16. Department of Engineering and Technical Services

The Department of Engineering and Technical Services covers a wide range of work in the design, fabrication, construction, and operation of experimental devices in the fields of software and hardware.

The department consists of the following five divisions. The Fabrication Technology Division oversees the construction of small devices and quality control of parts for all divisions. The Device Technology Division works on the Large Helical Device (LHD) and its peripheral devices except for heating devices and diagnostic devices. The Plasma Heating Technology Division supports the ECH system, the ICRF system, and the NBI system. The Diagnostic Technology Division develops, operates, and maintains all diagnostic devices. Finally, the Control Technology Division concentrates on the central control system, the cryogenic system, the current control system, and the NIFS network.

The total number of staff is 54 (2016). We have charge in the development, the operation, and the maintenance of the LHD and its peripheral devices with approximately 54 engineers.

1. Fabrication Technology Division

The main task of this division is the fabrication of experimental equipment. We also take care of technical consultation and supplies of experimental parts for the LHD experiment. In addition, we manage the administrative procedures of the department.

The number of requests of manufacturing was 110, and the total number of production parts was 580. The total numbers of requests and articles of electronic engineering were 8 and 61, respectively. The details of some of this division's activities follow below.

(1) DC offset voltage canceller

The circuit shown in figure 1 is to cancel the DC offset voltage of the signal from the FIR laser interferometer. The canceller consists of an ADC board (AD7626), an FPGA board (eXstick) and a DAC board (LTC2601), and it can transfer the output data signal to a remote PC using an Ethernet LAN. This supplies signal source for electron-density feedback control to the ECRH system of LHD.

Fig. 1 DC offset voltage canceller.

(2) Corrugated Resonator

To excite a cylindrical Bloch wave at the frequency of 300 GHz, we fabricated a cylindrical cavity wall and a central conductor with a periodic waveform shown in figure 2 for Niigata University. The cylindrical cavity and center conductor have 160 corrugations. Parameters of the rectangular corrugation are 0.15mm in width, 0.075mm in depth, and 0.25mm in periodic length.

(3) The beam profile monitor of HIBP for deuterium experiments.

We shielded an LED for wire position detection and a beam profile monitor (BPM) photo transistor to the basement, so that the detection beam can be transmitted and received by an optical fiber (Fig. 3).

Fig. 2 Corrugated resonator.

Fig. 3 The parts shielded against a strong neutron using an optical cable.

2. Device Technology Division

The Division supports the operation, the improvement, and the maintenance of LHD. We also made preparation for the deuterium experiments in this fiscal year.

(1) Operation of LHD

We started pumping of the cryostat vessel for cryogenic components on December 15, 2016 and of the plasma vacuum vessel on December 17. Subsequently, we checked air leaking from the flanges of the plasma vacuum vessel. The number of checked flanges was 120 . As a result, 3 flanges were found to leak and repaired. The pressure of the cryostat vessel reached the adiabatic condition ($< 2\times10^{-2}$ Pa) on December 17 and the pressure of the plasma vacuum vessel reached below 1×10^{-5} Pa on December 27.

The LHD experiment of the 19th experimental campaign began on February 6, 2017 and is scheduled to continue until August 3, 2017. During this experimental campaign, the vacuum pumping systems must eliminate air from both vessels without trouble.

(2) Operation of the exhaust detritiation system

In the LHD, a small amount of tritium is produced by deuterium plasma experiments. In 2015, an exhaust detritiation system (EDS) was installed to treat tritium exhausted from the LHD, and began operation continuously from December 2016.

The EDS has two systems; one is a vacuum gas detritiation system (MS type system), and the other is a purge gas detritiation system (PM type system). Each system consists of compressors, blowers, heaters, valves, and controllers that control these devices

In the hydrogen plasma experiments in February 2017, it was possible to operate without any trouble rough pumping of the vacuum vessel, and exhaust gas of the Neutral Beam Injection (NBI) system with the EDS.

In the deuterium plasma experiments in March 2017, exhaust gas contain tritium was treated by the EDS. One of the important parameters of the EDS is the recovery rate. This recovery rate is calculated from the concentration of the tritium at the inlet/outlet port of the EDS.

As shown in Fig. 4, a measurement system was installed to research the concentration of the tritium. A water bubbler system (WB) was installed at both the inlet/outlet of the MS type system. When the sample gas from the EDS is introduced into the WB, the tritium is captured. The amount of captured tritium in the WB is measured by a liquid scintillation counter. By this research, we can estimate the concentration of the tritium in the exhausted gas, and the recovery rate of the EDS. From the measurement in March 2017, it was confirmed that the recovery rate of the EDS reached 95% or more, which is the design specification of the EDS.

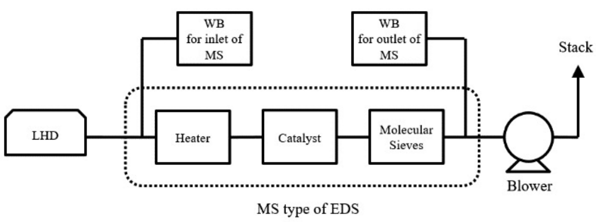

Fig. 4 System diagram of the measurement system for tritium in EDS

(3) Development of gas switching system

In LHD plasma experiment, gas (H2, D2, He, Ne, N2, etc.) is injected as a fuel gas. We switched gases manually in past years. In order to facilitate gas exchange, we developed a new system (Fig. 5) this time. The gas exchange system consists of relay circuit and PLC. This system uses a switch box to quickly change gases and operate without causing errors due to switch circuits. Thus, we could secure safety of fuel gas and respond quickly to the plasma experiment.

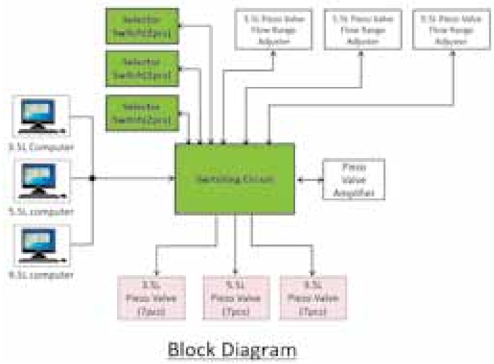

Fig. 5　Block diagram of gas switching system

3. Plasma Heating Technology Division

The main tasks of this division are the operation and the maintenance of three individual types of plasma heating devices and their common facilities. We have also performed technical support for improving, developing, and newly installing these devices.

In this fiscal year, we mainly carried out device improvement and modification which enable the deuterium plasma experiment and plasma injection. The details of these activities are as follows.

(1) ECH

An ECH group has been concentrating on improving the system to prepare the next deuterium plasma experiments in LHD, and we anticipated that the radiation dose affecting the ECH devices will increase. After 1 year of experiment cancellation, all devices were perfectly prepared. One of the preparations was setting the radiation shields with polyethylene composite panels in front of rotary encoders of the ECH launchers to avoid miscounts due to radiation effects. We also installed a remote controller of the vacuum components in the LHD hall. Installing the water leak detector on the transmission line is very effective against boundary gate valves that can operate quickly to shut off the waveguide in case of accidental leakage in the transmission line through the LHD. These and other ECH devices certainly have functioned as plasma heating from the start of this campaign to the present, and have contributed to the achievement of the first deuterium plasma generation with only the ECH of LHD #133301 (Fig. 6).

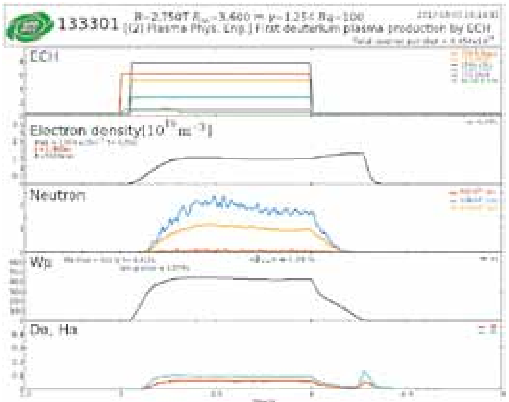

Fig. 6　Parameters of deuterium first plasma in LHD (2017/March/7)

(2) ICH

As a preparation for the deuterium experiment, ICRF antennas have been removed from LHD. In addition to the removal of a pair of Poloidal Array antennas from the 7.5U&L ports of the LHD the last year, we decided to remove a pair of HAS antennas from the 3.5U&L ports and another a pair of FAIT antennas from the 4.5U&L ports this time. We kept them except Poloidal Array antennas at the Heating Power Equipment Room for considering possibility to reinstall to the LHD again. We also moved the control devices, such as a motor driver, to the basement of the LHD experimental hall and took measure to reduce the troubles due to the effects of neutrons. Moreover, the control devices which could not be transferred out of the LHD experiment hall were covered with the polyethylene board for radiation shielding.

(3) NBI

(a) The operation and maintenance of NBI in the 19th experimental campaign of LHD.

This campaign's top topics of NBI group were deuterium beam operation and its preparation (gas piping for deuterium gas, neutron shielding, and relocation of control and measurement equipment, etc.). At the end of this March, BL-4 and BL-5 marked 9MW as deign vale (with 4 ion-sources by deuterium beam) successfully.

Fig. 7 shows the shot-history of total injection beam power of negative-NBI (BL-1, 2, 3). Approximately 4,000 shots of beams were injected into LHD plasma in this campaign (before the end of March). The maximum total injection power of negative-NBI was 14.3MW due to some minor trouble. BL-1 kept up? 4.8-5.6MW, BL-2 kept up 4.0-4.6MW, and BL-3 kept up 4.0-4.8MW for plasma heating. The maximum total injection power of positive-NBI (BL-4, 5) was 12MW by hydrogen beam, 18MW by deuterium beam. BL-4 kept up 6.0-9.0MW, BL-5 kept up 6.0-9.0MW, and covered a broad range of injection power as plasma diagnostics-beam.

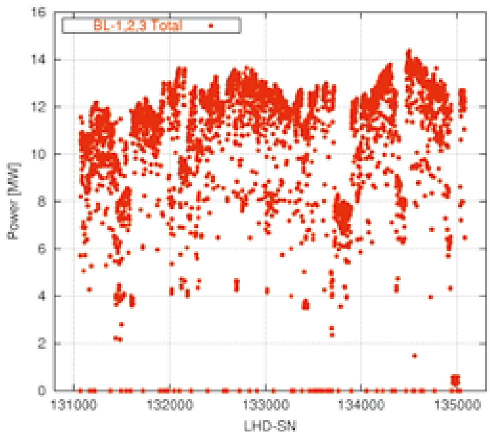

Fig. 7 Shot-history of negative-NBI injection beam power

(b) Preparation of the maintenance room

The maintenance room maintains devices used for LHD deuterium experiments. Green houses, gas supply system, and vacuum system have been installed in this room. In the green house, parts of ion sources of NBI are polished with exhausting inside air by the dust collector. The gas supply system supplies nitrogen, argon, helium, and compressed air. Ion sources of NBI are tested for vacuum leak by using the vacuum system. Figure 8 shows the preparation status of the maintenance room.

Fig. 8 Overview of the maintenance room

(4) Motor-Generator (MG) with flywheel

The motor generator (MG) supplies pulse power to the NBI and the ECH of the LHD. The MG generated 14,910 shots in this fiscal year and 596,880 shots since its construction. The operation time was 850 hours in this fiscal year, and 27,999 hours in total. Programmable logic controllers for controlling MG and auxiliary machines, and the high speed circuit breaker in the speed control panel have been renewed.

4. Diagnostics Technology Division

This division supports diagnostic devices, radiation measurement, and radiation control. We have made preparations for the deuterium experiments in this fiscal year. Our main tasks are described below.

(1) Preparing plasma diagnostics for deuteron operation

The neutron flux monitor installed in the LHD for deuteron operation was calibrated using radiation source. This calibration experiment is operated 24 hours a day seven days a week by a staff of 30 technicians.

For the diagnostic apparatus we used an intelligent control unit, and the controllers have been removed from the torus hall. The controller position is limited by length of the control cable, those have been removed to the system rack at the basement of the torus hall. About 30 of 19-inch system rack have been removed to lifted stage of the basement. Those racks are arranged with a polyethylene board which can protect from radiation. If those can't remove to the basement, the intelligent control units have been covered by the polyethylene board at the torus hall. 30 ton of the polyethylene boards as 25 kg/plate have been provided.

As an example, figure 9 shows a shutter control system at the torus hall. This system consists of two solenoid valve units that control the supply of compressed air and one programmable logic controller (PLC) unit that supplies the control voltage to the solenoid valve. The PLC unit was removed outside of the torus hall. However, the solenoid valve unit with the integrated circuit could not been removed from the torus hall. This is because compressed air must be supplied to the diagnostic system of about 20seconds. To protect the solenoid valve unit from radiation, several polyethylene plates are attached to the side of 19-inch system rack (Fig. 9).

Fig. 9　19-inch system rack covered by polyethylene plates

(2) Radiation monitoring

We measure the safety of radioactivity with the radiation measuring equipment such as high-purity germanium (HPGe) detectors, liquid scintillation counters, the stuck tritium monitoring system, the gas monitors, and the drain water monitor. The tritium monitoring system of the stack monitors the tritium concentration of exhaust in the stack by using a tritium sampler. The third tritium sampler was installed to record backup data of the current fiscal year as shown in Fig. 10.

The gas monitor is installed for the stack of the torus hall and the LHD building. Since the deuterium experiment began. The drainage monitor from the control area also started formal operation. All the measured values were below detectable levels.

Fig. 10　The newly installed tritium sampler

(3) Integrated radiation monitoring system

In order to integrate information for radiation safety, the integrated radiation monitoring system has been continuously prepared from last fiscal year.

(a) Control console

The control console of the integrated radiation monitoring system is installed in the control room (Fig. 11). In order to start LHD experiment, an authorized person must release the key-lock and control the console.

Fig. 11　The control console and the integrated monitoring display installed in the control room

(b) Integrated monitoring display

The displays are installed in the control room. These display important numerical values measured by fusion products diagnostics system and the radiation monitoring devices.

(c) ITV

An ITV was introduced last year. This fiscal year, some ITV cameras were added in the exhaust gas processing room.

(d) Access control system in the controlled area

We introduced an access control system within the controlled area last fiscal year. ITV system was completed at November 11 when the 19th LHD experiment began and officially started operation.

(4) Operation and maintenance of diagnostics devices

The 19th Experimental Campaign maintains diagnostic devices and maintains these components (high voltage power supply, vacuum pumping system, gas supply system, phase detection circuit, water cooling system, etc.).

Fig. 12 Maintenance of a methanol supply unit for FIR and operation of YAG lasers for Thomson scattering diagnostics.

(5) Data processing of diagnostic devices

For starting the 19th LHD experiment campaign, we prepared the “Data Acquisition (DAQ) System.” In this year, many diagnostics systems were transferred from the LHD room in order to take measures against radiation in the D-D experiments. Also, we moved many DAQ machines. We adjusted the timing system which did not work properly due to having become obsolete. We confirmed new functions and bug fixes for “Retrieve + dbStore ver. 19.1.0,” a new version of the LHD data management library.

5. Control Technology Division

The Control Technology Division contributed to important technological aspects of the LHD, such as operation and management, and development of the system. The division contributed also to management of the network system. The work in system operation and system management is as follows: operation of the cryogenic system and the power supply system for the superconducting coils, updating the central control system and cryogenic control system, and management of the network system. The work in system development this year is as follows: development of a new simulation algorithm for the cryogenic system, system development of the control system for LHD, and others. Details of the activities in this division are described below.

(1) LHD cryogenic control system

The cryogenics system has been found 11 bugs. However we were able to drive this control system without any trouble for one year. The total operating time system operating time was 360 days (8662 hours). Among the 11 software bugs, we fixed 4 bugs, and the remaining 7 logs were carried out by placing survey logs, etc., and this has been in investigating.

(2) LHD central control system

The central control system requires high reliability. Since starting 21 years have passed; and the signal conditioners more than 500 of status monitoring system were replaced with new signal conditions in 2013. We updated the remaining one-half of the signal conditioners status monitoring system and changed the data communication line from the optical fiber to the hard wire this year.

(3) Network management

The NIFS campus information networks consist of several clusters. We manage the Research Information Cluster (NIFS-LAN) and the LHD Experiment Cluster (LHD-LAN).

(3.1) NIFS-LAN

NIFS-LAN is for general use, and covers the entire region on the campus. We have administrated the Routers, layer-2 / layer-3 switches, the quarantine authentication system, the mail server, the SSL-VPN server, the DNS server and the DHCP server.

New contributions in FY 2016 are as follows:

(a) Renewing the video conferencing system

We introduced the new teleconference system multipoint control unit RPCS-1800 (Polycom) (instead of RMX-1000). RPCS-1800 requires one-half as much traffic speed as RMX-1000 on HD teleconference. The RPCS-1000 is able to provide full-HD teleconference.

RPCS-1000 needs to be careful about the maximum number of concurrent connections because of the number of ports occupied by RPCS-1800 per connection on video protocol H.263.

(3.2) LHD-LAN

(a) Renewal of the “LHD-LAN Core Switch System”

Since LHD-LAN service started in 1996, we replaced the “LHD-LAN Core Switch System” for the second time.

We reduced the cost by combining two core switches into one (Cisco Ltd.’s Nexus7009 (performance: 8.8Tbps), and new one (Cisco’s Nexus 5672UP (performance: 1.44Tbps)) has been installed for a highly reliability. These two switches are connected with 160Gbps link aggregation

(b) LHD Access Gateway

A firewall was installed to limit the connection between NIFS-LAN and LHD-LAN, and MAG4610 (Juniper Network) is operated as the authentication server.

We dealt with user account management (32 initial registrations in FY2016), questions and inquiries related to requests from users, etc. corresponded.

Since December 2016, Mag4610 has finished with those who sent questions and inquiries. Thus, we are currently in the process of selecting the successor model.

(4) Development of monitoring software for the Radiation Integrated Monitoring System

The Control Technology Division developed multiple monitoring software which is a radiation integrated system for the deuterium experiments.

With the exhaust plant monitoring software (Fig. 13) and with the air flow trend collecting software (Fig. 14), programs running on .NET Framework regularly receive the data from each device via a PLC (Programmable Logic Controller), and display it.

Fig. 13　The exhaust plant monitoring software

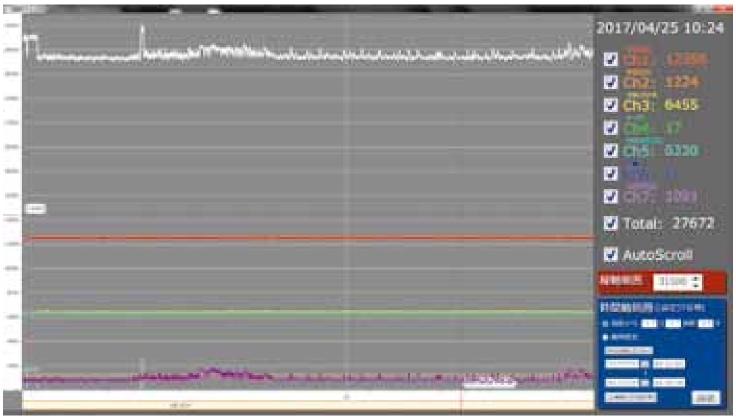

Fig. 14 The air flow trend collecting software

(5) Modeling and simulation of supercritical helium (SHe) loop of the Poloidal Field coils (PF) and Collection Coils (CC) in ITER cryogenic system by C-PREST

In the past, we implemented the model and conducted the dynamic simulation of SHe loop of the TF-ST, CS, and TF to investigate the impact of large pulsed heat load. In 2016, we carried out modeling of a forced-flow SHe cooling loop of the PF/CC and simulated its thermal-hydraulic behavior. Furthermore we created a model that integrates TF-ST, CS, TF, and PF/CC, and simulated.

(6) Update of the control computers for LHD superconducting coils power supply system

About 20 years have passed since the control computer of the LHD superconducting coil power supply system was installed, thus we updated for a new one.

We replaced two embedded computers and one integrated computer (desktop) with a new computer. By updating the VME bus system to compact the PCI bus system (Fig. 15), the transmission rate between each computer has been improved from 100Mbps to 1000Mbps.

Fig. 15 Embedded computer (compact PCI bus)

(7) Update of LHD helical coil measurement system (for pickup coils)

Pickup Coils are installed in the LHD helical coil measurement system which measures the uneven current density of the coil current.

We are trying to reduce costs by replacing WE7000 made by Yokogawa Electric Corporation with GL7000 made by GRAPHTEC Corporation. Both models have nearly the same resolutions with the sampling rate and the attenuation rate of filter. Among these comparisons, we discovered that the differences in the performance of frequency response went down. (WE7000(DC~40kHz:-1.5dB), GL7000(DC~1kHz:-3dB)), however considering the time constant of the coil is not a problem.

(S. Iima)