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ELEVENTH MEETING OF THE ITER MANAGEMENT ADVISORY COMMITTEE (MAC-11)

by Dr. M. Yoshikawa, MAC Chair

MAC-11 was held at the JAERI Headquarters in Tokyo on 21 and 22 November 1996. The replacement of an RF MAC Member was announced: Dr. Nikolai P. Kornev was replaced by Dr. Sergey Reprintsev, who will also be the RF MAC Contact Person.

The MAC noted that Dr. Robert Iotti, Administrative Officer, left ITER as of 1 November 1996. It further noted that Dr. Iotti's responsibilities have been distributed among appropriate staff members throughout the JCT, who will report to the ITER Director.

The ITER Director, Dr. R. Aymar, summarized the progress made in the ITER Engineering Design Activities in the period between IC-10 (July 1996) and November 1996. The overall focus of the Project has been the preparation of the Detailed Design Report, Cost Review and Safety Analysis for presentation to IC-11. A major component of the DDR preparations was the completion, with valuable contributions from the four Home Teams, of a comprehensive assessment of ITER Safety and Environmental characteristics. The progress of ITER, especially as concerns Physics, was reported at the Sixteenth IAEA Fusion Energy Conference held in Montreal, Canada, 7-11 October. ITER was the subject of 34 papers or posters with over 400 JCT/Home Team authors drawn from almost 60 different organizations.

Following the Director's Status Report, MAC reviewed the Work Program and a schedule of ITER Meetings.

Participants in the Meeting

Work Program

MAC noted that the EDA Work Program has been updated to reflect the overall ITER schedule shown in the DDR and to be consistent with the current levels of EDA resources. Against this background, the Director considered that the deliverables expected from the Work Program will provide, at the end of the EDA, the technical information necessary for a construction decision, thus satisfying the purpose of the EDA Agreement. MAC supported this conclusion.

MAC, therefore, recommended to the ITER Council:

- to approve the EDA Work Program, including the proposed allocation and sharing of tasks and the statement of EDA resources;
- to ensure that resources are maintained at current levels so as to permit implementation of the EDA Work Program;
- to note the expected deliverables of the EDA arising from the EDA Work Program which, given maintenance of the current levels of resources, is considered to satisfy the purpose of the ITER EDA Agreement.

Concerning the possible actions to be proposed, MAC supported the Director's view of the need for continuity in the transition from the EDA to the construction activities. It recommended to the ITER Council to invite the Director, in consultation with the Home Team Leaders, to elaborate further the technical activities and estimated resources that would provide the required continuity.

MAC recommended the ITER Council to approve a supplement, shared equally by the Parties, to the ITER Joint Fund Budget for 1997 to permit increases in Design Support contracts as proposed by the Director.

Schedule of ITER Meetings

MAC reviewed and supported the schedule of Technical Meetings and Workshops proposed by the Director. Following are the Meetings scheduled for 1997:

ITER Meetings

2nd Technical Meeting (TM) on Neutral Beam Injection	17-20 February 1997	Naka
NSSR-2 and Final Design Report Safety TM	March/April 1997 (3 days)	San Diego
Diagnostics TM	10-12 March 1997	Naka
4th TM on Quality Assurance	April 1997 (3 days)	Naka or Garching or St. Petersburg
Test Blanket Working Group - 4	14-16 April 1997	Japan
Diagnostics TM	September 1997 (2 days)	Varenna

ITER Physics Meetings

Confinement & Transport Expert Group (EG) Workshop to be combined with Confinement Modelling & Database EG Workshop	February 1997 (4 days)	Naka or US
MHD, Disruptions and Plasma Control Expert Group Workshop	March 1997 (4 days)	RF
Divertor Modelling & Database Expert Group Workshop (emphasis on Database)	March 1997 (3 days)	San Diego
Diagnostics Expert Group Workshop	10-12 March 1997	Naka
3rd Energetic Particles, Heating & Current Drive EG Workshop (Heating & CD Emphasis)	July 1997 (3 days)	Germany

Divertor Expert Group & Divertor Modelling Database Expert Group Joint Workshop	July 1997 (5 days)	Germany
Confinement & Transport Expert Group Workshop to be combined with the Confinement Modelling & Database EG Workshop	September 1997 (4 days)	Garching
4th Energetic Particles, Heating & Current Drive Expert Group Workshop (Energetic Particles Emphasis)	September 1997 (3 days)	JET
Diagnostics Expert Group Workshop	September 1997 (2 days)	Varenna

MAC tentatively decided that the MAC-12 meeting will be held on 26 and 27 June 1997 in San Diego or Garching, depending on the place for the ITER Council meeting.

THIRD WORKSHOP OF THE ITER CONFINEMENT AND TRANSPORT EXPERT GROUP

by Dr. V. Mukhovatov, ITER JCT, and Prof. M. Wakatani, Kyoto University

The 3rd Workshop of the ITER Expert Group on Confinement and Transport was held in Montreal, Canada, on 12-13 October 1996, between the 16th IAEA Fusion Energy Conference and the ITER Technical Advisory Committee (TAC)/ITER Physics Committee (IPC) Meeting. The objectives of the Workshop were as follows:

(1) Review and comment on draft sections of the Physics Chapter of the ITER Detailed Design Report (DDR) regarding the plasma confinement;
(2) Assess the progress towards meeting the ITER Confinement Research Needs; assess whether the coverage of the needs is adequate; if necessary recommend new priorities for the ITER Research Needs for 1997;
(3) Prepare the report to the TAC/IPC;
(4) Draft plan for the future work.

The Workshop began with reports from DIII-D and ASDEX-Upgrade on a Special Topic, i.e., tokamak operation above the Greenwald limit. Both machines show a possibility of H-mode operation at densities up to 1.5 times the Greenwald limit with controlled pellet injection. The pellet fuelling from the high toroidal field side was shown in ASDEX Upgrade to be much more effective compared to that from the low field side.

Five topics included in the ITER Physics Research Needs were discussed, i.e.:

3.1: H-mode power threshold,
3.2: Tokamak discharges with ITER non-dimensional parameters,
3.5: Confinement improvement in discharges with L-mode edge,
3.6: Development of transport models, and
3.7: Investigation of advanced tokamak scenarios for ITER.

High Priority Need 3.3 "Differential Transport of Helium and Hydrogen Isotopes" has been completed for nominal discharges in 1995. This need has been converted to a Long-Term Need focused on helium confinement in negative central shear discharges. It has not been included in the agenda of this Workshop. High Priority Need 3.4 "How can we ccontrol ELMs?" has been transferred (according to the TAC recommendation) under direction of the ITER Divertor Database and Modeling Expert Group.

Because of a very tight schedule, 30-minute rapporteur reports have been presented instead of original reports from various tokamaks on each of research topics. The rapporteur reports were followed by ~1-hour discussions. Most research teams have prepared Progress Reports and made them available for the rapporteurs before the Workshop. Rapporteurs had also assimilated experimental and theoretical materials presented at the 16th IAEA Conference in their topical areas.

The main results regarding the Urgent Research Needs 3.1 and 3.2 revealed at the Workshop are as follows:

(i) despite the extension of the H-mode threshold database, the uncertainty in predictions of the power threshold for ITER remains large, i.e., P_{thr} = 50 - 200 MW at $\overline{n}_e = 0.5 \times 10^{20}$ m^{-3}; and
(ii although the ITERH93-P confinement scaling is broadly confirmed, e.g., the scaling of τ_E with non-dimensional variables $\rho^* = r_d/\alpha$ and υ^*, there are new experimental data which call for a revision of the scaling (in particular, scaling with β has been found to be more favourable in JET and DIII-D).

Results from ASDEX Upgrade, Alcator C-Mod, COMPASS-D and TEXTOR-94 show that discharges with good confinement, comparable with that in the ELMy H-mode, can be obtained with L-mode like edges (Need 3.5). Significant progress is observed in studies of the advanced tokamak scenarios, i.e., discharges with internal transport barriers in both L- and H-modes (DIII-D, JT-60U, JET, TFTR, PBX-M, TORE-Supra, Alcator C-Mod) (Need 3.7). These results are generally favourable for ITER although their applicability to ITER operation is not yet fully clarified. Further progress has been achieved in development of transport models based on gyro-fluid turbulence simulations taking account of flow shear and flux surface geometry, and first steps have been made in addressing an edge pedestal model (Need 3.6). The results of the 1996 Confinement and Transport R&D discussed at the Workshop are given in greater detail in the following boxes, along with remaining issues and plans for 1997:

URGENT RESEARCH NEED 3.1: H-MODE POWER THRESHOLD (S. WOLFE)

During 1996, additional data has been collected which helps to improve understanding of the H-mode transition physics. Increased attention to local, rather than global, parameters is proving fruitful. However, progress in reducing the error bar on the projection of the necessary power for ITER has been minimal. The physics of the back-transition and H-L hysteresis is being addressed by several experiments; however, there is not yet a fully consistent picture. The role of neutrals remains unclear. Edge plasma temperature and/or ion gyro radius have been identified as candidate parameters controlling the transitions (DIII-D, ASDEX Upgrade, Alcator C-Mod). Further experiments and/or a viable theoretical model are needed to narrow the range of the threshold predictions for ITER. Studies of edge parameters are planned on Alcator C-Mod, ASDEX Upgrade and DIII-D. Effect of divertor geometry on the power threshold will be studied on ASDEX Upgrade, JT-60U and JFT-2M.

URGENT RESEARCH NEED 3.2: ITER DEMONSTRATION DISCHARGES (J.G. CORDEY)

ITER demonstration discharges, i.e., those with all dimensionless parameters except for ρ^* close to ITER, have been produced and analyzed in DIII-D, JET, ASDEX Upgrade and JT-60U. The DIII-D/JET identity experiments have demonstrated the validity of the dimensionless approach to predicting confinement in ITER, and that ρ^*, υ^* and β are the key physics parameters defining the plasma confinement in tokamaks. The ρ^* scaling of the thermal diffusivity χ_i in H-mode plasmas with Type I ELMs is close to gyro-Bohm type for the region $0.2 < r/a < 0.8$ (DIII-D, JET, ASDEX Upgrade). The υ^* scaling of τ_E is very similar to that of the ITERH93-P scaling, i.e., $\tau_E \propto \upsilon^{*-0.28}$, while the degradation of τ_E is with β is very weak in contrast with the ITERH93-P scaling prediction (DIII-D, JET). JT-60U shows gyro-Bohm like scaling for τ_E at a high triangularity $\delta \sim 0.35$, whilst it is Bohm like for $\delta < 0.1$ in ELMy H-mode. This difference has been attributed to the different ELM behaviour. Alcator C-Mod has the H_H factor above unity. This puts into question a strong R dependence in the ITERH93-P scaling. Other possibilities are confinement improvement with divertor closure or wall boronization. On the other hand, JT-60U data taken at relatively high aspect ratio show $H_H < 1$, which casts doubt on the aspect ratio dependence in the scaling. Investigations are under way to resolve these discrepancies.

HIGH-PRIORITY RESEARCH NEED 3.5; CONFINEMENT IMPROVEMENT IN DISCHARGES WITH L-MODE EDGE (K. TOI)

Discharges with L-mode like edge and improved confinement are of interest to ITER as alternative, ELM-free, scenarios with reduced requirements on β-values. They include:

(i) discharges at increased L-H power threshold, e.g., with ion ∇B drift from X-point (ASDEX Upgrade with $H_{ITER89P} \leq 1.5$ using NBI, Alcator C-Mod with the same H-factor using ICRH, and COMPASS-D with $H_{ITER93P} \sim 1$ using ECRH);
(ii) radiative l-mode (RI-mode) with edge radiation cooling (radiated power fraction of ≈90%) and H factor of ~1 with respect to the ITERH93-P ELM-free scaling obtained in TEXTOR-94 at $\overline{n}_e/\eta_{Greenwald} \approx 0.8 \sim 1.1$ with neon seeding in the presence of the pumped toroidal belt limiter;
(iii) improved L-mode in JET with $H_{ITER89P} \approx 2$ using ICRH and pumped divertor; and
(iv) improved L-mode in TORE-Supra with $H_{ITER89P} \leq 2$ using LH and fast wave heating. Further studies of these discharges are planned on ASDEX Upgrade, JET, TORE-Supra and TEXTOR.

HIGH-PRIORITY RESEARCH NEED 3.6: TRANSPORT MODEL DEVELOPMENT (J.W. CONNOR)

There are areas of inadequate coverage which include models for ELMs, particle diffusivity and pinches, plasma rotation, wall conditioning effects on confinement, role of fast ions, and edge boundary conditions. New priorities have been identified, i.e., the effects of ELMs on transport globally near the β-limit; a validated model for the L-H transition; the development and benchmarking of transport codes with sources, emphasizing particle transport; an ITG model elongation scaling; a self-consistent model for flow shear stabilization in gyro-fluid turbulence codes. Plans for 1997 include:

(i) further development of transport models based on gyro-fluid/gyro-kinetic simulations;
(ii) development and validation of models for L-H transition and self-organized criticality;
(iii) inclusion of E_τ in energy balance codes, and
(iv) further exploitation of the transport models based on the self-sustained turbulence of the current diffusive ballooning mode.

LONG-TERM RESEARCH NEED 3.7: INVESTIGATION OF ADVANCED SCENARIOS FOR ITER (P. GOHIL)

Reserve-shear, high bootstrap current discharges are considered as a candidate steady-state operating mode for ITER. Discharges with negative central shear (NCS) have been produced in DIII-D, JET, JT-60U, TORE-Supra, TFTR, ALCATOR C-Mod and COMPASS-D. Significant reductions in plasma transport have been observed in such discharges at heating powers above a threshold value. High-β NCS discharges with improved confinement ($\beta_N H \sim$ 10-15) are still transient, although long-pulse (up to 7.5 s) LHCD-sustained NCS discharges have been obtained in JT-60U at low density and low β. Further studies are planned to improve the physics understanding of internal transport barriers and test their compatibility with reactor requirements (impurity transport, i.e., helium accumulation, is one of the major concerns).

The recommendations of the Expert Group regarding the 1997 R&D plan are as follows:

- keep the topics 3.1 and 3.2 as Urgent Needs*) and the topic 3.6 as a High Priority Need with revised issues and deliverables;
- combine topics 3.5 and 3.7 in one High Priority Need "Investigation of alternative scenarios for ITER", listed under 3.5;
- add High Priority Need 3.4: "Effect of ELMs and sawteeth on energy and particle confinement"; and
- add Long-Term Need 3.7: "Effect of wall conditioning on core plasma confinement".

The Joint Meeting with the ITER Confinement Database and Modelling Expert Group was held on the 2nd day of the Workshop. The status of uncertainties in the ITER confinement predictions and Confinement Sections of the ITER Detailed Design Report were discussed at the Meeting.

O. Kardaun noted that the 95% confidence intervals for τ_E(ITER) of $\pm$30% given by standard statistical techniques for the ITERH93-P(ELM-free) and ITERH92-P(ELMy) confinement scalings are correct only if the power law functional form of the scalings is correct and there are no hidden variables. Arguments were presented to assess the uncertainty also while taking into account the fact that a simple power law may not hold and that there exist systematic experimental differences between various measurements of the thermal energy content. In this broader context, this led to a 95% interval estimate for τ_E(ITER) of 3.5 to 9 seconds.

A log-non-linear scaling with a lower RMS error, compared to the ITERH93-P, predicting for ITER a 30% lower energy confinement time has been proposed by W. Dorland. He noted that the density and aspect ratio exponents in the ITERH93-P scaling could not be justified by using the available database.

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*) Definition for 1997 R&D Needs is as follows (note that this definition is different from that for the 1996 R&D Needs):
"Urgent" - Information needed for the Final Design Report (therefore by 1 September 1997)
"High Priority" - Information needed during the ITER construction period
"Long Term" - Information that will better define ITER operations and/or lead to improvement in our confidence for ITER projections.

J.G. Cordey argued that a constrained power law form of confinement scaling has a clear physics basis for ITER similarity pulses, and hence should be used in the first place. He noted that the more sophisticated non-linear models must have a clear physical basis or their ITER predictions become unbounded.

D. Boucher discussed effects on the ITER performance of $\pm$30% changes in the energy confinement time relative to the ITERH93-P scaling, and F. Perkins discussed possible actions to improve confidence in confinement projections.

It was proposed that the Confinement Database and Modelling Expert Group should revise the ITERH93-P confinement scaling, taking into account new experimental data and recommend a 95% interval estimate for τ_E in ITER by the end of 1996.

A series of comments on the draft Confinement Sections of the ITER Detailed Design Report have been prepared by the Experts before the Meeting, and many additional comments were made at the meeting. It was advised that the DDR document should be self-contained and reference to the IDR should be avoided. Many comments called for clarification and more detailed description of particular issues, e.g., the role of the 1.5-D transport simulation in the ITER performance predication; the use of the H-mode hysteresis; consistency of core confinement and divertor requirements, etc. These comments were integrated by M. Wakatani and J.G. Cordey for presentation at the joint TAC/IPC Meeting.

It was proposed to hold the 4th Workshop of the Confinement and Transport Expert Group in Naka (Japan) or in Garching (Germany), February 1997, with the focus on:

- Assessment of the progress in implementing the Urgent Tasks:
  3.1 H-mode Power Threshold
  3.2 ITER Demonstration Discharges
- Discussion of Alternative Tokamak Scenarios for ITER (High Priority Task 3.5), and
- Discussion of Effect of Wall Conditioning on Core Plasma Confinement (Long-Term Task 3.7)

LIST OF PARTICIPANTS

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