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TRITIUM SUPPLY

Tritium Supply for Japanese Fusion Research

Ontario Hydro International, Inc. (OHII) has contracted with the Japan Atomic Energy Research Institute (JAERI) to supply Canadian tritium for fusion energy research in Japan. The tritium is to be used at Tritium Process Laboratory, in the JAERI Tokai Establishment, near Tokyo. The tritium will be used for studying the technology of tritium processing in the fusion fuel cycle, and in developing tritium safety systems, such as containment and removal systems for large-scale tritium handling.

Under the supply agreement, JAERI may take delivery of up to 60 grams of tritium over a four year period ending by 1999.

The tritium will come from Ontario Hydro's Tritium Removal facility at Darlington, where Ontario Hydro routinely extracts tritium from heavy water removed from the moderator and heat transport systems of its Candu nuclear power reactors. JAERI has designed and manufactured a tritium transportation package specifically for shipments of Canadian tritium to Japan. The tritium will be shipped as a metal tritide, formed by adsorption of gaseous tritium on a metal getter bed in the shipping package. The shipping containers will be filled and prepared for shipment at AECL Chalk River, where there are special facilities for preparing international shipments. After shipment, gaseous tritium is regenerated by heating the getter bed.

As in other export agreements for supply of Canadian tritium for fusion research, the JAERI-OHII agreement provides for tritium accounting and record-keeping, and for review of the facilities where the tritium is to be used. The agreement also provides for regulation of the shipping process and the tritium's subsequent destinations after JAERI takes delivery. The agreement complies with the requirements of the Atomic Energy Control Board of Canada governing the end use of tritium exported from Canada. To establish bilateral agreement to meet these obligations, a diplomatic protocol between the governments of Japan and Canada was executed.

TRITIUM SAFETY AND TECHNOLOGY

1995 Tritium Conference

Three Tritium Workshops Proposed

Evaluation of submitted abstracts was completed in October for the ***5th Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications,*** to be held in Italy at Belgirate, on Lake Maggiore, May 28-June 05, 1995. About 220 abstracts have been accepted for the conference, promising a lively meeting, according to Joan Miller (AECL) and John Quelch (Ontario Hydro), who helped evaluate the abstracts as members of the Meeting's technical program committee.

Three tritium workshops, on safety and technology, are being proposed by Canadian workers, to be held at the Lake Maggiore Tritium meeting. The three workshops are proposed to further internationally-shared research in programs conducted under the auspices of the International Energy Agency (IEA).

Please contact the persons named below for information, to express interest in the workshops, or to suggest workshop topics.

Tritium in the Environment. Phil Davis, of AECL, proposes

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TRITIUM SAFETY AND TECHNOLOGY

1995 Tritium Conference *continued*

this workshop to discuss ideas for future internationally-shared environmental tritium work, including field studies and validation of environmental models. Results from the organically-bound-tritium intercomparison exercise, carried out using samples from the 1994 tritium release test, will be presented. Dr. Davis organized the 1994 tritium release test, conducted in August at AECL Chalk River with participants from four countries *(see separate article in this issue of FusionCanada).*

Tritium Dosimetry. Richard Richardson is leader of the internal dosimetry team at AECL Chalk River. He is proposing a workshop for identifying international collaborative work relating to better understanding of uptakes of tritiated species including water, particulates and organics. Dr. Richardson's dosimetry work includes improving human dosimetry models for evaluating tritium uptakes, and dosimetry of inhaled tritiated particulates such as metal hydrides.

Tritium Processing. Walter Shmayda, of Ontario Hydro Technologies, proposes a workshop to discuss three topics: to summarize the *status quo* in selected tritium handling and processing topics; to discuss the need for generic R&D in support of facilities and devices using tritium; to identify tritium-using facilities with common interests. R&D thrusts which address tritium issues in addition to ITER-driven technological goals, and which look beyond ITER, will be discussed.

The *Tritium in the Environment* and *Tritium Dosimetry* workshops are connected with the IEA program *"Environmental, Safety and Economic Aspects of Fusion Power"*. The *Tritium Processing* workshop is connected with the IEA program *"Nuclear Technology of Fusion Reactors"*.

To enquire about the workshops:
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INTERNATIONAL

Canada to Host 1996 IAEA Fusion Conference

October 6 - 12, 1996, Montréal

16th International Conference on Plasma Physics and Controlled Thermonuclear Fusion Research

In 1996, Canada will host the ***16th International Conference on Plasma Physics and Controlled Thermonuclear Fusion Research.*** The IAEA (International Atomic Energy Agency) organizes this fusion Conference every two years, and holds it in the country of an IAEA member state.

The 1996 Conference will be held in Montréal, October 6 - 12, at a site in the city centre.

The conference is being held under the auspices of Canada's National Fusion Program, with support from Centre canadien de fusion magnétique (CCFM), the Canadian Fusion Fuels Technology Project (CFFTP) and other Canadian agencies with an interest in thermonuclear fusion.

As normal for these IAEA fusion conferences, the scientific and technical programs and the conference arrangements will be coordinated by the IAEA in Vienna. Visits to technical sites including CCFM and the TdeV tokamak will be offered to delegates.

The 15th IAEA fusion conference was held this year in Seville, Spain, September 25-October 01. The IAEA's International Fusion Research Council (IFRC) met at this conference. At the IFRC meeting, the recommendation was made that Canada should host the 1996 conference, the 16th of its kind. The IFRC is the scientific coordinating body for IAEA-sponsored fusion R&D programs and activities.

CCFM-Centre canadien de fusion magnétique

CCFM/TdeV Update

On the TdeV tokamak, a five month experimental campaign, emphasizing radiofrequency lower hybrid power injection, was concluded in mid-November. After a brief maintenance shut-down, TdeV has just begun a new three month campaign.

Much of the autumn campaign featured simultaneous electrical plasma biasing and lower hybrid power injection at higher plasma densities. The program involved detailed, systematic exploration of tokamak and divertor behaviour under these complex conditions. The maximum toroidal magnetic field on TdeV has been increased to 1.9 Tesla, from a

FUSION MATERIALS

Erosion Studies on Plasma Facing Materials

University of Toronto Institute for Aerospace Studies (UTIAS)

- High temperature erosion studies on a range of metal-doped graphites are nearing completion at UTIAS.
- Erosion by low energy hydrogen particles (~100 eV and less, for H, D, T) is now being studied for beryllium and carbon.

Doped graphites. The erosion resistance of graphite exposed to plasma is modified if the graphite is doped with metal atoms. The reasons are imperfectly understood, but this potentially useful behaviour is being studied at UTIAS. At temperatures up to 1,800 K, under hydrogen species bombardment (hydrogen and deuterium) and molecular oxygen exposure, the erosion resistance of six metal-doped graphite varieties is being measured. Graphites doped with boron, silicon, titanium, aluminum, nickel and tungsten, with dopant concentrations up to ~20% atomic dopant/carbon ratio, were made in Ontario by Ceramics Kingston for testing at UTIAS. Measurements of resistance to chemical erosion (dominant in the 600-900 K temperature range) and radiation-enhanced sublimation (dominant above 1,300 K) have been made. Thermal conductivities were measured up to about 1,000 K. UTIAS is now completing the doped graphite study by measuring hydrogen retention of the samples over wide temperature ranges.

This work is part of Canada's contribution to the ITER EDA 1994 tasks ***T59*** (concerning hydrogen retention and re-emission for plasma facing materials) and ***T62*** (concerning plasma compatibility of materials, particularly erosion by hydrogen species and oxygen).

Low energy particle erosion. This UTIAS work is relevant to the design of 'detached-plasma, radiatively cooled divertors', a concept gaining recognition in fusion reactor design. In fusion reactor service, such divertors should run cooler than earlier divertor concepts because the 'detached' plasma does not fully contact the divertor's plasma facing surfaces. Consequently, the bulk of plasma particles (mostly hydrogen isotopes) impacting on the detached-plasma divertor surfaces will have fairly low energies, in the 10's of eV. Unfortunately, there is little data available about material erosion by such low energy particles. This UTIAS work sets out to provide that data, so that material erosion in detached-plasma divertors can be better predicted. Beryllium and carbon are being exposed to low energy hydrogen species, including tritium, in a program expected to occupy most of 1995. Principally, the program will study chemical erosion of carbon, and sputtering of beryllium under the impact of hydrogen, deuterium, and tritium ions in the energy range 25 eV - 100 eV (corresponding to plasma temperatures of 5 - 20 eV).

Both of these materials research efforts are supported by the Canadian Fusion Fuels Technology Project (CFFTP) as part of its fusion materials R&D program.

More Information: Prof. Tony Haasz, University of Toronto Institute for Aerospace Studies. (416) 667-7734, Fax (416) 667-7799, or Paul Gierszewski, CFFTP, (905) 855-4717, Fax (905) 823-8020.

DIVERTORS

Tokamak Divertor and Edge Plasma Studies

University of Toronto Institute for Aerospace Studies (UTIAS)

- The divertor behaviour of the Alcator CMOD tokamak will be studied in 1995 at UTIAS using the Toronto DIVIMP code, designed by Prof. Peter Stangeby of UTIAS. DIVIMP is an interpretive code which uses experimental observations of plasma impurities in a tokamak divertor, and specific machine parameters, to yield information on the production and transport of impurities in the tokamak plasma, particularly in the divertor region.
- The divertors of JET (Joint European Torus, UK) and the ASDEX-Upgrade tokamak (Garching, Germany) are currently being studied with DIVIMP. The JET work has been going on for several years.
- UTIAS is developing a *predictive* version of DIVIMP, for predicting the divertor performance of the ITER reactor and other next-step machines. Staff at the TEXTOR tokamak (Jülich, Germany) are collaborators in this.

Understanding plasma impurity production and transport is crucial to designing successful divertors and for controlling the nostics were especially useful in these studies.

- Rapid ramp-down of plasma current, 250 kA ⇒ 150 kA at B_T to 1.8 T, with high LH power, to explore characteristics of plasmas with higher internal inductance (that is, with a more peaked radial current density profile).
- Measured efficiency of lower hybrid plasma current drive under negative plasma biasing, at low plasma densities, as a function of n_e, I_p, and $N_{//}$.
- Explore plasma heating by LH RF power injection at moderate plasma densities, up to 4.0 x 10^{19} m^{-3}, with 1 MW LH power and B_T to 1.8 T.

A new, redesigned divertor will be installed on TdeV during an extended shut down beginning in April next year. Other planned TdeV modifications include installing new equilibrium field power supplies, modifications to the LH multijunction antenna, and an upgrade of the tokamak control system.

More information: Brian Gregory (Scientific Director) or Réal Décoste (Operations Director). See Contact Data.

GUENTHER PACHER

Guenther Pacher returns to Canada

After five years at Europe's Garching site, fusion scientist Guenther Pacher returned to Canada in October to work on the TdeV tokamak at Centre canadien de fusion magnétique (CCFM). Part of Dr. Pacher's work at CCFM involves examining future operating scenarios for TdeV.

At Garching, Dr. Pacher was a member of The NET Team, which forms the core of Europe's ITER Home Team. His contributions to NET/ITER included ITER optimization studies for major parameters such as the reactor's major radius and plasma shape. His other contributions include work on ITER's divertor physics and plasma ramp-up scenarios. He also provided the physics input to Europe's study of the *Safety and Environmental Aspects of Fusion Power* (SEAFP), which is now complete.

To contact Guenther Pacher: e-mail: = pacherg@toka.ireq-ccfm.hydro.qc.ca. Telephone (514) 652-8882. Fax (514) 652-8625.

TRITIUM IN THE ENVIRONMENT

Tritium Field Release Experiment in Canada

Chalk River Laboratories

The 1994 Tritium Field Release Experiment took place over 12 days, July 27 - August 8, 1994 at AECL's Chalk River Laboratories in Ontario. The main purpose of the test was to obtain information on the steady-state concentrations of tritiated water vapour (HTO) in air, soil and vegetation, arising from the oxidation of HT in soil. Other goals of the test included studying the dynamics of the approach to steady state HTO conditions, and the buildup rates of organically bound tritium in vegetation. Information from the test will be used in environmental modelling of tritium behaviour.

Observers and participants were present from Japan, Germany, the USA and Canada. Phil Davis of AECL, coordinator of the field test, will formally present its results at the Lake Maggiore tritium conference in June 1995. He is coordinating analysis of the test's measurement and sampling data by the four countries that took part. Intensive sampling of air, soil, and vegetation was done continually during the test.

Over the test's 12 day span, 300 Curies of elemental tritium (HT) were released continuously at a steady rate over a prepared 'field', 10 m x 10 m, planted with tomatoes, radishes and a leafy green vegetable, and containing some old, wild local vegetation. Average HT concentration near the ground was about 2.5 x 10^5 $Bq.m^{-3}$ during the test period.

Preliminary Assessment

It was found that HTO concentrations built up over time and achieved equilibrium by the end of the study. HTO concentrations in air and in soil decreased rapidly with distance from the surface of the soil. HTO concentration in air moisture 20 cm above the soil surface was similar to that in water in the plants, and both were much less than HTO concentration in water in the top 2 cm of soil. Average HTO-in-air concentration at 20 cm height above the old vegetation was about 6 x 10^3 $Bq.m^{-3}$ in the last days, with the HTO/HT ratio being about 0.02 when averaged over the study's last 8 days.

More information from Phil Davis, AECL, (613) 584-3311 ext. 3294, Fax (613) 584-1221.

previous maximum of 1.5 Tesla. Because of excellent plasma chamber wall conditioning produced by the new boronization system, plasma density on TdeV can now routinely be obtained up to 8 x 10^{19} m^{-3}, a density relevant to next-step fusion reactors and useful for studying radiating-plasma divertors.

Recent TdeV Results

The 3.7 GHz lower hybrid wave radiofrequency injection (LH) system has shown excellent performance, and behaves just as designed. It drives the full TdeV plasma current of 200 kA at lower plasma electron densities, around 2 x 10^{19} m^{-3}. Plasma duration has been increased from one second to about four seconds by using the LH system, with little assistance from the inductive ohmic system.

Maximum radiofrequency power coupled into the plasma has easily reached 900 kW, producing a power density in the plasma chamber well in excess of 1 MW. m^{-3}. At these power levels, radiofrequency power flux at the LH antenna grill mouth has routinely been at record levels around 4.2 kW.cm^{-2}.

The LH system was designed to drive full plasma current on TdeV for 30 second plasma pulses, and appears capable of doing so, although several cooling systems would need to be upgraded before this was attempted. As expected, lower hybrid waves launched with the present antenna do not penetrate the plasma well at densities greater than 4.5 x 10^{19} m^{-3}. It is well understood that LH penetration at higher tokamak plasma densities becomes difficult at toroidal magnetic fields in the range $\leq$ 2 Tesla, where TdeV operates. LH current drive efficiency also decreases linearly with increasing plasma density, as expected.

An unexpected difficulty is the short antenna-separatrix gap required to maintain good coupling of the LH waves to the plasma. The GLIDCOP copper-alumina material used for the 3.7 GHz antenna grill exhibits low material outgassing rates, favouring the record high power fluxes achieved without arcing inside the grill mouth. However, the high power fluxes lead to low plasma densities in front of the grill, and these low densities diminish LH coupling. To compensate for this, the antenna grill must be moved closer to the plasma separatrix, resulting in high heat loads on the grill mouth.

H-mode plasmas have not been achieved so far on TdeV with auxiliary heating by the LH system, even though the required power threshold for H-mode has been well exceeded in experiments. Several reasons for this are being considered. One reason may be that the magnetic geometry of TdeV is inadequate at the high plasma betas obtained with auxiliary heating.

Possible Changes to TdeV

The experimental objectives of CCFM change with advancing knowledge, and CCFM is inclined to believe now that a more ITER-relevant scientific yield can be obtained from TdeV by concentrating on higher density plasmas and radiative divertors, with tokamak pulse lengths in the 5 - 10 second range. A second source of auxiliary plasma heating may well be needed for such a program, as would an upgraded magnetic geometry, and a divertor more capable of withstanding higher heat loads. Significant TdeV upgrades are planned for 1995 to improve the divertor and the magnetic geometry.

Recent detailed studies with TdeV

These are some of the themes in which detailed studies have been performed in the recent TdeV experimental campaign.

- Extended studies of helium removal from the plasma, via the pumped biased divertors, were done at lower plasma densities, with LH power injection. Helium pumping out of the plasma is very effective with auxiliary heating and biasing.
- Accessibility of lower hybrid (LH) waves into the TdeV plasma under these conditions: Plasma density n_e range 2.0 - 6.0 x 10^{19} m^{-3}; Toroidal magnetic field B_T range 1.5 - 1.9 Tesla; Plasma current I_p up to 250 kA; Lower hybrid $N_{//}$ range 3.0 - 3.3.
- Extensive studies of the transport and confinement of suprathermal (high energy) electrons, with energies up to about 100 keV, which originate from LH injection. Studies were made with and without electric plasma biasing.
- Modification of plasma current radial profile by LH RF injection has been studied as a function of plasma current and plasma electron density. At low plasma current, with normally peaked radial profiles, LH injection broadens the profile. At higher plasma currents, with relatively broad profiles, LH injection produces a slightly more peaked current profile. The laser polarimeter and 2-D X-ray tomography diag-

main plasma.

The DIVIMP code was developed specifically for **divertor impurity** studies. It was designed by Prof. Peter Stangeby of UTIAS, and has been developed at JET and in Toronto over several years. Prof. Stangeby spends several weeks each year at JET studying impurity transport and continuing DIVIMP development. JET staff use the code routinely to interpret JET results. JET funds DIVIMP development, as does the Canadian Fusion Fuels Technology Project.

DIVIMP is now used also at ASDEX-Upgrade (Max Planck Institute, Garching, Germany). Impurity measurements made on ASDEX, interpreted using DIVIMP, have indicated the critical role played by chemical sputtering. The latest chemical sputtering data from Garching are being incorporated into DIVIMP, as well as a model of methane (CH_4) breakup in the plasma.

Work on modelling the Alcator CMOD divertor results has already begun in Toronto. The work will intensify in 1995.

DIVIMP is being used to study 'detached' plasmas in divertors, a topic currently of great interest. With a detached plasma in a divertor, the temperature and density of the plasma in contact with the divertor target plate surfaces is reduced to very low values (about 5 eV temperature, and about $10^{19}.m^{-3}$ plasma density). Such detached divertor plasmas are the basis for the ITER design and are being studied on several tokamaks including JET, ASDEX-Upgrade and Alcator-CMOD. Detached plasmas may be due to the formation of a neutral "gas cushion" at the target plate surfaces, associated with local recycling of hydrogenic fuel particles.

More information from Prof. Peter Stangeby, UTIAS. Phone/fax (416) 667-7729. e-mail pcs@starfire.utias.utoronto.ca.

National Fusion Program

Director, *Dr. David P. Jackson*

The National Fusion Program (NFP) co-ordinates 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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