INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

ITER EDA NEWSLETTER

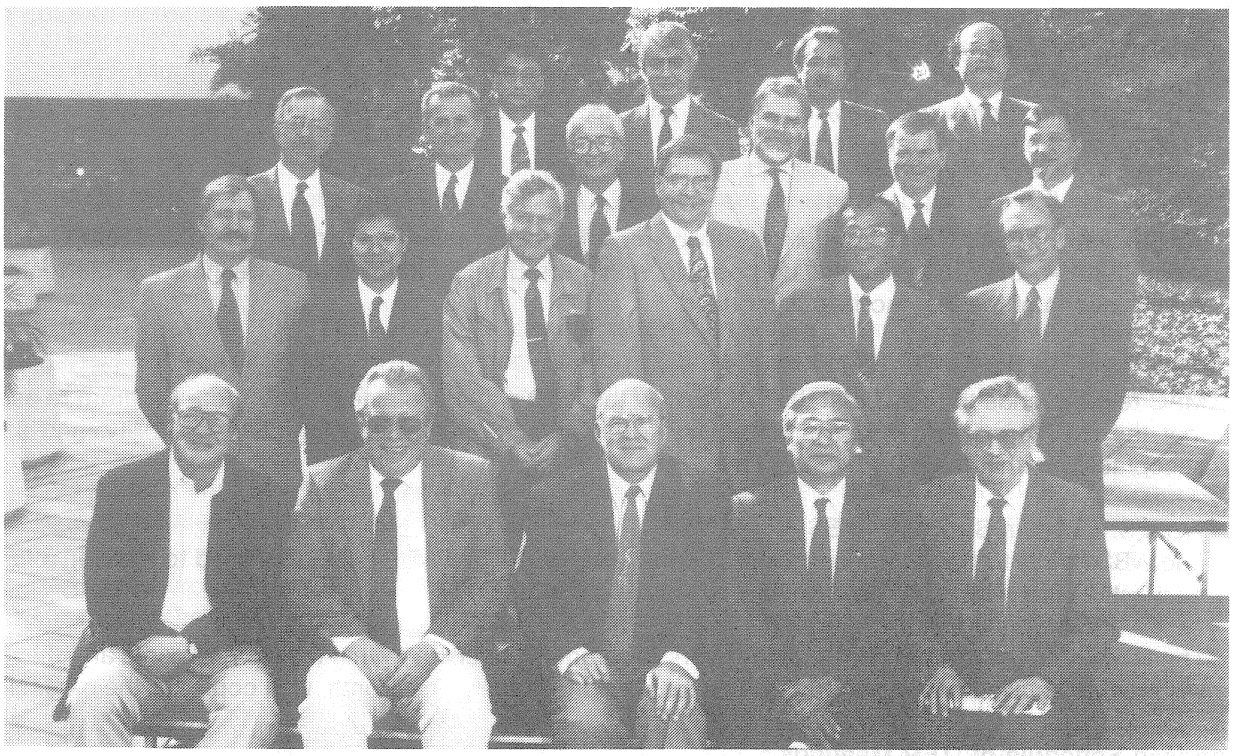
VOL.3, NO. 1 JANUARY 1994

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, AUSTRIA

FOURTH MEETING OF THE ITER MANAGEMENT ADVISORY COMMITTEE (MAC)

by Dr. M. Yoshikawa, MAC Chair

The fourth meeting of the ITER Management Advisory Committee (MAC) was held at the ITER Joint Work Site, San Diego, USA, on 13-14 January, 1994. All MAC members attended the meeting. The MAC invited three Deputy Directors, Dr. Y. Shimomura, Dr. V. Chuyanov and Dr. R. Parker, as experts for the MAC as a whole, Mr. T. Ide as an expert for the Japan delegation, Dr. B. Montgomery as an expert for the US delegation, Administrative Officer, Dr. R. Sheldon and Mr. M. Drew as experts for the JCT. Dr. D. Gambier was invited to explain the IPMS as proposed.



Participants in the Meeting

The MAC reviewed various proposals by the Director including a proposed Work Program for the ITER EDA, a schedule of ITER meetings and proposals for task agreements. Among other things, the MAC also considered technical information related to a proposal for the involvement of the Republic of Kazakhstan through RF contribution to the ITER EDA.

Proposed Work Program

The MAC recommends to the Council the approval of the Director's prepared ITER EDA Milestones, as revised at the meeting. The Director presented a proposed Work Program for the ITER EDA. An earlier version of the

Work Program was submitted to the ITER Council at IC-3 and was reviewed by MAC, which commented on it in detail in the MAC-2 report to the IC. The revised Work Program proposal includes thoughtful responses to the MAC-2 recommendations.

The MAC takes note of the proposed Work Program and makes, inter alia, the following recommendations:

- Deliverables
  MAC recommends that the IC ask the Director to define in detail what deliverables are possible, based on the estimated resources [see Art.12(1)], and thereby enable the Parties to determine whether this would provide for the start-up of construction at the end of the EDA. The implications of the estimated EDA effort regarding the start of actual ITER construction and the required design during construction should be specified by the Director. This assessment should be completed within six months. An updating should be considered after the Council has taken into account recommendations from the Director and MAC on the relationship between deliverables/milestones and available sources.

- Milestones
  The planning is based on the assumption of a site selection in mid-1996. Guidance concerning this assumption is needed. The Director has stated that two years is the minimum required period following site selection to accomplish site specific design, negotiate a site agreement and complete the site specific safety evaluation. All this would be required before access to the site and initiation of site construction would be possible.

  The proposed interim design report needs to include a conceptual level definition and cost estimates of all elements of the construction phase of the project. It is proposed to have an in-depth TAC review of the cost at the time of this report. It is MAC's understanding that industry will be asked to develop cost estimates for most of the Tokamak components.

  The milestone charts and detailed design and R&D schedules should show how these activities are integrated together and interlinked.

- Test Facilities
  MAC notes that test facilities must be built or modified over multi-year periods. If commitments are not made in 1994, their use may not be possible within the EDA period. Further definition of the technical specifications of the test facilities is required.

- Technical Content
  MAC recommends to the IC that the TAC review the R&D plans contained in the Work Program to assure that the R&D provides all results necessary to confirm the design, construction feasibility, and safety acceptability within the EDA period.

- Work Breakdown Structure (WBS)
  The WBS needs to be developed to a greater level of detail. The WBS should be used to develop a formal cost estimating procedure and format.

  The HTLs note that further review of the Work Program is underway within the Home Teams and that they will provide detailed comments to the Director in approximately one month, with copies to the other HTLs.

Proposed Schedule of ITER Meetings

Physics R&D Meetings
The Director proposed ITER Physics R&D Meetings, following the Council decision that the Director should interact with persons designated by the Parties regarding Physics R&D for ITER, as appropriate for the benefit of the Project (IC-2 ROD 14.5). MAC agreed to the Director's proposal for Physics R&D Meetings to discuss the Parties' contributions on a voluntary basis, outside of the normal Technology and Design Task arrangements. The meetings should be held as Workshops.

MAC recommends to the ITER Council to accept that separate meetings are required between the Director and designated persons for the conduct of ITER Physics R&D based on the IC-2 ROD 14.5.

Technical Meetings
MAC has reviewed the schedule of Technical Meetings (TM) set out in the proposal by the Director. In accordance with the IC-3 ROD 5.2, this review constitutes IC endorsement.

Date	Meeting	Location
21-25 Feb.	TM and Workshop on Divertor Physics Design	Garching
22-25 Feb.	TM on Magnets & Magnet Safety	Naka
28 Feb.- 3 March	TM on Power Supply	Naka
14-18 March	TM on Tritium Plant	Naka
21-25 March	TM on Neutronics Experiments for ITER Design	Garching
25-29 April	TM on Test Program and Test Module Integration; Electromagnetic	Garching
27-30 June	TM on Magnets	Naka
June	TM on Plasma Heating and Current Drive (RF and Neutral Beams)	to be determined
October	TM on Nuclear Testing	San Diego
November	TM on Assembly and Tooling	San Diego
November	TM on CODAC	San Diego

Proposals for Task Agreements
The Director provided six proposals involving seven Task Agreements of more than 300 IUA to the MAC for review. The total budgeted credit is 49,245 IUA.

- Insulation Survey, Screen Sample Fabrication and Text with the four Parties.
- The ITER Model Coils.
- The TF Test Facility with the EC Party.

Reports by the Director on the Task Agreements valued at no more than 300 IUA equivalent are presented. All are design tasks whose total effort is 11.35 PMY. The MAC recommended to the Council general approval of the proposals for the Task Agreements more than 300 IUA and took note of the proposals for the Task Agreement for design tasks costing no more than 300 IUA.

At the fourth meeting, the ITER Council accepted recommendations from the MAC on streamlining the procedures for task assignment. The Director, working in close collaboration with the Home Team Leaders, developed and implemented new procedures. The agreed list of tasks are that the total IUA for R&D Tasks amounts to 46,219 IUA and the total PMY credit for the Design Tasks amounts to 115.3 PMY.

The MAC recommends approval of the Director's Proposal for Comprehensive 1994 Task Agreements by the Four Parties. In view of the decisions taken by IC-4, with regard to the relative priority within the blanket area between the steel/water and the vanadium/lithium concepts, two Parties have expressed concern about the high level of resources allocated to the vanadium/lithium concept in the Comprehensive 1994 Task Agreements. In about six months the Director will provide a complete schedule of deliverables and resources for the blanket area.

Technical information related to a possible proposal for the involvement of the Republic of Kazakhstan through RF contribution to the ITER EDA
The MAC considers that the Republic of Kazakhstan possesses relevant specific capabilities for involvement in the EDA through the Russian Federation. MAC took note of the information by the RF delegation that a formal proposal for Kazakhstan's involvement through the RF contribution to the ITER EDA pursuant to Article 19 will be made at IC-5.

Future meetings
It was tentatively agreed that the next meeting (MAC-5) will be held on 13-14 April 1994 at the ITER Joint Work Site in Naka.

TECHNICAL MEETING ON PLASMA EQUILIBRIUM AND CONTROL

by P.-L. Mondino, Head, Plasma and Field Control Division, Naka Joint Work Site

The second Technical Meeting on Plasma Equilibrium and Control was held at the Naka Joint Work Site on 9-12 November 1993 with representatives of the four Home Teams and the JCT.

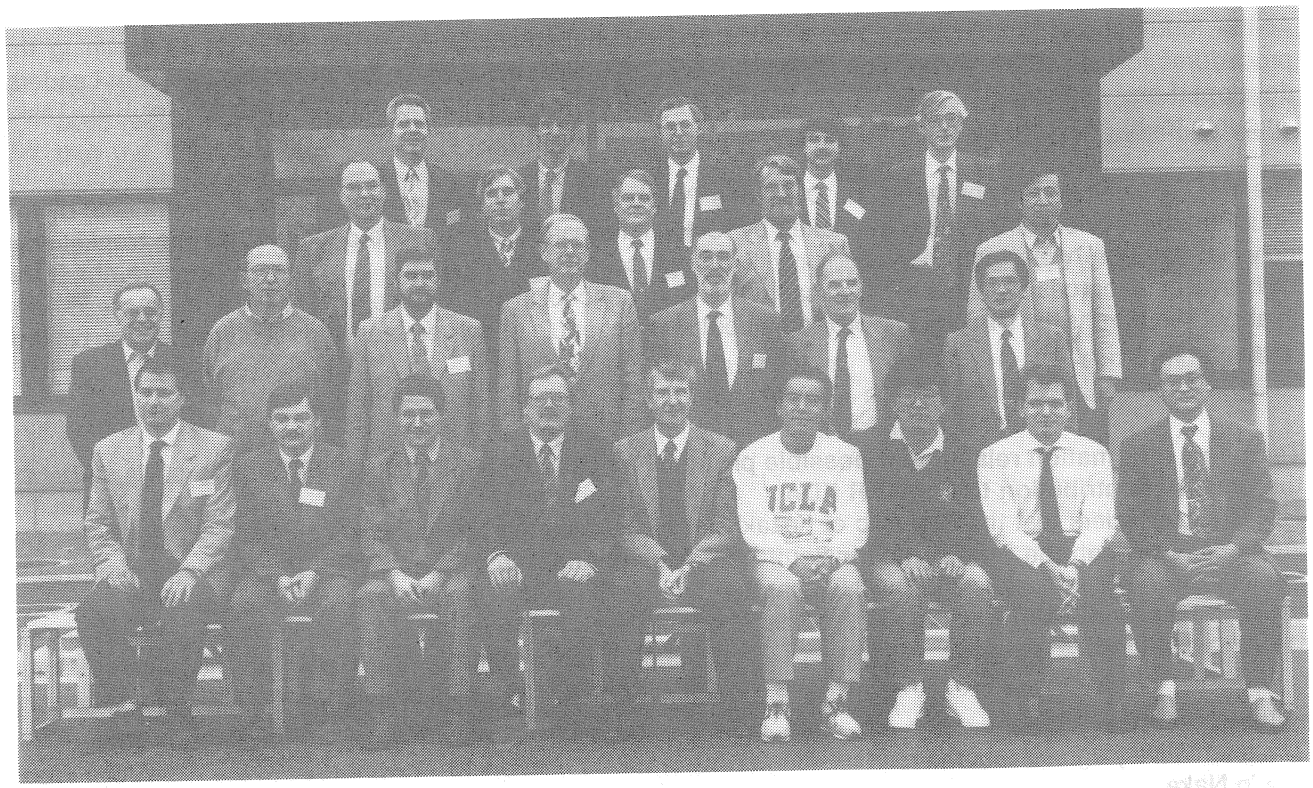
The topics discussed at the meeting were:

1. Plasma scenarios;
2. Vertical stabilization and plasma control; and
3. Diagnostics for plasma control (the responsibility for this work lies with the Garching Joint Work Site which was appropriately represented).

A preliminary meeting was held on 8 November, involving JCT members from all three Joint Work Sites to discuss the above topics, as well as disruptions and the interfaces of the design work involved in the plasma equilibrium and control systems. For example, good radio frequency (RF) heating requires appropriate plasma shape control near the antenna, and good divertor operation requires appropriate control of the magnetic field lines in the X-point and divertor regions.

LIST OF ATTENDEES

EC Delegation	JA Delegation	RF Delegation	US Delegation	JCT Members
R. Albanese	T. Kimura	V.A. Belyakov	D.R. Baker	P. Barabaschi
E. Coccorese	K. Kurihara	Y. Gribov	R.H. Bulmer	K.J. Dietz
O. Gruber	S. Nishio	A. Kavin	D. Humphreys	M. Huguet
P.-L. Lomas	K. Shinya	A. Polevoi	S.C. Jardin	L. de Kock
P. Noll	T. Tsunematsu		J.L. Luxon	M. Matsukawa
G. Pacher	R. Yoshino		L.D. Pearlstein	P.-L. Mondino
				K. Odajima
				A. Portone
				M. Sugihara
				R.J. Thome



Participants in the Meeting

The technical meeting, chaired by P.-L. Mondino, started on 9 November with plenary sessions on all three topics and lasted until 10 November in the evening. Members from the JCT and each delegation made several presentations in which the work performed on the various aspects of each topic was reported. The work of the Home Teams was covered by various design task agreements identified at the first technical meeting held in April 1993.

A reception hosted by JAERI on Tuesday evening allowed the participants to enjoy Japanese specialities and to establish a very pleasant and friendly atmosphere for the full week.

On 11 November the technical meeting was split into separate sessions: plasma scenarios, chaired by P.-J. Lomas; vertical stabilization and plasma control, chaired by P. Noll; and diagnostics for plasma control, chaired by L. de Kock. In the late afternoon these chairmen presented their conclusions during the plenary session and discussions followed.

On 12 November after a plenary session dedicated to conclusions and review of homework, the summaries and the conclusions were prepared and then distributed to all participants in the evening.

The following are the main conclusions of the meeting:

- the new Poloidal Field coil configuration is good,
- the flux swing available should allow the maintenance of a plasma current of 24 MAC for 1000 s burn with a small margin,
- error fields could have serious consequences and should be compensated,
- 0.25 MA/s should be the current ramp in the reference scenario, and
- breakdown and current initiation will need assistance from a radio frequency heating system.

There was also consensus that plasma control and vertical stabilization are closely coupled. Different alternatives for vertical stabilization were considered; the most promising approach could make use of all outer superconducting coils, each connected to a dedicated power supply. As an alternative, a circuit dedicated to vertical stabilization could be considered. Work will now start on plasma control with design tasks allocated to this subject.

Diagnostics for plasma control were extensively discussed, i.e.:

- proximity of sensors to the plasma boundary;
- effects of eddy current;
- optimization of sensors;
- utilization of integrators for long pulses; and
- boundary identification codes.

The accuracy of the plasma boundary identification procedures was discussed: it was concluded that errors within a range of $\pm$ 10 mm in the reconstruction are achievable under optimum conditions.

The members of the JCT and the Home Team Delegations found the meeting to be fruitful and the atmosphere very constructive. Many informal discussions took place in parallel to the formal sessions. The status of the design tasks already allocated was reviewed and new design tasks were discussed. In the session dedicated to the conclusions the chairman stressed the need to produce timely and well prepared written technical reports at the conclusion of the work on each design task. The quality of the technical reports will be an important element in the allocation of future design tasks. In the future, progress reports will be requested every two months.

In conclusion, the second technical meeting was very productive and valuable in preparing the outline design report to be presented to the Technical Advisory Committee at their fourth meeting (TAC-4).

TECHNICAL MEETING ON RF HEATING AND CURRENT DRIVE

by Dr. T. Nagashima, Head, In-Vessel Ancillaries Division, Garching Joint Work Site

A Technical Meeting on "RF Heating and Current Drive" was held at the Garching Co-Center from 21-26 October 1993. This meeting was the first on the subject for the ITER EDA. The objectives were to identify ITER requirements for the Ion Cyclotron Range of Frequencies (ICRF) and for the Electron Cyclotron Range of Frequencies (ECRF); to present new experimental data and the most recent theories of heating and current drive; to discuss antenna design; to review gyrotron and window development; and to define the requirements for the principal R&D and design tasks.

The main discussions and conclusions are as follows:

- *In the ICRF session the present status of heating and current drive was summarized. A strong, well established, experimental and theoretical database exists for heating. This database includes fundamental minority, second minority/majority and direct electron heating. However, only a small experimental database exists for current drive. Present results agree with theory, but details remain to be checked. Particularly, estimates of current drive efficiency vary and have no strong experimental support.*

- *It is recommended for physics scenarios that the principal frequencies for the D-T phase should be 60 MHz tritium second harmonic heating (first priority), or 43 MHz corresponding to fundamental deuterium minority heating (second priority). The preferred frequency for current drive is 20 MHz, below all ion cyclotron resonances and harmonics. Additional possible frequencies are 35 MHz and 70 MHz, corresponding, respectively, to possible mode conversion to KAW heating/current drive, and inboard ^{3}He minority current drive. Scenarios for the non-activated phase are ^{3}He minority (60 GHz) in ^{4}He or H (low concentration and no D required). The above possibilities indicate that a system which encompasses 20 MHz to 60 MHz at full power with extension to 90 MHz (at possibly reduced power) will be appropriate.*

- *Antenna concepts for heating and current drive by fast waves with ICRF were also discussed. The concept of a progressively phased loop array located in the blanket was generally accepted. This antenna should operate over the entire frequency band, but may be optimized (for maximum power at minimum line voltage) at some preferred frequencies still to be determined. Requirements for remote maintenance of the antenna main frame and the Faraday shield were discussed. Removal through the side port was proposed (together with the related lower blanket segment) for the antennas located in the central shield/blanket modules. Removal of those located in the lateral modules would be more difficult and extraction through the top port would be more convenient. For the Faraday screen, some Parties indicated that remote maintenance would be required, because the surface of the Faraday screen may be damaged more severely than those of other general parts of the first wall due mainly to RF, disruptions and ripple-trapped fast ions. Based on the stand-off voltages of the antenna system achieved on many tokamaks, the values recommended for ITER are 30 kV for routine operation and 50 kV for design and component testing.*

- *There was general agreement of the RF source requirements. The design should be able to deliver 2.5-4 MW to each current strap. 2.5 MW can be delivered by one tube for current system designs over the required frequency range. For 4 MW, two tubes would be required. The RF source frequency range was set at 20-90 MHz. Full power is required up to 60 MHz, but some decrease in power would be acceptable in the 70-90 MHz range, determined by available tube capabilities.*

- *As for the electron cyclotron (EC) sessions, all Parties agreed that a simple EC Wave system based on ordinary mode (OM) launched from the low-field-side with perpendicular injection is suitable for heating the ITER plasma to ignition. It was recommended that for central heating the ECW frequency should be chosen within the range 150 GHz$\leq f_{ECW} \leq$170GHz. Further definition of the ECW frequency can be based on other requirements (e.g., RF sources, start-up scenarios, MHD control scenarios).*

- *ECW start-up assist has been shown to be a reliable tool in many tokamaks. ECW start-up assist would also be useful in ITER to ensure that plasma formation occurred at a time and location consistent with the PF current ramp-up scenario, to expand the allowed operating window in prefill pressure, and to reduce the loop voltage required for reliable start-up. Experimental results (from, e.g., JFT-2M, DIII-D) should be compared with theoretical predictions, and these benchmarked theories used to develop scenarios that minimize the preionization power requirements in ITER.*

- *All Parties recommended core current drive scenarios based on upshifted ($\omega > \omega_{ce}$) absorption of ordinary modes launched from the outboard midplane. For the purpose of developing steady-state operating scenarios, it is recommended that a current drive figure-of-merit of $Y_{EC} \approx T_{eo}/100$ keV x 10^{20}A/W m^2 be used when estimating the efficiency of central electron cyclotron current drive (ECCD). Core current drive can be accomplished with low-field-side launch of the O-mode in the plasma midplane at an angle $30^o < \phi < 40^o$. Further refinement of this angle will depend on the choice of frequency for current drive and convergence in the modelling. It is also suggested that initial ECCD experiments could be carried out at reduced toroidal field ($B_o \geq 4.6$ T) using the same RF sources as in the ECH system.*

- *Stabilization of sawtooth oscillations and m = 2 MHD activity by ECW has been demonstrated in several experiments. It was recommended that active control schemes with m-wave injection phased with the O-point of unstable tearing modes are most attractive. MHD mode suppression for 1000 second pulses in the ITER environment is a difficult task. Progress on a time scale relevant to the ITER EDA will require a serious effort aimed at the development of ITER-relevant MHD mode suppression scenarios.*

- *As for status of ITER-relevant gyrotron R&D, the four ITER Parties all reported results which are very promising for reaching the goals of the ITER project. Gyrotrons operating at frequencies in the 110 to 167 GHz range with pulse lengths of 1 sec and power levels greater than 0.4 MW were reported by three Parties. The energy of the gyrotrons is in the 0.5 to 1.5 MJ range. Efficiencies of up to 35% have been achieved. A limited sample of results reported at this meeting includes: 0.41 MW, 1.3 sec, 110 GHz gyrotron developed by JP, 0.55 MW, 2.1 sec, 140 GHz gyrotron and 0.7 MW, 0.7 sec 167 GHz gyrotron built by RF, 0.5 MW, 2.5 sec, 110 GHz gyrotron and 0.32 MW, 3.6 sec 140 GHz gyrotron and 0.4 MW (0.2 MW average) 140 GHz built by US. These results are a very promising step in the program to develop the sources required by ITER. Some of these gyrotrons are now being used in ECH and ECCD experiments. We have very high confidence in the ability of industry to develop the gyrotrons needed for the ITER project in time to meet the requirements of high CW power and reliability.*

- *Window development is being performed by all four Parties and the progress reported during the meeting gives confidence in meeting the ITER requirements. Two approaches to window design are being explored:*

  - *Cryogenic sapphire window at temperatures from 80 K to 13 K (EC, JP, RF);*
  - *water-cooled distributed window (US).*

  Calculations show that a window based on either concept could handle microwave power up to 1 MW if the power is distributed (top hat or annular distribution) across the whole area. Experiments with cryogenic windows were performed at a power level of up to 0.4 MW (1 sec) or 0.3 MW (3 sec), and they confirm favourable scaling of the loss tangent of sapphire with temperature T (tgδ proportional to T^3 at cryogenic temperature), a requirement which is very important for this concept. Regarding the manufacture of the distributed window, the technology of brazing the ceramic to the cooling channel has been demonstrated.

- *The antenna specifications are determined by the functions assigned to the ECW system. The following guidelines are proposed for its design:*

  - *it should be independent of the blanket;*
  - *its design must make use of the extremely high power density achievable by the ECW system (many hundreds of MW/m^2) in order to minimize the opening in the blanket;*
  - *the material used must fulfil all the safety criteria set forth by the JCT, while it must still be compatible with the specific RF, mechanical and thermal constraints imposed by the ECW system and the tokamak environment.*

- *ECW systems have become of growing interest due to the possibility of efficient and localized heating and current drive. Due to quasi-optical propagation of the waves, all antenna components can be installed remote from the plasma and will reduce engineering problems. All transmission components are already highly developed. On this basis, their design to meet the specifications needed for an ITER ECW system is seen as a solvable engineering problem.*

The meeting secretary, Frau Doris Spiegel, and her team were well organized in supporting this meeting.

LIST OF PARTICIPANTS

EC:	JA:	RF:	US:	JCT:
F. Engelmann	T. Imai	V.V. Alikaev	R. Freeman	G. Bosia
J. Jacquinot	H. Kimura	Y. Dnestrovsky	D. Hoffman	M. Makowski
R. Koch	S. Moriyama	A.G. Litvak	W. Nevins	T. Nagashima
B. Lloyd	K. Sakamoto	N.A. Obysov	D. Swain	R. Parker
D. Moreau	T. Yamamoto	V.L. Vdovin	R. Temkin	F. Perkins
M.Q. Tran			J. Wilson	D. Remsen

NEWS IN BRIEF

The 18th Symposium on Fusion Technology (SOFT) will be held on 22-26 August 1994 in Karlsruhe, Germany.

The objective of SOFT is to exchange information on the design, construction and operation of fusion experiments and the technology which is being developed for the next-step devices and for fusion reactors.

The Symposium will include invited and contributed papers on the following topics:

- **First Wall, Divertors and Vacuum Systems**
- **Plasma Heating and Control**
- **Experimental Systems**
- **Magnet and Power Supplies**
- **Fuel Cycle and Tritium Processing Systems**
- **Blanket Technology/Materials**
- **Remote Handling**
- **Safety and Environment, Reactor Studies**

For further information contact: SOFT Conference Secretariat, Kernforschungszentrum Karlsruhe GmbH, P.O. Box 3640, D-76021 Karlsruhe, Germany. Tel.: (0)7247-825461, Fax: (0)7247-825467.

FORTHCOMING EVENTS *)

- Technical Meeting on Magnets & Magnet Safety, Naka, Japan, 22-25 February
- Technical Meeting and Workshop on Divertor Physics Design, Garching, Germany, 21-25 February
- Technical Meeting on Power Supply, Naka, Japan, 28 February - 3 March
- Meeting between the Director and Designated Persons for the conduct of ITER Physics R&D, San Diego, USA, 2-3 March
- Technical Meeting on Tritium Plant, Naka, Japan, 14-18 March
- Technical Meeting on Neutronics Experiments for ITER Design, Garching, Germany, 21-25 March
- Technical Meeting on Test Program and Test Module Integration; Electromagnetic Analysis for In-Vessel Components, Garching, Germany, 25-29 April
- IC-6, Moscow, Russia, 15-16 June

*) Attendance at all ITER Meetings by invitation only.

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kouvchinnikov, ITER Office, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: 43 1 237762 (phone 23606392).

Printed by the IAEA in Austria

94-00491