JETInsight

EFDA JET

Quarterly News & Views of Europe's largest Fusion Device

December 2009

The shutdown commenced on 26 October. Here, Rob Fenn is in the JET Clean Room, inserting the fixing bolts for the individually numbered tungsten tiles.

Dear Reader

With the beginning of the shutdown, the installation of the components of the new ITER-Like Wall is now underway. For JET this marks the end of an era, but more importantly, the beginning of a new one. For 26 years, as a mainly carbon-walled machine, JET has been at the forefront of fusion research. This has resulted in numerous scientific and technological achievements that have led to the design of ITER. From 2011 onwards JET will, to all intents and purposes, be a new machine. With the same wall materials and similar heating powers as ITER, the new mission of JET will be to support ITER in the final preparation of its operating scenarios. This will be a very exciting time for everyone involved in the JET programme. To follow the progress in one of the most significant JET upgrades ever performed, I invite you to look at the Shutdown Weekly section of the redesigned EFDA-JET website.

When I wrote this letter a year ago in December 2008, JET had been in operation for almost a year and I commented that 2009 would require the best from all the people involved. Experiments on JET continued to the end of October and I am happy and thankful to say today that the commitment of the JET team and the Operator staff has exceeded all my expectations. I wish to extend my thanks to the Associations, who have maintained a high level of participation in the JET programme throughout this very long period of almost uninterrupted operation.

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The financial future of JET was uncertain at the beginning of this year but demonstrating strong faith in JET and its role, the EFDA Steering Committee has resolved the situation for 2011. I very much appreciate the support I got from many Heads of Research Units in this matter. The combined efforts of the JET team are evident from the large number of experiments which were successfully carried out during 2008 and 2009. Many of these addressed scientific and technical issues vital to ITER, such as the ones you can read about in the main article of this JETInsight.

Wishing you and your family a Merry Christmas and a Happy New Year.

Francesco Romanelli

Main article in this issue

“JET and ITER: similar on **purpose**”

It often said that JET is similar to ITER. In fact, it is more correct to say that ITER is similar to JET. JET, with its long history of operation and many scientific achievements, has provided the basic template for the ITER design. As a result, JET's mission is clear: support ITER in all possible aspects!

JET and ITER: similar on **purpose**

In the last two years of operations, the JET team has made substantial achievements in improving system performance, testing new technologies for ITER and resolving remaining physics issues. In addition new hardware and new and upgraded diagnostics have been successfully commissioned. The machine is now in a period of enhancement 'shutdown' which will last for a year, during which new ITER-like plasma facing components will be installed (*see JETInsight June 2009*) and the neutral beam power increased by 50 per cent.

This shutdown is an excellent opportunity to look back and summarise the achievements of the last two years. The following few examples highlight the impact JET experiments have had on the design of ITER components and on the operating scenarios.

ITER will operate in three different phases: the first, a non-activated phase will use hydrogen or helium plasmas to test the machine performance while keeping it accessible for repairs. Then there will follow two phases with increasing fusion power, one to test shielding provisions and another to reach full fusion power. Thanks to JET's remarkable flexibility, its experimental programme has been able to imitate the ITER non-activated phase and compare its performance to normal deuterium operation. This will increase the ITER team's confidence in being able to predict the ultimate fusion performance right from the first phase of operation.

JET influences ITER's hardware

From 2007 onwards, JET has performed experiments focusing on toroidal field ripple effects. In every tokamak the field generated by the toroidal field coils is imperfect. The coils produce a small scale fluctuation in the magnetic field a "ripple". Some ions and electrons get trapped in the lower magnetic field areas, resulting in energy and particle losses so it is important to reduce the ripple as much as possible. The more coils on the machine, the smaller the ripple between them. In other words JET, with a total of 32 toroidal field coils, has a very small ripple level while ITER, with only 18 coils, might face a substantial loss of energy from the plasma. To consolidate the ITER design, JET carried out a series of experiments taking advantage of its ability to operate with various combinations of currents in odd and even numbered toroidal field coils. The results led to a revision of the ITER design of the ferritic inserts in the wall between the toroidal field coils. These should reduce the amount of ripple to a tolerable level allowing ITER the high fusion gain ($Q \geq 10$) it is designed to achieve.

There is also a need to test possible designs for the Ion Cyclotron Resonance Heating antenna (ICRH, *see JETInsight October 2008*) for ITER. Its baseline scenario is the High Confinement Mode, which is, in most cases, accompanied by Edge Localised Modes (ELMs). These instabilities cause abrupt changes in the edge density of the plasma that results in large amounts of the Radio Frequency power being reflected back to the antennas. The Radio Frequency generators then have to power down briefly to avoid overloading. As a result the amount of power coupled into the plasma is significantly reduced. Experiments in the last two years with the JET ITER-Like Antenna have showed that the concept chosen for ITER is indeed capable of powering through ELMs and that the power coupled to the plasma should meet the requirements of ITER.

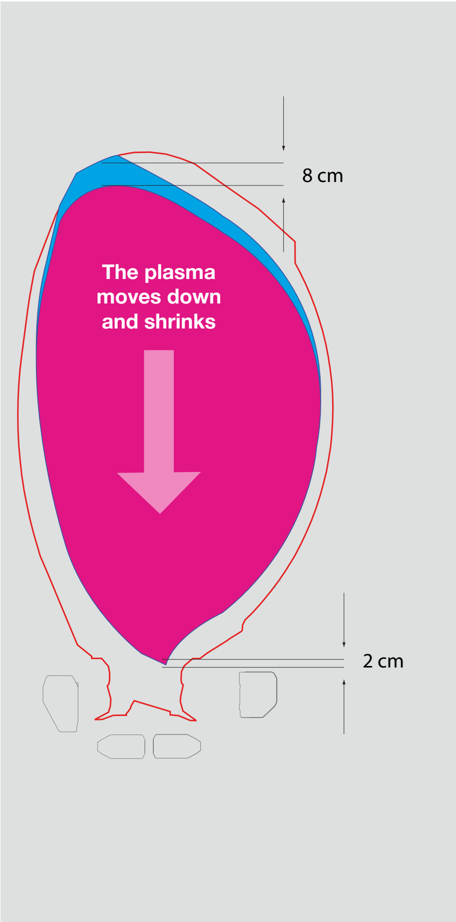
> *"We currently have approximately 350 scientists from Europe and 100 scientists from other international collaborations participating in the JET programme. They will be involved in the analysis of the data taken over the last two years, a period in which we have carried out some very successful experiments."*
>
> *Francesco Romanelli, EFDA Associate Leader for JET*

Dealing with disturbances

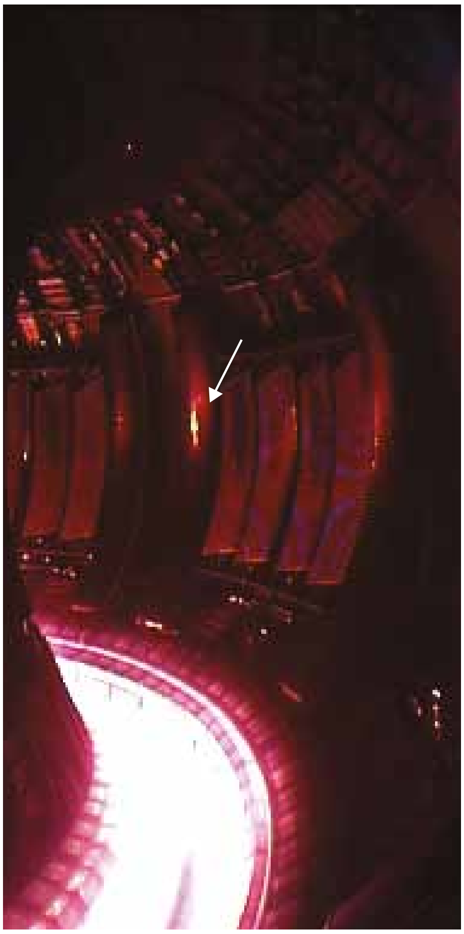
ELMs are also a concern because of the heat loads and the erosion they cause on plasma facing components. Another JET contribution to ITER is to develop and test techniques to moderate the ELMs. One possibility is to add a voltage pulse to the vertical stability coils, in effect giving the plasma a vertical kick. As a result the plasma moves down a few centimetres and shrinks before it recovers its original position and size. Each kick triggers an ELM and high kick frequencies result in many small ELMs instead of fewer large ones. Fortunately, this technique does not reduce energy confinement to a significant degree. Another concept for reducing the size of ELMs uses a set of coils to produce so-called Resonant Magnetic Perturbations (RMP) at the plasma edge. Yet another is the injection of a train of small pellets, each triggering an ELM. Six pellet injectors are planned in ITER for fuelling fusion reactions and for mitigating the ELMs. ELM control with kicks, RMPs and pellets has been extensively studied in 2009 and will be again in the 2011 experimental campaign.

Over the years, ITER has benefited from the experience gained at JET. Paul-Henri Rebut, leader of the JET design team and JET Director until he became Director of ITER-EDA, said in 2006, on receiving the Hannes Alfvén Prize:"Without JET, ITER would not exist today." That is certainly true; however the honour comes with important responsibilities.

Petra Nieckchen



Moderating Edge Localised Modes (ELMs): An additional voltage pulse to the vertical stability coils momentarily move the plasma down a few centimeters and shrinks it, triggering an ELM each time.



Picture taken with visible light camera shows Toroidal Field ripple induced losses (indicated by the arrow) on the polodial limiter for a plasma with one per cent ripple. The experimental results are consistent with the calculations done beforehand.

The ITER-Like Antenna fully mounted in JET. Hidden behind the rods, but clearly visible, are the copper 'straps' that radiate the power into the plasma.

JET support for ITER in 2008-2009:

- Advanced scenario experiments in JET bolster expectations for ITER
- Full ITER discharge simulations prompt design improvements for ITER coils
- Experiments with increased toroidal field ripple show necessity of having low ripple in ITER
- Threshold power for high confinement regime (H-mode) in helium plasmas, as planned for initial phase of ITER operation, is not higher than in deuterium plasmas
- Ion cyclotron heating used to control sawteeth and avoid neo-classical tearing modes, which deteriorate confinement
- ITER-like ion cyclotron antenna tested and confirmed to be tolerant to ELMs
- Severity of Edge Localised Modes (ELMs) mitigated by several different techniques, controlled vertical plasma displacements ('kicks'), resonant magnetic perturbations (RMP), trains of small pellets and even gas puffs
- Severity of plasma disruptions mitigated by powerful puffs of gases such as neon and argon
- Documentation of deuterium retention in carbon and material migration in the vessel for future comparison with ITER-Like Wall

New Task Force leaders **appointed**

Now the shutdown has started, there will be no more experiments until 2011. The Task Force teams of the recent experimental campaign are analysing and publishing the results of the last two years. In parallel, newly appointed Task Force Leaders and Deputy Leaders who have been integrated into a revised structure, have already started preparing the next set of experiments.

Task Force E1 will be responsible for commissioning the ITER-Like Wall and for operation in ITER-relevant conditions. Task Force E2 will investigate the physics of plasma-wall interactions in the new conditions as well as many other issues in preparation for ITER operation. In the March issue, JETinsight will present the team of the Fusion Technology Task Force.

E**1**

Rudolf Neu
(IPP, Germany),
Task Force Leader

"I am really looking forward to a safe and successful operation with the ITER-Like-Wall in JET. Working with all-metal plasma facing components will be a challenge. However, it is an essential prerequisite for the ITER operation during its nuclear phase and JET can make a substantial contribution to promoting the necessary techniques and experimental experience."

Emmanuel Joffrin
(CEA, France),
Deputy Task Force Leader

"I'm looking forward *to producing a plasma scenario relevant for ITER with Q=10 in a machine with the same features that the wall of ITER will have and defining the operation space of these scenarios. I do like working with new people and I want to encourage the participation of newcomers in this undertaking."*

Marie-Line Mayoral
(CCFE, UK),
Deputy Task Force Leader

"What I am looking forward the most is probably to the overall increase in fusion community knowledge that the exploitation of the ITER-Like Wall will bring. The more prepared we are for ITER; the higher the chances of success in fusion."

Marc Beurskens
(CCFE, UK),
Deputy Task Force Leader

"I am truly looking forward to the work ahead. We have a great team and I feel privileged to work with the E1 leadership, Rudi, Emmanuel and Marie-Line as well as the E2 leaders. However, we need the expertise of scientists and engineers from all the EU associations for physics and diagnostic exploitation; I do not think that such an exciting, complex and international endeavour can easily be found elsewhere."

E**2**

Guy Matthews
(CCFE, UK),
Task Force Leader

"I'm looking forward to the excitement of the first early plasmas and to see if the things that we have predicted will really happen. It's going to make JET very much the ITER test bed because it will be so like ITER. It's going to be also very challenging working in this very integrated way."

Peter de Vries
(CCFE, UK),
Deputy Task Force Leader

"What I personally look forward to is the challenge to operate with this completely new machine. I think what the Task Force should do is to involve people and make sure they participate in this very interesting campaign and that we can get as much scientific knowledge out of this as possible."

Sebastijan Brezinsek
(FZJ, Germany),
Deputy Task Force Leader

"The exchange of the first wall in JET is one of the most important experiments for ITER and in particular for plasma-wall interaction studies in respect of material migration, fuel retention and lifetime of plasma-facing components. I hope that we will be able to give an answer to the grade of reduction in the fuel retention in the almost carbon free environment."

Mathias Groth
(TEKES, Finland),
Deputy Task Force Leader

"My research projects include developing optical instruments to diagnose the exhaust gas and recycling sources and flows in the tokamak main chamber, leading experiments to elucidate impurity transport processes, as well as validating state-of-the-art edge fluid simulations on experimental data. I am looking forward to combining dedicated experiments with interpretative analysis and predictive modelling of the performance of JET with the ITER-Like Wall."

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