SNS Carbon Bed Research Project Design, Commissioning, and Initial Results

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Abstract. The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) has three operating cryogenic facilities: Central Helium Liquefier (CHL), Cryogenic Test Facility (CTF) and Cryogenic Moderator System (CMS). All three systems use vessels filled with activated carbon as the final major component to remove oil vapor from the compressed helium circuit prior to insertion into the system’s cryogenic cold box. However, different versions of carbon are used in different systems. A skid was designed which contains two separate carbon containing vessels for the purpose of comparing the relative efficacy of different versions of carbon filtration media. The design, fabrication, installation, commissioning, and initial results of this dual-bed test skid will be presented. Future testing plans utilizing different filter media will also be discussed.

1. Background

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) operates a Superconducting Linac (SCL) containing 81 Superconducting Radio-frequency (SRF) cavities housed in 11 medium-beta and 12 high-beta cryomodules. The SCL beam produces neutrons after striking a liquid mercury target. The Cryogenic Moderator System (CMS) optimizes the energy of these neutrons to produce effective science at SNS. These SRF cavities require cooling from a liquid helium bath at 2.1 K for desired performance. The SNS Central Helium Liquefier (CHL) is responsible for providing this cooling. [1] Cooling from the CHL facility is provided by several pieces of equipment: a 4-K cold box, a 2-K cold box, three first stage warm compressors, three second stage warm compressors, liquid nitrogen (LN2) storage tank, warm gas helium storage tanks, a helium purifier, and all necessary cryogenic transfer lines and warm piping.

The target neutrons require cooling from 20 K hydrogen. To produce this cooling, a 20-K helium cold box with heat exchangers maintains the hydrogen temperature and pressure within the target CMS system. Cooling from this CMS facility is provided by several pieces of equipment: 20-K cold box, warm compressor, helium gas storage tank, hydrogen systems, heat exchangers and all necessary cryogenic transfer lines and warm piping.

Both the CHL and CMS compressors are oil flooded, making the oil removal system of vital importance to the long term reliable operation of the facility. Even small amounts of oil vapor passing the oil removal system and entering the 4-K or 20-K cold box would have a negative effect on heat exchanger performance, turbine lifetime and pressure drop through the box.
The CHL and CMS oil removal systems for both installation are comprised of bulk oil separators on each compressor and then three liquid coalescers in series on the common high pressure header. After the final coalescer is a carbon bed designed to remove any aerosolized oil vapor. The carbon bed is a packed bed designed with helium flow going from the top of the vessel to the bottom to minimize carbon dust formation.[2] After the carbon bed is a final filter meant to trap any carbon dust. After the final filter, the high-pressure helium enters the cold box.

2. Experiment

2.1. Design
The two helium refrigerators at the SNS use different carbon media as the final filtration to remove the oil needed as part of the compressor systems. There is a desire to compare the relative effectiveness of different types of carbon because industry data is not currently available on which carbon is best for this type of oil removal process. As a result, a dual bed carbon R&D skid was designed and procured to allow simultaneous testing of two different types of oil removing media. The CHL facility has a small recovery rotary screw (RS) compressor with a total of 20 g/s of helium flow with 25 ppb of oil contamination upstream of the compressor’s own adsorber. Each bed on the R&D skid was designed to have the same flow characteristics as the larger CHL carbon bed. While the RS compressor is not able to match the CMS helium flow of 260 g/s, each carbon test bed has the same flow velocity (0.3 m/s) and carbon contact time (4 seconds).

The dual bed skid is designed with a total of 10 sample ports distributed equally across the two beds. Each bed has one sample port at the inlet and outlet. Each bed also contains sample ports located inside the carbon media at roughly 25%, 50% and 75% through the vessel height. Figure 1 shows a view inside one of the test vessels and the sampling ports located along the length of the vessel. A valve panel mounted on the front of the skid allows for a single analyzer to sample from any port without disconnecting any tubing.

![Figure 1. Carbon bed internal with sampling ports](image)
2.2. Commissioning

Two different types of carbon were loaded into the parallel cylinders of the test setup. The carbon used in the CHL and CTF, Calgon OVC 4x8, was loaded into the A-side. The carbon used in the CMS, Cabot Sorbonorit B4, was loaded in the B-side of the skid. Once the vessels were sealed and leak checked, both sides were wrapped in insulation and dried with heated nitrogen flow for several days until no moisture was detected on the nitrogen exhaust. A vacuum cold trap was then used to verify that all the moisture had been expelled from the carbon. Figure 2 shows the setup used to load the carbon media into one side of the experiment.

![Figure 2. Filling experimental vessels with experimental carbon media](image)

Once the carbon was ready, the skid was moved into position across the aisle from the RS compressor. Tubing was installed to connect the skid to the appropriate location just upstream of the RS adsorber. Valving installed with the tubing allowed for isolation and bypass of the skid if operations required isolation of the skid. During the testing period, no appreciable pressure drop was observed from flowing helium through the R&D carbon skid. Figure 3 shows the location of the test skid and the connection piping to the RS compressor overhead.

The dual bed skid is equipped with two flowmeters, allowing manual valve balancing of the flow between the two sides. The average flow through each side of the skid was 10.5 g/s for the duration of
the testing. This varied only slightly between 10 and 11 g/s depending on what the RS compressor suction pressure was operating at.

![Figure 3. Dual-bed experiment in service with CHL RS compressor](image)

A LINDE analyzer was installed on back of the skid to minimize the length of 1/8 in. tubing required to connect to the sampling distribution panel. This is believed to provide the quickest response and most accurate readings possible.

During the commissioning of the skid, it was consistently observed that the exhaust was reading 2 ppb oil. Flowing the analyzer sampling through a small liquid nitrogen dewar verified this as a real reading. Oil was captured in the tubing, and the analyzer reading dropped to zero. Figure 4 pictures the filling of the LN2 cold trap during the calibration testing.
2.3. Results
The LINDE gas analyzer [3] was used to sample each port at a frequency of one sample per day. This was done to avoid any transients in the pyrolyzer sampling. The result of this methodology is that each sample location had about 8 readings taken over the three months of testing. As shown in figure 5, most of the oil adsorption occurred in the first 25% of the carbon installed in the bed. This validates the expected lifetime of the carbon to full breakthrough at several years. The error bars for each data point represents one standard deviation from the average of the data points taken over the three months of testing.
Figure 5. Carbon experiment average results at different sampling locations

3. Conclusions
The SNS dual carbon bed experiment proved to be a reliable testing platform that produced repeatable results for both types of carbon installed. The internal sampling ports provided valuable feedback about the effectiveness of the carbon throughout the length of the adsorber. Both types of carbon were shown to be effective at removing aerosolized oil from helium gas flows. Future tests utilizing this R&D platform will test different types of carbon and other adsorbing media to compare relative effectiveness to these initial tests.

4. References
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