FusionCanada

Bulletin of the National Fusion Program

Issue 5, August 1988

In this Issue

ISSN 0835-488X

- ITER-Canada Accord
- EC-Canada 1988 Meeting
- Materials Radiation Damage - IEA Directions
- CCFM - Experimental Update
- U of Saskatchewan Tokamak Research
- SPAR Aerospace

ITER

Canada to Join Europe in Iter

On July 27, 1988 the ITER Council welcomed the impending involvement of Canada in EURATOM'S contribution to ITER (International Thermonuclear Experimental Reactor). The ITER Council directs the ITER Conceptual Design activities and exercises overall supervision of their execution. The four participants in the Conceptual design activities of ITER are Euratom, Japan, USSR and the USA.

Canada is the first country to qualify for involvement under Article 9 of the ITER terms of reference, which permits the involvement of "...other countries which possess specific fusion capabilities. "To this end, the ITER Management Committee evaluated the specific fusion capabilities of Canada, the potential contribution to the ITER design and R & D activities, and the qualification of the possible participants in the joint work. It concluded that Canada could make a valuable contribution to the ITER design and R & D activities.

The ITER cooperation is carried out under the auspices of the International Atomic Energy Agency (IAEA) and has the overall objective of demonstrating the scientific and technological feasibility of fusion power. Conceptual design activities began in May this year at the technical site for joint work, the Max Planck Institute for Plasma Physics in West Germany. These design activities will continue until December 31, 1990.

Authority to conclude a Memorandum of Understanding between the Government of Canada and Euratom was granted to the Commission of the European Communities (EC) on July 25, 1988. Canada's involvement in EURATOM's contribution to ITER will become effective once the respective authorities have signed the MOU. The MOU provides that Canada will contribute to design activities proper and to the supporting research and development. The research and development assistance will be performed in Canada.

This is an important development for the small Canadian fusion program. It provides an additional focus for Canadian work and an opportunity to contribute Canadian technology and expertise to a major international fusion initiative.

The involvement in Euratom's contribution to ITER follows several years of Europe-Canada cooperation in the development of controlled thermo-nuclear fusion. Based on this history of cooperation, Canada and Europe signed in March 1986 a broad scope MOU enabling formal Canada-EC collaboration in fusion development. The current MOU is within its overall framework.

Experimental Update

CCFM - Tokamak de Varennes

Since May this year, satisfying results are reported in:

- Plasma control (stability at $q = 2.1$)
- Fast current rampdown
- Refractory coating tests
- Ultra-violet wall outgassing

Good control of plasma current, position and density is achieved, giving constantly reproducible pulses of 0.75 seconds with a 0.4 seconds plateau at routine plasma current of 200 kA, and a best value of 280 kA ($q = 2.1$). Current and density are simultaneously ramped up to plateau, with no observable disturbance as $q = 3$ is passed at 195 kA.

Global confinement time is measured at 9.3 milliseconds. Central electron temperatures of 850 eV (about 8.5 million °C) are seen, with ion temperatures of 400 eV. Normal line average electron density is $3.2 \times 10^{19}/m^3$, and $3.8 \times 10^{19}/m^3$ has been possible. Plasma position is dynamically controlled within 10 mm. These results are made possible by use of a high speed programmable controller regulating magnet and ohmic heating coil currents. The control system employs dynamic variation of gains and transfer functions during rampup, plateau and rampdown of plasma current.

Continued on back page

INTERNATIONAL

Radiation Damage in Fusion Materials

IEA Research Directions

Five members of the International Energy Agency (IEA), including Canada, participate in collaborative R & D programs in fusion materials under an international implementing agreement. This agreement is administered by an Executive Committee which initiates new activities and evaluates current programs. At the 1988 June meeting of the Committee, three of the several new programs discussed were:

International Fusion Materials Irradiation Facility. This is a proposal to collaboratively fund and construct a high energy, high intensity radiation source for the development of structural materials for fusion reactors. The Steering Committee for this task is planning an international workshop to be held in San Diego in 1989 February to consider possible IFMIF concepts. Workshop coordinator is Dr. D.B. Doran of PNL. The aim is to identify a source capable of generating relevant radiation damage effects in reasonably large materials samples. Exposure time and facility costs will also be significant parameters.

Fusion Materials Data Base. The objective is to create a computerized data base and data handbook for fusion-relevant materials. An initial workshop was held at Petten, Netherlands in 1988 June. Proposed initial data categories include structural materials, non- structural blanket materials, plasma facing materials, ceramic insulators and magnet materials. Initial efforts will concentrate on data relevant to near term research devices such as NET, FER and ITER.

Low Activation materials. This task is intended to explore the use of alternative materials (e.g. vanadium) in fusion reactors to reduce radiation levels present in operation and decommissioning. An initial workshop is tentatively planned for 1988 December, probably in Atlanta, Ga. The Coordinator is Dr. E.E. Bloom.

Other IEA initiatives in radiation damage are in Safety, Economic and Environmental impact, as well as the long-standing BEATRIX materials irradiation program, in which Canada plays an active experimental role.

Economic, Safety and Environmental Impact. Several international meetings have been held to consider economic, social and environmental effects of fusion reactors. Summary reports have been prepared by Japan, USA and Europe. Further collaborative activities are being planned.

Canada currently participates in the BEATRIX materials irradiation program which comes under this IEA agreement. Dr. Gil Phillips (NFP) is currently chairman of the Executive Committee. Other member countries to the Agreement are Japan, USA, Switzerland and the European Community.

More information from Dr. Gil Phillips, NFP

INDUSTRY IN FUSION

SPAR Aerospace Ltd.

Fusion remote maintenance

SPAR is helping develop remote maintenance manipulator designs for the NET project. The company is also involved in remote manipulator concept development for the Compact Ignition Torus (CIT) at Princeton.

SPAR has been applying the 'harsh environment' expertise of its Remote Manipulator Systems Division to fusion reactor engineering since CFFTP arranged for the involvement of SPAR, Canadian Aviation Electronics (CAE) and other Canadian companies in the TFTR remote maintenance design work. SPAR's best known remote manipulator application is the 'Canadarm' Space Shuttle payload manipulator, supplied to NASA by SPAR and others.

For the NET (Next European Torus) project, SPAR is participating in a conceptual design for a large multi-jointed manipulator arm, the NET In-Vessel Handling Unit. The arm is intended to perform maintenance tasks inside the NET fusion reactor vessel, including replacement of heavy components deep inside the vessel. NET is designed as a power-producing, tritium-burning machine, so the maintenance system would see elevated radiation fields and radioactive contamination levels. An advanced dynamic computer simulation of the concept and its control system is being carried out in Toronto, to optimize IVHU performance and control. The dynamic computer model is being tested on a previous SPAR fusion manipulator design, being built in West Germany at KfK Karlsrühe for TFTR.

SPAR is also evaluating an alternative In-Vessel Vehicle system for NET as a possible alternative for IVHU, and is helping define the entire NET maintenance plan.

The Canadian Fusion Fuels Technology Project (CFFTP) funded SPAR's involvement in TFTR, and with contributions from SPAR has co-funded the NET work, which is being done under a NET contract.

SPAR design staff are attached at JET and NET and were attached to TFTR (Princeton, USA) when SPAR developed the concept for the TFTR remote manipulator system. The TFTR system will operate in high vacuum and high magnetic fields, and can be baked for degassing.

More information from Paul Stefow, SPAR Aerospace or Alan Meikle at CFFTP (See Contact Data).

UNIVERSITY RESEARCH

University of Saskatchewan Tokamak Research

Aiming for high Beta

Principal Investigators:
Prof. Akira Hirose
Prof. Harvey Skarsgard

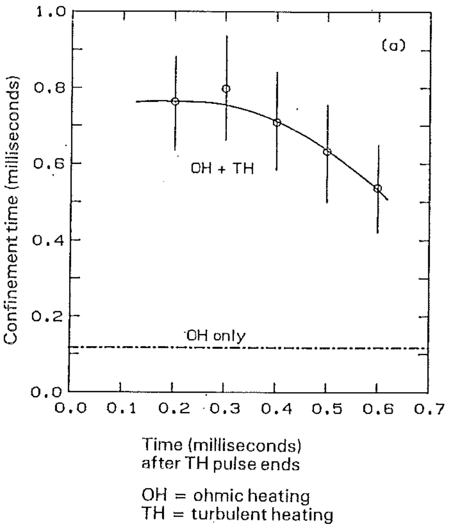
Two small tokamaks (STOR-1M and STOR-M), designed and built at University of Saskatchewan, are used for plasma heating studies. The turbulent plasma heating technique is an important investigative tool. Interesting results showing improved confinement times have recently been achieved using turbulent heating, on the smallest (STOR-1M) tokamak. The larger STOR-M machine is performing its first series of high confinement experiments to continue the work.

The Saskatchewan studies aim at contributing to knowledge of "high Beta" tokamak operation, for improving plasma confinement performance toward the levels needed in viable power-producing fusion reactors of the future. The U of Saskatchewan Plasma Physics Group is investigating the factors affecting increase of the Beta parameter in tokamaks, to add to knowledge of plasma confinement dynamics.

With STOR-M, completed last year, the Saskatchewan Group is extending its long standing STOR-1M studies. They hope to reach toroidal Beta values of 10 percent with the turbulent heating technique, and to investigate tokamak plasma behaviour with those conditions. With ohmic heating alone, a safety factor of less than 2 has been achieved in STOR-M.

Broadly speaking, Beta can be considered as an index, or figure of merit, indicating the efficacy of a tokamak's magnetic field system. Beta values indicate the maximum plasma pressure that the magnetic field system can confine. Plasma pressure is related to plasma energy content. Future commercial fusion tokamaks will require Beta figures of around 0.1 (10 percent) or better. With present large tokamaks, Beta values over about five percent remain elusive; attempts to further increase Beta generally result in plasma disruptions or saturation in Beta value.

Present research builds on U of Saskatchewan's long history of plasma heating studies, which began in the 1960s. Some original discoveries include turbulent heating induced by magnetic ripples (1972), anomalous electron viscosity (1972), and anomalous radially-inward thermal transport (1976). The group completed the STOR-1M tokamak in 1983, after many years research with non-tokamak toruses beginning with the Plasma Betatron built in 1958 by Prof. Skarsgard.



Research with STOR-1M

In 1985, this machine was successfully used to study alternating current tokamak operation, demonstrating stable AC tokamak discharges.

STOR-1M has a 1 tesla toroidal field and electron temperatures around 100 eV (1 million °C) with ohmic heating, increasing significantly with turbulent heating.

Between 1985 and the present, STOR-1M was used mainly to study turbulent heating (TH) effects. With this technique, a short and very fast current pulse comparable to the plasma current is superimposed by induction on the plasma current of a normal ohmic heating pulse. At tokamak plasma densities, the induced TH current pulse flows mainly in the outer 'skin' of the plasma, creating skin heating, microturbulence in the skin region and an anomalous increase in plasma resistivity. The overall effect is an increase in effective Beta value, permitting plasma behaviour studies at high Beta levels.

Reports on turbulent heating and AC operation in STOR-1M: IAEA Kyoto Conference (1986), also Nuclear Fusion, Letters, Vol. 27 No. 4, 1987).

Recent Results

The effective plasma heating by TH pulses seen in STOR-1M was expected, based on experience. Unexpected was the delayed plasma heating observed, and the significant improvement in energy confinement time well after the TH pulse had ended. (See graph).

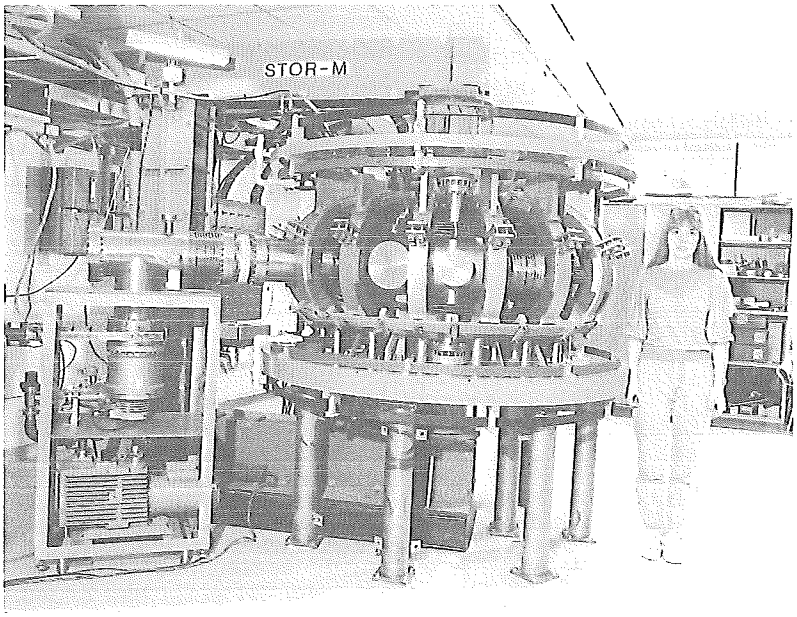
Density increases (to 3×10^{19} m^{-3}) and delayed electron heating (up to 300 ev increase) were seen following the TH pulse, and the energy confinement time increased by a factor of 5 from that given by ohmic heating alone. The improved confinement phase is accompanied by reduced MHD activities, diminished density fluctuations, and reduced radiation at the hydrogen H-alpha wavelength. Such H-mode-like transition following additional heating has also been observed in ASDEX with neutral beam heating. Average poloidal Beta approaches 3 during the improved confinement phase, with overall Beta near 0.6 percent.

These results will be reported in detail at the IAEA Conference in Nice (October 1988) in a joint paper with the Jutphaas (Netherlands) group. They were first reported at the Annual Conference of the Canadian Association of Physicists, June 1988, Montreal.

New Studies - STOR-M Tokamak

The Group has designed and built STOR-M to obtain higher Beta values with the TH technique for longer periods with hotter and denser plasmas than available with STOR-1M. Target Beta value is over 5 percent, with 10 percent as a longer goal. Diagnostics include a novel neutral beam probe (10 mA at 30 kV) for measuring ion temperature by Rutherford scattering or active charge exchange. Core temperature measurements with a time resolution of one millisecond will be possible. Measurements of plasma density fluctuations with a CO_2 laser will provide vital information about the mechanisms of turbulent heating and anomalous electron thermal conduction. The larger size of STOR-M improves spatial resolution of plasma measurements. First experiments with TH will examine whether the H-mode like transition observed in STOR-1M occurs in STOR-M with its larger minor radius (12 cm vs 3.5 cm in STOR-1M).

U of Saskatchewan collaborates with the TORTUR group (FOM-Institute for Plasma Physics, Netherlands) and the TRIAM group (Kyushu University, Japan), both of which study turbulent heating.



The STOR-M tokamak

Major radius	46 cm	Plasma current (ohmic)	>40 kA
Minor radius	12 cm		
Toroidal field	1.0 tesla	Plasma current pulse (turbulent heating)	40 kA

Publications

The Group has published many experimental and theoretical studies in plasma physics. Principal authors in recent years have been Hirose, Skarsgard, Wolfe, Mitarai and Ishihara. Most recent paper "Two Fluid Analysis of Ballooning Mode in Tokamaks," Hirose, 1988 (submitted for publication).

More information: Prof. Akira Hirose (see Contact Data)

Attachments

Three long term attachments to JET (UK), arranged by CFFTP, have recently begun. Engineers Paul Ballantyne and Dominic Wong are working on fuel processing and tritium systems during the procurement, installation and commissioning phase. Martin Galley is working on safety assessment and licensing. All three are long term attachments, initially for one year.

Ronald Matsugu (CFFTP staff engineer) has just returned from a three month attachment at the Tokai Research Establishment, JAERI, Japan. He assisted in commissioning the Tritium Process Laboratory, which has now performed hot commissioning tests with tritium.

INTERNATIONAL

Canada-Europe 1988 Joint Committee Meeting

A European delegation, headed by Dr. Charles Maisonnier, visited Canada May 30 - June 2 for the Second Joint Committee Meeting under the ongoing Canada-Europe bilateral agreement in fusion. During their four-day visit, the delegates met leaders in Canadian fusion work, and visited the Tokamak de Varennes at CCFM, the tritium facilities at both Chalk River and at Darlington Nuclear Generating Station, and toured the remote handling facilities of SPAR Aerospace in Toronto. The Joint Committee Meeting itself was held at Chalk River Nuclear Laboratories.

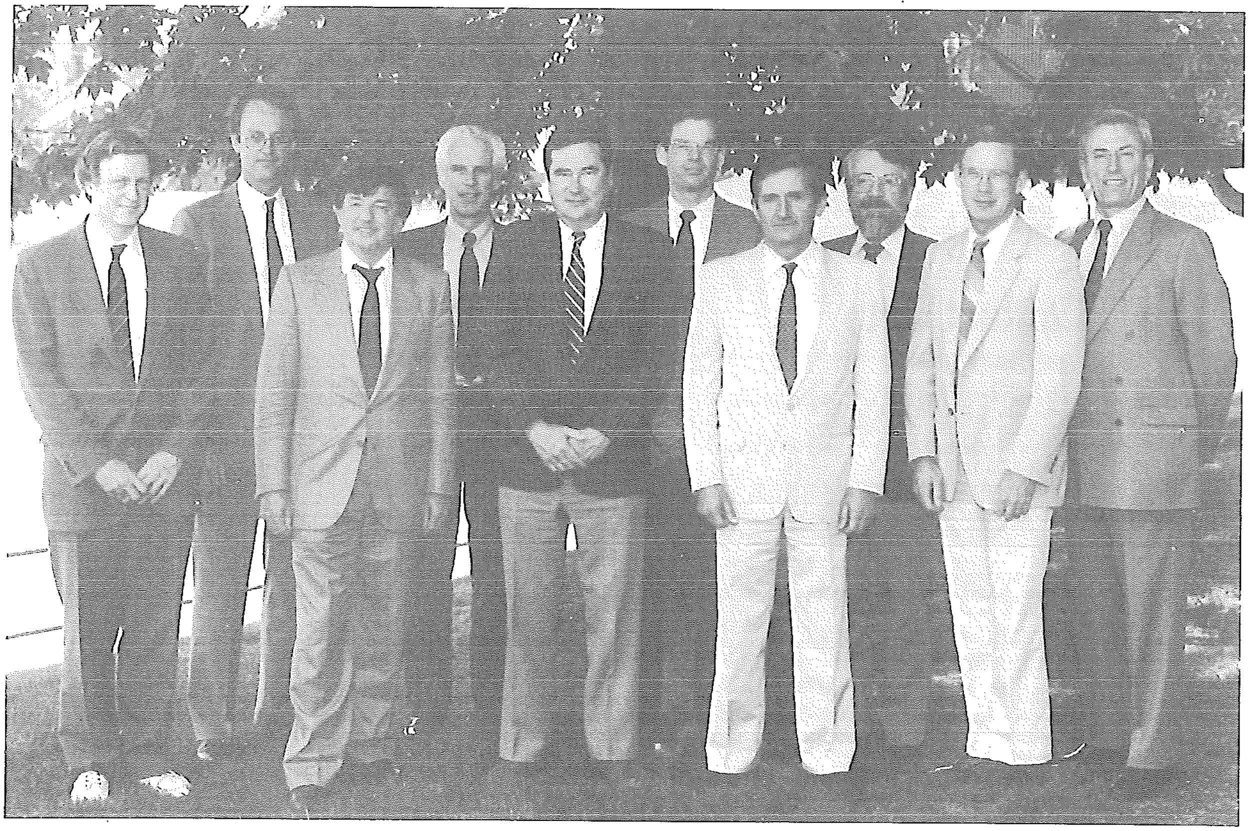
European delegates were Dr. Ch. Maissonier (Director of the EC Fusion Program), Dr. J. Darvas and Dr. A. Malein (Euratom Fusion Technology Division).

The Committee expressed satisfaction with cooperation to date, which has included direct contact between researchers in addition to project-to-project collaboration. The involvement by electrical utilities was considered to be an important and unique aspect of Canadian fusion work.

A review of the European fusion program was presented during the meeting. Overall European fusion spending during the next four years is about 450 million European Currency Units (ECU) annually, about equal to Can $600 million. The European Community supplies about 40% of this from community funds, the remaining 60% coming from national organizations of EC members.

The Third Joint Committee meeting is scheduled for April 1989 in Europe.

Joint Committee Meeting — Chalk River Nuclear Labs.



FRONT - left to right; Anthony Brace, (NFP); Janos Darvas, (Head - Fusion Technology, Euratom); David Jackson, (Director - NFP); Charles Maisonnier, (Director - EC Fusion Program); Bill Holtslander, (NFP - International Relations);
BACK - left to right; Donald Dautovich, (Head - CFFTP); Richard Bolton, (Head - CCFM); Charles Daughney, (NFP - Magnetic Fusion); Gil Phillips, (NFP - Fusion Fuels); Anthony Malein, (Euratom)

Experimental Update

Continued from front page

Forced plasma current rampdown rates of 4 Megamps/second were achieved in August, using preprogrammed and feedback control of the vertical magnetic field. Current ramps down smoothly to zero without disruption, with some vertical and some horizontal (26 mm peak-to-peak) plasma motion. Installation of the fast position control system late in 1988, with field coils inside the vacuum vessel, will facilitate studies of higher rampdown rates and stability during rampdown.

In-tokamak tests on titanium carbide refractory surface coatings have begun, as part of CCFM's research into low-Z refractory plasma-facing materials. A plasma spray technique for producing TiC coatings has been developed with NRC's Industrial Materials Research Institute. First tests of TiC 250 microns thick on a singly-curved stainless steel test limiter showed continued adhesion to the steel substrate during plasma exposures, despite flaking at the coating's edge. An improved hemispherical TiC-coated limiter head will be used in further experiments.

Ultraviolet outgassing of the vacuum vessel has proved effective. Mercury arc lamps (four at 7 watts each), installed in the vacuum vessel, have reduced pressure in four hours from 4 x 10^{-7} to 8 x 10^{-8} mbar, removing 15 equivalent gas monolayers from the vessel surface.

More information: Dr. Horst Pacher, Scientific Coordinator, CCFM.
(514) 652-8726

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.

NFP is managed for Canada by Atomic Energy of Canada Limited. Federal funding is provided by the Department of Energy, Mines and Resources through the Panel on Energy Research and Development.

'FusionCanada' Bulletin

'FusionCanada' is available free to interested person., It is published four times each year, in French and English editions. Write to NFP Office, 'Bulletin Subscriptions' (see Contact Data). Please specify French or English edition, (or both if desired), and number of copies if several are required.

Editors are invited to freely use or reprint items from 'FusionCanada'. Please credit 'FusionCanada' and National Fusion Program of Canada. Please also send to the NFP office a copy of the publication, or a proof or copy of the printed piece.

Contact Data

National Fusion Program

National Fusion Program
Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories
Chalk River, Ontario
Canada K0J 1J0

Telephone (613) 584-3311

Dr. David Jackson
Director—National Fusion Program
ext. 3175

Dr. Charles Daughney
Manager—Magnetic Confinement
ext. 3247

Dr. William Holtslander
Manager—International Program
ext. 3241

Dr. Gilbert Phillips
Manager—Fusion Fuels
ext. 4321

Program Office
ext. 3174

Fax (613) 589-2663

Telex 053-34555

Ce Bulletin est aussi disponible en français

Canadian Centre for Magnetic Fusion
(Tokamak de Varennes)

1804 Montée Ste-Julie
Varennes, Québec
Canada J0L 2P0
Telephone: (514) 652-8700
Fax (514) 652-8526

Director-CCFM: Dr. Richard Bolton

Canadian Fusion Fuels
Technology Project

Dr. D.P. Dautovich
Program Manager
CFFTP
2700 Lakeshore Road West
Mississauga, Ontario
Canada L5J 1K3

Telephone (416) 823-0200

Fax (416) 823-8020

Telex 06-982333

FusionCanada Editorial Office:

c/o Macphee Offices
Suite 300
980 Yonge Street
Toronto, Ontario
Canada M4W 2J5

Telephone (416) 925-3117

Fax (416) 925-2809

University of Saskatchewan

Physics Dept.
University of Saskatchewan
Saskatoon, Canada
S7N 0W0

Tel: (306) 966-6414
Fax: (306) 373-6088

SPAR Aerospace Ltd.
Remote Manipulator Systems Division

1700 Ormont Drive
WESTON, Ontario
Canada M9L 2W7
Tel (416) 745-9680
Fax (416) 745-4172

Contact Update:

New:	U of Saskatchewan SPAR Aerospace
Changed:	CCFM Address, Fax