# F4E NEWS

Fusion for Energy Newsletter

No. 21 / May 2017

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The ITER Vacuum Vessel is taking shape - October 2016 © Walter Tosto Spa

Aerial view of the ITER construction site, October 2016, ITER IO ©

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# Civil engineering works reach a crescendo on ITER construction site

Under the supervision of F4E, in collaboration with ITER International Organization (IO), and their contractors, more than 1 700 people have been working round the clock to meet the tight deadlines. The field hosting the biggest energy experiment to date has witnessed the construction of new buildings and the progress of some extremely sophisticated civil engineering works. We look back at some of the impressive achievements paving the way for the arrival of more equipment and the handover of facilities to assembly teams.

F4E and ITER International Organization have hailed a historic moment after having connected the construction site of the biggest fusion device to France's grid. Up until now, there has been a temporary connection supplied by France's CEA, offering 15 000 V. As of the end of March, a direct connection has been established offering a supply of 400 KV, which thanks to the ITER transformers provided by China and the US, will be converted to 22 KV and 6,6 KV for the needs of the ITER site and components.

To achieve this milestone the teams of technical people have been working for nearly a year in order to have everything ready to perform trials.

The great deal of symbolism behind this technical achievement can be interpreted in two ways: first, this connection will let us explore the full potential of the machine that promises to test the feasibility of fusion energy like no other, and second, we have been entrusted with the responsibility to contribute to the energy grid in the decades to come.

At the Tokamak Complex, where the heart of the ITER machine will beat one day, under a thick mesh of rebars and concrete, the water detritiation tanks – Europe's first equipment delivered to ITER, have been installed. In order to accelerate the pace of construction, different floors are being built in parallel. The slab and walls of the first floor have been completed. Perhaps the best way to grasp the evolution of the works is by monitoring the rise of the bioshield. The cylindrical concrete structure which will crosscut the entire Tokamak building from top to bottom, in order to host the ITER cryostat, has risen with civil engineering works unfolding on the third and fourth floors. Nearly half of the bioshield has been completed and the entry point for the Neutral Beam Injectors has become visible on the walls of the second floor of the building.

The civil engineering works at the Assembly Hall have been successfully completed. The massive 60 m tall building overlooking the platform has attracted the attention of all visitors on-site. Its impressive size and the spectacular lifting operation of its huge girders, able to lift up to 1 500 T, have marked last year's narrative. Two additional auxiliary cranes, able to lift 50 T each, have been placed in the Hall and earthing plus lightning have been completed. More progress is being made with the installation of electrical cabling, together with the fitting of the Heating Ventilation and Air Condition (HVAC) infrastructure, in order to have the building ready this spring for the assembly of the first equipment.

Due to the delivery of the ITER Cryoplant compressors and the 35 m long quench tanks, there has been a growing momentum for the cryogenic system of the biggest fusion device. Civil engineering works for the first columns kicked off in November last year. The workforces have started installing the steel structure and by August 2017 this facility is expected to be ready for assembly operations. Currently, all concrete columns have been installed, slabs have completed together with cladding and roofing nearly finalised.

Construction in progress at the Cryoplant facility, April 2017, © E. Riche/ITER Organization

Technical teams checking the cabling where the ITER substation will be connected to France's grid to receive 400 kV, November 2016, © LNM

Civil engineering works progressing at the water basin and cooling water stations of the ITER device, April 2017, © E. Riche/ITER Organization

In the Site Services facility, where the chiller and deminelarised water plants will be housed together with the air compressors, maintenance and instrumentation workshops, more than half of the internal doors have been fitted and the external doors are being manufactured. Lightening and the HVAC installation have also started in the 60 m long facility.

The civil engineering works, where the ITER transformers are located, have finished. And there has been more progress vis `a vis the installation of the oil and drainage pipes.

Works at the basin and the cooling water stations are also on track. Almost 70% of the slab is ready, 12% of the columns have been installed and the first walls have started to be erected. The basin has the capacity to store approximately 20 000 m³ of water.

Meanwhile, the first alarm survey system to be used on the ITER site has been successfully installed. This is the result of a fruitful collaboration between F4E, ITER IO and the Spanish system and software engineering company GTD Sistemas who have integrated the F4E requirements into an efficient solution.

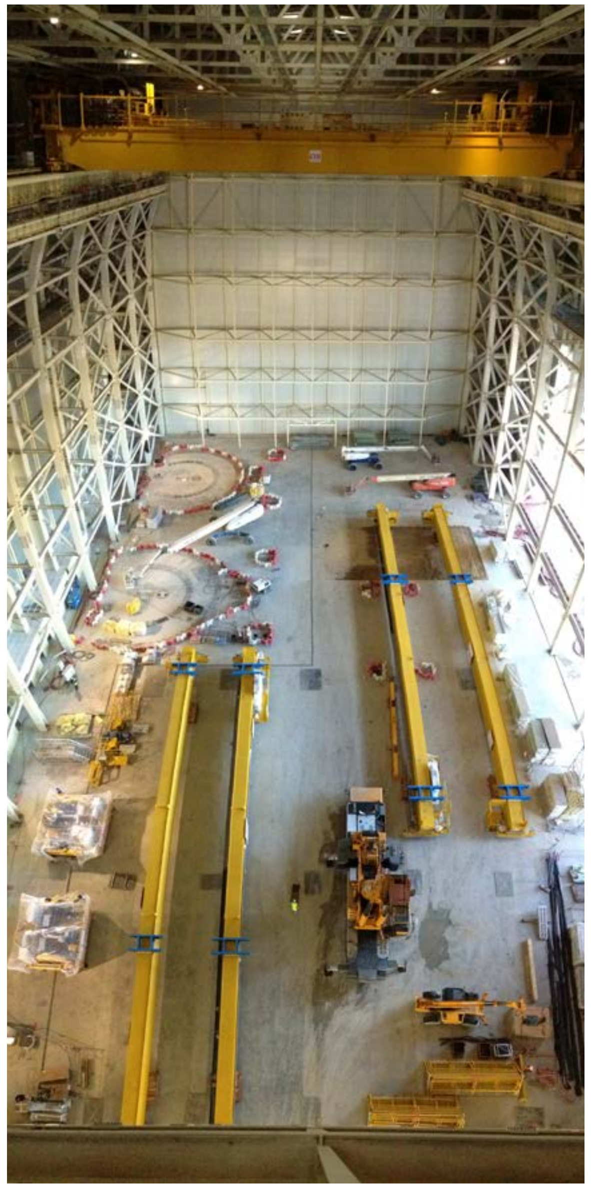
This alarm survey system aims first and foremost to protect the people working on the ITER site and its facilities, for example by detecting a fire. It is an electrical system which processes information inputs received





The entry points of the ITER Neutral Beam Injectors at the second floor of the Bioshield, Tokamak Complex, December 2016, © Engage

Aerial view of the Site Services building, Septemberber 2016, © LNM



The two auxiliary 50 T cranes at the Assembly Hall, November 2016, © Engage

from sensors. The information received from the sensors and the programming of the software within the system allows it to transfer these alarms to a permanent alarm survey guard in order to undertake relevant actions. Should a sensor detect an event such as a fire, an alarm will be immediately triggered in the control room, providing details of the source and displaying a list of sequential actions to be taken by the guards on duty.

"Work has taken approximately one year but the alarm survey system is a tool which will be constantly developed", says Roberto Campagnolo, F4E's Project Manager responsible for dealing with the development of the alarm system. "For the moment, it is being used for the ITER site's contractor areas, as well as the Poloidal Field coil building. The plan is that all the buildings on the ITER platform will be connected to this system within the next few years", says Cyril Lescure, in charge of the integration of all sensors, actuators and operator interfaces.

Without a doubt 2016 has been a turning point for the construction site. The civil engineering works have unfolded in complex buildings, underpinned by strict safety requirements, and more conventional facilities ready to host tooling and people. The arrival of the first components on-site, the connection to the grid and the handover of the Assembly Hall suggest that this year will be even more promising!

# First sector of Vacuum Vessel is coming together

The ITER Vacuum Vessel, the heart of the ITER machine housing the fusion reaction, is a complex component of fine engineering. Due to its enormous dimensions, its shape necessitates massive stainless steel pieces of metal being joined together by welding challenging geometrical forms.

Each sector of the Vacuum Vessel consists of four poloidal segments joined together. For the first time, smaller parts of a poloidal segment have been welded together to form a bigger piece – the first sub-assembly of the poloidal segment 2 of one of the Vacuum Vessel sectors.

The successful completion of the welding of this part of Vacuum Vessel sector is an important milestone. This is the first piece which exemplifies how forgings in different sizes are machined into different shapes which are then joined together and welded onto two very large stainless steel plates which make up the first part of a Vacuum Vessel sector. In total, this sub-assembly of sector 5, boasts a length of 2.2 m, a width of between 2.3-3.3 m, and a height of 35-50 cm. In total, the sub-assembly weighs over 6 T.

The AMW consortium, consisting of companies Ansaldo Nucleare S.p.A, Mangiarotti S.p.A and Walter Tosto S.p.A, in charge of supplying five sectors to F4E, have been dealing with this crucial sequence in the fabrication of Europe's contribution to the ITER Vacuum Vessel. It was carried out jointly at the AMW sub-supplier ProBeam facility in Germany and at the Walter Tosto facility in Italy.

In total, 20 weldings, with an overall welded length of around 25 m, were completed during the short time period of two days. Initially the separated, smaller parts were assembled together at the Walter Tosto facilty and then transported to the ProBeam electron beam welding chamber (the only such big chamber existing in Europe – it has a volume of 6 300 m$^3$, roughly the same volume as an Olympic-size swimming pool). Each individual part is welded separately in the vacuum chamber – the complexity of the welding technique and the precision needed means that each welding takes around three hours to complete.

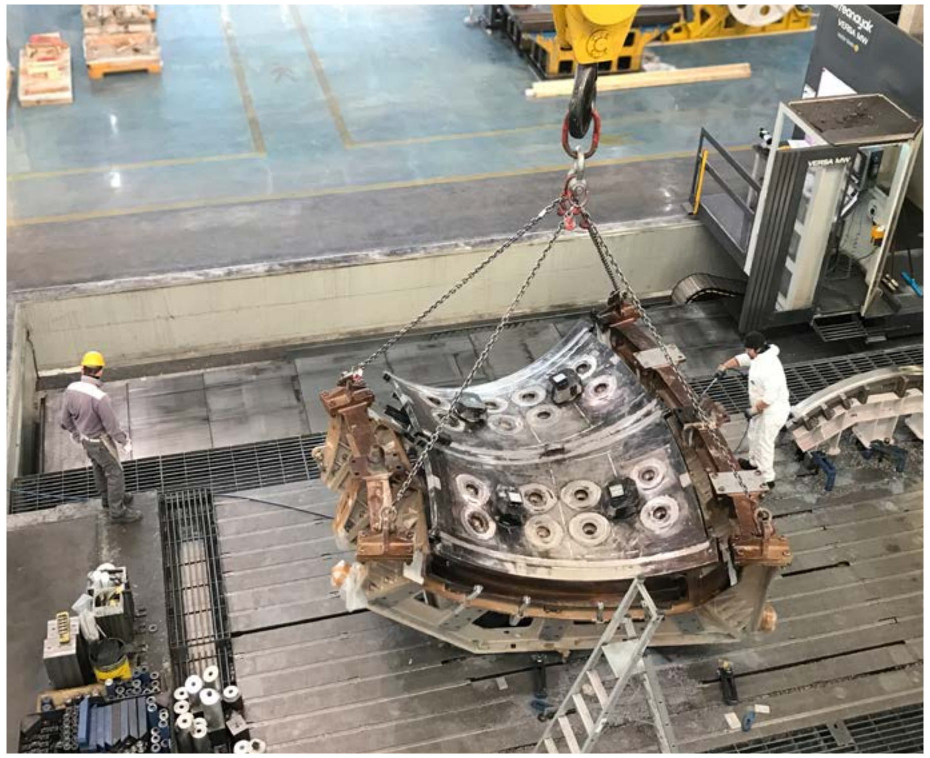
*“F4E and AMW have worked together intensely to ensure a successful outcome of this manufacturing. We are grateful to the AMW members of staff who have worked both double and triple shifts, including weekends, in order to keep the tight schedule on track and bring about this achievement. We see this development as a stepping stone to full fabrication.”*

**Francesco Zacchia**
F4E Vacuum Vessel
Project Team Manager



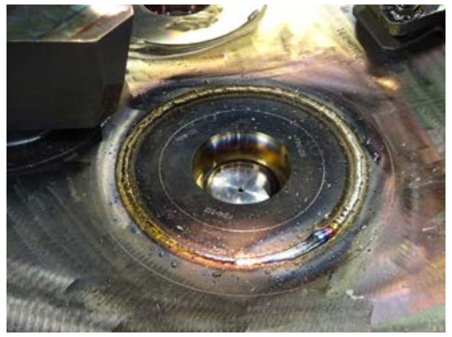



For the first time, smaller parts of a poloidal segment have been welded together to form a bigger piece (Image courtesy of Walter Tosto)



The first sub-assembly ready for lifting by crane at Walter Tosto

The sub-assembly in the vacuum chamber ready for electron beam welding of flexible housings

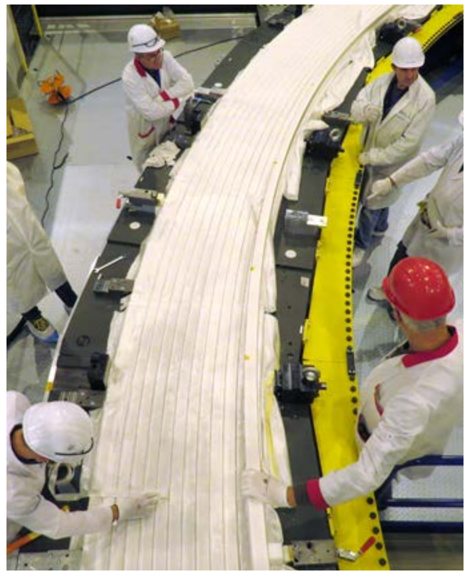


Close-up of the sub-assembly in the vacuum chamber after electron beam welding of flexible housings

# Success for ITER Poloidal Field coils manufacturing trials using dummy conductor

The momentum in the impressive Poloidal Field (PF) coils facility is growing as works are accelerating. In ITER's first industrial on-site hub some of the most powerful magnets will be manufactured. A range of bespoke equipment, heavy cranes, a vacuum chamber and assembly stations are already in place to produce the coils that will maintain the shape and stability of the ITER plasma.

The first complete layer using a dummy conductor reflecting the dimensions of ITER's fifth Poloidal Field coil, Cadarache, November 2016



Team of technicians checking the manufacturing of the insulated dummy conductor, ITER Poloidal Field coils Facility, Cadarache, November 2016

Due to their impressive size and weight, four out of the six gigantic coils ranging between 17 and 25 m in diameter, and weighing between 200 and 400 T, will be made in this facility. F4E is responsible for another coil, currently fabricated in China, under an agreement signed between the two ITER Domestic Agencies, and Russia will also produce one.

With all F4E contracts signed in the area of PF coils and contractors working hard, there is visible progress. In the PF coils facility, where temperature needs to be rigorously controlled, there is confidence in the air. First, a large part of the tooling is fully assembled. Second, the successful manufacture of the first complete layer of the dummy coil, in which all main winding activities have been carried out, open a new chapter for the six ITER magnets. Which are the main fabrication stages so far? First, the conductor has been unspooled, straightened, cleaned with in a ultrasound bath, bent to the correct radius and then sandblasted, washed and dried before being finally insulated with five layers of glass/polyimide. A team of ten people from F4E, CNIM, Sea Alp and ASG, has been involved in this task.

The winding of the second coil layer of conductor has been completed. It has formed, as it is known in the ITER jargon, the first dummy Double Pancake (DP) for the fifth Poloidal Field coil, which has a diameter of 17 m and a weight of roughly 30 T. Two Helium Inlets will also be welded on these inter-layer joggles to supply the DP with helium at a temperature close to -269 °C. Then, the DP will be insulated and then electrically tested. When the second layer is completed, the dummy DP will be lifted and moved to the next working station in order to prepare the electrical connections between conductors





Representatives of F4E and ASIPP in front of the first layer of the dummy double pancake

The dummy double pancake completed, ASIPP, China

and add further insulation. Subsequently, the DP will be moved to the next station where it will be impregnated with epoxy resin. Finally, the DP will be sliced in eight sections and stacked to reproduce a mock-up of the entire PF coil.

For Pierluigi Valente, Technical Responsible Officer for the supply of the European share of PF coils, the installation of tooling and the development of engineering processes are of great importance. "What you see today in the PF coils facility is the result of the work which started almost three years ago. We have been collaborating with ASG to integrate all these manufacturing stages and seeing them in practice is extremely gratifying" he explains. "All these stages are essential and need to be carried out carefully in order to validate the manufacturing processes. For example, it is challenging to control the exact length of conductor that we need to unspool and then accurately measure the turns wound on the table" explains Pierre Gavouyere-Lasserre, F4E's Technical Officer overseeing the PF coils' winding. The progress of tooling has also been an important achievement for F4E's Technical Officer, Gian Fachin, who has been following this task. "We started almost a year ago the assembly of the winding table, which was produced by the SEA Alp consortium, and today nearly 80% of the equipment, manufactured by Elytt Energy, Alsyom and Seiv has been delivered" he explains. By the end of this year, the tooling for the stacking of the DPs and the final fabrication stages will be in place. In case you are wondering how many DPs will be produced for each PF coil, manufactured in Europe, the answer is between 6 and 8. So rest assured that the workforces in the facility will be busy for a while making some of the biggest magnets ever made in history.

A similar scenario is unfolding more than 8 000 km away from Europe's PF coils facility in China's Hefei province. PF 6, the sixth and one of the smallest in diameter, is being manufactured through a collaboration agreement signed in 2013 between F4E and ASIPP (China's Institute for Plasma Physics).

The team behind the PF coil manufactured in China at ASIPP (China's Institute for Plasma Physics), on behalf of Europe, has celebrated a milestone: a full-scale prototype of a double pancake has passed the final winding qualification test. Trials started early in autumn last year and reached a peak towards November. The new year started with the completion of the trials in ASIPP when the component was moved from the winding facility to the termination and joint preparation areas. Winding the coil took roughly two months, including the manufacturing of the Helium inlets, the entry points of cold Helium inside the massive magnets. A team of 20 workers, engineers, inspectors and F4E staff have been working on extended shifts to meet this objective.

Peter Readman, F4E's Technical Officer, highlights the extremely good collaboration between F4E and ASIPP and praises the high quality of work. "Thanks to the good team spirit between the two organisations, we have managed to stick to our schedule and carry out the technical work with rigour and precision. When we carried out a pre-qualification test of a joint at the SULTAN facility in Switzerland, the centre of excellence where conductors are tested to their limits, the technicians there acknowledged that the work was of high quality" he explains.

Overall, the production of the two dummy coils for the fifth and sixth PF coils are neck and neck.

*"We have made great progress with both coils this year, a clear testament to the very good work and diligence of the teams in Cadarache and Hefei. We are excellently positioned for handing over the two coils to the ITER Assembly team in the first half of 2019!"*

**Kevin Smith**
F4E Poloidal Field Coils
Project Team Manager

# SIMIC concludes production of its share of radial plates for ITER Toroidal Field coils

An impressive metallic component has been carefully wrapped and is ready to leave for the port of Marghera, near Venice, in order to be delivered to La Spezia, near Genoa. Due to its large size (13 x 9 m) and heavy weigh, close to 10 T, it will travel by sea to reach the facility where F4E is manufacturing Europe's Toroidal Field coils. The cranes lift the component and carefully load it on the vessel.

The final radial plate manufactured by SIMIC is loaded on the vessel



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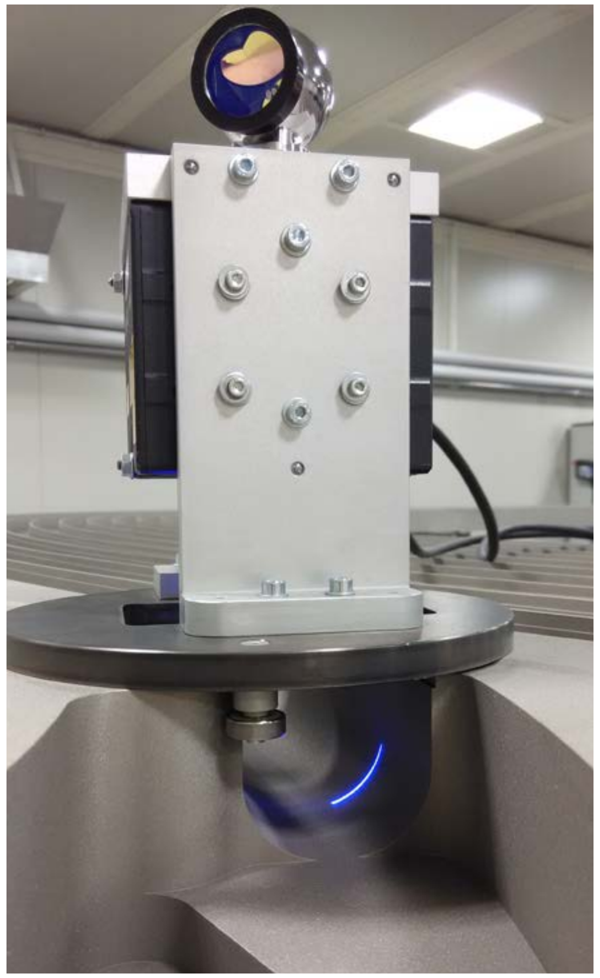
Tool machining the grooves of a radial plate

Representatives of SIMIC and F4E standing in front of the vessel that will deliver the radial plate to ASG, the facility where the Europe is winding its TF coils


Measuring with extreme precision the grooves of the radial plate

SIMIC, an Italian SME specialised in engineering and manufacturing of large machined components, has recently completed the production of its share of radial plates. Together with CNIM, the two companies have been entrusted by F4E to manufacture a total of 70 stainless steel plates. Inside the grooves of the D-shaped plates, the superconducting conductor of the one of the biggest magnets in history will nestle in order to contribute towards the confinement of the ITER plasma.

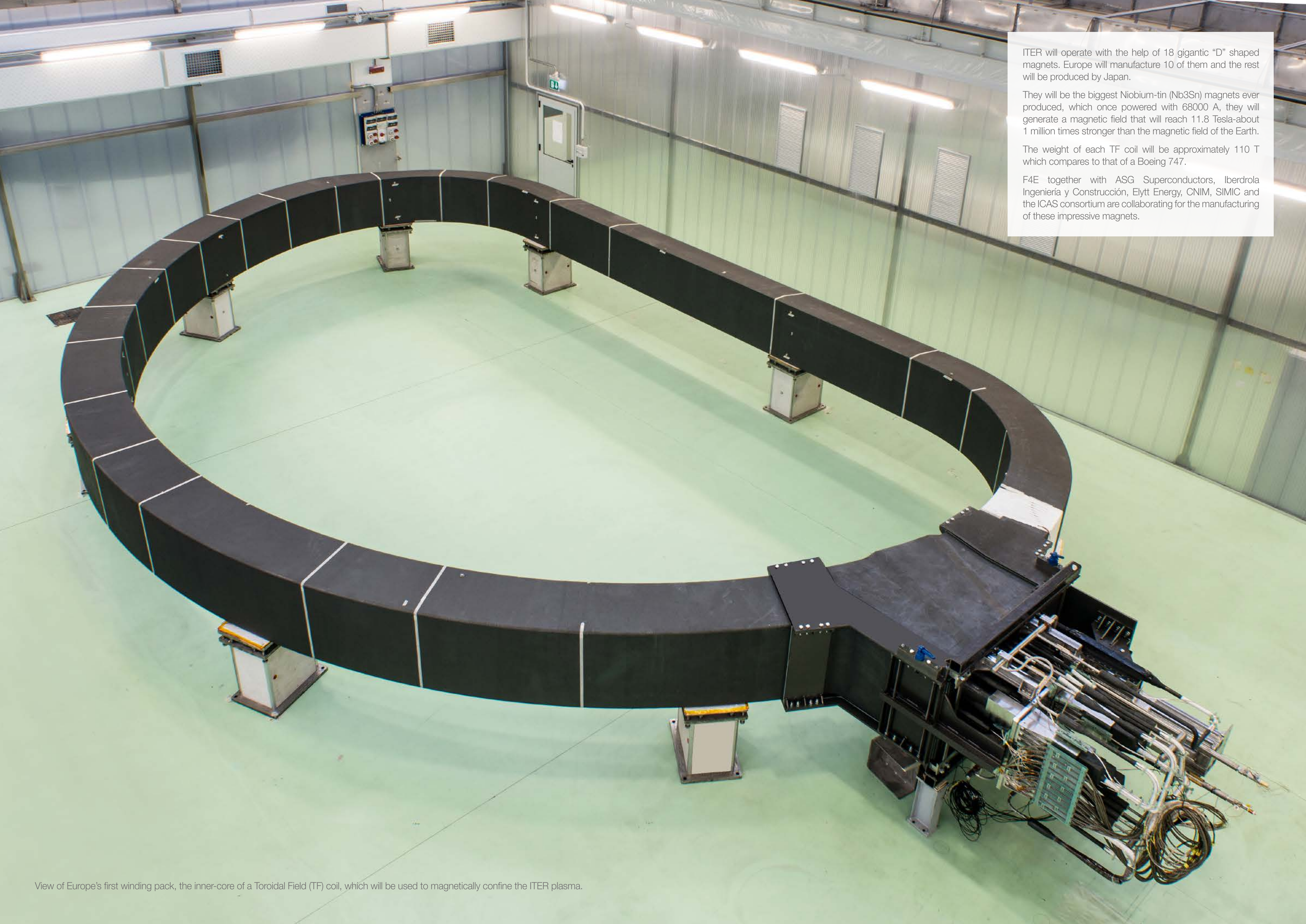
It has taken more than four years to complete the series of production involving up to 70 people. Marianna Ginola, SIMIC Commercial Director, explains that "the teams have been working three shifts and very often during weekends and bank holidays. We moved our most experienced resources to our factory in Marghera in order to capitalise on their expertise in the most critical production stages. With their support and commitment, coupled with the good collaboration with F4E, we have managed to achieve this result."

In order to understand what is challenging about the fabrication of this component, we asked Alessandro Bonito-Oliva, F4E Magnets Project Manager, to elaborate. "After the superconducting conductor of the TF coils is heat treated and electrically insulated, it is inserted into the grooves of the radial plates. Its trajectory must match the one of the radial plate. For this reason, all radial plate grooves are machined perfectly matching the trajectory of the conductor." Once the radial plate has been electrically insulated and impregnated, a so-called Double Pancake module is formed. And after seven Double Pancake modules have been stacked, electrically connected and impregnated they form a winding pack – the core of the TF coil.

The successful completion of the series production is also a contractual achievement for F4E and its supplier. Eva Boter, F4E's Technical Officer managing this contract, recalls how it all started: "We needed to develop a series of smaller prototypes and then work our way to full-scale components. Naturally, the production of the first series was more difficult because we had to develop processes and standards upon which the rest would follow. With time, we gained confidence and production accelerated. We had to be extremely precise with fabrication and measurements. Parallel to this, we needed to be sufficiently flexible to accommodate any possible modification."

*“This achievement has been possible due to the trust we share and a clear sense of partnership. It demonstrates that smaller companies with a proven track record in their field, and the enthusiasm to grow, can play an important role in the biggest fusion experiment.”*

**Alessandro Bonito-Oliva**
F4E Magnets
Project Team Leader



ITER will operate with the help of 18 gigantic “D” shaped magnets. Europe will manufacture 10 of them and the rest will be produced by Japan.

They will be the biggest Niobium-tin (Nb3Sn) magnets ever produced, which once powered with 68000 A, they will generate a magnetic field that will reach 11.8 Tesla-about 1 million times stronger than the magnetic field of the Earth.

The weight of each TF coil will be approximately 110 T which compares to that of a Boeing 747.

F4E together with ASG Superconductors, Iberdrola Ingeniería y Construcción, Elytt Energy, CNIM, SIMIC and the ICAS consortium are collaborating for the manufacturing of these impressive magnets.

View of Europe’s first winding pack, the inner-core of a Toroidal Field (TF) coil, which will be used to magnetically confine the ITER plasma.

# First EU diagnostic components delivered to ITER site

## Five Continuous External Rogowski (CER) coils – have been delivered to the ITER site and their acceptance testing by ITER IO has been concluded successfully.

The CER coils are to be located outside the ITER Vacuum Vessel, within the cases of three Toroidal Field (TF) coils. Their purpose is to measure the total electric current flowing in the ITER plasma, a key measurement required for plasma control that also has relevance for safety. By contrast to other common methods of measuring the plasma current, the Rogowski method works with a single sensor, resulting in very high reliability, despite the cryogenic temperatures, high vacuum and mechanical stresses it will be subjected to during operation of the TF coils.

Each of these coils has a flexible, cylindrical structure, measuring approximately 40 m in length and 12 mm in diameter. A special groove will be made in the TF coil cases to house these coils. The ends of the CER coils, emerging from the TF coils, will be housed in protective steel structures that have also been supplied by F4E. Axon (France), which supplied the electrical parts of the system, and Sgenia (Spain), which supplied the mechanical parts, are the two companies responsible for the manufacturing of the coils. ITER IO will transport them to Japan to be installed in the TF coils by Japan's ITER Domestic Agency, with F4E's support. Once the TF coils have been installed in the machine, F4E will commission the CER coils for use during first plasma operations.

There has also been progress with a network system that will be used for the real-time communication between different ITER diagnostics, actuators and the plasma control system allowing scientists to monitor and control the operation of the machine.

The real-time communication system has been developed by ITER IO and uses a cutting edge technology. As an example, the exchange of data on the magnetics measurements of the plasma allows the plasma control system to compute and control the plasma shape and size accordingly to the scientist's needs (e.g. by moving or shrinking the plasma or by increasing/decreasing the power to be delivered by one of the additional heating systems).

The system is based on Gigabit Ethernet, the same technology that is used in offices and houses around the world to connect devices to the internet. So far the system has been successfully used in JET and in the Korean tokamak (K-STAR). As well as being used to transmit information between different ITER systems, F4E has taken the use of this real-time communication platform one step further by adapting it to inter-connect in real-time different components that are being designed and integrated by F4E. For example, the Electron-cyclotron plant consists of 24 different gyrotrons and this network can be used to monitor and control the information coming from each individual gyrotron control systems.

"This sharing of technology saves us both time and money, enabling us to gather real-time information and control the ITER sub-systems at various levels", says André Cabrita Neto, F4E Technical Officer dealing with fast control technologies for ITER.

One of the Continuous External Rogowski (CER) coils undergoing acceptance testing earlier this week at the ITER site


The CER coils arriving at the ITER site earlier this week





# Excellent results for the European gyrotron prototype

## Excellent results have been obtained for the first high-power 1MW gyrotron prototype manufactured in Europe by French company Thales Electron Devices (TED) on behalf of F4E.

Designed to transform electricity power into 1 MW electromagnetic waves equivalent to about 1000 microwave ovens during a continuous use of up to one hour, the gyrotrons will be sources of ITER's Electron Cyclotron (EC) heating system which will heat the plasma in the ITER machine to the sweltering temperature of 150 million ° C necessary for the fusion reaction to occur by transferring the energy from electromagnetic waves at 170 GHz of frequency into the plasma electrons.

During testing, the gyrotron had repeatedly produced up to 0.8 MW of output power during periods of 180 seconds – the maximum time possible at the test facility at Karlsruhe Institute of Technology (KIT – as part of the European Gyrotron Consortium (EGYC)).These results have been assessed by an independent expert panel who concluded that for a first gyrotron prototype, they are impressive.


The 1 MW gyrotron prototype manufactured in Europe by French company TED on behalf of F4E

"With these tests a large majority of the F4E objectives for the validation of the EU gyrotron design, have been verified", says Ferran Albajar, F4E Technical Officer responsible for the gyrotron. "The design of this gyrotron has been carefully optimised for the specific environment of ITER, and the assessment was based on the ITER's stringent technical requirements in terms of power, quality and stability of the electromagnetic waves. The assessment has also included aspects linked to quality control procedures and collecting and sharing know-how in order to allow European industry to reproduce future gyrotrons."

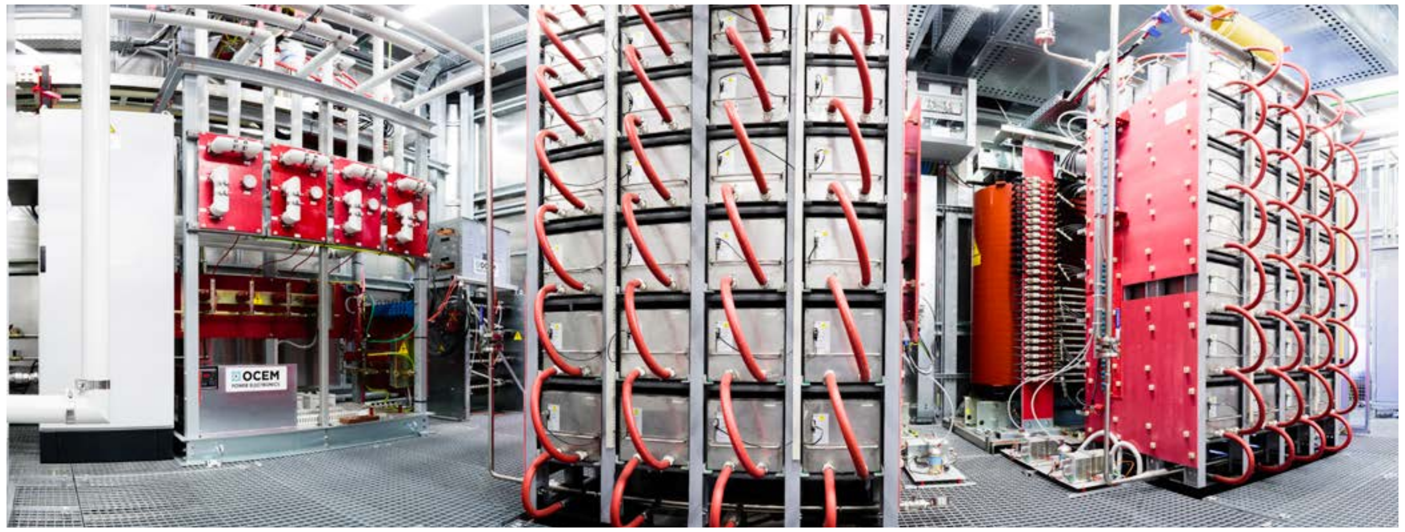
In addition to the gyrotron, testing has been carried out on the superconducting magnet necessary for the gyrotron to work. The magnet is special for three reasons: it is the first time such a magnet for a high-power gyrotron is built in Europe using a state of the art cryogen-free cooling technology; the strength of the magnetic field within the magnet corresponds to the high expectations the scientists have had (reaching 7.1 Tesla – equivalent to the magnetic force of 1420 fridge magnets); and the magnetic field lines are well-placed and form a virtual cylinder equivalent to the approximate diameter of a human hair in order to assist the gyrotron in generating the electromagnetic waves.

Next steps will now involve joining the gyrotron and magnet together and carrying out testing at the Swiss Plasma Centre (SPC). Each test session will last for one hour and thus simulate the time needed for these components to work in ITER.

The magnet which will be joined to the gyrotron prototype and tested at SPC.

# Significant progress within the Neutral Beam Power Supplies area

Two important events have recently taken place in F4E's Neutral Beam Power Supplies area. Both concern the Neutral Beam Test Facility (NBTF), where prototypes of the ITER Neutral Beam Injector are under construction.




The Ion Source and Extraction Power Supply (ISEPS) for the SPIDER test bed (photos courtesy of OCEM ET)

Following successful site acceptance tests last year, the ownership and responsibility for the Ion Source and Extraction Power Supply (ISEPS) for the SPIDER test bed were officially transferred from F4E to the ITER Organization on 6 February 2017. As the test facility is located in Italy, its operation is in the hands of Consorzio RFX — for this reason, the responsibility for use of this power supply was transferred on the same day to them. Occupying a full room at the NBTF, and feeding the radio frequency ion source, ISEPS constitutes an important component for SPIDER, the test bed where the first full-scale ITER ion source will be tested and developed. The design, manufacture, installation and testing of the power supplies were carried out in collaboration with F4E, the supplier OCEM ET (Italy) and its main subcontractor Himmelwerk GmbH (Germany), facility host Consorzio RFX and ITER IO.

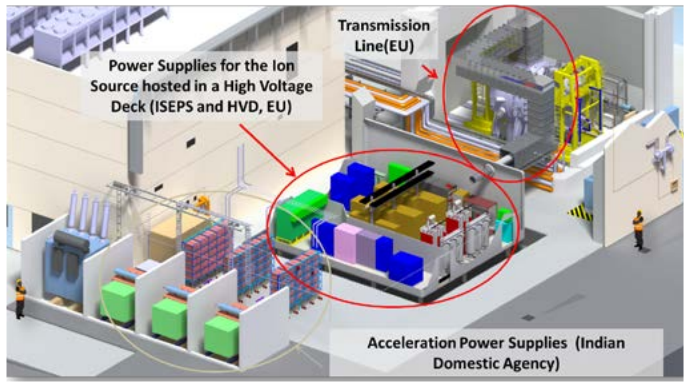
F4E also concluded in December 2016 the procurement of the Transmission Line and High Voltage Deck for the SPIDER experiment. It is the first full-scope contract involving design, manufacturing, installation and commissioning of equipment for the NBTF to be completed. The Transmission Line connects the power supplies ISEPS to the Beam Source of SPIDER while the High Voltage Deck is the electrically insulated mechanical structure hosting ISEPS. COELME SpA (Italy) was responsible for the supply of these components.

The achievement of these two milestones concludes the contribution of F4E to the power supplies of the SPIDER experiment.

Meanwhile, the European contribution to the power supplies of MITICA — the second experiment of the NBTF consisting in a full-scale injector — is well underway. The procurement of the second ISEPS unit for MITICA has been completed and manufacturing activities have started.








The power supplies and Transmission Line for SPIDER

F4E signing the transfer of the ownership and responsibility of the first ISEPS unit to the ITER Organization

Neutral Beam Test Facility, Padua, Italy

The manufacturing and factory testing of the High Voltage Deck hosting the power supplies of MITICA Ion Source and connecting them to the 1 MV Transmission Line (procured by Japan's ITER Domestic Agency), via the High Voltage Bushing Assembly (a container which holds the power leads from the power supplies located in the High Voltage Deck) is now completed, with installation already taking place. This equipment is being supplied by SIEMENS AG (Germany), together with main subcontractors HSP GmbH (Germany) and Andreas Karl GmbH (Germany).

In parallel, the design activities are now finished for the Ground Related Power Supplies of MITICA (GRPS) and for the European part of the power supplies of the accelerator (AGPS), which is shared between F4E and the Japan's ITER Domestic Agency. The manufacturing of these power supplies is underway and their installation at the NBTF is scheduled to start at the end of the summer. The European part of AGPS is supplied by NIDEC-ASI (Italy) while the GRPS are supplied by OCEM ET (Italy).

A cryogenic system will be needed for the operation of MITICA's high-energy beams in order to ensure the necessary vacuum during its operation. In spite of the fact that the plant is classified as conventional, the auxiliary system can be described as sophisticated because it will have to cope with a range of operational modes. The cryoplant will supply helium at - 269 ˚C and - 196 ˚C so that the cryopumps absorb all gas coming from the high-energy beams. Periodically, however, warmer gas of 127 ˚ C will be supplied in the pumps to extract any gas stored. F4E has signed a contract with Air Liquide for the design and manufacturing of the cryoplant which is expected to be ready by April 2019.

# Using the power of water to bring the energy of the sun

Even in the biggest fusion device the amount of free space will be limited. The bulky components with their multiple parts will require an extreme level of precision to be installed and subsequently maintained. And to make matters more complicated, the majority of these tasks will be performed without being physically present in the machine.

Operator performing a water-hydraulics test relevant to ITER's Remote Handling system, TUT, Finland

Remote Handling systems will help us carry out such tasks from a distance deploying a vast range of technologies, including sophisticated robotics and virtual reality. In some cases, hydraulically-driven systems will need to be deployed, and given the fact that systems using oil cannot be used in case it is slips in the machine's vacuum vessel, power systems operating with water will need to be considered. So here is an interesting contrast: the 54 divertor cassettes, which form the ITER machine's ashtray, and receive most of the heat of the superhot plasma reaching 150 million ° C, will need to be transported with the help of a sophisticated water-hydraulics system. Fire and water will work side by side to operate the machine.

Assystem UK and the Technical University of Tampere (TUT) have tried a water-hydraulics system replicating ITER conditions by monitoring its performance during a 2000 hours endurance test. The lifting of a load weighing 1 T, using a valve operating in a confined space with high temperatures, has been successful. The performance of the prototype and wear of components have been satisfactory. The team of engineers, however, spotted an Achilles' heel in the valves. Although, servo valves offer accurate tracking they lack robustness and wear off easily. On top of that, any particle in the water could block them easily and could cause significant problems to the operation of ITER's Remote Handling system for the cassette divertors. For this reason, F4E has started to look for alternatives and has signed a contract with Tamlink and Hytar Ltd., part of Fluiconneto by Manuli, to explore the possibility of using digital water hydraulics to replace the servo valves. The system relies on the use of fast, small and simple on/off valves to achieve the required performance. Overall, they are more resilient and capable of operating even with a small degradation in performance.

Tamlink and TUT have invested in digital hydraulics for almost 20 years and Bosch Rexroth has licensed this technology. In fact, the digital oil valves of such kind are being used in some of Finland's high speed trains. The next step is the commercialisation of water digital hydraulic valves and ITER will yet again prove to be a driving force in promoting more innovation.





# Special metal to be used in ITER gets tested

F4E has signed a contract with Studsvik, a Swedish company, to perform tests on the steel that will be used in the first wall of ITER's Test Blanket Modules (TBMs).

EUROFER97 specimens to be irradiated at NRG's High Flux Reactor, Petten, Netherlands

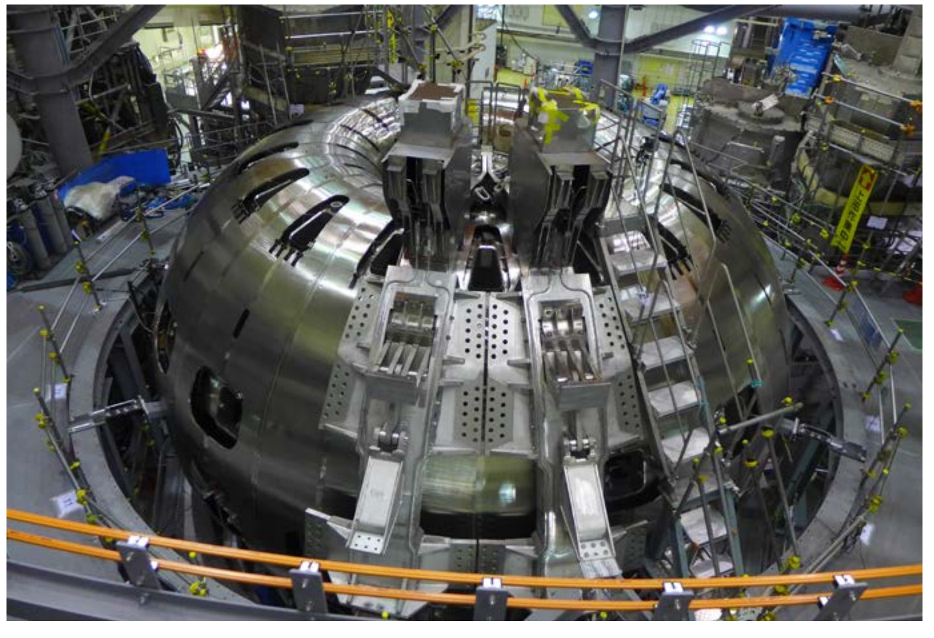
The biggest fusion machine will operate with a hot gas, whose temperature will be ten times the one in the core of the sun, reaching 150 million° C. A wall will cover the TBMs to protect them from these extreme temperatures. Therefore, the need for materials able to cope with high heat fluxes and irradiation is pressing. Europe, responsible for nearly half of the components of the machine, has opted for a low-activation steel, known as EUROFER97. It will be tested in ITER and depending on its performance it will be used in future fusion machines. What is so special about this metal? It can take the heat and is sufficiently resistant to fusion's radiation environment.

The tests have now entered a new phase and with the help of NRG, Netherlands, a subcontractor of Studsvik, the teams will study the performance of the steel after being irradiated. Basically, the materials will be put to similar conditions as in the future fusion reactor. The High Flux Reactor, Petten, is the home of these tests, where four rigs will be irradiated. The work which started in late 2016 is expected to be completed by early 2018. After each irradiation phase, the metal will be transported to Studsvik to examine its impact, the brittleness of the materials, the microscopic changes that take place and the extent to which the strength characteristics are affected. On the basis of these tests we should know whether the materials will be suitable for future fusion devices.

ITER, the world's most ambitious fusion machine consists of approximately one million main components. The TBMs are part of them and these tests will feed into their development. One can describe them as steel cases inside which tritium will be produced through interaction with the neutron generated by the fusion reaction. Six different concepts have been designed among the ITER parties, two of them in Europe. Ultimately, the most effective concept will be used in future. As tests proceed and more data are being collected, scientists around the world will be getting closer to the materials that will be used to generate this sustainable, unlimited and safer energy–fusion.

# JT-60SA Assembly of Toroidal Field coils has started

With the placement of the first two, of the total 18, Toroidal Field (TF) coils in the tokamak, the complex process of assembling this magnet has started at the JT-60SA site in Naka, Japan. This is a major achievement resulting from a fruitful collaboration between Japan's ITER Domestic Agency QST and F4E.



The process of assembly has started: The first two of JT-60SA's TF coils are in place in the tokamak


F4E Director J. Schwemmer highlighted the fruitful collaboration between F4E & QST

"The technical challenges in developing and assembling these superconducting magnets that are amongst the largest in the world should not be underestimated. Indeed, each TF coil is eight metres high, five metres wide, and weighs 30 T", explained Johannes Schwemmer, F4E Director. The TF coils are the backbone of the JT-60SA machine, one of the three projects within the Broader Approach Agreement between Europe and Japan. They are large "D" shaped superconducting magnets whose main task will be to create the main magnetic field needed to confine the plasma.

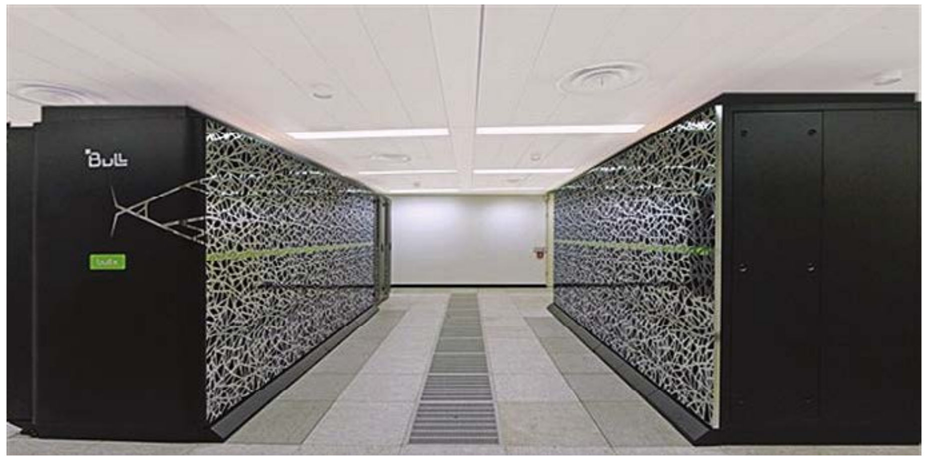
A ceremony to mark this auspicious event was hosted by F4E and QST and held at the JT-60SA site in mid-January. Attended by several high-level Japanese politicians such as the Research State Minister Mr Mizuochi and Members of the House of Representatives, the event attendees also included the top management from QST, Drs Hirano, Nakamura, Shimada, Tajima, Mori, Kurihara, Ishida and Kamada. In attendance from Europe were F4E Director Johannes Schwemmer, Pietro Barabaschi, Home Team Project Manager for Europe's contribution to the BA project, and Head of F4E's Broader Approach JT-60SA Unit, Enrico Di Pietro. Gerassimos Thomas, Deputy Director-General in the Directorate-General for Energy at the European Commission was present and the EU Voluntary Contributors CEA (France) and ENEA (Italy) were represented by CEA Administrator General Daniel Verwaerde and ENEA President Federico Testa.





# The sunset of "Helios"

One of the most powerful supercomputers is switched off after having completed its mission with great success. "Helios" has been one of Europe's key contributons to the Broader Approach Agreement, giving scientists the opportunity to perform complex calculations in plasma physics.




Helios supercomputer, bullx® series. © Bull

The International Fusion Energy Research Centre (IFERC), hosted by the Japanese Atomic Energy Authority (JAEA), has been the home of "Helios" one of the world's most powerful supercomputers. In Greek the word "Helios" means "Sun", the star that runs on fusion. To those scientists who have dedicated their career to fusion research, it represents the energy of the future and ITER will demonstrate its feasibility. The Computational Simulation Centre (CSC) was established in the IFERC Centre in Rokkasho, Japan, and has provided the fusion communities of Europe and Japan the opportunity to use a state-of the art equipment without any cost. Between 2012 and 2016, the computer has been shedding its light on plasma physics, reactor technologies and materials. Earlier this year, "Helios" witnessed its sunset when all shut down operations were completed.

The main tasks of the European contributors (F4E, and CEA on its behalf, through a contract with ATOS/Bull) have been to procure the machine and to take care of its operation and maintenance. Japan had to prepare the building and services, the cooling system, and to contribute to the seamless integration of the IT equipment and services, in particular by providing support to the users.

The operation and day-to-day services have been performed by different teams and suppliers. The tasks of selecting computational projects, assigning resources, and evaluating the scientific output have been given to a panel of independent scientists representing the European and Japanese fusion communities. Through its operation, the usage of the supercomputer has been very intense, exceeding at times 98% capacity on average/week. This very good result has been matched with the excellent management of time slots, accommodating most of the proposals submitted by the scientific community. For instance, there have been reserved sessions for large jobs or specific queues for longer jobs.

Due to the geographical position of the centre, almost all users have been accessing "Helios" remotely. To help users to make the best use of it, training sessions have been organised, both in Europe and in Japan from where scientists had the possibility to submit their proposals. These sessions covered basic training and webinars on specific topics or tools for advanced users. For each submission cycle, a Standing Committee had to organise calls for proposals; select the projects from the proposals by peer review; allocate the computational resources to the selected projects; evaluate the performed projects; and make a written summary report of the calls.

Users have been able to draw comparisons between fusion experiments such as JET, JT-60U, ASDEX-Upgrade, MAST, Tore Supra, W7X, LHD, Heliotron J. They had the opportunity to run predictive simulations of future devices such as JT-60SA and ITER Moreover, 639 peer-reviewed papers have been prepared using the resources offered by "Helios". To help scientists carry on with their work during the next two years, Europe has made available Marconi, another supercomputer whose availability is being managed by EUROfusion, and Japan has decided to launch a procurement to purchase a new machine that will be ready by 2020.

# ITER Business Forum 2017: the road to first plasma is paved with commercial opportunities

What used to be once the prestigious residence of the Pope and a symbol of power became the venue of the largest business event for the fusion community. The Palais des Papes in Avignon, the biggest gothic palace in the world, opened its doors to the fifth edition of the ITER Business Forum (IBF).

The impressive fortress welcomed 1 000 participants from more than 400 companies operating in at least 25 countries. This has been by far the most successful IBF in terms of attendance, demonstrating the determination of Agence ITER France (AIF) to raise the bar higher by offering the fusion community an unprecedented opportunity to network, exchange information and establish new business partnerships. There was enthusiasm in the air because this IBF was taking place after the ITER Council had formally adopted the date for the first plasma of the biggest fusion device.

For Jacques Vayron, Director of AIF, the event showed the commitment of the South of France, the host to the project, where more than 3 200 people are currently being involved in ITER activities. The region has been keen to support companies in setting up their business and therefore, a network called "Welcome around ITER" has been set up to help with this task. The manufacturing of ITER components will also rely on the R&D generated by various laboratories around the world. For this reason, Bernard Bigot, Director-General of ITER Organization, highlighted in his opening speech the need for more interaction between companies and the research community in order to capitalise on their complementary skills. In order to promote this dimension further, Sabine Portier, France's Industry Liaison Officer (ILO) for ITER, and Philippe Olivier, France's Deputy ILO for ITER, offered attendees the possibility to interact in multiple ways. First, by means of an exhibition spreading on two floors, the ITER Domestic Agencies together with companies and laboratories presented their achievements and unveiled samples of their work. Second, plenty of business to business meetings (B2B) were organised to bring different parties together and explore ways to collaborate. In parallel, an interesting thematic programme was carefully designed to offer insight to the technical progress.

During the plenary session, which brought together senior policy-makers, the importance of international collaboration in tackling the production of clean energy was addressed. The European Commission's Deputy-Director General for Energy, Gerasimos Thomas, reminded the audience that energy has always been inextricably linked to European integration, referring to Euratom, and stressed the need to strive towards decarbonisation and the elimination of fossil fuels by the end of the century. The various EU investment packages were also presented to illustrate the incentives offered to Europe's economic operators so as to promote sustainability. F4E's Director, Johannes Schwemmer, highlighted Europe's contribution to ITER by unveiling the latest key figures and thanking ITER partners for their dedication and collaboration. His presentation offered an overview of the progress on-site and in different European facilities. "We are at a point of no return and will continue to deliver" was his key message. And for those not yet involved there was good news in the horizon. During the next four years F4E will launch tenders for a total value of approximately 1 600 million EUR.

During the 11 thematic sessions, which grouped representatives from the different ITER parties, companies and laboratories, future market opportunities were communicated in more detail, together with their respective timelines and types of expertise in need. F4E's Market Intelligence Group was actively involved in the B2B meetings to showcase F4E's Industry and Fusion Laboratories portal, helped companies to share contacts and with the assistance of technical members of staff, and procurement officers, the F4E business requirements were explained.

As the two day event was coming to an end, one could hear the strong echo coming from the footsteps of the participants as they were walking on the cobbled street of the Palais des Papes. Judging from the sound, it definitely proved to be the rendez-vous that no one in the ITER fusion community wished to miss.





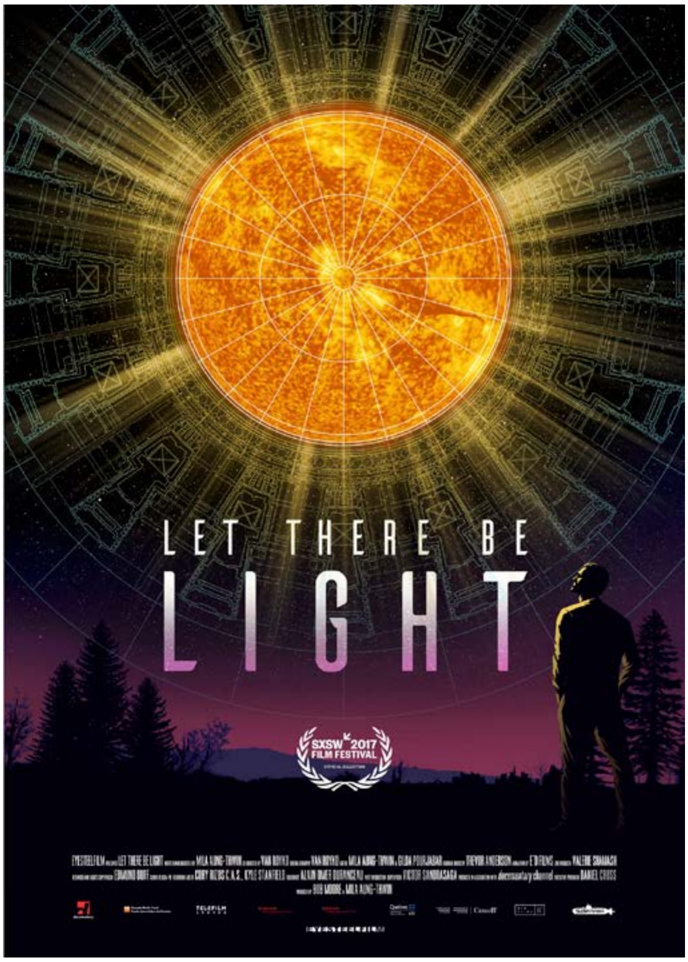

Johannes Schwemmer, Director of F4E, welcomes Bernard Bigot, Director-General of ITER Organization, and representatives from the regional and local authorities of the Provence-Alpes-Côte d'Azur region ©AIF.C21

Participants exchanging ideas during the B2B meetings © AIF.C21

The IBF 2017 plenary session bringing together senior ITER figures and policy-makers © AIF.C21

# Let there be fusion!

It all started roughly three years ago when Mila Aung-Thwin and Van Royko joined us at our annual ITER media event. In a crowd of 40 delegates from international media, the two stood out partly because of the cameras they carried along but mainly because of their insatiable curiosity about fusion – this new source of energy that could change everything.




What were two filmmakers from Canada, with a proven track record and various awards in documentaries, doing on the ITER site? The answer is simple: a new film on the energy crisis and the potential of fusion power.

Against the tide of nationalism and the go it alone syndrome, "Let there be light" is a wakeup call of internationalism and the need to collaborate in order to solve global issues like energy. How much will it take to bring the power of the sun to Earth? To portray the complexity of the project and the lives of those involved in it, the filmmakers conducted interviews with many engineers, followed technical reviews, were given access to senior policy meetings and travelled to many locations to witness the manufacturing of different components. They flew to different continents, drove hundreds of miles from one industrial facility to another and crossed the sea to witness the loading and delivery of some major equipment.

Their "behind the scenes" approach has captured in a magnificent way the tension and enthusiasm that underpin this one-of-a kind project. The questions they pose are extremely relevant and promise to generate a lively debate: how can we address the energy crisis? Can we afford not to explore alternatives? Can fusion be part of the solution or are we taking a big gamble?

"Let there be light" has already received its first award for Artistic Vision at the Big Sky Documentary Film Festival and it has already been screened at the Copenhagen CHP:DOX. In May, the documentary will be screened at DocsBarcelona.

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

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F4E News is a newsletter published by Fusion for Energy (F4E)

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For free subscriptions, please specify your requirements via e-mail: press@f4e.europa.eu

Printed in Belgium on chlorine-free paper
ISSN 1831-5887 (Print)
ISSN 1831-8800 (PDF)


FU-AB-17-001-EN-C (Print)
FU-AB-17-001-EN-N (PDF)