EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT JET

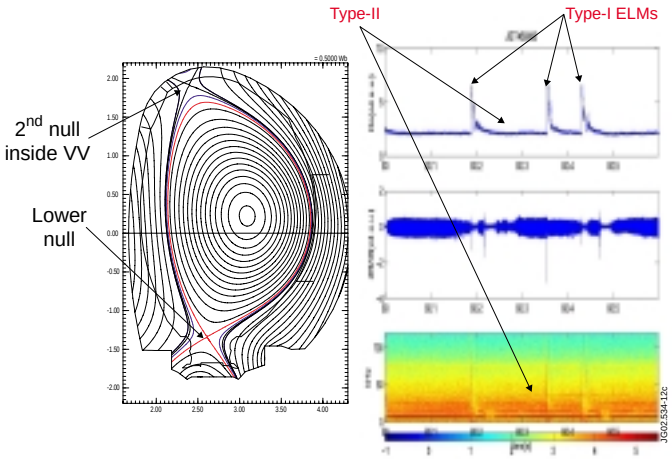
EFDA-JET Bulletin

Issue1
December 02

*This issue of the JET bulletin is dedicated to the memory of **Derek Robinson** who passed away on the 2nd December 2002. His contribution to Fusion Science is known and recognised across the world (see last page).*

Highlights of 2002 Campaigns

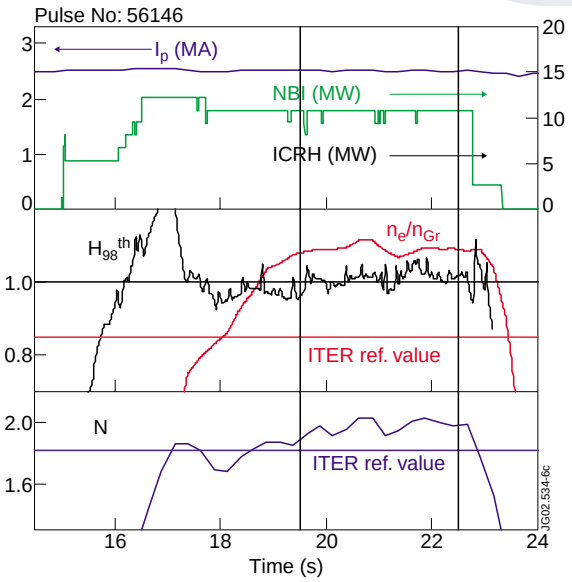
The removal of the septum during the 2001 shutdown has increased the flexibility in plasma shape. **New plasma configurations** have been developed including a **high triangularity configuration with reduced disruptive forces** (HT3), which will make it possible to extend the high performance studies of ITER like configurations to higher current. In this new HT3 configuration, the achieved confinement enhancement factor (H), normalized density (ne/nG) and normalized pressure (bn) are simultaneously equal to or above the values required for ITER (see figure).



Near double null configuration

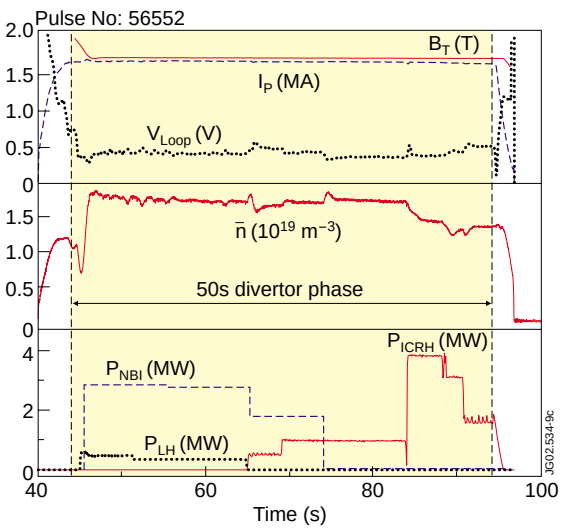
The **longest divertor pulse** ever has been produced in JET with a divertor phase of ~50s. This will be further developed to study long-time divertor plasma and wall processes (see figure).

Diagnostic optimised configurations have been developed, allowing the pedestal and edge density and temperature gradients to be resolved for the first time in JET.



HT3 Configuration

A **'Near Double Null' configuration** has also been developed for the study of Type-II Edge Localised Modes (ELMs) to explore the extrapolability of ASDEX-Upgrade results. A mixed Type-I Type-II ELM regime has been identified in preliminary experiments (see figure).

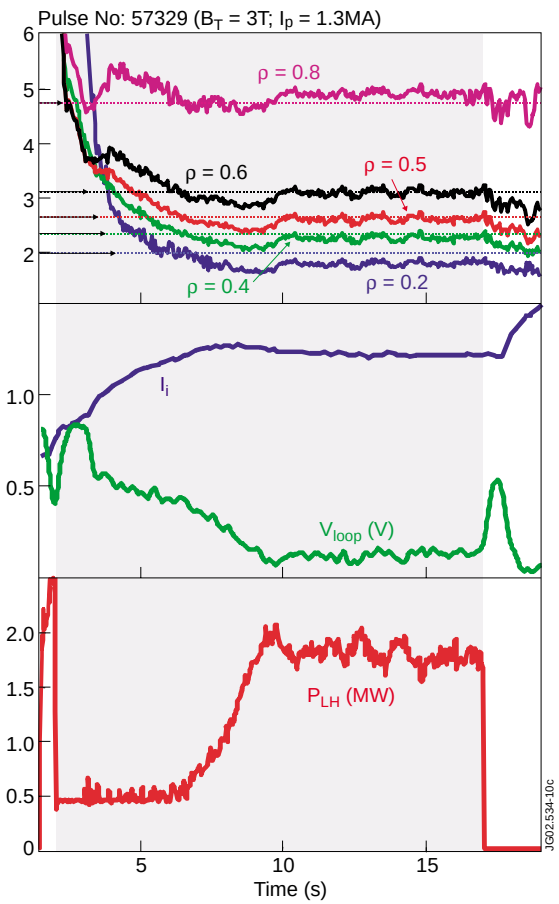


Long pulse divertor plasma

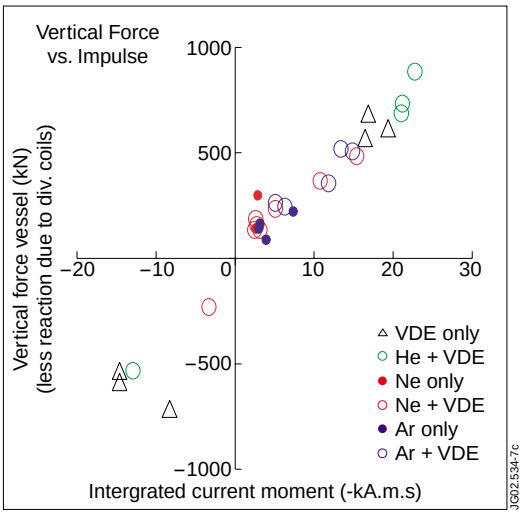
The **Quartz Microbalance (QMB)** diagnostic mounted at the entrance to the inner divertor pump duct in front of the louvres delivered pulse by pulse resolved deposition rates of hydro-carbon molecules for various plasma and divertor configurations. The deposition rate in-creases strongly with decreasing distance of the inner vertical strike point position to the louvre entrance and is greatest under conditions with large low frequency ELMs.

Ion Cyclotron Resonance Frequency (ICRF) mode conversion heating has been further developed and used as a localized on-axis and off-axis source of electron heating. Electron heat modulation experiments in L-mode discharges indicate that the electron temperature pro-file is relatively stiff, in agreement with theoretical predictions. With ICRF, work has continued to investigate the origin of plasma rotation in the presence of minimum toroidal momentum in-put, as would be the case with alpha particle heating in ITER. A scheme for inducing local ExB sheared plasma flows to suppress turbulence has also been investigated.

Rapid **vertical displacements** of plasma can lead to significant forces on vessel components and have been studied experimentally. The modelling of such events in JET has improved through a better representation of eddy currents in the vacuum vessel: growth rates have been estimated within an accuracy of 5%. The characterisation of the halo currents that arise during these events has also been studied extensively for ITER-like configurations, validating the ITER design assumption.



Real Time current profile control



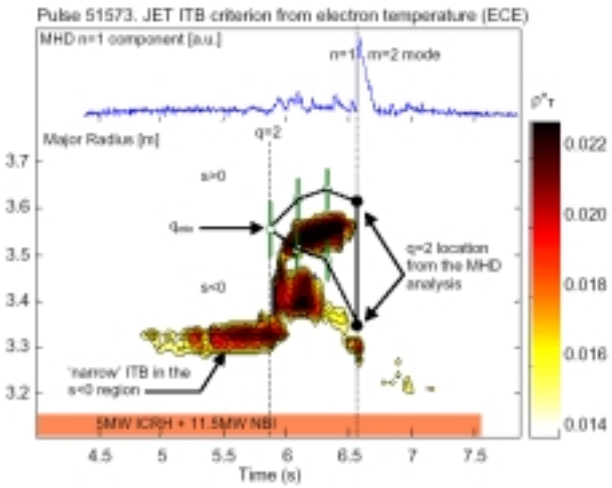
Disruption Mitigation

Recent **disruption mitigation** experiments using large puffs of helium, argon and neon have shown that the heavier gases, argon and neon, can considerably reduce the force experienced by the vessel due to the halo currents. These gases accelerate the current decay and so the plasma does not move as far (lower current moment) and the forces are reduced. Results are similar whether the disruption is due to a vertical displacement event or when the gas puff is used to terminate a normal plasma.

Active control of plasma pressure and current profiles is an important feature of Advanced Tokamak scenarios which has been demonstrated for the first time ion JET. In recent experiments **plasma current profile has been controlled in real time** during an extended (up to 10s) Lower Hybrid Current Drive (LHCD) prelude phase (see figure).

Highlights of 2002 Campaigns

Advanced Tokamak regimes have been further developed closer to ITER requirements. Pellets injected after the prelude phase lead to Internal Transport Barriers (ITBs) with Te~Ti at high density. The recent modification of the divertor geometry has allowed ITB operation with plasma shapes closer to ITER. A clear link between rational values of the tokamak safety factor q and the forma-tion of ITBs has been established. This is exemplified in the figure which shows the formation of a double transport barrier at the q=2 surfaces when q_{min} crosses q=2. The study of Alfvènic instabilities in non-monotonic q profile (Alfvèn cascades) are proving to be valuable for determining qmin in advanced plasma scenario.



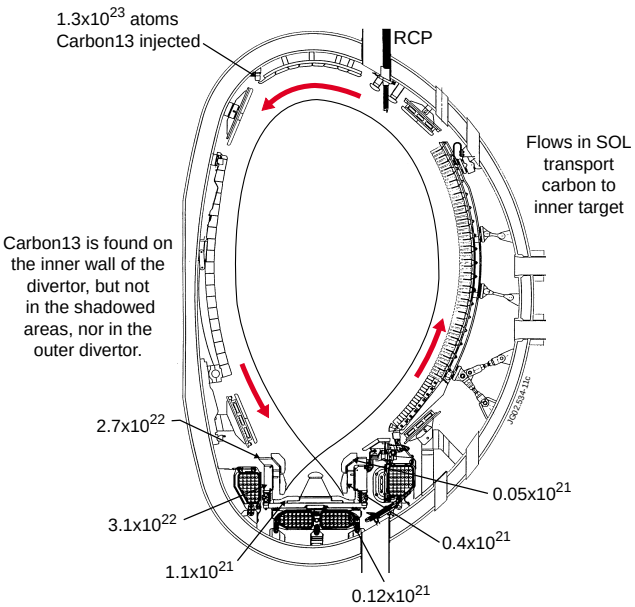
Transport barriers and q=2 surface

2002 JET Fusion Technology

The JET Fusion Technology (FT) programme covers R&D areas that can provide relevant contributions to the research programme of both JET and ITER in the following fields:

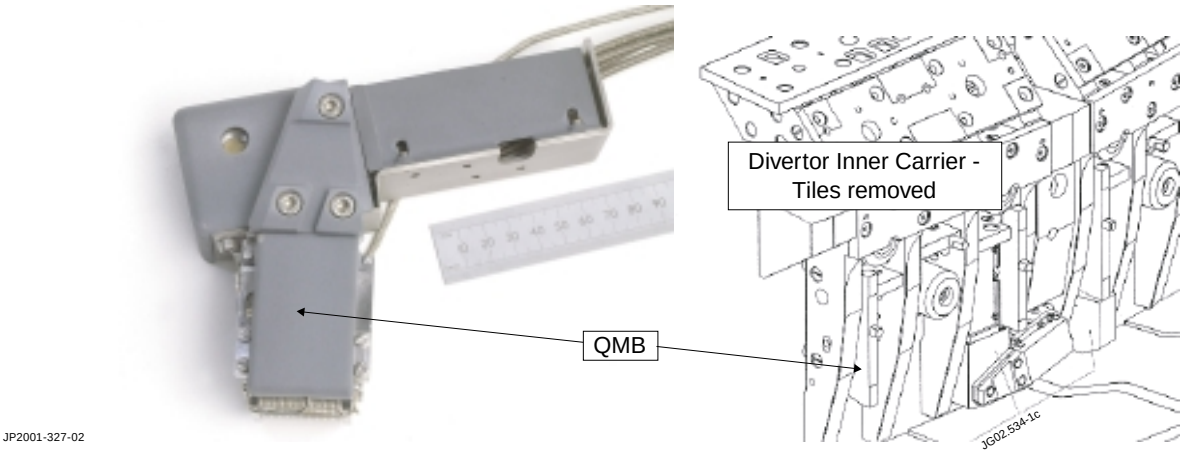
- **Tritium distribution** in the Tokamak: analysis of tiles and flakes
- Tritium processes and **waste management**: water detritiation R&D and system design, test of ITER prototype components in the JET Active Gas Handling System (AGHS), detritiation of components
- **Plasma facing components (PFC)**: characterisation of tiles, model validation of PFC behaviour un-der plasma loads, causes and mechanisms for erosion/re-deposition of CFC materials
- **Engineering**: qualification of components (optical fibres, ITER switches, …), Remote Handling operating experience at JET
- **Safety**: In-Vessel neutronics activation model validation, operating experience data collection and relevant component failure rate evaluation.

Carbon 13 was injected from the top of the Vessel. Carbon 13 deposition has been measured by secondary ion mass spectrometry on components removed during the 2001 shut-down. Deposition is found on the inner wall of the divertor, but not in the shadowed areas, nor in the outer divertor. This confirms the pattern of flows in the scrape-off layer as indicated by the red arrows (see figure).



Transport of Carbon13 in the SOL

Systems installed and brought to operation in 2002



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- **Quartz Micro-Balance** (see figure): measurements of carbon deposition in the shadowed region on a shot-to-shot basis. This is related to tritium retention, an important ITER issue.
- **Reciprocating Probe Head Upgrade** (see figure): measurements of plasma edge quantities like Ti, Te, impurities, mass transport
- **Reflectometer**: new emitters-receivers in the range 75-110 GHz to improve ECE reflectometry for understanding the role of turbulence in the appearance of transport barriers (Collaboration with US)
- **Pellet ablation spectrometer**: high time resolution measurement of Deuterium Balmer lines to study the properties of the ablation cloud which surrounds injected pellets (collaboration with US)
- **Motional Stark Effect Upgrade**: measurement of the q-profile has been improved by upgrading one Neutral Beam Source (PINI) at 130kV/60A on Octant 4 Neutral Beam Injector (NBI) and the optical system (collaboration with US)
- **ECE Radiometer**: upgrade of heterodyne receiver, full radius, high resolution: 20-40mm, 100 kHz.
- **Real Time Control**: a first stage was successfully used in ITB realtime control plasmas (see “Highlights“)

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Systems under commissioning for the next campaigns

- **ECE Michelson**: absolute measurement of Te, 5ms time resolution and repetition rate, 10 cm space resolution (supplied by ENEA, Frascati)
- **Error field correction Coils**: to substitute the saddle coils for MHD studies

Systems under development / tests to become operational in 2003

- **Octant 8 Neutral Beam Injection**: up to 7.5MW additional power by mid Summer
- **Pellet Upgrade/Extruder**: new extruder able to produce pellets in a range of size variability from 1/2 up to 2 times the size of the present full-sized pellet.
- **Edge LIDAR Thomson Scattering**: new detectors to measure temperature and density of edge plasma with improved sensitivity
- **Extreme Shape Controller**: software for extremely shaped plasmas and vertical stabilisation even in the presence of large disturbances, like ELMs, with the existing active circuits and control hardware.

People

New Task Force Leaders

During Campaigns C6 and C7 (2002 Workprogramme), Simon Pinches (IPP) replaced Sibylle Günter (IPP) as Deputy Task Force Leader in Task Force M and Xavier Litaudon (CEA) acted as Task Force Leader in Task Force S2 in the absence of Robert Wolf (IPP).

The EFDA Steering Committee approved the appoint ments of the Task Force Leaders and Deputies for the Campaigns related to the JET 2003 and 2004 Workprogrammes (C8-C14).

Task Force	Task Force Leaders and Deputies
S1	**Joerg Stober**, IPP-Garching **Geoff Maddison**, UKAEA-Culham **Pascale Monier-Garbet**, CEA-Cadarache
S2	**Angelo Tuccillo**, ENEA-Frascati **Xavier Litaudon**, CEA-Cadarache **Flavio Crisanti**, ENEA-Frascati
M	**Richard Buttery**, UKAEA-Culham **Simon Pinches**, IPP-Garching **Duarte Borba**, IST-Lisbon
E	**Guy Matthews**, UKAEA-Culham **Volker Philipps**, FZJ **Richard Pitts**, CRPP-Lausanne
H	**Jean-Marie Noterdaeme**, IPP-Garching **Mervi Mantsinen**-TEKES
T	**Xavier Garbet**, CEA-Cadarache **Paola Mantica**, CNR-Milano
FT	**Rainer Lässer**, FZKDeputy position open
DT	**Derek Stork**, UKAEA-Culham
D	**Andrea Murari**, RFX-Padova **Joaquin Sanchez**, CIEMAT-Madrid **Francesco Orsitto**, ENEA-Frascati

CSU Renewal

A major renewal of CSU staff was carried out in 2002. This meant the departure of P Bayetti, D Borba, J-P Caminade, P C Caminade, T Hellsten, F Orsitto, P Pale, F Scaffidi-Argentina, M Siegrist and E Solano whose significant contributions to the EFDA-JET Programme we wishto acknowledge.

On a positive note, we are pleased to welcome the following new members in the respective departments:

Programme Department

Shakeib Arshad	Responsible Officer for TF M
Didier Moreau	Responsible Officer for TF S2
Roberto Pasqualotto	Responsible Officer for TF D

Operational Department

Jürgen Rapp	Head of Operations
Martin Dentan	Responsible Officer

Enhancement Department

Carlo Antonucci	Responsible Officer

Administration Department

Catherine Soltane	Head of Administration
Christopher Gibbons	Database and Contracts
Armin Scherber	Contracts

Office of the EFDA Associate Leader for JET

Giuliano Buceti	Senior Officer/Publication RO

VIPs at JET

March:	Den Dover, Member of the European Parliament (MEP)
April:	Robert Key, MP and Roger Helmer, MEP
May:	François-Xavier De Donnea, Belgian Minister for Research
June:	UK Parliamentary Science and Technology Committee
September:	Luigi Amaduzzi, Italian Ambassador
	Groupe Permanent DOS ITER, Cadarache
	French licensing Authorities, Cadarache
November:	Lord Sainsbury, UK Parliamentary Under Secretary of state for Science
December:	Volker Klein, Counsellor at German Embassy
	Laser Mega Joule (LMJ) delegation, France

Media - Polish and Czech film crews both filmed in the summer and a UK film crew filmed in November for a very short commissioned video for Fusion Expo

European Science and Technology week - Couldn't Be Without It!

As part of a major initiative for **European Science and Technology week 4-10 November** a Europe-wide poll "Couldn't be without it!" was carried out on-line at www.cern.ch/sci-tech. This was initiated by EIROFORUM, a collaboration of seven European research organisations of which EFDA is a member. Europeans were asked to vote for their favourite technologies and given a chance to learn all about the basic science behind items such as CDs, PCs, antibiotics etc.

A **on-line poll** was also held in Oxfordshire throughout the summer and in November 10 local schools came to JET during the European Science and Technology Week to demonstrate their knowledge of the basic science be-hind Oxfordshire's favourite top technologies. The prize on offer - an expenses-paid trip to the European Space Agency in the Netherlands - was won by the team from the Faringdon Community College for their outstanding presentation on the refrigerator, which was No 4 in the "Top Ten" - the No 1 was the Car (see the photo).

Josh Silver of Oxford University and an authority on using sci-ence in developing countries as the inventor of novel, self adjustable spectacles was one of the judges. He told the teams that all the presentations had been excellent and that they had found it extremely difficult to come up with a winner.

The teams also took part in a live webcast with CERN in Switzerland and toured JET during a packed day at Culham. Their enthusiasm and that of their teachers for the whole event was such that similar competitions could become a regular event at Culham.

Framework Programme 6 Launch Conference in Brussels

The European Commission staged an impressive three-day conference in November in the Palais du Heysel in Brussels to launch the next Framework Programme 2002-2006. The conference was attended by over 8000 visitors and featured sessions on the main thematic areas of the Framework Programme and how to participate, plus a participants' forum to discuss the main topics and an exhibition showcasing EU-sponsored research projects.

EFDA-JET was involved in the exhibition as part of the EIROForum stand: EFDA is a member of this high-profile collaboration with CERN, ESA, ESO, EMBL, ESRF and ILL and shared a large stand in the main exhibition hall. The stand attracted a lot of interest and was visited among other VIPS by EU Com-missioner Busquin, who visited JET last year. The centre-piece poster of the stand was the photograph of the interior of the JET torus.

Jerome Pamela took part in a very successful round table discussion on "JET - a bridge to ITER", where he was joined by Paola Mantica and Tim Hender Task Force Leaders on JET, Carlos Varandas chairman of the EFDA Steering Committee and Hartmut Zohm from IPP Garching, and MEPS Gerard Caudron and Gordon Adam, both of whom have visited JET and are very supportive of the European fusion programme.

Dr Pamela also gave a talk on the European Fusion programme as a forerunner of the European Research Area, one of the main themes of the conference.

JET Operation

The JET operation in 2002 was far from being smooth but all the actors (Operator, Task Forces and Close Support Unit) reacted with great flexibility. This has allowed to go ahead with the experimental campaigns and obtain a number of important scientific results.

After the 2001 shutdown the Restart activity **campaign C5 started on 18th Marchand finished on 31st May** with a total of **101 experimental sessions** planned and the participation of 200 scientists from **15 Associations**. There was good progress with many aspects of the S/T programme even if various technical problems occurred during the campaign like the failure of the baking plant control system or of a fan on the PF flywheel generator; some time has been spent for investigation of a suspected air leak (which turned out not to be a new leak) or of a suspected in-vessel water leak arising from the connection of an unpumped volume to the Torus. Some constraints on the S/T programmes arose from the delayed availability and reduced power from the Octant 8 NBI system. This required significant reshuffling of the programme.

During the intervention period between the campaigns C5 and C6 a number of tasks were successfully carried out: window replacements; repair of the SF6 tower (NBI); preparation in view of the neutral beam upgrade; replacement of turbo pumps; installation of a new vertical track and new selector for the pellet injection system; final installation of the error field correction coils. However, during the restart of the campaign C6 problems with the commissioning of the complete pellet system occurred, as a result of a late delivery of a valve. This sub-sequentially disabled the operation with pellets in the campaign C6. Furthermore during the restart programme a fault in a toroidal field busbar prevented in time commissioning of the heating systems.

The **campaign C6 itself started on September 16th** with generally good performance until the rotary valve of neutral beam injector became stuck in a half open position. It was not possible to fully open the valve even by application of higher forces. As a result no neutral beam injection was possible in the remainder of campaign C6 and most of campaign C7 was postponed in order to replace the rotary valve of octant 4. It is planned to start the postponed experimental programme of campaign C7 (6 weeks) after the rotary valve replacement in January 15 th 2003.

User's Web site

The EFDA-JET Users website http://users.jet.efda.org allows scientific, technical, social and administrative in-formation to be readily shared amongst EFDA-JET staff, the fusion community and fusion associates. It isn't accessible to the general public but if you're at the JET Facilities, have a web password or a SecurID card then all the pages can be reached. If you don't already have access you can apply for a web password by following the instructions on http://www.jet.efda.org/pages/expert.html.

The Users' website is the result of collaborative effort between many user groups. For example, web space has been given to each Task Force and to various technical and scientific groups. If you have a JET-related project then we can give you space on the website! The content isn't all technical - there's a Message Board for placing adverts (such as rooms for rent) http://users.jet.efda.org/php/messageboard/pages/, and a Social Events page http://users.jet.efda.org/pages/social.html with details of the many clubs at the Culham site. However, the most dynamic part is the Pinboard area http://users.jet.efda.org/pages/pinboard.html where authors can post their conference papers or journal articles for peer review.

You are recommended to visit the Users' website regularly to read the frequent news of technical and general in-terest. Every effort is made to keep the page topical and newsworthy, and should you have any suggestions for contributions, improvements or comments, the webmaster wants to hear from you! webmaster@jet.efda.org

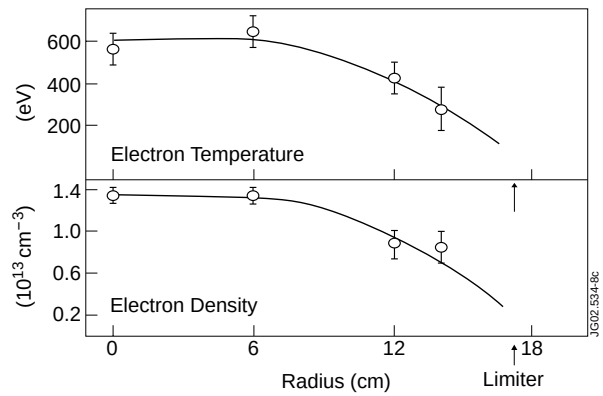
Derek Robinson

Dr. Derek Charles Robinson, Director of the EURATOM/UKAEA Fusion Association and Culham Science Centre died at the age of 61 on Monday 2 December 2002 in Oxford.

Derek Robinson's exceptional ability to work both as a theoretical and an experimental physicist was characteristic of his entire career. More recently Derek played a key role in building-up political support for fusion research. His career is too broad to be fully illustrated here. I have therefore chosen to focus on his direct and indirect contributions to JET.

Let's take as the starting point the well-known visit of a British team of fusion physicists in Cold War Russia. Russian scientists had claimed that they had made a breakthrough in achieving temperatures of 10 million degrees - 10 times higher than had been achieved before using a new magnetic confinement system, the tokamak. Culham was invited to send a team to confirm these results.

The team, led by Dr Nicol Peacock and including Derek Robinson, Mike Forrest and Peter Wilcock, took Thomson scattering apparatus to the Soviet Union. In 1968, Derek spent a year at the Kurchatov Institute in Moscow, using lasers and photomultipliers then not available in USSR. The Russian claims were confirmed, and the results published in Nature - Vol. 224 November 1 1969 (see figures).



Radial variation of electron temperature and density. The lines shown are drawn through the experimental points. (I_s = 60kA, H_s = 17kOe, t = 25ms)

This work altered the course of fusion research throughout the world. In particular it established the tokamak as the most promising line of development. Tokamaks rapidly blossomed all over in Europe at the beginning of the 1970's and this culminated with JET, whose construction started in 1978. A measure of the success of the tokamak is that JET's volume was three orders of magnitude larger than the T3 tokamak on which Derek worked only 10 years earlier in Russia!

Derek played a big part in pushing forward the new tokamak line. Not only was he the driving force behind the construction of several new tokamaks at Culham in the 1970s and 1980s, but he also made a big contribution to the design of JET. He was for many years a member of first the JET Scientific Council, and then the JET Council.

As Director of the Culham Science Centre since 1996, Derek supported strongly the continuation of JET under EFDA after the termination of the JET Joint Undertaking at the end of 1999. More generally Derek was as adept in fusion "politics" as in the actual science, working tirelessly to promote fusion as an energy source. He managed to develop an in-depth understanding of the potential of fusion among key decision makers all over Europe. This resulted in an unprecedented political support for fusion, in particular to ITER and JET.

Derek Robinson was fond of music. Therefore I would like to end this short homage with a musical reference. In French music there has been a tradition for composers to write a "Tombeau" to the name of their great predecessors, a piece of music in the style or spirit of those. This tradition was continued in the XXth Century with Ravel writing a magnificent "Tombeau de Couperin", which I guess Derek knew. The most beautiful "Tombeau" we can make for him is to succeed with our next tokamak, ITER, in preparation of which Derek achieved so much.

Jérôme Pamela