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CCFM

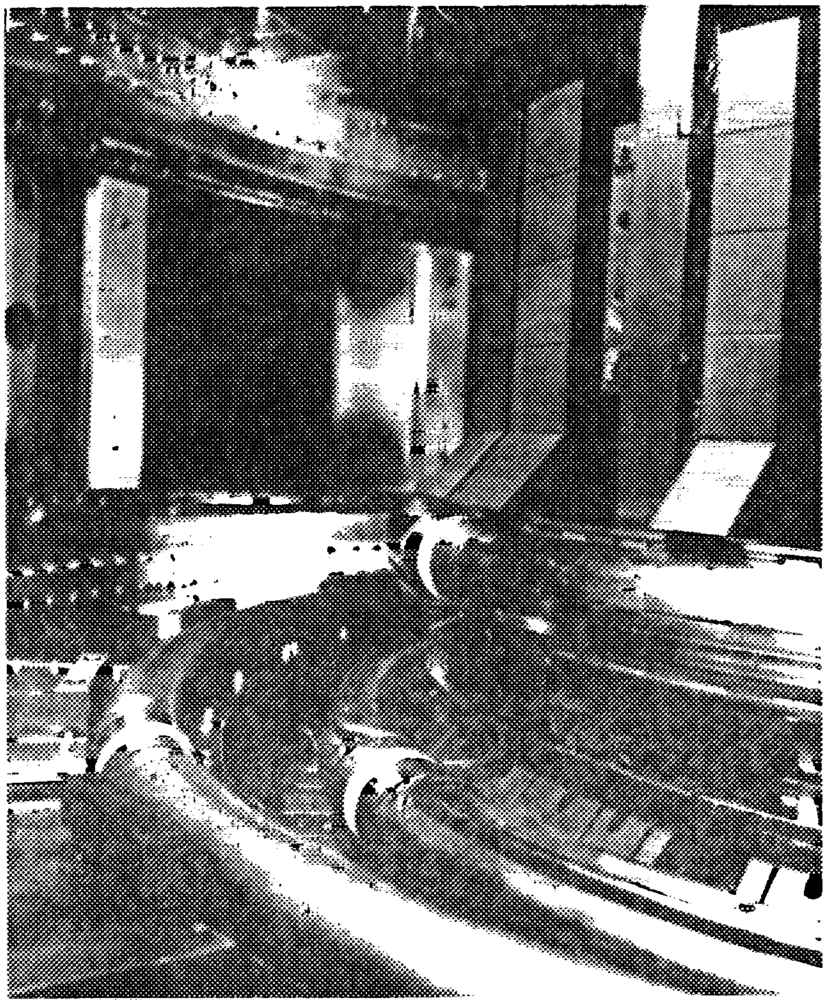
Centre canadien de fusion magnétique

Tokamak de Varennes Returns to Operation.

Divertor Installation Complete

Reconfiguration of Tokamak de Varennes for divertor operation was finished on May 25, when the vacuum vessel was sealed up to begin the new experimental phase. First plasma with the modified Tokamak de Varennes, in limiter mode, was obtained June 15. Recommissioning and adjustment of the Tokamak, its systems and diagnostics will continue through the summer.

Réal Décoste, Director of Operations, said on May 22, 'In effect, we have a new machine. Our first objective is to achieve reliable, repeatable plasma shots in both limiter mode and divertor mode. After that, the main thrusts of our experimental program will continue to be impurity control and transport, plasma-wall interactions and fusion materials testing. Naturally, we hope to contribute in a range of operational and scientific topics in those areas. For example, limiter and divertor plate biasing experiments will hopefully contribute to impurity control and knowledge of confinement.'



Lower divertor [illegible] installed in Tokamak de Varennes. The fixed inner [illegible] right

The Tokamak is now fitted with a double null divertor system as well as limiters, and will be able to operate in limiter or divertor mode. The machine is capable of operating in double-null divertor mode or in single-null divertor mode, as proposed for ITER, by adjustments to vertical plasma position.

A number of other improvements were made to the machine (See 'New Additions to Tokamak'). They include:

- a fast horizontal plasma position control system for stabilizing the major radius of the plasma, for example during current rampdown experiments.
- various diagnostics additions.
- provision for carbonizing or boronizing the machine interior to help reduce plasma impurity levels.

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Tokamak de Varennes Returns to Operation.

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After proving plasma operation with both limiters and divertors, the full set of diagnostics will be fitted in July, including a number of new ones.

Summer 1990 will be spent commissioning the divertor system, and refining plasma conditions, and obtaining reproducible high quality plasmas. Of prime interest is reduction of plasma impurity content. The Tokamak team would like to achieve a Z_{eff} below 2.0. In the first operations phase the best Z_{eff} was near 3.0.

Autumn 1990 will be devoted to comparing limiter and divertor modes of operation, and to experiments in electrical biasing of the plasma. All limiters and divertor plates are electrically isolated, so that various plasma biasing schemes can be observed. The plasma can be biased via the divertor plates, or via the limiters. Effects of biasing and current injection on plasma behaviour will be observed with keen interest.

CCFM-UCLA materials tests

An interesting experiment on materials testing is scheduled for later in 1990, in collaboration with University of California at Los Angeles (UCLA). Boronized graphite heads will be fitted to the Tokamak de Varennes test limiter and exposed to numerous plasma shots. The PISCES team at UCLA, led by Yoshi Hirooka, is coordinating a thorough evaluation of bulk boronized carbon as a plasma facing material. Tokamak de Varennes is at present the only tokamak testing that material. Samples of bulk-boronized graphite (up to 3% boron), fabricated in Japan, have been surface-conditioned in a helium ion beam facility at UCLA. Several US laboratories are involved in studying the characteristics of the material, before and after plasma shots. Temperature and power deposition conditions on the Tokamak de Varennes test limiter are suitable for evaluating the erosion behaviour of the material in the 600-800 K temperature range.

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

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New Additions to Tokamak de Varennes

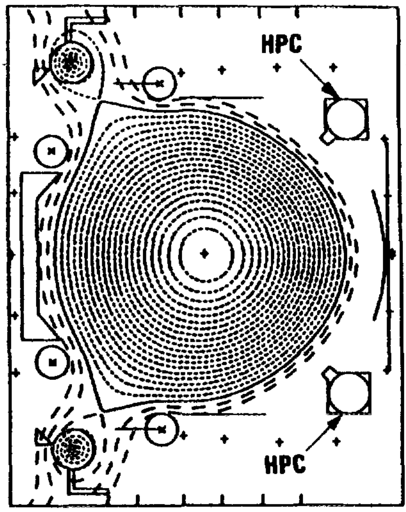
In addition to the fitting of divertors, numerous other systems and components were improved. Some points of interest are:

Divertors. The photograph shows one of the double null divertors, with the fixed graphite inner limiter above it. Each of the two divertors is a triplet of coils, each coil being contained in a welded, vacuum-tight Hastelloy can. An Inconel liner is fitted inside the plasma chamber to encase the plasma, and minimise recycling of neutral particles from the divertor chambers.

Divertor plates are of graphite, electrically isolated for biasing experiments.

The divertor chambers can be fitted with up to 30 metal getters (Zr/V/Fe) for pumping impurities. Each getter could pump at up to 1,000 litres/second.

Horizontal position coils. Internal coils for fast control of plasma radial position have been installed for the first time. These coils are fitted inside the vacuum vessel, within the liner, to improve response time of horizontal plasma position. Changes in magnetic fields from coils outside the vacuum vessel are delayed in propagating into the plasma chamber interior by eddy current effects in the vacuum vessel.



Plasma cross section simulation showing magnetic flux surfaces with divertors operating. MHD equilibrium, Plasma current = 200 kA. HPC marks new horizontal position coils.

Limiters. All limiters can now be heated or cooled, and all (including the test limiter assembly) are electrically isolated from the vacuum vessel. Upper, lower and outer limiters are movable, as is the test limiter head; only the inner limiter is fixed. Heating will aid outgassing and conditioning of limiter surfaces. Cooling is installed in readiness for long-pulse operation.

Power Supplies: Horizontal plasma position. A new fast response horizontal position power supply feeds the horizontal position coils. Full current in the horizontal position coils (£ 6 kA max.)

New Diagnostics

In addition to re-installation of the diagnostics set retained from Phase 1 tokamak operations, a new set of diagnostics is also being fitted, including:

- **Neutral beam charge exchange analyzer.**
- **Far-infrared laser polarimeter.**
- **Electron cyclotron emission.**
- **Multichannel vacuum ultraviolet spectrometer (can produce time-resolved and space-resolved emission measurements of impurity spectral lines).**

can be reversed to opposite polarity full max. current in under 5 milliseconds. The power supply will maintain radial plasma position to within £ 1 millimetre.

Power Supplies: Limiter/divertor biasing and helicity injection. New 400 volt power supplies have been installed for plasma biasing and current injection experiments. Possible effects on confinement and impurity control will be observed with considerable interest.

Injection of currents up to 0.3 kA into the plasma from the plasma edge should be possible. Because an injected current follows a multiple-turn helical path around the torus before meeting the opposite-polarity injection electrode, it can produce some of the effects of a much larger change in the main plasma current, and change the poloidal field vector.

Gas injection. A multi-point gas injection system is now installed, permitting gas injection into the divertor chambers as well as into the plasma chamber. Operation with deuterium is expected in early 1991.

Impurity injection. Laser ablation of solid targets inside the vacuum vessel will permit controlled impurity transport studies.

- Limiter/divertor plate temperature probes.
- Fast scanning Langmuir probe to measure electron density, temperature and plasma potential at the plasma edge.
- Laser ablation for measuring plasma edge electron temperature and density.
- Bolometry.
- Hoα line emission measurement.
- New magnetic flux measurement coils.
- Diamagnetic loops.

Ceramic Breeders

CRITIC Irradiations at AECL

Gas bubble formation

Information summarized from the paper 'Fusion Solid-Breeder Irradiation Experience at CRNL' by Richard Verrall and Joan Miller, AECL Chalk River, presented at annual conference of Canadian Nuclear Society, Toronto, June 3-6, 1990.

Interesting gas bubble formations were observed in irradiated lithium oxide ceramic after long-term in-reactor irradiation of the ceramic in the CRITIC-I experiments at AECL Chalk River. It is thought that the bubbles are helium, formed simultaneously with tritium by neutron reactions with lithium.

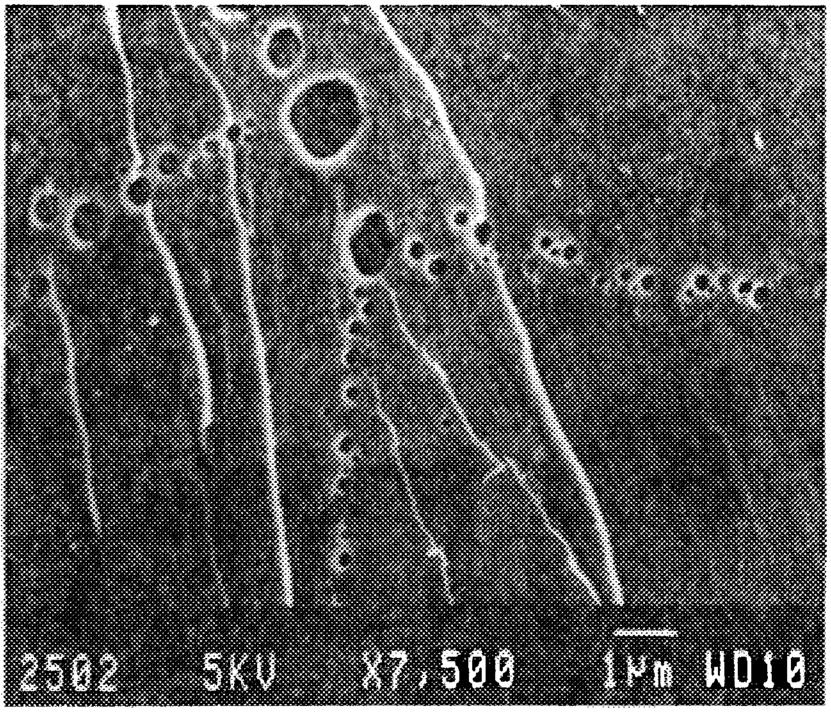
In the CRITIC-I experiment, a 100 gram sample of Li_2O was irradiated for 20 months in the NRU high flux reactor, resulting in more than one percent burnup of lithium and the recovery of 2,000 curies of tritium (total) over the 20 months. The tritium produced in the ceramic was removed for online analysis by a helium sweep gas containing 0–1% hydrogen. The experiment was conducted to investigate, among other phenomena, the processes controlling tritium evolution from breeder ceramics.

A significant conclusion from the CRITIC-1 irradiation was that tritium release from the ceramic was controlled by the kinetics of surface desorption, not by diffusion.

The CRITIC-II experiment, planned to begin later this year, will irradiate Canadian-made lithium zirconate microspheres. The Blanket and First Wall R&D program of the Canadian Fusion Fuels Technology Project cofunds the CRITIC experiments with AECL.

This information was first presented at the ICFRM-4, Kyoto, Japan, December 1989.

More information from Richard Verrall or Joan Miller at AECL Chalk River, or from Paul Gierszewski at CFFTP (see Contact Data)



Gas bubbles formed in Li_2O ceramic during 20 month in-reactor irradiation. Note hexagonal shape of some bubbles, indicating thermal equilibrium with the Li_2O. Largest bubbles are about one micrometre diameter.

INTERNATIONAL

TFTR Completes Tritium Systems

The US Tokamak Fusion Test Reactor (TFTR) finished installation and commissioning of its tritium fuelling systems and facilities in March 1990. TFTR, at Princeton University, is scheduled to begin experiments with deuterium-tritium plasmas in 1993, in pursuit of its ultimate science goal of scientific breakeven. It is equipped to fire not less than 1,000 deuterium-tritium tokamak pulses.

The computer-controlled tritium systems at TFTR were originally installed starting 1982, and have undergone considerable redesign and upgrading since then as tritium technology has advanced. Sophisticated heating, ventilation and atmospheric tritium control systems are installed. Tritium and atmospheric control systems are seismically qualified, and designed so that radiation doses at the Exclusion Zone Boundary are no more than 10 millirem/year (0.1 millisieverts).

The main systems are:

- Tritium Storage and Delivery System. System inventory is 25,000 curies maximum. Storage is on uranium beds. Design tritium flowrate to the Tritium Injection Systems fuelling the torus is 400 curies/5 minutes.
- Tritium Cleanup Systems. These are:
  - Torus Cleanup System
  - Tritium Vault Cleanup System
  - Tritium Storage and Delivery Cleanup System

In the event of a breach of torus vacuum, the Torus Cleanup System would extract and immobilise tritium from the torus.

Bob Sissingh, from the Canadian Fusion Fuels Technology Project, is on a long term attachment at TFTR as Tritium Branch Head, responsible for redesign work, installation, commissioning and operation of tritium systems and facilities. Bob joined TFTR as Tritium Branch head in 1986; he will stay at TFTR until 1994.

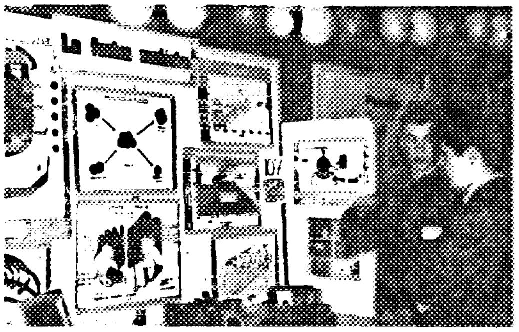
Dominique Fréchette.

It is refreshing to note an example of spontaneous interest in fusion among younger students. Mr. Dominique Fréchette, a 17 year old high-school student in Bernières, Québec, has won an invitation to an International Science Fair in Prague next year, to show the fusion exhibit he constructed for display at student science fairs in Canada.

His exhibit is an exposition on fusion R&D and fusion reactors. The impressive display includes a cutaway model of a future power generating tokamak, a PC computer simulation of D-D and D-T fusion reactions, and an array of posters explaining fusion reactor construction and operation. Mr. Fréchette wrote the simulation software himself in BASIC, designed and constructed the tokamak model, and wrote an explanatory paper on fusion which includes an excellent bibliography.

At the Expo-Science Pan-Québécoise, an all-Québec science fair held in May 1990 in Hull, Québec, Mr. Fréchette's exhibit took first prize and was selected with nine others to go to Prague. The Prague science fair, to be held July 1991, is organized by the Paris-based Mouvement internationale pour le loisir scientifique et technique (MILSET). Students from 33 countries will provide exhibits.

In May this year his exhibit also won a Bronze medal at the Canada-Wide Science Fair in Windsor, Ontario. His research for the project was very extensive, and included two visits to Centre canadien de fusion magnétique.



Dominique Fréchette (facing camera) explains tokamak operation to visitor at Canada-Wide Science Fair, Windsor, Ontario, May 1990.

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804 St-Joseph
Bernières, Québec
Canada G7A 1Z7

CFFTP

Fusion Technology Fellowships

Fusion Technology Fellowships, to support graduate studies and research in fusion technology, have been offered to Canadian Masters and Doctoral students by the Canadian Fusion Fuels Technology Project. The Fellowship program seeks to unite university research with established fusion R&D projects through jointly sponsored research and *practicum* assignments at fusion R&D centres.

Each fellowship consists of a stipend of up to $10,000 per annum plus tuition fees. To be eligible, students must be engaged in fusion-related studies. A partial list of the acceptable topics includes:

- fusion fuels (tritium) processing and handlinfusion blanket technology.
- fusion materials science and technology.
- fusion reactor systems engineering.
- fusion safety.

More information: Fusion Technology Fellowship Program, CF-FTP (See Contact Data).

CCFM Physics Contributions

EDA Siting

CFFTP Contributions

Three years of ITER Conceptual Design activities will end in November this year. The ITER Joint Summer Work Session in Garching West Germany runs from July 2 to November 16. Present plans call for the ITER design concept to be virtually complete in August. A draft report describing the design concept is expected by the ITER Council in November.

CCFM Physics Contributions

CCFM has begun to contribute to the European Community's ITER Long Term Physics R&D effort. At a January 17 meeting on Europe's ITER physics effort, it was agreed that CCFM could contribute in three of the physics areas identified in the ITER Long Term Physics R&D Plan. These are:

- Power and particle exhaust physics. This is an integration of plasma edge physics, plasma-wall interaction and plasma impurity control.
- Characterization of disruptions.
- Long pulse operation.

Two submissions were made for the March 1990 reporting date:

'Importance of Production Mechanisms of Carbon Monoxide and Hydrocarbons' (Investigator: Bernard Terreault).
'Plasma Current Rampdown in the Tokamak de Varennes' (Investigators: Juris Kalnavarns, Magdi Shoucri).

More submissions may be made from the existing Tokamak de Varennes database. When the machine is fully operational again, new work will be contributed.

EDA Siting

Five years of ITER Engineering Design Activities (EDA) are expected to begin in 1991, following completion of Conceptual Design Activities. The site for the EDA has not yet been chosen. The feasibility of a Canadian site for EDA was investigated in a study submitted to the April 1990 meeting of the ITER Council. The study considered both commercial office facilities and facilities associated with five universities in the Province of Ontario. Several locations appeared to be suitable for siting the EDA. The study was submitted jointly by the Ontario Ministry of Industry, Trade and Technology and by Ontario Hydro.

CFFTP Contributions

In addition to the ongoing R&D contributions, two other areas of CFFTP ITER activities can be identified:

- Design concept contributions for a number of systems.
- Assistance with integration of systems, reactor, reactor building and site layout into the complete ITER Conceptual Design.

Design concept contributions:

- ITER Cryogenic Isotope Separation System. For this contribution, CFFTP and Ontario Hydro cooperated with staff at the US Tritium Systems Test Assembly at Los Alamos National Laboratory.
- ITER Fuel Processing Loop, including reactor exhaust processing and a fuel cleanup system. This concept is also being prepared through a CFFTP/Ontario Hydro/TSTA collaboration.
- Extraction of tritium from ceramic breeder helium purge gas.
- Tritium extraction from Aqueous Lithium Salt Blankets.
- Report on thermal analyses of ceramic breeder blankets.
- Tritium storage beds using a zirconium-cobalt getter.
- A flexible, collapsible containment envelope concept, for movement of radioactive components on site.

Integration of Systems, Reactor, Reactor Building and Site:

Design integration has emerged as a significant part of the Conceptual Design Activities. Some of the areas of CFFTP contribution include:

- Assistance in preparing a site layout for the ITER Design Concept final report.
- Assistance in preparing siting requirements for ITER (draft document).
- Proposal for a building layout for the ITER tritium systems reference design concept.
- Proposals for a hot cell and waste disposal facility.
- Concept design proposal for site power systems, including emergency power supplies.
- Containment/confinement concepts using inert gas atmospheres, closed loop ventilation and active isolation concepts.

Effective June 1, Otto Kveton of CFFTP joined the European Community ITER team. Mr. Kveton replaced Bob Stasko, who was an ITER team member for two years.

INDUSTRY IN FUSION

Tokamak Timing Systems for MIT, LANL, IGI

Three fusion centres in the United States and Italy have agreed to purchase a Canadian timing system to synchronize and control the data acquisition systems of their fusion experiments. MPB Technologies Inc. of Montréal is supplying the timing system, which is used on Tokamak de Varennes.

The three fusion centres are at MIT Plasma Fusion Center, (Alcator C MOD experiment), the Los Angeles National Laboratory (CPRF/ZTH experiment) and the Instituto Gas Ionizzati, Padua, Italy (RFX experiment). They are jointly developing a data acquisition system, and all chose the MPB timing system to synchronize their machine control systems and data acquisition systems.

The timing system uses master timing signals generated by a tokamak control computer during a tokamak pulse, and processes them to trigger control and data acquisition sub-systems synchronously.

MPB developed the timing system. It consists of sets of timing signal Encoder and Decoder modules, linked by a fibre optic cable that carries a 1 MHz timing reference signal. When significant events occur, such as Start of Countdown, the Encoder input devices modulate digital codes on the 1 MHz signal. Each Decoder can be programmed to recognize a selection of the digital codes, to generate various trigger and clock sequences.

Equipment for MIT and IGI has been delivered; the Los Alamos equipment will be delivered later in 1990.

More information from [illegible]achynski, President, MPB Technologies Inc., (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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