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CONTENTS

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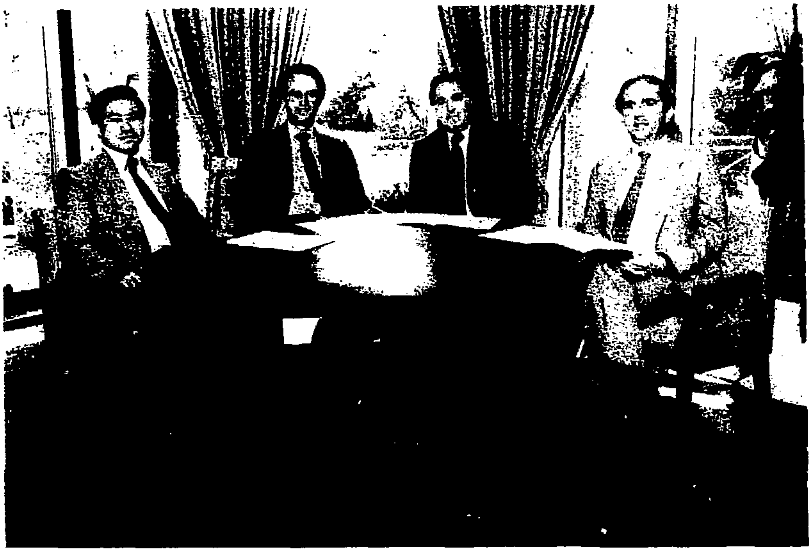
The Canadian Fusion Fuels Technology Project represents part of Canada's overall effort in fusion development. The focus for CFFTP is tritium and tritium technology. The project is funded by the Government of Canada, the Ontario Government and Ontario Hydro.

Funding (50%) by the Government of Canada is through the Department of Energy, Mines and Resources' Panel on Energy, Research and Development, managed by the National Research Council of Canada. Funding (25%) by the Government of Ontario is through the Ministry of Energy. Ontario Hydro also funds (25%) and manages the project through their Design and Development – Generation Division.



From right to left;
Program Manager – Tom Drolet; Manager, Technology Applications – Jack Richman; Manager, Technology Development – Don Dautovich; Manager, Technology Safety – Kam Wong

The Canadian Fusion Fuels Technology Project

CFFTP was launched in 1982 to coordinate Canada's provision of fusion fuels technology to international fusion power development programs. The project has a mandate to extend and adapt existing Canadian tritium technologies for use in international fusion power development programs.

1985-86 represents the fourth year of the first five-year term of the Canadian Fusion Fuels Technology Project (CFFTP). This reporting period coincides with an increasing trend in global fusion R&D to direct more effort towards the management of tritium.

This has resulted in an increased linking of CFFTP activities and objectives with those of facilities abroad. In this way there has been a continuing achievement resulting from CFFTP efforts to have cooperative R&D and service activities with organizations abroad. All of this is aided by the cooperative international atmosphere within the fusion community.

This report summarizes our past year and provides some highlights of the upcoming year 1986/87, which is the final year of the first five-year phase of the program. AECL (representing the Federal Government), the Minstry of Energy (representing Ontario) and Ontario Hydro, have given formal indication of their intent to continue with a second five-year program. Plans for the second phase will continue to emphasize tritium technology and remote handling.

It is my feeling that the second five-year phase will be even more exciting and challenging and will provide several opportunities for all individuals and organizations involved with the program.

T.S. Drolet
Program Manager
Canadian Fusion Fuels Technology Project

Accomplishments in 1985/86

In 1985/86, 60 R&D contracts were awarded for a total program expenditure of $4.9 million. Supplementary funding by subcontractors added another $1.1 million worth of effort. The R&D contracts were placed with industry, universities, AECL, and Ontario Hydro.

The Canadian Fusion Fuels Technology Project (CFFTP) arranged for just under $1 million worth of technical service contracts for Canadian industry funded by international programs. Staff assignments continued at JET[1] (remote handling and tritium safety) and NET (tritium technology).

Figures 1 and 2 indicate the CFFTP FY1985/86 expenditure and the distribution of contracts (dollar value) awarded by sector respectively.

Technical Highlights

Important technical highlights in 1985/86 included the following:

- Reference tritium flow sheet and system designs were developed for NET;
- Definition and assessment of tritium systems were performed for NET;
- Gas chromatography process for hydrogen isotope separation was improved;
- High-tritium-content irradiation tests to determine tritium behaviour in solid breeder material were conducted;
- Sintered pellet and microspheres of solid breeder were fabricated for Canadian and international test programs;
- A simple, conventional technology tritium breeding blanket concept was proposed for next-generation experiments such as NET or ETR;
- Techniques for measuring tritium profiles in near-surface regions were developed;
- A review of tritium permeation barrier approaches was carried out;
- The TFTR in-vessel manipulator conceptual design was completed;
- A family of tritium monitors was developed, covering a wide-range of capabilities needed for fusion;
- Dose effects of tritium uptake from metal surfaces was documented;
- The tritium safe handling course was attended by international audience;
- A one-day seminar for contractors and partners describing CFFTP research activities and discussing technology transfer in Canada was held.

Communication Highlights

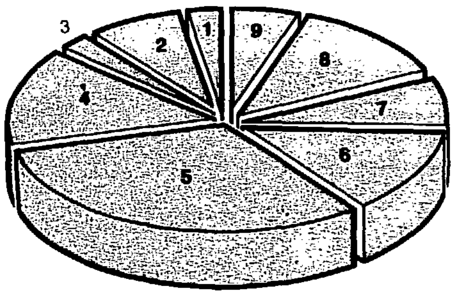
Two major educational initiatives were completed in 1985/86. A fusion teaching aid consisting of written materials and film strips was prepared for use by secondary schools. Fusion was established as part of the required core curriculum for secondary schools in the provinces of Ontario, British Columbia, Manitoba and Prince Edward Island. An earlier fusion educational booklet titled "Fusion Energy and Canada's Role" continues to be in popular demand.

Technical communication has continued in 1985/86 through the issue of 21 technical reports and the circulation of the CFFTP newsletter to more than 1500 recipients in 500 organizations in 18 countries.

A portable poster display unit was created to introduce fusion energy. This display has appeared at energy conferences, public information areas, and educational facilities.

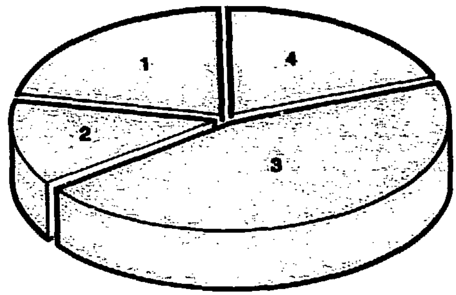
1. Refer to Appendix A for glossary of acronyms and abbreviations.

FIGURE 1
CFFTP-FY 1985/86 Costs

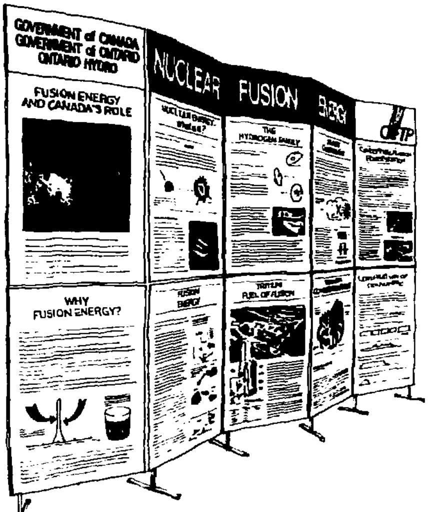


1	Administration	$ 141.799
2	Operations	$ 380.161
3	Technical Program Development	$ 113.267
4	Tritium	$ 754.543
5	Blanket	$ 1.556.323
6	Material	$ 646.216
7	Equipment	$ 402.973
8	Safety	$ 638.079
9	Net Technology Support	$ 271.552
	Total Project Cost	$ 4,904,913

FIGURE 2
Distribution of R&D Contracts Awarded (In FY 1985/86)



1	Industry	$ 891.355
2	Universities	$ 439.438
3	AECL	$ 1 736.503
4	Ontario Hydro	$ 754.710



Portable Poster Display

Status of International Fusion Programs

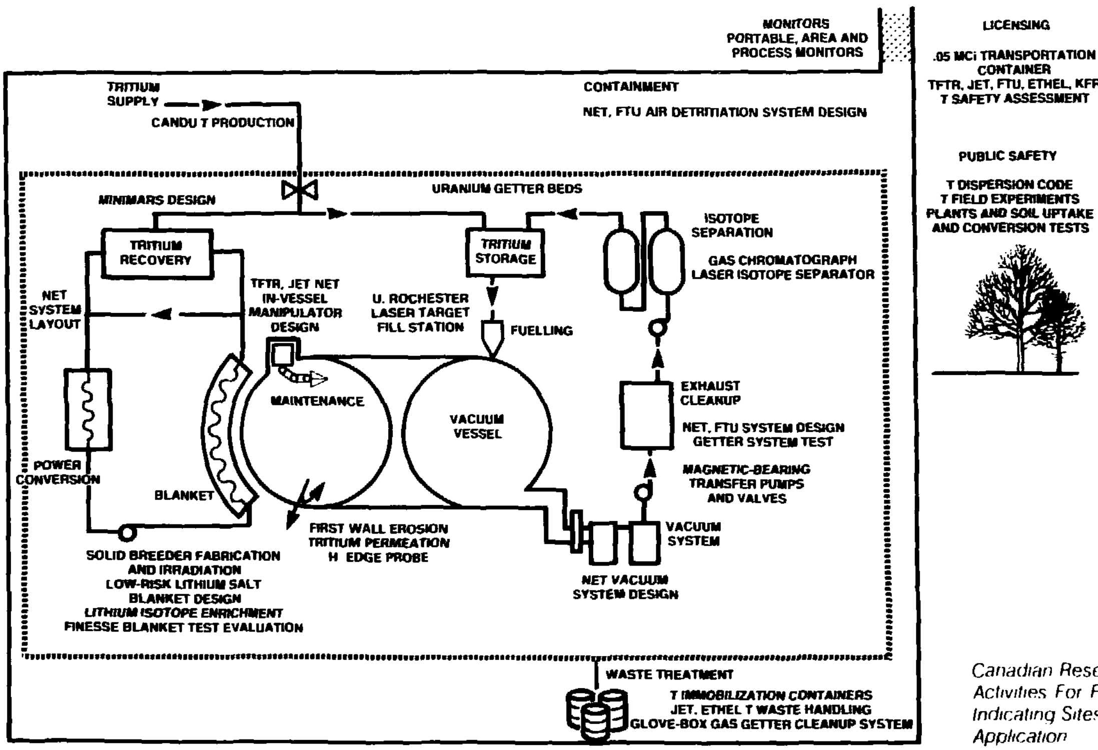
Confinement Experiments

JET and TFTR have largely completed their ohmic heating phase of operation. Both devices confirm the fundamental scaling of energy confinement time with density and machine size as found in many smaller devices. These devices are presently facing density limits (JET) and reduced energy confinement with auxiliary heating (TFTR). Resolution of these limits is important to achieving scientific breakeven. Both JET and TFTR are in the process of adding multi-megawatts of rf and neutral beam heating. JT-60 continues its ohmic testing phase from first plasma in early 1985.

The United States decided to focus its resources on toroidal devices, and is planning to shut down the mirror experimental programs, including TMX, MFTF-B, and TARA. Moderate-to-large experiments recently approved include ZT-H, a 2-4 MA reversed-field pinch at Los Alamos (U.S.), a small field-reversed configuration experiment at Spectra Technology (U.S.), and a helical concept at Nagoya University (Japan). Significant devices under construction include FRX, a 2-MA RFP at Padova (Italy); ATF, a stellarator at Oak Ridge (U.S.); TORE-SUPRA, a superconducting coil Tokamak at Cadarache (France); and T-15, the USSR equivalent of the TFTR, JET and JT-60.

In inertial confinement fusion, results accumulated over the past few years have established that laser wavelengths longer than about 0.5 microns have unacceptable coupling and electron preheating. Consequently, the ANTARES CO_2 laser (Los Alamos, 10 micron wavelength) has been shut down. However, frequency doubling and tripling of the 1 micron wavelength glass lasers at OMEGA (University of Rochester), NOVA (Livermore), and GEKKO-VII (Japan) has been successful. The AURORA 20-TW KrF laser (Los Alamos) is exploring this short-wavelength laser, with 10 kJ first shots in 1985. The light-ion driven PBFA-II experiment (Sandia) had its first shot at 70 per cent of design energy. This experiment will eventually deliver 3.5 MJ/100 TW onto a half-centimetre pellet. It is possible that PBFA-II will achieve ignition, although not energy breakeven.

Plans for next-generation devices continue, with the United States receiving moral support from Japan and Europe for an ignition experiment operating by 1992. The definition of FER (Japan) and NET (Europe) continued, with concern over tritium supply affecting fluence goals and blanket design. The Reagan-Gorbachev Initia-



Canadian Research and Development Activities For Fusion Fuelling Systems Indicating Sites of Actual and Potential Application tive has renewed hope for a four-party engineering test reactor, and discussions are underway regarding whether and how such a device could be designed and constructed. This device could be a version of NET or FER, although an early United States concept, TIBER from Livermore, proposes more aggressive physics in order to reduce the fusion power from 600 MW to 300 MW, and consequently reduce the tritium consumption rate.

Technology Experiments

A number of solid breeder fabrication and irradiation experiments are underway, exploring the wide variety of possible materials. The most significant are the 1986 *in-situ* tritium recovery tests, which include CRITIC (Canada), EXOTIC (Netherlands/Belgium/UK), LILA (France), LISA (Germany), and VOM (Japan). The BEATRIX/FUBR-1B experiment in late 1986 will have a large matrix of internationally fabricated materials placed in closed capsules and irradiated for two years (up to several per cent lithium atom burnup) in the United States EBR-II fast reactor. Liquid metal blankets have enjoyed renewed popularity in recent design studies. Europe has active lithium and lithium-lead corrosion loops, and is starting experiments aimed at the critical tritium recovery issue with lithium-lead. The United States continues to view self-cooled liquid metal blankets as more attractive than separately-cooled blankets and is addressing MHD issues in a single-channel facility at Argonne.

TSTA had commissioned the isotope separation and some auxiliary systems with tritium in 1984. More recently, the plasma exhaust system was 'hot' commissioned. The JAERI Tritium Processing Laboratory (2-3 g) was completed, although tritium operation will not begin until 1987. The tritium lab at KfK (10-200 g) is in the engineering design stage, and JRC-ISPRA has contracted out for the development of tritium lab proposals, with engineering design to commence in 1986.

In neutronics, the 1986 United States-JAERI research program at the FNS facility (Japan) will incorporate a lithium-based reflector around the blanket mockup in order to better simulate the fusion environment. Tests with Li_2O are planned to try to resolve data and modelling uncertainties enough to determine whether Li_2O can provide adequate tritium breeding without a multiplier.

The Large Coil Test Facility at Oak Ridge has all six international superconducting magnets installed. Evaluation of the magnets at up to 8 T field strength is underway.

Materials Experiments

The United States has focussed on ferritic steels and vanadium alloys for commercial reactors, with secondary emphasis on austenitic steels and copper alloys. Europe and Japan, with their near-term NET/FER focus, continue to emphasize modified austenitic steels. Recent United States fission irradiation data extend to 120 dpa for ferritic steel, 80 dpa for austenitic steel, and 60 dpa for the vanadium alloy. The steel data are consistent with the anticipated design life of about 200 dpa (15-20 MW-yr/m^2) and 120 dpa for the ferritic and austenitic steels, respectively. Radiation-embrittlement appears to be a significant problem for the present United States reference vanadium alloys, although not for others such as V-Ti alloys. Corrosion experiments indicate that vanadium alloys are reasonably compatible with lithium and lithium-lead, and in contrast to earlier predictions, compatible with reactor-grade helium at high temperatures.

Budgets

General fusion spending is comparable among the United States, Europe and Japan (and presumably USSR, although there is no reliable measure). Budgets are anticipated to be roughly constant over the next few years at about $300-400 million United States equivalent. The United States budget is decreasing somewhat under the present deficit-cutting mood in Congress, while Europe's and Japan's budgets are increasing slightly in support of their NET and FER devices. Most of the funds are directed towards physics experiments, particularly (about 75 per cent) TFTR, JET and JT-60.

Agreements

Canada-Japan

Canada and Japan have signed a memorandum of understanding linking the programs of the two countries in the areas of fusion physics and in development of fusion fuel technologies. The agreement facilitates the exchange of expert staff, to share scientific and engineering information, and to participate in some aspects of each others' programs. In 1985/86, progress was made in establishing the detailed nature of collaboration.

Canada-Europe (EEC)

A memorandum of understanding between Canada and the Commission of European Communities has been signed. This agreement provides for cooperation in the field of fusion research and development and includes plasma physics, remote manipulators, fusion fuels, safety and environment, plus high power electro-technology.

A memorandum of understanding expressing interest to collaborate was signed by the Junta de Energie Nuclear for Spain and CFFTP with endorsement by NRCC. The memo will lead to mutual review of programs and supportive activities.

Canada-United States

An agreement with the United States is currently under negotiation. The agreement is intended to cover all aspects of fusion programs.

CFFTP Outlook for 1986/87

Plans for the second phase program (1987/92) continue to emphasize tritium technology and remote handling. There will continue to be a strong involvement by universities and industry with significant transfer of technology to industry. Details of the program will be worked out between the partners during 1986/87.

For 1986/87 programs will be designed to meet objectives established in the previous years. They can be summarized as follows:

- Provide close technical support in the development of fusion fuels related technology and data required for tritium burning fusion devices in the next five years;
- Undertake longer term development for second generation machines (NET, U.S. "ignition device") which will require significant advances in technology;
- Contribute to the overall advancement of fusion energy development by addressing generic critical tritium issues such as tritium-material interactions, safety and environmental areas, and by

participating in conceptual reactor design studies.

Within the program plan, the following activities will be highlighted:

- Continued efforts will be made to secure opportunity for Canadian industrial participation in fusion projects, in providing engineering services and hardware in fusion fuels technology and remote handling areas;
- Continued efforts will be undertaken to secure strategic opportunities and staff for assignment to foreign projects. This will provide training, develop opportunities for Canadian technology and promote Canadian capability.

TABLE 1
CFFTP OPERATIONAL SUMMARY FOR FY85/86

Item	FY 85/86 Budget	ACTUAL FY 85/86 Program Cost (Cash Basis)	Supplementary Funding[1]
Administration	211,000	141,799	–
Operations	288,975	380,161	–
Technical Program			
Development	115,000	113,267	100,000
Tritium	789,246	754,543	162,950
Blanket	1,289,246	1,556,323	386,000
Materials	539,246	646,216	204,740
Equipment	459,246	402,973	–
Safety	619,248	638,079	261,900
Technology Cost		946,612	
Technology Revenue		(675,060)	
Net Technology Support	185,000	271,552	
Total Project Cost FY 85/86	**4,496,207**	**4,904,913**	**1,115,590**

Notes:
1. Supplementary funding refers to funds contributed by contractors.

Steering Committee of CFFTP

The Steering Committee oversees the Project and represents the interests of the funding partners. It approves the Annual Project Management Plan and Budget, and the Annual Report. Representation is proportional to funding with two members representing the federal government and one member each representing the Ontario provincial government and Ontario Hydro. The Steering Committee members and their alternates are listed below with their affiliations:

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CFFTP Steering Committee and Project Staff - clockwise from bottom left. T.S. Drolet, H.S. Irvine, T.S. Brown, E.P. Cockshutt, W.G. Morison, G.J. Phillips, N.D. Markettos, K.Y. Wong, H.K. Rae, D.P. Jackson, J.W. Richman, D.P. Dautovich

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Advisory Committee

The Advisory Committee is an appointed body assembled to advise the Project through the Steering Committee and Project Manager on objectives, directions and technical activities. It has representatives from the European, United States and Japanese programs as well as four Canadian members representing the various technical resource sectors of the CFFTP. The members and their affiliations are as follows:

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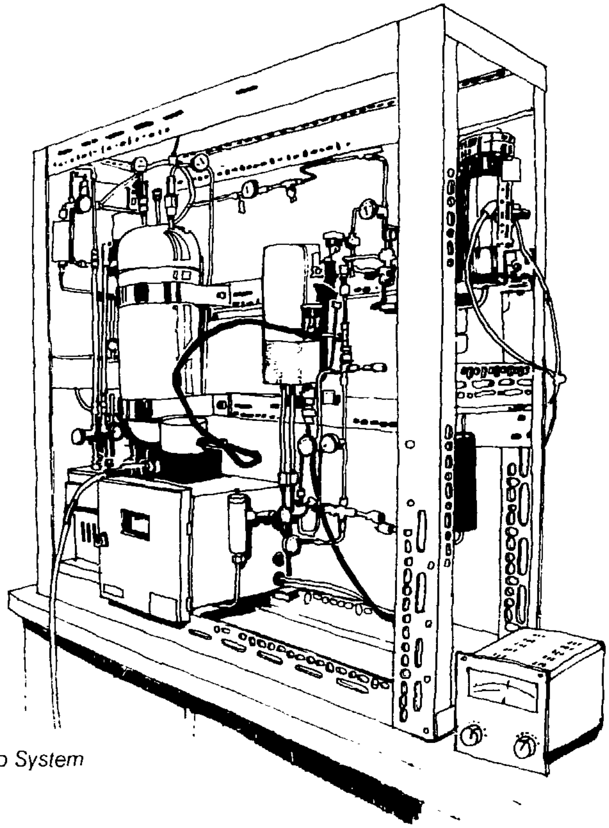
* Effective July 1, 1986, T.S. Drolet accepted a position with New Business Ventures Division, Ontario Hydro. D.P. Dautovich succeeds him as Program Manager CFFTP.

Objectives and Priorities

The objectives of the tritium technology program are to apply existing tritium technology to near-term international fusion programs, and to develop new and innovative processes for tritium management for the next-generation of industrial scale applications. Critical issues include reduced inventory, improved reliability and efficiency, lower cost, and increased safety.

The program priorities include tritium storage and management, plasma fuelling and exhaust purification, isotope separation for process streams such as coolant detritiation, recovery of tritium from breeding blankets, recovery of tritium from building (air) and secondary containment envelopes (inert gas), and extraction and disposal of radioactive wastes.



Fuel Clean-up System
AECL-CRNL

Accomplishments

Reference Tritium Systems Flowsheet Development for Fusion Devices

A reference tritium flowsheet was developed for NET. System selection was made considering NET to be a near-term physics and engineering test facility having relatively low availability requirement (10-25 per cent), with an emphasis on reliable and more conventional processes.

For the longer-term, MINIMARS is a conceptual 600 MWe tandem mirror power generating device, with high capability factor (75 per cent). The tritium extraction methods for various tritium production blankets were selected and costed. The entire reference design concept of the tritium systems has been completed. This work was done in conjunction with the Lawrence Livermore National Laboratory and will be published late in 1986.

Both studies were undertaken by a team from Ontario Hydro (Design and Development), Atomic Energy of Canada Limited (Chalk River Nuclear Laboratories) and CFFTP and made a major impact on tritium systems design.

Process and/or Equipment Development Studies

- A conceptual design study for a hydrogen isotope separation system, with a corresponding storage and delivery system was undertaken for a European client. A unique solution to the problem of maintaining pure HT, DT and HD species was conceptually developed, based on gas chromatography, and a patent has been applied for.
- A mathematical model for an air detritiation system study was produced at CRNL. The model predicts initial HT reduction factors which are in good agreement with the observations at Sandia Laboratories with a similar system.

Gas Chromatography Isotope Separation Process Development

The development of a small, low inventory isotope separation process based on gas chromatography was undertaken through various laboratory experiments aimed at producing scale-up factors for diameter, column length, optimum temperatures, and sample sizes. The main objective was to maximize the throughput and separation of the isotope species. A throughput of 1.7 L/hr was achieved with acceptable separation in a very small, low inventory unit. A gas chromatography system also successfully completed six component separation and initial scale-up tests with a near industrial scale unit. The research was undertaken by Ontario Hydro.

Reactor Exhaust Cleanup

A fusion fuels cleanup system, based on uranium gettering, was built and successfully tested with hydrogen earlier in the year at the CRNL tritium laboratory. The work demonstrated that a simple metal getter process can effectively clean fusion fuels. Future operation with tritium is now planned.

Glovebox Detritiation System

A test facility built by OHRD and installed at TSTA has operated successfully since May 1985. Detritiation tests were carried out for two flow rates: 0.35 L/min and 0.6 L/min and for tritium concentrations ranging from 10 to 1000 mCi/m^3. Typically, an order of magnitude reduction in the tritium concentration can be achieved within 10 minutes.

Outlook for 1986/87

The focus of R&D work in the year 1986-87 will be in the following areas:

- Tritium extraction from air without conversion to the oxide form;
- Getter-based glove box cleanup systems;
- Tritium extraction from helium;
- Gas chromatographic isotope separation;
- Laser based isotope separation;
- Canadian Tritium Laboratory capability development;
- Completion and update of existing reference tritium systems studies; and
- Start of work on a new study: TITAN-RFP.

Objectives and Priorities

The fusion blanket surrounds the burning hydrogen core of the fusion reactor. It is in this blanket where most of the energy released by the DT fusion reaction is converted into useful product, and where tritium fuel is produced to enable further operation of the reactor. Energy removal and tritium production will be needed in the next generation of fusion devices in the late 1990's, and certainly for subsequent devices.

However, the technology involves new materials, conditions and processes, and is in a very early stage of development. Since the blanket is an important part of the fusion fuel cycle, and since blanket research may lead to other useful technological capabilities, CFFTP has established a fusion blanket technology research program. The objectives of this program are to understand tritium transport and recovery in blanket systems, and to develop applications of blanket technology based on tritium and other relevant expertise.

Accomplishments

The fusion blanket program includes a variety of tasks. The largest part of the effort was located at, and co-funded by, AECL-CRNL. Other participants included Grumman Aerospace, Rensselaer Polytechnic Institute, AECL-WNRE and AECL-CANDU Operations. The work has been presented in 10 reports, 3 journal articles and 16 conference papers.

A major emphasis has been to utilize Canadian ceramic expertise and irradiation test facilities in order to fabricate, characterize and irradiate candidate solid breeder materials. CFFTP/CRNL are participating in the International BEATRIX program, in which breeder specimens are exchanged among Europe, Canada, Japan and the United States for comparative testing in various fission reactors.

Irradiation Tests

Six solid breeder static capsule (CREATE series) irradiations were completed at CRNL, including $LiAlO_2$ fabricated by ANL (US), $LiAlO_2$ fabricated by CEA-Saclay (France) and Li_2O fabricated by JAERI (Japan). Post-irradiation testing has indicated the influence of temperature, sweep gas composition and container material on the rate and form of tritium release.

Fabrication of Lithium Ceramics

Although material specimens were obtained from other sources for comparison and to develop the test procedures, the facilities and expertise at CRNL are being used to produce Canadian materials. Sintered pellets of $LiAlO_2$ have been fabricated and sent to CEA-Saclay (France). The sphere-pac form of solid breeder is of substantial interest, but there is limited international effort. At CRNL, 2 mm diameter $LiAlO_2$ spheres were fabricated by an agglomeration process, and sol-gel processes are under development to make even smaller spheres. Alkoxide and other methods are being tested for the production of breeder ceramic powders with the desired characteristics.

Lithium Isotope Chemistry

Many blanket concepts require ^6Li concentrations far above its 7.5 per cent natural isotopic abundance. Liquid/liquid exchange is one of the most attractive methods for lithium isotope separation and several promising agents have been prepared for testing. However, the enrichment factor is only about 1.04 per pass, consequently fast and accurate measurement techniques are necessary for screening tests. Experimental work has resulted in lithium concentration measurement methods (over a 10^5 range in concentration) with commercial electrodes, and in NMR and mass spectrometer techniques to measure $^6Li/^7Li$ isotope ratios.

Fundamental Studies

The elastic recoil detection and nuclear reaction analysis methods for tritium profiling in near-surface layers (within 1 micron) have been developed. Initial measurements of implanted hydrogen, deuterium and tritium in Li_2O and $LiAlO_2$ have been completed. Unique measurements of defects in Li_2O through the perturbed angular correlation method were also made.

Structural Materials

A unique cryogenic irradiation facility has been constructed at the CRNL tandem accelerator. A Zygo scanning laser for very small strains measurement has been tested. Zirconium samples have been irradiated to low damage rates in 14-MeV neutrons (RTNS-II at LLNL), thermal neutrons (IPNS at ANL), high-energy electrons (West Germany), and 15-MeV protons (CRNL) for comparison of the effects of source particle and energy. Studies with zirconium have shown the importance of the surface structure in helium blistering.

Aqueous Lithium Salt Blanket

The next generation of fusion experiments may require some tritium breeding. Unfortunately, these will be the first fusion devices with significant engineering testing capabilities, so it will not be possible to provide fusion testing of a blanket prior to depending on it in the fusion device.

A 'low-risk' blanket concept has been proposed based on lithium salt dissolved in low temperature, low pressure water in a steel shield. This concept can provide, for example, a net tritium breeding ratio of 40 per cent with 10 per cent structural fraction and only 50 per cent torus coverage. The use of other structural materials (especially zirconium alloys), neutron multipliers, heavy water, higher salt concentrations, and higher temperature allows this concept to provide reactor-relevant power and tritium.

Other Activities

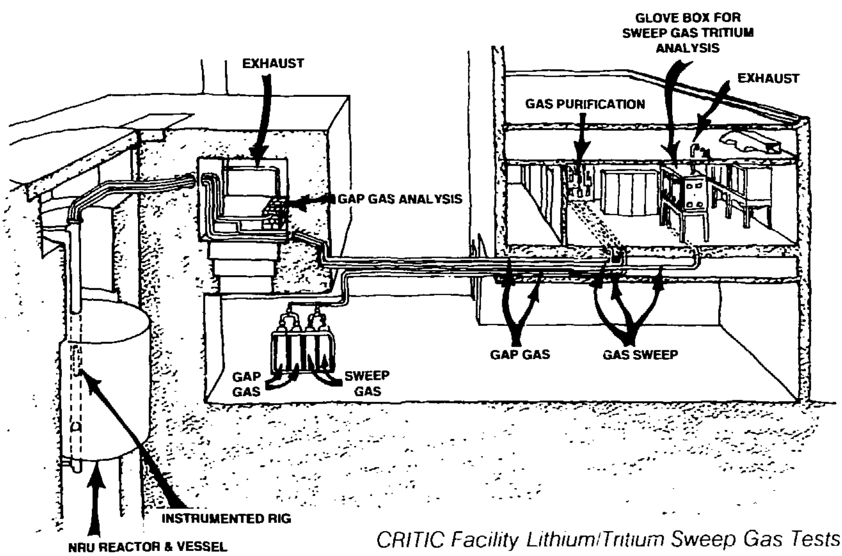
The United States FINESSE effort, with CFFTP participation, studied the issues experiments and facilities for nuclear technology. This study is serving as a framework for individual program plans and experiments, as well as for international cooperation.

Organic coolants were also assessed. They offer high temperature, low pressure, limited reactivity with liquid metals, reduced corrosion and activation, good heat transfer, and no MHD effects. It was shown that decomposition and flammability can be controlled in fusion conditions. High heat flux components and intermediate heat exchangers are particularly interesting applications.

Outlook for 1986/87

Cooperation with international organizations will be maintained through the BEATRIX solid breeder program and the various engineering test reactor design groups.

The highlight of the solid breeder effort will be the CRITIC-I open capsule irradiation of Li_2O. Results will include tritium release behaviour at low temperature (400°C) and at high temperatures (900°C). Breeder ceramic fabrication efforts will focus on developing $LiAlO_2$ spherematerial for a future CRITIC test. Analysis of the aqueous lithium salt blanket will emphasize the near-term application, with assessment of conventional tritium recovery techniques and corrosion issues.



CRITIC Facility Lithium/Tritium Sweep Gas Tests

Objectives and Priorities

Objectives of this program area are to:

- Contribute towards resolving critical issues in materials technology related to tritium required for fusion;
- Develop and evaluate special purpose materials for fusion applications;
- Provide training in fusion science and technology.

The focus of the program is on tritium. Priority areas addressed are:

- Interaction of plasma with the first wall and first wall protective coatings with emphasis on chemical erosion, retention and permeation of hydrogen species;
- Interaction of tritium with materials used in fusion reactor systems;
- Development of special materials to control permeation.

Accomplishments

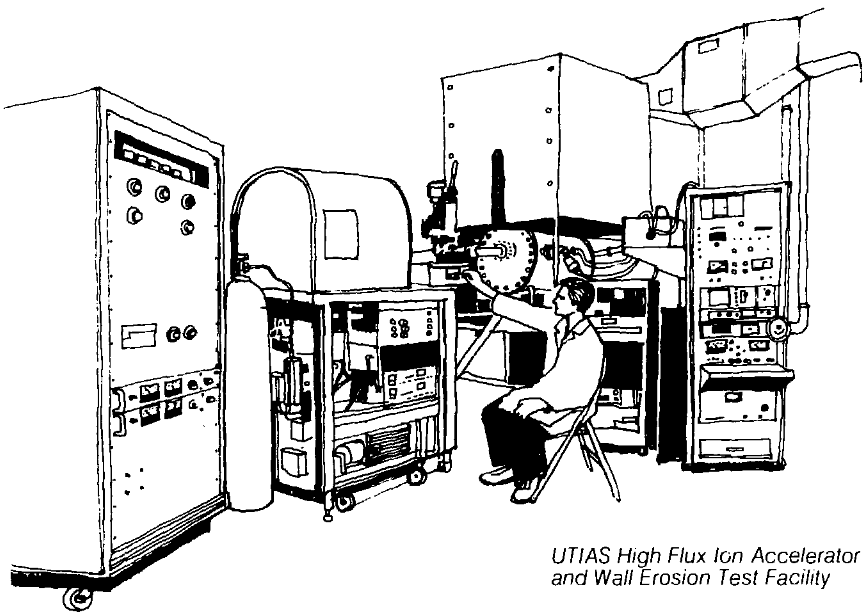
University Research Study

University of Toronto Institute for Aerospace Studies (UTIAS): data on the dependence of the chemical erosion rate of carbon on H^+ flux up to a flux of $2 \times 10^{16}/cm^2s$ were obtained. The erosion rate increased with flux up to a flux of about $3 \times 10^{15}/cm^2s$ beyond which it appeared to saturate and fall off. This is an important step towards establishing data for reactor operating conditions, at a flux of 10^{18} - $10^{19}/cm^2s$. The synergistic effects of H^+ and H^0 on erosion were established using sub-eV H^0 and 0.07 – 1 keV H^+, an energy range which complements data obtained elsewhere. Chemical erosion of carbon was also measured directly at the DITE device at Culham, using an internally heated carbon probe.

An international cooperative study on "carbonization" in Tokamaks was initiated involving research groups at TEXTOR (at Julich), INEL (U.S.), and UTIAS.

Construction of the tritium laboratory for plasma/first-wall studies at UTIAS was completed. Development and procurement of experimental equipment is in progress.

At McMaster University in Hamilton, an experimental facility is under construction for studying tritium permeation under temperature gradients and irradiation conditions, and for evaluating the performance of permeation barriers. A literature review on tritium permeation barriers was completed.



UTIAS High Flux Ion Accelerator and Wall Erosion Test Facility

Fabrication of a prototype tritium pump based on the principle of asymmetric permeation through bi-layer materials is nearly complete. A permeation probe which measures the flux of hydrogen atoms to the first wall was developed in collaboration with TEXTOR and tested with and without carbonization.

Broad expertise in the area of tritium interactions with materials is being developed. This is an important capability which complements tritium technology developments. Examples of potential future developments are: the testing of components for tritium service, evaluation of cryosorption pump materials, research on the cryogenic properties of tritium, and the compilation of a database on tritium-compatible materials and equipment.

Outlook for 1986/87

At University of Toronto Institute for Aerospace Studies, collaborative research with TEXTOR and INEL on Tokamak "carbonization" will be well underway during 1986/87. The research program on the interaction of plasma with protective carbon coatings will be directed towards addressing requirements of specific facilities or projects such as JET and NET. Methodology will be developed to predict the level of tritiated methane in the plasma exhaust of carbon coated Tokamaks. This will be useful in the design of plasma exhaust clean-up systems. The tritium laboratory is expected to be commissioned with tritium towards the end of the fiscal year and some tritium experimentation on plasma/first-wall interactions using tritium will be initiated. There will be staff attachments at JET to assist in the interpretation of data on plasma edge properties, and at Culham to continue work on direct measurements of chemical erosion of carbon.

At McMaster University, experiments will begin on the diffusion of tritium in metals under temperature gradient and irradiation. Tritium permeation barriers will be fabricated and evaluated.

The prototype passive tritium pump based on asymetric permeation will be tested for feasibility, and if promising, development of a specific product will be initiated.

Tests of the tritium compatibility of cryosorption pump materials, in particular charcoal, and of the cryogenic properties of tritium, may be initiated.

Objectives and Priorities

The safety-related aspects of tritium and its effects on the natural environment are areas where there is considerable Canadian expertise and where CANDU experience can be extrapolated to fusion applications. The objectives and associated strategies of this area are to:

- Conduct R&D to adapt and extend existing Canadian experience in tritium safe handling, safety assessment, control, monitoring, and personnel protection to meet the requirements of near-term fusion reactors and tritium laboratories; and
- Conduct research to address generic tritium safety issues related to dosimetry, in-plant and environmental behaviour with emphasis on the gaseous form of tritium.

The program is focussed on four main R&D areas.

- Development of tritium monitors;
- Dosimetry developments;
- Environmental impact assessment, and
- Fusion safety analysis.

Accomplishments

Highlights of 85/86 include:

- Commercialization of a portable tritium monitor, and a gamma-compensated general purpose area monitor. These instruments are now available from Scintrex of Canada, and are being marketed worldwide.
- Further development and prototyping of an HT/HTO discriminating monitor, and tritium process monitor such that these devices are ready for technology transfer to Canadian industry.
- Developing and prototyping of high range process tritium monitors.
- Completion of a study on the skin uptake of tritium from tritium-contaminated metal surfaces.
- Completion of a set of radiological safety criteria for application to the MINIMARS design study, in addition to engineering safety assessments performed as part of this study. Canadian contributions are documented in the MINIMARS conceptual report issued by Lawrence Livermore National Laboratories (LLNL) in California.
- Cooperation with European research agencies in precalculations and dispersion code comparisons in preparation for a tritium release experiment planned for France in May 1986.
- Further development of the Ontario Hydro Tritium Dispersion Code (OHTDC), in order to enhance OHTDC as a predictive tool, and increase speed of execution.
- Completion of an international comparison study of twelve tritium dispersion codes (including OHTDC and PATHWAY), with publication of results in the proceedings of the 1985 Dayton Tritium Conference.

Outlook for 1986/87

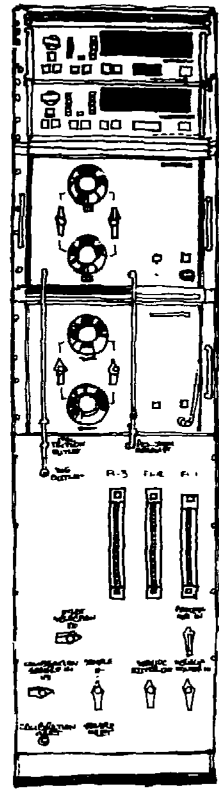
Initial safety studies were performed in support of the TITAN compact reactor design study directed by UCLA. CFFTP contributions to this project will continue through 1988, and will focus on issues of tritium removal, tritium control, and safety engineering.

Planning activities have commenced for a Canadian Tritium Release Experiment, which will examine such phenomena as T_2 oxidation in atmosphere and in soils, resuspension and redeposition rates, and uptake in plants. Although a site has not been formally selected at time of writing, international interest has already assured participation by Japanese and European scientists.

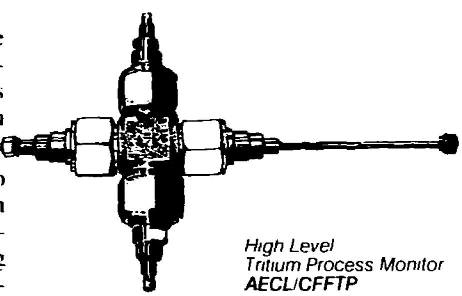
Work continues in refining protective suits for use in tritium environments. Currently available Canadian designed suits are being offered for use at several fusion projects.

Canadian safety expertise continues to be applied to various international fusion projects. Participation in several fusion design studies is ongoing, with input being sought on several upcoming design projects. Attachment of staff to fusion centres and facilities, and international collaborative studies in the safety and environment areas continue to provide recognizable Canadian contributions to the fusion community.

Development of tritium monitors will continue, with emphasis on those types of instruments which would have more immediate application and commercial potential. Present instruments will be refined as appropriate based on user feedback. Initial feasibility studies have commenced to evaluate various promising technologies associated with portable alarming tritium dosimeters. Active development of such a device, for which a real need is seen at future fusion/tritium facilities, will be initiated when the optimal concept has been identified.

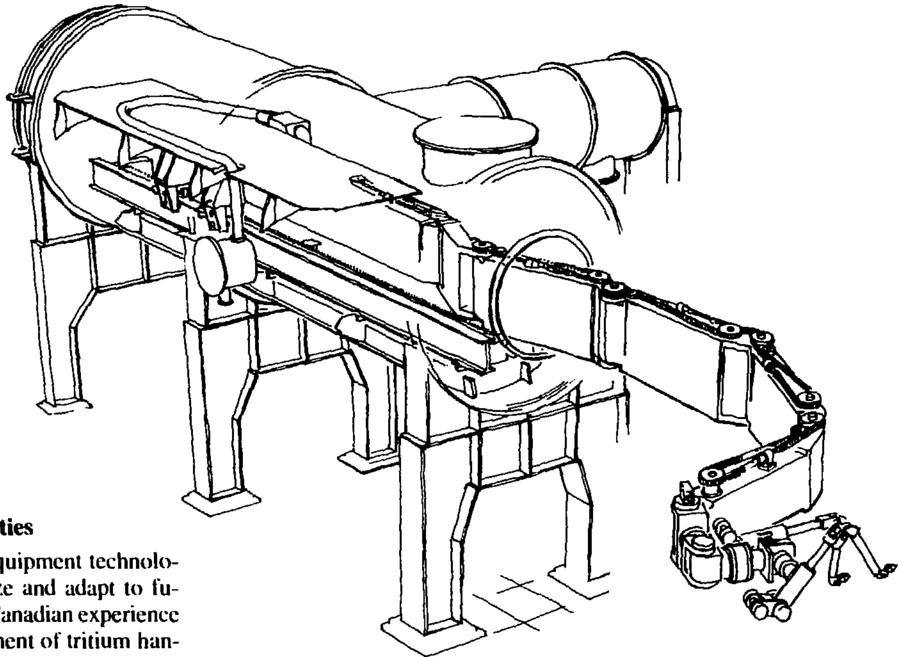


HTO/HT Discriminating Monitor
AECL/CFFTP



High Level
Tritium Process Monitor
AECL/CFFTP

Analytical tools for engineering safety assessments will continue to be developed. Specifically, enhancements to the OHTDC dispersion code; and development of other computerized safety-related codes will be initiated. Research will be carried out on tritium adsorption and outgassing in materials and surfaces, surface tritium contamination, monitoring and control.



TFTR Maintenance Manipulator Design Concept

Objectives and Priorities

The objective of the equipment technology program is to utilize and adapt to fusion applications, the Canadian experience gained in the development of tritium handling equipment for CANDU reactors, and the remote handling equipment developed for the space program and maintenance of CANDU reactors.

The equipment development program focuses on the development of remote handling equipment for use with diagnostics and maintenance systems and on the development, manufacture and testing of tritium compatible components such as tritium storage and transportation containers, tritium transfer pumps and leakproof valves.

Accomplishments

Contracts in the equipment technology program in 1985/86 were placed virtually exclusively with Canadian industry.

CFFTP was involved in remote handling activities at three of the major international fusion projects during 1985/86, specifically TFTR, JET and NET.

At TFTR, a Canadian team produced a conceptual design for an in-vessel maintenance manipulator in cooperation with personnel from the United States, France and Germany. The Canadian team included representatives from Spar Aerospace, DSMA Atcon, CAE and Ontario Hydro. The manipulator was designed to perform maintenance and inspection tasks at any point inside the torus including: detection of torus vacuum leaks at operating vacuum and temperature; scheduled maintenance tasks including tile replacement; visual inspection of the inside of the torus; and unscheduled maintenance tasks. To enable the manipulator to reach any point within the torus, an articulated arm nine metres long was designed with five motorized links. The arm was designed to support a 450 kg load at full extension and to carry a variety of "end-of-arm" tools.

The attachment which began in 1984/85 of a Remote Handling Applications Group Leader from Spar Aerospace to JET continued during 1985/86. This Remote Handling Group is responsible for:

- Establishing remote handling procedures for all JET components;
- Designing and developing special tools, devices and attachments for interfacing with manipulators and transporters;
- Setting up of man/machine interfaces and control room cabling, electronics and computer links; and
- Training of personnel in the use of tools and manipulators.

Some highlights of work in 1985/86 include development of a number of special cutting and welding tools and work on an overall control system for remote handling; an articulated boom master model; remote handling database definition; and design of a torus access cabin.

In addition, a conceptual design study for the NET team was initiated to assess the requirements for and develop a concept for the in-vessel manipulator. It is being carried out by Spar Aerospace.

In the area of hardware development, an award was made of a contract for construction of a 500,000 curie double-walled uranium getter bed based on a design by OHRD.

Outlook for 1986/87

The focus of the equipment technology program in 1986/87 will continue to be on the involvement of Canadian industry in the development of remote handling systems and of equipment suitable for use in the fusion fuels processing loops needed for fusion energy systems and for tritium laboratories.

The major effort will be on remote handling activities at JET and NET. At JET, the attachment of Dr. A. Rolfe of Spar Aerospace as Remote Handling Applications Group Leader will continue. AT NET, the study begun in March 1986 to assess the definition of requirements and develop a concept for the in-vessel manipulator will be completed. Further potential Canadian involvement in remote handling activities at NET will be evaluated at the conclusion of the in-vessel study.

With respect to equipment suitable for tritium service, the construction and testing of a 500,000 curie uranium getter bed will be completed. Two different designs for leakproof valves for tritium service will be evaluated.

Objectives and Priorities

Several of the research and development projects being undertaken in the five strategic technology areas have been successfully demonstrated in the laboratory and are ready to be commercially produced for use in the international fusion community. To ensure that the products developed are successfully manufactured and marketed, a technology transfer program was initiated during 1985/86.

The objectives of the program are to successfully transfer to Canadian industry promising fusion technology developments and to maintain a high profile of Canadian products in international fusion projects. Priorities include the identification of research and development activities most likely to be successfully industrialized, the selection and motivation of Canadian industries to which technologies should be transferred and the construction and demonstration of full-scale prototypes.

Accomplishments

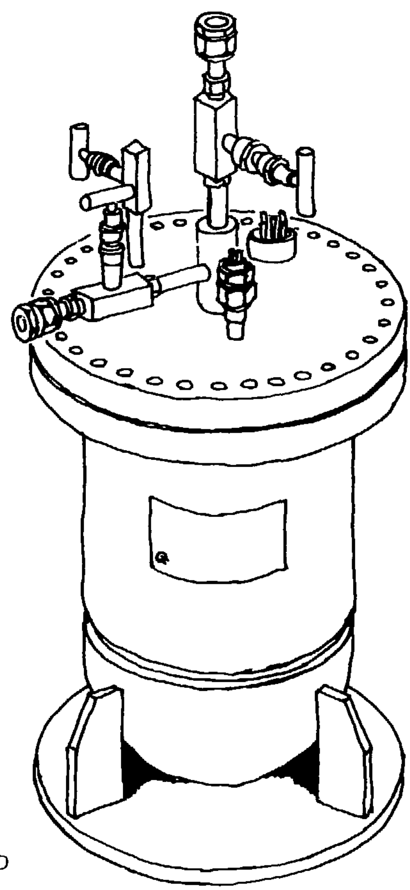
Technology transfer highlights in 1985/86 included:

- A tritium monitor user survey to establish R&D priorities in the safety and environment technology area;
- Initiation of procedures for selection of a Canadian supplier for the gas chromatography process for hydrogen isotope separation;
- Selection of a fabricator for the uranium getter bed, and
- A one-day seminar describing CFFTP research activities and discussing technology transfer in Canada. Seminar attendees included CFFTP contractors, and federal and provincial government officials.

Outlook for 1986/87

Technology transfer activities in 1986/87 will concentrate on:

- Finalizing the industrialization of the area tritium monitors developed by CRNL and manufactured by Scintrex;
- Selecting a Canadian company for manufacture of a process tritium monitor developed by CRNL;
- Completing the selection of a Canadian company for the production of the gas chromatography process.
- Negotiating a licensing agreement for the manufacturing rights for the uranium getter bed.



Uranium Getter Bed Developed by OHRD

Assignments

One of the methods for exchanging information between organizations is via staff assignments or attachments to international facilities. Eight people were on attachment in 1985/86 for terms ranging from five months to three and one-half years in length. They were assigned to projects in the United States, England and West Germany. The individuals on assignment and their parent organization, international facility and location, duration and nature of work are described below in more detail.

Facility: **Joint European Torus (JET), Culham, England**
Individual: Peter Stangeby
Organization: University of Toronto
Technology Area: Materials
Duration: April 1985 – August 1985
Studies in plasma edge diagnostics.

Facility: **DITE Tokamak, Culham, England**
Individual: Mr. S. Pitcher
Organization: University of Toronto
Technology Area: Materials
Duration: April 1985 – March 1986
Determination of chemical erosion rate of carbon by direct measurements at DITE.

Facility: **Joint European Torus (JET), Culham, England**
Individual: Alan Rolfe
Organization: SPAR Aerospace
Technology Area: Equipment
Duration: September 1984 – March 1987
The purpose of this assignment is to lead the remote handling applications group at Joint European Torus fusion reactor experiment located at Culham, England. Completed tasks include formulation of the remote handling overall control system, and definition of an 18-month work plan for the remote handling applications group.

Facility: **Next European Torus (NET), Garching, West Germany**
Individual: Paul Dinner
Organization: Ontario Hydro
Technology Area: Tritium
Duration: October 1984 – October 1986
Participate in review of NET technical objectives, critical issues, and design criteria; participate in the NET tritium systems definition and assist in the management of tritium technology research and development.

Facility: **TEXTOR, Julich, West Germany**
Individual: Walter Shmayda
Organization: Ontario Hydro
Technology Area: Materials
Duration: May 1985 – December 1985
Studies in the permeation of hydrogen isotopes through bilayer materials.

Facility: **FINESSE, UCLA, Los Angeles, California**
Individual: Paul Gierszewski
Organization: Ontario Hydro
Technology Area: Materials
Duration: September 1983 – December 1985
Participated in the FINESSE study led by UCLA to identify and rank critical fusion technology issues, to evaluate and quantify testing needs and to identify testing facilities.

Facility: **Joint European Torus (JET), Culham, England**
Individual: Charles Gordon
Organization: Ontario Hydro
Technology Area: Safety and Environment
Duration: March 1985 – March 1987
Assignment to UKAEA as safety engineer for JET Tritium Recycling System, including safety and licensing analysis on JET tritium systems and other work as requested by the Site Joint Safety Officer.

Facility: **Massachusetts Institute of Technology (MIT), Boston, Mass.**
Individual: Sandra Brereton
Organization: Grad Student Associated with CFFTP
Technology Area: Safety and Environment
Duration: September 1983 – March 1987
Analysis of the relative safety between Tokamaks and mirror fusion devices. Economic evaluation of safety comparison of D-D fusion.

Objectives and Priorities

The technology applications area of CFFTP was formed to offer services to international fusion projects. These services are based on established Canadian tritium technology gained from 30 years of experience operating CANDU nuclear power and experimental fission reactors and also, more recently, from the extensive R&D program focussed on tritium technology as applied to fusion fuel cycles. Services include design, design reviews, supply, installation, commissioning and project management. These activities help focus CFFTP R&D programs and ensure the relevance of these programs to the world's fusion developments.

Fusion Services

During 1985/86, CFFTP offered services based on demonstrated expertise in these applied technology areas:

- Fusion fuel systems and laboratory facilities for fusion reactors burning tritium;
- Fusion fuel storage and handling systems and laboratory facilities;
- Fusion reactor exhaust gas clean-up systems;
- Fusion reactor and breeder blanket technology;
- Remote handling systems for fusion reactor maintenance and operation;
- Safety assessment and equipment;
- Environmental studies for fusion establishments;
- Radioactive waste management.

Design Services

CFFTP offered design services to fusion laboratories and to projects supporting fusion development work. CFFTP design capabilities span the complete range from preliminary assessment of requirements through provision of complete detailed designs. Safety analysis is an integral part of the design process. Detail designs included feedback from safety assessments. Supporting documentation and manuals were supplied to customer's required standards.

In 1985/86, CFFTP provided customers expertise in all phases of design work:

- Assessment of customer requirements;
- Conceptual designs;
- Preliminary designs;
- Complete detailed designs;
- Equipment selection;
- Manuals, documentation and drawings to customer's standards.

Construction and Commissioning Services

CFFTP construction management teams can engineer and supervise construction of fusion fuel systems and laboratory facilities. CFFTP can also supply the skilled construction staff needed to install and commission the advanced equipment common to fusion development. CFFTP offers expertise in all construction phases:

- Construction planning and scheduling;
- Project management;
- Equipment and materials purchasing;
- Construction supervisors and crew;
- Testing of components and systems;
- Preparation of commissioning plans and startup and operating procedures;
- Commissioning of completed systems and facilities.

Accomplishments in 1985/86

Highlights of the contracts awarded to CFFTP Technology Applications during the year include the following projects:

Contract Awarded:	Accelerator Tritium Systems Phase I: Preliminary Engineering
International Facility:	ENEA Frascati Neutron Generator, Italy
Contract Duration:	Six months, commencing May 1985
Resource Organizations:	CFFTP, Ontario Hydro, AECL-CRNL

Preliminary engineering of a target exhaust clean-up system and an emergency air clean-up system was performed by CFFTP on behalf of Frascati in 1985. The exhaust clean-up system will remove tritium from the vacuum pump exhaust gases. In addition to the Vacuum Exhaust Clean-up System and its glovebox, a utilities glovebox and target changing glovebox have been conceptualized. A simplified flow diagram is given in Figure 3.

Contract Awarded:	Microballoon Filling Station for Inertial Confinement Fusion Studies — Phase I: Design
International Facility:	University of Rochester Laboratory for Laser Energetics
Contract Duration:	Five months, ending October 31, 1985
Resource Organizations:	Ontario Hydro, Nuclear Materials Management Department

The Laboratory for Laser Energetics (LLE) at the University of Rochester commissioned CFFTP to design its tritium handling and microballoon filling systems. The systems will be used for storing and handling tritium, and for filling microballoon laser targets with tritium. The microballoon targets will be irradiated by lasers in the study of inertial confinement fusion.

The systems designed included:

- Tritium storage and handling facilities;
- Microballoon target charging loop;
- Glovebox;
- Walk-in fumehood;
- Instrumentation and control systems.

The storage and charging systems use uranium beds as interim storage and transfer devices.

Operating inventory of the systems is expected to be 5 kilocuries.

Design work was directed so that for radiation safety purposes, radiation doses from tritium will meet the ALARA principle – As Low As Reasonably Achievable. This principle was applied to minimizing research worker radiation doses and public doses.

Contract Awarded:	ETHEL Conceptual Design (ISPRA, Italy)
International Facility:	JRC, Ispra – European Tritium Handling Experimental Laboratory (ETHEL)
Contract Duration:	Six months, commencing March 1, 1986
Resource Organizations:	CFFTP, Ontario Hydro, Ansaldo, Monserco Limited, AECL-CRNL, SNIA Techint

JRC, Ispra has awarded four contracts for conceptual design and costing of a tritium laboratory (Phase 1). The laboratory will handle up to 100 g of tritium which will be used in various experiments in support of the NET project. CFFTP teamed with Ansaldo, Nira (prime contractor) and SNIA Techint of Italy to bid for the contract and the team received one of the four awards. CFFTP's role is in the primary tritium process system design and in the safety analysis. The systems within CFFTP's scope are Tritium Receiving and Storage; Tritium Transfer System, Data Acquisition System; Waste Management System and the Monitoring System. Ansaldo is responsible for the building and services and SNIA is responsible for the secondary containment and Air Detritiation System.

Contract Awarded:	Vacuum Pump Study
International Facility:	NET Study Team, Garching, West Germany
Contract Duration:	Twelve months, commencing April 1, 1986
Resource Organizations:	CFFTP, AECL-CRNL, Grumman

A design study of the NET vacuum system is being performed. This will include both a compound cryopump and a turbomolecular pump option. Leybold-Heraeus of West Germany is the prime contractor. Tritium expertise and compound cryopump expertise are being provided by CFFTP and Grumman Aerospace, respectively. The study will establish the cost, safety and technical risk associated with each option. CFFTP's role will be in assessing tritium impact on radiological safety, maintenance and certain materials aspects of the two options.

Contract Awarded:	Study of Isotope Separation Methods
International Facility:	KfK, Karlsruhe, West Germany
Contract Duration:	Two months, commencing September 1985
Resource Organizations:	CFFTP, OHRD, AECL-CRNL

KfK/Karlsruhe has awarded CFFTP a contract to study the

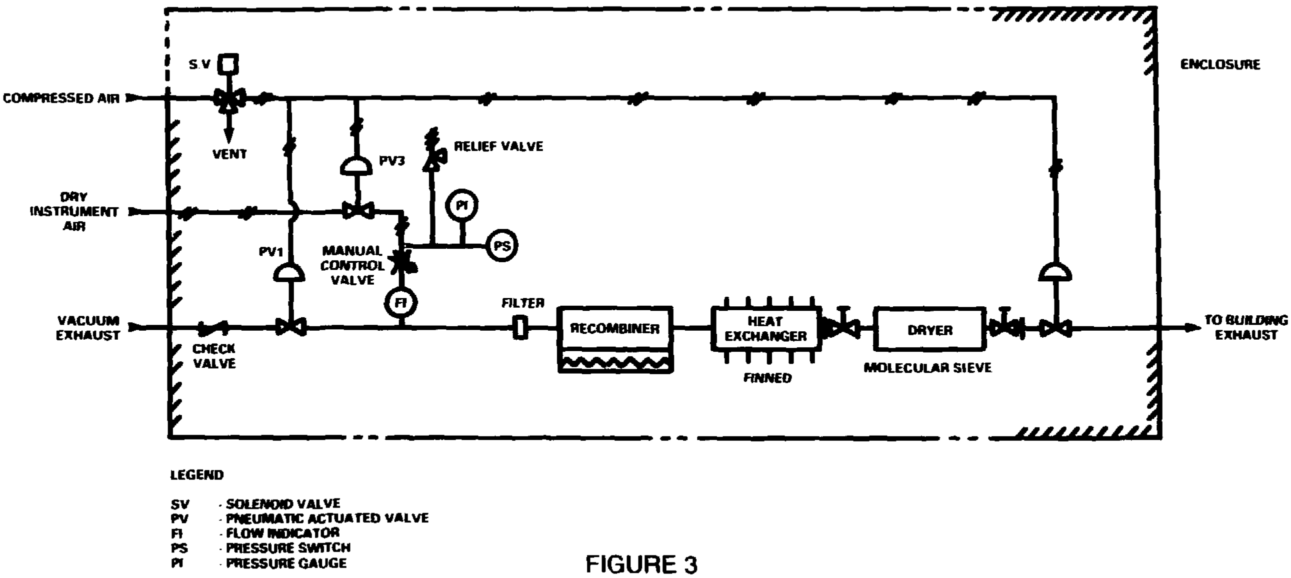


FIGURE 3
Simplified Diagram of Vacuum Exhaust Clean-Up System

options available to perform the separation of all six hydrogen isotope combinations. These are H_2, D_2, HD, HT and DT. The separation device is to be used as a service facility in the KfK laboratory project, which is currently in the design phase. The study showed that a Gas Chromatograph Column (GCC) would most suitably meet the requirements of the KfK tritium laboratory. Two separation systems based on GCC technology are now under development, one supported by Sulzer in West Germany and one by OHRD.

Tritium Safe Handling Training Course:

Tritium safe handling training courses were conducted at Princeton University (June 1984) and in Canada (September and November 1984). During May 1985, a fourth course was given in Canada with 19 people attending from eight different countries. A total of about 90 people from eight different countries in North America, Europe and Japan have now participated in these courses.

Outlook for 1986/87

The projection in 1986/87 is for a continued expansion of the volume of contracts, based on the increasing rate of expenditure on fusion fuel related facilities around the world. Several of the projects in which CFFTP has already been involved are moving into the detail design, procurement, construction and commissioning phases. CFFTP resource organizations have capabilities in all of these areas and we anticipate increased participation.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AECL	Atomic Energy of Canada Limited
ANL	Argonne Nuclear Laboratory
BEATRIX	Breeder Materials Exchange Matrix
BILD	Business Industrial Leadership Development
CAE	CAE Electronics Limited
CANATOM	Canatom Inc.
CANDU	Canada Deuterium Uranium
CEA	Commissariat A L'Energie Atomique
CEC	Commission of European Communities
CFFTP	Canadian Fusion Fuels Technology Project
CGE	Canadian General Electric Co. Ltd.
CRNL	Chalk River Nuclear Laboratories
DOE	U.S. Department of Energy
DSMA	Dilworth, Secord, Meagher & Associates Ltd.
EEC	European Economic Commission
ENEA	Comitato Nazionale per la ricerca e per lo sviluppo dell'Energia nucleare e delle Energie Alternative
ERD	Elastic Recoil Detection
ETHEL	European Tritium Handling Experimental Laboratory
ETR	Engineering Test Reactor
FBB	Fusion Breeder Blanket
FEDC	Fusion Engineering Design Centre
FEMP	Fusion Engineering Materials Program
FER	Fusion Engineering Reactor
FINESSE	Fusion Integrated Nuclear Experiment Strategy Study Effort
FNS	Fusion Neutron Source
FTU	Frascati Tokamak Upgrade, Italy
GAC	Grumman Aerospace Corporation
GCC	Gas Chromatograph Column
HVAC	Heating, Ventilation and Air Conditioning
IGNITOR	Ignition Torus
INEL	Idaho National Engineering
JAERI	Japanese Atomic Energy Research Institute
JET	Joint European Torus
JRC-ISPRA	Joint Research Centre, Ispra, Italy
KFA	Institut Fur Plasmaphysik der Kernforschungsanlage, Julich
KfK	Kernforschungszentrum Karlsruhe Nuclear Research Centre
LLE	Laboratory for Laser Energetics, University of Rochester
LLNL	Lawrence Livermore National Laboratory
MARS	Mirror Advanced Reactor Study (2000 MWe)
MIES	McMaster (University) Institute for Energy Studies
MINIMARS	Mini-Mirror Advanced Reactor Study (600 MWe)
MOE	Ontario Ministry of Energy
MOL	The Nuclear Research Centre (SCK/CEN) located at Mol, Belgium
MONSERCO	Monserco Ltd.
NET	Next European Torus
NMMD	Nuclear Materials Management Department
NMR	Nuclear Magnetic Resonance
NRA	Nuclear Reaction Analysis
NRCC	National Research Council of Canada
NRU	Nuclear Reactor Universal
NRX	Nuclear Reactor Experimental
OH	Ontario Hydro
OHRD	Ontario Hydro Research Division
OHTDC	Ontario Hydro Tritium Dispersion Code
OHTE	Ohmically Heated Toroidal Experiment
ORNL	Oak Ridge Nuclear Laboratory
PAC	Perturbed Angular Correlation
PPPL	Princeton Plasma Physics Laboratory
RPI	Rensselaer Polytechnical Institute
SPAR	SPAR Aerospace Limited
TEXTOR	Tokamak Experiment for Technology Oriented Research
TFCX	Tokamak Fusion Core Experiment
TFTR	Tokamak Fusion Test Reactor
TIBER	Tokamak Ignition/Burn Experimental Research
TSTA	Tritium Systems Test Assembly
UCLA	University of California, Los Angeles
UKAEA	United Kingdom Atomic Energy Authority
URLL	University of Rochester Laser Laboratory
UTIAS	University of Toronto Institute for Aerospace Studies
WNRE	Whiteshell Nuclear Research Establishment

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CFFTP-G-84025

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A.A. Haasz, O. Auciello, P.C. Stangeby, UTIAS, September 1985

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Fusion Energy and Canada's Role

July, 1986

P.J. Spratt & Associates

This sixteen-page colour booklet has been written by teachers to provide the layman with general background information on the topic of fusion energy.

Fusion Fuels Technology (Quarterly Newsletter)

This newsletter reports to the fusion energy development community and to stakeholders in fusion development. These are research institutions, fusion projects, industry, government agencies, utilities and universities. Each issue reports on achievements in the fields of activity and research undertaken by CFFTP, contracts awarded and completed, research projects completed and ongoing, and developments in cooperation agreements between members of the fusion community. Descriptions are given of available and developing technologies which have a broad appeal to fusion laboratories, development agencies and related industries.

CFFTP Activities Report

Yearly review of CFFTP activities and accomplishments along with a summary of future plans.

CFFTP PUBLICATION AVAILABLE FOR PURCHASE

Canadian Tritium Experience

CFFTP, 1984.

$150.00 US (Prepayment or invoice)

The objective of this document is to present key aspects of Canadian tritium technology, and CANDU operating data and experience, related to tritium handling and safety that may be of practical interest and use to the fusion community. Topics include tritium production and loss, tritiated heavy water management, airborne tritium control, tritium extraction and immobilization, occupational radiation safety, and environmental safety.

Most CFFTP publications are available free of charge upon request. Any charges are noted under the title.

For a copy of a publication or to be placed on the mailing list to receive a copy of the newsletter contact the:

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FY 1985/86

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1.05	Tritium Recovery from Exhaust Streams	14.1	AECL-CRNL
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1.30	General Consulting in Support of CFFTP	13.0	AECL-CRNL
1.35	Laser Tritium Separation – Phase II	38.6	OHRD
1.37	Attachment to NET	120.6	OH-FEMP
1.38	Testing of Fusion Fuel Cleanup System	95.0	AECL-CRNL
1.39	NET Fuel Loop & Blanket Tritium Systems Design	29.6	AECL-CRNL
1.40	NET Tritium Systems	21.2	OH-NMMD
1.42	Minimars Study for LLNL	32.0	OH-NMMD
1.43	Optimization of Air Detritiation System	12.3	AECL-CRNL
1.44	Air Detritiation by Electrolysis	24.3	AECL-CRNL
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1.47	FCU by Large Scale Gas Chromatography	31.2	OHRD-CHEH
1.48	Glove Box Atmospheric Detritiation	7.1	OHRD-Shmayda

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2.05	Lithium Compound Chemistry (IV)	130.4	AECL-CRNL
2.06	*Fundamental Breeder Studies* (V)	156.0	AECL-CRNL
2.07	Neutronics (VI)	52.9	AECL-CRNL
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2.10	Joint CFFTP-Grumman-RPI Breeder Development	82.7	Grumman-RPI
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	Attachment to Facilities	16.3	Sandra Brereton

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3.05	Attachment to UCLA	29.3	P.J. Gierszewski
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3.15	D&T Permeation Barriers	30.1	MIES
3.17	Material Carbonation, Bilayers and T Lab	305.1	UTIAS

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4.04	Attachment to PPPL	29.1	DSMA
4.16	Attachment of Group Leader to JET	65.7	SPAR Aerospace
4.17	Tritium Vacuum Pump	46.0	Nova Magnetics
4.19	PPPL-Remote Handling – Phase IIA	47.6	SPAR
	PPPL-Remote Handling – Phase IIA	43.6	OH-NSD

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5.06	Portable Tritium Monitor Development	1.6	OH-H&SD
5.12	Tritium Monitor Development Program	298.4	AECL-CRNL
5.15	Application TRITMOD Tritium Dispersion Code	5.0	Monserco Ltd.
5.18	International Comparison of Computer Codes	7.4	OH-NMMD
5.20	Minimars Study with LLNL	5.0	OH-NMMD
5.21	Attachment of C. Gordon to JET, Culham	76.8	OH-NSSD
5.22	Lung Microdosimetry for Metal Tritium and HT	4.1	OH-H&SD
5.24	Dosimetry of Tritium Uptake from Metal	22.9	AECL-CRNL
5.25	Environmental Tritium Oxidation	3.4	OHRD

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