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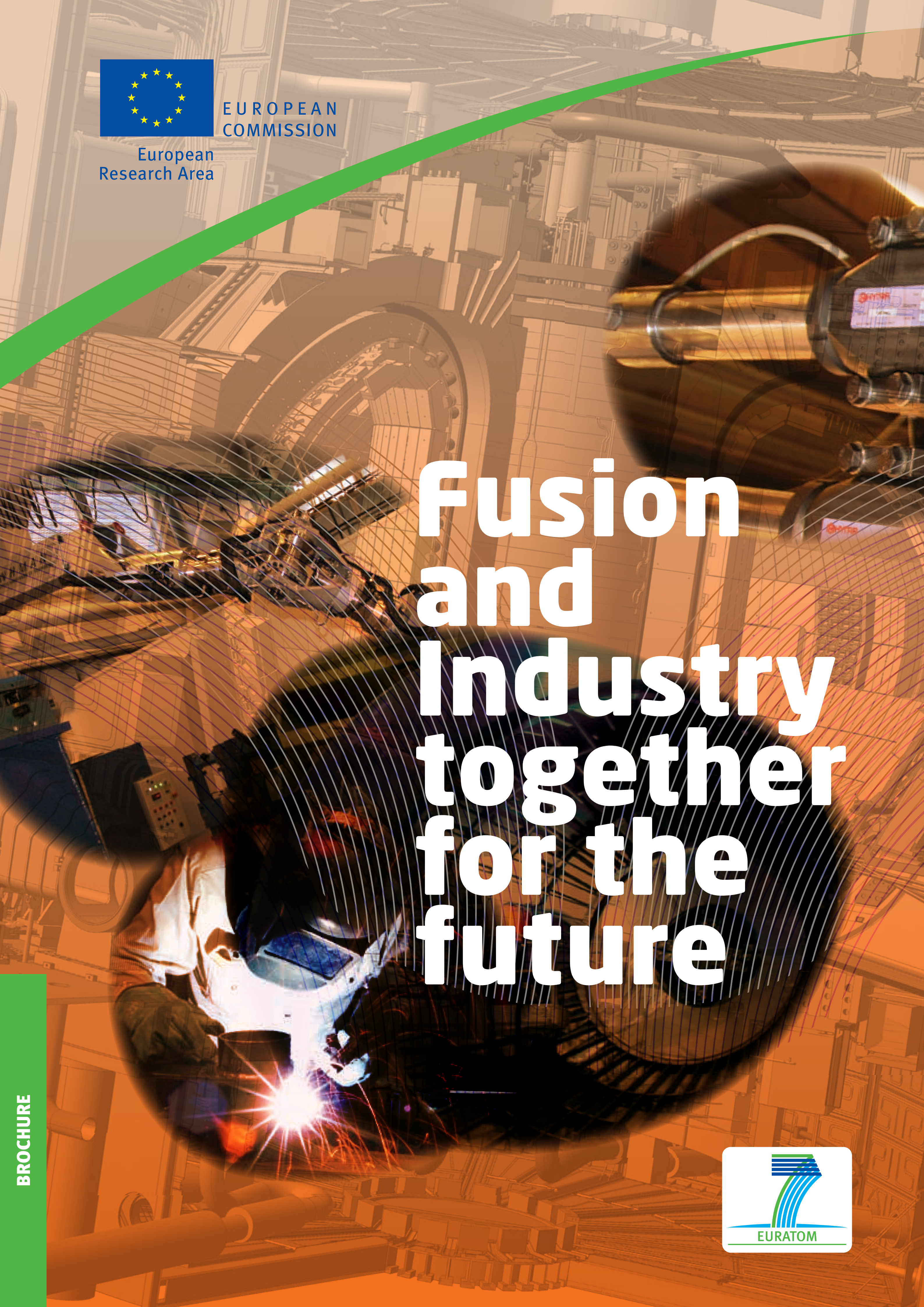

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EUROPEAN COMMISSION

Fusion and Industry together for the future

2009

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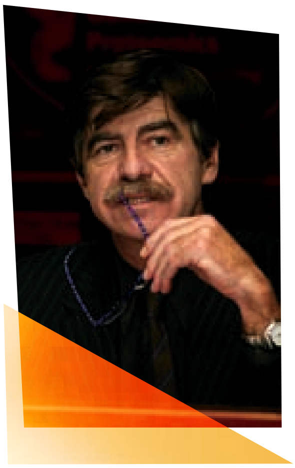


FOREWORD

The ITER project currently being built in the south of France is the vital link between research and the commercial power plants that can offer the World a potentially limitless, sustainable, safe and secure source of energy: fusion.

European research on fusion science and technology and our significant contribution to the exciting scientific adventure, ITER, will bring Europe many benefits in the future.

The project builds on the large body of experience and knowledge already gained in the European fusion programme. Europe has been a leader in fusion research globally in a wide variety of fusion technologies.

Europe, through Euratom, is hosting ITER and is the largest investor. The existence of this high technology, cutting edge research facility in the EU is already having considerable benefits for European industry. Industry is vital to the fusion programme and it is industry that will ultimately deliver ITER and the commercial power plants that will follow. ITER is a high profile joint project between the European Union, China, India, Japan, South Korea, the Russian Federation and the USA. Firms supplying components and equipment to the project will thus be able to showcase their products on a worldwide stage.

The ITER project is clearly aligned to the European "Lisbon Strategy" to make the EU the most dynamic and competitive knowledge-based economy in the world with sustainable economic growth and greater social cohesion combined with respect for the environment. ITER is also a key component of the EU's long-term Strategic Energy Technology Plan.

Much of the know-how in fusion technology is currently embedded in fusion research centres across Europe and a robust programme is now being developed to transfer this know-how to industry. This will allow us to capitalise on the public investment that Europe has already made in fusion.

Traditionally, intellectual property developed in fusion research has not been widely exploited. Now we are encouraging industry to use and exploit the results of this publicly-funded research. There are successful precedents for this approach: for example 38% of the industrial technology contracts at CERN have also brought innovative new products to market. Fusion can expect the same or greater results.

We are currently assembling all the intellectual property associated with the fusion programme and this will be made available to interested parties. This brochure presents a small selection of the cutting-edge technology that is available for exploitation and gives a taste of some current industrial success stories. As you will see, fusion technologies can offer EU industry some exciting competitive advantages and we encourage enterprises small and large to seize these unique opportunities.

Octavi Quintana Trias
Director, Energy (Euratom), DG Research

INTRODUCTION

Industry and fusion research

European Laboratories and Associations have gained valuable scientific expertise and knowledge in fusion energy through more than 50 years of coordinated research in the field. This important know-how is currently held in the collective experience of research groups in the fusion laboratories. But to ensure the successful development of fusion as an energy source, in particular building ITER and at a later stage a demonstration electricity generating reactor (DEMO), this intellectual property must be unlocked and shared with European industry.

The development of fusion is a fantastic opportunity for the European high technology industry. The skills and knowledge acquired when building systems and components for ITER can help boost competitiveness. The involvement of industry now is essential for it to participate fully in the development of fusion power technologies for the first demonstration reactor and exploit the opportunities for future power plant construction.

To meet this challenge, European industry must have access through efficient knowledge transfer to existing know how and marketable innovations with the possibility to exploit fusion R&D results.

High technology areas in fusion include joining, coating, heating and materials technologies, magnetic and power systems, robotics, fabrication and inspection.

Technology transfer has already contributed to many spin-off enterprises in areas such as high-heat flux components, super conducting magnets for medical imaging systems (MRI), high power industrial microwaves, plasma physics software and diagnostics adaptations for semiconductor and thin-film fabrication, new high tech textile weaving equipment and carbon-composite materials.

Accessing competitive advantage

To boost this process the Euratom Fusion programme is establishing a policy on intellectual property rights (IPR) that has the clear aim of increasing collaboration between industry and the fusion programme.

This will be achieved by:

- defining the existing IPR that has been generated with a view to making it available to industry,
- supporting the use of this IPR in industry,
- strengthening the communication links between industry and the fusion programme.

Both industry and the fusion research programme will benefit from this stronger collaboration: besides the increased competitiveness and the industrial preparation for DEMO for industry, the opportunities for SME's have to be mentioned, as well as the possibility to develop spin offs and broaden the industry base for the future.

Industry and fusion laboratories have already worked together successfully on numerous projects. This brochure highlights only a few of the many success stories. These collaborations are paving the way for a successful future of strong collaboration between fusion research and industry for mutual benefit.

To find out more about opportunities with fusion technologies and how to access the programme see the contact information at the end of this brochure.

What is fusion?

Fusion is the process that powers the Sun and makes life on Earth possible. When the nuclei of two light atoms (like hydrogen) are fused together to form a single new atom a large amount of energy is released. In the Sun these fusion reactions happen at very high temperatures (15 million ˚C) and under enormous gravitational pressure. At these temperatures the atoms are fully ionised- effectively an electrically charged gas – a state of matter known as a plasma.

On Earth, to achieve fusion requires even higher temperatures – over 100 million ˚C - and the use of immensely strong magnets to contain and control the very hot plasma. This is a significant scientific and technical challenge. But, if successful, the energy available from fusion could provide a source of sustainable, secure and virtually unlimited power. The fuel consumption of a fusion power station will be extremely low. A 1 GW electric fusion plant will need about 100 kg deuterium and 3 tons of natural lithium to operate for a whole year, generating abour 7billion kWh. A coal fired power plant requires about 1.5 million tons fuel to generate the same energy!

What is ITER?

ITER is the world's biggest energy research project. It is a global scientific and technical collaboration to produce an experimental facility that will demonstrate the potential of fusion power and test many of the components needed for a practical fusion power station.

It is being built at Cadarache in the south of France and will be the world's largest tokamak – a toroidal (or doughnut-shaped) device that uses complex magnetic fields to confine and compress the extremely hot fusion plasma.

ITER is designed to study, for the first time, a 'burning' plasma. It will be the first man-made fusion device to produce more energy than it consumes to heat the plasma. Fusion reactions in ITER will generate around 500 MW of heat. ITER will integrate the technologies essential for a fusion reactor.

The EU Domestic Agency Fusion for Energy

Fusion for Energy (F4E) is the European Union's organisation responsible for providing Europe's in kind contribution to ITER.

F4E also supports fusion R&D initiatives through the Broader Approach Agreement with Japan, a partnership for the accelarated development of fusion energy involving about € 340 million of voluntary in kind contributions by EU Member States. Ultimately F4E will participate in the development of demonstration fusion reactors.

F4E was created in 2007 for a period of 35 years and will manage a budget of around € 4 billion over the first ten years.

Its headquarters are located in Barcelona, Spain.
http://www.fusionforenergy.europa.eu/

1 Design, Fabrication and Inspection

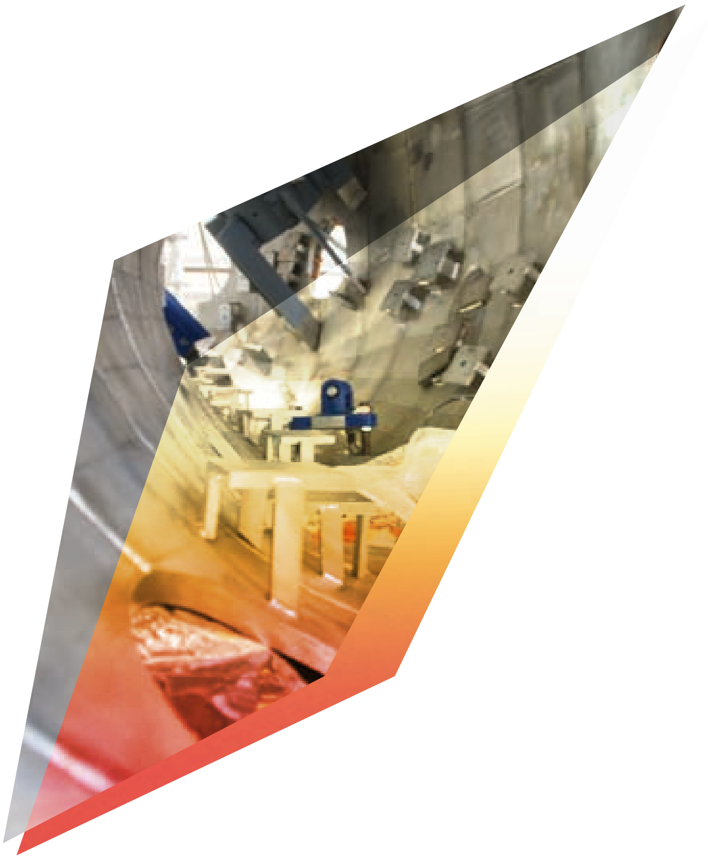
BUILDING THE 'STAR MACHINE'

Challenging production specifications for research purposes can boost innovative, high-technology developments in industry. One such example is the construction of the plasma vessel for the Wendelstein 7-X fusion experiment being built by the Association Euratom – IPP at the Greifswald site of the Max-Planck-Institut für Plasmaphysik.

Twisted design

When completed, Wendelstein 7-X will be the world's most advanced fusion device using the stellarator design concept. It will investigate the suitability of this design for future power plants. Unlike the more conventional tokamak fusion devices, the magnetic configuration used in a stellarator is produced entirely by external coils. The necessary helical twisting of the magnetic field lines is achieved by forming these coils accordingly.

The enclosing vacuum vessel is closely adapted to the twisted plasma shape it contains and looks correspondingly bizarre: a twisted, approximately ring-shaped, stainless-steel configuration with a circumference of about 36 metres. This complicated but elegant vessel is assembled from several hundred individual components. Its production is a masterpiece of craftsmanship and technology accomplished by the reactor and instrument engineering company, MAN DWE GmbH of Deggendorf, Lower Bavaria. After five years of production work, MAN DWE's head of instrument engineering Franz Kufner is proud of the company's achievements. "Enormous mutual technological benefit affording powerful advantages to both IPP as client and particularly MAN DWE as supplier have come from the project," he says. "In carrying out this extremely exacting assignment science and industry together have demonstrated what Germany is capable of achieving in the high-tech field."



A complex metal sculpture

It was a significant task to manufacture the complex vacuum vessel to the required precision: less than three millimetres in some places. To fashion the curved steel of the 35-tonne plasma vessel required assembly of 20 sections comprising 200 individual rings. Each ring in turn is composed of several finger-thick, 18-centimetre-wide sheet steel strips each sculpted to fit the twisting design. This called for thousands of individual bends in the metal. More than 1,600 metres of multi-layered, hand-welded seams were needed to join the eight hundred or more individual components of the vessel that must be capable of sustaining an ultra-high vacuum.

After vacuum testing, more than 250 ports were cut in the steel wall to allow access for heating and observation of the plasma. Each of the 20 sections was fitted with internal pins to secure the wall cladding. In addition 2,400 metres of cooling and heating pipes were brazed to the outside. All pipes were subjected to helium leak tests to certify fitness for ultra-high vacuum use. Three-dimensional measurements with a laser tracker were made throughout the production process, from the individual components to the completed sections, thus ensuring exact compliance to the specified shape.

New knowledge, new opportunity

This exacting assignment has been of lasting benefit to MAN DWE: for example, the system of three-dimensional computer-aided design introduced for the contract is now being used at 15 design work stations and such 3-D simulation of elaborate assembly scenarios is now standard practice in areas such as the refinery field. Likewise, the ultra-high vacuum technology has brought a great deal of new experience and secured for the company further orders in the field of physical plant engineering, including producing the 200-tonne vacuum vessel for the Tritium-Neutrino Experiment at Karlsruhe Research Centre. The robot initially used for exact positioning of the components in the vacuum vessel of Wendelstein 7-X is now being innovatively applied in instrument engineering and the laser tracker specially acquired for measuring the plasma vessel has been used to calibrate machine tools. Possible further applications in instrument engineering are also emerging for it.

MAN DWE's involvement in this work has also resulted in two diploma projects being given to students at Deggendorf Polytechnic with both graduates now on the staff of DWE's instrument engineering division. For Franz Kufner this is proof "that contracts from science and research secure jobs, create new jobs and boost innovation and development in industry".

The Partners

Euratom Association:

Association Euratom - IPP, Max-Planck-Institut für Plasmaphysik, Garching, Greifswald

Industry Partner:

MAN DWE GmbH, Deggendorf, Lower Bavaria

"Mutual technological benefit affording powerful advantages to both IPP as client and particularly MAN DWE as supplier have come from the project."

Franz Kufner, Head of Instrument Engineering, MAN DWE GmbH

BLANKET TEST LEADS TO IMPROVEMENT

A model example of collaboration between the European fusion community and industry that was directly triggered by the ITER project, has taken place in the Czech Republic. Due to the joint efforts of the Czech Technical University in Prague and two major industrial companies the design of the attachments for the ITER inner wall panel have been tested and modified.

Blanket brackets

The inner wall of fusion reactors is the closest solid structure to the extremely hot plasma where fusion reactions release immense energy. In ITER the inner wall will consist of panels that will be attached by special studs to the shield blocks (also known as blanket modules). Thermal and mechanical loads on panels will be challenging, so that the European fusion community – represented by the European Fusion Development Agreement (EFDA) – has called for coordinated computer simulation and experimental testing of the panel attachment system under operational loads that will check out the proposed panel design.

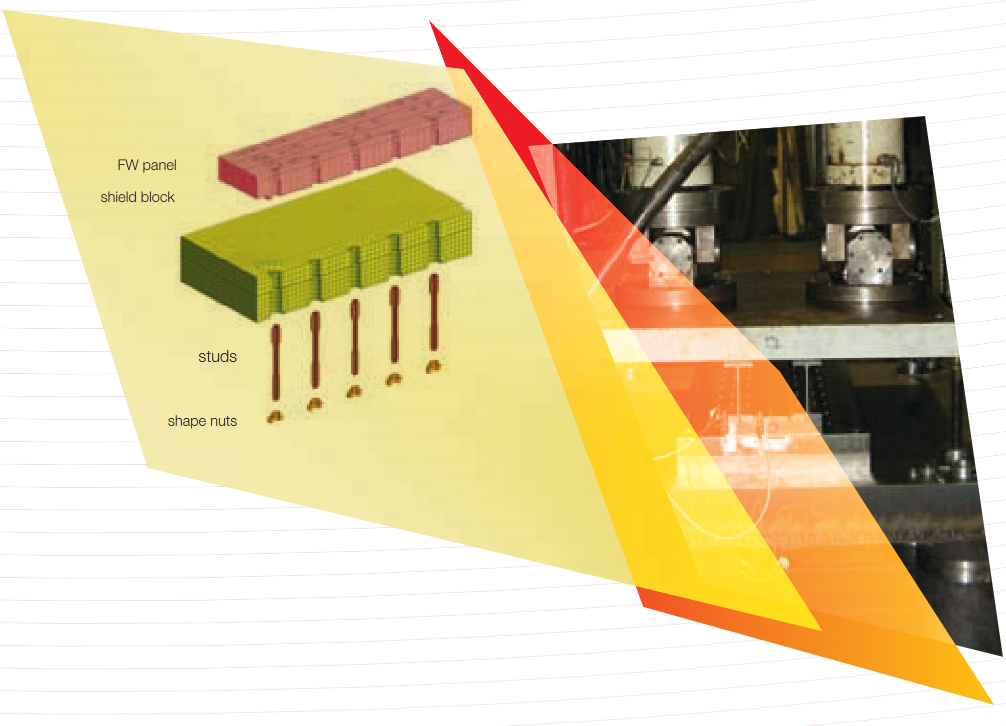
At this time, the Czech Republic was already a well-established partner in the European fusion research efforts. Within the Association Euratom – IPP.CR there has been a long-standing collaboration with academics institutions, coordinated by the Institute of Plasma Physics of the Academy of Sciences (IPP Prague), and including, among others, the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague (FNSPE CTU). In response to the above mentioned EFDA call, IPP Prague met its industrial partners and initiated their collaboration with the Department of Materials at FNSPE CTU who has broad expertise in the required computer simulations.

Nut thread issue

The initial task was to manufacture a full-size mock-up of the shield block and test panels in accordance with the ITER design from the specified stainless steel. The most suitable partner for this work – VITKOVICE Research & Development Ltd. - was found in the industrial north-east of the country. The company is related to one of the largest national steel-making companies and concentrates on forging and casting of special steels, in particular for the nuclear power industry.

These unique components then travelled across the country to undergo the necessary experimental testing in the engineering company ŠKODA Research Ltd. in Pilsen, which is focussed on research and accredited testing of components of power engineering devices. For the EFDA task, the company had to develop special tools in order to fix the studs to the panels in line with the design specifications and special device for simulation of a stud pre-load relaxation during oscillation of the panel temperature. Experiments showed that 30 000 thermal cycles between 100°C and 205 °C at the panel led only to the low drop of the stud pre-load. It was also found that the standard pitch diameter of the nut thread for the studs must be increased. Subsequent mechanical tests consisting of three fatigue experiments successfully demonstrated that the new panel attachment system is sufficiently stiff, strong and stable under the prescribed mechanical cyclic loads.

In parallel, a detailed nonlinear 3D finite element model of the mechanical system was set up in the Department of Materials at FNSPE CTU in order to interpret the experimental results. As another output of this finite element computation, additional experiments were recommended in order to validate the stability of the system during complex mechanical shock due to a sudden loss of plasma known as the Vertical Displacement Event.



Participation in procurement

It can be concluded that the fruitful collaboration of the Technical university with industry validated and amended the ITER design, and as an important side-effect has attracted the industrial knowledge base to participate in the ITER project. Both industrial parties involved in this exercise have declared their interest in future ITER procurement projects.

The Partners

Euratom Association:

Association EURATOM-IPP.CR, co-ordinated in the Czech Republic by the Institute of Plasma Physics, Academy of Sciences of the Czech Republic, v. v. i.

Academic Partner:

Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering (member of the Association EURATOM-IPP.CR)

Industry Partners:

ŠKODA Research s.r.o. in Pilsen
VITKOVICE Research & Development Ltd

"This is a good example of the key role of co-ordination in fusion research. Thanks to our knowledge of both Czech industries and Czech Universities we could initiate their collaboration which responded to an important ITER-relevant task."

Prof. P. Chráska, Director of the Institute of Plasma Physics AS CR, v.v.i.

"Complex solution of the 'ITER panel attachment' project will be presented also at university lectures as a good example of the cooperation between academic and industrial research and an illustration of relationship between the computational model and real experiment."

Ass. Prof. V. Oliva, principal investigator of the project, Czech Technical University in Prague

DIGITAL MANUFACTURING

Technical requirements for the fabrication of the ITER structure and associated components are extremely demanding and have required innovative new tools to be developed. The Association Euratom – TEKES in Finland has worked closely with academia and industry to develop such tools including advanced welding robots and digital manufacture concepts.

Demanding work

The research and development involved in producing the complex and demanding structures that make up ITER including the vacuum vessel itself and the tritium breeding blankets, require innovative tools to support fabrication. Some of these new tools have been developed in Finland through contracts initiated by the Association Euratom - TEKES– the Finnish Funding Agency for Technology and Innovation.

The Finish Fusion Programme is split roughly 30% physics and 70% technology with an emphasis in materials, joining and remote handling research. The funding and activities are coordinated by TEKES and the VTT-Technical Research Centre of Finland: an independent research organisation with expertise in many areas including remote handling, mechanical engineering and materials development.

Welding and robots

One of the most demanding fabrication tasks in the ITER project is the assembly welding of the vacuum vessel. This requires a completely new class of handling capabilities for the preparation, welding, inspection and repair operations that will be required. Lappeenranta University of Technology has particular expertise in robotics and hybrid laser welding. The university has developed novel robotic solutions for the ITER processes based on a parallel hybrid mechanisms, water hydraulics and industrial process controllers. The robotic welding technology can achieve the extremely large force stiffness, high accuracy and dynamic stability required for the fabrication of the vacuum vessel. Since 2001 several virtual and physical prototypes have been successfully built and tested in collaboration with industrial partners (Imatran Kone, Hytar, Stressfield and Componec).

Since 2004 the Finish Fusion Programme has promoted the use of digital manufacturing in applications such as the fabrication of the Vacuum Vessel Sector. The concept of digital manufacturing is based on the increased capability of enterprises to integrate various types of information, including on drawing, planning, fabrication, testing, analysis and simulation. The integration of all this product information is becoming an important element in product lifecycle management (PLM) strategies and for further integration of automated production equipment. This technology has great potential to increase efficiency, quality and flexibility of manufacturing – all key elements of industrial competitiveness.

A number of collaborative fusion development projects have taken place with VTT and industrial partners such as the mechanical engineering company Hollming Works and the software company Delfoi Oy. Hollming Works is one of Finland's most important mechanical engineering companies and is using its innovative 3D cold forming process in the vacuum vessel fabrication process. Delfoi develops, markets and supports digital manufacturing solutions and related consulting and integration services for the PLM.

Competitive edge

In both these examples the industrial partners are contributing to ITER manufacture and development work but also gaining or honing skills and expertise that can give then a clear competitive advantage in other manufacturing areas.

The Partners

Euratom Association:
Association Euratom TEKES

Academic partners:
VTT
Lappeenranta University of Technology

Industry Partners:
Hollming Works Oy
Delfoi Oy
Imatran Kone Oy
Hytar Oy
Stressfield Oy
Componec Oy

"The future mechanical engineering includes effective digital integration of all related information and operation. This is an enormous challenge that keeps us busy for at least the next 20 years."

Timo Määttä, Technology Manager from VTT

EXPLOSIVE METAL FORMING

Using an explosive process to shape metal could provide an innovative route to forming the complex structures needed for the ITER vacuum vessel. The process reduces the number of production steps and should still enable to fulfil the structural integrity requirements.

Going Dutch

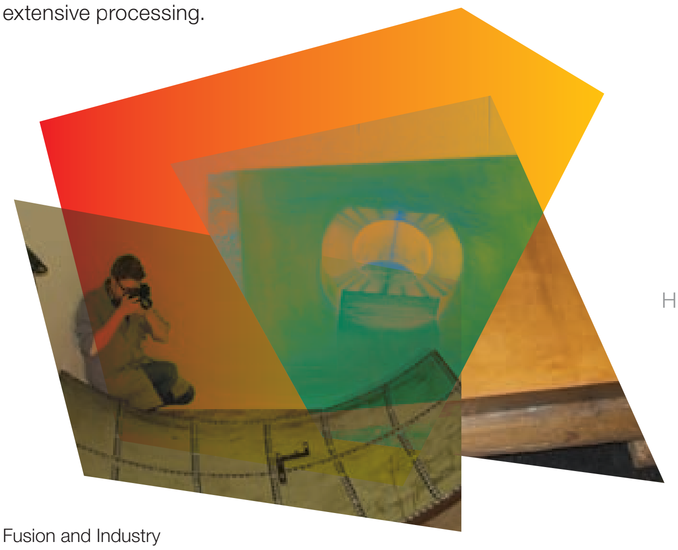
In the Netherlands the ITER-NL consortium has been formed with the specific goal to build a bridge between fusion science and industry. The partnership consists of three knowledge institutes: the Association Euratom - FOM and NRG, working in tokamak physics and nuclear technology respectively, and TNO, the organisation for applied scientific research in the Netherlands. The three partners cover all the fields needed for ITER R&D, procurement and effective liaison with industry thus creating a real synergy.

Since it formation in 2007, ITER-NL has built up a network of more than 200 specialised companies with whom regular contacts are maintained and to whom information on fusion project opportunities is distributed. With a subset of around 40 companies ITER-NL works more as a consultancy.

From these explorative actions, a 'technology initiative' can develop. This involves a technology or manufacturing technique that is developed or a material tested with a specific deliverable in mind: usually a demonstrator. The selection of such projects is subject to a strict set of rules, approved by the government and overseen by independent observers. Since 2007, six technology initiatives have been taken on by ITER-NL. It is specifically in these cases that scientists, engineers, project managers and industrialists get to work together to create real innovation.

Explosive results

On example is a Dutch company Exploform BV that has specialized in a novel process to deform thick plate material or join metal sheets to moulds using explosions. This technique allows the formation of 3-dimensional structures out of a single metal sheet of avoiding extensive processing.



The process was identified as a potentially interesting technique for parts of the ITER vacuum vessel. Working together with ITER-NL, the company formed a 60 mm thick ITER-grade stainless steel plate with an area of several square metres. The exact challenge was to form a doubly-curved shape whilst maintaining the material property specification. The end product was tested for conformity to design and the quality of the finished material.

The explosive technology also enables to join large surfaces of dissimilar metals. Demonstrators were made of copper to stainless steel and tungsten to copper.

Banging benefits

This technique is now being considered as a technology for the manufacturing of the ITER vacuum vessel. Successful completion of the challenge has encouraged the company to develop their capability to handle metal sheets of much larger size and thickness than previously formed using this process. As result of the development, the company is now in negotiation with a number of large non-fusion related clients and further success is anticipated. Already several spin-off projects are initiated with prospects for multi-million annual turnover.

The Partners

Euratom Association:
Association Euratom - FOM, research units FOM and NRG

Academic Partner:
TNO

Industry Partner:
Exploform BV

"Developing our technology for ITER applications really helped us to cross technological boundaries. This was rapidly appreciated by many high-tech industries. Not only for fusion and fission applications, but also for other energy sectors and even for several aerospace applications."

H. Groeneveld, Director R&D of Exploform BV

SATIR OFFERS INDUSTRIAL OPPORTUNITY

Components used in fusion devices, especially plasma facing components, must have high heat transfer capabilities. This requires a very high level of quality control during manufacture. The SATIR system is an advanced non-destructive examination technique developed by the Association Euratom-CEA in France for testing such components. The technology is now available for licensing to industrial partners.

SATIR – a novel NDE technique

The high technology components used in plasma fusion devices, especially those components that must endure high heat flux as plasma facing components, require an efficient heat transfer capability. This characteristic, which reflects the likely component lifetime, can only be guaranteed by a very high level of quality control during manufacture with a rigorous inspection method. Amongst the variety of non-destructive examination (NDE) techniques available, the active infrared thermography system SATIR (Station Acquisition et Traitement InfraRouge) is recognised as a highly efficient inspection technique for testing the cooling performance of many structures involved in extreme heat transfer.

The SATIR method was developed by the French Association Euratom-CEA to evaluate the manufacturing process quality of plasma facing components and has proved to be very efficient in terms of detecting defects in these structures. It also has potential application in other sectors that involve high temperature operations.

How it works

The principle of the SATIR test is based on the detection of a time delay in the surface temperature evolution produced when an abrupt variation of the water temperature flowing in a component cooling system is made. This delay is measured in comparison to the thermal behaviour of a “defect-free” reference target. The delay is measured as alternate flows of cold and hot water are made in the cooling channels for both materials.

The components are tested in parallel to the reference material and the main parameter evaluated is the maximum transient temperature difference (DTref_max) which is the maximum temperature mismatch of the sample material with respect to the reference. Over the years CEA has accumulated an extensive know-how and expertise concerning the SATIR facility which is effectively an industrial test bed that is both fully operational and fully validated.

Enterprise potential

Clearly there is a significant business opportunity for commercial use of SATIR both to check components destined for the Euratom fusion programme and ITER, for example the ITER Divertor components, as well as in other sectors. However, the core business of CEA is research, not to provide industrial process services, and the technology is being transferred to one or more industrial concerns that have, or can easily gain, the resources and competences to check the ITER component series. The CEA will guarantee the quality of the technology transfer to industrial recipients while retaining its own operational skills in this area.

The technology transfer offer will include a non-exclusive licensing contract with provision of technical and exploitation documents, advice on building a SATIR facility, assistance with commissioning tests including calibration on standard components and specific training for company employees on SATIR.

The Partners

Euratom Association:
Association Euratom CEA

Clearly there is a significant business opportunity for commercial use of SATIR both to check components destined for the Euratom fusion programme and ITER, for example the ITER Divertor components, as well as in other sectors.

HIGH HEAT FLUX DIVERTOR

The divertor in ITER will perform the vital task of removing impurities from the burning plasma. This means it is subject to extreme heat flux and therefore its production has required the development of novel manufacturing technologies. A joint research-industry collaboration has successfully demonstrated prototype components.

Failure not an option

The Italian Association Euratom - ENEA is involved in many aspects of R&D activities for ITER. These include the manufacture of high heat flux plasma-facing components such as the divertor targets. The divertor and especially the targets, will be subject to immense heat fluxes during operation. A failure of these plasma-facing components could ultimately compromise the performance of the divertor and shut down ITER. Recently ENEA has manufactured actively cooled mock-ups of various ITER components using different technologies, including brazing, diffusion bonding by Hot Radial Pressing (HRP) techniques. A new manufacturing process that combines two techniques PBC (Pre-Brazed Casting) and HRP (Hot Radial Pressing) has been set up and widely tested. A full monoblock vertical divertor target, having a straight Carbon-Fibre Composite (CFC) armoured component and a curved Tungsten (W) armoured part, was manufactured using this process.

Rigorous testing

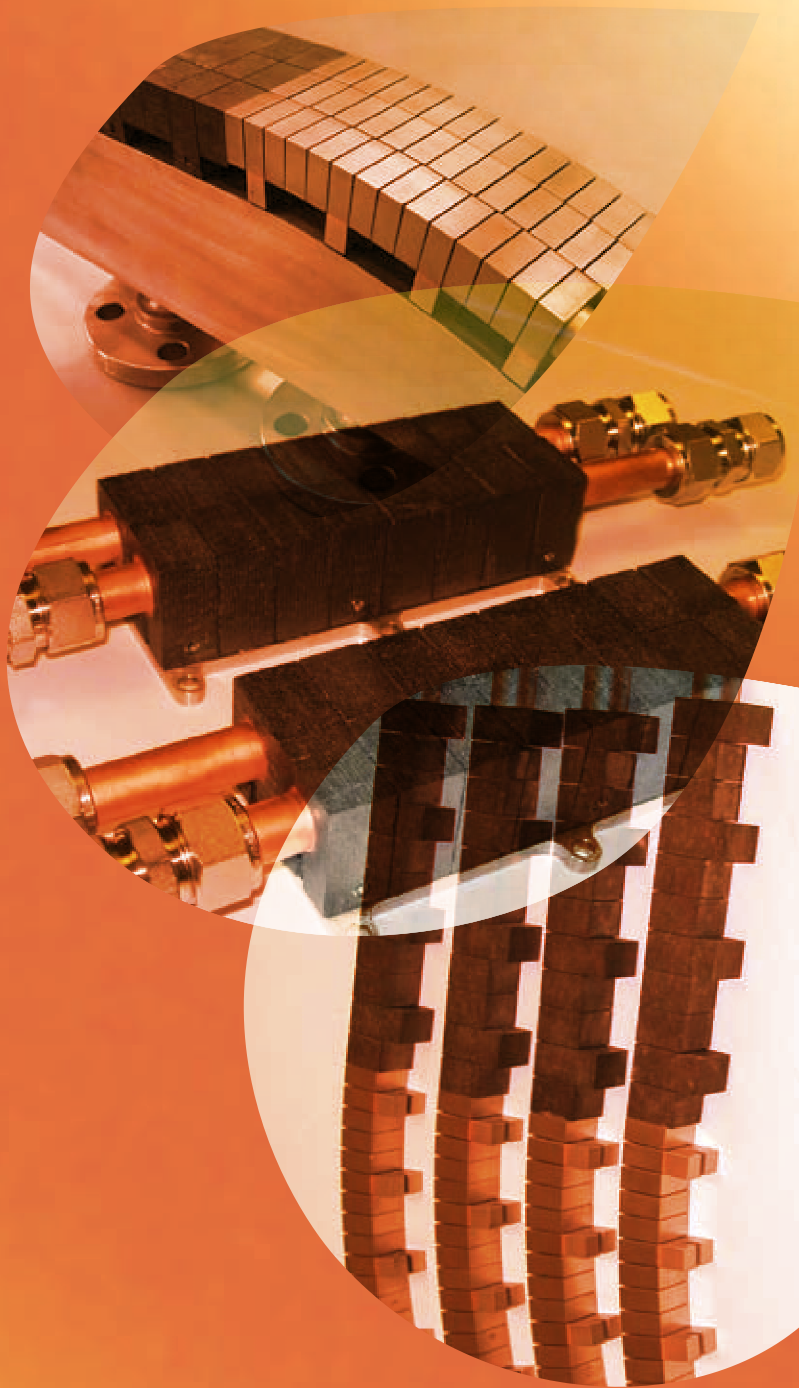
An ultrasonic method was used for non destructive testing during manufacture of the component from preparation of the blocks to the final mock-up assembly. The component was also examined by thermography at the SATIR facility run by CEA in France. It was then thermal fatigue tested at FE200, a 200 kW electron beam facility, run by CEA/AREVA also in France.

The successful results of the thermal fatigue testing performed under ITER-like conditions (10 MW/m^2, on both CFC and W parts, then 20/15 MW/m^2, on CFC/W part respectively) have confirmed that the developed process is capable of manufacturing monoblock divertor components. Furthermore, an incredible 35 MW/m^2 Critical Heat Flux was measured at relevant thermal-hydraulics conditions at the end of the testing campaign.

These encouraging results have been achieved thanks to a close collaboration between ENEA and ANSALDO RICERCHE S.p.A.. The collaboration has managed the qualification of the manufacturing process, made a comparison between different armour materials, produced the manufacturing mock-up for the test aimed at assessing the effect of the loads due to the HALO current and manufactured mock-ups with a reference defect for the study of acceptance criteria for ITER divertor components.

Know-how for qualification

The collaboration culminated with the manufacturing of a qualification prototype that will be used for the EU company qualification. This final component covers all the technology aspects needed for manufacturing the ITER plasma facing units consisting of three plasma facing units with a CFC armored straight part and a W armored curved part mounted on a steel cooled support. The qualification prototype was successfully manufactured under this collaboration exploiting the know-how of both partners and newly developed technologies. Two patents have resulted from this development and European industry has now the possibility to exploit this technology.



The Partners

Euratom Association:
Association Euratom - ENEA

Industry Partner:
Ansaldo Richerche SpA

"The collaboration between the Association Euratom – ENEA and ANSALDO RICERCHE S.p.A culminated with the manufacturing of a qualification prototype that will be used for the EU company qualification. This final component covers all the technology aspects needed for manufacturing the ITER plasma facing units."

BERYLLIUM PLASMA FACING COMPONENTS

The beryllium wall tiles of ITER must absorb the heat from the fusion plasma and transfer it to the heat sink components to provide the reliable operation of the tokamak. To bond the tiles to the heatsink components, high quality manufacturing processes and controls are required, while working with a material that is hazardous in the manufacturing environment. When EFDA (the European Fusion Development Agreement) wanted to place a contract for this work, the EURATOM/UKAEA Fusion Association nominated UK engineering firm AMEC – which has long experience in fusion projects – for the tender list

Hotter than the Sun

The success of ITER will depend on a wide range of advanced technologies. One such technology has been developed to manufacture the plasma facing components in the form of First Wall Panels (FWPs). These FWPs are covered with beryllium and form the majority of the internal tokamak surface. Their job is to endure and absorb the heat from the plasma and transfer it rapidly to the coolant systems. The plasma temperature, which may range upwards of 100,000,000 degrees Celsius, is expected to radiate a heat flux of 500,000 watts per square metre to the beryllium tiles and provides a challenging environment.

Heat sink production

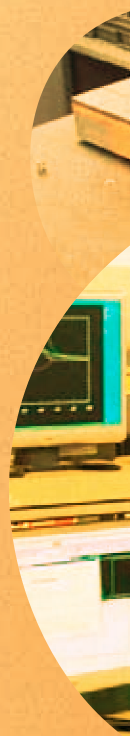
Following ten years of research and development, including extensive validation through the production and heat flux testing of components at heat fluxes greater than 2,000,000 watts per square metre, the technology is now at the industrialisation stage. An effective industrialisation, with process characterisation, will be essential to realise cost-effective manufacture of full-scale components for ITER. UK engineering company AMEC worked with its supply chain to refine the individual processes and control systems and has bonded beryllium tiles to a full-scale ITER FWP.

The current manufacturing route involves two main stages. The first stage is the production of a composite stainless steel and copper alloy heat sink base using Hot Isostatic Pressure (HIP) bonding. The second stage is the HIP bonding of the beryllium tiles onto the copper alloy surface of the heat sink. Many exacting processes and process controls are used in the manufacture.

Integral to the future

Although the integrity of the latest FWP prototype will ultimately be proven by high heat flux testing, an ultrasonic inspection provided the final quality control prior to release. The inspection results indicate that there are no defects in the beryllium / copper bond of the FWP. Alain Chevalier, Business Director at AMEC, comments that: “The application of effective project controls to the manufacturing process route was key to the successful production of the FWP.”

The prototype FWP is currently being heat flux tested under ITER conditions at the JUDITH2 facility at FZJ Jülich. Alain Chevalier is enthusiastic about the long-term commercial opportunities in fusion: “We see a continuing involvement in ITER and related fusion projects giving AMEC a strategic position as an integrator for the design and engineering of future fusion power plants.”



The Partners

Euratom Association:
Association Euratom - UKAEA, Culham Science Centre, UK

Industry Partner:
AMEC

“We see a continuing involvement in ITER… giving AMEC a strategic position as an integrator for the design and engineering of future fusion power plants.”

Alain Chevalier, Business Director, AMEC

“This is one example where a UK company has provided technical expertise in the realisation of key components needed in fusion. Other companies are also viewing opportunities, and we hope they will play a key role in the construction/operation of ITER by the international community.”

Dan Mistry, UKAEA’s Fusion & Industry Manager

3 Coating Technologies

NEW COAT FOR HOT TILES

Plasma facing components in ITER have to survive intense thermal loads. The Fusion Association Euratom-MEdC from Romania has developed and industrialised a tungsten coating technology that can take the 'heat' and shows good signs of application in other industrial sectors.

Tungsten technique

The plasma temperature in a fusion reactor is in the range 50 – 100 million °C. Under these conditions, the first wall of the reactor chamber is subjected to an intense thermal loading with some areas of the plasma-facing wall reaching 2000 °C or more. There are not too many materials that can take this heat. One of them is carbon, particularly CFC (Carbon Fibre Composite), and another is tungsten (W). Both of these materials have advantages and disadvantages, but a combination of W coating on CFC material is a good solution from many points of view including cost.

Currently, the primary materials choice for ITER is a full beryllium main wall with CFC materials at the strike points and tungsten at the divertor baffles and dome. Since this combination has never been tested in a 'live' reactor, an ITER-like Wall project has been launched at JET in Culham, UK to test the new wall design. Combined Magnetron Sputtering and Ion Implantation (CMSII) technology, developed by the Association Euratom - MEdC in Romania, has been chosen as the best coating technique in terms of resistance to high heat fluxes (HHF) and will be used to provide a 10 micron (μm) W coating of around 1000 tiles for the new JET wall.

Industrial-scale

The transition of this technology from laboratory to industrial scale was a big challenge for MEdC. The small-scale laboratory coating unit measuring 300mm diameter by 420mm high was equipped with one magnetron with a maximum power of 800 W. For industrial scale coating, a chamber of 800mm diameter and 750mm height with 24 magnetrons and a corresponding higher power supply of 25 kW were necessary. Such equipment could provide the desired coating productivity of around 1 m2/week and accommodate tiles with a length up to 370mm. Two options were analyzed: the first being direct transfer of the technology to a SME and the second being the development of the technology to industrial scale in the National Institute for Laser, Plasma and Radiation Physics (NILPRP-MEdC).

Taking into account the lack of knowledge on the design and technological aspects of the industrial unit, as well as the short time available and limited financial resources, the second option was chosen led by the Plasma Surface Engineering Laboratory (PSEL) at MEdC. Following initial experiments the mechanical equipment was manufactured by SC Nuclear & Vacuum SA, a Romanian Company specialized in vacuum techniques with the electrical equipment designed and manufactured by PSEL. The software program was developed by a specialized Romanian Company, SC Inter-net SRL. By the end of 2007, within two years of the initial commissioning, the CMSII industrial coating unit was installed and and ready for use.

Thermal expansion

A major issue with W coatings on CFC tiles is the anisotropic thermal expansion of the bidirectional fibre-reinforced CFC. This was overcome by the deposition of an intermediate molybdenum (Mo) layer of 2 – 3 μm which compensated for the thermal expansion mismatch. The qualification of the CMSII technology was based on the results of High Heat Flux tests using the GLADIS hydrogen beam facility at IPP Garching. Testing up to 2000 °C has taken place without delamination of tile coatings.

Application

More than 200 CFC tiles have already been coated for JET after successful tests on prototypes at the Association Euratom - IPP Garching in Germany. The same coating technology is being used for almost 300 plasma facing components made of Fine Grain Graphite (FGG) and CFC for the ASDEX Upgrade tokamak at IPP Garching. Intensive research is carried out with the aim to produce by the same technique, on some particular CFC tiles, W coatings with a thickness of 20-25 µm.

CMSII is a very versatile thin coating, competitive technology, which can also be successfully applied in other sectors such as cutting tools, forming and forging tools, amongst other applications. The Association Euratom - MEdC is now enquiring on further exploitation of this technology with potentially interested parties.

The Partners

Euratom Associations:

Association Euratom – MEdC National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania

Association Euratom – IPP, Max-Planck Institut für Plasmaphysik, Garching, Germany

Association Euratom - UKAEA, Culham Science Centre, UK

Industry Partners:

SC Nuclear & Vacuum SA, Romania

SC Inter-net SRL, Romania

A reference price for 10 µm W coating of carbon based materials (CFC or FGG) is 8,500 EUR/m2, but this depends on the geometry and number of tiles.

C. Ruset, NILPRP, Romania

FINLAND SHOWS MATERIAL STRENGTH

Finish industry has made a significant contribution to a number of material technology developments for fusion research. These include superconductors, special copper applications, plasma processing, plasma coating, mechanical testing, non-destructive examinations (NDE) and research and development activities of nuclear materials. A selection of the collaborations is outlined here.

Products, technologies, methods

Research on the very demanding materials required for ITER, such as superconductors, first wall materials and diagnostics, has led to significant developments in superconductors, in-reactor testing methods, plasma coating and plasma incinerator technology.

Luvata is a company that specializes in high-end copper products, typically hollow conductors and other components with demanding profiles, and is a world leader in superconductor materials. Luvata copper is found in components from computer processors to solar panels around the world.

The company has been developing and fabricating superconductors since 1985 and started co-operation on fusion power with the NET (Next European Torus) team and EFDA in 1995. Today Luvata is working with European Joint Undertaking for ITER, Fusion for Energy (F4E) and also with the US ITER team. Major community partners in Europe for fusion are ENEA (I) and TEKES (FIN). In the magnetic resonance imaging (MRI) market all the major manufacturers are customers of Luvata and in the scientific market the LHC-project at CERN has been a major client. Luvata was also the main supplier of superconductors for the South Korean fusion project KSTAR superconductors.

Ion exchange

Finex Oy, a privately owned company that manufactures tailor-made performance polymers and ion exchange resins, together with Finnish power companies Fortum and TVO, has developed a plasma incinerator for significant volume reduction of spent organic ion exchange materials from nuclear power stations. The application was developed in collaboration with the Association Euratom-Tekes, namely the Helsinki University of Technology (TKK) and VTT-Technical Research Institute of Finland. The design of the power source and plasma instrumentation for the device was based on the learning accumulated in plasma engineering on various fusion machines within the Finnish fusion community. The prototype device exploits an inductive coupler for plasma generation, and Optical Emission Spectroscopy (OES) is used for plasma characterization. Presently, some fusion-related OES diagnostics studies are conducted on this pilot device.

Since 1994, also in cooperation with the NET Team and EFDA, VTT has been doing research on materials performance in the nuclear environment including experiments and modelling. As a part of this effort VTT has developed and instrumented material test devices for mechanical studies under the in-core conditions of a nuclear reactor. Recently, several in-reactor tensile and creep fatigues test have been carried out in the BR2 test reactor in collaboration with the Associations Euratom-Belgian State, Research Unit SCK.CEN and Risø in Denmark.

Plasma Coating Technology

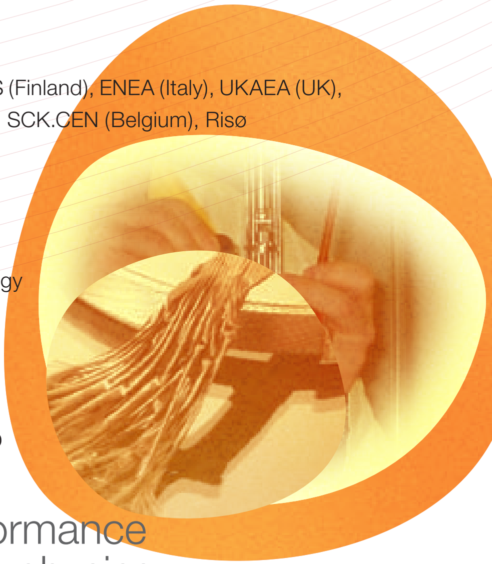
The divertor and first wall structures of fusion power devices are subject to very high heat loads. From 1995 to 2004 the plasma coating company DIARC Technology, the Association Euratom – TEKES, namely VTT and the University of Helsinki cooperated with the NET Team and EFDA to produce and develop different types of plasma coatings for various fusion machines, including JET and the Asdex Upgrade, with vastly improved heat flux resistance. DIARC-Technology Inc. is a company specialising in the manufacture of carbon, metal and nanocomposite coatings for a wide range of tools, machine parts, optical and electronics equipment and consumer products.

The Partners

Euratom Associations:
Associations Euratom – TEKES (Finland), ENEA (Italy), UKAEA (UK), IPP (Germany), Belgian State - SCK.CEN (Belgium), Risø (Denkmark)

Academic Partners:
University of Helsinki
Helsinki University of Technology
VTT

Industry Partners:
DIARC Technology Inc.
Finex Oy, Fortum, Luvata, TVO



"Materials performance as opposed to physics will determine the commercial feasibility of fusion energy. In shorter term, materials development also serves the next generation fission reactors."

Head of Fusion Research Unit, Seppo Karttunen from VTT

4 Heating Technologies

ACTIVE COLLABORATION BRINGS PAM SUCCESS

The Tore Supra tokamak of the Association Euratom-CEA features intense microwave energy injection to stimulate high power, long duration plasma operation. To achieve this required the development of a new Lower Hybrid Passive Active Multi-junction (PAM) microwave launcher that could also test ITER-relevant features for neutron shielding and efficient cooling. Its successful fabrication required close industry collaboration.

Radio frequency plasma heating

One of the major objectives of the French Tore Supra tokamak programme is to achieve high power, long duration plasma operation with the use of lower hybrid radio-frequency energy injection to yield a non-inductive current drive. The large amount of power required (more than six MW) will be coupled to the plasma by two radio frequency antennas. One antenna was already installed in Tore Supra, but a new concept was chosen for the second. This device was designed to evaluate the operation of antennas with a reactor relevant capability. The new launcher was conceived to couple routinely 2.5 MW of power and was based on the “Passive Active” concept being composed of two major radio frequency components incorporated into a device called the Lower Hybrid Passive Active Multi-junction (PAM) microwave launcher. This ITER-relevant concept provides space between the narrow waveguides facing the plasma for neutron shielding and an efficient cooling system.

The device was ordered, following a European tender call, from the French company SDMS of Saint Romans near Grenoble. This company, with around 120 employees, specialises in pressure vessel technology, cryogenic and vacuum equipment and high technology assembly methods including fabrication using “noble” materials such as stainless steel, aluminium alloys, titanium and copper.

Multi-waveguide structure

The main fabrication challenge for the launcher device was the creation of a multi-waveguide structure requiring the machining of 17 copper to stainless steel bonded sandwich layers joined by brazing. Manufacturing the device called for a number of novel technologies including copper-stainless steel explosion bonding for double and triple material layers, high temperature vacuum brazing between copper structures, electron beam and TIG welding for cooling channels in stainless steel components, copper coatings on passive stainless steel wave guides, high temperature vacuum testing, and non destructive inspection methods. One of the issues was residual internal stress that could deform the explosion-bonded copper-stainless steel layers after stress relief heat treatment and final machining. This required the use of a special brazing tool that could operate reliably at high pressures and temperatures.

New brazing tool key to success

The cooperation between the company and CEA was excellent during the entire fabrication period, which lasted over three years. A particular point was the high level of information exchange and the atmosphere of mutual confidence, which was a key factor when difficulties appeared such as major technical fabrication problems during the copper multi-layer assembly-brazing cycle of one of the two halves of the launcher structure weighing 1.6 tonnes.

The simultaneous brazing of such large, both in terms of quantity and size, multi-layers was a novel technique. As a consequence meetings between CEA representatives and the company were intensified to study the problem and discuss possible solutions. CEA proposed a repair technology that resulted in a new brazing tool that allowed component contact pressure control under vacuum at high temperature. As a spin-off, CEA initiated a patent registration of this tool which, if accepted, will be available under license to any interested parties.

The fabrication of the two halves of antenna structure resulted in a total success with delivery to CEA in December 2008 representing a small slip in the planned fabrication time of around 20 % which is typical for high technology manufacture of essentially prototype components. In general the project showed that success can be achieved through close collaboration and open information exchange, yielding technical synergy and the sharing of effort.

The Partners

Euratom Association:
Association Euratom CEA, France

Industry Partner:
SDMS, Saint Romans, Grenoble, France

"This project showed that success can be achieved through close collaboration and open information exchange, yielding technical synergy and the sharing of effort."

Pierre MACCIONI, Ph.D.
Business Development Vice President
SDMS, Saint Romans, Grenoble, France

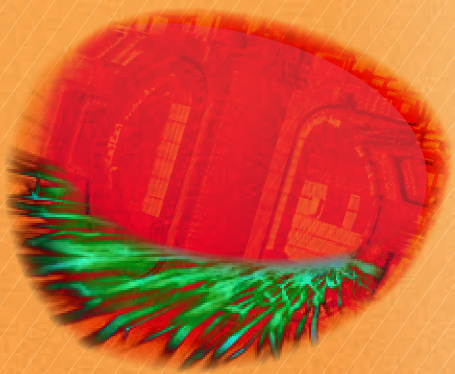
CORRUGATION BOOSTS POTENTIAL

When the ITER design called for a novel waveguide capable of extreme power transmission and with tight production tolerances, some companies in the Netherlands were able to rise to the challenge.

Megawatt microwave

ITER-NL is involved in the development of the Upper Port Electron Cyclotron Resonance Heating (ECRH) system for ITER. The ITER-NL consortium consists of three knowledge institutes: TNO, FOM and NRG. FOM and NRG – research units of the Association Euratom-FOM - are working in tokamak physics and nuclear materials respectively, and TNO is the Netherlands organisation for applied scientific research.

For one of the design options for the ECRH a so-called 'square corrugated waveguide' was needed. Such a waveguide would require extensive cooling in view of the very high power (1-2 MW) that it would transmit into the ITER plasma. Such a product did not currently exist and providing a high-precision manufactured, vacuum-tight, high-power, millimetre wavelength technology device posed a significant technology challenge.



Precision tolerance

The challenge was to combine a very high precision in the corrugations of the unit with high tolerance, vacuum-tight welds over a long length of waveguide. The key to the performance of the ECRH were the deformations on the surface of the waveguide, which also had to be kept within strict tolerances. In collaboration with two small companies [Schelde Exotech and Heeze Mechanics, both specialised in advanced manufacturing technology] a novel manufacturing technology was developed.

Upgrade benefits

A prototype waveguide was developed, tested at high power and found to perform very satisfactorily. Due to a design change on ITER the waveguide will probably not be required now, but a result of this technological development, the Heeze Mechanics has obtained an order for delivering around 100 metres of cylindrical corrugated waveguide for the ASDEX UpGrade tokamak experiment at IPP-Garching in Germany.

ITER-NL has also assisted in this process by advising the company on setting up an appropriate quality assurance programme for the production process.

The Partners

Euratom Association:
Association Euratom - FOM, research units FOM and NRG.

Academic Partner:
TNO Netherlands Organisation for Applied Scientific Research

Industry Partners:
HEEZE MECHANICS BV, Kapelstraat 10, Nl 5591 HE Heeze
SCHELDE EXOTECH BV, Glacisstraat 165, Nl 4380 AM Vlissingen

“Shared interest in nuclear fusion technology made both Schelde Exotech and our company familiar with fabrication of special components of high power transmission lines. Years of close cooperating with scientists from FOM Rijnhuizen and Dutch organisation of applied research TNO have laid the basis for some successful challenging spin-offs...”

Michael Koot, Heeze Mechanics B.V.

5 Power Storage

FLYWHEEL SYSTEM BOOSTS COMPASS TOKAMAK

A remarkable win-win situation for fusion research and industry resulted during the installation of the COMPASS tokamak at the Institute of Plasma Physics of the Academy of Sciences in the Czech Republic (IPP Prague). A new collaboration helped to resolve a critical power storage issue and provided a boost for local industry.

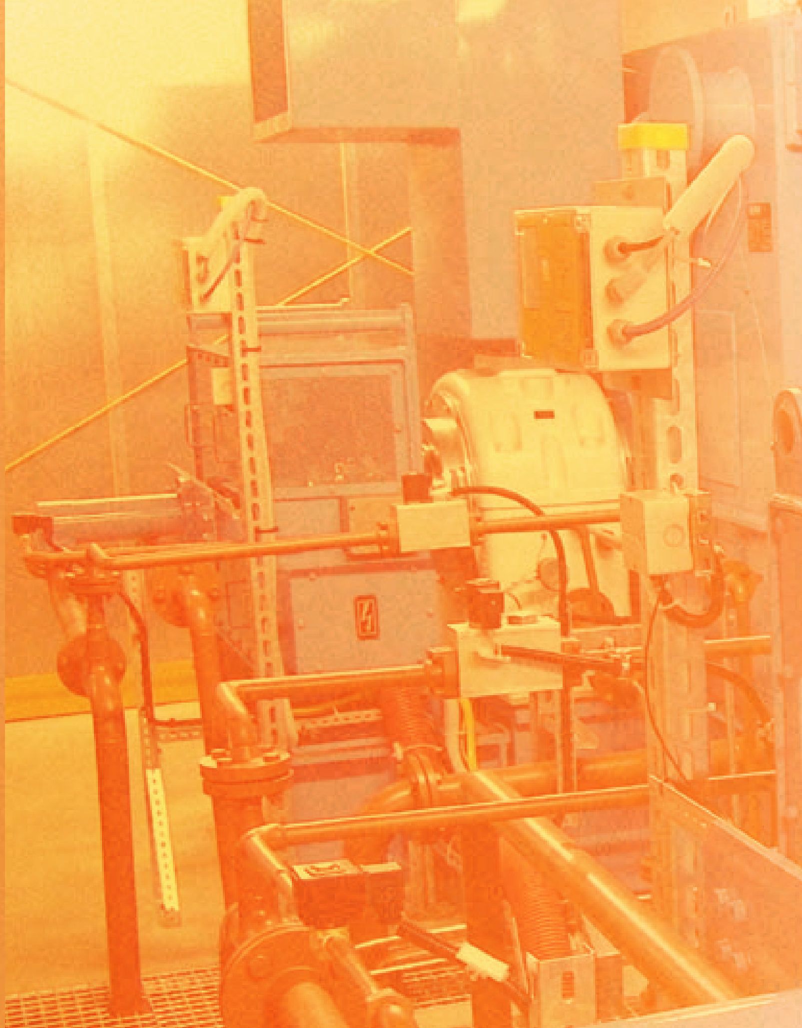
Power limited

The successful relocation of the experimental fusion reactor COMPASS from the Association Euratom – UKAEA, Culham Science Laboratory in the UK to the Association Euratom – IPP.CR in Prague provided a number of challenges including the provision of an adequate power supply for the tokamak. The power input required for COMPASS during its very short (≤ 1 second) plasma discharge can reach up to 50 MW. This is too much for the local power grid and another solution had to be found. However, necessary 20 minute breaks between consecutive plasma discharges for cooling of the tokamak's copper coils, offered a possible opportunity for a gradual energy accumulation for the short but powerful energy pulse required.

One solution is to store the required energy in the rotational energy of a massive flywheel linked to a generator. This principle has been exploited in a number of experimental tokamak facilities such as the German ASDEX-U and was proposed for the COMPASS re-installation. However, when the Association Euratom - IPP asked for expressions of interest in the procurement of a system there were no positive responses.

Flywheel or super capacitors

"The issue of power supplies for the COMPASS tokamak in Prague appeared on the critical path," recollects Dr R Pánek, head of the tokamak department at IPP Prague. "So we organised a brainstorming meeting to discuss alternative options with experts from the Czech technical university in Prague and also collaborators from Czech industrial companies." Two alternative methods were suggested: charging banks of 'super capacitors' or using several smaller flywheel generators that are commonly used as UPS power back-up in data centres.



At this time (second half of 2005), the COMPASS project was officially launched and received Czech governmental support, so a quick solution for the power issue was needed to obtain EURATOM Priority support. Deadlines were short so an independent consulting company undertook a technical study on the power options concluding that a solution with two massive flywheels would be preferable provided the price was right. Interestingly, the study highlighted the Czech company ČKD Nové Energo, a.s. which had done feasibility studies on similar generators for other interested parties.The ČKD Group is a significant player in Czech industry working in integrated power generation, chemical process technologies, gas and power distribution, electricity conversion and controls.

Fast solution

The resulting contract was mutually advantageous: IPP Prague was able to propose a standard solution which was accepted as a part of the EURATOM Priority support (and awarded in 2006) while ČKD Nové Energo, aw.s. has broadened the scope of its expertise, establishing a highly quality reference with a national research institution and gaining new experience with a potentially critical technology for future fusion power stations.

Even though the deadlines were tough, all the milestones in the re-installation of COMPASS have been met. IPP Prague has procured two flywheel generators that will enable the experiment to operate even if one of the generators is shut down. The two machines (each with a 30 ton rotating mass) were delivered within one year and in September 2008 achieved their maximum rotation speed of 1700 rpm for the first time. The flywheels can supply up to 70 MW of electric power during plasma discharge giving enough reserve power to allow the use of additional heating systems such as neutral beams in the future. The project was successfully completed when the re-installed COMPASS facility used the flywheel generators to supply power for its first plasma discharge in Prague on December 9, 2008.

COMPASS prepares and cares for ITER a joint public project on the European continental level that cannot be effectively carried out through bilateral negotiations of two (or more) European countries.

The Partners

Euratom Association:
Association EURATOM / IPP.CR, in particular Institute of Plasma Physics, Academy of Sciences of the Czech Republic, v.v.i.

Industry Partner:
ČKD Nové Energo, a.s

“The issue of power supplies for COMPASS appeared on the critical path.”

Dr R. Pánek,Head of the Tokamak Department, IPP Prague

“I see the ČKD type of generator as an essential part of future fusion-type power plants. Generators will allow storage of electrical energy for immediate use to start and control the fusion reaction. What other technology can give you immediately 100s of megawatts of electrical power within seconds?”

Mr O. Mikuš, Director for Technology, ČKD Nové Energo, Prague

6 Robotics

REMOTE HANDLING – A CRITICAL JOB

Remote handling (RH) and robotics have been significant technology areas for the Finnish Association Euratom – Tekes. RH research projects have included work on virtual engineering, robotics, novel manipulators, water hydraulics and control software. Success in this area has led to the country hosting DTP2, the ITER Divertor Test Platform Facility, which will develop the advanced RH technology and maintenance techniques required for long term operation of ITER.

Virtual Engineering

Virtual Engineering is a rapidly growing technology used in design and analysis. In research for Divertor RH maintenance and for handling and tools related to the ITER Vacuum Vessel Assembly Welding, virtual engineering technology has had a central role.

The Association Euratom – Tekes, namely VTT-Technical Research Centre of Finland and Tampere University of Technology (TUT) are developing ITER Divertor Maintenance concepts and processes, including virtual and real prototypes of RH tools, movers and manipulators. Since 2001 robotic tools for ITER Vacuum Vessel Assembly Welding have also been under development at Lappeenranta University of Technology. VTT and the two universities are continuously working with industry and applying virtual engineering in product development, simulation, virtual prototyping, maintenance planning and personnel training. MeVEA Oy, a spin-off company supplying services and systems based on virtual engineering has resulted from this collaboration offering solutions for product development and operator training based on its special know-how on real-time simulation of dynamics, multi technical and virtual systems.

Water Hydraulics and Controls

Working closely with the original Next European Torus (NET) Team and EFDA, TUT also started research activity in the area of water hydraulics and RH. The industrial use of water hydraulics has steadily grown since 1995 and TUT's Department of Intelligent Hydraulics and Automation (TUT-IHA) has had a central role in this development worldwide. The industrial companies involved are Hytar Oy, a leading European engineering manufacturer for industrial water hydraulics systems and components, and Adwatec Oy, producing water hydraulic components and systems for industrial applications including cooling circuits for demanding applications. TUT-IHA specialises in intelligent heavy-duty machines and manipulators. Virtual prototyping is widely used in developing intelligent solutions for complex industrial problems.

Divertor Maintenance

The ITER machine requires very advanced RH capabilities: considerably greater than anything currently required in normal industrial applications. DTP2, the ITER Divertor Test Platform Facility, is hosted by VTT and TUT and was formally opened early in 2009. It is part of ROViR – the Remote Operation and Virtual Reality Centre - that provides cooperation and services for both industrial and academic projects.

The design and manufacture of the full-scale divertor prototype at DTP2 took four years and is the culmination of efforts from scientists from all over Europe, working together with four industrial partners based in Finland, Luxembourg and Spain. As the divertor will be a major plasma facing component it will suffer from erosion and it is estimated that the divertor will need to be fully replaced at least three times during ITER's proposed 20-year lifetime. Any maintenance or repairs must be carried out in a remote manner, which is where the DTP2 platform comes in.

The purpose of the DTP2 facility is to test and demonstrate all the remote handling operations of the ITER divertor, providing input to the final specifications of the maintenance platform.
VTT Systems Engineering and TUT constructed the mock-up that replicates a section of the ITER divertor region using components manufactured by companies in Finland (TP-Konepajat Oy) and Luxembourg (Gradel SA).

The Partners

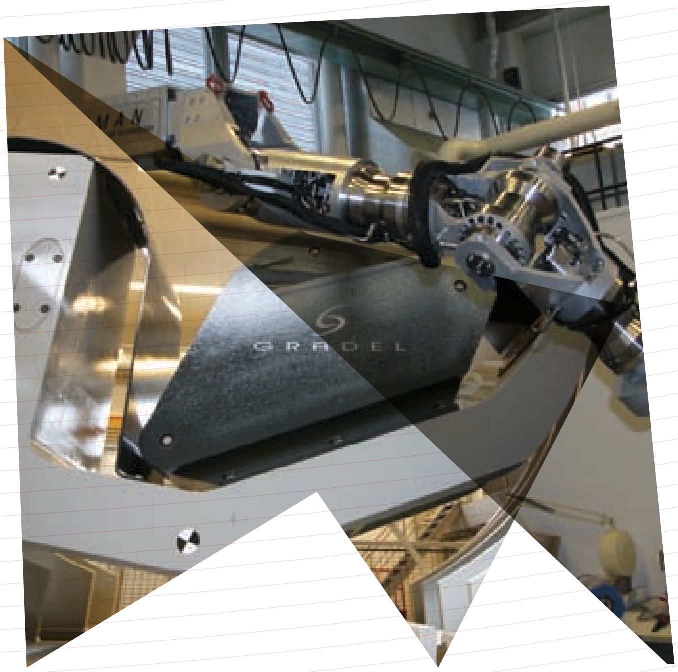
Euratom Association:
Association Euratom TEKES

Academic Partners:
VTT
Lappeenranta University of Technology
Tampere University of Technology

Industry Partners:
Adwatec Oy
Hytar Oy
Delfoi Oy
MeVEA Oy
TP-Konepajat Oy
Comatec Oy

"It is not only the planned function but also the worst case scenarios that have to be operated remotely. This leads to a very comprehensive preparation process including both virtual and real prototyping."

DTP2 Manager Mikko Siuko from VTT



Magnets

7

SUPERCONDUCTING SUCCESS

A long and mutually beneficial collaboration between the Association Euratom - ENEA and industry partners has helped establish world-beating expertise in superconducting device manufacture in Italy. The collaboration is contributing to both future fusion power projects and the development of applications for renewable energy.

Long term collaboration

For over 30 years the Association Euratom - ENEA Frascati Labs have been involved in research on superconductivity. At the very beginning the activities where basically focused on low critical temperature (Tc) superconductors (LTS), but with the discovery of the new ceramic high Tc superconductors (HTS) materials such as BSCCO (Bi2SrCa2Cu2O8 system) and YBCO (YrBa2Cu3O7 system) became the object of interest and study. Most recently MgB2 has also been added to the list of ENEA Superconductivity Division research targets.

In parallel the design, development and manufacture of superconducting materials and devices such as conductors, coils and magnets has been carried out in collaboration with Italian industry. Europa Metalli (now Luvata Fornaci di Barga) and Ansaldo Superconduttori (now ASG) have been the two main industrial partners in developing superconducting components such as strands, cables, conductors and coils for fusion magnets.

World-beating performance

In 1978 under the guidance of ENEA, Europa Metalli first started producing the conductor for the winding of the first large superconducting coil entirely designed in Italy. The device was realised by Ansaldo in 1980. This device is still working in the SULTAN facility, contributing 6 Tesla (T) to the overall background magnetic field of 12T for superconducting cable characterisation.

Thanks to this experience and to the collaboration with ENEA laboratories, Ansaldo and Europa Metalli manufactured the ITER Toroidal Field Model Coil (TFMC), successfully tested at Forschungszentrum Karlsruhe and which still holds the world record for the highest operating magnet current of 80kA. This collaboration with industrial partners continues with a focus on the design and manufacture of full size conductor samples for the ITER toroidal field coils and related projects including the Japanese Tokamak JT-60SA.

In this framework ENEA, in collaboration with Luvata, has achieved an excellent result in designing and producing a Nb3Sn CICC (cable-in-conduit conductor) sample that exhibited outstanding performance. This ITER prototype, named OST2 and cabled with strands produced in Europe by Oxford Instruments Superconducting Technologies, presented an innovative design which significantly outperformed the ITER specifications. Its Tc has been measured in SULTAN to be around 7K (target value 5.7K) at operating conditions of 68kA and 11T.

HTS strategy for innovation

Building on the expertise gained over the decades of shared R&D activities with industry, ENEA promoted the creation of the Italian Consortium for Applied Superconductivity (ICAS) between ENEA and industrial partner Luvata Fornaci di Barga e Criotec to promote power application of superconductivity and technology transfer to Italian industry.

The current front line in superconductivity is the application of HTS to magnet technology, which is still in its embryonic phase, but shows great promise. The use of HTS magnets in fusion applications will bring huge advantages through operation at fields as strong as 20T and at higher temperature close to liquid nitrogen temperature (77K), which will result in a significant cost reduction. To this end ENEA superconductivity laboratories are initiating a collaboration with CRIS (Finmeccanica Group) to produce and test a double pancake coil made with YBCO tape to study quench propagation, joint techniques and winding issues.

This winning strategy to promote HTS industrialisation will manufacture, at applied research level, a HTS based device which could then be mass produced. ENEA, working in collaboration with EDISON and CRIS, will design and make a HTS-based superconducting power unit for wind power applications. Candidate HTS materials are MgB2 or latest-generation YBCO coated conductors. The proposed unit will provide advantages such as improved efficiency improvement and a 50% reduction in size and weight compared to equivalent conventional components.

The Partners

Euratom Association:
Association Euratom ENEA, Frascati, Italy

Industry Partners:
Luvata Fornaci di Barga (previously Europa Metalli) and Criotec
ASG (previously Ansaldo Superconduttori), CRIS EDISON

This winning strategy to promote HTS industrialisation will manufacture, at applied research level, a HTS based device which could then be mass produced. ENEA, working in collaboration with EDISON and CRIS, will design and make a HTS-based superconducting power unit for wind power applications.

MORE INFORMATION

Fusion Knowledge Management

The fusion knowledge management team has been specifically formed to assist industry to exploit the high technology fruits of fusion energy research.

The unit is available to provide more information and technical details on the technologies described in the brochure other technology packages developed by the various Euratom fusion research centres across Europe.

The usual method of exploitation would be via the conclusion of licensing agreements.

Information on forthcoming industrial opportunities in ITER can be provided by the EU Domestic agency, Fusion for Energy: http://fusionforenergy.ec.europa.eu

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Fusion and Industry together for the future

The ITER experimental facility in the south of France is the vital link between research and the commercial power plants that can offer the World a potentially limitless, sustainable, safe and secure source of energy: fusion. Europe, through Euratom, is hosting ITER and is the largest investor. The existence of such a high technology research facility in the EU is already having considerable benefits for European industry. And industry is vital to the fusion programme as it will ultimately deliver ITER and the commercial power plants that will follow. ITER is a high profile joint project between the European Union, China, India, Japan, South Korea, the Russian Federation and the USA. Firms supplying components and equipment to the project will thus be able to showcase their products on a worldwide stage.

Much of the know-how involved in fusion technology is currently held by fusion research centres across Europe and a robust programme is being developed to transfer this know-how to industry to capitalise on the public investment that Europe has already made.

This brochure presents a small selection of the cutting-edge technology that is available for exploitation and gives a taster of some current industrial success stories. Fusion technologies can offer EU industry some exciting competitive advantages and European enterprises, small and large, are encouraged to seize these unique opportunities.

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