INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

ITER EDA NEWSLETTER

VOL.10, No. 1 JANUARY 2001

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, AUSTRIA

ISSN 1024–5642

ITER PHYSICS COMMITTEE MEETING

by Dr. M. Shimada, Head, Physics Unit, ITER JCT

This article provides a summary of results of the ITER Physics Committee Meeting, which was held on 14 October 2000 at the ITER Garching Joint Work Site, Germany. The ITER Physics Committee is the body responsible for overseeing, through the seven specialized Expert Groups, the R&D activities contributed voluntarily by the ITER Parties. The Parties' Physics Designated Persons, the Chairs and Co-Chairs of ITER Physics Expert Groups and the JCT members involved attended the Meeting. As usual, the meeting was chaired by the ITER Director, Dr. R. Aymar, who reported on the status of the ITER EDA. Dr. Aymar described the steps being taken in preparing the ITER-FEAT Final Design Report (FDR), and further stated that the Report would be available in time to be of benefit to the Negotiations on the ITER Joint Implementation, expected to start around May 2001.

All Parties recognize that the ITER Physics Expert Group structure has been useful in focusing the tokamak physics activity on the ITER-relevant issues and provides an efficient worldwide collaboration on confirming innovative solutions. The concept of an international workshop to be organized as a pre-meeting of each Expert Group meeting, in order to involve U.S. scientists in the discussion of generic tokamak physics issues, was introduced in 2000, with some success, and its goal should be pursued.

The International Fusion Research Council (IFRC), an advisory body to the IAEA, at its meeting of 2 October 2000 at Sorrento (Italy), endorsed a proposal for an "International Tokamak Physics Activity (ITPA)" to continue and broaden the co-ordination of the voluntary physics activities beyond the ITER EDA Agreement; it has invited the members of the IEA Fusion Power Co-ordinating Committee (FPCC) to participate, concluding that the participants should make the necessary arrangements to facilitate the conduct of this Activity.

Chairs of the Expert Groups reported the following results of the Groups' activities:

Diagnostics (A.J. Donne)

Good progress was made on the tasks designated as 'high priority' for the year 2000:

- Two techniques for measuring the q-profile are being pursued.
- Work has continued on the plasma facing mirrors. An extensive, co-ordinated three party experimental programme has shown that mirrors made from monocrystalline refractory metals can have a long lifetime even at the neutral particle flux levels expected at the first wall.
- The measurement requirements in the divertor region are being critically re-assessed in collaboration with the Divertor Expert Group.

MHD, Disruptions, and Control (O. Gruber)

The complete stabilization of Neoclassical Tearing Modes (NTM) and subsequent recovery of plasma confinement were demonstrated in ASDEX-Upgrade, JT-60U, DIII-D and COMPASS at low current drive powers.

Resistive wall modes (RWM) are observed in DIII-D and JT-60U, and preliminary tests to stabilize them have started on DIII-D.

As for disruptions, in ASDEX-Upgrade, a neural network predicting the time till disruption is now routinely in real-time operation, triggering avoidance and mitigation (killer pellets) measures.

Runaway electrons are rarely observed in divertor experiments having VDE's during disruptions. If they do occur, they are eliminated by helical instabilities at $q \approx 2$ (JT-60U).

Edge and Pedestal Physics (Y. Kamada)

ELMs with small amplitudes are observed in JT-60U, ASDEX-Upgrade, and Alcator C-Mod with triangularity higher than 0.4 and safety factor (q95) higher than 3.5-4. Collaborative work between JT-60U and DIII-D suggests that a type-I ELM is triggered by an ideal mode with medium mode number (>5-8), and a type-II ELM with higher n (>10), thus narrower radial distribution. Multi-machine analysis shows a favorable effect of triangularity for achieving higher pedestal pressure (and consequently higher confinement).

SOL and Divertor Physics (N. Asakura)

A multi-machine analysis of ELM energy, deposition and reduction has been presented at the IAEA Sorrento Conference. The predicted ELM energy is 12 MJ in ITER and the deposition time is 200 μs, raising concern about the ablation of divertor plate material; but it is recognized that the present understanding of ELM physics is far from being satisfactory. More detailed measurements in the SOL and divertor revealed transport characteristics (drift, diffusion and wall neutral source) not included in the simulation codes. The electron density profiles are significantly different between JET and ASDEX-Upgrade, which produced different performance in divertor radiation.

Energetic Particles, Heating, and Steady State Operation (C. Gormezzano)

- High-energy particle ripple losses in advanced scenarios will be negligible in ITER with ferritic inserts.
- Good current drive efficiency is observed from neutral beams and electron cyclotron (EC) waves.
- Design of an ITER type ion cyclotron antenna to be tested in JET.
- Improved coupling is observed for Lower Hybrid waves in H-modes.
- EC is shown to be efficient in stabilizing NTM. The power required is in agreement with a simple theory. For ITER, EC power of 20 MW appears to be adequate.
- Promising steady state scenarios ($q_{95} \approx$ 4-5, $q_{min} \approx 1.5$, $I_{BS}/I_p \approx 50\%$) are demonstrated; the performances of these discharges appear to be limited by RWM. Substantial development is still needed (active profile control, fuelling, He ash removal, divertor compatibility).

Transport and Internal Barrier Physics (M. Wakatani)

For the optimized shear configuration corresponding to the high β_p plasma with monotonic q(r), the threshold power to achieve an internal barrier appears to scale with the increase of B_T (in contrast with the result shown by JT-60U). The threshold power for reversed shear configurations was reduced in JET with Lower Hybrid wave pre-heating.

For the high-density operation close to the Greenwald limit, it is shown that impurity injection can be used to keep the improved confinement. As suggested by the numerical simulations for the ITG or ETG turbulence, evidence of critical temperature gradient is shown in DIII-D, ASDEX-U and Tore Supra. Particularly for ASDEX-U, the stiffness of the temperature profile is also seen.

Confinement Database and Modeling (J. G. Cordey)

The new improved ELMy H-mode confinement database still fits rather well the IPB98 (Y,2) scaling and the JCT is advised to continue to use this expression in performance studies. The confinement time confidence interval of ±14.5% is currently being revised but it is not expected to change significantly.

Work on the profile database has been somewhat limited during the year; however, the Nuclear Fusion paper on the structure of the database has been published, and a plan to reactivate this work has been agreed.

Reports by the Designated Physics Persons (ITER Parties representatives)

Designated Physics Persons reported their Parties' research plans for 2001, which supported the research goals proposed by the Expert Groups. Among them the High Priority Research areas for 2001 were agreed and are listed in the following Table.

High Priority Physics Research Areas

	Research Areas	Issues
*	Finite-β effects in H-mode	Tolerable ELMs ($\delta W/W<2\%$) with good confinement alternate to type-I ELMs (e.g. type II, Type III+core confinement) Stabilisation of neoclassical islands at high β and recovery of β
*	Plasma termination and halo currents	Runaway electron currents: production and quenching, e.g. at low safety factor
*	SOL and divertor	Achievement of high n_{sep} and relation of $n_{sep}/<n_e>$ in ELMy H-modes, especially at high n and δ Carbon chemical sputtering, redeposition and deuterium retention/cleaning methods
*	Core confinement	Non-dimensional scaling and identity experiments; effect of finite β and flow shear Determine dependence of τE upon shaping, density peaking etc.
*	H-mode power threshold	H-mode accessibility in ITER-FEAT, data scatter
*	Good H-mode confinement at high n	Confinement degradation onset density; its dependence on aspect ratio, shape and neutral source
*	Pedestal physics	Scaling of pedestal properties and ELMs Effects of plasma shape on pedestal and ELMs MHD stability analysis of transport barrier
	Internal transport barrier properties	ITB power thresholds versus n, B, q, Te/Ti, V-rotation etc. for strong reversed shear ($q_{min}>3$), moderate reversed shear ($q_{min}>2$), and weak shear ($q_{min}>1$). Compatibility with impurity exhaust and divertorAccessibility of ITBs in reactor scale devices at low toroidal rotation, $Ti/Te \approx 1$, and flat density profile, etc.
	Resistive Wall Mode	RWM analysis and experimental verification
	Heating/CD, Steady State	Development of steady state scenarios: active current and pressure control Active control of LHCD coupling Assess fast particle effects (ELMs and ITBs)
	Diagnostics	Continue assessment of possible methods for measurement of q(r) and search for new approaches Continue study of First Mirrors especially effects of deposition and possible mitigating methods Assess impact of RIEMF on magnetic measurements and perform improved measurements on prototype magnetic coils Complete determination of measurement requirements for divertor target and divertor plasma parameters (in collaboration with the Divertor Expert Group), and complete assessment of probable performance of proposed diagnostic methods
* : relevant to main scenario (ELMy H)		

LIST OF PARTICIPANTS

CHAIR: R. Aymar, CO-CHAIR: M. Shimada
JA: K. Miyamoto, M. Wakatani, T. Tamano, H. Ninomiya, N. Asakura, Y. Kamada
EU: A. Loarte, D. Campbell, O. Gruber, H. Zohm, F. Romanelli, G. Cordey, A. J. Donne, C. Gormezano
RF: N. V. Ivanov, Y. N. Dnestrovski, S. Mirnov
ITER JCT: Y. Shimomura, A. Costley, Y. Gribov, V. Mukhovatov, G. Janeschitz, A. Polevoi

IAEA ACTIVITIES RELATED TO ITER

by Drs. T. J. Dolan and U. Schneider, Physics Section, IAEA

The purpose of this article is to describe some recent and future IAEA fusion research activities that are relevant to ITER.

As agreed between the IAEA and the ITER Parties, special sessions are dedicated to ITER at the IAEA Fusion Energy Conferences. At the 18th IAEA Fusion Energy Conference, held on 4-10 October 2000 in Sorrento, Italy, in the Artsimovich-Kadomtsev Memorial opening session there were special lectures by Carlo Rubbia (President, ENEA, Italy), A. Arima (Japan), and E. P. Velikhov (Russia); an overview talk on ITER by R. Aymar (ITER Director); and a talk on the FTU experiment by F. Romanelli. In total, 573 participants from 34 countries presented 389 papers (including 11 post-deadline papers and the 4 summaries).

The oral session on ITER had the following presentations:

- M. Huguet, Key engineering features of the ITER-FEAT magnet system and implications for the R&D programme;
- Y. Shimomura, ITER-FEAT operation;
- A. Loarte, Predicted ELM energy loss and power loading in ITER-FEAT;
- S. Kukushkin, Basic divertor operation in ITER-FEAT;
- G. A. Janeschitz, Divertor design and its integration into the ITER-FEAT machine;
- H. Tsuji, Progress of the ITER central solenoid model coil programme;
- K. Ioki, ITER-FEAT vacuum vessel and blanket design features and implications for the R&D programme;
- V. Mazul, Status of R&D of the plasma facing components for the ITER divertor.

Many other detailed reports were presented in the ITER poster session at the Conference about the plasma, magnets, vacuum vessel, divertor, plasma facing components, system integration, experimental operations, and safety. In total, 31 papers were presented, the authorship of which includes the members of the ITER Joint Central Team, the Home Teams and the ITER Physics Expert Groups. The ITER papers were an essential contribution to the Conference, which provided a comprehensive picture of this leading worldwide activity, and ITER participants benefited from interaction with related research done elsewhere.

In conjunction with the Conference, there was also an informal presentation in which the past, present, and future ITER activities were discussed (see separate article in ITER EDA Newsletter Vol. 9, No. 11, November 2000).

For the previous IAEA Fusion Energy Conference there had been great difficulty receiving electronic manuscripts for the proceedings, due to the incompatibility of computers and file formats and incorrect submission procedures. This year Agency staff implemented a new, password protected, web-browser-based file transmission system called LISA. This system guided authors to modify their submissions until they were in the correct "Portable Document Format" (PDF) for receipt. Practically all of the 378 files submitted to the IAEA were received correctly within two months after the conference, which is a big improvement over the previous conference in timeliness of production and reduction of staff time required.

The 19th IAEA Fusion Energy Conference will be held in Lyon, France, in October 2002, and the 20th IAEA Fusion Energy Conference is tentatively planned for Portugal in 2004, pending a formal agreement. It is planned to have dedicated oral and poster sessions on ITER at those conferences, as in the past.

Some of the latest IAEA Co-ordinated Research Projects are of relevance to ITER issues, namely:

- Plasma-wall interaction data for divertor modelling (1995-2000)
- Charge exchange data for fusion plasma (1997-2000)
- Plasma-material interaction data (1997-2000)

Among the Co-ordinated Research Projects being executed now or being planned for the near future, the following will address issues relevant to ITER:

- Atomic and molecular data for plasma diagnostics (2000-2003)
- Data for molecular processes in edge plasma (2001-2005)
- Tritium inventory in fusion reactors (2002-2004)

In 2001, the IAEA will hold the following Technical Committee Meetings (TCM):

• TCM on Research Using Small Fusion Devices	25-27 June	Sao Paulo, Brazil
• TCM on Control, Data Acquisition and Remote Participation for Fusion Research	16-19 July	Padova, Italy
• TCM on Spherical Tori	1-3 Aug.	San Jose dos Campos, Brazil
• TCM on H-Mode Physics and Transport Barriers	5-7 Sep.	Toki, Japan
• TCM on High Average Power Drivers	9-14 Sep.	Kyoto, Japan
• TCM on Divertor Concepts	11-14 Sep.	Aix-en-Provence, France
TCM on Energetic Particles in Magnetic Confinement Systems	8-11 Oct.	Gothenburg, Sweden

The following Technical Committee Meetings are tentatively planned for 2002-2003:

2002
- Steady State Operation of Tokamaks
- ECRH Physics and Technology for Fusion Devices
- Inertial Fusion Energy

2003
- Research Using Small Fusion Devices
- H-mode Physics and Transport Barriers
- Control, Data Acquisition, and Remote Participation for Fusion Research
- Energetic Particles in Magnetic Confinement Systems
- Transport Modelling in Magnetic Confinement Fusion Devices
- Spherical Tori.

The IAEA activities include the Nuclear Fusion Journal, of which a special issue was devoted to the ITER Physics Basis (NF, Vol. 39, No. 12, Dec. 1999, pages 2137-2638). Nuclear, atomic, molecular, and plasma-material interaction data are collected, evaluated, and provided by the IAEA Nuclear Data Section. In addition, the Agency's programme has included and will include many other technical meetings of relevance to ITER. For example, fusion safety issues were covered in a recent Technical Committee Meeting held in Cannes, France (see separate article in ITER EDA Newsletter, Vol. 9, No. 9, September 2000).

The International Fusion Research Council (IFRC), an advisory body to the IAEA, will continue to meet annually to advise the Agency on its fusion-related activities. The relationship of the International Energy Agency (IEA) and IAEA programmes was discussed in the article "IAEA and IEA roles in international fusion energy research", published in the May 2000 issue of this Newsletter (Vol. 9, No. 5). The IAEA will continue to participate in the Fusion Power Co-ordinating Committee Meetings of the IEA, and an IEA representative will

continue to participate in the IFRC meetings of the IAEA, in order to continue the good co-ordination of the two agencies' programmes.A panel of five outside experts conducted, in the second part of 2000, a Programme Performance Assessment System (PPAS) review of IAEA fusion research activities. The panel noted that some previous recommendations to the Agency had not been carried out, due mainly to lack of staff and financial resources. They recommended that the Agency should:

- make fusion activities a major long-term mission of the Agency at the Subprogramme level;
- continue to facilitate the ITER collaboration;
- implement a new Research & Development Collaboration Programme;
- undertake an intensive public information campaign to tell people about the importance of fusion energy development.

In preparation for the Joint Implementation of ITER, the current ITER EDA Parties conducted non-committal discussions ("Explorations") to prepare for negotiations concerning Joint Implementation. In the report on the results of Explorations the participants recommended that the Co-ordinated Technical Activities (CTA), deemed necessary to maintain the integrity of the international project, so as to prepare for the ITER Joint Implementation, be conducted under the auspices of the IAEA.

After receiving the report on Explorations, the IAEA Director General ElBaradei sent letters to the current ITER EDA Parties in January 2001. The final paragraph stated, "Against this background, I would be grateful if your Government were to confirm its intention to participate in Co-ordinated Technical Activities in preparation for the joint implementation of ITER, in accordance with the Terms of Reference and the recommendations contained in the record of the fourth meeting of ITER Explorers. In that event the Agency is ready to continue to provide services in support of such activities consistent with the Terms of Reference and its attachment." In this way the Agency is helping to facilitate agreement between the Governments of the ITER Parties for participation in the CTA.

The IAEA is ready to support ITER during the Co-ordinated Technical Activities by:

- maintaining an ITER office in Vienna;
- assisting with intergovernmental relations;
- publishing ITER documents;
- producing the ITER Newsletter;
- hosting some ITER meetings;
- managing the ITER Joint Fund.

In conclusion, the IAEA is pleased to be associated with ITER, and many of its activities are relevant to ITER issues.

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kuvshinnikov, ITER Office, IAEA, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: +43 1 2633832, or e-mail: c.basaldella@iaea.org (phone +43 1 260026392).

Printed by the IAEA in Austria
April 2001

01-00559