FusionCanada

Bulletin of the National Fusion Program

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NATIONAL FUSION PROGRAM

Increased Five-year Funding for Canadian Fusion Program.

The Government of Canada has approved a new five-year federal funding term for the National Fusion Program, with a 52% increase in annual funding levels.

The new funding, for the period April 1992 - March 1997, will support Canada's commitment to participating in international fusion programs, and provide long-term stability for Canada's fusion effort.

For fiscal 1992-93, total combined fusion funding will be nearly $30 million for the National Fusion Program (NFP) and its two key project centres, Centre canadien de fusion magnétique (CCFM) and the Canadian Fusion Fuels Technology Project (CFFTP), when provincial contributions matching the federal funding, and funds from other sources are included.

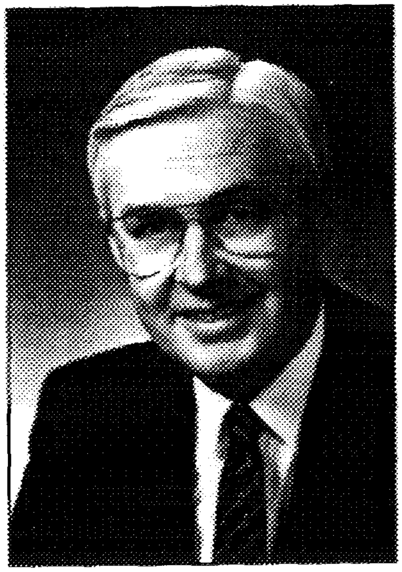
Federal funding for the NFP is provided by the Department of Energy, Mines and Resources, through the Panel on Energy Research and Development. Canada's federal Minister for Energy, Mines and Resources is the Honourable Jake Epp.

News of the increased fusion funding was released by the office of the Honourable Marcel Danis, federal Minister of Labour. Mr. Danis is Member of Parliament for Verchères, the riding in which CCFM is located. "Canada's participation in international fusion projects is basic to the Canadian fusion program", stated Minister Danis recently. "By supporting fusion research and development, Canada is also promoting industrial expansion. The technologies developed through the Canadian fusion program are already being used in other sectors of industry.", he added.

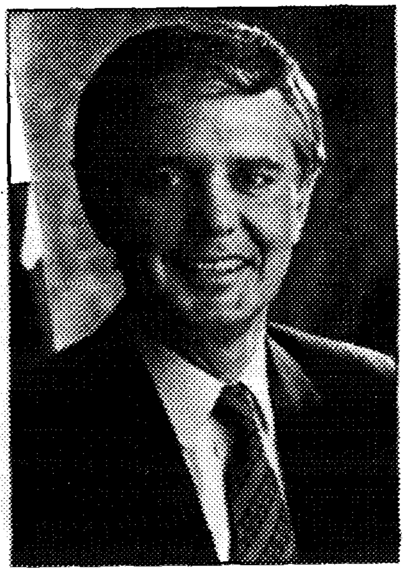
The communiqué from Minister Danis' office said that 'the additional federal contribution for fusion work is testimony to the Canadian Government's ongoing commitment to research and development directed toward discovering new sources of energy for the future.'

For CCFM, the enhanced funding levels will ensure the site's long term viability and the international relevance of its research programs. Completion of the planned upgrades to the Tokamak de Varennes will permit CCFM to perform physics tasks in support of the International Thermonuclear Fusion Reactor (ITER) project.

CFFTP will use the additional funds primarily to support Canadian participation in the technological and design aspects of ITER. The established R&D activities of CFFTP will continue, and CFFTP will continue its exports of Canadian technology to international fusion projects.



The Honourable Jake Epp, Minister of Energy, Mines and Resources.



The Honourable Marcel Danis, Minister of Labour.

JOINT ENTERPRISE

Compact Toroid Fuelling Gun

Three Canadian fusion sites, and UC Davis at Livermore, are cooperating to build a Compact Toroid (CT) fuelling gun, to be installed later this year on Tokamak de Varennes (TdeV). The gun will test the concept of fuelling fusion reactors with dense compact toroids of plasma, launched at high speed into the fusion plasma by electromagnetic acceleration.

For fusion reactors, it will be important to inject fuel into the central region of the burning fusion plasma. Current data suggests that most tokamak fuelling methods - such as injection of cold, solid deuterium-tritium pellets - will not be able to perform efficient plasma centre fuelling.

CT fuelling guns may be able to overcome this difficulty. It is anticipated that small, dense toroids of plasma (the compact toroids), if injected at speeds up to 1,000 $km.s^{-1}$ into a fusion reactor, might penetrate deeply into the burning plasma and provide satisfactory plasma centre fuelling. CT fuelling also offers the prospect of controlling a reactor's plasma density profile. It is further suggested that CT injection devices may be able to drive plasma current in tokamaks. Canada is one of several countries working on the CT fuelling concept.

The CT gun was designed at UC Davis in a joint effort by Roger Raman of the Canadian Fusion Fuels Technology Project (CFFTP), and a UC Davis team led by David Hwang. The CT gun will produce hydrogen plasma toroids up to 15 cm diameter, 20 cm long with a mass up to 50 micrograms. Maximum CT injection speed will be about 1,000 $km.s^{-1}$.

Design and construction of the CT gun was funded by CFFTP. Detailed design, and manufacture of the CT gun's launcher components, was done by University of Saskatchewan Plasma Physics Group, led by Akira Hirose. The U. Saskatchewan Group has finished assembling the complete CT gun, with power supplies and diagnostics installed, and operational tests have begun. UC Davis has loaned special test equipment and diagnostic instruments to U. Saskatchewan.

Starting about July, the Group will install and test the gun on a U. Saskatchewan tokamak, STOR-M. After the STOR-M tests, the gun will be shipped to Centre canadien de fusion magnétique (CCFM) for installation on TdeV late this year. CCFM is providing tokamak interfacing equipment for the CT gun, and making TdeV available for fuelling tests.

More information: Akira Hirose (306) 966-6414, or Paul Gierszewski, CFFTP (416) 855-4717, or François Martin, CCFM (514) 652-8726.

CCFM - CENTRE CANADIEN DE FUSION MAGNÉTIQUE

TdeV Update

Plasma impurity pumping with biased divertors

Tokamak de Varennes (TdeV) was shut down on April 3 for upgrade work on its closed divertors; experiments should resume in June this year. In the month before shutdown, good results in impurity pumping with the existing divertors, using electrical plasma biasing, were obtained. TdeV also recently achieved a 'personal best' electron density (line average) of $5x10^{19}$ m^{-3}; peak density was $6.5x10^{19}$ m^{-3}. These densities are good for a low magnetic field tokamak like TdeV (1.5 Tesla toroidal field), and were obtained after boronizing the plasma chamber.

Divertor upgrading. The upgrade work presently going on is aimed at improving electrical isolation in the plasma chamber so that TdeV divertors can be biased to ±500 volts or more. Biasing research to date suggests that at the higher biasing voltages, significant improvements in plasma confinement and divertor performance might be possible.

Divertor Impurity Pumping. Tokamak divertors are conceived as a way to perform the vital duty of removing impurity atoms - those other than hydrogen isotopes - from fusion plasmas. Impurity removal - or 'pumping' - is one of TdeV's principal lines of research, and TdeV was designed with closed divertors to pursue this work. A prototype cryogenic pump is fitted in the TdeV upper divertor chamber, to condense impurity atoms accumulating there.

An important concern for fusion researchers is to find reliable technologies for removing from fusion plasmas the helium created during the fusion reaction, as well for removing heavier impurities such as oxygen atoms and carbon monoxide or dioxide molecules. Pumping of helium from plasmas has yet to be demonstrated on a significant scale.

Recent plasma impurity pumping tests on TdeV show that its divertors - as presently configured with one cryopump - are capable of pumping helium from the plasma. The divertors gave excellent results in pumping neon. Neon is used as a test gas in pumping experiments because its atomic weight of 20 is near that of the common impurity oxygen, and neon is easily traced because it does not occur as a natural impurity in plasma experiments. With an electrically biased plasma, the divertors removed half of the test charge of neon injected into the plasma in about 500 milliseconds, condensing the neon on the helium-cooled cryopump.

Helium pumping tests did not give such dramatic results as for neon, but accumulation and cryopumping of helium in the upper divertor chamber were clearly demonstrated with a biased plasma.

New installations. For the planned autumn shutdown of TdeV, three important installations are scheduled.

- Four additional cryopumps for impurity pumping experiments will be installed in the upper divertor chamber, to greatly increase the divertor pumping capacity.
- The Compact Toroid fuelling gun (see article in this issue) will be installed.
- A Heavy Ion Beam diagnostic will be installed, for measuring edge plasma potential and density by use of a steerable scanned beam of thallium atoms passing through the plasma edge, inside and outside the magnetic separatrix. This is a US device, designed and built with USDoE support by InterScience Inc. of Troy, New York.

More information from Réal Décoste, (514) 652-8715 or Brian Gregory (514) 652-8729.

INTERNATIONAL

Oak Ridge Tokamak Concept

Replaceable Divertors

CFFTP and Wardrop Engineering of Toronto have assisted Oak Ridge National Laboratory (ORNL) to prepare its design proposal for the Steady-State Spherical Tokamak, known as TST. The TST project proposes building a small low-cost research tokamak (major radius 0.5 m) with plasma currents of about 2 - 5 megamps, intended to serve mainly as a divertor test bed and fusion technology development machine.

Divertors are plasma-facing assemblies in a tokamak, integrated in the plasma chamber interior, intended to pump impurities out of fusion reactor plasmas and help control plasma shape.

CFFTP and Wardrop designed a novel divertor support and alignment system for TST, wherein pre-aligned divertor segments, built into 'cassettes', can be installed or replaced from outside the TST vacuum vessel. Since TST is designed for trials with four different divertor designs - open and closed configurations for each of two plasma shapes - this interchangeability of divertor components is important to the machine's mission.

The cassette concept allows TST's complete divertor ring assembly to be installed accurately - and removed and reinstalled repeatedly - without the need for difficult in-vessel work or sophisticated robotics. Each divertor cassette is inserted radially into the TST machine on built-in rails, through divertor ports in its vacuum vessel wall. Divertor cassettes are aligned during machine construction on an external jig; when inserted into the TST vessel, they are automatically aligned with divertor segments already positioned in the machine. Each divertor segment cassette is a self contained assembly, complete with its own vacuum pump and cooling lines. Using computer controlled remote actuators, the entire divertor assembly can be tilted, and moved horizontally, to accommodate planned plasma shape changes.

John Blevins of CFFTP and Jeff Stringer of Wardrop Engineering jointly devised the TST divertor support and alignment system during February and March this year. Wardrop's contribution was made under a contract from CFFTP.

Further information from John Blevins, CFFTP (416) 855-4721; or Jeff Stringer, Wardrop Engineering (416) 673-3788, or Martin Peng, ORNL (615) 576-7476.

NEWS NOTES

News Notes *will print update news and late items. To include an item in* **News Notes**, *contact the editor.*

Breeder program. In-reactor tests of solid lithium ceramic breeder materials, under the BEATRIX international breeder materials program, have been halted by the shut-down of the US FFTF reactor which was being used for the BEATRIX Phase II irradiation program. At press time, plans for continuing the BEATRIX irradiations in the EBR II fast reactor, at Idaho Falls, are being discussed by the three BEATRIX program partners - Canada, USA and Japan. The European Community has recently approached the partners with a view to participating in the BEATRIX program.

Plasma biasing at U. Saskatchewan. H-mode-like transitions have been generated by plasma biasing on the STOR-M tokamak at University of Saskatchewan. The plasma was biased over the range -400 to +160 volts through an electrode inserted into the plasma to a position r/a = 0.83. For positive and negative biasing, except for the range 0 to -150 volts, increases in electron density and decreases in H_α emission were observed, implying improved particle confinement. Also, global energy confinement time increased by as much as 60% during biasing, depending on the biasing voltage. *Contact Akira Hirose (306) 966-6414.*

PROMETHEUS ICF Reactor Study. Since 1990, CFFTP and SPAR Aerospace (Brampton, Ontario) have been taking part in the PROMETHEUS ICF reactor study, launched by USDoE in 1990 to produce cost estimates and preliminary designs (laser and heavy ion beam drivers) for an inertial confinement fusion power reactor. CFFTP recently delivered preliminary fuel cycle systems designs and cost estimates to McDonnell Douglas, prime contractor for PROMETHEUS. SPAR Aerospace performed a range of design and analysis studies for PROMETHEUS, as a McDonnell Douglas subcontractor. SPAR contributions include: design of a number of remote maintenance concepts, and design of maintenance equipment, for the ICF reactor; reactor vessel layout work; proposals for improving reliability and maintainability; detailed reliability and maintainability analyses. *Contacts: Julian Millard, SPAR Aerospace (416) 790-2800 ext 4568, or Ron Matsugu, CFFTP (416) 855-4727.*

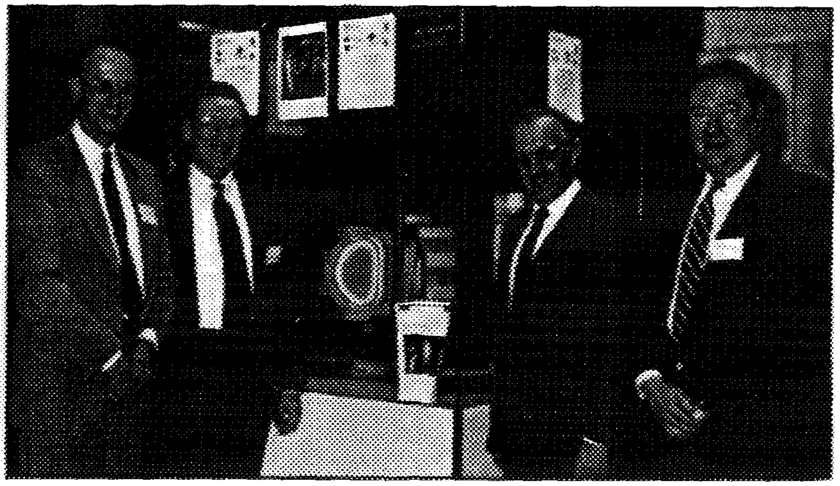
New Director at INRS. Henri Pépin has been appointed Director of INRS Énergie et Matériaux, the research institute of Université du Québec participating in fusion research on the TdeV tokamak. He says that he intends to maintain the institute's strong fusion studies and graduate programs. INRS Énergie et Matériaux is a full partner in Centre canadien de fusion magnétique.

Public Fusion Seminar

Nearly 400 people turned out to attend a public seminar on progress in nuclear fusion, held at the Ontario Science Centre (a public science museum) on January 23, 1992. The occasion was prompted by widespread news of the production of two megawatts of fusion energy in November 1991 by the Joint European Torus (JET), Europe's flagship tokamak fusion experiment at the Culham site in England. The main themes of the Seminar were: *Prospects for Fusion Energy, Fusion's Technical Basis, Canada's Fusion Program* and *The Global Fusion Effort.* The audience size, and the good level of technical interest, indicated considerable public interest in fusion energy.

Four leading fusion experts addressed the meeting, including John Maple, head of Press and Public Relations for the JET/Culham site. Mr. Maple provided a first-hand account of the events surrounding JET's fusion 'burn'. David Jackson (Director-National Fusion Program), Don Dautovich (Program Manager-CFFTP) and Archie Harms of McMaster University spoke on the Seminar's main themes.

A group of six science and engineering organizations jointly hosted the Seminar, led by the Toronto Overseas Centre of England's *Institution of Electrical Engineers* (IEE). After learning of JET's production of fusion energy, the IEE organized and publicized the January Seminar and arranged the participation of the other co-hosts, who were: *Ontario Science Centre; Royal Canadian Institute; Association of Professional Engineers of Ontario; Consulting Engineers of Ontario; IEEE Canada.*



Speakers at the January 23 Public Fusion Seminar with a model of the JET tokamak, loaned by JET, at the Ontario Science Centre. Left to Right: Don Dautovich (CFFTP), John Maple (JET), Archie Harms (McMaster), David Jackson (NFP).

Direct Measurements with New Diagnostic GUNDESTRUP

It has become clear to fusion researchers that conditions in the edge of tokamak plasmas - including speed and direction of plasma flow - can profoundly influence overall plasma behaviour. Lately, the ability to measure plasma flow velocity in the plasma edge and scrape-off layer has assumed new importance, given indications that edge flow velocity may be an influence on plasma energy confinement, and may also influence the transition from L-mode (low confinement regime) to H-mode (high confinement regime). Measurement of direction and speed of plasma flow in tokamak edge plasmas has to date been difficult and uncertain, depending largely on indirect techniques.

Researchers at CCFM and INRS-Énergie have developed the GUNDESTRUP probe, to directly measure direction and speed of flow in the plasma edge. The instrument simultaneously measures profiles of the plasma potential, and electron density and temperature. Radial electric field is calculated from the gradient of the plasma potential. Thus, as GUNDESTRUP measures plasma flow velocity, it simultaneously measures at the same place other parameters believed to be affecting plasma flow.

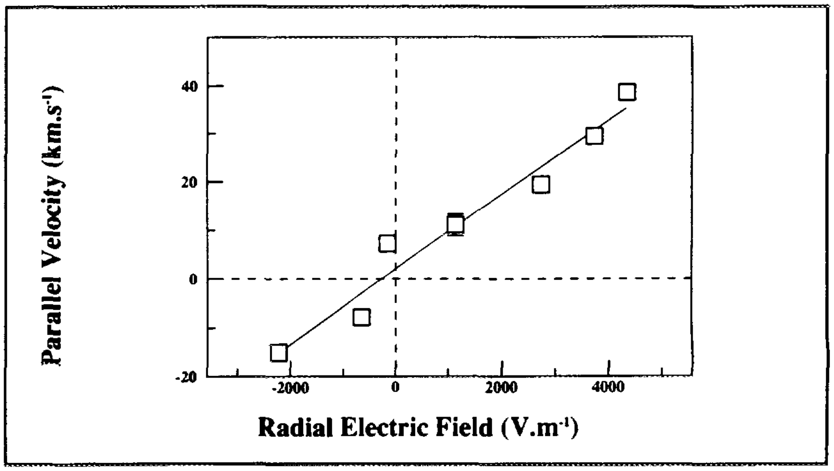
Some surprising results were obtained with GUNDESTRUP in 1992. With plasma biasing on TdeV, which produces large electric fields in the scrape off layer, plasma flow velocities up to 40 $km.s^{-1}$ (about Mach 0.7) have so far been measured. Such high velocities had not been foreseen. Flow direction has been found to be nearly parallel to the direction of the main magnetic field, which is inclined 8° to the TdeV toroidal axis in the plasma edge. Significant velocity components perpendicular to the magnetic field were also measured, though they were smaller than the parallel velocities.

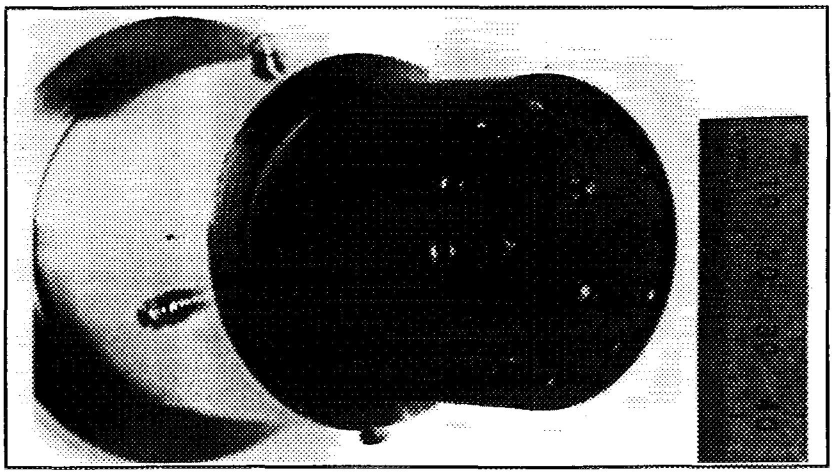
Parallel plasma flow velocity was found to be a direct linear function of radial electric field (see graph), and inversely proportional to the poloidal magnetic field at the point of measurement. In fact, reversing the poloidal magnetic field by changing the direction of the plasma current reverses the flow. These effects were predicted by Hazeltine and others in the early 1970s, but not known to have been confirmed until now.

Plasma velocities are strongly influenced by electrical biasing of the TdeV plasma, through the divertor plates. Biasing affects the velocity, even reversing the flow at bias voltages of -100 volts or more. This is consistent with flows being directly affected by the radial electric field.

GUNDESTRUP is a multi-pin Langmuir/Mach probe, which can be used to scan the scrape-off layer of the TdeV plasma. It is mounted in the TdeV equatorial plane. Ion saturation currents from a ring of 12 pins and two central electrodes are analyzed to reveal the speed and direction of plasma flow, as well as the plasma temperature, density and potential. The probe design and data analysis techniques are based on research done at INRS-Énergie.

Further information from Claude Boucher, CCFM (514) 652-8710 or Cyrus MacLatchy, Acadia University (902) 542-2201.





The GUNDESTRUP probe tip.

CANADA-US

Canada-US Fusion Meeting

Representatives of the National Fusion Program and the US Department of Energy convened January 16-17 at Centre canadien de fusion magnétique, to hold the fourth meeting of the Canada-US Fusion Coordinating Committee for Cooperation in the Field of Magnetic Fusion Energy.

The Coordinating Committee is the executive body managing the magnetic fusion collaboration, under a 5 year Canada-US Memorandum of Understanding (MoU) signed in November 1987 covering cooperation in magnetic fusion. The Co-Chairmen of the Committee are Robert Dowling, US Department of Energy and David Jackson, Director - National Fusion Program of Canada. The Coordinating Committee conducts regular reviews of Canada-US magnetic fusion cooperation.

The agenda of the Committee's January meeting included discussion of renewal of the current five year Canada-US magnetic fusion MoU, which remains in force until 1992 November. A new draft MoU is in preparation.

Forty identified Canada-US scientific and technical collaboration projects were active or proposed in 1991, involving nine Canadian sites and fifteen US sites including several National Laboratories, universities and corporations.

A list of these collaborative projects is available from Bill Holtslander, NFP Manager-International Relations (see Contact Data), or Arthur Katz, USDoE Office of Fusion Energy (International Relations) Tel. (301) 903-3068, Fax (301) 903-2791.

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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