§1. Reliable Long-Term Operation of the Cryogenic System for the Large Helical Device

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1. Introduction

Reliability is discussed during long-term operations of the cryogenic system for the Large Helical Device (LHD). The LHD cryogenic system, which permits complicated cooling schemes for each cooled object, was designed to focus on the reliable long-term operation. Impurities in the helium gas should be controlled carefully to prevent a blocking of filters, malfunction of control valves and deterioration of heat exchanger performance.

2. Measures of cryogenic system against impurities

he flow diagram for the LHD cryogenic system is shown in Fig. 1. The cold box of the helium refrigerator/liquefier simultaneously has a cooling capacity of 5.65 kW at 4.4 K, 20.6 kW from 40 K to 80 K and 650 L/h liquefaction. The helium purification system consists of the drier (molecular sieve adsorber) and the cryogenic purifier (liquid-nitrogen cooled activated-carbon adsorber). Both drier and purifier have twin units with an automatic-switching method every 12 hours. Very small quantities of impurities, which remain in the system after the cool down are removed by three stages of activated-carbon adsorbers (ADS-1, -2, -3), installed in the cold box of the helium refrigerator/liquefier. ADS-1 and ADS-2 have twin units, and these are regenerated every seven days. Filters are also installed in the inlet of each superconducting coil and superconducting bus line for the purpose of coil protection and impurity elimination.

3. Results of long-term continuous operation

Progression of the operating modes for the 1st and the 2nd operating cycles of the LHD cryogenic system are shown in Fig. 2. Each cycle consists of a purification, cool down, steady state, and warm-up operation. Impurity concentrations during the steady state operation are below the detection sensitivity of the optical-emission-spectroscopy type analyzer made by Linde AG, whose measuring range is from 1 ppm to 50 ppm for N2, O2, H2O, CxHy. The inlet strainer of the 1st turbine (T1) was blocked with impurities. However, no other trouble from impurities occurred and the system was operated stably under steady-state conditions. The impurity concentration of the warming gas used for regeneration of the T1 inlet strainer was measured. Impurities, such as hydrocarbons, were not detected but a deterioration of the dew point was observed.

4. Summary

The LHD cryogenic system completed 6400-hours of operation during the first year, and proved its high reliability. In order for the cryogenic system to obtain this high reliability under continuous operation over a long period of time, careful attention was directed to the high-precision control of impurities during the design and construction phase. To measure the very low impurity concentrations during the period of steady-state operation, we developed a low-temperature condensation type impurity measuring apparatus. Concentrations of hydrocarbons during the steady-state operation were measured to be less than 10 ppb using this apparatus. Concentrations of oxygen and nitrogen were measured as several 10s to several 100s ppb. These results and actual continuous operation demonstrated that these impurity components with these concentration levels do not adversely influence continuous operation. However, it is easy to obtain an accumulation of water in the system. Even water with a low concentration level of 15 ppb can block a strainer, filter, etc. Management of the water contamination is critical for continuous operation of the cryogenic system.

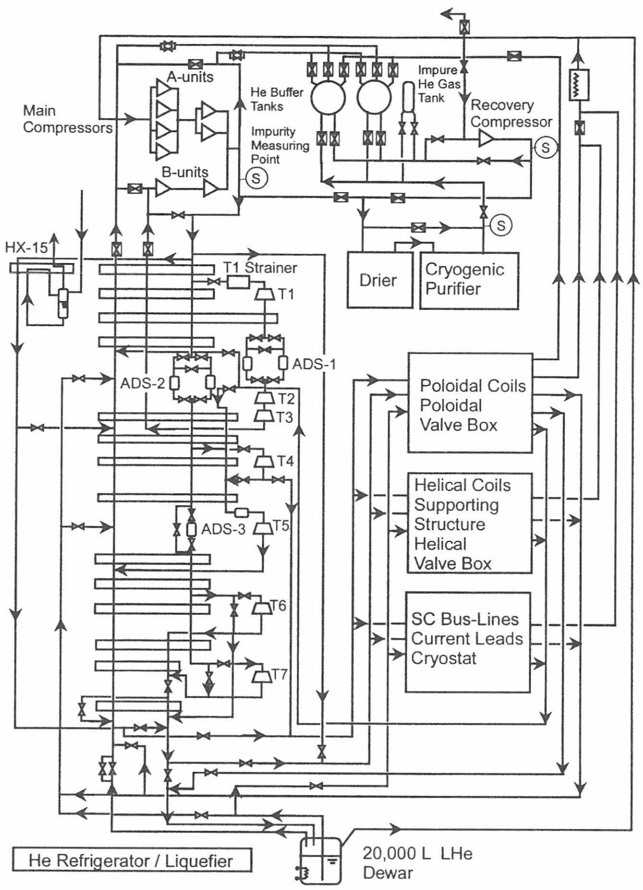

Fig. 1 Flow diagram of the LHD cryogenic system

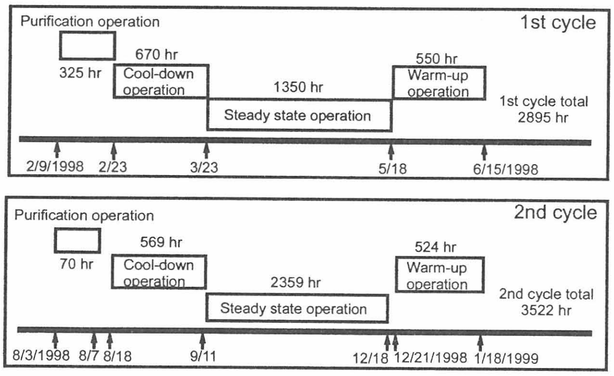

Fig. 2. Operation of the LHD cryogenic system