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FIFTH MEETING OF THE ITER TECHNICAL ADVISORY COMMITTEE (TAC-5)

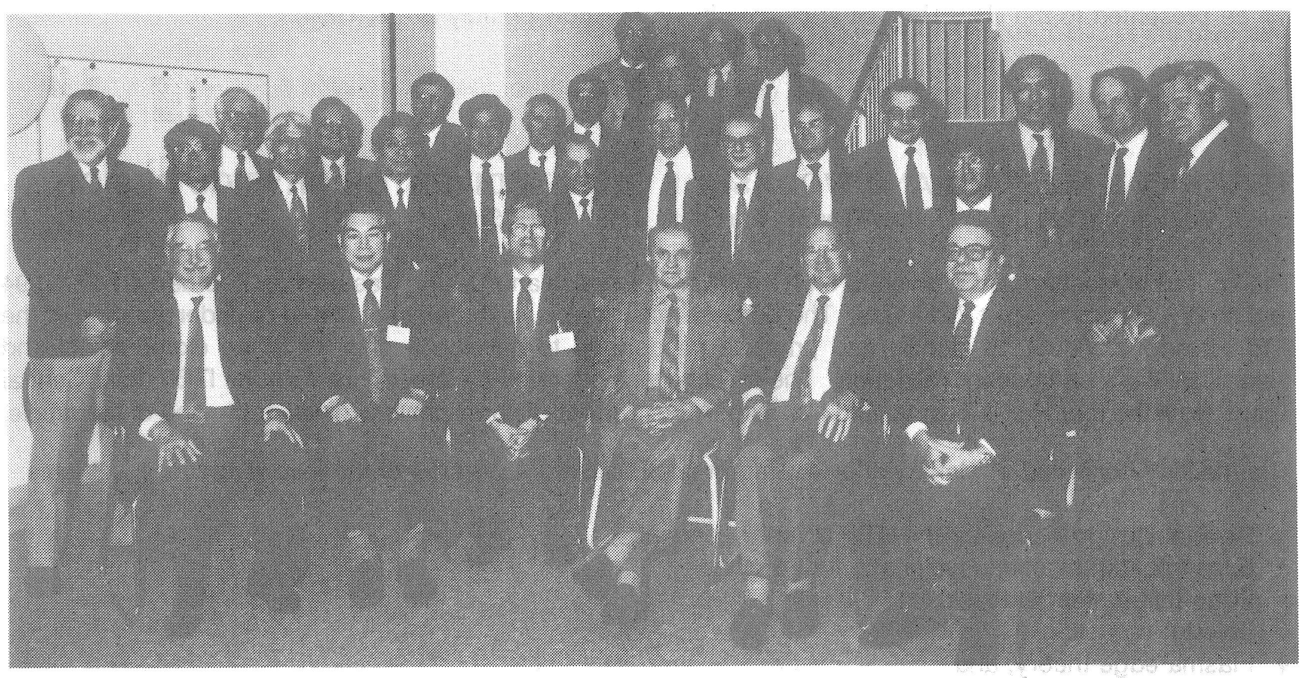
by Prof. Paul H. Rutherford, TAC Chair

TAC-5 was held at the ITER Joint Work Site, Garching, Germany, on 11-13 April, 1994. All sixteen TAC members attended the meeting, as well as four experts nominated by the ITER Parties: Dr. W. Dänner (EC), Dr. M. Seki (JA), Dr. O. Filatov (RF) and Dr. C. Baker (US). Presentations to the TAC were given by the ITER Director, Dr. P.-H. Rebut, and by eleven other members of the Joint Central Team (JCT).

The TAC-5 meeting was called to address the following charge from the ITER Council:

> *"The ITER Council requests the TAC to assess from a technical viewpoint the ITER Work Program so as to confirm that the proposed R&D supports the design in such a way as to allow a high probability of starting ITER construction in 1998. The Council also encourages TAC to complete its interactions and evaluations with the Director and JCT on the various technical concerns regarding the outline design which were raised in the report of the TAC-4 meeting. The TAC is asked to address these charges as soon as practical."*

In preparation for the meeting, the JCT had prepared a report, "ITER R&D Program: Major and Critical R&D", which described technical aspects of the major and critical R&D being carried out as part of the ITER EDA in support of the outline design presented to TAC-4. The JCT report included data in tabular form on the resources proposed to be allocated to each of the major R&D areas.



Participants in the Meeting

The TAC commended the Director and the JCT for developing a relatively detailed R&D plan in support of the present outline design, including schedules and costs, and for the organization of this R&D plan, as described in the report to TAC-5.

The TAC noted that the design is still evolving to a significant extent for many major systems, making it difficult to produce a definitive R&D plan in all areas. Thus, in TAC's view, the present R&D program should be regarded as reflecting the present status of the design, and it must be expected that significant updating will be required in the future as the design becomes more firmly established. Accordingly, the TAC anticipates that additional interactions with the JCT on the R&D program will be required in the future.

In regard to the allocation of R&D resources, the TAC noted that approximately 90% of the total 750 KIUA available for R&D in the EDA has now been proposed by the Director to defined R&D areas - in many cases to specific defined R&D tasks. About 25% of the allocated resources has already been committed to task agreements; this fraction will increase substantially if at present proposed task agreements are approved.

In developing detailed findings and recommendation, the TAC found it useful in its review of the R&D proposed for each major system to consider the following questions:

- ♦ Has a reference concept been selected?
  - ● If there is no reference, what are the candidate options?
  - ● What are the critical issues for these candidate options? When are the R&D results needed, and what resources are required to select the reference?
- ♦ What are the critical issues for the reference concept? When are the R&D results needed and what resources are required?
- ♦ If the R&D results fail to confirm the reference, what time is required to make corrections?
- ♦ What "back-up" design concepts are being carried in case of failure of the reference?

The TAC formulated specific findings and recommendations in regard to the proposed R&D in each of the following areas:

- Magnets
- Vacuum Vessel
- First-Wall, Shield-Blanket
- Divertor
- Heating and Current Drive
- Remote Handling
- Tritium Plant
- Safety-Related R&D
- Design Standards and Codes

These findings and recommendations are contained in the TAC's report "Minutes and Report (TAC-5)", which will be presented to the ITER Council at its meeting in Moscow on July 27-28, 1994.

TECHNICAL MEETING AND WORKSHOP ON ITER DIVERTOR PHYSICS DESIGN

by G. Federici, ITER Joint Central Team, Garching Joint Work Site

The Technical Meeting and Workshop on ITER Divertor Physics and Design was held on February 21-25, 1994 at the ITER Garching Joint Work Site. The purpose was to discuss the present status of understanding of the ITER divertor concept, to identify and prioritize needs, and to develop a plan for future experimental and theoretical work on concept validation. The meeting was attended by specialists from the ITER Joint Central Team, from the four Home Teams, and from the IAEA. The list of participants is given at the end of the article.

The meeting consisted of plenary and working breakout sessions devoted to the following critical subjects:

- ♦ Divertor design issues for the ITER divertor concept;
- ♦ Experimental tokamak results and future plans;
- ♦ Edge parameter database;
- ♦ Divertor modeling;
- ♦ Plasma edge theory; and
- ♦ Divertor simulators.

For a concise summary of each technical session, except for the first one on Divertor Design Issues for the ITER Divertor Concept, see the boxes on the following pages.

The physics relies upon extinguishing the plasma before it reaches the target plate. This process occurs due to the interaction of the plasma with hydrogen neutrals along the length of the divertor channel and therefore redistributes the scrape-off layer (SOL) power onto a much larger surface than a conventional target plate design permits.

Generally, the validation of the ITER divertor concept has to be based on an extensive experimental database provided by all existing divertor tokamaks which demonstrates the viability of the ITER divertor concept. In addition, 2-D plasma edge codes which are able to reproduce the above experimental data have to be used for scaling from the existing experiments to ITER. In order to build the essential physics effects into these codes, a significant input from plasma edge and divertor theory is needed. Due to the required interaction between experiments, modeling and theory, as well as due to the nature of physics research, a scheme which uses task agreements similar to the engineering R&D program is not feasible. The physics R&D needs a permanent close interaction between the ITER JCT and the experts in the fusion community who work in the above-mentioned areas. Therefore, a new organization scheme based on seven expert groups of which two are for the divertor (i.e., the Divertor Database and Modeling Expert Group and the Divertor Physics Expert Group) has been agreed upon between the four Parties and the ITER JCT.

These two groups will provide a close contact between the JCT and the Home Teams in the divertor physics area. The expert groups will define the ITER divertor concept and generate the physics basis for it together with the JCT. They will, in particular, allow the JCT to keep in contact with the ongoing developments in the fusion community and they will, on the other hand, provide the community with a direct path of information as well as influence on the ITER divertor design.

An example of objectives of the Divertor Database and Modeling Expert Group are: definition of the needs for the ITER physics R&D program for divertor modeling, and of the structure of the divertor plasma parameter database, as well as the program to validate the divertor models in order to increase their reliability as a design tool for ITER; development and analysis of global and profile databases of edge plasma parameters from divertor experiments; and development of divertor tokamaks (e.g., from the edge profile database), their application to assist in the development of a divertor concept for ITER, and collect the results of the modeling studies in a model database. On the other hand, the Divertor Physics Expert Group should

- define the needs for the ITER physics R&D program for the divertor physics in the four Parties;
- define new experiments for providing data required to develop the ITER divertor concept;
- assess the data from the divertor experiments in terms of the development of a concept for the ITER divertor;
- develop theoretical models for divertor plasma phenomena and improve the theoretical basis of the divertor modeling codes; and
- develop and validate a physics concept for the ITER divertor on the basis of experimental, theoretical and modeling results.

Experimental tokamak results and future plans

The presentations of experimental results showed that all the tokamak programs (ASDEX-U, C-Mod, DIII-D, JET, JT-60U, TEXTOR, and Tore Supra) are studying how to reduce the first-wall power loading by increasing edge radiation (main chamber and divertor region). Indeed, all these devices have obtained large reductions in power loading. These activities are consistent with the needs of the ITER program, which now requires that less than 10% of the alpha power reach the divertor targets. This dynamic gas target regime has been observed on all divertor tokamaks in high density operation and causes a detachment of the plasma from the target plates in terms of energy and particle flux. The operational window (defined to be between the density at which detachment starts to occur and the density at which a main plasma MARFE develops, which ultimately leads to a density limit disruption), was found to be relatively small in most cases and to be strongly dependent on the target and divertor area geometry. It was concluded that recirculation of neutrals inside the private region as well as outside the divertor plasma fans is important to achieve a gas target regime across the whole divertor SOL. Under this hypothesis only JT-60U and JET have achieved the gas target regime in full due to the openness of their divertors. Regardless of the open divertor, DIII-D only achieved partial detachment at both strike zones because of the strong wall pumping depleting the outer parts of the divertor from neutrals. ALCATOR C-Mod has a divertor with vertical targets which provides a baffle for neutrals again at the outside of the divertor plasma fans and thus also only achieved partial detachment. ASDEX-U observed detachment only at the inner strike zone. The reason could be that the outer target plate shields the outer strike zone from neutrals in the private region. A strong asymmetry in power loading due to the chosen ion grad B drift direction might also contribute.

The upgrade of the hardware of some of the existing divertor tokamaks to better reproduce conditions similar to those anticipated in ITER (i.e., gas box) is being explored among the Parties.

Edge parameter database

The Working Group on Experimental and Modeling Edge Parameter Databases reviewed the present status of the experimental edge parameter databases from all of the major divertor devices. The Group then discussed the ITER requirements for the experimental and modeling edge databases, and identified the needs and possible implementations to fulfill these requirements, based on the review of the existing edge database. A potential organizational structure for the establishment of the database, the time schedule (both short-term and long-term) and the necessary actions to be taken were suggested.

The basis for a comparison between code results and experiments as well as between the codes themselves will be an edge parameter database which consists of three sub-databases: a scalar-oriented database, an experimental profile database, and a model database. The purpose of such a database is to compare the global behaviour of different machines and thus should provide additional information which is not accessible by analysing the data of only one experiment. In addition, it will be partly used for model validation (models should be able to reproduce global scalar data) and for comparison with analytic models. Empirical scaling on the basis of the scalar database as well as profile data might be also possible in the future, but due to the too large uncertainties and due to the lack of understanding they are not envisaged for the time being.

A new kind of database will be a model database, where the optimized results of code calculations which used data from the profile database as input are stored. Besides the calculated plasma parameters, this database should also contain all the input parameters used to define the model run as well as a written comment. With such information a comparison between codes becomes feasible which should find errors as well as the relevant physics effects more effectively. In addition, a comparison of several different modeling attempts with different input parameters to each other and to experimental data will be also possible. All three databases will be installed in a trial version, where formats and usefulness will be assessed within the next few months. The final versions should be operational by the end of 1994.

Divertor modeling

The Working Group for Divertor Models assessed the ability of the existing divertor models to reproduce present experimental results from divertor tokamaks, especially results from experiments with detached plasmas and MARFEs, the status of the existing divertor modeling codes, the modeling that has been carried out recently for the ITER divertor design, and the status of the atomic and plasma surface interaction data needed for the modeling. While there has been substantial progress in the development and application of divertor models since the assessment by ITER at the workshop in Garching in June 1992, the models are only now reaching a state where they can be seriously used to analyse experiments and give some guidance for development of a concept for the ITER divertor. The needs for further development were identified and recommendations for meeting those needs were formulated. The needs include better and more extensive experimental data to test the models and improved atomic physics and plasma surface interaction data. The group drafted a recommended list of experimental data and made suggestions for how the important atomic physics and surface physics data could be produced within the fusion programs of the four Parties and the IAEA.

Plasma edge theory

These theoretical investigations and assessments are extremely important for the understanding of the experimentally observed phenomena. Only theoretical understanding of experimental results will enable identification of important physics effects which are missing in the codes and thus improve the performance of the edge models. Theoretical work for ITER should include basic theory as well as analytical and semi-analytical approaches to solve the basic SOL equations. Basic theory covers a wide area of topics and proves, in particular, the basis for the fluid approximation of the SOL plasma (transport coefficients, sources, boundary conditions, limits of applicability) and supplements the modeling work. Analytical or semi-analytical fluid models provide insight into the physics structure of the subject, which has been otherwise difficult to achieve. The models have been successful in identifying the basic mechanisms and regimes of interest and help clarify the parametric dependence of the SOL plasma. Theoretical effort should concentrate on the outstanding questions related to this concept, which include: (1) impurity behaviour in the presence of a gas target; (2) location of the cushion, including questions of sensitivity, stability, and density limits; and (3) neutral particle behaviour and control. Theoretical work should continue on alternative concepts, including a high density gas target. It is essential that theoretical work evolves in conjunction with experimental work on detached plasmas in divertor tokamaks.

Divertor simulators

While the regimes desired for ITER may have been assessed to some degree in existing devices, these devices are not operating with ITER-like temperature profiles nor collisionalities, making direct extrapolation to ITER operation problematic. This gives particular importance to the possibility of using a divertor simulator for wind-tunnel-like tests of proposed ITER divertor designs.

During the breakout session, several approaches to a simulator were discussed, including a linear device, a toroidal machine without current, a pulsed tokamak and a steady-state tokamak. In order to prevent unwarranted discussion on machine design details, only the general principles were discussed. Thus, the linear device was considered to be a long (≈20-30 m) linear machine with quadrapole stabilizing fields such as the IDEAL proposal. The toroidal device was pictured as a torus with R≈2m, and a helical field formed by a combination of toroidal and poloidal fields, the latter being produced only by coils (i.e., no plasma current). Both the pulsed and steady-state tokamaks were considered to be devices having sufficient power, d_{xp} values and density to at least approximately satisfy the scaling constraints. Construction of a new facility meeting the requirements of a Tokamak Divertor Test Facility (TDTF) is clearly beyond the scope of the ITER divertor R&D budget. One possibility is to modify an existing tokamak in order that it could better achieve the required parameters (mainly P / R and $n\ d_{xp}$). The funding for such a modification would need to come mainly from the voluntary physics R&D budget of one of the Parties.

LIST OF PARTICIPANTS

EU: K. Borass (JET), G. Fussmann (IPP)*, P. Ghendrih (CEA)*, M. Kaufmann (IPP), K. Lackner (IPP), A. Loarte (JET), J. Neuhauser (IPP), H.D. Pacher (NET), D. Reiter (KFA), A. Taroni (JET), U. Samm (KFA), R. Schneider (IPP), P. Stangeby (CFFTP), G. Vlases (JET), J. Winter (KFA)*, M. Watkins (JET)*

JA: M. Shimada (JAERI), T. Takizuka (JAERI), M. Tanaka (Century Res. Ltd.)*, H. Tawara (NIFS), K. Ueda (MAP Ltd.)

RF: A.Y. Pigarov (KIAE), V.I. Pistunovich (KIAE), V.A. Pozaharov (KIAE)

US: B. Braams (NYU), C. Bolton (DOE)*, S. Cohen (PPPL), R. W. Conn (USCD/ITER, TAC)*, G. McCracken (MIT), R. Goldston (PPPL)*, D. Hill (LLLN/TPX), J. Hogan (ORNL), C. Karney (PPPL), S. Krasheninnikov (MIT), A. Mahdavi (GA), M. Peng (ORNL), G. Porter (LLNL), T. Rognlien (LLNL), L. Schmitz (UCLA)

JCT: P.-H. Rebut, R. Parker, J. Dietz, Y. Igitkhanov, A. Kukushkin, G. Janeschitz, F.W. Perkins, D. Post, M. Rosenbluth, M. Sugihara

IAEA: R. Janev

* Observers

FORTHCOMING EVENTS *)

- Kickoff Meeting for ITER Task Agreements on Generic Access Routes for Diagnostics, Garching, Germany, 6-10 June
- Divertor Design and Materials Technical Meeting, Garching, Germany, 8-10 June
- Magnets Technical Meeting, Naka, Japan, 6-7 July
- MAC-6, Garching, Germany, 6-8 July
- TAC-6, St. Petersburg, Russia, 12-14 July
- IC-6, Moscow, Russia, 27-28 July

*) 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).

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