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.

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 420 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) Production of Long Tapered Microwave Transition

The production technology of a long tapered microwave transition has been developed. In order to reduce the spurious wave, this transition has a log tapered structure, as shown in Figure 1.

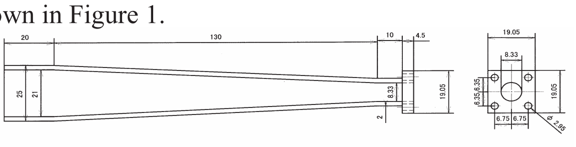


Fig. 1 Long tapered structure

The length of this transition is 164.5mm. Both sides of this transition are straight sections, of which axis is the same as that of the taper section. The dimensions of this taper are the length of 130 mm, the input aperture diameter of 8.33 mm, and the diameter of output aperture of 21 mm. The material is aluminum alloy A12017.

The usual way to produce a tapered pipe is as follows: firstly making a hole smaller than 8.33 mm; then enlarging the hole gradually. However, such a thin cutting bit is so weak that it cannot enlarge the hole due to vibration. Therefore, firstly we made a stepped hole by drills of different sizes. Then we made the smooth tapered cylinder by using a specially designed cutting tool.

Figure 2 shows the specially designed cutting tool. The cutting part is made of SKH (steel for high speed cutter) and is soldered to a tapered holder of SK (steel for cutting bit). The base size of the tapered holder is 32 mm in diameter. The cutting bit is shaped by using a grinder.

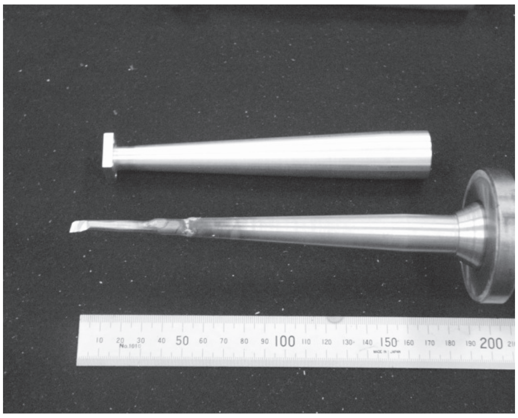


Fig. 2 Specially Designed Cutting Tool

Installing this special cutting tool to a numerical controlled (NC) lathe, the tapered hole is cut little by little. The starting point of the cutting bit is 54 mm from the end of the tapered hole. This starting point moves by 0.2 mm in the radial direction with every cutting motion. A computer program, developed in this work, controls this movement and determines the starting point to the NC lathe via the network from a personal computer. The NC lathe works for 5 hours to produce the tapered hole.

(2) Corrugated miter bend

The corrugated miter bend is a component of the vacuum waveguide system which is installed in the part of 90 degree bend. In order to improve the transmission efficiency of the 3.5inch- corrugated waveguide, it is necessary to cut 124 corrugated slots in the surface of the inside diameter of the miter bend. The size of the corrugated slot is 0.6mm deep and 0.2mm tooth width. The wave guide system requires precise rectangular ridges. We used a machining center, which was installed at the central work shop in the last year. The machine gave us precision processing.

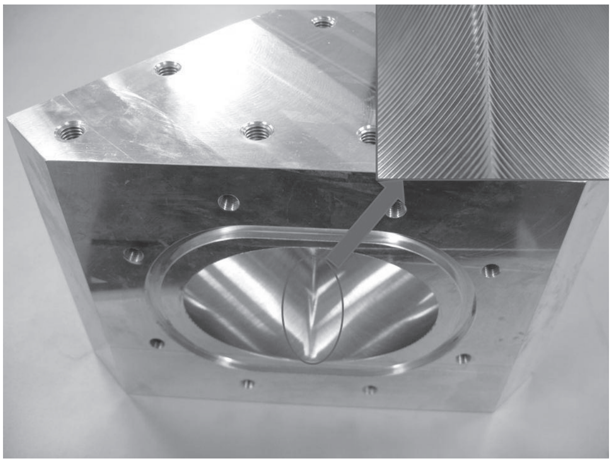


Fig. 3 Corrugated miter bend

(3) Web remote control circuitry

Three types of remotely operated circuits on the Web were manufactured. These are a 15 channel pulse generator for a microwave reflecto meter, a 2 channel delay pulser for a high-speed camera using the repetitive fueling pellet injector and the 20 channel delay pulser with the clock generator for the development of the 3 amperes positive ion source. These circuits are mainly integrated into a FPGA (Field Programmable Gate Array) device on the board of an embedded microcomputer system (SUZAKU-S, Atmark Techno Inc). In order to remotely control the circuit from the Web browser of a remote PC, a CGI program runs on a thttp server on Linux OS. The FPGA into a microcomputer and an onboard Ethernet LAN controller have allowed the remote control. We designed and manufactured the circuit without the microcomputer, the device driver and the CGI program.

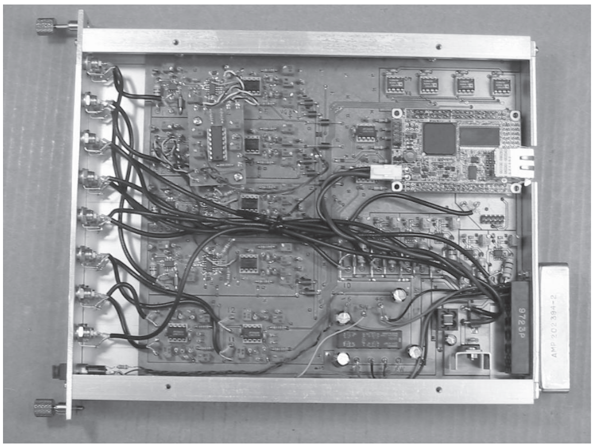


Fig.4 Clock generator

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 2 in the eleventh-experimental campaign, the cryostat was evacuated as usual. The evacuation of the plasma vacuum vessel began on August 3. The number of the maintained flanges was 110. We found five vacuum leaks. The vacuum leaks were fixed on Aug. 16, and the coil cool-down was started at Aug. 29. The cooling down was completed on Sep. 21.

The first energizing of LHD in the eleventh-campaign was on Sep. 25. The number of operation days of the SC-coils was 65 days. The number of days of the plasma experimental period was 143 days. The warm up of the S.C.-coils was started on March 21.

During this period, the interruption of commercial power occurred three times due to thunderstorms. They were on Aug. 19, 30 and 31.

The availability of the cooling water system and the vacuum pumping system achieved 100% in this campaign. In the refrigerator system, the operation time was 5184 hours.

In this period, the control system of the refrigerator system was stopped by the failure of a memory board. This failure caused the control system to freeze. This problem is the first time for us and it is not easy to find the reason for this frozen system. We stopped all the refrigerator system by the emergency stop program. 1300Nm3 of helium gas was lost in this stop period (about a half day). It took two weeks to recover the temperature of the S.C. coils.

The availability of the refrigerator system was 99.5 % in this period.

(2) Product of the signal changer of gas species for the LHD data acquisition system.

The gas-puff device used mainly Hydrogen, Helium, Argon, Xenon, and Krypton gas on the LHD experiment.

In the previous system, gas species data was inputted to the database and the data display system manually when we changed the gas species. This data has to be saved to the LHD data acquisition system during the 3 minutes of the experimental period. Sometimes, it was not entered in time, so the database has no record of the gas species.

This time, the automatically gas species data registration system was made for the LHD data acquisition system.

This system is composed of the signal changer, the indicator of the gas species, the PC to process the data of a kind of gas, the 64 bit digital input board and the software to save the data of gas species not only to the LHD database but also to the data display system.

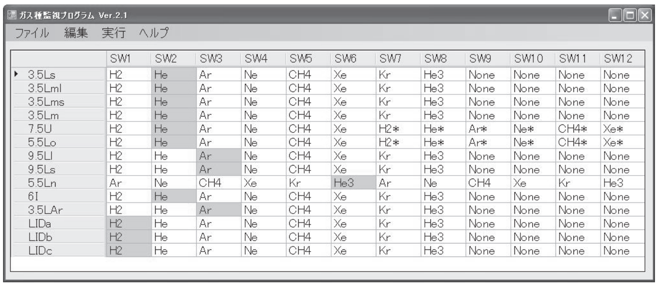
The signal changer and indicator of the gas species is on the surface, for changing and indicating the gas species on the piezo-valve of the gas-puff device selected by a rotary switch, converting the 12 bit decimal signal of gas species to the 4 bit BCD signal. And this signal was sent to the 64 bit digital input board.

The 10 signal changer and indicator of the gas species is shown in Fig. 5.

Fig. 5 10 signal changer and indicator of gas species

This data was made by following the experimental condition. The software converted the 4 bit BCD signal to the data of the kind of gas, and save it to the LHD data acquisition system.

The gas species monitor and on the PC monitor is shown in Fig. 6.



ガス種監視プログラム Ver.2.1
ファイル 編集 実行 ヘルプ

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12
3.5Ls	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
3.5Lml	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
3.5Lms	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
3.5Lm	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
7.5U	H2	He	Ar	Ne	CH4	Xe	H2*	He*	Ar*	Ne*	CH4*	Xe*
5.5Lo	H2	He	Ar	Ne	CH4	Xe	H2*	He*	Ar*	Ne*	CH4*	Xe*
9.5Ll	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
9.5Ls	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
5.5Ln	Ar	Ne	CH4	Xe	Kr	He3	Ar	Ne	CH4	Xe	Kr	He3
6I	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
3.5LAr	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
LIDa	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
LIDb	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None
LIDc	H2	He	Ar	Ne	CH4	Xe	Kr	He3	None	None	None	None

Fig. 6 Gas species monitor on the PC monitor

(3) Maintenance of the diverter plates

In a Helical plasma confinement system, most of the heat flux comes from the fish-tail region. In LHD, we set the 1700 carbon diverter plates in this area for the protection from the thermal problem.

These plates were already used more than 10 years. Impurities accumulated on the surface of the plates.

So we checked the accumulation and the setting position, and damage to the screws. After that 580 plates were removed, polished 0.4mm in depth, and reset. It took more than 3 months.

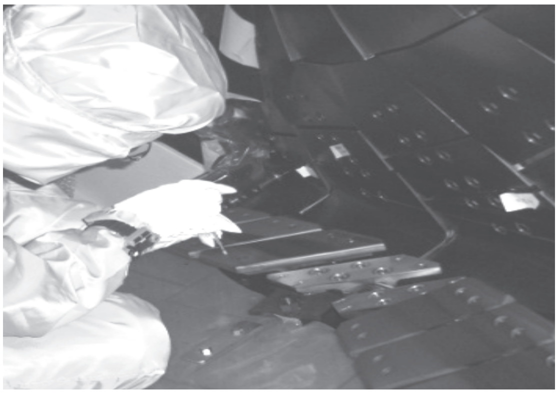


Fig. 7 Setup of divertor plates in vacuum vessel

(4) Thermal analysis of a getter pump in closed divertor

Particle pumping in the closed divertor area is important for improvement of the plasma confinement. This getter pump will be set between the LHD vacuum vessel and the inside cover of the closed divertor. The surface temperature of this getter pump will be 480℃. This is thermally transmitted to the first wall of LHD vacuum vessel. Figure 10 shows the temperature behavior of the getter pump.

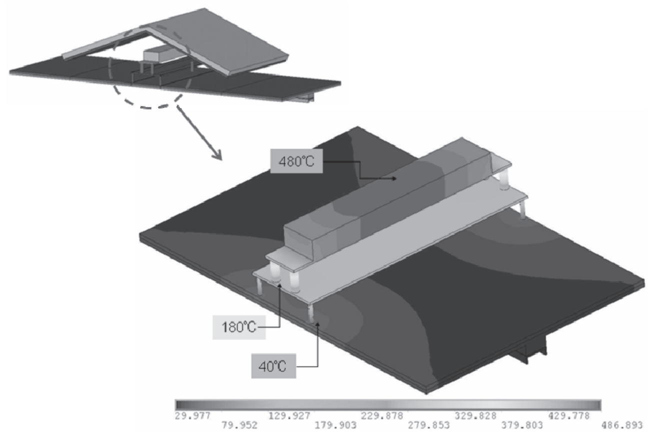


Fig. 8 Thermal distribution and decay

(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 11th experimental campaign, the total injection power of three beam lines (N-NBI) exceeded 15MW into LHD. This value was over their specification. The total injection power including P-NBI exceeded the previous maximum value, and contributed to an increase on the ion temperature record. As for the other heating devices, 1 MW output gyrotron at 77 GHz was newly installed before this experimental campaign and was used in the ECH. For the ICRF, the installation of a new oscillator was completed by the end of this fiscal year.

The details of these activities are as follows.

(1) ECH

(a) Gyrotron Operation & LHD experiment

At the beginning of the 11th experimental campaign, we could operate the 8 gyrotrons, but toward the middle of the campaign, two gyrotrons (84GHz and 77GHz) suffered vacuum leaks one after the other. The 84GHz gyrotron (#4) seems to have had the collector wall melted. The other gyrotron (#2) had the output CVD diamond window broken. Although the total number of available gyrotrons was reduced to 6, the total injection millimeter wave power into LHD reached 1.9MW for the pulsed operation as shown in Fig. 9. During the gyrotron operation, two 168GHz gyrotrons could not be started up at the same time because of the transient unstable situation in the gyrotron power supply. This situation can be avoided by setting the time delay in the start up time between two gyrotrons. Another 168GHz (#7) gyrotron, this had not been in operation since the last experimental campaign due to the lack of the transmission line, was put into operation in this experimental campaign using the line that had been used for the other damaged gyrotron.

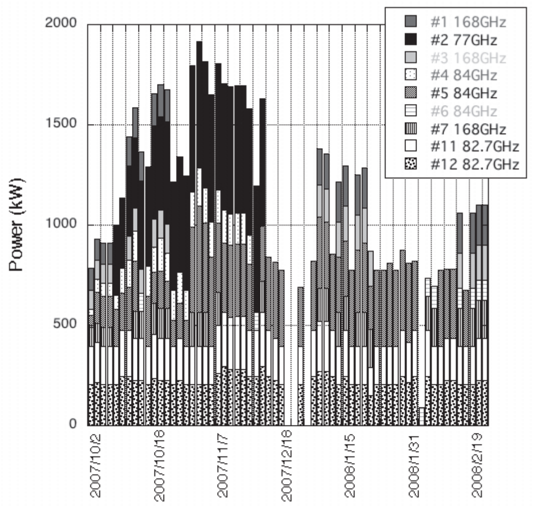


Fig.9 History of ECH injection power during 11th experimental campaign

A new powerful 77GHz gyrotron was developed in the collaboration with the Plasma Research Center of Tsukuba University. Its specifications are 1MW/5sec or 300kW/CW. It had been installed and conditioned in NIFS before the beginning of this experimental campaign. Due to its lower frequency, 77 GHz, on axis heating at the fundamental resonance became possible at the standard magnetic axis of 3.6 m with the field of 2.75T. The preparation work needed to be done prior to the gyrotron oscillation test were the following: upgrading the cooling water system, vacuum system for evacuating the transmission line, power and temperature monitoring system including the interlock, control cabling and checking and so on. The oscillation test of the new gyrotron was performed using the newly installed high power dummy load on the heating equipment room, which has an absorption power capability of the level of 1MW under CW conditions. The oscillation test set is shown in Fig. 10. Until the start of the experimental campaign, the conditioning of the gyrotron was continued by transmitting the power to this dummy load. After the start of experimental campaign, we continued the aging of the gyrotron by injecting the millimeter wave into LHD since the period of the conditioning was not enough. The aging of the gyrotron had gone up smoothly. The injection power achieved 800kW/3.6sec and much contributed to the experiment with its power and pulse width. But unfortunately, the output CVD diamond window of the gyrotron had a crack and the leakage of the air and/or coolant (FC75) occurred at nearly the end of the 800 kW/3.6 sec pulse in the middle of the experimental campaign. For the next experiment campaign, we have a plan to install an additional similar type new gyrotron as well as the repaired one. We will achieve the CW injection to LHD by two gyrotrons, confirming the reliability of the new protection system.

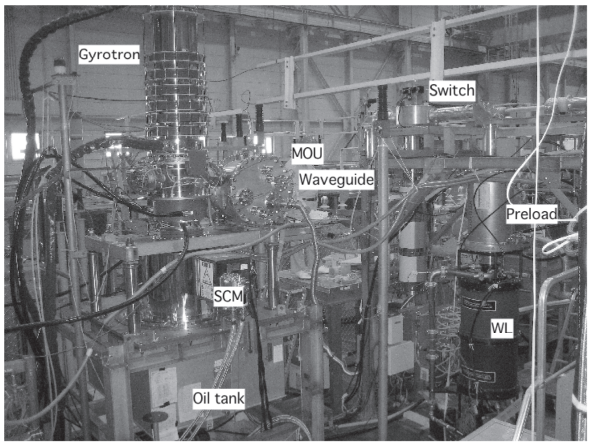


Fig. 10 Transmission line from a new gyrotron to dummy load (Water Load).

(b) The upgrade of the microwave transmission waveguide components associated with the installation of a high power CW gyrotron.

We installed high power CW gyrotron this year. More care should be taken a against temperature rise, arcing and leaking microwaves for this system. We upgraded the existing transmission waveguide systems for this purpose. The transmission line had been evacuated to reduce arcing. In order to be more reliable against the possibility of microwave leakage, the Viton O-ring vacuum seals are replaced to the extent possible by those of a metal O-ring.

The vacuum level in the waveguide reached as low as $5x10^{-2}$ Pa. In addition, the TiO_2 window at LHD is replaced by that of CVD diamond. Special waveguide section with installation an arc sensor and an infrared temperature sensor to monitor the window surface were designed, fabricated and installed just in front of the window at LHD. A sliding waveguide that absorbs the thermal expansion is also developed using a bellows. Cooling units are also attached around almost all the waveguides. Fig.11 is a waveguide section in the neighborhood of LHD that we changed this time. Miter bends including a corrugated part of the waveguide, the vacuum flanges those we installed were designed and fabricated by the NIFS machine shop. Therefore, further upgrade of the transmission components became easy and inexpensive.

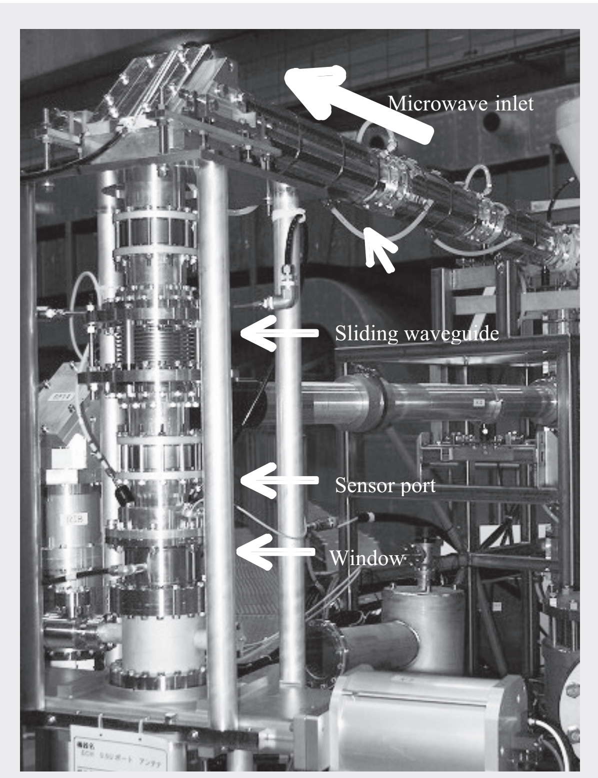


Fig.11. Improvement of 3.5inch diameter waveguide components on LHD.

c) Measures for false detection of the arc detector.

We have used a photo sensor (an arc detector) to protect the gyrotron and waveguide components from damage by arcing. 64 sensors have been installed in the eight transmission lines. We have connected a sensor to a component of a transmission line by an optical fiber of 1m length. The arc inside of a transmission line is detected by a photo detector. We adjusted all the sensor circuit so that the threshold levels of arc detection are 100nW at the input of the fiber. But the sensor circuit at some certain places often causes false detection signals due to noise. The sensor circuits placed near the high voltage and high current power supply are especially under severe noise circumstances. The shields of these circuits are reinforced, and filters are inserted in the power and signal lines, but frequent miss detections were not reduced. It was effective to increase the cross section of the sensor and increase the S/N ratio for detection. However, the cross section is normally limited by the diameter of the cut-off hole to see through the inside of the transmission line. The other way to reduce the false detections is to block noises in time by gating the activation of the detection circuit only during the necessary duration. Such a gate circuit using the high voltage pulse of each gyrotron was added to each detection circuit from the 11th experimental campaign. This method worked well and contributed much to reduce the miss operation of the arc sensor. In order to further improve the reliability and the safety, fine adjustment of the sensitivity and threshold level are necessary.

(2) ICRF

(a) Revision of feedback control circuits in ICRF heating system after introducing a new RF generator

At present a new RF generator system is under construction for ICRF heating. For that feedback control circuits are added including revision for auto gain control (AGC), RF amplifiers at low power level, interlock circuits as well as a remote control system for RF generators and control unit of incoming panels etc. The remote control system has a function to be equipped in a LAN system, which makes the RF power and its pulse length able to be controlled at any place in NIFS. The reduction of the AC voltage in the 6.6.kV line has been observed in the high RF reduction in the RF output and the limitation in the maximum RF power because of the increase in the screen grid current, which also is caused by the reduction in the anode voltage. To mitigate the phenomena a DC power supply circuit was added to the main DC power supply. The additional circuit has a capability of feedback control to keep the DC anode voltage constant for variable loading of the RF generator. It is expected that the constant RF output can be transmitted even at high RF power heating and the maximum RF power is available at more than 1.5MW for one RF generator.

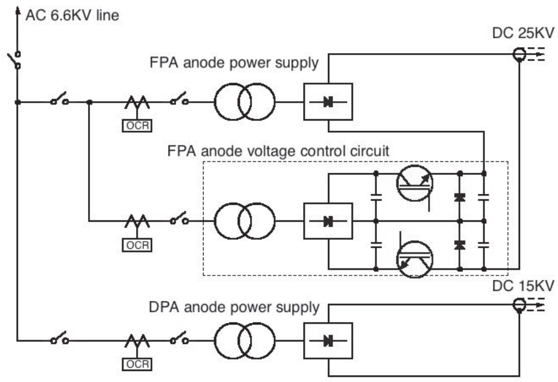


Fig. 12 FPA anode voltage control circuit

(b) Precise piston-position measurement of the ICRF liquid stub tuners

Precise liquid (silicon oil) surface position control in the stub tuner is important for steady-state operation in the ICRF heating scenario, because the electrical length of the ICRF heating system gradually changes as the plasma discharge is extended. The surface position of the silicon oil inside the stub tuner is deduced by the distance between the piston-position and the cylinder unit. In order to measure the precise piston-position we advanced the research and development of that as follows:

i) Observation of actual stub movement using CCD camera

Four CCD cameras are installed to observe the real-time actual stub movement, and movement and rough position of the piston are monitored in the case of feedback control operation. In this campaign feedback control was successful, however precise actual position measurement remains.

ii) Optical distance measurement using semiconductor laser

A sensor using a semiconductor laser is an easy measuring tool, and it has a wide measuring range of distance from a few cm to 1.5 m. That sensor unit which includes emitting parts and detecting parts is installed on the support of the cylinder unit, and the laser reflection unit is on a movable plate of the piston. This optical measuring method is able to directly measure the distance, but there are some problems in measuring speed and accurate distance.

iii) Mechanical distance measurement using a pulse motor encoder

To install the encoder of a pulse motor, some control circuits were improved in this campaign, and an initial position moving test was finished. In the RF local control room the signal from the encoder is detected using a pulse counter, but the program for feedback control using the encoder signal is not constructed. When a reset circuit is initiated by operators in the system, the recorded position values vanish. At the time we can count the difference between the present position and the moved position, but the absolute present position value is unknown. A combination of optical and mechanical measurement is important for precise distance measurement, and the combination work is planned for the future work.

(3) NBI

(a) The Operation and the Maintenance of NBI Devices in the 11th experimental campaign of LHD.

About 8000-shots of beams were injected into LHD plasma in this campaign. The maximum total injection power marked 16MW, which is over the design value of the LHD-NBI, and the beam of more than 14MW was reliably injected. BL-1 kept up 5-6.5MW, BL-2 kept up 4-5.5MW, and BL-3 kept up 3.5-5MW. BL-1 has already reached specified injection power several years ago, BL-2 and BL-3 achieved at last in this campaign. The history of total injection beam power is shown in Fig. 13

In this campaign, none of the Beam-Lines had any big trouble which stopped the LHD plasma experiment, but had several minor troubles. BL-1 had the cooling-water leak from a Calorie-Meter, but it was a small leak rate. BL-2 had the failure of mini-TMP (350l/s) for maintenance vacuum pumping. BL-3 had a break of an insulation sleeve for the Ion-Sources screw bolt, during which time the high voltage was not applied.

It was first time that all the Beam-Lines reached the design value of the injection power. We will continue efforts to increase the injection power and to provide stable operation of the NBI.

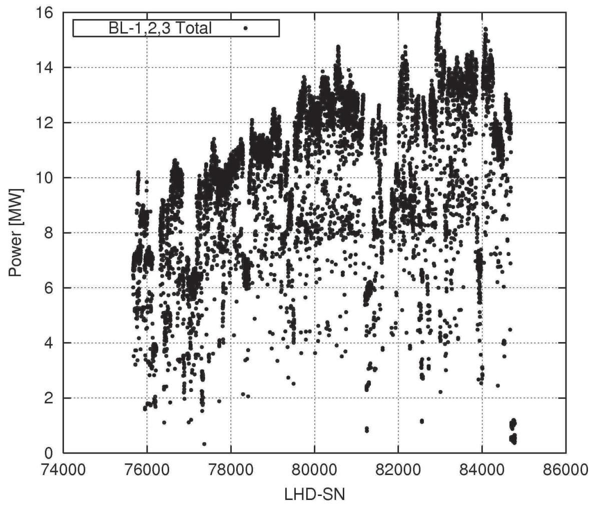


Fig. 13 The history of total injection beam power in the 11th experimental campaign of LHD

As for the positive-ion-based neutral beam injector, BL4 started the operation in the 9th campaign. In the 11th campaign, BL4 injected about 6,000 shots and the injection power achieved over 7MW. Long pulse beam injection was also performed. The temperature control of the beam line components is a key issue for safe operations. A real time monitor system was developed and applied to the long pulse beam operation. The beam injection with 69s-0.4MW was achieved due to sequential operation of four ion sources.

(b) Management of liquid nitrogen

LHD-NBI is a device that produces neutral particle beams of which species is hydrogen. The hydrogen gas should be evacuated during the neutral beam transportation in the vacuum vessel and cryo-sorption pumps with a large pumping speed are installed inside the vacuum vessel. The pumping mechanism is gas-capture: cryo-panels as pumping surfaces are cooled to an extremely low temperature with refrigerators where helium gas is cooled by adiabatic expansion and heat exchange, and the gas molecules get adsorbed on these cooled surfaces. Radiation shields cooled with liquid nitrogen cover the cryo-panels to shield the thermal radiation from the vacuum vessel's wall. The helium gas is circulated because the helium refrigerators utilize the closed compressed circuit. On the other hand, the liquid nitrogen is continuously consumed because the evaporated nitrogen gas is discharged into the gas exhaust lines outside the cryo-pumping system. Cryo-sorption pumps are installed with the every injector: five units in BL1, six in BL2, six in BL3 and four in BL4. The consumption of the liquid nitrogen in all cryo pumps adds up to 11,000 liters per day. The consumption is increased by about 15% at the initial cooling-down after the regeneration and the warm-up of the cryo-panels on the weekend. There is a liquid nitrogen supply facility outside of the experimental building. A storage tank is placed there and transfer lines are connected from the tank to the NBI devices. These transfer lines are thermally insulated tubing, in which the space between outer pipe and inner pipe is evacuated. There is no facility for producing liquid nitrogen in this institute. It is transported from suppliers and is stored in the tank. The gross capacity of the tank is 40,100 liters, and the net capacity is 36,000 liters which corresponds to 90% of the gross capacity. During the LHD experimental campaign, everyday the replenishment of liquid nitrogen is needed in order not to empty the tank. So, the proper schedule must be planned for replenishing it efficiently, and therefore the consumption over a couple of days and the following week should be estimated from the number of running NBI devices and from the amount remain in the tank at that time.

(c) Development of the remote control system for re-entering fast ion probe

We have newly installed a re-entering fast ion probe on LHD and started its operation since the 11th experimental campaign of LHD. The probe is aimed to measure the amount of fast ions which are recursively going out and into the LHD plasmas at their periphery. The heat load onto the probe by these fast ions is expected to be high at the measurement location. Therefore, we only insert the probe when it is necessary for measurements, and the probe is usually removed away from the plasmas. We developed the remote control system for the probe. The schematic diagram is shown in Fig. 14. In this system, the probe position is controlled by a Programmable Logic Controller (PLC) which is installed in the LHD hall. The temperature of the probe head is monitored by this PLC. The applied bias voltage of the probe is also controlled by the PLC. In changing the position of the probe and the bias voltage, the PLC is remotely accessed through the LHD-LAN by a Personal Computer (PC) in the LHD control room using a GUI program. Any probe positions and its applied voltages can be set by this program within its designed range. The system also has a function of interlock, i.e., the probe is automatically pulled out when the temperature of the probe head exceeds a certain threshold level. The system was successfully operated without any troubles during the 11th campaign.

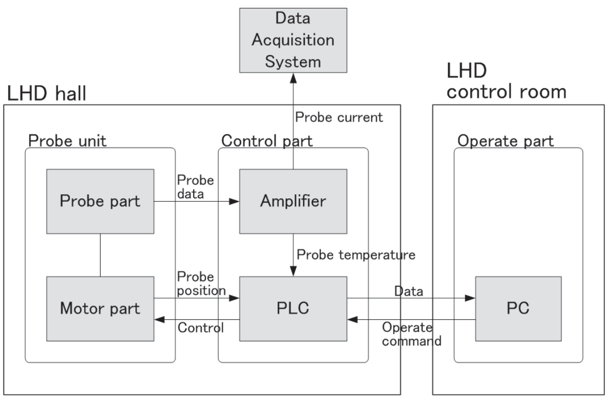


Fig. 14 Diagram of remote control system for probe

(4) Motor-Generator (MG)

The MG is used to supply the pulsed power to the NBI for LHD. The MG had generated 36,976 shots in this fiscal year and 424,252 shots since its construction. The operation time counted 1,557 hours in this fiscal year and 19,206 hours in a total. Under the annual inspection in this fiscal year, the following components were checked: oil in the MG, a circuit breaker, two air-breaker switches, a thrust elevation system, 14 vacuum circuit-breakers and a brake dust collector. In another case, three cooler fans' bearings and two frozen prevention heaters were exchanged that were installed in the cooling tower.

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 eleventh experimental campaign, some of the diagnostics and the data acquisition system were improved. The Thomson Scattering Diagnostic was improved to derive accurate density data. In the WE7000 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. Our principal tasks in this fiscal year are described in the following.

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

In this fiscal year, the five radiation monitoring posts around the experimental buildings and on the site boundary in the NIFS site were checked and calibrated with the standard checking radioactive sources. After this maintenance, a old X(γ)-ray detector in use since1992 was replaced with a new one.

The new data acquisition system of the radiation monitoring system has been developed with a PXI-PCI system. In future, the old acquisition system will be replaced with a new one.

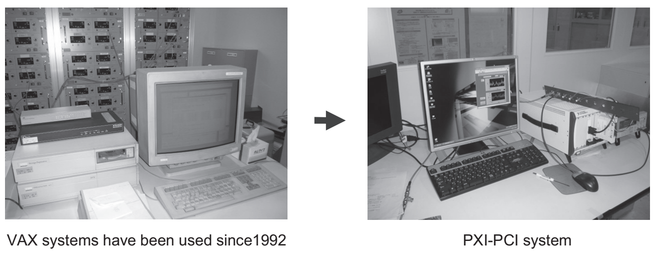


Fig.15 New data acquisition system which has been developed and the old one (VAX system).

(2) Thomson Scattering Diagnostics

In the LHD Thomson scattering diagnostic, various improvements have been made to derive accurate density data. One of these is readjustment and aspherizing of the collection mirror.

The collection mirror is a mosaic mirror (～1.8×1.5m) that consists of 138 hexagonal mirrors whose one side is about 87mm. By adjusting individually each mirror, the efficiently of the light focus can be improved.

The scattering light is collected with the collection mirror and focused on the fiber sections. When the mirror is spherical as a whole, the spot diagram for each scattering points is shown in Fig. 16. This is a collection of the intersections of scattered lights and the surface that include fiber sections. When the mirror is aspherized to optimize the focal points, the spot diagram is improved as shown in Fig. 17.

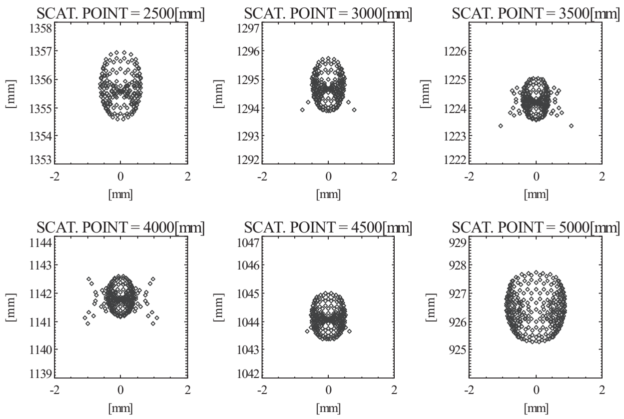


Fig.16 The spot diagram focused with the spherical mirror.

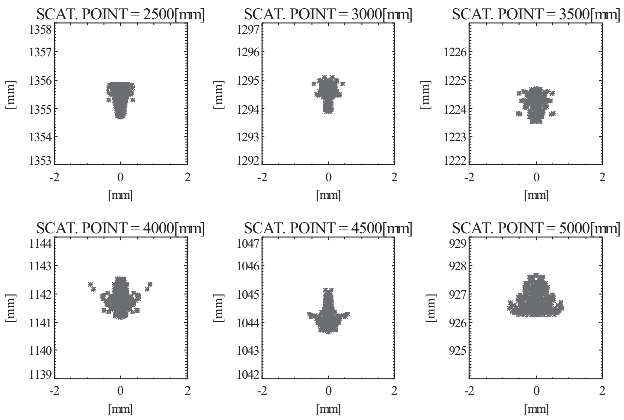


Fig.17 Spot diagram focused with the aspherical mirror.

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

The operation and the maintenance(for example, high voltage power supply, vacuum pumping system, supplied gas system, phase detection circuit, dehydrater, water cooling system etc.) were responsibly executed. Therefore in this 11th experimental campaign, in almost all shot, electron density data was taken completely. So it contributed greatly to the plasma experiment.

(4) Improvement of the Design of the HIBP components

a) Beam monitors remodeled in the vacuum container.

To detect the primary beam in the plasma discharge, the beam monitor was remodeled. An aluminum foil was installed in front of the detection plate. Additionally, it was covered with the stainless steel case.

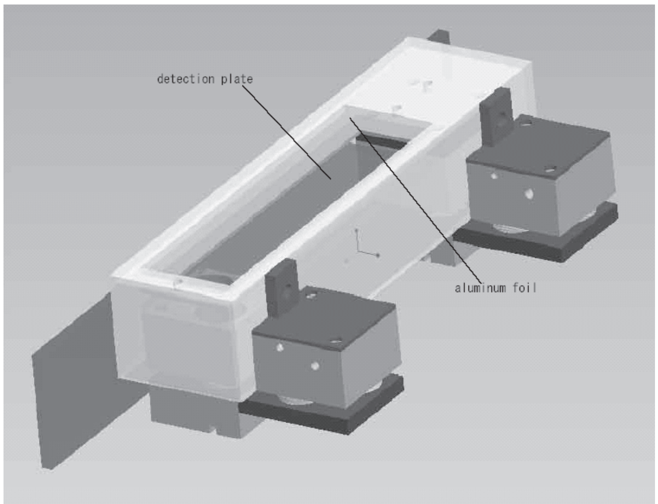


Fig.18 First beam monitor remodeling in vacuum container.

b) Exit side sweeper 2nd electrode installation design

To improve the sweeping of the beam, we installed a 2nd electrode in the exhaust chamber. The previous electrode is not enough to sweep the beam. If we sweep the beam wider, the beam hits the electrode. We made it wider, and installed the 2nd electrode. The length of the 2nd electrode was optimized for the exhaust chamber. Figure 19 shows the 2nd electrode in the exhaust chamber.

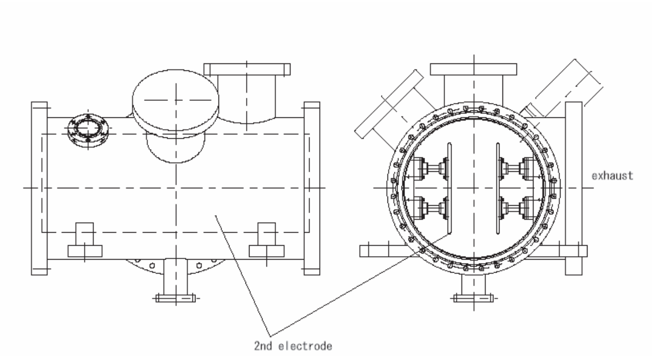


Fig.19 2nd electrode installation design of exhaust chamber

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

Preliminary vacuum leak tests were carried out on 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 eleventh plasma experimental campaign, some diagnostics elements were tested (for example, parts of the Absolute Extreme Ultraviolet Silicon Photo Diode (AXUVD), Multi Layer Mirror Spectroscope(MLM), Angular Resolved Multi Sightline (ARMS), Bolometer and etc). We carefully tested these vacuum components. Therefore, in this experimental campaign, the plasma experiment was not stopped because of diagnostic device vacuum leakage.

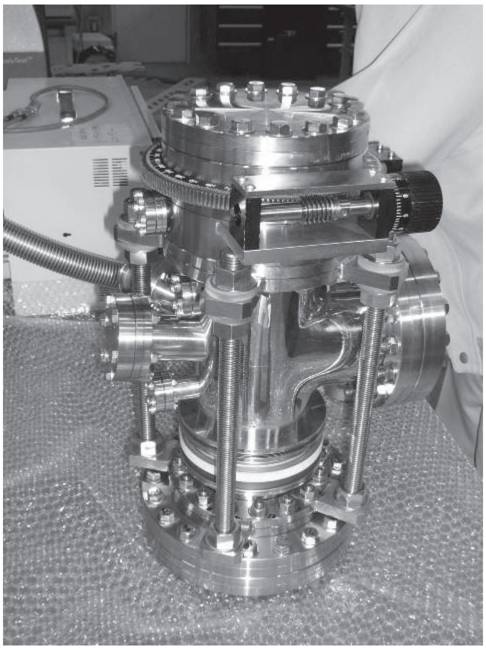


Fig. 20 Snap shot of the vacuum leak test of the ARMS in the Plasma Diagnostic Laboratories

(6)Maintenance and control of centralized monitoring system for the graphical summary of plasma parameters

The experiments are performed with the plasma which is produced repeatedly with an interval of 3 minutes per shot in LHD. The raw data, which is acquired with the diagnostic by the researcher in charge of the diagnostic, is processed with a first and second step by using researchers' own computers to estimate the plasma parameters. The researcher displays the parameter graphically on the screen within the interval to have other researchers see the physical quantity of the diagnostic. The graphically plotted data sets of 14 kinds of the diagnostics including Thomson scattering, charge exchange spectroscopy, and some diagnostics for the fluctuations are also displayed on 14 screens of computers located near the center tables of the LHD control room, for a centralized monitoring. Recently, many updates for the OS and anti-virus are delivered by the venders, and our workload for the maintenance has increased. If we neglected the update, the related networks connected to the computers would suffer large damage. We have experienced sudden crashes of the computers, which are caused by aging, and we are going to replace the crashed computer with new ones which work on Linux to gain security and working stability. Now we have 14 computers for the centralized monitoring, and two of them have already been replaced by Linux systems. We considered that replacing the crashed computer after the other is better than replacing these old computers together according to the viewpoint of the compatibility and the stability of the programs, which display the graphical data. Thus we try to get stability in the maintenance and control of the computers for the centralized monitoring systems.

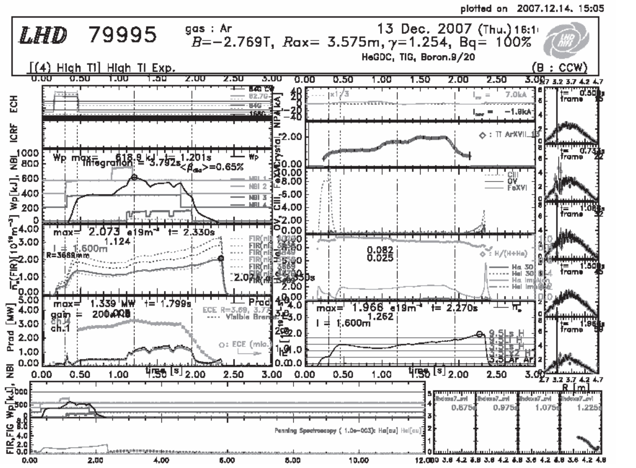


Fig.21 Sample of the graphical summary of Plasma parameters

(7) Development of Data Acquisition System

In the LHD data acquisition system, WE7000 DAQ-Box system on Linux platform has been developed. In the eleventh campaign, it was on Windows and used Compact Flash for a system disk. The newer system on Linux is network-booted with no disk.

Also a FPGA demodulator has been developed. It costs is lower and has more clock channels than the VME demodulator.

For data storage, the RAID system has been increased and a blue-ray library has been introduced. It stored all the past data of the LHD plasma in this experimental campaign.

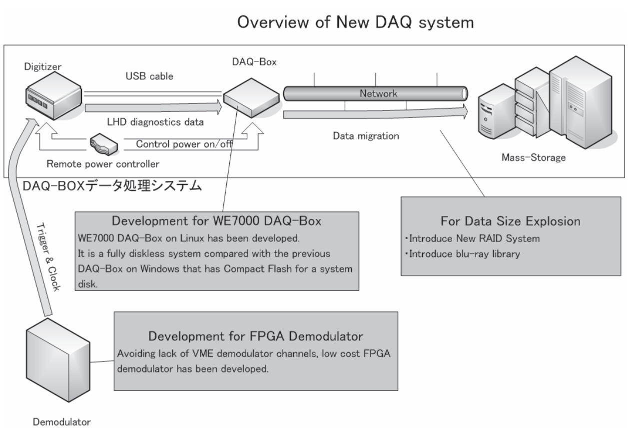


Fig. 22 Change to new DAQ system with DAQ-Box

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, etc. The work of system development in this year is as follows; remodeling of the LHD man-machine interface system, a development the advanced control algorism for Cryogenic, an upgrade of gigabit routing switches in the LHD-LAN, improvement of the ICRF stub tuner control system, 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 LHD man-machine interface system (LMS) in the plasma experiment, which is the core component of the LHD central control system. It covers the management of various experimental conditions, the acquisition of the operational data and their presentation on the terminal displays. Since the experimental environment has considerably changed in the 10 years LHD experiment, we are promoting the modification of the LMS as a two years plan.

There are two purposes. The first one is to review the data flow of the recent complicated LHD operation and then unify the management of operational data using a database. Based on the successful R&D in the first year, we have put into full operation of the new scheme, where new items such as injection timing of heating power and gas-puffing, gas species, coil current for LID and etc. are added.

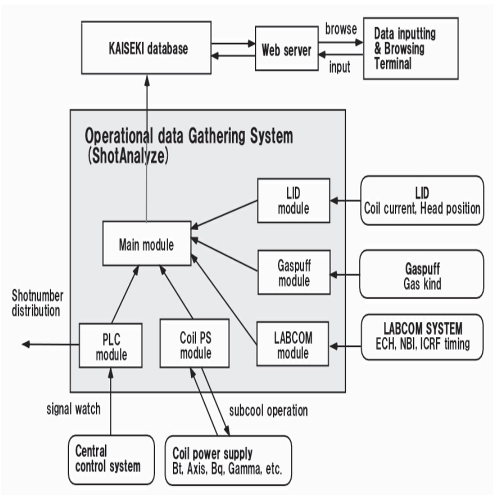


Fig.23 Control and document data flows of LMS

The second purpose is to separate the coil preset function from the LMS, which aims to change experimental parameters more quickly and precisely. The separation work was completed in the last fiscal year. In order to apply the new system to the sub-cool operation in this year, we have changed the conversion rule between four magnetic parameters, Bt, Axis, Bq and Gamma, and the currents for the super-conducting coils. An alarm function has been added, which is to notify the coil operator when parameter setting does not satisfy normal operational conditions. Figure 11 shows a block diagram of the LMS data flows from/to other periphery devices.

(2) Simulation Study of Advanced Control Algorithm for Cryogenic Plant

A Cryogenic Process Real-Time Simulator (C-PREST) has been developed to understand dynamic behaviors of a large-scale cryo-plant, to find optimum operational conditions and to inspect the sequence program for emergencies, etc. The C-PREST has so far been successfully applied to the 10kW helium refrigerator/liquefier for LHD. It was confirmed that the simulation result described well the data from the real machine.

In order to improve the stability of the cryogenic plant, a new function has been added in the control algorithm which connects MATLAB with the C-PREST. Figure 24 shows a block diagram of the new algorithm. The FF (Feed Forward) controller is installed to operate the pressure control valve for the compressor and suppress the disturbed tank pressure. We have tested this advanced control algorithm in a model refrigerator/liquefier of 300W class. Items to be tested are a quick convergence and stabilization of the disturbance when the heat-pulse perturbation is added to the liquid-helium tank. Figure 25 shows a comparison of the two simulation results between the advanced FF control algorithm and the conventional PID algorithm. It is shown that both amplitude and convergence time are improved with the new algorithm.

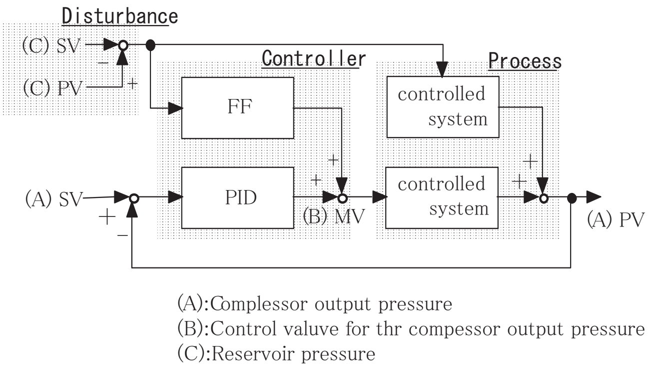


Fig.24Block diagram of advanced control algorism

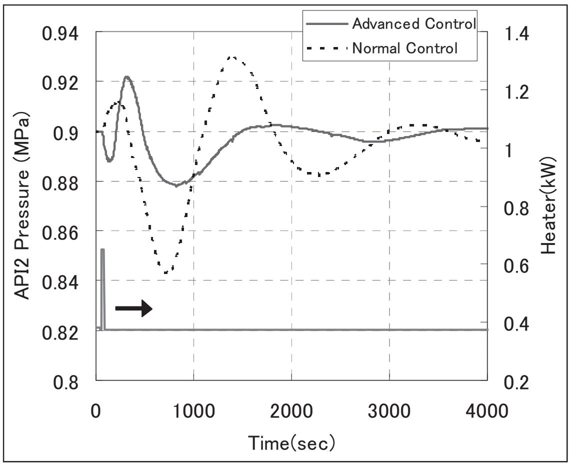


Fig.25 Result of simulation

(3) Improvement of stub feedback system for the ICH Stub Tuner

Feedback control of the liquid stub tuner is the key technology for long pulse plasma discharges using ion cyclotron heating (ICH). Four liquid stub tuners are connected to four high power RF oscillators and are controlled independently. Two improvements have been carried out for better control efficiency of the feedback system.

1. With the conventional feedback control system, mechanical vibration of the stub tuner was observed during power-off phase of the RF oscillator, because the control system continued working to keep the liquid level of the stub tuner constant. It induces mechanical stress on the stub cylinder. It also causes difficulty in feedback control at the starting phase of the next RF injection. We have modified the control system so that it stops immediately when the RF power is terminated. The above problems are solved with this modification.

2. The control system has ten channels of liquid level sensors that monitor the physical length of the stub cylinder. The sensors detect the air pressures inside the stub tuners, which are converted to the liquid level. However, the time response is rather slow in this sensing method. We have installed a one channel laser position sensor to test a possible improvement of the response time, in which reflected laser power from the liquid surface is monitored. The feedback control with the new position sensor has been verified to improve the response time.

Figure 26 shows the improved multi-computer system for the fast feedback control of the stub tuners.

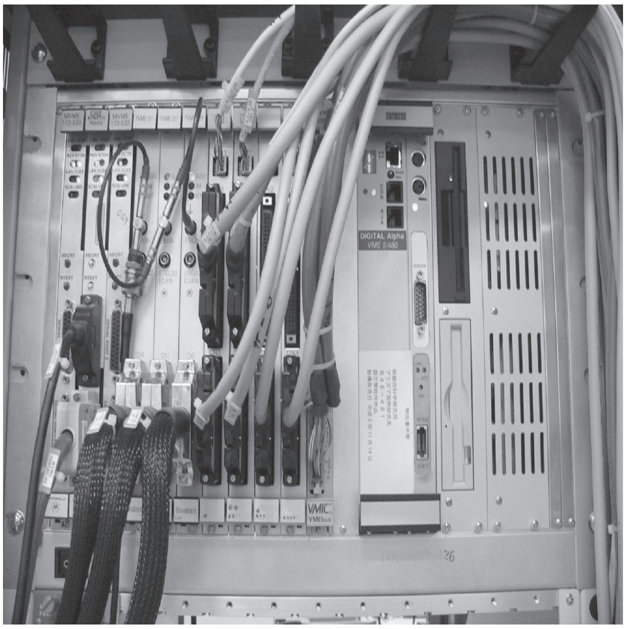


Fig.26 Adding the new control methods and level sensor devices in the multi computer feedback control of Cinos

(4) LHD-LAN

The LHD-LAN has been provided for the LHD experiment since 1996. As LHD experiments progressed, a larger number of computers had been connected to the LHD-LAN. These computers store a large amount of data, and therefore, require the high-performance data transferring environments. Thus the Gigabit Ethernet system had been installed in LHD-LAN since FY 2001. In addition to regular management work, our new contributions in FY 2007 were as follows.

(a) Urgent measures for security improvement in LHD-LAN

At the end of FY 2006, a personal computer connected with NIFS-LAN was infected with a virus. It spread to the NIFS-LAN and LHD-LAN. After this accident, the below-mentioned urgent measures for security were performed based on the LHD-LAN security policy.

(1) Installation of a new firewall system between NIFS-LAN and LHD-LAN.

(2) Install SSL-VPN system for secure access from NIFS-LAN to LHD-LAN.

(3) Termination of DHCP service in LHD-LAN.

(4) Check network cable tags of all computers connected to LHD-LAN nodes. Remove the computers without cable tags.

(5) Isolate computers using un-secure operating systems, such as Windows 95, 98, Me and NT into a restricted LAN area.

(6) Register computers into Active Directory of LHD domain for remote security check.

(7) Remote security checks of user PCs using Active Directory management functions.
(8) Establish the security procedures for connecting a new computer to the LHD-LAN.

(b) Upgrade of gigabit routing switches.

The Gigabit Ethernet system had been installed in FY 2001. Mainly, it consisted of 3-gigabit routing switches and many gigabit switching-hubs. These gigabit routing switches acted as the backbone of LHD-LAN. Before the End of Life of these gigabit routing switches, these were upgraded to "LHD-LAN Core Switching System" in FY 2007. It consists of 2-gigabit routing switches, with a throughput of greater than 210 million packets per second. These have a 10-gigabit port, 48-gigabit SFP ports and 48 10/100/1000 UTP ports. These are connected at a speed of 10 gigabit mutually in order to realize high performance data transfer and act as a new backbone of the LHD-LAN. One of them was installed in the control device room in control building, connected with the NIFS-LAN router and the SNET router. The other was installed in the diagnostic computer room in the same building. The new Block Diagram of the LHD-LAN is shown in Fig. 27.

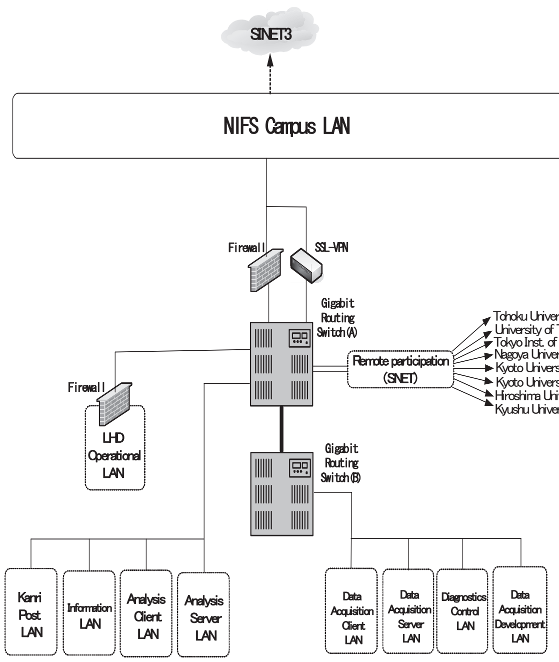


Fig. 27 Block diagram of LHD-LAN

6. Symposium on Technology, Technical Exchange and dual system

(1)The Symposium on Technology

The Symposium on Technology was held on March 10 and 11, 2008 at Ceratopia Toki in Toki city, Gifu Prefecture, Japan, which was hosted by the National Institute for Fusion Science(NIFS). There were 296 participants from many Japanese universities, national laboratories, technical colleges, and some industries. In this symposium 97 papers were presented in 4 oral sessions and poster session. Technical experience and new techniques were reported and discussed. Eight papers were presented from our department.

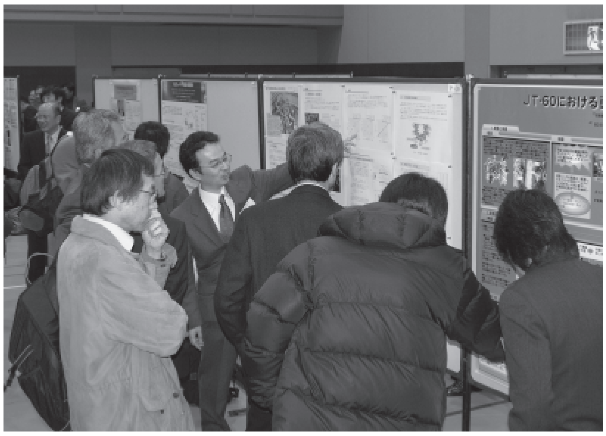


Fig. 28 a snapshot of the poster session

(2) Technical exchanges

The 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 6 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 6 institutes,
"Mechatronics Technology" from Tsukuba University and Nagoya University,
"Measurement and control technique using a PC "from Tohoku University and the High Energy Accelerator Research Organization,
"3-Dimensionl CAD Simulation Technology" from the National Astronomical Observatory of Japan and Nagoya University,
"Electronic Publishing Technology" from the Japan Atomic Energy Agency,
"Vacuum Technology" from Yamaguchi University.

(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 had accepted students from the Tajimi Technical High School (TTHS) from fiscal year 2005 to 2006 under the program of the Ministry of Education, Culture, Sports, Science and Technology. In this fiscal year at TTHS's request, NIFS has accepted to continue the program. The theme was "Design and production of a camera for inside of LHD". We instructed the students to dig up the conditions for devices on the design and then set about the production. They learned many technical points through this experience. The main ones are as follows.
1. An artifice to store a device in a limited space.

2. Application and control of a super sonic motor under the conditions of a strong magnetic field.
3. Usage of an optical communication technique for remote control.

They reflected these points in the production of the device and could drive it remotely at will. For a practical use of this system, there are many assignments such a proof of a stable movement, but it is expected that this experience will be transfered to a new approach next year.

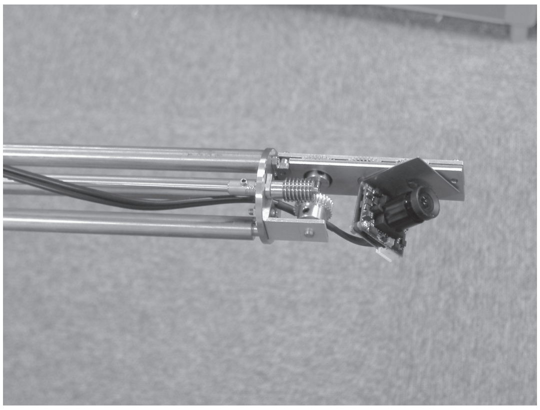


Fig. 29 Drive mechanism of the CCD-camera