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SEVENTH ITER TECHNICAL MEETING ON SAFETY AND ENVIRONMENT

by Drs. J. Raeder and C. Gordon, ITER JCT, Garching Joint Work Site

Introduction

An important feature of the ITER design activities has always been extensive safety and environmental assessments to ensure the attractiveness of ITER in particular and of fusion in general. In addition, the design, including all safety aspects, has to aim at a facility that can be sited in any of the sponsoring Parties' countries with a minimum of site-specific adaptations. The associated safety guidelines for the project have been based on internationally recognized principles and criteria, most notably IAEA recommendations. The comprehensive safety and environmental assessment of the 1998 ITER design has been documented in the Non Site-Specific Safety Report-2 (NSSR-2). Subsequently, strong efforts were made to establish ITER options with minimum cost and reduced detailed technical objectives, which still satisfy the overall programmatic objective. This work resulted in the outline design of a facility, provisionally named ITER-FEAT, documented in "Technical Basis for the ITER-FEAT Outline Design", January 2000. ITER–FEAT is now being assessed with regard to safety and environmental impact, and this assessment will be documented in a Generic Site Safety Report (GSSR).

From February 15 to 18, 2000, the Seventh Technical Meeting on Safety and Environment was held at the Garching Joint Work Site which now hosts the Safety, Environment and Health Group (SEHG) of the ITER Joint Central Team. At this meeting, safety experts from the Home Teams (HT) worked with the SEHG members towards the following main objectives:

- Review and agreement on the contents of GSSR,
- review and agreement on the tasks and the schedule for the production of GSSR,
- review and final specification of the design information to be used and of the analyses to be done for GSSR.

Issues presented and discussed

The participants heard a concise presentation of the ITER-FEAT characteristics and a related talk on site layout and building design. Both contributions expanded in particular on design issues with a bearing on safety and drew upon the results from the ITER-FEAT Point Design Meeting held from February 7 to 11, 2000 at the ITER Naka Joint Work Site. Changes, mostly favourable for safety, are as follows:

- Reduced neutron flux and fluence, entailing less decay heat, lower temperatures of the plasma facing components and less material damage;
- smaller surface loads from disruptions;
- reconsideration of the armour materials, in particular of tungsten vs. carbon;
- lower limits on hydrogen generation to account for the smaller volume of the vacuum vessel;

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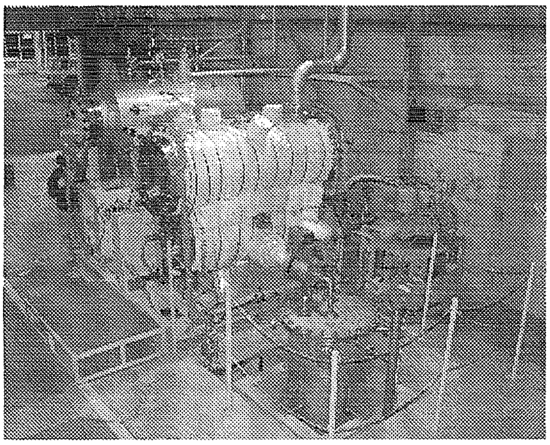
- fewer cooling loops, which should lead to less occupational exposure;
- tritium inventory guidelines below 0.5 kg in each of the vacuum vessel, the tritium system, the hot cell, and the site storage;
- tokamak and tritium building with a common seismic isolation.

The overall safety approach for ITER-FEAT was presented in terms of objectives, principles, criteria and implementation. The top level is documented in the ITER-FEAT Plant Design Specification and will be reflected in the GSSR. The production schedule for the GSSR and the expected input from the Home Teams was introduced in this context.

The Home Teams presented their thoughts on GSSR in terms of changes relative to NSSR-2, suggestions for GSSR and experience from domestic licensing exercises. In this context, extended discussions took place and eventually focused on accident analyses and related details. These discussions helped to reach a better understanding and consensus on issues such as:

- The maximum permissible first-wall temperature driven by decay heat together with a loss of cooling;
- the impact of run-away electrons on plasma facing components;
- ex-vessel loss-of-coolant accidents (LOCA), and
- confinement of radioactivity in the course of a maximum ex-vessel LOCA.



Experimental ICE facility which simulates the ingress of cooling water into the vacuum vessel

The Home Teams presented their results from R&D and design tasks. This work aims at the provision of basic safety data as well as at benchmarking and validation of computer codes for safety analyses, an activity involving all Home Teams. A major example is represented by the figure which shows the experimental ICE facility (of the JA HT at JAERI Tokai) to simulate the ingress of cooling water into the vacuum vessel. The experiment will provide data for code validation as well as a demonstration that the ITER-FEAT safety design approach (including a pressure suppression system) is capable of accommodating such events. The facility consists of a boiler, two vacuum volumes simulating plasma chamber and vacuum vessel, and a suppression tank. Water from the boiler is injected into the plasma chamber, steam and water are released from the vacuum vessel into the suppression tank through a safety valve which opens at a specified pressure.

The GSSR volume editors presented the envisaged scope, contents and some technicalities of the volumes, the working titles of which read as follows:

Volume I	Safety Approach
Volume II	Safety Design
Volume III	Radiological and Energy Source Terms
Volume IV	Normal Operation
Volume V	Radioactive Materials, Decommissioning and Waste
Volume VI	Occupational Safety
Volume VII	Analysis of Reference Events
Volume VIII	Ultimate Safety Margins
Volume IX	External Hazards
Volume X	Sequence Analysis
Volume XI	Safety Models and Codes.

Summary and conclusions

All participants from the Home Teams agreed that the meeting provided a most important forum for discussions on the ITER-FEAT safety approach and was very fruitful, since it strongly enhanced the mutual understanding. The main product of the combined effort, the Generic Site Safety Report, has been put on its way so that the detailed technical work can start. The schedule for the GSSR production is challenging and needs everyone's co-operation and best efforts.

Since the ITER-FEAT design is still underway, GSSR analyses will need to bound the design rather than analyze the exact design. The work on GSSR will make maximum use of the extensive assessments of the 1998 ITER design as documented in NSSR-2 and its references.

The GSSR, if prepared as discussed, is expected to meet the Home Teams' and the potential Host Countries' requirements with regard to preparing regulatory submissions. It is understood that the ultimate submissions must be prepared by experts from the Host Country. The GSSR will support siting decisions, but further design detail and specific Host Country safety assessments are likely to be needed for obtaining regulatory approval for the construction.

The tasks to the Home Teams, which will provide a major contribution to the GSSR, were agreed, although formal approvals are still pending.

There exist some issues, which received substantial attention and discussions during the meeting, for which the approach needs further improvement, justification and final agreement:

- Use of probabilistic arguments in the safety approach;
- use of Safety Importance Classification (SIC) with regard to implications, implementation and assessment, and to the role of components with SIC-4, which is intended to mean 'not safety class';
- application of the As Low As Reasonably Achievable (ALARA) principle and the demonstration that the related requirements are met;
- justification of bounding cases, and the selection of initial and boundary conditions;
- assumptions on important plasma physics issues, in particular on passive plasma shutdown and maximum in-vessel component damage;
- more R&D on the mobilization of co-deposited tritium and dust under accident conditions;
- confinement approach for the tokamak cooling water system vaults in the context of large ex-vessel loss-of-coolant accidents, and the related assumptions on the break type (double-ended guillotine rupture or leak-before-break).

The next ITER Technical Meeting on Safety & Environment, tentatively planned to be held by mid-November 2000, is intended to review the GSSR results and contents,as well as the summary of safety in the global presentation of ITER-FEAT in the Plant Description Document.

List of Participants

EU Home Team:	S. Ciattaglia, L. Di Pace, W. Gulden, J. Handbury, G. Marbach, N. Taylor
JA Home Team:	T. Araki, K. Hada, M. Hashimoto, T. Inabe, T. Maruo, E. Tada, T. Tsunematsu
RF Home Team:	B. Kolbasov, M. Krivosheev, Y. Petrov
JCT:	H.-W. Bartels, V. Chuyanov, C. Gordon, R. Hemmings, T. Honda, M. Iseli, K. Moshonas (VHTP), J. Raeder, L. Topilski

EXECUTIVE SUMMARY OF THE ELEVENTH ITER SCRAPE-OFF LAYER AND DIVERTOR PHYSICS EXPERT GROUP MEETING

by Dr. A. Loarte, EFDA Close Support Unit, Garching, and Dr. N. Asakura, JT-60U, JAERI, Naka

The 11^{th} ITER Scrape-off Layer and Divertor Physics Expert Group Meeting was held at the Naka ITER Joint Work Site on 16-17 of December 1999. The workshop assessed:

- The latest experimental results on divertor operational regimes and their implications for ITER-FEAT;
- the measurements and mechanisms for Scrape-off Layer (SOL) parallel and perpendicular flows and their influence on impurity contamination of the bulk plasma and wall/divertor material erosion and re-deposition;
- the integration of plasma regimes with good confinement and good divertor performance (good He-pumping and tolerable power load) for the two ITER-FEAT reference regimes: ELMy H-mode (for the Q_{DT} = 10 inductive regime) and optimized shear discharges (for the Q_{DT} = 5 steady-state regime);
- the role of chemical processes in divertor carbon erosion and deuterium/tritium co-deposition in existing experiments;
- the status of ITER-FEAT plasma edge modelling and of the validation of models against the most recent experimental data. The status of the required atomic and molecular database was reviewed as well.

Results from existing experiments indicate that operating at higher triangularities (typical of the ITER-FEAT design) allows the achievement of plasma densities well within those required for ITER-FEAT, while maintaining good H-mode energy confinement. These regimes, however, have the drawback of being associated with very large Edge Localized Modes (ELMs) which are linked to large pulses of energy being dumped on the divertor targets and, therefore, may lead to intolerable power loads when extrapolated to ITER-FEAT. There are regimes which seem to be an exception to this, where high pedestal pressure can be achieved with good confinement and with small or no ELMs (EDA in Alcator C-mod and Type II ELMs in JT-60U). Preliminary results from ASDEX-Upgrade indicate that such features may have been seen in this experiment as well. These regimes will be investigated in all experiments to determine in which parameter range they are observed. The group noted that new results reported at the APS Conference by DIII-D have shown the importance of maintaining a low recycling inner divertor (by pumping) in achieving high densities and good plasma confinement in ELMy H-modes with tolerable ELM power loads. This is an area which deserves experimental investigation in other devices. During 1999 the results of inner side pellet injection, which was pioneered in ASDEX-Upgrade, have been confirmed in JET (and DIII-D, following reports at the APS Conference). The results show that densities in excess of the Greenwald value can be achieved by this method with some peaking of the density profiles, although confinement degradation at high densities remains an issue.

Experiments in JT-60U (at outer midplane) and JET (at plasma top) show large parallel flows in the SOL plasma from the outer to the inner divertor (for operation with the normal B_T direction, where the grad-B ion drift direction is directed towards the X-point), previously seen in Alcator C-mod. These flows (which reverse direction when the B_T direction is changed) cannot be explained in terms of ionization sources in the SOL/divertor. The present understanding is that these flows are due to plasma drifts, which are not routinely included in the modelling of the SOL plasmas. The typical magnitude of these flows is M = 0.3-0.6, which is larger than the particles injected with gas puff and removed with pumping. These plasma flows may influence the effectiveness of improving impurity retention by gas puffing and divertor pumping and the in-out asymmetry of the particle flux to the divertor. With respect to predictions to ITER, it is worth pointing out that such flows are seen to decrease with increasing density and divertor detachment, which are the typical conditions for the ITER divertor. Thus, it is possible that the modelling done so far (without drifts) remains valid. However, this must be properly assessed to optimize the divertor design in ITER-FEAT.

The group re-assessed the present knowledge on divertor geometry effects with respect to detachment (including new results from TCV) and divertor pumping. The conclusion adopted by the group was that the present ITER-FEAT vertical divertor design, which includes a dome, is in accordance with the aim of achieving optimum divertor power handling and particle control.

The subject of Helium transport and exhaust was reviewed by the group. After several years of research, it has been demonstrated that Helium can be efficiently pumped in ELMy H-mode discharges, which are the basis for the ITER-FEAT inductive regime. However, the exhaust issue remains unresolved for optimized shear discharges (candidates for the ITER-FEAT steady-state regime) as it has been demonstrated in JT-60U. At this point, it is not clear, if by achieving higher densities in these discharges the problem can be ameliorated; further research in this area is in progress.

The area of plasma-surface interactions has received renewed interest because of the problems of tritium co-deposition in ITER. Many experiments find large carbon deposits in the inner divertor, particularly in cold structures. In JET, these deposits (including dust and flakes) contain a large amount of deuterium and tritium, which has very serious implications for the extrapolated tritium retention in ITER-FEAT. However, the issue of carbon chemical erosion and tritium co-deposition is at an early state of research with some contradicting results from various experiments. Therefore, this remains an active area of research and the extrapolation to ITER-FEAT (including tritium cleaning methods) remains unclear. Due to the importance of this problem for ITER-FEAT, this topic will be considered at the next ITER Expert Group Workshop, in order to reach more definite conclusions. Some experiments can operate successfully with high-Z divertor/wall materials which do not lead tritium co-deposition, such as in Alcator C-mod. A recent experiment in ASDEX-Upgrade, where tungsten has been successfully tested as main wall material, was reported in the meeting. Despite the attraction of using tungsten from the tritium retention point of view, questions remain over the risk of tungsten melting with large power fluxes, such as ELMs and disruptions. Assessment of these problems in existing tokamaks is required in order to evaluate this material option for the ITER-FEAT divertor.

The meeting was attended by 29 Expert Group members and invited experts:

EU: P. Coad, A. Loarte, G. Matthews, J. Neuhauser, V. Philipps, R. Pitts, D. Reiter

JA : N. Asakura, A. Hatayama, S. Higashijima, K. Itami, T. Kato, S. Konoshima, H. Kubo, K. Masaki, A. Sakasai, S. Sakurai, S. Sengoku, S.Takamura, T. Takizuka, H. Tamai, T. Tamano, T. Tanabe, K. Uehara, Y. Watanabe

JCT: G. Federici, A. Kukushkin, M. Shimada, M. Sugihara.

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kuvshinnikov, ITER Office, IAEA, Wagramer .Strasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: +43 1 2633832, or e-mail: c.basaldella@iaea.org (phone +43 1 260026392).

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