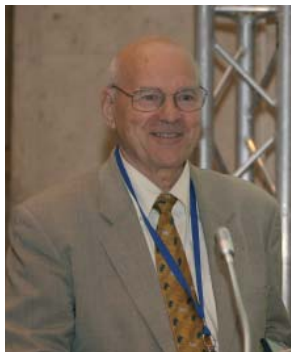
EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT
JET

EFDA-JET Bulletin

"I am sure that all who have been associated with Paul-Henri would join me in applauding the outstanding qualities of Dr Rebut and the major impact which he has had on JET and on fusion research in general."
Dr Jérôme Paméla, EFDA Leader

October 2006

2006 Hannes Alfvén Prize awarded to Dr Paul-Henri Rebut



The Plasma Physics Division of the European Physical Society has awarded the 2006 Hannes Alfvén Prize to Dr Paul-Henri Rebut, for "his seminal contributions to progress in magnetic confinement fusion, including his pioneering work in plasma theory, and his contributions to the development of various early magnetic confinement configurations. For his innovations in tokamak design, first with the construction of TFR, subsequently with the design and construction of JET, which remains after 25 years the world's leading magnetic fusion device, and culminating in the EDA Outline Design of ITER. For his vision, leadership and technical accomplishments in planning and carrying out the first deuterium-tritium experiment in a magnetically confined plasma, which broke new ground in fusion physics and produced multimegawatt fusion power in a controlled way."

Dr Henri-Paul Rebut was the pivotal force in the design, construction and operation of JET for almost 20 years. He ensured a robust and flexible design which, even 30 years on, will allow further major modification - the ITER-like Wall - and further unique JET contributions to fusion research in support of ITER.

The prize was presented to Dr Paul-Henri Rebut on the first day of the Annual Conference of the EPS Plasma Physics Division in Rome on Monday 19 June 2006. "Without JET, ITER would not exist today," commented Dr Rebut in his presentation, and added: "The role of JET is also to train physicists to be ready to work on ITER, with the key aim of increasing its absolute performances in Deuterium-Tritium fusion. JET and ITER will be judged on the power and the energy produced in Deuterium-Tritium experiments."

In the JET Control Room, Dr Marco de Baar and Dr Sandra Grünhagen (sitting left), engrossed in the discussions with the ESOF participants by videoconference link.

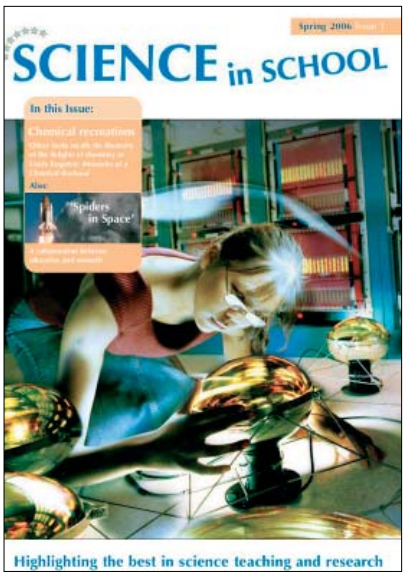
JET Status

Experimental Campaign C16 started on 25 September 2006, devoted to studies of ITER-like operation scenarios. This concluded the unplanned summer intervention due to a vacuum leak. The campaign follows on a successful machine restart, in which all milestones have been met.

Fusion at ESOF 2006

In the week beginning 15 July 2006, the second Euroscience Open Forum (ESOF 2006) welcomed over 2100 participants from 58 countries to Munich, Germany. JET as a key part of European fusion research was represented on three different occasions:

- In a round table seminar on 16 July 2006 "Fusion research: bringing the Sun down to Earth", organised by Alexander Bradshaw (IPP Garching) and hosted by Jérôme Paméla (EFDA Leader), Thomas Klinger (IPP Greifswald), Günter Janeschitz (FZ Karlsruhe), Nadine Baluc (CRPP Lausanne) and Thomas Hamacher (IPP Garching).
- In the ESOF Exhibition area as one of the partners of the EIROforum partnership. EIROforum is a co-operation between seven European Intergovernmental Research Organisations, see http://www.eiroforum.org.
- In the live video conference on 17 July 2006, which was again organised under the auspices of EIROforum. The ESOF participants had an opportunity to watch and talk to scientists working at four different places: CERN in Geneva, ESO in Chile, EMBL-ILL-ESRF in Grenoble and EFDA JET in Culham.



Science in School, a new journal freely available to European science teachers, is published quarterly by EIROforum. For more details visit http://www.scienceinschool.org

One of the key elements within the "JET programme in support of ITER" are experiments with an ITER-like wall. The ITER-like wall project, presented at the 17th Conference on Plasma Surface Interaction (PSI), 22-26 May 2006, Hefei, China, aims at a full replacement of the first wall materials in JET (presently Carbon Fibre Composite, CFC) with the combination of metallic plasma facing materials foreseen for ITER: beryllium (Be) wall and tungsten (W) divertor. The scientific objectives are to provide answers to urgent plasma-surface interaction questions, such as tritium retention, and provide operational experience in steady and transient conditions with ITER wall materials under relevant geometry and relevant plasma conditions.

A total of 4404 main wall tiles currently installed in JET will be replaced by 1700 solid Be tiles (for instance of the poloidal limiters or inner wall guard limiters) machined from 4 tonnes of solid Be in addition to the Be-coated inconel tiles of the inner wall claddings. The technical solution foreseen for the full tungsten divertor includes bulk tungsten for the load bearing septum replacement plate (most heavily power-loaded tiles) and tungsten coating on Carbon Fibre Composite for the remaining tiles.

Main chamber tile design and tests

In view of the need to preserve the power, energy handling and force limits set for the present Carbon Fibre Composite wall at JET, dedicated studies have led to the design of solid Be tiles which are inertially cooled, sliced and castellated toroidally and poloidally in order to minimise electromagnetic forces and increase heat shock resistance (see Fig 1). This design will serve also as an excellent test for ITER in view of the mechanical integrity and the possible material migration into gaps and the associated fuel retention. In addition, R&D activities on Be coatings have been launched in two areas: (a) Be coating on inconel tiles; (b) marker films on bulk Be limiters tiles for the assessment of erosion rates in the main chamber. Using Be evaporation the Nuclear Fuel Factory Pitesti, Romania, carried out the manufacturing of samples of 7-9μm thick Be film on inconel substrate. The R&D process comprised global characterisation (structure, purity, etc) of the evaporated films and testing of their performance under heat loads. The coatings where found to be of high purity, to well adhere to the substrate and no exfoliation was observed during long term storage in air. High heat flux tests performed in the electron beam facility JUDITH (FZJ Germany) showed that the deposited layers survived energy loads up to 18.1 MJm^{-2} (see Fig 2) thus significantly exceeding the required level of 5 MJm^{-2} which corresponds to the energy level typically deposited onto the wall cladding during regular JET operation. Several solid Be limiters tiles are planned to be coated with a higher atomic number (Z) metal interlayer 2-3 μm thin covered by a 7-8 μm Be film to allow erosion measurement up to this depth. For the measurements to be conclusive the Be marker layer must adhere well to the substrate and be compact in order to resemble bulk Be. Therefore, the Thermionic Vacuum Arc technique based on the electron-induced evaporation was selected as the coating technique. Nickel was selected for the composition of the interlayer because of its linear expansion coefficient at room temperature being close to that of Be. Testing of the marker layer performance under power loads in the JUDITH facility will be the next step concluding this R&D process.

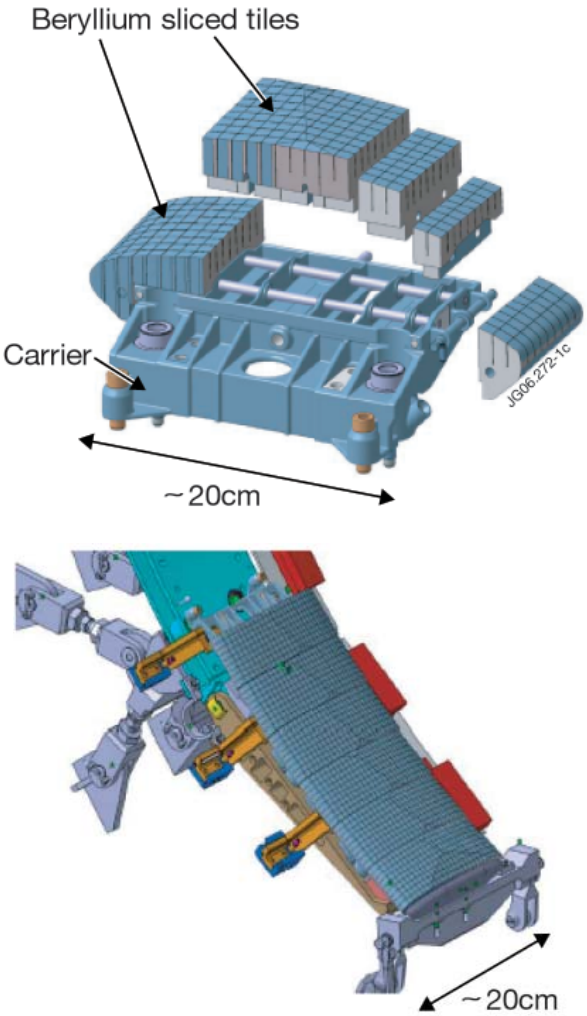


Figure 1: Example of tile design for the JET main wall structure (here a poloidal limiter)

Tungsten-coatings on Carbon Fibre Composite tiles: a European collaboration

In view of the need to select the most reliable W coating technique for most of the divertor tiles and some specific main chamber tiles (e.g., tiles that are intercepted directly by neutral beam injection shinethrough), a coordinated R&D programme was launched in early 2006. As a result, 14 different types of W coatings, including Chemical Vapour Deposition (CVD, 4, 10, 200 μm), Physical Vapour Deposition (PVD, 4, 10 μm) and Vacuum Plasma Spraying (VPS, 200 μm), have been produced on CFC tiles and tested under cyclic heat loading under coordination of IPP Garching in cooperation with CEA Cadarache, ENEA Frascati, TEKES Finland, MEdC Romania and FZJ Germany. All coatings were subjected to a thermal screening at the GLADIS test facility (IPP Garching) with stepwise power loads increasing from 4 MW/m^2 in 6s up to 22 MW/m^2 in 1.5s. The surviving 9 out of 14 coating types were exposed afterwards to cycling tests for 200 high heat flux pulses. The different and anisotropic thermal expansion between CFC and W often led to cracking

perpendicular to the fibres, inducing de-lamination by buckling along the fibres, melting and partial loss of coating. A 200µm VPS coating and a thin 10µm ion assisted magnetron sputtered layer performed best. These coatings were additionally exposed to 1000 typical JET-like ELMs (0.35 GW/m^2 for 1ms) in the electron beam facility JUDITH, demonstrating their robustness to this number of cycles (note that more than 100 ELMs of this energy can occur in one high performance JET pulse).

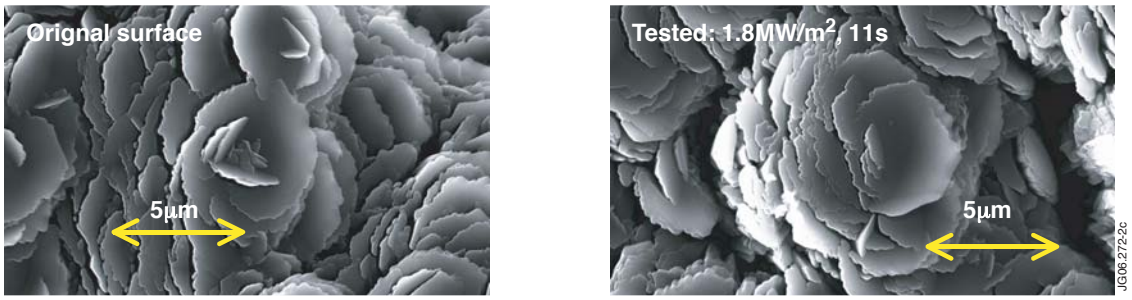


Figure 2: Scanning electron microscope image of a beryllium coated tile before and after the high heat flux test. The comparison shows that the coating survived the test without lost of quality.

Bulk Tungsten tiles: a newcomer in fusion research facilities

For the most heavily power-loaded divertor tiles - where the lifetime of the best achievable W-coating to date would be strongly reduced to a few high performance discharges - a bulk W tile concept has been developed under the leadership of FZJ Germany. The design was mostly determined by the strong constraint of minimising electromagnetic forces during disruptions and optimising mechanical stability. A design was made of 6mm W lamellae, packed together in 4 poloidal stacks and bolted together in toroidal direction but with electrical isolating spacers to reduce eddy currents (see Fig 3). Each lamella has dedicated electrical contact points to the support structure to reduce halo forces and avoid arcing. A prototype of this concept has survived cycling heat flux tests (200) with 7 MW for 10s and failure test with 10 MW for 14s with temperatures exceeding 3000°C.

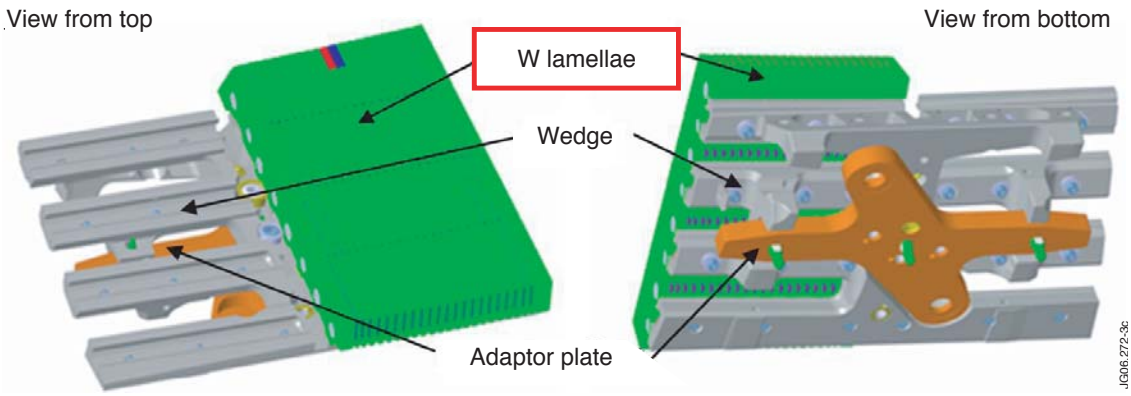


Figure 3: Example of the design of a bulk tungsten tile for the heavily power-loaded areas of the future JET tungsten divertor.

JET programme in support of ITER presented at SOFT 2006

On 11 September 2006, in the first plenary session of the 24th Symposium on Fusion Technology in Warsaw (SOFT 2006), the EFDA Leader Dr Jérôme Paméla presented the multi-annual "JET programme in support of ITER". In his contribution, Dr Paméla said: "The JET programme in support of ITER has been designed with the aim to provide significant advances and solutions to the ITER-related key research areas by exploiting JET's unique capability to handle tritium and beryllium." In order to meet this target, it was underlined that the JET programme had been elaborated in a coherent approach along the following 3 main axes:

(i) experimentation with an ITER-like wall,
(ii) development of plasma configurations and parameters towards the most ITER-relevant conditions achievable today,
(iii) integrated experimentation in deuterium-tritium.

Dr Paméla concluded that the comprehensive set of enhancements of the JET facilities is planned "in order to consistently, effectively and efficiently address" what he sees as "the corner stone of fusion: the compatibility between plasma operation and the surrounding materials."

Left to Right: J. Ongena, L. Cardozo, F. Romanelli, his Excellency Count J. M. V. A. de Marchant et d'Ansembourg, H.E. Hoefdraad, M. Beurskens, M. deBaar.

Ambassador of the Netherlands visits JET

On Wednesday 19 July 2006, His Excellency Count Jan M. V. A. de Marchant et d'Ansembourg, the Ambassador of the Kingdom of the Netherlands to the United Kingdom and the Counsellor for Science and Technology Dr Henk E. Hoefdraad visited the JET Facilities.

PhD research prize awarded to Kristel Crombé

At the 33rd EPS Conference on Plasma Physics in Rome on 22 June 2006, Dr Kristel Crombé was awarded a PhD Research Prize for her thesis "Spectroscopic Studies of Impurity Ion Dynamics on the JET and TEXTOR Tokamaks" which she presented last year at Ghent University, Belgium.

"I am really happy to receive this award, which comes as a total surprise to me" said Kristel.

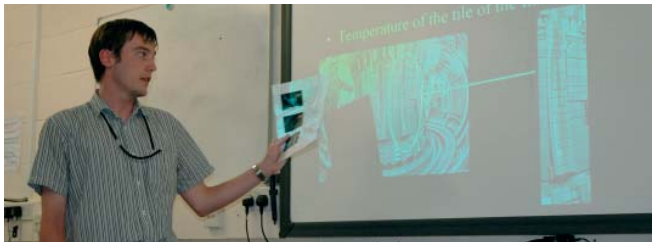
Kristel Crombé studied plasma poloidal rotation velocity profiles in JET advanced mode plasmas using the charge exchange spectroscopy plasma diagnostic. Her work was carried out within the Core Spectroscopy Group at JET. Several improvements to the analysis of the spectra have led to first observations of a strong increase in plasma poloidal rotation in the presence of internal transport barriers.

JET on prime time TV broadcast in Sweden

On 9 August 2006 a TV crew from SvT (Swedish national news) visited JET. They filmed both in the Control Room and Torus Hall and recorded some footage of Swedish scientists at work. The TV crew also interviewed Dr Jerzy Brzozowski. The footage was broadcast, together with brief information on the ITER project in Cadarache, on 15 August 2006 in the "prime time" news in Sweden. Following the broadcast, the Head of Research Unit Professor James Drake from the Royal Institute of Technology in Stockholm was delighted: "This was a very successful broadcast, a good day for fusion".

Summer placements at JET

Every year a dozen university students from Europe (France and Italy in particular) succeed in obtaining a summer placement at JET. This gives them a unique opportunity to gain work experience from a large international research project and a valuable chance to enhance their knowledge of the English culture and language.



At the end of August students finalise their research projects and present the results to the staff at JET (photo: Fabien Trohay from INSA Lyon).

Delegation from the Aosta Valley visit JET

On Friday 15 September 2006, a delegation from the Aosta Valley Observatory in Italy (see **http://www.oavda.it**) visited the JET Facilities. The visiting party of 18 included Prof Enzo Bertolini (Director of the Foundation Clément Fillietroz – Onlus, and former Chief Engineer at JET) as well as Adriana Vierin, Roberto Vicquery, Giulio Fiou and Dario Frassy (members of the Regione Autonoma Valle d'Aosta parliament).

Close Support Unit in Culham

The Programme Department was reinforced by Dr Emmanuel Joffrin from CEA in August 2006. In September 2006, Ronald Wenninger from IPP Garching joined the Operation Department.

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