RENSSELAER POLYTECHNIC INSTITUTE
TROY, NEW YORK 12181

MASTER

TECHNICAL PROGRESS REPORT
(COVERING THE PERIOD 1 JANUARY 1979 - 30 JUNE 1980)

UNDER

DOE CONTRACT No. DE-AS02-76ET53004

ENTITLED

ION BEAM PROBE DIAGNOSTIC SYSTEM

REPORT No: DOE/ET/53004-1

RPDL REPORT No. 80-17

PREPARED BY

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: \$6.00
Microfiche copy: A01

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ABSTRACT

This report describes the work done under DOE Contract No. DE-AS02-76ET53004 for the period 1 January 1979 through 30 June 1980. Tokamak plasmas suitable for diagnostic development were produced during this period in RENTOR following technological improvements in the vacuum chamber and discharge cleaning systems. Secondary ion signals were obtained from the heavy ion beam probe on RENTOR leading to initial estimates of the plasma space potential, which appears to vary by several hundred volts during the plasma pulse. The principle of measuring space potential in a minimum-B geometry was established using an ion gun mounted at the center of the ALEX baseball coil. The neutral beam probe was installed for measuring the space potential using actual secondary ion signals from a hollow cathode arc in ALEX and preliminary tests have begun. The ion beam test stand was significantly altered to allow more flexibility in testing energy analyzers, ion guns, and ion focusing concepts. The test stand and RENTOR were moved to an entirely new laboratory provided by Rensselaer, and operation has been re-established in both systems. Technology transfer has progressed through the continued operation of a heavy ion beam probe system on EBT-S, the successful installation and operation of a similar system on the central cell of TMX and the preliminary design of a beam probe system to measure the edge potential in ISX.

PROGRESS REPORT

I. INTRODUCTION

This Technical Progress Report covers the period 1 January 1979 through 30 June 1980 for research conducted under Contract DE-AS02-76ET53004. The Principal Investigator, Dr. R. L. Hickok, Jr., devoted approximately 25% of his time to this program. Other principal participants and the amount of time they have devoted to this program are:

Dr. W. C. Jennings	-- Associate Professor	-- 40%
Dr. J. T. Woo	-- Associate Professor	-- 25%
Dr. K. A. Connor	-- Associate Professor	-- 25%
Dr. A. Herscovitch	-- Research Associate	-- 65%
Dr. J. Pipkins	-- Research Associate	-- 50%
Mr. J. Lewis	-- Research Engineer	-- 75%
Mr. J. Schatz	-- Engineering Assistant	-- 80%

At the present time, there are no Research Associates working on this program (Drs. Herscovitch and Pipkins have left). The remaining participants will continue to devote the indicated percentage of their time during the remainder of the contract.

The primary objective of this program is the advanced development of sophisticated particle beam diagnostic techniques for making space and time resolved measurements on high temperature magnetically confined plasmas related to the development of controlled fusion energy systems. The procedure that is followed is to develop and test the techniques on small scale laboratory experiments having relevant magnetic geometry, and

then transfer the technology to major confinement experiments. In addition to developing particle beam diagnostic techniques that are applicable to present day plasma devices, we also devote some effort to evaluating the requirements that will be needed for future plasma systems.

The principal facilities for carrying out this program consists of the research tokamak, RENTOR, the minimum B "baseball" mirror facility, ALEX, and the ion beam test stand, IBTS. The test stand is used to develop and test component parts of the particle beam systems and to simulate measurements from plasma devices. Demonstration measurements are carried out on RENTOR and ALEX. Neither RENTOR nor ALEX are particularly good plasma devices, but they provide reasonable target plasmas for diagnostic development. RENTOR has a major radius of 45 cm, a minor vacuum chamber radius of 15 cm, a plasma radius of approximately 7 to 8 cm, and a toroidal field of 4-5 kgauss. Base pressure is 5×10^{-7} Torr and typical pulses are 6-8 msec long with an O.H. current of 10-20 kamps. It has large toroidal field ripples and substantial stray magnetic fields from the air core O.H. transformer. Typical plasma parameters are a density in the low 10^{12} cm^{-3} range and a peak electron temperature of the order of 50 eV. ALEX utilizes a hollow cathode arc plasma that has a density of the order of 10^{13} cm^{-3} and an electron temperature of a few eV. Both plasmas are very strong sources of ultraviolet radiation and, in addition, RENTOR produces a substantial amount of hard ($\geq 100 \text{ keV}$) x-radiation. The relatively low densities and temperatures produce weak beam probe signals and the hostile ultraviolet and x-radiation produce large background noise. This provides a very severe test bed for developing beam diagnostics and requires that we pay very

careful attention to all components in order to optimize the signal-to-noise ratio. A very positive consequence of this is that when we have transferred the technology to other plasma systems, we have invariably obtained good signal-to-noise ratios.

The major emphasis of this research program is the continued development of heavy ion beam probing. The basic concept is to direct a beam of heavy ions across the confining magnetic field and through the plasma. Some of the probing ions undergo impact ionization collisions with the plasma electrons to form higher charged state secondary ions. The magnetic field separates the secondary ions providing three dimensional spatial resolution. The intensity of the secondary ion signal provides a measure of $n(T_e)$, the momentum of the secondary ion provides information about the magnetic field, and the difference in energy between the injected primary beam and the exiting secondary ions provides a direct measurement of the plasma space potential. Spatial resolution of the measurements is less than 1 cm^3 , time resolution is of the order of $10 \text{ } \mu\text{sec}$. The measurements are continuous in time and quasi-continuous in space. Measurements of plasma density, electron temperature, and space potential have been demonstrated, and correlation studies between density and space potential fluctuations have been carried out. Most of the results have been obtained on a hollow cathode arc operating in a solenoidal magnetic field. To establish the validity of the techniques and to facilitate the transfer of the technology to confinement experiments, it is necessary to demonstrate the measurements in more realistic magnetic geometry, so for the past few years principal attention has been directed towards obtaining useful target plasmas in the RENTOR and ALEX facilities.

During the period covered by this report, major effort has been devoted to improving the operation of RENTOR to provide a satisfactory target plasma for diagnostic development, initiating heavy ion beam probe measurements on RENTOR, installing the arc plasma and neutral beam system on ALEX, upgrading IBTS and testing new modifications to an electrostatic energy analyzer and moving the plasma laboratory to the new Jonsson Engineering Center.

In Section II we describe the improvements in RENTOR and the present operating characteristics. The initial beam probe measurements on RENTOR are given in Section III. The status of ALEX and IBTS are described in Sections IV and V. The new Plasma Lab in the Jonsson Engineering Center is described in Section VI, and our effort in technology transfer to confinement devices is presented in Section VII. The results we have obtained in relation to the goals set out at the beginning of this contract period are summarized in Section VIII.

II. STATUS OF RENTOR

At the beginning of the period covered by this report (1 January 1979 through 30 June 1980), equilibrium pulses had been obtained in RENTOR but they were characterized by relatively short duration (~ 4 msec) and high radiation levels. Base pressure was of the order of 5×10^{-6} Torr and it was fairly well established that the discharges were dominated by a large runaway population. Our first priority was to obtain improved operation of RENTOR to provide longer pulses and less radiation. The major problem was believed to be a large impurity flux, so major attention was devoted to reducing the base pressure and improving the discharge cleaning system.

A turbomolecular pump was installed on RENTOR and all detectable leaks were sealed with vacuum epoxy. Thin stainless steel shields were installed to protect the epoxy from the plasma and minimize the possibility that the epoxy would be a source of impurities. This reduced the base pressure to the high 10^{-7} Torr range.

The repetition rate of the ringing capacitor bank used for discharge cleaning was increased to three pulses per second. The residual gas analyzer indicated that major components being pumped out during discharge cleaning were water vapor and methane. This indicated that the major problem was clean up of the vacuum surfaces and not leaks. The combination of new turbopump and improved discharge cleaning reduced the base pressure to the mid 10^{-7} Torr range. With the improvement in base pressure, we began to obtain increased pulse lengths. Pulses stretched out to the 6 to 8 msec range (maximum pulse length obtained so far is 9.2 msec). This is typical of the pulse length we would expect with the existing O.H. capacitor bank.

The O.H. firing sequence on RENTOR consisted of a ringing capacitor bank to provide a preionization R.F. breakdown, a fast O.H. to establish the current, and a slow O.H. to maintain the current for the length of the pulse. This scheme worked as long as the heavy ion beam probe was on to provide some free electrons for the preionization breakdown. The coupling of the beam probe to tokamak operation made it impossible to independently control these two systems. To overcome this problem, an electron gun was installed to provide the initial concentration of free electrons. This has worked very well by increasing the repeatability of the tokamak pulses and making the beam probe system independent of tokamak operation.

To further improve the vacuum characteristics of RENTOR, a glow discharge cleaning system was installed. This has the advantage that it works with no toroidal magnetic field and the glow fills the appendage vacuum systems that are attached to RENTOR. The primary beam line and the large detection chamber have a surface area that is of the same order or larger than the surface area of the main toroidal chamber. The ringing capacitor bank discharge, which requires a weak toroidal field, did not clean the surfaces of the appendages. The combination of glow discharge and ringing capacitor bank has reduced the base pressure to 4×10^{-7} Torr. This has permitted reasonably reliable operation with 6 to 8 msec pulses and a reduced hard x-ray radiation level. Typical current-voltage characteristics are shown in Fig. 1.

With the improved operating characteristics of RENTOR and reduction in the noise susceptibility of the beam probe system, reliable secondary

ion signals were obtained in August 1979. The preliminary beam probe data is described in the next section. After accumulating some beam probe data, RENTOR was shut down on January 13, 1980 in order to move into the new Jonsson Engineering Center. Tokamak operation was reestablished on May 27. The toroidal chamber was moved under vacuum (this required knocking down a cinder block wall of the old Plasma Lab in the Materials Research Center Building) in order to monitor any damage to the vacuum welds caused by the move. Fortunately, no major problems were encountered and tokamak operation was reestablished in less than 4 1/2 months (original estimates were 3 - 9 months).

Some improvements were implemented during the move that delayed reestablishing operation by a small amount. The major improvement was the installation of coaxial aluminum leads between the capacitor room and the tokamak. This reduced both the resistance and inductance of the lead wires so that the pulse shape of the TF and OH system is now essentially determined by the windings and capacitor banks and is relatively independent of the connecting cables. Minor improvements were also implemented in the charging, monitoring, and control systems. A completely new digital monitoring and control system is under test, but has not been implemented yet. A new mounting structure for the primary beam line of the heavy ion beam probe has been installed and the beam line mounted. The final connection of the beam line to the tokamak vacuum chamber has not yet been implemented. The microwave interferometer has been placed back into operation on RENTOR and an improved Langmuir probe system has been installed. Primary attention at the present time is on

documenting the radiation associated with RENTOR operation. Preliminary indication is that it is down compared with the runaway discharges that were observed earlier. More documentation is required, but it is hoped that with the addition of some shadow shielding we will be permitted to run on a 24 hour basis rather than being restricted to night time operation as we were in the old Plasma Laboratory.

The Thomson scattering system has been reinstalled on RENTOR, but we must install a replacement ruby rod in order to place it into operation. Just prior to the move to the new laboratory, Rayleigh scattering had been obtained, but before Thomson scattering could be tried the ruby amplifier rod was destroyed (a small bubble developed in the rod shortly after purchase and finally about 1 inch of the rod broke off). The replacement rod has recently arrived, and testing of the Thomson scattering system will resume in the near future.

At the present time, the status of RENTOR is that 6 to 8 msec equilibrium pulses have been reestablished, the base pressure is less than 5×10^{-7} Torr the radiation level appears to be down, the microwave interferometer, Langmuir probe and current-voltage measurements are back in operation, the Thomson scattering system has been installed and installation of the beam probe system is near completion. Preliminary results after reestablishing operation in the new laboratory indicate that RENTOR will provide an adequate target plasma for diagnostic development.

III. INITIAL HEAVY ION BEAM PROBE MEASUREMENTS ON RENTOR

Secondary ion signals from the heavy ion beam probe on RENTOR were first demonstrated on 8 August, 1979, a few weeks after reliable plasma operation had been established. A considerable amount of data was obtained before RENTOR was shut-down on 13 January, 1980 for the move to the new laboratory. This data is still in the process of being analyzed, with particular emphasis on determining the plasma space potential and identifying the location, size, and quality of the RENTOR plasma.

Several technological improvements were made in the beam probe system during the Spring of 1979, in parallel with the efforts to improve RENTOR itself. The major changes were:

- (1). A reduction in the noise level on the split plate detectors from ≈ 200 nA to ≤ 5 nA. Some of this reduction was due to the improved operation of RENTOR, but most was due to technological changes in the beam probe system. A completely new shield box was built to house the electrostatic energy analyzer, and improved shielding was installed on all electrical connections to the analyzer. The top plate of the analyzer was replaced by a screen, and a "venetian-blind" structure was mounted above the screen to prevent scattering of ultraviolet radiation onto the split plate detectors. DC batteries were installed to bias the split plates to +9 volts to reduce the signal level caused by secondary electron emission. The shielding of the external electrical connections and characteristics of the current to voltage amplifiers were also improved, resulting in a basic noise level of 3-5nA during the plasma pulse.

- (2). The computer simulation of the ion beam trajectories was substantially improved through the development of magnetic field codes to determine the structure of each of the various fields of RENTOR from the actual location of the windings. This simulation showed the significant steering of the beam in the toroidal direction due to the return field of the OH primary current. A steering signal slaved to the OH primary current was then used to drive the toroidal steering plates and resulted in "holding" the beam in the analyzer for the duration of the plasma. The improved simulation also led to a better understanding of the detection grid and sample volume for the beam probe data.
- (3). A revised version of the ion gun, developed as part of our program with LLL to install a beam probe on TMX, resulted in a substantial increase in the probing beam current density delivered to the sample volume. The total path length of the beam probe system on RENTOR is ≈ 2.5 meters and well-focused ion beams had been impossible with the old gun. Beam widths of 4-5 cm had been routine. The new gun used an additional focusing element, and produced $10\mu\text{A}$ beams that could be focused to less than 1cm at 2.5 meters, and $50\mu\text{A}$ beams focused to 2cm.

A typical shot of beam probe data is shown in Fig. 2. A 6 kHz triangle wave was used to sweep the beam radially through the plasma. Most of the beam probe data were obtained from plasmas characterized by a slow fall-off of the plasma current at the end of the pulse. This was produced by lowering the vertical field late in the plasma. Typical signal levels early in the

pulse are $\approx 10\text{-}20\text{nA}$, but a substantially higher level, $\approx 40\text{-}50\text{nA}$, was observed at the end of these plasmas. It is believed that the plasma is slowly moving vertically and somewhat outward at the end of these shots. The beam probe sample volume is mainly at the outer edge of the central core of the plasma until the very end of the current pulse. Mechanical apertures, which have been removed during the recent move, prevented us from locating the sample volume in the core of the plasma early in the discharge.

The magnitude of the signal levels are reasonably consistent with microwave measurements of the line density and conductivity estimates of the electron temperature. However, comparison with Thomson scattering measurements was not possible during this period and remains to be done. Analysis of the data to provide space potential measurements is still in progress, but preliminary information is now available. The potential appears to change by several hundred volts over the course of the discharge, decreasing monotonically except for possibly coherent fluctuations. Absolute measurements are extremely difficult due to a poor voltage correction function of the analyzer used and the accuracy of the trajectory calculations. It appears that for most plasmas the potential starts out positive by ≈ 200 volts, and decreases to ≈ -100 volts at the end of the plasma. Considerable variation in the potential is observed on a shot to shot basis. Radial information concerning the space potential is not yet available, and is complicated by the movement of both the plasma and the sample volume during the discharge. The installation of an additional capacitor bank in the TF system should aid radial measurements in the future.

The system has clearly demonstrated that space potential can be measured, and shows that there is a considerable change in the potential during the course of the plasma. Further work is necessary to reduce the error bars and improve the signal-to-noise ratio.

IV. ALEX MIRROR FACILITY

The minimum B "baseball" mirror facility, ALEX, has been placed in operation. A hollow cathode arc has been installed to provide a target plasma for demonstrating the measurement of space potential in this geometry using a neutral probing beam. Microwave and Langmuir probe measurements indicate that the arc is providing a plasma with a density of the order of $10^{13}/\text{cm}^3$ with an electron temperature of approximately 5 eV. This should be sufficient for testing the neutral beam system.

The arc operates on argon or a mixture of argon and helium, but pure helium operation has not been demonstrated. Operation with pure helium would be desirable since it would reduce the UV loading of the electrostatic energy analyzer used to detect the 1^+ secondary ions. Preliminary measurements with the argon-helium mixture, however, indicate that the loading can be reduced to an acceptable level. Although routine arc operation has been obtained, some problems still remain with the vacuum feedthroughs of the anode mounting system and with the arc spreading past the anode structure and running into the wall.

A complete analog simulation of measuring space potential in this geometry was carried out by installing an ion gun at the center of the magnetic system and detecting the beam with an electrostatic energy analyzer mounted at the appropriate detector location. The simulation showed that ions created by a neutral beam injected into a plasma could be detected. Space potential measurements were simulated by modulating the beam energy, and signal levels were simulated by reducing the beam current from the ion gun. This demonstrated, in principle,

that if a neutral beam can be delivered to the plasma, then the plasma space potential can be measured.

The complete neutral beam line for ALEX has been assembled and tested, but consistent neutral beam production has not been obtained. The Cs heat pump neutralizer has produced a neutral beam, but operation deteriorated fairly rapidly with time and the wick in the neutralizer burned up. A new wick is presently being fabricated. The major problem appears to be in delivering the appropriate ion current to the neutralizing cell. In an attempt to minimize the length of the primary neutral beam line, the neutralizing cell was used as part of a focusing lens structure. This prevented independent control of the ion beam and neutralizing systems. Under some conditions this worked well, but the results were not consistent or reproducible. We are presently decoupling the two systems in order to have independent control and isolate the source of any problems.

The modulation-synchronous detection system for the neutral beam probe has been checked out and is ready for use. The coherent noise at the detector with the arc operating is less than the anticipated signal from the beam probe. The expected signal is based on delivering a 10 microamp equivalent neutral beam to a plasma having a density of 10^{13} cm^{-3} and an electron temperature of 5 eV. The arc provides the required plasma parameters and a 20 microamp ion beam should provide the necessary equivalent neutral beam.

V. ION BEAM TEST STAND

The ion beam test stand was moved to the new Plasma Laboratory in JEC and placed back in operation. One of the first tasks carried out on the reestablished test stand was the calibration of the analyzer for the TMX beam probe system. This analyzer incorporated a number of new design concepts including mounting the voltage divider resistors for the guard rings and the preamplifiers inside the vacuum chamber and remote control from outside the vacuum system of both the entrance slit opening and the position of the split plate detectors. The tests showed that internal mounting of the resistors and amplifiers worked very well, the angular correction function could be measured in situ and that the desired correction function could be dialed in by adjusting the location of the split plates. (Figure 3 shows some typical angular correction functions for the TMX analyzer.)

Equipment for modulating the beam energy was installed on the test stand. This permitted energy calibration of the analyzers and the measurement of the frequency response of the system. This was installed in anticipation of carrying out direct comparison between feedback controlled and off line processing of space potential measurements. Analyzer calibration was done by setting the beam entrance angle and then sweeping the top plate voltage while monitoring the difference current to the two split plates. The expected curve was a positive saturation signal while all the current was on the top plate, a linear transition region as the beam moved across the plates and ending with a negative saturation when all the beam was on the lower plate. This general characteristic was observed, but there were

small pulses superimposed on the curve. A detailed evaluation showed that these pulses were caused by the beam walking across the 90% transmission mesh covering the entrance and exit apertures in the ground plane. Replacing the 90% mesh with 97% mesh, reduced the pulses to negligible levels.

One of the problems with the parallel plate electrostatic energy analyzer is that it only measures the component of the beam energy that lies in the plane of the analyzer axis. On most systems the magnetic field has small components that induce a transverse velocity to the beam. With a finite beam, the transverse velocity may not be uniform over the beam size and, in addition, the transverse component of velocity at the detector in general is a function of the observation point in the plasma. Since the energy associated with the transverse velocity is not measured it can introduce a small error in the space potential measurement. This error can be minimized by using curved detector plates. The line defining the separation between the upper and lower split plates should lie on a circle whose center is at the center of the entrance aperture. This would provide perfect compensation if the entrance aperture were a point source. It still provides very good compensation even when the beam fills a wide (2 inch) entrance aperture. This compensation is illustrated in Fig. 4 where we show test measurements on the same analyzer using plane and curved detector plates. The analyzer top plate voltage required to center the beam on the split plates is plotted as a function of entrance angle with respect to the plane of the analyzer. The solid curves represent the expected analytical results and the points are the experimental measurements.

The results show that the use of curve detector plates can reduce the error due to transverse velocity components to negligible levels even for a large range of angles ($\pm 15^\circ$). Another possible use of the curved detector plate analyzer is to flatten out the normal angular correction function. For example on a system that provides high signal levels and very little transverse dispersion so that a small entrance aperture could be used, the analyzer could be rotated by 90° and provide a flat angular correction function over $\pm 15^\circ$ range.

Some additional testing of commercial thermionic ion sources was also carried out on the test stand. In general we could obtain better focusing characteristics with the commercial sources, but their lifetime and current output were less than what we can obtain with our homemade sources. We expect that the better focusing is due to more uniform heating of the commercial sources. We intend to try to improve the uniformity of heating in our homemade sources and to try to obtain more rugged commercial sources that will have longer lifetime and more current output.

VI. NEW PLASMA LABORATORY

All facilities are now in place in the new plasma laboratory which is located in the high bay wing of the new Jonsson Engineering Center. ALEX was originally installed in JEC and RENTOR and IBTS has been moved from their former location in the Materials Research Center.

The new laboratory provides us with slightly more floor space but more important is the 22 ft. high ceiling with overhead crane facilities. More electrical power and cooling water is also available in the new laboratory. A mezzanine was constructed at one end of the laboratory to house the computer and data acquisition systems and also to provide office space for graduate students. A new larger, cinder block wall capacitor room has also been completed. This room meets all the safety requirements for housing high power electrical equipment and provides better access to the capacitor banks and charging supplies. There is also room to expand the capacitor bank to upgrade the TF and OH systems for RENTOR.

The new laboratory also provides better access control which prevents non-members of the plasma research group from wandering into the area. This is important when we are operating RENTOR, because of the potential x-ray hazzard and also when we are firing the ruby laser for Thomson scattering experiments. We are presently carrying out radiation survey experiments on RENTOR and hope that with the addition of some shadow shields, we will be able to obtain permission from our Radiation Safety Office to return to 24 hour a day operation.

VII. TECHNOLOGY TRANSFER

We are presently operating heavy ion beam probe diagnostic systems on EBT and the center cell of TMX. Although these programs are supported by contracts with ORNL and LLL, they are direct outgrowths of the developmental work supported by this contract.

The EBT beam probe system has been in operation for several years now. During the past year we have improved the space potential measurements, started evaluation of the $nf(T_e)$ signals and demonstrated that the $3^+/2^+$ ratio shows a definite peak in the area of the high energy electron rings. The negative potential well inside the ring region can be fitted very nicely to a parabolic distribution. If the ring radius is changed by varying the magnetic field, then the well increases in both depth and radius. The same parabola fits all of the data. The profile of the 2^+ signal as a function of radial scan across the ring region shows very little change when the ring in the beam probe sector is turned off. The 3^+ signal on the other hand, shows a definite change when the ring is turned on and off. We do not have sufficient cross-section information to fully interpret the results but best estimates are consistent with the hot resonance electrons generating increased 3^+ signal, but have very little effect on the 2^+ current. The data has to be corrected for changes in T_e of the background plasma across the ring region. The preliminary results indicate that the beam probe may be a very useful diagnostic for studying ring physics.

The first beam probe signals were obtained on TMX in August, 1979. Preliminary potential measurements indicate that the center cell potential is consistent with normal mirror scaling and estimates of T_e from the $nf(T_e)$ signal are consistent with Thomson scattering measurements in the end plug.

Comparison of the beam probe measurements with estimates of plug potentials obtained from end loss analyzers indicates the build up of a potential barrier in the plug. We have recently obtained multiple radial scans on a single plasma pulse which indicate that the potential is reasonably flat out to 15 to 20 cm and then falls off at around 30 volts per cm. Tl^{+++} signals have also been observed on TMX indicating reasonably high (order of 100 eV or higher) electron temperatures. Considerably more work needs to be done, particularly in detailed calculations of beam trajectories with the full TMX magnetic field and in situ calibration of the energy analyzer in order to obtain accurate evaluation of the potential with respect to machine ground.

During the past year we have carried out a preliminary evaluation of a beam probe system for measuring the edge potential in ISX. We constrained the design to beam energies of less than 100 kV. The preliminary calculations indicated that we should be able to carry out measurements over nearly 1/2 the plasma radius, beam attenuation would be noticeable but not a severe problem and that the expected signal levels should be large. We have discussed the preliminary results with the ISX group, and they were enthusiastic about the possibilities. We are presently refining the results to see if the beam probe system would be consistent with the available ports on ISX.

VIII. SUMMARY

Considerable progress has been achieved during the period covered by this report and most of the objectives listed in the proposal submitted in January, 1979 have been achieved. More reliable operation of RENTOR has been obtained and initial space potential measurements with the heavy ion beam probe have been carried out. An arc plasma has been established in ALEX and an analog simulation of space potential measurements in this geometry has been completed. The neutral beam line has been fabricated and tested. Good neutral beams have been obtained but consistent operation has not yet been achieved. Major improvements in the mechanical design of electrostatic analyzers have been developed and tested. A curved detector plate analyzer which should reduce the error in space potential measurements has been fabricated and tested. IBTS and RENTOR have been moved to the new plasma laboratory and placed back into operation. Beam probe systems on EBT and TMX are working well and the preliminary design of a beam probe system to measure the edge potential in ISX looks encouraging.

At the present time we have reasonable target plasmas in realistic geometries (RENTOR and ALEX) that appear to be adequate for particle beam diagnostic development. The test stand is a very versatile system which permits rapid testing of new technological concepts and simulations of plasma measurements. A new CAMAC based data acquisition system is being assembled which will enhance our data handling capabilities and permit the testing of off-line processing. We do not plan on the addition of any new major facilities but do expect to upgrade the toroidal field system in RENTOR so that it is uniform over the length of the pulse and to gradually increase the size of our data acquisition system. Eventually we plan on

implementing an ECRH plasma in ALEX to replace the arc so that we can test some near axial particle beam probing concepts and to evaluate the use of beam probing to study ECRH ring physics.

NOVEMBER 20, 1979

SHOT No. 39

V_{LOOP} , 2 VOLTS/DIV.

I_P , 6.3 kA/DIV.

X-RAYS, NAI (T)

FIGURE 1 TYPICAL CURRENT AND VOLTAGE TRACES FROM RENTOR

1/5/80 SHOT #108
PANORAMIC VIEW OF THE
DETECTOR CHANNELS

RADIAL SWEEP VOLTAGE:
500 V/CM @ 6 KHZ
-482.5 V OFFSET

SECONDARY ION CURRENT:
FRONT SPLIT PLATE:
10 NA/CM
REAR SPLIT PLATE:
10 NA/CM

TIME: 0.2 MS/CM

RB^+ PRIMARY ION BEAM,
19,420 V

ANALYZER VOLTAGE = 4747 V

FIGURE 2 SECONDARY ION SIGNALS FROM RENTOR

TYPICAL ANGULAR CORRECTION FUNCTION FOR ELECTROSTATIC ENERGY ANALYZER

FIGURE 3
TMX ANALYZER CORRECTION FUNCTION

FIGURE 4 VOLTAGE CORECTION FUNCTION FOR CURVED PLATE DETECTORS

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M. Kristiansen -- Texas Tech	P. Willis -- GE
K. Gentile -- U. of Texas	D. Priester -- DOE
E. Powers -- U. of Texas	C. Damm -- LLL
J. L. Cecchi -- PPPL	P. Demchenko -- Kharkov
F. C. Jobes -- PPPL	L. Krupnik -- Kharkov
J. C. Glowienka -- ORNL	V. Tershin -- Kharkov
J. F. Pipkins -- General Atomic	V. Yakubouski -- Kharkov
K. McCormick -- Garching	
J. Fujita -- Nagoya University	
P. Vandenplas -- Ecole Royale Militaire	
F. Cap -- U. of Innsbruck	
R. K. Feeney -- Georgia Tech	
A. Dellis -- Culham Lab	
W. Ard -- McDonnell Douglas	