F4E NEWS

Fusion for Energy Magazine

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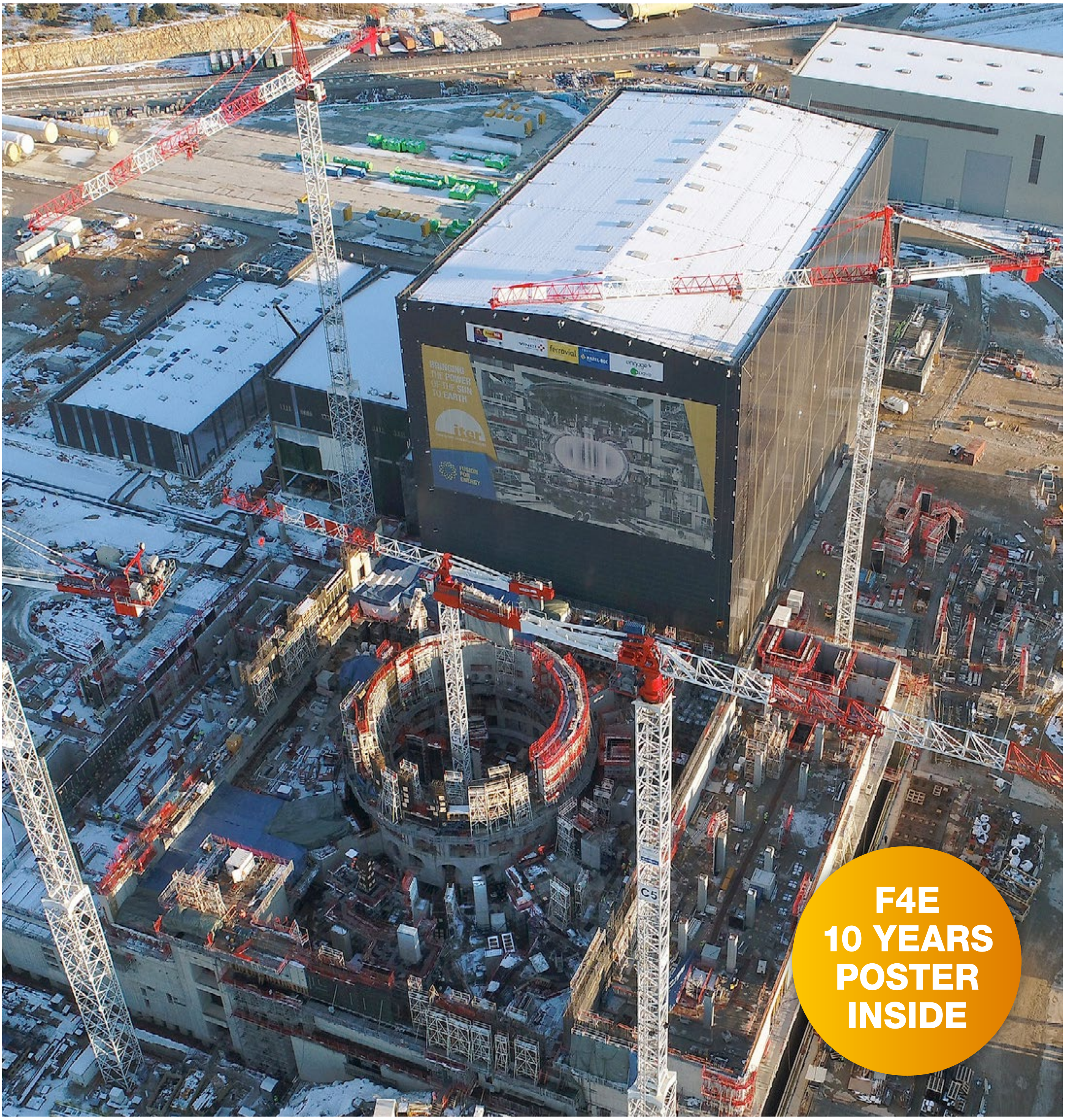

Aerial view of the ITER Tokamak Complex December 2017, © ITER Organization/EJF Riche

Celebrating 10 years of F4E

This was the event to pay tribute to the work of F4E staff, acknowledge the contribution of various companies and laboratories that we have been collaborating with, and finally, thank our stakeholders for their support. Under the same roof, more than 500 people gathered to celebrate Europe's involvement in ITER and F4E's role in making this a reality.

(L-R) Thörsten Lower, Chief of Development, Equipment and Technology of Probeam; Sibylle Günter, Scientific Director of Max Planck Institute for Plasma Physics; Valerie Jamieson, New Scientist's Editorial Content Director; Rafael Triviño, General Manager of ENSA; François Darchis, Senior Vice-President of Air Liquide

The ten year anniversary offered the possibility to look back on our achievements and put into context the work that we do and its impact. An uplifting clip, setting the tone of the ceremony, felt like an emotional tour de force asking attendees "what is this energy that we are trying to harness and can it change the future?". This was in fact the underlying theme which brought together the interventions of all speakers.

The Director of F4E, Johannes Schwemmer opened his addresses by saying "few projects in the world combine such ambition, cutting-edge science and technology and energy for future generations. Only by working together we will deliver fusion as a sustainable energy for the future." To introduce each speaker we asked members of staff from different teams and countries to act as masters of ceremony. They gave a more personal touch to the event with their presence and voice reflecting our collective efforts. European Commissioner for Climate Action and Energy, Miguel Arias Cañete, highlighted the human capital behind this one-of-a-kind project and wanted to "praise the work of so many scientists and engineers, and the fact that countries, industries and research centres are working together to translate a common vision into a reality." The Mayor of the city of Barcelona, Ada Colau, explained that it was "...an honour to host the European Agency and this was also proof of Barcelona's commitment to science and innovation." For Spain's Secretary of State for Research, Development and Innovation, Carmen Vela, ITER will "...also open the door to the commercialisation

Clockwise from the left: Johannes Schwemmer, Director of Fusion for Energy, opening F4E's 10 year anniversary, European Commissioner for Climate Action and Energy, Miguel Arias Cañete, delivering the keynote speech, The Mayor of Barcelona, Ada Colau, highlighting the merits of clean energy and the threat of climate change, Spain's Secretary of State for Research, Development and Innovation, Carmen Vela, highlighting the importance of big science projects

of fusion energy by laying the industrial foundations in each of its parties."

A clip summarising the technical achievements in different factories and facilities offered a smooth transition to the business aspect of ITER. Valerie Jamieson, New Scientist's Editorial Content Director, warmed up the audience by reminding us all of the value of big science projects acting as wheels of change. Then, she skillfully moderated a panel discussion with François Darchis, Senior Vice-President of Air Liquide; Thörsten Lower, Chief of Development, Equipment and Technology of Probeam; Rafael Triviño, General Manager of ENSA, and Sibylle Günter, Scientific Director of Max Planck Institute for Plasma Physics, the participants explained how Europe's participation in ITER offered them the possibility to demonstrate their know-how and improve it, grow and tap on new markets and above all, collaborate.

The event closed with an emotional 10 year anniversary clip gathering wishes from all over the world from ITER Parties, stakeholders and big science projects. A big puzzle made out of the faces of many of our members of staff was the final image. Without their work and commitment none of this would have been possible.

A cocktail, where guests were invited to visit the F4E exhibition narrating the history of the ITER construction site, the progress of the various components, and the contribution of our industrial partners, offered a memorable crescendo with photo and networking opportunities. It was a night to remember!

Glide over the ITER site

New Buildings, facilities and the arrival of more equipment mark a new era.

Aerial view of the ITER Tokamak Complex, December 2017 © SNC Engage

They say that taking distance helps us see the big picture. And this is exactly our impression every time we fly above the ITER site. The size of the impressive platform is comparable to that of a high-tech village. On the 42 hectares, where more than 2000 people are working during different shifts, the scenery is rapidly changing. New buildings are being erected, more facilities are being completed and additional pieces of equipment are being assembled. Let's land on the ground to find out why.

Romaric Darbour, F4E's Deputy Project Manager for Buildings Infrastructure and Power Supplies, supervising the construction, explains that "the number of buildings entering into their final stage is increasing; highly-technical work, like the one performed at the Tokamak complex, is accelerating. The new year is considered to be a turning point for the civil engineering works for some of the main facilities and infrastructures of the project."

The Tokamak building can be described as the cornerstone of the ITER facility because it is there that the biggest fusion machine will be located. A cylinder made of concrete that will act as a safety barrier between the machine and the edifice is known as the bioshield. It is already reaching its final level (L3-the fourth floor of the building) and is expected to be completed later this year. Inside its structure, a 30 m diameter lid has been firmly fixed and beneath it the teams of people working for Nuvia are installing reinforcement and will soon start pouring concrete to build the so-called "crown". 18 massive blocks of steel will be 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 $400 m^3$ and each of the 18 supporting steel blocks weighs more than 3 T. "A specific formula has been developed to produce this concrete in order to withstand a compression three times higher than that of a normal housing building" highlights R. Darbour.

Meanwhile, the consortium of Vinci Ferrovial and Razel (VFR) has been making progress with the works on the rest of the Tokamak building. The second floor has been completed and works on the third floor are to be completed by March 2018. The first plots of concrete are being poured on the fourth floor. At the Diagnostics building the fourth floor is being erected and by 2019 it is expected to be completed. Meanwhile, at the adjacent the Tritium building, the slab of the third floor is advancing and it is expected to be finished by mid-2018.

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(L-R) Aerial view of the two ITER Magnet Power Conversion Buildings and the ITER Cryoplant, December 2017 9 © SNC Engage

In the pit of the ITER Bioshield, January 2018 © ITER Organization

Starting to plan the installation of equipment at the ITER Cold Basin and Cooling Towers facility, December © SNC Engage

The civil engineering works of the ITER Assembly Hall have been completed. Inside the massive workshop, where some of the most high-tech equipment in history will be put together, the two 750 T cranes are being tested, undergoing qualification by simulating the weight of the heavy components they will have to lift. The Heating Ventilation and Air Conditioning (HVAC) installation is nearly finished. And as workforces are putting their finishing touches, new tooling is making its way on the premises of the building from across the world in order to be assembled. At the recently-finished Assembly Area, where fresh deliveries are dropped, one can sense the buzz. The construction works of the Cleaning Facility and the Site Services building are also completed paving the way for the installation of HVAC and cable trays.

The facility of the ITER Cryoplant is nearly completed and the installation of the massive cryogenic tanks is imminent. The structural works and cladding, the installation of the doors, and painting have been completed. The workforces are currently carrying out the final wave of works. In parallel, the HVAC works and the installation of the cable trays are coming to an end in order to hand over the building to the engineers who will supervise the fitting of the cryogenic components. Next to it, the Magnet Power Conversion buildings are now reaching the stage to be weathertight and nearly 60% of the slabs where the transformers will be located are finished.

There has also been rapid progress at the Cooling Towers facility where teams of engineers are starting to plan their installation. The lower slab and the walls are completed together with the top slab which is nearly finished. The steel structure of the Heat Exchangers building has started and cladding is progressing. Similarly, at the edifice of the Cooling Water Pump Station, expected to be completed in April, the foundation slab and steel structure are halfway there. On the other end of the ITER site, close to the power grid and the transformers, the structural works of the Electrical Distribution building, which is responsible for the power supply on-site, are completed. The HVAC works and electrical distribution works are advancing as planned.

We conclude our visit on-site by going deep underground. Nearly 30% of the construction of the concrete galleries and the associated infrastructure works, have been completed. Trenches as big as tunnels, filled with tubes the size of humans, give visitors the impression that there is an entire city below the ground. It is advancing at galloping pace and it is as fascinating as the one we see from high above.

Europe delivers to ITER all of its tanks for the Cryoplant and the first cryopump

The successful delivery on-site of the gigantic pieces of equipment is considered an important milestone for F4E's team of experts working in the fields of cryogenics and transport logistics.

Europe's first tank passed-through the gates of the ITER facility in November 2016 and almost a year later all other tanks followed departing from different countries (Sweden, Czech Republic, China, and Turkey). The manufacturing of all components was undertaken by Air Liquide, and its subcontractors, while the logistics were handled by DAHER

The biggest fusion device will require a massive "refrigerator" to perform several tasks: first, it will have to cool down its magnets to -179 ° C so that they become superconductive, second, it will help the cryopumps to minimise any thermal losses in the cryostat, and third, it is going to improve the thermal insulation of ITER's massive vessel in order to create a vacuum.

ITER's Helium (He) plant is estimated to handle approximately 24 T of He, which corresponds to the gas needed to fill up 14 million helium balloons. The plant will consist of seven warm Gaseous Helium (GHe) tanks (7 x 360 m³); one Liquid Helium (LHe) storage tank with a capacity of 175 m³ at 4.5K (-268.5 °C), able to store up to 85% of the gas that the plant will need, and two quench tanks.

The LHe tank, widely considered as the "jewel" of the ITER Cryoplant, has finally reached the construction site. This double walled vessel measuring 25.5 x 3.8 m, manufactured by CryoAB (Sweden), has the capacity to handle 20 T of Helium. The whole manufacturing and testing activities required for the acceptance of this tank took one and a half year since the approval of its design. The transportation from Göteborg has been performed in two phases: one by boat up to Fos-Sur-Mer, the industrial port of Marseille, and the final trip to the ITER site by a special convoy.

Representatives of the Vacuum Teams of F4E and ITER IO © ITER IO

Assembly of the cryopump at Research Instruments, Germany © F4E

The other arrival on-site has been that of the GN2 buffer tank which also plays an important role in the LN2 plant. This vessel has been manufactured in China by FURUI. The main function of this carbon steel pressure tank is to cope with different pressure levels of the LN2 Plant. It will be connected to the Nitrogen compressors where a panel of control valves will stabilise the pressure levels. Earlier this year, the LN2 tank was delivered on-site

Thanks to the excellent collaboration between all parties, F4E, DAHER and its suppliers, as well as Air Liquide, the components were delivered with less risk avoiding night transport, without highway closures, and intensive police escorts. Ben Slee, following on behalf of F4E the contract signed with DAHER, explains that "good co-ordination can generate substantial financial gains. For instance, the transportation costs have been significantly reduced because of these new measures. In addition, combining the delivery of these components with those of other ITER Parties resulted to more savings."

The GN2 buffer tank, part of ITER's Cryogenic system, has been delivered on-site, Cadarache, October 2017

The LHe tank, widely considered as the "jewel" of the ITER Cryoplant, has finally reached the construction site, Cadarache, October 2017 © DAHER

Parallel to this, F4E's vacuum pumping specialists have celebrated an important milestone together with their counterparts from ITER International Organization: the first cryopump has been successfully manufactured following the specifications of the cryopumps to be used in the torus of the machine and cryostat. The component has been delivered on-site and will go through a series of tests. F4E has been responsible for the procurement of this component, which took roughly four years to be manufactured and reached a cost of approximately 3 M EUR.

Research Instruments, Alsyom and SDMS are some of the companies that have contributed to this technical achievement with the support of their subcontractors. The equipment which measures 3.4 x 1.8 m and weighs close to 8 T, has been developed in different stages and has been progressively assembled.

After the performance testing of this cryopump is successfully completed, eight more will be manufactured under the supervision of F4E. Six of them will be installed in the torus of the ITER device and two in the cryostat. When ITER is operational, the gases resulting from the fusion reaction will be pumped with the help of the six cryopumps from the lower part of the torus to the roughing system, where they will be processed and treated in a closed loop as part of the fuel cycle. Europe is the only party responsible for the production of the cryopumps. The successful completion of the first one will help towards the finalisation of the design of the reaming eight, which are expected to be delivered in 2022.

Europe's first ITER Toroidal Field magnet enters final manufacturing stage

The world's most high-tech magnet has departed from the ASG factory, La Spezia, where Europe is manufacturing its share of the ITER Toroidal Field coils. It is the first out of the 10 TF coils that will be produced in this factory and will eventually be installed in the machine in order to confine the super-hot plasma.

The case containing Europe's first magnet departing from the ASG factory, La Spezia, Italy

The component weighing 120 T, and measuring 9 x 16 m, has been transported by a remotely controlled truck to the harbour of La Spezia to reach the port of Marghera. The magnet will be delivered to SIMIC, where the cryogenic tests will be performed and finally, it will be inserted in its coil case. Then, the impressive component, weighing with the case a total of 300 T, will head to its final destination, the ITER site in Cadarache, France.

The magnet is the result of accurate design and manufacturing, combining robotised and computerised machining with limited manual intervention. F4E is financing the production of the ten magnets. At least 26 companies, counting more than 600 employees, have been involved in their fabrication.

A superconducting cable of 5.5 km length has been used to manufacture this first magnet. This special cable has undergone various fabrication procedures using state-of-the-art robotics such as automated welding, "vacuum chamber" testing phases so as to check the high quality of the component under operating conditions. The coil contains superconductive cables, made by the Italian Consortium for Applied Superconductivity (ICAS), coordinated by ENEA, involving the Italian companies Criotec Impianti and TRATOS Cavi. The steel plates, where the superconductive cable is inserted, have been manufactured by CNIM and SIMIC. The winding of the conductor and the manufacturing of the entire magnet has been carried out by ASG, Iberdrola Ingeniería y Construcción and Elytt for a cost of 158 million EUR awarded by F4E.

Alessandro Bonito Oliva, Head of Magnets for F4E, explains that: "the departure of Europe's first magnet from the ASG factory is a milestone of symbolic importance. This factory has been its "home" during the last five years. Various companies and their workforces have been daily working to reach this objective and I am proud to say that we are entering into the final manufacturing stage. Congratulations to all!"

ASG Superconductors Chairman and Shareholder, Davide Malacalza, said: "our company collaborates daily with the leading companies in the industry as well as with the main scientific research institutes and centers like CERN, ENEA, INFN, Fermilab, GSI. Working for the ITER project with F4E is another example of a virtuous partnership between the public and private sectors. ASG Superconductors CEO Sergio Frattini stated: "Today an impressive magnet left our factory. This confirms our leading position among the world leaders in the sector of superconducting magnets. We are extremely proud of the work we have put in collaboration with other companies. Many thanks to all the people who made this achievement possible. As we still have to deliver nine more magnets by 2019, we can't stop working and some of the remaining nine units are already at the final phases of the manufacturing."

Nine rings to cope with ITER's powerful magnetic fields

To cope with the fatigue exercised on the machine's Toroidal Field coils, and with the deformation resulting from the powerful magnetic fields, Europe is manufacturing nine Pre-Compression Rings (PCRs). Three of them will be placed on top of the coils and three below them. An extra set of three will be manufactured as spare in case there is a need in future to replace the lower set.

Every legend has a ring in its narrative. Most of the times it is lost but when found it has the power to awake us, liberate us or even make us invincible. ITER, embarking on an epic journey to bring the energy of the sun to Earth, could be no exception. In fact, one ring will not suffice to "save" its impressive magnets from the electromagnetic loads as they confine the super-hot plasma. The biggest fusion device will require nine rings and F4E is responsible for delivering them.

ITER will rely on a sophisticated system of superconducting magnets consisting of the central solenoid, which can be described as its backbone; the correction coils, which will reduce the range of magnetic errors created by imperfections due to the location and geometry of other coils; six Poloidal Field coils responsible for the shape and stability of the plasma, and 18 Toroidal Field (TF) coils which will create a magnetic cage to entrap the hot gas. To cope with the fatigue exercised on the TFs, and with the deformation resulting from the powerful magnetic fields, nine pre-compression rings will be manufactured. The fiberglass composite rings, consisting of more than a billion miniscule glass fibers, will be glued together by a high performances epoxy resin. They will have a diameter of approximately 5 m, a cross-section of nearly 300 mm x 300 mm and will weigh slightly more than 3 T.

We visited the workshop of Airbus Defence and Space (Airbus D&S) in Madrid where teams of engineers and technicians are aiming to complete a full-scale prototype so that "real" production of pre-compression rings can kick-off in future. The components are manufactured using a well-established technology in the field of aerospace known as "automated fiber placement." To reach this stage, three full-scale ring slices of fiberglass epoxy resin have been cured. Previously, one additional full-scale slice has been produced and has undergone the first stage of the qualification phase. F4E experts will soon examine the results of the full-scale prototype in detail before production advances.

Several kilometres away, another team of technicians is working at CNIM's workshop in Toulon (FR) trying to develop the three spare pre-compression rings. They have been building on the work already performed by companies such as Exel (FI), Solvay (UK), CMF (IT), CMC (FR) and test laboratories such as Rescoll (FR), Etim (FR) and KIT (DE). As standard practice requires, they have started with the fabrication of a mock-up, which is roughly 1005 mm in diameter, almost 1/5 of the real size of the component. The material they have opted to use is pultruded laminate, which will be wound along the trajectory of the ring. As the tooling is slowly bending the material, a bonding tape is applied on its layer. This helical movement is repeated several times until the pre-compression ring mock-up consists of multiple layers which will then be cured. Afterwards, the mock-up is placed on an equipment to be machined to the final dimensions and to remove excessive material.

Next, it will go through non-destructive testing (NDT) and in the end it will be transported to ENEA's facility where final destructive tests will be performed. What is the state of play now? A series of mock-ups has been produced and qualification tests are being performed. It is estimated that by next year the "real" production of the spare pre-compression rings will begin.

Technician examining the lay-up of the full-scale prototype of the Pre-Compression Ring's slice © AIRBUS D&S Spain

Installing the Pre-Compression Ring prototype in order to perform checks © CNIM

Europe and China closely collaborate for the production of ITER's sixth Poloidal Field (PF) coil and celebrate the completion of China's first PF coil feeder

Five of the six Poloidal Field (PF) coils that will manage the shape and stability of ITER's powerful plasma are under Europe's responsibility. One of them is being fabricated in ASIPP, The Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, following an agreement between Europe and China.

The progress of PF6 is impressive. It consists of 9 double layers of superconductor, known in the ITER jargon as Double Pancakes (DP) because of their shape, which need to go through various fabrication steps. One of the first steps is winding the conductor with extreme accuracy to achieve the geometry of the coil. Around 30% of the entire coil has been successfully wound. If we were to cluster the main manufacturing activities of the DPs in four main steps these would be: winding, insulation, the manufacturing of the joints where cold Helium and current will be injected to make them superconducting, and vacuum pressure impregnation, where any air left in the component is removed and epoxy resin is carefully injected, and then cured to make it solid.

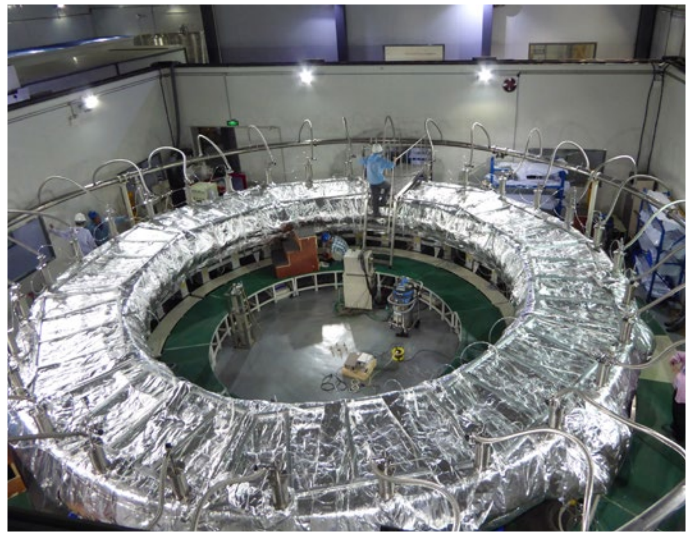
The winding of a new DP has started, making it the fourth in a row to undergo this process. The terminations of two DPs have been completed and the first DP is in its final stage of vacuum pressure impregnation. It will soon move to the stacking station so that the second DP goes through impregnation. "It's a sequential process that requires very good co-ordination so that one component moves to the station of the other. The collaboration with the team here is excellent. We are learning by doing and they are extremely committed to this task" explains Carlo Sborchia, F4E's PF6 Responsible Officer, who spends half of his time in Hefei. Peter Readman, F4E's Technical Officer, who is there a quarter of the year, is commenting on the excellent results of the termination works. "You will hear a lot of talk about this because it is an extremely delicate technical task and the results have been very good! If we don't get the joints right, where the Helium and current will flow in the magnet, they will quench and this would be a massive setback in operation" he explains.

After impregnation, one DP gets stacked above the other until all nine are impregnated together as one piece. Parallel to the manufacturing of the DPs, the ASIPP engineers are testing with mock-ups the next fabrication steps, in order to be ready to proceed with the real component. The next step for the mock-up will be to undergo full coil impregnation.

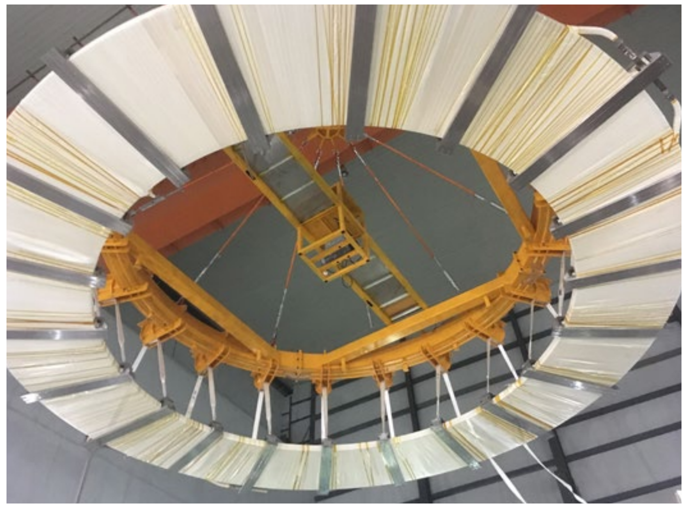
There is without a doubt a sense of pride and responsibility in being part of the biggest energy project that could make history. In line with this spirit, Johannes Schwemmer, F4E Director, during his recent visit to China he succeeded in establishing closer ties. Meetings with senior representatives from China's ITER Domestic Agency, in order to discuss the overall progress of the project, combined with visits to key manufacturing facilities, have proven extremely informative and productive for both parties.

Johannes Schwemmer took the opportunity to tour the PF6 coil workshop to see all stages of the coil fabrication from the winding to the impregnation and meet the F4E team. The Director of F4E congratulated the Chinese colleagues on meeting the main milestones, in particular, the qualification work and the winding of the dummy double pancake as well as the excellent working relationship between F4E and ASIPP. Building on the good progress achieved, all participants agreed on the importance of maintaining the manufacturing schedule.

Working on the terminations of one Double Pancake of Poloidal Field coil 6, ASIPP, China



Performing impregnation on a Double Pancake mock-up of Poloidal Field coil 6, ASIPP, China



Crane lifting a Double Pancake of Poloidal Field coil 6 in order to be placed on another station, ASIPP, China

Working on the joint terminations of one Double Pancake of Poloidal Field coil 6, ASIPP, China

Another highlight of his visit has been the ceremony marking the completion of the first ITER Poloidal Field (PF) coil feeder manufactured in China. Representatives from China's authorities, ITER China, ITER Organization, F4E, and industrial partners, were invited to ASIIP to celebrate this impressive technical achievement. To honour the presence of Europe at the ceremony, and underline the value of international collaboration, the Director of F4E was asked to cut the ribbon marking the successful fabrication of the component. Media were also present to capture this important moment and Johannes Schwemmer took the opportunity to congratulate ITER China. "It's a very difficult component with a lot of new technologies like high-temperature superconductors…so China is showing that it is the strongest supporter for ITER" he said.

Magnet feeders perform two vital tasks for the operation of the ITER Tokamak: they control the cryogenic liquids which are needed to cool down the temperature of the magnets, and they connect the magnets to their power supplies. In total, 31 superconducting feeders will relay electrical power and cryogens through the warm-cold barrier to the ITER magnets.

(L-R) Prof Jiangang Li, ITER STAC Member for China, Johannes Schwemmer, F4E Director, Luo Delong, Head of ITER China, cutting the ribbon

Europe has delivered major components to the ITER Neutral Beam Test Facility

The most powerful beam source to date has arrived at SPIDER paving the way for commissioning and operation in early 2018. Meanwhile at MITICA, the High Voltage Deck and Bushing that will contribute to its mythical electrical power have been installed.

To heat up ITER's plasma at 150 million ˚ C, roughly ten times the temperature at the core of the sun, we will need powerful heating systems using high-energy beams. By raising the temperature of the hot gas we accelerate the speed of the two nuclei (deuterium and tritium) to make them crush in order to trigger off a fusion reaction. The principle is simple. In practice, however, this requires the fabrication and testing of new equipment before manufacturing the components for ITER. For this reason a facility has been set up at the premises of Consorzio RFX in Padua (Italy) to develop and test a Neutral Beam Injector (NBI) prototype.

The recent delivery of Europe's beam source to the SPIDER experiment (Source for Production of Ion of Deuterium Extracted from Radio Frequency plasma), one of the test beds of ITER's heating systems, has been an important achievement for F4E, the ITER Organization, Consorzio RFX and the companies involved. During the first half of 2018 the temperatures in the vast hall where the equipment is being installed will rise because operations will kick-off and a new chapter for the NBTF (Neutral Beam Test Facility) will begin.

SPIDER will help engineers to finalise the development of the ion sources required for the ITER NBI, and to test the essential 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 generated by this beam source in one hour are equivalent to the energy required by roughly 1 000 medium-sized apartments in one day. As a matter of comparison, it is twice as big as the largest existing beam source, ELISE, operating at the Max Planck Institute for Plasma Physics, Garching.

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 equipment, which started almost 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. The SPIDER beam source, weighing about 5 T and measuring 3 x 3 x 2 m, will be installed inside its vacuum vessel with the help of a sophisticated handling tool. Both have already been delivered and were part of the same contract.

Antonio Masiello, F4E's Technical Officer for this contract, explains that "the fact that such a beam source is a first-of-a-kind and that many of the sub-assemblies had never been manufactured before, represent a challenge in itself. It's an R&D equipment requiring an exceptional effort in terms of project management to deal with the large number of parts counting 2 000 in total, and in particular to guarantee that they will all fit together during the final assembly. During the various phases of the project, a lot of planning was required involving more than 30 companies from all over Europe counting on the contribution of at least 50 professionals."

Representatives of F4E, Thales and RFX posing in front of the SPIDER beam source, ©Thales_All rights reserved

Charles-Antoine Goffin – DefSI and Transformation Director of Thales, confirms that "Thales is very proud to have delivered the SPIDER beam source to F4E. We are proud to be part of this first step towards the development of ITER's heating systems. The finalisation of SPIDER has only been possible thanks to the very high competency and motivation of the teams, because in such "state-of-the-art" project, one never knows what difficulties may emerge. Thales is very thankful to its partners Galvano-T, Cecom and Zanon and to F4E, RFX and ITER Organization for the great collaborative spirit making SPIDER a success."

Meanwhile at MITICA, which stands for Megavolt ITER Injector and Concept Advancement, tests will be performed with "mythical" levels of beam energy and electrical power. It relies on the in-kind contributions of F4E, ITER Organization, the ITER Domestic Agencies of India and Japan, plus Consorzio RFX.

F4E and Siemens started working together three years ago in order to develop three units that will be part of the power supplies for the Neutral Beam Injection system. Each unit is made of: i) an electrically insulated box, so-called "High Voltage Deck", that hosts the power supplies for the ion source of the injector, ii) a gas-insulated bushing, called "High Voltage Bushing Assembly", bringing the electrical power through the transmission line all the way to the ion source. To reach the required high voltage insulation levels of 1 MV they are using SF6, a potent greenhouse gas, as electric insulator.

The insulated box is distributed over two floors covering a surface of 150 m^2. Think of it as a Faraday cage that can maintain a level of voltage of 1 MV isolating the power supplies of the ion source from the ground. Inside its shiny metallic shell there are transformers, power distribution systems, converters and control cubicles weighing approximately 50 T. The box rests on eight insulated "columns" which are more than 6 m high above the floor. The installation of the High Voltage Deck has now been completed. It has successfully passed the electrical acceptance tests in a factory, and has concluded the mechanical, structural and seismic tests at the MITICA facility.

In the meantime, there has been excellent progress on the bushing assembly, also supplied by Siemens and its subcontractor HSP GmbH, which is connecting the power supplies of the ion source to the transmission line. The equipment has been fully installed and all tests required have been properly completed. It is now ready to be connected to the transmission line supplied by Japan and then to proceed with the final tests of the entire system.

"The bushing is a-first-of-a-kind equipment which was not available on the market at the time of procurement. We collaborated closely with our industrial partners to manufacture it and worked out together the challenging logistics for its installation at the MITICA facility. The bushing assembly has a height of 12 m and weighs approximately 19 T. This European equipment will be connected to the transmission line which has been designed and built by Japan. This is the outcome of strong international collaboration which is in line with the spirit of the ITER project" explains Muriel Simon, F4E's Technical Responsible Officer following the contract with Siemens.

Michael Krohn, Project Manager of Siemens, explains that "the involvement of our company in this project offered us the opportunity to bring in our experience in global business together with our excellent technical expertise delivering standard and customised solutions. Thanks to our collaboration with F4E, we have become familiar with the ITER project and fusion energy."

Tullio Bonicelli, Head of F4E's Neutral Beam and Electron Cyclotron, Power Supplies and Sources, highlights that "the successful delivery and installation of these "beyond the state-of-the-art" components at the MITICA facility paves the way for more tests that will be performed during the second half of the year after the equipment is connected to the transmission line. The operation of such extensive system at 1 MV is not only challenging but also unprecedented. The fusion community will be looking at us for answers in order to take our next step towards the fabrication of the ITER Neutral Beam components."

The installation of the High Voltage Deck inside the MITICA High Voltage hall, October 2017. © Consorzio RFX

The installation of the High Voltage Deck inside the MITICA High Voltage hall, October 2017. © Consorzio RFX

All five European Vacuum Vessel sectors are under fabrication

This proves Europe's industrial capacity to produce high-quality components which need to follow stringent rules in terms of design and manufacturing in order to adhere to international nuclear rules.

All actors involved in delivering the ITER vacuum vessel during their visit to the workshop of MAN Diesel & Turbo SE in Deggendorf, Germany (copyright: Steve Schnieke)

The fabrication of all five Vacuum Vessel sectors that Europe is responsible for ITER is progressing well. This parallel production of such a large number of geometrically complex mechanical sectors in ITER grade stainless steel is in contrast to F4E's previous production of one sole sector and shows the commitment of F4E to the ITER project. This proves Europe's industrial capacity to produce this type of mechanical, high-quality component which needs to follow stringent rules in terms of design, manufacturing and materials in order to adhere to international nuclear rules. The know-how accumulated during this process is key in increasing Europe's competitiveness in the nuclear and mechanical engineering fields. The simultaneous production of all five sectors is a big milestone for the ITER project and shows that F4E is able to manage the large workload involved in delivering Europe's ITER Vacuum Vessel contribution.

With contractors and subcontractors within the Vacuum Vessel consortium, located across Europe, the AMW consortium (consisting of Ansaldo Nucleare S.p.A, Mangiarotti S.p.A and Walter Tosto S.p.A – Italy), and its main subcontractors: CNIM (France), Equipos Nucleares SA – ENSA (Spain), MAN Diesel & Turbo SE (Germany), and ProBeam (Germany), has vastly increased its manufacturing capacity and has already proven in its early stages its drive to deliver. Fabrication consists of the following steps: qualification, manufacturing design, material procurement, machining into the correct shapes, welding of the parts to form the bigger sectors for the Vacuum Vessel –

Parts placed together before assembly of the segment PS3 for the first VV sector, sector 5, at Walter Tosto

each of the five sectors is at a different stage of fabrication but definitely moving forward. Notable in terms of qualification, is that in part due to the past experience, CNIM was able to qualify its welding techniques according to the nuclear code in less than two months, a record in comparison to earlier welding qualification times.

The increased production speed is also due to the improvement seen in the preparatory activities leading to better quality welding used to join the different pieces that make up the Vacuum Vessel sectors. "We have been able to hone the welding techniques, thus allowing us to complete welding more rapidly and with a better end-result", says Francesco Zacchia, Project Manager of the Vacuum Vessel Team.

The manufacturing of the Vacuum Vessel sectors is time-consuming and labour intensive due to their first-of-a-kind geometry and size, where each one measures 6.5 m high, 3 m wide and 6.3 m deep, and weighs around 500 T. The ITER Vacuum Vessel sectors are unique, as despite being made of stainless steel, they will have complex shapes, thus resulting in a most challenging design and manufacture. "The shape of the Vacuum Vessel sectors is far more sophisticated and delicate than what is usually the case for components made of stainless steel where the shapes are usually more conventional", says Max Febvre, manufacturing coordinator of the Vacuum Vessel Team.

At the end of last year, a meeting bringing together all actors involved in delivering the ITER vacuum vessel: the ITER IO Central Team, F4E and the three other Domestic Agencies from India, Korea, Russia, as well as international industry, namely the AMW consortium, Hyundai Heavy Industries (HHI), Avasarala Technologies Limited, MAN Diesel & Turbo SE, was held at the premises of ITER IO in Cadarache, France, as well as MAN Diesel & Turbo SE in Deggendorf, Germany.

While Europe through F4E is responsible for delivering five of the nine vacuum vessel sectors for ITER, Korea is responsible for providing the remaining four. Korea started work on the vacuum vessel sectors one year ahead of Europe and has completed the final welding of the first of the four segments for sector number 6 – thus allowing for a substantial sharing of concrete technical knowledge from Korea to the involved Domestic Agencies participating in the meeting. In exchange, Europe also provided Korea feedback on its own manufacturing experience. "Since Korea is more advanced in its manufacturing, its contribution on manufacturing technologies, including non-destructive control methods, has been very valuable for Europe, as we can then use this knowledge in the fabrication of our own vacuum vessel sectors", explains Francesco Zacchia, F4E's Vacuum Vessel Project Team Manager. "The meeting also provided the opportunity for the participants to develop synergies and share experience", he adds.

The group also visited the ITER IO offices and the cryostat on the ITER site (photo courtesy of MAN Diesel & Turbo SE)

Arial view of the ITER worksite December 2017 © SNC Engage

Europe makes progress in Remote Handling tooling and reaches out to Japan to work closer together

Remote Handling is one of ITER's most fascinating technology chapters. Not only because of the futuristic man-in-the-loop robotics combined with virtual reality, but mostly because of the new unchartered territory that industry and engineers will enter. Maintaining the ITER machine by deploying lengthy robotic arms; using tooling to cut and weld in tiny spaces filled with equipment; lifting heavy loads with precision are tasks that unleash our imagination.

How will all this be possible in fusion's biggest Babel Tower? Europe will deliver the remote handling systems of the ITER Divertor;Neutral Beam cell; Cask and Plugs and its in-vessel viewing. Japan is responsible for the ITER Blanket remote handing system, which will be hosted inside six of the casks delivered by Europe, and ITER Organization will have to integrate them all and follow their operation.

At the margins of ISFNT, the international fusion technology symposium recently celebrated in Kyoto, F4E's Carlo Damiani, heading the team of Remote Handling, took the initiative to meet with counterparts from Japan's ITER Domestic Agency and some of its suppliers working in this field. "Now that Europe has placed all of its contracts in this area, it is important to build bridges with the suppliers of other ITER Parties to promote more co-ordination and standardisation" he explains. A visit to Toshiba, entrusted with ITER's blanket wall remote handling system, was planned to receive an update on the progress of the works and exchange information on the procurement of the European components. The milestones and the delivery of equipment highlighted the need for a more integrated schedule so that all ITER Domestic Agencies with their companies and engineers are in the loop. Europe made also the case for various robotic applications, used in the control system area among others, which could help Japan's ITER Domestic Agency and Toshiba to address some technical challenges.

Meanwhile, European laboratories have been developing and testing tooling that will potentially be used in the field of Remote Handling. For instance, the ITER Divertor will require remote maintenance. It can be described as a massive ashtray, consisting of 54 heavy metallic components known as "cassettes", where the impurities of the fusion reaction will be driven to. These cassettes will take most of the heat from the super-hot plasma which will reach 150 million °C and during the lifetime of the ITER machine will need to be maintained and replaced. Europe will supply 104 of them because it is envisaged to replace the entire set with another one during ITER's operation. How can one fix these bulky components without being physically present in the chamber of the machine? The answer lies in remote handling.

F4E has signed a contract with Assystem UK for the remote handling system of the ITER Divertor, which among other parties includes RACE (Remote Applications in Challenging Environments), the new centre of the UKAEA for robotics development. The laboratory builds on the know-how it has acquired in the field of remote handling used in JET (Joint European Torus) and is currently extending its expertise through its contribution to ITER.

For more than a year, a team of experts has been working to identify key technologies to perform the cutting and welding operations required for the pipes of the cassettes. For experts working in the field of remote handling for the ITER Divertor, this is one of the most complex tasks to be performed. Indeed, in order to cope with the high temperatures that the cassettes will be exposed to, each of them will contain pipes which will be connected to ITER's piping system where cooling water will be circulating through them. The piping system of the ITER Divertor will go through the vacuum vessel. Cutting the pipes, when we will have to replace the cassettes, will be no easy task because no lubricants will be applied due to the fact that no liquids can be used in the vacuum vessel. Therefore, dry cutting techniques will be deployed to perform the delicate procedures.

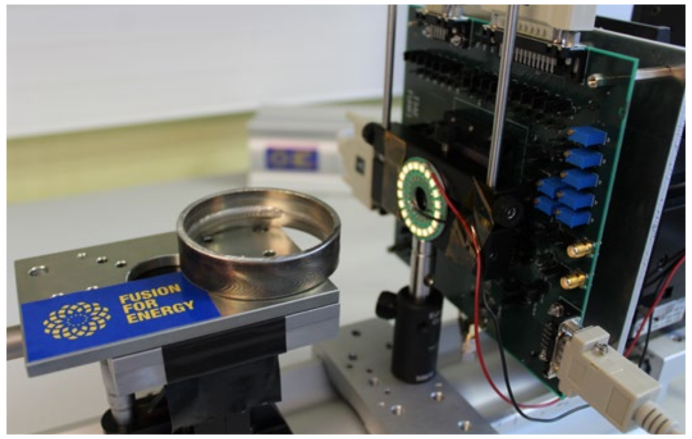
Welding together 3 mm thick stainless steel pipes, will also prove to be a challenging task because they will need to be carefully aligned, bearing in mind that they will have to operate in vacuum. Before operation, the resulting welds will need to be tested remotely through nondestructive examination (NDE) which is a complex task to perform in remote conditions. To make matters a bit more complicated, a number of factors will need to be taken into account such as space, which is limited in ITER forcing engineers to find the most compact solution; the levels of radiation in the vessel and the suitability of tooling for remote deployment.

How did RACE tackle this mission impossible? First, a technology survey was launched identifying the technics available to carry out these operations and were subsequently narrowed down to those complying with the ITER environment. After having analysed possible alternatives, and conducting risk assessments, RACE identified the best options and successfully performed various trials of welding and cutting. We visited the laboratory when these tests took place and we were able to observe step-by-step how they were carried out. Although trials have been performed with the intervention of technicians, so as to identify the best technologies, in ITER this type of repair work will be performed remotely. Therefore, the quest for the right tooling is now on. When the design work is completed the teams will move ahead with the fabrication of tooling expected to start in 2020.

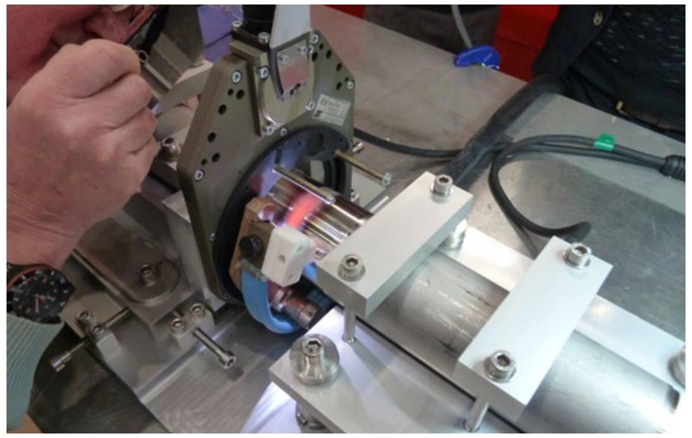
To perform these repairs, a sophisticated system is being developed and it counts at least 100 cameras. The conventional black and white tube cameras, widely used in fission reactors, are not an option for ITER because of the space restrictions. Instead, smaller digital cameras will be developed to be installed.

The tiny "eyes" will be scattered inside the machine giving either a wide angle of the vacuum vessel or a narrow angle of specific tooling systems by being embedded on the robotic arms performing repairs. Almost like a sci-fi movie, the engineers will operate with extreme precision receiving live images from the cameras. F4E in collaboration with Oxford Technology Limited (OTL) have developed different sub-system mock-ups by bringing onboard the expertise of ISAE, Toulouse, for the image sensors; CEA for the illumination system and the Jean Monnet University Saint Etienne for the optic system.

After having concluded the development and validation of these subsystems, experts have been testing their resistance in a nuclear facility for almost a year and the results have been extremely good. In Belgium's SCK-CEN the equipment has been exposed successively to different levels of Gamma radiations (up to 1 megagray/ MGy) and after each irradiation step it has been analysed. Laura Mont Casellas, F4E Remote Handling, explains that "...on the basis of the results we have received, our cameras can sustain the demanding ITER environment. This means that we are ready to start a new chapter in the project." For Marco Van Uffelen, F4E Remote Handling, "...this positive development brings us closer to a camera prototype which will constitute the precursor of the 100 cameras to follow. Currently, F4E is working together with OTL so as to identify potential candidates in this field to act as camera integrators and eventually develop the camera prototype."



Test set-up to validate the performance of the demonstrator using a real-size ITER weld © F4E



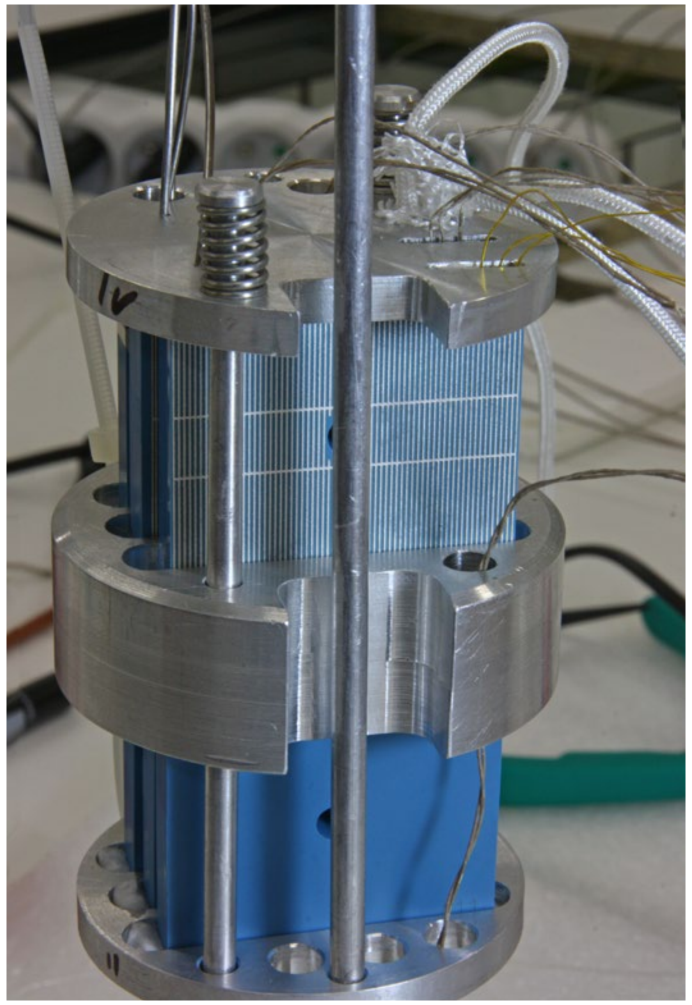
Testing welding technologies at RACE, UK

Representatives from F4E and ISAE, Toulouse, responsible for the image sensors; CEA for the illumination system, and the Jean Monnet University Saint Etienne for the optic system. © F4E

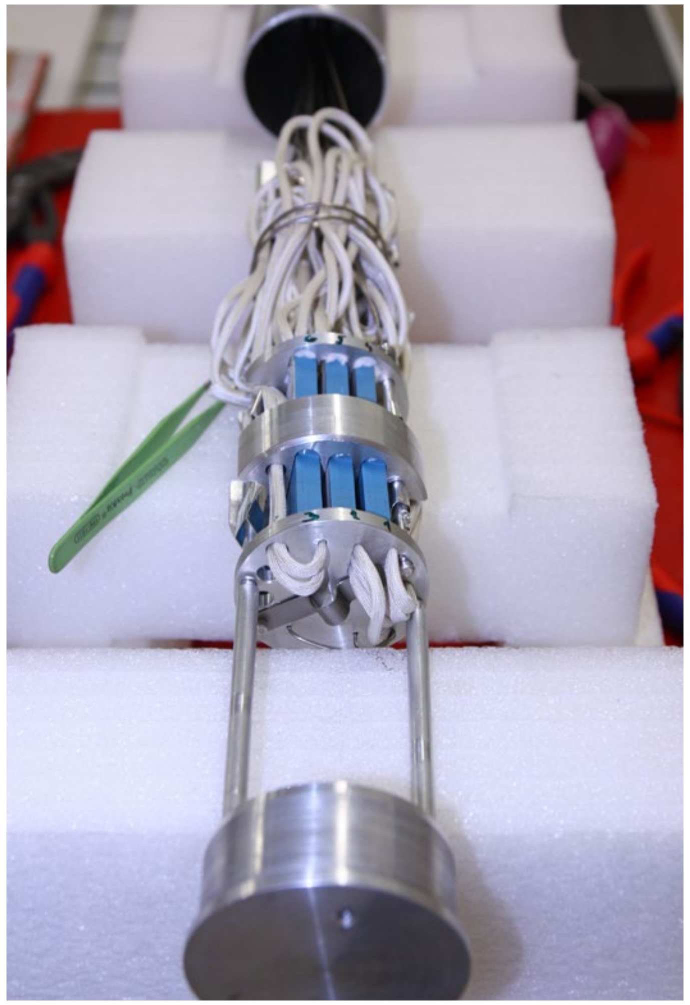
(L-R): Kiyokazu Sato, Senior Fellow at Toshiba Keihin Products Operation, Carlo Damiani, F4E Remote Handling Project Manager, Dr. Nobukazu Takeda, Group Leader, Remote Handling Technology Group and Takahito Maruyama, Naka Fusion Institute, National Institutes for Quantum and Radiological Science and Technology.

Neutron testing of diagnostic sensor prototypes now completed

F4E's Diagnostics Project Team is celebrating the successful completion of neutron testing of the diagnostic sensor prototypes, based on Low-Temperature Co-fired Ceramic (LTCC) technology, which will be installed in the ITER Vacuum Vessel, the heart of the ITER machine.



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



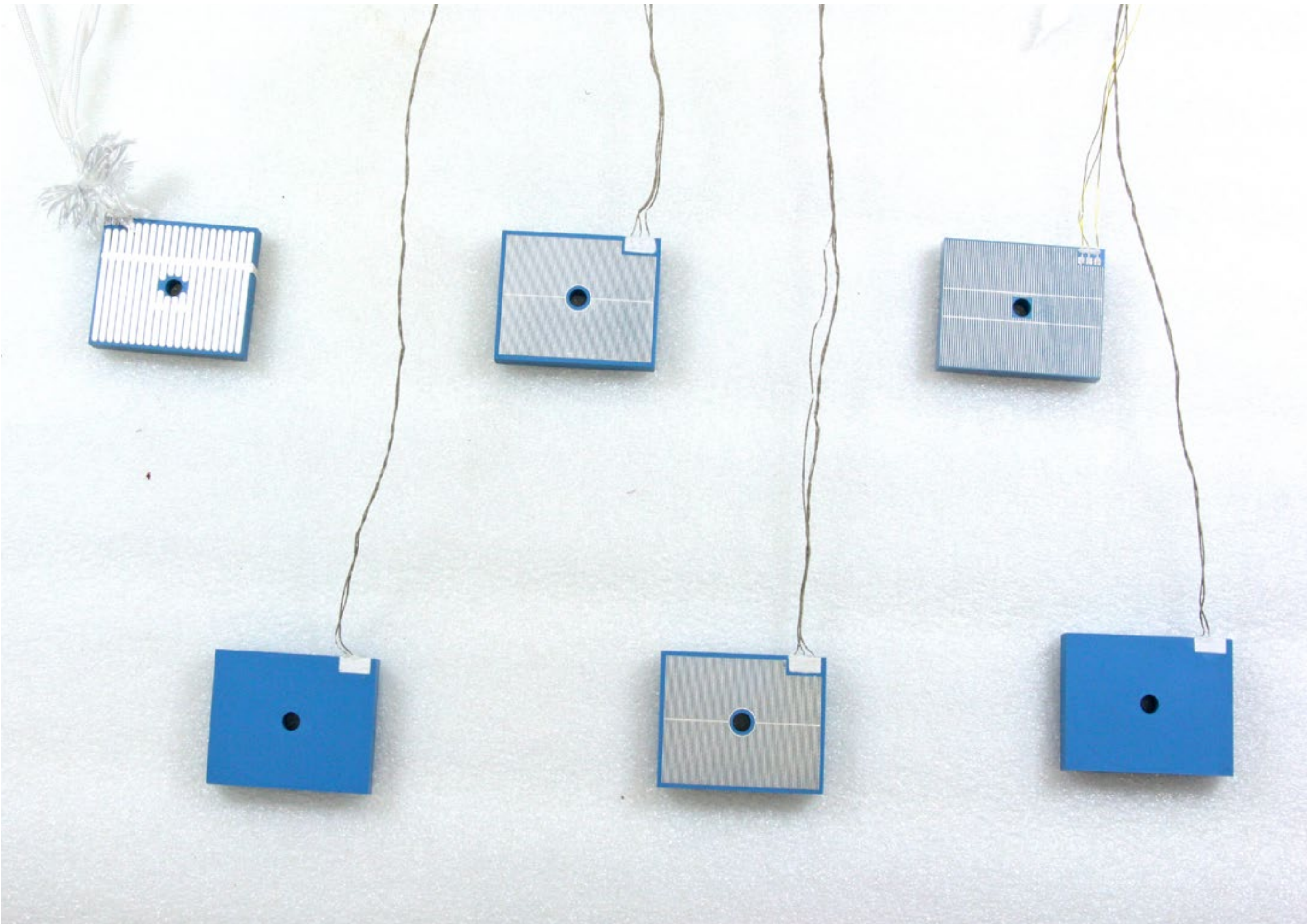
The LTCC sensor prototypes (in blue), installed on a supporting structure and fully connected, in final preparation for testing

Testing was carried out on behalf of F4E by Belgian (SCK-CEN) and Czech (REZ) laboratories, and focussed on assessing whether, once installed, the diagnostic LTCC sensors will be able to withstand the exposure to neutrons which will be created during the fusion process in ITER. With ITER currently being built, it is not possible to reproduce an exact replica of the ITER environment at the present time, so a testing method using two existing low and high neutron flux fission reactors was developed.

"It's the most reasonable approach we have right now for assessing the sensors' resistance to neutrons", says Benoit Brichard, who is responsible for neutron testing of diagnostic components at F4E. "The low flux neutron reactor was used to check the short-term electrical damage the neutrons caused in the sensors, while the high flux neutron reactor enabled us to estimate the time period the sensors could survive the ITER neutron environment."

What exactly do the diagnostic LTCC sensors do? They can be likened to eyes of the ITER machine, measuring the magnetic field around the plasma core and thus yielding vital information regarding its position and shape. In total the ITER machine will house more than 1500 magnetic field sensors of various different types, but neutron testing has focused on two varieties, both based on LTCC, which will be most exposed to neutrons in ITER. Prototypes of these sensors subjected to neutron testing were manufactured by EPFL (Switzerland), Via Electronic (Germany) and VTT (Finland).

"The results from testing have been very encouraging", says Shakeib Arshad, who is responsible for Magnetics Diagnostics at F4E. "We were happy to see that all the LTCC sensor prototypes survived. The testing also provided data regarding the sensors' electrical performance in the presence of neutrons. Minor differences were noted in the behaviour of the various prototypes related to differences in manufacturing details and these observations will help optimise the final design. We are pleased because these results mark successful conclusion of a complex development plan, spanning several years".



Several of the LTCC sensor prototypes, before testing

Validating the welding techniques to fabricate the Test Blanket Modules (TBMs) and handing over to ITER Organization the safety report of Test Blanket Systems (TBSs)

Engineers working in the field of Test Blanket Modules (TBMs) are seeing beyond the near future. Here is why: to achieve a fusion reaction we need deuterium and tritium— two hydrogen isotopes that in the case of ITER will be supplied. In future, scientists would need to find a way to breed tritium in the machine. The role of TBMs is to explore this possibility to make the fusion power plants of the future self-sufficient.

Europe has developed two types of TBMs that will be located at the 16th equatorial port of ITER. Each of them will consist mainly of a steel box containing the tritium breeder, neutron multiplier materials as well as a series of heat extraction plates. During the last two years, technicians had to manufacture mock-ups of these boxes in various sizes, in order to identify the best welding techniques that will be applied at the time of production. F4E together with a large group of partners consisting of Atmostat, CEA Saclay/Grenoble, Alsyom, Commercy, Airbus, Bodycote and CETIM have successfully developed a preliminary welding procedure on a full size mock-up of the TBM box measuring 1.7 x 0.5 x 0.7 m.

The challenging task was carried out using a Tungsten Inert Gas (TIG) welding robot to carry out the welding operations in the tight and limited space of the box. In order to cope with any distortions resulting from the operation, and keep the surface of the box intact without damaging any of its internal channels, special clamping tools were designed and used during tests.

The exploration of welding procedures is expected to come to an end during the next two years in order to draw some technical conclusions. After welding procedures conclude the cycle of qualification, in line with the regulatory requirements, then the real manufacturing phase will begin. In future trials the box will be made of EUROFER97, the candidate steel that Europe is considering to use for TBMs, which responds well to neutron activation with a good resistance to neutron. The production of EUROFER97, contracted to Saarschmiede GmbH Freiformschmiede, has been completed. A total of approximately 27 T have been manufactured in the form of special plates and bars of various thicknesses from 1.2 to 45 mm.

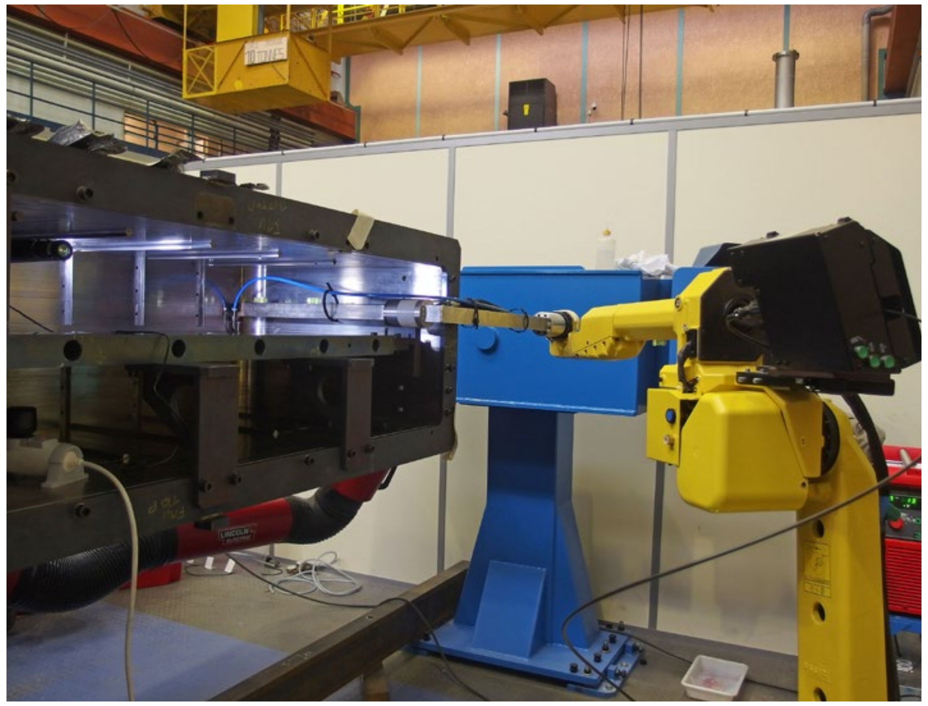
Safety is an integral aspect of ITER and a top priority for ITER Organization, F4E and all the ITER Domestic Agencies. Because the project is located in France, it must follow French safety rules and the French Safety Authority (ASN) has required ITER Organization to integrate the Test Blanket Systems (TBSs) into the safety demonstration (a compilation of documentation and analysis which demonstrates the safety of ITER). An international Task Force, encompassing ITER IO and the ITER Parties developing TBSs (F4E is developing two TBSs and the ITER Domestic Agencies of China, India, Japan and Korea are each developing one TBS), was established at the beginning of 2016 in order to deliver the technical documentation needed to integrate the TBSs into the larger ITER safety demonstration. After one year of intensive work this technical documentation which will be used by ITER IO to answer to the ASN request has now been delivered.

The TBSs consist of in-vessel and outer-vessel components or systems. The in-vessel components are the TBMs (Test Blanket Modules) which are test versions of the Breeding Blankets modules and will be tested in ITER in order to assess their technical potential. The Breeding Blanket modules, an integral part of the future DEMO machine, will produce tritium in-situ, the fuel needed for the fusion process to occur. It will also transform the energy of the neutrons produced in the plasma into heat with the objective of ensuring that this heat can be recovered and transformed into electricity. The outer-vessel systems connected to the TBMs ensure key functions for the TBMs to operate: cooling, coolant purification and tritium extraction.

Joelle Vallory, the nominated member representing F4E in the Task Force, worked together with each involved ITER Party representative, experts and safety officers in numerous workshops in order to ensure consistency in the methodology adopted by all involved ITER Parties and allow for each involved Domestic Agency to deliver technical data to be used for ITER IO to answer ASN. The Task Force evaluated key data such as tritium production, tritium modelling (the way tritium will is transported within the TBSs), neutronics (analysing the effects of neutrons on the TBMs and on other ITER components), and accident analysis (describing possible accident scenarios, their consequence and analysis on how to prevent or mitigate them) in order to present one solution to ITER IO.

"The ITER IO Central Team dedicated to safety matters created a series of templates of exhaustive checklists that we used as a basis for our work when producing the necessary technical documentation", explains Joelle Vallory. "We went through every issue in a methodical and thorough manner in order to reach an acceptable consensus and all participants clearly showed their will to progress in this very demanding task."

In total, the technical documentation provided by F4E consisted in 13 checklists for the two TBSs that Europe is responsible for. "As safety is a top priority for F4E, we have put a lot of effort in being proactive in this Task Force. In total, we have dedicated 1.6 man years. The documentation that we delivered to ITER IO corresponds to the weight of a newborn baby", says Joelle Vallory. The TBS technical documentation from all involved Domestic Agencies is currently being reviewed by ITER IO with the objective of harmonising its content with the overall safety demonstration file which will be submitted to the French Safety Authority during the first half of 2018.



TIG welding robot performing preliminary welding procedures on a full size mock-up of the Test Blanket Modules box

Representatives of Saarschmiede GmbH Freiformschmiede (L-R) A. Neumann, V. Wagner and N. Lang next to EUROFER97 boxes

JT-60SA cryostat vessel body manufacturing completed and in Japan

With the full completion of the manufacturing of the JT-60SA cryostat vessel body and successful pre-assembly and metrology at the Asturfeito S.A. factory in Aviles, Spain, the Spanish voluntary Broader Approach contributor, through CIEMAT, fully completed its contribution to the JT-60SA project in September 2017.

The F4E/CIEMAT/Asturfeito S.A. team in front of the JT-60SA cryostat vessel body

The 12 sectors which make up the vessel body and when assembled measure around 11 metres in height, were dismantled and underwent final minor refurbishments to eliminate potential superficial damages that may have occurred during handling and pre-assembly. A final cleaning of the large surfaces of the cryostat vessel body was carried out, as well polishing of the inner surfaces of the sectors and sandblasting of the outer surfaces. After a final visual inspection and other checks, the sectors were inserted in ten strong transport frames (two frames have been designed to hold two sectors each as these sectors are similar in shape and width). These frames have been specially designed to resist to the heavy transport loads and any potential earthquakes or other natural disasters that could occur.

Following wrapping and sealing in strong plastic, the transport frames were covered by wood panels and a thick Tarpaulin cover. These robust and rather expensive protection systems were not only to withstand the long travel by ship and land from Spain to the JT-60SA site in Naka, Japan, but also to allow for a period of outdoor storage of the sectors in Naka as their arrival is one year ahead of their scheduled final assembly in the JT-60SA Torus Hall.

In addition to the cryostat vessel sectors, an 11 metres long lifting beam, and an ad hoc manufactured lifting frame (which will handle the lower sectors when they have arrived in Naka) were also shipped. All lifting equipment

The cryostat vessel body seen from above.

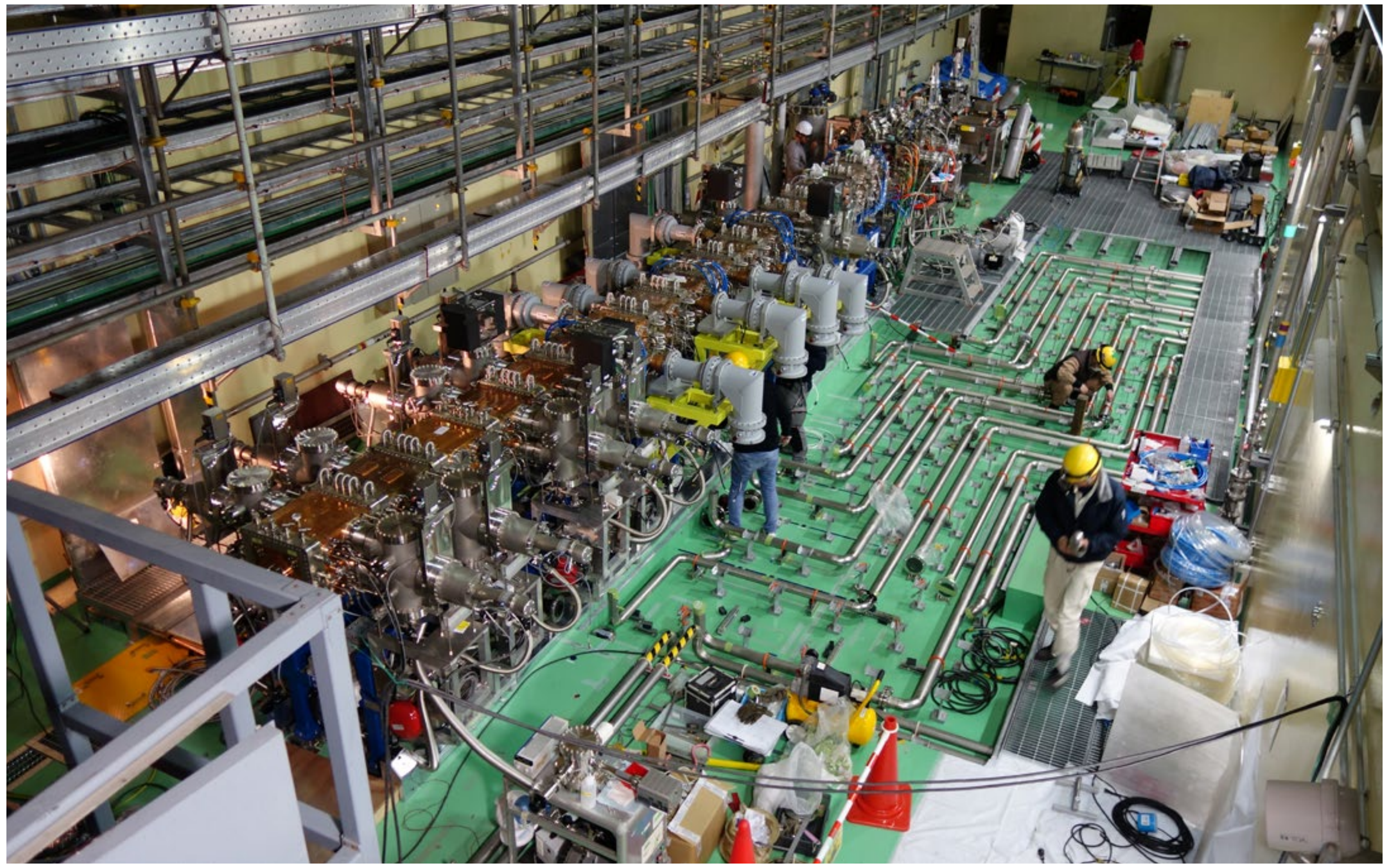
From left to right: The packages being loaded on to the ship in Aviles port (photo courtesy of DAHER)

used in Aviles for handling the sectors (e.g. removable lifting hooks, assembly devices, bolts, spacer sleeves, nuts) and excess material from the manufacturing of the sectors were also included in the shipping.

In total, 36 packages and the two lifting devices, together weighing a total of 322 T, were loaded on a ship which left from Aviles Harbour in December 2017. Transportation was carried out by French company DAHER and the goods arrived at the Hitachi port in Japan in mid-January 2018.

The JT-60SA machine is a precursor to ITER: the know-how about optimising plasma operation obtained through the JT-60SA project will be used to develop and benefit ITER. The cryostat vessel body works as a large containment vessel which will enclose all core JT-60SA components. It consists of 4 individual upper sectors (with a height of around 4 metres) and 8 individual lower sectors (with a height of about 7 metres) which have each been separately positioned and precisely adjusted to form a cylindrical shape which measures about 14 metres 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 4 Kelvin) for their superconducting functions. Made of 30 mm single-walled stainless steel, the cryostat vessel body can be likened to a thermos in the sense that together with the thermal shields and suprainsulation (multi-layer insulation) inside its shell, it is able to minimise the energy losses by conduction, convection and irradiation.

Discover LIPAC-the accelerator that will bring us closer to fusion energy. Europe and Japan are ready for the beam operation.



Top view into the LIPAc accelerator vault during the installation of the cooling loops for the “Radiofrequency Quadrupole”, Rokkasho, Japan

The Broader Approach Agreement (BA) between Europe and Japan has created a successful collaborative framework in the field of fusion energy focusing mainly on those technological challenges beyond ITER. The BA projects bring together some hundreds of European experts from Belgium (SCK-CEN), France (CEA), Germany (KIT), Italy (ENEA, INFN and RFX), Spain (CIEMAT), co-ordinated by F4E and a comparable number of Japanese experts supervised by the Japanese National Institutes for Quantum and Radiological Science and Technology (QST). The nature of voluntary contribution underpinning the BA has fostered a collaborative spirit among the parties helping them to tackle successfully the “typical” difficulties associated with international Science and Technology partnerships such as project management, manufacturing, logistics, and communication.

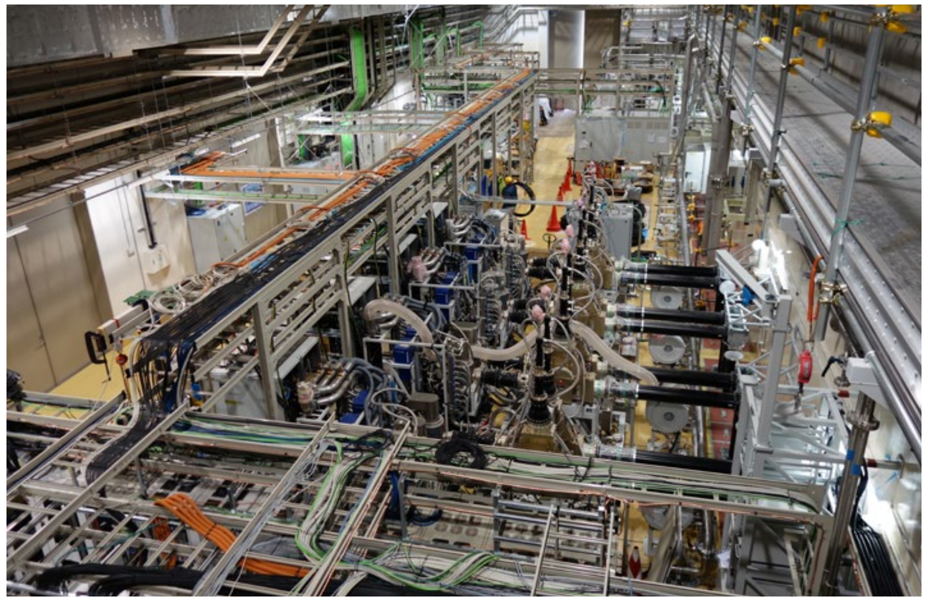
LIPAc, the Linear IFMIF Prototype Accelerator, located at the International Fusion Energy Research Center is under assembly and commissioning at the BA site in Rokkasho. LIPAc is a prototype accelerator going through validation in order to be used in a future fusion neutron source, like IFMIF-DONES. The assembly of the equipment is now complete for its intermediate phase, where proton and deuteron beams of will be accelerated to 5 MeV in 2018, using a normal conducting accelerator element known as “RF Quadrupole”. For its final phase, expected to be concluded in March 2020, the ion beams will be accelerated to 9 MeV, installing in addition a superconducting accelerator element known as “SRF linac”. The needed cold temperatures are generated by a cryoplant which was commissioned and handed over to QST in September 2017.

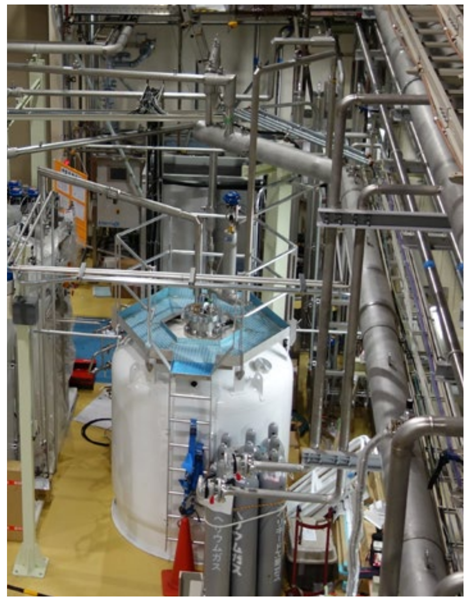
The clock is ticking as the start of beam operation is scheduled for February 2018. This linear accelerator, small in size yet powerful, is expected to turn a new page for those working in the field of ion accelerators with major spin-offs for Accelerator Driven Systems (ADS) heading for waste treatment of fission power plant by transforming long lived radioisotopes or producing them for medical treatments.

During the recent BA Steering Committee held on 14 December in Mol (Belgium), the teams of IFMIF/EVEDA were congratulated for their work contributing to the concept of a fusion neutron source to be put into operation during the next decade; an essential step in the world fusion roadmap. The years ahead promise to be exciting with LIPAc providing breakthroughs in accelerators technologies by operating both proton and deuteron beams in unprecedented conditions.

The Project Leader, Juan Knaster, affirms that “leading IFMIF/EVEDA these last five years has been a unique experience. We have demonstrated how organisational and technical difficulties in an international context can be overcome fostering communication and mutual trust among stakeholders. In-kind projects are inherently difficult but the F4E-QST partnership has proven to be so successful that it has generated spin-offs in the European-Japanese technological collaborations. In addition, the on-going success of LIPAc is having a positive impact on the credibility of the fusion programme since we are achieving unprecedented operational conditions in accelerators technologies.”

NEWS
F4E NEWS – FEBRUARY 2018





Top view of the Radiofrequency Area of the LIPAc facility, Rokkasho, Japan

The equipment of the Cryoplant which has been handed over to QST

(L-R): Bertrand Renard (CEA), Stéphane Chel (CEA), Juan Knaster (F4E) IFMIF/EVEDA Project Leader, Philippe Cara (F4E), Keishi Sakamoto (QST), Guy Phillips (F4E)

F4E prepares Europe's industry for the production of In-Vessel components

In the core of the ITER machine the temperature of the fusion reaction will reach 150 million ° C. To protect the surface of the vacuum vessel, which will be exposed to the super-hot gas, a layer made of 440 first wall panels, resembling to heavy metallic tiles, will "dress" it from top to bottom. Each of these panels measure 1 m x 1.5 m and weigh up to 1.5 T. Together with shield blocks installed behind the panels they form the "blanket" as it is known in the ITER jargon.

Europe is responsible for the production of 215 of these panels. During the last three years, F4E has been laying the manufacturing foundations of these critical components through its collaboration with: i) AREVA N.P, ii) ATMOSTAT (group ALCEN); and iii) a consortium consisting of IBERDROLA, Wood (formerly AMEC Foster Wheeler) and LEADING Enterprises. All of them have completed the testing of materials and bonding techniques, and produced semi-scale prototypes which have successfully undergone high heat flux tests. Since then, they have taken a step forward and are in the process of producing full-scale prototypes.

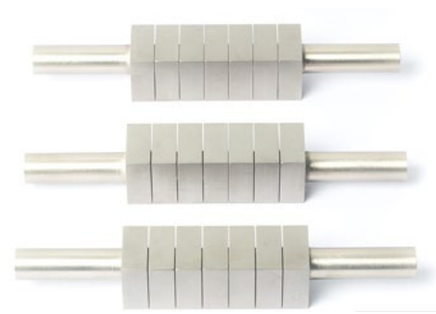
F4E took the initiative to organise a workshop to help them network with companies specialised in automation. Following a market survey, conducted by F4E, six companies from all over Europe were invited to present their skills and expertise. Through presentations and bilateral meetings, automation companies and manufacturers were invited to explore how the manufacturing costs could be decreased and quality could be improved the moment Europe starts producing its share of first wall panels.

"This first workshop gave us the opportunity to introduce the ITER project to new companies, explain in more detail the technical requirements of the first wall panels, one of the In-Vessel components, and move from the stage of prototypes to an industrial phase" explains Stefano Banetta, F4E's Technical Responsible Officer following this component.

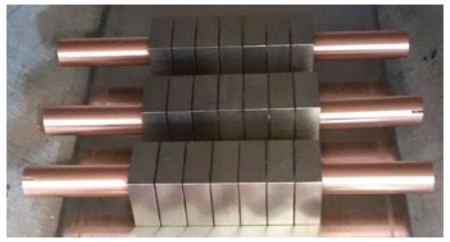
Meanwhile, stage 1 of the divertor inner vertical target pre-qualification programme has been completed with the successful manufacturing and testing of small-scale mock-ups by three companies namely ATMOSTAT-ALCEN (France), CNIM (France) and Research Instruments (Germany). This stage involved validating the fabrication technologies the companies have proposed through the manufacture of representative mock-ups of the inner vertical target measuring around 1/19th of the actual size of the future ITER divertor inner vertical target. Together with the already approved contractor Ansaldo Nucleare, all partners will now move forward to the second stage of the pre-qualification programme with the manufacturing and testing of full-scale inner vertical target prototypes. As a key part of the pre-qualification process, the mock-ups were subjected to high heat flux testing at the Efremov Institute in Russia where the conditions (5 000 cycles at 10 MW/m^2 plus 1 000 cycles at 20 MW/m^2) were in excess of the ones expected in ITER in order to check the margin for resistance.

This positive development comes following the launch of the multiple framework contracts which F4E signed with these three partners in June 2015. With different companies contracted, F4E ensures that competition is healthy and fair. Additionally advantageous is the different technologies which are developed and which will mitigate technical risks also avoiding the establishment of industrial monopoly.

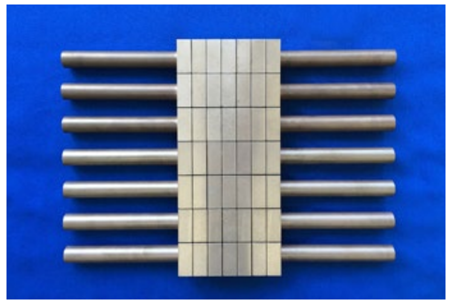
F4E is responsible for providing the inner vertical target and the cassette bodies. The Japanese and Russian ITER Domestic Agencies are responsible for providing the outer vertical target and the dome respectively.Following the completion of the manufacturing of the full-scale prototypes and their high heat flux testing, which is scheduled to last about three years, the Call for Tender for the series production will be launched.



The divertor inner vertical target prototypes from ATMOSTAT-ALCEN



The divertor inner vertical target prototypes from CNIM



The divertor inner vertical target prototypes from Research Instruments

Poland unleashes its potential in big science projects

Who would turn down an invitation to "fly to Mars" if representatives from ESA, NASA and Poland's Space Industry Association acted as the captains on board? Imagine if your co-passengers were some of the most promising scientists, entrepreneurs, engineers and business developers working in Poland? It sounds like a-one-of-a-kind mission to Mars inviting experts to step to the unknown and use their skills to survive.

"Fly me to Mars" opening session, Wroclaw's University of Technology, Poland

Getting ready for the B2B Meetings, Fly me to Mars" conference, Wroclaw's University of Technology, Poland

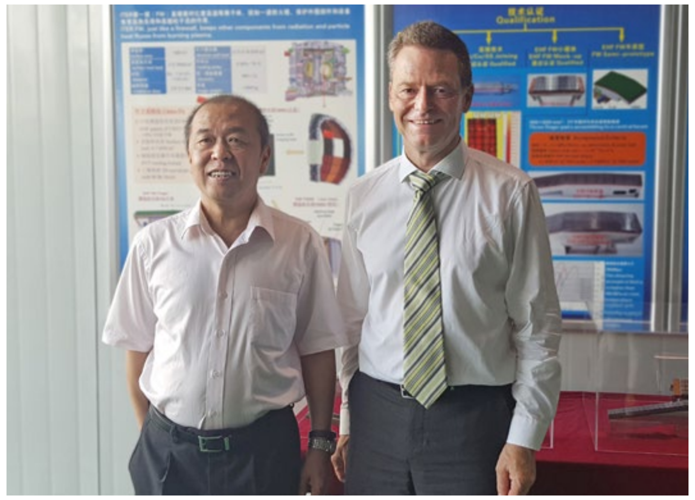
Science and technology breakthroughs have been woven in the fabric of Poland and its appetite for doing business makes it a perfect candidate for big science projects. For this reason, members of the big science community coming from F4E, CERN, the European Space Observatory (ESO) and the European Spalation Source (ESS) contributed to a two day-event, organised by the Wroclaw Technology Park on 23-24 November, to explain the state of play of the various scientific collaborations and the business opportunities in each of them. A fine mix of keynote speeches, workshops, presentations, and business to business (B2B) meetings gave the possibility to at least 400 participants to receive updates and get in touch with those running the projects.

"By bringing together big science projects we help companies to learn more about the emerging technical needs, offer them incentives to export their know-how and make them think big" explains Leonardo Biagioni, F4E's Head of Procurement. "The truth of the matter is that big projects are made of smaller ones and if a company has the skills it can surely find its way to participate. And this is what we are here to do" explains Benjamin Perier from F4E's Market Intelligence Group. A number of companies expressed an interest in the ITER domains using robotics, aerospace technologies and the testing of new materials. For those who felt that they may not have the financial capital to target projects of such scale, a representative of the European Investment Bank (EIB) was there to present the different financial instruments that could trigger off investment and growth.

The value of gathering different projects under the same roof helps all parties to be more aware of who does what and how much they share in terms of business incentives and technology transfers. For those wishing to become more familiar with the universe of collaborative procurement for research infrastructures, a Big Science Business Forum is planned to take place on 26-28 February 2018 in Copenhagen.

F4E Director strengthens ties with Russian and Chinese ITER partners

The success of ITER depends on a strong partnership between Europe and the six other countries involved in the project. To this end, F4E's Director, Johannes Schwemmer, is further developing the relationships with the ITER partners.



From right to left: F4E Director J. Schwemmer with Chinese ITER Domestic Agency Director General Prof. D. Luo

The F4E Director visited the ITER PF6 coil manufacture workshop

In June 2017, Mr Schwemmer visited the Budker Institute of Nuclear Physics (BINP), the largest institute in the Russian Academy of Sciences and a world-renowned centre of excellence for particle and plasma physics, accompanied by the Head of Russia's ITER Domestic Agency, Anatoly Krasilnikov. BINP is making some key ITER components including the “port plugs” which house diagnostic systems to measure ITER's performance. Johannes Schwemmer was welcomed by BINP Director, Academician Pavel V. Logatchov, who showed, amongst other things, a recently fabricated full-size mock-up of a key component of the ITER's equatorial port-plug – the Diagnostic Shield Module. The visit to BINP also provided the opportunity for F4E's Director to have a tour of the test stand for a negative ion-based neutral injection plasma heating system under development in collaboration with Tri Alpha Energy Inc. in the United States. A similar system, albeit based on a different technical concept, is under development by F4E and other international partners at ITER's Neutral Beam Test Facility in Padua, Italy. The one-day visit concluded with fruitful discussions on possible areas of future collaboration for ITER.

The F4E Director further strengthened ties with the Chinese ITER partners by accepting an invitation to visit the Chinese ITER Domestic Agency and two major fusion research organisations at the end of July 2017. To begin the visit, productive meetings took place in Beijing with the Head of the Chinese ITER Domestic Agency (CNDA), Professor Delong Luo, and other senior managers from CNDA, which is part of the Ministry of Science and Technology (MOST). The participants reviewed the progress of the shared ITER work as well as the status of the work CNDA does for F4E. Interesting exchanges took place on the organisation of ITER work in Europe and China and possible areas for deeper collaboration in the future.

Johannes Schwemmer visited the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) and met with Professor Yuntao Song, the Deputy Director General of ASIPP, who gave him a

During the meeting at SWIP with Prof. D. Luo, Prof X. Duan and other colleagues

From left to right: Y. Poitevin, F4E; K. Baker, F4E; H. Jahreiss, F4E; P-Y Chaffard, F4E; J. Schwemmer, F4E; G. Leidenfrost, F4E; L. Delong, ITER China; B. Zhang, MOST; M. Wang, ITER China; Q. Xiaoyong, MOST; C. Chunyu, MOST; and Y. Zhu, ITER China.

From left to right: J. Schwemmer (F4E Director) presenting F4E's work and stakeholders during the meeting at the Chinese ITER DA with Dr M. Wang (Director), Dr T. Fang (Director) and Prof. D. Luo (Director General)

Inspecting the full-size mock-up of the Diagnostic Module recently fabricated at BINP (left to right: Aleksandr Burdakov (BINP Deputy Director), Anatoly Krasilnikov (Russian DA Head) and Johannes Schwemmer

tour of the factory that produces the ITER Toroidal and Poloidal field conductors (see article on pages 10-11), as well as of the ITER magnet power supplies test facility. The Director of F4E also visited the factory where ASIPP is manufacturing the 18 superconducting correction coils which will reduce imperfections in ITER's magnetic field. Last but not least he viewed the EAST Tokamak – which had recently achieved the major milestone of a 100 s long H-mode plasma.

To conclude his visit to China, the F4E Director travelled to the Southwestern Institute of Physics (SWIP) in Chengdu. SWIP, like ASIPP, is providing important contributions to the ITER project as well as running fusion research experiments. Professor Xuru Duan, Deputy Director of SWIP, welcomed Johannes Schwemmer and provided a tour of the HL-2A tokamak which focuses on research in advanced divertor concepts. Mr Schwemmer also toured the First Wall R&D facility run by SWIP which is well-advanced with developing the production line for the enhanced heat flux panels for the blanket inside the ITER vessel following the successful completion of the stringent ITER qualification programme.

In September 2017, a joint Chinese delegation which included ITER China's Director General, Professor Luo Delong and the Deputy Director General for Policies, Regulations and Supervision at MOST, Mr Bingqing Zhang, as well as other senior managers from both organisations visited F4E in Barcelona and Garching. The Chinese delegation also held meetings with the European Commission Representation in Barcelona and EUROfusion. They visited the Max-Planck Institute for Plasma Physics (IPP), met German governmental officials and toured the fusion experiments in Garching (ASDEX Upgrade) and Greifswald (Wendelstein 7-X). “We were honoured to welcome this high-level delegation to Europe and look forward to intensifying collaboration with our Chinese partners in areas of common interest such as next-generation fusion devices and Breeding (Test) Blanket Modules”, said F4E's Director Johannes Schwemmer.

Spain and Croatia join forces to host the DONES facility

Will the prestigious R&D project find its way to Europe?

DONES facility meeting

In order to prepare the ground for future fusion reactors beyond ITER, Europe and Japan have established a scientific collaboration known as the "Broader Approach" Agreement.

Five European countries (Belgium, France, Germany, Italy, Spain and Switzerland) contribute on a voluntary basis to three R&D projects carried out in Japan. Fusion for Energy (F4E) is managing the European participation to these projects. One of them is IFMIF/EVEDA, which stands for International Fusion Materials Irradiation Facility (IFMIF) Engineering and Validation Design Activities (EVEDA). Apart from fulfilling its specific project objectives it is also paving the way for the DEMO Oriented Neutron Source (DONES) . This infrastructure will help scientists to test materials in an environment of neutron irradiation similar to that of a Demonstration fusion reactor (DEMO), the machine that will follow ITER. Such a facility has been considered essential for a long time in order to design DEMO.

Earlier this year, Spain and Croatia flagged their interest to host DONES. Consequently, a technical group of experts was put together to visit the sites proposed by the two countries, evaluate their compliance with the technical requirements and communicate the findings in a report. The Governing Board of F4E, consisting of the member states of EURATOM and the European Commission, received this report towards the end of the year. A few weeks later, it was announced that the two EU member states have agreed to join forces and either to host the project in Granada (Spain) or, if this would not be possible for technical reasons, in Moslavacka Gora Hill (Croatia). The joint team has declared its commitment to work together in order to bring DONES to Europe. An encouraging statement made by the technical group declaring the Granada site as "fully operational" and acknowledging that construction works could start immediately has increased their confidence.

What happens next? While it is still not clear whether Japan will also express an interest in hosting the DONES facility, opening a new round of negotiations, the Europeans are moving ahead. The joint team has started to explore the availability of EU structural funds in order to raise more financial resources for the realisation of this project. In parallel, the joint team will seek the help of F4E and the European Commission to develop the best possible approach and discuss the different phases of the project if in the end our continent ends up being its host.

Fusion for Energy
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