



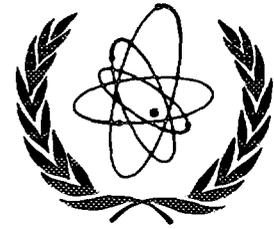
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TENTH MEETING OF THE ITER TECHNICAL ADVISORY COMMITTEE (TAC)
 by Prof. P. H. Rutherford, TAC Chair

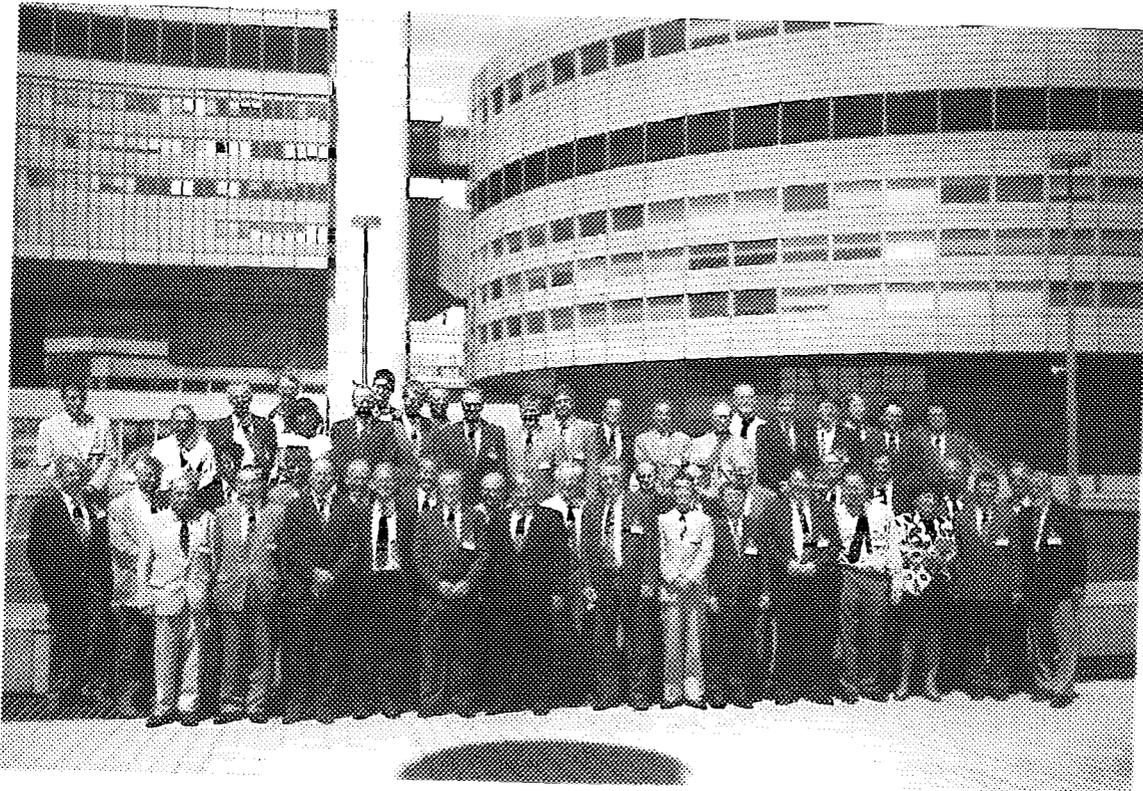
The Tenth TAC Meeting (TAC-10) was held on 8-10 July 1996 at the IAEA in Vienna, Austria. The List of Participants is shown at the end of this article.

At the Ninth Meeting of the ITER Council (IC-9), the following new charge was given to the TAC:

"The Council requests the TAC to carry out an informal assessment of those aspects of the ITER design where there have been important improvements introduced by the Director following the Interim Design Review. The TAC is requested to report on this charge at IC-10. This assessment should be preparatory to the review of the Detailed Design to be held toward the end of 1996."

TAC-10 was called to address this charge.

Presentations at TAC-10 were given primarily by JCT staff, with one presentation by a member of a Home Team (HT). Participating HT experts gave additional presentations during two parallel sessions.



Participants in the Meeting

The major design improvement topics assessed at this meeting were the following:

- ◆ Seismic Design Policy;
- ◆ Tokamak Building and Pit Layout;
- ◆ Tokamak Assembly;
- ◆ Remote Handling;
- ◆ Fueling, Pumping, Tritium Processing;
- ◆ Safety;
- ◆ Vertical Displacement Events (VDEs) and Halo-Current Induced Loads;
- ◆ Central Solenoid (Segmented Option).

The TAC noted that several important improvements have been introduced into the ITER design following the Interim Design Review. Some of the improvements responded to concerns previously raised by the TAC. Many of the improvements are already intended to be incorporated into the Detailed Design Report (DDR) to be reviewed by the TAC in December 1996; others could be introduced after the DDR. Improved definition of safety requirements and responses will be reviewed in greater detail at a special safety review in October 1996. The TAC commended the JCT and the four HTs for the continued improvement and increased engineering detail evident in the design.

The topic which occupied most of the time at TAC-10 was that of the Central Solenoid (CS). As a result of the Interim Design Review (TAC-8) held in July 1995, the TAC had recommended to the ITER Council that the JCT carry out a study of a segmented alternative to the reference monolithic layer-wound CS. The JCT, working with the help of the HTs, was commended for having now completed this study to the point at which its principal conclusions can be assessed. Specifically, the JCT has considered a segmented solenoid composed of five modules of pancake-wound coils. Both reference and segmented solenoids fit within the same machine inner envelope; the layer-wound reference solenoid and all five modules of the segmented solenoid use niobium-tin (Nb_3Sn) conductor at a peak field of 13 T.

Two "hybrid" solenoid concepts, described by members of the RF and US HTs, seek to realize the physics advantages of the segmented solenoid, while avoiding the major engineering disadvantage, namely the high-field joints.

LIST OF PARTICIPANTS

TAC Members

EU:

Dr. R. Andreani
Dr. J. Jacquinet
Dr. D. Robinson
Prof. F. Troyon

JA:

Prof. N. Inoue
Prof. K. Miya
Dr. K. Tomabechi

RF:

Dr. E. Adamov
Acad. V. Glukhikh
Acad. B.B. Kadomtsev
Dr. M. Solonin

US:

Dr. H. K. Forsen
Dr. P.H. Rutherford
Dr. J. Sheffield

Secretary

Mr. C.A. Flanagan

Home Team Leaders

Prof. R. Toschi
Dr. S. Matsuda
Dr. O. Filatov
Dr. T. James (for Dr. C. Baker)

JCT:

Dr. R. Aymar
Dr. V. Chuyanov
Dr. M. Huguet
Dr. R. Parker
Dr. Y. Shimomura
Dr. C. Ahlfeld
Dr. P. Barabaschi
Dr. H.-W. Bartels
Dr. Yu. Gribov
Dr. R. Haange
Dr. J.-L. Hélaye
Dr. G. Janeschitz
Dr. E. Martin

JCT (cont'd.)

Dr. P.-L. Mondino
Dr. N. Mitchell
Dr. R. Thome
Dr. M. Wykes
Dr. H. Yoshida

Home Team Experts

Dr. D. Maisonnier, EU
Dr. D. Murdoch, EU
Dr. B. Turck, EU
Dr. T. Shoji, JA
Dr. E. Tada, JA
Dr. T. Tsunematsu, JA
Dr. V.A. Belyakov, RF
Dr. V.P. Muratov, RF
Dr. P. Heitzenroeder, US
Dr. G.H. Neilson, US
Dr. B.E. Nelson, US

Home Team Presenters

Dr. W. Nevins, US HT

TAC concluded that the present reference solenoid should be retained for the DDR, as the JCT intends. The TAC's assessment of the CS options was that there is some potential that the reference solenoid design could evolve toward a "hybrid" design, examples of which were given by the RFHT and USHT, in which the physics advantages of the segmented solenoid are realized, without the need for 13 T joints; if this evolution is supported by further engineering assessment of hybrid options, utilizing additional HT resources, it could occur after the DDR.

The TAC Chair wishes to thank the officials and staff of the IAEA for hosting the meeting.

The TAC-10 Report was presented at IC-10 in St. Petersburg, RF, on 24-25 July 1996.

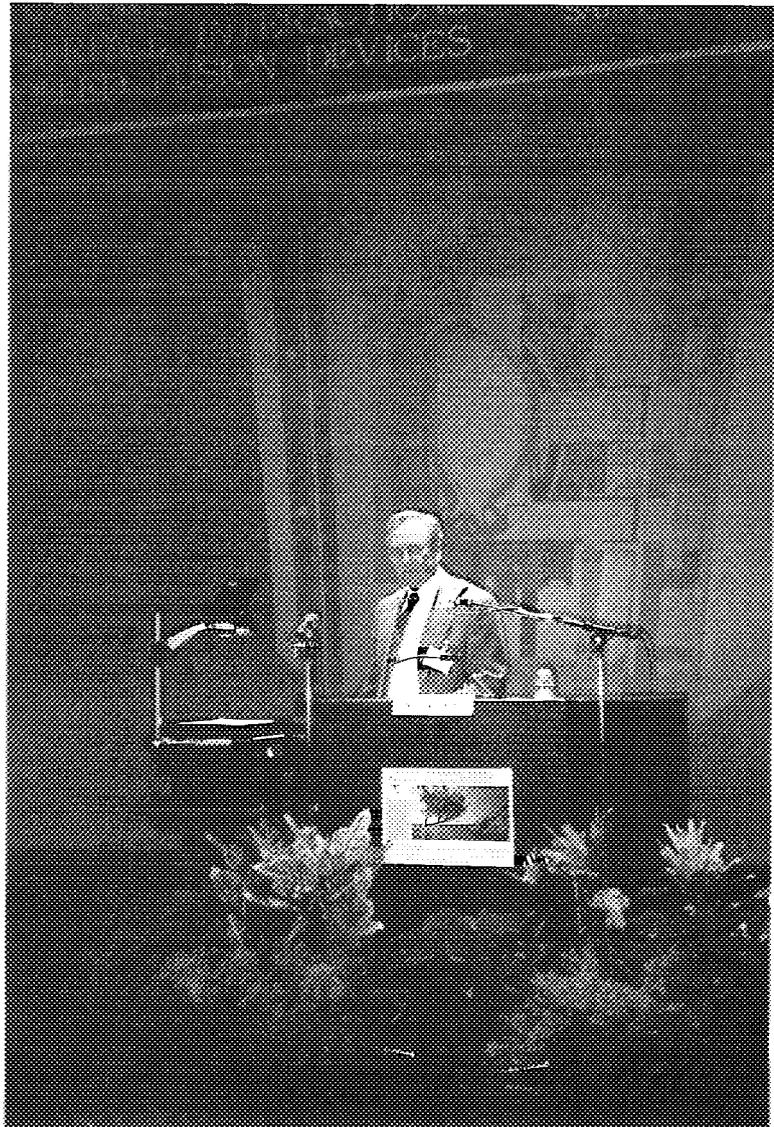
ITER AT THE 12TH INTERNATIONAL CONFERENCE ON PLASMA-SURFACE INTERACTIONS IN CONTROLLED FUSION DEVICES

by Dr. G. Federici, Divertor and Plasma Interface Division, ITER Garching Joint Work Site, and Dr. D. Post, Physics Unit, ITER San Diego Joint Work Site and In-Vessel Physics Group, ITER Garching Joint Work Site

The 12th International Conference on Plasma-Surface Interactions in Controlled Fusion Devices (PSI-12) was held at St. Raphael, France, on 20-24 May 1996. It is the major conference for research on the physics aspects of power and particle control in fusion and is, therefore, particularly relevant for ITER. About 200 papers were presented at the meeting covering recent results on theoretical and experimental research on divertors, limiters, the interaction of plasmas with surfaces and disruption effects.

R. Parker gave the keynote paper, an overview of the ITER power and particle control system. It consists of a single null poloidal divertor located at the bottom of the machine, a set of 16 cryopumps for pumping and gas and pellet injection systems. The ITER divertor components are located in 60 cassettes which can be removed and replaced a number of times during the operating life of ITER. To reduce the heat loads on the divertor plates to acceptable levels and minimize the erosion of the plasma facing components, the heating power will be spread out over the divertor and main chamber walls by radiation. The exhaust will be facilitated by high neutral gas pressures in the divertor chamber achieved by localizing the recycling to the divertor chamber. Disruptions will lead to high peak heat loads and large electro-mechanical forces on the plasma facing components and set challenging requirements for their design.

The general concept of radiating most of the energy to the walls was supported by results from all the major divertor experiments. These experiments were all able to reduce the peak heat loads on the divertor plates by a factor of five or more by the use of a combination of intensive gas puffing and impurity fuelling.



Dr. R. Parker presenting the keynote paper

This resulted in partial or complete "detachment" of the plasma from the divertor plate.

The energy confinement in many of the experiments deteriorated with "detached" conditions, but the better confinement of recycling neutrals to the divertor chamber should improve that situation for ITER. The conditions for achieving detached operation were reported to depend on the plasma density, impurity level, heating power and divertor configuration.

ITER PAPERS AT PSI 12

Plenary Speaker

- ◆ **Plasma Wall-Interactions in ITER.** R. Parker, S. Chiochio, G. Federici, G. Janeschitz, P. Ladd, H.D. Pacher, D. Post

ITER Poster Presentations

- ◆ **Power Balance in the ITER Plasma and Divertor,** D. Post, B. Braams, J. Mandrekas, N. Putvinskaya, M. Rensink, T. Rognlien, W. Stacey, F. Wising
- ◆ **Modelling of Transition from Attached to Detached State and Self-Consistent Calculations of He Levels in ITER,** M. Sugihara, T. Amano, D. Boucher, Yu. Igitkhanov, G. Janeschitz, H. Pacher, D. Post, P. Yushmanov
- ◆ **2-D Modelling of Radiating Divertor Regime for ITER,** A. Kukushkin, H. Pacher, M. Baelmans, D. Coster, G. Janeschitz, D. Reiter, R. Schneider
- ◆ **Impurity Fuelling to Terminate Tokamak Discharges,** S. Putvinski, N. Fujisawa, D. Post, N. Putvinskaya, M. Rosenbluth, J. Wesley
- ◆ **The Influence of Key Operation Parameters and Material Properties on the Quantification of Tritium Inventory and Permeation in the PFCs of ITER,** G. Federici, D. Holland, G. Janeschitz, C. Wu
- ◆ **Erosion Lifetime of ITER Divertor Plates,** H. Pacher, I. Smid, G. Federici, Yu. Igitkhanov, G. Janeschitz, A. Raffray, G. Vieider

Other Poster Presentations Directly Related to ITER

- ◆ **Assessment of Erosion and Surface Tritium Inventory Issues for the ITER Divertor,** J. Brooks, R. Causey, G. Federici, D. Ruzic
- ◆ **On the Possibility of Light or Not Seeded, Partially Detached ITER Divertor Operation,** G. Vases
- ◆ **Plasma Wall-Interactions in ITER Tokamak Hard Disruptions,** H. Wuerz, B. Bazylev, V. Belan, V. Engelko, I. Landman, S. Pestchany, V. Safronov, A. Zhitlukhin

Computational simulations of divertor experiments and the use of those codes for ITER have made substantial progress since the previous PSI Conference in 1994. The models now routinely included detailed treatments of the plasma and neutral transport in realistic geometries and the transport of impurities. They can reproduce many aspects and experimental signatures of divertor experiments including the radiation levels and the two dimensional distribution of the plasma temperature and density in the divertor. Projections for the ITER divertor performance indicate that the required levels of impurity radiation losses can be achieved with reasonable impurity levels. Calculations by Kukushkin, et al., indicate that a new "virtual target regime" may also be feasible for ITER. In this regime, strong ionisation and recombination of the hydrogen ions form a sharp front which has high radiation losses and acts like a divertor plate. Simpler models were also described which have been used to determine the operational window for detached divertor operation in ITER. Calculations were reported which indicate that impurity pellet injection can be used to radiate quickly the energy in the plasma to mitigate disruption effects, but that the production of runaway electrons which can damage the first wall is then a problem. An analysis of the erosion lifetime of the ITER divertor plates indicated that the lifetime with Be is too short, but that W and C are acceptable. A detailed analysis of the tritium inventory in the plasma facing materials in ITER indicated that the inventory would be between 1.5 and 4.5 kg, depending on the surface conditions and assumptions about the surface recombination rate and other effects.

Due to improvements in divertor diagnostics, very detailed divertor plasma data is becoming available. DIII-D, for example, reported measurements of two-dimensional electron temperature and density profiles in the divertor obtained with their new Thomson scattering system. All of the divertor experiments reported two-dimensional measurements of the radiation emission profiles, including detailed charge state distributions in some cases. These measurements indicated that the electron temperature during detached operation was as low as 1 eV. Such detailed information will lead to substantial improvements in the divertor models and much better understanding of the physics of divertor operation.

Plasma conditioning continues to be a major factor in energy confinement. New examples of conditioning the wall with chemical getters and coatings included boron on Alcator C-Mod and JT-60/U and Li on TFTR, all of which resulted in substantially improved confinement. Other interesting physics results reported for highly radiating "detached" operation indicated that volume recombination processes play a significant role in reducing the plasma pressure and ion flux at the divertor plates, providing support for the possibility of the "virtual target" regime.

Experiments on ASDEX Upgrade with tungsten clad divertor plates and low temperatures in the divertor plasma generally resulted in very low tungsten contamination of the main plasma providing reassurance for their use in the ITER divertor. Results reported from He transport studies in a large number of limiter and divertor experiments indicate that He does not accumulate in the plasma center, as had been feared, for any of the standard confinement regimes. Results were reported, however, which continue to indicate that the helium concentration in the divertor may be reduced as much as 20% compared to the concentration in the main plasma, supporting the need for the planned pumping speed for He exhaust for ITER.

Experimental and modelling results were reported for sputtering erosion/redeposition, disruption erosion and tritium retention and release. Experiments were reported which indicated that chemical erosion of carbon based materials was reduced when doped with Si and Ti. Initial experiments and modelling of the erosion due to disruptions were also presented which addressed the effectiveness of the shielding layer and the stability and loss of the melt layer.

TFTR reported that between 40 and 45% of the tritium injected into the experiment remained in the chamber and graphite walls and limiters even after extensive plasma conditioning to remove it. Similar experience exists in JET. This indicates the importance of developing an efficient and viable in-situ technique to be used periodically in ITER to remove tritium from the co-deposited layers. Data presented at a working session on this topic indicated that the desorption of implanted hydrogen in the Be first wall is likely to be very rapid in ITER due to the increase in the effective surface area due to micro-damage from the formation of hydrogen bubbles. The larger surface area leads to increased surface recombination and, therefore, to lower tritium retention. On the other hand, co-deposition of tritium with sputtered Be appears to be as large as with carbon, which will likely lead to increases in the estimates for tritium trapped in co-deposited layers.

The plasma facing surfaces in ITER will be coated with a mixture of the plasma facing materials which will alter their surface properties. Results reported from the PISCES linear device indicate that a thin carbide layer can form on high temperature Be surfaces (~400°C) which has much lower erosion rates than pure Be. The presence of carbon contaminants on the Be surfaces could, however, retard or inhibit recombinative desorption and in turn increase the net tritium uptake. R&D is ongoing and new increased focus is being redirected in the four Home Teams, both in tokamaks and laboratory experiments, to better understand the mix-material problems.

The progress in this field since the previous conference in Mito in 1994 has been substantial and has greatly aided the development of the design of the ITER power and particle control system. The necessity to resolve many of the issues in this field for the ITER design has also helped focus much of the work in this field, and the beneficial results of that focus were apparent from the material presented at the meeting. The next meeting is planned for 1998 in San Diego, and it is clear that there will be substantial progress reported at that meeting for most of the issues described above.

NOTE BY DR. A. GROSMAN *) ON THE INTERRELATIONSHIP BETWEEN ITER AND THE PSI CONFERENCE

The PSI Conference was initiated more than 20 years ago by surface and solid-state physicists; only afterwards edge plasma physicists, including both experimentalists and theoreticians, became interested in this event. First Wall and Divertor engineers are now encountered more and more often in the lobby of the poster sessions. This fact demonstrates how the disciplines involved develop and where they are leading.

This Conference has certainly become the major fusion physics meeting to take into account ITER as such. Besides accepting a number of papers related to specific ITER activities, it is a tradition of the Conference to include an invited talk on ITER. At PSI-12, Dr. R. Parker, Director of the ITER JCT Garching site, was allotted almost twice as much time as any other invited speaker to summarize the Plasma-Wall Interactions in ITER. Still, this time appeared very short in view of the extraordinary number of technical and physics questions involved. The Programme Committee of the Conference straightforwardly decided to open the Conference with Dr. Parker's presentation, thus emphasizing the value of the ITER EDA for the whole fusion community and, especially, for its plasma edge and wall specialists.

The ITER contributions are an essential tool for the physicists to become acquainted with some of the engineering problems to be encountered at any stage of future fusion research, diagnostics included. They also emphasize the fundamental questions of material selection. During the history of fusion, the quest of performance led to extensive use of low-Z materials already available for other purposes. ITER clearly introduces the problem of material lifetime inside the fusion device, its ability to be used in a sound technical environment (resistance to disruptions, bonding to cooling structure, etc.), and, finally, its eventual tritium retention. A clear evaluation of the use of high-Z materials and in particular tungsten will be carried out in actual fusion devices. The first reported results at this Conference show the way to be pursued in the near future.

Finally, I would like to thank all the ITER JCT and Home Team members for having participated and contributed to the success of the Conference, not only by giving interesting talks and presenting posters, but also by stimulating a multitude of microforums in the lobby and in front of the posters during the whole week, in spite of the continuous competition of the beautiful scenery and the bright sun that surrounded the Conference at St. Raphael.

**) Dr. André Grosman, PSI-12 Chairman, joined the CEA in 1981. He was in charge of the plasma edge measurements and of the pump limiter program on TFR up to 1986, before moving to Cadarache, where he worked with diagnostics in TORE SUPRA. From 1987-1989 he was responsible for conditioning techniques implementation and then for the experiments with the TORE SUPRA ergodic divertor program. Dr. Grosman has been a member of the PSI Conference Programme Committee since 1988 and of the JET Scientific Council since 1991.*

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kouvcinikov, ITER Office, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: +43 1 237762 (phone +43 1 206026392).

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