FusionCanada

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INTERNATIONAL

Canada-US fusion meeting in Montréal: 'Joint CNS/FPA Fusion Symposium'

Montréal, Canada, September 6-8, 1995

Evgeny Velikhov (ITER) to give keynote address

N. Anne Davies (USDOE) to review US Fusion Program

The program for the Joint CNS/FPA Fusion Symposium in Montréal, September 6-8, has been finalized. The Canadian Nuclear Society (CNS) and the USA's Fusion Power Associates (FPA) are jointly presenting the Symposium.

Dr. Evgeny Velikhov, Chair of the ITER Council, will deliver the keynote address.

Dr. N. Anne Davies, USDOE Associate Director for Fusion Energy, will discuss the US program.

Senior European officials have been invited to review Europe's fusion work.

Dr. David Jackson, Director of Canada's National Fusion Program will review Canada's fusion work and will introduce Dr. Richard Bolton and Robert Stasko to describe work at CCFM and CFFTP.

There will also be several presentations on:

- Tokamak progress (TdeV, ALCATOR C-Mod, DIII-D).
- ITER (JCT and Home Teams work).
- Tritium work (Canada, US, TFTR).
- Spherical tokamaks and TPX.

Other presentation topics include: compact toroid fuelling, inertial confinement (NIF), educational activities and plasma-aided manufacturing.

A discussion on Canada-US cooperation and small business in fusion will cap the meeting.

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INTERNATIONAL

Fusion Breeder Work in Chile

Canadian experts assist Chilean fusion breeder researchers

Chilean researchers have a long-term goal of manufacturing lithium ceramic tritium breeder materials for fusion power reactors. Researchers at Chile's **La Reina** nuclear research site near Santiago have been developing their lithium ceramics fusion breeder program for several years. A tritium measurement laboratory is being established at La Reina for this work.

Canada-Chile cooperation in fusion breeders began in 1993, and is centred on the eventual manufacture of lithium breeder ceramic materials for fusion reactors. Breeder materials - to be contained in the breeder blanket systems of fusion reactors - will produce the needed tritium component of fusion reactor fuel.

The latest act in the continuing Canada-Chile collaboration occurred in June this year, when Canada's senior expert in lithium breeder ceramics irradiation, Dr. Richard Verrall, visited Chile's La Reina site during June 19-30 to help plan Chile's solid fusion breeder R&D program, which includes in-reactor ceramic breeder irradiations. Dr. Verrall is Manager of AECL's Fusion Breeder Blanket Program at Chalk River Laboratories. Dr. Carl Johnson of Argonne

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CFFTP - Canadian Fusion Fuels Technology Project

New Manager for CFFTP

New CFFTP structure: R&D program focus only

Robert Stasko, of Ontario Hydro, became the new Manager of the Canadian Fusion Fuels Technology Project (CFFTP) on May 15 this year, taking over from Don Dautovich.

Don Dautovich was Manager of CFFTP from 1986 until he handed the position over to Mr. Stasko. Don has gone on to a position of wider responsibility with Ontario Hydro Technologies (OHT), a business unit of Ontario Hydro responsible for developing and commercializing new energy technologies. OHT is responsible for managing CFFTP on behalf of Canada's National Fusion Program. In his new position, Dr. Dautovich is managing several programs in emerging energy technologies. He remains connected with CFFTP, however, because CFFTP is one of the programs under his overall supervision at OHT. We wish Don Dautovich success in his new position.

Robert (Bob) Stasko returns to CFFTP as its Manager, after being away for a number of years. During much of the interval he was managing programs in the development and commercialization of modern energy efficiency technologies for Ontario Hydro, at increasing levels of responsibility. He also spent two years seconded to Ontario's Ministry of Energy as a Senior Policy Advisor. Before that, Mr. Stasko was a CFFTP R&D program supervisor for seven years; he was responsible for ITER-related fusion R&D for part of that time.

At the same time that Mr. Stasko took over as Manager of CFFTP, there was a change in the focus of CFFTP activities, initiated before Mr. Stasko's appointment. Since May, CFFTP no longer acts as a sales agent for fusion fuels technologies and tritium technologies developed in Canada. The CFFTP project will concentrate on initiating and supporting R&D programs in fusion- and tritium-related technology, and remote handling. Work relevant to the ITER reactor will continue to be a central part of CFFTP R&D programs, and CFFTP remains committed to all aspects of the ITER program, including international R&D collaboration.

Sales of fusion- and tritium-related technologies developed in CFFTP programs are now performed by a commercial unit of OHT called ***Isotope Technologies.***

CFFTP Key Staff
Two key technical staff members now supervise CFFTP's fusion and tritium R&D programs:

- Paul Gierszewski supervises R&D programs in fusion fuel systems and remote handling.
- Ron Matsugu supervises R&D programs in tritium systems and tritium handling.

For more information on CFFTP R&D programs contact:
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Commercial activities - Fusion Technologies.
In future, please contact Bob Stasko one of the following persons for sales and commercial information about CFFTP technologies:

Fusion and related technologies:
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Marketing and Business Development:
John Blevins, OHT: (905) 855-4721, Fax (905) 823-8020.

CANADA-USA

Canada-USA: Exchange of Views on Fusion Collaboration

Senior officials of the Canadian and US fusion programs met May 10 in Washington D.C. to share information about their fusion programs and Canada-US fusion collaboration.

Representing the two fusion programs on May 10 were:

USA
(All participants from the Office of Fusion Energy, US Department of Energy)
N. Anne Davies - Associate Director for Fusion Energy
Ira Adler - Deputy Associate Director for Fusion Energy
Mike Roberts - Director of International Programs
Ronald McKnight - Acting Director, Advanced Physics and Technology
Steve Eckstrand - Group Leader, Burning Plasma Physics
Gene Nardella - Manager, Fuel Cycle and Safety Program
Carol Sege - Manager, International Operations
Arthur Katz - Manager, International Research

Canada
David Jackson - Director, National Fusion Program
Gil Phillips - Manager, International Program, National Fusion Program
Richard Bolton - Director General, Centre canadien de fusion magnétique (CCFM)
Don Dautovich, Manager, Canadian Fusion Fuels Technology Project (CFFTP)

Both sides agreed on the desirability of continuing US-Canada fusion collaboration, and agreed that there had been an excellent working relationship in the past with valuable benefits for both. The continuing productivity of many joint Canada-US activities in fusion theory, modelling and experimental work was mutually agreed. Each side recog-

Fusion Breeder Work In Chile *continued*

National Laboratory (ANL) also visited La Reina during June 19-30 to collaborate with Dr. Verrall and La Reina staff in planning the breeder program.

AECL Chalk River last year supplied La Reina with a tritium assay system for post-irradiation breeder research, and has trained La Reina staff in tritium handling and measurement methods.

Chile is the world's largest producer of lithium, the favoured fertile element for breeding tritium fuel for fusion power reactors. The COMISION CHILENA DE ENERGIA NUCLEAR [**C.CH.E.N.**, or Chile Atomic Energy Commission]) has a long-range goal of helping to exploit Chile's lithium assets by establishing Chilean production of lithium breeder materials. Lithium titanate (Li_2TiO_3) is the material currently receiving most attention at La Reina, although other lithium ceramics including lithium zirconate are being explored.

The first in-reactor irradiations at La Reina will start in August 1995, and will be Lithium Titanate ceramics in simple closed capsules. The main short-term goal is to make lithium ceramic breeder samples at La Reina, and irradiate them in La Reina's 5 MW research reactor. In-reactor tests help to assess characteristics of tritium release from the ceramics, as well as testing their chemical and therm-mechanical properties.

The closed capsule tests will be followed, in 1996, by so-called 'open capsule' ceramic irradiation tests. These may use a version of the French CHOUCA in-reactor capsule. In 'open capsule' tests, a purge gas (generally hydrogen with some helium) is passed through the capsule during the irradiation to carry away the released tritium. On-line analysis of the purge gas can determine tritium release rates as they vary with neutron flux, temperature and purge gas composition. The ratio of oxide vs. elemental forms of released tritium can also be measured. In La Reina's open-capsule tests, different ceramics and sample batches will be irradiated with various purge gas compositions during an irradiation run. Measurements of post-irradiation tritium inventory for the ceramic samples will also provide critical data for future solid breeder design.

During the June visit, Dr. Verrall and Dr. Johnson helped to specify the design particulars and cost factors of the of the La Reina CHOUCA-like capsule, so that it can be ordered and manufactured. Dr. Johnson is Associate Director - Chemical Technology at ANL. Together, Verrall and Johnson helped La Reina researchers with their plans for Chile's breeder program.

Verrall and Johnson also discussed choice of ceramics and ceramic fabrication processes for future Chilean work. These working visits to Chile - Dr. Verrall's second visit, and Dr. Johnson's third, were funded by the International Atomic Energy Agency (IAEA), which is helping to fund the Chilean breeder work.

La Reina may also irradiate and test ceramic breeder samples from Argonne, because ANL itself has no suitable research reactor for such irradiations.

Earlier Collaborations

In May 1993, Dr. G. Piderit, Executive Director of C.CH.E.N. visited AECL Chalk River to explore Canada's breeder ceramics work and attend the CFFTP Tritium Safe Handling Course provided by Chalk River. He was accompanied by Dr. Eduardo Saravia, who currently leads the La Reina breeder program. This visit marked the beginning of joint Canada-Chile breeder materials work.

In autumn 1994, AECL Chalk River shipped to La Reina a CREATE system for post-irradiation measurements of tritium retained in lithium ceramics in closed capsule irradiation tests. A tritium standard was sent also, to help calibrate the system. The CREATE system technology, employed in the CREATE system acquired by C.CH.E.N., was developed at AECL Chalk River.

Dr. Luis Peña, responsible for La Reina's CREATE system, visited the Tritium Group at Chalk River in March this year for training in tritium safe handling and specific tritium measurements including tritium assay. Dr. Juan Klein, responsible for La Reina's research reactor received training in CREATE system operation in autumn last year at Chalk River.

Canada's fusion workers look forward to continuing cooperation with Chilean workers as the La Reina program develops.

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CCFM - Centre canadien de fusion magnétique

CCFM/TdeV - Review of Progress and Plans

Advisory Committee endorses continuing emphasis on divertors and plasma boundary physics in medium density plasmas ($5x10^{19}$ m^{-3}), with lower hybrid RF current drive and heating and biasing.

In April, CCFM's Advisory Committee of fusion experts reviewed the project's progress and plans at the CCFM site in Varennes, Québec, where the TdeV tokamak is located.

This article presents notes on the research goals and directions of CCFM with the TdeV tokamak, and some of the recommendations made by the Advisory Committee.

CCFM Area of Expertise: "The understanding of boundary plasma conditions in a tokamak with a divertor geometry." This, being CCFM's choice of research area, was endorsed wholeheartedly by the Advisory Committee, especially since this field of research has become one of the critical areas for magnetic fusion in general.

The Committee noted that CCFM has come to be regarded as an expert centre in plasma biasing via divertor plates, as for example indicated by the fact that CCFM's plasma biasing results have influenced work at the USA's DIII-D tokamak. Also noted by the Committee was the interest shown from several directions - including CEN de Cadarache in France - in the Lower Hybrid current drive and plasma heating research at CCFM.

Recommendations on Planning for CCFM and TdeV

Plasma parameters: **Basic operating regime.** CCFM should push forward, the Committee agreed, with its plans to establish, as the basic TdeV operating regime, plasma pulses of 5 seconds (or more) duration with an average density of $5x10^{19}$ m^{-3}, with non-inductive current drive and distributed heat load on the divertor plates. In the past, longer pulses have been at lower densities. The $5x10^{19}$ m^{-3} density range was chosen because divertors work better at higher plasma densities, and because this is a reasonable plasma density range for next-step fusion machines with a high fraction of plasma current driven by non-inductive means.

The new regime will most likely be attained after TdeV has been upgraded during the 10 month refitting program now scheduled to begin this coming autumn.

ECRH: The new density range will required non-inductive current drive and heating that couples efficiently into the plasma at $5x10^{19}$ or greater. The Committee therefore recommended that CCFM continue with its plans to install 1 MW of electron cyclotron radiofrequency heating (ECRH) operating at about 110 GHz. The Committee recommended retaining the TdeV lower hybrid current drive and heating system, which should still provide useful heating and plasma current drive at the increased density.

Lower Hybrid Current Drive. The Committee recommends continuing research into current drive with the LH system, since there is much still to be learned in that field, and TdeV has excellent diagnostics for the fast current-carrying electrons generated by LH injection.

Divertor Design: The upgraded divertors planned for TdeV should include, as planned by CCFM, high-Z divertor plates. The ongoing program of exploring plasma detachment in divertors should be an influence on divertor design.

Science Program: Divertor and Scrape-Off Layer: Recognizing the admirable progress made at CCFM in understanding and modelling the plasma boundary, the Committee recommended emphasis on enhanced diagnostics and MHD modelling to more precisely locate the plasma separatrix. This would be valuable, in view of the envisaged flexible divertor operating scenarios, where small changes in separatrix position will be important. The Committee noted that TdeV already has one of the most complete sets of plasma edge and divertor diagnostics.

Compact Toroid Fuelling: Continuation of the Compact Toroid (CT) fueller program was recommended. Although recognized as a "..long shot..", the Committee said that CT fuelling has, "..potential for significantly affecting future fusion research programs ". CCFM and CFFTP are building an upgraded CT fueller which will match with and penetrate the higher TdeV toroidal field (currently 2 tesla).

More information from Réal Décoste or Brian Gregory at CCFM (See Contact Data).

CCFM Advisory Committee Members Present, April 5-7, 1995:

Dr. Larkin Kerwin, (Chair), *Consultant.*
Dr. Charles Daughney (Secretary), *National Fusion Program.*
Dr. Paul Gierszewski, *CFFTP.*
Dr. Ian Hutchinson, *Plasma Fusion Centre, MIT, USA.*
Dr. Jan Hugill, *AEA Culham Laboratory, UK.*
Dr. Didier Moreau, *CEN de Cadarache, France.*
Dr. Franz Söldner, *JET Joint Undertaking, EC.*
Dr. Ronald Stambaugh, *General Atomics, USA.*
Dr. Jörg Winter, *Forschungszentrum Jülich, Germany.*

nized the value of the working relationships between laboratories and universities of both countries, and between individual scientists.

Current and past US-Canada collaborations were reviewed. Particular note was made of a number of them, including the following:

- The success of the TFTR tokamak, and CFFTP's role in supplying a tritium purification plant for TFTR for on-site processing of TFTR exhaust during deuterium tritium fuelling experiments.
- The compact toroid tokamak fuelling work at CCFM, made possible by collaboration between UC Davis and LLNL, CFFTP and CCFM.
- Collaboration in breeder materials work, especially the BEATRIX program.
- The US noted the value of the Canadian Tritium Release experiment.
- Testing of Canadian aluminum nitride coatings at ANL.
- A Canadian alpha particle probe used on TFTR.
- A thallium neutral beam plasma edge probe from Inter-Science, NY, now mounted on the TdeV tokamak.
- The electron cyclotron transmission diagnostic from University of Maryland, now mounted on the TdeV.

Another US-Canada fusion review meeting is expected in Montréal in 1996, during the IAEA fusion and plasma physics meeting.

CANADA-USA Collaboration

Measurement of Fast RF-driven Electron Spectra in Tokamaks

Rapid Energy Spectrum Fluctuations Found:

New Electron Cyclotron Transmission (ECT) measurement diagnostic opens questions in tokamak fast electron spectra

A Canada-USA collaboration has provided a new instrument for measuring the energy distribution of the fast electrons generated by radiofrequency (RF) plasma current drive, on the TdeV tokamak. The measurement method could be applied to other tokamaks.

Dr. Derek Boyd and Dr. Fred Skiff, from the University of Maryland, mounted their Electron Cyclotron Transmission (ECT) diagnostic gear on TdeV last year, to measure energy spectra of fast electrons driven by TdeV's radiofrequency lower hybrid current drive and heating system. CCFM and Maryland have been collaborating for three years on this installation. Prof. Boyd is now at CCFM for a year, working on TdeV with the ECT diagnostic, with CCFM collaboration.

Using the ECT gear, unexpected results have been seen in recent months in the fast electron energy spectra on TdeV, when the lower hybrid RF system was operating.

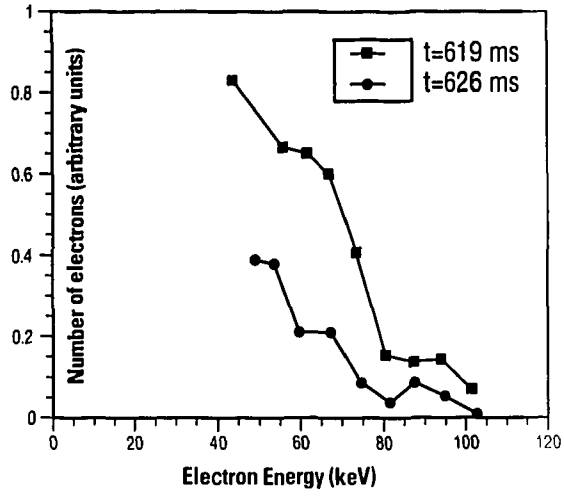
Rapid fluctuations in fast electron energy distribution have been seen (see graph). This was a surprise. Also, electron energies up to 200 keV have been measured - about double the maximum electron energy expected from RF current drive. The reasons are not yet known.

Fast electron energy spectra are seen to fluctuate rapidly, over periods of a few milliseconds. The graph shows two spectra, taken 7 milliseconds apart during one TdeV plasma pulse. This illustrates the rapid variability observed in the fast electron spectra, which seems to continue throughout the duration of a plasma pulse with LH RF injection.

The high energy electrons up to 200 keV seen in other data (not in this graph) were unexpected, though some sophisticated computer codes have predicted them.

The technique of radiofrequency power injection to drive plasma current still requires exploration, and the ECT work is providing fresh data. The ECT diagnostic transmits counter-propagating microwave beams through each of two chords of the plasma. For each chord, the two counter-propagating microwave beams are tilted about 10 degrees in the toroidal direction so that the final resonance absorption signal from the fast electrons depends on a doppler shift. The beam propagating in one direction in a chord suffers this absorption, while the counter-propagating beam on the same chord provides a reference signal. The two pairs of beams permit simultaneous observations at two radial locations.

Further information from Derek Boyd (514) 652-8817, Fax (514) 652-8625, e-mail: boyd@toka.ireq-ccfm.hydro.qc.ca, or from Fred Skiff, University of Maryland, (301) 405-4977, Fax (301) 314-9437, e-mail: skiff@Glue.umd.edu.



Two fast electron spectra, taken 7 ms apart during the same pulse on TdeV with the LH RF injection (3.7 GHz) in use. This type of energy spectrum fluctuation continues throughout each LH-augmented pulse.

NEWS NOTES

Dr. Sung Kyu Kim, Manager of the Nuclear Fusion Laboratory at the Korean Atomic Energy Research Institute, visited CCFM in June to present a review of Korean fusion work, and to explore the potential for collaboration between his laboratory and CCFM. Work on the TdeV tokamak and CCFM's theoretical work are of interest to Dr. Kim's laboratory. An article outlining the scope of Korea's fusion programs, and participating sites, appeared in *FusionCanada No. 23, January 1994.*

Dr. Colin Allan of AECL has joined the Conseil d'administration of CCFM and the Steering Committee of CFFTP. He represents the management of AECL in these two bodies, replacing Dr. Gerald Dolling of AECL. Dr. Allan is AECL's General Manager - Physical and Environmental Sciences.

David Anderson of Canatom Inc., an engineering company, has joined the Steering Committee of CFFTP. Canatom was heavily involved in design and construction of the TdeV tokamak, and continues to be involved in TdeV upgrade work.

A special course in safe handling of tritium was given in June at the Joint European Torus (JET) in England, by two visiting Canadian tritium specialists. Joan Miller of AECL Chalk River and Walter Shmayda of Ontario Hydro Technologies (OHT) gave the course June 26-27 to a group of JET staff, at the invitation of JET management. Joan Miller and Walter Shmayda are tritium specialists who have been providing CFFTP's tritium safe handling courses in Canada for a number of years. In the past, they have also provided a special tritium safety training course to staff at the TFTR tokamak at Princeton.

National Fusion Program

Director, *Dr. David P. Jackson*

The National Fusion Program (NFP) co-ordinates 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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