F4E NEWS

Fusion for Energy Magazine
No. 24 / June 2018

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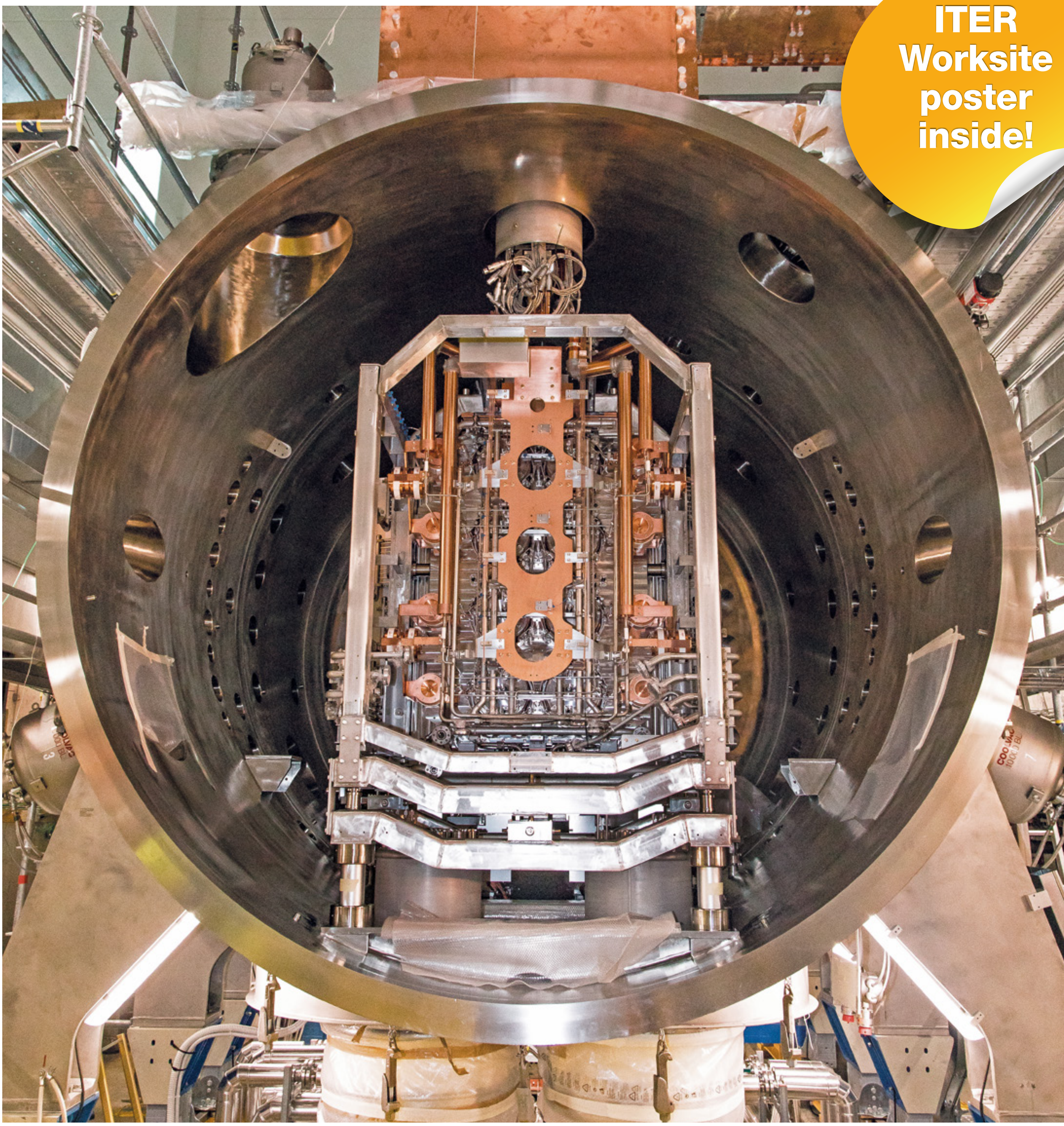
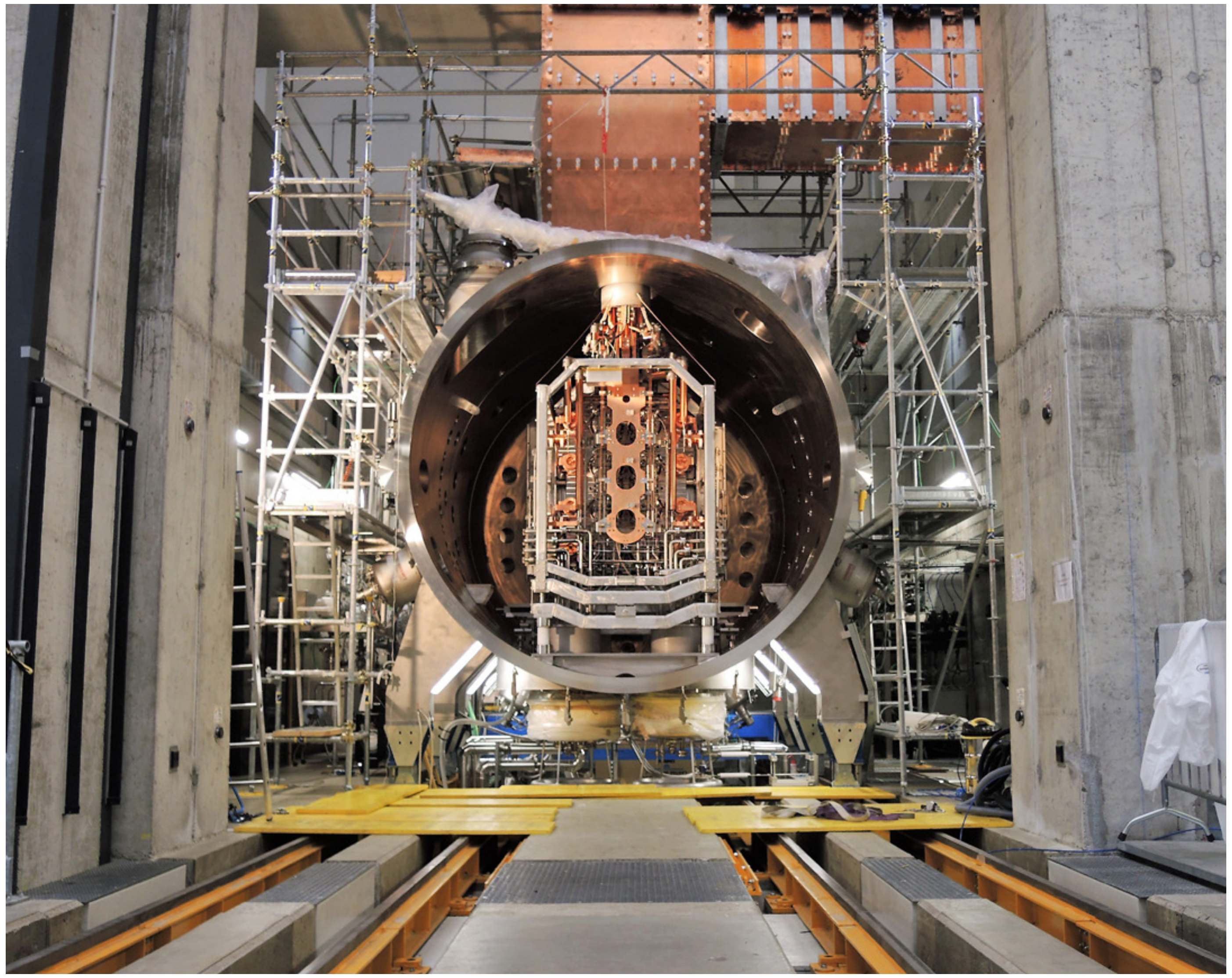


SPIDER beam source installed in the vacuum vessel, ITER Neutral Beam Test Facility, Padua, Italy © RFX

Europe is ready to switch on SPIDER - the most powerful negative ion source experiment to date

The final countdown for the operation of SPIDER has started. All its systems are connected and engineers together with scientists are getting ready to turn the switch on and start testing.



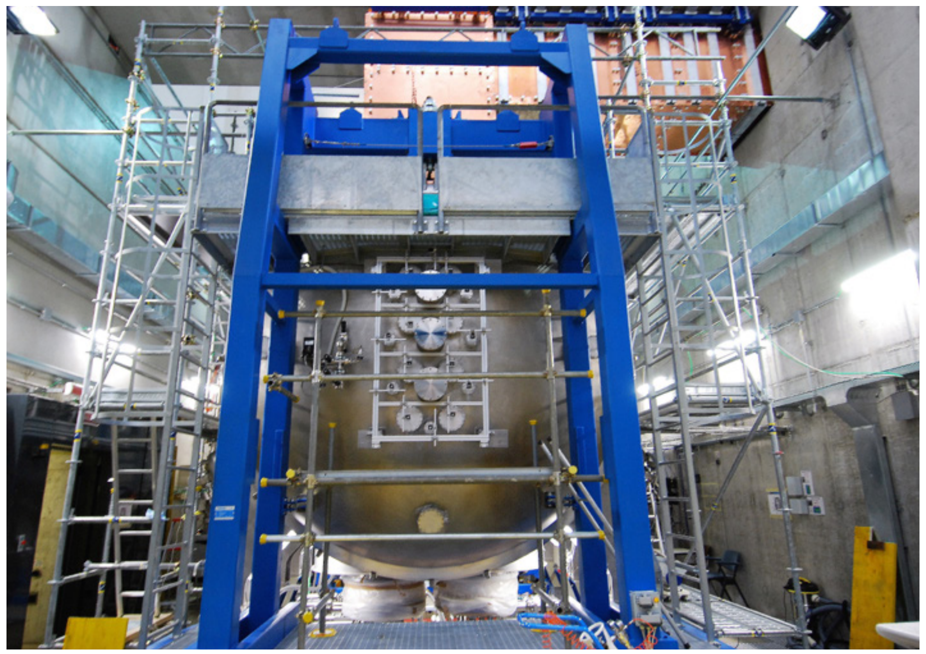
Positioning the SPIDER beam source with the handling tooling to its final location, ITER Neutral Beam Test Facility, Consorzio RFX, Padua, Italy

It's the result of a successful international collaboration of various Parties, from inside and outside Europe, working together to bring fusion energy a step closer. The thinking behind this experiment is similar to that of ITER: various components have to be produced in different parts of the world, and subsequently they need to be assembled in a facility specifically built for it. What started as an idea on paper is now an operational state-of-the-art test bed that will improve our knowledge on ITER heating systems and help us manufacture them.

Financed mostly by F4E, and with contributions from Consorzio RFX, ITER International Organization, and India's ITER Domestic Agency, this is the first of the two experiments at ITER's Neutral Beam Test Facility located in Padua, Italy. A second one called MITICA, which will mimic the full power of the ITER injectors, also under the same roof a few metres away, will be operational in a few years from now.

SPIDER, which stands for Source for Production of Ion of Deuterium Extracted from Radio Frequency plasma, will help engineers to finalise the development of the ion sources required for the ITER Neutral Beam Injectors (NBI), and to test key aspects of the diagnostic neutral beam accelerator. This is the first full-scale ITER ion source, capable of running pulses of up to 3 600 seconds at maximum power with hydrogen or deuterium. The 6 MW beam generated for one hour by 1280 powerful beamlets are equivalent to the energy required by roughly 1 000 medium apartments in one day.

An army of F4E suppliers and subcontractors worked hard to deliver various components of the SPIDER experiment. A European consortium consisting of Thales Electron Devices SA, CECOM Srl, Galvano-T GmbH, and E.Zanon SpA has been responsible for the manufacturing of the beam source, which weighs 5 t and measures 3 x 3 x 2 m, and of its vacuum vessel. Works started four and a half years ago, for value of 10 million EUR approximately, which also includes the costs for the fabrication of the vacuum vessel and handling tool. OCEM Energy Technology and COELME provided the power supplies that will energise SPIDER. The cooling plant was delivered by Delta Ti Impianti, and the vacuum and gas injection plant system by Angelantoni Test Technologies. Last but not least, URS and NIER offered valuable engineering support. ITER India collaborated with PVA Tepla for the beam dump and with ECIL for the accelerator grid power supplies. Consorzio RFX in collaboration with the Italian authorities undertook the construction costs of the buildings, and procured diagnostics and control systems which were agreed in collaboration with F4E.



Getting ready to lock the SPIDER beam source in its vessel, ITER Neutral Beam Test Facility, Consorzio RFX, Padua, Italy

To understand the importance of this milestone, which has also been highlighted by the ITER Council, the political body that brings together all ITER Parties to monitor the overall progress, we need to make sense of history. We spoke to Tullio Bonicelli, F4E's Head for Neutral Beam & Electron Cyclotron Power Supplies Systems and Sources, who has been following the evolution of this project the last 15 years. "Early in 2000 when the fusion community was finalising ITER's engineering design activities, the conclusion was reached that specific R&D activities were required to develop the neutral beams. In 2005, J. Potočnik, European Commissioner for Research, and L. Moratti, Italy's Minister for Education, Universities and Research, reached an understanding to host in Italy the Neutral Beam Test Facility. EFDA (European Fusion Development Agreement) was asked to set the wheels in motion and Consorzio RFX, in Padua, was selected as the Host of the experiment.

As soon as F4E was established the EU responsibility of the project was transferred to us. Until the end of 2011, we were busy trying to convert the concept of the facility into a concrete project involving also ITER International Organization. In a way, it felt like putting together a mini ITER. From 2012 onwards, we opened a new chapter making this facility a reality and laying the foundations of a legal framework to channel our contribution. Thanks to a dedicated team of 20 people bringing on board their expertise from the fields of engineering, planning, quality assurance, project management, law and procurement, today F4E has honoured its contribution vis `a vis all other Parties involved in this facility. We have come a long way, if you think about it…and now the exciting part for the fusion community starts with testing".

> *"In a way it felt like putting together a mini ITER"*
>
> **T. Bonicelli**
> F4E Project Manager
> Neutral Beam & Electron Cyclotron Power Supplies and Sources

Europe's equipment that will be used to heat up ITER plasma passes factory acceptance tests

Various powerful heating systems will need to be deployed to heat up ITER's plasma to approximately 150 million °C. The Electron Cyclotron (EC) is one of them. Try to think of it a bit like a powerful microwave oven that will heat up the super-hot gas. How? Basically, the EC will convert electricity from the grid and supply it to the gyrotrons, devices that generate strong electromagnetic waves, which in turn, will transfer their energy to the electrons of the ITER plasma to heat it up and confine it better.

Representatives from F4E, Ampegon, ITER IO and Swiss Plasma Centre during the tests of the first high voltage power supply unit © F4E

In order to operate the gyrotrons we would need to "feed" them with high and stable voltages. This is a twofold challenge for the EC power supplies because they need to guarantee the accurate amount of power, and ensure that its supply is in line with ITER's operation. It takes expertise to develop a piece of equipment that can provide this amount of power and switch it off in less than 10 micro-seconds! Europe has been asked to manufacture 8 of the 12 main high voltage power supplies (55kV/110A) and 16 body power supplies (35kV/100mA) that will be required to perform this important task in the biggest fusion device. To put things into perspective, the eight high voltage main power supplies can generate enough household electricity for 270 000 people, which is the population of a medium-sized city in Europe.

Ampegon, a Swiss small medium enterprise, has been entrusted by F4E to deliver these units. The first main high voltage power supply and two of the body power supplies have successfully passed the Factory Acceptance Tests. They have reached the operational benchmark set for ITER. The collaboration started nearly four years ago and the company had to design an entirely customised equipment, given the fact that this was the first time that they would be used. The successful results have been welcomed by Ferran Albajar, following the design and

F4E and Ampegon checking the equipment during testing © F4E

High voltage power supply unit financed by F4E and manufactured by Ampegon © F4E

manufacturing progress of this equipment on behalf of F4E. "All these years of work basically have come down to these tests. We started developing these units step-by-step bearing in mind that nothing like this has been manufactured before. The results of today's tests prove that we are on the right track. The performance of the equipment exceeds the demanding specifications set by the contract and makes us confident that we can generate additional heating for ITER's plasma".

This technical achievement stems from the superb collaboration between F4E, Ampegon and ITER International Organization, with contributions from the Swiss Plasma Centre, and experts, where teams had to work hand in hand to manage the various interfaces smoothly, ensure timely execution and cope with any risks and delays. Tullio Bonicelli, Head of F4E's Neutral Beam and Electron Cyclotron, Power Supplies and Sources, stated that "this achievement is extremely gratifying for the F4E teams and our industrial partners. The excellent collaboration with ITER IO has also been vital in meeting this objective. We can now go ahead with the production of the remaining units which should be completed during 2020".

For Josef Troxler, Ampegon CEO, working with F4E has given the company the opportunity to transfer their know-how from the field of radio frequency used in broadcasting to fusion. "Ampegon has been proud to contribute to the ITER project by pushing forward the boundaries of knowledge, both directly through our novel power supply design, and indirectly by being part of the largest scientific experiment in history— ITER. This ambitious project has the potential to revolutionise society and provide the means for the generation of clean energy for everyone on the planet. In this respect, it is a noble cause, and one that everyone should work to accomplish. This idea has motivated Ampegon to achieve this latest success, and we look forward to supporting F4E and the members of the ITER project in any way we can".

Success for Europe's ITER Toroidal Field coil cold tests

Close to Venice, the final act of Europe's Toroidal Field (TF) coil magnets will be played. The breathtaking beauty of this city has inspired authors and directors to narrate some of the most powerful stories we have read or seen on screen. This time, however, engineers from all over Europe will join forces to link its legacy with the manufacturing of the most high-tech magnets in history. Europe's ten ITER TF coils will undergo the final stage of manufacturing there.

At the workshop of SIMIC, an Italian company close to the port of Marghera (Venice), the container of the first TF winding pack – the core of the magnet – has arrived. It left from the port of La Spezia where at the factory of ASG Superconductors the 14 m coil had been produced. Now, it will have to go through a series of mechanical tests, and to be inserted in a massive case weighing 180 t, so as to protect it almost like a knight's panoply. Basically, the winding pack is going to turn into a magnet. Marianna Ginola, SIMIC Commercial Manager, is no stranger to the project. "It feels like coming full circle in a way…for years we worked hard to shape this component, and now we get to oversee its final production stage. To do so, we have invested in the infrastructure of our plant, collaborated extensively with our subcontractors, and trained our workforces for the delicate operations that we will have to carry out. The fact that this is the first of the ten winding packs that we will have to handle, makes this moment even more special", she says. The company has been previously involved in the fabrication of half of the radial plates which protect the superconductor inside their grooves.

After having unpacked the winding pack, the teams of SIMIC and its subcontractor, Babcock–Noell (BNG), had to perform a series of dimensional and electrical checks to inspect the coil. "The successful results have paved the way for the cold tests, which have been successfully concluded. In essence, the coil enters into the cryostat to be cooled down at 80 K (-200 °C) for nearly 20 days using a combined cycle of nitrogen and helium. Meanwhile, its electrical connections are placed at the exits of the cryostat so that they are tested with a current of 1000 A" explains Paolo Barbero, SIMIC Project Manager.

Piergiorgio Aprili, who has been following closely the commissioning of the cryoplant and the cold tests on behalf of F4E, explains: "…it took us roughly one year to get the equipment ready. All the tooling had to be manufactured from scratch and will be used during the next years to test the inner-core of Europe's TF coils. We will test them at extreme temperatures to check that the insulation is robust enough and that no cracks appear. Before they confine the superhot plasma they will have to experience freezing temepratures". Boris Bellesia, also working in F4E's Magnets team following the same contract, summarises the fabrication steps that will follow: "now that the cycle of cold tests has been successfully completed, dimensional and electrical checks will be performed again to inspect the state of the coil. Then, the coil will be moved to the assembly rig so as to be inserted into its case by using state-of-the art tooling and laser dimensional technology. The technical teams will have to move 110 t and fit them in the cases with millimetric precision. Subsequently, the cases will need to be welded in order to lock the metallic structure around the coil".

Two important aspects will add to the challenge: first, the weld will be 120 mm thick, and second, the welding will be carried out only from one side within very complex geometries. For these reasons, ultrasonic technology will be pushed to the limits to inspect the component. Meanwhile, the gap between the TF coil case and the winding pack will have to be filled with reinforced resin to glue the two together. The high density of the resin makes this task particularly challenging. Try and imagine filling a tight gap of 4 mm thick and 35 m long with 1 m^3 of resin that has the thickness of honey. It's hard to imagine it but it will be performed.

Alessandro Bonito-Oliva, heading F4E's Magnets team, highlights the success of the tests and the various interfaces of the ITER project. "The successful completion of the cold tests of Europe's first winding pack pave the way to the final steps of its manufacturing until it gets inserted into its coil case. Try to think of it like a puzzle where the pieces need to come together. Most TF coil components like the winding packs and the radial plates are manufactured in Europe. The TF coil cases, however, are fabricated in Japan, and the thermal shields' support of the Vacuum Vessel, are produced in Korea. All these pieces of equipment will need to be put together as part of ITER's TF coils. It is an exercise of unprecedented complexity and planning. And we are working together with our industrial partners and the other ITER Parties to make this a reality", he explains.

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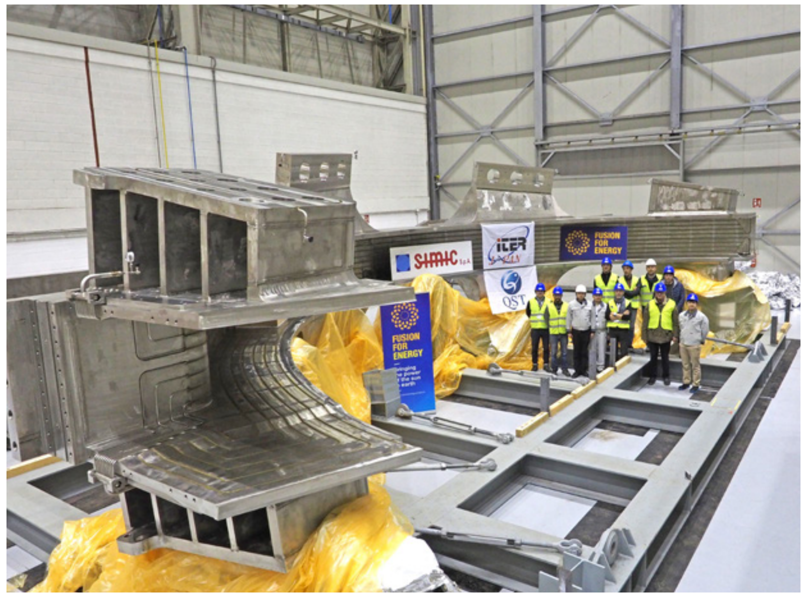
Europe's first Toroidal Field coil winding pack to undergo cold tests, SIMIC, port of Marghera, Italy © SIMIC



Representatives from F4E, Japan's ITER Domestic Agency, and SIMIC, next to the first Toroidal Field coil case which travelled from Japan to SIMIC, port of Marghera, Italy, © SIMIC

Europe's second winding pack leaving from ASG to be delivered to SIMIC © ASG

Important manufacturing milestone for ITER's sixth Poloidal Field coil

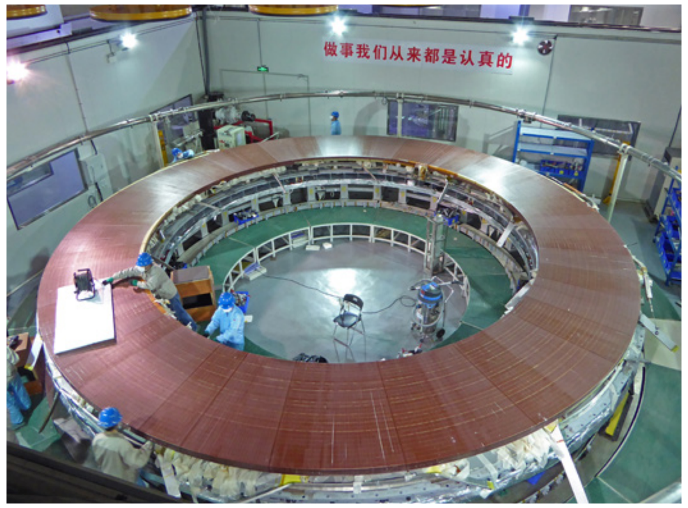
Six massive magnets will embrace the ITER machine from top to bottom to control the shape and stability of its plasma. Europe is responsible for five out of the six Poloidal Field (PF) coils, one of them being manufactured in China. In line with the spirit of the ITER project, the biggest international collaboration in the field of energy, F4E and ASIPP, the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, have signed an agreement to manufacture this coil together, in order to mutually benefit from their expertise and deliver the component faster.

A team made of 80 engineers and technicians has been working hard to deliver the first PF coil and the result of this collaboration has been extremely successful. Day by day, the smallest of the PF coils is taking shape and is advancing. And when we mean small its weight is approximately 400 t and it has a diameter of 10 m. This coil is made of nine double layers of superconductor which need to be wound, known as Double Pancakes (DPs).

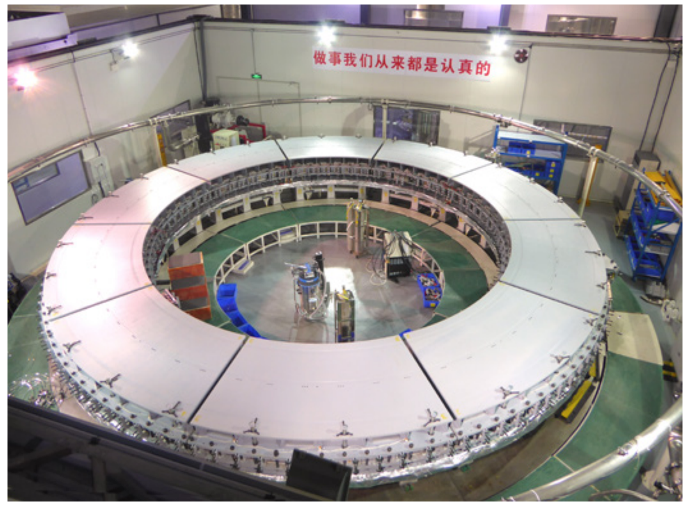
Half of the DPs have already been completed. Six of them have already been wound and the seventh one is currently in progress. Electrical joints, which will allow helium and current to flow in the magnet, have been fabricated for five out of the six DPs, one is in the making and three more to be produced in the coming months.

The next manufacturing step consists of impregnating the DPs with resin in order to electrically insulate them. Four out of nine have already been successfully impregnated. It is expected that by September this stage will be completed for all nine of the DPs paving their way for stacking, where they will be placed one on top of each other to be collectively electrically and hydraulically connected. Then, the whole component, known as a winding pack in the ITER jargon, will be ground insulated, impregnated and then the final assembly will take place before being shipped to the ITER site in France.

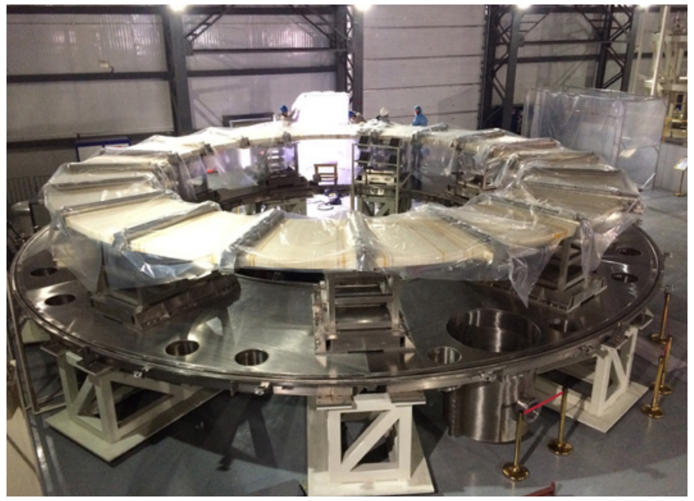
To celebrate this manufacturing milestone all members of the team working together for this achievement took part in a group photo. They wanted to capture this moment of collaboration and look back at it as a precious gift, as they were heading towards the Chinese New Year festivities. For all them, it is a symbol of mutual learning and partnership between Europe and China. And on the human side, it is a souvenir of a big team that will gradually shrink in size as manufacturing steps are being completed.



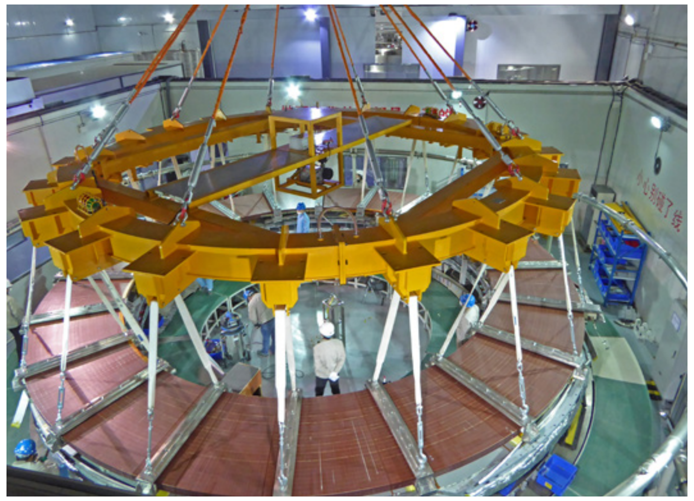
Double Pancake 7 after having completed Vacuum Pressure Impregnation at ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China © F4E



Preparing the mould for Vacuum Pressure Impregnation at ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China © F4E



Completing Double Pancake 5 at ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China © F4E

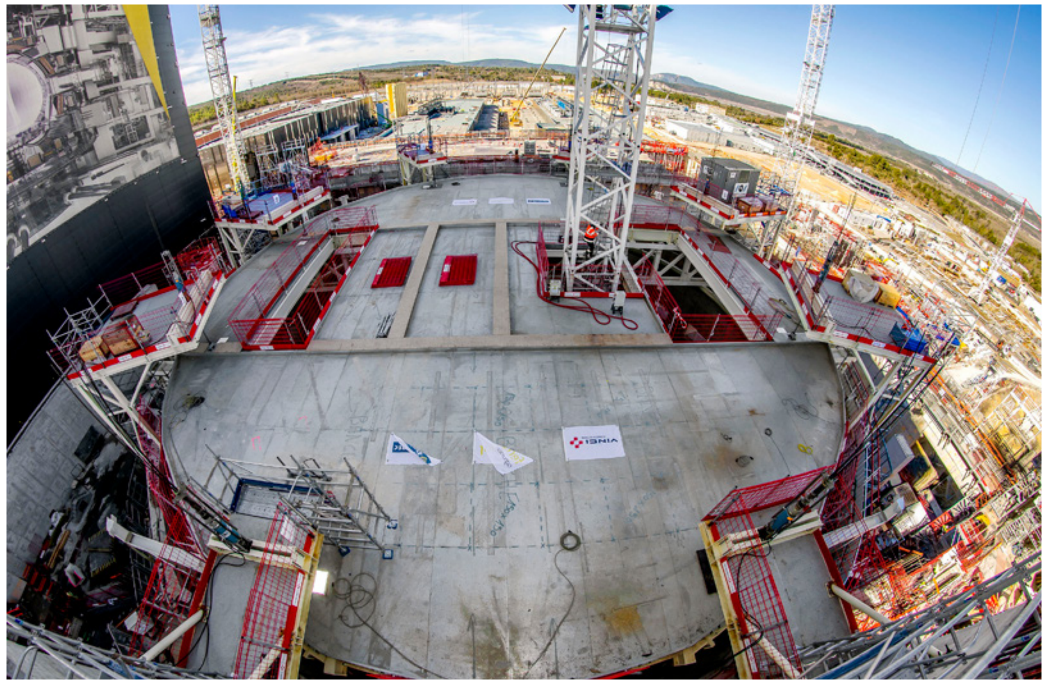


Lifting Double Pancake 7 to move it to another station at ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China © F4E

Members of Fusion for Energy and ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China, taking part in a group photo to celebrate the technical milestone they have achieved © ASIPP

The lid of the ITER Bioshield is on!

Sometimes a week can end with an adrenaline rush. This was the case on the ITER construction site, when on Friday 9 March, a spectacular lifting operation unfolded at the Tokamak Complex, the emblematic building which will house the world's biggest fusion device. Early in the morning the teams of F4E and their contractors, together with ITER International Organization, took positions to lift the 30 m diameter lid of the bioshield.



The ITER Bioshield lid has been lifted, March 2018, ITER construction site, Cadarache © ITER IO

The VFR consortium (consisting of Vinci, Ferrovial, Razel), responsible for the civil works of this building, put its trust on VSL Heavy Lifting, a company specialised in heavy-load lifting operations, to perform this task.

All in all it took three hours to complete this operation and every minute counted for the 10 people participating in it. This is one of the key construction milestones set by the ITER Council and everybody is extremely focused. The day before, they run a drill lifting the lid only 10 cm so that they make sure all tooling was working well. The technical teams placed eight hydraulic jacks on eight metallic structures, resembling to small platforms hanging 30 m high, in order to lift with cables the 150 t lid that will cover the cylindrical "tower" of the Tokamak building. Then, it will be fixed on beams and will remain on top until April 2020 when the first assembly operations begin.

In August 2017, the 30 m metallic diameter cover made its first appearance on the ITER construction site. It was fabricated and positioned in the bioshield 15 m above the ground to allow the teams of workers to carry on with building more floors above, and in parallel, go ahead with the construction of the Tokamak concrete supporting structure below. Basically, 18 massive blocks of steel are being embedded in heavily reinforced concrete to form a "crown" that will support the ITER machine weighing 23 000 t. The volume of the concrete required is about 400m³ and each of the 18 supporting steel blocks is weighing more than 3 t. "A specific formula has been developed to produce this highly-reinforced structural concrete able to withstand a compression three times higher the concrete of a normal housing building" highlights R. Darbour, F4E's Deputy Project Manager for Buildings, Infrastructure and Power Supplies.

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Lifting operation of the ITER Bioshield lid, March 2018, ITER construction site, Cadarache © ITER IO

View of the ITER Bioshield lid, positioned 30 m high, ITER construction site, Cadarache, March 2018 © ITER IO

Beneath the lid of the ITER Bioshield, ITER construction site, Cadarache, March 2018 © ITER IO

Europe installs all cryogenic tanks and cold boxes on the ITER site

Finalising the installation of Europe's cryogenic tanks on-site, ITER Cryoplant, April 2018.

Temperatures are on the rise on the ITER construction site as the sunlight is showering its vast platform. The workforces on the ground are fixing their hard hats and roll up their sleeves as they are heading to the different buildings. The site is the home of the experiment that will recreate a small sun on Earth with a burning plasma of 150 million ° C. Usually, the project's high temperatures capture our imagination when we talk about ITER. This time, however, the installation of Europe's massive equipment on the premises of the Cryoplant, which can be described as a massive "refrigerator", puts on the spotlight the low temperatures that will reach -269° C. Eleven cryogenic tanks, cold boxes, and the first compressors, have taken their final position to deliver plenty of cold power.

Europe is one of main contributors to ITER's impressive cryogenic system which is needed to cool down the powerful magnets to become superconducting in order to confine the superhot plasma. F4E is responsible for the procurement of half of the Cryoplant's components. Its construction and the successful installation of Europe's equipment on its premises make this a landmark achievement for F4E's teams working in the teams of cryogenics and transport logistics. The first European cryogenic tank was delivered in November 2016 and almost a year later all tanks followed departing from different countries. In parallel, the cold boxes and the first compressors followed. Air Liquide and its subcontractors have been responsible for their production and DAHER for their transport and logistics.

Lifting one of the two quench tanks financed by F4E and produced by Chart Ferox. ITER Cryoplant, April 2018.

More components produced by Europe have been installed on-site: the two quench tanks on the ground, the LHe tank on the level above, and the cold boxes. At the far end the remaining cryogenic tanks.

Everything about ITER is epic — its partnership, scale, complexity and the forces of nature that will work together to win the fight against climate change. The people behind this milestone and the companies involved are an important part of the story. Didier Magnet, Large Projects Director of Air Liquide Advanced Technologies describes in detail the involvement of the different suppliers. "The main pieces of equipment of the cryogenic plant are now delivered on site, including the impressive Helium and Nitrogen storage tanks, cold boxes and compression stations. We faced many challenges that our teams took up alongside our customers. After having ensured the design of equipment and manufacturing, Air Liquide's teams are moving ahead with the installation of the cryogenic plant.This important milestone is the result of more than 100 members of staff from Air Liquide working in engineering activities, 80 main suppliers and up to 150 people on site".

On ITER's Helium (He) plant an army of cryogenic tanks have been installed: six warm Gaseous Helium (GHe) tanks manufactured by Zhangjiagang Furui Special Equipment Co. LTD (China); one Liquid Helium (LHe) storage tank manufactured by CryoAB (Sweden), able to store up to 70% of the helium that the plant will need; and two quench tanks produced by Chart Ferox (Czech Republic).

Europe is also responsible for the Liquid Nitrogen (LN2) plant. One liquid nitrogen (LN2) tank, manufactured by Aritas (Turkey) has been installed on its premises, plus the gaseous nitrogen (GN2) buffer tank manufactured in China by Furui. In parallel, the race for the installation of auxiliary pieces of equipment has started with the compressors and cold boxes. The installation of all cold boxes, manufactured by Nuclear Industry 23 (China) has been completed, together with the LN2 compressors produced by Atlas Copco Energas (Germany/Belgium).

Alain Teissier, F4E Project Manager for Cryoplant and Fuel Cycle, explains that "the installation of the equipment on-site is the culmination of years of work. We have followed the full manufacturing cycle of these components from the stage of conceptual design to fabrication; travelling to different facilities around the world to check their progress and putting in place the logistics for their arrival and installation on-site". Marc Simon, F4E Deputy Project Leader for Cryogenics, elaborates on the installation process which started unfolding the last three months: "We had to develop excellent logistics to overcome some of the obstacles bringing the components on-site and deal with strong wind and heavy rain. In parallel, we had to plan carefully the lifting operations of the tanks to minimise any impact on the construction activities nearby. Reaching this milestone would not have been possible without the effective collaboration of all F4E industrial partners and ITER parties".

European prototypes for ITER Divertor Cassette completed

During the fusion reaction the lower part of the ITER machine will receive a significant amount of the heat coming from the 150 million°C burning plasma. The impurities will be directed to fall, just like ashes do, in a massive "ashtray" called the divertor, which covers an area of 142m². The ITER Divertor is made of 54 pieces of stainless steel which can be removed, known as "divertor cassettes", measuring 0.8 x 2.3 x 3.5 m and weighing roughly 8 t. The insertion of these components and their maintenance will be carried out remotely.

European real-size prototype of ITER Divertor Cassette manufactured by Walter Tosto © Walter Tosto

European real-size prototype of ITER Divertor Cassette manufactured by CNIM-SIMIC © CNIM

Before embarking on the manufacturing of the 54 ITER Divertor Cassettes , F4E in collaboration with industry had to develop real-size cassette prototypes to demonstrate the feasibility of their fabrication. For this reason, Europe developed a procurement strategy which encouraged several suppliers to get involved in order to check whether they had the skills to manufacture this component with the required quality and at minimum cost.

It all started in 2012 with the signature of a procurement arrangement with ITER International Organization. Then, F4E conducted a market survey, identified the technologies required for the fabrication of this component, and one year later launched a call for the production of the first real-size prototypes. The race started with three candidates which presented the best set of skills matched with value for money. Two of them decided to carry until the finish line: Walter Tosto, and a consortium consisting of CNIM-SIMIC. A few weeks ago the final dimensional checks were completed, offering proof that the companies were able to manufacture the prototypes. This has been the fruit of the hard work, undertaken by F4E and its industrial partners, which started approximately four years ago.

Bruno Riccardi, F4E Divertor Technical Co-ordinator, and Laurent Guerini, F4E Technical Project Officer responsible for these contracts with the support of Montse Felip, José Andrade and Quality Officers, explain that "…due to the demanding requirements of this component we had to work closely with other teams inside F4E and with our external suppliers. To give you an idea of the rigour with which our work has been carried out…more than 700 documents per prototype have been processed and each prototype had to undergo extremely demanding tests. We have come a long way".

The ITER Divertor Cassette is one of these components which may deceive the eye. It may give the impression that it is fairly straightforward to machine, but the moment fabrication kicks in then all sorts of manufacturing details come to play making it a far more complicated job. It is a piece of equipment that requires extreme precision and expertise in welding. In the case of the CNIM-SIMIC consortium and Walter Tosto there are at least 100 welds on the real-size prototypes produced. Furthermore, the components have to go through nondestructive testing (NDT), and a series of inspections regarding their volume and fabrication using radiographic and ultrasonic techniques.

F4E's suppliers have successfully performed the tolerance assessments and the cold/hot helium leak tests. With these results in hand, F4E is now getting ready to launch the call for the production of the first series of ITER Divertor Cassettes, which will not exceed at this stage the total number of 20. To find more about the forthcoming tender, check F4E's industry and fusion laboratories portal. Patrick Lorenzetto, FE4 Head of In-Vessel Project Team, confirms that "this is an important milestone because it demonstrates Europe's industrial capacity to manufacture this component and paves the way to new business opportunities".

All forgings and plates for European vacuum vessel sectors have been delivered

Five sub-contractors, namely Acciaierie Valbruna (Italy), Forgiatura A. Vienna (Italy), Industeel (France), Rolf Kind GmbH (Germany) and ThyssenKrupp (Germany), have produced and delivered all the remaining forgings and plates which will be used on the five vacuum vessel sectors out of the total nine that Europe is contributing to the ITER project.

The LTCC sensor prototypes (in blue) before testing, installed in the supporting structure used in the tests

All in all, for the 5 EU sectors, around 1100 forgings (big blocks of 316 LN ITER grade stainless steel) with a total weight of approximately 1900 t, have been delivered. This delivery comprises individual forgings weighing up to 3750 kg depending on where in the vacuum vessel it is to be placed. The forgings come in various different shapes and sizes (round bars, rectangular bars, square blocks etc.) and will at a later stage be machined into subcomponents which will be assembled together to make up the remaining vacuum vessel sectors.

Around 150 plates boasting a total weight of 1120 t have also been delivered. These plates (flat stainless steel slabs which have rolled flat to become plates in various different thicknesses) will be used to manufacture the inner and outer shells making up the inner and outer walls of vacuum vessel sectors.

The forgings and plates have been manufactured by mixing pellets of materials such as chromium, nickel with low alloyed steel in order to produce 316 LN ITER grade stainless steel which is low on carbon and high in nitrogen. "This is an exceptionally strong, corrosion resistant high-quality stainless steel which has good weldability. It has been especially selected and developed because of its suitability for a fusion machine such as ITER", says Stefan Wikman, F4E Technical Officer dealing with materials. The mixture for the forgings is heated to a temperature of approximately 1 500° C and poured into block moulds for cooling. "The next stage is what we call hot pressing: the steel block is shaped by being heated to a temperature of approximately 1 000° C and then hammered into shape using a large steel hammer, pressed or rolled. The plates also start as stainless steel slabs that are rolled flat using high temperatures and equipment to become plates in various different thicknesses," explains Vassilis Stamos, F4E Technical Officer, responsible for material fabrication procurement for the nuclear fabrication of the vacuum vessel sectors.

The forgings and plates are now at the Mangiarotti S.p.A and Walter Tosto S.p.A premises for cutting and machining into desired shapes and sizes. "We are pleased that the delivery of the vacuum vessel forgings and plates has been finalised as this marks the completion of another step to streamline the fabrication of the ITER vacuum vessel sectors, the heart of the ITER machine", says Francesco Zacchia, Project Manager for F4E's Vacuum Vessel team.

Simulation of tritium transport for the European Test Blanket System

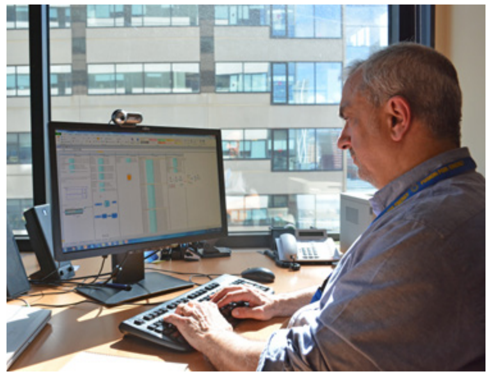
Tritium and deuterium are two isotopes of hydrogen that will be used to fuel the fusion reactions in ITER. While deuterium can be extracted from seawater in virtually boundless quantities, the supply of tritium is very limited – only about thirty kilos of tritium are currently available in the world.

DEMO will operate by generating the amount of tritium it will need to consume. In a tokamak fusion reactor this "in situ" tritium generation takes place thanks to the fusion neutrons leaving the plasma and interacting with a specific element – lithium – contained in the so called "breeding blanket", a complex structure surrounding the plasma chamber. Because of its complexity and associated costs, the breeding blanket will not be present in ITER. However, ITER will provide a unique opportunity to test mock-ups of different possible breeding blankets concepts and connected circuits, called Test Blanket Systems (TBS), in a real fusion environment. Within these TBS, viable technologies for ensuring the expected tritium generation and recovery will be explored and validated, with the final aim to demonstrate the tritium self-sufficiency of the parent DEMO breeding blanket concept.

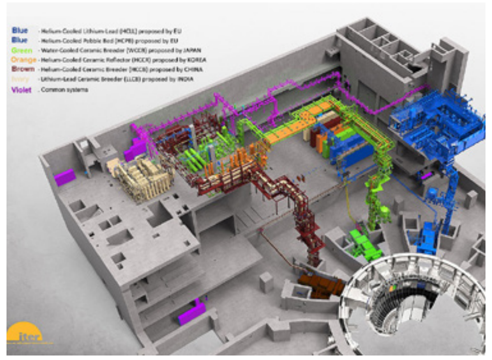
The tritium atoms are very small and then they may easily diffuse and permeate through all types of materials to which they are in contact. Tritium confinement is essential in order to recover the generated tritium and to strictly control the potential spreading of tritium within ITER.

In close collaboration with CIEMAT (Spain) and Empresarios Agrupados (Spain), F4E is developing a computer code based on the EcosimPro simulation platform which is able to predict the transport of tritium through the different components and materials of the two European Test Blanket Systems which will be installed inside the ITER machine. "With the help of a computer code based on advanced physics, we are able to predict over time the tritium transport along the different components and materials of the TBS and finally into the surrounding environment. The outcomes of the computer code are data of tritium concentration and flux in the form of tables and graphs which can be used not only to support the design of the two European TBS but also to comply with the nuclear safety requirements imposed by the Nuclear Operator (ITER Organization)", says Italo Ricapito, F4E Group Leader working in the TBM Project Team. "The code implements complex mathematical models and, once completed and validated against the results coming from TBS experimental campaign in ITER, it could be used to support the design of a breeding blanket for DEMO. This is one of the most important objectives of the whole European TBM Project".

The development of the code is currently at 70% completed – the basis and extra features are already in place. "We aim now to complete the work on the code and continue to implement more complex features mainly focusing on multi-physics issues and detailed operational conditions. However, the activities of code verification and validation will still require several years of work and a significant technical effort", says Italo Ricapito.



F4E TBM Group Leader, I. Ricapito, manages the development of the computing code used to predict the tritium transport in the European TBS.



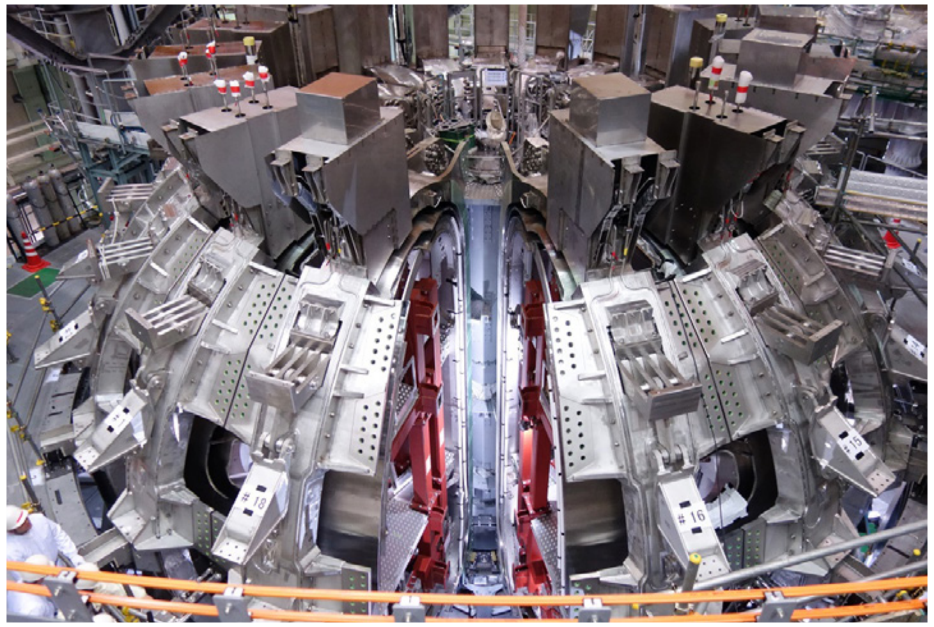
F4E will be able to predict the tritium transport along the different components and materials of the European TBS sub-systems (in blue). (Image courtesy of ITER IO).

Closing the circle: Final JT-60SA Toroidal Field coil is installed

The assembly of JT-60SA at its Naka site, Japan, has moved a step closer to completion with the installation of the 18th and last Toroidal Field (TF) coil. Pre-assembled together with the final sector of the vacuum vessel, which will contain the superheated plasma at the heart of the experiment, and its thermal shield, which will reduce the heat radiating to the cryogenically cooled coil, the TF coil was lifted high over the tokamak assembly frame and lowered into the waiting space on the cryostat base. The installation of these "missing pieces" is a major milestone for the whole JT-60SA project.

Now each part of the subassembly must be precisely located and joined to its neighbours. The thermal shield is challengingly flexible and access to connect it is very restricted. The welding of the vacuum vessel has had to be carefully planned to allow for the slight change of shape that occurs when the welds cool.

The TF coils form the backbone of the JT-60SA tokamak – the container which houses the fusion reaction. It is their magnetic field that provides the primary confinement for the superheated plasma, and the assembly of JT-60SA cannot proceed without them. For F4E the connection of the last TF coil is particularly significant – a testament not only to the care of the assembly contractor Toshiba but to years of preparation by F4E. "We engineered those coils so they would slot together like Lego, and the last one has to fit on both sides, so this is the final test", explains Sam Davis, F4E Technical Officer. "The first 17 coils have been aligned with high accuracy and their positions have been 'frozen' by bolting and pinning them together. But only with all the coils acting together does the structure function as intended", says Valerio Tomarchio, who will provide expert on-site support during the positioning and the final connection.


The 340 degree JT-60SA tokamak assembly ready for the insertion of the final sector (Photo courtesy of QST).

The TF coils arrived in Naka after an intense journey by road, air and sea. They were carefully packed and transported by road from CEA Saclay to Paris Vatry Airport (France) and then left in style from Europe to Japan in one of the biggest airplanes in the world, an Antonov-124 exclusively chartered by F4E through French transport company, DAHER. Upon arrival at Nagoya Airport, the coils were shipped to Naka. The TF coils, each 7.5 m high and 4.5 m wide, were supplied in partnership with ENEA (Italy) and CEA (France) as part of the Broader Approach agreement between Europe and Japan. Packed on their transport frames the two coils make a payload of 64 tonnes – oversized cargo by any standard.

Until ITER is finished, JT-60SA will be the largest superconducting tokamak in the world and F4E has led the European contribution to the project for the last 10 years. After the TF magnet is complete, the attachment of the Poloidal Field coils will start – beginning with the 12 m in diameter EF1, currently the world's largest pulsed superconducting coil – the next spectacular lifting operation!

Further good news concerning the JT-60SA project is the delivery of the cryostat vessel body from Europe to the Naka site. The cryostat vessel body works as a large containment vessel which will enclose all core JT-60SA components and consists of four individual upper sectors (with a height of around 4 m) and eight individual lower sectors (with a height of about 7 m) which have each been separately positioned and precisely adjusted to form a cylindrical shape which measures about 14 m in diameter. The cryostat vessel body will provide a thermal insulation and vacuum around the magnet components within the machine in order to ensure that they stay at the cryogenic temperature necessary (at four Kelvin) for their superconducting functions. The 12 sectors arrived by ship from Spain together with an 11 m long lifting beam, an ad hoc manufactured lifting frame, other lifting equipment and the spare steel material – together weighing a total of 322 t.

“We are both happy and proud that this vital piece of JT-60SA arrived safely on-site and several months ahead of its final assembly date”, says Antonino Cardella, F4E’s Technical Officer who supervised the whole transport operation for Europe. “This is the successful result of hard work and excellent team-work between F4E, CIEMAT and our European partners, as well as our Japanese colleagues”.

Watch the transport of the last TF Coils from Europe to Japan on F4E Youtube.

View on F4E YouTube


The road convoy from CEA Saclay to Paris Vatry airport


Loading of the last JT-60SA TF coils on to the plane bound for Japan.

Take-off at Paris Vatry airport.

F4E informs about Diagnostics Engineering Services contract

F4E's biggest meeting room, the Aula Mar, was filled with anticipation and curiosity when members of F4E's Diagnostics team opened the Information Meeting about the recently launched Call for tender for the provision of manufacturing engineering support for the Diagnostics systems (F4E-OFC-0905). Around 28 companies from all over Europe such as AVS (Spain), Alsyom (France), Thales Alenia Space (Italy), KT Optics (Germany) and ISQ (Portugal) attended the meeting which sought to present the main points of F4E's requirements, answer questions from the potential bidder participants, as well as provide networking support for similar or complimentary companies.

The participants of the information meeting about the Diagnostics Engineering Services Call for tender.

F4E contributes to about 25% of overall ITER Diagnostics which provide essential information to protect the machine from damage, as well as control, optimise and understand the plasma. Diagnostics use a very wide range of techniques; every Diagnostic is a complete system: front-end (optics/antenna), transmission lines (optical, waveguides), back-end (electronics). While the design of F4E's Diagnostics contribution is being conducted under Framework Partnership Agreements with European Fusion Laboratories (EFLs) most of the Diagnostics are currently under preparatory design stage and they are approaching the subsequent phases of the design. The reason behind the launch of this call for tender is because F4E requires manufacturing engineering support during the design phases in order to ensure the designs meet the manufacturing requirements and can be manufactured within cost and schedule.

The Framework Contract which F4E aims to sign with an engineering company with expertise in manufacturing of complex scientific equipment will complement the manufacturing engineering works performed by the EFLs. "We are looking to secure services from engineering experts who can evaluate if the designs that are being produced can be manufactured within cost and schedule baselines and be compliant with the ITER requirements. Concretely, we will need experts to assess Diagnostics design works in terms of manufacturability, costs and risks and provide accordingly expert guidance (e.g. evaluating and analysing current designs and solutions from an industrial perspective, proposing potential modifications to manufacturing plans, and carrying out engineering analysis in order to substantiate the proposed modifications. F4E wants to have a stable team involved for the whole duration of the contract", explains Sandra Julia, F4E Diagnostics Technical Officer. The duration of the contract will be four years, plus two possible extensions of one year each and the total contract effort is estimated to 33 persons per years (PPYs). "This contract will provide a good opportunity for a European company or consortium to gain knowledge about the European Diagnostics systems of ITER and develop different state of the art technologies", highlights Anthony Courtial, F4E Market Intelligence Officer.

Spanish companies reaffirm benefits from their participation in ITER

On 18 April 2018, the Catalan Association of Industrial Engineers held an Information Day on the ITER project with the participation of F4E, CIEMAT, CDTI and various Spanish industrial companies.

(L-R): Stavros Chatzipanagiotou (F4E), Jordi Prenom (President AEIC), José Mª García Casasnovas (AEIC)

(L-R) Jesus Izquierdo (F4E), Josep Canós (AEIC), Joaquin Sanchez (CIEMAT)

In welcoming the participants, Jordi Renom, President of the Association, and Stavros Chatzipanagiotou, F4E Head of Communication, insisted on the importance of energy in the world, the challenges of climate change and the potential of fusion to provide abundant, clean and safe energy in the future. Joaquin Sanchez, Head of fusion research at CIEMAT and Chair of the F4E Governing Board, explained the fundamentals of fusion, while Jesus Izquierdo, Associate to the F4E Chief Engineer, presented the progress and engineering challenges of the ITER project. Finally, Victor Saez, Head of F4E Market Intelligence, and Ana Belen del Cerro, Spanish Industry Liaison Officer, explained business opportunities and how to get involved in the project.

The audience consisted of numerous members of the Catalan engineering community, companies interested in possible business opportunities, as well as graduate and postgraduate engineering students looking for a career in fusion. The ITER Day would not have been complete without the voice of the industrial partners. Four companies - Ferrovial, Empresarios Agrupados, APPlus+ Laboratories and FUS_ALLIANZ Science, Engineering & Consulting - ranging from large engineering to small innovative ventures, took the floor to provide testimonies of their involvement to the project. Working for ITER provides them with a "quality label" opening other business opportunities, it stretches their frontiers of knowledge and forces them to innovate and go a step beyond. Oriol Ribas from Ferrovial highlighted the feeling of being part of ITER: "we take great pride in working for the greatest international collaboration in energy – at the same time, we feel the importance of the mission we have to bring fusion energy to mankind".

F4E participates in the first Big Science Business Forum (BSBF2018) alongside Europe's largest Big Science organisations

Nine of Europe's largest Big Science organisations – CERN, EMBL, ESA, ESO, ESRF, ESS, European XFEL, F4E, and ILL – have come together to create the Big Science Business Forum 2018 (BSBF2018). They want to contribute to a stronger, more transparent and consolidated Big Science market in Europe for the benefit of both science and businesses. BSBF2018 has become Europe's new one-stop-shop on business opportunities worth more than 12 billion EUR for the next five years.

Representatives from some of the world's largest high-tech research facilities gathered for the first time to offer insight into procurement opportunities and orders spanning from advisory engineering work and architectural tasks, to advanced technical equipment, concrete building projects and radiation-resistant materials. The conference took place in the Tivoli Congress Centre in Copenhagen during 26-28 February 2018, hosted by the Danish Ministry of Higher Education and Science and BigScience.dk. More than 1000 delegates from more than 500 companies and organisations from approximately 30 countries participated to this first edition.

F4E is one of the founding organisations of the initiative, together with CERN, EMBL, ESA, ESO, ESRF, ESS, European XFEL, F4E and ILL. A further nine Big Science organisations joined the conference programme – ALBA, DESY, ELI-NP, ENEA, FAIR, MAX IV, SCK•CEN – MYRRHA, PSI and SKA – thereby gathering 18 of the world's most advanced Big Science organisations under one roof. "In terms of reputation and image, the participation of F4E alongside renowned science institutions, is a clear sign of the maturity that F4E has reached 10 years after its creation", underlined Leonardo Biagioni, F4E's Head of Contracts and Procurement and one of the F4E members of the International Organising Committee of the event.

In the open exhibition space, participants met more than 200 companies and organisations and in 19 conference sessions, they listened to leaders and experts from the Big Science organisations. More than 800 "1-to-1" business meetings were arranged between delegates. The key speakers opening the conference were high-level representatives from the nine organising Big Science organisations, together with the EU Commissioner for Research, Science and Innovation Carlos Moedas and the Danish Minister for Higher Education and Science Søren Pind.

F4E was represented by Richard Cobben, Head of ITER Delivery Department and a number of colleagues who presented the business opportunities arising from the construction of ITER and the manufacturing of the European components. Companies who had previously worked for other Big Science organisations showed a lot of interest in the work of F4E, many technical explanations were offered and many more business cards were exchanged. Apart from attracting new companies and providing a stable market for industry, some other – more unexpected – benefits of the Big Science market became apparent. Carlo Damiani, F4E Project Team Manager for Remote Handling: "I was glad to find that there are possible synergies with some of the other Big Science organisations and that the technical work in remote handling and maintenance bears many similarities. I will be contacting my colleagues in the respective Big Science organisations for further discussions. We don't need to reinvent the wheel every single time."

Following on from this very successful first Big Science Business Forum, the founding organisations are already looking at the next edition planned to take place in the Spring of 2020.

EVENTS
F4E NEWS – JUNE 2018

Opening session at BSBF 2018 © F4E

Richard Cobben, Head of ITER Delivery Department, delivering a keynote speech © F4E

Leonardo Biagioni, F4E Head of Contracts and Procurement, explaining the business opportunities in ITER © F4E

Europe reiterates its firm commitment to ITER

Commission proposes EU budget following green light on new baseline.

© Marie-Françoise Plissart

At its meeting of 12 April 2018, the Council of the European Union adopted "conclusions" on the reformed ITER project, underlining its fundamental importance in the European roadmap to make fusion energy a reality in the second half of this century. The representatives of the EU member states acknowledged the improvements on the project governance and the efforts of the new management to bring the project back on track in line with the staged approach which forms the basis of the new baseline. The Council confirmed the European commitment to the successful completion of the ITER project and its intention to look for the necessary funds within the next EU Multiannual Financial Framework.

The good news from Europe continued when the European Commission presented, on 2 May 2018, its proposal for the European Union budget for the period 2021-2027. The Commission recalled that "Europe's future prosperity depends on the investment decisions we take today", and underlined the strategic contribution of ITER "to develop a viable source of safe and environmentally friendly energy for the future". The amount of 6 billion EUR proposed by the Commission is fully in line with the project estimates adopted by the ITER Council and included in its previous Communication on the "EU contribution to a reformed ITER project", presented in June 2017.

Building on this recent communication, the Commission will present detailed financial proposals for the future thematic programmes. The decision will then fall to the Council, acting by unanimity, with the consent of the European Parliament. European Commission President, Jean -Claude Juncker, called for negotiations to be given the utmost priority, so that agreement can be reached before the European Parliament elections and the European Council summit of May 2019.

Fusion for Energy
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F4E News is a magazine 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-18-001-EN-C (Print)
FU-AB-18-001-EN-N (PDF)