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CONCEPTUAL DESIGN ACTIVITIES OF THE ITER TEAM

by K. Tomabechi, IMC Chairman

The joint work at Garching from May to September achieved its objective of defining the ITER concept that will serve as the basis for the conceptual design activities over the next two years. The five-month effort by forty highly capable scientists and engineers was also a striking demonstration of commitment by ITER participants and effective organization of a multinational team. In contrast to previous multinational studies, the ITER activities entail full time dedication of large numbers of people on a year-round basis. These extensive conceptual design activities are off to an encouraging start as a result of the effective joint work this summer.

The organization that was adopted for the definition phase work was designed to utilize most effectively the talent that was made available by the parties. As outlined in the accompanying diagram, a matrix organization was used, 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.

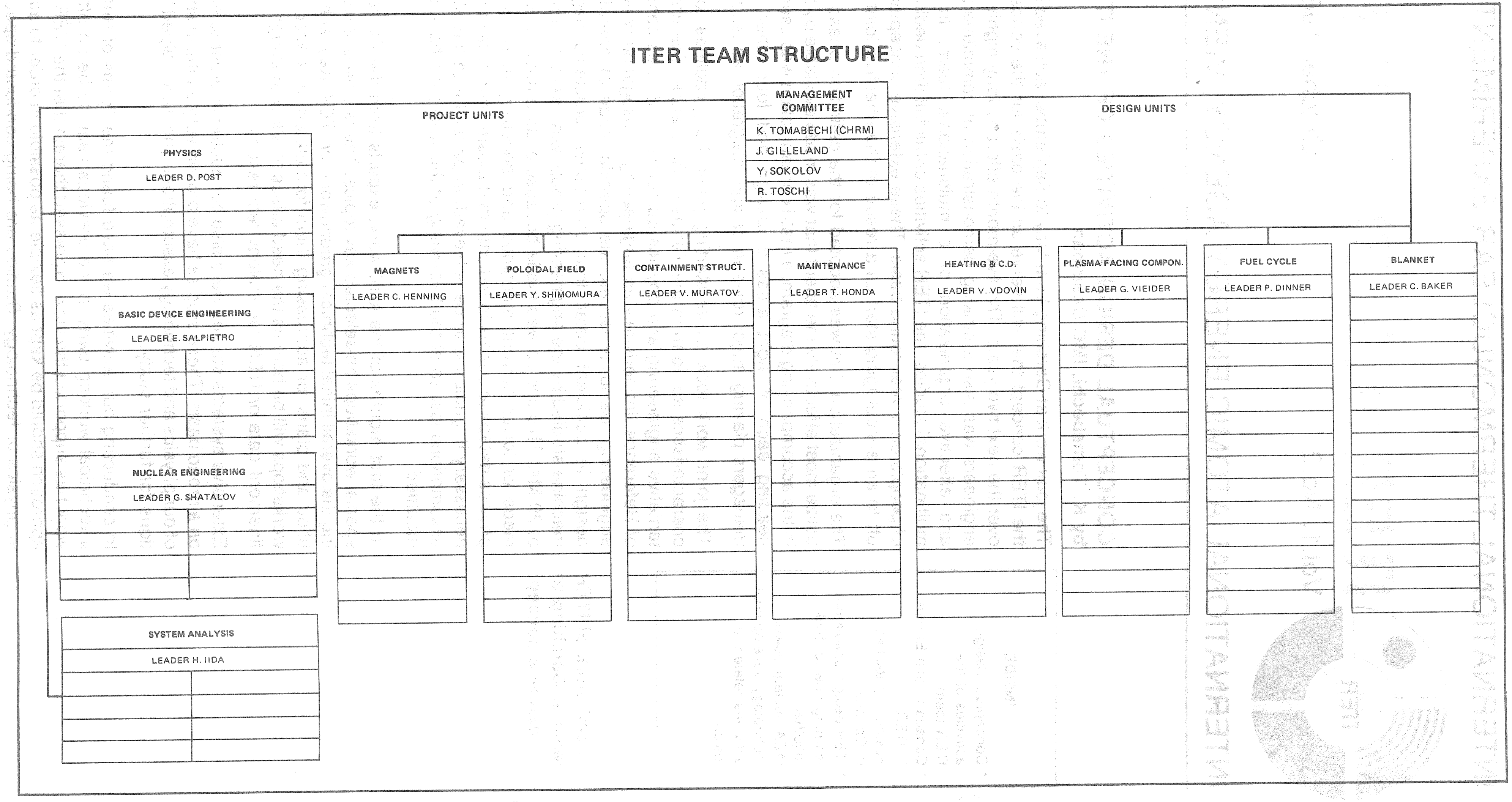
Joint work of ITER team at Garching to define a concept

The joint work took as its starting point the guidelines, objectives and desired characteristics set forth in the Terms of Reference. The first step was to develop tentative engineering and physics guidelines and rules consistent with the Terms of Reference. Immediately an engineering investigation was begun to identify any engineering feasibility issues; the specific mode of operation was to conduct a design in sufficient detail that unforeseen problems might be detected. The machine studied by the engineering group was based on a nominal plasma current of 20 MA. This choice was made because a fair amount of study has already been made of lower current machines and because, more importantly, the current physics database seems to indicate that plasma currents in the range of 20 MA are necessary if ignition is to be achieved. In parallel with this study, the basic physics assumptions issued at the beginning of the workshop have been re-examined and modified.

In the first months of the joint work, experts from the Parties were also invited to special workshops on selected key topics. These sessions were highly useful in laying the overall initial technical groundwork for ITER. Key technical issues were identified and plans for addressing them formulated. It is anticipated that a few more workshops will be held as the need arises to allow thorough integration of new confinement data or ITER technology test results.

Extensive systems studies were also conducted in order to examine design options on a broad basis. These studies have proven very useful in showing the implications of our physics and technology assumptions and have helped to identify fruitful directions for further study.

In conducting our activities we have found the Terms of Reference, developed by a technical working party in the previous year, to be an effective document. Our work has supported the view expressed therein that the ITER concept and technical approach should be kept as flexible as possible in order to accommodate advances in physics or technology. Studies are being conducted specifically targeted at the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HEATING & C.D.
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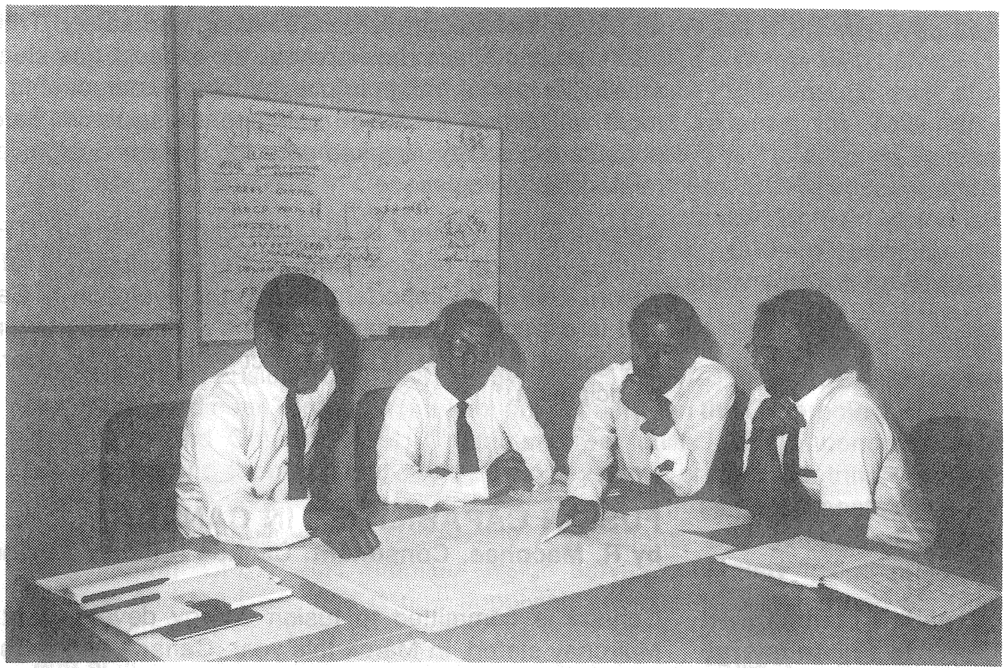
LEADER G. VIEIDER
FUEL CYCLE
LEADER P. DINNER
BLANKET
LEADER C. BAKER



ITER Management Committee Meeting

meaning and possibilities for a flexible tokamak configuration and operational approach. Ideas being explored in order to provide enhanced ignition margin include analysis of limited operations at higher than nominal currents and fields, possible use of current drive to save volt-seconds or raise the plasma current, and the possibility of changing the plasma configuration or size during the physics phase of the operation.

During the final two months of the workshop we shall be attempting to integrate the technical output from all of these studies into a single reference concept. This reference will be used as a basis for initial work in the design phase of ITER beginning this autumn. We plan, however, to carry a limited number of scientific and technical options that could have favourable impact and to incorporate them into a reference design if proven to be realistic by further experiment, development or study. The final outcome of this summer's work will be published by the IAEA this autumn and will be discussed at the IAEA Conference on Plasma Physics and Controlled Nuclear Fusion Research at Nice.

The first joint work session has been very intensive. The Garching participants are to be commended for their hard work and the large amount of work produced to date. We also appreciate very much the strong support given by the home institutions.

CANADA TO JOIN EUROPE IN ITER

by R. Toschi, EC member of the ITER Management Committee

Canada's involvement in EC contribution to the project

On 27 July 1988 the ITER Council welcomed the involvement of Canada in Euratom's contribution to ITER. Canada is the first country to qualify for involvement under Article 9 of the ITER Terms of Reference, which permits the involvement of "Other countries which possess specific fusion capabilities". To this end, the ITER Management Committee evaluated in detail the specific fusion capabilities of Canada, the potential contribution to the ITER design and R&D activities, and the qualification of the possible participants in the joint work. It concluded that Canada could make a valuable contribution to the ITER design and R&D.

Canada will contribute to joint work at the technical site, and through design activities and supporting R&D to be performed in Canada. The Canadian effort will be at the level of about 10% of the Euratom contribution. Specific technical areas will be tritium technology, remote handling and safety. Tritium technology will include purification process development for exhaust gas cleanup and blanket recovery, and behaviour of tritium in plasma facing components. Remote handling development will aim at in-vessel maintenance systems. Safety studies will emphasize engineering safety requirements for system design, and development of safety related technologies.

Canada's involvement in Euratom contributions to ITER follows several years of Europe–Canada co-operation in the development of controlled thermonuclear fusion. This is an important step in the evolution of Canada's fusion programme, and is expected to enhance Europe's major efforts within the ITER project. It is anticipated that the ITER project will have an overall benefit from Canada's participation.

FUSION CAPABILITIES IN CANADA

by R. Macphee, Consultant, Canada National Fusion Programme

Canada's commitment to fusion energy development

Canada is committed to fusion energy development. As Prime Minister Brian Mulroney stated, in March this year, Canada brings its specialized fusion skills to ITER.

"Fusion research and development is one of the most significant and exciting areas of science and technology. The next decade will be a challenging and exciting time for fusion. In particular, the proposal by President Reagan and General Secretary Gorbachev to design an International Thermonuclear Experimental Reactor (ITER) in co-operation with Japan and the European Community is in my view a very positive step. Canada is particularly well positioned to meet these challenges."

Mr. Mulroney refers, in his final sentence, to specialized fusion skills and resources built up in Canada over the last 15 years. Realizing the importance of fusion, but recognizing that a full scale fusion programme was beyond Canadian resources, the Government of Canada embarked on a co-ordinated programme based on three concepts:

- Canadian fusion R&D adapts and extends established technology strengths, such as the CANDU nuclear programme, to specific fusion needs,
- the number of R&D areas pursued is limited so as to make good progress with limited resources,
- federal R&D funding is matched by contributions from the Provinces, electrical utilities or other partners.

Three fusion R&D areas were chosen: tokamak-based magnetic fusion studies focusing on plasma-materials interactions; technologies for fusion fuel systems and reactor maintenance and operations; fundamental inertial confinement studies.

Today, the Canadian fusion infrastructure is extensive. Fusion capabilities exist in industry, electrical utilities, universities, research institutes and government agencies. The infrastructure was constructed around the National Fusion Programme (NFP) and its two key project centres, the Centre Canadien de fusion magnétique and the Canadian Fusion Fuels Technology Project.

The NFP is Canada's central funding and policy agency for fusion development. It provides core funding and programme co-ordination for the majority of Canada's fusion work, in co-operation with Provincial Governments, power utilities, industry, universities and other centres of science and technology. Its active international programme works to consolidate collaboration with the fusion programmes of other countries. Bilateral fusion agreements now exist with Europe, the United States of America and Japan. Canada has had a broad scope bilateral fusion agreement with Europe since 1986. A separate, special Canada–Europe agreement, signed this year, covers Canada's contribution to Europe's participation in ITER. NFP is managed by Atomic Energy of Canada Limited (AECL), and is funded by the Department of Energy, Mines and Resources through the Panel on Energy Research and Development.

The Centre canadien de fusion magnétique (CCFM) is the main magnetic fusion research centre, located in Varennes, Quebec. CCFM is a joint project between the Government of Canada (via NFP), Hydro-Quebec and INRS-Energie (part of the University of Quebec). It houses Canada's largest tokamak, the Tokamak de Varennes, a long pulse tokamak with poloidal divertors. The Tokamak de Varennes was designed and built in Canada at a cost of $14 million. CCFM concentrates on plasma–wall interaction studies, fusion reactor materials development, diagnostics design and testing and plasma control. The tokamak has been operating since March 1987; the poloidal divertors and final internal components will be fitted later this year.

The Canadian Fusion Fuels Technology Project (CFFTP) is an R&D management centre located near Toronto. It is a joint project between the Government of Canada (via NFP) and Ontario Hydro, Ontario's power utility. CFFTP concentrates on developing and supplying engineered fusion systems, primarily for tritium fuel cycle systems and remote handling for fusion reactors. Its three departments are Fusion Systems and Engineering, Technology Applications, and Safety and Facilities Engineering. CFFTP has supplied design services to many fusion projects in Europe and the USA, and is now supplying engineered systems and hardware. CFFTP staff are currently attached at the ITER technical site in Garching, at NET and at JET. CFFTP has collaborated with many foreign projects in Europe and the USA, supplying expertise and workers from the Canadian fusion community.

Several universities perform independent fusion research programmes, separate from the programmes of NFP and its key project centres. Programmes include a modest collaborative inertial confinement effort and specialized tokamak based confinement studies.

ITER DESIGN PHILOSOPHY — LEARNING HOW TO THINK TOGETHER

by C.C. Baker, Leader, ITER Blanket Design Unit

ITER team is well on the way to demonstrate international co-operation

The output of the ITER activities that are now under way is described in the Terms of Reference as a Conceptual Design, supporting R&D, cost and schedule estimates, and siting requirements. While these will be the tangible results, there is another vital dimension to the ITER work; we are learning and demonstrating how an international team, which begins an extremely complex design task with differing design philosophies and concepts, can co-operate effectively to produce a well integrated design that is accepted enthusiastically by all Parties.

All of the scientists and engineers who are collaborating on ITER have come from programmes with extensive experience and capabilities in fusion development. However, each of the nations represented has its own culture, political system and energy policy, which give rise to differences among team members. These differences manifest themselves in various ways. Some, such as design codes and computational procedures, are obvious. Others are unwritten but nonetheless important.

The process of recognizing and accommodating differences among team members requires constant awareness, a determined effort to understand the other person's position, and a willingness to change when it becomes clear that change is in the best interests of the ITER project. Because of national differences, such accommodation requires a degree of patience, tact and persistence well beyond that which would be required in a design project of comparable complexity that is carried out by a less heterogeneous team.

But such extra efforts are well worth while. By accommodating the differences, we are producing an integrated conceptual design of ITER. We are also demonstrating the ability of technical people from our various nations to work together on a scale and to a degree of detail not previously attempted.

The differences requiring the most effort and patience to overcome in ITER relate to basic design philosophy, which affects the outcome of the trade-offs that are inevitably required. At this point a great deal of judgement is required in the conceptual design of a fusion reactor. There is still substantial imprecision in the theoretical and empirical relationships between performance and design parameters. There are also questions of technology that must be resolved by development work. For all these reasons there is much room for differences of opinion on design choices. Convergence on a single design is thus very difficult.

The appropriate degree of conservatism in the design is a prominent example of an area where differences existed and are being dealt with. One position is that greatest weight should be given to design credibility, that is, credible in the sense of minimizing extrapolation from the current physics and engineering databases so as to minimize the risk of failure to achieve ITER's mission. Conservatism in design margins and provision of flexibility to cope with contingencies is expensive, however, which raises concerns about project cost and implications for the future. Also involved in the decisions on the degree of conservatism are opinions on how far ITER should attempt to go toward the ultimate goal of an economically and environmentally attractive power reactor. This goal in itself is envisioned differently by team members. In any case there are risks. Calculation of the appropriate degree of risk-taking is affected as much by culture, social factors, and the perception of fusion's competitors as by technical and economic considerations.

In view of the challenges presented by the international character of ITER activities, it is encouraging to see how the definition phase work has made progress. I see physicists and engineers from all the different cultures and societies, discussing, arguing and finally resolving the important questions of plasma transport models, beta limits, material choices, design margins and the like. Clearly the ITER team is well on the way to the demonstration of international co-operation that will be one of the major benefits of the ITER Conceptual Design Activities.

"IAEA NUCLEAR POWER TECHNOLOGY DEVELOPMENT ACTIVITIES RELATED TO FUSION"

by J. Kupitz, Advanced Nuclear Power Technology Section, IAEA

IAEA support to ITER

During the past years the NPTD Section has convened various meetings on key technological aspects of Fusion. The purpose of these meetings has always been to provide an international forum for specialists for the review and discussion of the state of the art of fusion technology and engineering aspects. Among these meetings were:

— Technical Committee on Lifetime Predictions for the First Wall on Blanket Structure of Fusion Reactors, Karlsruhe, Federal Republic of Germany, November 1985
— Technical Committee and Workshop on Fusion Reactor Safety, Culham, UK, November 1986 (in co-operation with NENS)
— Technical Committee on Robotics and Remote Maintenance Concepts for Fusion Materials, Karlsruhe, Federal Republic of Germany, February 1988.

The meetings, which were endorsed by the International Fusion Research Council, usually had about 30–50 participants from most countries with fusion technology programmes. Small meetings of this kind provide for intensive discussion and effective information exchange at an international level. At the end of these meetings conclusions are elaborated on the current status and recent results achieved within the frame of the meeting topic and recommendations are set up for the directions of future R&D and technology programmes.

The 1989 NPTD Fusion Technology programme contains two meetings.

— Technical Committee on Fusion Safety (in co-operation with NENS), Idaho Falls, USA, April 1988.
— Technical Committee on Superconducting Magnets and Materials, Tsukuba, Japan, August 1989.

Topics for future meetings will be selected in close co-operation with ITER.

Following a recommendation made at the Technical Committee on Lifetime Predictions for the First Wall on Blanket Structure of Fusion Reactors, Karlsruhe, Fed. Rep. of Germany, November 1985, the NPTD Section has initiated a Co-ordinated Research Programme (CRP). The CRP on "Lifetime Predictions for Plasma Facing Components" will provide for a verification of computer codes that are being developed for the lifetime evaluation of first wall structures. During the first step of the CRP an experiment currently performed at Ispra will provide for input data for the numerical assessment of the cyclic inelastic behaviour of an SS 316 specimen.

For the next step the lifetime evaluation of an ITER relevant geometry and material is planned. Relevant input is expected from the ITER project.

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