## *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 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 sixteenth cycle are summarized.

## *2. Sixteenth Cycle Operation of LHD*

The history of the sixteenth cycle operation of LHD is shown in Table 1. Main compressors of the cryogenic system started on July 17, 2012, and the cool-down started on August 1. On the way to the cool-down, sudden increase of pressure in the cryostat by a helium leak was observed on August 12, and the pressure was raised with the cool-down. Therefore, we decided that the leak was repaired. Before warm up, the leaking line was identified by separating the helium cooling lines with valves. After warm up, the leaking break was detected with suniffer method, and it was fixed by inserting resin from outside with pumping the inside. 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 sixteenth cycle operation.

| Operation mode | Month/Day/Year |
|---|---|
| <Vacuum pumping system> | |
| Pumping a cryostat | 7/5/2012-12/27/2012 |
| (Stop pumping for repairing | 9/5/2012-9/14/2012) |
| Pumping a plasma vacuum vessel | 7/6/2012-12/18/2012 |
| <Cryogenic system> | |
| Purification | 7/17/2012-7/30/2012 |
| Cool-down | 8/1/2012-8/20/2012 |
| Warm-up | 8/20/2012-9/7/2012 |
| Repairing a leak | 9/7/2012-9/13/2012 |
| Purification | 9/14/2012-9/18/2012 |
| Cool-down | 9/19/2012-10/14/2012 |
| Steady state operation | 10/15/2012-12/7/2012 |
| Warm-up | 12/8/2012-12/28/2012 |

## *3. Device Engineering Experiments*

Excitation tests of the superconducting coils before plasma experiments were conducted on October 15 and 16. 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). These new systems are utilized at the warm up of the sixteenth cycle.

The titles of the researches are listed in the following;

(1) Rotational vibrations of the rotor shafts of the cold compressors in the helium subcooling system for the LHD helical coils. (Hamaguchi, S. (NIFS))

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

(Imagawa, S.)