The main aim of fusion research is to confine fusion plasma at high temperatures and at a high enough density whilst still ensuring sufficient insulation. The quality of the confinement is directly connected to transport which describes the motion of particles, momentum, and heat in the plasma. Transport in a radial direction from the centre to the periphery of the plasma is particularly important as this causes an unwanted loss of energy and particles. The physical understanding and the quantitative prediction of these transport processes play a crucial role within fusion research and in the design and operation of present and future fusion devices. EFDA established the EFDA Transport Topical Group to coordinate research work in this very important field.

Continued on page 6.
Express to the future rolls through Germany

The Federal Republic of Germany is about to celebrate its 60 years and is marking the occasion with its role in research in particular. The extent to which science and research have contributed to the development of the country and what important courses they are setting for the future are to be conveyed to the visitor by the 330-metre-long “Expedition to the Future” exhibition train. When Federal Chancellor Angela Merkel waves the express to the future off on 29th April at Berlin Central Station on its journey through Germany, fusion research will also be on board. In the energy and environment theme carriage, a model of the ITER international experimental reactor supplied by IPP could provide an answer to the question, “What comes after coal and oil?”. More information: http://www.forschungs-expedition.de/

European Fusion Computer Comes to Jülich

At the beginning of January the signatory process of a new implementing agreement under EFDA was launched. Under this agreement, the EFDA member Forschungszentrum Jülich – one of the world’s leading supercomputing centres – shall construct and operate a new supercomputer for fusion research. The computer, known as HPC-FF, or “High Performance Computing for Fusion” – will provide computing power of approximately 100 terafl oops and is ideally suited for the simulation codes used by fusion scientists. FLOPS (Floating Point Operations Per Second) is a measure of the speed of a computer system. A Pentium-4 processor in a PC, for example, can reach around six gigaflops, which is roughly 20,000 times slower than HPC-FF.

Having a whale of a time learning about fusion at JET

Report of Polish Association’s Helena Howaniec

The Polish association IPPLM organised a visit for 45 science teachers to JET at Culham in the UK, which took place between 12th – 14th March 2009. IPPLM is running a teacher project called “Fusion at school and in society” which began in January 2008. Teachers are given materials about fusion and are able to use them in their classes and in local events. They are able to visit IPPLM with their students and can invite IPPLM into their schools for fusion sessions. IPPLM also organises teacher training courses. About one hundred people, from all over Poland, are involved in this project.

The trip to the biggest European tokamak was a reward given to the most enthusiastic people, who had worked very hard for the project over the last year.

At JET, we received a warm welcome and attended presentations given by Michael Watkins, Chris Warrick, Anna Czerwinska and Jef Ongena. Later on, we were given a tour around various JET facilities: The assembly hall, control room, remote handling, and the models.

In the evening, after completion of machine operations, we were very privileged to be allowed to enter the Torus Hall. We were all impressed by the immensity and splendour of the machine. Our guides showed a great deal of enthusiasm, fascination and pride in their work. This emotion was also shared by the visitors.

The teachers asked a lot of questions, they were all curious and eager to learn as much as possible. It was the first time any of them had had the opportunity to see a fusion laboratory and a tokamak. It just so happens that the very first tokamak they saw, also appears to be the biggest one in the world. Our next stops, the Department of Physics at the University of Oxford and the Rutherford Appleton Laboratory, completed our JET visit thematically.

During our stay in Oxford, we also found time to go sightseeing in the beautiful old town. We had the great pleasure of attending a concert in the Sheldonian Theatre on Saturday, 14th of March. Our lovely friend and great fusion enthusiast Jef Ongena, a researcher at JET choir singer, invited us to attend their concert in this old and well-known theatre.

All teachers felt themselves fortunate to have been able to participate in the training course in Oxford and the IPPLM association hopes that the visit is only the start of a series of teachers’ visits to JET. There are a great number of very active science teachers in Poland who would very much like to see this great, world famous device.

EFDA Fusion News

The supercomputer will help us to understand the complex physical effects taking place inside JET, ITER, and future fusion power plants. HPC-FF will be closely linked to the Jülich 200-terafl oop system, JuRoPA, so that, if required, fusion researchers are able to access a total of 300 terafl oops computing power. Scientists will soon have a much better opportunity to develop computer simulations capable of reproducing the important physical effects more realistically than is possible as yet. Supercomputing is indispensable, for instance, when it comes to understanding the turbulent processes which determine the extraction of energy from the plasma at the material surfaces of the first wall of the vacuum chamber.

HPC-FF is being funded by the European Commission (EURATOM), the member institutes of EFDA and Forschungszentrum Jülich. The installation will be inaugurated in early summer this year. The use of the computer is coordinated under EFDA. All EFDA member institutes will have access to the machine. An HPC-FF Board supervises the operation and selects the best proposals for using the computer. A high-level support team will be formed to support code development in the European Fusion Community.

Ralf Schorn
Fusion has recently become a popular topic on the streets of Ljubljana. One of the radio stations carried out an interview with the head of the Slovenian Fusion Association and, for the purposes of demonstration, they asked people walking alongside the Ljubljanica, the city’s river, what fusion is. As well as the “don’t knows” and the various suggestions mentioning “diffusion”, “illusion” and the CERN accelerator, surprisingly, some people referred to atoms and energy very suddenly. In high-energy machines, like ITER, they will limit the wall and divertor lifetime and may cause the degradation of the plasma performance by increased impurity release. Hence, ELMs and the ways to mitigate them by generating a stochastic magnetic field layer in the plasma edge have been of utmost interest at the workshop this year. Complete suppression of ELMs with this method was demonstrated at DIII-D tokamak in San Diego – and ELM mitigation at JET. The Dynamic Ergodic Divertor (DED) is a supporting experiment in this context which elucidates the basic physics aspects of stochastic magnetic edge layers. It is a subsystem of Jülich’s TEXTOR tokamak, comprising special coils, the magnetic field of which perturbs the tokamak field at the plasma edge. In 2007, the ITER Design Review added ELM control coils to the ITER Design.

For more detailed version of this article please follow the link: http://www.efda.org/news_and_events/FN_supplements/SFP_2009.pdf

Ralph P. Schorn and Bernhard Unterberg Forschungszentrum Jülich
The European Test Blanket Module Consortium of Associates starts working for F4E

On February 10th and 11th, the kick-off meeting for the “F4E-2008-GRT-09 (PNS-TBM)” grant was held at the F4E premises at Barcelona. Six EURATOM associates and affiliated organisations will cooperate on this grant and they submitted a joint proposal in September 2008. They formed the “European Test Blanket Module Consortium of Associates” (TBM-CA) in November 2008 and agreed to continue their cooperation throughout the entire TBM development phase. This is the first multi-beneficiary grant awarded by F4E in 2008.

While ITER will receive its required tritium fuel from external sources, DEMO and future fusion power plants will need to produce their own tritium themselves. Tritium is bred in special blankets at the vessel walls, utilising the neutrons produced during fusion reaction. Therefore, one of the objectives of ITER and thus the Test Blanket Module Consortium is to test suitable tritium-breeding processes. At the moment, there are two basic approaches studied in Europe: On the one hand, a liquid-metal concept based on Helium-Cooled Lithium-Lead (HCLL) with lithium as the tritium breeder and lead as the neutron multiplier. On the other hand, a solid material concept based on Helium-Cooled Pebble-Bed (HCPB), which features lithium ceramic pebbles as the breeder and beryllium pebbles as the neutron multiplier. The task of TBM-CA is to complete the TBM design in 2009. Once this is done it will be followed by a qualification phase to verify and finalise the design which will last until 2015, then the first TBM systems will be commissioned in ITER. From its start, ITER will be equipped with an ancillary equipment unit (AEU), which allows the TBM-CA to test the various TBMs inside the vessel. TBMs for each of the two concepts will undergo a series of experiments to test electromagnetic effects on the TBMs, their behaviour under high neutron flux, their characteristics and thermal and mechanical stresses. Finally, all these conditions will be combined in one last test.

The start of the TBM grant project constitutes a remarkable step forwards from the earlier collaborative, programmatic work under the EFDA framework and brings us closer to a project approach that will, of course, be the basis for all ITER-related work under F4E. The partners in the TBM-CA are: CEA, France, CIEMAT, Spain, ENEA, Italy, the Nuclear Research Institute, Husinec-Rez, Czech Republic, the KFKI Research Institute for Particle Nuclear Physics, in Budapest, Hungary, and Forschungszentrum Karlsruhe, Germany, which coordinates the TBM Consortium.

Contributed by the European Test Blanket Module Consortium of Associates and Fusion for Energy.

For more detailed version of this article please follow the link: http://www.efda.org/news_and_events/FN_supplements/Test_Blanket_Module_Grant.pdf
Advances in modelling the performance of fusion steels

The Tritium Breeding Blankets (TBB) are major in-vessel components of the future fusion demonstration reactor DEMO. They have three main functions: breeding tritium, a necessary fuel for the fusion reaction, extracting the energy deposited by neutrons produced in the fusion process and contributing to the shielding of the superconducting magnets. As the blankets will be exposed to high temperatures and high neutron irradiation, it is essential to investigate their performance under these extreme conditions. Prof. S.L. Dudarev of UKAEA, a co-chairman of Fusion Materials Development Topical Group, and his colleagues Prof. R. Bullough (UKAEA), Dr. P.M. Derlet (PSI, Switzerland), Dr. S.P. Fitzgerald (UKAEA), Dr. M.Y. Lavrentiev (UKAEA), and Dr. D. Nguyen-Manh (UKAEA), have made a significance advance in modelling the behaviour of steel, one of the main components of the blankets, at high temperatures.

EUROFER, a material based on an alloy of iron (Fe) containing chromium (Cr) as a major alloying element, is a potential material for the TBB. It will be tested in the ITER Test Blanket Modules. EUROFER is a low-activation ferritic-martensitic steel. Martensite is a very hard form of steel microstructure which can be described as having “needle-shaped” crystal grains. The behaviour of any material is controlled by its chemical composition and microstructure. Under DEMO operating conditions, the martensitic microstructure of EUROFER will be affected by defects generated by high energy neutrons. Furthermore, the microstructure will be affected by high operating temperatures. The Radiation Effects Modelling & Experimental Validation (MAT-REMEV) project pursued by the fusion materials topical group has the task of understanding these crucial phenomena. In order to ensure good and safe functioning of TBB during the operation of a fusion device, the project also aims at developing modelling tools and means for their validation to predict the behaviour of EUROFER steel at high temperatures and high neutron irradiation.

Most materials exist in various stable forms (liquid, solid, gaseous), depending on temperature and pressure conditions. These stable forms are called phases and are described by the phase diagram. The stability of EUROFER is closely related to the phase diagram of the Fe-Cr alloy. Iron is a transition metal, the atoms of which are arranged in body-centred cubic (bcc) crystal lattice. It is known that pure iron undergoes three phase transitions at high temperatures. At 1185 K and at 1667 K it changes its crystal structure from α to γ, and back, whereas beyond 1811 K it melts and becomes liquid. The terms α and γ refer to body centred (bcc) and face centred (fcc) cubic crystal structures, respectively. Ferritic-martensitic steels also exhibit those transitions at similar temperatures. It is also known that on approaching the α–γ transition temperature, bcc iron, or ferritic-martensitic steels, soften. Mankind used this effect for thousands of years since it makes iron and steels forgeable. It is also what may be responsible for causing the collapse of tall buildings during fires, such as the World Trade Center fire on 11th September 2001. In the case of fusion, this effect limits the upper operating temperature of TBB in fusion reactors like DEMO to ~ 550°C. In order to develop steels that can withstand high temperatures, one needs to understand the microscopic cause of this softening effect. The new development in the modelling methodology is a step towards this goal.

So far, the phase transition points could be observed experimentally and could be predicted using thermodynamic methods. Thermodynamics alone, however, cannot identify the various effects, which drive the phase transitions. Hence it does not suffice to explain the connection between the phase transitions and various related phenomena, like softening. In the case of iron, it was already known that magnetic excitations and lattice vibrations are responsible for the phase transitions. At the same time, it was not clear how magnetic excitations and lattice vibrations affect the strength of steels. How magnetism influences the structure of defects generated by the fusion neutrons, was also a still open question. The work performed in 2008 by the above mentioned scientists provides a way of understanding and quantifying these effects. A unified model has been developed, linking the notions of phase transitions, mechanical properties of steels, and radiation damage effects.

The UKAEA group is now working on modelling the phase transitions in Fe-Cr alloys (not just pure iron), which also fully includes the effects of high temperature magnetism. They call this new method the “Magnetic Cluster Expansion” (MCE). It employs quantum mechanics to parameterize a model Hamiltonian describing magnetism of specific configurations of atoms in alloys. Using Monte-Carlo methods, it proves possible to model the statistical properties of distributions of iron and chromium atoms in an alloy. Also the random changes of direction of the magnetic moments of atoms at high temperatures can be calculated by this means. The first applications of the MCE method are promising – the group has managed to predict rather accurately the magnetic properties of iron and Fe-Cr alloys. This is especially the case for the Curie point where the macroscopic ferromagnetism vanishes.

Initially the observed α–γ phase transitions of iron could not be reproduced by the model. It was assumed one has to include the second effect, which contributes to the phase transitions of iron: lattice vibrations, or phonons. To test this assumption, the contributions of lattice vibrations were introduced, using experimental neutron diffraction data. The improved model indeed predicts that phase transitions do take place at temperatures very close to the experimentally observed ones.

It is the first time that the various contributions to the phase transformation of iron at high temperature have been identified and assessed starting from ab-initio quantum mechanical calculations. This pioneering work proves that magnetism is not the only factor responsible for the α–γ phase transitions of iron: the lattice vibrations are also essential contributors. Magnetism is responsible for the stability of the α-phase, and softening of iron at high temperatures, still below the melting point. But only the combined effect of magnetic fluctuations and lattice vibrations explains the stability of the γ-phase. The next step will involve including lattice vibrations into the magnetic cluster expansion analysis. It will enable this model to describe all the aspects of phase stability of Fe-Cr alloys and EUROFER ferritic-martensitic steel.

Contribution of Sergei Dudarev from UKAEA and Jean-Louis Boutard from EFDA.
Focus on

EFDA during FP7 –
Reinforced coordination of physics and technology in EU laboratories Part 3

Transport Topical Group (TTG) under EFDA
Continued from front page

Transport mechanisms
A good method that can be used to explain transport phenomena is to look at particle transport. Heat or energy transport can be described in a similar way. Magnetic fusion devices create magnetic fields to confine plasma particles thus preventing them from touching the wall of the machine. Inside the plasma, the particles follow the magnetic field lines spiralling or gyrating around them (Larmor movement).

In the interior region of the plasma, these field lines are “closed”, they run around the doughnut shaped device in never ending loops. Near to the plasma edge, the field lines are “open”, meaning that they eventually intersect with the vessel walls. Particles on these field lines are lost to the plasma and will hit the wall. Rather than following magnetic field lines, which is called parallel transport, the particles can also start out in the “safe” and confined plasma core, and move out to the edge. This movement is called perpendicular transport since it is perpendicular to the magnetic field lines. To ensure confinement those plasma particles, which have not yet been involved in fusion reactions, must be prevented from exiting the inner plasma region.

There are several mechanisms by which these particles can move across the field lines. Firstly, collisions can cause transport. Plasma particles which gyrate around the field lines, collide with other particles, deviate from their original trajectory and start gyrating around other field lines.

The structure of the magnetic field is another possible cause of transport. For example, the strength of the magnetic field in the fusion devices decreases from the inner to the outer region and the field lines are bent as a result of the shape of the machines. This results in transport effects which can nevertheless be balanced by the helical magnetic structure of the devices. While the classical model describes transport based on the Larmor movement of the plasma particles and collisions between them, the so-called neoclassical theory also considers the geometrical considerations mentioned above.

The neoclassical model is an effective tool that can be used to explain many of the phenomena taking place in fusion plasmas. Transport processes, for instance, which take place in the direction parallel to the magnetic field lines, are well described. However, in magnetic fusion devices, the observed perpendicular transport is significantly higher than estimations based on neoclassical transport theory. In particular, electron heat transport is measured at two orders of magnitude larger than the neoclassical predictions while ion heat transport is up to one order of magnitude larger. For many decades, this difference has been referred to as “anomalous” transport.

In the last two decades, increasing scientific research has been devoted to understand the main sources of this anomalous transport, both experimentally and theoretically. Attention has turned to the instabilities which create turbulence and thus contribute to transport. Temperature, density, and other plasma parameters are not uniform in the direction perpendicular to the magnetic field lines, but instead they have radial gradients. It has been found that, as a consequence of these gradients, instabilities can occur in the plasma, at both the ion Larmor radius as well as the electron Larmor radius scales. The scales are caused by the considerable difference in mass between deuterium, tritium nuclei and electrons.

Carlos Hidalgo received his PhD degree from the Madrid Complutense University in 1984 with his PhD work on structural defects in solids and positron annihilation spectroscopy.

His next area of research was related to plasma turbulence, transport and diagnostics in CIEMAT, where he is currently leading the Experimental Plasma Physics Division. He has worked in different international laboratories, initially as a PhD student (Technical University of Denmark, Nuclear Research Centre of Grenoble, Technical University of Helsinki) and later as a visiting scientist (Fusion Centre at Austin, Oak Ridge National Laboratory, JET, Max Planck Institute). Teaching experience, including his present involvement at the Plasma Physics and Nuclear Fusion EM Master, complements his research activity.

He was head of the European Transport Task Force on Turbulence between 1994 and 2000. And he has been head of the EPS Plasma Physics Division since 2008.
The main issue open today is writing a code which calculates the entire plasma from the centre to the edge. The question of how turbulent transport can be reduced and controlled during the plasma operation by reliable external means remains one of the most challenging open problems. The production of regimes of improved confinement is of extreme importance in present research on magnetic fusion, particularly in view of optimising the efficiency of a fusion reactor.

A practical example

One of the many practical aims of transport research is the determination of the power threshold of H-mode. Today, scientists assume that fusion devices will be operated in the so-called H-mode, at which the confinement time of the plasma is 100% longer than in normal L-mode. H-mode is characterised by a sharp temperature gradient near the plasma edge (the temperature pedestal) and an associated pressure gradient called the transport barrier. The transition from L-Mode into H-Mode is spontaneous and occurs when the heat flux exceeds a certain threshold. This power threshold rises with the plasma density or the magnetic field, or with the size of the machine. Both the heating power above which the transition from L- to H- mode occurs as well as the pressure produced at the top of the edge barrier, can thus far only be predicted by means of empirical scaling based on present experience.
The role of the EFDA Transport Topical Group (TTG)

The investigators of transport phenomena in a plasma work with many unknown quantities. There are indeed too many variables to be calculated, unknown parameters to be defined, or effects of known parameters to be understood. Because of the openness of the task, the different scientific groups use a variety of approaches. The TTG addresses these open scientific questions with the practical challenge of developing the knowledge to design and optimise a fusion reactor. The TTG provides an overview over the different approaches, results, models and experiments. It provides a common framework, monitors the scientific activities in the area of transport, encourages cooperation between the individual groups whenever it looks promising and provides a platform for all transport investigators to discuss their ideas. The creation of specific task oriented research projects will be a key element in the TTG activities when there is a need to focus efforts on a specific question. The group will also provide an interface, at the European level, to other connected fields by means of the existing European collaborations under EFDA. On an international level, the TTG is an interface to work on transport worldwide, and in particular, to the existing and future ITPA groups and the US Transport Task Force. Carlos Hidalgo chairs the TTG with Clemente Angioni and Clarisse Bourdelle as vice-chairs.

Within the EFDA Transport Topical Group, both the requirements of the experimental observation and identification of basic plasma behaviours and the related understanding in terms of first principle theory are considered concurrently. The TTG takes into account long-term challenges as well as short-term answers to specific open questions relevant for ITER. The successful development of TTG Task oriented research projects will require an improvement in the diagnostics development and implementation on the EU devices, as well as strong links with modelling/theory activities.

The TTG research programme for 2008/09 has been organized on the basis of four research areas:

- Edge and scrape off layer (SO) transport physics
- Core heat and particle transport
- Core and edge momentum transport
- MHD and fast particles interactions with transport

A pilot TTG research project was started on April 2008 on “Long-range correlations and transport barrier physics”, which is coordinated by Carlos Hidalgo. It is intended to address the question of understanding and determining the H-Mode power threshold as discussed above. The project is evolving successfully and showing promising results. Another three projects were subsequently launched in 2008. The first TTG Meeting was held in Denmark in September 2008. The second meeting will be held at JET on 16–18 September 2009.

Clemente Angioni obtained his PhD degree at CRPP, EPFL Lausanne (CH) at the end of 2001, under the supervision of Olivier Sauter. During the PhD, his research was dedicated to neoclassical transport, electron heat transport modelling of TCV plasmas as well as the integrated modelling of sawtooth oscillation in both TCV and JET plasmas.

After his PhD, he did his Post Doc on experimental and theoretical aspects of particle and heat transport at IPP Garching with a Marie Curie Individual Fellowship supervised by A.G. Peeters.

Since 2004, he has been working as staff scientist in the theory division at IPP Garching.
JET prepares for final phase of “Enhancement Programme 2”

The forthcoming shutdown of the JET facility will see the implementation of a number of enhancements designed to improve its scientific and technical capabilities. These activities are cast within the “JET programme in support of ITER” aimed at providing ITER with answers needed to consolidate its design choices and to allow and plan its efficient exploitation. The installation of an ITER-like wall with beryllium and tungsten tiles in JET will be one of the central objectives of this shutdown. This will mean having to replace around 4,500 carbon tiles actually present in the machine. To perform the shutdown as efficient as possible, all the work will be done by Remote Handling. The final step in upgrading an articulated boom to further improve the efficiency was marked by an impressive presentation given by the Remote Handling Group.

On 23 February Bernhard Haist and colleagues from the JET Remote Handling Group proudly demonstrated picking up and moving of a component with the newly upgraded articulated boom. This proof of principle was the final step in the several year-long process of extending an already existing boom and bringing it to readiness for the challenging tasks ahead. The rationale for opting for the extension of this boom has been the dramatic time saving (up to 30 percent) resulting from using two booms with high equal space coverage capability. To gain access to the inside of the JET torus, two of the eight main horizontal ports are reserved for Remote Handling. Both booms are hyper-redundant multi-joint devices to allow them to “snake” their way through the narrow ports and around the torus. The upgraded boom will work in parallel with the other one to transfer components and tools between storage facilities outside the torus and the workplace within the torus.

Shutdown means a planned refurbishment or enhancement of the JET experimental reactor. In the recent years Remote Handling has come to play a central role in the planning and execution of the entire task. However, the work to prepare a Remote Handling shutdown starts several years before the actual shutdown. Already at the stage of conceptual design of the new components required to serve the purposes of the enhancement/refurbishment Remote Handling engineers are involved, to ensure that the design of all new components is compatible with Remote Handling tooling.

The JET Remote Handling system makes use of special manipulators to extend the operators own arms into the torus environment. These manipulators provide the operator with a sense of touch and feel and together with the associated Closed Circuit TV system create a sense of being inside the Torus. The net effect is to enable the human operator to do the task even though it is being done within a hostile environment.

One of the major activities during the coming shutdown will be the replacement of the entire first wall armour using Remote Handling. This project aims at installing an ITER-like wall and diverter in JET. ITER, the next generation fusion experiment, will use beryllium and tungsten as first wall materials within the torus. The combination of these materials has never been tested in a tokamak with a geometry and plasma parameters close to those of ITER. A key aim of the experiments with the ITER-like wall will be to develop regimes of operation for ITER compatible with beryllium and tungsten as first wall materials.

Final preparations are currently underway for the various tasks within the different projects to be completed during the shutdown. The projects also include, for instance, the upgrade of the neutral beam power and the installation of new diagnostics. With regard to Remote Handling, the preparations for the more challenging tasks have to be completed and verified in so-called mockup trials. The in-vessel tasks trials are performed using the real remote handling equipment commanded from the remote handling control room. The trials are conducted on a mock-up facility comprising three-quarters of the Torus in-vessel environment with both dummy components and also spare and prototype real components.

With the start of the shutdown the Remote Handling group at JET will be giving a final demonstration of their wide range of expertise which is unique within the fusion community and covers mechanical, electrical and electronic engineering, software, real time control, ergonomics, pneumatics, hydraulics, welding and cutting.

You will find more information, impressive pictures and stunning movies about Remote Handling on the EFDA-JET web page.


Richard Kamendje & Petra Nieckchen

The newly refurbished articulated boom of JET’s remote handling system will save considerable time for the installation of the ITER-like wall during this summers’ shut down.
Divertor Test Platform in Finland: Shifting heavy weights with the greatest of precision

Work on the divertor test platform (DTP2) in Tampere, Finland, is in full swing now, after it was inaugurated on January 29th. The divertor is the region in the plasma vessel, which is located nearest to the hot plasma and collects ash, such as helium, which is produced during the fusion process. Its centerpiece are the divertor cassettes, each 3.5 m long, 2.5 m high and weighing 9 tons. The only way to maintain these devices is to build a special machine which moves them remotely.

A prototype of this machine, called Cassette Multi-functional Mover (CMM), forms the heart of DTP2. DTP 2 also possesses a full size replica of a section of the ITER divertor region along which the CMM will eventually move. The entire set-up is 20 m long and weighs nearly 100 tons. The design and manufacture of these components has taken four years under the management of Euratom and the Fusion research centres via EFDA. Now it is the responsibility of the Euratom Association TEKES, comprising the Tampere University of Technology (TUT) and VTT, to test the prototypes and develop a fail-safe handling mode for the final ITER device.

Currently, VTT and TUT are very carefully operating each joint of the CMM’s end-effector (see picture), which will eventually move the divertor cassette into the plasma vessel. For each joint, the parameters, which will ultimately be used by the remote controls, are fine-tuned. This way VTT ensures that all joints work in absolute synchronisation and in exact positions when finally moving the heavy divertor cassette. In a few months time, VTT will install the manipulator arm, which sits on top of the CMM. It will operate the tools to lock and unlock the divertor cassette. When the parameters for each joint of arm and end-effector are fixed, VTT can start operating the CMM from the control room.

Setting up the control room is another VTT task. The control room screens display all of the necessary information, for example, speed and distances of the components and provide an insight into otherwise invisible spots. Invisible spots are a challenge at ITER: Space is tight and only very few cameras can be fitted to monitor the cassette movement. Whenever no camera information is available, pictures created using virtual models must assist the operator placing the device. These models have been developed by TUT.

At DTP2, the CMM is operated using cameras as well as virtual models. The pictures created by the models are compared with the “real” camera picture. Any dimensions that the models display incorrectly, are corrected to ensure that the virtual models are ultimately accurate enough to safely move the divertor cassette. Furthermore, the virtual models are used to find the best operation procedures and to train operators. During the entire testing phase extreme care must be taken. Errors or mishaps would be fatal considering the weight and size of the components. Hence, while humans operate the controls, preset limits to trajectories, velocities and forces ensure safe movements at all times.

VTT is already planning the next steps for DTP2: The divertor region mock up (DRM) will be extended to a larger section of the torus, namely 63°. This is necessary to include an in-vessel mover, called cassette toroidal mover (CTM) in the test programme. The CTM will be designed and built in 2009 and 2010. The ultimate goal of VTT is to develop the entire maintenance sequence, identify potential risks, verify the operations,

COMPASS tokamak in Czech Republic now up and running

Since the official start of operations on 19th February, the COMPASS tokamak at the Institute of Plasma Physics Academy of Sciences of the Czech Republic (IPP Prague) has had its share of visitors. A group of Members of the European Parliament visited on 26th February. The event, linked to the current Czech Presidency of the EU, was initiated by Vladimir Remek, Member of the European Parliament and Member of the ITRE (Industry, Transport, Research and Energy) Committee of the European Parliament. Remek was the first non US/USSR astronaut and is a significant supporter of fusion. On 23rd March, the EFDA Steering Committee held its meeting in Prague. On 2nd and 3rd April, over 40 experts from Euratom Associations and Russia met for the COMPASS programmatic conference. This ad hoc conference was combined with the annual meeting of the International Board of Advisors of Association Euratom-IPP.CR. The next important group of foreign visitors is expected on 6th May in conjunction with the EC Research Connections conference.

COMPASS is a truly European device. It was previously operated by UKAEA, who, after starting its new tokamak MAST, decided to close it down. Since COMPASS still presented many scientific opportunities, UKAEA and Euratom started to look for a new operator. IPP Prague, with its long history in fusion research and its small tokamak CAS-TOR, managed to gain substantial support from the Czech Government and offered to host COMPASS. Overall, the pledge to operate the COMPASS tokamak led to a request for approximately 13 million euros investments. Most of the funds have come from national resources, with a significant contribution from Euratom. After COMPASS arrival in Prague in October 2007, new power supplies consisting of two flywheel generators with 35 MW each were installed.
On 9th December 2008, the COMPASS team successfully achieved the first plasma discharge. During the official start of operation on 19th February 2009, they were able to demonstrate the generation of a plasma current of 100 thousand amperes.

COMPASS has a divertor and a D-shaped vacuum chamber. It is linearly ten times smaller than ITER and has the same geometry. Hence it is useful when conducting similarity studies related to the ITER tokamak and compared to larger European devices such as ASDEX-Upgrade and JET. COMPASS is the only tokamak located in the new EU countries and will eventually become a regional centre for top level research, education and training of new experts.

At some time in the future, IPP Prague will install a neutral beam heating system which will enable ion temperatures of up to 3 keV. A state-of-the-art fully digital control and data acquisition system is being introduced. The young team also makes all key diagnostic systems. IPP Prague has a long-standing tradition of experimental studies on plasma edge, including edge turbulences (see our article on EFDA Transport Topical Group in this issue). The scientific programme of the COMPASS tokamak will extend this expertise to ELMy H-mode plasmas which is the standard operation scenario planned for ITER. Therefore, most of the diagnostic systems are designed to achieve high spatial and temporal resolution in the pedestal and scrape-off layer (SOL) regions of the plasma. The intention is also to study suppression of the Edge Localised Modes (ELMs) by resonant magnetic perturbation (RMP) as discovered on the US DIII-D tokamak. The COMPASS tokamak is already equipped with a suitable system of saddle coils for RMP experiments. These topics are very important for the future operation of ITER. IPP Prague researchers expect their scientific programme to enhance the scientific cooperation between the Czech Republic and Europe and to attract a young generation of Czech scientists to fusion research.

Contribution of Jan Mlynar from IPP Prague

Magnum PSI reached first milestone

Researchers and engineers at the Dutch FOM-Institute for Plasma Physics Rijnhuizen have recently reached an important milestone: They completed the vacuum system of the new experiment on Plasma Surface Interaction, Magnum-PSI, and found that it behaves exactly as it was designed. Scientists want to use Magnum-PSI to investigate the interaction between the reactor wall and hot plasma in future fusion reactors, such as ITER.

In designing a fusion reactor, it is essential to understand the effects that the hot, magnetised plasma has on the structure of the wall material. Furthermore, the wall surface will erode under these stressful conditions and possibly release material into the plasma. This will affect the plasma conditions and behaviour. The Magnum-PSI experiment is unique because it is specifically designed to study plasma-wall interactions in the ITER-relevant regime. It allows scientists to create specific plasma conditions and to use diverse wall materials. The experiment will allow studies of dust formation, re-deposition, migration, and the possible absorption of hydrogen into the wall material (retention).

In the linear steady state experiment, the plasma is also heated by microwaves and focused by a superconducting magnet into a 10 cm wide beam. This beam size is necessary to ensure that the experiment captures the various effects, which may occur near the wall in a fusion reactor – for instance, ensuring that the eroded wall-material has sufficient time to interact with the plasma before leaving the beam. A manipulator arm brings the wall material into the plasma beam. An analysis chamber is connected to the target chamber and is equipped with various tools used to investigate the structure and condition of the wall material without releasing the vacuum. The plasma itself is analysed through viewing ports just in front of the target area. The following factors are of interest: Its general condition, density and temperature as well as, for example, potential areas with different concentrations of ions and electrons. The aim is both to investigate the proposed wall materials for ITER, and to experiment with more advanced materials that could be used in DEMO, ITER’s planned successor. Furthermore, in the Magnum-PSI facility, numerical models will be validated against controlled and well-diagnosed experiments.

The research is intended to contribute to the design of the divertor, the part of the reactor in which plasma comes into direct contact with the wall material and where the fusion product helium leaves the vacuum vessel. Construction of Magnum-PSI will be completed at the end of 2009, and the first experiments are expected to start early 2010.

Contribution of Gieljan de Vries, FOM-Institute for Plasma Physics Rijnhuizen
Research Connections Conference in Prague

The European Commission Directorate General Research is organising the high level conference “Research Connection 2009” in Prague on 7th – 8th May.

The event gathers 2500 leading scientists, policy makers, science communicators, and representatives of the industry and of European research organisations. Focusing specifically on the challenges and opportunities afforded by the European Research Area for new EU Member States, Research Connection 2009 aims at taking stock of the progress achieved, introduce EU research success stories, encourage networking, and foster innovative new partnerships. The Euratom plenary session takes place on 7th May at 11 am and tackles “Industrial opportunities in the new era of the nuclear research”. The Association Euratom-IPP.CR is coordinating the presentation of the Fusion Mini Expo in the exhibition area. Fusion for Energy is also represented on the stand. The Association Euratom-IPP.CR and Fusion for Energy are also proposing a 1 hour forum on the topic “ITER: opportunities for industries in new Member States”.


RFX-Mod Programme Workshop 2009

After a successful 2008 experimental campaign, the European Reversed Field Pinch RFX-mod held its 2009 Programme Seminar on January 20-22, 2009 in Padova. The seminar followed an open call for experimental proposals, which resulted in more than 130 proposals submitted to 4 task forces by various European Associations and international collaborators. Proposals came also from tokamak laboratories in the EU, Japan and USA, interested in MHD active control experiments. RFX is equipped with a state of the art system for feedback control of MHD stability and is collaborating with several laboratories. A lively debate allowed to build an exciting programme for 2009.

This effort is part of the RFX’s goal to provide a facility open to the needs of the international community, and to realize an experimental programme, which is fully integrated in the European effort. This is realized in a research environment strongly committed to training and education, and tightly connected to universities.

More information: http://www.igi.cnr.it/rfxmod2009/

Piero Martin

The 3rd Karlsruhe International School on Fusion Technologies

The 3rd Karlsruhe International School on Fusion Technologies will be held at Forschungszentrum Karlsruhe, Germany, from 31st August to 11th September, 2009.

The international course will give an overview on the key fusion technologies, their current status and on long term R&D, particularly in view of the next step beyond ITER, the demonstration power station DEMO. It is intended for students of engineering and physics currently in technical colleges and universities, particularly those who have successfully completed an intermediate diploma, as well as PhD students and post-docs in relevant subjects.

More information: http://www.kit.edu/summerschool-fusion/

Associations

EFDA Close Support Unit – Garching
Boltzmannstr. 2
D-85748 Garching / Munich – Germany

phone: +49-89-3299-4263
fax: +49-89-3299-4197

http://www.efda.org
http://www.jet.efda.org
http://www.iter.org

ISSN 1818-5355

For more information see the websites:

Örs Benedekfi
layout: Stefan Kolmsperger

© Jérôme Pamela (EFDA Leader) 2009

This internal newsletter or parts of it may not be reproduced without permission.

Text, pictures and layout, except where noted, courtesy of the EFDA Parties.

The EFDA Parties are the European Commission and the Associates of the European Fusion Programme which is co-ordinated and managed by the Commission.

Neither the Commission, the Associates nor anyone acting on their behalf is responsible for any damage resulting from the use of information contained in this publication.

European Reversed Field Pinch RFX-mod held its 2009 Programme Seminar in Padova. The seminar followed an open call for experimental proposals, which resulted in more than 130 proposals submitted to 4 task forces by various European Associations and international collaborators. Proposals came also from tokamak laboratories in the EU, Japan and USA, interested in MHD active control experiments. RFX is equipped with a state of the art system for feedback control of MHD stability and is collaborating with several laboratories. A lively debate allowed to build an exciting programme for 2009.

This effort is part of the RFX’s goal to provide a facility open to the needs of the international community, and to realize an experimental programme, which is fully integrated in the European effort. This is realized in a research environment strongly committed to training and education, and tightly connected to universities.

More information: http://www.igi.cnr.it/rfxmod2009/