# IV. Department of Engineering and Technical Services

The Department of Engineering and Technical Services is involved in all kinds of work in the design, fabrication, construction and operation of experimental devices in the fields of software and hardware.

This department is composed of engineers, and their tasks fall under the following five goals:
To develop advanced and systematic engineering capabilities on the basis of basic engineering results which have been obtained thus far.

To educate excellent engineers with responsible administration.
To cultivate creative engineering abilities.
To improve the documentation of and the transfer of engineering knowledge to the next generation.
To perform tasks with a systematic responsibility.

The department consists of the following five divisions: the Fabrication Technology Division takes care of the construction of small devices and the quality control of parts for all Divisions. The Device Technology Division is responsible for LHD and LHD peripheral devices except for the heating devices and the diagnostic devices. The Plasma Heating Technology Division has responsibility for the ECH system, ICRF system and NBI system. The Diagnostic Technology Division develops, operates and maintains all diagnostic devices and the Control Technology Division has responsibility for the central control system, the current control system and the LHD network. The number of staff is 46 engineers and several part-time workers. We take care of the development, the operation and the maintenance of LHD and the LHD peripheral devices with about 47 operators.

This year, the review for our Department was successfully finished, and our efforts were acknowledged by external evaluators. We made the report of our activities, and it was recorded in the Peer Review Report in FY 2006.

## 1. Fabrication Technology Division

The main tasks are the fabrication of the experimental equipment, technical consultation, research development of apparatus, technical cooperation and supply of experimental parts and materials. The division also administers all the office work of the department. The staff of our division is mainly working in the central workshop. In our division, we received about 400 jobs for the fabrication of devices in this fiscal year. 95% of them could be fabricated in our central workshop. We support the construction of devices and their control systems as requested from each research division.

(1) Timing demodulator
The circuit (Fig.1) receives an experiment timing signal from the LHD central control system through optical fibers. The information for triggering the plasma diagnostics instruments are piggybacked onto an experiment timing signal, then the circuit de-modulates it. The process of manufacturing the circuit was finished to the proto-typing phase. We have made 10 circuits for practical use, which being tested in experimental environments. The circuit includes a Linux computer to communicate with a PC for operation of the de-modulator. The software is written in C language.

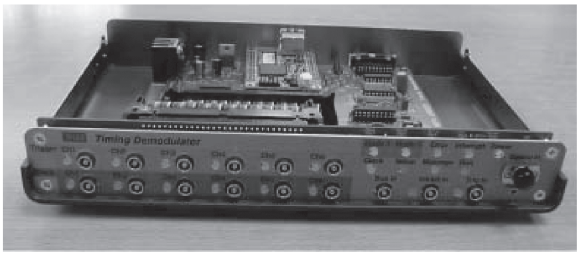
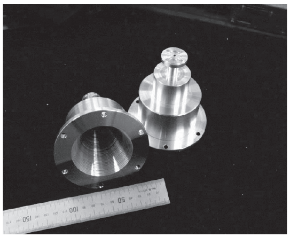



Fig. 1 Timing demodulator

(2) The corrugated horn antenna
We manufactured three kinds of different corrugated conical horn antennas. The antennas are used for three bands of microwave radiometry devices. 1) The size is a diameter of the nose Φ2.8mm, a diameter of open-end Φ63.5mm and a depth of 83.4mm (Fig.2). 40 corrugated slots are cut on the surface of the inside diameter. The size of the slots is a maximum depth of 1.7mm, a width of 1.2mm and a pitch of the slot of 1.7mm.



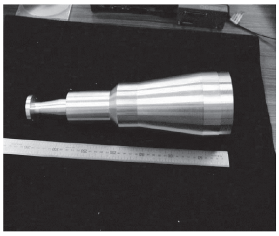


Fig. 2 Φ63.5mm horn Fig.3 Φ100mm horn

2) The size is a diameter of the nose of Φ11.6mm, a diameter of the open-end of Φ100mm and a length of the taper of 83.4mm (Fig.3). We cut 95 corrugated slots on the surface of the taper. The tooth size of a corrugated slot is 1.5mm, and the depth is decreased gradually 1.88mm to 0.02mm. It is difficult to make a tapered horn of a long length. Consequently, in order to manufacture easily the tapered horn, it was divided into two half-lengths. Their divided parts are threaded to be connected to each other, and must be cut while maintaining continuity of the corrugated slots. 3) The size is the diameter of the nose of Φ27mm, the diameter of the open-end of Φ141.4mm and the length of the taper 171.4mm. (Fig.4)

The 20 corrugated slots must be made carefully. In this process, if the shank diameter is much smaller than the horn diameter, the cutting surface becomes rough from reduced stiffness. The cuts on are made by reducing the cutting depth and increasing the cutting cycle. Their works use a CNC lathe controlled DNC operation.

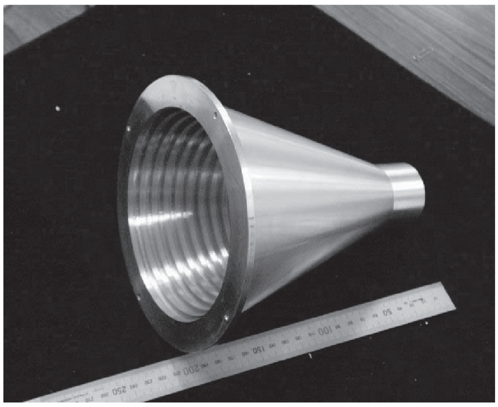


Fig. 4 Φ141.4mm corrugated horn antenna

(3) Components of the vacuum waveguide system

In order to improve the transmission efficiency of 3.5inch-corrugated waveguide, it is necessary to make the components of the vacuum waveguide system.

a) The vacuum flanges for connecting waveguide

The material of the vacuum flanges is an aluminum alloy. The numbers of the manufactured components are about 500. (Fig.5) Currently, the flanges are installed in two out of six ECH transmission lines.(Fig.6) We chose an aluminum pipe as the material of the flanges. It was very useful to reduce quantity of metal chips and to save processing time. We manufactured some prototype flanges, and discussed the problems with the ECH staffs.

Fig. 5 Vacuum flanges

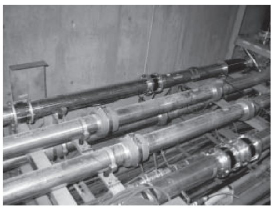


Fig. 6 ECH transmission lines

b) The vacuum pumping outlet tees

The material of the vacuum pumping outlet tees (Fig.7) is an aluminum alloy. We cut 25 corrugated slots on the surface of the inside diameter.(Fig.8) The size of the corrugated slots is 0.6mm depth, 0.6mm width, 0.02mm chamfering, and 0.2mm tooth width. The wave guide system requires precise rectangular ridges.

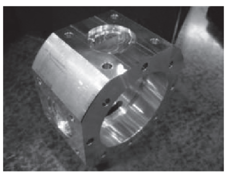


Fig. 7 Outlet tee

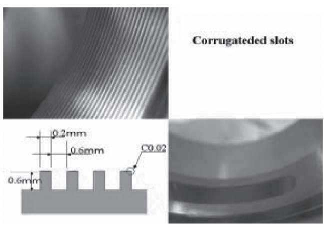



Fig.8 Corrugated slots

We used a CNC Lathe, which was installed at the central machine shop in the year before last. The lathe is Y-axis Control Turning Center, which can do cutting, milling and drilling work at the same time. The machine gave us efficient and precision processing.

## 2. Device Technology Division

The Division supports the operation, the improvement and the maintenance of LHD, the peripheral devices, the cryogenic system for LHD and the super conducting R&D devices at the SC magnet Laboratory.

(1) Operation and Maintenance of LHD

LHD operation started on August 7 in the tenth-experimental campaign, the cryostat was evacuated as usual. The evacuation of the plasma vacuum vessel began on August 8. The number of the maintained flanges was 126. We found nine vacuum leaks. The heaviest problem is the leakage from the water cooling line for the NBI inlet port. The vacuum leaks were fixed on Sep. 6, and the coil cool-down was started at Aug. 31. The cooling down was completed on Sep. 26.

The first energizing of LHD in the tenth-campaign was on Sep. 28. The number of operation days of the SC-coils was 73 days. The number of days of the plasma experimental period was 137 days. The warm up of the S.C.-coils was started on Feb. 16.

During this period, the interruption of commercial power occurred five times due to thunderstorms. They were on Aug. 1, 12, 20, 22 and March.30.

The availability of the refrigerator system, the water cooling system and the vacuum pumping system achieved 100% in this campaign. In the refrigerator system, two new cold compressors and a heat exchanger were installed for making the sub-cooled helium. This system could cool from 4.4K to 3.2K the temperature at the inlet of the helical coils. Figure 9 shows the time behavior of the temperature of the helical coil.

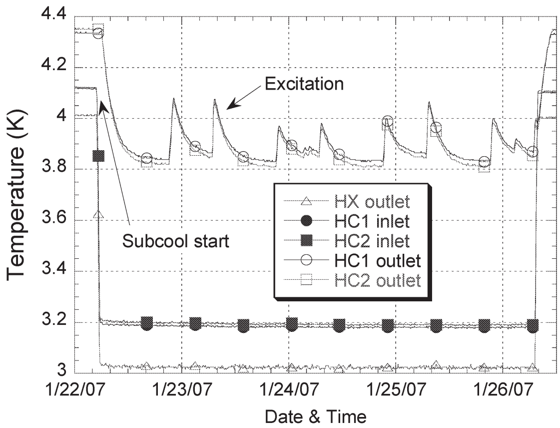



Fig. 9 Time behavior of the temperature of the helical coil

(2) Water leak detection system for LHD

We installed water leak sensors and sensor cables in about 180 points in the LHD room.

This system provides an early warning of the water drips and leaks, and will prevent damage and downtime from water leaks and spills.

In the LHD control room (300 meters away from the LHD room), we will be able to detect the water alerts immediately, and in the NIFS site, we can grasp the situation by the WLD web server.

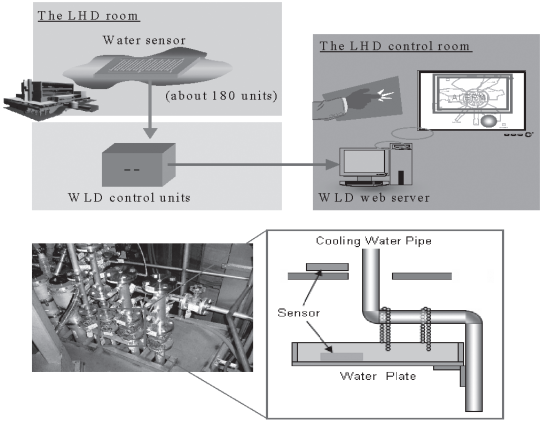



Fig. 10 Water Leak Detection System for LHD

(3) Ar diffusion simulation from the LHD building during a D-D experiment.

We calculated the Ar diffusion from the LHD building if the LHD building is crushed by a strong earthquake during the D-D experiment. If trouble occurred in LHD building during D-D exp, the radiated Ar gas will diffuse from the LHD hall.

Figure 11 shows the time evolution of the Ar Density from the LHD building. (Observation point; 180m from the LHD building)

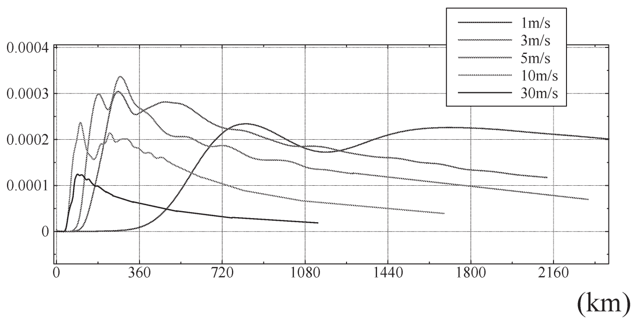



Fig. 11 Ar Density from the LHD building

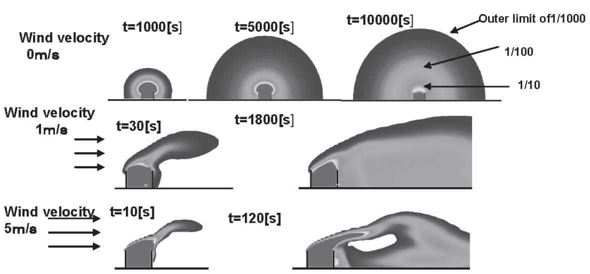



Fig. 12 Ar diffusion pattern from the LHD building

(4) Technical support of thermal analysis.

We supported to the staff of the Imaging Bolometer Group regarding thermal analysis. The bolometer group is developing the calibration of imaging bolometer foils. They requested a thermal analysis to compare with the experimental data.

As one example, when a laser(15mW φ1.3mm) irradiated a Au foil(t=2.5micro meter), figure 13 shows the temperature distribution of Au foil in steady state operation, and the time dependence. This picture shows the decay in time. Then were calculated by changing the thermal diffusivity.

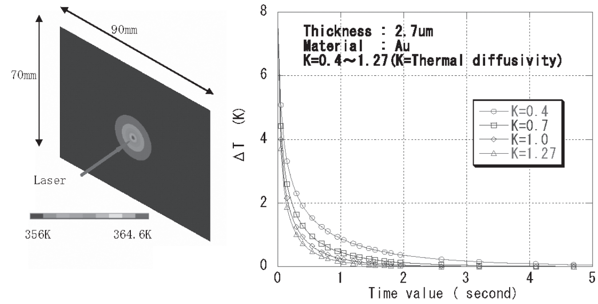



Fig. 13 Thermal distribution and decay

(5) Technical Support for the SC magnet Laboratory

A cryogenic system with a capacity of 200 l/h (500 W at 4.2 K) and a high dc current supply of 75 kA at 21 V, including a cooling water system with an 800 kW heat exchanger, was installed at the SCL. Operation of these test facilities and daily inspection of them are carried out by the members of the Device Technology Division. In particular, we are responsible for the annual duty inspection of the cryogenic system, regular maintenance of the cooling water system and preparation for the experiments.

## 3. Plasma Heating Technology Division

The main works of this division are the operation and maintenance of plasma heating devices and common facilities. We have also performed technical support for the improvement and the development of these devices, and the installation of new devices.

In the 10th experimental campaign, steady state plasma sustainment by the ICRF with a power level of more than 1MW was one of the main targets of the mission experiment, continued from the former experimental campaign. However, as the heating power is increased in the steady state plasma experiments, plasmas often experienced radiation collapsed by impurities from the vacuum vessel wall or the diverter triggered by arcing. It is a future subject to solve this problem. As for the NBI, two ion sources of the P-NBI (BL4) were constructed additionally before the experimental campaign and the total ability of the NBI heating power increased up to about 20MW. The details of these activities are as follows.

(1) ECH

(a) Gyrotron Operation & LHD experiment

During the 10th experimental campaign, we could inject millimeter waves with a total power level of 1.8MW into LHD by using 8 gyrotrons for the pulsed operation. But the total number of available gyrotrons was reduced from 8 to 7 from the middle of the experimental campaign because of a vacuum leak in the 84GHz(#4) gyrotron. It was found that the vacuum leak was caused by a melting of a part of the inside bottom of the collector cause by a concentration of the beam heat load for some reason. The other gyrotrons could be operated reliably and stably. Especially 168GHz(#2) gyrotron whose transmission line #2 is newly evacuated to a high vacuum level has worked steadily with the higher power injection. This transmission line has been prepared for the next experimental campaign to connect a 77GHz gyrotron which can generate a higher power than others. We have modified the transmission lines from an atmosphere type to a vacuum type one by one. During this modification, all of the waveguide connection flanges were replaced by those for the higher vacuum. As a result, the wider margin for arcing in a transmission lines is kept due to the higher vacuum levels at high power gyrotron operation. In the steady state experiment, the continuous wave (CW) gyrotron worked well and assisted the mission experiments by ICRF as in the previous campaigns.

(b) Installation of thermometry device at vacuum window in evacuated microwave transmission waveguide

Corresponding to the increases of the incidence power and the pulse width, it became urgently necessary to protect the vacuum window from destruction by measuring the surface temperature. We installed an infrared temperature sensor port. To install a sensor, it is required for the port to be a vacuum-tight and to reduce the microwave leakage but not to degrade the sensitivity in the infrared region. The diameter of the viewing holes is set at 1 mm for 84 GHz to be a cut-off with the thickness of 3 mm, while 37 holes are closely drilled inside about 0.5cm$^2$. In figure 14 is a picture of the port which is installed on the 2-O port. In figure 15 are shown the time evolution of the measured window surface temperature by the infrared thermometer installed to this port. The temperature rise at the time of a pulse width of 600ms. 400kW (gyrotron beam voltage, Vb=81kV) incident power was about 40 degrees. It is also seen that the peak temperature increases as the gyrotron power increases by changing Vb. It is shown that this measurement is quite stable and reliable. This measurement can be used as a safety monitor for the protection of the window.

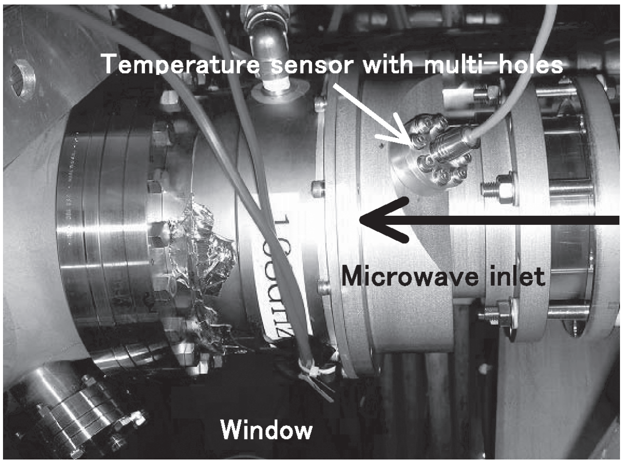



Fig.14 The microwave vacuum transmission waveguide with a port for infrared thermometry of a vacuum window.

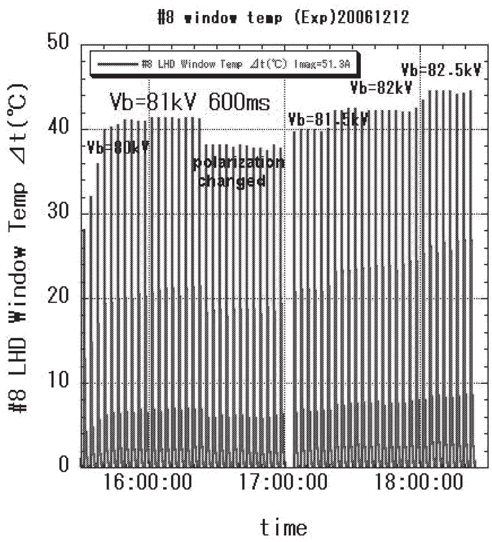



Fig. 15 An example of the time evolution of the window temperature measured by an infrared thermometer during the LHD experiment

(c) Upgrade of the control system for ECH.

We have updated the control system for ECH. The control workstations had been used for ten years, but they recently often caused hardware and software troubles. In the case of updating the workstation, we needed to update not only the hardware but also the OS.

The new OS for the workstation is found neither to correspond to communication tools and the software which have been used in the present system, nor to have a plan to support them by the maker. Then, we have renewed the control network for ECH as shown in Figure 16, using a Windows PC though the application needed to be newly developed. By the newly adopted a multi-purpose software, we can make a GUI with relative ease using prepared parts, and can input the registry number of the sequencer for each button and I/O column. In this updated system, one PC server has generalized and controlled four gyrotron power supplies in contrast with the former system that had controlled each power supply individually. Moreover, the operator can access through the LAN by multiple terminals, and can operate this system on Internet Explorer. In this update, the PC for data acquisition was newly set up to make the operating parameter log that accumulated information on the remote control PC for the transmission system and for the power supplies based on the signal of the shot number delivery server.

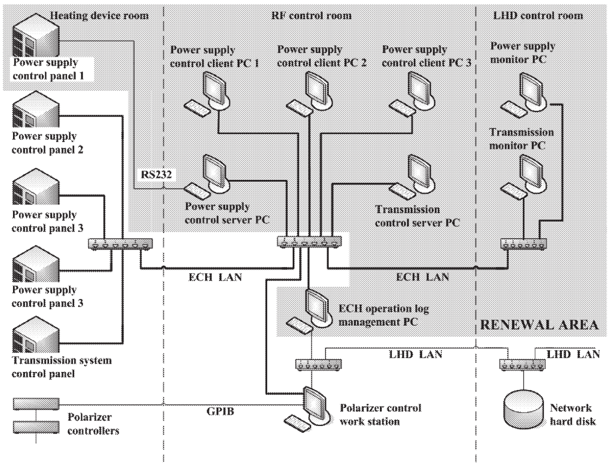



Fig. 16 Renewed control system for ECH

(2) ICRF

(a) Design of RF Power Feedback Control using Auto Gain Control

The ICRF heating experiment has been successfully carried out partly by employing an RF wave-form generator circuit and AGC (auto-gain control) in the RF power generator system. However we found that there was not a direct proportion between the selected value in the RF power level and the output power, and we could not control the RF power from the heating device room and the LHD control room. In the newly developed system reported here a rectified signal of the input RF power would be employed as the reference for the feedback control.

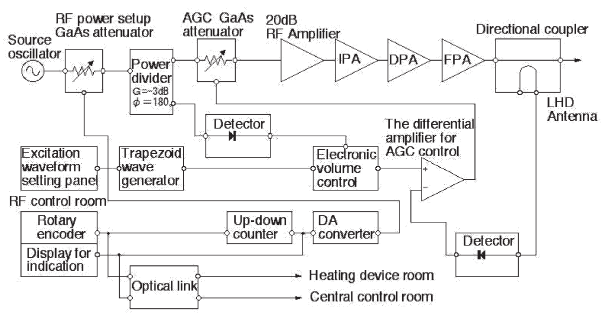



Fig. 17 Circuit of RF Power Feedback Control using Auto Gain Control

In addition to that a GaAs diode will be employed instead of using the PIN diode so far employed. The GaAs diode attenuator will be also used instead of the former programmable attenuator in the power-setting device, which is located in the RF control room and is digitally controlled from the above-mentioned three different places. The set value can be shown in the digital counter. This new system will be employed in the next fabricated RF generator system.

(b) Improving cooling for ceramic feed-through

In the ICRF heating system, the temperature of the transmission line rises by RF dissipation loss when this system is operated for CW or long pulse. Especially, it reaches a considerably high temperature at the flange of the ceramic feed-through compared with the other parts of the transmission line. This part might be damaged by a thermal stress and can lead to a further vacuum leak of LHD. Therefore, we have taken measures against a temperature rise at the ceramic feed-through as follows before this experimental campaign in addition to the cooling of the inner conductor.

i) We have put a water jacket for cooling made from a copper pipe surrounding the flange where the temperature had became higher than others.

ii) Furthermore, we have tried to cool by flushing nitrogen gas to the ceramic part inside the transmission line directly from the outside. This space is pressurized with the nitrogen gas of 0.3 MPa usually for electrical insulation. This time, for the purpose of cooling, we supplied nitrogen gas at a total flow rate of 350l/min at about 0.4 MPa from four ports, which are equipped in the feed-through. As results, the temperature rise at the flange of the ceramic feed-through was reduced from the former experimental campaign. However, we need to improve the cooling of this part, since heat removal from this flange was still poor.

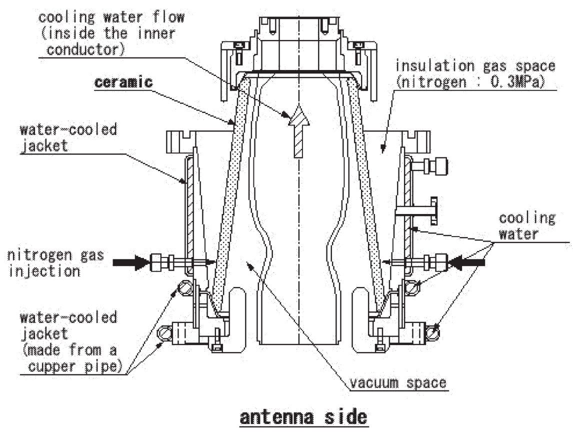



Fig. 18 Layout of cooling for ceramic feed-through

(3) NBI

(a) The Maintenance of NBI Devices

The two more positive ion sources have been installed to the fourth injector, BL4, in this fiscal year, and the beam injection with a full four ion sources has been accomplished in BL4. Consequently, the heating power, which is injected into the LHD plasma using four injectors, was increased. The plasma experiments in LHD have been performed for years. As the experimental campaign proceeds, the demand for heating power by neutral beam injection has increased. To meet the increasing power demand, additional neutral beam injectors have been constructed. It has been nine years since the first injectors of BL1 and BL2 started their operation. The NBI device consists of the beam producing and transport equipment as a main part, and the other related facilities. Their functions have been gradually degraded year by year due to the long-term operation. It could result in an interruption at the LHD experiment if an NBI device suffers from machine troubles during the experimental campaign. Therefore, maintenance is important to prevent it. The inspection and maintenance of the NBI device are carried out during the maintenance period (seven or eight months). The target components for the inspection are gate valves, electron beam dumps, ion source angle adjustors, cooling water pumps, vacuum pumps, high voltage switchgears and electric-optical converters in the control signal transmission system. Some electrical parts must be exchanged in the maintenance of the control systems and the power supplies. Some parts which should be exchanged for maintenance have gone out of production, and will possibly be out of stock in the near future. Therefore, the systems including these parts should be re-designed and will be reconstructed.

(b) Upgrade of the data acquisition system in P-NBI

In the positive-NBI system, we had developed a data acquisition system using WE7000 which is produced by Yokogawa Electric Co. Ltd., since the 9th experimental campaign of LHD. As two ion sources and their power supplies were added to the P-NBI, we have upgraded the data acquisition system. The number of data was increased to 380 points. The schematic diagram is shown in Fig.19

In addition to the increase of the hardware, we have improved the control program. The reliability of the system was improved by separating the real-time data-acquisition, such as the monitoring of vacuum pressures in the beam-line and the temperature of the cryo-pumps, from the batched-type data-acquisition being triggered by the beam injection pulse. The GUI was also improved and became easier to use and to recognize the important events of the beam-line.

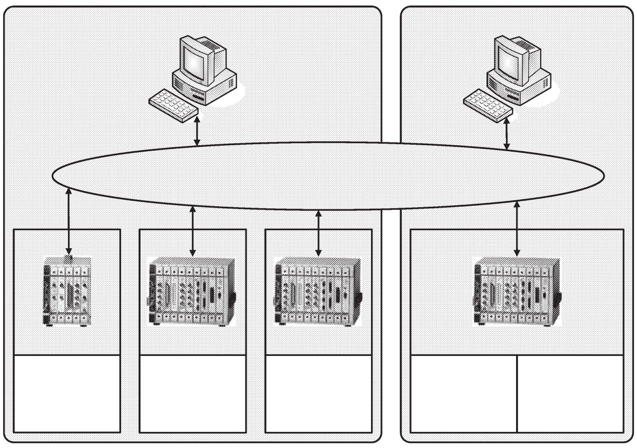
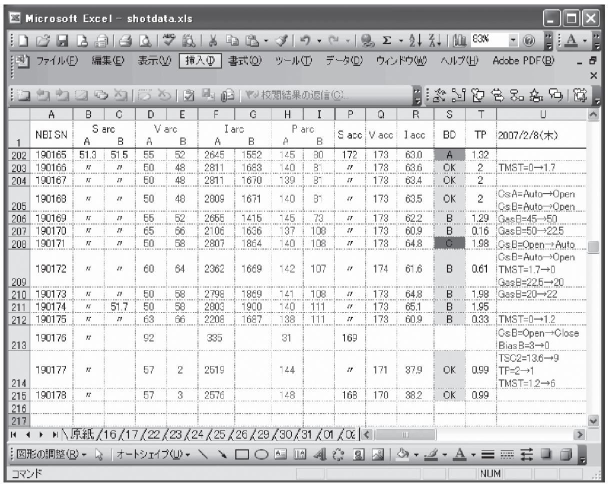


Fig.19 Diagram of P-NBI data acquisition system

(c) Auto-recording of Operating Parameters in Neutral Beam Injection System

It is necessary to adjust multiple-parameters to reliably operate the large scale ion sources for the neutral beam injectors (NBI). The operation of the negative ion sources have to control the cesium (Cs) amount inside the ion sources. In order to understand changes in the ion-source situation including the Cs condition, we have developed a monitoring system for setting input data and detecting output data, for instance electric and calorimetric data, requested for NBI operation. Although the system acquires those data with the use of linked multiple-personal computers (PC) and displays them graphically shot by shot, the tens of data recorded in the shot intervals of 3 min. have been written by hand so far. By introducing the auto-recording system into the multi-PC system, the recording errors are reduced and we can concentrate to monitor the movement of the ion-source condition. It is also possible for us to cope with the movement and to notice accidents occurring in the ion source and beam-line. The auto-recording system is coded with LabVIEW (National Instruments), and the recorded data are displays in a text-formatted table as shown in Fig. 20. The data table is saved in the hard disk drive with Microsoft EXCEL format.

The auto-recording system was applied to LHD-NBI beam-line 1 (BL1) as a test at the end of the 10th campaign. The system satisfied our all requirement and is going to be installed in the data acquisition systems of BL1 and BL4 in the next campaign.



| | A | B | C | D | E | F | G | H | I | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NBI SN | S arc A | S arc B | V arc A | V arc B | I arc A | I arc B | P arc A | P arc B | S acc | V acc | I acc | BD | TP | 2007/2/8(木) |
| 202 | 190165 | 51.3 | 51.5 | 55 | 52 | 2645 | 1552 | 145 | 80 | 172 | 173 | 63.0 | A | 1.32 | |
| 203 | 190166 | 〃 | 〃 | 50 | 48 | 2811 | 1683 | 140 | 81 | 〃 | 173 | 63.6 | OK | 2 | TMST=0→1.7 |
| 204 | 190167 | 〃 | 〃 | 50 | 48 | 2811 | 1670 | 139 | 81 | 〃 | 173 | 63.4 | OK | 2 | |
| 205 | 190168 | 〃 | 〃 | 50 | 48 | 2809 | 1671 | 140 | 81 | 〃 | 173 | 63.5 | OK | 2 | CsA=Auto→Open<br>CsB=Auto→Open |
| 206 | 190169 | 〃 | 〃 | 55 | 52 | 2655 | 1415 | 145 | 73 | 〃 | 173 | 62.2 | B | 1.29 | GasB=45→50 |
| 207 | 190170 | 〃 | 〃 | 65 | 66 | 2106 | 1636 | 137 | 108 | 〃 | 173 | 60.9 | B | 0.16 | GasB=50→22.5 |
| 208 | 190171 | 〃 | 〃 | 50 | 58 | 2807 | 1864 | 140 | 108 | 〃 | 173 | 64.8 | C | 1.98 | CsB=Open→Auto |
| 209 | 190172 | 〃 | 〃 | 60 | 64 | 2362 | 1669 | 142 | 107 | 〃 | 174 | 61.6 | B | 0.61 | CsB=Auto→Open<br>TMST=1.7→0<br>GasB=22.5→20 |
| 210 | 190173 | 〃 | 〃 | 50 | 58 | 2798 | 1869 | 141 | 108 | 〃 | 173 | 64.8 | B | 1.98 | GasB=20→22 |
| 211 | 190174 | 〃 | 51.7 | 50 | 58 | 2803 | 1900 | 140 | 111 | 〃 | 173 | 65.1 | B | 1.95 | |
| 212 | 190175 | 〃 | 〃 | 63 | 66 | 2208 | 1687 | 138 | 111 | 〃 | 173 | 60.9 | B | 0.33 | TMST=0→1.2 |
| 213 | 190176 | 〃 | | 92 | | 335 | | 31 | | 169 | | | | | CsB=Open→Close<br>BiasB=3→0 |
| 214 | 190177 | 〃 | | 57 | 2 | 2519 | | 144 | | 〃 | 171 | 37.9 | OK | 0.99 | TSC2=13.6→9<br>TP=2→1<br>TMST=1.2→6 |
| 215 | 190178 | 〃 | | 57 | 3 | 2576 | | 148 | | 168 | 170 | 38.2 | OK | 0.99 | |
| 216 | | | | | | | | | | | | | | | |
| 217 | | | | | | | | | | | | | | | |



Fig. 20 Shot parameter log table

(4) Motor-Generator (MG)

The MG is used to supply the pulsed power to the NBI for LHD and the CHS magnetic coils (until August). The MG had generated 43,948 shots in this fiscal year and 387,276 shots since its construction. The operation time counted 2,020 hours in this fiscal year and 17,627 hours in total. After overhaul in March 2002, the brushes of the motor were worn out abnormally. During the next LHD experimental campaign, the length of the brushes would be worn below the critical level. So, new brushes should be installed before the next LHD experimental campaign. We carefully investigated the brushes and the ring. However, no fault was found with them. The specialist of the producing company guesses that the cause of abnormal wear-out is too low current density, and proposes to decrease the number of brushes.

## 4. Diagnostics Technology Division

This division supports utility construction and device installation work for the LHD diagnostics, and the development, operation and maintenance of the diagnostic devices and of the data acquisition system for the LHD plasma experiments. For the tenth experimental campaign, some of the diagnostics and the data acquisition system were improved. The Thomson Scattering Diagnostic was improved for use in high-density plasma experiments. In some of the data acquisition systems, the DAQ box PC system has been used instead of the PC saver acquisition system, so the stability of these systems is increased. In this experimental campaign, we got the plasma potential data of the LHD plasma by the HIBP for the first time. The success was due to the modification of the beam alignment and improvement of the signal detectors and ion source of the HIBP. Our principal tasks in this fiscal year are described in the following.

(1) Development, Operation and Maintenance of the Radiation Monitoring System

The radiation monitoring system was consists of 48 radiation detectors and the data acquisition system. This system has been operated since 1992. The data acquisition system with a GPIB interface controller on Windows NT has become an obsolescent system. Therefore we have to develop a new data acquisition system with a PXI-PCI interface controller with Windows XP or LINUX. In this fiscal year, we set up the test stand for development of the new data acquisition system with a PXI-PCI module and interface controller on Windows XP.

Fig. 21 Test stand for development of the new data acquisition system of the radiation monitoring system

(2) Thomson Scattering Diagnostics

In the tenth experimental campaign of LHD, the high-density plasma experiments have been held many times. In the high-density plasma experiments, scattered light exceeds the dynamic range of the APD (Avalanche Photo Diode) that are installed in the polychromators of the LHD Thomson scattering diagnostics, because the light is too strong. So far, the diagnostic window is covered partially to control the scattered light intensity. In this experimental campaign, changing the high voltage (HV) on the APD is adopted to measure high-density plasma. Therefore, the data acquisition system was modified according to this modification. HV information is written in a file each time the HV is changed. Then the analyzing PC reads the file and writes the HV information in the header of the analyzed data.

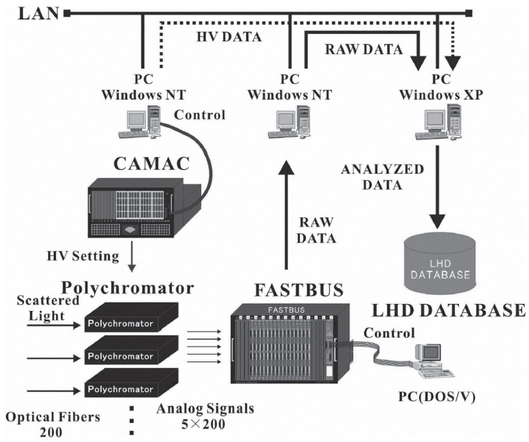



Fig. 22 The schematic view of the data acquisition system of the LHD Thomson scattering diagnostics

(3) Operation and Maintenance of FIR Diagnostics and Microwave Reflectometer

The operation and the maintenance (for example, high voltage power supply, vacuum system, supplied gas system, phase detection circuit, dehydrator, water cooling system etc.) were responsibly executed. Therefore in this tenth experimental campaign, in almost all shots, electron density data was taken completely. So it contributed widely to the LHD plasma experiment.

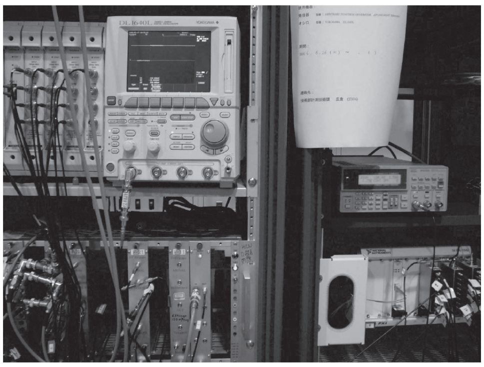


Fig. 23 View of the calibration of the FIR phase detection circuit

(4) Improvement of the Design for HIBP Ion Source Beam Monitor

It is requested that the loss of beam in the transmission system is minimized as a strategy to raise the signal level of the HIBP. The beam monitor to measure the beam pattern immediately after the ion source was designed. The scintillator is inserted on the center of the beam line and it emits light due to the beam. The luminescence of the scintillator is reflected with two mirrors (just like a periscope) and the luminescence pattern is confirmed with the video camera. During the operation of the HIBP, the scintillator and the attached mirror are extracted from the beam line not to cut the beam. The installation was scheduled soon after the remodeling was permitted because the application for remodeling is necessary for this device installation.

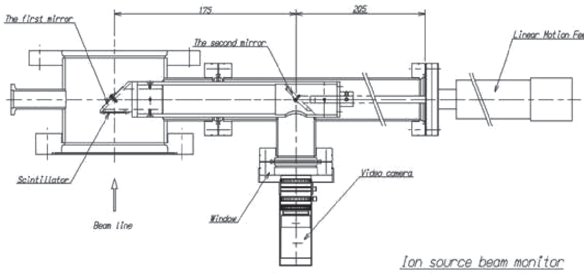



Fig. 24 HIBP ion source beam monitor

(5) Vacuum Leak Test with the Test Chamber in the Plasma Diagnostics Laboratories

The preliminary vacuum leak tests were carried out on the diagnostic devices to be used for the LHD plasma experiment and the parts to be used in these diagnostic devices by using the leak test chamber in the Plasma Diagnostic Laboratories.

Before the ninth plasma experimental campaign, many diagnostics elements were tested (for example, parts of the soft x-ray spectroscopy, penning gauge spectroscopy, laser blow off, MIR, AXUVD, NPA , Thomson, Bolometer etc). We carefully tested these vacuum components. Therefore, in this 10th experimental campaign, the plasma experiment was not stopped because of diagnostic device vacuum leakage.

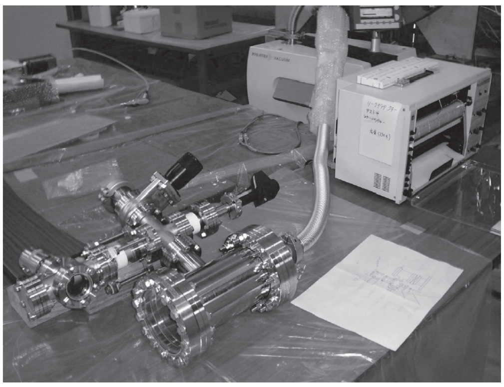


Fig. 25 Snap shot of the vacuum leak test in the Plasma Diagnostic Laboratories

(6)Installation support of Microwave Imaging system

Electron Cyclotron Emission Imaging(ECEI) measures the electron temperature profiles in the plasma. Microwave Imaging Reflectometry(MIR) measures the electron density distribution and the fluctuations precisely in the plasma. These measurement equipments are measuring instruments that offer important physical data that shows the performance of the LHD plasma. The ECEI-Diagnostic-Group installed an MIR-system improved for the tenth experimental campaign in the 4-O port of LHD. The well planned overall mechanical work and the strong support for them enabled the short-term assembly. The contents of the support work was a movement test of driving mirrors, an assembly of semi-optical components and an adjustment of an optical axis on the rotating ellipsoidal mirror, an oval plane mirror mounted at the internal side of the LHD plasma vacuum vessel and the dichoroic plate, the dielectric mirror and etc. mounted at the external side of LHD. The stray light absorbers to decrease optical noise were installed little by little measuring the strength of the light. A set of these detectors and LHD were joined on each vacuum flange with (~2m) metallic gasket seals. As a result of this, the numerical value of the attained vacuum level on the LHD side easily exceeded the required level. As for the ECEI-system that had broken down in the previous experimental campaign, important functional components were exchanged and it was operated without trouble in the tenth experimental campaign.

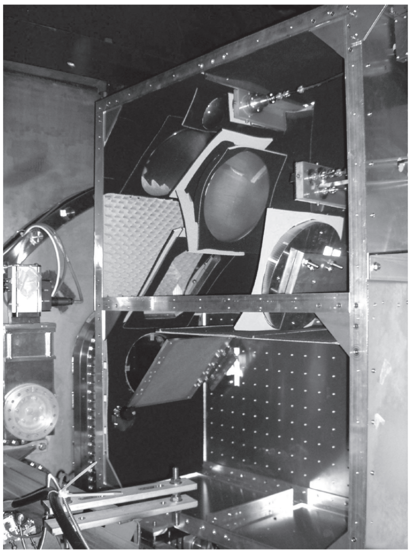


Fig. 26 View of the microwave imaging system combining ECEI and MIR in LHD

(7) Development of Data Acquisition System

In the parallel-processing DAQ (Data AcQuisition) system of LHD, a lot of digitizers, timing modules, DAQ servers and disks are used. The number of diagnostics increases every year, and there are about 70 diagnostics in the current year. Due to this increase, also the maintenance cost has increased.

For the LHD DAQ system, practical solutions have been investigated against such an increase in the cost. Therefore, for example, we shifted from normal PCs to DAQ-Boxes as DAQ servers. Because parts in normal PCs that have an especially high failure rate are movable parts such as disks and fans, using diskless and fan-less DAQ-Boxes reduces the failure rate. Moreover, even when breaking down, an early return and rise in utilization rates are expected by turning on the power supply by remote control.

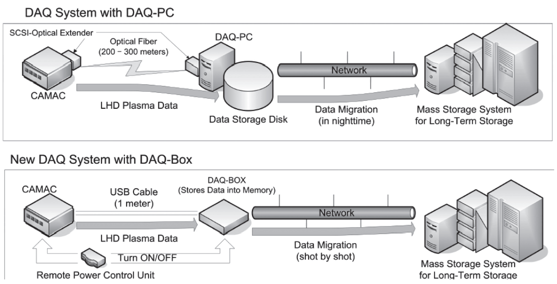



Fig. 27 Change to new DAQ system with DAQ-Box

## 5. Control Technology Division

The Control Technology Division has contributed important technological parts in the system management and system development for the fusion research in this institute. The work of system management is as follows; the LHD control room and LHD central control system, the LHD super-conducting coil power supply system, the LHD-LAN system, the LHD numerical analysis system, the NIFS campus LAN system, the CHS data acquisition system, etc. The work of system development in this year is as follows; remodeling of the LHD man-machine interface system, a development of a movie data acquisition program for a high speed camera of the pellet injector, an improvement of the ICRF stub tuner controller, improvement of data analysis system for CHS, etc. The activities in detail of this division are as follows.

(1) Remodeling of the LHD man-machine interface system

We have developed and operated the LMS (LHD man-machine interface system) for the plasma experiment. It is a core system of the LHD central control and takes charge of the management of the experimental condition data, the operational data gathering and its presentation. The environment surrounding LMS has considerably changed since it started 8 years ago. Therefore, we made a two-years-scheme for a major modification regarding the following two items. The first, we separated the coil preset function which was originally built in the LMS to simplify its internal structure. At the same time, we added a new function which converts the four magnetic parameters i.e. Bt value, Axis point, Bq value, Gamma value to the coil current values for each super-conducting coil automatically. It improves the reliability and realizes safety operation under a fool-proof philosophy. Secondly, we unified the operational data which was managed by LMS, Shot Summary System, and Data Analysis System independently. In the new policy, the Data Analysis System takes charge of the data storage and presentation, and the new system takes charge of the data gathering. Due to this modification, the functionality and the maintainability have greatly improved.

The new system has already taken over some data management without any serious problem. We are going to complete the transition before the beginning of the next experimental campaign.

(2) Development of a Movie Data Acquisition Program for a High Speed Camera of the Pellet Injector

The high-speed camera which can record a movie of tens of thousands of frames per seconds is installed to the pellet injection system for recording a movie of an injected pellet into the plasma. The movie can be acquired by using the application program attached to the camera, but the application program can't acquire the movie according to the LHD experiment automatically. To solve this problem, a new program was developed with C language and Visual Basic using the API (Application Program Interface) for the high-speed camera.

The program is automatically able to record and acquire the movies according to the LHD experiment sequence and the shot numbers are put on the file name. Since the acquired movies data is very large (max 4GB/shot), the movie data is transferred to the Labcom DB which is a common huge database. The collected movie data is stored by a frame unit for fast reading. At the 10th experimental campaign, the movies automatically were recorded and acquired, using this new program. Figure 28 shows a typical captured image of pellet injected to the plasma.

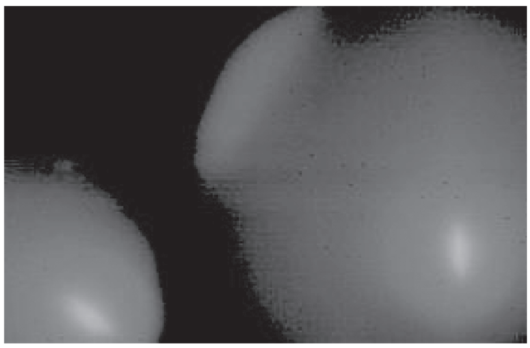


Fig. 28 A typical captured image of pellet injected plasma

(3) Data Acquisition and Analysis system for CHS

The CHS experimental project was shut down at the end of August 2006 after 17 years of research activities. The data acquisition and analysis system has been changed and upgraded in this long period. The history can be found in the series of annual reports published previously. All the data taken from the beginning of the CHS experiments are now stored in the data storage system. The total number of stored data is about five tera byte (uncompressed data file). Most of them have been managed with the two data management systems called DMG and MDSplus. Generally they have provided a comfortable environment for users. However, these two data management systems are incompatible. Sometime users have to undertake some mental works in combining two data sets stored in the different systems. Since the data acquisition system will not be used from now on, we decided to combine the DMG data with the MDSplus data. It will be useful for users who are continuing CHS data analysis. The following work has been carried out in this fiscal year;

1. Data analysis computers had been added. (DS20E x 2 units with UNIX and VMS)
2. Data storage system had been upgraded. (Two RAID system with three tera byte)
3. Two-generation backup of all experimental data. (Continuing to fiscal year 2007)
4. The DMG data are converted into the MDSplus data format and are stored in the new data analysis computers. (Continuing to fiscal year 2007)

(4) Improvement of the stub tuner controller for ICH

We had developed a feedback control system of the liquid stub tuner over three years. The purpose of this feedback control is being able to maintain low reflective electric power from the antenna by a time change of the plasma load resistance, and being able to mitigate the burden to an oscillator. The speed of the feedback control is important for this. Therefore, the pulse motor that is the controlled object was exchanged for a higher speed motor than the old one. Furthermore, since there is much noise in the LHD main hall, optical fiber was used for the signal line in order to operate the feedback control stably. A workstation was installed to separate the function of analysis from Cinos to make processing fast. Figure 29 shows a block diagram of the stub tuner control system. As a result of these improvements, the reliability of this system improved.

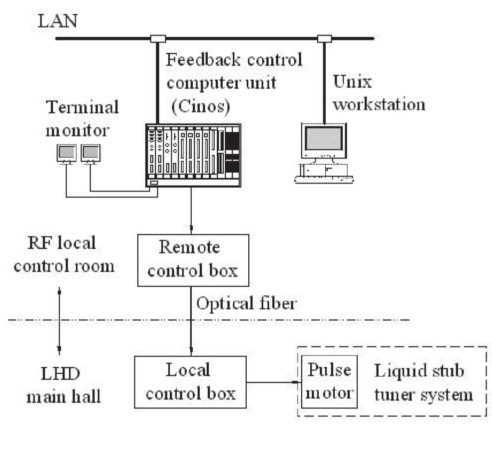



Fig. 29 A block diagram of the stub tuner control system

(5) LHD-LAN Management

The LHD-LAN has been provided for the LHD experiment since 1996. As LHD experiments progressed, a larger number of computers have been connected to the LHD-LAN. They store a large amount of data, and therefore, require the high-performance data transferring environments. Thus the Gigabit Ethernet (GbE) system has been installed in the LHD-LAN since FY 2000. In addition to regular management work, our new contributions for FY 2006 were as follows;

(a) Upgrade of the LHD operational LAN system.
(b) Upgrade of the SNET router and increase of nodes.

(a) The LHD operational LAN router and 3 switching hubs installed in 1996 have been upgraded. The new router consists of two Layer-3 switches interconnected with stack technology for redundancy. The new switching hub with 24 Fast Ethernet ports and 2 GbE ports have been connected to the new Layer-3 switch by CISCO Ether-channel technology for redundancy.

(b) The LHD's remote participation system via Super SINET, namely, SNET was initiated in FY 2000. The SNET router system consisted three Layer-3 switches has been upgraded to a Layes-3 switch. The new switch is a modular switch which can include 7 modules. By FY 2005, 11 nodes of SNET were established at the University of Tokyo (Depart. of Technology and High Temperature Plasma Center), Nagoya University, Kyoto University (Uji and Yoshida Campus), Kyushu University, Tohoku University, Tokyo Institute of Technology, Hiroshima University, Nagoya University (Yamazaki Laboratory) and Kyushu University (Research Institute for Applied Mechanics). In this FY 2006, two additional nodes have been installed at Tokyo University (Kashiwa campus) and Japan Atomic Energy Agency (Naka Fusion Institute).

(6) Management of LHD control room

In order to accomplish a smooth experiment, it is necessary to manage the LHD control room environment. There are many important utility systems in the room, for example; presentation systems with the large-scale screens of 150 inches and 120 inches, audio systems for experiment and meeting, TV monitoring systems and many OA systems, etc. These systems must be maintained and be managed to be kept in good condition. In recent years, electrical devices are increasing in the control room. Therefore electric outlets were added in the room. In addition, the order of the room is maintained continuously.

(7) Malfunction investigation during the LHD operation

Malfunction investigation is important for the safe and reliable operation of LHD. We investigated malfunctions that occurred all over the experiment period in detail. This investigation was held from the fifth experimental campaign for the purpose of making a document to maintain experimental device soundly. Each malfunction was classified in nine following causes; a operational mistake, a setting mistake, lack of check or part exchange, defectiveness of design or production / a software bug, defectiveness of wiring or plumbing, deterioration, lack of experience, inevitability, unidentified. Table 1 shows a result of this investigation during 6 years. Figure 31 shows ratio according to the cause of the malfunction over the past 6 years.

Table 1 Results of this investigation during 6 years.

| Cause (include repetition) | Experimental Campaign 5th | 6th | 7th | 8th | 9th | 10th |
|---|---|---|---|---|---|---|
| unidentified | 29 | 20 | 26 | 49 | 60 | 61 |
| inevitability | 8 | 12 | 2 | 29 | 34 | 32 |
| deterioration | 11 | 12 | 12 | 28 | 23 | 30 |
| lack of check or part exchange | 12 | 9 | 13 | 5 | 10 | 7 |
| defectiveness of design or production / software bug | 34 | 14 | 26 | 28 | 27 | 25 |
| defectiveness of wiring or plumbing | 4 | 3 | 9 | 5 | 10 | 8 |
| setting mistake | 4 | 2 | 3 | 3 | 6 | 3 |
| Operational mistake | 9 | 5 | 3 | 9 | 8 | 10 |
| lack of experience | 5 | 0 | 3 | 3 | 5 | 8 |

The features of the malfunctions are as follows. Initial troubles (defectiveness of wiring or plumbing and defectiveness of design or production / a bug of software) and deterioration troubles (lack of check or part exchange, deterioration) occurred continually with about the same probability. The malfunctions based on human error (mistake operation, a setting mistake) do not decrease.

The preparation of a part for maintenance and the necessity of early exchange of a deteriorated part were recognized by sharing these findings and we were able to reduce the malfunction that had an influence on the LHD experiments.

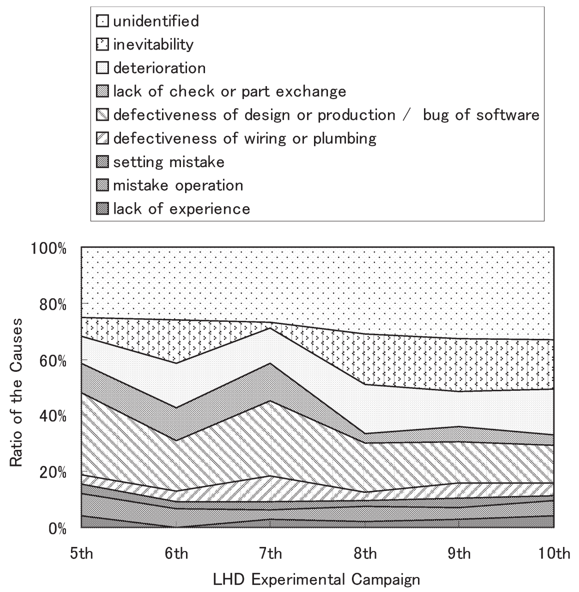



Fig. 31 The ratio according to a cause of malfunction of the past 6 years.

## 6. Symposium on Technology, Technical Exchange and dual system

(1)The Symposium on Technology

The Symposium on Technology was held on March 1 and 2, 2007 at the Higashiyama campus of Nagoya University. There were 756 participants from many Japanese universities, national laboratories, technical colleges and some industries. In this symposium 308 papers were presented in 8 oral sessions and a poster session. Technical experience and new techniques were reported and discussed. Six papers were presented from our department. The titles of the presentations were as follows:

- Development of the System for Balanced Voltage Measurements and Normal Transition Automatic Judgments in the LHD Superconducting Helical Coils.
- Maintenance and improvement of the liquid stub tuner for ICRF steady-state experiment.
- Renewal of the control system for LHD-ECH.
- The transition and the perspective about the optical media storage system which has stored the data of LHD plasma diagnostics
- Operation and maintenance of the LHD experiment LAN of more than 10 years.
- Consideration of future signal processing through CHS computer technological history over 18 years.

In the steering committee held during the symposium, our institute was adopted as the next host organization, moreover there were new hopes of a host organization from some universities. We exchanged our opinions frankly about how this symposium ought to be run. Figure 32 shows a snapshot of the poster session.


Fig.32 Snapshot of the poster session

(2) Technical exchanges

Technical exchanges between our department and other institutes or universities were held in order to improve the technical skill of the staff.

Forty-six technical officials of other laboratories participated in our 4 exchange programs in this fiscal year. The program names and participants were as follows; "Symposium on Safety and Health Management in a Laboratory" from 10 universities and 4 institutes, "Mechatronics Technology " from Tsukuba University, "Measurement and control technique using a PC " from Kyushu University, "Electronic Publishing Technology " from the High Energy Accelerator Research Organization. Figure 33 shows a scene of the technical exchange.

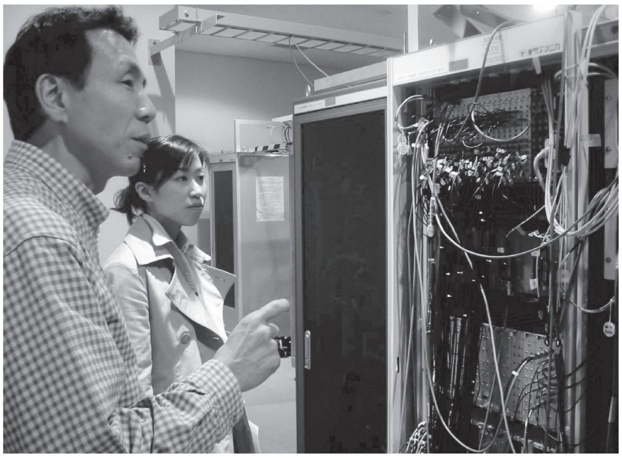


Fig. 33 A snap shot of the technical exchange

(3) Educational coordinated activity on "A dual system in Japanese version"

A dual system in Japanese version is an education system aiming to developed independent skilled workers by concretely combining an education by lectures in school with practice in enterprises. NIFS has accepted students from the Tajimi Technical High School since fiscal year 2005 for training from the point of view of a researcher and an engineer. The students asked to develop a mini rocket by using Lorentz's force. First, the rail-gun method was tried at their request, but this system could not accelerate a mini rocket enough to fly. So we try the magnetic force by using a solenoid. This year, two solenoids were used to get enough acceleration. This work took over 20 days and a total of 80 hours. Finally, the rocket was accelerate to 27m/s and flew to 35m in height. It seems that being positively immersed in a developed scientific environment and experiencing trial and error for the accomplishment of a goal became a valuable work experience for them.

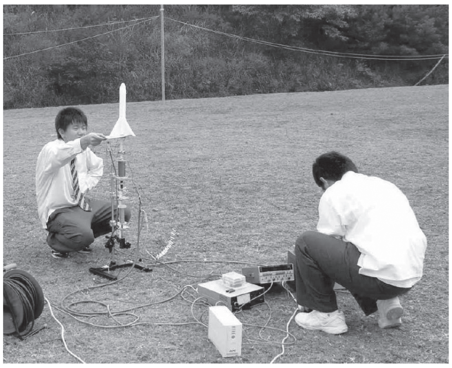


Fig. 34 A snap shot of a flight test in the dual system