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

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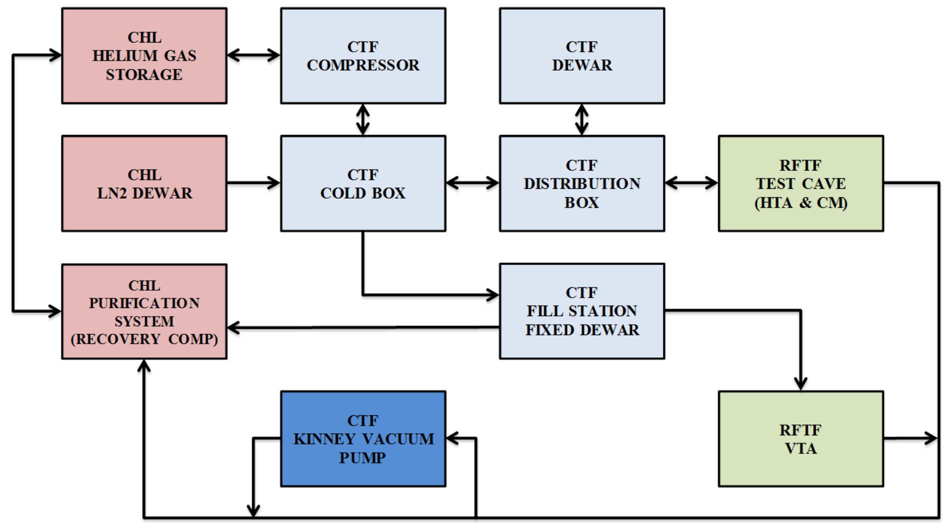
Abstract:
The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) has built and commissioned an independent Cryogenic Test Facility (CTF) in support of testing in the Radio-frequency Test Facility (RFTF). Superconducting Radio-frequency Cavity (SRF) testing was initially conducted 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.

Introduction:
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). 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.

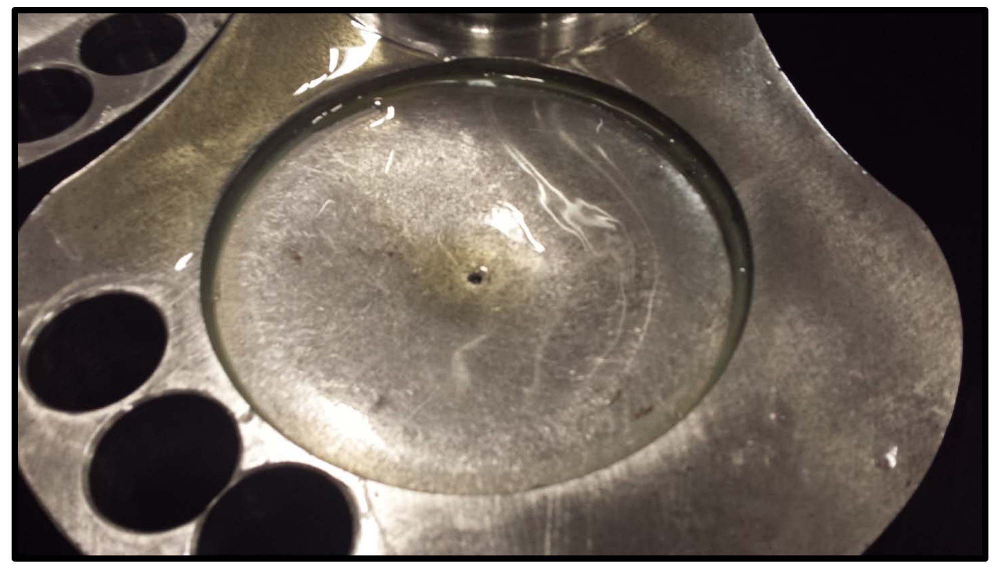
To facilitate dropping the temperature of the CTF system, a warm vacuum Kinney pump skid was added to decrease the operating pressure of the liquid helium bath from 1 atm (760 torr) down to 0.042 atm (32 torr). This new operating pressure correlates to a two phase bath temperature of 2.1 K. The Kinney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



SNS Kinney Skid With FNAL Modifications:
One of the SNS Kinney skids was shipped to Fermi National Accelerator Laboratory (FNAL) for hardware and software modifications. At the time, FNAL was operating two Kinney skids, identical to the SNS skid, with their custom modifications. 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. After the FNAL modifications, the Kinney skid was returned to SNS and connected to the CTF system. No operational difficulties have been encountered as a result of the custom FNAL modifications. Alterations made to prevent contamination during operation have been very successful.

Oil Carryover Into Suction Piping:
Issue –
- The skid oil level in the bulk oil separator was observed to have dropped significantly.
- 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.

Solution –
- 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.



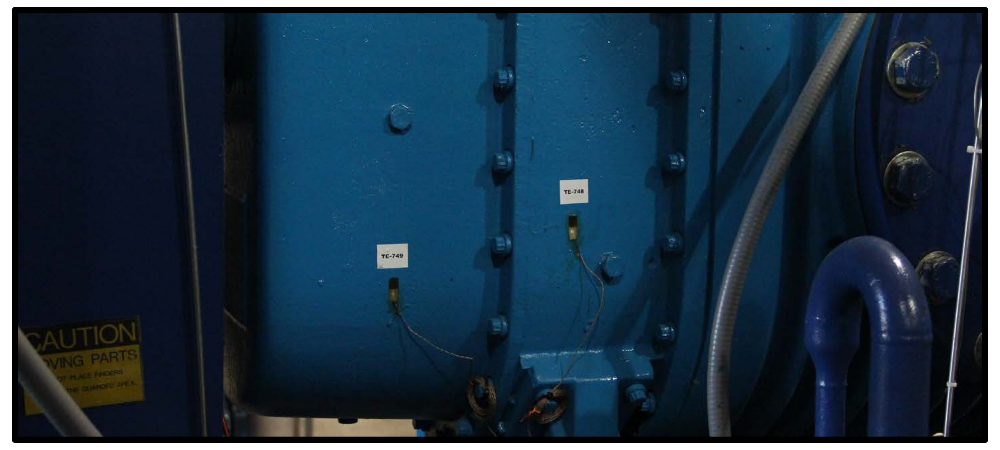
Oil Migration Into Blower Lobes:
Issue –
- The blower exhibited excessive vibration on startup.
- This vibration was duplicated on vendor test bench at low speed.

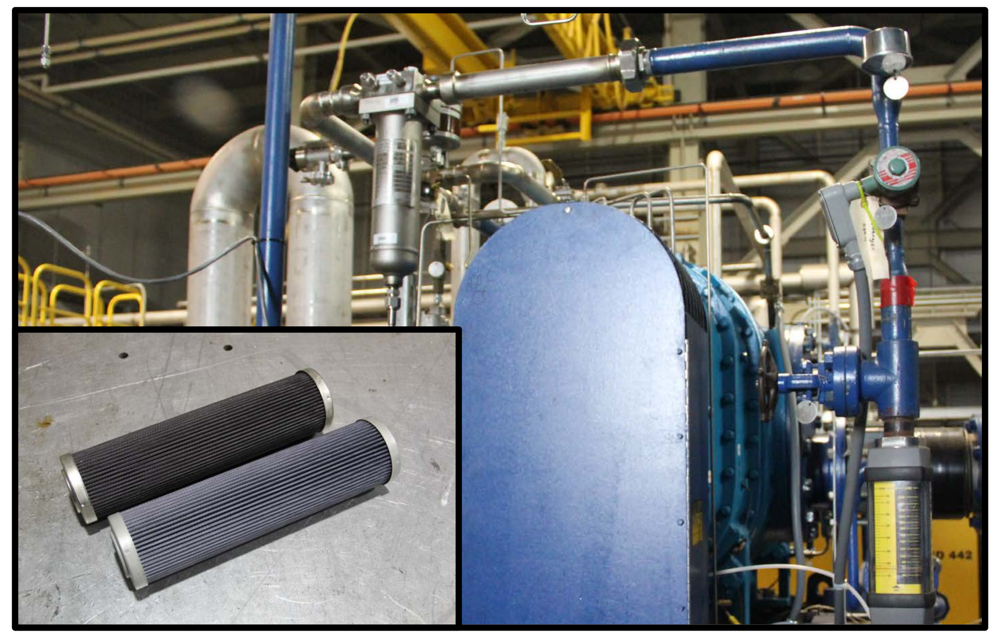
Solution –
- Weep holes were discovered in the welch plugs of the rotors.
- Since the SNS skid has oil injection at the inlet, the lower lobe was filling with oil through the weep holes after the skid was turned off at the end of testing.
- New welch plugs were installed without any weep holes.
- No excessive vibration observed since repair.

CHALLENGES DURING COMISSIONING

Plugging Oil Injection Nozzles & Overheating Bearing:
Issue –
- Epoxy used to seal pipe threads on blower oil circuit.
- Caused a plug in the bearing oil cooling nozzle leading to overheating and bearing failure.

Solution –
- Oil circuit thread sealant switched to Locktite #567
- Diodes placed on blower housing to monitor bearing temperatures in order to catch oil flow issues early.





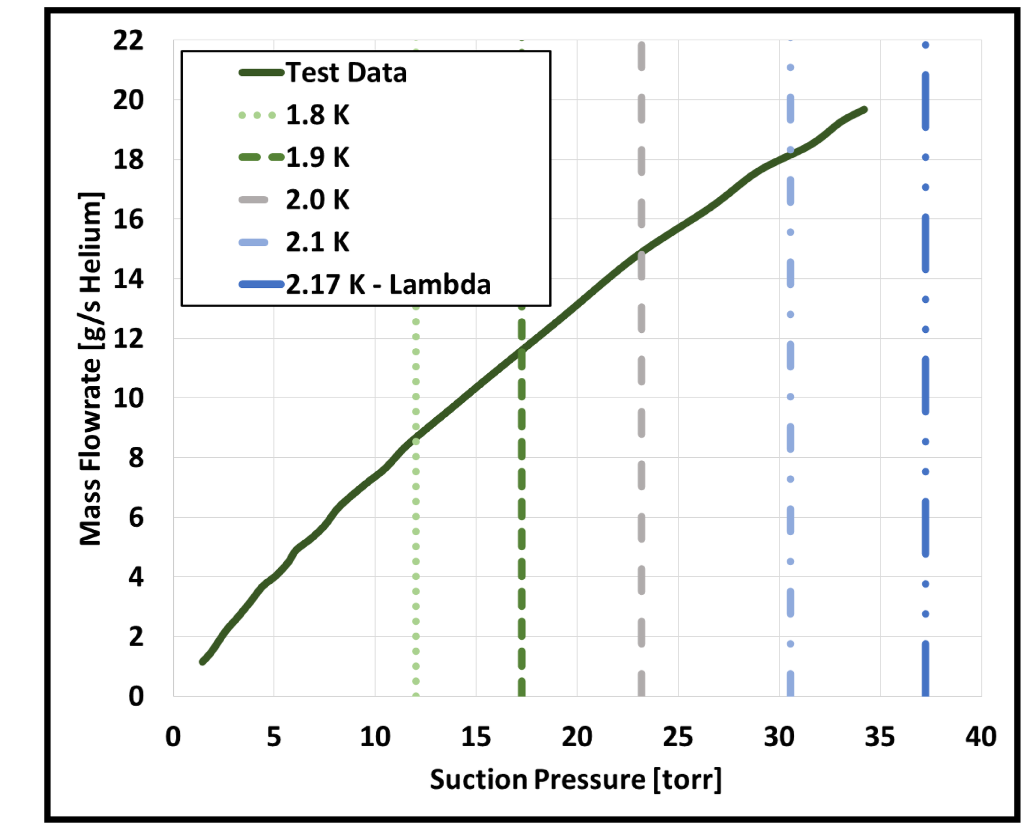
Particulate Contamination in Oil:
Issue –
- Discoloration observed on the bulk oil removed from skid.
- There is a possibility for small particulates generated in the oil piping to be injected into blower suction.

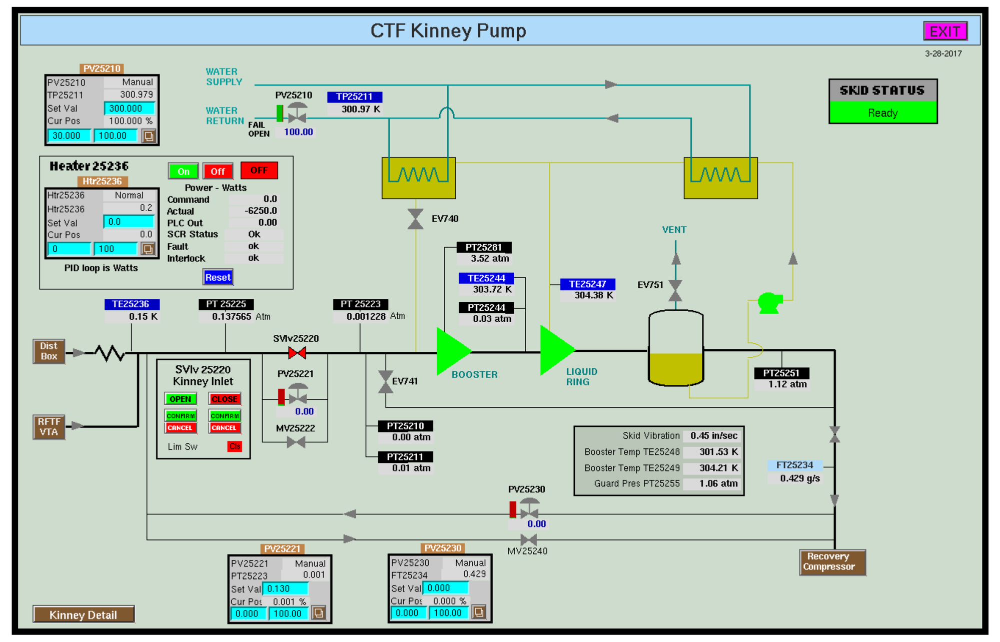
Solution –
- Installation of the filter housing on the blower oil injection line of the common oil circuit.
- Operation with 50, 25 and 5 micron filters is slowly cleaning particulates in the common oil circuit
- Regular oil analysis has confirmed that the number and average size of particulates in the skid oil circuit is decreasing.

Large Contamination From Suction Piping:
Issue –
- Large particulate contamination from suction piping caused blower rotors to seize

Solution –
- 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.
- This geometry allows for 80 percent of the effective cross sectional area to be available.

Capacity Measurements:
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.





Acknowledgements:
The authors would like to thank many colleagues and support groups at SNS and FNAL for their assistance in commissioning and operating the Kinney pump, especially personnel from controls, electrical and water groups. This work was supported by SNS through UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE.

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.