F4E NEWS

Fusion for Energy Newsletter

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ITER Worksite
An overview of past and present construction activities

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Europe develops the tooling for ITER magnets

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Setting up the conductor winding tooling station, ITER PF Coils facility, Cadarache.

How has the ITER construction site evolved?

Looking back at some of the prolific moments of last year and disclosing important details about the works to come.

Clockwise from left to right: ITER Assembly Hall building; ITER bioshield; works in the galleries of the Cryoplant building; installation of ITER transformers.

The construction activities on the vast 42-hectare ITER platform are counting five years. Currently more than 1000 people are involved and day by day this construction site is evolving. Buildings and facilities are being erected and more civil engineering works are shaping this small high-tech village that will support the operation of the biggest fusion device. To help you grasp the progress on the construction site we look back at the most exciting achievements of last year.

The roof lifting of the Assembly Hall represents the most symbolic milestone. This impressive heavy lifting operation, which gave rise to a Gulliver made of steel, has definitely changed the landscape for good. One computer and 22 hydraulic jacks lifted in perfect coordination a roof weighing 750 tonnes. The cladding of this huge facility is on-going and the works can be clearly seen at the west wing of the building. The building is getting ready for the spectacular installation of the crane rails, estimated to take place during the second quarter of 2016, which will be used to transfer the heavy ITER components to the Tokamak. Next to the Assembly Hall, one can notice the ground slab of the Cleaning Facility which is expected to be completed in early 2016. The components of the machine will enter this airlock facility to be thoroughly cleaned before they are assembled.

Standing at the Tokamak pit from high above, one can notice a 3.5 metres wide ring emerging at the centre of the Tokamak building. This shield made of concrete will be more than 30 meters high and will protect the ITER cryostat, whose task will be to generate the freezing temperatures surrounding the machine. “The concrete that will be used for the Tokamak bioshield is a type of concrete that doesn’t need to be vibrated” explains Luis Aspilcueta, working for Energhia. “The density of the metallic framework, the thousands of embedded plates weighing several tonnes and the bioshield concrete make this shield one of the most complex elements of the ITER buildings”. To understand how this protective shield will have to be constructed, a mock-up representing $1/18^{th}$ of the Tokamak bioshield was built. It is currently located at the entrance of the worksite and it represents the first stage of the bioshield’s construction. The works for the 3.5 metres thick wall have started and 620 m^3 of concrete have already been poured for the first half of wall in basement 2 with a high density of reinforcement.

Turning now to the Tokamak complex, the construction design of its first four levels has been approved, giving us a flavour of the type of works that will unfold on the site this year. The erection of the first wall on the second level (B1 level) of the Tokamak building, separating it from the Diagnostics building, has already started and will be achieved ahead of time. The efforts to deploy resources effectively and stick to schedule have started to pay off. There has also been progress in the works for the Diagnostics building. The last plot of concrete for the second level slab of the building has been poured, initiating the works of the walls and columns of this new level. Then, the reinforcement works and the positioning of embedded plates have followed, and finally the pouring of the slab in three parts. This is the most advanced building in the Tokamak complex and during the first quarter of 2016 its evolution will be further noticed. This year the construction of basement 1 will reach the Tokamak and Tritium buildings.

For several other infrastructures such as the Site Services building, the Cryoplant and the Radio Frequency buildings, 2015 has been a game changer making their presence more noticeable on the site. After having completed the gallery and walls of the Site Services building, the steel structure has become the new priority. The secondary structure is currently on going, offering a new aspect to the facility. This building, which will be providing the site with hot and cold water, as well as gas, is already weathertight.

The ITER Cryoplant facility has also started to attract the attention of civil engineers since its construction kicked off. After having excavated 22 000 m^3 and pouring the blinding concrete, the works of the galleries have started. The first wall was poured in December 2015 and the reinforcement of the building’s basement is advancing. With respect to the ITER transformers, first four Hyundai Heavy Industries transformers were delivered by the US. These powerful converters have been installed on their pits and have been filled with oil. Each of them will connect the ITER site's 400kV substation, from the French operator RTE, to the ITER distribution system. Three more transformers will be installed in the years to come.

How is ITER's sixth Poloidal Field coil shaping up?

ITER's superhot plasma is expected to reach 150 million°C and thanks to powerful superconducting magnets it will be confined. Toroidal Field (TF) coils will entrap the plasma and keep it away from the walls of the vacuum vessel. Poloidal Field (PF) coils will embrace the TF coils from top to bottom to maintain the plasma's shape and stability.

From top to bottom and left to right: Technicians carrying out manually the insulation of the joggle, PF6 Coil Manufacturing Workshop; Insulation winding tooling, PF6 Coil Manufacturing Workshop; Vacuum chamber to perform leak tests, PF6 Coil Manufacturing Workshop, ASIPP China.

The ITER machine will have six PF coils in total. Europe is responsible for five of them (PF2, PF3, PF4, PF5, PF6) and Russia for one (PF1). Due to their impressive diameter and weight, four of the European PF coils will be manufactured in a facility located on the ITER site. PF 6 is being manufactured through a collaboration agreement signed in 2013 between Europe's F4E and China's ASIPP laboratory. We travelled to the province of Hefei to see how the tooling and testing are coming along.

The sixth PF coil will have a diameter of 10 metres and will weigh approximately 350 tonnes. It will consist of nine pairs of conductors that will form nine double pancakes or 18 individual layers. The nine double pancakes will be stacked to form the PF6 superconducting coil. The ICAS consortium is responsible for the production of the conductors to be used; six conductors have already been delivered to ASIPP together with two copper dummy conductors. It is expected that by the end of the year the rest of the conductors will travel from Europe to China in order to carry on with manufacturing. This idea of working together around the globe is entirely congruent with the spirit of the ITER project where teams collaborate in a seamless manner to manufacture components.

ASIPP has already been conducting several trials to qualify the tooling where the conductor will be wound and tested in different conditions. Currently, the engineers are working on the winding of a 2x2 dummy conductor. In parallel, vacuum chamber leak tests, welding and insulation qualification tests are being carried out. Electrical insulation testing will be conducted on a 2 metre 3x3 (three by three) dummy coil mock-up and a full-size joint sample will travel to the Sultan facility for testing at the Swiss Plasma Centre, the only installation worldwide capable of testing the superconductors used in fusion devices like ITER.

First tooling for magnets manufacturing on its way to ITER

The ITER construction site is becoming an engineering hub. The first equipment for the manufacturing of some of the most powerful magnets has been assembled in the Poloidal Field (PF) coils facility in Cadarache. This is a new chapter for the facility where all the steps of coil manufacturing–winding, impregnation, stacking and cold testing–will be carried out.

The Poloidal Field coils winding tooling table, SEA ALP workshop, Turin (Italy).

The equipment has been produced under the contract signed between F4E and the SEA ALP Engineering Consortium responsible for the detailed design, manufacturing, installation on-site and commissioning on-site of the tooling needed for the winding of the PF coils. The contract is in the range of 14 million EUR, will run for approximately six years, during which time the consortium will also train personnel, maintain the equipment and decommission when all winding is completed. Gian Battista Fachin, F4E responsible for the winding tooling, explains that "This is an important milestone which comes after serious negotiations and extremely good collaboration with our contractors and other ITER parties". Moreover, the developed engineering process will be brand new. It is the first time ever that the "two in hand" technique will be used for the winding and wrapping of such a large conductor. "Two in hand" means working with two conductors winding them together in a concentric spiral and eventually connecting them at the end to form a double pancake coil.

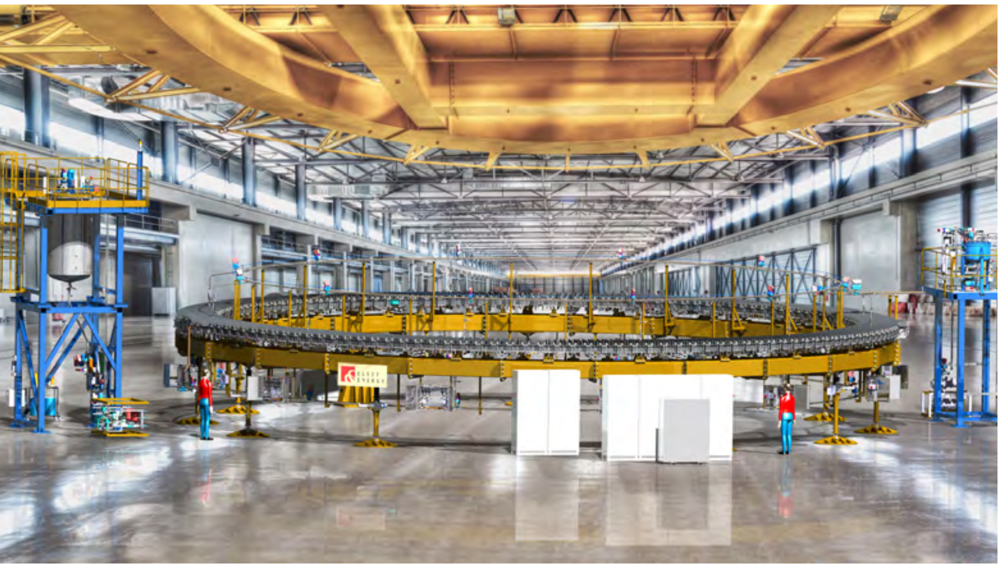
ITER will have six PF coils that together create a magnetic cage to maintain the plasma's shape and stability. Due to their impressive diameter and weight, four out of the six coils will be manufactured in the PF coils building facility on the ITER site. Europe is responsible for five out of the six PF coils and the fifth of its coils is being manufactured through a collaboration agreement between F4E and the ASIPP laboratory in Hefei, China. To give you an impression of their size and weight, the diameter of the largest PF coil is around 25 metres and the weight of the coils varies between 200 and 400 tonnes. All five European coils will be cold tested in the PF coils' facility whilst for the sixth coil, manufactured by Russia, it is currently being considered if it will also be tested in the facility.

The construction of the PF coils building has been financed by F4E through a contract signed with the consortium of Spie batignolles, Omega Concept and Setec. The building is approximately 250 metres long, 45 metres wide and 17 metres high. It includes regular services (HVAC, electrical, piping), two large cranes (one standard crane with a capacity of 25 tonnes and another crane especially adapted with a capacity of 40 tonnes), offices, technical rooms and workshop space.

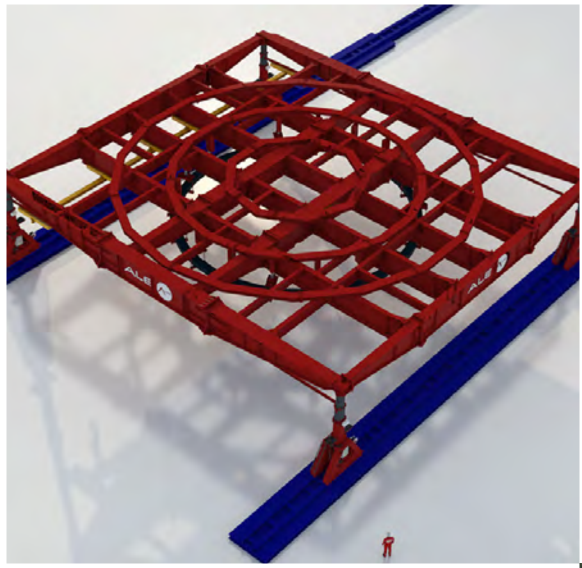
View on F4E YouTube

Europe develops the tooling to manufacture powerful ITER magnets

One of the most sophisticated engineering hubs in Europe will be located on the ITER site. The Poloidal Field (PF) coils facility will house the tooling to manufacture some of the most powerful magnets deployed in a fusion device. A range of bespoke equipment, heavy cranes, vacuum chambers and assembly stations will be developed to fabricate the magnetic coils that will maintain the shape and stability of the ITER plasma.



3D image of PF coils tooling station, Elytt Energy / Christian Lünig/ VG Bild und Kunst ©



3D image of gantry crane able to support a load of 400 tonnes , Elytt Energy ©

Due to their impressive diameter and weight, four out of the six coils will be produced in the facility, and the remaining two will be delivered to the site to be tested.

F4E has signed a contract with a consortium formed by ELYTT ENERGY, ALSYOM and SEIV for the supply of the handling and impregnation tooling required for the production of the PF coil magnets. The works will be completed in eight years and their value will be in the range of 30 million EUR. For Julio Lucas, Technical Director of ELYTT ENERGY, "This contract is a milestone for our company supplying high technology components and services. Together with our collaborators, we feel very proud and honoured that our work is going to contribute to the development of a future inexhaustible energy source for all mankind."

Initially through this contract, design and manufacturing studies will be carried out to develop the design. Then, the tooling will be manufactured and tested by the contractors, before being finally shipped, assembled, commissioned and tested at the premises of the PF coils facility. Mechanical equipment that will lift, insulate and stack the layers of conductor will be developed. The impregnation tooling will conclude the electrical insulation of the coils by applying a vacuum, following by injecting and then curing resin in the coil. Last but not least, a gantry crane able to lift a load of 400 tonnes will be installed together with a set of stations for the final assembly of the coils.

F4E collaborates with the Dalkia-Veolia consortium to equip the ITER magnets facility

F4E has signed a contract with a consortium formed by Dalkia, part of the EDF Group which is one of the world's leading electric utilities, together with Veolia, through its subsidiaries Propreté Industries Services (VPIS) and the Water activity of Veolia in France, for the infrastructure supply, operation, maintenance and waste management of ITER's Poloidal Field coils building.

The contract will run for at least five years and has a value of approximately 12 million EUR. Jean-Michel Mazalérat, CEO and General Manager of Dalkia, stated: "Thanks to this contract Dalkia has the opportunity to bring its energy services expertise to the table and contribute to a major international energy project. Together with Veolia we count ourselves among the most committed and ambitious contractors of the ITER project. We are proud to cooperate on this project and we are sure of its success."

The Dalkia-Veolia consortium will furnish the building with the appropriate infrastructure: clean areas, additional workshop rooms, electrical and other utility distribution systems as well as the construction of an external building where superconductor spools will be stored in. Furthermore, the contractor will have to maintain and operate the facility, train manufacturers and suppliers' personnel to operate the two cranes, supervise loading and unloading operations, offer surveillance and be in charge of waste management.

Once the 1 100 tonnes of the stainless steel clad niobium titanium conductor arrive on the ITER site, in order to manufacture the European PF coils, they will progressively move from the external storage area to the manufacturing hub, where the winding and vacuum impregnation processes will be carried out. During the moulding stage, epoxy resin will be uniformly applied to help the layers of the conductor to bond tightly in order to create a coil known as double pancake. Then, a second impregnation process will take place to bond the stack of the double pancakes to form one complete massive coil. The diameter of the largest PF coil is around 25 metres and their weights range between 200 and 400 tonnes.

Aerial view of the ITER construction site, October 2015© MatthieuColin.com

How are we going to lift the massive ITER components?

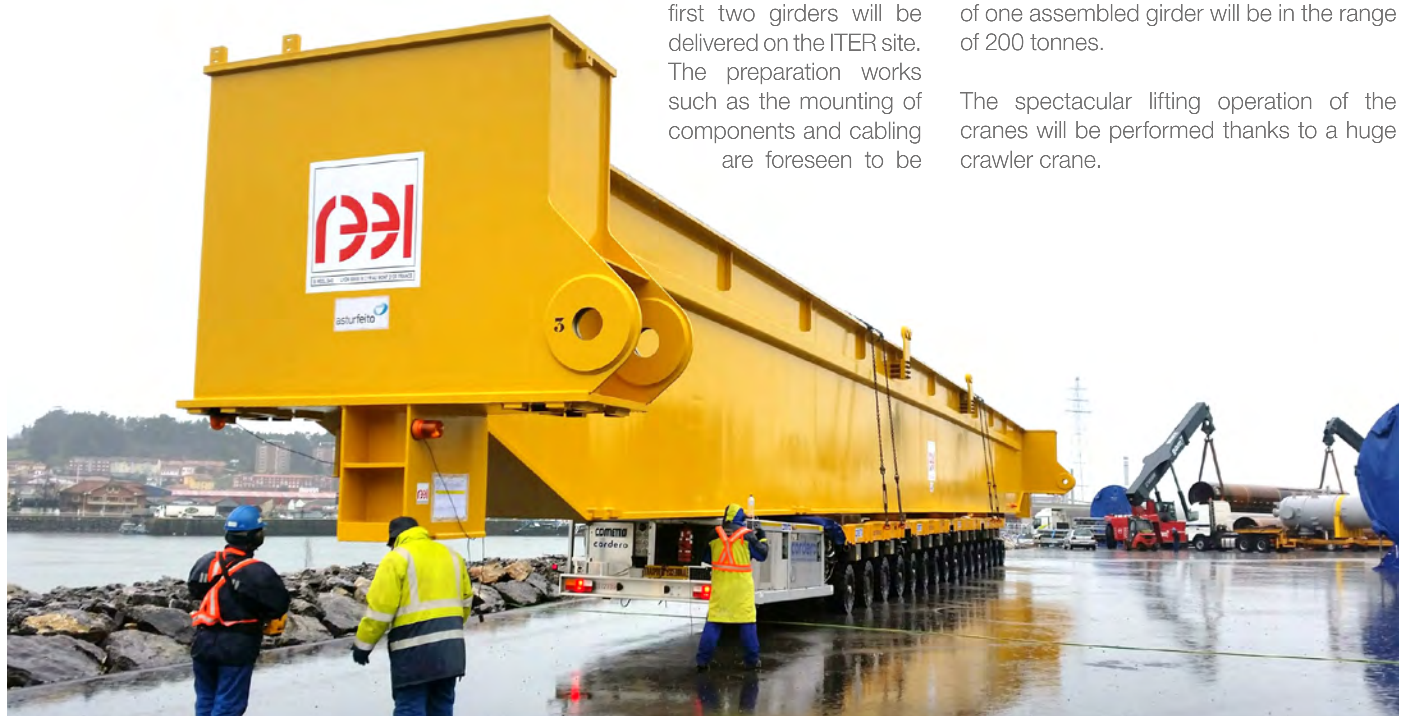
Some of the most high-tech components ever manufactured will be assembled in the Assembly Hall and transported to the Tokamak building to be fitted in the machine. Due to their impressive size and extraordinary weight, a group of cranes are being manufactured to lift the ITER components. In 2013, F4E and the NKMNOELL-REEL consortium signed a contract for their production. We got exclusive access to the facilities where they are currently being assembled and we report on their state of play.

The four electric overhead travelling cranes will be moving between the Assembly Hall and the Tokamak building, split in two areas housing the Tokamak machine and a crane hall above the machine. The heavy components will be lifted by two 750 tonne cranes. Each of them will be equipped with two trolleys, each carrying a single 375 tonne hoist. All in all they will be able to lift 1 500 tonnes, which is approximately the weight of 187 London double-decker buses. The cranes will be synchronised to work in tandem and will also rely on auxiliary cranes of 50 tonnes capacity each, used for lighter assembly activities.

The girder of the first crane has been completed by the NKMNOELL-REEL consortium. Meanwhile, the first two trolleys are being assembled. The first two girders will be delivered on the ITER site. The preparation works such as the mounting of components and cabling are foreseen to be carried out in June. With respect to the trolleys, once their assembly is completed, and have undergone factory tests, they will be delivered on site by May.

The progress of the girders and trolleys of the second crane are exactly the same at an interval of about two weeks. The girders are more than 46 m in length with overall cross dimensions of about 4.0 x 3.5 m. The weight of one assembled girder will be in the range of 200 tonnes.

The spectacular lifting operation of the cranes will be performed thanks to a huge crawler crane.



One of the four girders manufactured to support the 2 x 750 tonnes crane that will be installed in the Assembly Hall building. F4E – NKM/Reel ©

The liquid helium inner-tank, designed and manufactured by CryoAB, part of the contract signed between Air Liquide Global and EC Solutions and F4E.

Major equipment of ITER cryoplant is ready

It's hard to miss the inner tank of ITER's liquid helium tank even in the spacious facility where it has undergone a leak detection test. This massive piece of equipment, whose volume is 190 m³ and measures 23 m in length by 3.5 m in diameter, will store part of ITER's liquid helium and will be assembled subsequently inside a bigger tank. The impressive size of components is one of the underlying themes of the ITER project and as you may have guessed its cryoplant will be the biggest-ever.

Manufacturing of the inner-tank started in November 2015 and was completed earlier this year. This piece of equipment stems from a lengthy process of preliminary and final design reviews where F4E, Air Liquide Global E&C Solutions, ITER International Organization, ITER India, together with independent experts, critically assessed specifications before production started. The inner-tank, designed and manufactured by CryoAB, is made of stainless steel and has multi-layer insulation to minimise any thermal losses so that the temperature inside remains at 4 K/-269 °C. Externally it will be covered by another component, known as a thermal shield, which will be made of aluminum and its function will be to minimise any thermal losses as well. When the tank is filled with liquid helium, its weight will reach 88 tonnes, the equivalent of 58 mid-sized cars. Now here comes a twist: after the one tank goes inside the other and the entire structure is fully assembled it will be positioned 7.6 metres high. The entire system has been designed in such way so as to cope with the potential of a seismic event.

To complete the manufacturing process of the inner-tank, it had to undergo a leak detection test. It took almost half a day for technicians and engineers to inspect 500 m of linear welds performed to join the different sectors of the tank. Representatives from F4E together with teams of Air Liquide Global E&C Solutions, witnessed the exercise managed by CryoAB and acknowledged that it was successfully completed. The equipment will arrive to the ITER site towards the end of the year.

Cryoplant valves ready to be assembled on cold boxes

In the heart of the biggest fusion device extremely cold and hot temperatures will coexist. Magnets will be cooled with super critical helium to reach a superconducting state at 4.5 K, close to absolute zero, to confine the hot plasma. Europe will provide the Liquid Nitrogen (LN2) Plant and auxiliary systems. Two nitrogen refrigerators will be manufactured along with two 80 K helium loop boxes, warm and cold helium storage tanks, dryers, heaters and a helium recovery and purification system.

A valve that will control the helium flow from the 80K loop boxes to the thermal shields and cryopumps of the ITER machine, manufactured by Flowserve, India.

Technician inspecting the valve that will control the helium flow from the 80K loop boxes to the thermal shields and cryopumps of the ITER machine, manufactured by Flowserve, India.

The six valves that will control the helium flow from the 80K loop boxes to the thermal shields and cryopumps of the machine, have been manufactured by Flowserve, India, a subcontractor of Air Liquide Global E&C Solutions France, holder of the contract to deliver the LN2 Plant and Auxiliary Systems. The valves are almost five times bigger than the average cryogenic valves found on a standard helium liquefier: they measure 2.5 metres high, 0.7 metres wide and weigh over 1.5 tonnes. The maximum flow through these valves is over 4.4 kg/second which is more than twice of what is normally released through a helium valve in the biggest helium liquefiers.

India is the ITER party contributing to the cryoplant, which among other items, has under its responsibility the delivery of interconnecting lines and cryodistribution equipment. In line with the motto "one project-one team", the ITER International Organization coordinated the valves inspection exercise and delegated the responsability of validating the manufacturing of the equipment paid by Europe, to India's Domestic Agency. The equipment has passed the acceptance criteria and is on its way to China where it will be assembled on the cold boxes.

Technical progress for cryoplant equipment

The most advanced cryogenic technologies will be deployed to generate the extremely low temperatures needed for the ITER magnets, thermal shields and cryopumps. The magnets will be cooled with super critical helium to reach a superconducting state at 4.5 K, close to absolute zero, to confine the hot plasma which is expected to reach 150 million°C.

Europe has entrusted Air Liquide to provide the Liquid Nitrogen (LN2) Plant and the auxiliary systems that will cool down, process, store, transfer and recover the cryogenic fluids of the machine. Two nitrogen refrigerators will be manufactured plus two 80 K helium loop boxes, warm and cold helium storage tanks, dryers, heaters and the helium purification system.

Last year the first two heat exchangers for the 80 K loop boxes, manufactured in Amagasaki, Japan by Sumitomo Precision Products, have passed their factory acceptance testing.

At Heatric, UK, two additional heat exchangers have successfully passed a global helium leak test consisting of liquid nitrogen cold tests and a helium leak test to check the compliance of the equipment. In a nutshell, the heat exchangers were exposed to a thermal shock with temperatures ranging from to 23 ˚ C to -196 ˚ C and passed all technical hurdles and inspections without any problems.

The heat exchangers are "key components" for the refrigeration of the cryogenic system. Basically, they exchange heat between two circuits: one with helium gas and another with liquid nitrogen. They have been designed and produced meeting the highest quality requirements. The Heatric units are manufactured by a unique process known as 'diffusion bonding', a process that creates an exchanger core with no joints, welds or points of failure.

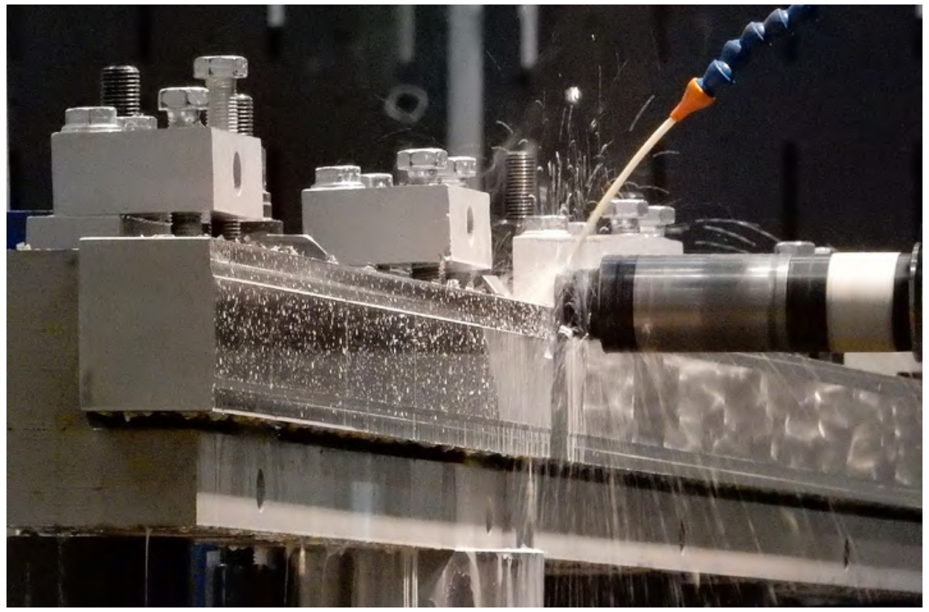
Having concluded the tests successfully, the heat exchangers will be packed and delivered to China. There they will join the two heat exchangers manufactured in Japan and will be integrated in the cold box that will be manufactured.

Heatric technical staff carrying out the liquid nitrogen test.

Heatric technical staff carrying out the helium leak test.

F4E vacuum vessel forgings are progressing

Within the framework of the contract between F4E and the AMW consortium (Ansaldo Nucleare S.p.A, Mangiarotti S.p.A and Walter Tosto S.p.A) for the fabrication of 7 vacuum vessel sectors for ITER, stainless steel forgings, which will used in the manufacturing of these sectors, are currently being produced.



A forging being machined

The ITER vacuum vessel is located inside the cryostat of the ITER device and its basic function is to operate as the chamber that hosts the fusion reaction. Within this doughnut-shaped vessel, or torus, plasma particles collide and release energy without touching any of its walls due to the process of magnetic confinement. Each vacuum vessel sector is 13 metres high, 6.5 metres wide and 60 cm thick. The weight of each sector is approximately 500 tonnes and the weight of the entire component, when welded together, will reach an impressive total of 4 500 tonnes.

Three sub-contractors, Rolf Kind GmbH (Germany), Acciaierie Valbruna (Italy) and ThyssenKrupp (Germany), have carried out the task of producing different kinds of forgings which will be used on the first three of the seven sectors (out of the total nine) that Europe is manufacturing (the two other sectors of the vacuum vessel are supplied by Korea). For the first three sectors, around 1 000 forgings will be produced in various different shapes and sizes. They are of several different weights, although the maximum weight of a forging produced is 10 tonnes, depending on what part of the vacuum vessel it will be assembled into.

The total of different forgings will weigh around 300 tonnes per vacuum vessel sector.

The forgings consist of big blocks of 316 LN ITER grade stainless steel (a type of steel which is made up of a low carbon and high nitrogen content). These blocks have been produced by mixing pellets of materials such as chromium, nickel, and of course, steel. The mixture is heated to a temperature of approximately 1 500 ˚C and poured into moulds for cooling. "Following production of these square blocks of steel, where the metal is shaped of using hot pressing – the steel block is heated to a temperature of approximately 1 000 ˚C and then hammered into shape using a large steel hammer," explains Angel Bayon, F4E Senior Technical Officer.

While the blocks are being produced by sub-contractors, the first available blocks will be shipped to the Mangiarotti S.p.A and Walter Tosto S.p.A premises for machining (when the steel block will be cut into a desired final shape and size). Following completion of machining, they will be welded in order to create parts of the vacuum vessel segments.

"... the vacuum vessel forgings are vital in contributing to the fabrication of the ITER vacuum vessel sectors, the heart of the ITER machine."

Francesco Zacchia,
Project Manager for F4E's Vacuum Vessel team.

New numerical model facilitates calculations for vacuum vessel electromagnetic loads

Imagine a force equivalent to the weight of the entire Eiffel Tower confined in one metallic doughnut-shaped container in the heart of the ITER machine (the vacuum vessel) – this is basically what will happen when the plasma, with light atomic nuclei that fuse together to form heavier ones and thus produce fusion energy, becomes instable.

Pietro Testoni using the new numerical model in order to carry out calculations of electromagnetic loads in the ITER vacuum vessel

Producing fusion is a very difficult process to recreate on Earth – gases need to be heated to extremely high temperatures (about 100 million° C) to produce a plasma which then needs to be contained for a sufficiently long period for fusion to occur. To reach these temperatures there must first be powerful heating, and thermal losses must be minimised by keeping the hot fuel particles away from the walls of the vacuum vessel. This is achieved by creating a magnetic "cage" made by strong magnetic fields, which prevent the particles from escaping and thus keeping the plasma "stable". An instable plasma (i.e. uncontained and moving around) will result in electromagnetic forces in the magnitude of 100 MN (equivalent to the weight of the Eiffel Tower) created by electrical currents interacting with the magnetic fields (electromagnetic loads) produced by the set of superconducting coils which are necessary to keep the plasma in place in the vacuum vessel.

F4E has collaborated with Guglielmo Rubinacci, an external expert from the University of Naples Federico II, in order to develop a mathematical model in a computer programme which will simulate the behaviour of the ITER vacuum vessel, during the fusion process when it is under the effect of the electromagnetic loads. It is the first time such tool has been developed and the objective is to check and test how the vacuum vessel, or also other components, of ITER will deform during the operation of the ITER machine.

Previously, other numerical models (which for example are used in the engineering simulation software ANSYS) have been used for such kind of analysis. F4E's collaboration with the University of Naples has however focused on improving the already existing numerical analysis by increasing the information available from the simulations. It is now possible to obtain the full history of the deformation of the vacuum vessel, including the magnetic damping (this means having more accurate information about the movement of the vacuum vessel during the plasma instability). This further developed numerical model allows for a better evaluation of the mechanical behaviour of the ITER vacuum vessel.

"The numerical procedures carrying out the calculations are extensively tested and validated against available experimental results", explains Pietro Testoni, Technical Officer responsible for F4E's work in this area. "We have actually managed to calculate more accurately than was originally foreseen and this allows us to fine-tune the design of the supporting structure of the vacuum vessel and improve the safety margin during the operation of the machine", he adds.

The application of this numerical model to the analysis of the ITER vacuum vessel received a great deal of praise when it was presented to the scientific fusion community during the ISFNT conference held in the South Korean Jeju Island last September. As well as facilitating the work with ITER, this numerical model will be also used in the work of developing the next generation fusion machines, such as DEMO.

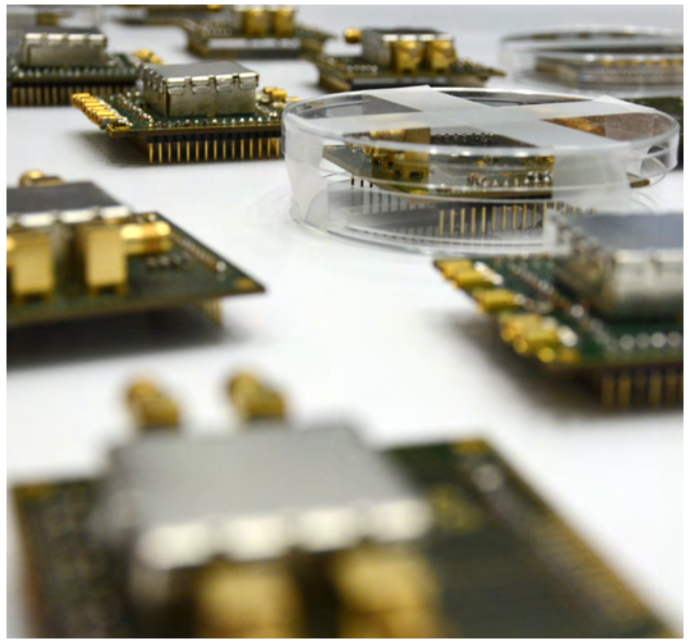
Developing the chips that will speak to ITER sensors

The bulky pieces of equipment that will operate in ITER will have to fight for the limited space inside the machine. Some components will be exposed to radioactivity and prohibit any manual intervention inside the vessel. Therefore, myriads of interconnected tools, manipulators and cranes will have to be routinely operated and inspected with the help of the remote handling system. Sensors scattered in the machine will help us collect data on the temperature, pressure and position of all equipment to carry out the maintenance works.

If the above context seems like a challenge here are two additional parameters to take things up a notch: first, how to make sensors speak the same language and second, how to decrease the volumes of polymeric cables connecting the sensors given the space limitations in the machine.

F4E, Oxford Technologies Ltd (OTL) and the Katholieke Universiteit of Leuven (KU Leuven) have been collaborating for nearly five years to solve this conundrum. The answer lies in the development of electronic chips that will be able to sustain the radiation environment; convert the analogue data picked up by sensors to a digital format and transmit the information through a single wire. A full-fledged prototype using Taiwanese technology has been created and irradiated at the SCK-CEN facility. The results are promising and the know-how is expected to have an impact on the development of other electronics to be deployed in the ITER device. In fact, the spare chips delivered through this contract will be used for demonstration activities to illustrate how they work in practice. The industrial potential of the chips is also ensured thanks to a cooperation agreement signed between F4E and KU Leuven, granting the university the possibility to make use of the foreground knowledge in future commercial activities.

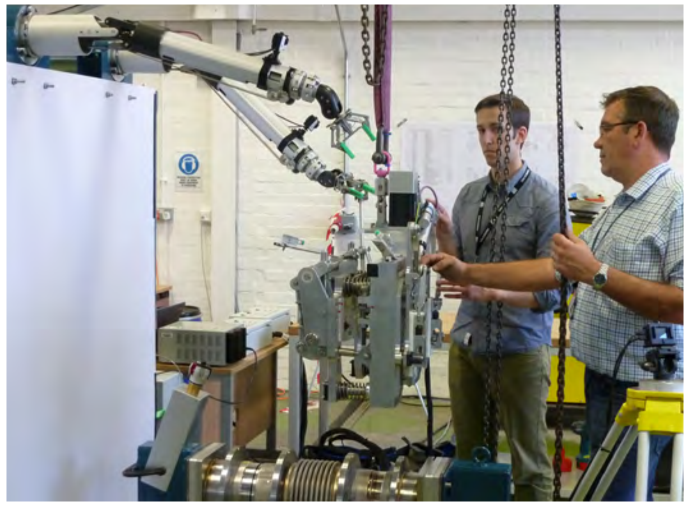
This breakthrough has pushed the R&D envelope further and has simultaneously raised questions about the fabrication of electronics which are able to sustain the ITER environment. A newly created Nuclear Integration Unit in ITER International Organization (ITER IO) will develop a procurement policy which will specify how to qualify electronics equipment to be used in the machine. Europe is expected to make a valuable contribution on the basis of the first results stemming from this fruitful collaboration.



A sample of the electronic chips stemming from the collaboration between F4E, Oxford Technologies Ltd (OTL) and the Katholieke Universiteit of Leuven (KU Leuven).

F4E and CCFE collaborate to develop tomorrow's remote handling equipment

ITER will be the first fusion device where welding and cutting of pipes will be routinely performed through remote handling. Like an orchestra, a conductor acting as the man-in-the-loop would manipulate in a seamless manner the sophisticated robotic equipment performing the different engineering tasks.



Manipulator working with a crane.

Demonstration of a manipulator master arm performing an alignment.

Cutting and welding tooling must be made together with rigorous mock-up testing in order to ensure the consistent creation of the optimum joint. The need for R&D activity in this domain and its potential spill-over as part of ITER's remote handling system led to a collaboration between F4E and the Culham Centre for Fusion Energy (CCFE). The main objective was to assess the current state of play and the development of future remote handling equipment for the alignment, cutting and welding of pipes taking as a case study the ITER neutral beam injectors. The works carried out under this contract started almost two years ago and amounted to 187 000 EUR contribution from F4E.

CCFE had to develop prototype proof of principle pipe maintenance tools and evaluate the tools and welded samples produced through parametric testing. At the end of 2015, the final meeting was celebrated at the premises of CCFE, close to where the UK's future centre of excellence for Remote Applications in Challenging Environments (RACE) will be located. During a series of demonstrations, the CCFE and F4E teams were able to witness the performance of different mock-ups and acknowledge the progress and confidence in the tooling. The mock-ups are expected to feed in two contracts managed by F4E in the fields of the divertor and neutral beam remote handling systems. The advances stemming from this R&D activity are expected to generate savings in the two contracts and decrease technical risks.

The successful collaboration between F4E and CCFE demonstrates how important the transfer of know-how is from the lab to industrial hub and highlights the fact that ITER can act as a catalyst for greater innovation and breakthroughs.

Designing the ITER Divertor Remote Handling system

F4E and Assystem UK have started working on a long list of activities leading to the preliminary design of the ITER Divertor Remote Handling system.

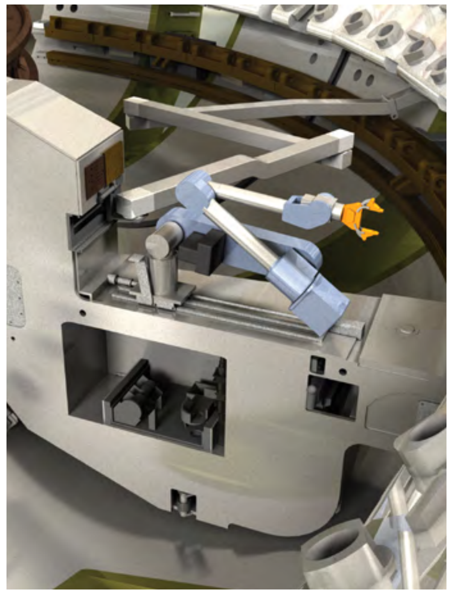
Representatives of F4E, Assystem, CCFEE, VTT and TUT at the kick-off meeting.

The kick-off meeting took place in Sunderland, at the offices of Assystem UK, gathering 30 experts who will have the opportunity to shape some of the most high-tech technologies combining man in the loop robotics and virtual reality platforms.

Generally speaking, the design phase just launched is one of the most important stages in the lifecycle of components. Technical experts tussle with issues like: how to integrate components in the machine, conduct risk analyses and finally come up with a preliminary design of the handling systems. It is a process underpinned by a lot of reviews and a continuous exchange of expertise. When this stage is completed, two more years will be required to reach the maturity of the final design prior to manufacturing.

The work stems from the contract signed between the two parties setting as an objective the manufacturing of two multifunctional movers and two toroidal movers for the ITER divertor. Other pioneers in the field of remote handling, such as the UK's Remote Applications in Challenging Environments (RACE) facility linked to Culham Centre of Fusion Energy (CCFE) and Soil Machine Dynamics Ltd (SMD) together with Finland's Technical Research Centre (VTT) and the Tampere University of Technology (TUT), will also contribute with their know-how.

Due to the nature of maintenance activities that will need to be carried out remotely and with extreme precision, a number of potential risks on tooling for cutting and welding, affecting remotely handled operations, will be addressed. The use of water hydraulics at a 50 ˚C radiation environment will be explored as well as the identification or the development of a suitable manipulator to perform complex maintenance tasks inside the ITER machine.



3D image of the remote handling system for ITER divertor – Photo credit: Assystem

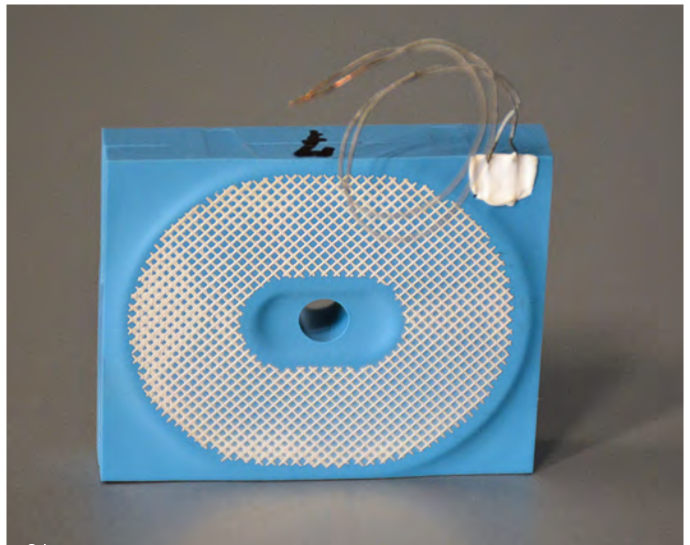
Diagnostic sensor prototypes successfully manufactured

Work is progressing in the field of ITER Diagnostics under F4E's collaboration with German company Via Electronic, which is manufacturing prototypes of sensors to be installed inside the vacuum vessel, the heart of the ITER machine. More than 200 such sensors will measure the local magnetic field in ITER during operation, contributing vital information for control of the plasma.

Each prototype consists of 34 layers of ceramic, 30 of which contain a screen-printed spiral coil circuit made out of pure silver (the remaining layers of ceramic provide external protection and electrical screening in the form of a printed grid on the external faces of the device). The individual spirals, which have a width of 400 µm and a height of 12 µm, are connected together with inter-layer 'vias' so that the whole assembly forms a single pick-up coil. The manufacturing technology is termed "Low-Temperature Co-fired Ceramic" (LTCC) and offers a very robust product because the sensor is fully encapsulated in ceramic. "It's important for these sensors to be particularly robust as they will be located in a very harsh environment, close to the plasma, with extremely limited access once ITER operation begins", explains Shakeib Arshad, F4E's Technical Officer for this development. "Although this type of technology has been used extensively in other applications, for example in medical equipment, it is unconventional in fusion because simpler technology was adequate in the smaller tokamaks built up until now."

The collaboration between F4E and Via Electronic covers the production of 40 prototypes. This follows the manufacture of a first batch of prototypes by Via Electronic in 2014 which led to several refinements to the original design. In the quest to further optimise the design, eight variants are being produced with different wiring schemes and electrical screen thicknesses.

F4E is also preparing two additional contracts for manufacture of similar prototypes by other suppliers. "As the next step, these prototypes will be irradiation tested in a fission reactor, in order to establish their performance in an ITER-like environment", says Sandra Julià Torres, the F4E officer responsible for the prototyping contracts. "Irradiation testing is costly and the results can depend on subtle manufacturing details. Prototypes from several manufacturers are desirable for this reason." The irradiation testing will be carried out by the Nuclear Research and Consultancy Group (NRG) in the Netherlands and the Centrum výzkumu Řež s.r.o. (CVŘ) in the Czech Republic. Additionally, a computer model is being developed by the Belgian Nuclear Research Centre (SCK-CEN) in order to help with interpretation of the irradiation tests.



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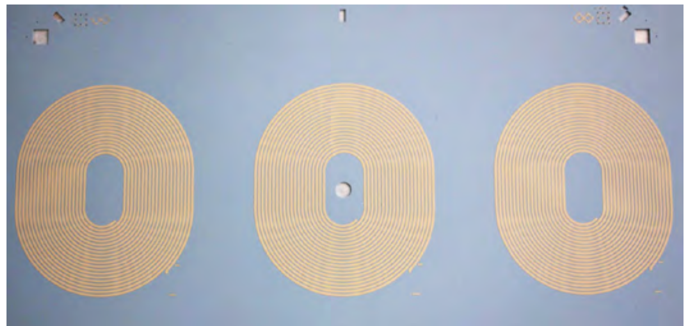


02

01 One of the LTCC sensor prototypes manufactured by Via Electronic
02 Example of the printed spiral coils which are used on the ceramic layers

F4E, industry and European Fusion Laboratories collaboration results in successful gyrotron prototype progress

The European Continuous-Wave (CW) gyrotron prototype has successfully passed the final Factory Acceptance Tests. The gyrotron is part of ITER's Electron Cyclotron Heating (ECH) system, one of the three systems that will heat the plasma in ITER to the sweltering temperature of 150 million˚C necessary for the fusion reaction to occur. The ECH system provides the heating by transferring energy from electromagnetic waves into the plasma. The other two heating systems are the Neutral Beam and the Ion Cyclotron Heating.


F4E, TED and EGYC representatives with the CW gyrotron prototype that passed all Factory Acceptance Tests

F4E is responsible for providing six of the ITER gyrotrons (the remaining 18 gyrotrons will be delivered by the Russian, Japanese and Indian ITER Domestic Agencies).

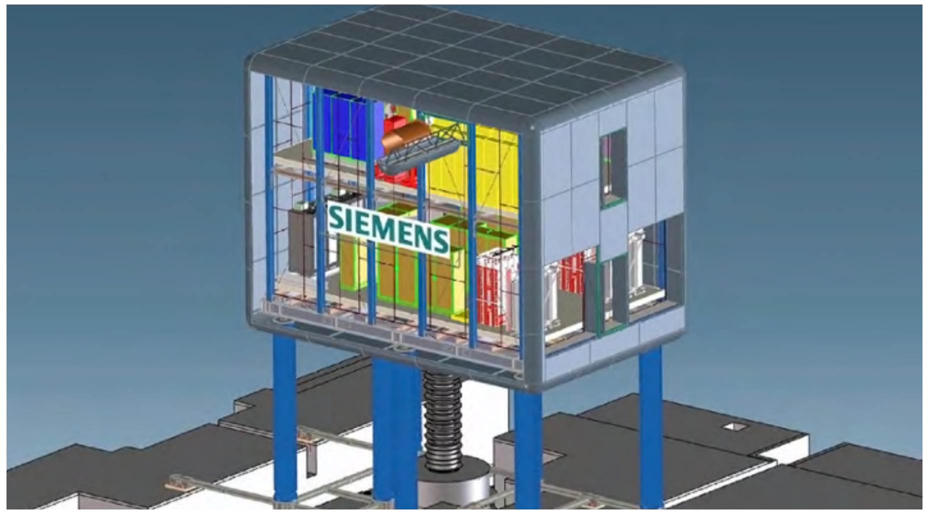
"It's the first time in Europe that a gyrotron is fabricated using this design. This work is a wonderful example of strong and productive collaboration during many years between European Fusion Laboratories (EFLs), European industry (in this case, Thales Electron Devices, a French company) and F4E – obviously, also in close collaboration with ITER IO Central Team", enthuses Ferran Albajar, F4E Technical Officer dealing with the development of Europe's gyrotron contribution to ITER in the Electron Cyclotron and Neutral Beam Power Supplies and Source Team. The EFLs are working together within the European Gyrotron Consortium (EGYC), which consists of KIT – Germany, SPC (formerly CRPP) – Switzerland, HELLAS – Greece, CNR – Italy, as well as USTUTT – Germany, and ISSP – Latvia. This gyrotron prototype incorporates novel concepts developed by the EFLs to improve further the quality of the energy beam, while making an optimal use of the technical heritage in Europe of the successful series production of gyrotron tubes for the W7-X Stellarator.

With the Factory Acceptance Tests now completed, the next step entails the gyrotron being shipped to KIT for the start of the RF tests in order to check that it fully complies with ITER requirements. The KIT facility in Germany is one of the only two facilities in Europe that has the unique infrastructure where this type of testing can be done. Testing in KIT is expected to last six months.

F4E is progressing towards a critical phase of the validation of the European gyrotron for ITER. The design needs to give solutions that meet the high ITER standards. Design and technology of high power and long-pulse gyrotrons is still rare. Requirements on the manufacturing techniques, tolerances, and materials used are outside the current industrial practices. The experience that both European industry and EFLs gain in working within this particular project will advantageously serve them in developing spin-off applications for other projects.

F4E and Siemens collaborate to develop powerful heating system for ITER

F4E and Siemens, have started to collaborate on the development of three units of equipment that will host power supplies as part of ITER's Neutral Beam Injectors (NBI). Powerful heating systems using high-energy beams will be used to push together the nuclei and trigger off a fusion reaction.



Background information: F4E and Siemens collaborate for the powerful heating system of ITER

One unit will be manufactured for a research facility operating in Italy, whose aim is to help scientists test the NBI components before they go into production mode for ITER. The other two units will be manufactured as part of the ITER powerful NBI system, designed to deliver 33 MW of power in order to inject neutral particles to the core its super-hot plasma. The works are expected to last seven years and their overall value will be in the range of 18 million EUR. Michael Krohn, Project Manager for High Voltage Decks and High Voltage Bushings at Siemens, stated that "our company is proud to be part of this international research project and to play an active role in the construction of units for the ITER Neutral Beam Injectors. We look forward to a fruitful collaboration."

The scope of the contract

Through this contract Siemens will design, manufacture and test three High Voltage units to contain the power supplies of the NBI high energy beams that will heat up the ITER plasma. Similarly, the High Voltage bushing assemblies, connecting the power supplies to the transmission lines, procured by Japan's Domestic Agency for ITER, will also be delivered through this contract. Following the successful completion of the factory acceptance tests, the components will be shipped and installed to different locations. The first unit will be delivered to the Megavolt ITER Injector and Concept Advancement (MITICA) facility in Padua, financed by F4E, Japan's Domestic Agency for ITER and Italy's Consorzio RFX, the host of the infrastructure where the NBI tests will be carried out. The other two units will be delivered to ITER, in Cadarache, where they will be integrated in with the other components of the NBI power supply system.

Think of the High Voltage decks as air insulated Faraday cages, distributed over two floors and covering a surface of 150 m^2. They will contain transformers, power distribution systems, and control cubicles weighing approximately 45 tonnes. The entire box with its structure will reach 100 tonnes and will stand on tall post insulators more than 6 metres high above the floor. The units will be manufactured in line with the seismic requirements applying to the respective installation locations (Italy/France). The bushing design also presents a degree of novelty due to the very high voltage insulation levels (1 MV) in a compact structure using SF6, a potent greenhouse gas used as electric insulator. Siemens, responsible for the manufacturing of the bushing assembly, and Hitachi, responsible for the production of the transmission lines, will have to collaborate closely so that their components fit together in a seamless manner in order to operate.

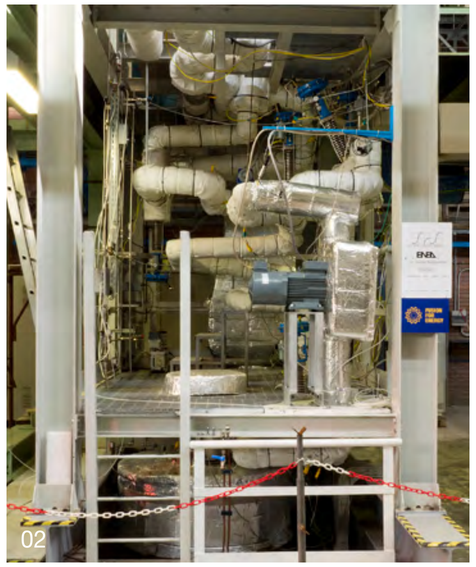
Check out where Europe is manufacturing some of the ITER components!

Towards the end of last year F4E organised a photo tour in several facilities to capture the manufacturing progress of different ITER components. The main objective was to showcase the laboratories and companies where production takes place and acknowledge the contribution of the workforces to the biggest scientific international collaboration in the field of energy.

We kicked off the photo tour in Italy to witness the progress unfolding in the ITER magnets, the vacuum vessel and test blanket modules. We visited ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo económico sostenibile, Brasimone) where F4E uses the helium loop facilities to carry out tests as part of the work for the test blanket systems. SIMIC was next on our list to see the workshop where half of Europe's radial plates for the TF coils are being manufactured. And we concluded our visual narrative on magnets stopping by ASG where the TF coils are being assembled.

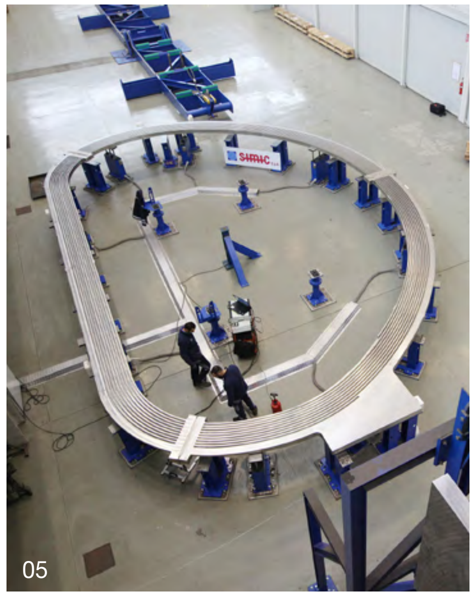
The vacuum vessel was another component that we covered through this photo tour. First, we visited the Mangiarotti workshop located in the North of Italy, which has a milling machine that supports 600 tonnes. And then concluded the tour at the facilities of Walter Tosto, where the housings - the pieces which attach the blanket modules to the vacuum vessel - are manufactured.

To view the facilities where Europe is manufacturing some of the ITER components we invite you to visit our image library on Flickr.



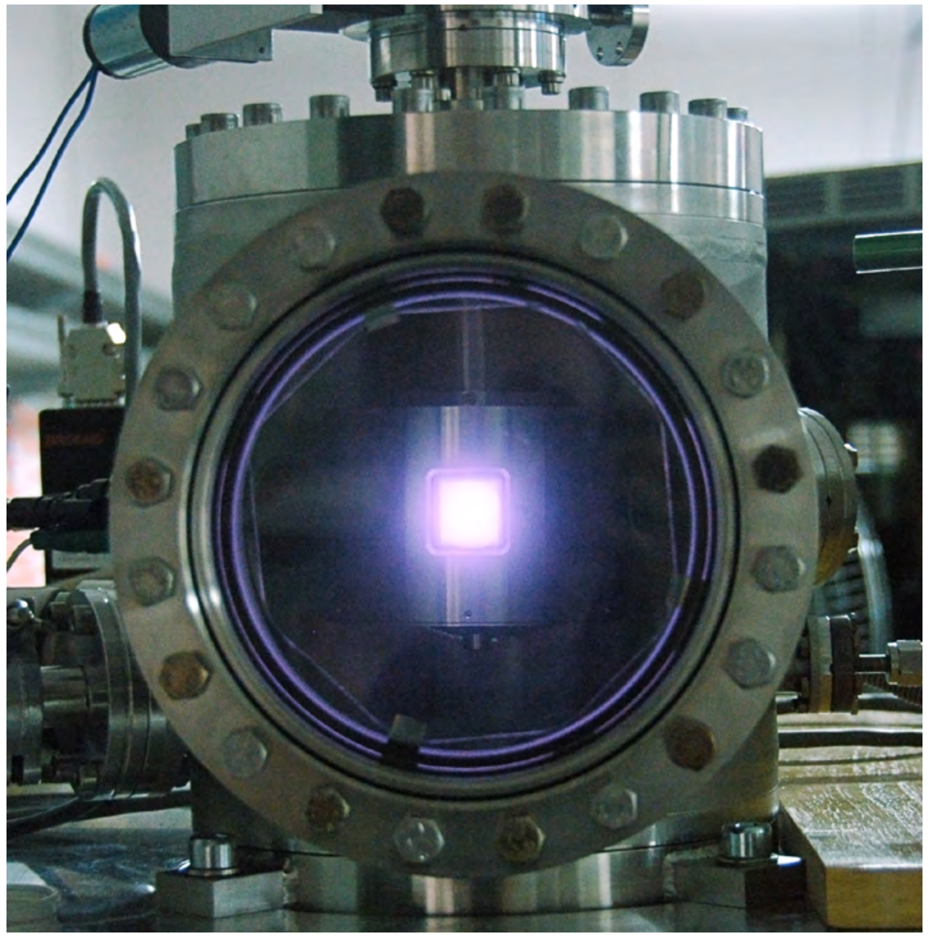
01 Neutral Beam Test Facility - Padua, Italy
02 ITER Test Blanket Modules - ENEA, Brasimone, Italy - IELLLO, one of the biggest forced circulation Lead Lithium Loops in Europe

03 ITER Vacuum Vessel manufacturing - Walter Tosto - Dimensional survey of one flexible housing for ITER vacuum vessel
04 ITER Vacuum Vessel manufacturing - Mangiarotti - Machining tool used for machining the forgings
05 ITER Radial Plate manufacturing - SIMIC - Welded side radial plate
06 ITER Radial Plate manufacturing - SIMIC - Radial plate semi-finishing to 1.5 mm over metal
07 Manufacturing the ITER TF Coils - ASG - insulation machine operating
08 Cover plate laser welding, ASG Facility, November 2015



Reflective research – F4E and partners develop mirrors for ITER diagnostics

Mirror, mirror on the wall, who is the cleanest of them all? This is the question the F4E Diagnostics Project Team, experts at Basel University in Switzerland and ITER IO, have been working together to find out. F4E is to provide several optical Diagnostics, to be located in the ITER port plugs, in order to monitor the plasma necessary for the fusion reactions in ITER to occur.

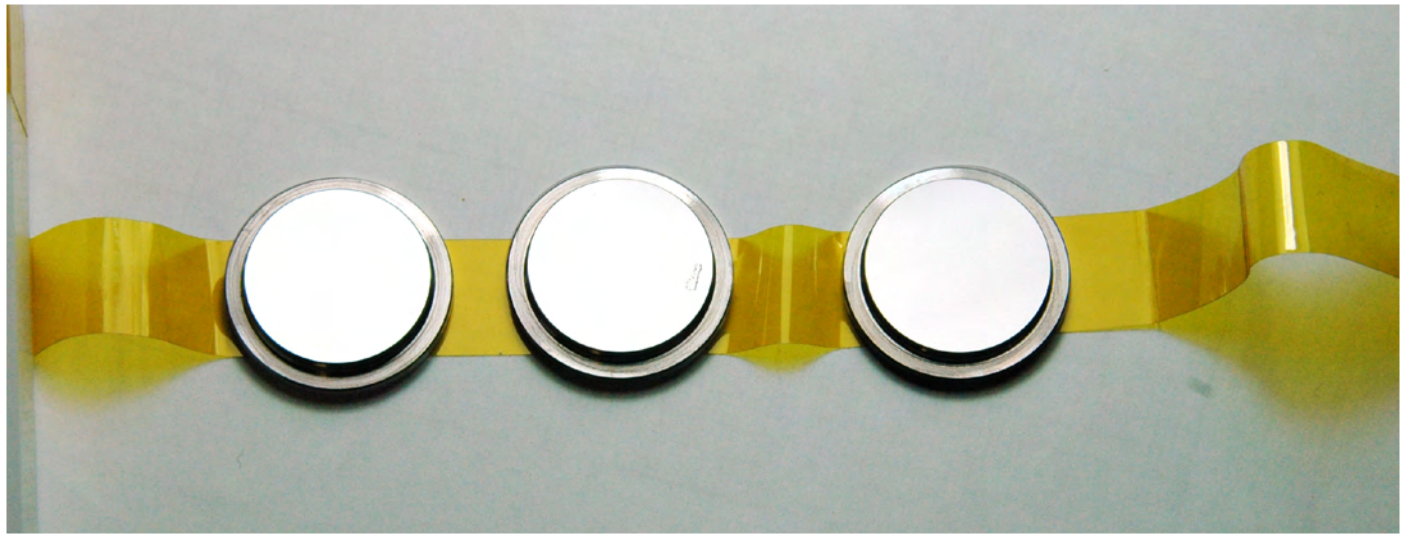


The vacuum chamber where the mirror is being cleaned with the RF plasma.

These Diagnostic systems use mirrors in various different shapes and sizes, but typically measuring up to 250 x 200 mm, to reflect light from the plasma towards detectors and cameras. When the data are analysed, they provide key information to help monitor and control the plasma. While the number of mirrors can vary depending on the Diagnostic system, all in all, the ITER optical Diagnostic systems will contain more than 100 mirrors.

The conditions that the mirrors will be subjected to on ITER are not very well known. The inner walls of the ITER machine core, where the fusion reaction will take place, are made up of tungsten and beryllium. These metals are designed to withstand the high temperatures in ITER, but are likely to create deposits on the mirrors when ITER will be operating. These deposits would cause the mirrors to lose their reflectivity, reducing the light that they bring from the plasma to the detectors and thus the decreasing the performance of the Diagnostic.

In order to learn more about the problem and develop ways of mitigating the loss of reflectivity, the University of Basel is carrying out testing on how to clean the mirrors and to determine the best mirror surface to use for the ITER environment. For these tests, small mirror samples, with



Samples of the mirrors currently being tested

deposits of tungsten and aluminium, are placed in a small vacuum chamber into which a low pressure gas is added. A radio frequency power source of around 100W connected to the mirror is switched on, creating a changing electromagnetic field in front of the mirrors. This field creates a plasma, in which some of the atoms of the gas are turned into fast-moving negatively charged electrons and positively charged ions. These energetic particles strike the mirror surface and, in doing so, 'kick-off' some of the atoms from the tungsten and aluminium deposits on the mirror surface. This process is known as sputtering and is the basis of the 'radio-frequency (RF) cleaning' scheme that F4E and ITER IO hope will give the mirrors a long life.

Research is also being carried out to find out what materials make the best mirrors to use in conjunction with an RF cleaning system. The mirrors under investigation consist of stainless steel coated with the highly reflective metal rhodium, aluminium-coated stainless steel with a protective zirconium dioxide layer (a hard material, similar to diamond) as well as the hard metal molybdenum. These three different types of mirrors are being tested to see which material will perform best after many cycles of RF cleaning. There will always be some small damage to the mirror when it is cleaned, but the amount of damage can vary depending on the material of the mirror. For example, a mirror made up of aluminium has a high reflectivity but gets damaged easily in comparison to other materials (hence the need for a protective coating).

The gas which is added to the vacuum chamber is important for determining the efficiency of the RF cleaning. For example argon, helium and neon all have different cleaning properties – which also need to be tested and optimised. For example, it is easier for the energetic ions produced from heavier gases such as argon to clean heavy deposits (i.e. with a high atomic mass such as tungsten) but these cause more damage to the mirror surface; and helium, which is a very light gas, is able to clean deposits of beryllium, which are also light, and damages the mirror surface less but is not as efficient in cleaning heavier tungsten deposits. Each mirror sample will be tested many times in order to see how long in the real operational conditions on ITER, where cleaning may be required frequently to keep the mirrors shiny and bright. Prior to testing, deposits are made on only one half of each mirror – this is done to see how the RF cleaning affects a clean surface compared to a dirty one. As the process removes the top layer no matter what the material is, it has the potential to damage the pristine mirror surfaces. By doing this test it is possible to measure this effect and at the same time see how uneven deposits will affect the cleaning.

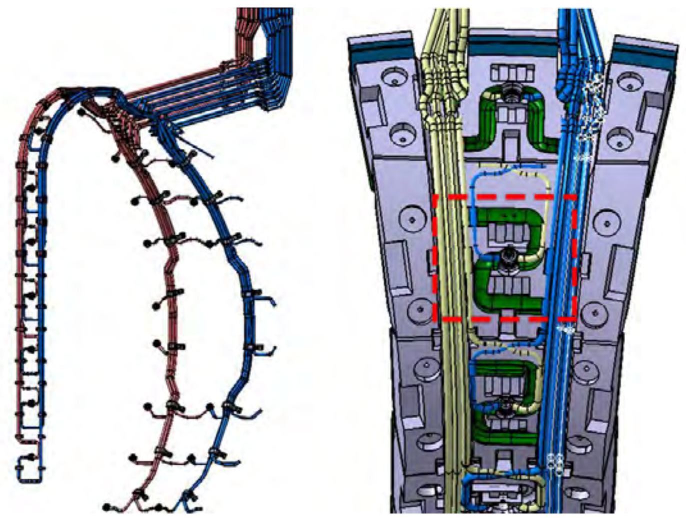
"It is the first-time that such varied (multi-cycling) tests are being carried out. In addition it is the first time special equipment will be used enabling six mirror samples to be tested at once – meaning that all six samples are subjected to the same conditions", explains Ulrich Walach, F4E's Technical Officer working with Basel University on this contract.

This first stage testing will continue until the beginning of next year, after which testing will continue on bigger sized mirrors.

Final Design Review for Blanket Cooling Manifolds completed

An important milestone for the F4E and ITER schedule, the Final Design Review (FDR) for the ITER Blanket Cooling Manifolds (BCM) has been completed.

G. Dellopoulos, F4E Technical Officer, gives details about the BCM prototype to the FDR participants



The Blanket Cooling Manifolds (BCM) which cool the blanket modules during the fusion reaction

The blanket modules are the part of the ITER machine that act as a first barrier and protects the vacuum vessel, which is the heart of the ITER machine, from the neutrons and heat produced by the hot plasma during the fusion reaction. The cooling of the blanket modules is ensured by the Blanket Cooling Manifolds which are connected to the Tokamak Cooling Water System (TCWS) and provide pressurised cooling water to the Blanket system. The BCM system is based on the multi-pipe concept, i.e. it consists of bundles of separate stainless-steel pipes running inside recesses at the back of the blanket modules. In total, the pipes make up a total length of approximately 6.5 km and together weigh around 45 tonnes.

The FDR meeting was held in order to identify, solve and finalise outstanding issues on the Blanket Cooling Manifold and check that the design solution meets the ITER requirements. It marked the final stage before the Call for tender and the manufacturing of components begins. The FDR was led by an official review panel, appointed by ITER International Organisation and chaired by Bradley Nelson, Chief Engineer of the US ITER Project Office. F4E and ITER IO representatives in areas such as materials, stress analysis, safety, control and Quality Assurance took part. The conclusions of the panel were generally positive regarding the state of readiness of the BCM design. The only exception is the readiness of the support design, which is the object of an on-going analysis that will be completed in the coming months.

The launching of the Call for tender for the manufacturing of the BCM series is planned for early 2018. The signature of the manufacturing contract is foreseen by December 2018. The time of delivery of the BCM series will be staggered from 2022 until the end of 2023.

Europe is testing steel material for the fusion reactors of the future

F4E and its contractors are together breaking new ground in the field of Test Blanket Modules and are exploring the merits of EUROFER97.

ITER will help us explore the viability of fusion energy and operate as a test bed for tritium breeder blanket concepts, known as Test Blanket Modules (TBMs) that will be located in the equatorial ports of the machine. F4E is responsible for the design, manufacturing and delivery to the ITER site of these European high-tech components. Particular importance is attached to the materials of these components because they will be exposed to neutron irradiation, which can have a negative impact on their performance. Therefore, a set of parameters need to be taken into consideration before fabrication.

The candidate steel material that Europe is considering to use is EUROFER97. Amongst its many advantages, this steel responds well to neutron activation with a good resistance to neutron irradiation. It is compatible with liquid metal and ceramic breeders and its properties seem to respond well at high temperatures. The specific elements and impurities of this steel have been carefully defined to limit its activation and the overall radioactive waste in a future fusion reactor.

Through a contract signed between F4E and Studsvik (Sweden), a series of tests will be performed to help us learn more about the physical and mechanical properties of this steel. Studsvik and their subcontractor, NRG (Netherlands), have signed a contract to carry out the work and come back with a detailed technical analysis. The works are expected to last five years and will cost approximately 3.7 million EUR.

NRG will irradiate specimens in the High Flux material test Reactor (HFR) under controlled conditions similar to those in ITER at 300 °C and 500 °C. After irradiation, the material samples will be transported to Studsvik for post-irradiation examination and characterisation of the materials. The irradiated specimens will be compared with non-irradiated ones. These tests and examinations will be conducted to quantify how far neutron irradiation affects fatigue properties, fracture toughness, causes deformation and or influences the mechanical properties of this potential structural material for blankets of future fusion reactors.

The successful partnership of the two SMEs is another example of the potential contribution made by companies that are small in size but big in innovation.

Parallel to these developments, F4E has signed a contract with Saarschmiede GmbH Freiformschmiede, Germany, to deliver various EUROFER97 finished products. A total of approximately 27 tonnes will be manufactured in the form of special plates and bars of various thicknesses from 1.2 to 45 mm. The completion of the manufacturing, testing operations and acceptance of the EUROFER97 finished products, storage and delivery is foreseen over 17 months. The supplied EUROFER97 products will be used by F4E, and its future contractors, for the TBM fabrication development and qualification of welding procedures according to industrial standards. The knowledge acquired will feed towards the licensing of the TBMs which will be installed in the ITER machine.

The latest breakthroughs from the International Fusion Materials Irradiation Facility

The Broader Approach Agreement signed between Europe and Japan consists of three scientific projects that will contribute towards the design of future fusion reactors beyond ITER. The International Fusion Materials Irradiation Facility (IFMIF), in its Engineering Validation and Engineering Design Activities (EVEDA) phase, is evolving successfully celebrating important milestones in line with schedule and budget.

Team photo in the LIPAc Control Room celebrating the successful acceptance test of the deuteron source designed and constructed by CEA

J. Knaster, F4E Project Leader of IFMIF/EVEDA explaining to Carmen Vela, Spain's Vice-Minister of Science the progress of IFMIF (from left to right: S. Herrero, Spain's Scientific Counselor to Japan, C. Vela, T.Diez-Iturrioz and J. Knaster)

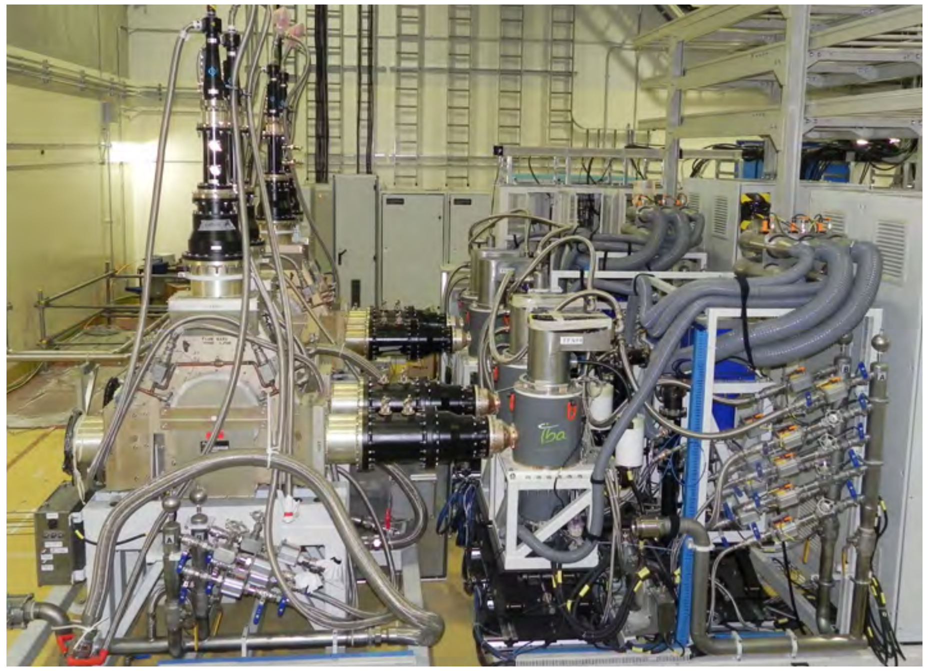
IFMIF will be a neutron source for the qualification of materials capable to withstand the impact of high energy neutron fluxes equivalent to those of deuterium-tritium reactions in a future fusion reactor. Two years ago, EVEDA provided the engineering design of the IFMIF plant and is currently validating the operation of each of its main three sub-systems consisting of the Linear IFMIF Prototype Accelerator (LIPAc), presently under installation and commissioning in the International Fusion Research Centre of the Japanese Atomic Energy Agency located in Rokkasho; the lithium loop successfully validated with the EVEDA Lithium Test Loop (ELTL); and the High Flux Test Module Double Compartment (HFTM-DC) validated in Karlsruhe (KIT).

As 2016 kicks off, IFMIF has started ticking off plenty of tasks from its list. The activities that included the validation of the lithium loop were accomplished last year. Meanwhile, the corrosion/erosion tests of reduced activated ferritic martensitic steels (Europe's EUROFER and Japan's equivalent F82H), are being carried out in Brasimone (ENEA).

All validation activities related with the Test facility have also been accomplished. For example, it has been demonstrated operating the HFTM-DC in HELOKA loop where specimens can be irradiated at temperatures between 250 °C and 550 °C with a uniformity of +/-3%. Two sets of around 40 specimens can be tested each at 12 different temperatures.

In turn, LIPAc, is designed to run a deuteron beam of 125 mA at 9 MeV in continuous wave that will validate the IFMIF accelerators. This linear accelerator, small in size but with a 1.1 MW beam power is under installation and commissioning in Rokkasho. Works are advancing at the International Fusion Energy Research Centre of the Japanese Atomic Energy Agency where the commissioning of the deuteron injector, designed and manufactured by CEA is being accomplished. The arrival of the radio frequency quadrupole by Italy's Instituto Nazionale de Fisica Nucleare is expected in February this year. It will be commissioned together with the accelerator systems provided by CIEMAT such as the radio frequency power sources, the medium energy beam transport line, and the diagnostic plate. The superconducting cryomodule, which is going to accelerate the beam to meet the target energy output, will be assembled in a clean room facility in Rokkasho during 2017.

There is also good news in terms of planning. During the Broader Approach Steering Committee meeting held towards the end of last year, a resource-loaded schedule for the accomplishment of the Accelerator facility was approved together with an extension until December 2019 with no additional funds respecting the credits assigned to these projects in 2007 when the Broader Approach Agreement was signed.



Two modules of the radio frequency power sources from CIEMAT installed at the LIPAc building of the International Fusion Energy Research Centre (Rokkasho, Japan).

First JT-60SA TF coil completed and delivered

Colleagues at F4E, CEA, ENEA and JAEA celebrated the delivery of the first JT-60SA Toroidal Field (TF) coil from the General Electric (GE) (formerly Alstom) factory in Belfort, France, to the Cold Testing Facility at CEA Saclay.

"This outstanding achievement is the result of an intense, fruitful and efficient international collaboration between all parties involved in the JT-60SA project under the Broader Approach Agreement between Europe and Japan", said Pietro Barabaschi, Home Team Project Manager for Europe's contribution to the Broader Approach (BA) project. "We are especially grateful for the voluntarily contributions by France and Italy in making the JT-60SA TF coils become reality and we congratulate CEA, the designated French contributor, responsible for the completion and delivery of this first TF coil". Indeed, together with his team, Patrick Decool, JT-60SA Toroidal Field Coil Project Leader at CEA Cadarache has worked tirelessly for several years with members of the team led by Marc Nusbaum and Gérard Billotte at Alstom/GE, the company responsible for manufacturing the TF coil.

The GE/Alstom team by the TF coil before its transportation to CEA Saclay for testing

"This outstanding achievement is the result of an intense, fruitful and efficient international collaboration..."

Pietro Barabaschi
Home Team Project Manager for Europe's contribution to the Broader Approach project.

The manufacturing process includes several steps which necessitate an unprecedented high level of precision and state of the art manufacturing tools. At each step the manufacturer has to complete a dedicated testing and quality control programme.

The remaining TF coils which need to be delivered are currently being produced. They will all be delivered, at a regular rate, by mid-2017. Throughout the process F4E has managed the technical and organisational interfaces to ensure that all the coils and all their supporting structures fit together and work together – a task that has required extensive involvement in the detailed design and quality assurance implemented by the different contributors.

Following delivery at the Cold Test Facility at CEA Saclay, the first TF coil will now be tested to ensure that it will be able to work well in the ITER machine. It will then be transported to the JT-60SA site in Naka, Japan.

What is a Toroidal Field (TF) coil?

The TF coils are one of the key components for the scientific success of any tokamak. They are gigantic "D" shaped superconducting magnets which will create a magnetic cage where the plasma will be confined – that is to say, to keep the hot plasma from touching the walls of the vessel of the JT-60SA machine. The JT-60SA superconducting coils are among the largest in the world. Together the 18 coils, each 7 metres high and 4.5 metres wide, will produce a magnetic field at the core of the plasma which is equivalent to around 100 000 times the Earth's magnetic field.

European Parliament Rapporteur Marian-Jean Marinescu witnesses first-hand ITER progress

On 5 February 2016, Marian-Jean Marinescu, Budgetary Control Committee Rapporteur for Fusion for Energy (F4E) and European Joint Undertakings made his first visit to Cadarache where ITER, the world's greatest energy research experiment, is under construction.

F4E Director Johannes Schwemmer, MEP Marian-Jean Marinescu and F4E Project Managers visit the Tokamak complex during the tour of the buildings F4E is currently constructing.

F4E Director Johannes Schwemmer welcomed MEP Marinescu and accompanied him on a tour of the different buildings being constructed by F4E, with key stops at the Tokamak complex and the Poloidal Field coil facility where a production line for some of the world's largest ever superconducting magnets is being set up. Along the way he had the opportunity to meet several of F4E Project Managers and hear directly about the challenges of working on such a technically demanding international project.

MEP Marinescu, an aerospace engineer himself, took the opportunity to find out more about the way in which the project is being managed and how costs are controlled: "With the implementation of the ITER and F4E Action Plans, I am pleased to see that project management is being put at the heart of the ITER project". Bernard Bigot, the Director General of ITER Organization (IO) and members of his senior management team provided further explanations on the overall ITER project progress.

The Romanian MEP took the time to meet and interact with a number of staff members from ITER IO, F4E and the industrial contractors. He also did not miss the opportunity to shake hands with many of his compatriots who were eager to share their experiences on working to make fusion energy a reality. Mr Marinescu concluded his visit with a "virtual" tour through a 3D computer model that shows the complexity of assembling the million components that make up the ITER experiment.

MEP Marinescu is the Rapporteur of the European Parliament Budgetary Control Committee which recommends to the European Parliament the granting of the annual budgetary discharge procedure.

The Budgetary Control Committee is expected to make its recommendation for the 2014 budget in time for a European Parliament decision in April 2016. The visit allowed for a better understanding of the current status of the ITER project, as well as of the progress of the different actions which are being implemented by ITER IO and F4E to put the project back on track.

The 'discharge' is the final approval of the EU budget for a given year following the audit and finalisation of the annual accounts. It is granted by the European Parliament on a recommendation from the Council. The 'discharge' means, in simple terms, the approval of the way F4E implemented the budget in that financial year.

Business opportunities and the roadmap towards the new ITER schedule are unveiled

The Monaco International ITER Fusion Energy Days (MIIFED) gather representatives from the seven parties of the biggest energy collaboration, together with multiple companies and laboratories currently involved. Those flirting with the idea to contribute with their know-how also show up to get first-hand information about existing subcontracting opportunities and future contracts.

Johannes Schwemmer, Director of Fusion for Energy (F4E), presenting the direct and indirect ITER benefits, MIIFED-IBF 2016.

This MIIFED edition came, however, with an aggressive business twist aiming to boost the entrepreneurial spirit of all participants: the organisers of the ITER Business Forum (IBF) joined forces to convert this three-day meeting point into the rendezvous of commercial deals.

The participation rate was impressive bringing together 556 participants from 26 countries representing 285 companies and fusion labs. To help attendees network and form future partnerships, the organisers offered the possibility of business to business (B2B) meetings. The majority of them grabbed this opportunity and more than 653 meetings took place. When needed, F4E representatives were there to assist and clarify any questions regarding Europe's strategy. An exhibition consisting of 34 stands served as a complementary space for more informal exchanges. To give some context to the nature of the talks and offer a glimpse of the latest technical developments, three technical tours were planned for 60 participants taking them to the ITER construction site, the facilities of CNIM and SIMIC, where some of Europe's components in the field of magnets are being manufactured.

A total of 75 speakers addressed the political landscape that surrounds ITER and a wide range of technical presentations tackled the progress of components and the contracts in the pipeline. H.S.H. Prince Albert II opened the event delivering an inspiring speech about climate change, the recent developments resulting from COP21 and the role of fusion energy and ITER. Under his reign Monaco will use best practice to tame its CO_2 footprint and promote a sustainable model. Bernard Bigot, Director General of ITER International Organization, explained the wave of changes that have

Company representatives meeting with F4E members of staff during business to business meetings (B2B), MIIFED-IBF 2016

been initiated during his mandate and elaborated on the path towards a new ITER calendar. The merits of stronger integration between teams, the design revision of critical components and the comprehensive bottom-up review of all activities were spelled out. For Bigot "the challenge is to switch from a research oriented approach to more project management structure." There were references to November's 2015 ITER Council (IC 17) meeting where organisational improvements have been acknowledged and the recruitment of senior management together with the mapping of integrated operations have been deemed as positive. "The next target is to establish a new baseline and for this we need a political decision," explained Bigot. The ITER Council has agreed to instill a better project culture and by 2016-2017 to approve the schedule that will be communicated to all parties. Meanwhile, the ITER Council will monitor the achievement of 29 key milestones to verify that ITER is on track. When will the schedule for first plasma be communicated? The revised calendar was presented last year and would require some further adjustments so that it is formally communicated in June 2016.

The European Commission's Massimo Garriba, Director for Nuclear energy, safety and ITER, highlighted the financial, environmental and strategic importance of ITER. He stressed that approximately 75 % of the funding for ITER construction (i.e. around 4.5 billion EUR) is for components and activities that result in the creation of new knowledge and cutting-edge technology. More than 766 procurement contracts for a value of 3.5 billion EUR have already been awarded to European companies; and more than 145 grants have been signed with European industries and research centres. ITER is seen as a key step to demonstrate the viability of fusion as an energy source which can lead to future fusion power plants. As such, ITER is considered a strategic element of President Juncker's objective for clean and secure energy.

F4E Director, Johannes Schwemmer, echoed Europe's determination to honour its obligations and follow up rigorously all manufacturing activities. He used this occasion to formally introduce himself to the fusion community, referred to the main achievements of the project and offered an overview of the business prospects in the years to come. To showcase the direct and indirect financial benefits stemming from ITER, he presented a selection of case studies demonstrating commercial, financial or RD breakthroughs and concluded with the views of some contractors.

The hospitality of the Principality of Monaco and the hard work of colleagues from ITER IO and Agence ITER France left the best impressions. This time, however, there was a tone of confidence and assertiveness that ITER is moving in the right direction and that all parties are determined to ensure its success.

Johannes Schwemmer takes up duties as Fusion for Energy's Director

Revamping Europe's contribution to ITER will be his main priority which will underpin most of the actions that are being carefully designed in collaboration with stakeholders.

Johannes Schwemmer, F4E Director

A close and effective collaboration with all ITER parties to build further and firmer synergies; a constructive interaction with policy-makers based on transparency and trust; a dynamic industrial policy meeting the needs of companies are some of the challenges that he plans to tackle. His solid background on project management is also expected to trigger off a series of improvements in the way F4E is organised and delivers.

Joaquin Sánchez, Chair of the Fusion for Energy Governing Board, expressed on behalf of all members, their will to collaborate and offer their guidance to the newly appointed Director so that Europe honours its commitment in the various projects that aim to bring fusion energy closer.

"It is a great honour to be appointed Director of Fusion for Energy and to serve this organisation with leadership, loyalty and vision. I'm fully committed to managing effectively the European contribution to ITER, this unique global collaboration that has the ambition to make fusion a viable option for abundant and clean base load energy supply", Schwemmer said.

Johannes Schwemmer has been working in the fields of information, telecommunications and business technology for more than 25 years. He has a proven track record in international collaboration, project management and business strategy. He was a partner at Antevorte, a German consultancy specialising in performance management. Previously he worked for eight years at Unify GmbH & Co. KG, a global market leader in unified communication solutions present in 100 countries, where he held different positions as Vice-President for Global Project Management and Service Optimisation, and Vice-President for Global Training. Earlier in his career he worked at Siemens Business Services, as Vice-President for Risk Management and Strategic Alliances Management. He holds a European Joint Degree in Electrical Engineering from the University of Karlsruhe (KIT), Germany, in collaboration with the University of Essex, UK, and ESIEE Paris, France.

The Director is appointed by F4E's Governing Board for a period of five years, once renewable up to five years. The appointment is made on the basis of a list of candidates proposed by the European Commission after an open competition, following a publication in the Official Journal of the European Communities.

Fusion for Energy
The European Joint Undertaking for ITER and the Development of Fusion Energy

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