(4) LHD Device Engineering Experiments

1. Introduction

The LHD superconducting system consists of a pair of pool-cooled helical coils (H1 and H2 coils), three pairs of forced-flow-cooled poloidal coils (IV, IS, and OV coils), nine superconducting bus-lines, a helium liquefier and refrigerator in the 10 KW class, and six DC power supplies.

The output voltage of the main power supplies for the helical coils and poloidal coils are ±45 V and ±33 V, respectively. They have capacities to charge all the coils to the full currents within 15 minutes. In addition, thyristor rectifiers with the output voltage of ±180 V and current capacity of 6.2 kA are added to the power supply systems for IV coils and IS coils for dynamic control of the plasma axis. They can change the plasma axis by approximately 0.1 m/s at 0.5 T. Remote switches to change the polarity of coil currents have been installed after thirteenth cycle.

The reliable operation of the large superconducting system has been demonstrated, and researches to examine properties of the superconducting coils are continued toward fusion reactors. Results of device engineering experiments and the operations in the fifteenth cycle are summarized.

2. Fifteenth Cycle Operation of LHD

The history of the fifteenth cycle operation of LHD is shown in Table 1. Main compressors of the cryogenic system started on June 17, 2011, and they stopped on November 11. The total operation hours of the system until the end of the fifteenth cycle was 67,278 hours, and the steady state operation hours for keeping the system in the superconducting state have reached 44,741 hours.

Table 1 The history of the fifteenth cycle operation.

Operation mode	Month/Day/Year
<Vacuum pumping system>	
Pumping a cryostat	6/9/2011-11/10/2011
Pumping a plasma vacuum vessel	6/10/2011-11/10/2011
<Cryogenic system>	
Purification	6/17/2011-6/28/2011
Cool-down	6/29/2011-7/24/2011
Steady state operation	7/25/2011-10/20/2011
Warm-up	10/21/2011-11/11/2011

3. Device Engineering Experiments

Excitation tests of the superconducting coils before plasma experiments were conducted on July 26, 27. Propagation of a normal zone was not observed in the fifteenth campaign. The following values were attained in subcooled helium;

(1) *#1-o, B*=2.65 T @ 3.75 m (H-O/M/I = 11.042 kA)

(2) *#1-d, B*=2.896 T @ 3.60 m (H-O/M/I = 11.8/11.75 /11.2 kA), plasma axis shift from 3.5 m to 3.75 m at 11.4 kA of the helical coil, and mode transition at 11.0 kA of the helical coil (radii of the plasma axis were 3.75 to 4.1 m, quadrupole components were 72 to 200%)

4. Research activities

We have promoted device-engineering researches using the LHD. Their main purpose is optimization of the subcooling system. In order to improve the reliability of the LHD cryogenic system, two upgrading programs are preceded. The first is the addition of redundant compressors. Two kinds of redundant compressors are added to back up even when which one of eight compressors breaks down. The second is the update of the cryogenic control system, in which update the hardware of control system from VME controllers to CompactPCI controllers + remote I/O (EtherNet/IP).

The titles of the researches are listed in the following;

(1) Analysis on the winding motions of the LHD coils by correlation of AE and balance-voltage signals. (Ninomiya, A. (Seikei Univ.))

(2) Highly reliable operations of the LHD cryogenic system. (Mito, T. (NIFS))

(3) Improvements of the LHD cryogenic system for highly reliable operations. (Mito, T. (NIFS))

(4) Mitigation of mass flow change of cold compressors by heater in saturated helium bath during quick discharge. (Hamaguchi, S. (NIFS))

(5) Reconsideration of evaluation of balance voltages during a normal zone propagation in the LHD helical coils. (Imagawa, S. (NIFS))

(Imagawa, S.)