

# INVESTIGATION OF MOISTURE CONTAMINATION IN THE CRYOGENIC SYSTEM AT NSRRC

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## Abstract

In NSRRC the helium cryogenic plant began its normal operation in year 2002. Several events of moisture contamination forced the cryogenic plant to cease operation because the cooling performance degraded evidently. After long-term observation we found, through internal inspection of the helium gas buffer tank, maintenance of the compressor station, and warming the superconductive magnet, that moisture contamination occurred. This paper presents the effect of those conditions on the moisture contamination. The solution to decrease the moisture contamination is demonstrated here.

## INTRODUCTION

NSRRC has operated the helium cryogenic plant over one decade with a duty period above 95 % every year. In normal operation the cryogenic plant is a closed system, and contamination should not exist in the helium stream except the oil to cool the helium compressor. The closed system becomes opened to air at regular intervals under conditions such as safety inspection of the high-pressure vessels and maintenance of the compressor station. Contamination inevitably remains in the system even after several cycles of pumping the helium circuit and then purging with pure helium gas. Other situations according to which contamination might appear in the closed system include warming the superconductive magnet or cavity at the downstream side, modifying the piping for helium gas, or leakage event in the helium circuit. The major components of contamination are oxygen, nitrogen, and moisture. Inside the cold box, two cryogenic adsorbers for on-line and full-flow operation are used to capture the oxygen and the nitrogen contamination. Due to operating the two adsorbers by turns and on-line regeneration of the off-duty adsorber, concentration of the oxygen and the nitrogen can be controlled at an acceptable level for long-term operation of the cryogenic plant. The remaining issue is moisture contamination as the cryogenic plant has no dryer capable of on-line and full-flow operation.

Because of the low temperature the moisture solidifies into a thin layer of ice and accumulates in the first heat exchanger of the cold box. The accumulated ice decreases the cross section of piping and an increased pressure drop appears as helium gas passes through the heat exchanger. As the ice has a poor rate of heat transfer, the efficiency of the heat exchanger decreases; thus the cooling capacity of the cold box degrades and the gas

helium leaving the cold box is abnormally cold such that the condensed water appears along the surface of piping for the warm helium gas returning to the compressor station.

## PHENOMENON OF MOISTURE CONTAMINATION

A period of two weeks is planned for the annual maintenance of the cryogenic plant during the long shutdown of the storage ring. The cooling oil in the oil separator of the compressor and the charcoal in the oil-removal module are changed to new ones during the annual maintenance. Warming the superconductive wavelength shifter (SWLS), which is cooled with both the cryocooler and the liquid helium, is executed also during the long shutdown every year, to replace the cold head of the cryocooler. The cooling capacity of the cryogenic plant had deteriorated seriously after this annual maintenance.

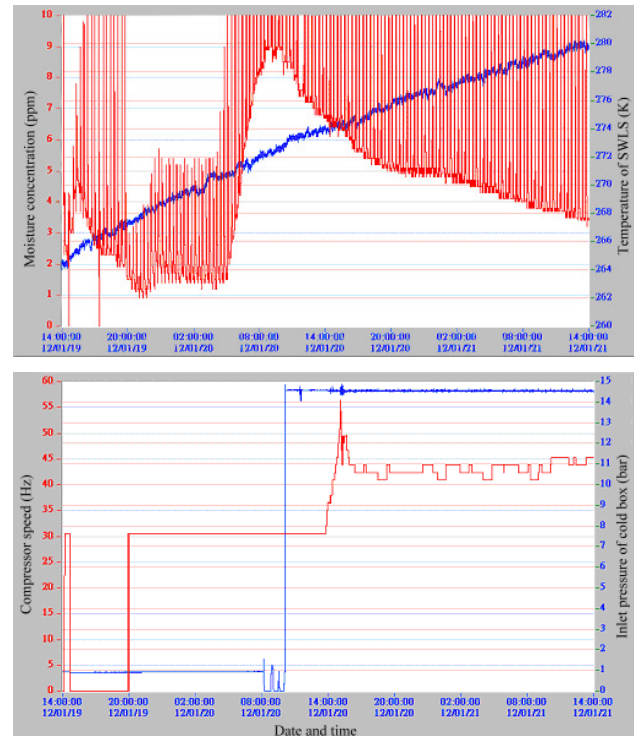


Figure 1: Exploration of moisture contamination after the annual maintenance.

Figure 1 shows the results measured by the moisture sensor after restarting the cryogenic plant. The moisture concentration increased to 1.5 ppm after the compressor started. Further increase of moisture concentration began as the temperature of SWLS increased to 270 K; then the

concentration rose to a maximum value 9 ppm. The concentration decreased gradually as the cold box cooled and began to trap the moisture in the first heat exchanger, but the moisture contamination exceeded 1 ppm even after continuous operation of the cryogenic plant for ten days and the temperature of the gaseous helium at the outlet of cold box was cold. To avoid the risk of damaging the expansion turbine we stopped the cold box and warmed it for a drying procedure. According to Fig. 1, the SWLS contributed most moisture contamination. Although the helium vessel of the SWLS was not opened to air during the maintenance of the cryocooler, the impurities trapped by the cold helium vessel after long-term operation became released into the helium stream during the warming period. Because there are four superconductive magnets, which are kept at 4.2 K the whole year, sharing the same piping with the SWLS for recycling the warm helium gas [1], the SWLS cannot be isolated and the impurities enter the cryogenic plant during the warming of SWLS.

The annual maintenance of the power station suspends electric power for 8 hours. During this period the cold box stopped, but the dewar kept supplying liquid helium to the superconductive devices. Figure 2 shows the variation of moisture concentration during the maintenance of the power station, in which the heat exchanger warmed to 200 K and a small part of moisture was released from the cold box. We realize that the moisture eventually accumulates in the cold box after long-term operation. The moisture sensor of the system with accuracy 1 ppm is inadequate to monitor the tiny moisture contamination of the cryogenic plant. A highly precise moisture analyzer with accuracy 5 ppb and response time 3 min was installed in year 2013 to clarify the moisture concentration of the helium stream.

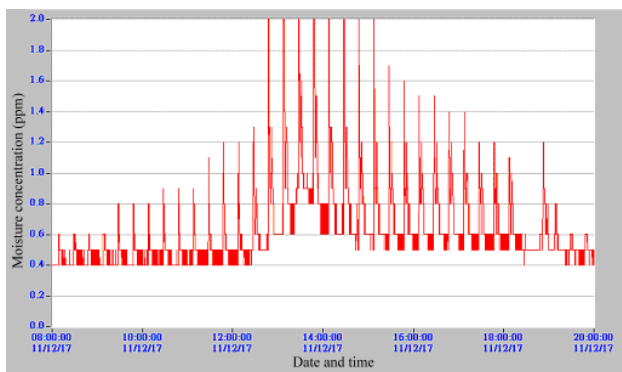


Figure 2: Moisture released from the cold box during the annual maintenance of the power station.

## STRATEGY TO REMOVE MOISTURE

The objects encountering moisture contamination might be the compressor, the cold box, the buffer tank, or the recycled helium gas from the superconducting devices. A dryer system capable of continuously processing a full flow of the cryogenic plant requires great cost and a large space. Continuous operation of the cryogenic plant

requires that the moisture concentration of the contaminated buffer tank should be decreased to an acceptable level as soon as possible. Instead of a big dryer system, a commercial small purifier cooled with liquid nitrogen is adopted to process the flow of the recovery compressor, which restores the vaporized helium gas into the buffer tank when the cryogenic plant stops. Each purifier allows 4.2 g/s (95 m<sup>3</sup>/hr) helium flow and ten purifiers divided into two arrays are arranged to treat the flow (11.2 g/s) from the recovery compressor, as shown in Fig. 3. The purifier system is modified from manual operation into automatic operation for the filling of the purifiers with liquid nitrogen and regenerating the array of saturated purifiers [2, 3].



Figure 3: Two arrays of purifiers cooled with liquid nitrogen.

The purifier system finished the function test in August 2013 and operated during the maintenance period of the cryogenic plant. The main compressor of the cryogenic plant is also connected to the purifier system for partial flow cleaning during the restarting of the compressor. Figure 4 shows the records of moisture concentration during the maintenance period, in which the peak concentration was 1.3, 1.4 and 2.6 ppm respectively in the period of restarting the compressor station, drying the cold box and warming the SWLS. The purification was aborted because the office was closed during the holiday for Chinese New Year. The moisture concentration decreased rapidly after the cold box restarted and the value attained to 65 ppb after operation of the cryogenic plant for one month.

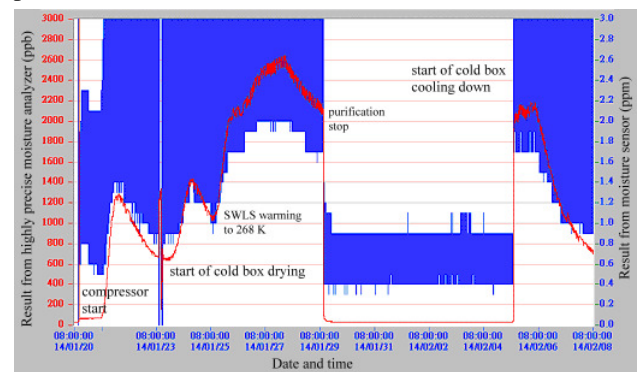


Figure 4: Moisture concentration during the maintenance period (with purifier system in operation).

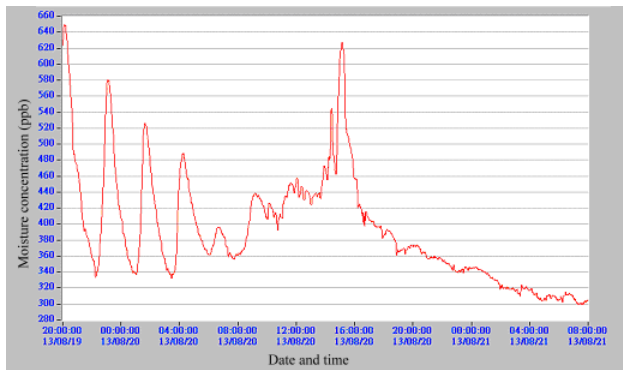


Figure 5: Purification of a buffer tank after the internal inspection.

The largest high-pressure vessel is the helium buffer tank of volume 100 m<sup>3</sup>. Because the safety regulation requires internal inspection of a high-pressure tank every five years and because there are three buffer tanks, on average the internal inspection of one buffer tank is performed every two years. Fresh air is infused into the buffer tank before the inspector enters the buffer tank for internal inspection. After the inspection the particle number and moisture concentration are decreased on flushing the buffer tank with clean and dry nitrogen gas for several weeks. A procedure of pumping the tank pressure to 50 mbar and then purging pure helium gas to increase the tank pressure to 1 bar is executed three times before the buffer tank is reconnected to the cryogenic

plant. Because the buffer tank is large, the process for cleaning takes a long time and the residual contamination level is about 600 ppb. Figure 5 shows the result of the purifier system processing a buffer tank, after the internal inspection and cleaning procedure, on using the recovery compressor to cycle the helium flow. The moisture contamination was decreased to 300 ppb after operation of the purifier system for two days.

## CONCLUSION

Sources of moisture contamination are clarified to arise from the maintenance of the cryogenic plant, the warming of the SWLS, and the internal inspection of the buffer tank. A purifier system combined with the recovery compressor is demonstrated to decrease effectively the moisture contamination.

## REFERENCES

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