40 years of JET operations: a unique contribution to fusion science

F.G. Rimini[1] and JET Contributors*

[1]*UKAEA, Culham Campus, Abingdon, OX13 3DB,UK*

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The end of tokamak operations at the Joint European Torus in December 2023 brought to a close the experimental life of an extraordinary fusion research facility.

The JET design activities, starting in 1973, had the ambition of building a device capable of studying plasmas in conditions and dimensions approaching those of a reactor. This aim was articulated into four main areas of study: plasma-wall interaction, plasma heating, behaviour as as parameters approach the reactor range and the study of alpha particles. The latter was the most groundbreaking, requiring the tokamak to operate with D-T mixture plasmas.

The paper will review the remarkable contributions of JET in various fields of tokamak science, including the D-T experiments, and their impact on the fusion research progress.

We will discuss how the JET size, significantly bigger than any other tokamak, has supplied unique results to H-mode studies, complementing those of smaller experiments, contributing to development of scaling laws and providing data for validation of numerical modelling and bridging the size gap to future burning plasma devices.

The unique combination of large size, ~ 80-100m^3 of volume, low toroidal field ripple < 1% and high plasma current, up to 6MA in magnetic X-point configuration, also allows effective confinement of highly energetic ions. This is essential for Radio Frequency Heating and alpha particole studies and this paper will look specifically at how JET results on heating scenarios for burning plasmas have led to major improvements in understanding.

We will, also, cover some results directly relevant for ITER, for example the exploration of disruption mitigation with Shattered Pellet Injection technology. We will detail how, in joint JET-ITER experiments, conditions of high magnetic and thermal energy not available on any other experimental device have been accessed, thus providing crucial support to the preparation of ITER operations.

Finally, the contributions of JET in the area of Plasma-Wall Interaction will be reviewed, from the early results on operation in a beryllium First Wall environment, to the divertor physics studies in CFC and, eventually, to operation in the all metal Be/W conditions.