# SNS Central Helium Liquefier Spare Carbon Bed Installation and Commissioning

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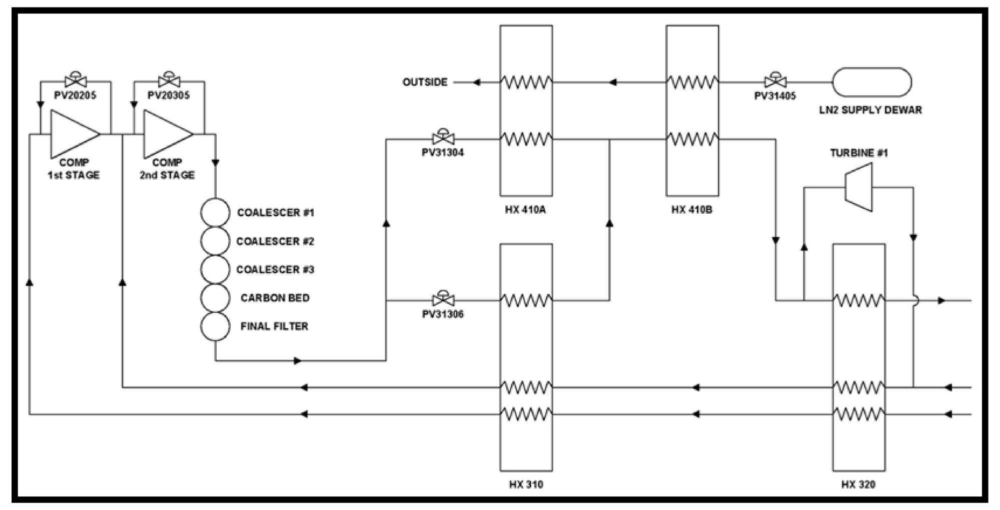
**Abstract:**
The Spallation Neutron Source (SNS) Central Helium Liquefier (CHL) at Oak Ridge National Laboratory (ORNL) has been without major operations downtime since operations were started back in 2006. This system utilizes a vessel filled with activated carbon as the final major component to remove oil vapor from the compressed helium circuit prior to insertion into the system's cryogenic cold box. Design calculation showing the expected lifetime of 10 years for this vessel will be presented. The fabrication, installation and commissioning of a spare carbon vessel will be presented. The plans for connecting the new carbon vessel piping to the existing infrastructure will be discussed.

**Introduction:**
The first stage and second stage CHL 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 cold box would have a negative effect on heat exchanger performance, turbine lifetime and pressure drop through the box.

The SNS CHL oil removal system is 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 flowing going from the top of the vessel to the bottom to minimize carbon dust formation. After the carbon bed is a final filter meant to trap any carbon dust. After the final filter, the high pressure helium enters the 4 K cold box.

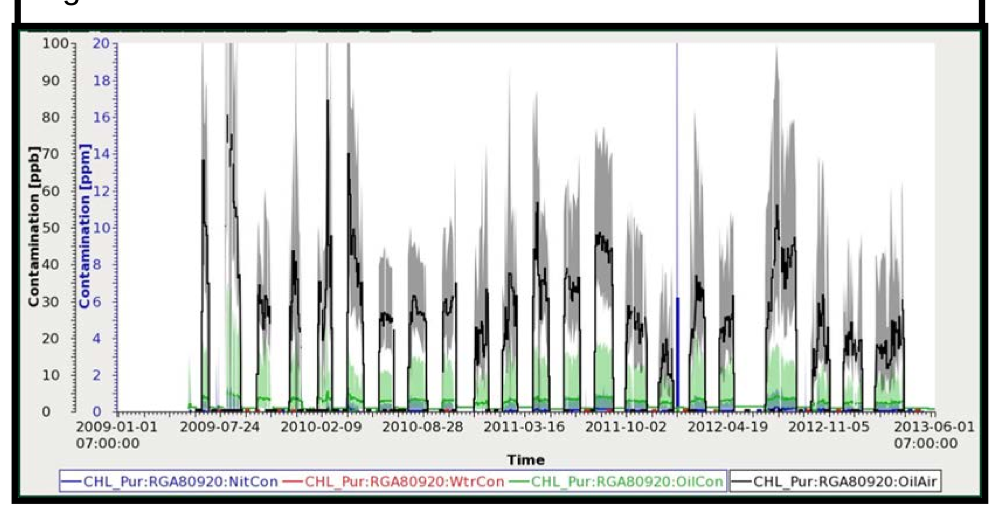
The design of the CHL carbon bed does not allow maintenance while continuing to operate. The existing carbon bed represents a single point failure for the CHL system. If the carbon bed were to start showing contamination at its outlet, the entire CHL would have to be shut down and the Linac warmed to room temperature for a minimum of 4 months to facilitate removal of the current carbon adsorbent, filling with new carbon, and drying of the installed carbon.

Existing CHL Carbon Bed and Final Filter




Simplified Flow Diagram With Oil Removal System

**Carbon Bed Performance:**
The CHL uses a single LINDE multi-gas analyzer to monitor the CHL carbon bed. The plot below shows the contamination levels from this analyzer. The alternating periods of high and low readings are from a period between 2009 and 2013 when the analyzer was regularly shifted between the inlet and outlet of the carbon bed. No contamination was recorded on the outlet and the inlet is dominated by a 30 to 60 ppb oil vapor reading. Since 2013, this analyzer has been kept on the carbon bed outlet with no sign of contamination.




CHL Contamination Monitoring From 2009 to 2013

**Carbon Bed Lifetime Calculation:**
The lifetime of carbon media can be calculated by solving for t in the following equation.

$$M = \frac{\dot{m} \cdot R \cdot t}{1000 \cdot L \cdot E}$$

Using values of 1000 g/s for the mass flow rate (m), 100 ppb for the oil contamination level (R), 4500 kg for the mass of the installed carbon (M), 0.75 for the effective length (L) and 0.01 for the adsorption efficiency of the carbon (E), the existing SNS carbon bed has a design lifetime (t) of 11 years. SNS commissioning began in 2003 and full time operation started in 2006, meaning that according to the original design calculations, the SNS carbon bed has already reached the end of its expected lifetime. It should be noted that there is a high degree of uncertainty in the values used to calculate the bed's lifetime. The SNS contamination may be lower by ~50% than the design contamination level. The adsorption efficiency of the carbon for oil vapor in helium flow is not something highly studied by the carbon manufacturers. There is some suspicion that this value of 0.01 adsorption efficiency may be off by a factor of two or three; however there is no data to validate this conjecture.

**Carbon Selection:**
The CHL spare carbon bed requires 10,000 lbs of carbon media. SNS procured 56 drums of OVC 4x8 coconut granular activated carbon media from Calgon. While not identical to the carbon media in use on the existing CHL carbon bed, this replacement media was chosen to have the same absorption properties. This carbon media has a maximum ash weight of 3%, a maximum moisture content of 5%, a density of 0.45 g/cc, a hardness number of 97, a carbon tetrachloride weight of 60%.

**Vessel Installation:**
A general contractor was hired to perform the installation of both vessels, the installation of the carbon media and the fabrication of the piping connecting the two vessels. Before starting the installation of the spare carbon vessel, the lower screen was installed with the vessel resting on its side in the construction lay-down area. This lower screen consists of mechanical supports to take the load of the weight of the carbon media, two sheets of perforated plates and a fiberglass blanket. Once the lower screen was installed, the vessel was transported to the CHL. Two cranes were used to both remove the spare carbon vessel from the truck and to rotate the vessel to the vertical position. Then a large crane was used to lift the spare carbon vessel over the CHL gas helium storage tanks onto a newly poured concrete pad. The image below shows the spare carbon vessel being flown into position over the CHL gas helium storage tanks.

The crane was used to remove the upper elliptical head of the carbon vessel. In order to minimize dust generation during filling the spare carbon vessel, a transport hopper was used with a fabric chute attached to the bottom. The carbon drums were emptied into the hopper on the ground and then the hopper was lifted into position above the open head of the spare carbon vessel. The carbon was then released slowly as to minimize the generation of carbon dust. Even with proceeding slowly, the entire process took less than one shift for the general contractor's personnel. The image below shows the hopper in use for filling the spare carbon vessel.

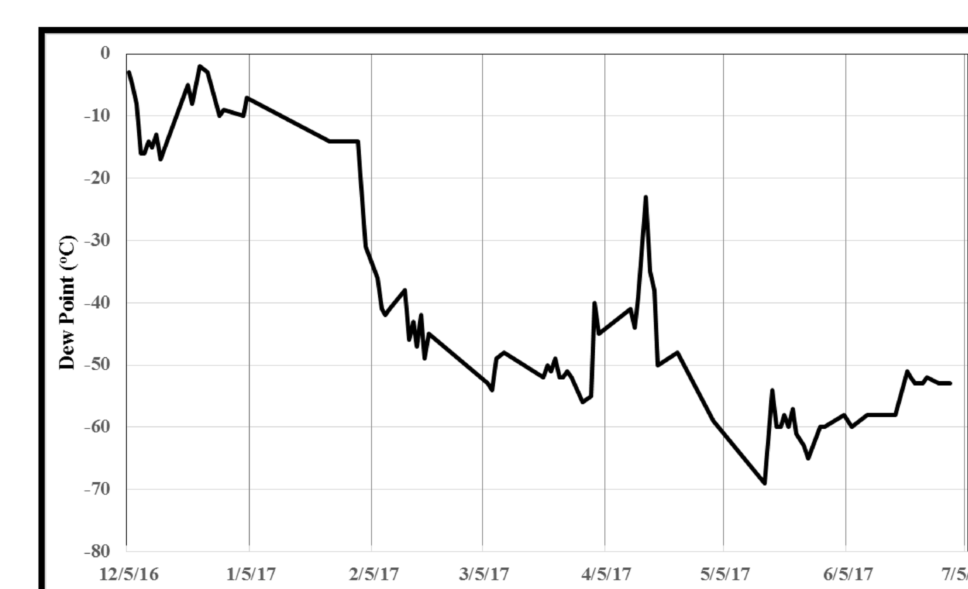
Crane Installation of Carbon Bed

Hopper Delivering Carbon Media

Installed Final Filter with Connecting Piping

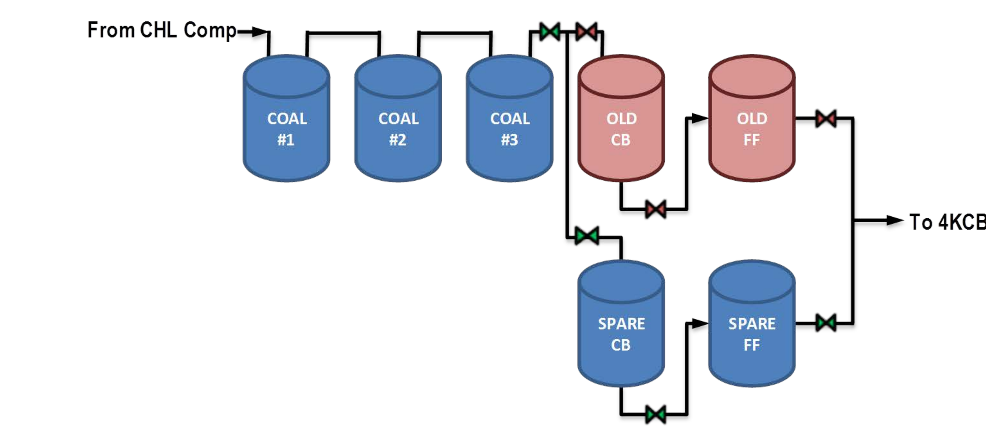
**Spare Carbon Bed Cleanup:**
CHL personnel were tasked with cleaning the carbon media by flowing gaseous nitrogen through the carbon media. The CHL LN2 dewar was used to supply LN2 through an ambient vaporizer to produce a gaseous flowrate of between 15 to 18 SCFM. The dew point of the exhaust nitrogen gas coming off the spare carbon bed is measured by a Shaw Automatic Dewpoint Meter (SADM) with a range of 0 to -80 $^{o}$C. The SADM is in calibration and was tested on the LN2 boil off gas to confirm the quality of the dry nitrogen at -80 $^{o}$C. In contrast to the original CHL carbon bed, the spare bed did not have heaters or insulating blankets installed as it was suggested that the same dry conditions could be achieved with simply flowing gaseous nitrogen for a longer period of time. Nitrogen flow was started into the spare carbon bed on December 5th, 2016 with initial reading of the dew point at -3 $^{o}$C.

Readings were taken once a day by CHL personnel and the below plot shows the cleanup progress over time. While initially the gas flow showed a steady rate of dew point decline, eventually the progress seemed to stall. On May 5th, the meter was checked for calibration and found to be only slightly off. After recalibration however, a similar flat trend continued. Shortly after, a 1500 watt inline heater was added to the gaseous nitrogen flow immediately before entering the spare carbon bed. It does not appear that this heater had much positive effect. The rising dew point numbers observed in the past few weeks are likely due to the high ambient temperatures.

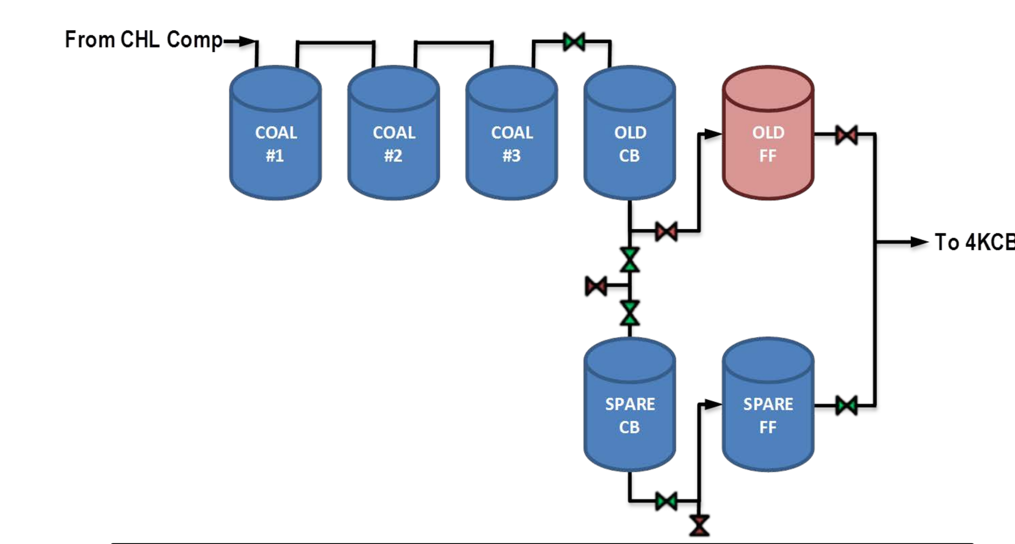



Dew Point Measurement During Nitrogen Purge

**Future Options:**
Two options exist for how to tie the spare carbon bed in with the CHL piping system. It could be placed in parallel, with one bed online and the other being restored/spare, or it could connected in series. In this series configuration, the existing carbon bed would flow directly into the spare carbon bed, bypassing the existing final filter. While this solution has not been tried before, one benefit is that it allows the existing carbon bed to be operated until failure without any consequence to the facility.




Ideal Parallel Carbon Bed Configuration




Proposed Series Carbon Bed Configuration

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**Summary:**
The spare carbon bed represents a vital component in reducing the operating risk for the SNS CHL. The desire for SNS is to continue to operate without warming the Linac for the next several years. With an additional carbon bed installed in series with the current carbon bed, the CHL should gain an additional 15 plus years before further effort is required. At that time, it is hopeful that using the taps installed during the upcoming piping project will provide sufficient flexibility that no further outage is required to establish parallel operations with two carbon beds. It is also hoped that the end of life carbon data gained from operating the current carbon bed to failure will provide valuable information in support of future cryogenic installations.

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