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CCFM - Centre canadien de fusion magnétique

TdeV Restarts

Lower hybrid system now operational

The TdeV tokamak restarted in mid-December, beginning a new experimental phase. TdeV had been shut down to install the microwave antenna for the lower hybrid current drive (LHCD) system, for maintenance and minor modifications, and to install new tokamak control system software.

In 1994, the experimental focus will be to use the newly installed LHCD system to increase plasma temperature and density so as to explore divertor operation and plasma edge (or scrape off layer, SOL) behaviour with hotter, denser tokamak plasmas. At full radiofrequency power of 1 MW at 3.7 GHz, the LHCD system should raise plasma temperature substantially if TdeV's energy confinement is not degraded.

First operations of the LHCD system in December were successful. Injected radiofrequency LHCD power had exceeded 200 kW by the year's end. Although these are early trials, the LHCD antenna seems to be functioning well, coupling more than 90% of RF power into the plasma and driving a portion of the plasma current.

In studying plasma biasing and SOL behaviour, CCFM has begun collaboration with a team of theorists in Sweden and Russia. Interesting progress looks possible now in predicting SOL behaviour under varying plasma conditions, including changes in SOL thickness and SOL plasma velocity with plasma temperature and radial electric field. Barry Stansfield and Claude Boucher of CCFM are cooperating in SOL studies with theorists Michael Tendler of the Alfvén Laboratory at the Royal Institute of Technology, Stockholm, and Vladimir Rozhansky of the Physics and Technology Faculty at Leningrad Technical University. Profs. Tendler and Rozhansky are developing models of tokamak plasma edge behaviour; Profs. Stansfield and Boucher test some of the Tendler/Rozhansky model concepts on TdeV.

Knowledge of scrape off layer thickness at elevated temperatures is important. For one thing, SOL thickness will very much affect design of advanced divertors, especially the electrically biased divertors planned as part of the TdeV-M tokamak upgrade for TdeV. If the SOL is consistently more narrow at high plasma temperatures, plasma biasing via divertors will require rather special divertor plate design. Biasing of plasmas through divertors may be possible for high power fusion tokamaks.

More information:
Plasma edge studies -
Barry Stansfield (514) 652-8735 or Claude Boucher (514) 652-8710.
TdeV Programs -
Brian Gregory or Réal Décoste (See Contact Data).

INTERNATIONAL

Fusion Research in Korea

In October, two envoys from Canada's fusion program visited fusion sites in Korea, to explore possibilities for Canada-Korea fusion collaboration. Dr. David Jackson *(Director - National Fusion Program)* and Dr. Don Dautovich *(Manager - Canadian Fusion Fuels Technology Project)* met fusion researchers and toured fusion research facilities at Korea's four fusion sites.

- Seoul National University
- Korea Atomic Energy Research Institute
- Korea Basic Science Centre - Daedeok Joint Research Facility
- Korea Advanced Institute of Science and Technology

Three small tokamaks (major radius less than 0.7 m) are currently operating in Korea. A fusion mirror machine 15 meters long is under construction. An advanced divertor tokamak, major radius 1.2 m, is now being designed entirely in Korea. The Government of Korea actively supports the work of expanding Korea's indigenous fusion expertise. Training of new fusion workers has a high priority at the four current fusion sites, reflecting Korea's determination to develop a self-sufficient Korean science culture and infrastructure. Korean fusion sites enjoy wide international cooperation with other fusion sites including MIT, the Kurchatov Institute, and University of Texas.

continued inside

Fusion Research in Korea

continued

Drs. Jackson and Dautovich visited Korea as part of a Canadian Government mission aimed at further expanding Canada-Korea cooperation in energy research and electric power generation and distribution. Canadian CANDU fission power reactors are integrated into Korea's electric power generation operations and system planning. At the Wolsung site, 125 km north of Pusan, one CANDU 600 MW power reactor has been operating since 1983, and construction of a second one is at an advanced stage. Two more similar CANDU power reactors were ordered for Wolsung in 1992, to be completed in 1997 and 1998.

For the information of our readers, we present some brief notes on Korean fusion sites. One site is in Seoul, and three are in the area of the City of Taejeon and the adjacent Daedeok Science Town. Daedeok Science Town will also be the site of the 1994 Asia Pacific Conference on Plasma Science and Technology (APCPST '94); for Conference information contact any of the persons listed in *Fusion Sites in Korea - Contact Data.*

Seoul National University

Fusion research and training at Seoul National university is led by the widely respected Prof. Chung Kie-Hyung, who has for many years been a key figure in the development of Korea's fusion research programs. Prof. Chung, who has trained a number of Korea's senior fusion researchers, is head of the University's Laboratory for Accelerators and Nuclear Fusion which has more than 20 graduate students. The Laboratory's main fusion research tool is the SNUT-79 tokamak (R = 0.65 m), in operation since 1985. SNUT-79 was designed and built in Korea, starting in 1979, as its name suggests. Seoul National University is relatively new, although Prof. Chung has been a fusion researcher and trainer of fusion scientists for many years. His group cooperates with 25 other groups, in Korea and overseas. Other research tools in the Laboratory include a free electron laser, an ion linear accelerator, and superconducting magnets.

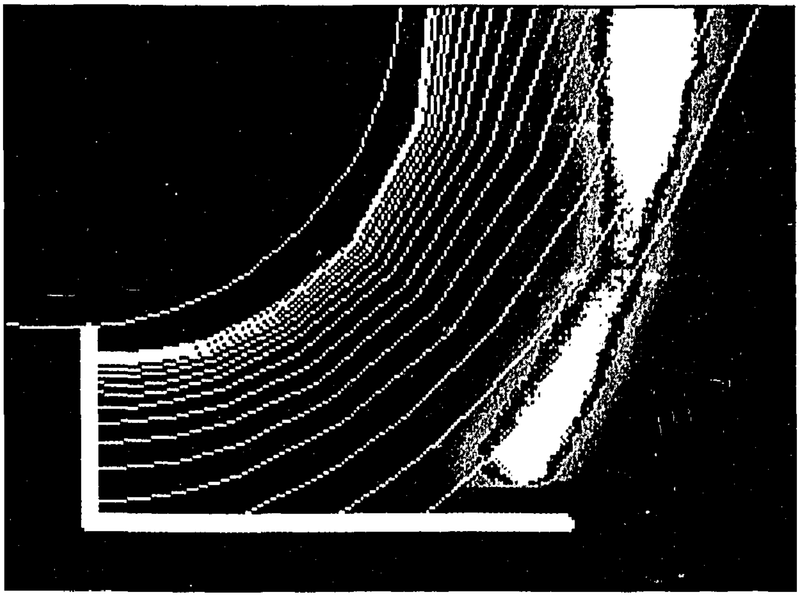
Korea Atomic Energy Research Institute (KAERI)

KAERI is Korea's nuclear research and development agency. The large KAERI laboratory site near Taejeon does fusion research as well as fission-oriented nuclear work. Dr. In Sang-Yeol of the KAERI Nuclear Fusion Department hosted the Canadian visitors on behalf of Department Leader Dr. Hwang Chul-Kyu. Dr. In studied at Seoul under Prof. Chung Kie-Hyung. The KAERI Nuclear Fusion Department designed and built the KAERIT tokamak (B = 2.6 Tesla, R = 0.27 m) which started operating in 1987. Improvement of KAERIT's digitally controlled power supplies continued until 1992. Research objectives include plasma feedback control and plasma-wall interactions, focusing on low-Z wall coatings. An electron cyclotron emission diagnostic is to be installed in Summer 1994, and a photoelectron spectroscopy diagnostic is being developed in collaboration with KAIST and the Kurchatov Institute (Russia). Design of an advanced medium sized divertor tokamak, KAERIT-U, began last August, and completion of detailed assembly and component drawings is scheduled for the end of 1995. Preliminary specifications for KAERIT-U include R = 1.2 m, B = 3 Tesla, and a plasma current of ~ 1 MA. KAERIT-U plasma electron temperature is targeted to be 1 keV with ohmic heating, and up to 5 keV with radiofrequency heating. A divertor is integrated into the plasma chamber design.

Korea Basic Science Center (KBSC)

KBSC is a national joint research institution funded by the Government of Korea. KBSC has five sites around Korea, the largest of which is the Joint Research Facility in Daedeok Science Town adjacent to Taejeon. The objective of KBSC is to provide and operate large, expensive items of research equipment for shared use by university research staff at all of Korea's universities. Equipment installed and planned for installation at KBSC sites would be beyond the budget of many university research departments. KBSC began operations in 1991.

The large Daedeok Joint Research Facility houses KBSC's fusion research machines and apparatus. Daedeok is a thriving research community, with a large number of research institutions, many of which belong to multinational corporations such as Goldstar, Samsung and Hyundai. Dr. Lee Gyung-Su is head of the Joint Plasma Research Facility at the KBSC Daedeok site. Dr. Lee has worked at several overseas fusion sites. The largest item of research equipment at the joint plasma facility is a 15 metre long fusion mirror machine provided to KBSC by Massachusetts Institute of Technology in 1992. This machine, called TARA at MIT, is currently being installed at Daedeok with some modifications, and is scheduled for initial operation in early 1995. It will be known as HANBIT, meaning "Tower of Great Light". This machine will be available to all Korean plasma and fusion researchers, and to those interested in non-fusion plasma applications such as materials and energy technology research. The hall housing TARA/HANBIT has room and structural pro-



TdeV Divertor Plasma Cross-section

Camera image of the divertor components and divertor plasma on the TdeV tokamak, showing location of the divertor plasma relative to the divertor plates (thick straight white lines), the divertor coil surface (circular arc, top left) and the calculated magnetic field lines (thin white curves) in the divertor. This image, printed at 90% of actual size, is from a camera looking along a tangent to the major circumference of TdeV; in effect, it gives a cross-section of the divertor plasma and components. This image, printed here in false colour, actually records the intensity of H_α hydrogen emissions (wavelength 656.3 nm), which increase with plasma density and temperature. False colour shows H_α emission intensity - yellow/white is most intense, blue/black is least intense. The picture shows a possible anomaly: CCFM expects the divertor plasma to be nearer the divertor coil (i.e. further left in this picture), and close to the magnetic field lines next to the divertor coil surface (the last closed flux surface). CCFM is investigating the phenomenon, since the position of the divertor plasma is crucial to design of closed divertors. Other sites have also noticed plasma position discrepancies in divertors. *Further information: Fernando Meo, CCFM, (514) 652-1309, or Fax CCFM.*

CFFTP - Canadian Fusion Fuels Technology Project

CFFTP Program Review

Technical Advisory Committee endorses focus on tritium technologies, isotope separation and remote handling

CFFTP's Technical Advisory Committee of fusion experts met in November 1993 to review the R&D programs of CFFTP and to transmit findings of its review to the CFFTP Steering Committee.

The Advisory Committee agreed that during the last year, as in previous years, CFFTP materially contributed to the world fusion effort. Especially useful contributions were in the technologies of tritium handling, hydrogen isotope separation, and remote handling for fusion reactors. These areas should continue to be the main focus of CFFTP's activities, the Committee concluded, though at the same time CFFTP should continue working on other innovative fusion technologies including compact toroid fuelling for fusion reactors.

As particular technology needs of fusion power R&D have emerged from worldwide fusion efforts, CFFTP has continually re-evaluated its range of R&D projects so as to make best use of its resources and maximize the usefulness of its output. CFFTP now concentrates its R&D efforts on six core technology areas, itemized below. A 1993 report by The Impact Group on CFFTP activities *(see FusionCanada No. 20, March 1993)* had recommended that CFFTP should indeed specialize in relatively few technology areas. The present CFFTP focus on six core technologies reflects CFFTP's adoption of The Impact Group's recommendation.

With its international perspective, the Technical Advisory Committee suggested broad priority categories for resource investment in CFFTP's six chosen technologies. Their suggestions were consistent with CFFTP's own strategic priorities.

High Priority Areas

The following three areas ought to receive the bulk of CFFTP's effort and resources:

Tritium Handling. This is the true core of all CFFTP's technologies. Tritium handling includes purification, storage, measurement and handling systems and components. There was agreement that CFFTP has made many well-recognized tritium processing technology contributions to the world fusion program.

Isotope Separation. Emphasis on isotope separation should also continue to be a mainstay of CFFTP's work in view of the acknowledged expertise and many recognized successes. This field concentrates on separation of tritium, deuterium and ordinary hydrogen.

Remote Handling. Spar Aerospace is now Canada's expert company in fusion reactor remote handling, helped very much to this point by introductions from CFFTP to world fusion projects, and by CFFTP funding and technical support for participation

TdeV-M configuration near the end of the decade. Intermediate-term upgrade steps for TdeV include a higher toroidal magnetic field, increased plasma current, a redesign of the divertor, and possible doubling of the injected radiofrequency power of the lower hybrid current drive system (LHCD). The final TdeV-M configuration will use many existing TdeV frame components, but with a new vacuum vessel, an advanced biasable pumped divertor, a higher plasma current (perhaps 400 - 600 kA) and higher plasma density and temperature.

Program Directions

Some of the principal CCFM program priorities were agreed as being:

- The CCFM science program will vigorously pursue investigation of the observed broad plasma scrape off layers (SOL), and of the reversed plasma flows seen in the TdeV divertor region. Equally, there will be exploitation and study of the LHCD system to provide relevant divertor studies. The LHCD injected power will increase particle density and temperature in the SOL plasma.
- A higher priority will be given to testing of high-Z divertor plates, since TdeV divertors have shown good retention of metallic impurities, and because the use of metallic divertor plates could simplify fusion power reactor design.
- Study of tokamak fuelling by compact toroid injection will continue.
- The design and exploitation of an innovative divertor design should be the special purpose of the TdeV-M upgrade. Design of the new divertor is to be accorded high priority, using research results from the 1994 TdeV research program.
- In view of additional power injected into TdeV by the LHCD system, attention will be paid to studying distribution of power deposition on tokamak components, and on mitigating possible deposition of power on divertor coils.

Committee Comments

Knowledge of electrical plasma biasing and scrape off layer properties at CCFM, said the Committee, has advanced to the level where it must form the basis for design of an advanced divertor for the envisioned TdeV-M machine upgrade.

The Committee "was most favourably impressed" with the development of the lower hybrid current drive system, including design and choice of the Glidcop material for the antenna, allowing very high antenna power levels. The well instrumented antenna will contribute to understanding of how LHCD energy couples with plasmas.

In overall assessment of CCFM's work, the Committee felt that CCFM and its programs are well managed both technically and scientifically, and the leadership is to be commended. In presenting results of the Advisory Committee review to CCFM's Board of Directors, Dr. Larkin Kerwin, Advisory Committee Chair concluded that, "CCFM is a vigorous, fruitful and successful project which must continue to show innovative determination in meeting difficult challenges".

CCFM - ADVISORY COMMITTEE

Chair:

Dr. Larkin Kerwin, *Consultant*

Members:

Dr. Charles Daughney (Secretary), *National Fusion Program.*

Dr. Paul Gierszewski, *CFFTP* (representing Dr. D. Dautovich).

Dr. Akira Hirose, *University of Saskatchewan.*

Dr. Ian Hutchinson, *Plasma Fusion Centre, MIT, USA.*

Dr. William Rowan, *University of Texas, USA.*

Dr. Franz Söldner, *JET Joint Undertaking, EC.*

Dr. Jörg Winter, *Institut für Plasmaphysik, KFA, Germany.*

Dr. Jan Hugill, *AEA-Research, Culham, UK* (absent).

Dr. Kerwin was president of the Canadian Space Agency until 1992, and before that was President of the National Research Council of Canada.

Further information from Charles Daughney, National Fusion Program, or from Brian Gregory or Réal Décoste of CCFM (See Contact Data).

6+ MW from TFTR

On behalf of Canadian fusion workers, the National Fusion Program wishes to congratulate the staff of Princeton Plasma Physics Laboratory on attaining a fusion power output of more than 6 megawatts from the TFTR tokamak, during the DT fuelling experiments in December 1993. Canadian researchers look forward with interest to the results of the alpha particle behaviour studies on TFTR.

visions for a medium-large tokamak to be added at some future date.

Korea Advanced Institute of Science and Technology (KAIST)

KAIST, also located in Daedeok Science Town, is an independent high level research institute with a department devoted to fission and fusion engineering and research. Like the other Korean sites interested in fusion, it gives high priority to education of scientists and engineers. KAIST conducts basic and applied research, and provides research and assistance services to industry, professional organizations other research organizations. KAIST research results are public records. Prof. Chang Hong-Young and Prof. Choi Duk-In, of the Department of Physics, lead the KAIST fusion research and training program. Experimental work centres on the KAIST-T tokamak acquired from University of Texas, where it was originally built as the PRETEXT tokamak. In addition to the training work, research interests include the physics of tokamak plasma startup, plasma-wall interaction and materials studies, and diagnostic apparatus and diagnostic technique development. KAIST-T has active plasma position control and gas injection, and employs plasma wall coating. Prof. Chang is also a former student of Prof. Chung Kie-Hyung of Seoul National University.

FUSION SITES IN KOREA -- CONTACT DATA

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CCFM Program Directions

Advisory Committee review: electrically biassed divertor research on TdeV tokamak to remain chief program priority for CCFM

The annual review of CCFM's research programs by the CCFM international Advisory Committee is an important event at the site, contributing toward setting research goals and priorities for the next year and the years ahead. The Committee met again in late October 1993 to make comments and recommendations concerning optimum exploitation of the TdeV tokamak, and to review research results obtained to date.

The Committee endorsed CCFM's emphasis on research into the science and operation of biased tokamak divertors, and on improving understanding of the behaviour of the plasma edge, also called the scrape off layer. This emphasis should not change, the Committee agreed.

Overall, the Advisory Committee endorsed the existing research plans of CCFM, the salient points of which are mentioned below. After reviewing these plans and hearing news of progress at CCFM in the last year, the Committee's recommendations to CCFM were aimed at arriving at a modest rebalancing of program priorities to optimize research output and maintain its relevance to current world fusion research.

The dialogue between CCFM staff and the Advisory Committee at the October meeting included discussions on the planned continuous upgrade of TdeV over the next few years, intended to culminate in the in world fusion projects. The Committee's opinion was that remote handling should remain a high priority in Canadian fusion work, with Spar taking the lead role. CFFTP could continue assisting Spar by promoting liaison between Canadian industry and international fusion projects, and by entering into CFFTP-Spar joint fusion projects in remote handling.

Other Areas

Materials. This work includes ceramic breeder development and hydrogen behaviour in beryllium and graphites. While still important to CFFTP, support for materials research could be reduced.

Plasma technology. This area includes some basic plasma behaviour work. Support for Compact Toroid tokamak fuelling technology should continue, in view of the potential for far-reaching results.

Gas Separation. CFFTP will continue increasing its expertise in extraction of hydrogen from helium.

CFFTP has made remarkable contributions to fusion, the Committee said, especially in view of the modest project funding. The Committee emphasized that the suggested rebalancing of priorities in no way detracts from CFFTP's achievements.

CFFTP - ADVISORY COMMITTEE

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Natural Resources Canada.

Members:
J. Anderson,
Princeton Plasma Physics Laboratory.

R. Bolton, *CCFM.*

A. Harms,
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G. Phillips (Secretary),
National Fusion Program.

J.-P. Rager,
Commission of the European Communities.

S. Shimamoto,
Japan Atomic Energy Research Institute.

Further information from Gil Phillips, National Fusion Program (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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