15. Department of Engineering and Technical Services

The Department of Engineering and Technical Services (DETS) is involved in the operation and maintenance of research platforms such as the Large Helical Device (LHD) and information facilities such as the research infrastructure network, as well as the design, development, and fabrication of equipment, radiation control, and safety promotion. The DETS contributes greatly to the creation of results in fusion research through advanced and specialized technical support. It consists of five technical divisions. and the total number of staff is now 50 (2025.6).

The FY2024, 25-cycle LHD Campaign was conducted from March 13, 2024 to June 20, 2024. The experimental schedule was successfully carried out, with no trouble, and almost 100% uptime was achieved, which was evaluated as a considerable achievement of the activities of the DETS.

The following is a report on its activities.

(H. Hayashi)

Mechanical Systems Technology Division

The main work of this division is the fabrication of experimental equipment. For example, we fabricated a type of notch filter and mirrors for micro-waves using a cutting process. Other processes such as welding and drilling were performed with vacuum parts and equipment mounting fixtures, etc. We also took care of technical consultation related equipment for design and drawing. The number of machined requests was 72 in this fiscal year (FY).

In order to supply some commonly used experimental parts, we operate and manage a parts room on the premises. The parts room handles about 1000 parts related to electric, vacuum functions etc.

In addition, we manage the administrative procedures of the technical department.

(T. Kobuchi)

(1) Focusing mirror for micro-waves for Q-shu University Experiment with Steady-State Spherical Tokamak (QUEST)

We have fabricated a focusing mirror for QUEST (Fig. 1). It has a spherical shape of a 800 mm radius. The material of the mirror is an aluminum alloy; the mirror is 270 mm in length and 270 mm in width. It took 12 hours to complete the cutting process.

(K. Okada and T. Shimizu)

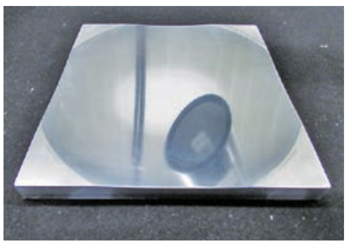

Fig. 1 Focusing mirror for micro-waves fabricated with a cutting process.

(2) Maintenance and modification of LHD-related equipment

We perform maintenance and modification of LHD-related equipment. The main equipment includes a cooling water system, water leak detection equipment, and a power-supply system for the Local Island Divertor (LID). We also carry out the installation management of vacuum flanges. The CAD office provides LHD drawings and other services.

(M. Kawai)

Design and Development Technology Division

This Division provides technical support for the operation, improvement, and maintenance of LHD, as well as support for collaborative and commissioned research.

(N. Suzuki)

(1) LHD vacuum pumping system

To carry out the 25th LHD experimental campaign, we started the vacuum pumping system operation for the cryostat vessel on February 1, 2024, and for the plasma vacuum vessel on February 2, 2024. The pressure of the cryostat vessel reached an adiabatic condition (< 2e-2 Pa) on February 2, 2024. After the initial pumping of the plasma vacuum vessel was completed, a leak check was conducted, and one leak was found. The leak was repaired by retightening the bolts. After approximately five days of baking the vacuum vessel, the pressure required for conducting a plasma experiment, below 1e-5 Pa, was reached. Fig. 2 shows the pumping process from the 23rd to the 25th campaigns. The operation of the vacuum pumping system was conducted until July 12, 2024 without any problems.

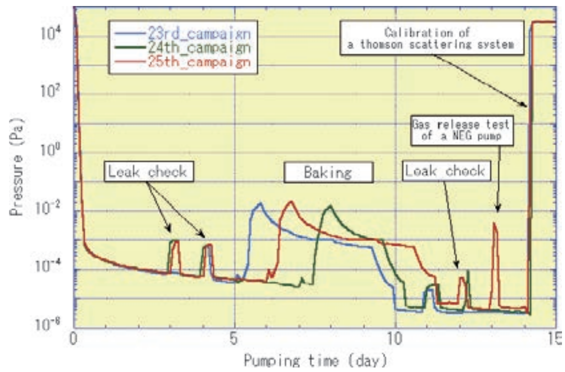

Fig. 2 The pumping process from the 23rd to the 25th campaign

(N. Suzuki)

(2) Tritium emission rate measurement method for plasma-facing walls in the LHD vacuum vessel

In the LHD, deuterium plasma experiments have been carried out for six years, during which tritium was produced in the vacuum vessel, with some remaining at the plasma-facing walls. In order to identify the location of tritium emission in the vacuum vessel, some parts of the plasma-facing walls were demounted and the tritium emission rate from them was calculated.

The demounted parts of the plasma-facing walls were set one by one in a vacuum desiccator and allowed to stand for one week. After that, the gas in the vacuum desiccator was exhausted into an aluminum bag using a vacuum pump, as shown in Fig. 3. The gas in the aluminum bag was collected to capture tritium using a water bubbler device (MARC7000, SDEC France). A flow diagram of the water bubbler device is shown in Fig. 4. The collected water was mixed with a liquid scintillator (Ultima GOLD LLT, Revvity) and measured with a low background liquid scintillation counter (LSC-LB-7, Aloka) to quantify the tritium content. The tritium emission rate per unit area

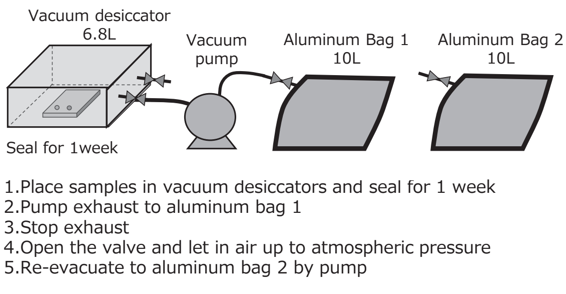

Fig. 3 Emission procedure

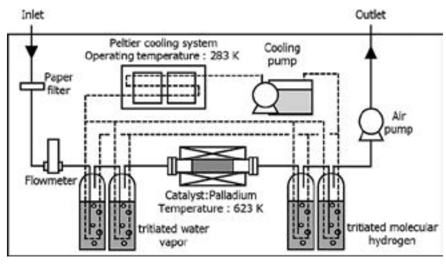

Fig. 4 Flow diagram of water bubbler system

was calculated and estimated based on the measured tritium amount, collected time, and sample area.

A total of 33 plasma-facing walls were evaluated.

(H. Kato)

(3) Development of a prototype pulsed magnetic field generator

This report is about the development of a prototype pulsed magnetic field generator. As an initial step, we developed a prototype capable of generating pulsed magnetic fields by momentarily applying a large current to a solenoid coil made of copper wire. The power supply system employed a capacitor charge/discharge method, where energy stored in a capacitor was rapidly released into the coil. Two sets of Insulated Gate Bipolar Transistors (IGBTs) were used as the switching device for both charging and discharging processes. The electrolytic capacitors with 2350 μF in total could be charged up to a maximum voltage of 140 V. The solenoid coil had a diameter of 40 mm and was wound with copper wire of 1 mm in diameter, totaling 75 turns. The fabricated coil resistance showed approximately 0.2 Ω. The circuit diagram of the prototype is shown in Fig. 5.

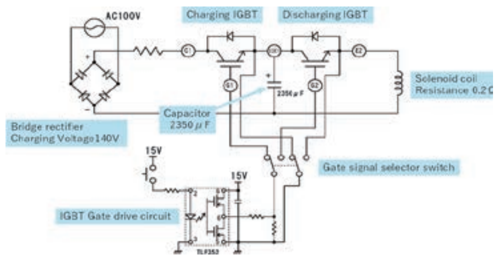

Fig. 5 Circuit diagram of the prototype pulsed magnetic generator

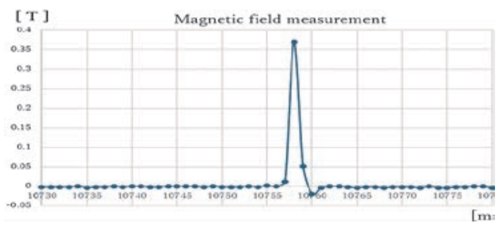

Fig. 6 Magnetic field measurement graph

In this prototype, the maximum current applied to the coil was 300 A. Magnetic field measurements on the coil using a gaussmeter revealed a peak field strength of approximately 0.37 T, with a pulse width of around 2 ms. The magnetic field measurement graph is shown in Fig. 6. In this investigation, a solenoid coil wound with copper wire was used, but in the future, we aim to develop another prototype using a High-Temperature Superconducting (HTS) coil to enhance the magnetic field strength.

(H. Noguchi)

Electrical and Electronic Technology Division

The main tasks of this division are the operation and maintenance of plasma-heating devices using high-voltage and high-frequency power supplies and their common facilities. We have also provided technical support for experimental equipment, including electrical and electronic circuits. The details of these activities are as follows.

(T. Kondo)

(1) Electrical and electronic work for experimental equipment

(a) GaN-FET inverter for RF-NBI

Fig. 7 shows a component of the high-frequency power supply for an NBI's RF ion source. This board has two GaN-FETs and operates at a switching frequency of 500 kHz to 4 MHz, with an output of up to 2 kW. This power supply forms a bridge circuit on two boards, and eight such boards make up one set. Four sets will connect in parallel to output more high-frequency power.

(Y. Ito)

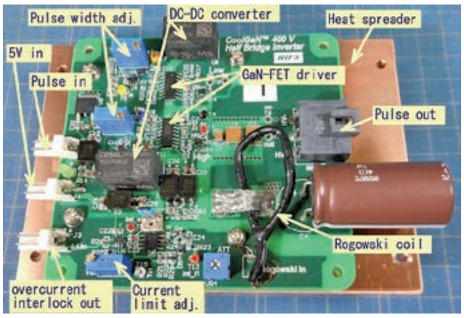

Fig. 7 Inverter power supply circuit board

(b) Installation of an auto-drain timer for a compressed air system

We modified a compressed air system in R & D Laboratories to enable the automatic drainage of water from the air compressor (Fig. 8). The new system has a solenoid valve and two timer relays, and it is possible to drain water for a fixed period on a regular basis by combining a timer, TMR1, for setting the repeat interval and another timer, TMR2, for setting the drainage time (Fig. 9).

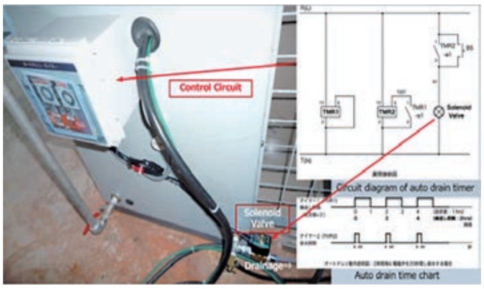

Fig. 8 Installation of auto drain timer

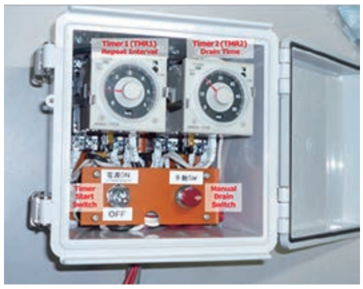

Fig. 9 Auto-drain timer circui

(K. Yasui)

(2) The operation and maintenance of plasma-heating devices for LHD

(a) ECH

During the 25th experimental campaign, we injected power up to 4MW to assist the plasma experiments. Major trouble in this experimental campaign occurred in the grounding device of the gyrotran's collector power source and its anode power supply. The reason for each was the deterioration over time of small switching power supplies for control boards. This trouble was resolved quickly by replacing them with spare switching power supplies.

(Y. Mizuno)

(b) ICRF

In the 25th experimental campaign, we carried out the LHD experiment with a total of two antennas with four antenna straps, that is, a handshake type (HAS) antenna with two antenna straps at the 3.5U&L ports and a Field-Aligned Impedance-Transforming (FAIT) antenna with two antenna straps at the 4.5U&L ports of the LHD. We changed the combination of an RF transmitter and an antenna strap. So, transmitters #3 and #4 connected to the 3.5U&L antenna straps and transmitters #6A and #5B connected to the 4.5U&L antenna straps. However, a problem began to occur early in the 25th experimental campaign when an oscillation of the #4 transmitter triggered an interlock in its high-voltage DC power supply, causing the #4 transmitter to stop operation. Therefore, a steady-state experiment was conducted with three antennas, excluding the HAS antenna at the 3.5L port. The resulting injection power and pulse length were 1.12 MW/114 sec.

(G. Nomura)

(c) NBI

In the 25th experimental campaign, we injected into the LHD plasmas approximately 6,000 shots of neutral beams. The negative-NBIs' (BL1, BL2, and BL3) maximum total injection power was about 14 MW. The positive-NBIs' (BL4 and BL5) maximum total injection power was about 10 MW. There were serious problems or trouble in the LHD plasma experiments.

(M. Sato)

(d) Motor-Generator (MG)

The MG has been used for supplying pulsed power to NBI and ECH for 3,623 shots in this fiscal year and 723,733 shots since its construction. The operation time was 184 hours. Brushes for the MG's drive motor have become shorter than the reference dimensions through wear, so all of them were replaced with spares. And we made a renewal plan for equipment including capacitor filters that were suspected of PCB contamination.

(Y. Mizuno)

(e) Cooling water equipment for plasma-heating devices

The measurement units of the outlet water temperature of the cooling tower and valve position did not work well. Our investigation found failure of parts for measurement, so we replaced them. Water sprinkler pumps for the cooling tower underwent disassembly and inspection work, including replacing V-belts and pulleys for the fan and a casing for pumps.

(Y. Mizuno)

Diagnostics and Analysis Technology Division

We are engaged in the development and maintenance of diagnostic devices and a data acquisition system. We also conduct radiation measurements and are responsible for radiation control.

From March to June 2024, the LHD experiment was conducted, during which we supported the startup, shutdown, and monitoring of the diagnostic devices related to the LHD device. Until now, these tasks had been carried out by operators, but due to the end of their contracts, this was the first time that technical staff handled the operations independently. Although there were concerns about potential operational errors, the manuals that had been developed since the previous fiscal year contributed to the successful execution of support activities without major issues.

The following describes modification of the Heavy Ion Beam Probe (HIBP) which is a main diagnostic device for the LHD, new RAID storage devices of the LHD data acquisition system and activities related to radiation management.

(H. Hayashi)

(1) Modification of Cesium Oven for HIBP Negative Ion Source

The cesium oven manufactured for use with negative ion sources has a double-walled structure for thermal insulation, with a cesium filled innermost chamber. However, a phenomenon occurs where the evaporated cesium condenses upon cooling and accumulates between the two layers. If the oven flange is removed while residual cesium remains between the double walls, it reacts chemically with moisture in the air, ignites, and may cause fire to spread. To prevent this, the cesium tank was modified to a single-walled structure.

(H. Takubo)

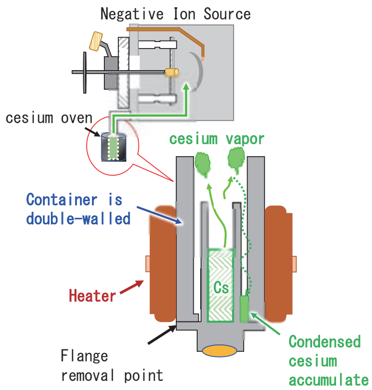

Fig.10 Cross-section of cesium oven

(2) LHD data acquisition (DAQ) system

For the DAQ operation in the 26th campaign of the LHD experiment, additional RAID storage devices with sufficient capacity for data to be generated were set up. The storage network has also been speeded up (mainly to 100Gbps) to enable efficient storage, transfer, and utilization of data which continues to grow in size year by year. In addition, three high-capacity storage devices with 106 HDDs have been installed for long-term storage and open access (OA), and all data stored in the LHD DAQ system are being copied to these units and made available as the OA system.

Fig. 11 New RAID storage devices in isolation racks

(M. Ohsuna)

(3) Online system for radiation measurement

To ensure radiation safety management for work conducted within the controlled area, contamination inspections using the smear method have been carried out. Since 2021, the entire process from application to approval for contamination inspections has been available online, and 438 requests have been received to date. A survey was conducted on the newly introduced online system with the aim of making improvements in the future. 86% of respondents said that the online system was easy to use, and the posted content that was requested to be improved was reviewed and updated.

(M. Nakada)

(4) Activation evaluation

In order to evaluate the degree of activation of the LHD torus hall and its basement due to the deuterium plasma experiment, NIFS has been conducting a survey in collaboration with the High Energy Accelerator Research Organization (KEK) since 2022. In the last fiscal year, neutron activation analysis was conducted in the Kyoto University Research Reactor (KUR) to analyze the constituent elements of concrete. Based on the results of these measurements, the validity of the radiation measurement results from the LHD in the previous year is being evaluated.

(M. Nakada and S. Kurita)

Fig. 12 Concrete sample of KUR

Control and Information Technology Division

The Control and Information Technology Division is in charge of important engineering tasks in the LHD project, such as system development, project management and system operation which are targeted at central control systems, cryogenic systems, coil power supply and super-conducting coils. We are also responsible for IT infrastructure, e.g., the LHD experiment network, the NIFS campus information network and internet servers in every phase of the project, including analysis, system design, implementation, operation and user support. The main activities for the last fiscal year are described below.

(K. Oba)

(1) LHD cryogenic system for superconducting coils

The cryogenic system operation in the 25th experimental campaign was performed without serious accident. Fig. 13 shows the operation result. On February 2nd, 2024, the He purification operation began. After that, a coil cool-down operation was performed for 600 hours. After approximately three months of plasma experiments, a coil warm-up operation was performed from June 21th to July 12th, 2024. The total operation time of the He compressors was 3860 hours.

(K. Oba)

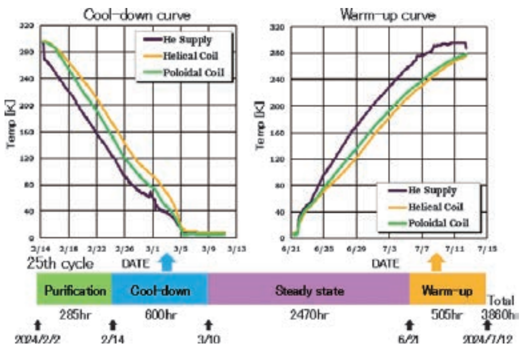

Fig. 13 Results of the 25th cycle operation of the LHD cryogenic system

(2) Management of utilities at the control building

The LHD Central Control System began in 1996 and had been operating without any major problems until the 25th experiment campaign. However, problems due to deterioration have occurred occasionally after more than ten years have passed since the core components consisting of the PLC and VME were updated in 2012. A communication error of the interlock signal between the PLC and remote terminal modules was a serious error which would interrupt a plasma experiment. Fig. 14 shows the part of the PLC configuration diagram that relates to the error. To solve the problem, we tried to identify its cause. Also, redesigning the entire PLC system was considered concurrently since some of the PLC components were no longer in production. Finally, the cause was determined by the optical-electrical converter, and the problem was solved by simply replacing the device. As the next experiment campaign will be the last campaign of the LHD project, we will continue maintaining the system to keep it in best condition.

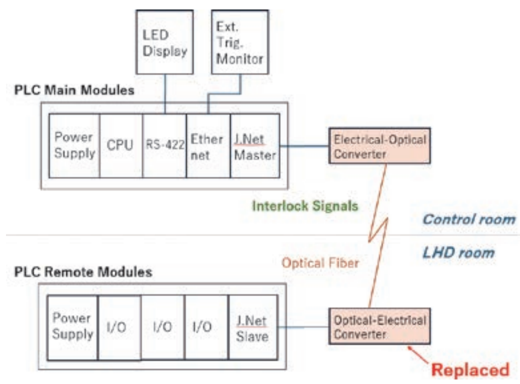

Fig. 14 Configuration diagram that relates to the error

(H. Ogawa)

(3) Network Management

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

The achievements in FY 2024 were as follows:

(a) Server migration due to end of life for CentOS 7

CentOS Linux 7 reached the end of its life on June 30, 2024. The web servers related to the Public Relations Office and network operation servers running on CentOS 7 were updated. AlmaLinux 9 was selected as the distribution to be migrated. After creating an installation template to improve work efficiency, efforts began in early April and were completed by the end of June.

(b) Wireless LAN Upgrade

The wireless network infrastructure has been upgraded in Research Building 1, the Administration Building and the Library Building. As part of this upgrade, we implemented Aruba Central, a cloud-based wireless LAN controller and deployed Aruba AP-615 (Fig. 15) units as new wireless access points. To provide power to the access points via Power over Ethernet (PoE), we introduced Aruba 6000 PoE switches (Fig. 16).

Fig. 15 Wireless access point (AP-615)

Fig. 16 PoE switch (Aruba 6000)

(c) LHD-LAN

Our security policy requires that network management staff must be present when connecting a new device to the the LHD-LAN. In FY2024, 25 new devices were connected to LHD-LAN, 28 devices were updated and 6 IP addresses were returned due to device removal.

(T. Inoue and O. Nakamura)

Technical Exchanges

Fig. 17 Group photos of the technical exchange meeting

Eight technical exchange meeting: “computation technology using finite element method”

On February 21, 2025, we held a technical exchange meeting to discuss numerical computation technologies based on the finite element method. This meeting, the eighth in the series, was attended by seven presenters and 27 participants, including those who joined remotely via the web conferencing platform Zoom, as shown in Fig. 17. The meeting featured two invited talks titled “Application of VR to Numerical Analysis and Evaluation, and Future Prospects in Combination with AI” and “High-Intensity Positron Source and Simulation.” In addition, five general presentations were given, all of which prompted lively discussions.

(T. Murase)

Internship

Fig. 18 Students in internship

We have accepted internships from high schools as part of the institute’s outreach activities every year. One example is as follows.

The Electrical and Electronic Technology Division accepted two second-year students from the electrical engineering department of Tajimi technical high school and taught them for two days. The practical training consisted of making a miniature car that moved toward light by controlling a stepping motor with a PIC microcomputer (Fig. 18). The first day consisted of a lecture on stepping motors and a motor drive system, and soldering electronic components to printed circuit boards. The second day consisted of a lecture on PIC microcomputers and their development environment, and the writing of a program for a PIC microcomputer in C Programming language. The students applied trial-and-error to control the appropriate rotation speed of two stepping motors according to the amount of light received by each of two sensors.

(T. Kondo)