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INSIDE

ORGANIZATIONAL STRUCTURE AND ACTIVITIES OF THE USSR IN SUPPORT OF THE ITER CONCEPTUAL DESIGN ACTIVITIES

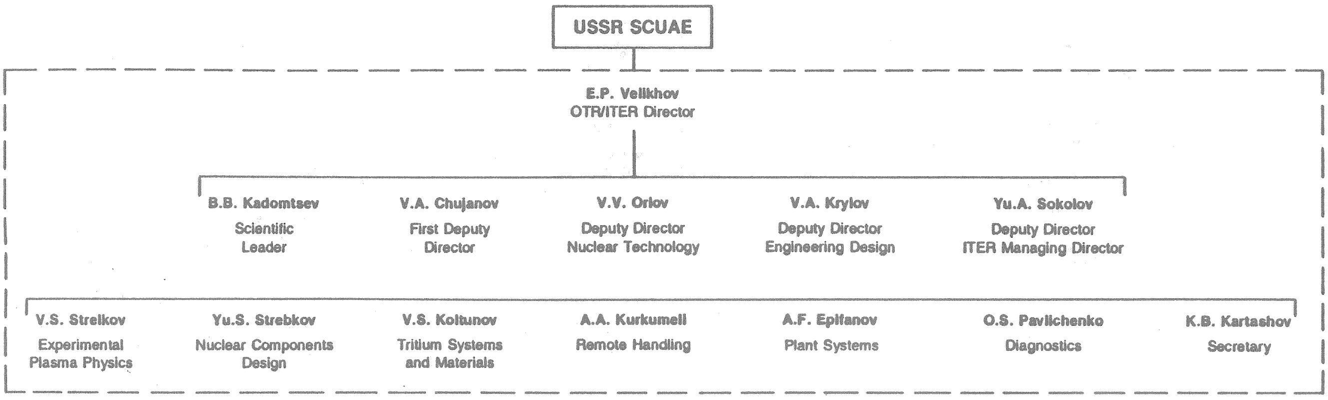
by Yu. Sokolov, Member of the ITER Management Committee

ITER-related activities in the USSR are supervised by the State Committee on the Utilization of Atomic Energy of the USSR (SCUAE), which is responsible for overall organization and co-ordination of scientific and technological researches, industrial applications and design and construction works in the field of nuclear science and technology. Research in plasma physics and controlled fusion are financed and co-ordinated by the Main Department of Fundamental Nuclear Physics Research and Thermonuclear Fusion of the SCUAE.

Executive Committee co-ordinates both national project and ITER support work

The activities in the Soviet Union in support of ITER are carried out based on the existing collaboration of the research institutes and industry which has been developed for years and was established for the project of the experimental thermonuclear reactor called OTR. This co-operation provides experimental and theoretical research in the field of engineering, nuclear technology and plasma physics. The OTR project is managed by the OTR Executive Committee (EC) led by the Director of the project, Academician E.P. Velikhov. To organize in the shortest possible time an effective and efficient management support to the USSR participation in the ITER activities, the SCUAE decided to charge control and overall co-ordination of the ITER-related work in the Soviet Union to the OTR EC and renamed it correspondingly to OTR/ITER EC. The USSR ITER Managing Director is a member of the OTR/ITER EC at the national level. The structure of the OTR/ITER EC is given in Fig. 1.

Fig. 1. OTR/ITER Executive Committee



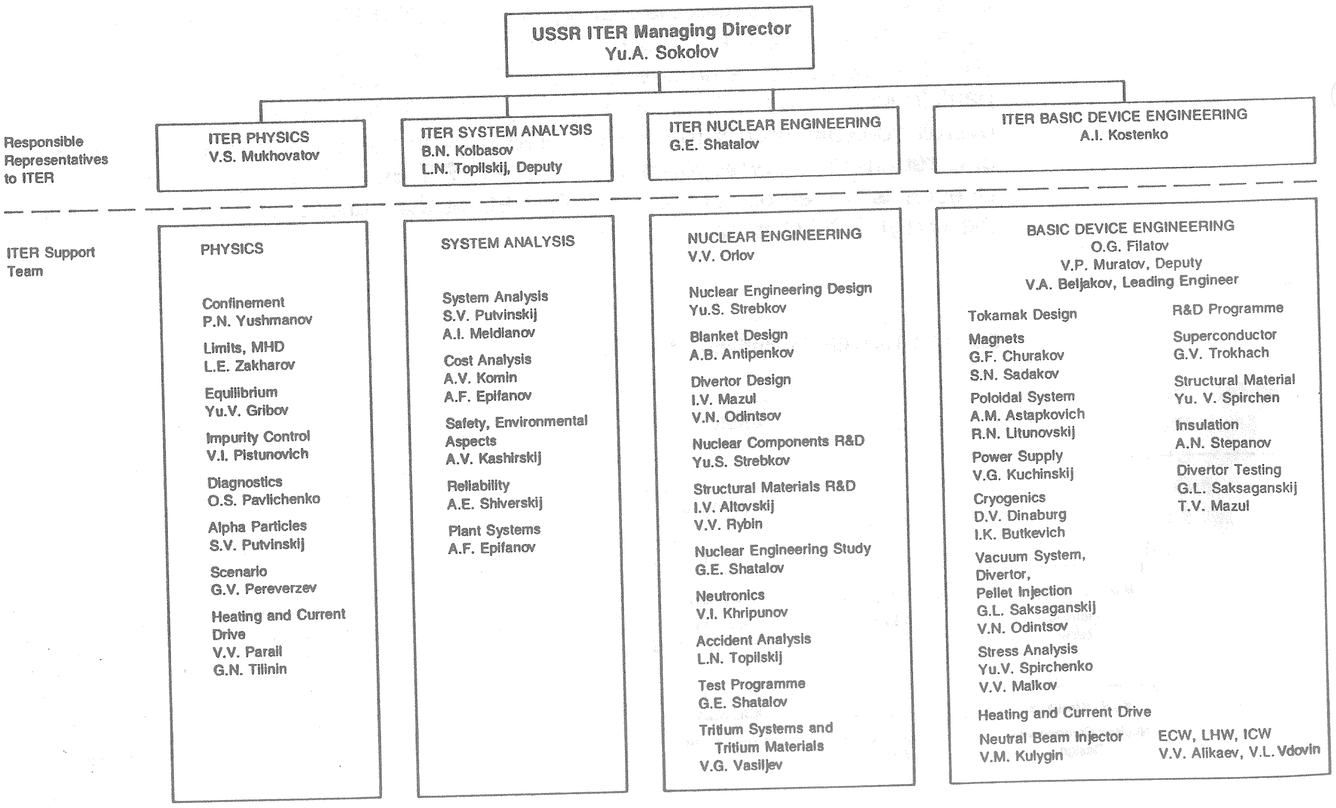
Leading research institutes perform and co-ordinate ITER work in the USSR

Five leading research institutes perform ITER-related activities and distribute ITER contracts and tasks to other institutes and industrial organizations. The number of research institutes and industrial establishments involved in ITER support in the USSR totals more than thirty. These five leading institutes and their areas of responsibility are:

- I.V. Kurchatov Institute of Atomic Energy, Moscow: overall project co-ordination, basic plasma physics, experimental and theoretical tokamak plasma physics R&D, heating and current drive technology R&D;
- D.V. Efremov Scientific Research Institute of Electrophysical Apparatus, Leningrad: basic device engineering, technology R&D for superconductors, toroidal field coil (TFC) structural materials and insulators, cryogenics, divertor plates testing, pellet injectors;
- Research and Development Institute of Power Engineering, Moscow: nuclear technology R&D, technology R&D for blanket, including structural materials for first wall and divertor plates;
- Institute of Inorganic Materials, Moscow: tritium systems and materials;
- Design Institute for Power and Technology, Leningrad: site selection criteria, plant systems.

All main areas of the ITER Conceptual Design Activities are covered by relevant works carried out in the Soviet Union. The organizational structure of the USSR participation and ITER support works including key managers, executives and experts is shown in Fig. 2. Most of these experts regularly participate in joint work sessions and special meetings held in Garching. The number of full-time participants in the design activities for ITER is over 30 professionals, the total number of people involved being more than one hundred.

Fig. 2. Organization of the USSR ITER Support Works



USSR ITER Managing Director
Yu.A. Sokolov

Responsible Representatives to ITER

ITER PHYSICS
V.S. Mukhovatov

ITER SYSTEM ANALYSIS
B.N. Kolbasov
L.N. Topilskij, Deputy

ITER NUCLEAR ENGINEERING
G.E. Shatalov

ITER BASIC DEVICE ENGINEERING
A.I. Kostenko

ITER Support Team

PHYSICS

Confinement
P.N. Yushmanov

Limits, MHD
L.E. Zakharov

Equilibrium
Yu.V. Gribov

Impurity Control
V.I. Pistunovich

Diagnostics
O.S. Pavlichenko

Alpha Particles
S.V. Putvinskij

Scenario
G.V. Pereverzev

Heating and Current Drive
V.V. Parail
G.N. Tilinin

SYSTEM ANALYSIS

System Analysis
S.V. Putvinskij
A.I. Meidlanov

Cost Analysis
A.V. Komin
A.F. Epifanov

Safety, Environmental Aspects
A.V. Kashirskij

Reliability
A.E. Shiverskij

Plant Systems
A.F. Epifanov

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V.V. Orlov

Nuclear Engineering Design
Yu.S. Strebkov

Blanket Design
A.B. Antipenkov

Divertor Design
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V.N. Odintsov

Nuclear Components R&D
Yu.S. Strebkov

Structural Materials R&D
I.V. Altovskij
V.V. Rybin

Nuclear Engineering Study
G.E. Shatalov

Neutronics
V.I. Khripunov

Accident Analysis
L.N. Topilskij

Test Programme
G.E. Shatalov

Tritium Systems and Tritium Materials
V.G. Vasiljev

BASIC DEVICE ENGINEERING
O.G. Filatov
V.P. Muratov, Deputy
V.A. Beljakov, Leading Engineer

Tokamak Design

Magnets
G.F. Churakov
S.N. Sadakov

Poloidal System
A.M. Astapkovich
R.N. Litunovskij

Power Supply
V.G. Kuchinskij

Cryogenics
D.V. Dinaburg
I.K. Butkevich

Vacuum System, Divertor, Pellet Injection
G.L. Saksaganskij
V.N. Odintsov

Stress Analysis
Yu.V. Spirchenko
V.V. Malkov

R&D Programme

Superconductor
G.V. Trokhach

Structural Material
Yu. V. Spirchen

Insulation
A.N. Stepanov

Divertor Testing
G.L. Saksaganskij
T.V. Mazul

Heating and Current Drive

Neutral Beam Injector
V.M. Kulygin

ECW, LHW, ICW
V.V. Alikaev, V.L. Vdovin

Contribution to the ITER R&D programme

The USSR contributes to the ITER Conceptual Design Activities both in the field of physics and technology R&D. Experimental and theoretical plasma physics research in the Soviet Union is carried out based on the data obtained from a number of tokamaks including T-10, T-11, TSP and T-15. The last two machines were put into operation recently and the main experimental results will be available for the ITER design activities in forthcoming years.

The USSR contribution to the ITER technology R&D programme is based on the advanced technologies for fusion developed in the Soviet Union. The efforts are concentrated on the development of 140 GHz/1 MW gyrotron, blanket concept with LiPb eutectic, 10-A negative-ion source, 25 kA superconducting cable for TFC, critical components of the large cryogenic systems, structural materials and others.

Leading Soviet scientists and scientific programme managers are the members of the ITER Council and the ITER Scientific and Technical Advisory Committee. They are: The Vice-President of the USSR Academy of Sciences and Director of I.V. Kurchatov Institute, Academician E.P. Velikhov; the Head of Department at SCUAE, Dr. N.S. Cheverev; the Deputy Director of the I.V. Kurchatov Institute, Academician B.B. Kadomtsev (ISTAC Chairman); the Deputy Director of the D.V. Efremov Institute, Dr. V.A. Krylov and the Head of Department at the I.V. Kurchatov Institute, Dr. V.A. Chujanov.

Fusion community is informed of ITER activities

The ITER activities are widely known among the USSR fusion scientists. In February 1989, by invitation of the Organizing Committee of the Seminar on Toroidal Systems in Controlled Fusion, held in Dubna, USSR, the members of the ITER Management Committee attended this Seminar and made presentations on ITER-related matters. These presentations attracted attention of about 150 participants of the Seminar resulting in follow-up discussions.

ITER-RELATED R&D PROGRAMME

by K. Tomabechi, Chairman of the ITER Management Committee

ITER R&D programme is based on the on-going national programmes

ITER Conceptual Design Activities are vitally connected with the broad programmes of fusion energy research and development of the four Parties. The inception of ITER stemmed from the recognition that this fusion R&D had advanced to the point that a device such as ITER was the logical next step in each programme. Since that time, extensive R&D activities in each Party's programme have continued and are generating a great deal of further information that is relevant to ITER. The ITER activities count on the on-going national programmes, carried out generally as planned, to make a broad spectrum of information available to ITER.

As part of the fusion R&D programmes of the ITER Parties, there are some tasks that have been especially planned so as to provide information that is essential for the ITER design activities. The Terms of Reference include the following statement concerning the R&D for ITER.

Guidelines for R&D programme provided by the Terms of Reference

"The R&D activities will focus on the feasibility issues critical to a conceptual design that meets the ITER objectives. The R&D tasks will include the physics and the engineering technology required for the realization of ignition, and also the development of a physics data-base, the auxiliary current drive technology and the nuclear technology required for the realization of steady-state operating and testing. . . . Each Party will make equal contribution to the R&D activities anticipated to be equivalent to approximately $10 M per year."

To provide the results in time for the design work, the R&D tasks are to be identified promptly and conducted expeditiously. The R&D activities considered should be completed or have achieved a main milestone by mid 1990 or sooner to be included in the Conceptual Design of ITER.

TABLE 1. ITER-RELATED PHYSICS R&D TASKS

1. Power and helium exhaust conditions.
2. Helium radial distribution in high-temperature tokamak discharge.
3. Viability of a radiative edge.
4. Sweeping of the divertor target load.
5. Characterization of low-Z materials for plasma-facing components.
6. Characterization of high-Z materials for plasma-facing components.
7. Characterization of disruptions.
8. Disruption control.
9. RF plasma formation and preheating.
10. RF current initiation.
11. Scaling of volt-second consumption during inductive current ramp-up in large tokamaks.
12. Alpha-particle losses induced by the toroidal magnetic field ripple.
13. Compatibility of plasma diagnostics with ITER conditions.
14. Steady-state operation in enhanced confinement regimes (H-mode and"enhanced" L-mode).
15. Comparison of theoretical transport models with experimental data.
16. Control of MHD activity.
17. Density limit.
18. Plasma performance at high elongation.
19. Alpha-particle simulation experiments.
20. Electron cyclotron current drive.
21. Ion cyclotron current drive.
22. Impact of Alfven wave instability on neutral beam current drive.
23. Proof of principle of fuelling by injection of field-reversed compact toroids.

ITER related R&D activities were decided to be implemented for physics tasks and technology tasks respectively that were identified in the early phase of the design activities. A plan for physics R&D is in the process of authorization and the plan for the technology R&D has already been commenced. The status of these R&D activities is described below.

Main areas of physics R&D

Two areas of physics investigations have been identified as particularly critical to the ITER design:

(i) the working conditions of the plasma-facing components ("plasma-wall interaction") and

(ii) the impact of plasma disruption.

It appears that, if an effort commensurate with the importance of these issues were made in the world-wide fusion activities, the necessary information could be obtained relatively soon. Of course, in the present situation it also remains essential to demonstrate that

(iii) satisfactory operation with enhanced energy confinement is possible.

A number of crucial design-related physics R&D issues on which additional information is urgently required to be able, in 1990, to confirm the technical working assumptions on which the ITER concept is based have been identified and are listed in Table 1. Issues of general plasma performance (energy confinement, operational limits, burn control, long-pulse operation) crucial for ITER being able to reach its objectives and not sufficiently covered by the on-going fusion programmes, are given also in the table. The table contains a few areas where work is urgently needed to be carried out to clarify the potential of unproven approaches for the ITER concept optimization. For each issue, the reasons explaining its importance were identified as well as the objective to be achieved, and the results expected to become available before or after the summer of 1990. In addition, a dedicated theoretical and modelling effort is needed in almost all areas.

A document which describes the physics R&D tasks was prepared and sent to the ITER participating Parties for soliciting contributions from their experiments. Very positive responses were given by all the Parties. The proposals of the Parties have been sorted out in a form of physics R&D plan which will be submitted for discussion at the ISTAC meeting and ITER Council meeting scheduled in June and July respectively.

Technology R&D programme is under way

The specific technology R&D needs for ITER, listed in Table 2, cover issues which are considered essential to prove that the main components of the apparatus can achieve the required performance. The tasks give major emphasis to the milestones to be achieved by 1990 but it should be understood that most of these tasks will only be completed by 1993.

ITER technology R&D has been divided into the six areas: "Blanket", "Plasma Facing Components", "Magnet", "Fuel Cycle", "Heating and Current Drive" and "Maintenance". The safety- related issues have not been separately listed, but are incorporated as an integral part of the individual component development. For each area, the rationale for the choice of the tasks and the objectives of each task have been defined. Together with the rationale and the objectives, all the tasks were compiled in a document, which was then sent to the Parties for soliciting contributions from their national fusion activities. For each task detailed proposals have been received from the Parties: the assessment of these proposals suggests that the balance of effort between the technical areas is generally appropriate and corresponds to the need of the programme, as seen in Table 2.

TABLE 2. ITER TECHNOLOGY R&D TASKS AND CONTRIBUTIONS FROM THE PARTIES

	EC	J	USSR	USA
Area: Blanket				
Ceramic breeder	+	+	-	+
LiPb breeder	+	-	+	-
H_20/Li solution breeder	+	-	-	+
Beryllium	-	-	-	+
Structure material	+	-	+	+
Area: Plasma Facing Components				
Low-Z material	+	+	+	+
High-Z material	-	+	+	-
First wall test	+	+	-	+
Divertor test	+	+	+	+
Area: Magnet				
Toroidal coil	+	+	+	-
Poloidal coil	+	+	-	+
Insulation material	+	+	+	+
Structural material	+	-	+	-
Radiation tolerant magnet	-	-	-	+
Cryogenics	-	+	+	-
Area: Fuel Cycle				
Fuelling	+	+	+	+
Pumping	+	+	-	-
Fuel purification	+	-	-	-
Area: Heating/Current Drive				
Source: EC: 150-250 GHz	+	-	+	+
Source: LH: 6-8 GHz	+	-	-	-
Source: NB: negative ions	+	+	+	+
Area: Maintenance				
Components qualification	+	-	-	-
In-vessel operations demonstration	+	+	-	-

Since the technology R&D plan has been authorized at the ITER Council meeting in 1988, intensive R&D activities have been under way in the respective laboratories of the Parties.

During the Definition Phase, it soon became clear that all the specific tasks needed for ITER could not be supported within the figure of $10 M per year per Party foreseen in the Terms of Reference. Because physics tasks can be executed by just a change of emphasis in the on-going programmes, only technology tasks specific to ITER design were presumed to be included in the supporting R&D budget category. This understanding does not imply any priority status between physics and technology tasks.

Finally, it should be noted that the R&D needs for ITER have been identified on the basis of the information available at the early phase of the ITER concept definition. The R&D plan will therefore be kept under review during the design phase and, when necessary, alterations and additions will be incorporated.

16th EUROPEAN CONFERENCE ON CONTROLLED FUSION AND PLASMA PHYSICS

by C. Beasley, IAEA

Presentation of 500 papers by the 560 participants from 31 countries at the recent Venice conference, 13-17 March, 1989, coupled with presentation of results by all major experiments, created an atmosphere of achievement. This was underscored by new results presented at the conference: central beta of 8 per cent and a confinement time of 0.45 second in a double-null divertor plasma, and a 5-second-long H-mode state in DIII-D; and record stored energy (0.6 second at 5 MW and 3.5 MA) and Q(total) of 0.3 in JET (D-T).

Emphasis on the importance of ITER

The meeting was opened on an optimistic note by Prof. U. Colombo, President of ENEA, who placed the fusion program in perspective of present needs vis-a-vis energy reserves, price, and environmental considerations. Emphasis was placed on the importance of ITER in the grand scheme of attainment of the fusion goal.

A synopsis of tokamak results presented emphasized that while the physics (i.e., theory) of tokamak confinement is not yet well understood, knowledge of the empirical behavior of various high-confinement regimes is rapidly being expanded through experimental studies. The well-established Goldston L-mode scaling seems to be a "worst-case scenario" with respect to energy confinement. Improvement over L-mode confinement ranges from 50 per cent (JET) to factors of 2-3 in DIII-D and TFTR. In fact, DIII-D reports H-mode confinement times with neutral beam injection (NBI) twice that of H-mode ohmic. In addition, pellet injection (JET,ASDEX,TFTR), counter-injection (TFTR), and Improved Ohmic Confinement (IOC)(ASDEX) offer other methods of achieving improved confinement.

Experimental studies relevant in assuring ITER goals are attainable

Extensive H-mode plasma studies have been carried out in DIII-D and ASDEX. In DIII-D, H-mode plasmas have been obtained in ohmic, NBI, and electron cyclotron heated plasmas in both divertor and limiter configurations. Also the H-mode was observed in ohmic and NBI plasmas with broad density profiles (DIII-D); this may be significant, since peaked-density H-modes, IOC, and pellet plasmas collect impurities in the center of the plasma through neoclassical transport; while this may be controlled to a limited extent by Edge Localized Modes (JET), these plasmas seem to succumb from radiated power from impurity accumulation. On the other hand, in TFTR, where particles are born in the center (through pellets and NBI co- and counter injection), no indication was given that the TFTR plasma suffers from central impurity buildup. Pellet injection may be used not only to increase central density, but as in JET may provide a target for NBI and ion cyclotron resonance heating. Finally, profile studies in ASDEX suggest that the tokamak density limit is determined by edge density, not central density. This is consistent with TFTR results, which are best for peaked profiles. These experiments on enhanced confinement are directly relevant in assuring that ITER can be operated in an optimum mode.

In other results, an encouraging report on lower-hybrid current drive was reported by JT-60. A new launcher of 8 modules, each with 3 waveguides, achieved about 50 per cent better efficiency than previous results. A large volt-seconds savings is realized; loop voltage goes down to 0.5. Finally, the superconducting T-15 was reported to have begun operation at low field.

MEETING ON IMPURITY CONTROL

by V. Demchenko, IAEA

Effective control of plasma impurities is vital to the achievement of sustained thermonuclear burning. Without effective control, particles that are evolved from exposed surfaces accumulate in the plasma where they increase energy losses and prevent achievement of the high temperature necessary for nuclear fusion.

Possible operating parameters for plasma facing components of ITER have a wide range due to required flexibility for different operation scenarios. The average heat flux to the first wall was estimated as 1 MW/m^2, with a peak heat flux to the divertor plates being higher than 5 MW/m^2. To avoid accumulation of high Z impurities, the ITER team decided that the plasma facing surface of the first wall and the divertor plates would be covered by a low Z armor. Carbon-based materials (graphite and carbon fibre composites) were recommended for this purpose considering their good performance at high temperature. Erosion of the carbon armor may become a critical life-time issue due to relatively high erosion rate of the divertor plates caused by plasma disruptions. Solving both impurity control and erosion problems is one of the most serious and demanding technical issues of the ITER design.

ITER-related innovations in impurity control were reported

Significant advances in impurity control in fusion plasmas were reported at an IAEA Technical Committee meeting in February. At the 3-day meeting, held at JAERI's Naka site in Japan, 24 reports were contributed by 30 participants from 6 countries. The level and scale of impurity control methods have been improved substantially during recent years. The meeting participants first reviewed the latest results, then discussed in detail some innovative ideas for applications to arrive at an evaluation of the feasibility of incorporating recent achievements in the design of near-future tokamaks. The proceedings are of significance to ITER because of the potential improvements in plasma performance promised by some of the innovations in impurity control, helium "ash" exhaust, and heat removal.

An Improved Divertor Confinement (IDC) regime characterized by an improved confinement and remote radiative cooling has been obtained in neutral beam (NB) heated divertor discharges at JT-60. The radiative cooling is the direct way to reduce heat flux to the divertor: it mainly cools the divertor plasma and does not directly cool the main part of plasma.

In some divertor experiments (JET, ASDEX, JFT-2M, DIII-D), impurity accumulation was observed, which resulted in loss of H-mode state with Edge Localized Modes (ELM). By controlling ELM characteristics, DIII-D experiments demonstrated that quasi-steady-state H-mode can be maintained for 4.4 seconds without impurity accumulation. Combination of H-mode and IDC characteristics, in principle, might provide an attractive operation scenario.

In the course of auxiliary heating experiments at JET, the scrape-off layer of discharges has been studied. At high additional heating power, it was observed that a strongly increased carbon influx can occur leading to a sharp decrease of the measured DD reaction rate. This occurs for all modes of operation, but at different power levels. NB heating of high-power discharges at JT-60 with graphite walls also resulted in carbon density increase; oxygen density decreased respectively. This phenomenon did not relate to the temperature of the divertor plates and there was a threshold density with the onset of the phenomenon. A high-power ion cyclotron resonance frequency (ICRF) heating experiment has been conducted at the JIPP-TIIU tokamak. The impurity problem has been overcome by usage of the carbon limiter and gas-puffing synchronized to the RF pulse. A remarkable reduction of the metal impurity has been achieved, suppressing the total radiation loss to less than 30% of the input power.

Slow alpha particles produced by thermonuclear reactions constitute ash products and they should be exhausted from the plasma to avoid deterioration of fusion reactivity. It was proposed to generate between the divertor plates and the tokamak chamber first wall a screening layer of a low-temperature plasma which would ionize and trap neutral atoms flowing from the divertor plates to the wall. The subsequent removal of these out of the chamber is supposed to be realized with replaceable pump limiters. Application of the 2-dimensional time-dependent simulation code UEDA (Japan) to the analysis of the divertor and scrape-off layer plasmas showed that:

a) stationary particle control is possible if the number of helium particles pumped from the chamber is equal to the source of the alpha particles in the core plasma,

b) sufficient ash exhaust is possible under the condition which is consistent with the scaling of the law of the particle and energy confinement of the main plasma.

Progress on the way to solution

In general, the meeting has shown rapid development of impurity control methods for large scale tokamaks. Based on discussions, the most straight-forward solution for impurity/ash/heat removal problems seems to be a dense, cold and radiative divertor with metal divertor plates or a semi-closed divertor and controlled ELM's:

- dense plasma in semi-closed divertor geometry ensures high ash exhaust rate and impurity screening,
- cold divertor plasma with metal divertor plates reduces sputtering, erosion and dilution,
- dense and cold divertor can radiate substantial power and reduces heat load of divertor plates,
- controlled ELM's suppress density/impurity build-up and make the heat/particle load quasi-stationary.

ITER EVENTS CALENDAR - 1989

Joint Work Session	Garching	1 June - 20 Oct
ISTAC Meeting	Garching	26 - 28 June
ITER Council Meeting	Vienna	12 - 13 July
Symposium on Fusion Engineering	Knoxville	2 - 6 Oct
ISTAC Meeting	Vienna	15 - 17 Nov
ITER Council Meeting	Vienna	30 Nov - 1 Dec

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