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INSIDE

ITER DESIGN AND R&D PLANS FAVOURABLY REVIEWED

by N. Pozniakov, ISTAC Secretary

At the midpoint of the 1989-90 Design Phase, the general design is consistent with ITER objectives and the current design process is adequate to take advantage of the scientific and technological database which is expected to be available by the time of the completion of the Conceptual Design Activities (CDA) at the end of 1990. Such was the opinion of the ITER Scientific and Technical Advisory Committee (ISTAC) after a comprehensive review in November of progress in the ITER Conceptual Design Activities.

General design is consistent with ITER objectives

The fourth official meeting of the ISTAC, hosted by the University of California, Los Angeles, was held on 16-18 November, in conjunction with a meeting of the American Physical Society at which ITER designers described progress to a large audience. In accordance with the ITER Council (IC) Charges to ISTAC, the principal subject of discussions was the Interim Report on ITER Conceptual Design prepared by the ITER Management Committee (IMC). The report describes the results of the ITER Counceptual Design Activities after the first year of the Design Phase, following the selection of the ITER concept in the fall of 1988. The ISTAC specifically addressed such issues as design optimization and design flexibility.

Design improvements based on ISTAC recommendations

The course of the conceptual design work from June through November 1989 demonstrated the effectiveness with which the ITER organization receives input from the broader fusion community, evaluates it and makes appropriate changes in the design. The ISTAC is an independent advisory body, made up of eminent scientists and engineers from the four ITER Parties. ISTAC reviews, involving comprehensive presentations by the IMC and in-depth discussions by the ISTAC and the IMC, produce specific comments and recommendations by the ISTAC. The ITER Council weighs the ISTAC advice and the IMC's proposed responses. The IMC then implements actions that have been decided. Thus the ISTAC review in June, the Council meeting in July and the IMC's responses led to distinct improvements in the conceptual design.

The principal improvements between June and November consist of the following:

- increase in volt-seconds capability of the machine, enabling an inductive burn pulse length of more than 200 seconds,
- a vacuum vessel configuration that allows for a permanent inboard and outboard blanket/shield, without the need to change-out this component between physics and technology phases,
- additional shielding behind the divertor, and
- more space for the divertor, especially greater distance between the X-point and the divertor plate.

Reasonably high level of overall optimization reached in ITER design

The ISTAC opined that design of ITER had progressed to a reasonably high level of overall optimization. In particular, the present 22-MA design provides for ignition with confinement enhancements of a factor two or less over all L-mode scalings. The ITER team has also clarified the origins of the differences between present day empirical scalings and has developed a new composite empirical scaling relationship. In addition to a low-density, non-inductive steady-state mode of plasma operation, the ITER team has also developed a 'hybrid' plasma operating mode, in which a pulse length of about 2,000 seconds at high plasma density and at a Q-value of about 10 can be achieved, by lowering the plasma current slightly and adding a non-inductive contribution to current drive.

Struggling for more design flexibility

The ISTAC particularly endorsed the steps that had been taken toward improving the ITER design in the area of divertor performance and recommended continuing the development of the present double-null concept in the baseline design. However, because the peak heat load on the divertor plates still approaches the engineering limit, the divertor performance remains a critical issue. In this connection, the ISTAC recommended studies of options designed to allow even more space in the divertor region. In particular, the ISTAC recommended that a separate parallel study be implemented of the single-null divertor option, while retaining the present double-null concept in the baseline design. It is assumed that this scoping study may be carried out within the limits of manpower available for conducting the CDA in 1990.

In view of possible continuation of the ITER design activities, some other recommendations were also made to provide more design flexibility to facilitate the incorporation in the design of those scientific and technological innovations which may become available in the future, particularly in the critical design areas. A conceptual schedule for the possible next stages, i.e. Engineering Design and Construction of ITER, which would require considerations and decisions by the Parties, as well as rough estimates of construction capital cost were also presented by the IMC. These figures will be published within the Interim Report following its consideration by the ITER Council.

In addition to the Interim Report, progress in both Physics and Technology R&D Programmes was reviewed and the long-term issues were discussed with the goal to ensure the necessary support to the Engineering Design Activities, should the Parties decide to continue their co-operation after completion of the CDA.

Long-Term Physics R&D Programme is under preparation

The IMC presented a preliminary draft of the Long-Term Physics R&D Programme which is generally responsive to ISTAC recommendations from its meeting of June 1989 called for an extended Physics R&D Programme beyond 1990. The current draft addresses five main areas:

- power and particle exhaust physics,
- disruption control and operational limits,
- enhanced confinement,
- long-pulse operation (including non-inductive current drive), and
- physics of a burning plasma.

Assessment of long-term technology R&D recommended

As to the long-term technology R&D, the process of development and prototype testing of the main components of ITER would dominate the cost and schedule of an engineering design phase of the project. Taking into account the long-term nature of the process, the IMC has already started the evaluation of a long-term technology R&D needed to establish the engineering basis of ITER.

The ISTAC endorsed the activity and recommended to the IC that the IMC consider:

- what can be regarded as a reliable demonstration of the performance required for each of the critical components to be developed,
- what existing facilities can be used for such demonstrations, and
- what new facilities are needed.

The early assessment of a possibility of the international co-operation in the development and joint operation of the test beds for prototype testing would significantly reduce the cost and shorten the schedule of engineering design.

HIGHLIGHTS OF ITER COUNCIL MEETING

by Paul N. Haubenreich, ITER Council Secretary

Notable progress in conceptual design, encouraging R&D results and a good beginning on development of supporting information for the Parties' consideration of a possible Engineering Design Phase: these were highlights of an ITER Council meeting at IAEA Headquarters on 30 November - 1 December. A fuller report on the meeting will appear in the next issue of the Newsletter.

DEVELOPMENT OF PLASMA-FACING COMPONENTS FOR ITER

by G. Vieider, Leader, Plasma-Facing Component Design Unit

Design requirements

Progress made in definition of "first" design options

During the summer work session ending in October 1989, significant progress was made in the definition of requirements and "first" design options for the ITER plasma-facing components (PC) mainly for the physics phase. These components, shown in Fig. 1., are:

- about 720 m^2 of first wall (FW) for protection of the blanket segments against heat and particle loads from the plasma, and
- about 200 m^2 of divertor plates (DP) for the removal of thermal power and helium ash from the plasma edge.

The PC design and performance is crucial both for the overall machine availability as well as for the plasma performance and depends on the operating conditions.

Table 1 summarizes the currently predicted PC operating requirements, which are severe and associated with uncertainties, in particular concerning plasma disruptions.

Operating requirements for plasma-facing components

TABLE 1: MAIN PC OPERATING REQUIREMENTS

Operation Phase	Physics		Technology	
Component	FW	DP	FW	DP
Normal operation				
- Mean neutron load, MW/m^2	1	0.6	0.8	0.5
- Peak surface heat flux, MW/m^2	0.6	15	0.6	15
- Number of pulses	10^4		$\geq 3.10^4$	
- Mean burntime/pulse, s	200		1200	
Disruptions				
Thermal quench: -time, ms	0.1 - 3		0.1 - 3	
- peak energy deposition MJ/m^2	2	20	2	20
Current quench: -time, ms	5 - 20		5 - 20	
- radiative energy deposition MJ/m^2	2		2	
- run-away electron energy MJ/m^2	<100		<100	

Other essential PC design constraints include:

- the need for remote maintenance, leading to segmentation into 64 DP and 80 FW/blanket units;
- the choice of water as the basic coolant, which allows a compact design, low temperature and low pressure operation with passive safety features such as natural convection shutdown cooling, and
- the choice of austenitic stainless steel as the basic structure material for the blanket segments because of the extensive data base and adequate performance of this material.

Basic first wall structure element is a water-cooled steel panel.

First Wall (FW) design

The FW structure in the form of a water-cooled steel panel is integrated with the blanket segments by welding to the box side walls. This is illustrated in Fig. 1.

- Poloidal coolant channels are selected in particular inboard with only 0.24 m wide and 12 m high FW panels.
- Cooling tubes are brazed into a welded steel structure, thus forming a double walled containment of the coolant for achieving the required virtual zero leakage.

Another FW design with toroidal cooling is being studied for the outboard FW. Structural analysis and first thermal fatigue experiments indicate that the FW fatigue life will be greater than required for a normal cyclic heat flux of up to 0.6 MW/m^2. The influence of thermal and dynamic stresses by disruptions on the FW life is now being investigated in depth as a potentially critical issue.

Armour tiles protect first wall steel structure

FW armour tiles in carbon fiber composite are assumed as in present large tokamaks as protection of the FW steel structure against:

- plasma impurities during start-up and disruptions,
- melting and thermal fatigue from disruptions, and
- neutral beams and injected pellets.

Remote maintenance taken into account

For remote maintenance these tiles are mechanically attached to the FW steel structure as shown in Fig. 2.

- Radiation cooling permits a predictable and robust solution; however peak tile temperatures of up to 1800°C will be reached, leading to safety and plasma purity concerns.
- Conduction cooling at <1000°C depends critically on the development of an elastic, compliant layer which maintains the contact pressure even under neutron damage.

A further critical issue with carbon armour is the high retention of impurities and hydrogen. This requires complicated conditioning procedures and will result in tritium inventories of up to several hundred grams. Therefore, for the technology phase it is envisaged to reduce the coverage by carbon tiles down to local "sub-limiters." This would be facilitated if disruptions could become rare events, due only to control system failures.

Divertor plate (DP) design

Optimum space utilization and minimum heat loads

The DP design chosen for the physics phase is illustrated in Fig. 3.

- A moderately shaped configuration was developed for optimum space utilization and minimum heat loads.
- Each of the 64 DP's consists of 16 poloidal modules which are electrically insulated to avoid large electro-magnetic disruption forces. The armour tiles are brazed onto cooling tubes made of a copper or molybdenum alloy.

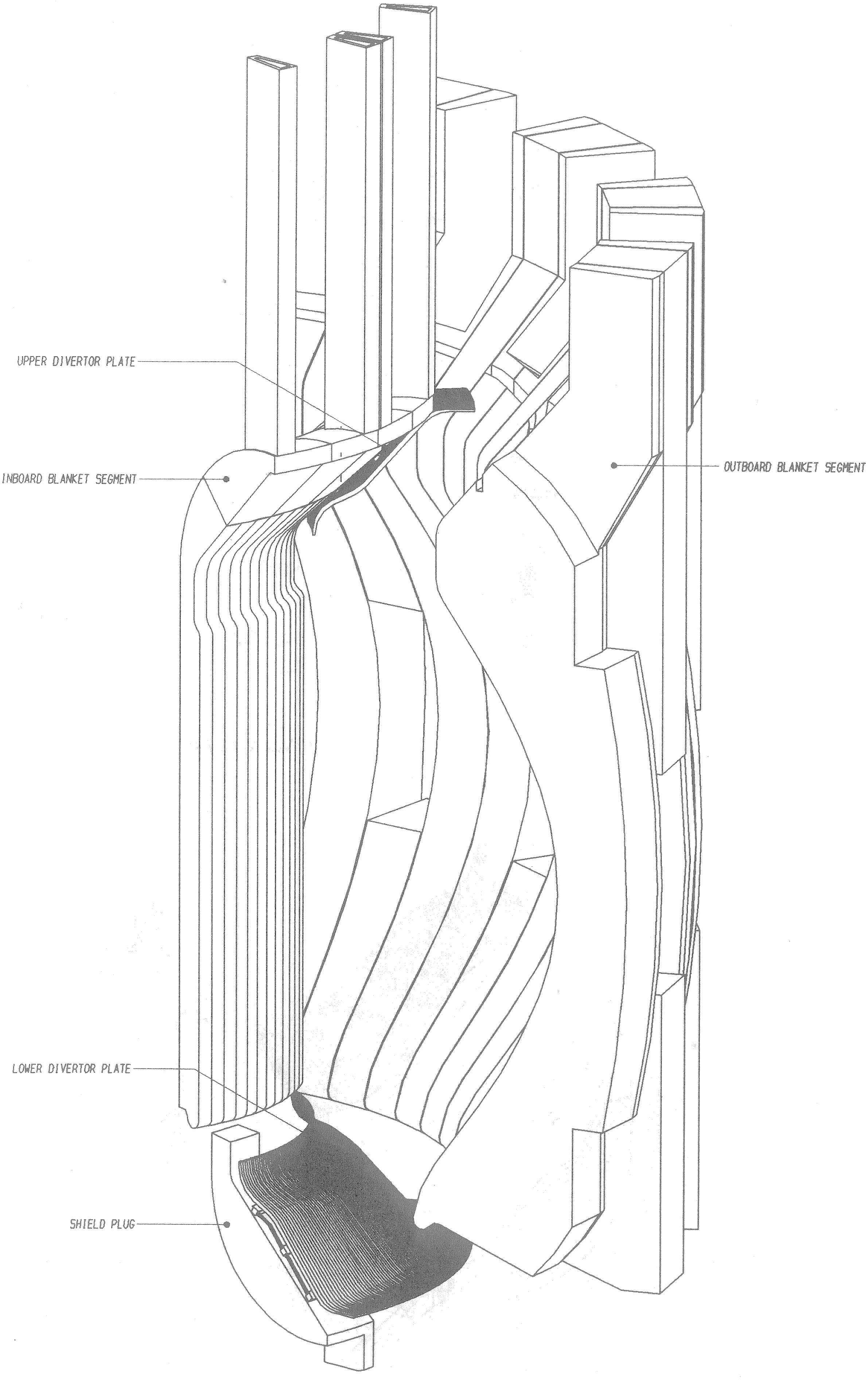

Fig. 1. View of ITER Plasma Facing Components

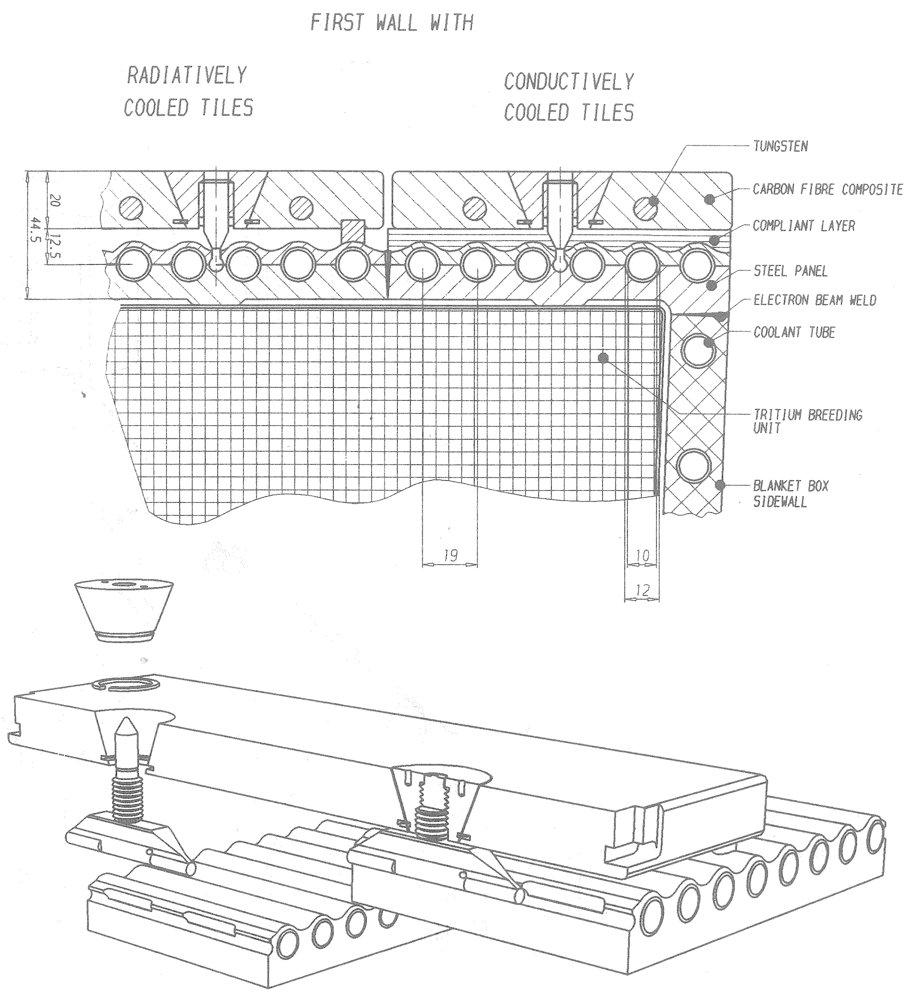

Fig. 2. ITER First Wall with Armour Tiles

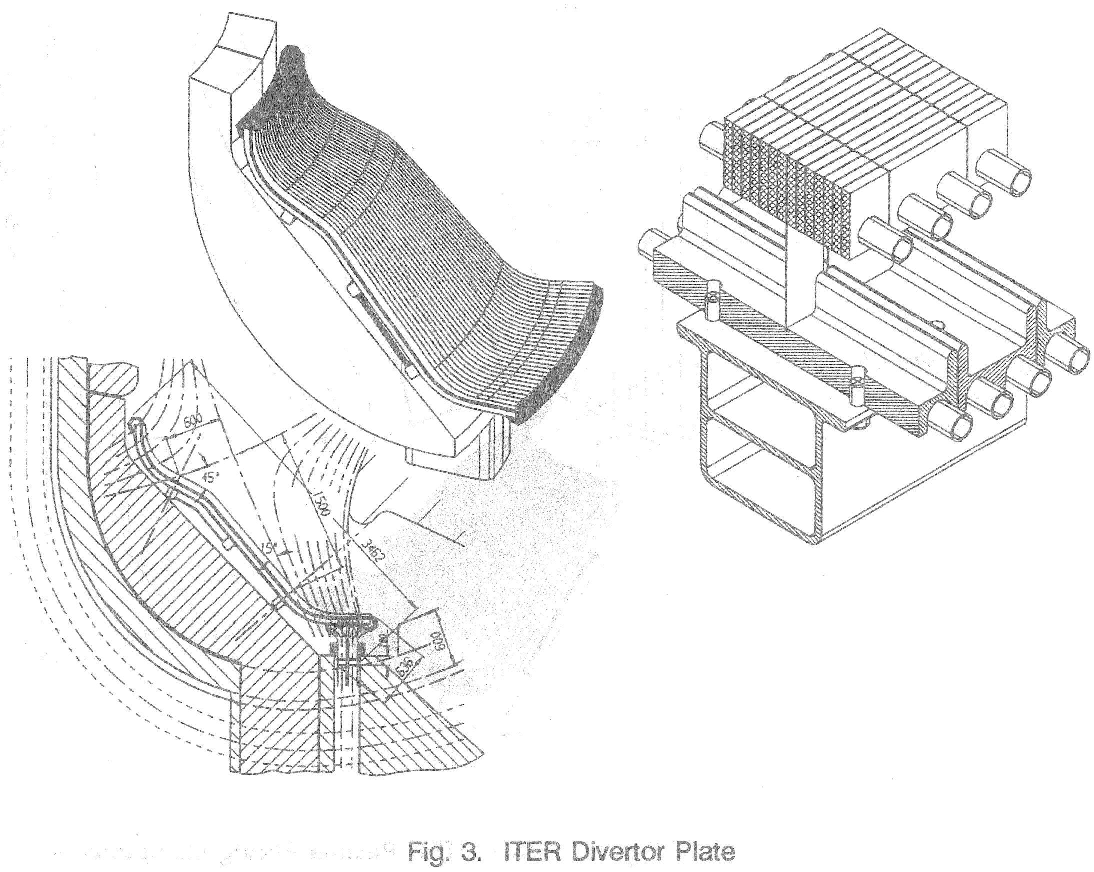

Fig. 3. ITER Divertor Plate

Carbon as an armour material for physics phase

As DP-armour for the physics phase, carbon is selected as for the first wall, primarily because of the extensive operating experience in current tokamaks. Pyrolytic graphite is preferred due to its very high thermal conductivity. This permits a sacrificial erosion layer thickness of 2 cm without exceeding 1000°C surface temperature to avoid excessive erosion. The erosion life of such carbon DP's is estimated:

- to last the whole physics phase for normal sputtering erosion including redeposition,
- to 50 - 100 disruptions, which would probably require DP-replacements every year.

Alternative armour materials for technology phase are beryllium and tungsten.

As alternatives to carbon as DP armour mainly for the technology phase, beryllium and tungsten are being considered. The peak DP heat flux with water cooling is limited by burnout caused by film boiling at about 50 MW/m^2. Taking into account likely peaking effects due to tolerances, the allowed nominal DP-peak heat flux should not exceed 15 MW/m^2.

Technology R&D programme

20% of ITER technology R&D is devoted to plasma facing components.

About 20% of the ITER R&D programme with a total annual effort of $40 M are devoted to the technology of plasma facing components. This effort is focused on:

- establishing the database for structure and armour materials, including neutron damage effects,
- demonstrating the manufacturing feasibility on prototypical mock-ups as shown e.g. in Fig. 4 for the first wall, and
- high heat flux testing of the mock-ups in partly new facilities as the basis for lifetime predictions.

The results from this vigorous R&D programme should be adequate to support the detailed engineering design of plasma-facing components that could start in 1991. The results so far from the collaborative design and development effort indicate confidence to arrive at first wall and divertor solutions with adequate performance.

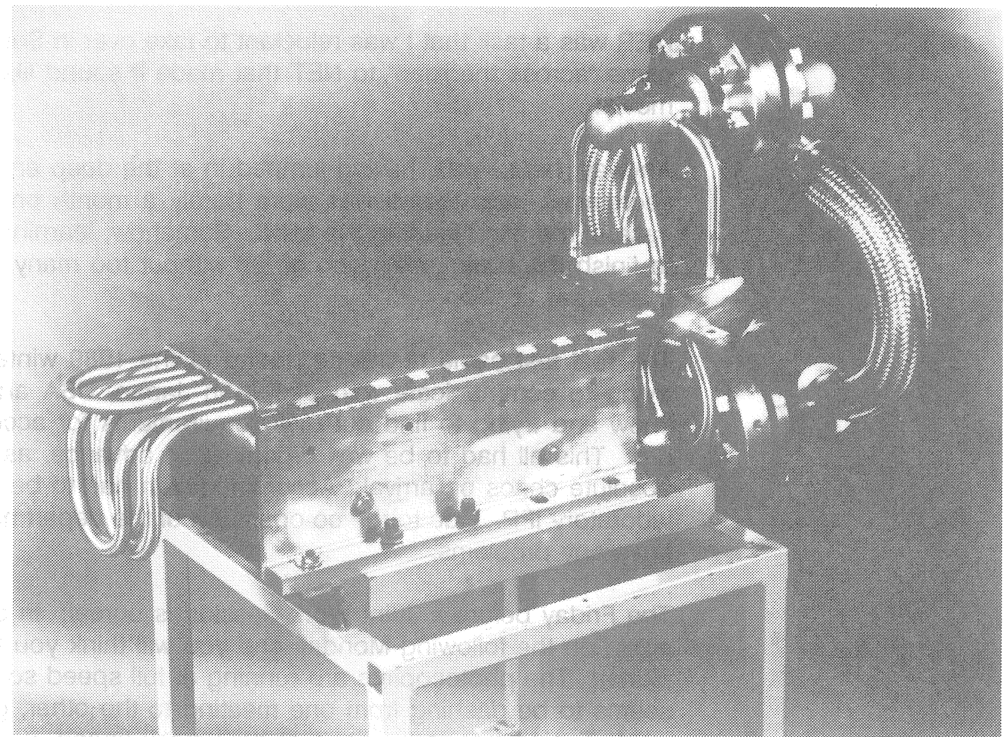

Fig. 4. Test Section of the First Wall

ITER PROGRESS PRESENTED IN THE USA

by John R. Gilleland, ITER Management Committee

Progress in ITER conceptual design and R&D activities was presented at the November meeting of the American Physical Society in Anaheim, California, USA. A poster session on ITER physics and engineering topics was held as part of the regular agenda. In addition there was an informal evening session on ITER chaired by Paul Rutherford of Princeton Plasma Physics Laboratory. Key speakers were Ken Tomabechi, "ITER Status"; Boris Kadomtsev, "A Perspective of the Role of ITER in World Fusion Development"; Romano Toschi, "Overview of the ITER Design"; and Douglass Post, "Physics Issues of the ITER Design".

Awareness of ITER is growing in the US.

About one hundred society members, mostly from universities and national laboratories, attended the special session. The questions and discussion both during and after the meeting reflected the growing interest and awareness of the ITER programme in the United States.

Editor's Note

People from different countries who work for ITER in Garching know Gloria as a person devoted to her duties and very helpful in making arrangements both in work and in every day's life. Gloria Boekbinder Mulder is one of the Secretaries of the ITER team in Garching. In her article are some reflections resulting from her work for ITER for more than a year.

ITER - FROM A SECRETARY'S VIEWPOINT

by G. Boekbinder Mulder, Secretary, ITER Team, Garching

ITER was a task that I was reluctant to take over in September 1988. Stories had come "across the road" to NET that made it sound like a snippet out of a horror movie!

Anyway, here I was, having jumped in at the deep end, working with three other secretaries, who themselves were barely a month on the job. For us, it was a case of the blind leading the blind. Somehow, learning on the way, we managed to finish the summer session of '88 without too many mishaps and then we had a breather session.

The real test came at the beginning of the 1989 winter session. Here we were trying to communicate with people in Japan, USA and USSR whom we barely knew and trying to find out their requirements for accommodation, office space, etc. This all had to be well organized in advance, as otherwise there would be absolute chaos on arrival. Accommodation had to be co-ordinated with the host laboratory IPP. Due to the co-operation of the department in question, we did not have any problems.

The Friday before a Joint Work Session is unreal; in one word: peace! Come in again on the following Monday and you will think you have landed on a different planet! The photocopiers are running at full speed so are the people! Everyone seems to be dashing from one meeting to the other, greeting colleagues on the way! Typing has to be done at breakneck speed, no time for errors! The air is charged with electricity and you can really feel the excitement and expectancy also getting to you.

The winter sessions are shorter, therefore more intensive. Also more draining, as things have to be done in such a short time. Long hours are worked, nobody complains and what makes it worthwhile is the "thank you" at the end!

The Summer Joint Work Sessions are more complicated in the sense that accommodation has to be found for many families with children. In some cases school and kindergarten have to be arranged. Also extra office space for people visiting ITER as experts for short periods.

On reflection, the Summer Joint Work Session of 1989 seems to have gone well. Accommodation was found for all, either in apartments belonging to the Institute or for the short term people in hotels in Garching and area. I hope, most of the people were satisfied, at least they did not voice their complaints!

On the lighter side, we had many possibilities to get together socially after work. During the summer months the US, USSR and Japanese sometimes held gatherings on Friday evenings. An outing was organized by the U.S. delegation to an old monastery at Andechs. In October both the USSR and Japanese delegations gave an official dinner, both of which went down very well. The EC gave a reception in the Restaurant on site which was less formal and gave the delegates the opportunity to mix, also with NET Team members. This is only part of the social scene which helps to breed understanding and is very important for establishing a harmonious working relationship.

I can sincerely say that working more than a year on ITER has helped me to understand how important and efficient this "melting pot" is and, at the same time, how much fun work can be!

ITER EVENTS CALENDAR - 1990

Joint Work Session	Garching	22 Jan - 23 March
Meetings of Working Party on Ways and Means	Vienna Vienna	29 - 31 Jan 13 - 16 March
ISTAC Meeting	Garching	21 - 23 March
ITER Council Meeting	Vienna	26 - 27 Apr
Joint Work Session	Garching	2 July - 16 Nov
ITER Council Meeting	Washington	8 - 9 Oct
ISTAC Meeting	Vienna	28 - 30 Nov
ITER Council Meeting	Vienna	13 - 14 Dec

Specialists' Meetings at Garching in support of joint design work:

Transient Electrogmagnetics and Plasma Control	5 - 9 Feb
Reference Materials Data Base	7 - 9 Feb
Shielding Experiments and Analysis	12 - 14 Feb
Magnet Materials	26 - 28 Feb
Current Ramp-up by LH	26 Feb - 2 March
ITER Profiles and Beta Limits	5 - 7 March
Plasma Operation Control in ITER	23 - 27 July
Advanced Divertor	20 - 24 Aug
Design Criteria	10 - 14 Sep

Related Events:

16th Symposium on Fusion Technology	London	3 - 7 Sep
13th IAEA Conference on Plasma Physics and Controlled Nuclear Fusion Research	Washington	1 - 6 Oct

Happy
New Year!

1990

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