and regulating as desired after only 6 hours as seen in Fig. 4.

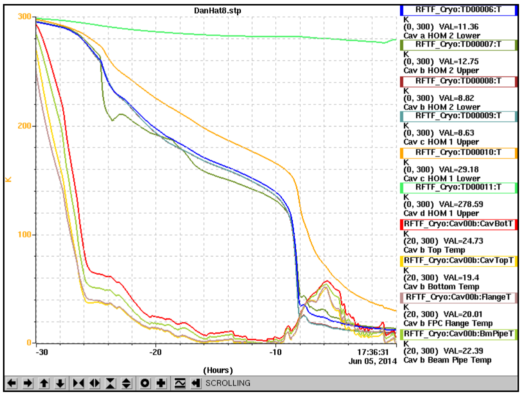

Figure 4: HTA cooldown graph.

Once liquid regulation was stable through the use of a cryogenic JT supply valve, heater power was slowly added to the liquid helium bath to determine the refrigeration capacity of the system at 4.5 K. The two heaters inside the HTA, one on the cavity and one on the internal dewar, were used in parallel. Together 230 W of heater power was added to the HTA liquid helium bath without any drop in liquid level in the CTF dewar, indicating stable steady state plant operation. Loop tuning on the plant side would be required for additional power to be added to the HTA.

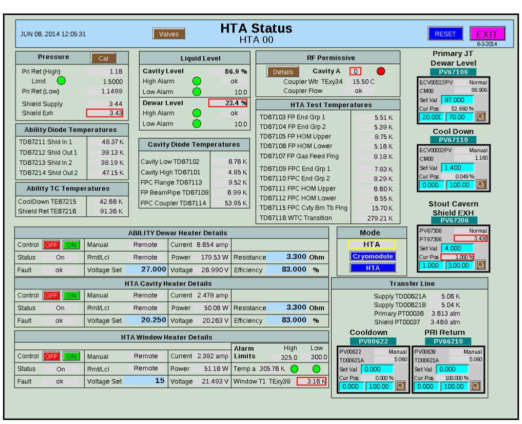

Figure 5: HTA EPICS control screen.

Prior to the termination of testing the HTA, an attempt was made to determine the static heat load to the helium cryogenic bath. Computer aided design (CAD) models of the HTA were used to determine the volume change of helium, both in the cavity and the internal HTA dewar, as a function of linear height. Flow to the cavity was stopped by closing the supply JT valve while allowing the shield to remain cold. The liquid level drop on the cavity level probe starting at 83% and dropping to 76% was recorded over a period of about 80 minutes. From these measurements, the static heat load of the HTA is determined to be 7.9 W. The pressure of the helium bath during this test was observed to be constant at 1.3 atm.

It is expected that 2 K capability of the CTF system will be available later in the fall of 2014. At this time, additional cryogenic testing and capacity measurements will be performed on the HTA.

CONCLUSIONS

The initial cryogenic commissioning of the HTA was a success. The vessel was able to integrate with the previously commissioned CTF system and control all required temperatures and pressure. The calculated static heat is acceptable and will allow for future 2 K operation of the HTA. The available steady state refrigeration capacity of the HTA exceeds expectations.

During the summer of 2014, the HTA will experience several cool downs to allow for successive RF measurements of the high beta cavity currently installed. In-between periods of cryogenic operation, a neon/oxygen mixture of gas will flow into the cavity beam line vacuum space to allow for R&D on a plasma processing technique for cleaning the inner surfaces of Niobium cavities. The successfully commissioned HTA system is poised to support these activities.

ACKNOWLEDGMENTS

We would like to thank all of the people that have made the fabrication, installation and commissioning of the HTA vessel possible. We recognize the dedication and hard work put forth by the SNS, Alloy Fabrication and Ability Engineering teams.

REFERENCES

[1] Kim, S-H., "SNS Superconducting Linac Operating Expereince and Upgrade Path", LINAC'08, Victoria Canada, September 2008.
[2] Howell, M., "Status of Spallation Neutron Source Cryogenic Test Facility", PAC2013, Pasadena, CA, September 2013, p. 1292 (2013).
[3] Kim, S-H., "R&D Status for In-Situ Plasma Cleaning of SRF Cavities at Spallation Neutron Source", PAC2011, New York, NY, October 2011, p. 2124 (2011).
[4] Doleans, M., "Plasma Processing R&D for the Superconducting Linac RF Cavities", SRF2013, Paris, France, September 2013, p. 545 (2013).

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