

Re-examination of Refrigeration Power of the LHD Cryogenic System after 18 Years of Operation

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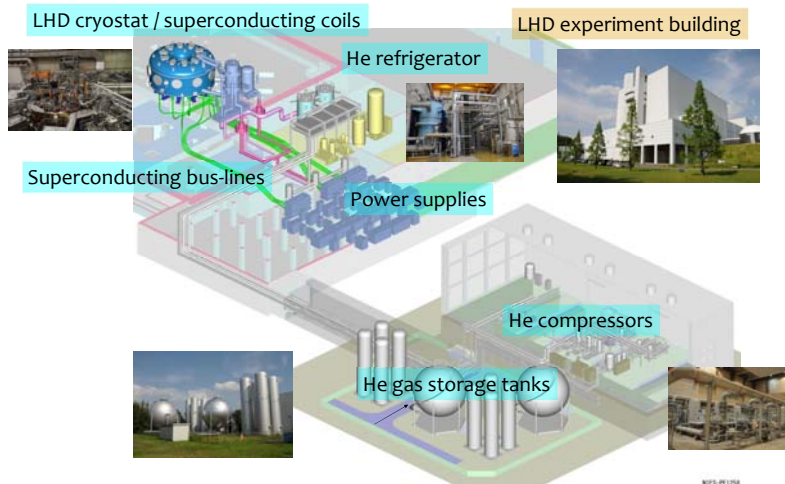


Fig. 1 Layout of LHD superconducting and cryogenic system

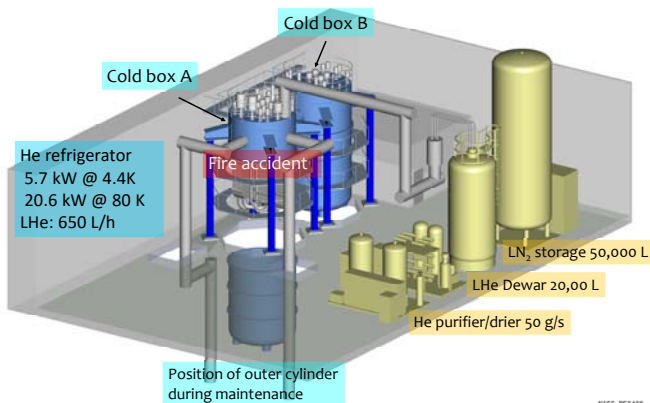


Fig. 2 Equipment layout in the He refrigeration room

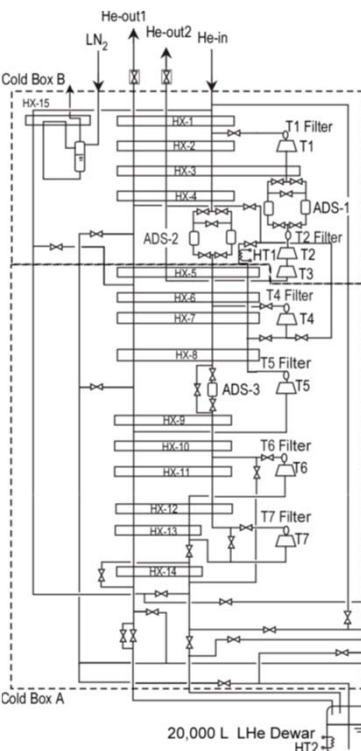


Fig. 3 Configuration in the cold box A and B

- The Large Helical Device (LHD) is a heliotron-type fusion plasma experimental device having the world first fully superconducting magnetic confinement system built in 1990's.
- The cryogenic system of LHD executed a long-term stable operation for 18 years from 1998 to 2015, and had been proving a high availability that passed 99 %.
- Unfortunately, a fire accident of the cold box of the helium refrigerator occurred during the maintenance period in August, 2015, and non-metallic components in the cold box, such as multi-layer insulation films, temperature sensors and measuring instruments, etc. were burnt down.
- After the accident, the restoration work started from November, 2015 and it was completed at the end of July in 2016.
- The test operation of the helium refrigerator was done in August, 2016, and the refrigeration power was compared with that measured in the initial performance testing done in 1995.

Table I Comparison of measured refrigeration power

Refrigeration power	Measurement on August 5, 2016	Measurement on June 17, 1995
4.4 K refrigeration power (Measured by heater input in LHe Dewar)	5.67 kW	5.67 kW
4.4 K liquefaction ability (Measured by He level sensor in LHe Dewar)	606 L/h	704 L/h
80 K refrigeration power (Measured by heater input of LTIC2023)	23.35 kW	20.7 kW
4.4 K equivalent refrigeration power	9.19 kW	9.38 kW

The measured equivalent refrigeration power at 4.4 K in 2016 was 9.16 kW, which showed a decrease of about 2 % from 9.38 kW that was measured in 1995.

The recovery items are listed below

- Cleaning of building and installation equipment in the helium refrigerator room
- Cleaning inside the cold box
- Cold box function recovery work
 - Check and cleaning of inner surface of piping in the cold box
 - Connection of piping for turbine inlet filters and ADS-1
 - Check of the control valves / manual valves
 - Helium leakage test
 - Check of integrity of piping / heat exchangers
 - Inspection of piping construction part
 - (The completion test on the High Pressure Gas Safety Act retrofitting application was included)
 - Exchange of 86 temperature sensors (include dual redundant sensors and sensors for interlock) in the cold box
 - Repair of power wiring for heaters and external wiring for sensors
 - Installation of multi-layer insulation films
 - Vacuum substitution with helium gas of piping system
 - Helium gas purification in the cold box
 - Overhaul of ADS-1 exit valve
 - Installation of seven turbines

- We consider that the slight decrease in this refrigeration power is due to a possible performance deterioration by the aging of 18 years operation such as the dirt of the heat exchangers and not by the direct influence of the fire accident.

LHD deuterium plasma experiment started in 2017

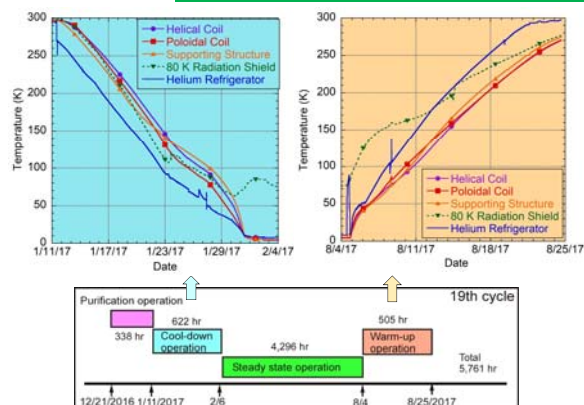


Fig. 4 19th operation of LHD was successfully conducted

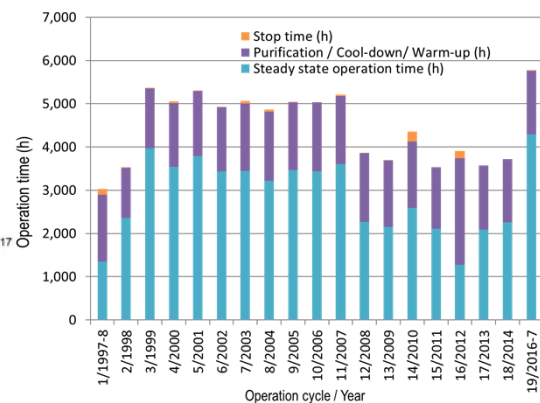


Fig. 5 Operation history of LHD

- LHD restarted operation in January, 2017, and the 19th cycle operation with deuterium plasma experiment was successfully conducted up to August, 2017.
- After the fire accident, the restoration work started from November, 2015 and completed at the end of July in 2016 and the cooling power was re-examined by the test operation in August, 2016.
- The LHD cryogenic system stays in a minimum aging by executing an appropriate maintenance, and keeping the sufficient performance though it has been experienced operation of 20 years.
- Highly reliable operations of the LHD cryogenic system have been achieved with availability of 99.1 %
- Total operation time became 84,073 hours from 1997 to 2017.