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DEVELOPMENT OF ION DIAGNOSTIC SYSTEM BASED ON
ELECTROSTATIC PROBE IN THE BOUNDARY PLASMA
OF THE JFT-2M TOKAMAK

June 1995

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An ion diagnostic system using electrostatic probes for measurements in the JFT-2M tokamak boundary plasma has been developed under the collaboration program between KFA and JAERI. The rotating double probe system, on which the Höthker double probe and Amemiya asymmetric probe can mounted, are manufactured at KFA workshop while the linear driver to support the rotating double probe, the ion toothbrush probe, the Katsumata probe and the cubic Mach probe are developed at JAERI. This report describes the hardware of this probe system for ion diagnostics in the boundary plasma and preliminary data obtained by means of this system. Furthermore, results on the transport are estimated on the basis of these porbe data.

Keywords: Ion Diagnostics, Electrostatic Probe, Rotating Double Probe, JFT-2M,
Ion Toothbrush Probe, Katsumata, Probe, Cubic Mach Probe

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JFT-2Mにおける静電プローブを用いた周辺イオン計測システムの開発

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静電プローブを用いたプラズマ計測は、荷電粒子の集合体としてのプラズマの情報を測定点で直接キャッチするので、空間分解能に優れており、電磁波などを用いる間接的な方法に比べて、情報量が多く、非常に有用である。トカマクプラズマにおける静電プローブを用いた計測は、いくつかの装置で最近漸く始められるようになったが、電子に関する情報は比較的多いが、イオンに関するデータは非常に少ない。磁気核融合装置ではプラズマ輸送の解明が急務の課題とされているが、この問題の解決には、周辺プラズマの挙動が鍵を握っているといわれている。しかし、周辺プラズマにおけるイオンの情報が殆どないために、プラズマ輸送の物理的メカニズムの追及に手間取っているのが現状である。このような状況を踏まえて、JFT-2Mではこの度、ドイツユーリッヒ研究所のHöthker の開発した回転プローブと理研の雨宮の開発した非対称プローブおよび原研で独自に開発した勝俣プローブ、イオン歯ブラシプローブ、三次元マッハプローブ等を整備して、周辺のイオン計測を開始した。この論文はJFT-2Mで測定の行われている周辺イオン計測に関する静電プローブシステムのハードウェアとこれを用いて得られた初期的データおよびこれらのデータから評価されるプラズマ輸送の研究について述べたものである。

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1. Introduction

Plasma transport is a very important subject to be studied on the way to a magnetic fusion reactor. If the plasma transport is clarified we can construct a more feasible machine for fusion reactor since the effective confinement method is established using the transport physics. The boundary plasma in a torus is a region where the closed magnetic surfaces in a core plasma change into the open ended surface, where the magnetic field lines are cut by the solid materials such as the limiter and divertor plate and the heat from the core plasma is lost by the contact with the solid materials through convection and conduction. Thus, the boundary plasma forms important boundary conditions to determine the confinement characteristics in a core plasma since the transport equations must be solved by using above heat and particle loss conditions. In this sense it is often said that the boundary plasma plays a key role to solve the transport problem.

The diagnostics in the boundary plasma is performed by using many methods. Among them, the diagnostics by using electrostatic probes is very useful compared with indirect diagnostics such as spectroscopic method since the electrostatic probe can catch many information of plasma with a good spatial resolution by gathering the direct current from plasma particles. Plasma diagnostics using electrostatic probes is applied to a large extent in tokamaks, however, there are few data on ions. Much remains to be done to study the transport of the boundary plasma to include also the contribution of the ions. Considering this situation, ion diagnostics such as the Höthker rotating double probe¹⁾, Amemiya asymmetric probe²⁾, Katsumata probe³⁾, ion toothbrush probe (ITP) and cubic Mach probe have been installed on the JFT-2M tokamak. The rotating double probe, on which the Höthker probe and Amemiya probe can be mounted at the top, are designed and manufactured at KFA. This work was performed within the international collaboration program at Fy 1993 between KFA and JAERI titled by "JAERI-KFA(Jülich) Joint Research on H-mode Plasma from Boundary Ion Temperature Measurement using a Rotating Probe". The other probes and related necessary instruments are developed at JAERI. In this program, JAERI bought the rotating double probe designed and manufactured for the JFT-2M tokamak at the KFA. The linear driver, which supports the rotating double probe and drives the rotating probe in the radial direction, and the power supply and controlling system are manufactured at JAERI.

Since the particles and energy losses via conduction, convection, radiation and charge exchange across the boundary region to the first wall the cross field diffusion coefficient and thermal conductivity can be estimated from the

plasma parameters in the boundary region if we can find the plasma parameter profiles. We have already shown experimentally that the cross field particle diffusion coefficient D_{\perp} and the electron thermal conductivity χ_e are determined due to the e-folding lengths of density λ_n and electron temperature λ_{T_e} and that these coefficients behave as rather Bohm-like and do not obey the neo-classical scheme on the JFT-2 tokamak.⁴⁾ However, the ion thermal conductivity χ_i could not be estimated due to the lack of ion temperature profile.

In this report, we describe the development of electrostatic probes including ion diagnostics in JFT-2M boundary tokamak plasma and the related transport study using the probe data. In the JFT-2M tokamak, the scrape-off Layer(SOL) has been extensively studied in order to clarify the physical process of transport using the ergodic limiter⁵⁾ and divertor biasing⁶⁾. The measurement of the ion temperature by means of the probes are aiming at a further understanding of the transport in the plasma edge. The data obtained by the above probes will help to clarify the transport process by delivering the experimental information.

2. Hardware of ion diagnostic system using electrostatic probes in JFT-2M

2.1 Linear driver

We have two ports for ion diagnostics in JFT-2M tokamak boundary plasma as shown in Fig.1 (a) (cross sectional view) and Fig. 1 (b) (plane view), respectively. One is a horizontal port (P-9) and the other is a vertical port (P-2). The linear driver is the vacuum vessel containing the support structure of the probe head and allows to vary in the radial position of the probe from shot to shot, due to bellows by 700 mm, having ± 100 mm of fine structure. We can insert the rotating double probe through both ports since the specification of the linear driver is common for both horizontal and vertical port. One of ion diagnostic probes is the rotating double probe, in which we can use this probe as the Höthker double probe¹⁾ and/or as the Amemiya asymmetric probe²⁾ by replacing the head of probe tip with the screw structure. We define this probe to be the horizontal ion probe. Other ion diagnostic probes are Katsumata probe, ion toothbrush probe and cubic Mach probe. These three probes are mounted in the same probe structure. We define these

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probe system to be the vertical ion probe. The vacuum of the linear driver is generated by means of a 50 l/sec turbo molecular pump. This vacuum can be separated from the JFT-2M vacuum by means of a valve in order to allow the replacement of the probe head without venting the tokamak. At the horizontal port the working area is due to the JFT-2M poloidal field coil very narrow. The replacement of the probe head is here performed by moving the linear driver by means of a handle in the radial direction as shown in Fig.1(a). In Fig.1(b), the plane view of the probe system is shown. Using these linear drivers the probes can be inserted into the plasma almost perpendicular to the magnetic field as shown in Fig.2. In this figure, the magnetic field line is for the lower single null (LSN) divertor plasma configuration. Before probe measurement the probe head is baked in an electric heater installed in the linear driver at 100 C about one week.

2.2 Rotating double probe

It is very difficult to measure the ion temperature by means of the electrostatic probes in a strongly magnetized plasma. As early as 1967, Katsumata invented an electrostatic probe in order to measure the ion temperature by using the difference of mean Larmor radii between electrons and ions.³⁾ One of the problems with the Katsumata probe is that the ion velocity distribution function is disturbed by the externally applied bias voltage on the probe. After that, Höthker invented an improved probe method to measure the ion temperature by means of a rotating, floating double probe. Almost at the same time, Amemiya invented a probe method to determine the ion temperature from the asymmetry of the signals from a probe due to the different size of a cylindrical pins of a double probe. The details of the Höthker rotating double probe and of the Amemiya asymmetric probe are given in elsewhere^{1),2).} The Höthker probe method relies, globally speaking, on the scanning of the ion orbits in the shadow of the probe pins while the Amemiya methods analyses the asymmetry of the signals due to the difference in the size of the pins. The total view of the rotating probe is shown in Fig. 3. The total length of the probe is 1200 mm from the flange of vacuum seal to the probe head. Because of the rotation the probe signals have to be transferred by means of a slip ring installed within in the vacuum of the linear driver. The structure of the probe consists of non-magnetic stainless steel. In table I, the items of the supporting structure of the rotating probe are listed. The precise design of the Höthker probe tips is shown in Fig.4 (a) for 4 pins and (b) for 2 pins. The items of the head of the rotating probe is shown in Table II. The probe tips are made of graphite, the partial insulation of the

graphite rods consists of tubes made of Boron nitride (NB). The tubes are fixed in a macor cylinder. The frequency of the rotation is variable up to 8.2 Hz in JFT-2M, in order to investigate rapid phenomena such as L/H-mode transition. In TEXTOR the frequency was in general 2 Hz.

The Amemiya probe head, which is shown in Fig.4(c), can also be mounted on the support structure of the rotating probe. It is fixed by a carbon screw. The Amemiya probe head, equipped with two cylindrical probe tips of different lengths and identical cross section are also rotated relative to the magnetic field direction. We can estimate the perpendicular ion temperature T_{\perp} by measuring the ratio R' of the ion saturation current flowing to the disk and the cylinder, respectively. The value of R' is an increasing function of the ion temperature. The more R' is, the higher T_{\perp} is obtained.

2.3 Ion toothbrush probe

The ion toothbrush probe is aimed at measuring the profiles by only one plasma shot. The vertical ion probe is shown in Fig.5, which includes the ion toothbrush probe, the Katsumata probe and cubic Mach probe. The Amemiya probe in singleness is mounted at the horizontal ion probe and have already yielded much data on the ion temperature.⁷⁾

Since the Amemiya probe head equipped at the rotating double probe can rotate around the axis we can more precisely know the position where the probe axis is parallel to the magnetic field by detecting the trough of the envelope of the ion saturation current. However, it is not always necessary to rotate the probe head in order to measure the ion temperature if only the probe train is set parallel to the magnetic field. In the ion toothbrush probe, the fixed multi-Amemiya probe head are mounted in parallel to the magnetic field. If all multi-Amemiya probe system are running simultaneously we can measure the plasma profile at one plasma shot. In order to estimate the ion temperature it is only necessary to observe the current ratio of the disk and the cylinder since the probe axis is set prior to the measurement in parallel to the magnetic field. In the conventional method to estimate the plasma profile by the electrostatic probe, it is necessary for the probe to be scanned in the radial position at each plasma shot. However, such a method cannot assure the reproduction of the same plasma profile with accuracy since each plasma shot has not always completely the same plasma profile even if almost the same plasma conditions are set up before the plasma shot starts. Furthermore, since in the conventional method the transport analysis must regard to deal with the same plasma although data are on the completely different plasma. The exact analysis of transport phenomena would not be

possible if we use the conventional probe. In the ion toothbrush probe, five pairs of Amemiya probe tips (in total 10 electrodes) are mounted in a rectangular box with the interval of 10 mm in the radial direction. The more precise design is shown in Fig. 6. Five pairs of the tips are fixed on the box made of macor and the probe trains are inclined by a small angle so as to make train along to the magnetic field line in the radial direction. The inclination angle is shown at the corner table in Fig.6.

The precise scale of the Amemiya probe head is shown in Fig. 4. The insulation is made by macor. The top of the ITP has plug-in type structure which can be replaceable into the spare probe tip by removing a few screws. This is so that the replacement work of the probe tip can be made easily since the damage of the probe is often limited to the probe tip only. The maximum inserting point in SOL is at the perpendicular distance $Z=0.475$ m, which is just around the separatorix in the divertor configuration plasma in JFT-2M.

2.4 Katsumata probe

The rotating probe is now installed at the horizontal port in JFT-2M and a similar probe can be also installed at the vertical probe, in which we want to know the information of ion temperature around the X point at the upper single null (USN) in the divertor configuration. When the rotating double probe is not installed at the vertical port the Katsumata probe, ion toothbrush probe are installed for the cross check of the ion temperature and the fast measurement of the plasma profile, respectively. The precise structure of the Katsumata probe is shown in Fig. 7. The position of ion collector can be changed by the external operation with fine structure without breaking the vacuum seal. The depth from the ion collector to the top of the electron guard is denoted by h . In the Katsumata probe, the value of h is responsible to determine the ion temperature. The higher h is, the smaller ion current is caught since only higher energy ions with the larger Larmor radius can enter into the collector at the case of large h . We can know the information on the energy distribution function of ions by varying this value. The ion collector is made of carbon and the electron guard is made of molybdenum. The insulation is made by the macor. The head of the Katsumata probe is a plug-in type structure which can be replaced by the spare probe by removing a few screws.

2.5 Cubic Mach probe

In Fig. 8, the precise structure of the cubic Mach probe is shown. The

cubic Mach probe is aimed at estimating the electric field in the scrape-off plasma by measuring simultaneously the ion saturation current in the toroidal, poloidal and radial direction. In total, six electrodes are inserted in the box for observing the ion saturation current. Among them, two electrodes are located towards the two poloidal directions, two electrodes are located towards the two toroidal directions and one electrode is oriented into a radial direction. The three components of the ion saturation current are estimated from the difference of saturation current towards the two directions. The method to estimate the electric field is explained in section 4.3.

2.6 Probe circuit and data processing system

The probe circuit and data processing system are shown in Fig.9. The probe voltage V_{pp} (about 50 - 150 V) is supplied by a triangle function generator with 200 - 800 Hz and is fed to the double probe P via BNC cable and structure L in the linear driver. The motor for the rotation (5 - 8 Hz) as well as all operations are performed by means of a personal computer (NEC PC-9821 Ap). The probe voltage and probe current are detected through a pick-up resistance with 1Ω and are fed into CAMAC module, which is monitored by the oscilloscope simultaneously. The master pulse from JFT-2M tokamak delivers a trigger pulse for detection and data from the probes are A/D transformed by the digitizer 8212 or 4008 through the delay circuit D connected to the CAMAC system. The obtained data are gathered via the interface INT and are processed at PC9821Ap to be stored on an optical disk OD. Two channels (probe voltage and probe current) use 16 k sample points each. The control of the rotating motor is performed by sending a control signal from the personal computer through a serial port to the controller of the step motor. we can drive many types of rotation (direction and absolute position) by pushing the function keys on the personal computer.

The probe circuit for the rotating double probe is shown in Fig. 10. In Fig.11, the probe circuit for ITP, Katsumata probe and cubic Mach probe is shown. Figure 11(a) is for ITP and Katsumata probe, in which the same five channels (ch1 - ch5) are equipped . When we use for Katsumata probe the switch SW2 is set to single line. Figure 11 (b) is for cubic Mach probe, in which almost constant bias voltage can be delivered to the probe. This probe circuit shown in Fig. 11(a) was first used in JFT-2 as early as 1977⁴⁾. As shown in this figure, the probe voltage is fed by the battery and is scanned with fast speed of about 5 msec by a thyristor (the rated current is 20 A in continuous and the rated voltage is 700 V in maximum). The switch 1 (SW1) is for the separation between the probe circuit and the battery, in which we put

on SW1 just before the probe measurement start to charge the battery. The voltage of the battery is applied to two condensers with $220 \mu\text{F}$. When the trigger pulse is coming to the trigger terminal two thyristers are turned on to start the discharge and the voltage is applied to the double probe. The switch 2 (SW2) is for the mode change between the single probe (Katsumata probe) and the double probe. The switch 3 (SW3) is for the discharge of condenser for safety, which is turned on to discharge the condenser voltage whenever the power supply is not used. The switch 4 (SW4) is for the exchange of shunt resistance. This circuit has five channels and are delivered to each five pair electrodes in the ITP independently. In the ITP circuit, a isolation amplifier is used for the isolation between the CAMAC digitizer and the probe circuit as shown in Fig.11 (c). The gain of the amplifier is 1, the frequency band is 20 KHz, and the withstand voltage is 1500 V. The probe current is detected through the voltage drop in the shunt resistance (c-d) and is sent to the isolation amplifier keeping the isolation. The input of the probe voltage is divided 1/100 (a-b) and is sent to the isolation amplifier keeping the isolation. The AD246 is the clock generator for the isolation power to drive in the isolation amplifier. The master pulse from JFT-2M tokamak delivers a trigger pulse for the detection with an appropriate delay signal and is sent to the probe circuit of the ITP and the "stop" input in the digitizer (8212). When a trigger pulse is sent to the probe circuit the fast speed probe ramp voltage from +150 to -150 V is generated. The digitizer use 1 k sample points per channel after the stop signal is received. Whether the data processing is finished or not is transmitted from the digitizer 8212 automatically by means of the PC program and then the personal computer reads the measured data into the memory. The battery for the probe voltage consists of four and two small batteries with 67 V and is connected to the probe circuit. The timer is for the automatic separation between the battery and the probe circuit when the start signal is coming. These are shown in Fig. 11 (d). The source programs of the data acquisition are shown in the appendix.

2.7 Problems and improvements

The list of the ion diagnostic probe of JFT-2M is shown including their feature in Table III. Since the component of the rotating probe were not all manufactured at the same place (Germany and Japan) there are many obstacles to be overcome for the assembling total system. In this section, we want to describe the list of the problems which have occurred during the collaboration and how we can overcome these problems.

For the rotating double probe, the angle of the probe axis relative to the

magnetic field direction is very important in order to measure the precise ion temperature. However, in the first period of measurements, the angle of the probe axis is deviated by 4.9 degree from the normal to the magnetic flux surfaces. This deviation would yield ion temperature values which are too large as described in ref. 1. This misalignment occurred because only the central port at the large flange is located at the left hand side of the large flange, is mounted almost parallel to the central port. During the second period of measurements this deviation was eliminated by an angular adjustment of the linear driver.

The vacuum gasket made of a synthetic resin (VESPEL), serves at the same time as vacuum seal and electric insulator. It was delivered from the Jülich workshop is normally not used in Japan and no spare gasket were available. We manufacture this substitute from the peek material, which is specially produced in JT-60 diagnostics group for the gasket⁸⁾.

The program to control the rotating motor for the rotating double probe was based on the IBM computer which is frequently used in Europe. The interface between the machine and the computer is a NEC-PC computer is frequently used in Japan. We had to change the source program for the control of the the motor in order to fit the PC-98 specification.

Since the pulse duration of the discharge is only one second (flat top is 0.5 sec) in JFT-2M the speed of the rotation had be increased up to 8.2 Hz, which has caused many troubles. The first trouble was a failure in the main controller of the rotating motor due to overheating. Since the motor often stopped for the case of higher speed during the rotation we run the rotating motor from before plasma shot to after plasma shot in order to reduce the heat damage. In the second period measurements it was necessary to increase the probe length in order to avoid an interference between the probe gate valve and other port in the large flange. We had to add a small pipe with 300 gram in weight and 160 cm in length and 34 mmφ in diameter, between the probe head and the main probe. This item is shown as the length adjust pipe in Fig.12. However, since the modified program in PC-98 computer does not have the softlanding of the rotation stop a large torque is exerted on the probe at the ramp-up and ramp-down phase of the rotation so that the probe head was detached from the support. The reason is that the ceramic support of the probe tips does not stand for the additional torque due to the length adjust pipe. This problem is solved by changing the support structure from ceramic to the metal.

For the measurements with the double probes, it is difficult to realize a perfect floating of the electric circuit. In our case also much efforts had to be paid to realize the floating circuit. The insulation between the probe and the

flange is effective but a second shielding at the probe circuit is useful.

Automatic processing of the probe data may have an effect on the value of the determined ion temperature for both the Amemiya and the Höthker probe. The absolute value of ion temperature strongly depend on the compression rate of data processing. A more convenient processing program must be developed for a more accurate estimation of ion temperature.

In future, the data acquisition system will be interfaced to the main data acquisition system VAX in JFT-2M.

3. Experimental data

3.1 Measurement of plasma profile by Amemiya probe

The raw data using the Amemiya asymmetric probe head is shown in Fig.13 (a), in which the rotating frequency is 8 Hz and we can see that the wave pattern of the probe current is modulated due to the rotating. The density relatively close to the wall in a Joule heated plasma are shown in Fig. 13 (b). The raw data and the profile with NBI heating are shown in Fig.14 (a) and (b), respectively. The experimental conditions are : mean plasma density $n_e = 2.5 \times 10^{13} \text{ cm}^{-3}$, plasma current $I_p = 220 \text{ kA}$, toroidal field $B_t = 1.3 \text{ T}$ and the ohmic heating phase in the divertor configuration with LSN point. The ion temperature is much higher than the electron temperature. The density decay is steeper than the temperature decay and the e-folding length of T_e and T_i are almost the same⁷⁾.

3.2 Measurement of plasma profile by Höthker probe

For the measurements by means of the Höthker probe the contamination of the JFT-2M plasma was exceptionally high. This may explain the splices on the probe signals of Fig.15 (a) which are attributed to arcing due to the burn-up of impurities on the probe pins. For the results of Fig.15 (b) the Höthker probe was first exposed to the TDC (Taylor type Discharge Cleaning) plasma. The probe signals are much smoother which is attributed to a significant reduction of arcing due to the reduced contamination. In the TDC plasma, we performed the probe measurement by means of the Höthker probe and we get $T_e = 4 \text{ eV}$ and $n_e = 1.53 \times 10^{12} \text{ cm}^{-3}$ for a hydrogen plasma at $r = 350 \text{ cm}$. The raw data in TDC plasma is shown in Fig.16. The raw data from the Höthker probe is shown in Fig. 17 for the case of the small

flange is effective but a second shielding at the probe circuit is useful.

Automatic processing of the probe data may have an effect on the value of the determined ion temperature for both the Amemiya and the Höthker probe. The absolute value of ion temperature strongly depend on the compression rate of data processing. A more convenient processing program must be developed for a more accurate estimation of ion temperature.

In future, the data acquisition system will be interfaced to the main data acquisition system VAX in JFT-2M.

3. Experimental data

3.1 Measurement of plasma profile by Amemiya probe

The raw data using the Amemiya asymmetric probe head is shown in Fig.13 (a), in which the rotating frequency is 8 Hz and we can see that the wave pattern of the probe current is modulated due to the rotating. The density relatively close to the wall in a Joule heated plasma are shown in Fig. 13 (b). The raw data and the profile with NBI heating are shown in Fig.14 (a) and (b), respectively. The experimental conditions are : mean plasma density $n_e = 2.5 \times 10^{13} \text{ cm}^{-3}$, plasma current $I_p = 220 \text{ kA}$, toroidal field $B_t = 1.3 \text{ T}$ and the ohmic heating phase in the divertor configuration with LSN point. The ion temperature is much higher than the electron temperature. The density decay is steeper than the temperature decay and the e-folding length of T_e and T_i are almost the same⁷⁾.

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compression and the large compression data. The envelop of the signal for the ion saturation current is excellent and we can estimate the ion temperature deduced from this method. The profiles obtained by means of the Höthker probe is shown in Fig.18 including results from Amemiya's method. In Fig.18 (a), the electron and ion temperature profile are shown and the density profile is shown in Fig.18 (b). These profile are very similar to those obtained previously on TEXTOR.

3.3 Measurement of Mach number by means of the Amemiya and the Höthker probe

Both methods to determine the ion temperature rely on the assumption that velocity distribution function of the ions is a non-displaced Maxwellian. However, the probe signals often indicate the existence of a flow. In such a case, we must modify the method to estimate the ion temperature, but we have to determine first the flow velocity from the probe signals. The flow velocity v_{\parallel} is expressed as Mach number M which is the velocity normalized by ion sound velocity v_s , i.e., $M=v_{\parallel}/v_s$. The ion distribution function must be modified as $f=(m_i/2\pi kT_i)^{1/2}\exp(-m_i(v-v_{\parallel})^2/2\pi kT_i)$.⁷⁾

In Amemiya probe case, when probe train is parallel to the magnetic field B and the flow, then ion current of probe 2 increases by the effect of the flow at $V_p > 0$ region and the ion current of probe 1 decreases by the shadow effect due to the flow at $V_p < 0$ region, where V_p is the probe voltage. When the probe train is inverse parallel to the magnetic filed and the flow, then the ion current of probe 2 decreases by the shadow effect at $V_p > 0$ and the current of probe 1 increases by the flow at $V_p < 0$. In total, the time behavior of the ion current becomes as Fig.19 (a) and the current increases for parallel phase to yield the relatively higher ion temperature. So we can determine the real ion temperature including the Mach number from the probe characteristics.

For the Höthker probe the probe signal also become asymmetric if the measurement is performed in a streaming plasma. This asymmetry occurs because the ion saturation current collected from the up-stream side is larger than from the down-stream side. From this difference between the collected up-and down-stream flows the Mach number can be determined by use of a Chung & Hutchinson theory.⁹⁾ The results can be expected to be correct only if the radius of the probe tips is large compared to the mean Larmor radius of the ions. This latter conditions is marginally fulfilled in the edge plasma of JFT-2M for the rotating double probe with a pin diameter of 5mm. The

straight forward extension of the method to determine ion temperatures seems to be justified for small Mach numbers because of the above mentioned linear dependence.

The ion saturation current becomes as Fig. 19 (b). When the probe train is perpendicular to B and v_{\parallel} , both current of probe 1 and 2 increases by v_{\parallel} and the probe characteristics is symmetric as shown in Fig.19 (b). When the probe rotate by the half turn the ion saturation current I_{is} increases for $V_p > 0$ region and decreases for $V_p < 0$ region. In total, the time behavior of I_{is} becomes as shown in Fig.19 (b).

The probe current as a function of time as measured by means of the Höthker probe is shown in Fig.20 for different radii. The probe position increases in the radial direction from up to down in the figure. The radial Mach number profile as determined from these signals is shown in Fig.21. In future, we will insert the probe deeper into the plasma, in order to determine ion temperatures and Mach numbers near the X point.

3.4 Preliminary data by Ion Toothbrush Probe (ITP)

The most important point for the measurement by means of the ITP is to assure the completely normal operation in five probe tips. If the electrical insulation is sufficient the coupling with neighbor probe is no problem. The probe characteristics of the ion toothbrush probe are shown in Fig. 22 including the time behavior of the probe voltage and probe current. It should be noted that the floating potential moves to the positive side as the probe channel approaches to the wall, in which we can know the existence of the radial electric field at SOL and we can estimate its absolute value. The typical T_e , T_i and n_e (ion saturation current) profiles which are obtained in one shot are shown in Fig. 23.

3.5 Preliminary data by Katsumata probe

Raw data from the Katsumata probe are shown in Fig.24. The ion current is about a few micro Ampere which is ten times smaller than the electron saturation current flowing into the electron guard. Since the ion current is so small it is largely disturbed by noise. In Fig.25 (a), the ion current in the saturation region is shown as dependent on the depth of the guard h . The inclination of this decrease is claimed to give the information of ion temperature. The absolute value of ion temperature cannot be determined because of large noise level, however, the gradient of I_{is} vs h which

corresponds to the ion temperature increases with increase of the probe position as shown in Fig.25 (b).

3.6 Density dependence of plasma profile

The density dependence of plasma profiles in the edge plasma is measured by both the Amemiya probe and the Höthker probe, in which we can check the theoretical one by using consideration in the next section. The experiment were performed in a program to study the density limit¹⁰⁾ and are shown in Fig.26. In Fig. 26 (a), the time behavior of radiation loss (up), density (middle) and loop voltage (down) in this experiment are shown. The radial profile of the density, electron temperature and ion temperature is shown in Fig.27 (a) and (b), respectively. The thermal conductivity is estimated in the next section.

3.7 Discussions

For the first measurements the estimated ion temperature may be relatively high because of the misalignment of the probe. But the ion temperature are similar to those determined in TEXTOR. From both, the Amemiya and the Höthker probe, clear evidence for plasma flow in the SOL is found for some radii. For specific conditions the values for the ion temperature and for the Mach number can be determined simultaneously. The Höthker analysis shows the existence of flow in the SOL. Similar data on the flow velocity is observed in the outer region and the inverse flow is observed in the inner region in SOL of JET¹¹⁾. The analysis of Höthker in the edge plasma of TEXTOR shows that the signatures of the measured flow velocity are those expected from neoclassical theory¹²⁾, however, another people try to analyze using the inverse flow of impurity¹³⁾. More studies on the flow are needed.

More experimental data on the impurities in the edge plasma is desirable since the mass of ion is much affective for the determination of ion temperature. However, the value of the ion temperature as determined by means of rotating double probe is weakly dependent on the uncertainties regarding the impurities in the SOL, as demonstrated in ref.1

In the measurement of the ITP, it is difficult to establish all channels are alive in just the measurement. The probe voltage is fed from the battery independently in order to eliminate noise due to the induction. Since the plasma impedance increases with increasing the edge density the rise time of

thyrister must be set for the minimum impedance. The induction effect in the neighbor the circuit is small, however, it is difficult to set the appropriate probe voltage for each channel.

For measurement by means of the Katsumata probe the signal comprises large noise contribution. Since the ion current is very small, as shown in Fig.24, an appropriate filter to eliminate noise may be necessary. The frequency of noise is typically several kHz. Since the ion saturation current decreases with increase of the barrier h , as shown in Fig. 25 (a), the gradient of I_{is} against h is claimed to contain information on the ion temperature, which is shown in Fig.25 (b). This value increases when the probe position move to the core plasma.

The measurement by means of the cubic Mach probe was not yet successful in JFT-2M.

The dependence of the ion temperature on the density cannot yet be presented because of the few ion temperatures measured up to now. In TEXTOR, the absolute value of T_i obtained by means of the Höthker rotating probe has been compared with the ion temperature as determined from Lithium beam activated charge-exchange spectroscopy¹⁴⁾. However, no ion temperature profile is obtained although rather good agreement has been found between the results from two methods. From measurements in JFT-2M, it has been found that the density and the density profile does not change and the electron temperature decreases with increase of main plasma density. On the other hand, the few measurements on the ion temperature values do not change so much and/or increase a little near the wall.

4. Explanation of experimental results and the study of transport

4.1 Transport model in SOL and the method to estimating the transport¹⁵⁾

The purpose to measure the ion temperature in SOL is, first, to investigate the transport process in connection with the improved confinement plasma such as H-mode plasma and, second, to estimate the heat to the divertor plate, limiter and the wall. If we can measure the e-folding length of density and temperature profile we can estimate the particle diffusion coefficient and the thermal conductivity in the following. As early as 1979 - 1980, one of authors (K.U.) first proposed the tokamak boundary model to estimate the transport coefficient, however, that model is not adequate since the unnatural

thyrister must be set for the minimum impedance. The induction effect in the neighbor the circuit is small, however, it is difficult to set the appropriate probe voltage for each channel.

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boundary condition that the diffusion coefficient is zero at infinitive.¹⁶⁻¹⁷⁾ So, we must modify the transport model in the following. The continuity of particle is,

$$\frac{\partial n}{\partial t} + \text{div} \Gamma = nn_n <\sigma v>_i \quad (1)$$

, where n is plasma density, Γ is the particle flux and the R.H.S. is the source term, in which n_n is density of neutral and $<\sigma v>_i$ is the rate of ionization. The value of Γ is the sum of parallel flow $\Gamma_{||}$ and perpendicular flow Γ_{\perp} as $\Gamma = \Gamma_{||} + \Gamma_{\perp}$. When the translation of coordinate represented by a finite straight coaxial cylinder as shown in Fig.28 is performed in the tokamak boundary plasma the above equation becomes

$$\frac{\partial \Gamma_{\perp}}{\partial r} + \frac{\Gamma_{\perp}}{r} + \frac{2\Gamma_{||}}{L_p} = nn_n <\sigma v>_i \quad (2)$$

where L_p is the connection length along the magnetic field line, which is $L_p = 2\pi R q$ for rail type limiter and/or divertor plasma and $L_p = 2\pi R$ for aperture type plasma, where q is safety factor and R is major radius in torus. We set $\Gamma_{||} = M n v_s$, $\Gamma_{\perp} = -D_{\perp} \nabla n$, where M is Mach number. Assuming that the value of D_{\perp} , v_s , $n_n <\sigma v>_i$ do not depend on the position the above equation becomes

$$\frac{\partial^2 n}{\partial r^2} + \frac{1}{r} \frac{\partial n}{\partial r} - \alpha_n^2 n = 0 \quad (3)$$

This equation can be solved using a modified Bessel function $K_0(r)$ as $n = n_0 K_0(\alpha r)$, which becomes very approximately as $n = n_0 e^{-\alpha n r} = n_0 e^{-r/\lambda_n}$ when $r/\lambda_n \gg 1$. The e-folding length of the density n is

$$\lambda_n = \frac{1}{\alpha_n} = \frac{\sqrt{D_\perp}}{\sqrt{2Mv_s/L_p - n_n \langle \sigma v \rangle_i}} \quad (4)$$

When a radial electric field E_r exists in the plasma, the flux must be changed as $\Gamma_\perp = D_\perp^e \nabla n + n \mu_e E_r$ for electron and $\Gamma_\perp = D_\perp^i \nabla n - n \mu_i E_r$ for ions, where μ is the mobility which is expressed as $\mu_e = -(e/T_e) D_\perp^e$ and $\mu_i = - (e/T_i) D_\perp^i$. We get

$$D_\perp^e = \lambda_n \left(\frac{2Mv_s}{L_p} - n_n \langle \sigma v \rangle_i \right) \left(\frac{1}{\lambda_n} - \frac{eE_r}{T_e} \right)^{-1} \quad (5)$$

for electrons and

$$D_\perp^i = \lambda_n \left(\frac{2Mv_s}{L_p} - n_n \langle \sigma v \rangle_i \right) \left(\frac{1}{\lambda_n} + \frac{eE_r}{T_i} \right)^{-1} \quad (6)$$

for ions. When $E_r=0$ eqs. (5) and (6) coincides with eq. (4). Thus, we can show that the density in SOL decays exponentially and the e-folding length decays at the limiter position since as shown in eq.(4) and that λ_n becomes smaller when L_p changes from $2\pi Rq$ to $2\pi R$ at the limiter.

On the other hand, we can get the heat transport equation using the same procedure. The heat transport equation is given by,

$$\text{div}(Q_\perp^e + Q_{\parallel e}^e) = -n n_n \langle \sigma v \rangle_i V_{ie} + 1.5(3m_e/m_i) \Delta T n / \tau_{ei} \quad (7)$$

for electron heat flow and

$$\text{div}(Q_\perp^i + Q_{\parallel i}^i) = -n n_n \langle \sigma v \rangle_{ci} T_i - 1.5(3m_e/m_i) \Delta T n / \tau_{ei} \quad (8)$$

for ion heat flow, where the parallel and perpendicular heat flux are

$$Q_{\parallel j}^j = -n \chi_{\parallel j} \nabla_{\parallel j} T_j + T_j \Gamma_{\parallel j} \text{ and } Q_{\perp j}^j = -n \chi_{\perp j} \nabla_{\perp j} T_j + T_j \Gamma_{\perp j} \quad (j=e \text{ or } i). \quad (9)$$

and $\langle\sigma v\rangle_{cx}$ are the rates of charge exchange loss, τ_{ei} is the equipartition time between ions and electrons, V_{ie} is the ionization potential, m_j ($j=e,i$) is mass of electrons and ions and $\Delta T (=T_i - T_e)$ is a temperature difference between ion and electrons. Similar equations as eq. (3) on the heat transport are obtained by using the same translation of coordinate as

$$\frac{\partial Q_{\perp e}}{\partial r} + \frac{Q_{\perp e}}{r} + \frac{2Q_{||e}}{L_p} = -nn_n \langle\sigma v\rangle_i V_{ie} + 4.5 \frac{m_e}{m_i} \frac{\Delta T}{\tau_{ei}} n \quad (10)$$

and

$$\frac{\partial Q_{\perp i}}{\partial r} + \frac{Q_{\perp i}}{r} + \frac{2Q_{||i}}{L_p} = -nn_n \langle\sigma v\rangle_{cx} T_i - 4.5 \frac{m_e}{m_i} \frac{\Delta T}{\tau_{ei}} n \quad (11)$$

Setting the term of $\nabla_{\perp} T_j = -T_j/\lambda_{Tj}$ appearing in the term of $(1/r + \Gamma_j) \nabla_{\perp} T_j$ of L.H.S. we can get similar equation of eq.(3) as

$$\frac{\partial^2 T_j}{\partial r^2} + \frac{1}{r} \frac{\partial T_j}{\partial r} - \alpha_{Tj}^{-2} T_j = 0 \quad (12)$$

Similar as in the case of density profile the solution of this equation can be expressed as $T_j = K_0(\alpha_{Tj} r) = e^{-r/\lambda_{Tj}}$, so we can say that the temperature profile also decays exponential in SOL. The perpendicular thermal conductivity can be expressed using the value of $\alpha_{Tj} (=1/\lambda_{Tj})$

$$\chi_{\perp}^e = \lambda_e \lambda_{T_e} \left\{ \frac{2}{L_p} \left(\frac{\chi_{||}^e}{\lambda_{||}^e} - \frac{\lambda_n}{\lambda_{T_e}} M v_s \right) + n_n \langle\sigma v\rangle_i \left(1 + \frac{V_{ie}}{T_e} \right) - \frac{4.5 m_e}{m_i \tau_{ei}} \left(\frac{T_i}{T_e} - 1 \right) \right\} \quad (13)$$

for electron heat flux and

$$\chi_{\perp}^i = \lambda_i \lambda_{T_i} \left\{ \frac{2v_s}{L_p} \left(\frac{\chi_{||}^i}{\lambda_{||}^i} - \frac{\lambda_n}{\lambda_{T_i}} M v_s \right) + n_n (\langle\sigma v\rangle_i + \langle\sigma v\rangle_{cx}) + \frac{4.5 m_e}{m_i \tau_{ei}} \left(1 - \frac{T_e}{T_i} \right) \right\} \quad (14)$$

for ion heat flux. Here,

λ_{Te} and λ_{Ti} are the e-folding length of electron and ion temperature, respectively, χ_{\parallel}^e and χ_{\parallel}^i are electron and ion heat conductivities in the parallel direction, respectively, λ_{\parallel}^e and λ_{\parallel}^i are the characteristics length of electron and ion temperature profile in the parallel direction, respectively ($\nabla_{\parallel} T_j = -T_j \lambda_{\parallel}^j$) and $\lambda_e^{-1} = \lambda_n^{-1} + \lambda_{Te}^{-1}$, $\lambda_i^{-1} = \lambda_n^{-1} + \lambda_{Ti}^{-1}$. This relation means that the heat flow in SOL is described by the picture that the heat flow entering from the main plasma is convected in parallel and is conducted in perpendicular direction due to the temperature gradient and is transported to the sheath in front of divertor plate, limiter and to the wall. This becomes a loss for electrons to be accelerated and for ions to be decelerated by the sheath potential. It should be noted that the radial temperature profile for both electrons and ions in some extent differ compared with the density profile case. It is known when we solve eqs.(13) and (14) on λ_{Te} and λ_{Ti} that the λ_{Te} becomes large and λ_{Ti} does not decrease so much compared with the density profile case even if the connection length becomes smaller at the inside limiter region. The estimation of λ_{Te} and λ_{Ti} are listed as well as the experimental data in the divertor region (SOL I) and the limiter region (SOL II) in table IV (a). In this estimation, we assume the probable perpendicular conductivity and we try to estimate the value of λ_{Te} and λ_{Ti} using the solution of eqs.(13) and (14) as the secondary equation on λ_{Tj} . As for the parallel electron and ion conductivity we use the data given by Braginskii.¹⁸⁾ Other experimental data in JFT-2M are as : R=1.3 m, $q_a=3$, $Z_{eff}=2$ and $M=0.3$, for deuterium plasma. In this estimation, λ_{Te} becomes large in SOL II region and λ_{Ti} is almost constant in both SOL I and SOL II regions. The dependence on plasma parameters is rather important than the absolute value since in order to know the transport physics it is better to clarify the inclination of these coefficients by changing the plasma parameters. In JFT-2M, the plasma profile at various conditions are obtained by both Höthker and Amemiya probes.⁷⁾ In Fig.27 (a), the electron temperature and the density profile obtained by Amemiya probe is shown in both joule heated case (denoted by OH) and NBI heated case (denoted by NB) at the higher ($n_e = 1 \times 10^{13} \text{ cm}^{-3}$ denoted by L) and lower density case of OH plasma. It is known from this data that the density profile is not changed and the electron temperature

decreases when the main plasma density increases. On the other hand, the ion temperature is almost constant and/or increases near the wall and the e-folding length increases a little when the main plasma density increases. In table IV (b), the estimation of χ_{\perp}^e and χ_{\perp}^i are performed using the experimental value in the higher density case and lower density case. In table IV (c), the estimation of χ_{\perp}^e and χ_{\perp}^i are performed using the experimental data in the joule heated plasma case (OH-P) and NBI heated plasma case (NB-P).

4.2 Estimation of heat flux to the first wall (divertor plate, limiter and wall)

The divertor plate and limiter are usually electrically floating. The floating potential V_f is negative in usual plasma against the plasma potential. So charged particles are flowing to the divertor plate and/or limiter through the ion sheath. Electrons are decelerated and ions are accelerated by V_f , which can be expressed in term of T_e . The heat flux to the divertor plate and the limiter is $q_{D\&L}$ is

$$q_{D\&L} = q_{D\&L}^e + q_{D\&L}^i \quad (15)$$

where $q_{D\&L}^e$ and $q_{D\&L}^i$ are the heat flux of electrons and ions, which are

$$q_{D\&L}^e = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{\sqrt{\frac{2qV_f}{m_e}}}^{\infty} \left(\frac{1}{2} m_e v_e^2 - e|V_f| \right) v_{ex} f_e(v_e) dv_{ex} dv_{ey} dv_{ez} \quad (16)$$

$$q_{D\&L}^i = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_0^{\infty} \left(\frac{1}{2} m_i v_i^2 + e|V_f| \right) v_{ix} f_i(v_i) dv_{ix} dv_{iy} dv_{iz} \quad (17)$$

where $v_j^2 = v_{jx}^2 + v_{jy}^2 + v_{jz}^2$ ($j=e$ or i). When we assume that the distribution function of electrons f_e and ions f_i are both Maxwellian, then $q_{D\&L}$ becomes

$$q_{D\&L} = \gamma_{//} n v_s T_e \quad (18)$$

where $\gamma_{//}$ is called as the parallel thermal transmission coefficient, which becomes

$$\gamma_{//} = 1 + \sqrt{\frac{2}{\pi}} \left(\frac{T_i}{T_e} \right)^{1/2} \left\{ \frac{T_i}{T_e} + \frac{1}{4} \ln \left(\frac{2}{\pi} \frac{m_i}{m_e} \right) \right\} \quad (19)$$

The heat flux to the wall is estimated as

$$q_w = Q_{\perp}^e + Q_{\perp}^i = \gamma_{\perp} n \frac{D_{\perp}}{\lambda_n} T_e \quad (20)$$

where γ_{\perp} is called as the perpendicular heat transmission rate, which is

$$\gamma_{\perp} = 1 + \frac{T_i}{T_e} + \frac{\lambda_n}{\lambda_{T_e}} \frac{\chi_{\perp}^e}{D_{\perp}} \left(1 + \frac{\lambda_{T_e}}{\lambda_{T_i}} \frac{\chi_{\perp}^i}{\chi_{\perp}^e} \frac{T_i}{T_e} \right) \quad (21)$$

The total heat flux to the divertor plate Q_D , the limiter Q_L and the wall Q_W are estimated by the surface integral of $q_{D\&L}$ and q_w as

$$Q_D = L_T \left(\int_0^{l_{in}} q_{D\&L} dr + \int_0^{l_{out}} q_{D\&L} dr \right) \quad (22)$$

and

$$Q_L = 2 \int_{r_1}^{r_2} q_{D\&L} 2\pi r dr \quad (23)$$

and

$$Q_W = q_W S_W \quad (24)$$

where l_{in} is the length of inner divertor plate perpendicular to the magnetic field line, l_{out} is the length of outer divertor plate to the magnetic field, r_1, r_2 are inner and outer radius of the limiter, S_W is the total area of the wall faced to the plasma. The value of $L_T (=l_D N)$ is the length of the divertor plate along the connection length line and all values of eq.(21) must be the value at the wall. Here, l_D is the length of a divertor plate along connection length and N is the number of divertor plate. The total heat flux to the first wall is $Q_{total} = Q_D + Q_W$ for the divertor configuration and $Q_{total} = Q_L + Q_W$ for the limiter configuration. The designed values in JFT-2M are : $l_{in} = 12.7$ cm, $l_{out} = 17.0$ cm, $l_D = 12.0$ cm, $N = 16$, $r_1 = 43$ cm, $r_2 = 70$ cm. In table IV (d), the estimation of the heat flux to the divertor plate (Q_D) and the wall (Q_{wall}) according to the above discussion in the case of higher density case ($H-n_e$) and the lower density case ($L-n_e$) are shown, respectively. In table IV (e), the estimation in the case of OH and NBI heated case are shown, respectively. It is known from this estimation that the heat flux to the divertor plate is much larger than that to the wall and decreases with increase of main plasma density, which is supported by the IR camera¹⁹⁾. The heat flux to the divertor plate also increases by NBI heating whereas the transmission rate in both parallel and perpendicular decreases by NBI. Since in OH plasma, the joule input power is about 350 kW and the radiation loss is about 30-40 % of joule input power the residual power may be occupied by the neutral particle and non-Maxwellian charged particles. NBI power is about 700 kW the estimation of the heat flux is reasonable value within ten percentage.

4.3 Method of estimation of electrical field in SOL using data of cubic Mach probe

Recent study of the confinement improved plasma, what we call, H mode indicates that the existence of the electric field in plasma is important to produce the H-mode. An electric field in plasma may affect on the flow in

the poloidal, toroidal and radial directions. We can detect these flows by observing the current flowing to the directional plate with a finite biasing voltage. The cubic Mach probe is designed so as to detect such a flow separately in the toroidal, poloidal and radial direction. In order to estimate the electric field the fluid equation for ions may be used,

$$nm_i \frac{d\vec{v}}{dt} + nm_i v \vec{v} = nZe(\vec{E} + \vec{v} \times \vec{B}) - \vec{\nabla}P \quad (25)$$

where $\nabla P = nkT_i$. In the case of $\vec{E} = E(E_x, E_y, E_z)$ and $\vec{B} = B(0, B_y, B_z)$ the current in the poloidal and toroidal direction are obtained as $J_x = Zenv_x$, $j_y = Zenv_y$ and $j_z = Zenv_z$, where v_j ($j = x, y, z$) is the component of velocity appearing eq.(25). In this case, the value of J_j ($j=x, y, z$) is given directly by those observing on the cubic Mach probe. From eq.(25), we obtain the current in radial, poloidal and toroidal components

$$J_x = -ZeD_B \frac{\partial n}{\partial x} - Zen \frac{B_z}{B^2} E_y - Zen \frac{B_y}{B^2} E_z \quad (26)$$

$$J_y = Ze \frac{\omega_{ciz}}{v} D_B \frac{\partial n}{\partial x} + Zen \frac{E_x}{B_z} + \frac{Z^2 e^2 n}{m_i v} \left(1 - \frac{B_y^2}{B^2}\right) E_y + \frac{Z^2 e^2 n}{m_i v} \frac{B_y B_z}{B^2} E_z \quad (27)$$

$$J_z = -Ze \frac{\omega_{ci\theta}}{v} D_B \frac{\partial n}{\partial x} + Zen \frac{B_y E_x}{B_z B_z} + \frac{Z^2 e^2 n}{m_i v} \left(\frac{B_y B_z}{B^2}\right) E_y + \frac{Z^2 e^2 n}{m_i v} \left(1 - \frac{B_y^2}{B^2}\right) E_z \quad (28)$$

where Z is the effective charge, $\omega_{ciz} = ZeB_z/m_i$, and $\omega_{ciy} = ZeB_y/m_i$. Using eqs.(26), (27) and (28) we can estimate the value of E_x , E_y and E_z as follows,

$$\begin{pmatrix} E_x \\ E_y \\ E_z \end{pmatrix} = \begin{pmatrix} a_x & b_x & c_x \\ a_y & b_y & c_y \\ a_z & b_z & c_z \end{pmatrix}^{-1} \begin{pmatrix} J_x - J_{BX} \\ J_y - J_{BY} \\ J_z - J_{BZ} \end{pmatrix} \quad (29)$$

where $a_x = 0$, $b_x = ZeB_z/B^2$, $c_x = ZeB_y/B^2$, $J_{BX} = ZeD_B \partial n / \partial x$, $a_y = Zen/B_z$,

$b_y = (Z^2 e^2 n/m_i v) (1 - B_y^2/B^2)$, $c_y = (Z^2 e^2 n/m_i v) (B_y B_z/B^2)$, $J_{BY} = (Ze\omega_{ci}v) D_B \partial n/\partial x$, $a_z = Ze n B_y/B^2$, $b_z = (Z^2 e^2 n/m_i v) (B_y B_z/B^2)$, $c_z = (Z^2 e^2 n/m_i v) (1 - B_y^2/B^2)$, $J_{BZ} = - (Ze\omega_{ci}v) D_B \partial n/\partial x$. The obtained ion saturation current by the cubic Mach probe in both direction are estimated as $J_x = J_p$, $J_y = J_{1y} - J_{2y}$ and $J_z = J_{1z} - J_{2z}$. These are determined experimentally and we can get the value of E_x , E_y and E_z , where we use the calculated values as the magnetic field. We use the fluctuation level γ_B of instability for Bohm-like diffusion coefficient 10^{-3} for main plasma and 10^{-2} for scrape-off plasma, which must be also measured by experimentally. Similar estimation was performed by Annaratone in JFT-2M.²⁰⁾

Here, we consider the radial diffusion coefficient is assumed to be Bohm-like and the radial flux is $\Gamma = - D_B \partial n/\partial x - n E_z B_y/B^2 - n E_y B_z/B^2$ since the classical and neo-classical diffusion is not dominant in usual plasma. Using the equation of continuity $\partial n/\partial t + \text{div}\Gamma = 0$, $n = n_0 e^{-t/\tau}$ and the boundary condition $\Gamma = 0$ at $x = 0$ we obtain the relation using the confinement time τ ,

$$\frac{\tau}{\tau_0} D_B^M = D_B^M + \frac{4a}{\pi^2} \frac{B_z}{B^2} E_y + \frac{4a}{\pi^2} \frac{B_y}{B^2} E_z \quad (30)$$

where $\tau_0 = (2/\pi) 2a^2/D_B$, which is the confinement time without electric field, is obtained by the boundary condition $n=0$ at $x=a$. We can represent the radial diffusion by the confinement time in main plasma. In this case, $J_x = D_x = (\tau/\tau_0) D_B^M$, $J_{BX} = D_{BX}^M = D_B^M$, where $D_B^M (= \gamma_B^{-1} T_e/B)$ is the Bohm-like diffusion coefficient in the main plasma.

4.4 Discussions

The information of ion temperature must be aid to clarify the transport process in tokamak plasma that is said to be no experimental information on ions in SOL²¹⁾. In the conventional transport model of SOL it is generally assumed that $T_e = T_i$ when no data on T_i in SOL are available. However, it is known from in this experiment that this assumption is not valid in SOL in

tokamaks. The determination of the ion temperature has been performed with a spatial resolution of a few mm in the radial direction by means of electrostatic probes. It had already been measured earlier in TEXTOR that the ion temperature in SOL larger than the electron temperature. Ion temperatures determined by means of the rotating double probe have been compared in TEXTOR with those obtained from Lithium beam activated charge exchange spectroscopy. The results from the two methods are fairly good agreement. It should be noted that the results obtained in TEXTOR and obtained in JFT-2M by using rotating probe and ITP are quite similar.

The transport model in SOL is developed including the heat flux and it is shown that both density and temperature profiles decay exponentially. The decay length of the density profile decreases inside limiter region (SOL II), which means that the connection length becomes small due to the limiter. It is shown from the modified transport model in SOL that the e-folding length of the electron temperature in SOL I region is often larger than that in SOL II and that the e-folding length of ion temperature often keeps almost constant value in SOL I and SOL II. This is because in the case of temperature profile by the parallel conductive flow the heat is transported to keep the temperature profile even if the connection length becomes smaller. The fact is in progress that the heat transmission rate can be estimated by the density and temperature profile due to the probe and heat flux to the divertor plate, limiter and the wall. The result of measurement by electrostatic probe supports the result of heat data due to IR camera¹⁹⁾. The heat fluxes to the divertor plate and the limiter are much larger than to the wall. Similar to the result obtained by IR camera, it is shown by the probe measurement in JFT-2M that the heat flux to the divertor plate becomes small with increase of main plasma density.

5. Summary

In summary, the measurement of ion temperature in SOL has just begun by means of the Höthker rotating probe and the Amemiya asymmetric probe in JFT-2M tokamak. The diagnostics was built in collaboration program between KFA and JEARI. The rotating double probe was developed, designed and manufactured at KFA and the ion toothbrush probe, Katsumata probe , cubic Mach probe and the linear driver developed in JAERI are installed at JFT-2M tokamak. Preliminary values on the ion temperature are obtained using above probe system. The ion temperature is much larger than the electron temperature and the existence of flow is observed in JFT-2M. The decay length of the temperature is larger than that of density profile and is almost constant at the position in the shadow of limiter. The transport

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model, in which the probe data can be explained, is developed and it is tried to estimate the diffusion coefficient, ion and electron thermal conductivities and the heat transmission rate according to the transport model. It is also tried to estimate the heat flux to the first wall (divertor plate, the limiter and the wall) by using the probe data. A model to determine the radial, poloidal and toroidal electric field from the measurement of ion saturation current on the cubic Mach probe is proposed.

Acknowledgements

This paper is dedicated for the memory of late Dr. Hikosuke Maeda, former head of Experimental Plasma Physics Laboratory (EPPL). We also want to thank to Dr. S. Tamura, former director of Department of Fusion Plasma Research, and Professor G.H. Wolf, head of IPP in KFA, Jülich, for their encouragements throughout this collaborating research. The authors also thank to KFA work-shop for their manufacturing the rotating double probe, to Miyamori Company for their manufacturing the linear driver, to Irie Technical Company for their manufacturing the vertical ion probe and Toyo Corporation for their manufacturing the power supply and the data acquisition system. The author also thanks to Mr. T. Ide for his administration work of the international collaboration program.

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Table I Items of the supporting structure of the rotating probe in Fig.3

1. supporting housing	34. hexagonal nut M6
2. supporting tube	35. U-type plate
3. inner tube	36. hexagonal screw
4. carry flange	37. screw bolt
5. end section	38. hexagonal nut M6
6. carry plug	39. U-type plate
7. supporting plug	40. screw bolt
8. adjust ring	41. hexagonal screw
9. spacing ring	42. hexagonal nut
10. clamp ring	43. hexagonal screw
11. screw pivot	44. screw bar
12. support disk	45. screw bar M4x10
13. support disk	46. cylindrical screw M3x10
14. support disk	47. hexagonal screw M3x8
15. holder	48. screw bar M3x5
16. clamp	49. hexagonal nut M3
17. clamp	50. U-type plate
18. coupling plug	51. cylindrical screw M2.5x6
19. supporting bolt	52. insulating plate
20. carry plate	53. bearing
21. insulation sheath	54. bearing
22. insulation sheath	55. helical wave-type coupling MCAL100
23. cable feeder	56. UHV-rotational feedthrough
24. support	57. CF-gasket NW35
25. socket plate	58. socket-unit 15 poles
26. socket holder	59. plug-unit 15 poles
27. clamp	60. stepping motor
28. nil	61. rotator
29. nil	62. capillary tube
30. hexagonal nut M8	63. insulation tube
31. U-type disk	64. lead wire
32. hexagonal screw	65. UNI-LAT-coupling
33. screw bolt	66. cylindrical screw M16

Table II Items of the rotatoint probe head in Fig.4 (a) and (b)

for 4 poles	for 2 poles
1. isolation plug Macor	1. isolation plug Macor
2. feedthrough	2. contact caps
3. feedthrough	3. probe tips graphite
4. shield Al_2O_3	4. isolation tube
5. open frame Macor	
10. hexagonal screw M3x8	10. screw bar M4x8
11. cylindrical screw M3x25	11. screw bar M2x4
12. U-type disk 3.4φ	12. cylindrical screw M3x5

Table III List of ion diagnostic probes in JFT-2M tokamak

ports	name	measurable values	remarks
horizontal ion probe	Höthker probe	n_e, T_e, T_i, M	rotation
	Amemiya probe	n_e, T_e, T_i, M	asymmetric
vertical ion probe	Ion toothbrush probe(ITP)	n_e, T_e, T_i, M	multi-Amemiya probe (5 channels)
	Katsumata probe	n_e, T_e, T_i	ion energy distribution
	cubic Mach probe	$n_e, M, E_j (j=x, y, z), v_e$	flow velocity

Table IV Estimation of e-folding length of the temperature profile,
thermal conductivity and heat flux to the first wall

(a)	λ_p	n_e^B	λ_n	T_e^B	T_i^B	$\chi_{//}^e$	$\chi_{//}^i$	λ_{Te}	λ_{Ti}
	(m)	($\times 10^{18} \text{ m}^{-3}$)	(m)	(eV)	(eV)	($10^4 \text{ m}^2/\text{sec}$)	($10^4 \text{ m}^2/\text{sec}$)	(m)	(m)
SOL I	24.5	2.0	0.11	10	100	69	143	0.164	0.209
SOL II	8.2	0.7	0.01	5	70	35	168	0.292	0.204

(b)	n_e^B	λ_{n1}	λ_{n2}	T_e^B	T_i^B	λ_{Te}	λ_{Ti}	χ_{\perp}^e	χ_{\perp}^i
	($\times 10^{18} \text{ m}^{-3}$)	(m)	(m)	(eV)	(eV)	(m)	(m)	(m^2/sec)	(m^2/sec)
L- n_e	2.0	0.03	0.01	20	100	0.24	0.29	510	64
H- n_e	2.0	0.03	0.11	15	75	0.15	0.35	147	41

(c)	n_e^B	λ_{n1}	λ_{n2}	T_e^B	T_i^B	λ_{Te}	λ_{Ti}	χ_{\perp}^e	χ_{\perp}^i
	($\times 10^{18} \text{ m}^{-3}$)	(m)	(m)	(eV)	(eV)	(m)	(m)	(m^2/sec)	(m^2/sec)
OH-P	0.5	0.06	0.0095	10	370	0.169	0.53	34	3.4
NB-P	1.1	0.051	0.01	16	320	0.68	0.109	16.4	12.5

(d)	$\chi_{//}^e$	$\chi_{//}^i$	$\gamma_{//}$	γ_{\perp}	Q_D	Q_{wall}
	($10^4 \text{ m}^2/\text{sec}$)	($10^4 \text{ m}^2/\text{sec}$)			(kW)	(kW)
L- n_e	393	143	13.7	3446	91	54
H- n_e	191	69	15.2	905	59	14

(e)	$\chi_{//}^e$	$\chi_{//}^i$	$\gamma_{//}$	γ_{\perp}	Q_D	Q_{wall}
	($10^4 \text{ m}^2/\text{sec}$)	($10^4 \text{ m}^2/\text{sec}$)			(kW)	(kW)
OH-P	24	19	13	9610	109	1
NB-P	34	27	277	589	261	3

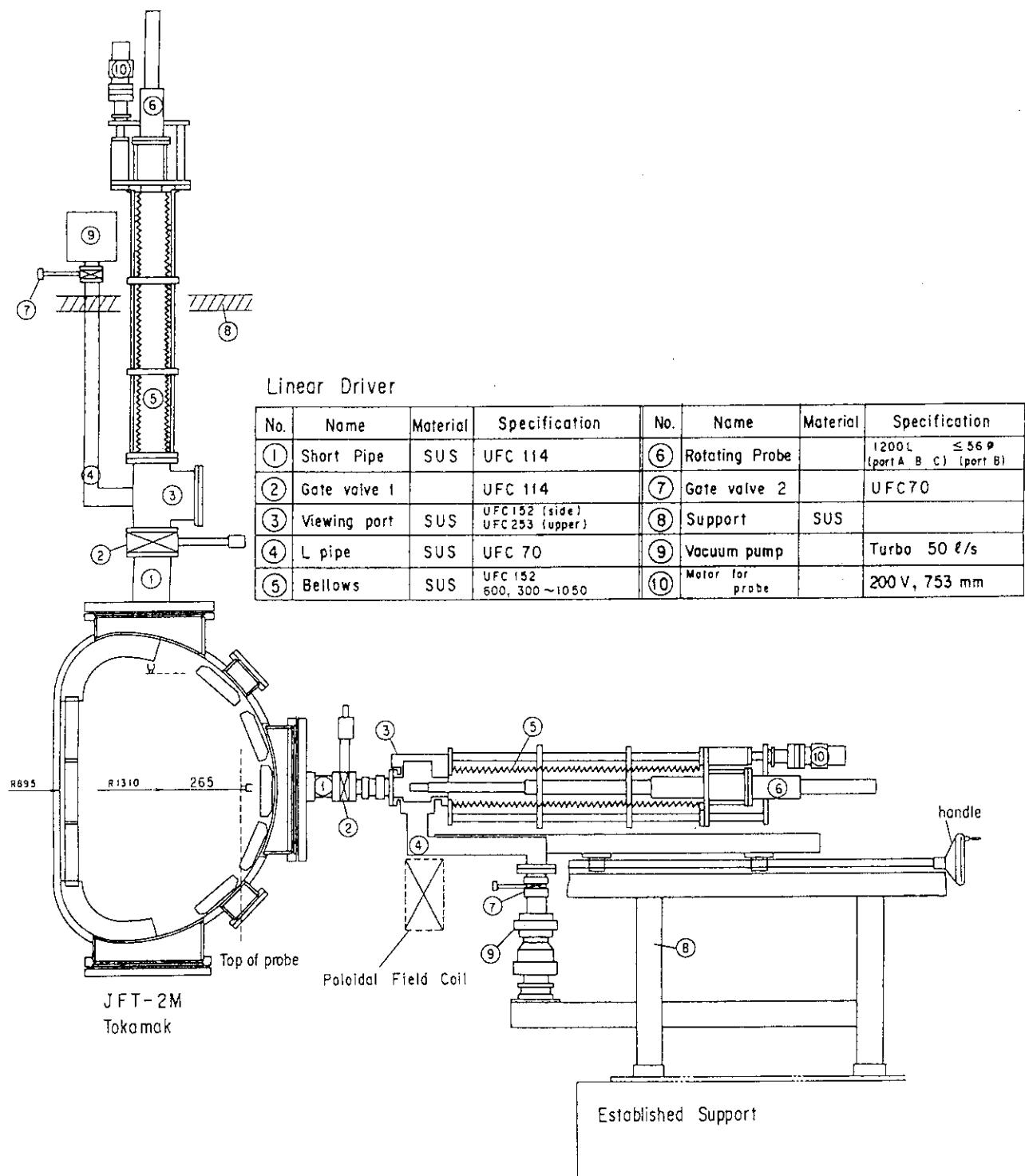


Fig.1 Installation of horizontal, vertical ion probes and their linear driver in JFT-2M tokamak. JFT-2M has sixteen diagnostic ports and ion probes are equipped at p-2 (vertical) and p-9 port (horizontal)

(a) Cross sectional view

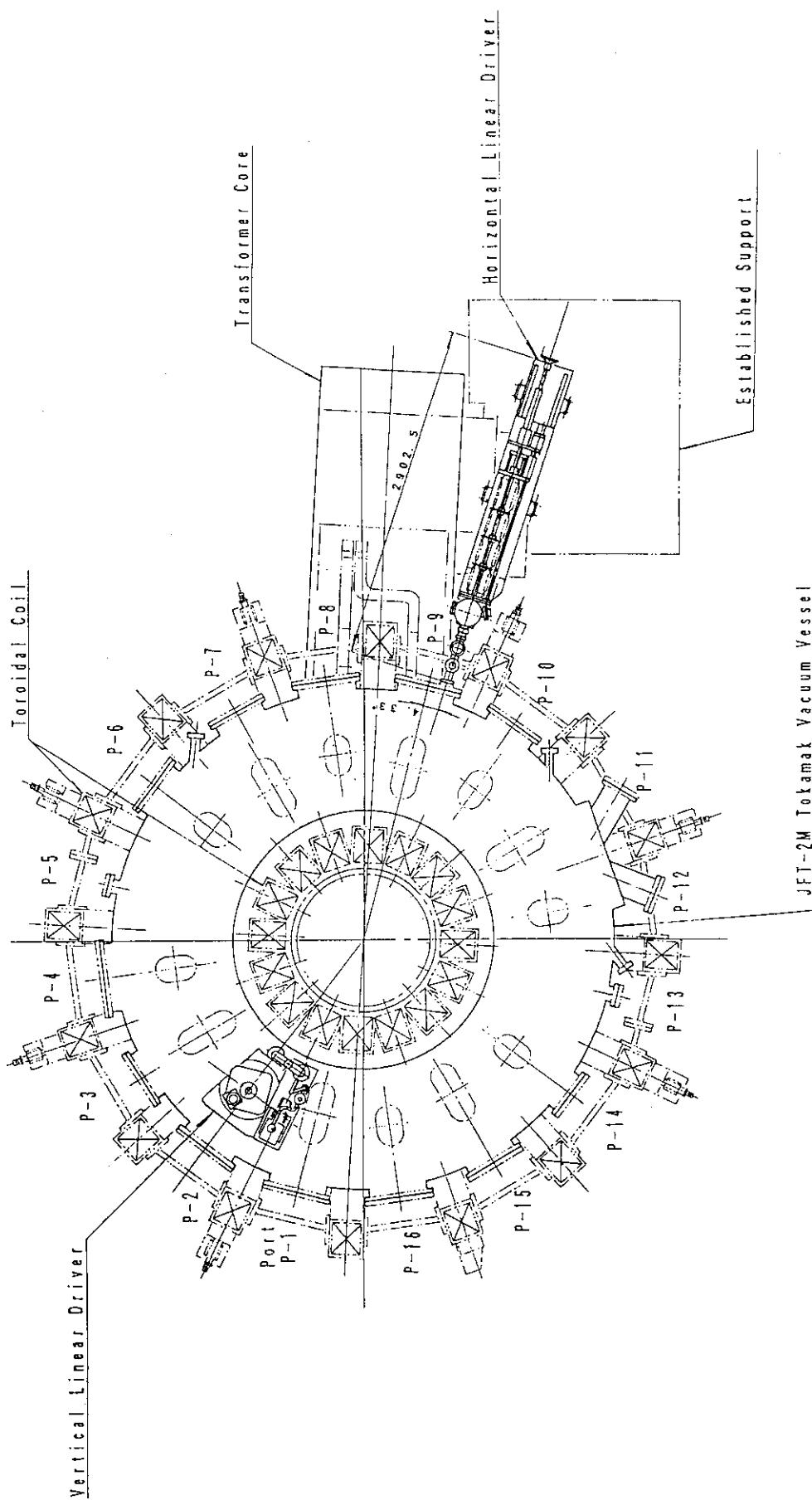


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(b)Plane view

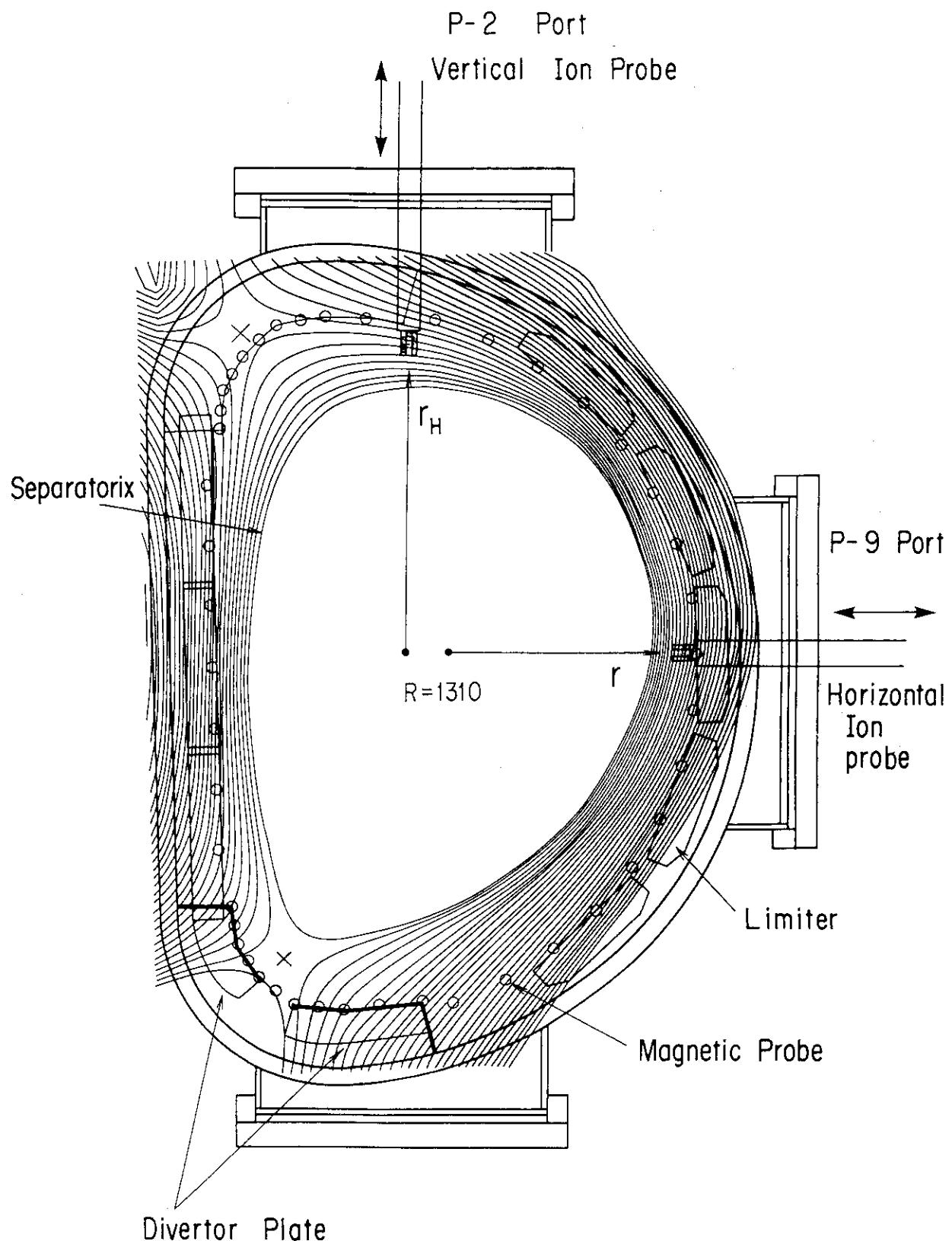
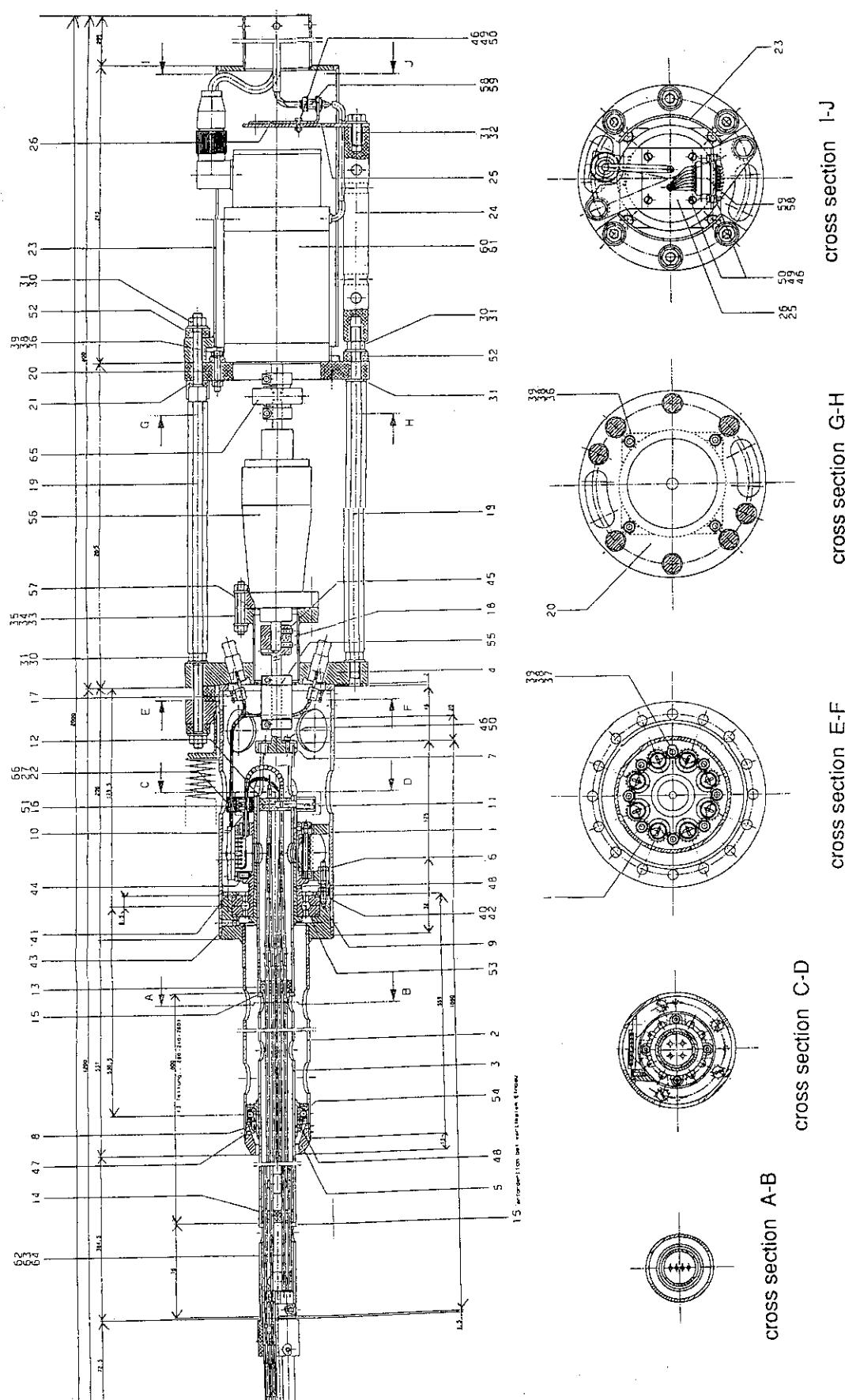
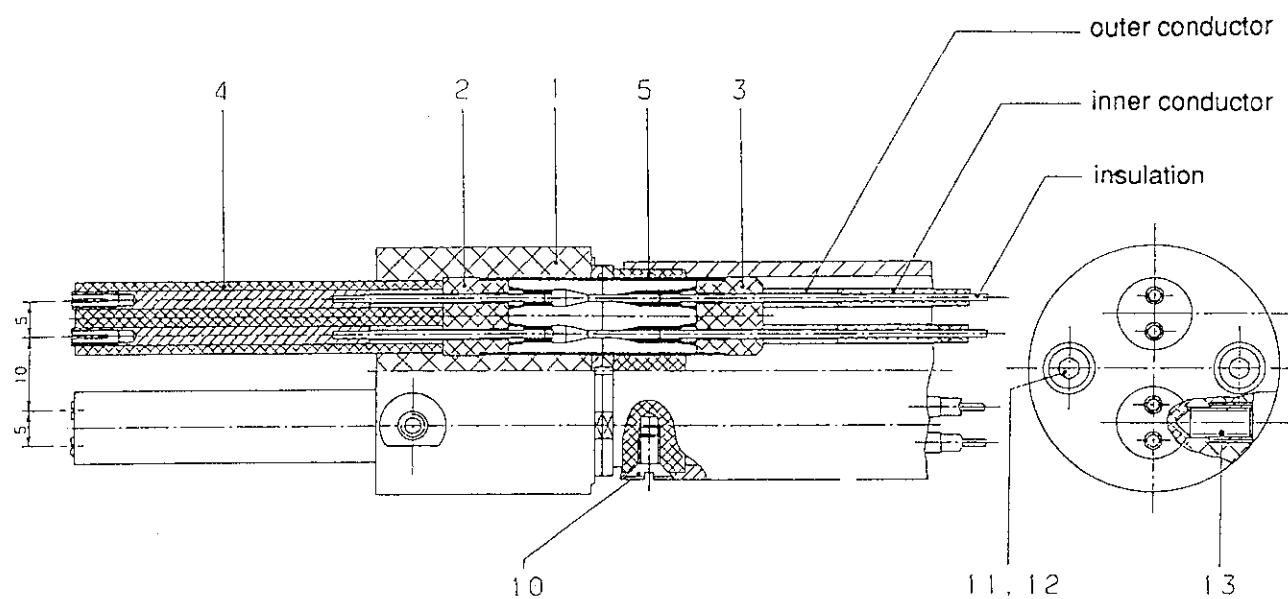
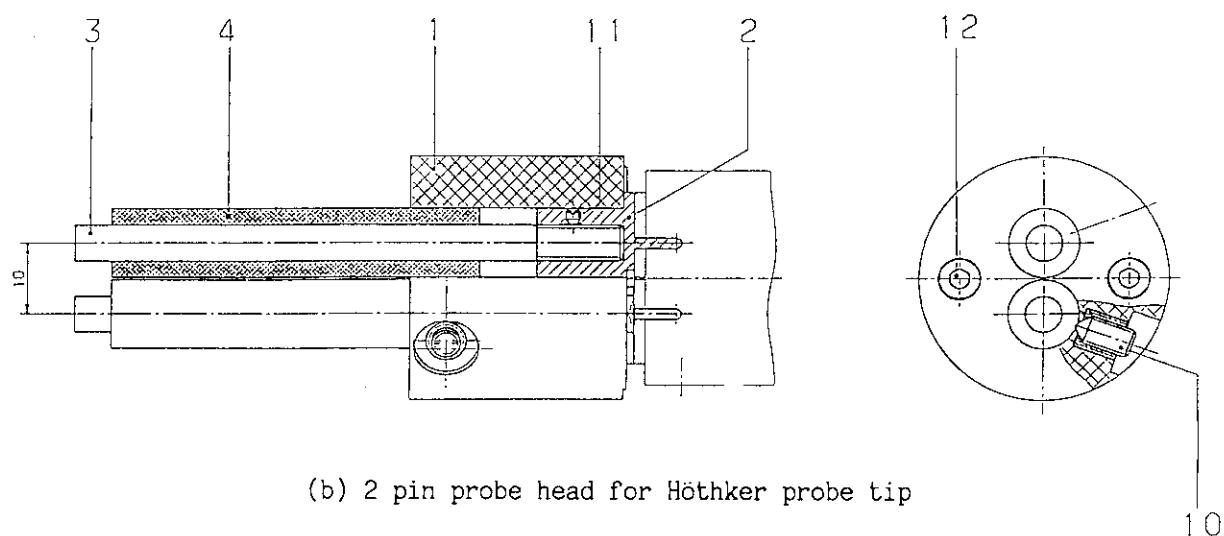


Fig.2 Magnetic configuration and the probe position in JFT-2M. The magnetic configuration is for lower single null(LSN) divertor plasma





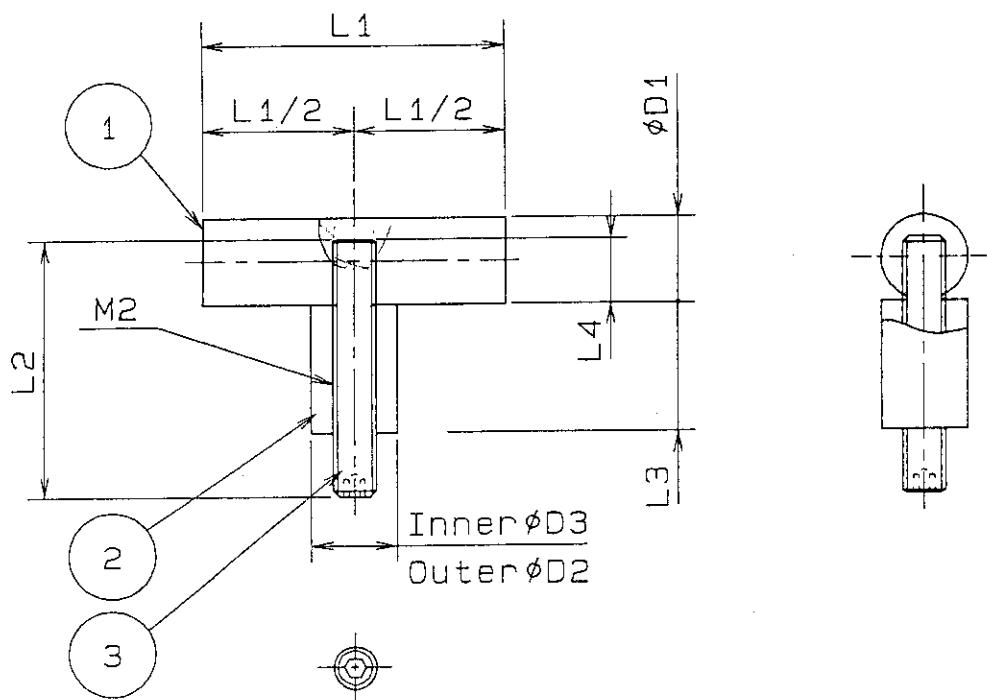
(a) 4 pin probe head for Amemiya probe tip



(b) 2 pin probe head for Höthker probe tip

10

Fig.4 Precise design of rotating double probe head

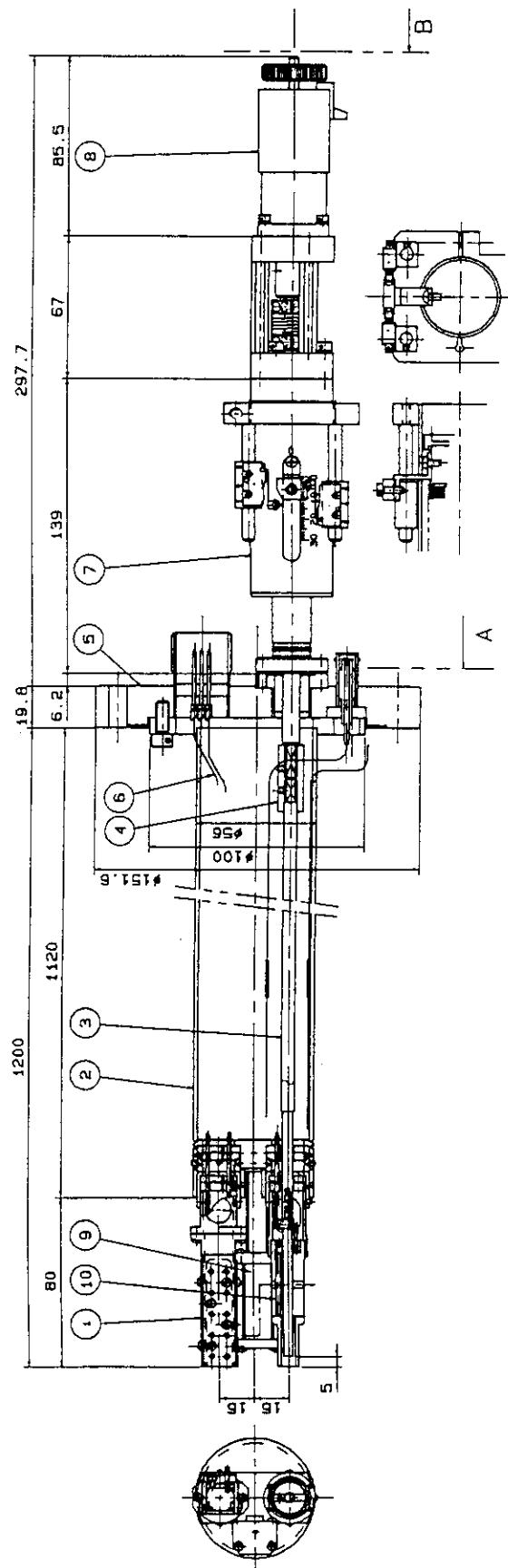


3	Hexagon Socket Screws	SUS304
2	Ceramic for Insulation	Macor
1	Carbon Probe	C

Type	L1	L1/2	L2	L3	L4	phi D1	phi D2	phi D3	Number
A	14	7	12	6	2	phi 4	phi 4	phi 2	5
B	14	7	12	6	2	phi 3	phi 4	phi 2	5
C	6	3	12	6	2	phi 4	phi 4	phi 2	5
D	6	3	12	6	2	phi 3	phi 4	phi 2	5

(c) Carbon probe tip of Amemiya probe tip and caption table. Figure captions in (a) and (b) are shown in Table II

Fig.4 Precise design of rotating double probe head



Number	Description	Material	Req'd	Note
10	Katsumata Probe	Assembly Instrument	1	c f: EQ0369500
9	Cubic Mach Probe	Assembly Instrument	1	c f: ES0110000
8	Stepping Motor		1	
7	Linear-Introduction	Assembly Instrument	1	
6	Lead Line		1	
5	Frangue With Feedthrough	SUS304	1	
4	Connection Metal Fitting	SUS304	1	
3	Driving Shaft	SUS304	1	
2	Support Pipe	SUS304	1	
1	Ion Toothbrush Probe	Assembly Instrument	1	c f: ER14B0000

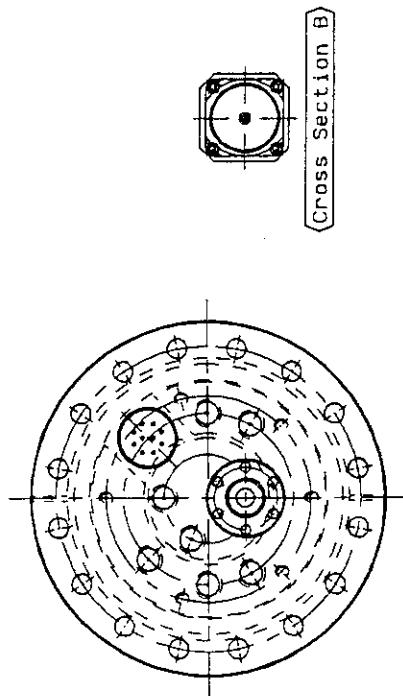
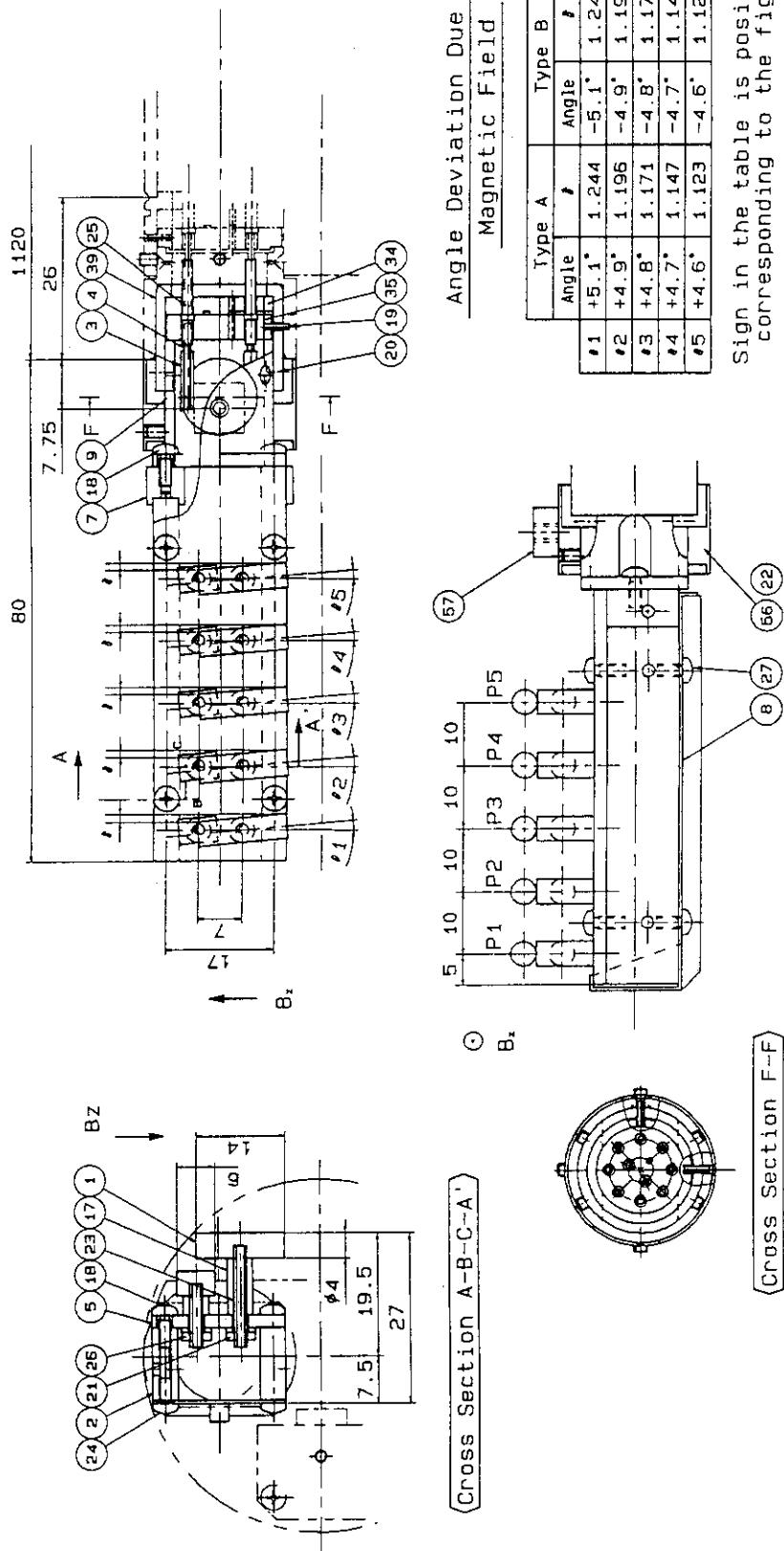


Fig.5 Total view of vertical ion probe, which contains Katsumata probe, Ion toothbrush probe (ITP) and cubic Mach probe, and the caption table



Sign in the table is positive corresponding to the figure

Type	Type B		
	Angle	#	Angle
Type A	+5.1°	1.244	-5.1°
#1	+4.9°	1.196	-4.9°
#2	+4.8°	1.171	-4.8°
#3	+4.7°	1.147	-4.7°
#4	+4.6°	1.123	-4.6°
#5	+4.5°	1.099	-4.5°

Number	Description	Material		Note
		BN	Cu	
5	Board	BN	1	CU-111387
4	Lead Line	Cu		Explicit radius #0.5
3	Insulation pipe (3)	Polyimid		
2	Main Cover	BN	1	2
1	Carbon Probe	C		

24	Grooved Head Machine Screw	SUS304	4	M2x4L	
23	Hexagon Socket Head Screw	SUS304	5	M2x10L, 16L Class 12	
57	Equip Board	SUS304	1	M2x3L	
56	Driver for Torque wrench Probe	SUS304	3	M2x3L	
40~55					
3B	Equip Ring for Contactor	SUS304	1	M2x4L	
36~3B					
35	Support Bolt for Sector Detector	Motor	1	(For 10P)	17 Insulation pipe (4)
34	Equip Board for Sector Detector	Motor	1	(For 10P)	BN
28~33				10~15	6 12
27	Grooved Head Bolts Series	SUS304	2	M6x5L	
26	Compressible Terminal	Standard	10	R Shape 1.25~2	7 Pipe (1) SUS304 1
25	Socket Contactor	Standard	12	03~5130~000	5 Back Side Cover SUS304 1 2

Fig.6 Precise view of ITP and cation table

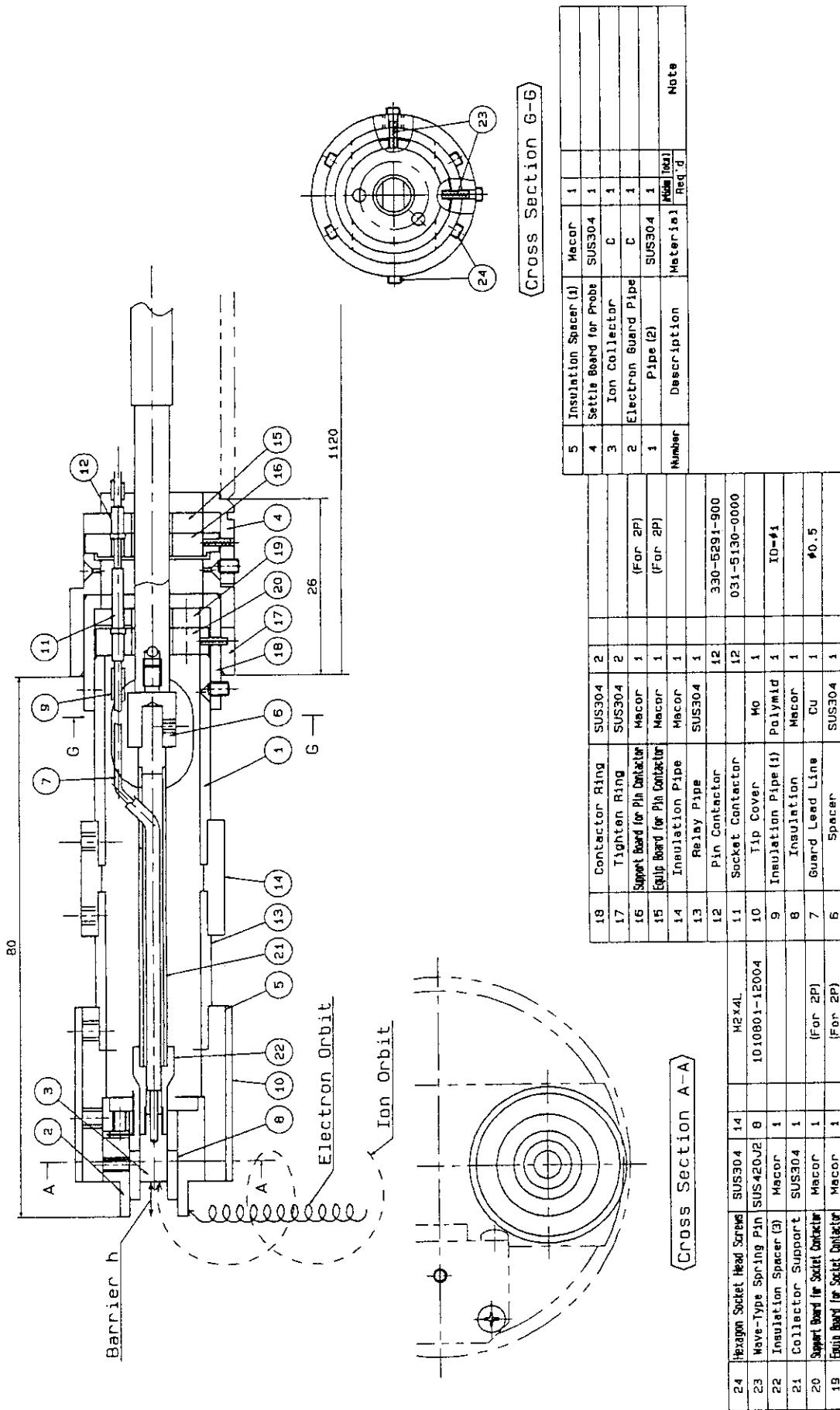
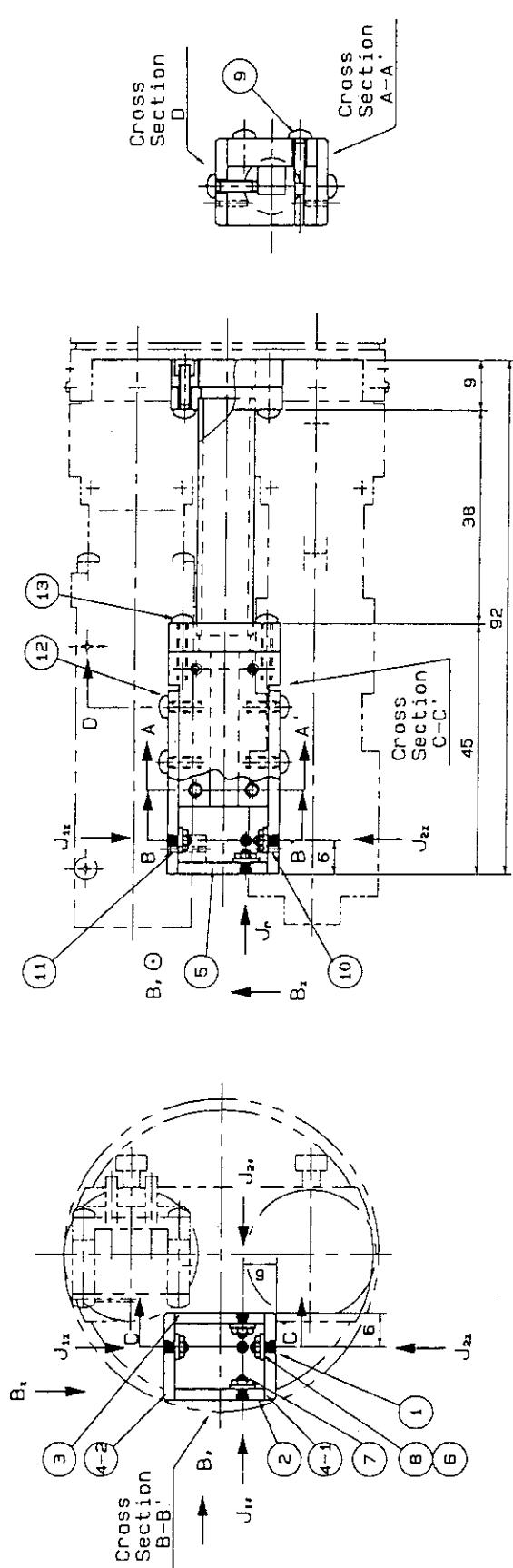


Fig.7 Precise view of Katsumata probe, in which barrier h can be varied by the external operation. By varying h ions and electrons are caught separately and the ion current are gathered at the ion collector



Number	Description	Material	Width	Total	Note
			Req'd	Req'd	
3	Poloidal Cover (2)	BN	1		
2	Poloidal Cover (1)	BN	1		
1	Ion Collector	Mo	5	6	
SUS304					
13	Cross-Recessed Head Machine Screws	SUS304	2	M2X8, With Spring Lite Washers	
12	Cross-Recessed Head Machine Screws	SUS304	4	M2X8L, With Spring Lite Washers	
11	Wave-Type Spring Pin	SUS304	1	1X5L, (For Light Load)	
10	Wave-Type Spring Pin	SUS304	1	1X4L, (For Light Load)	
9	Cross-Recessed Head Machine Screws	SUS304	4	M2X8, With Spring Lite Washers	
8	Compressible Terminal		5	R Shape, 1.25-2, Both end 0.5Cut	
7	Hexagon Nuts	SUS304	5	M1.6, Class 3	
6	Lead Line	Cu	5		
5	Radial Cover	BN	1		
4-2	Toroidal Cover (2)	BN	1		
4-1	Toroidal Cover (1)	BN	1		

Fig. 8 Precise view of cubic Mach probe and caption table. J_r denotes a radial current, $J_{1\theta}, J_{2\theta}$ does a poloidal current and J_{1z}, J_{2z} does a toroidal current

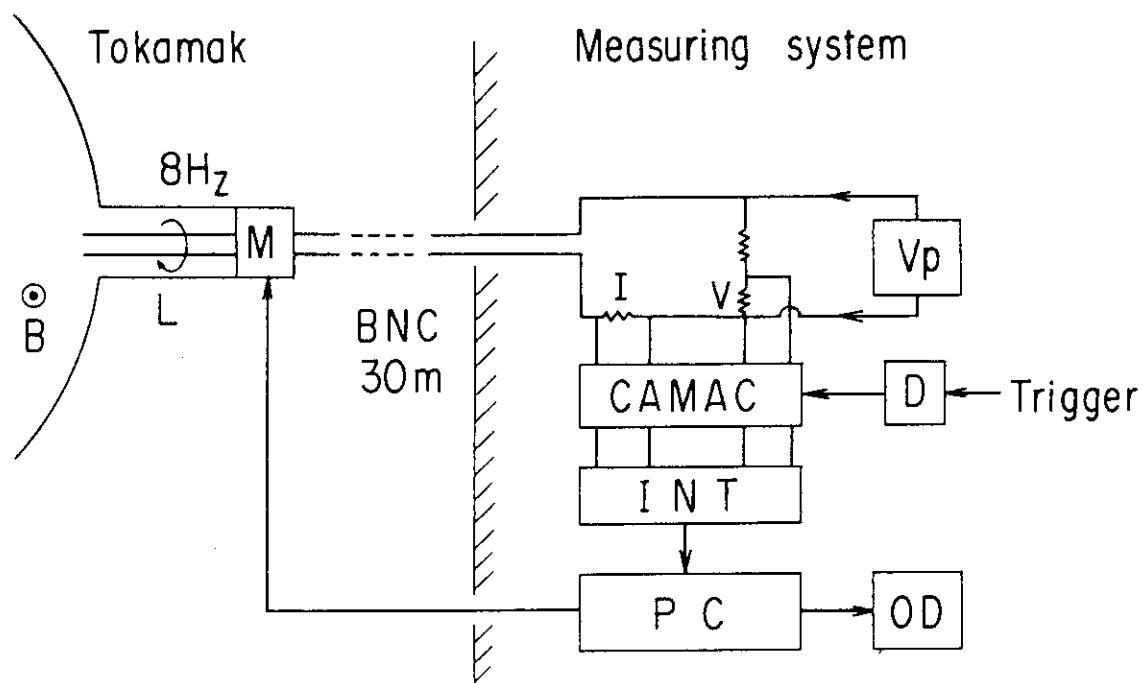


Fig.9 Probe circuit and data processing system

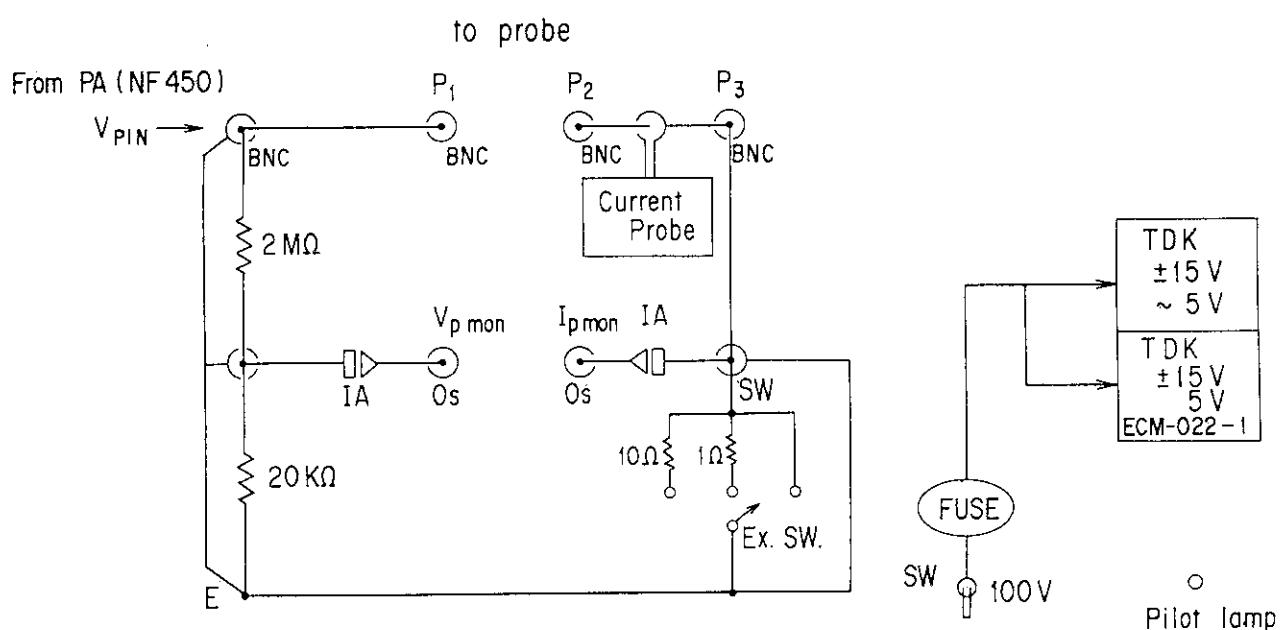


Fig.10 Probe circuit for horizontal ion probe

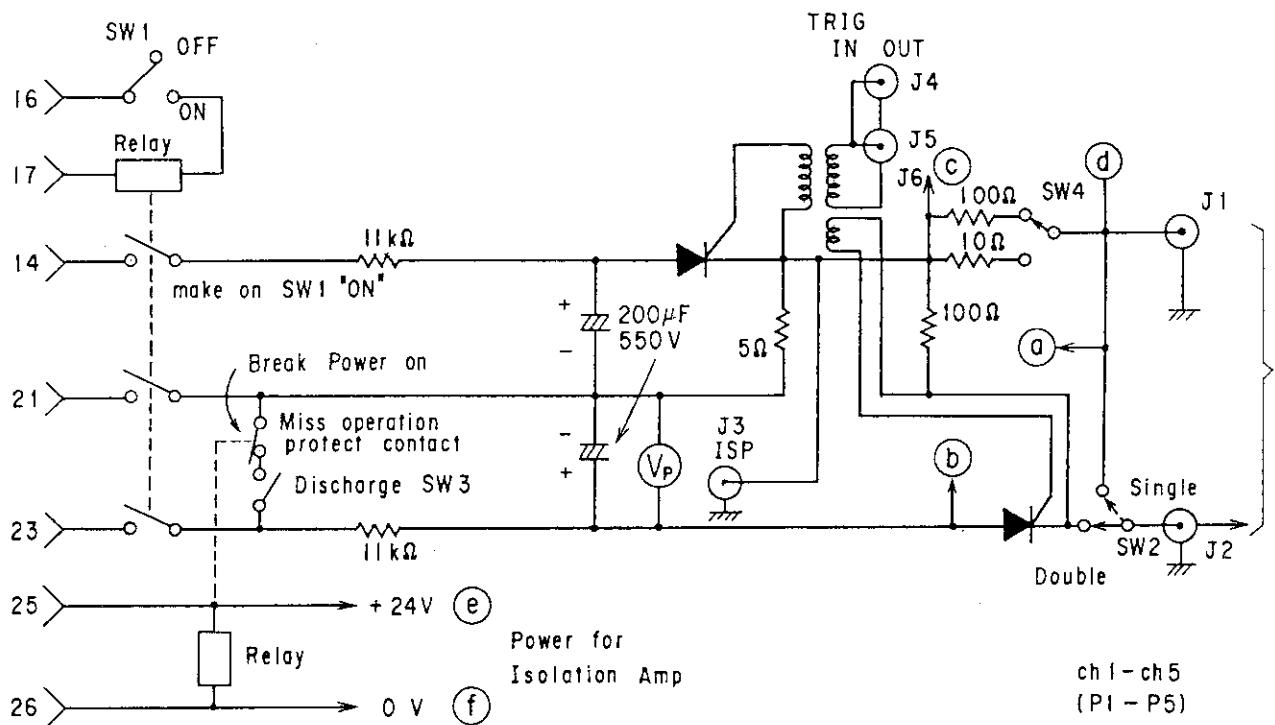


Fig.11 (a) Main probe circuit for ch1-ch6

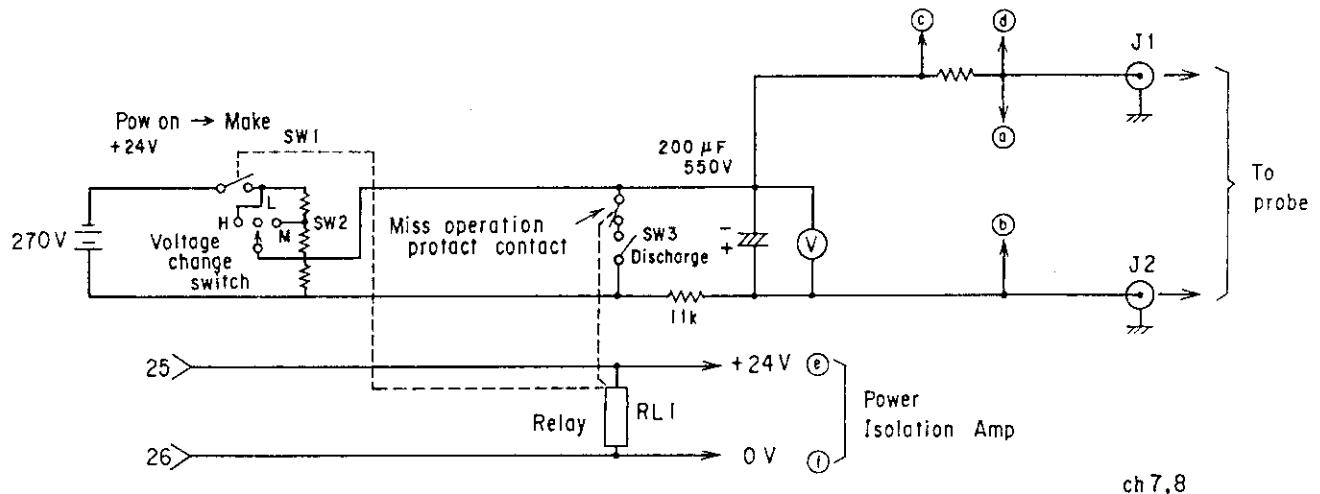
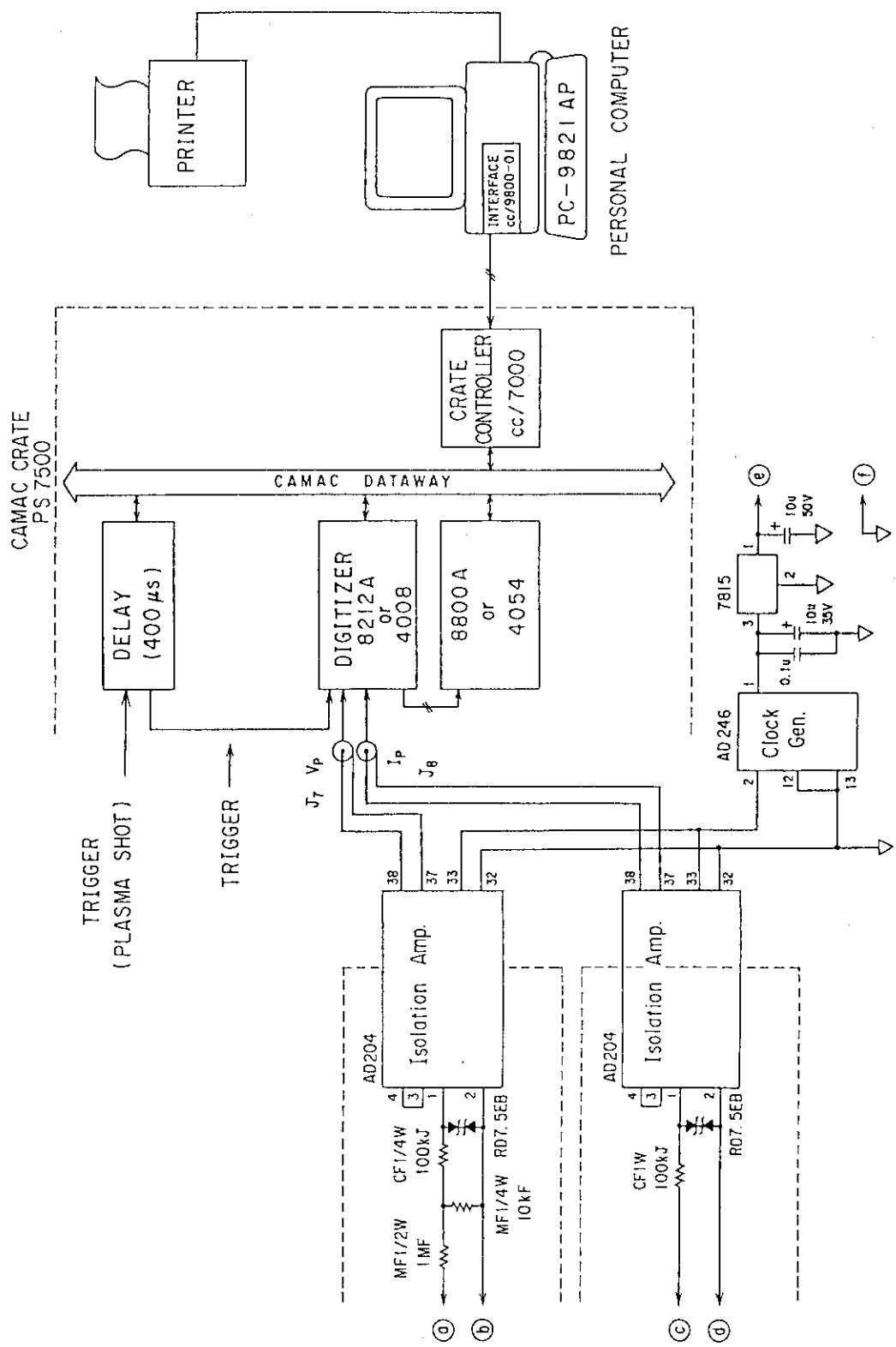


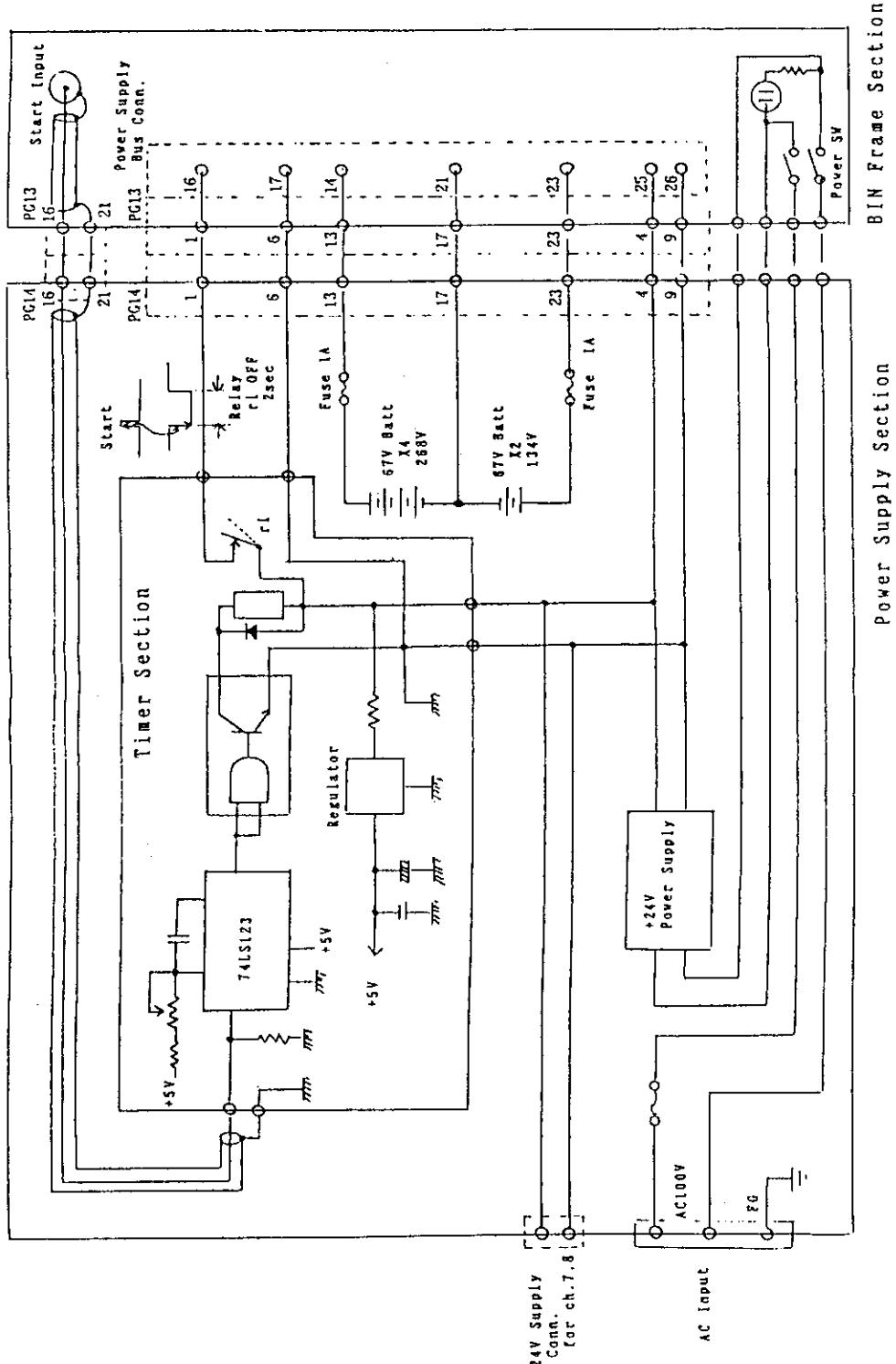
Fig.11 (b) Main probe circuit for ch7-ch8

Fig.11 Probe circuit for vertical ion probe. The channel 1-5 (P1-P5) is for ITP, ch 6 is for the Katsumata probe and ch7-ch8 is for the cubic Mach probe



(c) Isolation Amp. component to CAMAC system

Fig. 11 Probe circuit for vertical ion probe. The channel 1-5 (P1-P5) is for ITP, ch 6 is for the Katsumata probe and ch7-ch8 is for the cubic Mach probe



(d) The power supply component

Fig. 11 Probe circuit for vertical ion probe. The channel 1-5 (P1-P5) is for ITP, ch 6 is for the Katsumata probe and ch7-ch8 is for the cubic Mach probe

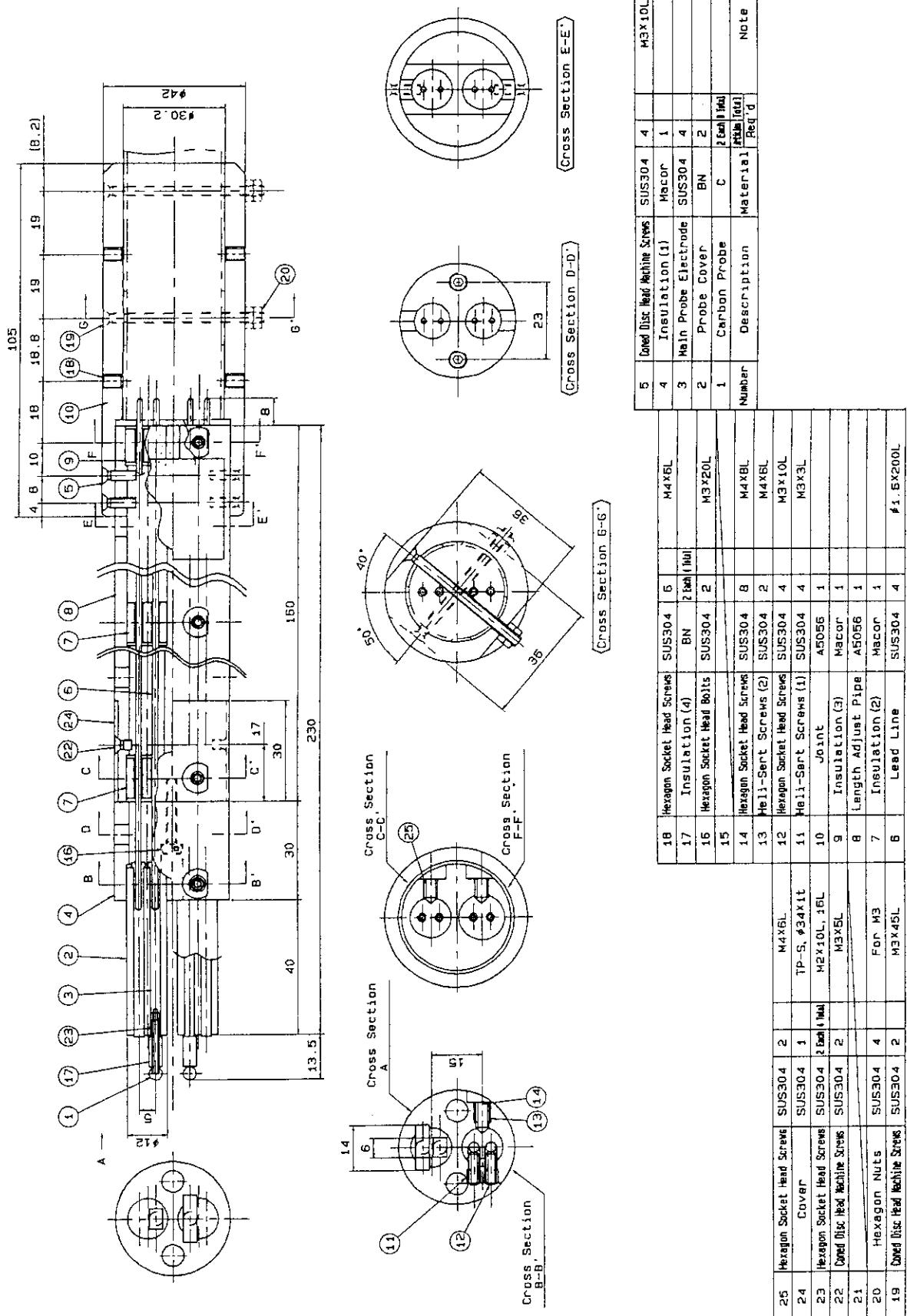


Fig. 12 Modified rotating probe head, in which the length adjust pipe (number 8) are included between B-B' and F-F'

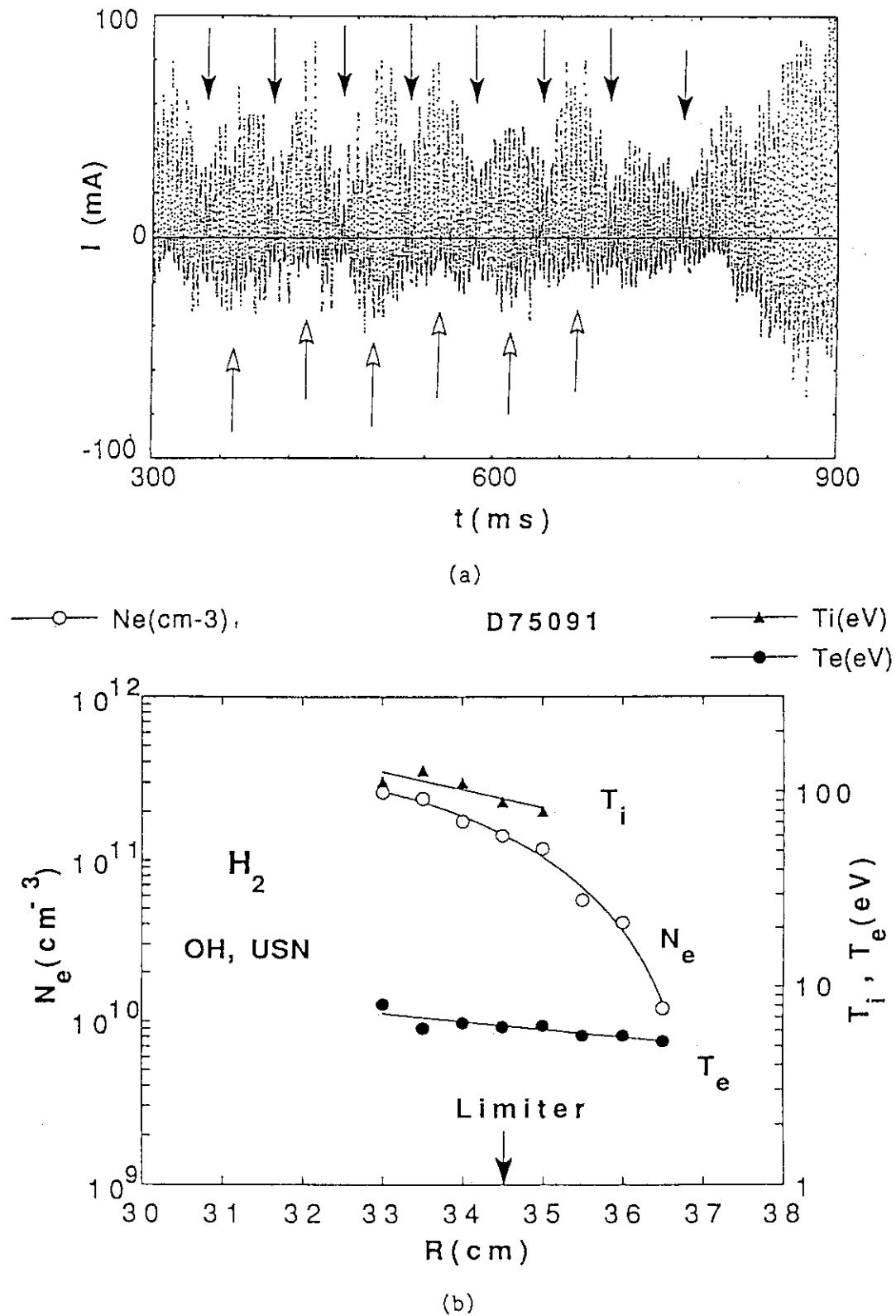
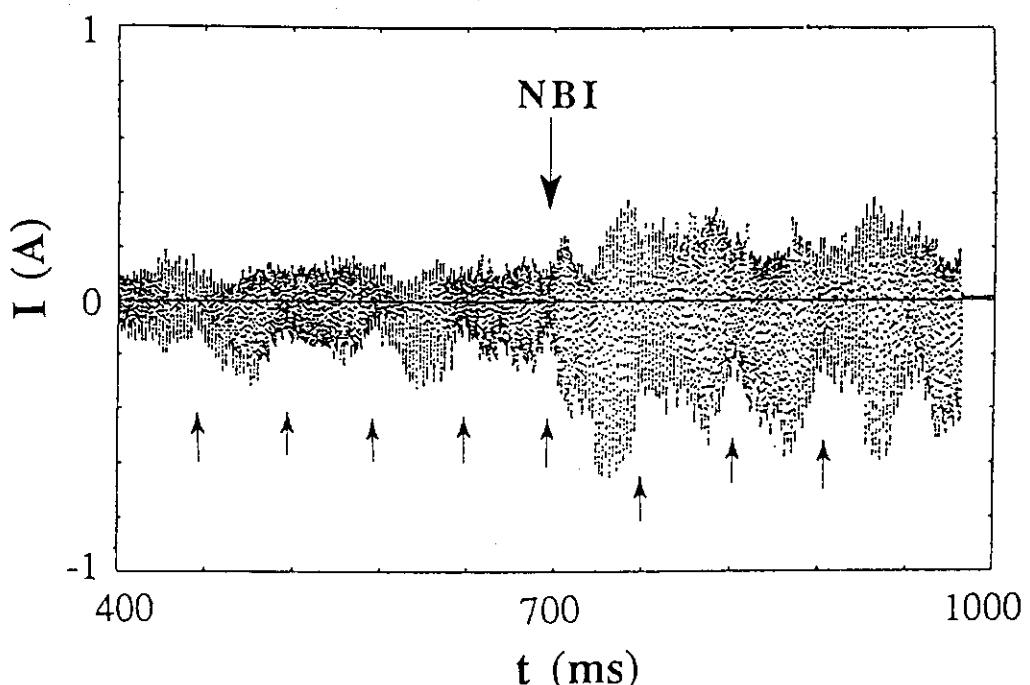
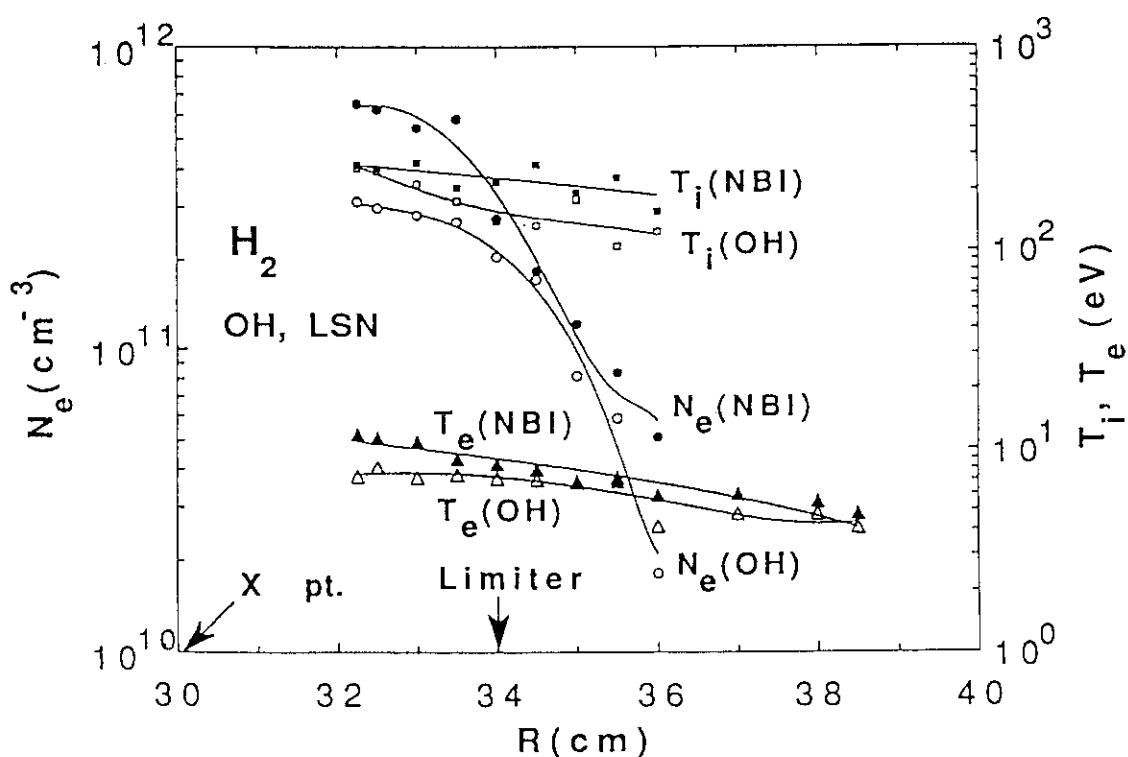


Fig.13 (a) Raw data of Amemiya probe (OH plasma case) The ohmic heating was applied at $t=300\text{-}800$ ms. At dips indicated by solid arrows, the double probe was oriented parallel to B . At dips indicated by open arrows, the double probe was oriented perpendicular to B
 (b) Radial profile of ion temperature, electron temperature and density estimated by Amemiya probe for OH plasma case

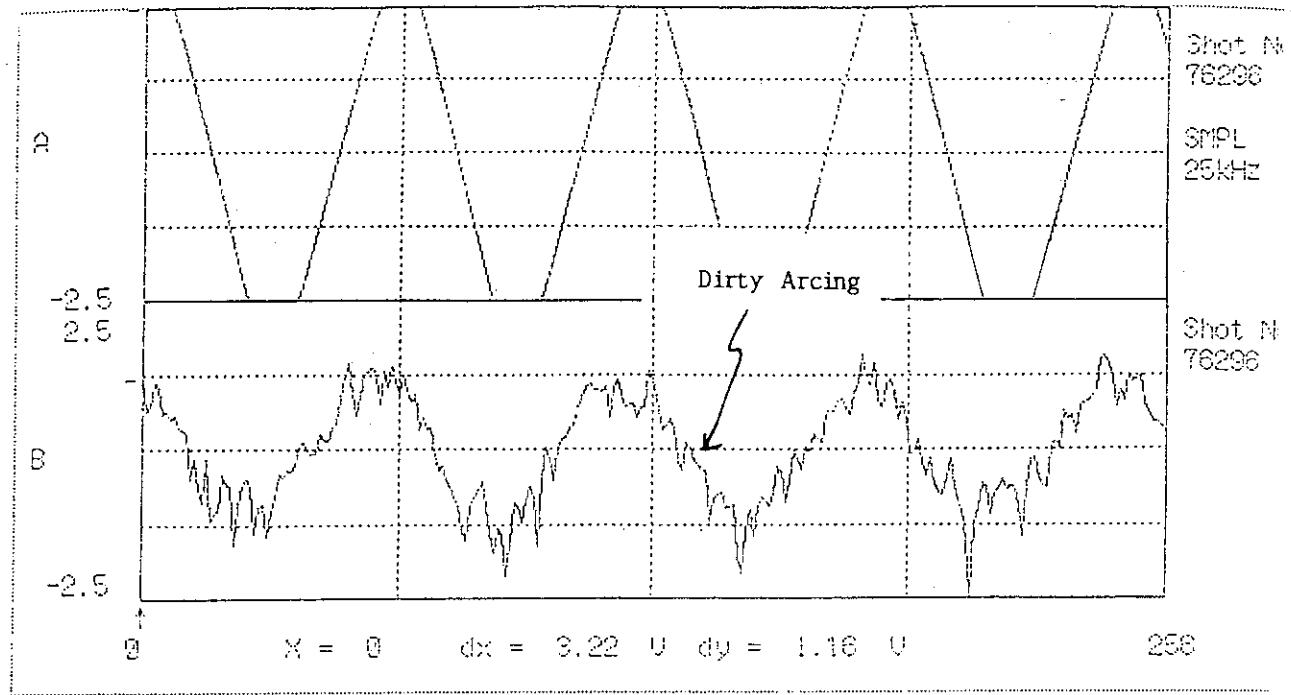


(a) Raw data After OH at $t=400-700$ ms NBI was applied after $t=700$ ms as indicated by NBI

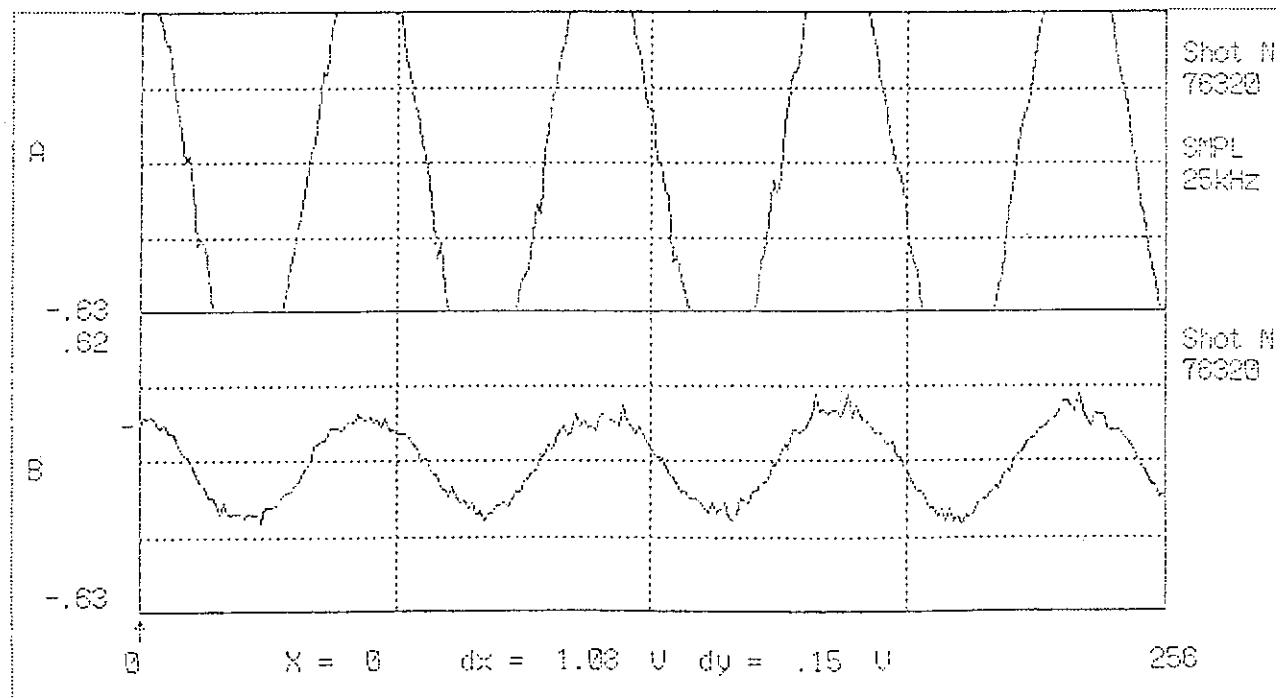


(b) profile

Fig.14 Radial profile of ion temperature, electron temperature and density estimated by Amemiya probe for NBI heated case



(a) before



(b) after

Fig.15 Raw data of Höthker probe (a) before and (b) after TDC plasma. Up trace is probe voltage and under one is probe current

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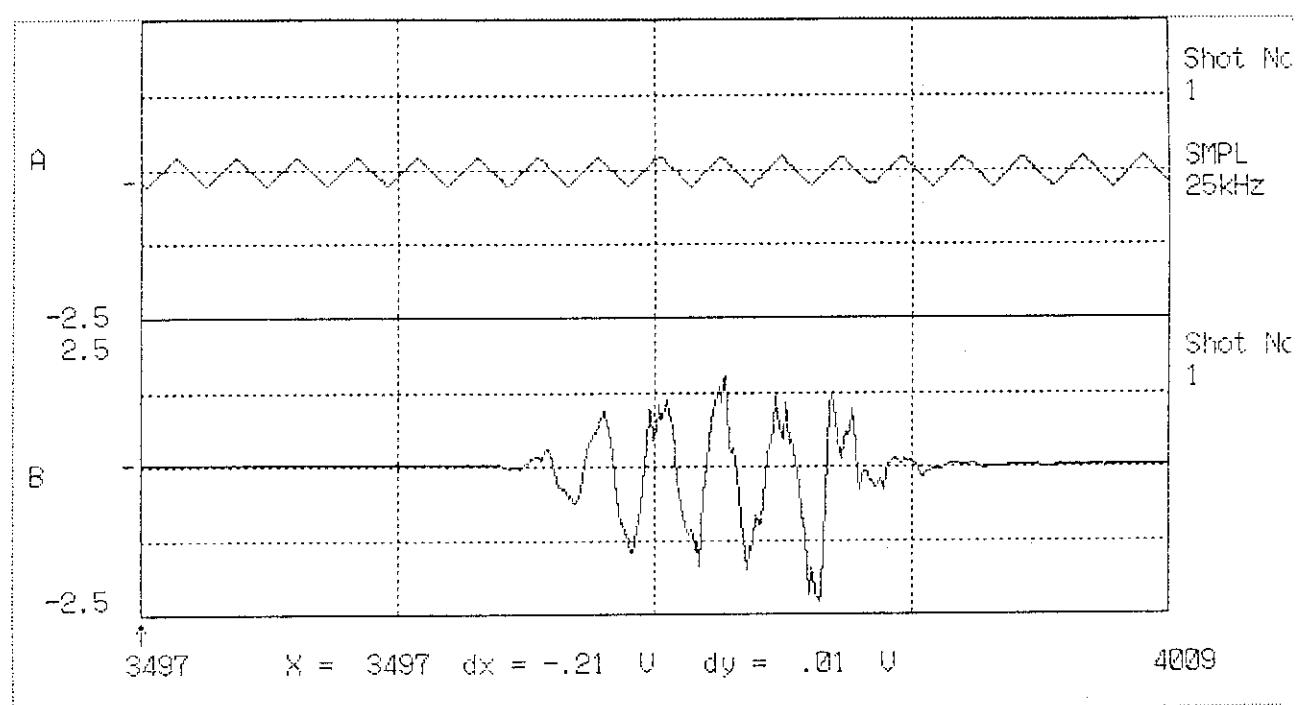
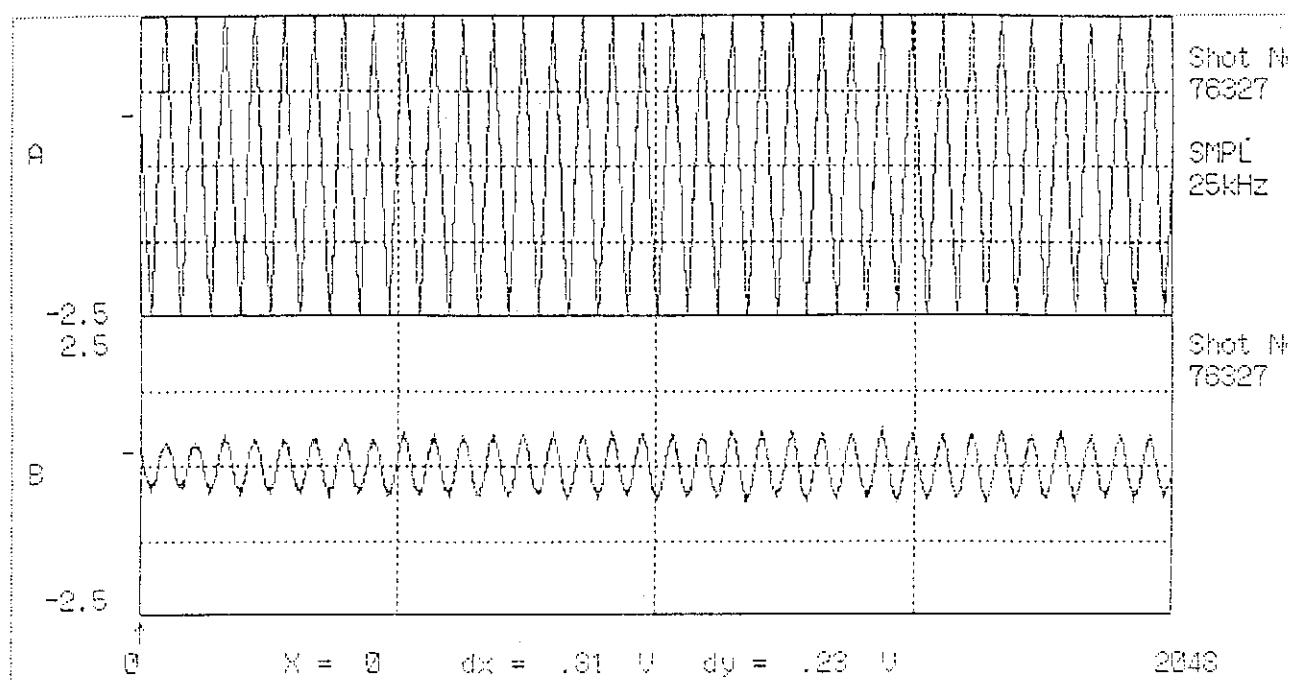
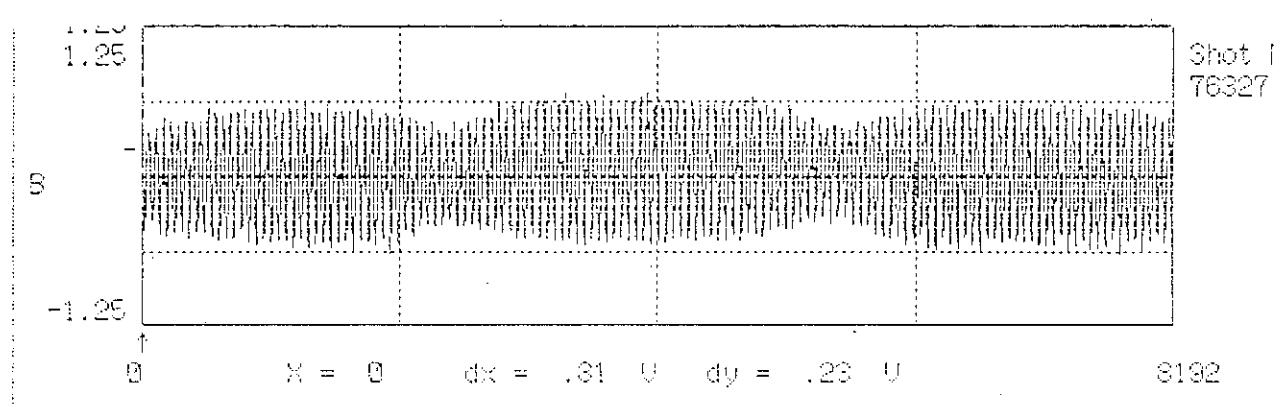


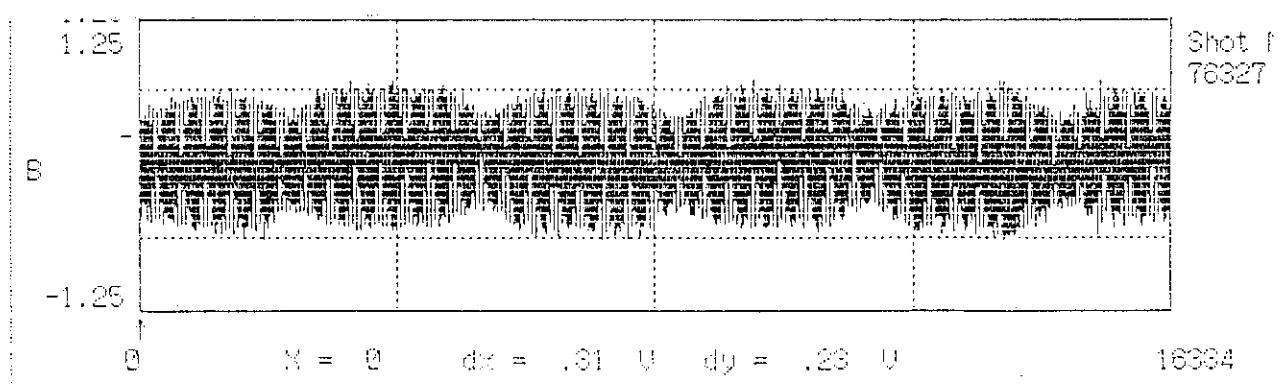
Fig.16 Raw data of Höthker probe in TDC plasma. Up trace is probe voltage
and down trace is probe current



(a) Probe voltage with 200 Hz. The sampling time is 25 kHz.
The probe current with the compression rate is 2043

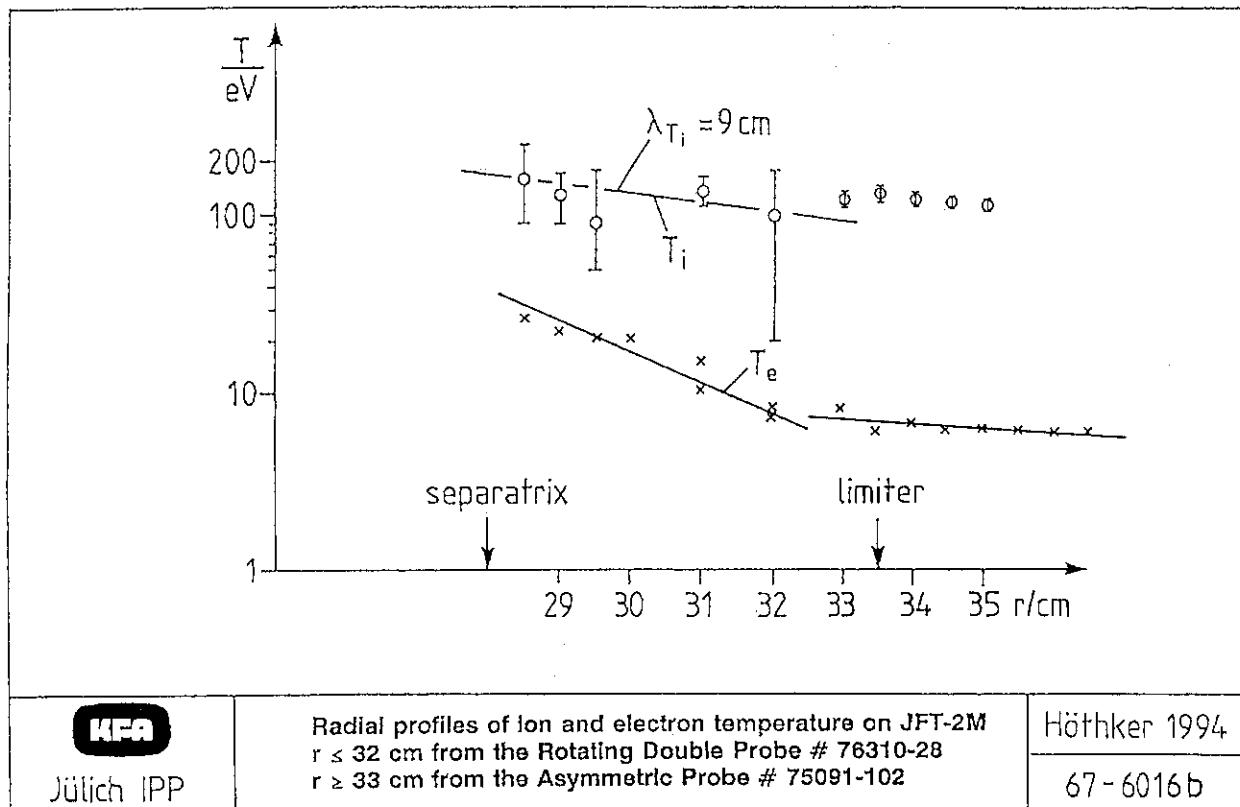


(b) The probe current with the compression rate of 3192

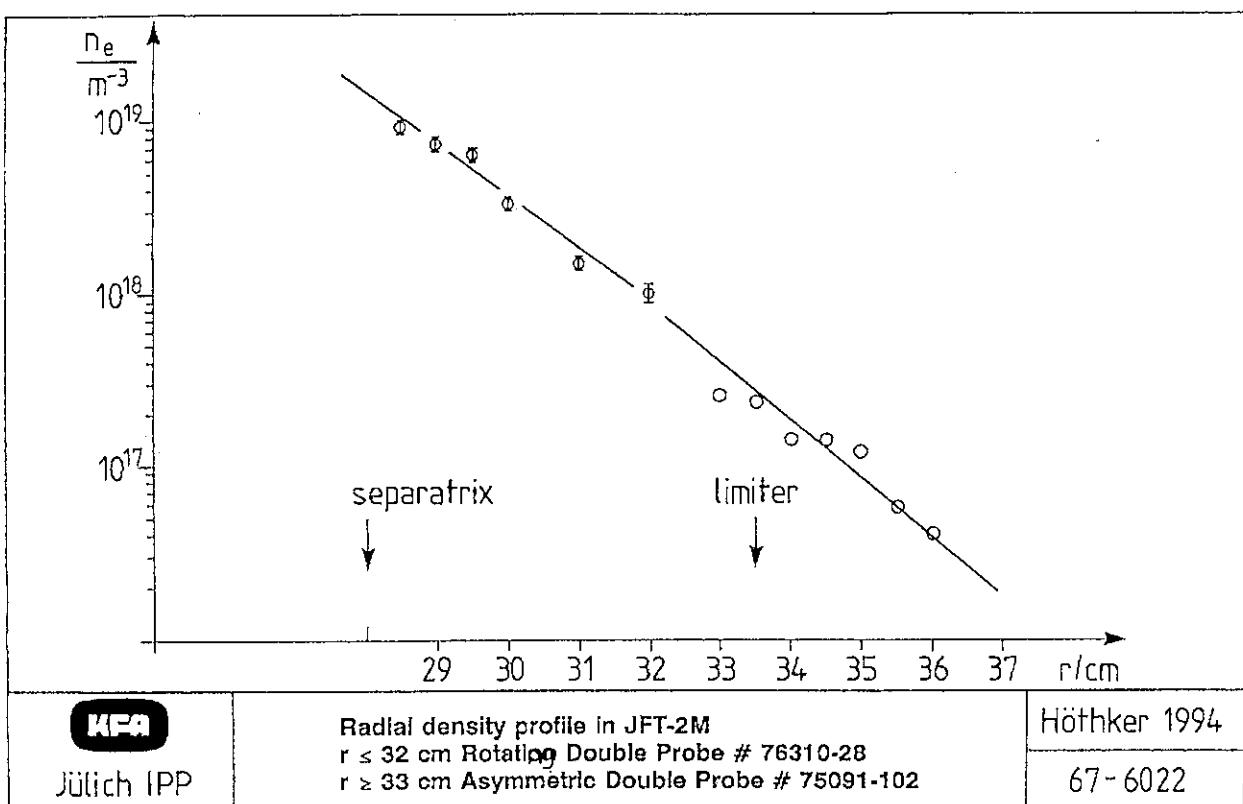


(c) The probe current with the compression rate of 16334

Fig.17 Raw data of Höthker probe with the small compression and large compression data acquisition



(a) Electron temperature and ion temperature profile



(b) density profile

Fig.18 Plasma profile by Höthker probe including Amemiya data

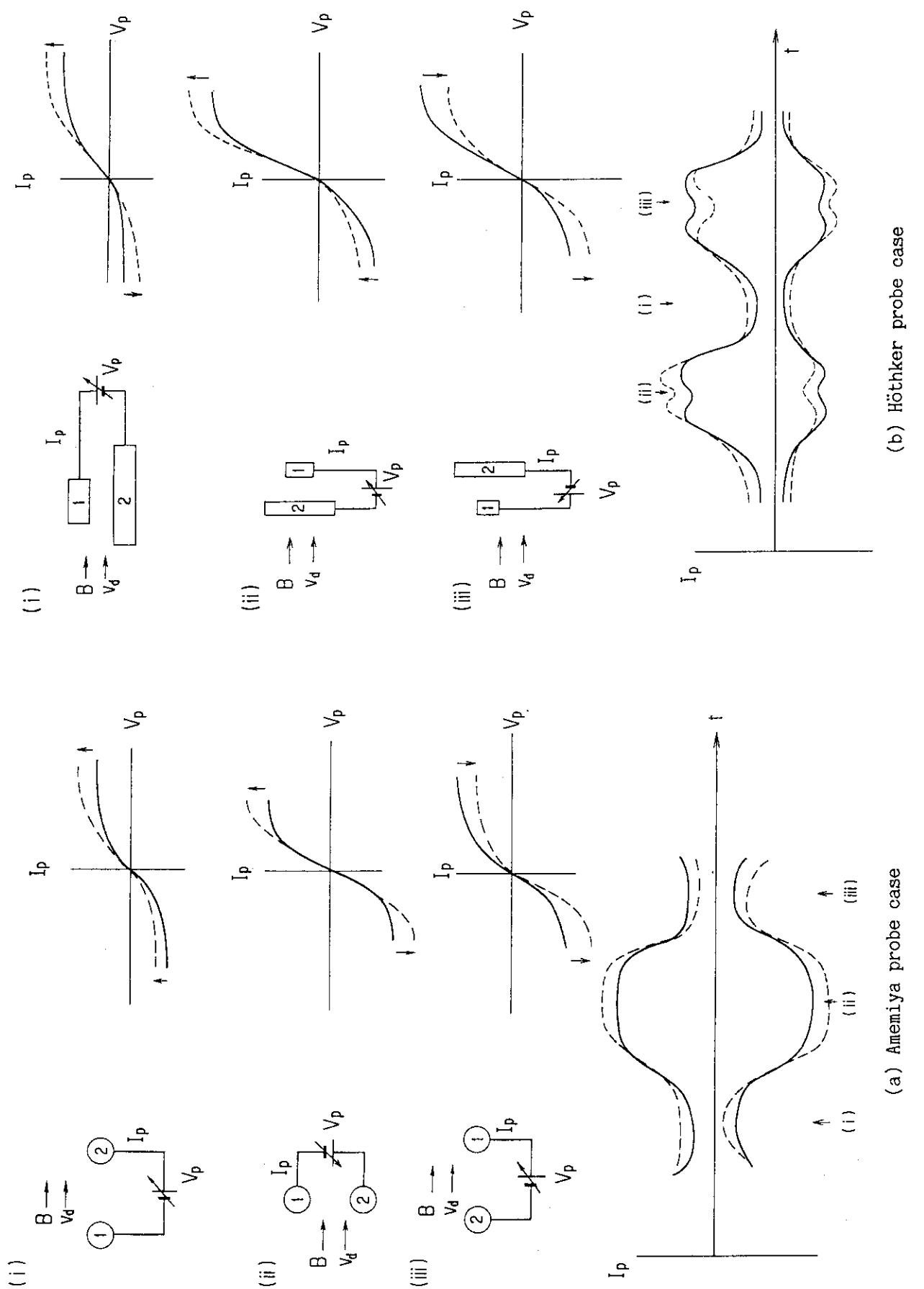


Fig.19 Flow and the probe characteristics

(a) Amemiya probe case

(b) Höthker probe case

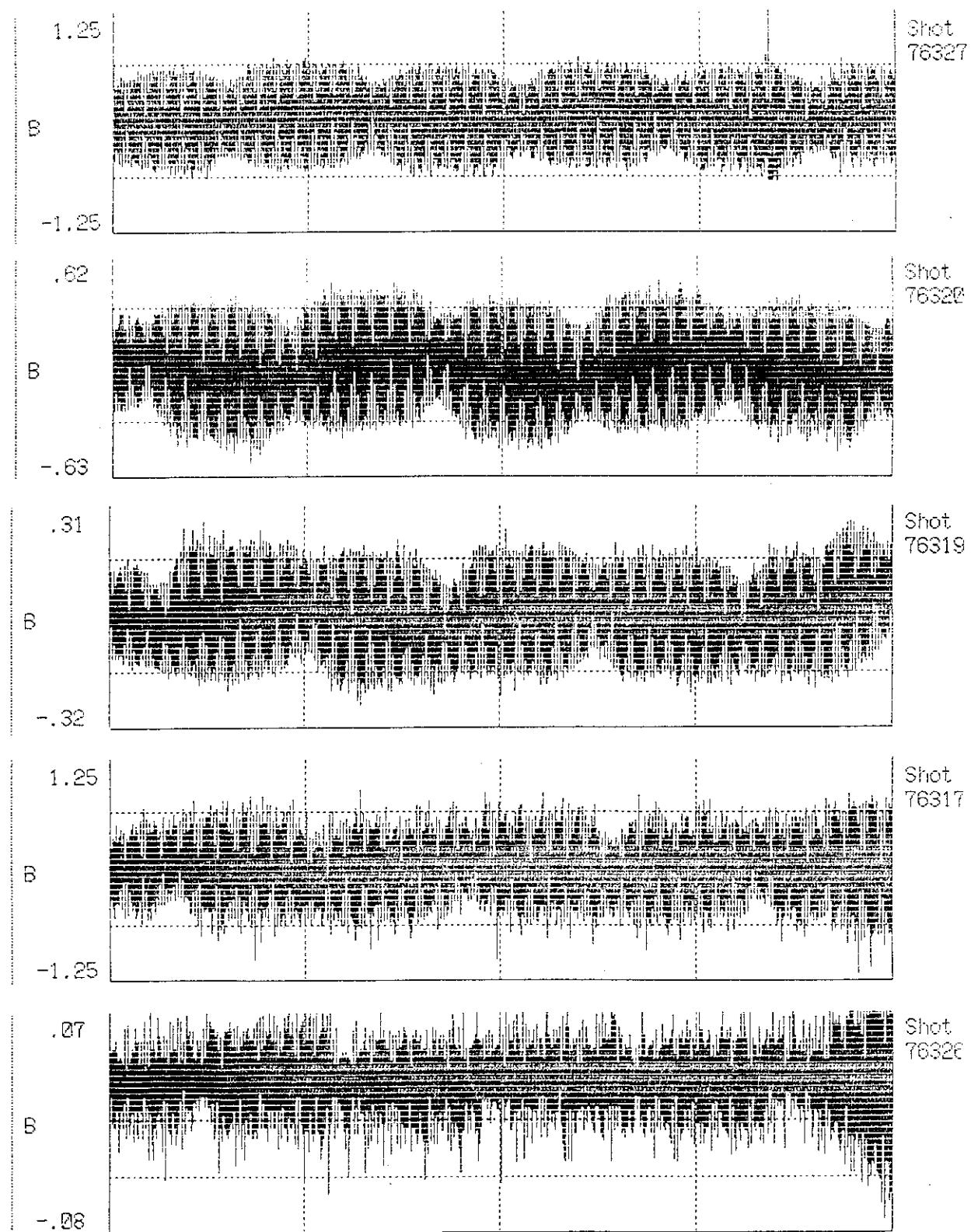


Fig.20 Radial dependence of raw data by Höthker probe, in which we can see the effect of the flow. The position of the probe approaches to sparatorix from up to down

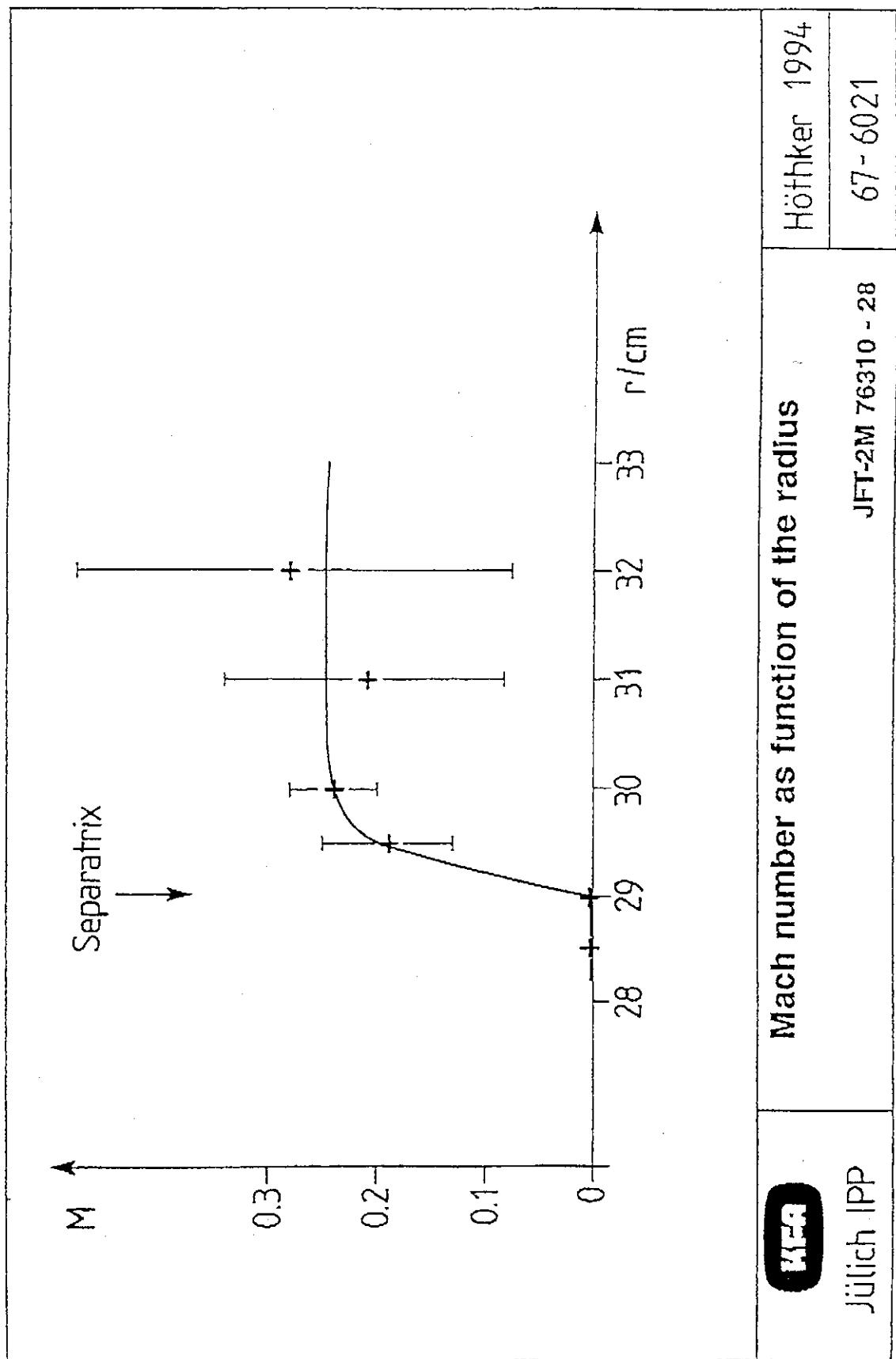


Fig.21 Radial dependence of Mach number estimated by Höthker probe

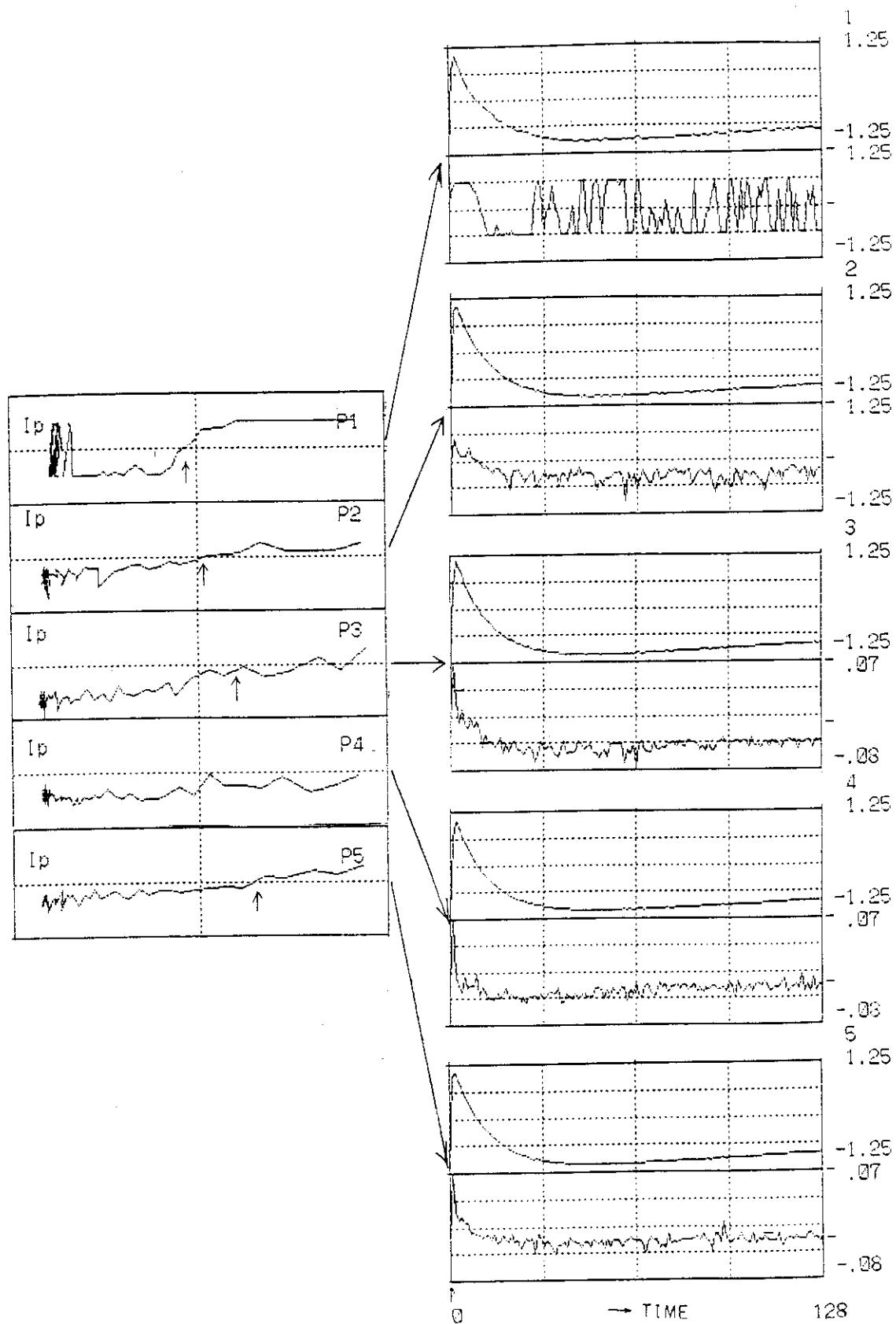


Fig.22 Raw data of Ion toothbrush probe including time behavior of the probe current and the probe voltage. Arrows in the light figure indicates the variation of floating potential.

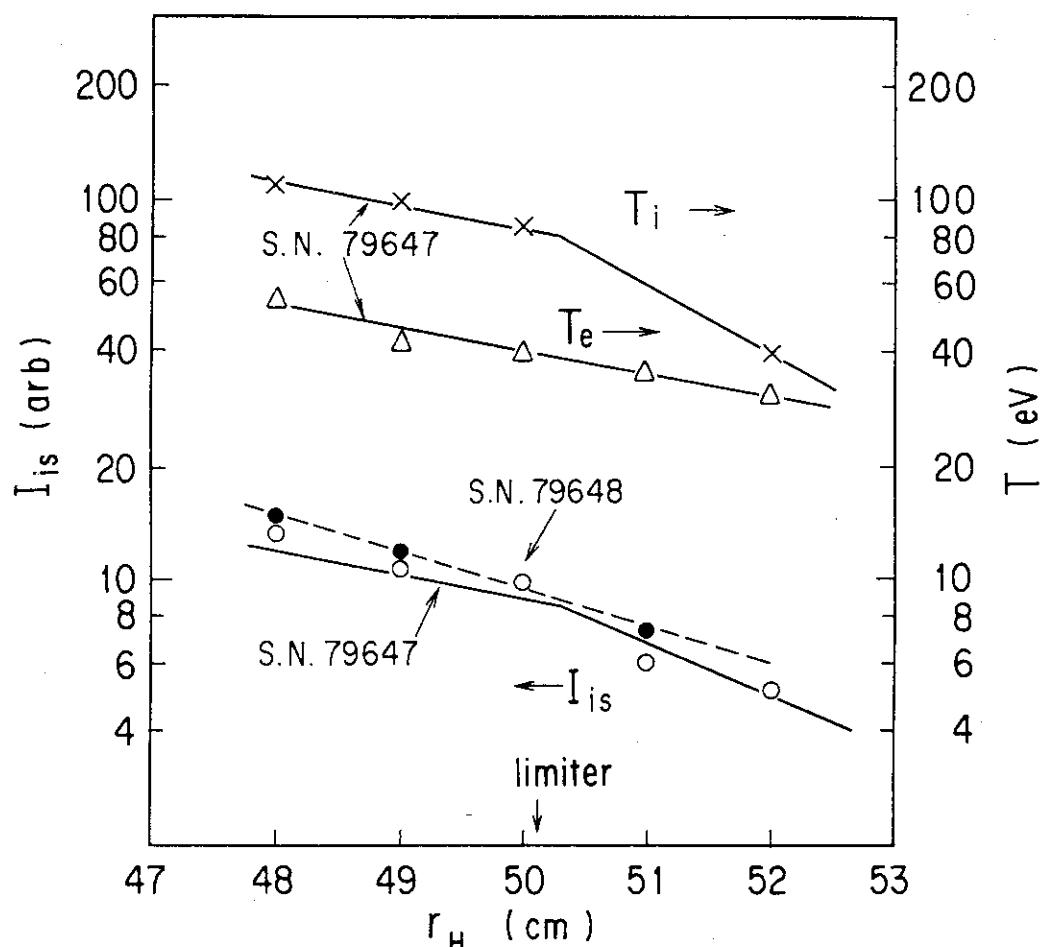


Fig. 23 Plasma profile obtained by ion toothbrush probe

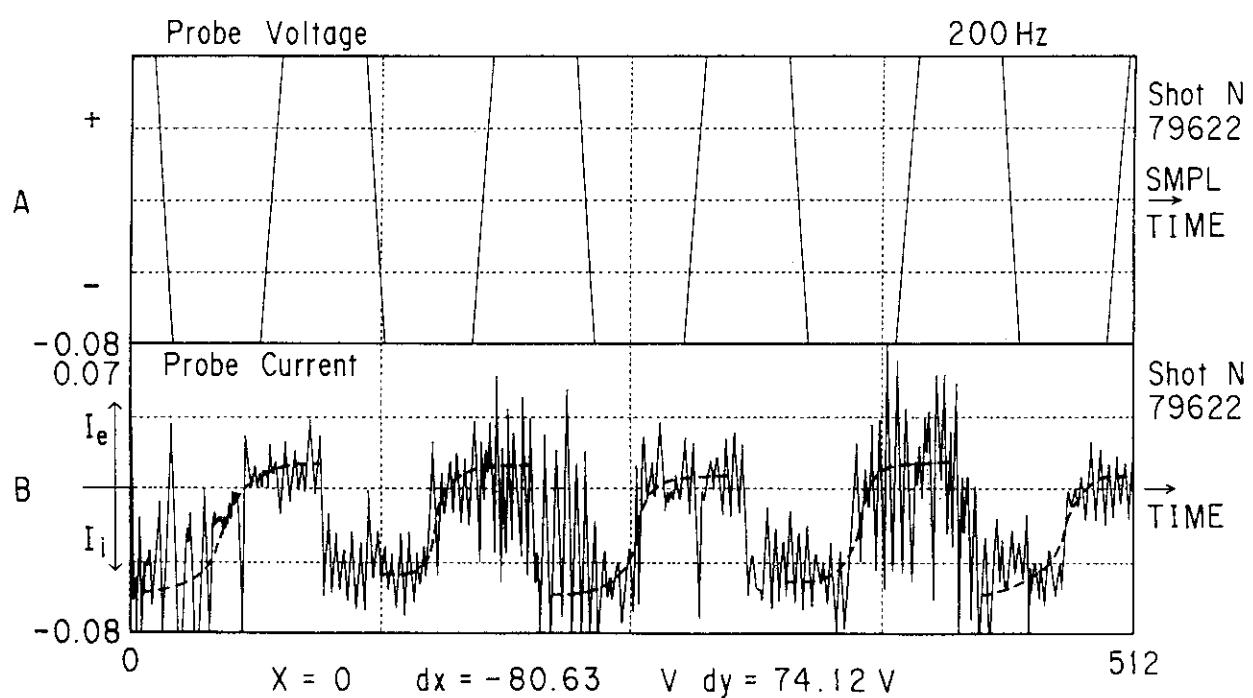


Fig. 24 Raw data of Katsumata probe. Up trace is probe voltage and down is probe current against time

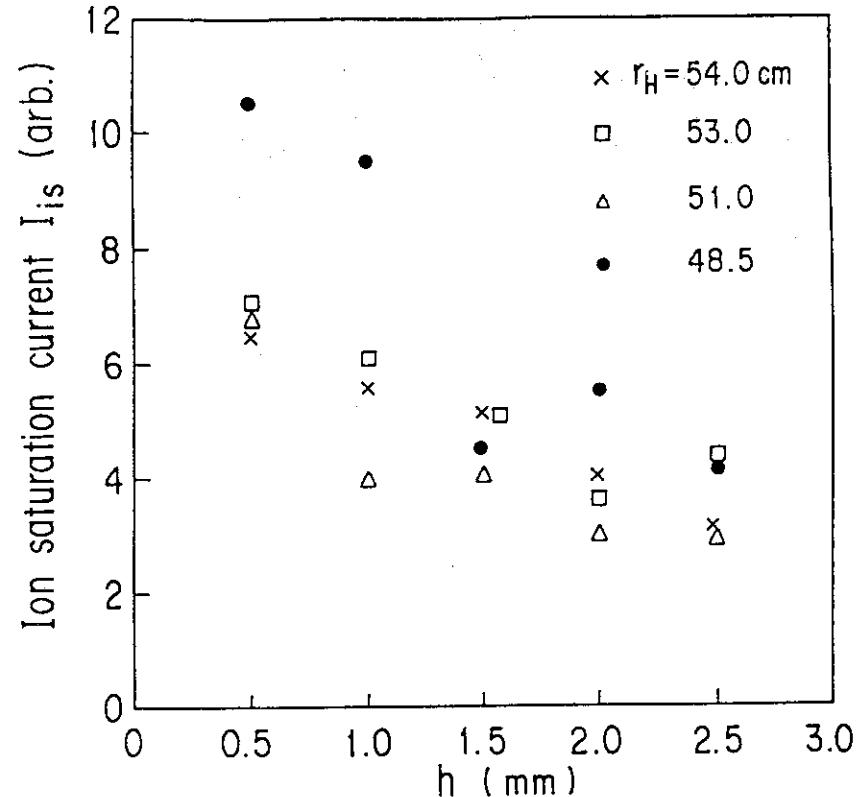
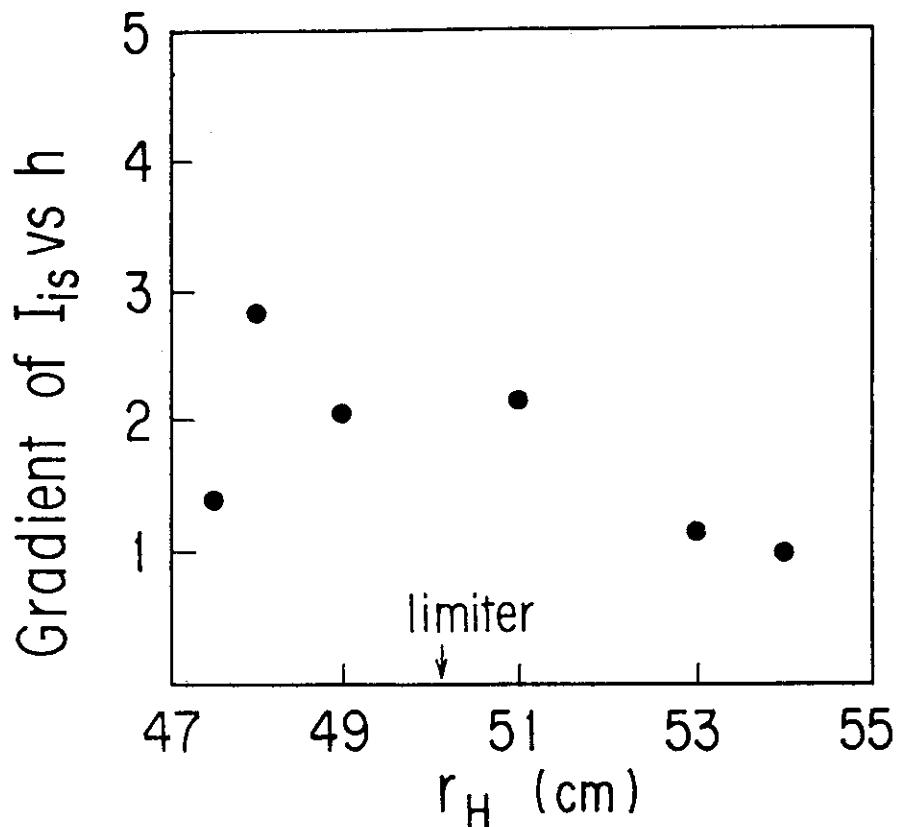
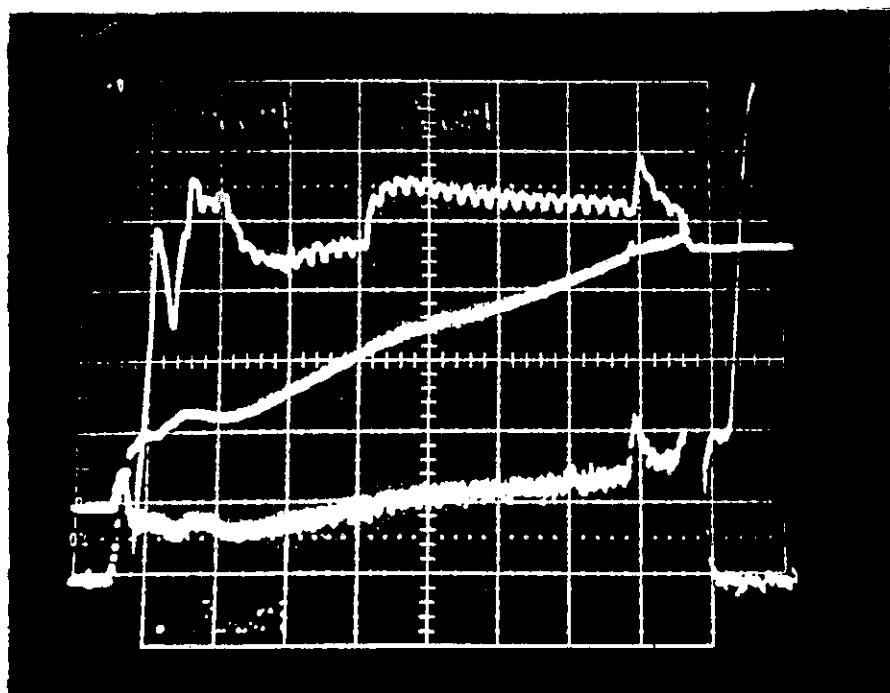
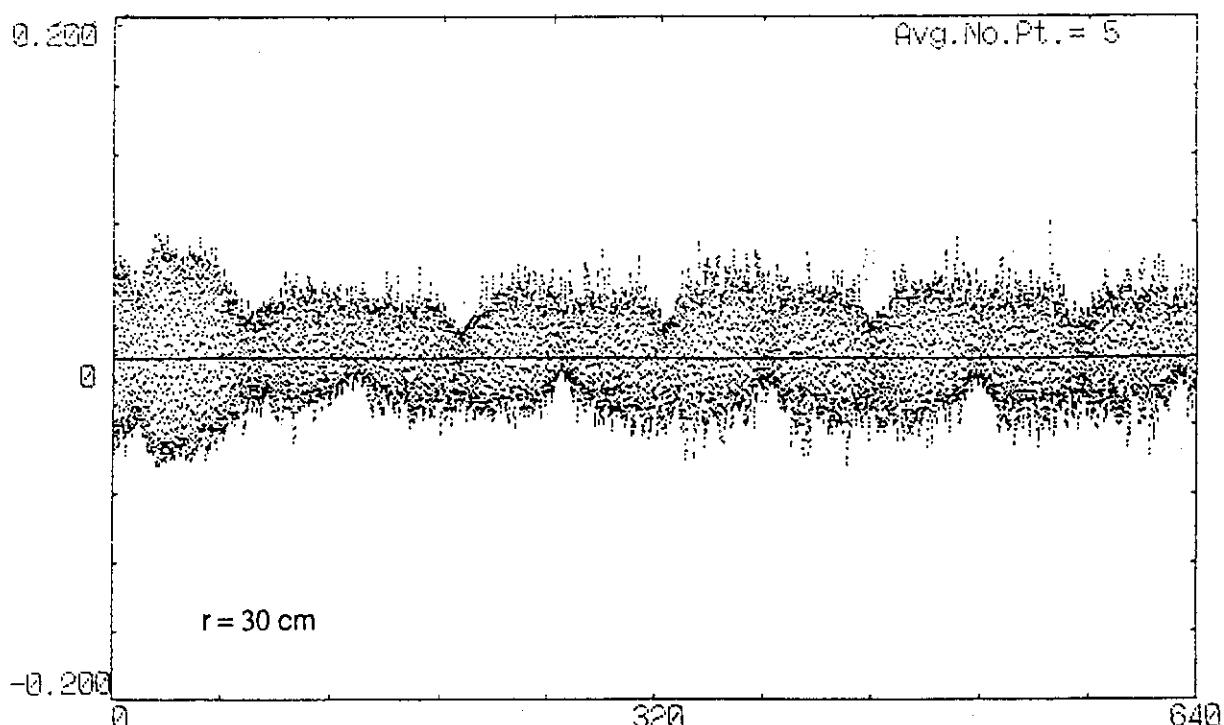
(a) Radial profile of the ion saturation current I_{is} against barrier h (b) The gradient of I_{is} against h , which may give the information of ion temperature

Fig.25 Data processing by Katsumata probe

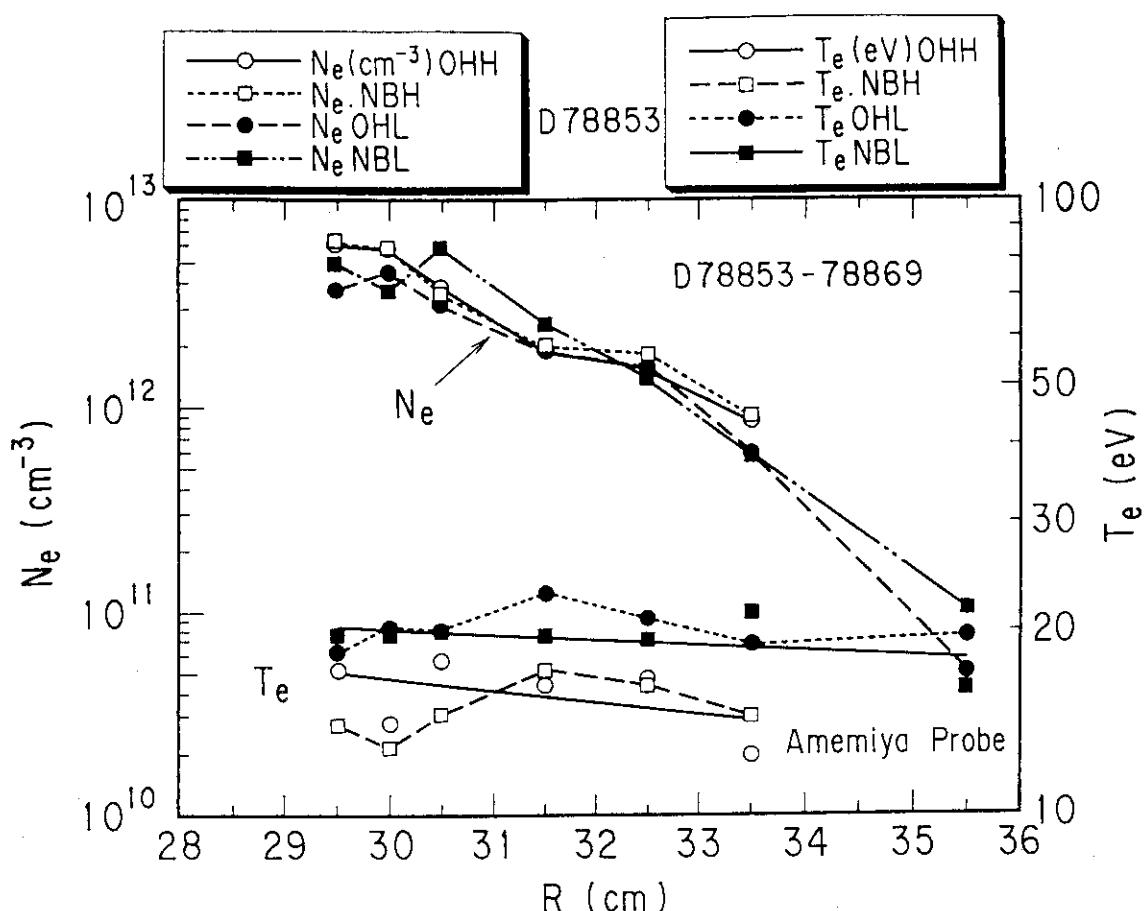
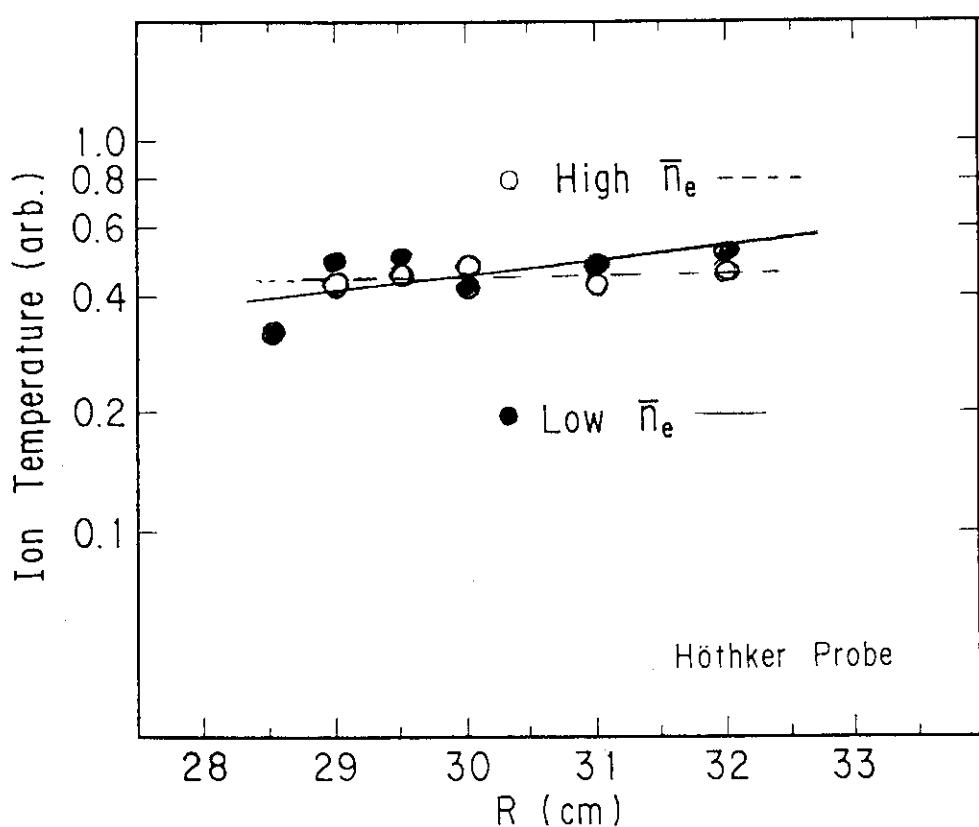


(a) Time behavior of radiation loss, density and the loop voltage in JFT-2M



(b) Time behavior of the probe current in Höthker probe, in which we can see the dip of the current gradually becomes shallow indicating the increasing ion temperature

Fig.26 Time behavior of main plasma density in JFT-2M and the Höthker probe characteristics in SOL

(a) Radial dependence of electron temperature T_e and density n_e by Amemiya probe

(b) Radial dependence of ion temperature by Höthker probe

Fig.27 Density dependence parameter

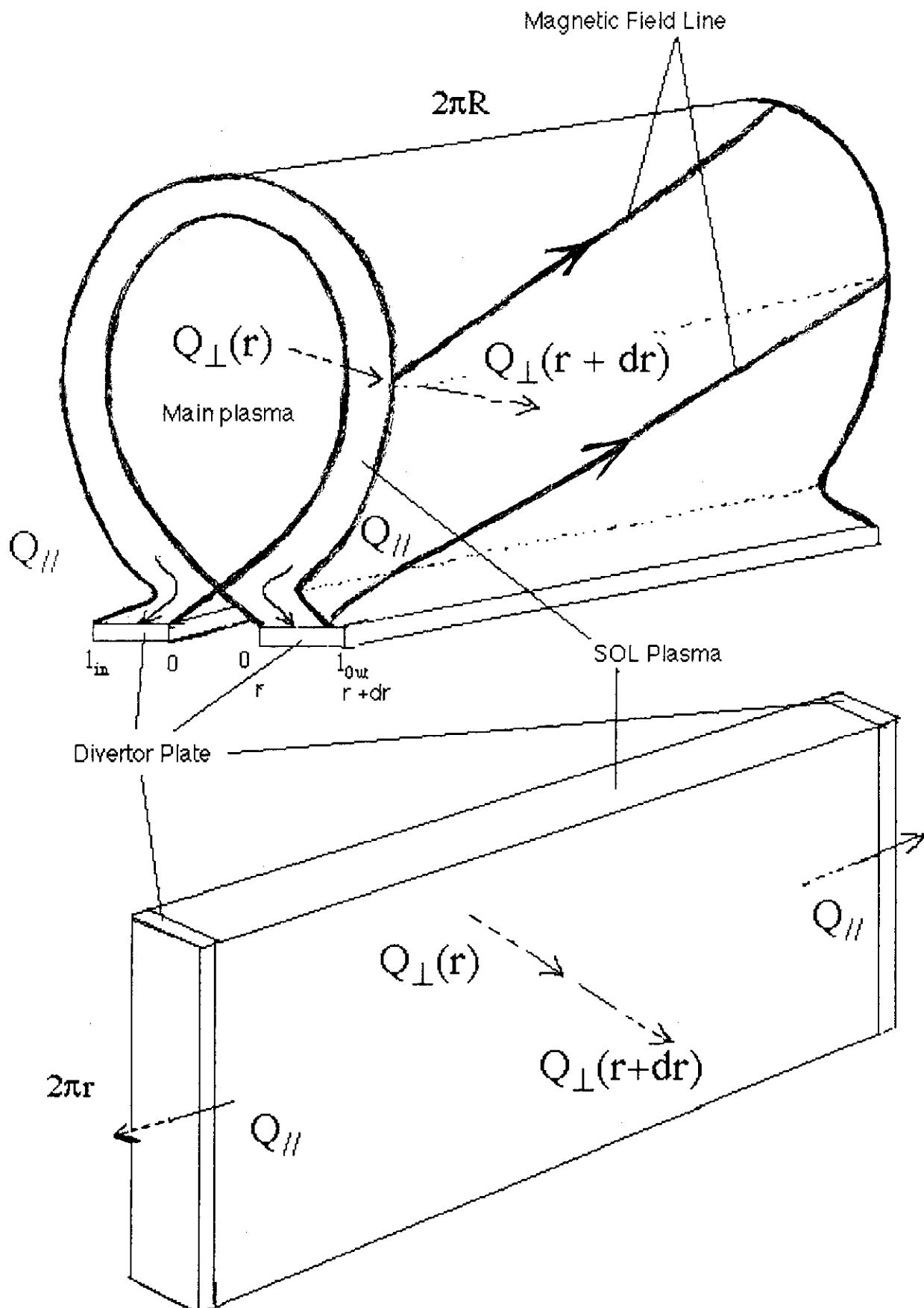


Fig.28 The boundary model represented by a finite cylindrical plasma for the transport study

Appendix

Table A-1 Source program of rotating double probe

```

1000 '=====Locrey 822A / KATTEN PROB=====
1020 '=====Ver 1.0 ===== Nov. 25.1993 =====
1030 'SAVE "KATTEN.BAS",A
1030 CLEAR 41100
1050 DEFINT H,A,F,D,I-K
1060 SCREEN 3,0,0,1
1100 CONSOLE 0,25,0,1
1110 CLS 3
1120
1130
1140 DIM DT(16385),DT2(16385)
1150 DIM DC$X%(100),DC$X%(100)
1160 DIM SFROM$(8)
1170 DIM DM$1151 : TM=0
1180 MAXZ=1000 : TM=0
1190 DATN=16384
1200 DATN=16384
1220 XST=1
1230
1240 YOFF=0 : YFSR=DATA : XC$L=1
1250 XG=0 : XFP=512/XFSR
1260 YOFF=0 : YFSR=2048 : YBL=0
1280 YG=0 : YP=3048/YFSR
1290
1300 XM0=0 : YM1=511 : YM0=2048 : YM1=2047
1310 XMAK=0 : XC$L11:XCSL
1320 XREF=0 : YREF=2048 : YREF2=2048
1330 XREF=0 : YREF=2048 : YREF2=2048
1340 FIPATH4="C:"
1350 FILPATHE4="C:"
1360
1370
1380 NB212=4
1390 NB501=8
1400 SHN0=0 : SHN02=SHNO
1410 D$PCH=1
1420 PTS=0
1430
1440 FREQ=5
1450 XUNO=0
1460
1470 RESTORE "BCANAC"
1480 FOR I=0 TO 7 : READ SFRQ$(I) : NEXT I
1490
1500 NOC=0
1510
1520 IF CFLACK<>1 THEN SCAMO
1530 D$F SEG$GPTR(2) : BLOAD "BCANAC.BIN",4H0
1540 GOSUB BCANAC
1550 CALL ENCFZ
1560
1570 OPEN "COM1:N01IN" AS #2
1580 GOSUB SETDB
1590 IF CFLACK>0 OR CFLACK<1 THEN XST=16
1600 IF CFLACK<>1 THEN SCAMO
1610 D$F SEG$GPTR(2) : BLOAD "BCANAC.BIN",4H0
1620 IF CFLACK<>1 THEN SCAMO
1630 DEF SEG$GPTR(2) : BLOAD "BCANAC.BIN",4H0
1640 GOSUB BCANAC
1650 CALL ENCFZ
1660
1670 OPEN "COM1:N01IN" AS #2
1680 GOSUB SETCOND
1690 FLAG0
1700
1711 *SCAMO
1720 ON ERROR GOTO *ERROR
1730 LOCATE 60,21 : PRINT "set CANAC active [1] or not [0] ->" : CFLAG
1740 IF CFLACK>0 OR CFLACK<1 THEN XST=16
1750 GOSUB *ARROW
1760 GOSUB *SETCOND
1770 GOSUB *SETDB
1780 GOSUB *ON
1790 *MAIN1
1800
1810 GOSUB *GRID
1820 CLS 2
1830 LOCATE 60,21 : COLOR 6 : PRINT "W1LINE" : COLOR 7
1840 GOSUB *PLOTD
1850 GOSUB *PLOTU
1860 LOCATE 60,21 : PRINT " "
1870 GOSUB *GRAPH
1880 LOCATE 60,21 : COLOR 6 : PRINT "W2LINE" : COLOR 7
1890 GOSUB *PLOTD
1900 LOCATE 60,21 : PRINT " "
1910 GOSUB *GRAPH
1920 LOCATE 60,21 : COLOR 6 : PRINT "W3LINE" : COLOR 7
1930 GOSUB *PLOTD
1940 LOCATE 60,21 : PRINT " "
1950 GOSUB *GRAPH
1960 LOCATE 60,21 : COLOR 6 : PRINT "W4LINE" : COLOR 7
1970 GOSUB *PLOTD
1980 LOCATE 60,21 : PRINT " "
1990 GOSUB *GRAPH
2000 LOCATE 60,21 : COLOR 6 : PRINT "W5LINE" : COLOR 7
2010 GOSUB *PLOTD
2020 LOCATE 60,21 : PRINT " "
2030 GOSUB *GRAPH
2040 LOCATE 60,21 : COLOR 6 : PRINT "W6LINE" : COLOR 7
2050 GOSUB *PLOTD
2060 LOCATE 60,21 : PRINT " "
2070 GOSUB *GRAPH
2080 LOCATE 60,21 : COLOR 6 : PRINT "W7LINE" : COLOR 7
2090 GOSUB *PLOTD
2100 LOCATE 60,21 : PRINT " "
2110 GOSUB *GRAPH
2120 LOCATE 60,21 : COLOR 6 : PRINT "W8LINE" : COLOR 7
2130 GOSUB *PLOTD
2140 LOCATE 60,21 : PRINT " "
2150 GOSUB *MEAS
2160 LOCATE 60,21 : PRINT " "
2170 INITFCG=0
2180 GOSUB *GRAPH
2190 GOSUB *GRAPH
2200 GOSUB *GRAPH
2210 RETURN : MAIN
2220 LOCATE 60,22 : PRINT SPC(79)
2230 ON KEY GOSUB *SETTRG
2240 GOSUB *K1OPEN
2250 LOCATE 74,23 : PRINT "TRIG"
2260 GOSUB *MEAS
2270 GOSUB *K1OFF
2280 LOCATE 74,23 : PRINT " "
2290 *ONHELP
2300 *HELP OFF
2310 *IF MODE=1 AND CFLACK>0 THEN GOSUB *C.OFF
2320 LOCATE 60,21 : PRINT " "
2330 LOCATE 60,21 : PRINT " "
2340 LOCATE 60,21 : PRINT SPC(78)
2350 GOSUB *GRAPH
2360 RETURN
2370
2380 *GRAPH
2390 LOCATE 60,21 : COLOR 6 : PRINT "W1LINE" : COLOR 7
2400 LOCATE 60,21 : COLOR 6 : PRINT "W2LINE" : COLOR 7
2410 GOSUB *PLOTD
2420 GOSUB *PLOTU
2430 LOCATE 60,21 : PRINT " "
2440 GOSUB *GRAPH
2450
2460 *GRID
2470 VIEW(0,19)-(639,367)
2480 WINDOW(XW0,YW0)-(XW1,YW1)
2490 LINE(XW0,YW0)-(XW1,YW1),5,B,$HAAAA
2500 VIEW(64,20)-(576,170)
2510 WINDW(XW0,YW0)-(XW1,YW1)
2520 CLS 2
2530 XOK=(XW1-XW0)/4
2540 YOK=(YW1-YW0)/4
2550 FOR I=1 TO 4
2560 LINE(XW0,YW0*(I-2))-(XW1,YW1),5,B,$HCCCC
2570 LINE(XW0,YW0)-(XW1,YW1),6,$HCCCC
2580 NEXT I
2590 LINE(XW0,YW0)-(XW1,YW1),5,B
2600 VIEW(64,170)-(576,320)
2610

```

```

3390 CLS 2
2620 FOR I=1 TO 4
2640 LINE (XW0,YW0)-(I-2)-(XW1,YW1),5 ,4HCCCC
2660 LINE (XW1,YW0)-(XW1,YW1),6 ,4HCCCC
2680 NEXT I
2690 LINE (XW0,YW0)-(XW1,YW1),5,B
2690 RETURN
2710
2710 PLOT()
2720 IF INT(PLG)=1 THEN RETURN
2730 VIEW(55,20)-(60,120)
2740 WINDOW(XW0,YW0)-(XW1,YW1)
2750 GOSUB 2
2750 LINE (64,20)-(576,170),
2750 WINDOW(XW0,YW0)-(XW1,YW1)
2760 XP1=0
2760 YP1=(-DT1(XW0)+YOFF*20.8)*YP2
2774 IF YP1>YW0 THEN YP1=YW0-10
2785 IF YP1<YW1 THEN YP1=YW1+10
2810 FOR I=XOFF TO XOFF+XPSP STEP XSTZ
2820 XP=(I-XOFF)*XP2
2830 YP=(-DT1(I))+YOFF*20.4)*YP2
2840 IF YP>YW0 THEN YP=YW0-10
2850 IF YP<YW1 THEN YP=YW1+10
2860 LINE (XP1,YP1)-(XP,YP),7
2870 XP1=XP1+P
2880 NEXT I
2890 IF XSP<20.8 THEN XSTZ=1 ELSE XSTZ=KST
2910 VIEW(64,170)-(576,320),
2910 WINDOW(XW0,YW0)-(XW1,YW1)
2920 XP1=0
2930 YP1=(-DT1(XOFF)+YOFF*20.4)*YP2
2934 IF YP1>YW0 THEN YP=YW0-10
2939 IF YP1<YW1 THEN YP=YW1+10
2940 IF XSP<20.8 THEN XSTZ=1 ELSE XSTZ=KST
2950 FOR I=XOFF TO XOFF+XPSP STEP XSTZ
2960 XP=(I-XOFF)*XP2
2970 YP=(-DT1(I))+YOFF*20.4)*YP2
2980 IF YP>YW0 THEN YP=YW0-10
2989 IF YP<YW1 THEN YP=YW1+10
3000 LINE (XP1,YP1)-(XP,YP),7
3010 XP1=XP1+P
3020 NEXT I
3030 RETURN
3040
3050
3060 *DATMAX
3070 LOCATE 60,21:COLOR 6:PRINT " Calcu :COLOR ?"
3080 DMAX=1:IMAX=0
3090 IF I>IMAX+1 TO 0 STEP -1
3100 IF DMAX<DT((1)) THEN DMAX=DT((1)):IMAX=1
3110 NEXT I
3120 ACSII=IMAX
3130 LOCATE 60,21:PRINT ..
3140 LOCATE 60,21:PRINT ..
3150 RETURN
3160
3170 .
3180 *DCLR
3190 DCLRFLAG=1
3200 LOCATE 57,22 : PRINT "REF : / ABS : *"
3210 FOR I=0 TO DATN
3220 DT((1))=0 : DT2((1))=0
3230 NEXT I
3240 IF DCLRFLAG=1 THEN GOSUB *GRAPH : DCLRFLAG=0
3250 RETURN
3260
3270
3280 *CURSOLX
3290 LOCATE 57,22 : PRINT "REF : / ABS : *"
3300 XY$=INKEY$()
3310 IF XY$=CHR$(4HID) THEN XCSL=CSL-1 : GOSUB *CURSOLX
3320 IF XY$=CHR$(4HIC) THEN XCSL=CSL+1 : GOSUB *CURSOLX
3330 IF XY$=CHR$(4HF) THEN XCSL=CSL-20: GOSUB *CURSOLX
3340 IF XY$=CHR$(4HE) THEN XCSL=CSL+20: GOSUB *CURSOLX
3350 IF XY$="." THEN GOSUB *RECSL
3360 IF XY$="," THEN GOSUB *PRCSL
3370 IF XY$=CHR$(4HD) OR XY$=CHR$(4HIB) THEN LOCATE 57,22:PRINT SPC(16):RETURN
3380 GOTO -CURSOLX

```

```

5010 '
5020 '
5030 *CVDISP
5040 LOCATE 15,21 : PRINT " XFSR+XOFF;" "
5050 CDIS=INT(DT(XCSL)-REF) / 2048*500 / 100
5060 LOCATE 27,21 : PRINT " dx = " ; CDIS;" v"
5070 CDIS=INT(DT2(XCSL)-REF2) / 2048*500 / 100
5080 LOCATE 42,21 : PRINT " dy = " ; CDIS;" v"
5090 RETURN
5100 '
5110 '
5120 *ORG
5130 XD=0 : YD=0
5140 XOFF=0 : YOFF=0 : XCSL=256
5150 XS=0 : TG=0
5160 GOSUB *XOFFSET : GOSUB *YOFFSET
5170 GOSUB *MAG : GOSUB *MAG
5180 GOSUB *STCSET : GOSUB *GRAPH
5190 RETURN
5200 '
5210 *ARROW
5220 VIEW(0,0)-(639,399)
5230 CLS 2
5240 LINE(10,0)-(10,10),6
5250 LINE(10,0)-(8,4),6
5260 LINE(10,0)-(12,4),6
5270 GFT@8,0)-(12,10),6
5280 CLS 0
5290 GFT@8,10)-(12,20),6CSX%
5300 CLS 2
5310 RETURN
5320 '
5330 *MENU
5340 CONDUIT *MENUBOX : GOSUB *BOX
5350 LINE(5,21,1)-(6,22),4,B
5360 AG=0
5370 RESTORE *MENU
5380 FOR I=0 TO 9
5390 LOCATE 8*I+1,0 : READ MENU$[I] : PRINT MENU$[I]
5400 KG=(8-I)*MSTEP : GOSUB *BOX
5410 NEXT I
5420 RETURN
5430 DATA SET,Mesa,Curso,Expand,Shift,Clear,H,COPY,F load,F save,Quit
5440 '
5450 *SELBOX
5460 MYS$INKEY$[AHID] THEN MYS=MKG-MSTEP : GOSUB *BOX
5470 IF MYS$CHR$(AHID) THEN MYS=MKG-MSTEP : GOSUB *BOX
5480 IF MYS$CHR$(AHIC) THEN MYS=MKG-MSTEP : GOSUB *BOX
5490 IF MYS$CHR$(AHIC) THEN MYS=MKG-MSTEP : GOSUB *BOX
5500 IF MYS$CHR$(AHIF) THEN MYS=MKG-MSTEP : GOSUB *BOX
5510 IF MYS$CHR$(AHIF) THEN MYS=MKG-MSTEP : GOSUB *BOX
5520 IF MYS$CHR$(AHIB) THEN MYS=MKG-MSTEP : GOSUB *BOX
5530 RETURN
5540 '
5550 *MENUBOX
5560 KG=6
5570 MAIN$=0 : MYINT=0
5580 MAIN$=12 : MYINT=0
5590 MSTEP=8 : MYSTEP=0
5600 MSTEP=7,8 : MYSTEP=0
5610 RETURN
5620 '
5630 '
5640 '
5650 VIEW(0,0)-(639,399)
5660 WINDOW(0,0)-(80,25)
5670 IF MYS=MMAX THEN MYS=MMIN
5680 IF MYS=MMIN THEN MYS=MMAX
5690 IF MYS=MMAX THEN MYS=MMIN
5700 IF MYS=MMIN THEN MYS=MMAX
5710 LINE(MKG+2,MKG,MYOFF) : MYS=MSIZE+MYOFF
5720 LINE(MKG+2,MKG,MYOFF) : MYS=MSIZE+MYOFF
5730 MKG1=MAG : MYS1=MGS
5740 RETURN
5750 '
5760 '
5770 *FILE
5780 CLS 5
5790 FILES FILPATH+V$1A1" : PRINT "
5800 FILES FILPATH+V$1A1" : PRINT "
5810 LOCATE 20,22 : INPUT "Load SHOT No. ?" : PRINT "

```

```

5820 LOCATE 0,22 : PRINT SPC(79)
5830 LOCATE 5,22 : PRINT "ID *FILENAME*",".DA1"
5840 LOCATE 25,22 : INPUT "OR ? THEN HIT [Y] -> ",XX$*
5850 IF XXX$>"Y" AND XX$*<>"Y" THEN *FILE
5860 LOCATE 0,22 : PRINT SPC(79)
5870 IF FILENAME$="." THEN LOCATE 0,22 : PRINT SPC(79) : GOTO *FILE
5880 OPEN FILEPATH$+"D"+FILENAME$+".DA1" FOR INPUT AS #1
5890 PRINT FILEPATH$+"D"+FILENAME$+".DA1" : INPUT XX$*
5900 LOCATE 60,21:COLOR 6:PRINT "Loading":COLOR 7
5910 GOSUB 60,21:COLOR 6:PRINT "Loading":COLOR 7
5920 INPUT #1,DT(1)
5930 FOR I=0 TO DATA
5940 INPUT #1,DT(1)
5950 NEXT I
5960 LOCATE 0,21 : PRINT SPC(79)
5970 CLOSE #1
5980 SHDO=VAL(MIDS(FILENAME$ 1,1,10))
5990 *FILE
6000 LOCATE 0,22 : INPUT "Load B filename ?????.DBN -> ",FILENAME$*
6010 LOCATE 0,22 : PRINT FILENAME$*
6020 LOCATE 23,22 : INPUT "OK? OR THEN HIT [Y] -> ",XXX$*
6030 LOCATE 0,22 : PRINT SPC(79)
6040 LOCATE 0,22 : PRINT XX$>"Y" THEN GOTO *FILE
6050 IF XX$>"Y" AND XX$*<>"Y" THEN GOTO *FILE
6060 IF FILENAME$="" THEN LOCATE 0,22 : PRINT SPC(79) : GOTO *FILE
6070 *FILE
6080 OPEN FILEPATH$+FILENAME$*
6090 OPEN FILEPATH$+FILENAME$ MIDS(FILENAME$,1,10)
6100 LOCATE 60,21:COLOR 6:PRINT "Loading":COLOR 7
6110 INPUT #1,DT(1)
6120 FOR I=0 TO DATA
6130 INPUT #1,DT(1)
6140 NEXT I
6150 LOCATE 0,21 : PRINT SPC(79)
6160 CLOSE #1
6170 SHDO2=VAL(MIDS(FILENAME$,1,10))
6180 XSP=DATA : XPF=512/XFSP
6190 XSP=DATA : XPF=512/XFSP
6200 CSLX=0
6210 LOCATE 60,21:PRINT " "
6220 *FILE
6230 LOCATE 60,21:PRINT " "
6240 LOCATE 0,22 : PRINT " "
6250 LOCATE 60,21:COLOR 6:MENU:GOSUB *GRAPH : GOTO *MAIN
6260 RETURN
6270 *FILE
6280 *FILE
6290 CLS 3
6300 LOCATE 15,0 : PRINT DATA FILES
6310 FILES FILEPATH$+"*.DA1" : PRINT " : PRINT"
6320 LOCATE 0,22 : PRINT " : SHDO : PRINT"
6330 LOCATE 20,22 : INPUT "Shot No. :SHDO : "
6340 LOCATE 0,22 : PRINT SPC(79) : FILENAME$*
6350 *FILENAME$ MIDS(FILENAME$ 2,8)
6360 LOCATE 5,22 : PRINT "D"+FILENAME$+".DA1"
6370 LOCATE 25,22 : INPUT "OK ? THEN HIT [Y] -> ",XXX$*
6380 IF XXX$>"Y" AND XX$*<>"Y" THEN *FILE
6390 LOCATE 0,22 : PRINT SPC(79) : GOTO *FILE
6400 IF FILENAME$="." THEN LOCATE 0,22 : PRINT SPC(79) : GOTO *FILE
6410 OPEN FILEPATH$+"D"+FILENAME$+".DA1" FOR OUTPUT AS #1
6420 LOCATE 60,21:COLOR 6:PRINT "Saving":COLOR 7
6430 PRINT #1,DT(1)
6440 FOR I=0 TO DATA
6450 PRINT #1,DT(1)
6460 LOCATE 0,21:PRINT SPC(79)
6470 CLOSE #1
6480 OPEN FILEPATH$+"D"+FILENAME$+".DA1" FOR OUTPUT AS #1
6490 LOCATE 60,21:COLOR 6:PRINT "Saving":COLOR 7
6505 LOCATE 0,21:COLOR 4:PRINT "Saving":COLOR 7
6510 PRINT #1,DT(1)
6520 FOR I=0 TO DATA
6530 PRINT #1,DT(1)
6540 NEXT I
6550 LOCATE 0,21:PRINT SPC(79)
6560 CLOSE #1
6570 *FILE
6580 LOCATE 0,22 : PRINT SPC(79)
6590 CLS 3:GOSUB *MENU:GOSUB *GRAPH : GOTO *MAIN
6610 RETURN

```

```

7420 IF K2<0 OR 9<KS THEN *SETCOND1: GOSUB *GRAPH: GOSUB *SDSP1: GOSUB *SETCH1: RETURN * GOTO *MA
7430 IF K2=0 THEN CLS 3: GOSUB *MENU: GOSUB *GRAPH: GOSUB *SDSP1: GOSUB *SNOC: *S8212: *FPATH
7450 CLS
7460 GOTO *SETCOND1
7470
7480 *SSHOT
7490 LOCATE 40, 2 : INPUT "set Shot number >" : STEM
7500 LOCATE 20, 22 : INPUT "IF ON THEN Hit [Y] " : XKC$*
7510 IF XKC$>"y" AND XKC$<"y" THEN BEEP : RETURN
7520 SINO=STEMP : SHNO=SINO
7530 LOCATE 0, 2 : PRINT SPC(78)
7540 RETURN
7550 *DDSP1
7560 *DDSP1
7570 STEM=1
7580 SUDSPMAX=2 : NOC
7590 IF STEM>1 OR STEM>2 THEN GOSUB *XBEEP : RETURN
7600 DSPP=DSPP+1
7610 DSPP=STEMP : PRINT SPC(78)
7620 RETURN
7700 LOCATE 0, 4 : PRINT SPC(78)
7710
7720 *STRIGUALLY
7730 LOCATE 60, 6 : PRINT " 0 - 7 "
7740 LOCATE 40, 7 : INPUT "set Post Trig Delay ->" : DTTRGL
7750 IF DTTRGL=0 OR DTTRGL>Y THEN GOSUB *XBEEP : RETURN
7760 LOCATE 0, 7 : PRINT SPC(78)
7770 LOCATE 0, 7 : PRINT SPC(78)
7780 LOCATE 0, 8 : PRINT SPC(78)
7790 RETURN
7800
7810 *SSMPLCLK
7820 FRQ = 0 1 2 3 4 5 6 7
7830 LOCATE 40, 14 : PRINT "Ext 0.5k 2.5k 12.5k 25k 50k 100k
7840 LOCATE 40, 15 : PRINT "n Sample Clk" : PRINT " 500Hz"
7850 LOCATE 40, 16 : PRINT " 0 -- Ext 1 -- 50Hz"
7860 LOCATE 40, 16 : PRINT " 2 -- 2.5kHz 3 -- 25kHz"
7870 LOCATE 40, 17 : PRINT " 4 -- 5kHz 5 -- 100kHz"
7880 LOCATE 40, 18 : PRINT " 6 -- 50kHz 7 -- 1MHz"
7890 LOCATE 40, 12 : INPUT "set Sample Clock ->" : DSZET
7900 IF DSZET=0 OR DSZET>7 THEN GOSUB XBEEP : RETURN
7910 END=DSZET
7920 RETURN
7930
7940 *ENOC
7950 LOCATE 40, 16 : PRINT " Number of Channel
7960 LOCATE 40, 17 : PRINT " 0 : 2 ch 1 : 4 ch"
7970 LOCATE 40, 14 : INPUT "set Number of channel ->" : STEM
7980 STEM=1: NOC = 0 1 2 3 : 16 ch
7990
8000 > 15212/8 1 2 4 8
8010 > 15212/16 2 4 8 16
8020 15212/32 4 8 16 32
8030 NOC=STEMP>3 THEN GOSUB *XBEEP : RETURN
8040 LOCATE 0, 14 : PRINT SPC(78)
8050 RETURN
8060
8070 *SB212
8080 LOCATE 40, 16 : INPUT "set 8212 module number ->" : STEMPS
8090 IF STEMPS<1 OR STEMPS>23 THEN GOSUB *XBEEP : RETURN
8100 NOC2=STEMP
8110 LOCATE 0, 16 : PRINT SPC(78)
8120 RETURN
8130
8140 *FPATH
8150 LOCATE 40, 18 : INPUT "set PATH ->" : STEMPS
8160 IF STEMPS<1 THEN GOSUB *XBEEP : RETURN
8171 FPATHH=STEMP
8180 LOCATE 0, 18 : PRINT SPC(78)
8190 RETURN
8200
8210 *XBEEP
8220 *XBEEP

```

```

9050 RETURN
9060 SETRG : BEEP
9070 IF CFLAG THEN F=25:CALL CAMAC
9080 RETURN
9090
9100 *DLY
9110 N$=03 : CALL CAMAC
9120 F=26 : A=3 : CALL CAMAC
9130 A=2 : DL=2 : CALL CAMAC
9140 B=16 : A=3;DL=PR;CALL CAMAC
9150 DL=0:BS=1 INPUT "BURST LENGTH = <65535" DL
9160 F=16 : A=0 : CALL CAMAC
9170 RETURN
9180
9190 *ABORTM
9200 GOSUB JK10OFF
9210 CCS 3:GOSUB *MENU:GOSUB *GRAPH: GOSUB *KON : GOTO *MAIN
9220 *OTO *MAIN
9230 .
9240
9250 *ERROR
9260 IF ERR5 THEN *LILFCIN
9270 IF ERR53 THEN *BADDFL
9280 IF ERR56 THEN *BADDFL
9290 IF ERR61 THEN *BADDFL2
9300 IF ERR62 THEN *BADDRL
9310 IF ERR68 THEN *BADDFL2
9320 IF ERR70 THEN *BADDRL
9330 RESUME *MAIN
9340
9350 *LILFCIN
9360 LOCATE 2,24 : PRINT "<#Error> %G!<#>!%(%!)<#>!";
9370 RESUME *MAIN
9380 RESUME *MAIN
9390
9400 *ADEF12
9410 LOCATE 2,24 : PRINT "<#Error> %X!%XX%, $,_$D+$!$-$S:$";
9420 CLOSE #1
9430 GOSUB *HIT
9440 RESUME *MAIN
9450
9460 *ADEF12
9470 LOCATE 2,24 : PRINT "<#Error> %G!%XX%, $$$CQ$$$$G!%>";
9480 CLOSE #1
9490 GOSUB *HIT
9500 RESUME *MAIN
9510
9520 *BADDRL
9530 LOCATE 2,24 : PRINT "<#Error> %X!%XX%, $$,$$$%!X%>";
9540 GOSUB *HIT
9550 RESUME *MAIN
9560
9570 *HIT
9580 LOCATE 79,23 : INPUT "",XXX$ :CLS
9590 RETURN
9600 -----"CAMAC.BAS"-----
9610 *CAMAC
9620 **** CC/9800-01 CAMAC %% BASIC %%----%Q-%P, (MS-DOS HG) ****
9630 *** CURE=4H12: CURE=4H15
9640 *** SET1=4H12: SET1=4H15
9650 *** SETLN=4H12: SETLN=4H15
9660 *** RSTAT=4H1E: RLAM=4H1B
9670 *** BLKSET=4H24
9680 CAMAC=4H13 EXEC2=4H16: EXEC2=4H10
9690 SET1=4HRC: CUR1=4HRC
9700 SET1=4H12: CURE=4H12
9710 SETLN=4H12: SETLN=4H15
9720 CALL,BEST(N,A,P,DL,DH,NQ,NK)
9730 OUT &HD1,0
9740 BLKSET=4H24
9750 BLKW=4H27: BLKW=4H2A
9760 BLKW=4H12D: BLKHW=4H30
9770 SEP=4H33
9780 N=0,F=0:DL=0:DH=0:NQ=0
9790 CALL,BEST(N,A,P,DL,DH,NQ,NK)
9800 OUT &HD1,0
9810 RETURN
9820
9830 DATA "Ext","500Hz",0,2,"5kHz",2,5kHz,"25kHz",5kHz,"50kHz",100kHz"
9840 DATA "Ext","500Hz",0,2,"5kHz",2,5kHz,"25kHz",5kHz,"50kHz",100kHz"

```

```

10650   10660 *SRR '      == Send "SR" ==
10670 GOSUB *T1M1 : LINE INPUT #2,E$      ==
10680 IF E$>"R" THEN GOSUB *T1M1 : GOTO *SRR
10690 RETURN
10700
10710 *T1M1
10720 WHILE T>0
10730 T=T-.1 :GOSUB *T1M01
10740 WEND
10750 RETURN
10760
10770 *T1M1
10780 FOR Z=1 TO 10 : GOSUB *T1M01 : NEXT
10790 RETURN
10800
10810 *T1M01 : FOR Z=1 TO MAXZ : NEXT Z : RETURN
10820
10830 SETB 1STMO 1FSAI 1FSB1 1FSCL 1OSC1 1OSC2 1OSSH1 1GH+0.5 1DD1 1G "
10840 Z=1
10850 RETURN
10860
10870 *T1M1
10880 CONSOLE ^1,1
10890 BLKS=CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)
10900 KEY 1,"AB$":KEY 2,"SP CW":KEY 3,"SP CCW":KEY 4,"STOP":KEY 5,""
10910 KEY 6,"BLKS":KEY 7,BLK$ :KEY 8,BLK$ :KEY 9,BLK$ :KEY 10,BLK$
10920 RETURN
10930
10940 *KOFF : KEY(1) OFF : KEY(2) OFF : KEY(3) OFF : KEY(4) OFF
10950 CONSOLE ..0,1
10960 RETURN
10970
10980 FK1ONN : KEY(1) OFF: KEY(2) OFF: KEY(3) OFF: KEY(4) OFF: KEY(1G) ON
10990 KEY(1) ON
11000 CONSOLE ^1,1
11010 BLKS=CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)+CHR$(4H87)
11020 KEY 1,BLK$ :KEY 2,BLK$ :KEY 3,BLK$ :KEY 4,BLK$ :KEY 5,BLK$ :KEY 6,BLK$ :KEY 7,BLK$ :KEY 8,BLK$ :KEY 9,BLK$ :KEY 10,"TR1"
11040 RETURN
11050
11060 *K1OFF : KEY (9) OFF : KEY(10) OFF
11070 CONSOLE ..0,1
11080 RETURN
11090
11100 *E ===== END =====

```

Table.A-2 Source program of vertical ion probe

```

1000 1. Data Acquisition Program
1010 2. Lectroy 812A Data Acquisition Processor
1020 3. for Haburria Probe/Aux Controller Mode
1030 4. Version 1.0 by TOYO Corp. Aug. 10, 1984
1040 5.
1050 6. SAVE JFTS623.BAS
1060 7. CLEAR RH100
1070 8.
1080 DEFINT N,A,F,D,I-K
1090 SCREEN 3,0,0,1
1100 CONSOLE 0,25,0,1
1110 CCLS 3
1120 CCLS 3
1130 .
1140 .
1150 DIM DT$(4096),DT2$(4096)
1160 DIM DT$16(2,1024),YFPQ(8,2),YQQ(8,2),YPPQ(8,2)
1170 DIM XDPMX(8,2),YDPMX(8,2)
1180 DIM DC51X(100),DC52X(100)
1190 DIM SFRQ$(8)
1200 DIM DTN=128,2048
1210 XST=1 . Display Xaxis Step ( Matlab )
1230 XOFFF=0 : XFSF=DATN : XCSL=1
1240 X$= 0 : XPP=512/XFSF : XD=0
1250 YOFF=0 : YFSF=2048 . Temporal
1260 YOFF=0 : YFSF=2048/YFSF . Temporal
1270 Y$=0 : YPP=2048/YFSF
1280 Y$=0
1290 .
1300 FOR I=1 TO 7
1310 VFSQ(I,0)=2048 : VFG(I,0)=VFSQ(I,0) : VOFQ(I,0)=0
1320 VFSQ(I,1)=64 : VFG(I,1)=5 : VOFQ(I,1)=0
1330 NXST 1
1340 .
1350 XW0=0 : XW1=511 : YW0=-2048 : YW1=2047
1360 XCSL=0 : XCSL1=XCSL
1370 YREF=0 : YREF=2048 : YREF=2048
1380 VSCL=100 : ASCL=1
1390 .
1400 NODETG=0 . O : Normal Mode, 1 : Call ch Mode
1410 FILPAT#="A"
1420 .
1430 NS212=4
1440 NS501=8
1450 SHNO=7726!
1460 DSP=1 . Shot Number
1470 PTS=7 . Display Channel : 1 - 7
1480 FREQ=0 . Port Trigger Sample
1490 .
1500 RESTORE *BCAMAC
1510 FOR I=0 TO 7 : READ SFRQ$(I) : NEXT I
1520 .
1530 NDC=5 . 16CH MODE ( 8212A/16 )
1540 INITFLG=0 . If Flag = 0 then Redraw Display
1550 INITFLG=1 . CAMAC Control Flag
1570 .
1580 *CAMIO
1580 LOCATE 10,9 : INPUT "set CAMAC active [1] or not [0] ->" ,CFLAG
1590 IF CFLAG<0 OR CFLAG>1 THEN *SCA10
1610 .
1620 IF CFLAG<1 THEN *SCAMO . ARROW
1630 DEF SEG=SEGPR(2) : BLOAD "BCAMAC.BIN",400
1640 GOSUB *BCAMAC
1650 CALL EXC2 . When CC/1000 is Aux then make this line to comment
1660 IF CFLAG=1 THEN GOSUB *DLY
1670 *SCAMO
1680 'ON ERROR GOTO *RERROR
1690 .
1700 GOSUB *MENU : GOSUB *GRID
1710 GOSUB *SETCOND
1720 GOSUB *IMAG
1730 GOSUB *YMACB
1740 .
1750 *MAIN
1760 .
1770 GOSUB *MENU : GOSUB *GRID
1780 *MAIN
1790 GOSUB *SELBBOX
1800 IF SELFLG=1 THEN SELFLG=0 : GOTO *MENUOUT
1810 GOTO *MAIN
1820 *MENUOUT
1830 LOCATE 60,21 : PRINT MENU[MAG/8]
1840 FN (MAG/8/1) GOSUB *CURSO1,*EXPAND,*ORG,*HDCPY,*CALLCH,*FILE,*FILS,*VALEN
1850 LOCATE 60,21 : PRINT "
1860 GOTO *MAIN
1870 .
1880 *ALLEND
1890 VIEW(0,0)-(630,390)
1900 CLS 3,0
1910 KEY 1,"load "+CHR$(4H22):KEY 2,"auto":KEY 3,"so to":KEY 4,"list":KEY 5,"run":CHR$(13)
1920 KEY 6,"save "+CHR$(4H22):KEY 7,"key":KEY 8,"print":KEY 9,"edit":KEY 10,"cont":CHR$(13)
1930 CONSOLE ..,1
1940 END
1950 .
1960 .
1970 *GO
1980 IF CFLAG=1 THEN *GO
1990 *GO
2000 FOR I=1 TO 7
2010 FOR J=0 TO 128
2020 IX=(I+J)*K*INT(4096*EXP(-J/50))
2030 IT3((I,J))=K*INT(4096*EXP(-J/50))
2040 IT3((I,J))=K*INT(4096*EXP(-J/50))
2050 NEXT J
2060 NEXT I
2070 LOCATE 0,21:PRINT "
2080 INITLG=0
2090 GOSUB *DATMAX
2100 GOSUB *GRAPH
2110 RETURN
2120 .
2130 *C02
2140 GOSUB *MEAS
2150 LOCATE 60,21:PRINT "
2160 LOCATE 0,23:PRINT SPC(78)
2170 RETURN
2180 .
2190 .
2200 *GRAPH
2210 LOCATE 60,21:COLOR 6,PRINT "Writing" : COLOR 7
2220 GOSUB *GRID : GOSUB *PLOT0T : GOSUB *CURSO1 : GOSUB *PARAM
2230 LOCATE 60,21:PRINT "
2240 RETURN
2250 .
2260 .
2270 *GRID
2280 VIEW(0,19)-(630,322)
2290 CLS 2
2300 IF MODEFLG=1 THEN *GRID2
2310 VIEW(0,19)-(630,35)
2320 WINDOW(XW0,YW0)-(XW1,YW1)
2330 LINE(XW0,YW0)-(XW1,YW1),5,B,4KAAAA
2340 XW=XW1-YW0)/4
2350 YW=YW1-XW0)/4
2360 _=XY_1-4_
2370 VIEW(64,20)-(320,320)
2380 WINDOW(XW0,YW0)-(XW1,YW1)
2390 CLS 2
2400 LINE(XW0,YW0)-(XW1,YW1),5,B
2410 FOR I=1 TO 4
2420 LINE (XW0,YW0)*(1-2) : (XW1,YW1)*(1-2),5
2430 LINE (XW0,YW0)*(1-2)-TOY/2,-TOY/2,6,,&HC0CC
2440 NEXT I
2450 LINE (XW2,YW0)-(XW2,YW1),6,,&HC0CC
2460 _=XY_3,6_
2470 VIEW(320,170)-(576,245)
2480 WINDOW(XW0,YW0)-(XW1,YW1)
2490 CLS 2
2500 LINE (XW0,YW0)-(XW1,YW1),5,B
2510 LINE (XW0,YW0*(-1))-(XW1,YW1*(-1)),6,,&HC0CC
2520 LINE (XW0,YW0*(1))-(XW1,YW1*(1)),6,,&HC0CC
2530 LINE (XW0,0)-(XW1,0),5
2540 LINE (XW2,0)-(XW2,YW1),6,,&HC0CC
2550 _=Time V =
2560 VIEW(320,170)-(576,245)
2570 WINDOW(XW0,YW0)-(XW1,YW1)
2580 CLS 2
2590 FOR I=1 TO 4
2600 LINE (XW0,YW0)*(1-2) : (XW1,YW1)*(1-2),5
2610 LINE (XW0,0)-(XW1,0),6,,&HC0CC
2620 LINE (XW1,0)-(XW1,YW1),6,,&HC0CC
2630 LINE (XW2,0)-(XW2,YW1),6,,&HC0CC
2640 LINE (XW2,YW0)-(XW2,YW1),6,,&HC0CC

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```

2620 NEXT I
2630 LINE(XW0,YW0)-(XW1,YW1),5,B
2640 VIEW(XW0,YW0)-(XW1,YW1),5,B
2650 " = Tine A "
2660 VIEW(320,245)-(576,320)
2670 CLS 2 FOR I=1 TO 4
2680 LINE(XW0,YW0)-(XW1,YW1),5,-&HCCCC
2690 LINE(XW0,YW0)-(XW1,YW1),5,-&HCCCC
2700 LINE(XW0,YW0)-(XW1,YW1),6,-&HCCCC
2710 NEXT I
2720 LINE(XW0,YW0)-(XW1,YW1),5,B
2730 RETURN
2740
2750 *GRID2
2760 VIEW(0,10)-(638,367)
2770 WINDOW(XW0,YW0)-(XW1,YW1)
2780 LINE(XW0,20)-(XW1,YW1),5,B,&HAAAAA
2790 VIEW(320,20)-(576,190)
2800 WINDOW(XW0,YW0)-(XW1,YW1)
2810 CLS 2
2820 XY=(XW1-XW0)/4
2830 YO=(YW1-YW0)/4
2840 FOR I=1 TO 6
2850 LINE(XW0,YW0)-(XW1,YW1),5,-&HCCCC
2860 LINE(XW0,YW0)-(XW1,YW1),6,-&HCCCC
2870 NEXT I
2880 LINE(XW0,YW0)-(XW1,YW1),5,B
2890 VIEW(320,170)-(576,320)
2910 CLS 2
2920 FOR I=1 TO 4
2930 LINE(XW0,YW0)-(XW1,YW1),5,-&HCCCC
2940 LINE(XW0,YW0)-(XW1,YW1),6,-&HCCCC
2950 NEXT I
2960 LINE(XW0,YW0)-(XW1,YW1),5,B
2970 VIEW(6,26)-(294,314)
2980 CLS 2
2990 WINDOW(YW0,YW1)-(YW1,YW1)
3000 WINDOW(YW0,YW1)-(YW1,YW1),4,B
3010 LINE(YW0,YW1)-(YW1,YW1),4,B
3020 LINE(YW0,YW1)-(YW1,YW1),4,,&HCCCC
3030 LINE(YW0,YW1)-(YW1,YW1),4,,&HCCCC
3040 RETURN
3050
3060 PLOTDT2
3070 IF MODFLG=1 THEN *PLOTDT2
3080 IF INTFLG=1 THEN RETURN
3090 TIME A plot =
3100 VIEW(579,20)-(584,320)
3110 CLS 2
3120 = Time A plot =
3130 VIEW(320,170)-(576,245)
3140 WINDOW(XW0,YW0)-(XW1,YW1)
3150 XP1=0 : YOFF=0FFQ(DSP,0)+2048 : YPP=YPPQ(DSP,0)
3160 YP1=-DT3(DSP,0,0,OFF)+YPP
3170 FOR I=1 TO XOFF+YSP
3180 XP1=(1-XOFF)*XP
3190 YP1=(1-YOFF)*YP
3200 XP1=0 : YOFF=0FFQ(DSP,0,1)+YPP
3210 IF YP>YW1 THEN YP=YW1+10
3220 LINE(XP1,YP1)-(XP1,YP1),7
3230 LINE(XP1,YP1)-(XP1,YP1),7
3240 NEXT I
3250 = Tine B plot =
3260 IF YP<YW1 THEN YP=YW1+10
3270 WINDOW(XW0,YW0)-(XW1,YW1)
3280 LINE(XP1,YP1)-(XP1,YP1),7
3290 XP1=0 : YOFF=0FFQ(DSP,1)+2048 : YPP=YPPQ(DSP,1)
3300 YP1=-DT3(DSP,1,0,OFF)+YPP
3310 FOR I=1 TO XOFF+YSP
3320 XP1=(1-XOFF)*XP
3330 YP1=(1-YOFF)*YP
3340 IF YP<YW0 THEN YP=YW0+10
3350 IF YP>YW1 THEN YP=YW1+10
3360 LINE(XP1,YP1)-(XP1,YP1),7
3370 XP1=XP,YP1=YP
3380 NEXT I
3390 " = XY plot "
3400 " = XY plot "
3410 DSFTMPDSP
3420 FOR IX0=1 TO 1
3430 FOR IY0=1 TO 3
3440 VIEW(IX0+1,XW*56,20+IY*75)-(320+IX*XW*56,95+IY*15)
3450 WINDOW(YW0,-1,YW1)
3460 DSP=IX*4,IY*4
3470 IF G<DSP THEN DSP=DSFTMP : RETURN
3480 YOFF=0FFQ(DSP,0)+2148 : YPP=YPPQ(DSP,0) : XOFF=0
3490 YOFF=0FFQ(DSP,1)+2048 : YPP=YPPQ(DSP,1)
3500 XP1=(-DT3(DSP,0,0,XDMX(DSP,0))+YOFF)*YPP
3510 YP1=(-DT3(DSP,1,0,XDMX(DSP,0))+YOFF)*YPP
3520 PSET(XP1,YP1),7
3530 FOR I=1 TO XDMX(DSP,0,1)+YOFF : PRINT DSP
3540 XP1=(-DT3(DSP,0,1)+YOFF)*YPP
3550 YP1=(-DT3(DSP,1,1)+YOFF)*YPP
3560 IF YPYW0 THEN YP=YPW0-10
3570 IF YPYW1 THEN YP=YPW1+10
3580 LINE-(XP,YP)
3590 LINE-(XP,YP)
3600 NEXT I
3610 LOCATE 36+IX*32,2+IY*5 : PRINT DSP
3620 NEXT IX
3630 NEXT IX
3640 DSP=DSFTMP
3650 RETURN
3660 PLOTDT2
3670 IF INTFLG=1 THEN RETURN
3680 VIEW(310,20)-(315,320)
3700 CLS 2
3710 VIEW(320,20)-(1576,170)
3720 WINDOW(XW0,YW0)-(XW1,YW1)
3730 XP1=(-DT3(DSP,0,0,OFF)+YOFF)*YPP : YPP=YPPQ(DSP,0)
3740 YP1=(-DT3(DSP,0,0,OFF)+YOFF)*YPP
3750 FOR I=XOFF TO XOFF+YSP
3760 XP1=(1-XOFF)*XP
3770 YP1=(-DT3(DSP,0,1)+YOFF)*YPP
3780 IF YPYW0 THEN YP=YPW0-10
3790 IF YPYW1 THEN YP=YPW1+10
3800 LINE(XP1,YP1)-(XP,YP),7
3810 XP1=XP,YP1=YP
3820 NEXT I
3830
3840 VIEW(320,170)-(576,320)
3850 WINDOW(XW0,YW0)-(XW1,YW1)
3860 XP1=0 : YOFF=0FFQ(DSP,1)+2048 : YPP=YPPQ(DSP,1)
3870 YP1=(-DT3(DSP,1,0,OFF)+YOFF)*YPP
3880 FOR I=XOFF TO XOFF+YSP
3890 XP1=(1-XOFF)*XP
3900 YP1=(-DT3(DSP,1,1)+YOFF)*YPP
3910 IF YPYW0 THEN YP=YPW0-10
3920 IF YPYW1 THEN YP=YPW1+10
3930 LINE(XP1,YP1)-(XP,YP),7
3940 XP1=XP,YP1=YP
3950 NEXT I
3960
3970 ==="""
3980 VIEW(6,26) ch X-Y Display ==="""
3990 WINDOW(YW0,-1,YW1)
4000 YOFF=0FFQ(DSP,0)+2048 : YPP=YPPQ(DSP,0) : XOFF=0
4010 YOFF=0FFQ(DSP,1)+2048 : YPP=YPPQ(DSP,1)
4020 XP1=0 : YOFF=0FFQ(DSP,0,XDMX(DSP,0))+YOFF*YPP
4030 XP1=(-DT3(DSP,1,0,XDMX(DSP,0))+YOFF)*YPP
4040 PSET(XP1,YP1),7
4050 FOR I=1 TO XDMX(DSP,0,1)+YOFF : PRINT DSP
4060 XP1=(-DT3(DSP,0,1)+YOFF)*YPP
4070 YP1=(-DT3(DSP,1,1)+YOFF)*YPP
4080 IF YP>YW1 THEN YP=YPW1+10
4090 IF YP<YW0 THEN YP=YPW0-10
4100 LINE-(XP,YP)
4110 LINE-(XP,YP),7
4120 XP1=XP,YP1=YP
4130 NEXT I
4140 RETURN
4150
4160
4170 "DATMAX
4180 LOCATE 60,21:COLOR 6:PRINT " Calcu :COLOR 7
4190 DMAX=0 :IMAX=0
4200 FOR I=1 TO 7
4210 XDMX(I,0)=0 : YDMX(I,1)=0
4220 YDMX(I,0)=0 : YDMX(I,1)=0
4230 NEXT I

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5050 LINE(XW0=6,YCSL2)-(XW1,YCSL2) : XCSL1=XCSL
5060 XCSL1=XCSL
5070 GOSUB *CVDISP
5080 RETURN
5090
5100 .4CURSLX2
5110 4CURSLX-(580,340)
5120 VIEW(318,320)-(XW,YW)
5130 WINDOW(XW,YW)-(XW,YW)
5140 IF XCSL<=YOFF THEN XCSL=XOFF+XFSF
5150 IF XCSL>=YOFF THEN XCSL=XOFF+XFSF
5160 PUT#(XCSL1,4),DCXX,PSET
5170 XCSL1=(XCSL-XOFF)*XP/2
5180 PUT#(XCSL1,4),DCSLX,PSET
5190
5200 VIEW(310,20)-(315,170)
5210 WINDOW(XW,YW)-(XW,YW)
5220 YCSL=(-DT3(DSP,0,2048)-(XW,YW))
5230 YCSL=(-DT3(DSP,0,XCSL11)+10)*YPP
5240 IF YCSL<YW0 THEN YCSL=YW0-10
5250 IF YCSL>YW1 THEN YCSL=YW1+10
5260 LINE(XW0=6,YCSL1)-XW1,YCSL1,0
5270 YCSL=(-DT3(DSP,0,XCSL1)+10)*YPP
5280 IF YCSL<=YW0 THEN YCSL=YW0-10
5290 IF YCSL>YW1 THEN YCSL=YW1+10
5300 LINE(XW0=6,YCSL1)-XCSL1,5
5310 XCSL1=XCSL
5320 .
5330 VIEW(310,170)-(315,320)
5340 WINDOW(XW,YW)-(XW,YW)
5350 YOFF=YFQ(DSP,1)-2048 : YPP=YPPQ(DSP,0)
5360 YCSL1=(-DT3(DSP,1,XCSL11)+YOFF)*YPP
5370 IF YCSL1<YW0 THEN YCSL1=YW0-10
5380 LINE(XW0=6,YCSL1)-XW1,YCSL1,0
5390 LINE(XW0=6,YCSL1)-XCSL1,0
5400 YCSL1=(-DT3(DSP,1,XCSL1)+YOFF)*YPP
5410 IF YCSL1<YW0 THEN YCSL1=YW0-10
5420 IF YCSL1>YW1 THEN YCSL1=YW1+10
5430 LINE(XW0=6,YCSL1)-XW1,YCSL1,5
5440 XCSL1=XCSL
5450 GOSUB CVDISP
5460 RETURN
5470
5480 *CURSQLX
5490 *CURSQL
5500 INITFILE=0
5510 LOCATE 37,21 : PRINT "REF : /, ABS : *"
5520 IF X$=CHR$(AH,D) THEN XCSL=CSEL-1 : GOSUB *CURSQLX
5530 IF X$=CHR$(AH,C) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5540 IF X$=CHR$(AH,B) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5550 IF X$=CHR$(AH,E) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5560 IF X$=CHR$(AH,F) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5570 IF X$=CHR$(AH,G) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5580 IF X$=CHR$(AH,H) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5590 IF X$=CHR$(AH,I) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5600 IF X$=CHR$(AH,J) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5610 IF X$=CHR$(AH,K) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5620 IF X$=CHR$(AH,L) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5630 IF X$=CHR$(AH,M) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5640 IF X$=CHR$(AH,N) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5650 IF X$=CHR$(AH,O) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5660 IF X$=CHR$(AH,P) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5670 IF X$=CHR$(AH,Q) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5680 IF X$=CHR$(AH,R) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5690 IF X$=CHR$(AH,S) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5700 IF X$=CHR$(AH,T) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5710 IF X$=CHR$(AH,U) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5720 IF X$=CHR$(AH,V) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5730 IF X$=CHR$(AH,W) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5740 IF X$=CHR$(AH,X) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5750 IF X$=CHR$(AH,Y) THEN XCSL=CSEL+1 : GOSUB *CURSQLX
5760 EXPAND1 : EXPMBD=0
5770 X$=INKYS
5780 *EXPAND1
5790 INTLG=0
5800 LOCATE 5,22 : PRINT "Origin : 0"
5810 LOCATE 63,21 : PRINT "A,B" : PR
5820 LOCATE 17,22 : PRINT "A <> B" : PR
5830 IF XY1="O" THEN GOSUB *ORG : GOTO *EXPAND2
5840 IF XY1="/" AND EXPMDA=1 THEN EXPMDA=0 : EXPMDA=1 : GOTO *EXPAND3

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5860 IF (X#3."/")AND(EXPMDB=1) THEN EXPMDA=1 : EXPMDB=0 : GOTO *EXPANDA
5870 IF X#3."/CH#3 (AH0) THEN GOSUB *EXPANDA
5880 IF X#3."/CH#3 (AH1B) THEN GOSUB *EXPANDA
5890 GOTO *EXPANDA
5900 *EXPANDD LOCATE 5,22:PRINT SPC(34):RETURN
5910 *EXPANDD LOCATE 63,21: PRINT "YA,YB": GOTO *EXPAND1
5920 *EXPANDD LOCATE 63,21: PRINT "X,YB": GOTO *EXPAND1
5930 *
5940 *XMAG
5950 IF (DATIN*(2^(XG*XD)))>(DATN-XOFF) THEN XD=0
5960 IP DATIN*(2^(XG*XD))<32 THEN XD=0
5970 XG=XG+ND
5980 *EXPANDN LOCATE 5,22:PRINT SPC(34):RETURN
5990 XG=XG+ND
6000 XG=XG+ND
6010 XG=XG+ND
6020 XG=XG+ND
6030 XG=XG+ND
6040 XG=XG+ND
6050 XG=XG+ND
6060 IF YG+XD>-4 THEN YD=0
6070 IF YG+XD<-10 THEN YD=0
6080 YG=YG+YD
6090 YFS=1048*(12*YG)
6100 YP=1048*YFS
6110 YQL(DSP,0)=YG : YFSQ(DSP,0)=YFS : YPFQ(DSP,0)=YPF
6120 GOSUB *VWDISP
6130 RETURN
6140 *TMACB
6150 YCB=GQ(DSP,1)
6160 YCB=YCB(GQ(DSP,1))
6170 IF YCB=0 THEN YD=0
6180 IF YCB+XD<-10 THEN YD=0
6190 YCB=YCB(YD)
6200 YFS=1048*(2*XG)
6210 YPB=2048*YFSPB
6220 IF YD>0 THEN YF=YOF/YFS/2 ELSE YF=YOF-YRP/2
6230 YCQ(DSP,1)=YCB : YFSQ(DSP,1)=YFSB : YPFQ(DSP,1)=YPB
6240 *VWDISP
6250 RETURN
6260
6270
6280 *OFFSET
6290 INITLG=0 : RETURN
6300 LOCATE 66,21 : PRINT "X"
6310 LOCATE 48,21 : PRINT "X < Y : "
6320 OPSMDX=1 : OPSDY=0
6330 *OFFSET
6340 X#3 = INKEY$()
6350 IF ((X#3=CHR$(41))AND(OFSMDX=1)) THEN XD=-1 : GOSUB *XOFSET
6360 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=1 : GOSUB *XOFSET
6370 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=0 : GOSUB *XOFSET
6380 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=-20 : GOSUB *XOFSET
6390 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=1 : GOSUB *XOFSET
6400 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=-1 : GOSUB *XOFSET
6410 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=10 : GOSUB *XOFSET
6420 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=0 : GOSUB *XOFSET
6430 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=-1 : GOSUB *XOFSET
6440 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN YD=0 : GOSUB *XOFSET
6450 IF ((X#3=CHR$(41))AND(OFSMD=1)) THEN GOSUB *GRAPH : LOCATE 48,21:PRINT SP(16):RETURN
6460 IF X#3=CHR$(41B) THEN LOCATE 48,21:PRINT SP(16):RETURN
6470 GOTO
6480 *OFFSET2 LOCATE 66,21: PRINT "Y : GOTO *OFFSET1
6490 *OFFSET2 LOCATE 66,21: PRINT "X : GOTO *OFFSET1
6500 *OFFSET
6510 *XOFSET
6520 IF (DATN*(2^(XG))-XD)>(DATN-XOFF) THEN YD=0
6530 IF XOFF*XD<0 THEN YD=0
6540 XOFF-XOFF*XD
6550 LOCATE 70,21: PRINT XFS*+XOFF;" "
6560 LOCATE 39,21 : PRINT XOFF;" "
6570 RETURN
6580 *YOFSET
6590 YCQ(DSP,0)
6600 YG=YCQ(DSP,0)
6610 IF (2048*(12*YG))+YD)>(32767-YOFP) THEN YD=0
6620 IF YOFF+YD<-XFSB THEN YD=0
6630 IF YOFF+YD>XFSB THEN YD=0
6640 YOFF-YOFF*YD
6650 GOSUB *VWDISP
6660 RETURN

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9100 *SETCOND
9110 CLS 3
9120 WINDOW(0, 0)-(630, 398)
9130 CLS 3
9140 LINE(7, 0)-(75, 22), 4, B
9150 LINE(7, 0)-(75, 22), 4, B
9160 LINE(7, 0)-(75, 1), 4, B
9170 LINE(7, 0)-(72, 23), 4, B
9180 COLOR 9, 0 : PRINT "==== SET CONDITION ==="
9190 COLOR 7
9200 LOCATE 9, 2 : PRINT "1 : Shot No : " ; SHNO : "
9210 LOCATE 9, 4 : PRINT "2 : Display Probe Ch : " ; DSPC : "
9220 LOCATE 9, 6 : PRINT "3 : MODEPLG : " ; MDPGLG : "
9230 LOCATE 9, 8 : PRINT "4 : Display Mode : " ; DPMODE : "
9240 LOCATE 9, 10 : PRINT "5 : Post Trig No : " ; PTPTN : "
9250 LOCATE 9, 12 : PRINT "6 : Full Post Trig number n / 8 : PTS" ; PTS
9260 LOCATE 9, 14 : PRINT "7 : Sample Freq : " ; SFRQ(FRQ) : "
9270 LOCATE 9, 16 : PRINT "8 : Number of Channel : " ; NOCHAN : "
9280 FRQ=0 : SFRQ(FRQ-7) : Sample Freq = 0 : NOCHAN = 1 : NOC=2;:
9290 LOCATE 9, 18 : PRINT "Ext 0.5k 5k 12.5k 25k 50k 100k"
9300 LOCATE 9, 14: PRINT "6: Number of Channel : " ; NOCHAN : "
9310 LOCATE 9, 16: INPUT "7: NOC<2;" : NOC=2;
9320 *NOC=0
9330 LOCATE 9, 14: PRINT "8: Number of Channel : " ; NOCHAN : "
9340 LOCATE 9, 16: PRINT "9: CANAC ZINABLE : " ; CFLAG : "
9350 LOCATE 9, 18: PRINT "10: PRINT SPC(79) : "
9360 LOCATE 9, 20: PRINT "11: PRINT SPC(79) : "
9370 LOCATE 9, 22: PRINT "12: PRINT SPC(79) : "
9380 LOCATE 9, 16: PRINT "13: LOCATE 10, 16 Slot : " ; NOCHAN : "
9390 LOCATE 9, 18: PRINT "14: FILE PATH : " ; FILEPATH : "
9400 LOCATE 9, 20: PRINT "15: CANAC ZINABLE : " ; CFLAG : "
9410 LOCATE 9, 22: PRINT "16: RETURN : "
9420 LOCATE 9, 24 : PRINT SPC(79)
9430 LOCATE 9, 22 : INPUT "SET MENU No. ? " ; K2
9440 IF K2<0 OR K2> THEN *SETCOND
9450 IF K2=0 THEN CLS 3:GOSUB *MENU:GOSUB *GRAPH:RETURN
9460 ON K2 GOSUB *SHOT,*DSP,*SETCOND,*STRIGLY,*SSMLCLK,*SNOC,*S8212,*PPATH
9470 CLS
9480 GOTO *SETCOND1
9490
9500 *SSHOT
9510 LOCATE 40, 2 : INPUT "set Shot number ->" ; STEMP
9520 *LOCATE 20, 21: INPUT "IF OK THEN HIT [Y] , XXX" : RETURN
9530 'IP XXX<>Y AND XXX<>T' THEN BEEP : RETURN
9540 SINO-STEMP
9550 LOCATE 0, 2 : PRINT SPC(79)
9560 RETURN
9570
9580 *DSP
9590 LOCATE 40, 4 : INPUT "set Display Channel number ->" ; STEMP
9600 *S8212*NOC
9610 IF STEMP<0 OR STEMP>1 THEN GOSUB *XBEEP : RETURN
9620 LOCATE 0, 4 : PRINT SPC(79)
9630 IF MODEFLG=1 OR STEMP=0 THEN MODEFLG=0 : RETURN
9640 IF MODEFLG=0 AND STEMP=0 THEN MODEFLG=1 : RETURN
9650 DSP=STEMP
9660 RETURN
9670
9680 *SETCH
9690 RETURN
9700 LOCATE 40, 6 : INPUT "set number of point->" ; DATNT
9710 IF DATNT=0 THEN RETURN
9720 IF DATNT>0 THEN DATNT : XSP=DATNT : XSP=5/12*XSP
9730 DATNT:PRINT SPC(79)
9740 LOCATE 0, 6 : PRINT SPC(79)
9750 RETURN
9760
9770 *STRIGLY
9780 LOCATE 60, 7 : PRINT "0 - 7" : INPUT "set Post Trig Delay ->" ; DTREG1
9790 LOCATE 40, 8 : INPUT "set Post Trig Delay ->" ; DTREG2
9800 IF DTREG1<0 OR DTREG2>7 THEN GOSUB *XBEEP : RETURN
9810 PTS=DTRG1
9820 LOCATE 0, 7 : PRINT SPC(79)
9830 LOCATE 0, 8 : PRINT SPC(79)
9840 RETURN
9850
9860 *SSMLCLK
9870
9880 LOCATE 40, 14: PRINT "n Sample Click" : EXT 1 -- 500Hz
9890 LOCATE 40, 15: PRINT "n Sample Click" : EXT 1 -- 500Hz
9900 PRG=DSETZ
9910 RETURN
9920 LOCATE 40, 17: PRINT "2 -- 2.5kHz" : 3 --- 5kHz
9930 LOCATE 40, 18: PRINT "4 -- 12.5kHz" : 5 --- 25kHz
9940 LOCATE 40, 12: INPUT "set Sample Clock ->" ; DSZET
9950 IF DSZET<0 OR DSZET>7 THEN GOSUB *XBEEP : RETURN
9960 PRG=DSETZ
9970 RETURN
9980 *SHOC
9990 LOCATE 40, 16 : PRINT "0 : 2 ch 1 : 4 ch" : 2 : 8 ch 3 : 16 ch
10000 LOCATE 40, 17 : PRINT "0 : 2 ch 1 : 4 ch" : 2 : 8 ch 3 : 16 ch
10010 LOCATE 40, 14 : INPUT "set Number of channel ->" ; STEMP
10020 LOCATE 40, 14 : NOC = 0 : SET 1 : 2 : 3
10030 NOC = 0 : SET 1 : 2 : 3
10040 18212/8 : SET 1 : 2 : 4 : 5
10050 18212/15 : SET 2 : 4 : 5 : 6
10060 18212/35 : SET 4 : 8 : 16 : 32
10070 IP STEMP<0 OR STEMP>3 THEN GOSUB *XBEEP : RETURN
10080 NOC=STEAP
10090 LOCATE 0, 14 : PRINT SPC(79)
10100 LOCATE 0, 14 : PRINT SPC(79)
10110 RETURN
10120 *SPATH
10130 LOCATE 40, 16 : INPUT "set 8212 Slot number ->" ; STEMP
10140 IP STEMP<1 OR STEMP>22 THEN GOSUB *XBEEP : RETURN
10150 NO215=STEAP
10160 LOCATE 0, 16 : PRINT SPC(79)
10170 RETURN
10180
10190 *SPATH
10200 LOCATE 40, 16 : INPUT "set 8212 Slot number ->" ; STEMP
10210 IP STEMP<22 THEN GOSUB *XBEEP : RETURN
10220 FILPATH=STEAP
10230 LOCATE 0, 16 : PRINT SPC(79)
10240 LOCATE 0, 16 : PRINT SPC(79)
10250 RETURN
10260 *XBEEP
10270 *XBEEP
10280 COLON 6:LOCATE 22,23:PRINT " [ Setting Error ] "
10290 INPUT WAIT 4,XXX: BEEP
10300 INPUT WAIT 7,LOCATE 22,23:PRINT "
10310 RETURN
10320 COLOR 7:LOCATE 22,23:PRINT "
10330 RETURN
10340 *
10350 *CLE
10360 CONSOLE 0,25,0,1:CLS 3
10370 RETURN
10380 *
10390 *CLEAR
10400 LOCATE 0, 23:PRINT SPC(79)
10410 LOCATE 0, 23
10420 RETURN
10430 *
10440 *
10450 *MCLEAR
10460 FOR L=0 TO 2048 : VT(L)=0 : D(Z11)=0 : NEXT L
10470 MAX=0 : MAX=0 : XSEL=0 : XSEL=0
10480 IF MODEFLG=1 THEN MODEFLG=1 : GOTO *CALICHI
10490 LOCATE 0, 23: INPUT "set Cn1 Channel number ->" ; STEMP
10500 SOSP=7 : 2: NOC
10510 IF STEMP=1 OR STEMP>SOSP THEN GOSUB *XBEEP : RETURN
10520 DSP=STEMP
10530 LOCATE 0, 23 : PRINT SPC(79)
10540 *CALICHI
10550 FOR L=1 TO 23 : LOCATE 0, L : PRINT SPC(79) : NEXT L
10560 IF MODEFLG=1 THEN MODEFLG=0 : GOTO *CALICHI
10570 IF MODEFLG=0 THEN MODEFLG=1
10580 LOCATE 0, 23 : INPUT "set Cn1 Channel number ->" ; STEMP
10590 SOSP=7 : 2: NOC
10600 IF STEMP=1 OR STEMP>SOSP THEN GOSUB *XBEEP : RETURN
10610 DSP=STEMP
10620 LOCATE 0, 23 : PRINT SPC(79)
10630 GOSUB *PXP
10640 GOSUB *GRAPH
10650 RETURN
10660 *CALICHI
10670 GOSUB *MENU : GOSUB *GRAPH
10680 RETURN
10690
10700 * ===== Data Transfer Routine =====
10710 *

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10720 *MEAS IF CFLAG<>1 THEN RETURN : GOTO *LPC
10730 IF CFLAG>1 THEN RETURN : GOTO *LPC
10740 *LOOP
10750 GOSUB *START1
10760 GOSUB *DL
10770 N=N$211:$F=0:CALL CAMAC
10780 N=N$211:$F=25: CALL CAMAC
10790 LOCATE 10,23 : PRINT "MAILED TO 1486C"
10800 LOCATE 0,23 : PRINT SPC(8)
10810 KEY (10) ON
10820 KEY (10) OFF
10830 GOSUB *SETTRG
10840 LOCATE 74,20: PRINT "TRIG"
10850 *LOOPQ
10860 *F=:CALL CAMAC
10870 LOCATE 0,23 : INPUT "Data Ready ? ",XXX$ : CALL CAMAC
10880 LOCATE 0,23 : PRINT SPC(7)
10890 KEY (10) OFF
10900 *LPC
10910 LOCATE 60,21:COLOR 6:PRINT "DataXfr":COLOR 7
10920 FOR IMEAS=1 TO 7
10930 GOSUB *IMEAS
10940 NEXT IMEAS
10950
10960 GOSUB *DTNG
10970
10980 GOSUB *DATMAX
10990 GOSUB *MENU : GOSUB *GRAPH
11000 *COPY
11010 SHN$=SHN$01
11020 UCATE 0,21 : PRINT SPC(15)
11030 LOCATE 60,21 : COLOR 6:PRINT "DataXfr":COLOR 7
11040 SCREEN 3,0,0,1,CLS 2:GOSUB *MERG : GOSUB *GRAPH
11050 RETURN : *MAIN
11060
11070 *IMEAS
11080 IF CFLAG<>1 THEN RETURN
11090 N=N$112
11100 A=0:F=16:CALL CAMAC
11110 A=0:F=16:CALL CAMAC
11120 F=2
11130 FOR K1=0 TO 128
11140 CALL CAMAC:DT(K1)=DL : DT3(IMEAS,0,K1)=DL
11150 NEXT K1
11160 FOR K1=129 TO 2047
11170 CALL CAMAC:DT(K1)=DL
11180 NEXT K1
11190 FOR K1=128 TO 2047
11200 CALL CAMAC:DT(K1)=DL
11210 A=0:F=16:CALL CAMAC
11220 F=2
11230 FOR K1=0 TO 128
11240 CALL CAMAC:DT3(1,1,K1)=DL
11250 NEXT K1
11260 NEXT K1
11270 FOR K1=129 TO 2047
11280 CALL CAMAC
11290 NEXT K1
11300 F=2
11310 *DTNG 1 8212A / CH 5 2' 2' 2' 2' CH 16 <*->
11320 A=0:F=16:CALL CAMAC
11330 LOCATE 0,16:CALL CAMAC
11340 FOR K1=0 TO 128
11350 CALL CAMAC:DT3(3,0,K1)=DL
11360 NEXT K1
11370 FOR K1=129 TO 2047
11380 CALL CAMAC
11390 NEXT K1
11400
11410 8212A / CH 2 2' 2' 2' 2' CH 15 <*->
11420 A=0:F=14:CALL CAMAC
11430 F=2
11440 FOR K1=0 TO 128
11450 CALL CAMAC:DT3(1,1,K1)=DL
11460 NEXT K1
11470 FOR K1=129 TO 2047
11480 CALL CAMAC
11490 NEXT K1
11500 RETURN
11510
11520 *START1 THEN RETURN
11530 DL=NOC+F0Q4+PT$32
11540 N=N$212 : F=17 : CALL CAMAC
11550 RETURN
11560 N=N$212 : F=25 : CALL CAMAC
11570 *SETTRG
11580 IF CFLAG=1 THEN N=N$212 : F=25 : CALL CAMAC
11590 LOCATE 0,23:PRINT SPC(7)
11600 RETURN
11610 *DL=N-N$8801
11620 NORGN=N-N$8801
11630 F=26 : AND : CALL CAMAC
11640 F=23 : OR : CALL CAMAC
11650 F=21:CALL CAMAC
11660 A=0:D=1 : CALL CAMAC
11670 N=NORG : RETURN
11680 *DL,Y2
11690 RETURN
11700 N=NORG : RETURN
11710
11720 *DL,Y2
11730 RETURN
11740 NORGN=N$0501
11750 F=5 : A=0:CALL CAMAC
11760 N=N+1:CALL CAMAC
11770 N=NORG : RETURN
11780
11790
11800 FREEB0R : BREP
11810 IP ER$5 THEM *ILLFCIN
11820 IP ER$53 THEM *BADFL
11830 IP ER$54 THEM *BADFL
11840 IP ER$55 THEM *BADFL
11850 IP ER$52 THEM *BADFL
11860 IP ER$66 THEM *BADFL
11870 IP ER$70 THEM *BADFL
11880 RESUME *MAIN
11890
11900 *ILLFCIN
11910 LOCATE 2,24 : PRINT "<#Error>" XG1<711:X(X1):X";
11920 GOSUB *HIT
11930 RESUME *MAIN
11940
11950 *BADFL
11960 LOCATE 2,24 : PRINT "<#Error>" XGK!X%K$, $_S$D$+$J$-$I$+$K$;
11970 CLOSE #1
11980 RESUME *MAIN
11990 RESUME *MAIN
12000
12010 *BADFL
12020 LOCATE 2,24 : PRINT "<#Error>" XGK!X%K$, $1$3C3Q$+$G$B$!X";
12030 CLOSE #1
12040 GOSUB *HIT
12050 RESUME *MAIN
12060 RETURN
12070 *BADFL
12080 LOCATE 2,24 : PRINT "<#Error>" X1$X$X$X$ , $A$3,$4$+$B$1$X";
12090 GOSUB *HIT
12100 RESUME *MAIN
12110
12120 *HIT
12130 LOCATE 79,23 : INPUT "",XXX$ : CLS
12140 RETURN
12150 -----"BCAMAC.BAS"-----
12160 *CAMAC
12170 **** CC$9800-01 CAMAC ベル BASIC ベル77 MQ A-FY -(MS-DOS 6c) ***
12180 *** SETIN=AH15: CUR1=AH15
12190 *** SETIN=AH16: CUR1=AH16
12200 SETIN=AH18: CUR1=AH18
12210 RSV1=AH12: RLM1=AH21
12220 BLSK1=AH24
12230 BLKW1=AH27: BLKR1=AH23
12240 SIF=AH33
12250 N=0:A=0:F=0:DL=0:DH=0:RX=0:NQ=0
12260

```

```
12340 CALL BSFT(N,A,F,DL,DH,NQ,NX)
12350 OUT ,MDI,0
12360 RETURN
12370
12380 , PRQ , "0 1 , "2 hz" , "3 4 Hz" , "5 6 Hz" , "7 8 Hz" ,
12390 DATA "Ext" , "00Hz" , "5kHz" , "12.5kHz" , "25kHz" , "50kHz" , "100kHz"
12400 *E ***** E N D *****
```

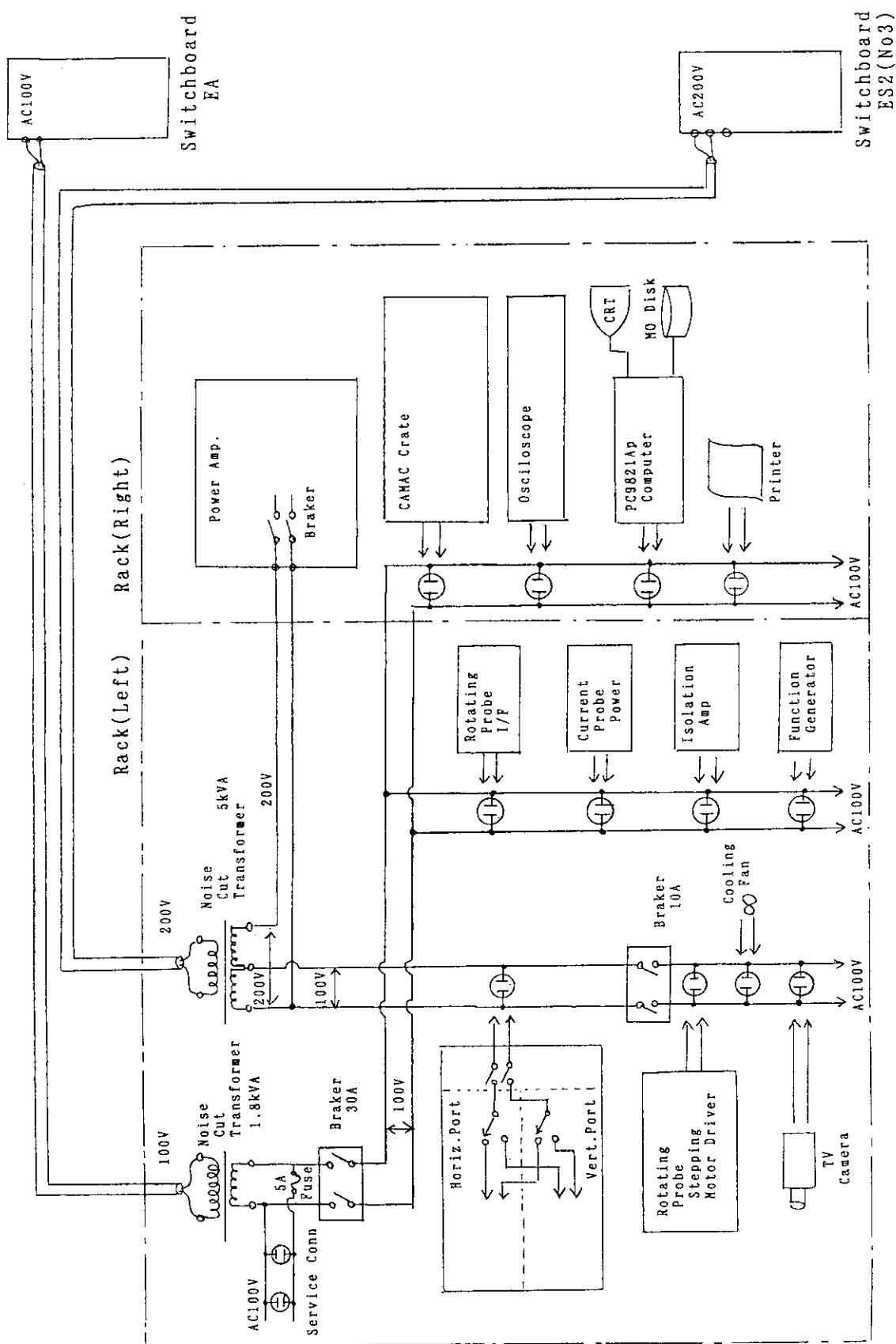


Fig.A-1 Power supply tree in the ion probe system

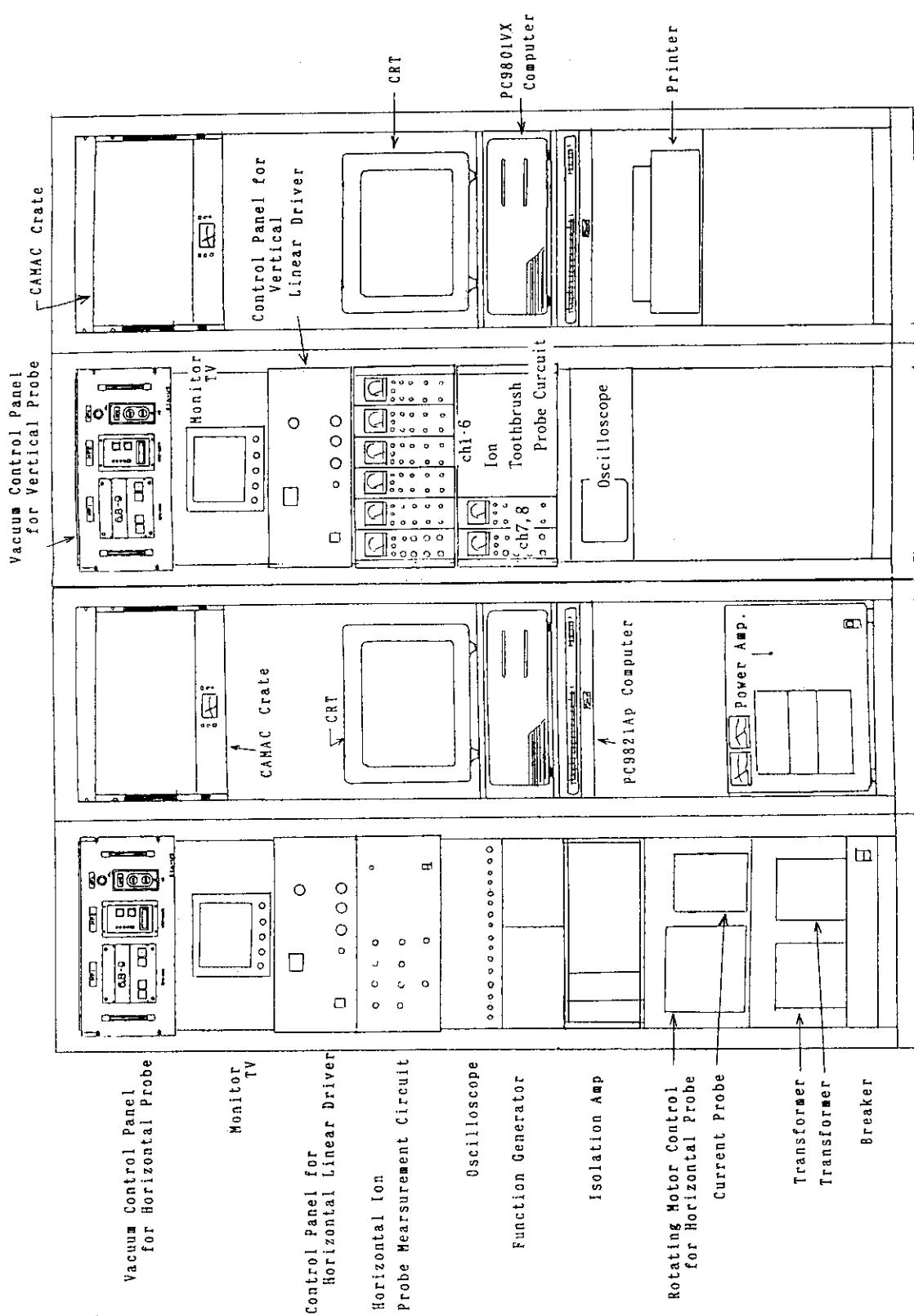
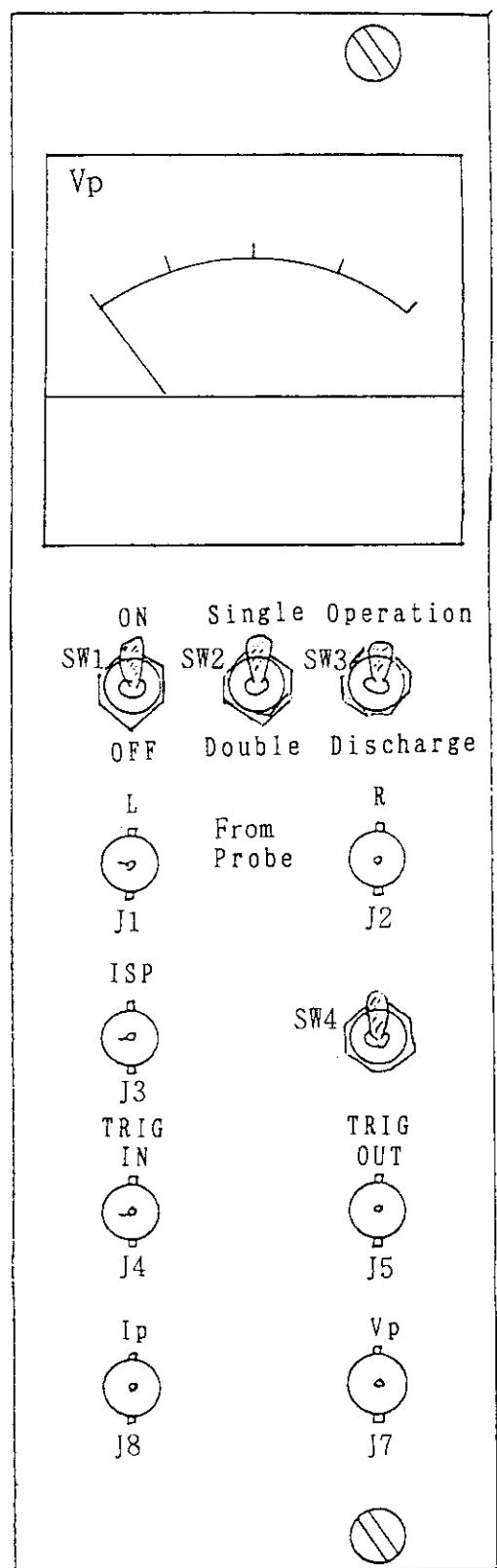
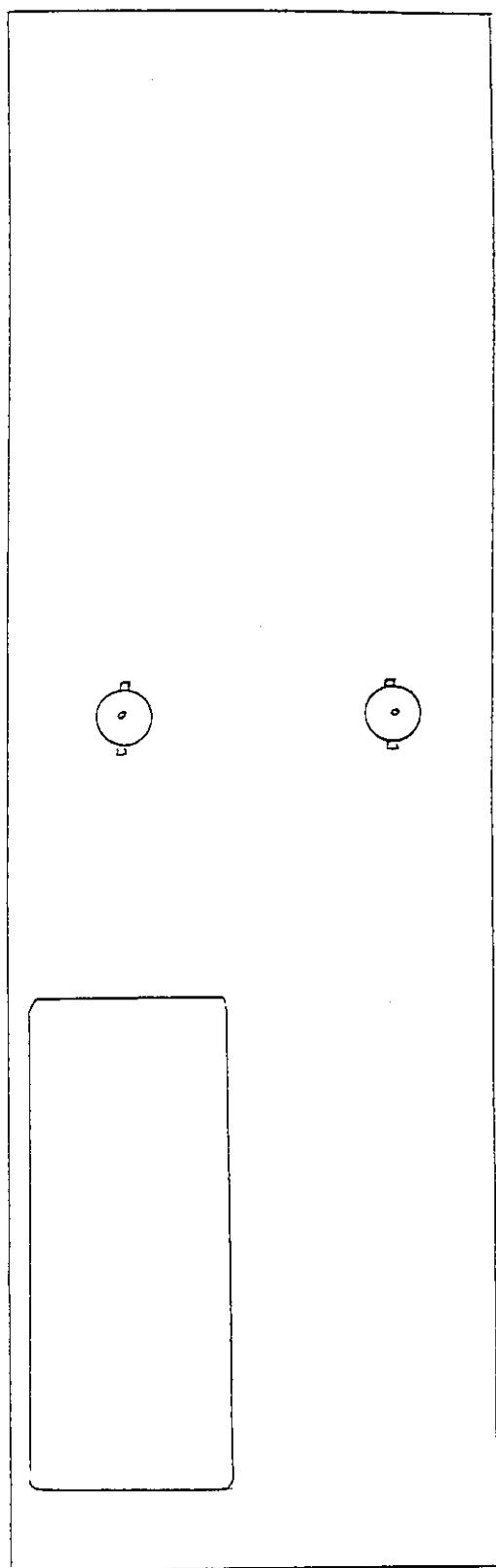


Fig.A-2 Control panel in the control room

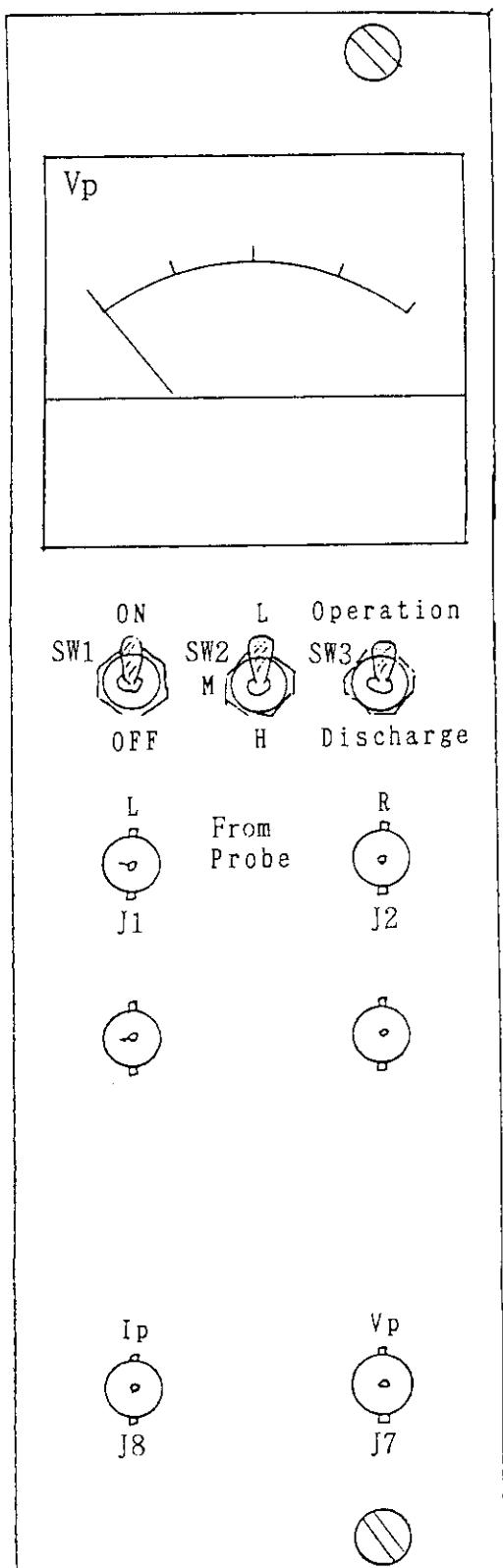


Front pannel

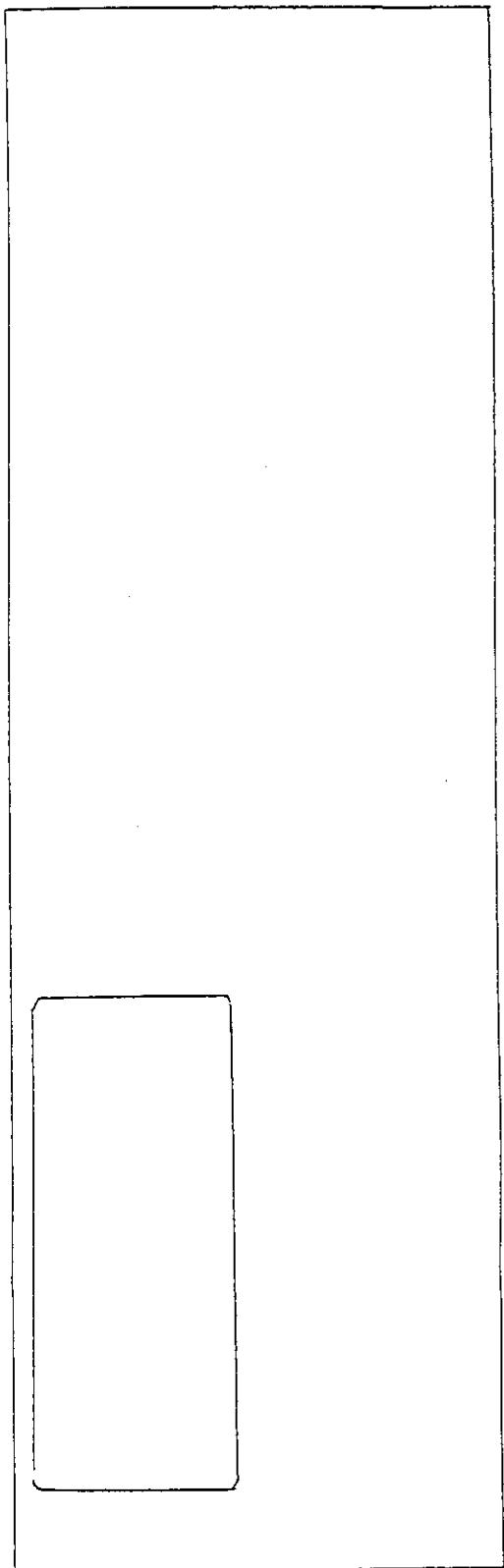


Rear panel

Fig.A-3 Front panel for ch 1-6 in the vertical ion probe circuit



Front pannel



Rear panel

Fig.A-4 Front panel for ch 7-8 in the vertical ion probe circuit