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INTERNATIONAL

1996 IAEA Fusion Conference Site

The National Fusion Program (NFP) has formally invited the International Atomic Energy Agency (IAEA) to hold its 16th International Conference on Plasma Physics and Controlled Nuclear Fusion Research in Canada. The invitation was extended August 01 in a letter from Dr. David Jackson, NFP Director, to Dr. Hans Blix, Director General of the IAEA.

Dr. Jackson proposed Montréal as the Conference site, with the Conference to be sponsored jointly by the NFP, the Canadian Fusion Fuels Technology Project, and Centre canadien de fusion magnétique (CCFM). Since CCFM and its laboratories, containing Tokamak de Varennes, are very near Montréal, CCFM is proposed as the local host for the conference.

The invitation was extended as a result of consultations this year with the International Fusion Research Council of the IAEA.

29-01

CCFM CENTRE CANADIEN DE FUSION MAGNÉTIQUE

Recent Results with TdeV

- Divertor pumping of impurities
- Rapid rampdown of plasma current
- Comparison of boronization methods

During the TdeV (Tokamak de Varennes) maintenance shutdown in October, a new cryogenic vacuum pump unit, containing a liquid helium cooled cryopump as well as cryopump panels cooled with liquid nitrogen, was fitted in TdeV's upper divertor chamber.

TdeV is now back in operation. During November and December 1991, experiments on TdeV will be concerned with current injection via the divertor plates, further plasma biasing experiments, and divertor performance experiments.

Over the next year, the new cryogenic divertor pumps will be used to help investigate the potential for permanent removal of impurities (including helium) from the TdeV core plasma by condensing the impurities in the divertor chamber.

Divertor Pumping of Impurities on TdeV

Fusion reactors will need to continually remove impurities from the fusion plasma, including the helium "ash" product of the deuterium-tritium fusion reaction. Because there is yet no existing, proven technology for reliably pumping helium or the other impurities (mainly oxygen, carbon, and metallics) from fusion plasmas, progress in the physics and engineering of impurity management technology is a pressing concern in fusion R&D. At present, magnetic divertor devices such as the type fitted on TdeV seem promising as "one-way valves" for impurity transport out of the plasma. There is, however, rather limited experimental data on closed divertor performance in removing plasma impurities on medium- or large-size tokamaks. CCFM's continuing exploration of impurity transport and divertor pumping on TdeV is in harmony with CCFM's commitment to ITER to study the physics of plasma exhaust control.

Divertor pumping of carbon monoxide and methane

Starting last year, successful pumping of these impurities has been demonstrated with the closed divertors on TdeV. Results were better than existing theory might predict.

It has been found that:

- Carbon monoxide (CO) and methane (CH_4) molecules accumulated significantly in the TdeV closed divertor chambers, after their removal from the TdeV main plasma chamber via the divertor throats.

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Recent Results with TdeV

continued

Depending on TdeV operating conditions, the partial pressures of CO and CH_4 in the divertor chambers were as much as 30 times greater than CO and CH_4 partial pressures in the TdeV main plasma chamber. This indicates that, in effect, the divertors can act as one-way valves for these molecules.

- Hydrogen did not accumulate significantly in the divertor chambers. The overall effect is that there is little net pumping of hydrogen out of the main plasma chamber through the divertors.

At present, there is no proven means of removing helium "ash" – the product molecule of the D-T fusion reaction – from burning fusion reactor plasmas. It is necessary to find a way to continuously remove helium from fusion plasmas, if future fusion reactors are to be able to operate in continuous mode. The divertor operation results outlined above give no clear picture of divertor pumping efficiency for helium. Both the mass number and the ionization potential of helium are closer to those for hydrogen than they are to those of CO or CH_4.

CCFM intends to investigate the behaviour of helium-4 in TdeV and its divertors during the next year. The cryogenic pump unit now in place in the upper divertor chamber should be capable of pumping helium from the divertor. By introducing helium into plasma discharges on TdeV, and observing helium transport in the divertors and main plasma chamber, it is hoped to learn something of helium physics in divertor operation.

More information from Bernard Terreault (514) 652-8693 or (514) 468-7711.

Importance of plasma current control

Routine fast rampdown and termination of plasma current in tokamaks, without plasma disruptions, will be very important for future fusion power reactors. Plasma disruptions at full plasma current have the potential to do considerable damage to the walls of the plasma chamber, by depositing a plasma's kinetic energy on material surfaces. In addition, plasma disruptions introduce the possibility of transforming some magnetic energy, from the tokamak's poloidal and toroidal fields, into sudden eddy current heating or increased plasma kinetic energy. For a large tokamak with about 25 megamps plasma current, the magnetic energy content of the plasma might be in the order of perhaps 50 gigajoules (50,000 megawatt-seconds). Since the magnetic energy in the plasma's poloidal field is proportional to the square of the plasma current, it can be important to reduce the plasma current as much as possible, rapidly and stably, before any plasma disruptions can impact the tokamak interior walls. Disruptions might arise from rapid-growth plasma instabilities or other causes. Mechanisms for rapidly reducing plasma current, so that plasma-termination disruptions deposit less energy, will therefore be very important for future fusion power reactors.

Rapid rampdown of TdeV plasma current

Very rapid, disruption-free rampdown of plasma current at uncommonly high current rampdown rates has been achieved on TdeV. The high rampdown rates were achieved by programmed control of the TdeV electric power systems, in combination with simultaneous hydrogen gas puffing into the plasma chamber when the fast rampdowns were initiated. The hydrogen gas injection appears to stabilize the plasma during the fast rampdown. It is strongly suspected that the hydrogen puffing cools the outer plasma layers, increasing their resistivity and modifying the plasma current profile evolution during rampdown to maintain plasma stability.

In tokamaks, the decay of plasma current is determined by plasma inductance L and resistance R; plasma current will decay – after ohmic plasma heating stops – at the characteristic L/R rate with no outside influences. On TdeV, this is typically about 1.5 MA/s. In recent weeks, rapid and stable rampdown of plasma current on TdeV has been achieved at rates up to 15 MA/s (that is, 10 times the typical L/R decay rate) without plasma disruptions. This is an uncommonly fast rate for disruption-free rampdown; it was achieved by programmed control of the TdeV ohmic heating power supply and associated switching. In the fastest (15 MA/s) forced fast rampdown trials, plasma current was smoothly ramped down from 150 kA to 50 kA in about 6 ms. Therefore, more than 90% of the magnetic energy in the plasma's poloidal field was transformed back into electrical energy in the power supply.

CCFM expects to continue its work in control of fast current rampdown, including possible early detection of instabilities to initiate smooth and rapid plasma termination.

More information from Juris Kalnavarns, CCFM (514) 652-8721.

Comparison of Boronization methods.

The following three methods of boronizing TdeV have been tested on TdeV in 1991, to assess their effects on plasma behaviour. All three methods deposit boron atoms on the plasma chamber walls:

- **Gaseous discharge with Trimethyl Boron (TMB) gas.** Before a series of tokamak pulses, a glow discharge is maintained for a few hours in the plasma chamber after filling it with a mixture of TMB gas ($B(CH_3)_3$) and helium.

- **STB - Solid Target Boronization.** This entails insertion of a boronized carbon target, during the tokamak pulse, into the core plasma through the outer plasma scrape-off layer. Ablation of the boronized carbon introduces boron into the tokamak.

- **Fuelling with TMB Gas.** During a plasma discharge, only TMB gas is used as fuel.

All three methods produce similar beneficial effects on the plasma, though for different lengths of time. The main effects are a significant reduction of plasma oxygen levels, and consequent significant reductions in global resistivity of the plasma. As a result, maximum plasma discharge duration after a boronization method had been employed was almost two seconds, whereas without boronization the maximum pulse length had been about one second under a given set of operating conditions (divertors in operation – no plasma biasing).

The effects of the gaseous glow discharge boronization method lasted for about 500 plasma shots, during the experiments which followed the glow discharge boronization. Global plasma resistivity was initially reduced about 50% after the boronization. Gradually, the effects of the glow discharge boronization diminished until, after about 500 plasma shots, TdeV was behaving as before boronization.

STB and TMB fuelling both produced global plasma resistivity reductions of about 30%. After initiating either TMB or STB, the

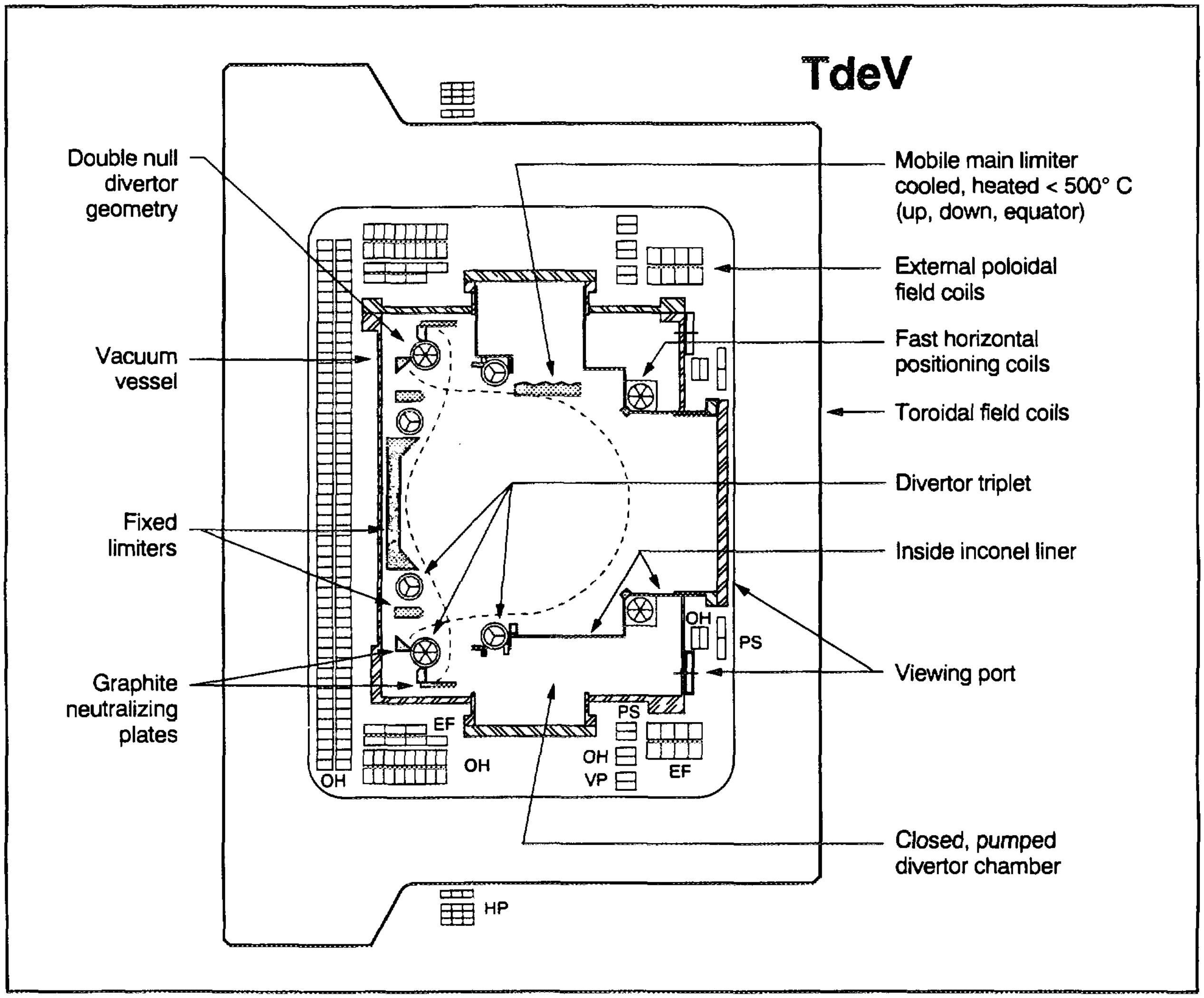

Diagram of internal components in the upgraded Tokamak de Varnnes, showing separatrix (broken line). Central axis of Tokamak is to the left.

effect increased gradually until after about 5 – 10 plasma shots, the full effects were observed. The effects were reproducibly maintained from shot to shot, as long as the particular method was being used in consecutive shots. After ceasing TMB or STB, the effects diminished after about 5 – 10 shots until, once more, the TdeV behaved as if unboronized. *More information from Claude Boucher (514) 652-8710 or (514) 468-7753.*

CONFERENCES

Albuquerque Tritium Conference

Canada made a solid contribution to the Fourth Topical Meeting on Tritium Technology in Fission, Fusion and Isotope Applications, held in Albuquerque, New Mexico September 29 – October 4. The Meeting, sponsored by Los Alamos National Laboratory, was considered a resounding success by those attending. Canadians cochaired four of the eight sessions, and three Canadians – Bill Holtslander (NFP), Joan Miller (AECL) and Otto Kveton (CFFTP) – were members of the Meeting's organizing committees. Canadians presented 23 of the 172 papers presented at the Meeting.

Canada cemented its international tritium reputation by winning the prestigious *Tritium Cup* in the Meeting's International Tennis Tournament. Canada's tennis players prevailed over teams from Japan, Europe and the Cup's previous holders, the USA.

Fusion Seminar - Ottawa

On October 24, the Fusion Sub-Committee of the Canadian Nuclear Association hosted, in Ottawa, a Seminar on *Canadian Participation in World Fusion: Opportunities and Challenges.* The 120 delegates who attended were from industry, governments, universities and research centres across Canada. The Seminar was held to present an update on the scope and scale of world fusion R&D and the progress being made towards building sustained-burn, tritium-fuelled fusion reactors – the Next Step machines. The Seminar's speakers, from Canadian sites as well as from Europe and the USA, discussed the status of ITER and other advanced fusion projects, and outlined the scale of world fusion efforts.

Part of the Seminar's purpose was to inform those sectors of Canada's high technology infrastructure which have not participated in fusion so far, about the scale of the world fusion effort. Areas of opportunity to participate in fusion were discussed. Transfer of fusion technology to industry was another important theme of the Seminar. Speakers from companies such as MPB Technologies, Inc., which has a long history of fusion research and engineering, outlined their experience in supplying goods and services to the fusion market.

CCFM/TdeV

CCFM Annual Report

Centre canadien de fusion magnétique (CCFM) has released for distribution its Annual Report for the year 1990. Much of 1990 was spent installing divertors and other important improvements on TdeV (Tokamak de Varennes). The Report summarizes this work and outlines salient experimental work performed after TdeV was recommissioned in September. A discussion of CCFM/TdeV programs beyond 1991 is also given. The report is written in both French and English. Copies may be obtained by writing (letter or FAX) to Georges Wilson, Manager-Administration CCFM (*See Contact Data*).

JAERI-AECL

Initial Cooperation Action

In August, the first formal activities began under the 1991-1996 bilateral fusion cooperation agreement between Atomic Energy of Canada Limited (AECL) and the Japan Atomic Energy Research Institute (JAERI). AECL operates Canada's National Fusion Program (NFP). The 1991-1996 bilateral agreement, signed earlier this year, provides for greater cooperation in fusion than the previous bilateral agreements between AECL and JAERI. Under the umbrella of the enhanced bilateral agreement, each significant area of cooperation will be governed by an individual *Implementing Agreement* signed by both parties.

On August 23, *Implementing Agreement No. 1* was signed, covering the exchange of personnel between Canadian and Japanese fusion sites. The current three-month attachment of Paul Gierszewski (of CFFTP) to work on breeder blanket engineering at JAERI, near Tokyo, is the first formal action under this Implementing Agreement.

Fusion Pilot Plant Study

An informal five-agency working group, including the Canadian Fusion Fuels Technology Project (CFFTP) and four US institutions, has begun the *Fusion Pilot Plant Study,* to design a pilot plant for demonstrating electricity production technology with a fusion reactor.

Members of the working group are:

- Fusion Power Associates (FPA).
- CFFTP
- Massachusetts Institute of Technology (MIT).
- Ebasco Services, Inc.
- Oak Ridge National Laboratory (ORNL).

Dr. Stephen Dean of FPA (Gaithersburg, Maryland) is the study leader. MIT and ORNL are experienced fusion reactor design sites; Ebasco is a designer of commercial nuclear power plants and participated extensively in TFTR. The first meeting of the group was in April 1991 at MIT. Representing the institutions at meetings are:

Dr. Stephen Dean; President, FPA.
Dr. Donald Dautovich; Program Manager, CFFTP.
Dr. Daniel Cohn; Head, Fusion Systems Division, MIT.
Dr. Charles Baker; Associate Director for Technology, ORNL.
Dr. William Ellis; Vice President, Advanced Systems Engineering, Ebasco.

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"We think it's possible to demonstrate electric power generation technology with a working fusion pilot plant within 15–20 years," said Dr. Dean.

The chief objectives in ultimately building a fusion pilot plant would be to:

- Demonstrate production of high grade heat from fusion.
- Provide operational experience of fusion plants.
- Provide operational engineering data for design and construction of commercial fusion power plants.

Guidelines for a successful Fusion Pilot Plant, as currently envisaged by the group are:

- Low capital cost.
- Short construction schedule.
- Small thermal power – 500 megawatts or less.
- Capacity to generate electric power – in the order of 100 megawatts.
- High availability for extended run periods – several weeks at a time.
- Short design life – less than ten full power years.
- High confidence in safe operation.
- Use of reduced-activation materials as much as possible.

A Fusion Pilot Plant, the group believes, would provide operating experience of fusion plants that would be indispensable in designing and building the first generation of commercial fusion power plants.

The Pilot plant will be designed so that it could yield practical experience of:

- Sustained high grade heat production and extraction, requiring sustained high reactor operating temperatures.
- Control of a fusion power plant, including reactor control dynamics and operational integration into a power grid.
- Maintenance issues and techniques.
- Operational fuel handling processes and fuel management.
- Safety and licensing issues and processes.
- Environmental impacts and benefits of a working fusion power plant.
- Waste management.
- Power utility needs and preferences.

Role of CFFTP

CFFTP's chief role is to provide the power utility viewpoint and tritium technology expertise during the study. This will be done by accessing Ontario Hydro engineering groups; the work will be assisted by Mr. W.G. Morison, former Vice President of Design and Construction Branch at Ontario Hydro. First-stage work is now in progress at CFFTP, to deliver data on fusion reactor design and performance requirements from a power utility standpoint. This includes data such as:

- Quantity and quality of steam for the electric power generators.
- Reactor control and trip requirements in response to power grid conditions.
- Licensing issues and criteria.
- Acceptable maintenance effort and cost.
- Emissions standards.
- Tritium requirements.
- Safety analysis.

Participation in the Study is now an integral part of CFFTP's program strategy for the next five years. Donald Dautovich, CFFTP Program Manager said in October, "A commercial fusion power reactor has to meet power utility requirements. We believe, at CFFTP, that power utilities must be involved in reactor and plant design, if a fusion power plant is to be a practical success. The entire CFFTP program is – in the ul-

Fusion Pilot Plant Study

continued

timate – oriented towards realization of fusion power plants, and their forerunners like NET and ITER. Just as we have committed to participating in ITER, CFFTP has now committed resources to participating in pilot plant studies. The Fusion Pilot Plant Study is an important step, and I am pleased that CFFTP is a team member. This Study, and our participation in it, will materially influence CFFTP R&D directions. Just as with our NET and ITER involvement, the Pilot Plant Study will help keep our R&D focused on producing the new technologies most needed for fusion power."

More Information: Stephen Dean, FPA President (301) 258-0545, or Donald Dautovich, CFFTP Program Manager (416) 855-4700.

Contact Data Corrections

ERRORS. In Issue No. 14 of FusionCanada (May 1991), the **Contact Data** listing contained a number of incorrect telephone and Fax numbers. We apologize for the errors, which occurred during data transfer in starting our new production process. All telephone and fax numbers in **Contact Data** in this issue have been verified as correct.

EDITORIAL OFFICE NEW ADDRESS. The FusionCanada Editorial Office has now moved to a new address, and has new telephone and fax numbers. Please See **Contact Data**.

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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'FusionCanada' Bulletin

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Ce Bulletin est aussi disponible en français

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