JET Experience in Preparation for the Systematic use of D-T in the Next Generation of Devices

A. Murari[1] and JET Contributors *

[1] Consorzio RFX (CNR, ENEA, INFN, Universita' di Padova, Acciaierie Venete SpA) and EUROfusion Consortium, JET.

With the construction of ITER and the design of DEMO, the European research in the field of Magnetically Confinement Nuclear Fusion (MCNF) is moving rapidly toward devices, which will make systematic use of tritium as fuel. Consequently, the MCNF community needs to prepare for the full nuclear age, compensating for a cultural weaknesses already identified by the EUROfusion roadmap. Indeed the systematic use of D-T as fuel will have a very significant impact on all the aspects of Tokamak operation, from the scenarios, to feedback control and diagnostics, safety procedures and technologies. In this perspective, JET presents some unique capabilities, which render the experiment the most relevant for the future generation of machines. The most important are the plasma facing components of ITER (W divertor and Be main chamber first wall) and the plasma parameters to confine the alpha particles. A series of experiments, foreseeing a complete scan of the isotopic composition, have already started and they are meant to culminate with T-T and D-T experimental campaigns, now scheduled for next decade. The total yield of the final D-T phase is expected to be 1.7 10^{21} neutrons, about a factor of six higher than the previous main D-T campaign on JET, DTE1. Therefore the radiation field will be quite relevant for next step devices, since the neutron flux at the first wall (~10^{16}n/s cm^2), for example, will be similar to the one in ITER behind the blanket. The experiments at various isotopic compositions on JET are going to provide an important contribution to fill major physics and technological gaps for the development of fusion energy. In particular, the added value will be relevant at least in the following fields: 1) scenario development and performance 2) physics and diagnostics 3) safety procedures and feedback control techniques 4) nuclear and tritium fuel technologies. With regard to the scenario developments, the performance of JET with a carbon wall have confirmed the values of confinement time predicted by the IP98(y,2) scaling up to a plasma current of 3.5 MA, which supports the ambition of achieving 15 MW of fusion power in full DT operation. Moreover it should be considered that the developed plasma configurations are fully compatible with the wall properties, from melting to retention (less than 0.5%) and dust production (less than 2 g in the last set of campaigns). An overarching programme to investigate disruptions is on-going, covering all the aspects from modelling to prediction, mitigation and runaway electrons, including 2 tritium compatible fast valves for massive gas injection and an already fully operational Shutter Pellet Injector.In terms of physics and general diagnostic capability, the main topics to address are isotopic effects (on confinement, the threshold to access the H mode, the ELM behaviour etc.) and the physics of the alphas. The scientific exploitation of these experiments will depend crucially on a series of diagnostic developments which have been already completed. With regard to the fusion products, JET now can deploy a consistent set of techniques to measure the neutron yield and neutron spectra and to diagnose the fast particles, from their redistribution to their losses. A full calibration of the neutron diagnostics (for both the 2.45 and 14 MeV neutrons) has been successfully implemented and tested. Regarding the safety procedures and the feedback control techniques, most of the work has already been performed. The tritium rehearsals have almost been completed and the main feedback schemes, from the beta control to the ELM and sawteeth pacing, have been validated over a wide range of experimental conditions. From a long term technological perspective, the D-T and T-T campaigns will provide a unique opportunity to test ITER and DEMO relevant technologies. Specific programmes are being put in place to investigate the following aspects: the radiation field, the induced activity and dose rates, the radiation damage in materials and components, waste production and occupational dose. The effects of neutrons and gamma on ancillary technologies and systems, such as fibre optics and electronics circuits, are also expected to be sufficiently high to derive useful information about the competitive advantages of various alternatives. Dedicated studies for DEMO, including the tests of a tritium breeding blanket mock-up and diamond detectors, are also foreseen and very advanced

* See the author list of E. Joffrin et al. in Nuclear Fusion Special issue 2019, https://doi.org/10.1088/1741-4326/ab2276