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ITER TECHNICAL MEETING ON NUCLEAR ANALYSIS

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The comprehensive nuclear analysis of the ITER-FEAT machine is a very important part of the overall ITER activity of this year.

The reduction of the ITER-FEAT dimensions, when compared with the 1998 ITER design, has brought new technical challenges in fitting in all required shielding, along with the need to reduce technical margins.

A preliminary analysis of ITER-FEAT has been performed by the Joint Central Team and the machine appears to meet the main nuclear shielding requirements. However, a more elaborate analysis needs to be carried out in order to achieve the required modelling accuracy. Therefore good co-ordination is important, especially during the short time when design development and optimization are progressing simultaneously. For this reason the special technical meeting "Nuclear Analysis for the Final Design Report" was organized *on 24-25 February 2000 at ITER Garching JWS so as to combine and specify the efforts of the Joint Central* Team and Home Teams.

It was confirmed at the meeting that only recommended and well known code systems and cross section libraries are to be used for the nuclear analyses of ITER-FEAT. Among them there are the well known MCNP system for neutron and photon transport calculations by Monte Carlo method, the FISPACT radionuclide inventory code system and the FENDL nuclear data library. Their use will enable reliable and consistent results to be calculated by different Parties.

The complex geometry of a tokamak-reactor continues to be a major factor in nuclear shielding performance modelling. A basic 3-D model of the ITER-FEAT machine is under development by the JCT and HTs. To avoid any overlap in their joint activity, it was decided at the technical meeting that the modelling will be shared between the Parties: the key structure elements of the machine such as the first wall and shielding blanket will be modelled by the JA HT, the divertor by the EU HT, the vacuum vessel, heating and diagnostic systems by the JCT. The model of the superconducting magnets and other cryogenic systems inside the cryostat and the biological shield will be developed by the RF HT, which plans to calculate nuclear heating of the magnets during operation, and external radiation fields after reactor shutdown.

In accordance with these plans the JCT will provide other developers with up-dated design information required for the 3-D modelling. Simultaneously, the JCT will control and merge different parts of the model in a self consistent way. After compiling, the model will be transferred to the parties for shared use. Further detailed modelling of the different systems in the ports and outside the vacuum vessel will be carried out by the parties in accordance with the specific objectives of their task agreements.

A new problem of accurate residual gamma-ray transport calculations in optically thick and geometrically complicated systems has been identified. The problem is accentuated by the strong requirement for personnel access to some important components around the ITER torus to carry out hands-on maintenance where remote controlled robotic maintenance is not desirable.

It was shown that the requirement to limit the allowable equivalent dose rate level after shutdown is more severe, in terms of radiation shield thickness, than, for example, the requirement to minimize the nuclear heat deposition in superconducting magnets.

The conversion factor methodology used in these residual dose calculations was accompanied by the uncertainty caused by the complex ITER geometry. This uncertainty in the dose rate prediction caused overshielding to guarantee occupational safety during hands-on maintenance.

For this reason two approaches to resolve this problem were discussed extensively at the meeting. A method developed by the EU HT as a first step requires calculations of neutron spectra in many important spatial segments of a 3-D systems. Then, based on these spectra, activation inventory calculations need to be performed in each segment. They provide a decay gamma-ray source distribution giving the residual afterheat distributions and local dose rates. A similar methodology, using sequential neutron-activation-residual gamma-ray transport calculations by Monte Carlo method, is under development by the RF HT.

To realize either procedure an interface is required to link prompt neutron and residual photon transport codes. Such an interface is partially available. Preliminary tests of these procedures presented at the meeting show a weak dependence of the average dose rate level in the in-cryostat space of ITER on the details of the neutron spectrum during irradiation.

A novel approach to the problem has recently been proposed by the JCT. The idea is to conduct the full neutron transport calculations, the activation and the residual gamma-ray transport calculations by Monte Carlo method in the same run and using a single 3-D model of a system. It is based on the fact that only a few of the radionuclides produced in single step isotope formation dominate in the irradiated ITER materials in all periods after shutdown. It was reported that in such a case a simple dose correction algorithm can be used for a pulsed operation scenario.

The new method also requires a modest change of the MCNP-code system and the nuclear data library, replacing the prompt gamma spectrum with the decay gamma spectrum. The main part of the work is already done and the first careful benchmarking confirms the accuracy of the results.

From the discussion, it was confirmed that both suggested approaches including intermediate or direct residual gamma-source calculations can be implemented in parallel for current purposes and can be harmonised finally.

Further benchmarking can be done on the basis of the neutronics experiments in the frame of the task "Experimental Validation of Shutdown Dose Rate" planned at the Fusion Neutron Generator in ENEA, Frascati. The experimental set up, irradiation conditions and measurement techniques required for a precise analysis and calculations were discussed at the meeting.

Calculated streaming effects in gaps and ducts will be checked also in the results of experiments on the Fusion Neutronics Source at the Japan Atomic Energy Research Institute. Two different configurations are to be used for streaming neutron spectrum measurements and for the direct shutdown dose rate measurements.

Intensive methodological, calculation and experimental work and benchmark activity discussed at the meeting will allow completion of detailed design analysis. The results of this activity will be summarized in the nuclear analyses report. There it will be demonstrated that the basic ITER-FEAT design will meet the specific design and regulatory requirements. In particular, it was mentioned at the meeting that items indispensable to the licence requirements in Japan for radiation shield design will be welcomed in the nuclear analysis report. These include radiation shield dimensions and composition, dose rate criteria, justification of the methodology, codes, models and cross section libraries used for nuclear analysis. In this context, the meeting was very useful in co-ordinating the nuclear analyses report preparation.

It was clear from the meeting that continuous nuclear analysis is a fundamental part of the design process. Specialists in neutronics not only check the current nuclear shielding performance but are actively involved in the design development. They recommend concrete technical solutions relating to the radiation shield dimensions, structure and material composition, and optimal system locations. The recent incorporation of nuclear analysis problems into the list of ITER Design Integration Unit responsibilities reflects this fact.

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