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NATIONAL FUSION PROGRAM

Canada's Fusion Centres Continue Work Under New Funding Arrangements

Canada's fusion centres are continuing their planned R&D programs under different funding arrangements. On March 31, the federal fusion funding program known as the National Fusion Program (NFP) officially expired after 15 years of nurturing fusion science and technology in Canada. The NFP provided 50% of program fusion funding for Canada's two key fusion sites, Centre canadien de fusion magnétique (CCFM) and the Canadian Fusion Fuels Technology Project (CFFTP). There was no interruption to work at CCFM or CFFTP. In April, alternative funding arrangements became effective for CCFM and CFFTP. Under the new funding arrangements, CCFM and CFFTP are continuing their fusion work with their R&D program objectives substantially unchanged.

CCFM received $19 million in April from the federal Government, to close the federal Government's involvement in CCFM. A matching amount of funding is being provided jointly by Hydro-Québec and INRS-Energie, an institute of Université du Québec. Over the next few years, CCFM will complete the planned scientific and technology mission of the TdeV-96 tokamak, emphasizing R&D into design and operation of advanced tokamaks and tokamak divertors, using RF plasma heating and current drive.

The Canadian Fusion Fuels Technology Program (CFFTP) continues to develop systems and technology for the fuel cycle of large power tokamaks, and supports development of fusion remote handling technology. In particular, CFFTP plans to continue its contributions to the ITER Engineering Design Activities (EDA) until the EDA is complete in 1998. All of CFFTP's funding is at present being provided by Ontario Hydro, Ontario's electric power utility.

'National Fusion Program'
Until March 31 this year, federal fusion program funding was provided by Canada's Ministry of Natural Resources, via the Panel On Energy Research and Development. Since 1985, these funds were managed by Atomic Energy of Canada Limited in a funding program known as the National Fusion Program. This funding program has now expired, and AECL's involvement with fusion development has ceased. As explained above, the new funding arrangements ensure that Canada's fusion R&D programs are continuing.

The federal Government's decision to cease its contributions to fusion R&D funding was part of a broad range of cuts in federal spending announced last year in the 1996 federal budget, designed to reduce the federal deficit. Natural Resources Minister Anne McLellan last year stated that the National Fusion Program is a good program, but also said that Canada's federal funding priorities in energy research will in future concentrate on short- and medium-term priorities.

NATIONAL FUSION PROGRAM

Last Edition of FusionCanada Bulletin

This is the final edition of FusionCanada, bulletin of the National Fusion Program. FusionCanada bulletin was funded out of NFP funds, and will therefore no longer be published.

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Back Copies of FusionCanada are available from MacPhee Technical Corporation. Price by e-mail from: macphee@sympatico.ca or write to:

MacPhee Technical Corporation
80 Richmond Street West
Suite 1901
TORONTO, Ontario
Canada M4H 1N9
(416) 777-1869
(416) 777-9804
e-mail: macphee@sympatico.ca

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CCFM - Centre canadien de fusion magnétique

CCFM

TdeV-96 Tokamak

The 1997-2000 Program: Advanced Tokamak Scenarios with ECRH + LHCD for plasma control and heating.

Beginning in August, the newly-modified TdeV tokamak will start its work on **Advanced Tokamak** scenarios. This is a three-year program called TdeV-96, for which funding has already been secured and paid. The new Electron Cyclotron Resonance Heating (ECRH) system will play an important part in this program, coupled to the existing Lower Hybrid Current Drive (LHCD) system and the recent major divertor upgrade.

Advanced Tokamak is a term used for a compact style of tokamak design, that can 'burn' a plasma continuously, and not depend on pulsing the plasma with electrical devices. Such machines will be 'steady state' machines. Commercial power-producing tokamaks of the future will have to be steady state machines, to be economically viable.

Last year the original TdeV tokamak became the TdeV-96 tokamak, a better equipped machine, after an overhaul to prepare it for this year's Advanced Tokamak R&D program. New advanced-design divertors and better divertor pumping were among the improvements, as well as new power supplies for 2 Tesla operation and much-improved plasma shape control. A larger Compact Toroid fueller was also installed.

During January-April, TdeV-96 was thoroughly tested to demonstrate that its new variable-geometry divertors, and its improved pumping and plasma control, and other systems, all operate as designed at 2 Tesla with maximum plasma current. The machine looks ready to embark on Advanced Tokamak work in September.

During the January-April trials, the CCFM team discovered that the divertor operating scheme which has been chosen for ITER may be less efficient than had been presumed. The code used to predict divertor behaviour does not seem to predict well under certain conditions, according to results from TdeV-96.

At this time (May 31), TdeV-96 is shut down, mainly to prepare for thecoming 2-3 year campaign of experiments: The CCFM engineering team is presently:

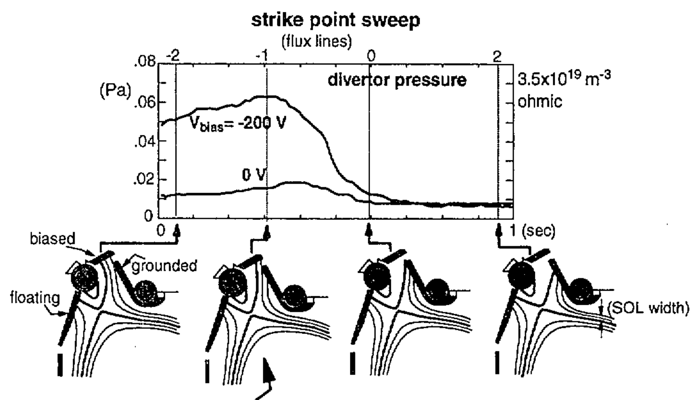
- installing the new 110 GHz ECRH system,
- installing a new neutral beam diagnostic for measuring plasma current radial profile by motional Stark effect.
- re-installing the 3.7 GHz Lower Hybrid radiofrequency system with an improved antenna launching grill,
- installing new divertor baffle plates to make the divertors a 'closed' physical geometry, and,
- doing routine maintenance

What is an "Advanced Tokamak" ?

As now envisaged, an Advanced Tokamak (AT) will be a commercial machine producing a continuously burning plasma at plasma currents of 10 - 15 megamps. A power-producing machine like this should be smaller (and so cheaper) than tokamaks based on ITER plasma conditions and design assumptions. An AT plasma will have better energy confinement than present power-tokamak design scenarios.

A critical factor for an AT plasma is the shape of the plasma's radial current profile, which must be somewhat hollow, or 'dished' on the centre. This creates the so-called 'reverse shear' plasma mode which has very good confinement of plasma energy. With this good confinement, it should be possible to economically increase the central plasma temperature (with, for example, ECRH

TdeV-96 *OPTIMIZED BIASING GEOMETRY*



- *Optimized stike point position for biasing and ExB flow to divertor.*
- *As predicted by a simple model for the radial electric field in the SOL.*

replacement robotics (L-7 task)
- Low-inventory cryogenic hydrogen isotope separation
- CFTSIM dynamic fuel cycle simulation code
- Plasma exhaust detritiation
- Compact toroid fuelling
- Water detritiation and air detritiation systems
- Safety analysis
- Radiation-hardened electronics
- Tritium retention in plasma facing materials

Further information from:
Paul Gierszewski,
416-207-5497,
e-mail
paul.gierszewski@oht.hydro.on.ca

Canadian Fusion Centres

Since this is the last edition of FusionCanada, we publish here a list of the more active Canadian fusion sites as a contact information reference list.

Web sites: Web site addresses given should of course be prefixed with **http://**

E-mail addresses are given after the telephone number for each person

CFFTP
Canadian Fusion Fuels Technology Project

R&D focus: Fusion fuel cycle systems and components, and fusion remote handling.

CFFTP Manager:
Robert Stasko (416) 207-5452
bob.stasko@oht.hydro.on.ca

Secretary: Julie Moir
(416) 207-5493
julie.moir@oht.hydro.on.ca

Mailing address:
Canadian Fusion Fuels Technology Project
800 Kipling Avenue, KR 108
Etobicoke, Ontario, Canada
M8Z 5S4

Fax: [all staff]: (416) 207-5555

Web Site: www.cfftp.com

CFFTP Technical Program Managers

Tritium Fuelling Systems
Paul Gierszewski
Tel: (416) 207-5497
paul.gierszewski@oht.hydro.on.ca

Remote Maintenance Systems
John Blevins
Tel: (416) 207-5501
john.blevins@oht.hydro.on.ca

Tritium Handling Systems
Ronald Matsugu
Tel: (416) 207-5510
matsugu@oht.hydro.on.ca

Engineering & Facilities
H. (Hank) Brunnader
Tel: (416) 207-5523
hank.brunnader@oht.hydro.on.ca

CCFM
Centre canadien de fusion magnétique

Research focus: This is the site of the TdeV-96 tokamak.
CCFM R&D Focus: Tokamak technology research and plasma physics, emphasizing research into Advanced Tokamak Design and the design and operation of tokamak divertors.

CCFM Director General:
Marc Hung
(514) 652-8701

Secretariat: Jeanne Boniffero
(514) 652-8702

CCFM Director - Operations
Dr. Réal Décoste
(514) 652-8715
decoste@ccfm.ireq.ca

CCFM Director - Research
Dr. Brian Gregory
(514) 652-8729
gregory@ccfm.ireq.ca

Mailing address:
Centre canadien de fusion magnétique
1804, boul. Lionel-Boulet
Varennes, Québec,
Canada J3X 1S1

Fax: [all staffl]:(514) 652-8625

Web site: ccfm.ireq.ca

CCFM Group Leaders

Yves Demers
Leader, RF Systems
(514) 652-8692
demers@ccfm.ireq.ca

François Martin
Leader, Machine Operations
(514) 652-8726
martin@ccfm.ireq.ca

Jean-Louis Lachambre
Leader, Central Plasma
(514) 652-8722
lachambre@ccfm.ireq.ca

Barry Stansfield
Leader, Edge Plasma
(514) 652-8735
stansfield@ccfm.ireq.ca

Jean-Marc Larsen
Leader, Computer Systems
(514) 652-8736
larsen@ccfm.ireq.ca

UNIVERSITIES

INRS-Énergie et Matériaux

INRS-Énergie et Matériaux is a research institute of Université du Québec. The Institute collaborates closely with CCFM in fusion research. It supplies key research staff to CCFM, provides some of CCFM's funding, and pursues independent fusion research programs.

Toronto) is the prime contractor, designer, and systems integrator. Numet Engineering (Peterborough, Ontario) is fabricating the vehicle and many of the specialized attachments. Numet also participated in designing the equipment.

Equipment being supplied to Brasimone includes:

- The main robotic vehicle.
- A set of attachments that are picked up by the vehicle as needed to perform different tasks.
- A command and control system (hardware and software) for operating the entire system.

Attachments used on the vehicle will include:

- A commercial manipulator arm (Japanese) that can "look back over its shoulder" and select various cutting, welding, manipulation, and inspection tools.
- A tool pack that the arm can use, for tasks like cutting and welding and holding.
- A door removal and replacement attachment, for removing/replacing the heavy cryostat door and the bioshield slabs.
- A rail deployment attachment, for laying the rails that permit the divertor cassette to be towed out and replaced in the reactor.

Further information from:
John Blevins, CFFTP
Phone: (416) 207-5501
Fax: (416) 207-5555
e-mail:
john.blevins@oht.hydro.on.ca
or from
Joe Sheppard, Spar Aerospace
(905) 790-2800 ext. 4878

NATIONAL FUSION PROGRAM

David Jackson becomes Fusion Advisor to Canadian Government

Dr. David Jackson, formerly Director of the National Fusion Program, will advise the Canadian government on fusion issues and facilitate the orderly transition of Canada's fusion activities to new means of funding and modified international arrangements. In addition, he will document the involvement of the Canadian government in fusion in order to preserve the necessary information upon which the government could base any future decisions it may have to take concerning fusion. In this new role, he will remain an AECL employee but working under the policy direction of Natural Resources Canada. His office has relocated to:

Dr. D.P. Jackson
Dept. of Engineering Physics
McMaster University
1280 Main St. W.
HAMILTON, Ontario,
Canada L8S 4L7

Tel: (905) 525-9140 ext. 24651
Fax: (905) 529-1975
e-mail: jacksond@aecl.ca

CFFTP - Canadian Fusion Fuels Technology Project

CFFTP ITER Technology Program Plans

CFFTP has formulated a three-year business plan for supporting ITER after the scheduled end of the ITER Engineering Design Activities (EDA) phase in July next year. It is anticipated, subject to approval by the ITER Council, that there will be an interim period of about three years between the end of the EDA and the start of ITER construction. During that Preconstruction period, CFFTP plans to focus its efforts mainly on technical support activities for a proposed Canadian site for ITER.

The Canadian ITER Siting Board is coordinating the proposal for an ITER site in Canada. The two proposed site alternatives are at Darlington and Bruce, both in Ontario, at licensed Ontario Hydro nuclear power sites.

Broadly speaking, CFFTP activities after July 1998 will concentrate on:

- Detailing site-specific ITER design adaptations and their cost estimates, including site layout.
- Working with Canadian regulatory authorities to prepare for making ITER license applications. This will include environmental assessment work and development of a Licensing Basis Document.
- Contributing central team design staff to ongoing ITER design efforts
- Further R&D and design work in CFFTP specialist areas as requested.

Until July 1998, CFFTP will be mainly occupied with completing its ITER EDA technology contributions and will keep its attached experts at ITER JCT co-centres and Home Team sites. At present, CFFTP has a total of 8 experts attached to ITER, working at Naka (Japan), Garching (Germany) and San Diego (USA).

During the ITER EDA, CFFTP has been contributing technology and expertise in these technical areas:

- Remote Handling - Divertor

radiofrequency heating) to increase the fusion reaction rate. Cheaper power injection equipment translates into reduced overall machine cost, meaning in turn cheaper power produced. Most of the AT plasma current will be produced by the 'bootstrap effect' which results from the dished plasma current profile and the rest at mid-radius with LHCD for example. This means that with acceptably low power input by RF and/or neutral beams, a steady-state fusion plasma should be obtainable.

The CCFM Program

Over the next two or three years, CCFM will use TdeV-96 to explore the production and characteristics of a range of AT plasmas, using the ECRH and Lower hybrid RF systems to tailor the plasma current profiles and other plasma conditions including central electron temperature. CCFM believes that TdeV-96 is the only tokamak with fully pumped, flexible-geometry divertors that will be exploring AT scenarios with RF systems only. The team hopes to add considerably to knowledge about AT plasma behaviour with different divertor operating schemes, and about Radiofrequency interaction with AT plasmas. With the present design of TdeV-96, for example, electrical biasing can be used to 'tune' the divertor operating pressure in a very predictable way and biasing can also be used to rotate the plasma. The flexible magnetic geometry allows different designs of divertors to be explored under reactor-relevant AT conditions.

Lower hybrid RF power mainly drives plasma current, in the outer regions of the plasma, where it is required to enhance the 'bootstrap' current drive effect that is needed for AT-type plasmas. The 110 GHz ECRH power will be injected via steerable optics, so that the ECRH power can be deposited at will in different regions of the plasma. ECRH mainly produces plasma heating but could also be used to drive plasma current if necessary to complement LHCD which is more efficient. Together, the two systems should give great flexibility in shaping the plasma profiles.

The ECRH gyrotrons and 110 GHz transmission lines were acquired from GYCOM of Moscow.

Divertor Performance with Varying Geometry

The graph (lower curve) shows how divertor pressure varies with the plasma strike point position, as determined by recent TdeV-96 experiments. Divertor pressure can vary by a factor of three with zero electrical biasing of divertor plates. The upper curve shows how electrical biasing can dramatically alter divertor pressure with the same strike point sweep.

More information from Réal Décoste, Operations Director, CCFM, (514) 652-8715, e-mail = decoste@ccfm.ireq.ca

CFFTP - Canadian Fusion Fuels Technology Project

SPAR/CFFTP ITER Divertor Maintenance Robotic Vehicle being Tested Now

Delivery to Italy in September 1997

The Canadian robotic vehicle for practicing ITER divertor replacement procedures is now undergoing final pre-delivery tests at Spar Aerospace in Toronto. The vehicle, with its manipulator arm and several other attachments, will be shipped from Canada in August for delivery in Brasimone, Italy in September.

Brasimone is the site for the ITER Divertor Test Platform being built as part of Europe's contributions to the ITER EDA. The Divertor Test Platform is a full scale mock-up of a 70 degree quadrant of the ITER reactor below the mid-plane, including divertor cassettes. It will be used for testing the methods for replacing divertor cassettes in the ITER reactor. Each divertor cassette weighs several tens of tonnes. During ITER operation, each of the 60 divertor cassettes will periodically need to be taken from inside the ITER reactor vessel and replaced. A complex series of precision robotic operations will be used to replace each divertor cassette.

The Canadian robotic vehicle is a heavy mobile precision device designed to enter the ITER reactor and prepare the divertor cassettes for removal. Its tasks include opening the sealed ITER divertor duct, removing reactor and cryostat access doors and shielding, cutting all piping connections to the divertor cassette, and laying rail track so that the divertor cassettes can be towed out on a skid. All these operations are to be done with millimetre accuracy.

The equipment is being supplied by CFFTP as part of Canada's contributions to the ITER Engineering Design Activities (EDA). Spar Aerospace, of Brampton, Ontario (near

Mailing address:

INRS-Énergie et Matériaux
1650, Boulevard Lionel-Boulet
Varennes, Québec, Canada
J3X 1S2

Secretariat: (514) 929-8100
Fax: [All personnel]
(514) 929-8102

Web Site: inrs-ener.uquebec.ca

Fusion research specialties:
Numerous special aspects of Magnetic fusion research, including plasma-materials interactions and fusion diagnostics. See personnel specialities below

Institute Director:
Dr Pierre Lavigne,
(514) 929 8106
lavigne@inrs-ener.uquebec.ca

Professors:

Claude Boucher: Electrostatic probes and Scrape-Off Layer Physics.
(514) 652 8710
boucher@ccfm.ireq.ca

F. Martin. Tokamak Operations and Compact Toroid Injection
(514) 652 8726
martin@ccfm.ireq.ca

J.M. Larsen: Programming
(514) 652 8736
larsen@ccfm.ireq.ca

B.L. Stansfield: Scrape-off Layer and divertor diagnostics
(514) 652 8735
stansfield@ccfm.ireq.ca

A. Sarkissian: Neutral beam diagnostic
(514) 929 8154
sarkissi@inrs-ener.uquebec.ca

R. Marchand: Modelling
(514) 652 8866
marchand@ccfm.ireq.ca

Plasma-surface Research: Surface conditioning and treatment:
G. G. Ross: (514) 929 8108
ross@inrs-ener.uquebec.ca
B. Terreault: (514) 929 8111
terreau@inrs-ener.uquebec.ca
Surface analysis and characterization: R. Paynter
(514) 929 8148
paynter@inrs-ener.uquebec.ca

UTIAS
University of Toronto Institute for Aerospace Studies

Mailing address:
University of Toronto Institute for Aerospace Studies
4925 Dufferin Street
North York, Ontario, Canada
M3H 5T6

Fusion Research Group

Research focus. Plasma erosion of graphite. Tritium, deuterium, hydrogen interactions with graphite, metals and composites at various particle energies (H, D, T inventory, retention, codeposition).

Fax: (416) 667-7743

Principal Researcher:
Prof. Anthony Haasz.
Tel: (416) 667-7734
aahaasz@utias.utoronto.ca

Fusion Energy Group

Research focus: Tokamak edge physics, impurity behaviour in the tokamak edge, tokamak divertor modelling, Langmuir Probes for tokamaks

Fax: 416 667 7799;

Principal Researcher:
Prof. Peter Stangeby
Tel: (416) 667-7729
pcs@starfire.utias.utoronto.ca

David Elder, Computer Scientist.
Tel: (416) 667-7729
pcs@starfire.utias.utoronto.ca

University of Saskatchewan

Plasma Physics Group
Plasma Physics Laboratory
Department of Physics and Engineering Physics
University of Saskatchewan
Saskatoon, Saskatchewan,
Canada S7N 0W0

Research Areas

Tokamak research: Ohmic H-modes, anomalous transport, compact torus injection, ac operation, fluctuation measurements

Basic plasma physics: Plasma waves and instabilities, nonlinear plasma waves, rf plasma production, plasma based x-ray sources

Theoretical work: Tokamak stability (drift and ballooning type modes), nonlinear magnetic islands, resonance broadening, numerical simulations, nonequilibrium plasmas

Group Members

Professor Emeritus:
H. M. Skarsgard
Tel: (306) 966- 6436

Group Director and Principal Researcher: Prof. A. Hirose
(Speciality: plasma waves and instability)
Tel: (306) 966-6414
hirose@sask.usask.ca

C. Xiao (compact torus, plasma spectroscopy)
Tel: (306) 966-6415
xiaoc@sask.usask.ca

A.I. Smolyakov (nonlinear plasma dynamics, nonequilibrium plasmas)
Tel: (306) 966-6432
smolyakov@sask.usask.ca

G. D. Conway (microwave reflectometry, rf plasma production and heating)
garrard.conway@jet.uk