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In this Issue

- Report - IAEA Plasma Biasing Meeting
- Announcement - IAEA Fusion reactor Safety Meeting
- New IEA Program - Nuclear Technology of Fusion reactors
- TFTR Tritium Purification System for DT Phase.
- CCFM Update: Machine Additions and Modifications
- New Compact Toroid Injector at University of Saskatchewan

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CFFTP - PPPL

Tritium Purification System for TFTR

The Tokamak Fusion Test Reactor (TFTR) at Princeton, USA, is scheduled to begin fuelling operations using tritium when it begins its Deuterium-Tritium (DT) Experimental Phase later in 1993.

Princeton Plasma Physics Laboratory (PPPL), where TFTR is located, has awarded CFFTP a contract to design, build and install a Tritium Purification System, for detritiating TFTR's plasma chamber exhaust gases during the DT Experimental Phase. TFTR will not consume, in fusion reactions, all the tritium injected as fuel during DT operations. Most of the tritium will be exhausted from the TFTR plasma chamber after each DT plasma shot.

The Tritium Purification System (TPS) is designed to recover essentially all of the tritium from TFTR exhaust gases, including detritiation of exhaust impurities such as hydrocarbons and nitrogen compounds. The TPS is intended to recover deuterium and tritium in a form pure enough for possible recycling as fuel for TFTR, and should produce a tritium-free reject exhaust gas stream suitable for discharge to atmosphere if so wished. The TPS is being designed and built in Canada, using low tritium inventory isotope separation techniques. Installation of the TPS at Princeton is scheduled for fall 1993.

More information: Allan Meikle, CFFTP (416) 855-4724, FAX 823-9644, (See Contact Data).

Change of Address and Telephone numbers for National Fusion Program Office

Please note that the National Fusion Program has changed its telephone numbers and mailing address.

See the **Contact Data** on the back page of this edition for the new information.

Please update your records. The FAX number remains the same.

CCFM - CENTRE CANADIEN DE FUSION MAGNETIQUE

CCFM Update:

TdeV installs divertor pumps

The TdeV tokamak at CCFM has been shut down since October 26, 1992 for modifications to its divertors, and for installation of cryogenic divertor pumps and other significant equipment including a neutral beam edge probe and a compact toroid (CT) fueller. TdeV restart is scheduled for early February. Experimental work for the first half of 1993 will concentrate on continued exploration of biased operation of TdeV's pumped "slot" divertors, as well as plasma edge explorations and CT fuelling. CCFM staff are emphasizing reactor-relevant research, including the possibility of using biasing to greatly increasing plasma density in the divertor with a view to exploring the potential for radiative cooling of divertor plates. Divertor cooling is an increasingly important topic, since the very high projected heat loads on fusion reactor divertor plates (in excess of 20 MW/m^2 for ITER) appear to be unmanageable with currently available technologies.

Divertor pumps. Three more helium-cooled vacuum cryopumps (for a total of four) are being fitted on TdeV to significantly increase TdeV's ability to pump impurities - including helium - out of the plasma via its biased "slot" divertors. Divertor pumping trials with one cryopump were very encouraging.

Thallium neutral beam probe. For exploring plasma potential, density and other parameters in the plasma edge, this US-built probe is being installed on TdeV. It was built with USDOE assistance by InterScience Inc. (Troy, NY), who will operate it at TdeV. The electrically scanned probe

continued inside

29-01

CCFM - CENTRE CANADIEN DE FUSION MAGNETIQUE

CCFM Update

continued from front page

beam of neutral thallium atoms penetrates the outer plasma very well, and will provide data from both inside and outside the last closed flux surface. Its high frequency scan rate in two axes permits it to rapidly map plasma edge parameters.

Compact Toroid Fueller. This device, built by University of Saskatchewan for CFFTP, is also being installed. Fuelling trials with this device on a machine as large as TdeV will be of a pioneering nature, since CT fuelling is a very new field.

Divertor plate modifications. Difficulties with arcing have precluded plasma biasing via the divertor plates at voltages greater than about ± 200 volts. Intense efforts to improve divertor insulation performance are in progress, and one set of divertor plates is being segmented circumferentially to help locate arcing points. CCFM staff wish to bias the TdeV plasma to ± 500 volts or more.

Papers Summarizing TdeV's work and results in 1992 with biased divertor operation have been presented this year at the American Physical Society Meeting in Seattle, Washington (November), the 14th IAEA Plasma Physics and Fusion Meeting in Würzburg, Germany (October), and the IAEA Plasma Biasing Meeting in Montréal (September).

Copies of the papers, or more information on TdeV modifications and experimental programs can be obtained from Réal Décoste, CCFM Operations Director (514) 652-8715, or Brian Gregory, CCFM Director of Research, (514) 652-8729.

ANNOUNCEMENT

Fusion Reactor Safety

IAEA Technical Committee Meeting

Toronto, June 7- 11, 1993

Canada has invited the International Atomic Energy Agency to hold its 1993 Technical Committee Meeting on Fusion Reactor Safety in Toronto next June. The host organization, the Canadian Fusion Fuels Technology Project (CFFTP) has chosen the week of June 7 - 11, 1993 for the Meeting. This Committee last met in Jackson, Wyoming, USA, in 1989.

Papers are invited from those working in fusion reactor safety and related topics. Topical areas already identified for the meeting include, but need not be limited to, the following:

- Recent progress in fusion safety work in participating countries.
- Progress on ITER safety and environment analyses.
- Operational experience in fusion facilities concerning safety matters.
- Source term data and calculations for radioactive releases to the environment.
- Modelling of environmental releases.
- Waste Management.

Participants will be notified of Meeting site, technical program and hotel arrangements early in 1993.

Gary Vivian of CFFTP is responsible for the Technical Program and local arrangements. Dr. F.N. Flakus of the IAEA is the Scientific Secretary for the Technical Committee Meetings on Fusion Reactor Safety.

Interested parties are asked to identify their interest, in contributing or attending, as soon as possible to:

Gary Vivian - CFFTP
Tel: (416) 855-4733,
FAX: (416) 823-8020.

For the CFFTP mailing address, see Contact Data.

Information can also be obtained from:

Dr. F.N. Flakus
Technical Committee on Fusion Reactor Safety
International Atomic Energy Agency
Wagramerstrasse 5, PO Box 100,
A-1400 Vienna, Austria.

or from:

W.J. Holtslander, Manager - International Program, NFP (See Contact Data - note new address and direct-dial telephone numbers for the National Fusion Program Office).

UNIVERSITY OF SASKATCHEWAN

New Compact Toroid Fueller

Second CT device at University of Saskatchewan

University of Saskatchewan is building a second Compact Toroid injector, for launching compact toroids (CTs) of high-density plasma at very high velocities - up to 500 km/s - into

EDUCATION/RESEARCH

Metallic Plasma Impurity Studies

continued

increasing central plasma aluminum concentrations by factors of two to three. Negative plasma biasing increases bulk plasma flow to the lower divertor through **ExB** flow effects; by mechanisms still to be exactly elucidated, the increased plasma flow improved retention of aluminum in the lower divertor.

This work raises the interesting possibility that if metallic impurity transport can indeed be controlled with biased divertors, then practical metallic plasma–facing components might possibly be fabricated from high atomic–number metals such as molybdenum. Without some sort of transport control for metallic impurities, the high particle fluxes that would impact on divertor plates in a real fusion device would sputter enough metal from the surface of a metallic divertor plate to effectively poison the plasma with metal. A practical fusion device could tolerate metallic impurity levels in the plasma of the order of about 0.1% maximum. The detrimental effects of excessive metal impurity levels include high radiated energy losses (with a consequence of reducing energy confinement time of a plasma below a useful level) as well as strong dilution of the fusion plasma fuel through multiple captures of electrons in the electron shells of each metal impurity atom.

The occasion arose, during Dennis' work, for some investigation of calcium transport from the divertor regions, including the susceptibility of calcium transport to control by biasing. Some surface contamination of calcium had inadvertently been deposited on a TdeV divertor plate during a maintenance opening of the TdeV vacuum vessel. Calcium was therefore directly sputtered from the divertor plates through particle impact during TdeV plasma shots, and CCFM workers were able to track its movement in the plasma. Divertor retention of calcium was also found to be influenced by plasma biasing through the divertor plates.

Aluminum and calcium transport were tracked using visible spectroscopy and very short wave ultra violet light (also known as vacuum ultra violet , or VUV) spectroscopy.

Dennis Whyte's Ph.D. supervisor was Brian Gregory; his internal examiner was Guy Ross of INRS. External examiners were Boris Grek (Princeton Plasma Physics laboratory) and Charles Daughney (National Fusion Program).

Dennis left CCFM in November to take up post–doctoral studies in plasma impurity transport with General Atomics (California, USA) at the D III D tokamak, which is also studying divertor electric field effects and current injection into the plasma edge.

Brian Gregory and Dennis Whyte are preparing a paper for publication on the laser–ablated aluminum transport work.

Interested parties should contact Brian Gregory (514) 652–8729.

INTERNATIONAL

Nuclear Technology of Fusion Reactors

New IEA Cooperative Program

The International Energy Agency (IEA) is coordinating a new international cooperative effort on the Nuclear Technology of Fusion Reactors. Canada, Japan, Europe and the United States are the four parties to this new IEA research program, and will cooperate under an *IEA Implementing Agreement*, expected to be signed by all parties in early 1993.

Four Tasks have initially been identified for this Program:

Task & Task Leader

Solid Breeder Blankets
M. Dalle Donne (KfK Karlsruhe, Germany)

Liquid Breeder Blankets
R.F. Mattas (Argonne National Laboratory, USA)

Neutronics
H. Maekawa (Japan Atomic Energy Research Institute).

Tritium Processing
W. Shmayda (Ontario Hydro, Canada).

Canada is participating in the Solid Breeder task, as well as in the Tritium Processing task. As leader of the Tritium Processing Task, Walter Shmayda is chair of that Task's Working Group, responsible for coordinating its technical program and activities. Paul Gierszewski of CFFTP represents Canada in the Solid Breeder Task Working Group.

As with other IEA programs, the *Co-operative Program on the Nuclear Technology of Fusion Reactors* will be coordinated by an Executive Committee of members from participating countries. Until the IEA Implementing Agreement is formally signed by all four participating countries, most likely in early 1993, a provisional Executive Committee is coordinating preparations and proposed research efforts. This provisional committee met for the second time at the SOFT Conference in Rome on September 17, 1992; its members are:

Canada	W.J. Holtslander (National Fusion Program)
Japan	Y. Seki (JAERI)
Europe	D.L. Ward (Euratom)
USA	S. Berk (USDOE)

Technical programs are still being evolved, with emphasis on

- Improvements in energy confinement.
- Alteration of plasma flow velocities.
- Control over divertor efficiency in retaining impurities.

The number and degree of the effects observed depended on the biasing method and the parameters of the individual machine. Biasing alters the interplay between many plasma parameters in a machine, including radial electric field profile, toroidal and poloidal plasma velocities, profiles of basic plasma parameters such as density and temperature, transport mechanisms and turbulence. One primary aim of biasing experiments is to control the radial electric field in plasmas, independent of other controllable machine parameters such as the plasma current, magnetic field and auxiliary heating. Much work remains to be done in understanding the plasma edge and its role in overall plasma behaviour; fine control of radial electric field in the edge helps in edge behaviour explorations.

There now seems little doubt that biasing has the potential to control plasma edge profiles and flows, impurity retention by divertors and the onset of improved confinement regimes. While high confinement regimes like H-mode exhibit improved energy confinement, they can also result in increased particle confinement, leading to undesirable increases in plasma impurity levels. For fusion reactor design, the prospect of using biasing to control impurity levels in divertor machines independent of energy confinement parameters is particularly appealing. Several of the presented papers were on plasma biasing via divertor plates, an area of active research on TdeV. The work presented indicates that impurity pumping from the plasma, by enhanced retention of impurities in divertors, can be controlled independently of plasma pressure.

Alain Boileau of CCFM chaired the Program Committee and organized the local arrangements in Montréal.

Proceedings of the Meeting, containing full-length papers, are being published by the IAEA.

Contact:

Dr. Vladimir Demchenko
International Atomic Energy Agency
Wagramerstrasse 5, PO Box 100,
A-1400 Vienna, Austria.

Tel: 011-43-1-2360-1702.

The IAEA journal *Nuclear Fusion* is publishing in January the Summary Report,'Tokamak Plasma Biasing', by Alain Boileau.

The journal *Fusion Technology* is to carry a review of the Meeting by Reece Roth of University of Tennessee.

Further information on the Meeting from Alain Boileau, CCFM, (514) 652-8706.

EDUCATION/RESEARCH

Metallic Plasma Impurity Studies

First Ph.D. granted with thesis research on TdeV

The first Ph.D. with a thesis centred on research with Tokamak de Varennes (TdeV), has been granted to Dennis Whyte by INRS–Énergie et Materiaux, which is part of Université du Québec. INRS is a partner institution in Centre canadien de fusion magnétique (CCFM), where TdeV is located. The thesis research investigated the transport of metallic impurities in the tokamak, and showed that the TdeV divertors could retain aluminum injected into the tokamak.

CCFM and INRS have a national mandate to train fusion researchers. Because TdeV began operation only in 1987, Dennis Whyte was the first Ph.D. student at INRS with a thesis program suitable for direct experimentation on TdeV. A number of other INRS graduate students are now doing their Ph.D. thesis research on TdeV. INRS has been training fusion researchers for over 20 years.

Dr. Whyte investigated the movement of aluminum impurities in the TdeV plasma, after injecting the aluminum by a laser ablation technique into TdeV in two places – into the plasma edge of the tokamak main plasma, and into the plasma region just in front of TdeV's lower divertor plate. There has, to date, been relatively little experimental data available on the transport of metallic impurities in a divertor tokamak.

The work demonstrated that the TdeV divertors can retain metallic impurities, and that plasma biasing via the divertor plates can affect divertor retention of metallic impurities.

Without divertor plate biasing, only about 1/20 of the aluminum injected into the divertor plasma finds its way back into the central plasma of the tokamak. This fraction is diminished further by a further factor of 5, to about 1/100, when the divertor plates are biased at –200 volts relative to the vacuum chamber walls. Conversely, positive plasma biasing had the opposite effect,

continues

tokamak plasmas. The device will be fitted to the University's STOR-M tokamak, with the main aim of studying tokamak fuelling and plasma current drive by CT injection. Compact toroid injectors are a new technology, being viewed as a possible method of fuelling fusion reactors by injecting fuel deep within a hot plasma, as will be required in next-step fusion machines with burning plasmas. CT injectors are also called CT Fuellers or CT Guns.

The new CT injector is called USCTI, for University of Saskatchewan Compact Torus Injector. The Saskatchewan Plasma Physics Group has already built and tested a CT injector for CFFTP; that CT injector is presently being installed on Tokamak de Varennes (TdeV).

The USCTI injector possesses a feature believed to be unique, allowing it to explore the feasibility of tokamak plasma current drive. As designed, the injector is to be mounted on a flexible 'neck' - a vacuum tight flexible bellows - to allow CTs to be injected at various angles relative to the plasma, because it is thought that CT-driven plasma current may be a function of CT injection angle.

Detailed investigations will be carried out with USCTI to characterize CT plasmas, including investigations of density, magnetic configurations and velocities. The program will also study the CT magnetic reconnection processes between injected CTs and the magnetic fields of the tokamak plasma. Optimization of fuel deposition in the STOR-M plasma will be made by varying the CT parameters and CT injection angle. Feasibility studies of plasma heating will also be made.

The STOR-M tokamak at Saskatchewan is at present being upgraded to increase the toroidal field to 2 Tesla with an ohmic plasma current of 100 kA. If CT current drive proves feasible, the Plasma Physics Group hopes to show pulsed plasma current increases of about 50% - to 150 kA - as a result of CT injections. STOR-M upgrade work will be completed in summer 1993. USCTI will be built by the end of 1993, and tested on STOR-M in 1994.

The new CT project is being funded by Canada's Natural Sciences and Engineering Research Council. USCTI is a cooperative program between University of Saskatchewan, CFFTP and CCFM.

More information from Prof. Akira Hirose, Physics Dept., University of Saskatchewan (306) 960-6400, Fax (306) 960-6414.

INTERNATIONAL

Plasma Biasing Meeting

IAEA Technical Meeting on Tokamak Plasma Biasing

This first-ever IAEA Technical Committee Meeting on Tokamak Plasma Biasing was held September 8-10 in Montréal, hosted by Centre canadien de fusion magnétique (CCFM) and Hydro Québec. Forty-three researchers representing 12 countries attended, to share plasma biasing experience from 26 research centres. Thirty four papers were presented.

The amount and breadth of current work in electrical biasing of plasmas surprised many at the Meeting. Important new work was presented, and the Meeting was judged to be useful, interesting and lively.

Research results presented seemed to indicate that plasma biasing research could well have a significant effect on understanding and control of plasma confinement, and on the design of fusion reactors. For example, work presented by several researchers demonstrated conclusively that particle and energy confinement of plasmas can be significantly altered by electrical biasing of the plasma. Impurity screening by the plasma edge and divertor efficiency, in terms of impurity retention, can also be altered by biasing. These findings have implications for reactor control. As well as offering the prospect of new control techniques, biasing research is also providing information on the role of various plasma parameters (such as electric fields, plasma rotation velocity and shear) in particle and energy transport and overall plasma behaviour.

Work with several methods of plasma biasing was reported, including biasing through probe electrodes, limiters (including an electron-emitting limiter), ring electrodes and divertor plates. Work was also reported on plasma self-biasing and biasing by turbulent heating. Most papers involved biasing of tokamak plasmas. Bias voltages, in both positive and negative biasing, ranged from a few volts to several hundred volts.

Reported plasma effects induced by biasing included:

- Triggering of H-mode high confinement regimes, with biasing voltages of several hundred volts.
- Narrowing of the plasma edge scrape-off layer.
- Steepening of radial electric field profiles.
- Stabilization of plasma turbulence.
- Degradation of particle confinement, without degradation of energy confinement.

sharing of experimental facilities. Participants in the Rome meeting agreed that this IEA cooperative effort in nuclear technology should have long range goals for general advancement of knowledge in the four Task areas, although these goals are expected to be in harmony with the needs of mission-specific projects such as ITER. Some of the ideas discussed at the Rome meeting included:

Solid Breeder Blankets: A workshop on beryllium was proposed for Fall 1993. An Electromagnetic Forces workshop was held at KfK Karlsruhe in October 1992.

Liquid Breeder Blankets: A focus on the development of ITER blanket modules was suggested, as was inclusion of divertor and limiter development.

Tritium Processing: In addition to tritium handling and processing, it was suggested that tritium sourcing and transportation might receive attention.

Members of the Working Groups are listed in the accompanying table.

More information: W.J. Holtslander, National Fusion Program, (613) 584-8039.

Nuclear Technology of Fusion Reactors
IEA Working Group Members

	Canada	USA	Japan	Euratom
Solid Breeder Blankets	P. Gierszewski (CFFTP)	C. Johnston (ANL)	H. Takatsu (JAERI)	M. Dalle Donne (KfK)
Liquid Breeder Blankets	None	R. Mattas (ANL)	S. Tanaka (U. of Tokyo)	L. Giancardi (CEA Saclay)
Neutronics	None	M. Abdou (UCLA)	H. Maekawa (JAERI)	W. Dänner (NET)
Tritium Processing	W. Shmayda (Ontario Hydro)	J. Anderson (LANL)	K. Okuno (JAERI)	David Ward (Euratom) *(Interim)*

National Fusion Program

Director, *Dr. David P. Jackson*

The National Fusion Program (NFP) coordinates and supports fusion development in Canada. NFP was established to develop Canadian fusion capability, in industry and in research and development centres. NFP develops international collaboration agreements, and assists Canadian fusion centres to participate in foreign and international projects.

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NOTE:
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