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**HEAVY NEUTRAL BEAM PROBE
FOR
EDGE PLASMA ANALYSIS IN TOKAMAKS**

Annual Progress Report

for Period December 1, 1992 - November 30, 1993

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ABSTRACT

The contents of this report present the progress achieved to date on the Heavy Neutral Beam Probe project. This effort is an international collaboration in magnetic confinement fusion energy research sponsored by the U.S. Department of Energy, Office of Energy Research (Confinement Systems Division) and the Centre Canadien de Fusion Magnetique (CCFM). The overall objective of the effort is to develop and apply a neutral particle beam to the study of edge plasma dynamics in discharges on the Tokamak de Varennes (TdeV) facility in Montreal, Canada. To achieve this goal, a research and development project was established to produce the necessary hardware to make such measurements and meet the scheduling requirements of the program. At present, the project is in the middle of its second budget period with the instrumentation on-site at TdeV. The first half of this budget period was used to complete total system tests at InterScience, Inc., dismantle and ship the hardware to TdeV, re-assemble and install the HNBP on the tokamak. Integration of the diagnostic into the TdeV facility has progressed to the point of first beam production and measurement on the plasma. At this time, the HNBP system is undergoing final de-bugging prior to re-start of machine operation in early Fall of this year.

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I. INTRODUCTION

At the midpoint of the second budget period of the Heavy Neutral Beam Probe (HNBP) project (Grant #DE-FG02-91ER54111), the development results and present status are discussed in detail in this report. This project is focused on the installation of a unique tokamak diagnostic to perform measurements which can contribute to the international magnetic fusion energy research effort. With the recent emphasis on tokamak transport and its relation to boundary plasma dynamics, careful diagnosis and analysis of the behavior of the plasma edge is critical. A thorough characterization of the plasma edge is fundamental to understand the development of the discharge. The L-H-VH transitions which occur delineate distinct modes of tokamak operation which are critical to the establishment of fusion energy as an economically viable option. The role of plasma fluctuations in particle and energy transport is a central issue in current tokamak research. One type of diagnostic which has proved valuable in addressing this problem is the particle beam probe. This diagnostic can make real time measurements of plasma density and potential by monitoring the characteristics of the secondary beam generated by ionizing collisions with electrons in the plasma. The instrumentation presently under development in this project has the capability of measuring edge plasma parameters with high temporal and spatial resolution.

By the end of this budget period, the diagnostic will be making its first measurements on the Tokamak de Varennes at the Centre Canadien de Fusion Magnetique. The past nine months have been focused on the completion of system tests at InterScience and the on-site installation and de-bugging of the HNBP at TdeV. The central theme of the program is the study edge plasma dynamics including fluctuation levels during plasma current ramping experiments, divertor plate biasing studies and the imminent start of the Lower Hybrid Current Drive (LHCD) program on TdeV. In this way, the hardware will contribute fundamentally to the study of plasma transport and confinement. The choice of the Tokamak de Varennes is based on compatibility of the diagnostic with the geometry and operating conditions of the machine. In addition, this group is enthusiastically involved in a formal collaborative arrangement which is a concrete display of their interest in the relevant transport studies possible with this diagnostic. The cost sharing aspect of this collaboration has been manifested by the supply of equipment, personnel and machine time from the CCFM.

The HNBP system for the Tokamak de Varennes facility is a versatile system capable of high resolution measurements of electron density, space potential and their corresponding temporal fluctuations over the edge region of the plasma. Operating characteristics of this instrument have been previously discussed. The HNBP diagnostic system is a variation of the Heavy Ion Beam Probe (HIBP) that has been extensively and successfully applied in tokamaks, tandem mirrors and bumpy torus facilities. The possibility of probing the plasma at a savings of at least a factor two in beam energy over a heavy ion beam probe, and with increased spatial resolution, makes the HNBP quite attractive. By concentrating on the plasma edge, fundamental measurements can be done which have not been possible until now. Recent research has revealed the extreme localization of the dynamic edge layer containing the plasma changes which demarcate L-H transitions.

The end result of this project will be an instrument which can perform measurements in the outer plasma region of the Tokamak de Varennes. This capability will overlap and extend existing edge diagnostics (reciprocating probes) and link with the outer cords of more central diagnostics such as interferometry and Thomson scattering. It will also provide the unique possibility to measure density, potential and their fluctuations during plasma current ramping for both limiter and divertor modes of operation. The study of particle and energy transport dynamics using a well diagnosed plasma boundary is a central part of the program of TdeV, and it constitutes an important contribution of this machine to the understanding of confinement and anomalous transport in tokamak plasmas.

II. OVERALL PROJECT STATUS

The work detailed in this report is sponsored by the U.S Department of Energy under Grant # DE-FG02-91ER54111 and was begun in December, 1990. The work has been carried out under the direction of Dr. James Castracane as Principal Investigator (15% of a person-year), Dr. Eduardo Saravia as Technical Manager (10% of a person-year), and Dr. Jeffrey Beckstead as Staff Scientist (80% of a person-year). In addition, Dr. Steven Aceto has been added to the project under the U.S. DoE Fusion Energy Postdoctoral Fellowship program. It is anticipated that these percentages will be continued throughout the remainder of the project. During this budget period, new integration tasks for installation of the HNBP on TdeV arose which required additional effort. This has delayed the operation of the beam probe but was necessary for

compatibility with existing and planned additions to the diagnostic set of the facility. The HNBP project is presently on schedule for initial measurements on the Tokamak de Varennes in the early Fall of 1993.

From a general perspective, the project has been divided into a variety of task levels. During this second budget period, the hardware development has been focused on the integration of the constituent sub-systems to result in total system tests and will be discussed in detail below. This effort took place in the laboratories of InterScience and achieved total diagnostic operation prior to shipping and installation at the Varennes site. This task involved the final assembly of the HNBP and development of the control and acquisition software system for compatible operation with the TdeV facility. The shipment and integration of the diagnostic on TdeV was a complex task and occupied the first half of 1993. This required extensive modifications to both hardware and schedule with the impending installation of the LHCD system in the adjacent port. On a second level, facilities, personnel and hardware from the TdeV project which constitute the Canadian contribution to the project have been negotiated and committed. As mentioned above, these have been in the form of the purchase of equipment, engineering design time and access to the machine. Port allocation and rearrangement of existing diagnostics involved extensive negotiation and discussion. A third level of this project has been the planning and coordination of activities on an international level. This activity has involved the integration of the HNBP experimental goals with the machine program plan including scheduling of relevant experiments. To accomplish this, InterScience has maintained a continued presence in Varennes by the establishment of housing, office and laboratory space for development. Attendance at TdeV staff meetings (Reunion Scientifique et Technique) and periodic presentations of the project status have been done. This effort has allowed the diagnostic to blend into the research plans of the facility and will continue during the entire project. In addition, customs and immigration details have been attended to for shipment of equipment to Canada. This is an open question to be addressed through the international branches of DoE and the CCFM.

As a point of reference, Figures 1 a) and b) show the HNBP on the TdeV. The diagnostic has been installed on Bay #2 with radial access to the plasma from below the equatorial midplane as can be seen in a). Figure 1 b) shows the output beamline with analyzer chamber. This hardware is installed on the top port at the same toroidal location as the input. With this configuration, a measurement line is established which extends radially inward at a poloidal angle of approximately 45° .

Figure 1 a): Input beamline and b): output beamline of HNBP on TdeV

To achieve this configuration, extensive design and development efforts as well as last minute modifications were required of the HNBP and the surrounding structure of TdeV. To accommodate not only the HNBP but also the LHCD hardware, a platform superstructure was assembled and installed by CCFM personnel prior to the integration of the output beamline. This development introduced a significant delay in the original schedule of the HNBP. During this time, a more detailed measurement of the magnetic field around the machine during discharges was done to make a detailed comparison to the code used for input to the trajectory calculations. The results of these measurements required a modification to the code which expanded the operating window of the HNBP. This is discussed below.

At present, the start of beam production is imminent and will be achieved during the down time of TdeV for installation of the LHCD hardware. This installation will occupy the machine schedule until November. The plan of action is to characterize the neutral Tl beam using the inline diagnostics, begin the search for secondaries during the conditioning shots of the LHCD and start full measurements when the machine comes back on the air in the Fall.

III. HNBP HARDWARE DEVELOPMENT AND INSTALLATION

During this second budget period of the project, primary concentration has been on completion of total system assembly and testing, shipment, installation of the HNBP on TdeV and first measurements. This effort was in parallel with the scheduling requirements of the CCFM for their programmatic and fiscal plans. Each of these topics is discussed in sequence below.

Figure 2 shows the complete diagnostic as it appeared in the InterScience laboratory prior to shipment. The complete probe was set up to allow for direct insertion of the ion beam into the analyzer chamber. The input beam diagnostic set was fully installed and the system was under remote control by computer. The data which resulted from the various measurements was digitized for analysis and presentation. In this configuration, final tests on the system were done including measurement of the analyzer gain and neutralization efficiency.

Figure 2: HNBP During Final Tests at InterScience

The gain of the analyzer was measured at various beam energies for both Cesium and Thallium primary beams. As discussed in the previous progress report, the gain of the analyzer is dependent on a variety of geometric and beam parameters. It is determined by varying the input angle of the ion beam and measuring the output from the split plates in the electrostatic analyzer. Representative results of this exercise are shown in Figure 3.

Figure 3: Analyzer Gain Calibration

The beam current in these measurements was kept to approximately 20 microAmps to conserve source life. As can be seen, the curves are relatively insensitive to beam energy as expected and there is a broad plateau from 28-35°. This allows for adjustment of the orientation of the analyzer. The accuracy of this measurement is approximately 0.1-0.2%. Further improvement is achieved by calibrating the analyzer on the tokamak using a background fill gas.

Following this measurement, the neutralizer performance was examined. As mentioned in previous progress reports, the neutralizer for this project is a classic heat pipe design. It is operable with a variety of gases such as Sodium and Cesium. The temperature of the central block is carefully adjusted by an automated controller with thermocouples as feedback sensors. The typical mode of operation uses Cesium with central block temperatures of approximately 110-130° C. The Cesium vapor is well confined to the central block of the neutralizer to minimize leakage into the tokamak. Cooling coils at both ends of the pipe ensure efficient condensation and recycling of the vapor. Estimates of leakage indicate that the amount of Cesium which enters the tokamak will be less than the typical amount for laser ablation impurity experiments. To measure the efficiency of the neutralization, two different methods were used. The first was a Faraday cup assembly which allowed both the neutral current and the remaining ion current to be measured simultaneously. This is seen in Figure 4.

Figure 4: System for Measuring Neutralizer Performance

Tests were carried out for several ion beams and working gases. As an initial trial, a Cesium beam was directed through the Cesium charged neutralizer. The initial ion current is collected in the ion cup by deflecting the beam with a steady voltage applied to the deflection plates contained in the diagnostic cross. In addition, the total beam current is monitored upstream at a quadrant aperture near the ion gun. In this way, any changes to the source can be measured and factored into the test results. As the neutralizer becomes effective, a drop in the ion current is measured with a corresponding increase in the signal from the on-axis collector of neutral current. The Cs^+ beam in use with a Cs^0 neutralization gas achieved in excess of 90% efficiency. The ion source was replaced with Thallium and the tests repeated. Figure 5 shows the results of these measurements. In this case, a neutralization efficiency of 40% was achieved.

Figure 5: Neutralizer Performance Tests (Tl^+ on Cs^0)

As can be seen, higher temperatures are required. Modifications have been done to the neutralization structure to allow for a higher working gas density in the central region. The tube which extends vertically from the central block has been removed. It is anticipated that higher efficiencies will be achieved with this new configuration because

there is a smaller surface area for condensation. Tests in Varennes are in progress. The second method used to measure neutralization efficiencies was through the use of an in-line Beam Profile Monitor. This instrument measures the spatial distribution of the beam with a rotating wire. By deflecting the ion beam as before, it is spatially separated from the neutral beam and is graphically displayed as a function of neutralizer temperature. An example of both types of ion beams is shown in Figure 6.

Figure 6: Beam Profile Monitor Results

As can be seen, the repetitive traces show the relative amplitudes of the ion and neutral beam. Again, the efficiency for Cesium is near 90% and for Thallium reaches a maximum of 40% at 140° C. The BPM provides a rapid evaluation of neutralization efficiency in addition to its normal use of measuring the position and spatial symmetry of the beam.

Following these final system tests, the HNBP was disassembled and crated for shipment to the CCFM. The equipment crossed the border in late October, 1992 by truck. This process was carried out under a temporary import permit with Canada Customs. There is a finite limit on this permit (February 28, 1994) and it remains to be resolved how the equipment will remain in Canada without being subject to duty and tax charges. Several avenues are now being pursued through both the International Programs division of U. S. DoE and the CCFM. Resolution of this problem has an obvious high priority.

Upon arrival at CCFM, the HNBP was unloaded and the components placed in a lab provided by the CCFM. For the next several months, the high voltage system was reassembled in this laboratory for testing. In parallel, the vacuum system was assembled and connected to the angled support shown in Figure 1 a). The control and data acquisition code for the HNBP was also written and tested during this time period to be ready for system tests and first measurements when the diagnostic was installed. This code allows for the remote operation of the HNBP under the TdeV computer architecture. Status and interlock functions are included as well as data transferal into the central archives of TdeV. In this way, the information can be compared graphically with other diagnostics and the machine operating parameters. The data analysis code for the HNBP is an extensively modified version of that used at ATF. At present, the fluctuation portion of the code is operational with the potential portion under study.

The installation of the output beamline with analyzer tank was delayed due to the assembly of a second story floor on TdeV extending from Bay 1 to 3. This structure combines the HNBP analyzer system, high voltage racks and part of the LHCD hardware onto one platform. The LHCD system is under installation in the adjacent radial port (Bay #3) and coordination of both "real estate" and schedules was required. During the vacuum break in the Spring, this floor was installed followed by installation of the high voltage cabinets, input and output beamlines of the HNBP. The required electrical power cabling, data lines and utility (air and water) connections have now been made. The system has been tested successfully to its required operating voltages. Figure 7 shows the high voltage cabinets in place on the second floor of TdeV.

Figure 7: Data Acquisition and Control Hardware for HNBP

At present, the HNBP system is prepared for production of beams and to begin the measurement campaign. In the upcoming weeks, the beam production, neutralization and analysis chain on the input side will be tested under computer control through the TdeV operating system. After a 5 week period in which the tokamak will be down for LHCD installation, conditioning discharges will be produced for targets for the LHCD antennae. Initial neutral beams will be injected into the discharge and secondaries produced and detected. This milestone will mark the beginning of the exploitation phase of the HNBP. The anticipated sequence of events will be pointwise measurement of density and potential fluctuations. After the calibration for potential measurements is performed on background gas, the absolute potential can be addressed. Dependence of ionization cross sections on temperature in the boundary adds to the uncertainty in density values from the HNBP. Measured density values will be correlated with existing diagnostics for radial profiles.

Nearly nine months of effort has resulted in the system being poised for commissioning and participation in the physics campaign of TdeV. The remainder of this budget period and the next will be devoted to maximizing the output of the diagnostic in addressing the original intentions of the experiment: high resolution fluctuation analysis in the plasma edge.

IV. TRAJECTORY MODELING AND MAGNETIC FIELD MAPPING

As mentioned above, prior to and during the installation phase of this project, a series of magnetic field measurements were carried out to be used as a check for the output of the field code used in the trajectory simulations. TdeV is an air-core machine and hence, large and sometimes asymmetric magnetic fields exist throughout the experimental area. Obviously, this can have a significant effect on ion trajectories and the performance of the analyzer. On TdeV, the OH coils produce the dominant fields outside the vacuum vessel. The current in these coils ramps from +20 kA to -20 kA during the discharge. For reference, Figure 8 shows the cross section of TdeV with the placement of all of the coil sets.

Figure 8: TdeV Coil Set Placement

Early trajectory simulations used maximum values for the coil currents for order of magnitude estimates. This was refined to include the actual TdeV current traces and it was discovered that the OH field limited the performance of the HNBP to the center 1/3 of the discharge time (near the zero crossing of the ohmic current). In order to verify the code predictions for the B-field outside the vessel, magnetic pickup coils (on loan from the University of Wisconsin) were used to measure the fields for each poloidal field coil set individually. As expected, the OH field was dominant around the analyzer and ion gun. Many of the other shaping coil sets were measured to be below a few Gauss outside the vacuum vessel. However, the measured fields were a factor of 2-3 below the predictions of the code.

By modifying the model used in the simulations to more closely represent actual conditions, the simulated fields are within 30% of the measured values. Trajectory simulations now indicate that nearly 90% of the discharge time can be sampled. Figure 9 shows a representative sample of the data set for the OH field map and the values predicted by the B-field code.

POSITION	Code				Measured	
	R(cm)	Z(cm)	Bz(G)	Br(G)	Bz(G)	Br(G)
Z=0 Diagnostic Cross	221.0	0.0	-200	0	-210	0
Z=0 Gun Box	306.0	0.0	-80	0	-81	1
Front of Gun Box	306.0	-39.4	-75	-29	-74	-33
Analyzer Tube-Front	173.0	111.0	-63	366	-66	479
Analyzer Chamber	246.0	113.0	-62	131	-71	145

Figure 9: Comparison of B-Field Code and Measured Values

A more detailed mapping of the B-field along the secondary ion trajectory may be required to fine tune the sampling volume. This will require a specially designed probe due to the large field values and their gradients near the TF coils. However, there now

exists sufficient confidence in the modeling to allow for the experimental acquisition of secondaries to begin.

IV. CONCLUSIONS

With the achievement of these results, the hardware and software for the Thallium HNBP is nearing full readiness for first measurements on the Tokamak de Varennes. The work effort during the first half of this second budget period has been focused on the completion of the preparation of the HNBP at the full system level, arranging for the international shipment of the equipment to Varennes and re-assembly for installation on the machine. The continued progress achieved on the project has been aided by TdeV contributions of equipment, personnel and design services. Their continued commitment to the project is evidenced by the inclusion of the HNBP in the machine plans and the renewal of their budget allocation for this diagnostic.

The exploitation phase of the HNBP project is underway. The diagnostic is mounted on the machine to begin the commissioning phase and enter into the physics campaign. The next years of the project will address the role played by boundary dynamics in the development of the discharge. Fundamental questions about edge density and potential profiles will be examined. Finally, it should be noted that the TdeV is currently involved in an upgrade design study (TdeV+ and TdeV-M) which will further extend the performance of the facility. It is anticipated that successful operation of the HNBP will pave the way for a continued presence in the diagnostic set of the TdeV.

APPENDIX

(Contains reprints of abstracts or articles produced during this budget period)

**35th Annual Meeting, APS Division of Plasma Physics
1-5 November 1993—St. Louis, MO
ABSTRACT SUBMITTAL FORM**

Subject Classification Category (see pg. 80) 2.6

☐ Theory ☒ Experiment

Initial Results from the Thallium Neutral Beam Probe on the Tokamak de Varennes.* J.A. Beckstead, S.C. Aceto†, J. Castracane, D. Edmans, E. Saravia, and J.T. Woo. InterScience, Inc. - During the spring of 1993, a Thallium Neutral Beam Probe was installed on the Tokamak de Varennes. This diagnostic was developed in order to study fluctuation induced transport during a wide variety of discharge conditions, such as plasma biasing, divertor operation and current ramping. Trajectory calculations indicate that a spatial resolution of 3-4mm can be obtained over a -10 cm radial measurement line which extends from the scrape off layer through the separatrix. The diagnostic uses a Pierce extractor and electrostatic lens system to accelerate and focus a Thallium ion beam to energies up to 60 keV. The beam is then neutralized by a heat-pipe neutralizer with Cesium as the working gas. The resulting ions from the plasma-neutral beam interaction are collected and measured with an electrostatic energy analyzer. Computer control of the beam energy and the injection angle allow for rapid radial profiles of the plasma density and space potential to be measured and correlated with changes in the plasma boundary conditions. Initial results of this diagnostic will be presented.

*Supported by the U.S. Department of Energy under Grant # DE-FG02-91ER54111 and the CCFM TdeV Project.

†Supported by US DOE Fusion Energy Postdoctoral Fellowship administered by ORISE.

- ☒ Prefer Poster Session
☐ Prefer Oral Session
☐ This poster/oral should be placed in the following grouping: (specify order)

- ☐ Special Facilities Requested
(e.g., movie projector)

- ☐ Other Special Requests

Submitted by:

(Signature of APS Member)

Dr. James Castracane
(Same Name Typewritten)

105 Jordan Road Troy, NY 12180
(Address)

This form, or a computer generated form, plus TWO XEROX COPIES, must be received by Friday, 2 July 1993, at the following address:

Saralyn Stewart
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Telephone (512) 471-4378

Division of Plasma Physics

November 16-20, 1992, Seattle, WA

Category Number and Subject 2.6

☐ Theory ☒ Experiment

The Thallium Neutral Beam Probe on the Tokamak de Varennes. J.A. Beckstead, M. Ampeia, J. Castracane, E. Saravia and J.T. Woo, InterScience, Inc. - A low-energy Thallium Neutral Beam Probe is scheduled to be installed on the Tokamak de Varennes in the fall of 1992. This diagnostic has been developed in order to study fluctuation induced transport during a wide variety of discharge conditions, such as plasma biasing, divertor operation and current ramping. Computer control of the beam energy and the injection angle allow for rapid radial profiles of the plasma density and space potential to be measured and correlated with changes in the plasma boundary conditions. Trajectory calculations indicate that a spatial resolution of 3 - 4 mm can be obtained over a 10 cm radial measurement line which extends from the scrape off layer through the separatrix. The diagnostic uses a Pierce extractor and electrostatic lens to accelerate and focus a Thallium ion beam to energies up to 60 keV. The beam is then neutralized by a heat-pipe neutralizer with Cesium as the working gas. The resulting ions from the plasma-beam interaction are collected and measured with an electrostatic energy analyzer. The overall status of the beam probe and its components will be presented.

*Supported by the U.S. Department of Energy under Grant #DE-FG02-91ER54111.

- ☒ Prefer Poster Session
☐ Prefer Oral Session
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- ☐ Special Facilities Requested
(e.g., movie projector)

Jeffrey Beckstead
(Same Name Typewritten)
InterScience, Inc.
105 Jordan Road
Troy, NY 12180

- ☐ Other Special Requests

(Address)

This form plus TWO XEROX COPIES must be received by Friday, July 10, 1992 at the following address:

Sara Lyn Stewart
The University of Texas at Austin
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28th & Speedway - RLM 11.217

TdK

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Thallium neutral beam diagnostic probe

CONFERENCE PRESENTATIONS

CCFM was very active in presenting research results at international conferences, and the papers were in general very well received, indicating that CCFM research is of interest to the international fusion community, especially in divertor operation and plasma biasing. The main conferences at which papers were presented in 1992 were:

- 10th International Conference on Plasma-Surface Interactions in Monterey, California (April).
- IAEA Plasma Theory and Modelling Meeting in Montreal (June).
- IAEA Plasma Biasing Meeting in Montreal (September).
- 47th Congress of the Canadian Association of Physicists in Windsor (June).
- 19th Conference of the European Physical Society in Innsbruck, Austria (June).
- 14th IAEA Plasma Physics and Fusion Meeting in Würzburg, Germany (October).
- American Physical Society Meeting in Seattle, Washington (November).

VISITING SCIENTISTS

As with many fusion centres, scientists visit CCFM to collaborate in research. Scientists visiting on longer term projects at CCFM in 1992 included:

- Cyrus MacLatchy, Acadia University, Wolfville, N.S., collaborating on edge plasma probes including the Gundestrup probe.
- Zhongtian Wang, Southwest Institute of Physics and Chemistry, China. Dr. Wang completed a two-year attachment as visiting scientist with the Theory Group in October. He worked chiefly on plasma biasing theory.
- Sergei Krasneninnikov of the I. V. Kurchatov Institute, Moscow, now occupies the position of visiting scientist with the Theory Group, having joined CCFM in September. He specializes in edge plasma and divertor physics applied to reactors.
- Roland Magne from CEA Cadarache, France, is on a long term attachment with the LHCD group as an RF specialist.
- Roger Raman of CFFTP arrived in late 1992, and will stay through 1993 to work on CT fuelling experiments.
- A team from InterScience Inc., NY, led by Jim Castracane arrived in late 1992 to install the InterScience thallium neutral beam diagnostic. Steve Aceto, Dan Edmans and Jeff Beckstead were on site at the end of 1992. Members of the InterScience team will be on site at CCFM through 1993 and possibly in 1994, to operate the device and interpret plasma edge data.

Scientists visiting for shorter durations included:

- Herman Tsui, from University of Texas, who installed and operated a reciprocating probe in the plasma edge.
- Minoru Sugawara, Gunma University, Japan, who worked on Langmuir probes in the plasma edge.
- Albert Nicolai, TEXTOR, Jülich, Germany, working on implementation of a transport code for simulations.
- Stephane Heuraux, Université de Nancy, France, working on analytical modelling of biasing experiments.

END

**DATE
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1/12/94