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Canada-US *Collaboration Agreement*

A United States-Canada fusion collaboration agreement was signed on November 19 last year by Atomic Energy of Canada Ltd. and the United States Department of Energy. The new agreement is a five year Memorandum of Understanding (MOU) covering collaboration in magnetic fusion. Under the agreement, the United States and Canada can make individual, topical agreements to collaborate on projects of mutual interest. Agreed means of collaboration include sharing of facilities, exchange of research data, and reciprocal working visits by scientists and engineers.

Dr. David P. Jackson (left) and Dr. John F. Clarke sign the new Canada-US fusion collaboration agreement in Germantown, Maryland, November 19, 1987.

The agreement "strengthens and formalizes existing US-Canada fusion cooperations" said Dr. David Jackson, Director of the Canadian National Fusion Program. Dr. Jackson signed the MOU for Atomic Energy of Canada Limited, and Dr. John F. Clarke signed for the United States Department of Energy. Dr. Clarke is Associate Director of Fusion Energy in USDOE's Office of Energy Research.

Dr. Jackson also remarked later that the agreement "provides the basis for several newer, mutually beneficial collaborations relevant to CIT and ITER."

At the signing ceremony, in Germantown, Maryland, both leaders said that the agreement completes the principal framework of bilateral agreements for their countries.

The Coordinating Committee which manages collaborations under the agreement held its first working meeting following the signing ceremony. The Committee agreed on the technology areas of mutual interest, and discussed specific projects and lines of research for early attention. (See inside; 'Technical Directions').

Among the items discussed were the International Thermonuclear Experimental Reactor (ITER), the Compact Ignition Torus (CIT), and work linking Tokamak de Varennes and the Canadian Fusion Fuels Technology Project (CFFTP) with US groups sharing similar interests.

TECHNICAL DIRECTIONS

Canada-US Agreement

At its first meeting November 19-20, the Coordinating Committee reached agreement on the technical directions of future fusion collaboration. The principal technical areas of mutual interest were identified as:

- The US Compact Ignition Torus (CIT) project activities.
- Collaboration on the International Thermonuclear Experimental Reactor (ITER)
- A range of fusion reactor technology and materials areas, particularly tritium and remote handling technology.
- Physics of magnetic confinement activities involving Tokamak de Varennes and US groups.

Past and present collaborations which have been ongoing for a number of years on an informal basis were documented and reviewed at the working meeting. The Committee discussed ways to strengthen present collaborations, such as Varennes' tokamak physics collaboration with Princeton and MIT, and participation by CFFTP in tritium activities at the Tokamak Fusion Test Reactor (TFTR).

The Committee identified new projects for which collaboration could be beneficial, and identified as well some new areas of collaboration at existing projects. Some of the new projects discussed were:

- the United States' ARIES reactor study,
- a workshop on aqueous self-cooled fusion reactor blankets,
- validation of the US Tritium Migration Analysis Program.
- tokamak current drive experiments
- BEATRIX II breeder materials irradiation study
- safety research

At Tokamak de Varennes, some of the planned experimental studies, such as plasma current ramping, are relevant to CIT. Canadian interest in CIT participation was welcomed by the US. In safety research, continuing development of consistent safety assessment methodologies was agreed as desirable.

The Coordinating Committee is the executive body managing collaborative actions under the agreement. For Canada, the Executive Secretary to the Committee is Dr. William Holtslander, Manager of NFP's International Program. His US counterpart is Dr. Michael Roberts, Director of International Programs for the USDOE Office of Fusion Energy. The MOU signatories, Dr. Jackson and Dr. Clarke, are the senior Committee members.

Dr. Richard Bolton (Director — Tokamak de Varennes) and Dr. Donald Dautovich (Manager — Canadian Fusion Fuels Technology Project) attended the signing ceremony and working meeting.

The next meeting of the Coordinating Committee will be held in Canada later in 1988.

TECHNICAL UPDATE

Tokamak de Varennes

Good progress has been made in plasma position control and installation of diagnostic instruments.

Plasma Position Control

Continued refinement of position control system operation has resulted in improved plasma position stability, plasma current and plasma electron density. Recently, plasma sawtooth relaxations have been observed. Their presence indicates improvement in plasma conditions, and indicates that the maximum possible central current density has been attained.

The plasma position control system is unusual in using only digital control. A programmable high speed digital controller controls currents in all tokamak magnets via the magnet power supplies. Recent adjustments to magnet current control algorithms are responsible for improved machine operation. The controller can recalculate all magnet currents every 200 microseconds.

Compensation in the plasma position control system for local magnetic field curvature has yet to be implemented. Further improvements in plasma conditions may be expected when this is done.

Machine Program.

Important current objectives are:

- Complete installation and testing of diagnostics.
- Complete commissioning of position control system.
- Perform tests on test limiters with thick coatings of Titanium Carbide.
- Perform machine particle and energy balance by early summer of 1988.

More information from Dr. Horst Pacher, Scientific Coordinator, Tokamak de Varennes (514) 652-8726.

X ray Imaging System

First signals from this diagnostic system were obtained early in December 1987. Like several other diagnostic systems on the tokamak, this one is designed to provide copious information on the spatial profile of the plasma. The system uses 80 X ray detector diodes arranged in five identical arrays of 16 diodes each. Spectral range is 1-10 keV.

This tomography system is designed to provide two dimensional pictures of soft X ray emission for a transverse section of the tokamak plasma. These X ray pictures will map plasma shape and portray its stability, and help to provide profiles of temperature, electron density, impurity movement and distribution, and other parameters.

One of the five X ray detector arrays was declared operational in December, coincidental with improvements in plasma position control and in general plasma condition. The detector array soon observed evidence of sawtooth relaxations in the plasma (see illustration).

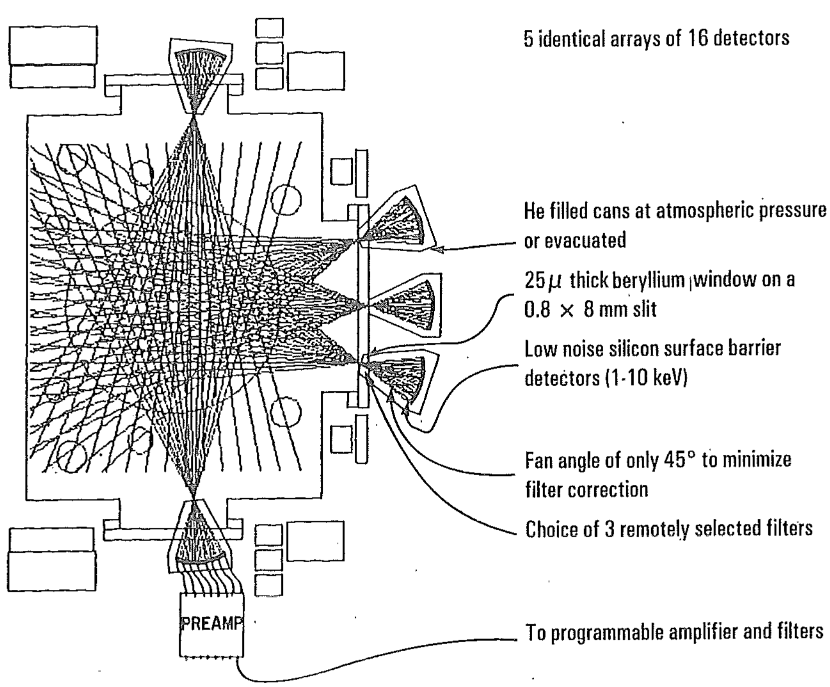
The detector arrays and their electronics are positioned within a few centimeters of the principal tokamak magnet coils; they must operate in the full toroidal magnetic field of 1.5 tesla, and an electrically noisy environment. The signals from the first array have demonstrated that the design is successful. Experience gained in commissioning the first detector array is being used to set up the other four identical arrays.

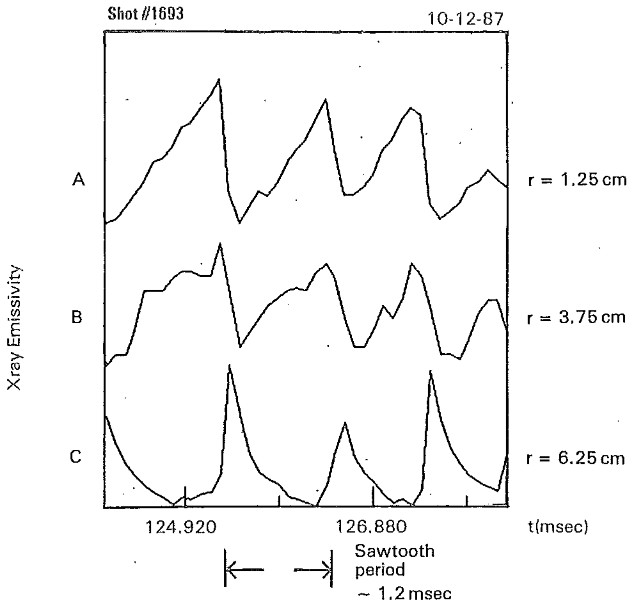
The system is very flexible in operation. Two-dimensional plasma profiles can be obtained in a variety of discrete energy ranges. Each of the arrays has variable X ray filtering arrangements, operated by remote control. A choice of solid filters can be selected for each detector array, or different gases can be introduced into the detector cans with helium for other filtering characteristics.

The system can provide complete profiles at sampling rates up to 200 kHz. Fourier harmonic expansion algorithms are used for producing the two dimensional plasma profiles from data acquired by the 80 detector diodes.

More information from Dr. Réal Décoste at Tokamak de Varennes (514) 652-8715

X-ray Imaging System on the Varennes Tokamak



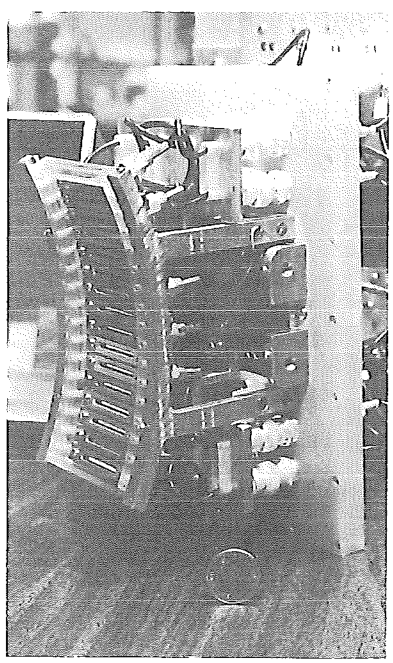


Sawtooth Plasma Relaxations

Selected traces, taken on December 10 from three of the X ray detectors, demonstrate so-called sawtooth plasma relaxations, showing a sawtooth period of about 1.2 milliseconds.

Sawtooth relaxations are characteristic of tokamak plasmas. They are continual, rapid fluctuations in plasma profile, in which the plasma density and temperature increase steadily near the centre of the plasma, and then collapse sharply, with a time waveform resembling a sawtooth. Further from the plasma centre, outside the 'inversion radius', the opposite happens simultaneously; the plasma cools and becomes rarified, and then quickly returns to a higher density. In the shot portrayed, the inversion radius is about 4.5 cm. The actual plasma radius was about 20 cm.

Each trace above represents X ray emission at a different radius on the plasma cross section. Trace A (at 1.25 cm radius, near the plasma centre) shows sawtooth buildup and sharp collapse of X ray emissions corresponding to plasma temperature and electron density. Trace C (r = 6.25 cm, outside inversion radius) shows the simultaneous decrease and sharper increase of plasma density. Trace B (r = 3.75 cm) shows a composite signal.



X ray Imaging System Detector. Curved array holds the 16 X ray diodes. The 2 cm coin shows scale.

INDUSTRY IN FUSION

We introduce another Canadian company working in fusion development.

Canatom Inc.

Montréal, Québec

Canatom developed its fusion engineering expertise over the last ten years, working principally on the Tokamak de Varennes. The company was responsible for the engineering design of the Tokamak, its civil works, and its electrical distribution and cooling systems. During the Tokamak's present commissioning operations phase, Canatom supplies engineering support and operations staff.

Fusion engineering is an integral part of Canatom's business, and the company continues to pursue fusion engineering projects. Canatom has specialized in nuclear and related plant engineering and equipment procurement since 1955.

The company was responsible for engineering of the Tokamak's vacuum vessel, its liner, internal structure, and the fixed and movable limiters. Canatom also designed the magnet coils, their mountings and their cooling systems, including toroidal and poloidal field coils. Some poloidal coils are inside the vacuum vessel, inside vacuum-tight jackets. Design coordination for all design components was provided, as well as procurement for much of the equipment and the components designed by Canatom.

Work began with preparation of conceptual designs from parameters specified by the physics team. Canatom then completed engineering analyses, detailed designs, and technical supervision of equipment procurement. Company staff helped supervise construction of the machine, and now continue to give engineering support.

Further information from Mr. T. Gellatly, Canatom (See Contact Data)

This is the second of a series of articles on ICF-related work in Canada.

'SMILE' Program at UBC

Vancouver, British Columbia

'SMILE' means Sub-Micron Laser Experiments. This program at University of British Columbia studies shock wave dynamics and transport of X ray energy in laser-irradiated matter. Shock wave pressures in laser targets can reach tens of millions of atmospheres (megabar). In such highly compressed matter, physical processes such as X ray energy transport are not fully understood. UBC's *'SMILE'* Program contributes in these and related fields. Program coordinator is Dr. Andrew Ng, UBC Physics Department.

The SMILE program began in 1980, and has contributed broadly in the laser-plasma field. Its pioneering work has included:

- detailed study of the formation of laser driven shock waves in solids,
- demonstration of high pressure equation of state studies from shock speed and shock-heated temperature measurements in aluminum targets,
- measurement of electrical conductivity of a strongly coupled and degenerate plasma.

New Program

The SMILE work has resulted in a new program "Advanced Materials Research at High Temperature and High Pressure", based on a dynamic impact facility incorporating a two-stage light-gas gun. The hypervelocity gun can accelerate a one gram projectile to a velocity of 7.5 kilometers per second. Installation should be completed by September 1988. Temperatures up to 10,000 °C and shock pressures up to five million atmospheres can be generated, depending on target and projectile materials. Materials behaviour and shock wave dynamics will be studied under these conditions.

Current SMILE Work.

Most experiments concern irradiation of metal targets (single and multi-layer) and quartz targets with 0.53 micron light from a Neodymium-glass (Nd:Glass) laser. Experimental data are used to refine models for shock wave dynamics and for X ray energy transport.

Metallic Targets.

Experiments using flat multi-layer metallic targets have begun, in addition to ongoing work with single-layer targets. One objective is to study shock wave and material behaviour as shocks propagate from low- to high-density materials. For example, shock wave pressures can double as they pass from, say, aluminum to gold because of the acoustic impedance mismatch at the interface. In one experiment with a gold + aluminum target, the aluminum surface is irradiated with the laser pulse, and shock wave arrival time at the rear surface of the gold layer is measured by observing shock-induced luminous emission. Final shock wave pressure is derived from such shock speed measurements. More experiments are planned with similar targets for measuring X ray transport and the complex interplay between radiative preheat and shock propagation. Smile workers have collaborated with Ecole Nationale Superiore de Mécanique et d'Aéronautique, France, in multilayer target work.

Quartz Target Work.

Initially-transparent quartz targets allow photography of the laser generated shock wave trajectories while the short (2 nanosecond) laser pulse is still ablating the target and launching increasingly stronger shock waves (See photo, FusionCanada, October 1987). The study showed up anomalies in shock propagation under certain conditions. Formation of the strong shock in quartz is slower than existing theories predict, when the ablation pressure in the irradiated target exceeds about one megabar (about 100 million kPa, or 15 million psi). The quartz appears to change to an as yet unidentified high density state and delays shock wave propagation.

Experiments are performed using a Nd:Glass laser, providing a 2 nanosecond pulse at energies up to 35 Joules at 1.06 micron wavelength, 18 Joules at 0.53 micron or 4 Joules at 0.27 micron.

Recent papers from *'SMILE.'*

Dynamics of Laser Driven Shock Waves in Fused Silica. A. Ng et al. *Physical Review Letters,* Vol 58, No. 3, January 1987.
Electrical Conductivity of a Dense Plasma, A. Ng et al. *Physical Review Letters,* Vol 57, No. 13, September 1986.
Hugoniot Measurements for Laser-Generated Shock Waves in Aluminum. A. Ng et al. *Physical Review Letters,* Vol 54, No. 24, June 1985.

More information or copies of papers from Dr. Andrew Ng, UBC (See Contact Data).

APPOINTMENTS

CFFTP

Safety and Facilities. Mr. Robert Stasko is now acting as Manager, Safety and Facilities Engineering at the Canadian Fusion Fuels Technology Project. The appointment reflects the CFFTP management philosophy of recognizing safety engineering as a specialized and significant work area. In recent years, Mr. Stasko has worked mostly on fusion safety development.

INRS-Énergie

Three researchers have joined INRS-Énergie to perform tokamak-oriented research. INRS-Énergie is a research partner in Tokamak de Varennes.

Diverter Modelling. Dr. Richard Marchand recently joined INRS-Énergie from University of Alberta to research plasma-wall interactions and do diverter modelling. His work concentrates on fuel and impurity transport in diverter plasmas.

Plasma Hydrogen Fluxes. Dr. Guy Ross joins INRS following a research period this year at The Institute for Plasma Physics, Hefei, China and earlier work at TEXTOR. Dr. Ross worked in Hefei at the invitation of China's Academia Sinica. At INRS-Énergie, Dr. Ross studies hydrogen gas flux using depth profiling of passive probes mounted on the Tokamak de Varennes.

Diagnostics. Dr. Christian Simm has arrived from the TCA tokamak at Lausanne, Switzerland, to work on soft X ray tomography and on a 40 keV, 1 amp neutral particle injector for charge exchange spectroscopy.

MAY 1988 TRITIUM CONFERENCE TORONTO CANADA

Third Topical Meeting on TRITIUM TECHNOLOGY IN FISSION, FUSION, and ISOTOPIC APPLICATIONS.

The call for papers has drawn a large and excellent response; more than 180 abstracts were received, with much interesting material and a high level of quality. The Program Committee is looking forward to a very successful and enjoyable conference.

Registration and Conference information from Dr. Carole Burnham, CFFTP. (See Contact Data)

Ce Bulletin est aussi disponible en français

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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