ISBN: 978-3-95450-232-5 ISSN: 2673-7000 doi:10.18429/JACoW-NAPAC2022-WEPA32

SPALLATION NEUTRON SOURCE CRYOGENIC MODERATOR SYSTEM HELIUM GAS ANALYSIS SYSTEM*

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Abstract

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) operates the Cryogenic Moderator System (CMS). The CMS comprises a 20-K helium refrigerator and three helium to hydrogen heat exchangers in support of hydrogen cooled spallation moderation vessels. This system uses vessels filled with activated carbon as the final major component to remove oil vapor from the compressed helium in the cryogenic cold box. SNS uses a LINDE multi-component gas analyzer to detect the presence of contaminants in the warm helium flow upstream of the cold box including aerosolized oil vapor. The design challenges of installing and operating this analyzer on the CMS system due to normal system operating pressures will be discussed. The design, fabrication, installation, commissioning, and initial results of this system operation will be presented. Future upgrades to the analyzer system will also be discussed.

SYSTEM OVERVIEW

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) operates a linear accelerator (LINAC) comprised of both normal conducting and superconducting radio frequency (SCRF) cavities to produce a 1 GeV beam. This beam strikes a liquid mercury target at a power level of 1.4 MW. Spallation then creates high energy neutrons that are used in multiple beamlines to conduct research. Critical to producing the correct energy neutrons for research are four moderators that tailor the energy of the neutron to the research needs of the experiments. The Cryogenic Moderator System (CMS) is responsible for producing 20 K supercritical hydrogen for cooling three of the four moderators surrounding the SNS target.

Instead of using a hydrogen cryogenic cycle to produce the required cooling in the SNS target moderators, the CMS uses a cryogenic helium cycle to then cool the hydrogen to the required temperature. The CMS consists of a helium compressor, a 7.5 kW at 17 K helium refrigerator, helium to hydrogen heat exchangers and three separate supercritical 20 K cooling loops for SNS target moderators. The reliable operation of the CMS cryogenic cooling system is essential to the successful scientific objectives of the SNS beamlines. Maintaining and monitoring the purity of the helium at the inlet to the 17 K cold box is critical to long term reliable SNS operations. The combined helium and hydrogen cryogenic cycle is shown in Fig. 1.

* This work was supported by SNS through UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE.
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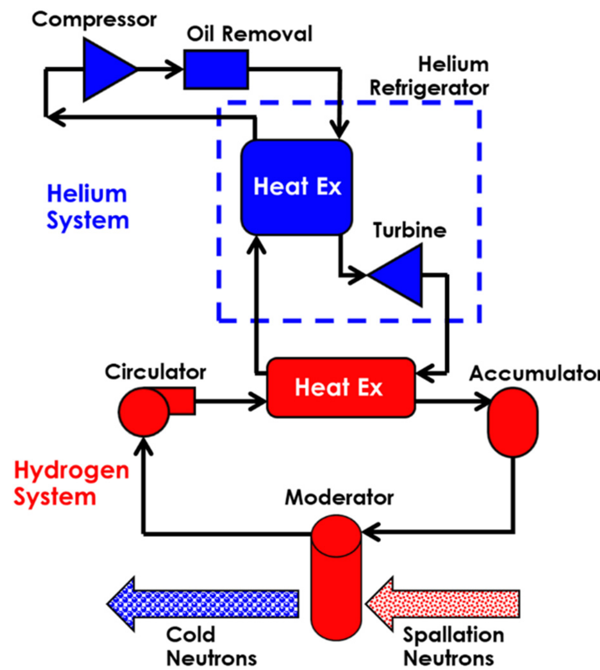

Figure 1: CMS cryogenic cycle.

HELIUM GAS ANALYSIS SYSTEM

System Layout

The CMS helium compressor is a single stage oil-flooded screw compressor which operates with a suction pressure ~40 psig and a discharge pressure ~260 psig. The system has suffered in the past from loss of capacity from suspected oil carryover into the helium cold box. A LINDE multi-component was purchased to analyze the helium both before and after the carbon bed on the oil removal system. However, this analyzer cannot provide accurate readings when discharging into suction of the main helium compressor. The only operating mode that was historically available to the CMS was occasionally turning the analyzer on to “spot-check” the system purity while venting the measured helium to atmosphere.

A project was started to install a small helium compressor and appropriate pressure control measures to maintain a pressure on the outlet of the LINDE analyzer. A diagram of the system layout is shown in Fig. 2. The hardware for the project contains the following pieces of equipment:

- Pressure regulator set to 200 psig on the supply high pressure supply

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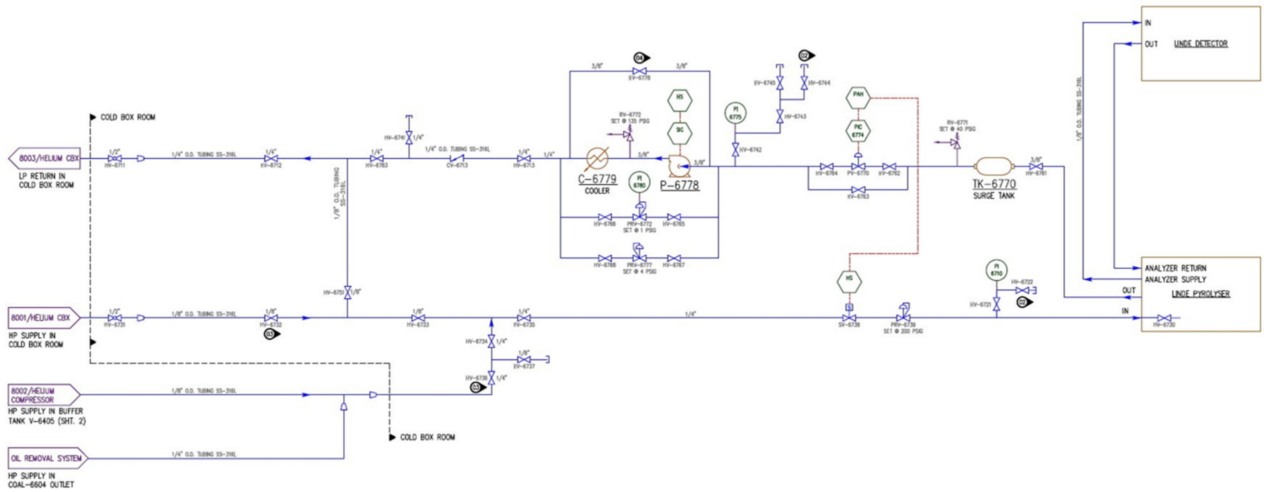

Figure 2: Process and instrumentation diagram (P&ID) for the LINDE analyzer connected to the helium recovery compressor and pressure regulating components.

- Shutoff valve on high pressure supply to stop helium flow if pressure high
- Buffer volume on the analyzer outlet to assist in pressure regulation on the outlet of the analyzer
- ALICAT flow controller on the outlet of the analyzer set to regulate its inlet pressure to 3 psig
- KNF helium compressor
- Ambient natural convection cooler for reducing the outlet temperature of the compressed helium
- Pressure regulator to maintain the suction pressure of the compressor to ~1.5 psig
- Pressure regulator to maintain the discharge pressure of the compressor to ~ 60 psig
- Safety relief valve on all trapped volumes to prevent pressurization above component maximum allowable working pressures (MAWP)
- Helium flow is returned though a check valve back to the main CMS helium compressor suction return header

The piping on the system was assembled with stainless steel tubing and compression fittings. The entire system was fabricated on the side of the LINDE cabinet and on a steel plate mounted to the wall next to the analyzer cabinet. The compressor is a dry diaphragm pump and is operated continuously at full speed. The installed system is shown in Fig. 3.

The LINDE multi-component detector has two hardware pieces. It contains an analyzer that is capable of reading water, nitrogen gas and liquid oil contamination from the helium sample down to the parts per million (PPM) level. The other piece of hardware is a pyrolizer that heats the helium sample and is able to detect aerosolized oil particles down to the parts per billion (PPB) level.

Figure 3: Installed helium gas analysis recovery system.

Commissioning

The commissioning of this new helium recovery system started April of this year. After the initial start-up and clean-up of the analyzer and pyrolizer, the reading for all four contamination levels were reading near zero. A pressure of 3 psig was successfully maintained at the outlet of the analyzer. When the sampling point was changed from the inlet to the cold box to the inlet of the carbon beds on the oil removal system, the pyrolizer reading for aerosolized oil read ~24 parts per billion, which is consistent with other cryogenic helium oil removal systems at SNS. The results of the initial clean-up and operation of the system are shown in in Fig. 4.

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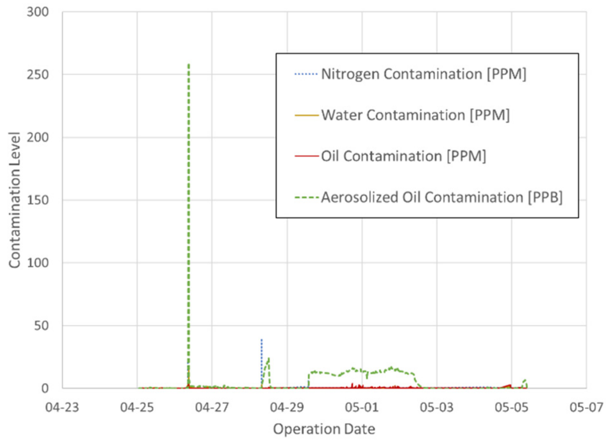

Figure 4: Contamination levels during initial commissioning and operation of LINDE analyzer.

The commissioning of the LINDE analyzer occurred after the CMS had gone through its standard cleanup cycle of running for several days will full helium flow through a liquid nitrogen cooled helium purifier. As a result, no significant contamination levels were ever observed for nitrogen, water or liquid oil contamination at the parts per-million (ppm) level. The initial clean-up of the system was the only time the aerosolized oil contamination level ever went above 30 ppb. The LINDE analyzer readout during sampling at the inlet to the carbon bed can be seen in Fig. 5.

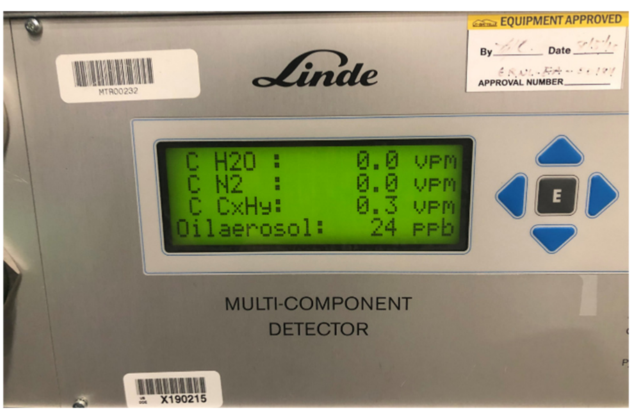

Figure 5: LINDE analyzer readings during sampling from inlet of CMS oil purification carbon bed.

Two issues were identified during commissioning. First, the noise level from the compressor operation was higher than expected. The noise in excess required establishing a hearing protection region of about 10 feet around the gas analysis installation. Second, the vibrations generated by the compressor mounted on the vertical metal frame were higher than expected. Care will be taken to ensure the system's compression fittings do not start leaking as a result of these vibrations.

CONCLUSION

The new CMS helium gas analysis system was successfully designed, installed, commissioned and operated in 2022. This system provides continuous monitoring of the helium purity in the CMS and will prevent the venting of helium under the old configuration. The pressure control system performed as desired, maintaining stable and low pressure at the outlet of the LINDE analyzer while also preventing the suction pressure of the helium compressor from going sub-atmospheric. The system has also confirmed that the recent changes to the helium compressor oil coalescing system has successfully prevented the migration of aerosolized oil into the helium cold box.

ACKNOWLEDGEMENTS

The authors would like to thank many colleagues and support groups at SNS for their assistance in commissioning and operating the CMS helium gas analysis system, 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.