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SNS Cryogenic Test Facility Kinney Vacuum Pump Commissioning and Operation at 2 K

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Abstract. The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) has built and commissioned an independent Cryogenic Test Facility (CTF) in support of testing in the Radio-frequency Test Facility (RFTF). Superconducting Radio-frequency Cavity (SRF) testing was initially conducted with the CTF cold box at 4.5 K. A Kinney vacuum pump skid consisting of a roots blower with a liquid ring backing pump was recently added to the CTF system to provide testing capabilities at 2 K. System design, pump refurbishment and installation of the Kinney pump will be presented. During the commissioning and initial testing period with the Kinney pump, several barriers to achieve reliable operation were experienced. Details of these lessons learned and improvements to skid operations will be presented. Pump capacity data will also be presented.

1. Background

The Spallation Neutron Source (SNS) operates a Superconducting Linac (SCL) containing 81 Superconducting Radio-frequency (SRF) cavities housed in 11 medium-beta and 12 high-beta cryomodules. In support of the reliable operation of these SRF cavities, the Cryogenic Test Facility (CTF) was commissioned in 2013 to provide 4.5 K cooling for both single cavity and cryomodule testing in the Radio-frequency Test Facility (RFTF). [1] During the construction of the CTF, provisions were included for an upgrade to ~2 K cooling capability. Since the cavities in the SCL operate in a liquid helium bath at 2.1 K, there was a need to increase the testing capability of CTF to accurately emulate SCL conditions.

To facilitate dropping the temperature of the CTF system, a warm vacuum Kinney pump skid was added to decrease the operating pressure of the liquid helium bath from 1 atm (760 torr) down to 0.042 atm (32 torr). This new operating pressure correlates to a two phase bath temperature of 2.1 K.

The Kinney pump skid is a two stage helium vacuum skid originally assembled by Kinney/Tuthill Vacuum. [2] The first stage is a model number KMBD-9400 roots blower. The second stage is a model number KLRC-2100 liquid ring pump. This pumping configuration has an ultimate pressure of about 0.001 atm (1 torr). The skid occupies a large footprint at nearly 15 feet by 11 feet. However, this space also contains an independent oil pump, a bulk oil separator, a single stage oil coalescer, cooling water circuits for both pumps and all necessary internal piping.

ORNL had originally acquired two Kinney skids during the original SNS project as a backup to the Central Helium Liquefier (CHL) 2-K cold box. Since commissioning of the 2-K cold box was successful, the Kinney pumps were not used in the CHL. In preparation of advancing the capabilities of the CTF, one of these skids was shipped to Fermi National Accelerator Laboratory (FNAL) for hardware and software modifications. At the time they were operating two Kinney skids, identical to the SNS skid, with their custom modifications. [3] Some of these modifications include new controls PLC hardware, new controls ladder logic including all necessary trip conditions, helium guard assembly for the roots blower shaft, and helium guard enclosures at both ends of the liquid ring pump.

The skid is installed at SNS in the CHL compressor building allowing use of the trench surrounding the CHL compressors to route all the process piping to and from the Kinney skid. A large 8-inch diameter pipe connects the skid suction to the common pumping manifold of the RFTF test cave and the VTA. 2-inch piping allows the skid to discharge into the suction of two CHL recovery compressors. Figure 1 shows the Kinney skid connected to the CTF piping utilizing the CHL trench.

Figure 1. Operational Kinney pump skid connected to CTF piping

Each of the CHL RS compressors is capable of pumping 20 g/s, and allows the Kinney skid to function in a closed cycle with the CTF. One benefit of this configuration is that these recovery compressors discharge into the CHL purifier, allowing any contamination from the Kinney skid to be removed before the compressed helium enters the CTF cold box.

Figure 2 shows how the Kinney is fully integrated into the CTF refrigeration cycle. Once the test load, either the RFTF test cave or the VTA is full of liquid helium at 4.5 K, manual valves are used to start the pump down procedure. A small manual valve at the inlet of the skid is slowly opened to begin flow to the Kinney pump while the manual bypass valve around the Kinney skid is simultaneously closed.

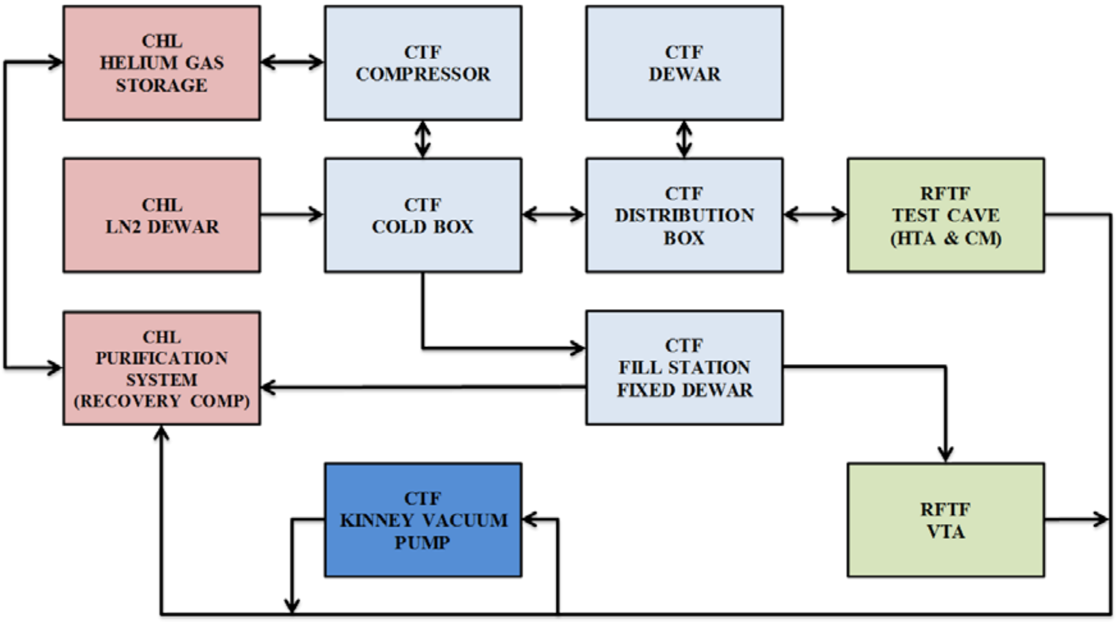

Figure 2. CTF system block flow diagram with Kinney vacuum pump

2. Pump Commissioning

The initial turn on and commissioning of the Kinney skid went very well. The liquid ring pump was started first and successfully established a stable suction pressure of 0.04 atm (30 torr). After the first several hours of blower operation with stable suction pressure less than 0.002 atm (1 torr), the skid oil level in the bulk oil separator was observed to have dropped significantly. Upon investigation it was discovered that oil injected into the inlet of the blower was migrating to the vertical section of the suction piping and pooling on the top of the inlet valve matrix.

Figure 3. Kinney inlet piping after addition of u-bend

Figure 4. Kinney inlet piping during initial commissioning

This oil injection into the inlet of the blower is necessary to decrease the operating temperature through removing the heat of compression of the helium gas. It was then necessary to modify the inlet piping so that oil could not migrate backwards into the suction piping. A 2-foot vertical section of pipe was added to create a u-bend section. After this modification, no further oil was observed on the inlet valve assembly. Figures 3 and 4 show before and after images of this change to the inlet piping.

Shortly after the first successful VTA test, the blower exhibited increased vibration. After about 20 hours of operation, the blower vibration level was approaching the analog PLC trip limit at 0.9 in-s. Attempts to restart the blower after this trip limit was exceeded were unsuccessful. Further investigation of the blower revealed that the shaft was not rotating, even with the mechanical assistance of a cheater-bar. The blower was then sent back to the manufacturer for repair and refurbishment.

During the repair, two discoveries were made. First there was a small section of scarring on both sides of the blower lobes that may represent a particulate from the suction piping. This represents the likely cause of the rotors seizing. The source of the particulate is still unknown, however it is suspected to be a spur leftover from the inlet piping repair. In spite of significant effort being placed into the cleanup of the piping after the repair, a single piece was enough to lock the rotors.

In order to address the issue of further process contaminants from the suction piping affecting the reliable operation of the Kinney blower, a screen was added inside the suction piping right in front of the blower inlet. The screen is a cone shape with 1/8-inch holes. The geometry allows for 80 percent of the effective cross sectional area to be available. The screen was placed inside the sealing o-ring between the blower suction and the flange on the suction piping. Tack welds were used to hold the ring centered in the suction piping. Operation with the screen had shown no appreciable pressure drop leading to a decrease in pump capacity. Figure 5 shows the screen before installation into the Kinney suction piping.

Figure 5. Screen installed at the inlet of the Kinney blower

The second discovery during the repair of the blower was the impending failure of one of the drive end bearings. This was an unexpected discovery because these bearing had been replaced during the FNAL modifications. It was uncovered that one of the blower oil spray nozzles was plugged. Without oil cooling for the bearing being supplied from this nozzle, the bearing would have failed prematurely.

The blower has a separate oil circuit from the rest of the skid. The non-drive end of the blower is geared to a small separate oil pump that operates whenever the rotors are spinning. This circuit has 6 parallel spray points throughout the blower assembly on both the drive and non-drive ends. While the pressure from this oil pump is measured and the blower will trip on low blower oil pressure, the parallel nature of the flow makes monitoring each individual nozzle very difficult. This circuit was assembled with pipe fittings coated in hard epoxy. It is believed that a small piece of cured epoxy had broken free and plugged the nozzle that sprayed the drive end bearing. The recommendation from the manufacturer was to rebuild the oil circuit using Loctite #567 instead of epoxy. Additionally, the outside of the blower housing was instrumented with diodes to hopefully catch any overheating due to a plugged nozzle before any damage could occur.

The skid was returned, reinstalled on the skid and commissioned with the CTF system. The initial month of operation was very successful, including a multi-day test on the VTA system. However, the week after this test, the blower exhibited excessive vibration on an attempted start. Unfortunately, after consultation with the manufacturer, the blower was once again sent back to the factory to inspection and rebuild, if necessary.

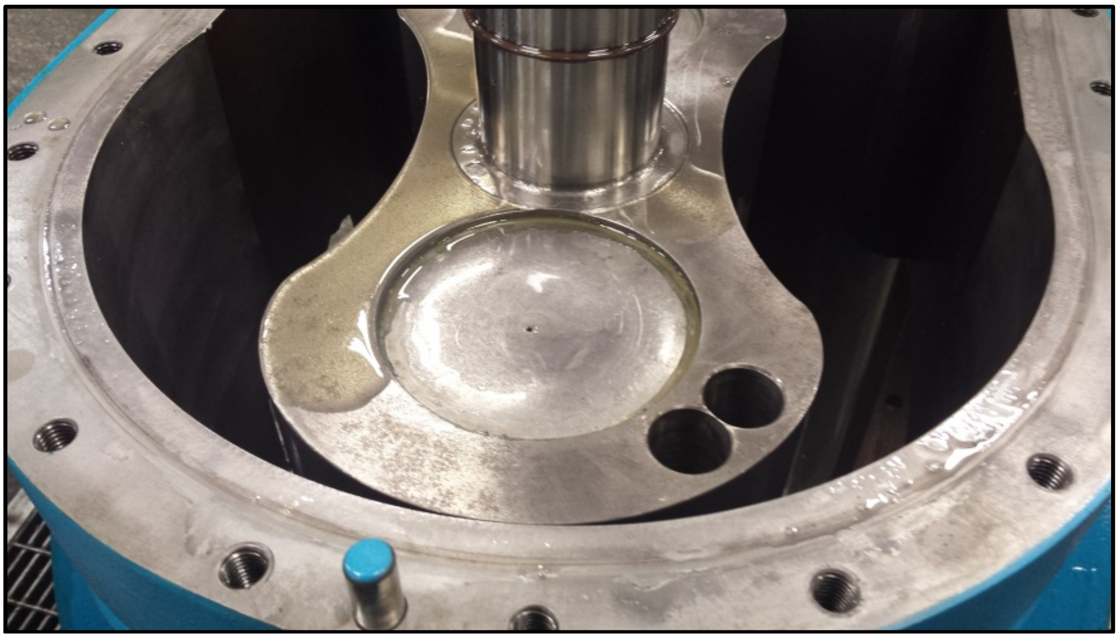

Figure 6. Kinney pump welch plugs with weep holes

At the start of this second return to the factory, the engineers were skeptical that a problem this severe could have arisen so quickly after a rebuild and promptly put the skid on the test bench. Their bench test facility has the ability to control the speed of the blower and at very low RPMs, the blower was already demonstrating severe enough vibrations that the test was cancelled and the blower disassembly was immediately started.

Upon disassembly of the rotors, weep holes were discovered in the welch plugs of the rotors. Each rotor is cast hollow to save on weight and then aluminum welch plugs are hammered into place and sealed with RTV around the edge. Weep holes are standard for rotors that are not exposed to liquids. Since the SNS skid has oil injection at the inlet, the lower lobe was filling with oil through the weep holes after the skid was turned off at the end of testing. The existence of these holes was a result of poor communication between the lab and the vendor. Figure 6 shows the placement of one of the weep holes in the rotor plug.

The SNS blower repair was completed with no additional deficiencies identified. The welch plugs were installed in the rotor, this time without any holes. The skid was then returned to SNS and another commissioning period began. During this startup, a representative from the manufacturer conducted a thorough review of the SNS pump. Several recommendations to improve pump reliable performance were observed. It was recommended to decrease the oil injection rate into the liquid ring pump to 40 GPM. Since we start the liquid ring pump before the blower, we need to limit the “wind milling” or blower free spinning time to less than 2 hours. Also the oil level in the liquid ring pump should be lower than the shaft centerline prior to starting.

3. Current Operations

The capacity of the skid was measured using a control valve that jumpers the skid suction and discharge headers. By controlling the flow into the suction header, the skid pumping capacity at different suction pressure levels can be measured. At the desired VTA testing pressure of 0.042 atm (32 torr), corresponding to a testing temperature of 2.1 K, the Kinney skid has 18 g/s of pumping capacity. Figure 7 shows the complete pumping capacity curve of the SNS Kinney skid.

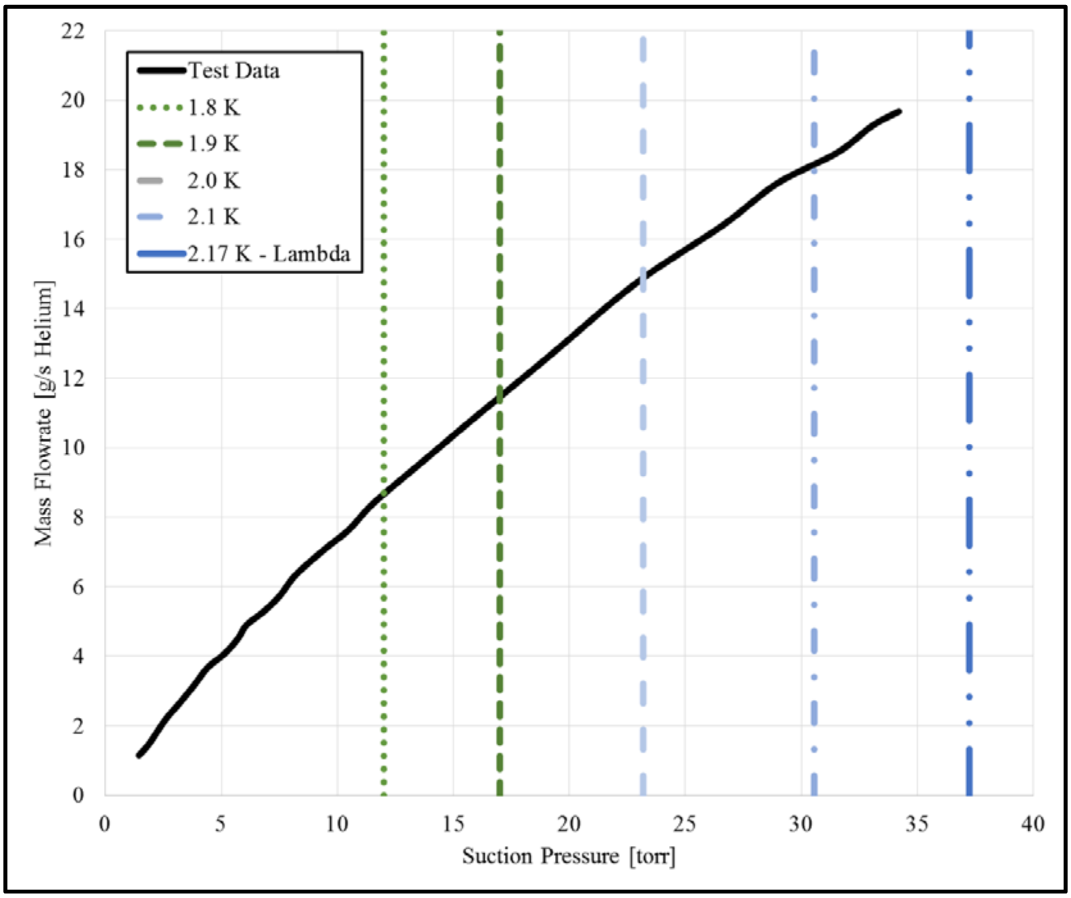

Figure 7. Measured Kinney pump skid capacity

To ensure that particulates from the skid oil circuit could not disrupt future blower operations, a small filter housing was installed on the Kinney blower oil injection circuit. Initially, the housing was installed with a 5 micron filter. Initial operation on this filter element lasted less than 10 minutes before it plugged. Oil samples sent out for analysis revealed a significant presence of particulates up to 100 microns. Additional filter elements of 25 and 50 microns were installed and the oil circuit was cleaned over the course of several weeks. There is suspicion that a source exists on the skid generating these particles, as the bulk oil transferred to the skid was clean when transferred. Figure 8 shows the addition of the filter element housing.

Figure 8. New filter element added to the Kinney blower oil injection line

4. Summary

After a long and challenging commissioning period, the Kinney pump at SNS is serving the SRF research needs of the laboratory. The many lessons learned through the commissioning have been shared with other facilities operating these skids improving reliable operation. The capacity of the Kinney pump will allow for all current and future SRF testing needs.

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References

[1] Howell M, et al., 2013 Status Of Spallation Neutron Source Cryogenic Test Facility, Proc. Particle Accelerator Conference (Pasadena, PAC2013) pp. 1292-1294
[2] https://www.tuthill.com/
[3] Soyars W, Bossert R, Darve C, Degraff B, Klebaner A, Martinez A, Pei L, and Theilacker J 2008 *Advances in Cryogenic Engineering*, AIP Conf. Proc. **985**, p 127