§1. Long-term Operational Performance of the LHD Cryogenic System

Mito, T., Iwamoto, A., Hamaguchi, S., Imagawa, S., Takahata, K., Yanagi, N., Chikaraishi, H., Moriuchi, S., Ooba, K., Takami, S., LHD Experiment Group

The Large Helical Device (LHD) is an experimental heliotron-type fusion plasma which consisting of a complete superconducting magnet system cooled by a helium refrigerator having a total equivalent cooling capacity of 9.2 kW@4.4 K. Eighteen plasma experimental campaigns have been performed successfully since 1997. Seventeen years have passed since beginning system operation. During the operational history, appropriate improvements have been implemented to prevent serious failures and to pursue further reliability.

The LHD superconducting coils are installed in the cryostat. The size of the LHD cryostat is 13.5 m in outer diameter, 8.8 m in height, and 1,500 tons in total weight. The cold mass at 4.4 K in the cryostat weights 820 tons. Three different cooling schemes are utilized; forced flow of supercritical helium for the poloidal coils, forced flow of two phase helium for the supporting structure for the large electromagnetic forces between the superconducting coils, and pool boiling of liquid helium for the helical coils. The excitation of the LHD superconducting coils has been performed with the superconducting bus-lines, whose maximum current capacity is 31.3 kA and the total length of 9 bus-lines becomes 497 m. The bus-lines are also cooled by forced flow of two phase helium.

All components of the LHD cryogenic system are installed as shown in Fig. 1. The helium refrigerator consists of two cold-boxes divided on high temperature side and low temperature side, the 20,000 liter liquid helium reservoir, the 50,000 liter liquid nitrogen reservoir, and the 50 g/s helium gas purifier. Eight oil-injected screw compressors (960 g/s, 1.9 MPa) with two redundant compressors are installed in the compressor room, which is 50 m apart from the He refrigerator room, and are connected with pipes running in the underground tunnel. Two 700 m^3 (2.0 MPa) spherical holders and four 100 m^3 (2.0 MPa) cylindrical holders are used as helium buffer tanks to stabilize inlet and outlet pressures of the helium compressors and are also used for balancing the helium inventory in the LHD cryogenic system. Four 100 m^3 (2.0 MPa) cylindrical holders are used as supplying tanks of impure helium gas.

The operational history of the LHD cryogenic system is summarized in Fig. 2[1]. The total operation time of the system was 78,312 hours, and the steady state operation hours for keeping the system in the superconducting state have reached 50,287 hours[2]. Fig. 3 shows the availability of each operation cycle. Here, the availability is calculated using the mean time between failures (MTBF) and the mean time to repair (MTTR). After the early failure period of the start of operation, the LHD cryogenic system have achieved a high average availability of 99 %.

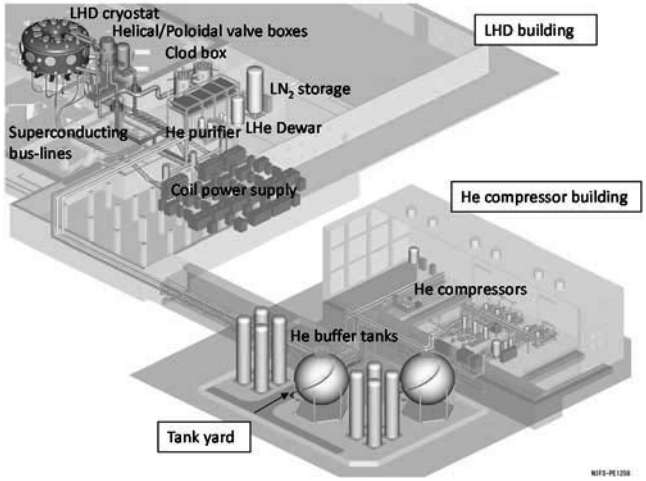

Fig. 1. Apparatus disposition of the LHD cryogenic system.

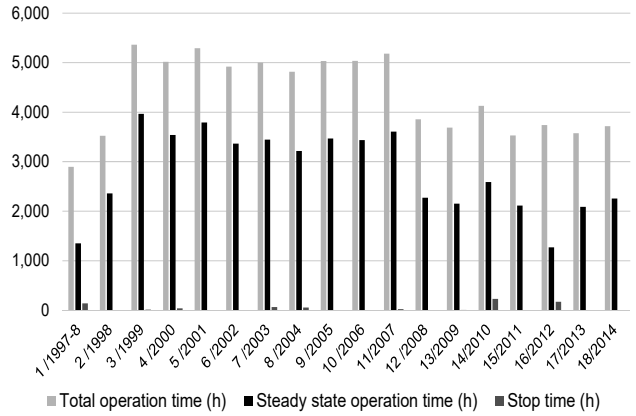

Fig. 2. Operation history of the LHD cryogenic system.

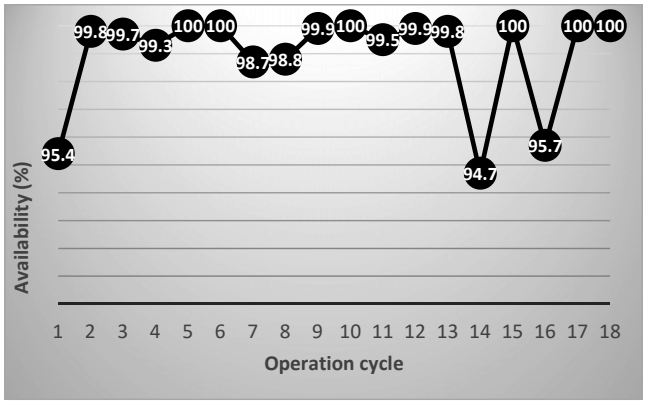

Fig. 3. Availability of the LHD cryogenic system.

1) Mito, T., Iwamoto, A., Oba, K., Takami, S., Moriuchi, S., Imagawa, S., Takahata, K., Yamada, S., Yanagi, N., Hamaguchi, S., Kishida, F., Nakashima, T., and the LHD group, "Renewal of control system and reliable long term operation of LHD cryogenic system," Physics Procedia PHPRO4696 (2015) S1875-3892(15)00395-8, DOI: 10.1016/j.phpro.2015.06.014

2) Mito, T., "Long-term Operational Performance of the LHD Cryogenic System," Teion Kougaku (Journal of Cryogenic and Superconductivity Society of Japan) (in Japansese), Vol. 50 No. 12 (2015) pp. 566 – 574.