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ITER

ITER: Canada plans for EDA

In the latter part of 1990, Canada informed the four parties to ITER (Europe Community, USA, Japan, USSR) that Canada is interested in participating in the proposed ITER Engineering Design Activities (EDA). During the EDA, the detailed engineering for the ITER machine would be performed, based on a design reference concept produced during the now-completed ITER Conceptual Design Activities (CDA). Canada contributed to the CDA, in a number of science and technology areas, through the European Community. The ITER Conceptual Design Activities ended in December 1990. It is anticipated that the EDA could begin in the spring of 1991.

Canada's two key fusion projects, Centre canadien de fusion magnétique (CCFM) and the Canadian Fusion Fuels Technology Program (CFFTP), have expressed interest in contributing to the ITER EDA and have for some time been developing their plans for contributions.

Canada also indicated to the ITER council in 1990 that it would welcome the opportunity to prepare a proposal for siting the ITER EDA in Canada, if the four parties to ITER commit to the ITER EDA, and decide to move the EDA from Garching, Germany. CFFTP explored the possibility of siting the EDA in Toronto.

Centre canadien de fusion magnétique

CCFM Update:

■ Plasma Biasing Experiments
■ Boronized Graphite Tests

On Tokamak de Varennes (TdeV), the October-December period was spent chiefly in experiments with plasmas controlled by the double-null closed divertors. Preliminary results were obtained in plasma electrical biasing experiments and in exposure tests of boronized graphite samples on the test limiter head.

TdeV was shut down on 21 December, 1990 for minor modifications, including enhancements to vacuum pumping systems. TdeV is expected to be back in operation by early March 1991.

Starting in summer 1991, CCFM plans to operate TdeV with deuterium plasmas.

The closed poloidal divertors on TdeV, which were brought into operation in September 1990, have resulted in reductions in plasma impurity levels. With divertors operating, the TdeV plasma shape was measured to be as predicted by MHD code calculations, and the plasma scrape off layer (SOL) radial thickness is markedly reduced. That is, SOL characteristic length diminishes to about 30% of that for a limiter-only plasma on TdeV.

Plasma Biasing.

Interesting results were obtained as a result of biasing the plasma in TdeV to voltages of ± 200 volts (max.) relative to the plasma vessel. The plasma is biased via the electrically isolated upper divertor plates. Long biasing pulses, about 300 milliseconds duration, were applied after a steady plasma had been established during each tokamak shot. Negative biasing of the plasma was found to produce improvements in divertor operation, significant reduction of plasma impurity content, and reduced turbulence in the plasma (as measured by CO_2 laser scattering. Among the specific observations during application of the negative biasing voltage:

- Reductions of up to 80% in levels of microturbulence fluctuations in the plasma with -200 volts biasing (see figure).
- Soft X-ray emissions from the plasma core decreased by about 30%.
- Reductions of plasma loop voltage by about 20%, from about 1.85 volts to about 1.5 volts for the same plasma current (about 200kA).
- Reductions in plasma-wall interactions, as evidenced for example by reductions in carbon monoxide and carbon fluxes inside the tokamak vessel.
- Increases in pressure by factors up to 3, in the upper divertor chamber with negative plasma biasing.

ExB flow effects are thought to be responsible for divertor chamber

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We regret that some of the pages in this report may not be up to the proper legibility standards, even though the best possible copy was used for scanning

Canada-Europe Cooperation

Canada-Europe 1990 Joint Committee Meeting

Washington, D.C.

Canada and the European Community (EC) participate in a bilateral cooperation agreement in fusion. Delegations from the Canadian and EC fusion programs met October 3, 1990 for their Fourth Joint Committee meeting present five-year agreement.

During their review, the European delegation mentioned that two of the main thrusts of the European fusion program are:

- The ITER project.
- A new, long range program centred on the economic, safety and environmental issues of fusion.

In reviewing Canada's program, the Canadian delegates mentioned:

- Canada's desire to continue contributing to ITER through the European Community, including participation in the planned ITER Engineering Design Activities.
- Increased Canadian federal and provincial funding for fusion.
- Government endorsement of Canada's continued participation in ITER.

The current five-year agreement is due for renewal in March 1991. The fusion programs of Europe and Canada are both interested in continuing collaboration after March 1991 under a revised agreement, and technical discussions to that end are at an advanced stage. Both parties are exploring the possibility of an enhanced level of collaboration in fusion.

Members of the Canadian delegation were David Jackson (Head of Delegation) and Charles Daughney of the National Fusion Program, Brian Gregory and Réal Décoste of CCFM, and Donald Dautovich of CFFTP.

Members of the European Delegation were: Charles Maisonnier (Head of Delegation), Janos Darvas, Ernesto Canobbio, Hardo Bruhns and Jean-Paul Rager, all of the European Community fusion program.

The significance of Canada's technical contributions to Europe's fusion program was highlighted by Paul-Henri Rebut, Director of the Joint European Torus (JET), and Romano Toschi, Leader of the Next European Torus (NET) Team, also present at the meeting.

Canada-US Cooperation

3rd Canada-US Bilateral Meeting

Arlington, Virginia

Canada and the United States are parties to a five-year bilateral cooperation agreement in magnetic fusion, formalized in a Memorandum of Understanding between the Canadian and US fusion programs. Representatives of the Canadian and US fusion programs met October 2, 1990 for their third annual review of cooperation under the MoU, which runs until November 1993.

Review of Canada-US cooperation initiatives elicited satisfaction from both parties with the status and degree of cooperation, and mutual agreement to continue cooperation under the MoU. Two of the numerous points of interest noted were:

- Mutual satisfaction with irradiation of Canadian breeder materials in the US FFTF reactor at Hanford, under the international BEATRIX-II breeder materials R&D program.
- Canadian contributions to the US ARIES fusion reactor design studies.

David Jackson (Canada) noted that Canada's fusion program now has additional federal and provincial funding for fusion activities through to 1992 March. The additional funds are for upgrading of facilities to undertake ITER-relevant R&D, and for participation in the ITER Engineering Design Activities. US delegates were informed of Canada's interest in continuing to participate in ITER through the European Community. US and Canadian representatives agreed that they would continue to utilize opportunities to work together in support of ITER activities.

Canada was represented at the meeting by: David Jackson (co-chairman) and Charles Daughney of the National Fusion Program, Brian Gregory of CCFM, and Donald Dautovich of CFFTP. Representing the United States were four members of the United States Department of Energy: John Willis (co-chairman), Michael Roberts, David Crandall and Robert Price. The next Canada-US MoU review meeting will be held September 1991 in Canada.

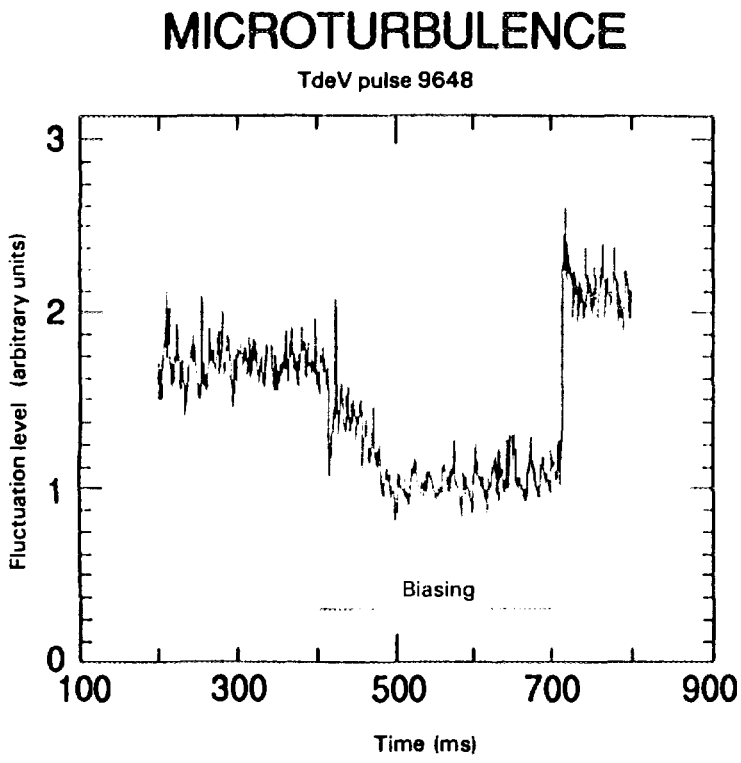
Continued from front page

pressure increases during plasma biasing pulses, over and above the normal divertor chamber operating pressures seen without plasma biasing.

Boronized Graphite Tests

More plasma exposure tests of boron-doped carbon are scheduled for TdeV early this year, as part of TdeV collaboration in the UCLA PISCES project. Results of the November in-tokamak plasma exposure tests on boronized graphite test limiter heads are still being evaluated. Three test limiter heads, with up to 20% boron in graphite, were inserted into the TdeV plasma edge. Power deposition levels by the plasma were in the tens of kilowatts range on an area of a few cm^2. Indications are that with carbon containing 20% boron, chemical sputtering of carbon was about 10–20% less than for the same carbon without boron, exposed to the same plasma conditions. The tests are part of the PISCES collaboration operated by Yoshi Hirooka of UCLA. Carbon samples were fabricated by Toyo Tanso of Japan. Analyzing the carbon materials after the TdeV tests, Hirooka found evidence of boron recycling on the samples. Areas of highest power deposition on the carbon test sample were depleted in boron, whereas adjacent areas receiving smaller power deposition levels were enriched in boron. Plasma spectral measurements during the tests indicate the presence of boron in the plasma when the 20% boron sample was under test.

More information: Brian Gregory, Real Décoste or Barry Stansfield at CCFM (See Contact Data). Plasma biasing – call Pierre Couture (514) 652-8216.



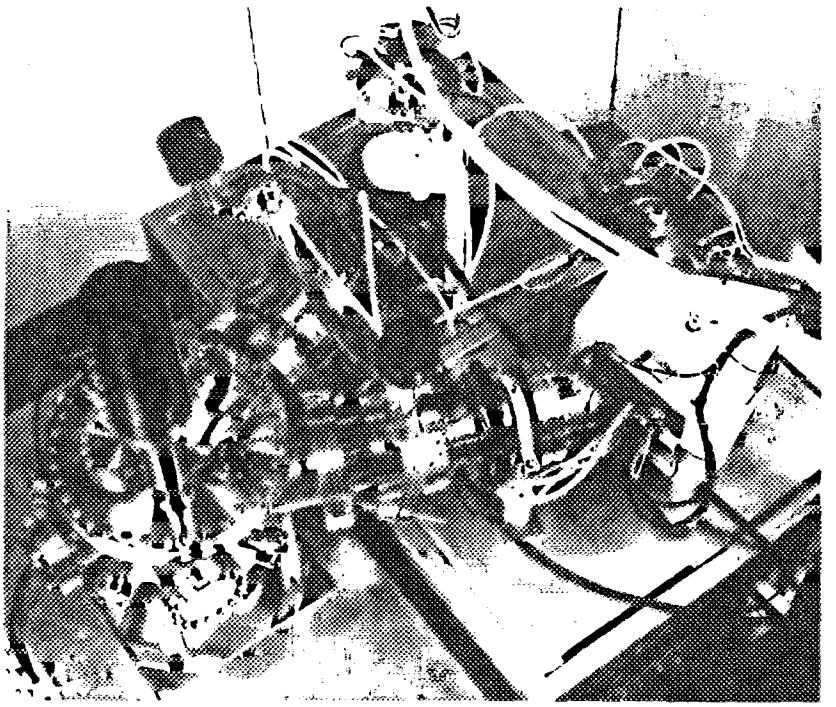
Reduction in microturbulence in the TdeV plasma during a 300 millisecond plasma biasing pulse of -100 volts.

UTIAS Dual Beam Accelerator

Fusion Materials Research

A new high-flux dual beam particle accelerator is in service now at University of Toronto Institute for Aerospace Studies (UTIAS). The accelerator will be used to investigate synergistic erosion mechanisms occurring on fusion reactor plasma-facing materials, and to assist in development of new plasma-facing materials more resistant to erosion by fusion plasmas.

Significantly enhanced, synergistic, surface erosion effects can take place when two or more particle species, such as energetic ionized carbon and thermal neutral hydrogen, impinge on graphite surfaces. Graphite is extensively used as a plasma-facing material in tokamak fusion machines. Synergistic erosion effects at low energies (around 100eV particle energies) and with the high fluxes expected in fusion



The new dual beam particle accelerator at University of Toronto Institute for Aerospace Studies (UTIAS).

reactors, have not yet been extensively investigated in the laboratory. The UTIAS program will systematically characterize synergistic erosion and hydrogen trapping mechanisms at temperatures up to 2000 K in graphite and other candidate plasma-facing materials.

The new accelerator has capabilities which do not, at present, exist elsewhere. It can generate high fluxes of atomic or molecular particles at low energies in two separate beams focused on the same target. Each beam accelerates one particle species, at energies from ~100eV to 10keV. Maximum fluxes of hydrogen species are about $10^{16}/cm^2$-s. For heavier species such as carbon and oxygen, maximum fluxes are about $10^{15}/cm^2$-s. These are in the range of those expected at the inside wall (first wall) of the fusion reactor plasma chamber in a next-step reactor such as ITER.

Erosion of carbon-based materials, including graphites and carbon composites doped with boron or silicon, will be investigated first. Radiation enhanced sublimation will be studied as well as chemical sputtering. Material samples will be exposed to particle combinations such as oxygen and hydrogen species together, carbon and hydrogen species together, and helium and hydrogen species together. Hydrogen retention in materials via codeposition of carbon and hydrogen ions, as well as trapping of hydrocarbon radicals, will also be studied.

Construction of the accelerator was funded by CFFTP, as part of its blanket and first wall R&D program, and by the Natural Sciences and Engineering Research Council.

More information: Prof. Tony Haasz at UTIAS Tel. (416) 667 7734, FAX (416) 667 7799 or Paul Gierszewski at CFFTP

CFFTP

Fusion Basics Seminar

In November, 85 people attended a two-day *Seminar on Fusion Basics* for engineers, scientists and technical managers. Those attending represented universities, engineering manufacturers, consultants, federal and provincial governments, research centres, AECL and Ontario Hydro.

The Seminar was designed for those involved in specific aspects of fusion R&D, such as fuel systems design, who wished to have a wider appreciation of fusion science and technology and its current and future directions. The topics covered were:

- Fusion physics overview; Tritium; Fusion reactor first wall and breeder blanket.
- Deuterium-Tritium Fuel cycle.
- Commercial Fusion Reactors: Issues, needs, the Competition.
- Remote Handling.
- Site and Reactor Building Design.
- Fusion Safety Considerations.
- Canada's Approach to Fusion.
- CCFM and Tokamak de Varennes.
- Fusion Energy: Where to from here.

Lectures were given by senior scientists and engineers from CCFM, Lawrence Livermore National Laboratory (USA), CFFTP, SPAR Aerospace and Ontario Hydro. The Seminar was organized and conducted by Robert Macphee, Macphee Technical Corporation.

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CCFM Review

CCFM Advisory Committee Review

CCFM's Advisory Committee of fusion scientists met November 28–30, 1990 to review research programs at CCFM including work with Tokamak de Varennes (TdeV).

Advisory Committee Members are:
Gilbert Bartholomew *(Chair)*.
Jan Hugill (Culham Lab, UK).
William Rowan (Univ. of Texas, USA).
Michael Saltmarsh (Oak Ridge National Lab., USA).
Franz Söldner (IPP Garching, Germany).
Jörg Winter (KFA Jülich, Germany).
Charles Daughney (National Fusion Program, Canada).
Don Dautovich (CFFTP, Canada).

Program Overview—CCFM and TdeV

CCFM, the Committee observed, had matured into a very capable site; its work on TdeV and its theoretical programs warrant the attention of the world fusion community. The Committee concluded that present and future programs at CCFM/TdeV have potential for making significant contributions relevant to current fusion issues. Examples are the ongoing plasma biasing experiments on TdeV, and the planned exploration of plasma edge dynamics during ramp-up/ramp-down of tokamak plasmas.

The main program thrusts of CCFM/TdeV work are:

- Plasma impurity control.
- Particle and current transport.
- Materials test and development.
- Long pulse studies (up to 30 seconds) using radiofrequency (RF) lower hybrid plasma current drive.

The Committee made special note of the RF plasma current drive for TdeV, which CCFM plans to have in operation in 1993. The preliminary design is complete, and the first 3.7 GHz klystron has been received. Annual funding for CCFM has now increased to $14 million from $10 million; in 1991 the bulk of the $4 million increase will be spent on building the RF current drive system.

Proposed boronization of interior walls of the TdeV plasma chamber, by glow discharges using boron trimethyl gas, was strongly supported by the Committee as a measure for further reducing plasma impurity levels.

Diagnostics capability continues to be a major strength at CCFM. Good examples are:

- Determination of electron temperature with the new electron cyclotron radiation diagnostic.
- Good progress in developing the laser polarimeter for measuring magnetic field contours.
- The planned 1992 installation of a heavy neutral beam plasma edge probe, developed by InterScience Inc. (Troy, NY), for exploring plasma edge dynamics.

In sum, the Committee was very favourably impressed with present and future programs at CCFM/TdeV. The control of power and particle exhaust is the number one concern of the ITER project; the emphasis on plasma biasing and plasma-wall interactions at CCFM is therefore very relevant to world fusion R&D. Further, it is possible that current drive technology will become a key issue for ITER; in the near future, TdeV will possess comprehensive capabilities in current drive and off-axis heating, including the relevant theory and diagnostics.

CFFTP Review

Advisory Committee Reviews CFFTP

CFFTP's Advisory Committee of fusion experts met November 21–22 for their 1990 review of CFFTP research and development programs.

CFFTP Advisory Committee members are:
Janos Darvas (European Community Fusion Program).
Kenji Okuno (Japan Atomic Energy Research Institute).
John Bartlit (Los Alamos National Laboratory, USA).
Stephen Dean (Fusion Power Associates, USA).
Robert Morrison, *(Chair)* (Energy, Mines and Resources Canada).
Archie Harms (McMaster University).
Richard Bolton (CCFM).
Gil Phillips (National Fusion Program).

The Committee reviewed CFFTP programs and performance, based on their own experiences and on presentations by CFFTP staff.

The Committee recognized that CFFTP has done well in developing and operating a credible, well focused program. CFFTP has made significant contributions to world fusion programs, the Committee indicated, particularly to the European program. The electrical power utility viewpoint brought to fusion by CFFTP is unique and valuable. The Committee viewed with favour CFFTP's strong linkages with all the major fusion projects, established through attachments of staff and collaborative activities.

The present and future R&D programs of CFFTP were considered to be well chosen and relevant to current world fusion programs. The Committee went on to comment that the fusion community

Continues on back page

was very much in need of strong contributions in certain key topics, including: tritium barriers, water detritiation, development of reliability data bases based on in-service equipment experience, fuel cycle code development, design of large shipping containers and research on tokamak dust. It seemed to the Committee that CFFTP has the skills and resources to make good contributions in these areas.

ITER R&D

The Committee recognized CFFTP contributions to the ITER Conceptual Design Activities, and voiced support for CFFTP's continuing involvement in ITER. The Committee mentioned that among other topics, contributions to ITER in the areas of plasma facing components and divertor cooling would be very welcome. It was noted that a growing involvement with ITER could substantially affect the directions of CFFTP programs.

1996 IAEA Fusion Conference

In 1996, Canada will host the 16th IAEA Conference on Plasma Physics and Controlled Nuclear Fusion. Germany will host the 14th Conference in Bavaria in 1992, and the USSR will host the 15th Conference in 1994. The location of the 1996 Conference in Canada was announced at the 1990 meeting of the IAEA's International Fusion Research Council in Washington, D.C., USA.

The 1996 Conference will be held in Montréal, and will be organized by the National Fusion Program, Centre canadien de fusion magnétique (CCFM) and the Canadian Fusion Fuels Technology Project (CFFTP). Visits to CCFM and to other facilities, in Québec and Ontario, will be arranged for delegates.

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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