INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

ITER NEWSLETTER

Vol.2, No.8 August 1989

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, AUSTRIA

INSIDE

ITER COUNCIL MEETING

by Paul N. Haubenreich, ITER Council Secretary

The four-party Conceptual Design Activities are progressing well, are on schedule for completion at the end of 1990 and have sucessfully focussed an appropriate part of the world's fusion research on ITER needs. These gratifying conclusions were reached by the ITER Council at its meeting on 12-13 July at IAEA Headquarters in Vienna, on the basis of information received and discussed there. The ITER Management Committee (IMC) summarized for the Council the results of the joint work on the conceptual design and the related activities by the Parties in supporting R&D. The ITER Scientific and Technical Advisory Committee (ISTAC) presented the Council with its findings and recommendations arising from its recent review of the Activities.

IC Working Party to explore characteristics of ITER Engineering Design, for each Party's use in decision on possible next joint step.

Based on the positive physics and technological results and the progress in design, the Council decided that it is timely to initiate work on certain elements of the Conceptual Design Report (CDR) in addition to the technical work already being carried out under the ITER Management Committee. The Council stated that the final CDR should also contain those supporting elements needed for the Parties' consideration of and decisions on the possible conduct of an Engineering Design of ITER, e.g., the organizational framework, information handling, etc. Thus, in conformity with Articles 2 and 5 of the Terms of Reference and its IAEA auspices, the Council prepared a charter for an IC Ways and Means Working Party, with representation from each of the four Parties, to develop suggestions on those supporting elements for use with the Interim Conceptual Design Report that will appear at the end of 1989. A final report from the Working Party is due in April 1990.

Design Activities

The IMC reported that since October 1988, when the Definition Phase was concluded, the joint work has proceeded effectively on database development, design integration and optimization, elucidation of possible solutions of the critical issues and further resolution of the safety and environmental aspects of the ITER design and planned operations. Investigations disclosed no acceptable way to substantially reduce the size and cost of ITER but drew attention to the potential for higher power (and perhaps net electrical generation) without increases in size. The IMC will give a modest amount of further consideration to the practical aspects of extending ITER operation to include a higher-performance phase.

Safety is being emphasized.

Emphasis is being placed on the design goal of passive safety. Analyses indicate that afterheat (due to activation of components near the plasma) will not pose a meltdown threat even in the event of coolant system failure. Public exposure from any accidental releases of tritium and activation products should be safely limited by reactor building containment and scrubbers.

ISTAC identified issues requiring special efforts.

The ISTAC concurred in the IMC's assessment that substantial strides forward had been accomplished in all major areas of the machine design. The ISTAC endorsed the emphasis on safety, specifically the attention being given to means of reducing tritium inventory and achieving passive safety. At the same time, the ISTAC noted the need for continued intensive efforts on some important design problems. Thermal design of the divertor target plates was identified as the single most critical task. Other problems that ISTAC particularly addressed included provision of ample volt-second capability and the practicality of proposed modifications of some internals during the envisioned transition from the physics phase to the technology phase of experimental operations.

Technology R&D

All Parties are progressing on tasks; longer range plan is recommended.

The IMC briefly summarized progress by the Parties in all areas of the ITER-Related Technology R&D Programme. The ISTAC concluded that progress had been good, but made several recommendations in each of the six areas. One recommendation was to proceed with development of breeding blanket technology to support an early choice among concepts. Another was emphasis on critical questions of design of plasma-facing components, including the use of beryllium. Regarding magnets, the ISTAC recommended further work on the influence of fabrication methods on problems of conductor performance degradation in large coils. Recommendations for R&D to support decisions on the optimal combination of systems for heating and current drive were made by ISTAC. The ISTAC also recommended preparation of an extended programme of coordinated technology R&D to ensure the availability of data that may be needed after 1990.

Physics R&D

Experimental programmes of all Parties provide valuable information. Focus on ITER beyond 1990 will be sought.

The ITER team under the direction of the IMC has identified physics R&D that can be carried out by the Parties in 1989/90 to improve the database for ITER design and operational planning. The ISTAC found that the resulting voluntary programme of ITER-Related Physics R&D provides generally good coverage of most of the major physics issues affecting the design of ITER, but there are some topics on which intensified or redirected activity is needed. Furthermore, the ISTAC recognized that it has generally not been possible to initiate new activities on such a short time-scale. Taking this into account, the ISTAC recommended that the joint work team propose an extended Physics R&D Programme that would ensure the availability of the additional data that would be needed if the ITER activities proceed into Engineering Design.

Conclusions

Progress commended and encouraged.

The Council commended the work under the management of the IMC and the thorough review by ISTAC. It expressed general agreement with and acceptance of the directions being taken and the recommendations of ISTAC. The Council encouraged all to proceed vigorously with work on the critical issues that they had identified and expressed confidence that timely resolutions would be achieved.

ITER CONTAINMENT STRUCTURES

by S. N. Sadakov, Leader, and S. L. Thomson,
ITER Containment Structures Design Unit

Responsibilities

Containment Structures provide controlled environments.

In the organization of ITER design work, the Containment Structures Design (CSD) Unit is responsible for those components whose primary function is to provide controlled environments in and around the tokamak machine. This includes producing the vacuum into which the fuel is introduced and the plasma is created, radiation and electromagnetic shielding of the superconducting coils, vacuum around the coils for thermal isolation, shielding around the tokamak to protect people from radiation, and the overall containment by the reactor building. Specifically, the CSD Unit is responsible for the plasma vacuum vessel and ports, the segmentation and attachment of the internal components, the overall cryostat surrounding the basic device (shown in Fig. 1), the gravity supports for the entire tokamak, the reactor building configuration, and the biological shielding.

Design is integrated with magnets and maintenance.

Much of the work by the CSD Unit is closely connected with that of the Magnet Design Unit, which is responsible for the toroidal and poloidal field coils, the cases and intercoil structures, the electrical and cryogenic leads, and the thermal shields. Both of these units work closely with the Assembly and Maintenance Design Unit to assure practical assembly and maintenance procedures.

The tasks of the CSD Unit have been broken down into structures internal to the tokamak assembly and those external to it. The first includes the vacuum vessel and the components inside of it. The second includes the cryostat that closely surrounds the basic device, the gravity and seismic supports for the tokamak, the biological shielding and the reactor building. The design analysis and selection to date has concentrated on the internal containment, particularly on the vacuum vessel and the arrangement of the in-vessel components. Work is progressing in the development of requirements and design options for the external containment.

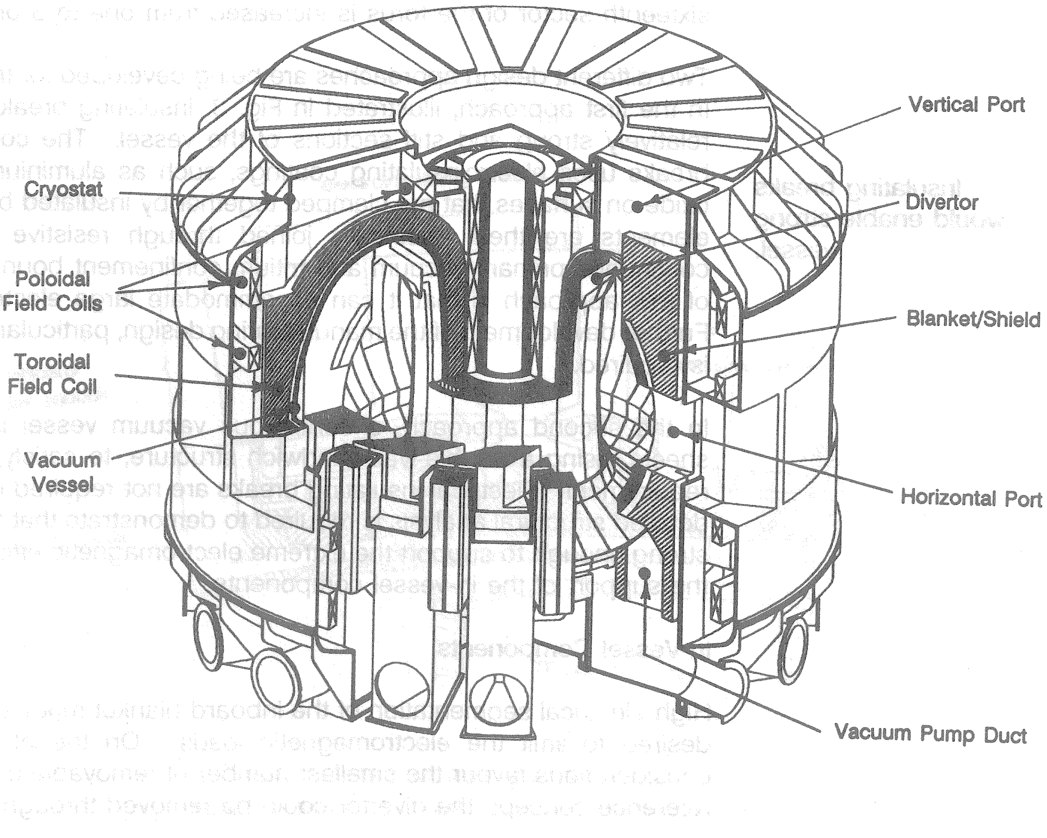

Fig. 1. ITER tokamak assembly

Internal Containment Structures

Components and functions

The principal functions of the internal containment structures are to provide the primary vacuum boundary, the first tritium confinement barrier, and the radiation shield for the magnet system. The internal containment is formed by the plasma vacuum vessel, including its upper, lower and horizontal ports and closures. The vessel contains the blanket modules, the shielding, the divertor plates, and the internal active coils. The port design and arrangement must accommodate the fuelling and vacuum pumping systems, the heating and current drive equipment, the internal component service lines and access routes for their replacement, the in-vessel maintenance and inspection systems, the plasma diagnostics, and the nuclear test modules. The structure must also provide an electromagnetic shield for the magnets during plasma disruptions, and a stabilizer for fast vertical plasma displacements, both during normal operation and disruptions. The vacuum vessel must have a toroidal loop resistance of 20 micro-ohms or greater to allow electric and magnetic field penetration, as required for intiation and control of the plasma.

Vacuum Vessel Design

Large forces are caused by plasma disruptions.

Design of the toroidal vacuum vessel must satisfy demanding, interdependent electrical and mechanical requirements. The greatest mechanical loads are those caused by the electromagnetic effects of the plasma disruptions that are expected to occur approximately 1000 times during the experiments. In such events, large forces are originated in the vessel itself and in the components located inside it. The complex pattern of the dominant forces is suggested by Fig. 2. Here a one-sixteenth sector of the vessel is subdivided into eight regions for the force calculations. This reveals the antisymmetry and resulting moments that tend to wrench the vessel out of shape.

Segmentation of blanket could reduce forces.

The magnitude of the forces is on the order of 20 MN for electrically continous sectors. This takes into account the electromagnetic loads on the blanket modules, which will be reacted partly through the blanket module structure and partly through the mechanical connections to the vacuum vessel. The forces can be reduced by electrically segmenting each sector. For example, the loads are reduced by a factor of 2 or 5 if the electrical segmentation of the blanket per one-sixteenth sector of the torus is increased from one to 3 or 9.

Insulating breaks would enable strong vessel.

Two different design approaches are being developed for the ITER vacuum vessel. In the first approach, illustrated in Fig. 3, insulating breaks are incorporated into relatively strong and stiff sections of the vessel. The conceptual design of the breaks uses electroinsulating coatings, such as aluminium oxide or magnesium oxide on surfaces that are clamped together by insulated bolts. The stiff structural elements are then electrically joined through resistive elements to form the continuous primary vacuum and tritium confinement boundaries. The advantage of this approach is that it can accommodate large electromagnetic disruptions. Further development of the manufacturing design, particularly the insulating breaks, is required.

In the second approach, a continuous vacuum vessel is assembled from thin sheets, using a double-wall sandwich structure, to satisfy the toroidal resistance requirement. Electrical insulating breaks are not required in this design, but more detailed structural analysis is required to demonstrate that the vessel can be made strong enough to support the extreme electromagnetic effects, taking into account the support of the in-vessel components.

In-Vessel Components

High electrical segmentation of the inboard blanket modules and divertor plates is desired to limit the electromagnetic loads. On the other hand, maintenance considerations favour the smallest number of removable pieces. With the present reference concept, the divertor could be removed through the center port as one

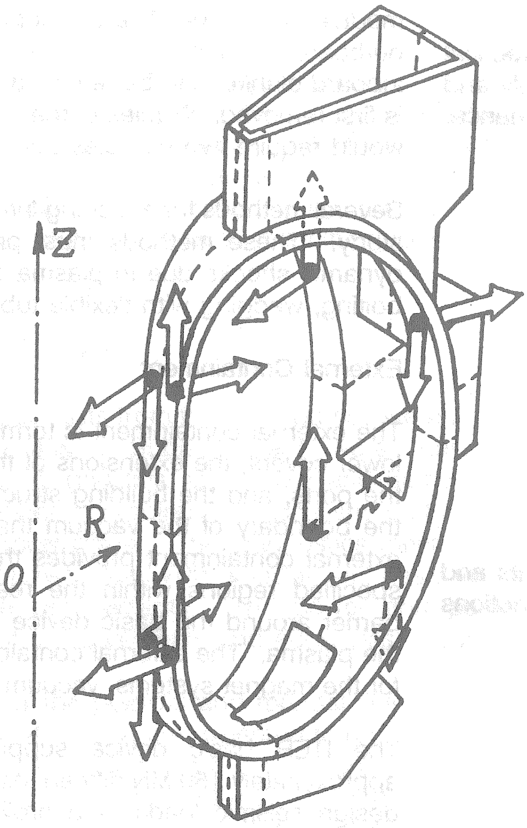

Fig. 2. Direction of forces on vacuum vessel sector as a result of a plasma disruption

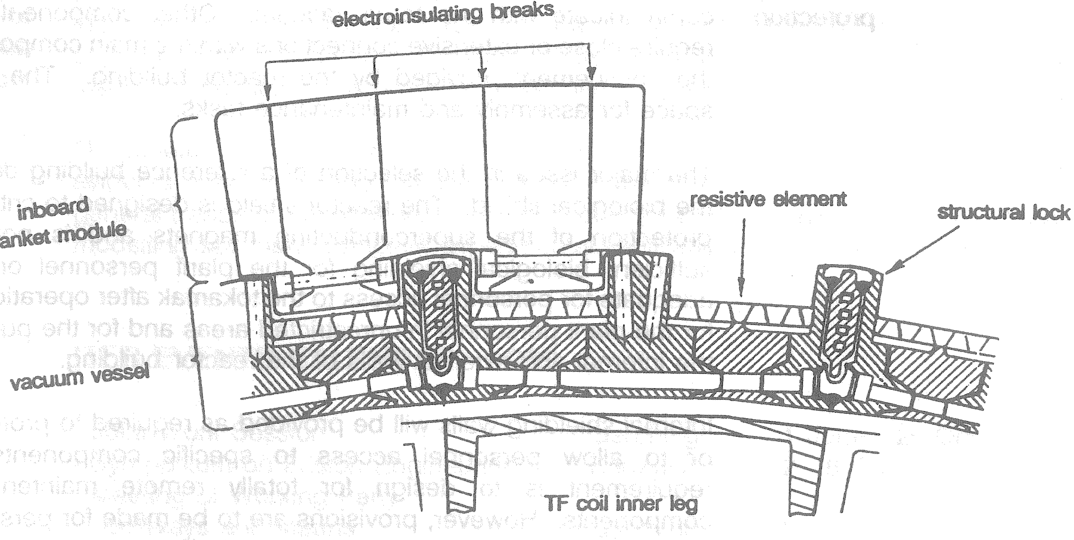

Fig. 3. Section of inboard blanket and vacuum vessel with electroinsulating breaks, resistive elements and structural locks

Designs allow practical disassembly and maintenance.

module per sector. The blanket modules are removed through the top ports. The outboard blanket must be segmented into three modules per sector, but the inboard blanket can be removed as one module per sector if the outboard blanket is first removed. Studies of the independent removal of the inboard blanket, which would require two modules per sector, are continuing.

Several methods for attaching internal components to the vacuum vessel are under study. These methods must preclude gaps between the elements to prevent dynamic shocks due to plasma disruptions. Among the candidate concepts are bolting, wedging with flexible tubes or with rails and soldering.

External Containment

Components and functions

The external containment is formed by the cylindrical cryostat wall, its upper and lower covers, the extensions of the containment around the equipment located in the ports, and the building structures. The function of the cryostat is to provide the boundary of the vacuum that thermally insulates the magnet systems. The external containment provides the biological shield to allow personnel access to specified regions within the reactor building, and the secondary confinement barrier around the basic device and its auxiliary systems that communicate with the plasma. The external containment is also designed to provide gravity support for the magnet systems, vacuum vessel, cryostat and upper levels of the building.

The ITER basic device support structures must carry a dead weight of approximately 150 MN (fifteen thousand tonnes), withstand the vessel dynamic and design seismic loads, and provide clear spaces for the tokamak services and maintenance. Both bottom-supported and suspended design concepts are being evaluated. The disadvantage of the bottom supports is that access to the bottom of the device, as required to disconnect service lines, is restricted. The suspended designs open up the maintenance space underneath, but complicate the installation and removal of the outer poloidal field coils. Studies are also being conducted on oblique truss concepts, which are intended to provide maintenance space and allow independent removal of the lower poloidal field coils.

Building Design

Confinement and protection

The reactor building is the outermost barrier between the tokamak and the external environment. It controls releases of radioactive materials to the environment during both routine operations and accidents and protects the reactor from external events, such as aircraft strikes. The reactor building contains all systems that communicate with the torus vacuum. Other components are included if they require close or extensive connections with the main components, or if they require the confinement provided by the reactor building. The building also includes space for assembly and maintenance tasks.

The major issue in the selection of a reference building design is the location of the biological shield. The reactor shield is designed to criteria established by the protection of the superconducting magnets and is not intended to provide sufficient biological shielding for the plant personnel or the public, or to be adequate for personnel access to the tokamak after operation. Biological shielding for the plant personnel in unrestricted areas and for the public will be provided by the internal and external walls of the reactor building.

Biological shielding

Internal shielding walls will be provided as required to protect auxiliary equipment or to allow personnel access to specific components. The maintenance requirement is to design for totally remote maintenance of all in-vessel components. However, provisions are to be made for personnel access wherever practicable. One design concept includes a concrete vault surrounding the tokamak just outside the cryostat. This is being evaluated for each building component to assess the utility and design complexity introduced.

Conclusions

The CSD Unit is progressively developing the requirements and conceptual design for the ITER basic device during the 1989 joint work session. The issues of electromagnetic loads, vacuum vessel design and internal component arrangement and supporting methods are well understood, and research needs are identified. The joint work will now progress to complete the concept definitions for the external systems, including the cryostat, machine support and building.

SPECIALISTS' MEETINGS

Three meetings of specialists from the ITER parties were held at the technical site in Garching during July. Subject areas were: basic device engineering requirements, plasma diagnostics, and power and particle control. The meeting on basic device engineering requirements focussed on two important subsystems: cryogenics and electrical power. The diagnostics meeting considered the entire complement of instrumentation with special emphasis on the unprecedented aspects of the ITER requirements. The power and particle control meeting assessed both recent measurements and edge plasma modelling capabilities.

Helium refrigeration system will cool magnets and other components.

Cryogenic systems for the poloidal and toroidal field magnets (superconducting niobium-tin or niobium-titanium) are expected to require on the order of 130 kw of cooling capability. It was recognized that after foreseeable loads are well defined, a contingency allowance should be added. About 15% is thought to be adequate. Use of refrigerator modules, each with 20 to 30 kW capability, is foreseen. With the thermodynamic efficiencies expected for such large systems, electrical power requirements are expected to be about 400 to 500 kW per kW of cooling at liquid helium temperature (4.2K). Total power requirements of the ITER cryogenic systems, which will serve not only the magnets but various other needs, should be about 100 MW or less.

Peak electrical power demand of ITER will be about 500 MW.

The total installed capacity of the power supplies required for the poloidal field magnet system is expected to be in the range of 1000 to 1600 MW (depending on the need for sweeping of the separatrix in the divertors). Peak demand in net power from the supplies should be about 400 MW, contributing to a peak demand for power from the electrical system serving the ITER site of about 500 MW.

Thorough diagnostic instrumentation of ITER plasma is being planned.

The diagnostics specialists discussed experience and preparations for future D-T experiments in existing machines. A large number of plasma diagnostics were identified as important for ITER. It was recognized that ITER entails some unprecedented demands. Conceptual design studies were recommended for many diagnostics, for which only preliminary concepts presently exist.

The meeting on power and particle control brought out encouraging experimental evidence relevant to the thermal design of the divertors. It was noted that the general trends of the observed behaviour of edge plasma have been simulated by modelling but more complete experimental verifications would be required.

ITER EVENTS CALENDAR - 1989

- Joint Work Session	Garching	1 June - 20 Oct
- Symposium on Fusion Engineering	Knoxville	2 - 6 Oct
- Meeting of Working Party on Ways and Means	Garching	9 - 11 Oct
- ISTAC Meeting	Los Angeles	16 - 18 Nov
- ITER Council Meeting	Vienna	30 Nov - 1 Dec

IAEA YEARBOOK

The International Atomic Energy Agency has just published the IAEA Yearbook 1989. The Yearbook presents the work of the IAEA in the context of scientific, technical and economic developments worldwide. There are descriptions of the Agency's major programmes, with articles on particular projects and areas of activity, together with reports of particular current interest and general information about the IAEA. Contents are: Foreword by the Director General; the IAEA's Contribution to Sustainable Development; Part A - Transfer of Nuclear Technology; Part B - Applications of Nuclear Techniques; Part C - Nuclear Power and Fuel Cycle: Status and Trends; Part D - Nuclear Safety Review; Part E - IAEA Safeguards; Part F - The IAEA.

The price of the Yearbook (STI/PUB/832) is Austrian Schillings 560. Parts A, B, C, and D are also available separately. Enquiries should be addressed to Publishing Section, IAEA, P.0. Box 100, Wagramerstrasse 5, A-1400 Vienna.

The ITER NEWSLETTER is prepared and published by the International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria. Telex: 1-12645, Cable: INATOM VIENNA, Facsimile: 43 1 234 564, Tel.: 43 1 2360-6393/6394. Items to be considered for inclusion in the ITER Newsletter should be submitted to N. Pozniakov, ITER Secretariat.

Printed by the IAEA in Austria
August 1989

89-03573