INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

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INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, AUSTRIA

INSIDE

JOINT WORK RESUMED IN GARCHING

Another extended session of joint work at Garching began on June 1. Scientists and engineers from Europe, Japan, the USSR and the USA are now vigourously working side by side in the second phase of the ITER Conceptual Design Activities. The first phase, Concept Definition, in 1988 produced agreement on principal features and dimensions of the tokamak machine that would be the heart of ITER (see Table 1). Since then assigned "homework" - specific tasks carried out in the laboratories of the four Parties - produced further basis for proceeding jointly with the second phase of the Activities. This Design Phase will include the current session and two more sessions at Garching in 1990, with homework in the intervening periods. The Conceptual Design Report is scheduled for completion by the end of 1990.

TABLE 1. ITER OPERATING PARAMETERS

Parameter	Physics Phase[a]		Technology Phase[b]	
	Inductive Operation	Extended Operation	Inductive Operation	Steady-state Operation
Major radius, R (m)	5.8	5.8	5.5	5.5
Minor radius, a (m)	2.20	2.25	1.8	1.8
Elongation,95% flux surface	1.9	2.0	2.0	2.0
Toroidal field on axis, B(T)	5.0	5.0	5.3	5.3
Current, I_p (MA)	22	25	18	18
Ion temperature, T_i (keV)	10	10	10	18
Confinement time, τ_e (s)	3.1	3.3	2.7	1.8
Fusion power, P_f (MW)	1000	1000	880	820
Neutron wall load (MW/m^2)	1.0	1.0	1.0	0.9

[a] *Initial configuration, without tritium-breeding blanket*

[b] *Modified configuration, with tritium-breeding blanket*

Preparation of an interim conceptual design report

The current session of joint work will last almost 5 months, ending on October 20. The major objective is to prepare an ad interim conceptual design report addressing major issues such as detailed review of parameters and performance, integration and design analysis of critical components; in addition the status of R&D and preliminary cost estimate of the machine construction will be included.

This year, a total of about sixty scientists and engineers from the four ITER Parties will be engaged in the ITER work at Garching for the entire time. The full-time workers will be joined by experts in six critical areas of design to work with the resident staff for up to two months. Other specialists will participate in more than ten workshops. The organization that proved so effective in the Definition Phase has been retained. That is a matrix organization, with a leading expert heading each of eight areas of design and four other experienced technical managers playing major roles in design integration as leaders of Project Units. Each group includes members from all four ITER Parties. Overall management responsibility rests with the ITER Management Committee, each of whose members is the Managing Director of the work carried out separately by one of the Parties.

Progress and plans to be reviewed by ISTAC and ITER Council

At the end of June the ITER Scientific and Technical Advisory Committee (ISTAC) will meet in Garching to examine the evolution of the design and progress in the continuing, ITER-co-ordinated research and development by each Party. This process will ensure that the broad thinking and the latest results of development work in all the world's fusion programmes will be properly incorporated in the ITER design.

An overall review of progress and plans will be made by the ITER Council (IC) at a meeting in Vienna in July. The IMC and the ISTAC will make presentations and the IC will consider issues and provide guidance.

International ITER Team, Garching, 5 June 1989

EDITOR'S NOTE:

A basic fact about magnetically confined fusion is that a plasma must be heated to temperatures in the range of 100 million degrees Celsius to achieve the desired thermonuclear reactions. In tokamaks, confinement relies partly upon the magnetic field caused by the current flowing in the plasma. In ITER, as in other tokamaks, electrical induction can produce a plasma current, which in turn raises the temperature by ohmic heating in the plasma. However, to reach ignition temperature and to keep the current going as long as desired in ITER, induction alone is inadequate. Other systems for heating the plasma and sustaining the current are absolutely essential for ITER success.

The following article, by the Leader of the Heating and Current Drive Design Unit, describes the approaches being followed in the ITER conceptual design.

HEATING AND CURRENT DRIVE IN ITER

by V.V. Parail, Leader, ITER Heating and Current Drive Design Unit

A requirement of the Terms of Reference is that "the ITER shall demonstrate controlled ignition and extended burn of deuterium-tritium plasmas, with steady state as an ultimate objective." The Definition Phase of the Conceptual Design

Activities set more specific criteria for the "extended burn" operation. The target for the energy gain factor (Q) is $\geqslant 5$. The burn duration must noticeably exceed the time of ohmic current redistribution in the plasma and also suffice for transient-free nuclear testing in the technology phase of the ITER operation programme; this requires a burn time, $\tau_b > 10^3$s. Steady-state current drive represents a more demanding requirement than heating to ignition, and it is this requirement that determines the choice of current drive and heating (CD/H) systems.

Four heating and current drive systems are being studied

Tokamak experiments have shown that either electromagnetic waves or neutral atom beams can drive such a current. At present, four systems are being studied for ITER. They are: neutral injection (NI), electron cyclotron (EC) waves, lower hybrid (LH) waves, and ion cyclotron (IC) waves. Six functions must be provided for ITER which are described below and are illustrated in Fig. 1.

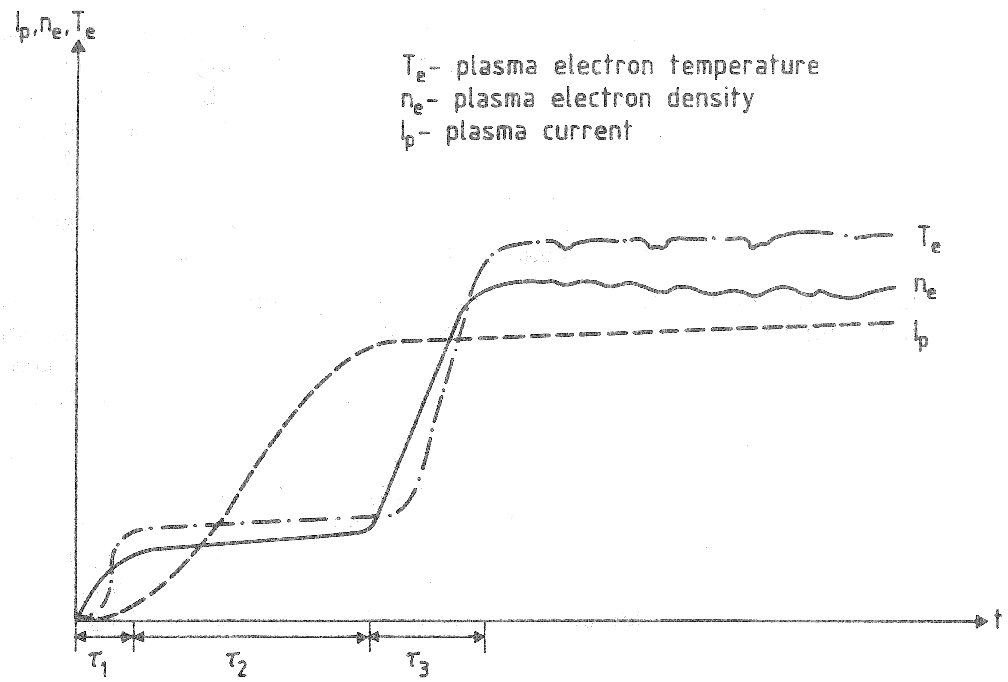

Fig. 1. Evolution of Plasma Parameters

Functions of heating and current drive systems in ITER

First, the system should provide a breakdown and plasma preionization at the initial stage of a discharge, when there is no longitudinal current providing the plasma confinement. The characteristic time of this process, τ_1, is of the order of some seconds and the plasma parameters can be much lower than at burn stage. At this time, it appears that EC-waves would be a good choice to provide this function.

The next typical phase of a discharge is the current ramp-up up to the rated value, I_p=18 MA. This process develops much slower than the first one; characteristic time of non-inductive current ramp-up, τ_2, is estimated as ten minutes. All of the systems under study theoretically can provide this function and, at this time, LH appears to be the best candidate.

To heat the plasma up to ignition is the next task. This function, as well as the two previously mentioned functions, will be performed by the CD/H-system during both physics and technology phases of the ITER operation. The analysis carried out shows that the considered techniques, except probably LH-waves, can efficiently heat the plasma up to ignition. The characteristic time of plasma heating, τ_3, is of the order of ten seconds, and the necessary power is $\leqslant$ 50 MW.

The fourth task, which requires the highest power, is to provide steady current drive under conditions of fusion burn with Q=5. All four systems theoretically can contribute to providing current drive with NB and LH best supported by experimental data. Though LH efficiently drives current in the moderate size tokamaks, it appears in ITER that the waves will not penetrate to the center of the plasma. Therefore, perhaps LH could be used to drive current in the outer plasma region and one of the other methods could be used to drive current in the plasma center.

And, finally, the CD/H-system should be able to rearrange the current profile to provide better MHD-stability of the plasma column. It may also be responsible for the burn stability control in both physics and technology phases. These last two functions do not require high power. For them, a much more important feature of the CD/H system is its ability to perform local changes in the current density or heating, or a change in the position of the zone of interaction with the plasma (for the time of the order of ten seconds). This requirement may be satisfactorily met by EC-waves.

Combination of systems will be used

So, the best solution which provides all the functions may be a combination of the systems under study. In the Definition Phase, three possible combinations (scenarios) were chosen for ITER. According to scenario 1, neutral injection should be used for the plasma heating and current drive in the central part of the plasma column, while LH-waves will be used for the current drive in the external half of the plasma column and for the current ramp-up. Plasma breakdown and preionization, as well as the current profile and burn control, would be provided by EC-waves. Comparing to scenario 1, in scenario 2, the function of NI is performed, partly or completely, by EC-waves, and in scenario 3, IC-waves are used instead of NI.

Operability under reactor conditions needs further study

Above, the various heating and current drive systems and scenarios were considered. Taking into account that the CD/H system should work under reactor conditions, i.e. in the presence of high-power neutron flux, γ -radiation and heat flux from the plasma, creates additional complicated and challenging problems. For example, operability of the system components under conditions with plasma disruptions, when a rapid change in the plasma current results in the emergence of considerable electrodynamic forces affecting the elements of the radio-frequency power launchers is probably the most critical issue for the LH and IC techniques. All these problems need further detailed analysis, and the Heating and Current Drive Design Unit of the ITER team will be engaged in their solutions during the 1989 summer session of joint work in Garching.

FENDL - REFERENCE NUCLEAR DATA LIBRARY FOR USE IN NATIONAL AND INTERNATIONAL FUSION REACTOR PROJECTS

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Progress in creating of international nuclear data library FENDL

The programme of activities of the IAEA Nuclear Data Section related to fusion reactor research has the objective of creating nuclear and atomic data bases for D-T fusion reactors in support of the design and test studies of national and international fusion reactor projects such as the International Experimental Thermonuclear Reactor (ITER), the Fusion Engineering Reactor (FER, Japan), the Next European Torus (NET) and other existing or planned projects. The ITER Newsletter has already briefly mentioned this potential IAEA support to the ITER-project in November 1988 and present note has the objective to show the significant progress in this field made by the IAEA Nuclear Data Section since then in co-operation with national nuclear data centres and that the files and libraries mentioned below are available for the ITER team upon request.

Nuclear data requirements for fusion reactor studies were formulated at the IAEA Advisory Group Meeting on Nuclear Data for Fusion Reactor Technology in Gaussig, German Democratic Republic, in December 1986. The nuclear data required for neutronics and safety calculations for D-T fusion reactors are summarized as follows: (1) neutron flux determination: total cross sections, neutron emission spectra, neutron multiplication cross sections, and dosimetry cross sections; (2) fuel production: mainly Li-6(n,α)T and Li-7(n,n'α)T cross sections and competing reactions; (3) radiation hazard: activation cross sections and decay data; (4) transmutation: cross sections for the production of hydrogen and helium, and stable isotopes of other elements; (5) power generation: gamma-ray production cross sections and neutron and gamma-ray KERMA factors; (6) radiation damage: DPA production cross sections; (7) fusion-reaction cross sections for the D-D and D-T reactions and (8) covariance data for uncertainty analysis.

The IAEA Nuclear Data Section is now creating a nuclear data library which eventually will include all the required information mentioned above. It is called Fusion Evaluated Nuclear Data Library (FENDL) and is intended to serve as a reference fusion nuclear data library for use in national and international fusion reactor projects and activities.

FENDL is based on five national evaluated nuclear data libraries

FENDL-1, the first version of the library is planned to be finished by the end of 1990. It will consist of nuclear data files, selected from five national evaluated nuclear data libraries that already exist or currently are under development:

- the ENDF/B-VI USA library maintained by the National Nuclear Data Center at the Brookhaven National Laboratory;
- the BROND library maintained by the USSR Nuclear Data Center at the Physics and Energetics Institute in Obninsk;
- the JENDL-2 and 3 Japanese nuclear data libraries mainained by the JAERI Nuclear Data Center;
- the EFF-1 European Fusion File maintained by ECN Petten, Netherlands.
- the ENDL-84 library maintained by the Livermore National Laboratory in the USA.

Currently available data

At present, FENDL-1 includes evaluated nuclear data for the main elements and isotopes of the following fuel, blanket, structural and shielding materials:

H, D, T, Li-6, Li-7, Be-9, B-10, B-11, C-12, N, O, F, Si, Al, Ti, V, Cr-50, Cr-52, Cr-53, Cr-54, Mn-55, Fe-54, Fe-56, Fe-57, Fe-58, Co-59, Ni-58, Ni-60, Ni-61, Ni-62, Ni-64, Cu-63, Cu-65, Zr, Nb-93, Mo-92, Mo-94, Mo-95, Mo-96, Mo-97, Mo-98, Mo-100, Sn, Ba-134, Ba-135, Ba-136, Ba-137, W, and Pb.

Most of them were recently received by the IAEA from national nuclear data centres. Several more materials will be added as further needs are identified.

In addition, FENDL will contain the following special purpose libraries:

- the International Reactor Dosimetry File for use in neutron dosimetry maintained by the Nuclear Data Section with the support of the Institute fuer Radiumforschung und Kernphysik, Vienna, Austria;
- the Charged Particle Data Library DATLIB maintained by the Technical University in Graz, Austria;
- large comprehensive activation data library covering several thousand activation reactions selected and compiled from various national files; and
- library of gamma-ray interaction data.

Process of data selection

The selection of nuclear data for the FENDL-library was organized using expertise of specialists from national nuclear data centres and laboratories. At the first IAEA Specialists' Meeting on FENDL (November 1987, Vienna) a preliminary choice of elements and isotopes was performed, and a programme of benchmark calculations for nuclear data testing was begun starting with the lead sphere measurements of the University Dresden, German Democratic Republic.

The second IAEA Specialists' Meeting on FENDL and Benchmark Calculations (May 1988, Vienna) analyzed the differences between the various evaluated nuclear data files available for each of the main fusion reactor materials and, in addition, compared these evaluations with experimental data from the international EXFOR-library.

The first stage of intercomparison included only neutron reaction cross sections. The next intercomparison exercise will be devoted to angular and energy neutron emission spectra, gamma production data, charged particle neutron production data and activation cross sections. As part of the long-term plan of the FENDL project, the results of these intercomparison exercises will be used to improve and supplement the data contained in the FENDL-1 library and a second improved version of the library, FENDL-2, be developed by 1992.

The processing of microscopic data files into forms usable in neutronic and safety calculations will be conducted by the Nuclear Data Section of the IAEA in collaboration with laboratories that contribute to the FENDL project. In particular, FENDL will be converted into a fine-mesh point data library and from this a multigroup data library for use in discrete ordinate codes and a library for use in continuous-energy Monte-Carlo calculations will be prepared.

Priorities in integral testing of data

The integral testing of the data files is an important process to examine the quality of the FENDL-1 files. It will identify the deficiencies of FENDL-1 and suggest actions for improvement for the development of FENDL-2. The integral data testing has been started with the lead benchmark problem and will be continued to include the beryllium benchmark in 1989 due to the importance of the neutron multiplication reactions needed for the design of the near term experimental reactors. Beginning in 1990, high priority structural, blanket and shield materials such as Fe, Cr, Ni, B, and C, will be considered in the international benchmark comparison activites. In addition to the benchmark data testing, the programme discussed at the second IAEA Specialists' Meeting on FENDL also includes calculational benchmarks for the verification of neutron transport codes.

The development of the FENDL library is an approved programme of the IAEA and is supported by several IAEA Co-ordinated Research Programmes involving the co-operation of a number of national nuclear data centres and research laboratories. In addition, it is expected that both the data processing and data testing efforts described above will benefit significantly from informal contributions from the participating data centres and research laboratories.

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

In support of the ITER team design work, several specialists' meetings will be held in Garching during the summer session of joint work on the following topics:

Current Drive/Heating Modelling	12 - 16 June
Electromagnetics	20 - 22 June
Basic Device Engineering Requirements/Siting	10 - 12 July
Diagnostics	10 - 14 July
Power/Particle Control (Model Validation)	17 - 21 July
Safety	31 July - 4 Aug
Tritium Fuel Cycle	1 - 8 Aug

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