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CFFTP Highlights

Karlsruhe Isotope Separation System

Tritium, Deuterium and Hydrogen Separation by Gas Chromatography

Kernforschungszentrum (KfK) Karlsruhe, West Germany, has ordered a complete hydrogen isotope separation system for the Karlsruhe Tritium Laboratory. The system will process gas mixtures of tritium, deuterium, and hydrogen (T,D,H) into their component gas species, and store them on uranium storage beds. Gas mixtures can be separated into the six isotopic species; T_2, DT, HT, D_2, HD, and H_2. A gas chromatography system accomplishes the separations, operating at liquid nitrogen temperatures.

KfK Karlsruhe ordered the system from the Canadian Fusion Fuels Technology Project (CFFTP), for completion and handover by November 1990. The medium-sized system will process up to 12 grams of mixed gas per day (three moles of equi-molar gas mixture). This is a turnkey contract, and includes design, fabrication, delivery and commissioning of the complete system. The system complies with West German design and safety regulations. Five Canadian companies and three German companies are collaborating in this project, with CFFTP as prime contractor and overall project manager. The fully assembled system will be tested in Canada during May–July 1990, before shipping to Karlsruhe. Contract value is in the $3 million range.

Labserco Inc. is the main Canadian contractor, in collaboration with Ontario Hydro, Atomic Energy of Canada, Monserco Ltd, and E.S. Fox. Kraftanlagen Heidelberg is the main German contractor, working with M. Braun and TÜV Baden.

The Karlsruhe Tritium Laboratory will contribute to the European Community's fusion fuel system development effort when it is completed in 1990.

More information: Alan Meikle, CFFTP.

ITER

ITER Tritium Process Systems

Canada presented a complete preliminary design for the ITER Isotope Separation System at the 1989 February-March ITER joint work session at Garching, FRG. The system is designed to separate out up to 310 grams of tritium per hour from a total of five tritium-bearing ITER source streams, including the reactor plasma exhaust stream, and to return the tritium to ITER's Fuel Storage and Preparation systems. The design has been accepted as the European reference design for the ITER Isotope Separation System. Design of the ITER Isotope Separation System is one of Canada's designated contributions to the European Community's technical input to the ITER conceptual design activities.

The sources providing gaseous tritium-deuterium-hydrogen gas mixtures for input to the Isotope Separation System are:

- Reactor plasma exhaust gas stream (reference 75 moles/hour of mixed deuterium-tritium.)
- Breeder blanket coolant/tritium extraction stream (either ALSB or solid breeder).
- Hydrogen propellant gas for the deuterium pellet injector.
- Neutral beam injector gas.
- Tritiated waste water.

Each tritium-bearing stream will be treated to produce a hydrogen isotope gas mixture, which is then processed in cryogenic distillation columns refrigerated with cold helium gas. The columns will produce a tritium-deuterium stream containing up to 90 percent tritium, and a deuterium stream purified of tritium. The deuterium-tritium stream output rate is 58 moles per hour maximum, which at 90 percent tritium content delivers 310 grams per hour.

Tritium inventory of the cryogenic portion of the ISS has been of particular concern in the design, and careful design of the cascade has resulted in a tritium inventory

Continues inside

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We regret that some of the pages in this report may not be up to the proper legibility standards, even though the best possible copy was used for scanning

Experimental Update

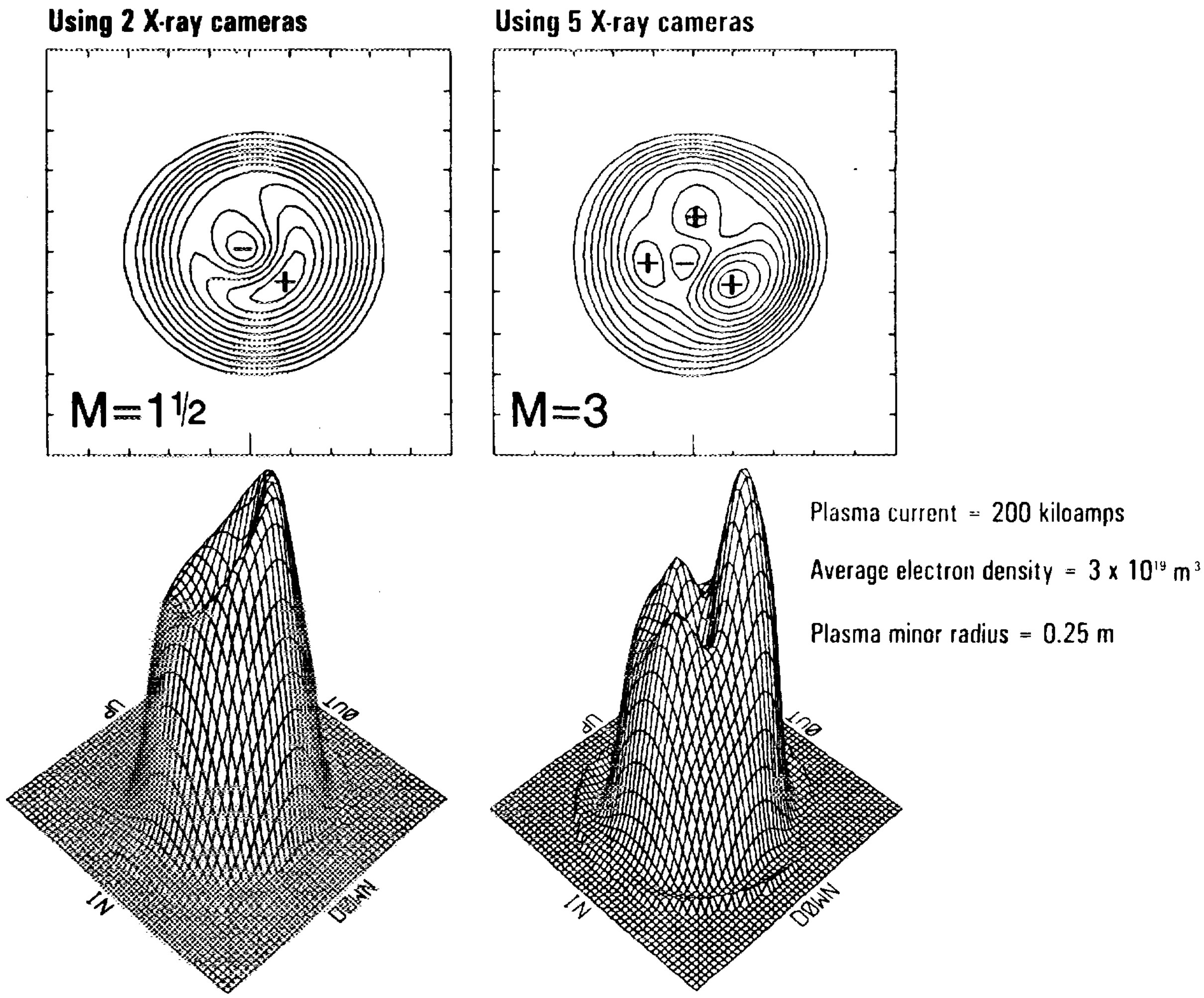
CCFM—Tokamak de Varennes

Sawtooth Oscillation Mechanism—New Observations

Oscillations in tokamak plasma density and temperature, known as sawtooth oscillations, are undesirable in a tokamak fusion power reactor. Their mechanism must be confirmed to permit the designing of sawtooth-free tokamaks. New work at Tokamak de Varennes has examined plasma behaviour during sawtooth oscillations, using the five-camera soft X-ray tomography diagnostic equipment. Intensity of soft X-ray emissions increases with plasma temperature and plasma density, so pictorial views of plasma behaviour can be made from multiple-viewpoint soft X-ray measurements.

Soft X-ray emissions from the Tokamak plasma have been reconstructed in to two- and three-dimensional pictures of soft X-ray emissivity. Depending on the number of viewing angles selected in the reconstruction process, one can obtain different cross section pictures of the same plasma.

The accompanying pictures show two different reconstructions of plasma cross section X-ray emissivity data, captured with a 10 microsecond time resolution, of the same plasma shot on Tokamak de Varennes during the collapse phase of a sawtooth oscillation. These pictures are of a period about 40 microseconds af-



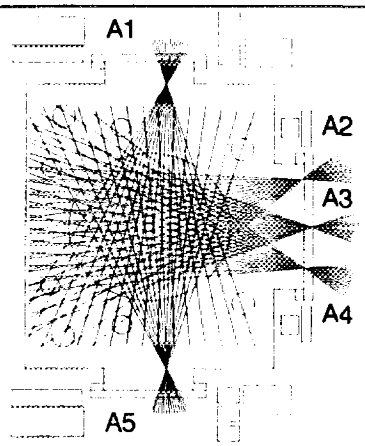
Sawtooth Crash on Tokamak de Varennes

Two reconstructions of same plasma cross section, 40 microseconds after start of crash.

ter the sawtooth crash began. A Fourier-Bessel harmonic reconstruction method was used.

On the left ($M = 1\frac{1}{2}$ reconstruction) the image was reconstructed using data from only two of the five 16-diode X-ray tomography cameras, separated by a 90° poloidal angle (arrays A1 and A3 on tokamak diagram). The result is typical of what can be achieved with two cameras.

On the right ($M = 3$ reconstruction) use of the data from all five cameras resulted in a reconstruction of finer angular resolution. Limitations of the reconstruction technique can still be identified in the picture, but the high emissivity region is seen to be more circular than in the low resolution picture on the left.



X-ray imaging system

Plasma viewing angles

5 cameras, A1—A5

16 X-ray diodes per camera

The result could be interpreted as an indication of support for the now-classical Kadomtsev model of plasma sawtooth oscillation, proposed in 1975. However, sawtooth crash times on Tokamak de Varennes are in the 60—160 microsecond range, still an order of magnitude smaller than Kadomtsev model predictions for this machine.

Further information from Dr. Christian Janicki (514) 652-8709 or Dr. Réal Décoste (514) 652-8715

Canada-US

Canada-U.S. Bilateral
Technical Collaboration Topics

The Coordinating Committee managing Canada-US collaboration in magnetic fusion held its second annual meeting February 22-23. The Committee met to review current technical collaborations and explore further topics where mutual benefit might be possible.

Collaborations over the past year have been numerous, and the majority are still in progress. CCFM-Tokamak de Varennes works with CIT, PPPL-TFTR, MIT, Lawrence Livermore, Oak Ridge and General Atomics. CFFTP is in liaison with CIT, INEL, Argonne, TSTA-Los Alamos, PPPL-TFTR, FEDC-Oak Ridge and Sandia Livermore. Two collaboration examples are liaison in tokamak current drive and in breeder blanket design. CCFM worked with PPPL and MIT on design of a CCFM lower hybrid drive, and supplied ray tracing computer code to several US sites to assist their current drive designs. In breeder blankets, CFFTP cooperated with Argonne and TSTA-Los Alamos in analysis of breeder blanket tritium extraction streams, received a computer program on tritium migration from INEL for evaluation and verification, and hosted a Canada-US workshop on aqueous lithium salt blankets in Toronto last February.

An initial list of possible future collaborations was grouped into three themes:
Physics: Tokamak current drive, plasma edge physics, plasma modelling.
Technology: Breeder blankets, materials development, tritium systems, facility safety, remote maintenance.
Systems design: ARIES project (Advanced Reactor Innovation Evaluation Study).

Defining of mutual objectives in these areas is now in progress. A revised list of themes and topics will be tabled at the third Canada-US Bilateral meeting next year.

The Coordinating Committee is the executive body managing the magnetic fusion collaboration, under a 5 year Canada-US Memorandum of Understanding signed in November 1987. The two Co-Chairmen of the four-man Committee are Dr. Robert Dowling, US Department of Energy and Dr. David Jackson, Director-National Fusion Program of Canada. Executive Secretary for the United States is Dr. Michael Roberts, US-DOE; Executive Secretary for Canada is Dr. William Holtslander, NFP. Observers at the meeting were Charles Daughney (NFP), Richard Bolton (CCFM) and Donald Dautovich (CFFTP).

ITER

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of less than 200 grams, varying somewhat with operating conditions. A total tritium inventory of 200 grams is the desired target level for any isolatable system in ITER. Optimization of the design using the FLOSHEET system design code made this low inventory possible. Anthony Busigin and Dr. Sav Sood, of Ontario Hydro's Design and Development Division, are responsible for the complete design.

System design will be refined over the next two years. Detailed design will begin in 1991, in ITER's Engineering Design phase.

The 1989 summer joint work session extends from June 1 to October 20, again at the ITER technical site, Max Planck Institute for Plasma Physics, Garching, Federal Republic of Germany. Canada is again contributing resident design effort to the European Community's design team participating in the ITER activities at Garching.

ITER Schedule

The following provisional ITER schedule milestones are envisioned if ITER continues beyond the conceptual design stage:

1990 **(end)** Conceptual Design Complete. Decision on continuation of ITER.
1991 Engineering design begins.
1991-1992 Site selection.
1994 Engineering design complete. Construction authorization obtained.
2000 Construction complete. Pre-operation tests start.
2002–2007 Physics test phase.
2008 onward Technology test phase.

More information: Robert Stasko, CFFTP.

INTERNATIONAL

New IEA Collaboration

Environment, Safety and Economics (ESE)

The fusion programs of Canada, Japan, Europe and the USA have joined in a Cooperative program on *Environmental, Safety and Economic Aspects of Fusion Energy.* Under the International Energy Agency aegis, an ESE Provisional Executive Committee met April 3 in Jackson, Wyoming to confirm the text of an IEA implementing agreement and agree on work assignments.

An initial program of eight tasks was proposed. Task organizers will prepare proposals for a cooperative programs in their subject by July. With their elected task organizers, these are:

J. Blevins (Canada): Tritium safety and environmental effects.
Y. Seki (Japan): Activation product codes.
D. Holland (USA): Mobilization of activation products.
H. Djerassi (Europe): Erosion dust generation.
P. Rocco (Europe): Dose calculations for activation products.
H. Djerassi (Europe): Risk assessment methodology development.
L. Cadwallader (USA): Failure-rate data base.
S. Herring (USA): Superconducting magnet safety.
John Blevins is a nuclear facility design specialist with CFFTP.

In the Tritium Safety and Environmental effects task, six topics are being collectively studied for inclusion. One of them is release and transport of tritium in buildings and structural materials. Work on this topic would be useful in reactor building design.

All partners agreed at the Wyoming meeting that flexibility in the agreement is essential; the agreement should permit study of future problems, and not be restricted to the initially accepted program if additional issues should appear. Tasks should have lives in the 3–5 years range, and should address next step or existing machines as well as future fusion power reactors.

The technical program should be confirmed later this year. The implementing agreement will be submitted to the IEA Fusion Power Coordinating Committee for approval in January 1990.

Further information: Dr. William Holtslander, NFP or John Blevins, CFFTP. See Contact Data.

INTERNATIONAL

Two Canadian fusion scientists visited the People's Republic of China last month to explore possibilities for fusion collaboration between the Chinese and Canadian fusion programs. Dr. Bill Holtslander, National Fusion Program and Dr. Kam Wong, Canadian Fusion Fuels Technology Project, visited four fusion centres in the People's Republic of China during their April 25–May 12 visit. Dr. Holtslander is Manager–International Program for NFP; Dr. Wong is Manager - Technology Development for CFFTP.

Claude Boucher of INRS-Énergie will work at the TEXTOR tokamak (KfA Jülich, FRG) as an invited researcher during May–September this year. Prof. Boucher is a specialist in plasma edge behaviour and tokamak wall conditioning, and is a member of the Tokamak de Varennes experimental team. He will investigate effects of first wall boronization and carbonization on plasma impurity transport, in collaboration with Dr. Jörg Winter of TEXTOR. The collaboration will continue after Prof. Boucher returns to Canada. INRS-Énergie is an institute of Université du Québec, and is one of the three partners in CCFM-Tokamak de Varennes.

Centre canadien de fusion magnétique

CCFM—Tokamak de Varennes

Scientific Program:

Advisory Committee Review

CCFM's present and future work programs were reviewed in April by the CCFM Advisory Committee, at its first meeting since experiments began in 1987.

Experimental Program 1989-1991

When it resumes operation in autumn this year for Phase II of the scientific program, Tokamak de Varennes will be equipped with double-null closed divertors, and internal fast horizontal plasma position control. Cooling systems are being upgraded now to prepare for multiple pulse operation. Operation with long multiple pulse trains will become a major operating mode in the next experimental phase. Over the next two years, the scientific program will have these main research topics:

- Plasma current profile measurements.
- Fast controlled plasma current rampdown, aiming at 20 megamps/second.
- Divertor and edge plasma studies (single pulses).
- Central plasma transport and impurity transport studies.
- Plasma impurity control via electrical biasing of plasma and impurity flux reversal using gas puffing.
- Vertical current injection into the plasma.
- Hydrogen retention, recycling and wall conditioning studies.
- Commissioning and operation with multiple plasma pulses.
- Divertor operation in multi-pulse mode, with getters in divertor chambers.
- Recycling and wall saturation studies in high duty factor, multi-pulse operation.
- Study of new materials—erosion, redeposition.

These areas will be studied with particular emphasis on new effects arising from repetitive pulses and changes induced by gas and impurity injection, vertical current and biasing, and current rampdown. A major facility upgrade will be the addition of a one megawatt, 3.7 GHz lower hybrid current drive system. With this installed, Tokamak de Varennes should be capable of continuous 30 second pulses. The usual single pulse operating mode of present tokamaks is dominated by plasma-wall particle recycling and energy exchange at the beginning and end of the pulse. It is important to know how these processes and their time scales will change as Tokamak de Varennes progresses through multiple pulses with comparable on-off times to 30 second steady-state pulses driven by non-inductive current drive.

In approving this program as relevant to fusion power reactor research, the Committee made some recommendations. Among these were the concentration of more resources on wall conditioning and on completing development of the multi-beam laser polarimeter for determining current density profiles in the plasma. Current density measurements would be particularly valuable under non-inductive current drive since few such measurements have yet been made.

Points of Interest

Some further points of interest in the experimental program:

■ In current rampdown studies, disruption-free controlled rampdown rates of 6.5 megamps/second have been achieved, and rates of up to 20 megamps/second will be attempted using the new fast horizontal plasma position control. The limits of disruption-free rampdown will be explored. Current control on this scale is particularly relevant to machines like CIT and ITER, where efficient use of ohmic heating transformer volt-seconds is essential for successful operation. Attention will be paid to magnetohydrodynamic (MHD) activity, current profile evolution and plasma turbulence accompanying the expected peaked current profiles.

■ Plasma biasing via limiters and divertors, and continuation of vertical current injection experiments were warmly encouraged by the committee. It will be most interesting to monitor limiter and divertor currents during all tokamak experiments, since these measurements are rare. All divertor plates on the new divertors are electrically insulated and equipped with current feeds.

■ Detailed study of edge and divertor plasmas is one of the important axes of the Tokamak de Varennes program. Some of the topics in this area are correlation between profiles and parameters of main and edge plasmas; evacuation of hydrogen to, and reflux from, the divertor chambers; power balance and deposition studies. Ultimately, modifications of the edge plasma during radiofrequency current drive will be studied. The Committee recommended study of radial transport of impurities through the plasma edge, and of impurity flow along the scrape-off layer to limiters and divertors.

The Advisory Committee review found that progress has been good and that the scientific yield

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so far was excellent. Tokamak staff were commended particularly on investigations of plasma biasing and vertical current effects, characterization of sawtooth oscillations, and interferometric measurements of plasma density perturbations. Work done so far, and the planned scientific program augur well for the Tokamak de Varennes to make significant contributions in a number of areas.

CCFM Advisory Committee members:

Dr. Gilbert Bartholomew (Chairman); *Consultant, Canada.*
Dr. Charles Daughney (Secretary); *NFP, Canada.*
Dr. Miklos Porkolab; *MIT, USA.*
Dr. Michael Saltmarsh; *ORNL, USA.*
Dr. Jan Hugill; *Culham Lab., UK.*
Dr. Jörg Winter; *KfA Jülich, FRG.*
Dr. Akira Hirose; *Univ. Saskatchewan, Canada.*
Dr. Donald Dautovich; *CFFTP, Canada.*
Dr. Peter Dyne; *Consultant, Canada.*

Further information: Horst D. Pacher, CCFM Scientific Coordinator (514) 652-8726.

Cold Fusion

Following the March 23 announcement from University of Utah, investigation of cold fusion has been active in Canada, including experiments at Atomic Energy of Canada Limited, Hydro-Québec, Ontario Hydro and several university and industry laboratories.

In Deep River, on April 11, the National Fusion Program hosted a meeting of some of the Canadian groups then known to be active in cold fusion. The meeting was useful for exchanging ideas and information between laboratories. Preliminary discussions were held on the possibility of establishing collaborative programs should the phenomenon be convincingly confirmed. By the deadline for this issue of FusionCanada, no Canadian researchers were known to have produced conclusive results.

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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ITER Newsletter

A monthly newsletter on ITER activities is published by the ITER Secretariat, IAEA, Vienna. The National Fusion Program distributes it in Canada. Interested parties should contact NFP, Fusion Office (address at left).

Correction:

CCFM FAX Number

Correct No. is (514) 652-8625

(not 652-8526 as printed in previous issue)