# F4E NEWS

Fusion for Energy Newsletter

No. 20 / December 2016



CARDBOARD VIRTUAL REALITY GLASSES INSIDE!

ITER construction site - October 2016

# ITER construction: drilling, building, lifting!

**The impressive complex consisting of the Tokamak, Diagnostics and Tritium buildings has been rising fast. The construction and reinforcement works of the floors, walls and ceilings offer a rare view of the inner-core of this iconic edifice. To reach this point of progress, F4E and ITER International Organization have been diligently co-ordinating a long list of contractors.**

A team of 330 people from the Vinci Ferrovial Razel (VFR) consortium have been working exclusively at the Tokamak Complex to deliver the seven floors of this facility on time. Workforces from the Engage consortium, Tiresia, Energhia and Apave have also been deployed to this delicate construction task. The ground floor has been completed and the progress of the first floor varies from 50% in the case of the Tritium building to 100% in the case of the Diagnostics building, where works for its second floor have advanced. The Tokamak Complex will be 80 m tall – of which 20 m will be below the ground, 120 m long and 80 m wide. Given the fact that this building will host the ITER machine, and more than 30 systems required for its operation, its total load will reach 400 000 tonnes. This complex will have to comply with high standards and accommodate the multiple interfaces and sub-systems that will be gradually integrated.

There has also been more progress in the construction of the bioshield. This concrete ring, which measures 30 x 30 m, is going to shield the ITER cryostat from top to bottom and ensure radio protection. Most of the works on the first floor have been completed integrating the heavy embedded plates, the robust metallic structures rooted under the concrete upon which tooling will be welded, and high density reinforcement. There has also been real progress on the second and third floors of the bioshield levels.

ITER Workiste Septembre 2016 ©LNM





At the vast ITER Assembly Hall, the two cranes with their equipment (hoists, trolleys) have been successfully installed 46 metres above the ground. The girders measure more than 46 m in length, with overall cross dimensions of about 4 x 3.5 m, and will be able to lift together a total of 1 500 tonnes, approximately the weight of four Boeing 747 planes at take-off. The tooling stems from a contract signed between F4E and the NKM NOELL-REEL consortium in 2013. The manufacturing of the different parts in the Netherlands, France and Spain, together with their transfer from the port of Marseille to Cadarache, have added additional layers of coordination.

The girders and trolleys were originally stored in the Poloidal Field coils facility and a few weeks before the spectacular lifting operations they were transferred to the Assembly Hall where one by one was lifted at 46 m high. Due to their impressive size and weight, a monster crawler crane came to give a helping hand all the way from Saudi Arabia. This was its first job in Europe and under the guidance of several technicians, and a team of 25 people on the ground, the various pieces of equipment had to be carefully positioned, balanced and loaded. It has taken roughly 3 hours to lift each girder and two weeks in total to complete this delicate operation. Thanks to the successful collaboration between F4E and the NKM NOELL-REEL consortium, the cranes have been installed earlier than planned and the entire operation was carried out smoothly.

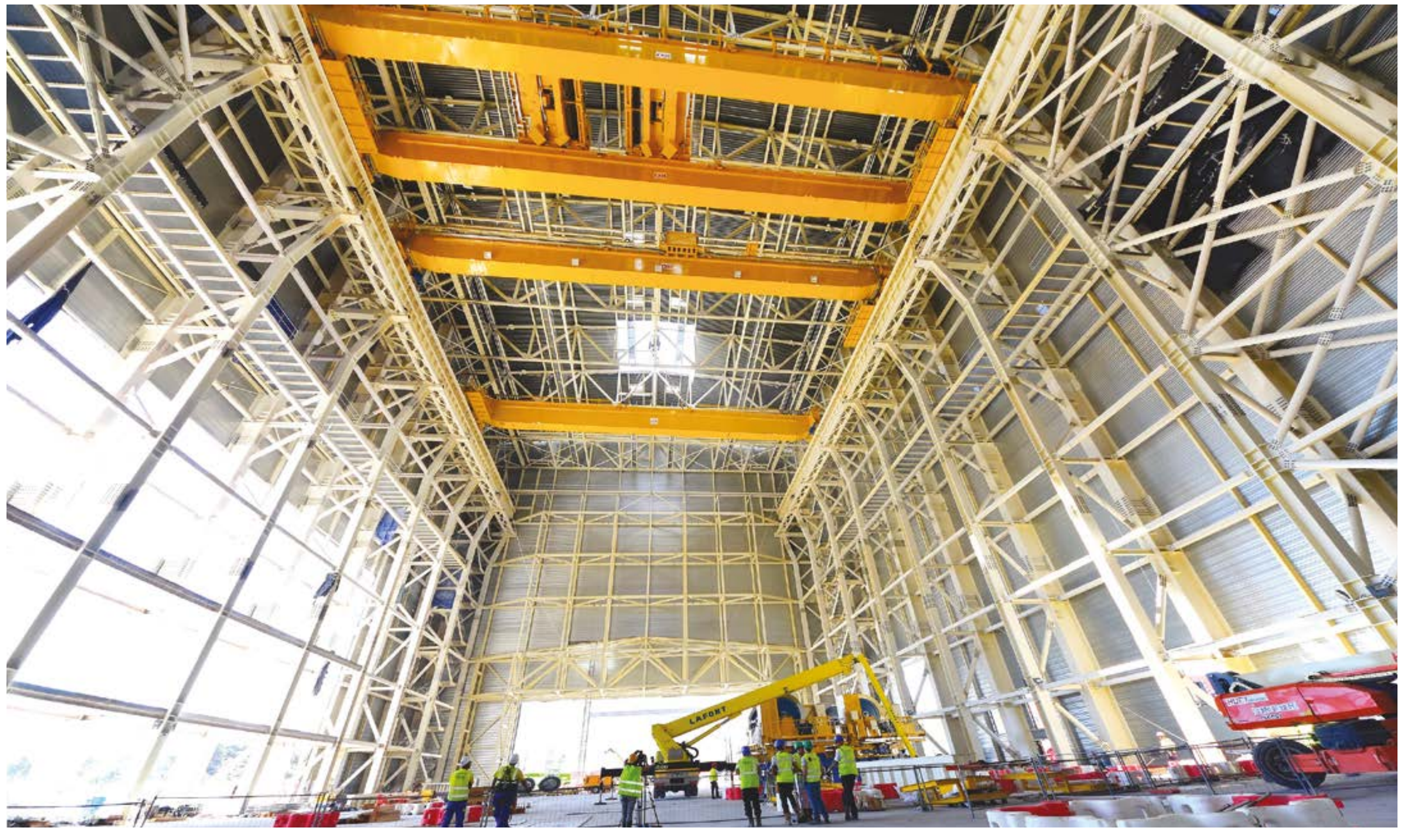
Following the successful lifting of two massive cranes, the workforces in the Assembly Hall have been focusing on the building's fire protection and the cladding activities on the East and West facades. The 50 tonne cranes have also been delivered at the Assembly Hall and their rail installation is on-going.

In the adjacent Cleaning Facility, where the ITER equipment will be cleaned from any impurities before it is assembled, all columns have been erected. The cladding of the West and East wings is nearly completed and that of the South wing is about to start. The 80 metre-long Site Services building is entering a new phase with the preparatory works of topography and measurement on-going. This facility will provide the ITER buildings and equipment with cold/hot water and compressed air amongst other things. It will also host other equipment like chillers and air compressors. The preparatory works for the installation of buildings services are nearly completed and the first cable trays will soon be installed.

For ITER to generate its 500 MW power it will require power. So at what stage are the power generating facilities? The excavation and drainage works have progressed in the area of the Magnet Power Conversion building, which will host the equipment that will convert 66 kV alternating current to direct current in order to supply ITER's superconducting magnets with power. The installation of a new transformer which has arrived from China has been completed.

More civil engineering works have been unfolding on the site, mainly in the Radio Frequency building, where the foundations and slab have been completed and the columns of the first floor have been erected. Similarly, excavation and drainage works for other facilities are being performed.

View on F4E YouTube



The four girders of the cranes that will lift the bulky ITER components have been installed in the Assembly Hall, July 2016, Cadarache

# The progress of ITER’s first Toroidal Field coil is impressive!

## One of the biggest magnets in the world is entering the final stages of manufacturing.

First impregnated winding pack, the core of an ITER Toroidal Field coil, ASG Facility, La Spezia, Italy

After having completed the insulation of ITER’s first-ever winding pack, the inner core of the massive Toroidal Field coils which will magnetically confine the hot plasma, the stage of resin impregnation followed.

Technically speaking this has been one of the most delicate operations to be performed on the most complex magnet to date. For Alessandro Bonito-Oliva, F4E’s Project Manager for Magnets, his team and their suppliers, this has been an important achievement underpinned by the collective commitment to deliver on time, plan carefully and be sufficiently flexible to adapt to the engineering challenges along the way.

A team of ten technicians worked relentlessly to get the magnet ready for this important manufacturing milestone. First, they had to apply the impregnation mould all over the surface of the 14 m high, 9 m wide and 1 m thick magnet. It has taken an entire week to cover its surface with pads in order to make sure that the resin injected during impregnation would flow in an even and controlled manner. Next, the magnet was enclosed in a layer of stainless steel sheets and clamped by heating plates to create a solid shell. Approximately 100 clamps, tightened one by one, sandwiched the magnet to compact the electrical insulation at the right level. Welding of the stainless





Applying special conductive paint to the surface of the winding pack, ASG Facility, La Spezia, Italy

The inner-core of the Toroidal Field coil covered with resin pads, ASG Facility

Compacting the inner-core of the first Toroidal Field coil, ASG Facility

steel sheets came next, and after having completed this step, the leak and electrical tests were carried out.

The successful completion of the works paved the way for the impregnation process. What were the main elements of this step? First, the component needed to be heat-dried in vacuum at 110 ˚C to eliminate any vapor or humidity trapped in the insulation. Second, with the mould under vacuum, resin was injected from the bottom of the magnet to fill in any gap, and pressure of approximately 3,5 atmospheres was applied to ensure complete filling of the mould. Finally, the winding pack went through a curing cycle, at temperatures reaching 155 ˚C during five days, before extracting the impregnated magnet from the mould.

After having completed this step, dimensional checks were carried out together with laser scans to examine the state of the component. In order to protect the component in operation a special conductive paint was applied all over its surface. So what works are currently ongoing? Magnetic measurements, checking the geometrical compliance of the magnet, are being performed. The mechanical works for the electrical joints are advancing together with the external helium piping, which is going to channel the cold helium in the coil, and the high voltage wire connection.

# The conductor is ready and the winding trials have begun!

The ITER PF coils will reach a diameter of 25 m and their weight will range between 200-400 tonnes. Due to their impressive size the only viable option is to manufacture them on-site. In order to do so, a specific facility has been built and is being equipped with the necessary tooling.

Winding tooling to be used for the manufacturing of ITER Poloidal Field coils, PF coils Facility, Cadarache, October 2016.



NEWS

F4E NEWS – DECEMBER 2016

Europe has completed the production of its conductor for the Poloidal Field (PF) coils. These powerful magnets will control the shape and stability of the ITER plasma. The six coils will embrace from top to bottom the hot gas which is expected to reach 150 million °C. Europe will deliver five of the PF coils and Russia the remaining one. The conductor is made of Niobium-Titanium (NbTi) superconducting strands.

In essence, more than 1 400 of superconducting strands have been bound together to form a cable, which has then been inserted into a stainless steel jacket, tightly compacted and finally, spooled. The PF strand (NbTi) has been produced by JSC ChMp (Chepetsk Mechanical Plant) and the cable by JSC VNIIKP (Joint Stock Company All-Russia Research Institute for Cable Industry).

The conductor that Europe has manufactured will be used for the sixth PF coil which consists of 18 conductor lengths. Through agreements signed between ITER International Organization, Europe and Russia, it has been decided that F4E will supply 10 of the conductor lengths and the remaining 8 will be delivered by Russia.

The production of the 10 conductor lengths, which are in the range of 7 km, marks the end of Europe's contribution to the conductors for the PF coils, and is another achievement that will accelerate the supply of the ITER magnets.

Meanwhile, the winding trials for the manufacturing of the ITER PF coils have already started at the facility. The ITER PF coils will reach a diameter of 25 m and their weight will range between 200-400 tonnes. Due to their impressive size the only viable option is to manufacture them on-site. In order to do so, the PF coils facility has been built and has started to be equipped with the necessary tooling.

Inside this building, which is 250 m long, 45 m wide and 17 m high, some of the biggest magnets will be produced. The spacious hall is divided between different areas where extremely delicate processes such as winding, stacking and impregnation will be performed. With the help of cranes, the massive coils will be lifted from one area to another. At a later stage, the magnets will undergo a cold test before they are transported and installed in the ITER machine.

In December 2015 the winding table, manufactured by Sea Alp, arrived on-site from Italy. After having completed its assembly, we kicked off with the installation of the equipment which will be needed to straighten, clean, bend, sandblast, and wrap the conductor. As always, the tooling trials have been carried out with pre-dummy conductors so as to monitor the first manufacturing steps and assess the performance of the equipment.

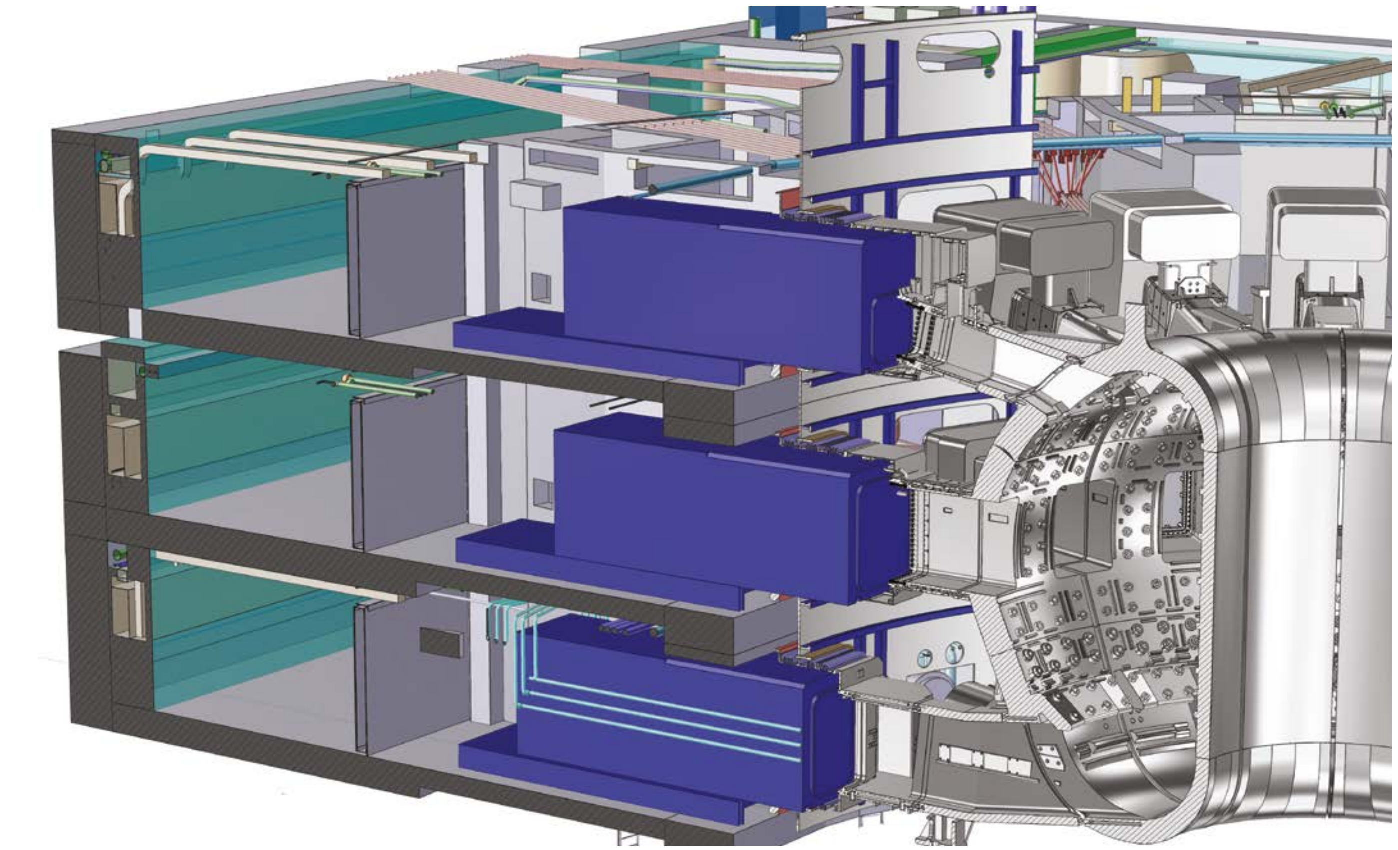
A team of 20 people from ASG Superconductors and CNIM worked closely to review the winding process and then, the button was pressed to start manufacturing 8 turns of a pre-dummy conductor Double Pancake (DP) weighing 10 tonnes. After having concluded this test successfully, the team of F4E contractors will make a complete DP to qualify all processes and finally, start manufacturing the first PF coils early next year.

View on F4E YouTube

Representatives of the ICAS consortium standing in front of the spool concluding Europe's contribution to the conductor for the manufacturing of the ITER Poloidal Field coils.

# Fusion for Energy signs multi-million deal with Airbus Safran Launchers, Nuvia Limited and Cegelec CEM to develop robotics equipment for ITER

F4E's final and biggest contract in the field of Remote Handling has been signed reaching a value of nearly 100 million EUR. It is considered to be the single biggest robotics deal to date in the field of fusion energy.



Cut-away image of the ITER machine showing the casks at the three levels of the ITER machine. ITER IO ©





The collaboration between F4E and a consortium of companies consisting of Airbus Safran Launchers (France-Germany), Nuvia Limited (UK) and Cegelec CEM (France), two companies of the VINCI Group, will run for a period of seven years. The UK Atomic Energy Authority (UK), Instituto Superior Tecnico (Portugal), AVT Europe NV (Belgium) and Millennium (France) will also be part of this deal which will deliver remotely operated systems for the transportation and confinement of components located in the ITER machine.

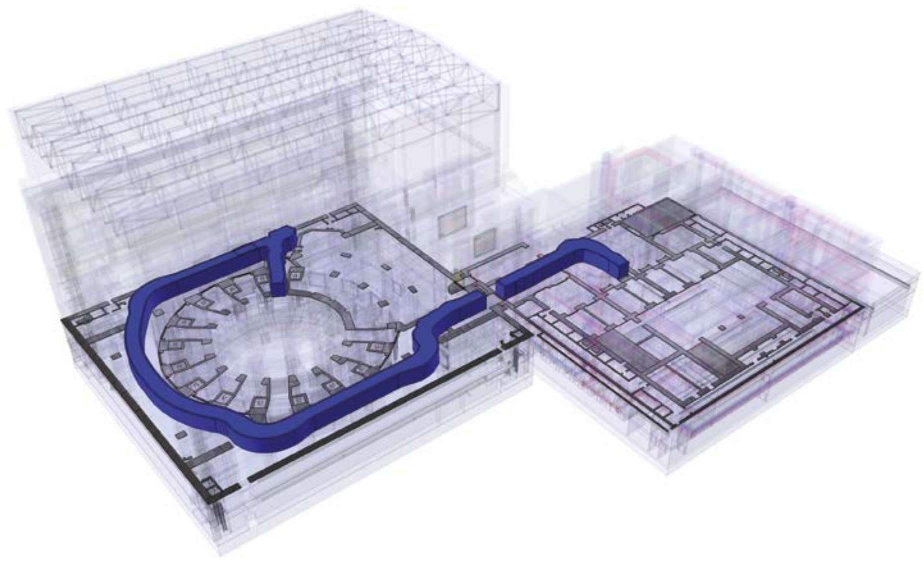
The contract carries also a symbolic importance as it marks the signature of all procurement packages managed by Europe in the field of Remote Handling. Carlo Damiani, F4E's Project Manager for ITER Remote Handling Systems, explained that "F4E's stake in ITER offers an unparalleled opportunity to companies and laboratories to develop expertise and an industrial culture in fusion reactors' maintenance."

**Why ITER requires Remote Handling?**

Remote handling refers to the high-tech systems that will help us maintain and repair the ITER machine. The space where the bulky equipment will operate is limited and the exposure of some of the components to radioactivity, prohibit any manual intervention inside the vacuum vessel.

**What will be delivered through this contract?**

The transfer of components from the ITER vacuum vessel to the Hot Cell building, where they will be deposited for maintenance, will need to be carried out with the help of massive double-door containers known as casks. According to current estimates, 15 of these casks will need to be manufactured and in their largest configuration they will measure 8.5 m x 3.7 m x 2.6 m approaching 100 tonnes when transporting the heaviest components. These enormous "boxes", resembling to a conventional lorry container, will be remotely operated as they move between the different levels and buildings of the machine. Apart from the transportation and confinement of components, the ITER Cask and Plug Remote Handling System will also ensure the installation of the remote handling equipment entering into the vacuum vessel to pick up the components to be removed. The technologies underpinning this system will encompass a variety of high-tech skills and comply with nuclear safety requirements. A proven manufacturing experience in similar fields and the development of bespoke systems to perform mechanical transfers will be essential.



Trajectory of the equipment from the ITER machine to the Maintenance Hall ITER IO ©

Illustration of lorry next to an ITER cask. F4E ©

# Bringing the power to the SPIDER beam source

**Under the stars and a bright shining moon, colleagues from F4E, COELME and Consorzio RFX celebrated: at eleven o'clock that night, the installation of the transmission line for SPIDER was completed at the Neutral Beam Testing Facility (NBTF) site in Padua, Italy.**

Part of the 35 metre long transmission line which is connected to the SPIDER vessel

F4E has collaborated with the Italian company COELME in order to design, manufacture and install the 35 metre long transmission line which will connect the power supplies to the SPIDER beam source and transmit the energy required for its operation. The transmission line itself is not straight but deliberately built in a winding manner within a concrete labyrinth to ensure the containment of the particles generated in the SPIDER vessel. In addition, it is made up of double-layered panels of copper and calcium silicate in order to mitigate electromagnetic interferences coming from SPIDER's ion source which could compromise the operation of the power supplies.

"Installation has involved a great deal of work on-site", says Daniel Gutierrez, F4E Technical Officer responsible for the transmission line. "With such a long component, there are many things that could have gone wrong and installation is very much dependent on the layout, indeed very little pre-assembly can be done in the factory", he explains.

Why was the installation completed only so late in the night? "In order to test that the transmission line is working properly, we need to ensure vacuum conditions in the SPIDER vessel", explains Gutierrez "It took several days to achieve the right conditions, and by the time the conditions were right, it was already seven o'clock in the evening. If we would have stopped then, we would have had to start over, so we decided to continue – right up until eleven o'clock in the night", he smiles.

The transmission line feeds power into the SPIDER (Source for Production of Ion of Deuterium Extracted from Radio frequency plasma) machine – a test bed where the first full-scale ITER ion source will be tested and developed. The ion source produces ions (particles with electric charges – either positive or negative), from which neutral particles originate. These neutral particles will be injected in the ITER plasma in order for the plasma to obtain the temperature and conditions necessary for the fusion reaction to occur. SPIDER is located in the Neutral Beam Test Facility – the facility which will test all main aspects of ITER's neutral beam heating system.





# Testing on MITICA's High Voltage Deck mock-up concluded successfully

**A shiny metallic box measuring 4 x 4 x 4 metres, resting 6 metres above floor level on four large gas-insulated columns, located inside a futuristic-looking high-voltage laboratory makes for an impressive sight. Add the fact that this Faraday cage is subjected to voltages in excess of 1 MV (1 million volts, compared to 230V for a typical electrical domestic appliance) and it becomes even more remarkable.**

The testing team at the High Voltage Laboratory at HSP GmbH © Siemens AG, 2016. All rights reserved.

The box, a mock-up of the High Voltage Deck (HVD) for MITICA – a test-bed currently being built at the Neutral Beam Test Facility (NBTF) in Padua, Italy, in order to test the Neutral Beam injectors that will heat the plasma in ITER – has been subjected to high-voltage testing in order to validate the design choices of the supplier SIEMENS AG. Withstanding such high voltages is extremely challenging and similar examples are very rare worldwide: checking of the test arrangements and meticulous adjustments are necessary before the actual tests can take place. Attended by staff from F4E and from Consorzio-RFX, the host of the NBTF, several electrical tests were carried out at the High-Voltage laboratory of Hochspannungsgeräte GmbH (HSP) in Troisdorf, Germany. These included one long-duration test (5 hours at 1.2 million volts DC) and several short-duration tests (impulses of 50 micro-seconds at 2.1 million volts) aiming to verify that the deck will sustain the different voltage levels which are expected during MITICA operation.

"As HSP is a world-wide leader in producing high-voltage equipment, their testing facility is in high demand and therefore with limited availability. Both SIEMENS and HSP assembled the mock-up during the night preceding the tests in order to accommodate our stringent planning", says Muriel Simon, F4E's Technical Officer in charge of the procurement of the high voltage deck for MITICA. "Thanks to their dedication and drive, all tests were concluded positively and on schedule, by the evening of the same day", she enthuses.

The completion of these electrical tests constitute an important step towards the full manufacturing of the HVD for MITICA, which will continue up to the end of the year. Its assembly at the NBTF site is scheduled to start in the spring of 2017.

# Europe's first cryoplant components ready for ITER

Europe is one of the ITER parties with a big stake in the field of cryogenics of the biggest fusion machine in history. The cryoplant can be described as a massive refrigerator which is going to generate extremely cold temperatures for some of the ITER components to achieve fusion power.

In order to confine the super-hot plasma, expected to reach 150 million °C, the magnets will need to be cooled with liquid helium to reach a superconducting state at 4.5 K, close to absolute zero. In 2014, F4E signed a contract for the European share of components for ITER's powerful cryogenic system with AirLiquide.

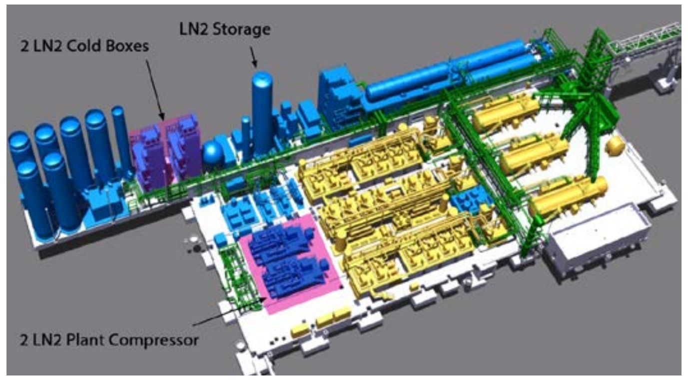
One of the facilities that F4E is responsible for, as part of its contribution to ITER's cryogenic system, is the Liquid Nitrogen - LN2 - plant. Basically, two nitrogen refrigerators with a power of 1 200 kW at 80 K will pre-cool ITER's Liquid Helium Plants and cool down the 80 K helium loop boxes. In turn, the two 80 K helium loop boxes will thermally shield the cryostat, the vacuum vessel and the cryopumps of the fusion device. It is estimated that 8 kg of helium per second will be processed.

The F4E workforces are eagerly expecting the delivery of four turbines which will be inserted in the cold boxes of the LN2 plant. Simon Saulquin, F4E's Technical Officer overviewing the production of this equipment, explains that "this will be Europe's first cryogenic component to be delivered and the first-ever for ITER's cryogenic system. The good collaboration between F4E and its contractors helped us to meet the tight schedule and manufacture this vital component on time." The role of the four turbines will be to generate vast amounts of cooling power for the ITER plant by expanding the gas previously processed by the nitrogen compressors. Two of the turbines will generate a cooling power of 500 KW and two others of 150 KW. The four turbines have been manufactured by Cryostar, one of AirLiquide's subcontractors.

The two nitrogen compressors of the LN2 plant, which have successfully gone through the Factory Acceptance Test (FAT), have been delivered to ITER in September. Representatives from F4E and AirLiquide, have celebrated the successful completion of this manufacturing milestone. The tests were carried out in the premises of Atlas Copco Energas, Cologne, AirLiquide's subcontractor for this specific component, responsible for the engineering, manufacturing and testing of the compressors. Manufacturing started in April 2015 and almost a year and a half later the two compressors weighing 85 tonnes each are ready to be transported to Cadarache. The compressors are 14.5 m long x 7.9 m wide x 4.6 m high and have a maximum working pressure of 37 bar. When they will be switched on they are expected to consume approximately 5 MW each in order to trigger off the cooling gas sequence of ITER's Cryoplant.

Turbo booster turbine able to generate 500 KW of cooling power fully assembled for testing, Cryostar (France)

Nitrogen compressor of the ITER LN2 plant successfully tested at Atlas Copc




Layout of ITER Cryoplant highlighting LN2 components to be delivered





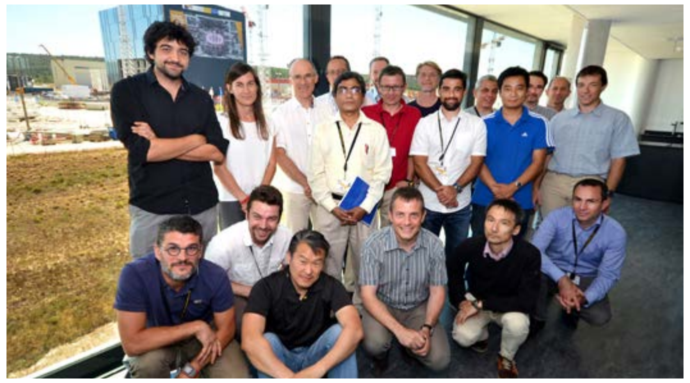
# New ITER Cryogenic Project Team unveiled

Closer integration, better coordination and more communication have started to change the project culture of ITER.

The seven parties of this ambitious experiment are responsible for the production of their share of components, which will be part of the biggest collaboration in the field of energy. The interfaces are multiple and the installation of all components needs to be seamless. Given the fact that the overall pace of manufacturing has accelerated, the need for more cooperation between all parties has become more apparent. Therefore, a stronger collaborative spirit has started to define the way the different parties will have to work from now on to honour their commitment.

The manufacturing and installation of the cryoplant, cryodistribution components, and their supervision, has generated the need for the creation of the Cryogenic Project Team, which will consist of staff from F4E, ITER International Organization and ITER India. David Grillot (ITER IO) is heading the team and ise assisted by Ritendra Bhattacharya (ITER India) and Marc Simon (F4E) as Deputies. The team will count 40 members of staff from the three organisations, and together with their contractors, they will be entrusted to deliver one of the biggest cryogenic facility in the world. The team will capitalise on shared resources and technical expertise. It will instill a more direct flow of information that will facilitate better project steering and risk management.

David Grillot, Cryogenic Project team leader, said that "we will work as one team for the same project and use in the best possible manner the potential of all members. We are now well advanced with the manufacturing and we are entering an exciting new phase of installation, which will require a lot of drive, commitment and enthusiasm." F4E's Marc Simon explains that "as we are entering the installation phase, a large part of the F4E team is moving to the ITER site to ensure an efficient supervision of these activities which are critical for the success of the project." The monitoring of manufacturing, the delivery of a large number of important components, including the arrival of the helium quench tanks in autumn, as well as the construction and commissioning of the cryoplant facility, will be some of the tasks that the members of the new team will have to tackle together.



Representatives of the ITER Cryogenic team based in Cadarache

Representatives of the ITER Cryogenic team working in Fusion For Energy

Representatives of the ITER Cryogenic team working in ITER India

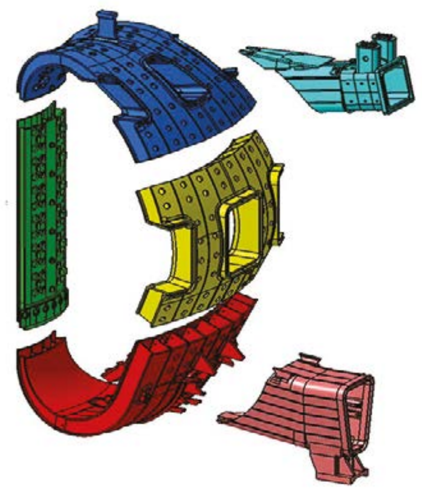
# Vacuum Vessel consortium reinforced by ENSA in delivering EU contribution

Spanish company Equipos Nucleares SA (ENSA) has joined the AMW consortium in delivering F4E's contribution to the ITER Vacuum Vessel. As a supplier to AMW (consisting of companies Ansaldo Nucleare S.p.A, Mangiarotti S.p.A and Walter Tosto S.p.A), ENSA will manufacture three segments, the poloidal segment number 1 for vacuum vessel sectors 3, 2 and 9.

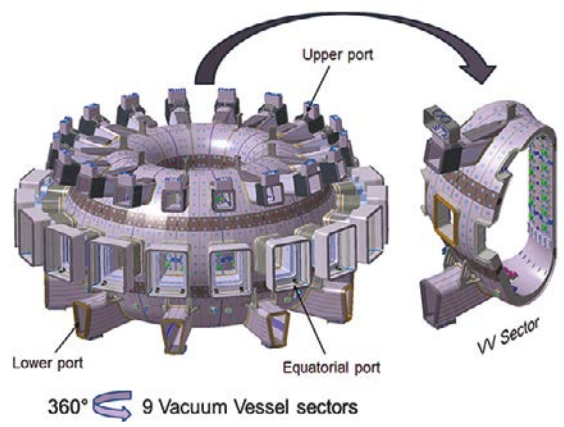
"By increasing the capacity of the consortium with ENSA, a company with significant experience in the nuclear field, we gain confidence to receive this critical component according to the ITER project delivery needs", says Francesco Zacchia, Project Manager for F4E's Vacuum Vessel Team. To kick-off this new collaboration, a meeting was held in July at ENSA premises between members of the AMW consortium, including its new subcontractor ENSA, and the Vacuum Vessel Integrated Project Team (consisting of representatives from F4E and ITER IO).

The fabrication of the poloidal segment involves a combination of high precision machining and welding, using different technologies including arc welding and electron beam welding. The highest challenge is to obtain a segment within the requested tight tolerances, considering that this is a first-of-a-kind component. The delivery of the first poloidal segment is foreseen for the second half of 2018.

The ITER plasma will be confined inside the vacuum vessel, a hermetically-sealed steel container, consisting of nice "D" shaped sectors, that houses the fusion reaction. In its doughnut-shaped chamber, or torus, the plasma particles will spiral around continuously without touching the walls. With an interior volume of 1 600 m³, the ITER Vacuum Vessel will contain a plasma volume (840 m³), which is ten times larger than that of the largest operating tokamak in the world today. It will have an outer diameter of 19.4 metres and an inner diameter of 6.4 metres, as well as measuring 11.4 metres high, and weighing approximately 5 200 tonnes, which is equivalent to the weight of the Eiffel Tower.



The poloidal segment number 1 is the green part of the Vacuum Vessel sector. It measures around 6 x 2 metres.




The ITER Vacuum Vessel





# ITER quench tanks reach the port of Marseille

F4E and its suppliers are ready to deliver two of the most impressive components of the cryoplant

Unloading the second quench tank at Fos-sur-Mer, the port of Marseille, November 2016

Two of the biggest tanks that will form part of ITER's Cryoplant have safely arrived at Fos-sur-Mer, the industrial port of Marseille. The massive components, produced by Air Liquide and their subcontractor Chart Ferox, are 35 m long and have a diameter of 4.5 m. They weigh approximately 160 tonnes each, which is the weight of a blue whale, our planet's heaviest mammal. How will these huge tanks reach the ITER site? The answer is simple: an exceptional convoy of 140 m will drive them from the port to "home". The transport will be overviewed by DAHER, responsible for the global logistics of the ITER project.

F4E and ITER International Organization (IO) have been closely supervising the manufacturing process of the two tanks, which was successfully concluded in May earlier this year. Due to this summer's heat wave, the water level of Elbe was too low to start with the first leg of the shipment. Therefore, we had to wait for the autumn rainfalls to set in motion the delivery of the quench tanks.

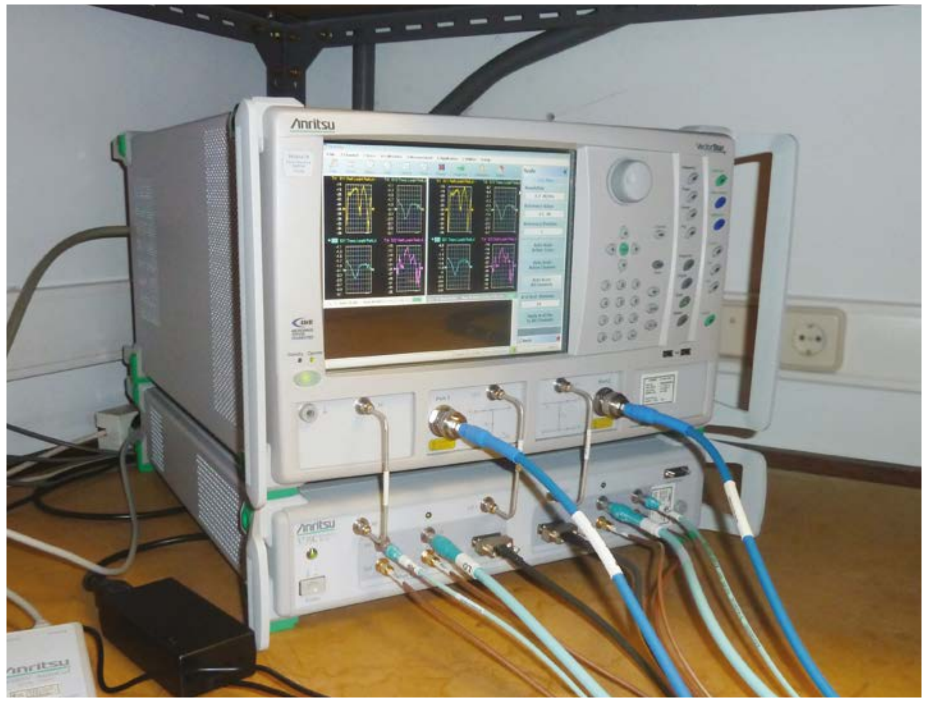
On 18 October, the teams got the green light to transfer the first tank to the port of Usti and load it onto the barge. Two days later, the second tank followed. Both components travelled safely to the port of Hamburg, where they stopped over to change vessel, and on 27 October left for the port of Berre-l'Etang, Marseille. Subsequently, they were transferred to the port of Fos-sur-Mer from where they are expected to leave for ITER.

The two pieces of equipment are extremely important to ITER's cryogenic system. The machine will use powerful superconducting magnets to entrap the hot plasma which is expected to reach 150 million ˚C. In order to achieve this, cold helium will circulate inside the magnets to bring their temperature down to -269 ˚C.

However, from time to time the magnets might experience a so-called quench. Basically, they will stop being superconductive, start becoming resistant and their temperature will start rising rapidly. Consequently, it will no longer be possible to confine the hot plasma. As the temperature rises, the helium circulating through the cryogenic system will start to expand and will need to be extracted from the machine. When this phenomenon occurs the gas will be directed to these tanks, where it will be stored at -196 ˚C.

# F4E invests in Vector Network Analyser for ITER and European fusion research.

The ITER machine will house around 50 different diagnostics systems which will enable scientists to monitor and control the plasma during the fusion reaction. F4E is currently developing around 25% of these systems in collaboration with various European Fusion Laboratories (EFLs) and, in support of these activities, has recently invested 350 000 EUR in purchasing a Vector Network Analyser (VNA).




The Vector Network Analyser measuring device used to qualify ITER diagnostic components

Through a Framework Partnership Agreement signed between F4E and the Instituto Superior Técnico (IST, Portugal), Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT, Spain); and Consiglio Nazionale delle Ricerche, Istituto di Fisica del Plasma "Piero Caldirola" (IFP-CNR, Italy), R&D and design in this area will be supported.

The Vector Network Analyser measuring device will be used to qualify one of the diagnostics which will evaluate the position and shape of the plasma, namely the ITER Plasma Position Reflectometry (PPR) system. By sending radio frequency signals to the ITER plasma, and measuring the arrival time of the reflection of these signals from the ITER plasma, the PPR system will be able to give information on the location of the plasma, which needs to be controlled to avoid contact with the wall of the ITER vessel.

"The Vector Network Analyser device gives us valuable information about how the PPR components will perform in ITER when transmitting information (radio frequency signals) about the plasma. It is a one-of-a-kind tool which can measure a wide range of radio frequency signals, thus offering new capabilities to the European Fusion community", says Paco Sánchez Arcos, F4E Technical Project Officer managing the PPR system. While the device will be kept at the IST premises in Portugal, its acquisition will benefit fusion laboratories all over Europe – access will be shared amongst other EFLs undertaking related work in support of ITER. "By purchasing this Vector Network Analyser, we also help the larger ITER family", explains Laura Sánchez García, F4E Technical Support Officer. "We can lend it to the ITER International Organisation for their use, or to other Domestic Agencies (such as the Russian Federation and the US) in support to their contribution to ITER".





# European Parliament renews its support to the ITER Project

On 27 October, the European Parliament (EP) gave its final approval on the accounts of Fusion for Energy (F4E) for the financial year of 2014 which had been postponed awaiting decisions on a revised schedule for the ITER project.

European Parliament

The EP, on the recommendation of its Budgetary Control Committee, decided with an overwhelming majority: 436 in favour, 170 against and 18 abstentions. With this decision, the EP has recognized the significant efforts and improvements which have been made in the last period in the ITER Project. Continued support of the European Parliament to the project is crucial to the success of Europe's efforts in bringing the international project 'back on track'.

The EP has the final say on approving the way EU bodies spend money from the EU budget. In the annual "discharge" procedure, it verifies whether EU funds were spent according to the rules. It may grant, postpone or refuse to grant a discharge, which is required for the formal closure of institutional accounts.

On 28 April, the EP had postponed the discharge for the 2014 annual accounts of F4E pending information on the revised schedule and cost estimate of the ITER project which were under discussion amongst the ITER Parties. The EP, while recommending a postponement of the discharge, had explicitly recognized the positive assurance given by the European Court of Auditors as to the reliability of F4E accounts and the legality and regularity of the underlying transactions. The recommendation thus did not put into question the management of the EU funds by F4E, but was instead a request for more solid information on the overall cost and timeframe of the project.

At its meeting of 16 of June 2016, and following a two-year effort by the ITER Organization and the seven Domestic Agencies to establish a new baseline schedule, the ITER Council (representatives of the seven ITER parties: Europe, US, Russia, Japan, China, South Korea and India) endorsed the updated Integrated Schedule for the ITER Project, which identifies the date of First Plasma as December 2025.

ITER is a complex international project, pushing the boundaries of current technologies. As a consequence, it requires adjustments in terms of budget and planning, common to such large-scale projects. All seven international ITER Parties, and Europe in particular, are conscious of these challenges and have taken significant steps to dramatically improve the way the project is being managed.

The ITER project is part of the European Energy Union which aims to ensure that Europe has secure, affordable and climate-friendly energy. Wiser energy use while fighting climate change is both a spur for new jobs and growth and an investment in Europe's future.

# Major JT-60SA magnet component arrives in Japan

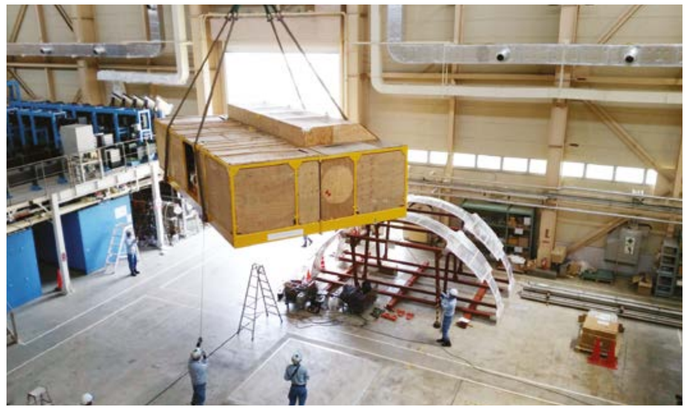
The first Toroidal Field (TF) coil has arrived from Europe at the JT-60SA site in Naka, Japan, where its assembly will soon begin.

F4E's Technical Officers A. Cardella & L. Novello stand by the first JT-60SA TF coil in Japan

After the coil's successful fabrication and testing, even its transportation has been somewhat of an achievement, in consideration of the component size: second only to those currently being fabricated for ITER, they are 8 m high, 5 m wide, and 33 tonnes heavy.

The TF Coils are the backbone of the JT-60SA machine, one of the three projects covered in the Broader Approach Agreement between Europe and Japan. They are large "D" shaped superconducting magnets whose main task will be to create the main magnetic field needed to confine the plasma.

In total, an additional 19 voyages are planned to carry the remaining TF coils for the tokamak and their two spares to Japan.



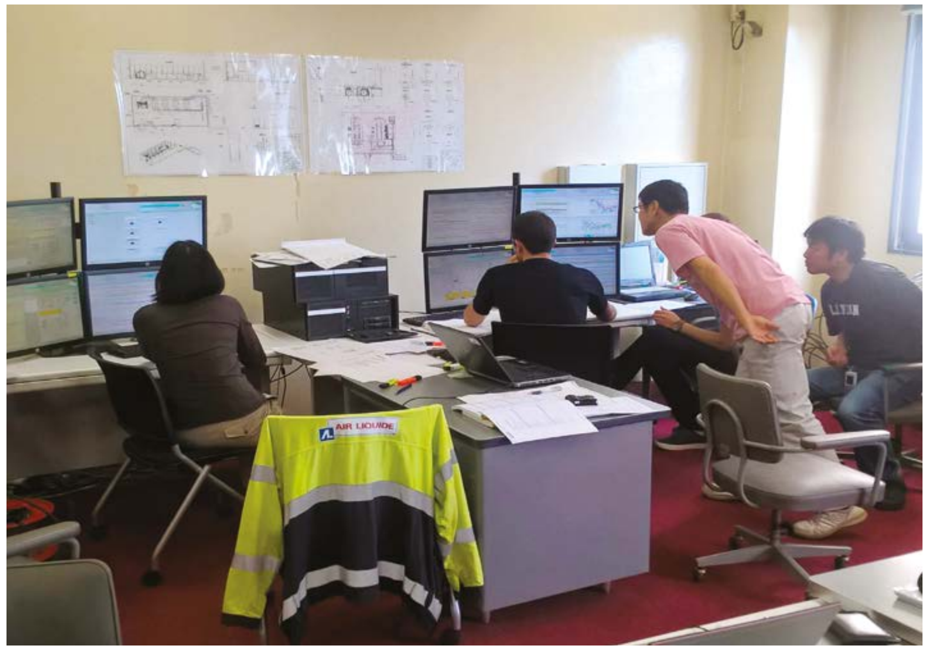
Unloading the TF coil upon its arrival in Japan





# JT-60SA cryoplant successfully passes its most demanding acceptance tests

A major project milestone for JT-60SA and for the Broader Approach has been reached: the JT-60SA cryoplant has successfully passed the most demanding of its acceptance tests.



During the JT-60SA cryoplant acceptance testing

The JT-60SA cryoplant is a powerful refrigerator producing helium at temperatures close to absolute zero for some of the JT-60SA components. To confine the super-hot plasma, expected to reach over 100 million ˚C, for periods exceeding 100 seconds, the plasma-confining magnets (an electromagnet made from coils of superconducting wire) need to be in a superconducting state in so that the wire can conduct much larger electric currents than ordinary wire, and thus create intense magnetic fields. In order to reach this state, the magnets are cooled with helium to 4.4 K and protected from external radiation by thermal shield cooled by helium at 80K.This necessary cooling is provided by the JT-60SA cryoplant, which, with a 9 kW equivalent refrigeration power at 4.4 K (this is a temperature where all known gases are made liquid and which is usually only reached in outer space). The JT-60SA cryoplant presently ranks among the largest helium refrigerators in the world.

The acceptance tests, which were carried out by F4E's supplier company Air Liquide Advanced Technology (AL-AT), consisted in simulating how the cryoplant would behave during the operation of JT-60SA. The full capacity of power pulses were applied within the plant electrical heaters, thus reproducing the calculated power profile to the plant during plasma operation.

"This is a success for JT-60SA which has been achieved thanks to an almost perfect combination of design, manufacturing, installation, commissioning and management skills by AL-AT, and the EU Voluntary Contributor CEA, with important contributions by QST (the Japanese ITER Domestic Agency) and F4E (both in terms of hardware and technical inputs). This is an example of the spirit that has allowed, so far, to advance on the way towards the successful completion of the JT-60SA project", says Enrico Di Pietro, Head of F4E's Broader Approach JT-60SA Unit.

In the coming months, after some final complementary tests of the crypoplant, JT-60SA's cryogenic system will be officially handed over to QST. In the next three years the cryogenic plant will be progressively integrated with the cryodistribution system and eventually the magnets system.

# Kick-off meeting for DEMO Oriented Neutron Source (DONES)

In the fusion energy roadmap the Demonstration fusion reactor (DEMO) will come after ITER. It will be a more powerful device which will be connected to the grid. To reach this stage of technology, however, we need to improve our know-how in several fields, including materials, which will be used inside the reactor. This is why the DEMO Oriented Neutron Source (DONES) is important.

DONES Technical information session, September 2016, Fusion for Energy

This new infrastructure will help fusion scientists to test materials in an environment mimicking DEMO conditions and on the basis of the tests we should be able to make progress.

Currently, within the framework of a scientific collaboration between Europe and Japan, known as the Broader Approach Agreement, three scientific projects will contribute towards the design of future fusion reactors beyond ITER. The International Fusion Materials Irradiation Facility (IFMIF), in its Engineering Validation and Engineering Design Activities (EVEDA) phase, has been evolving successfully. But when its operation will come to an end, DONES, a future version of IFMIF, will take over and help the scientific community to perform tests and start collecting data. Three European countries – Croatia, Poland and Spain- have expressed interest in hosting this prestigious facility and contribute to the fusion roadmap. Fusion for Energy (F4E), acting as co-ordinator for the European activities of the Broader Approach, has taken the initiative to invite representatives of the three countries at a technical information session in Barcelona to explain the scope of DONES, outline some first technical specifications and offer a tentative calendar for the different steps leading to the submission of their application.

During the meeting the delegates of the three countries had the opportunity to meet and discuss with senior experts from the fusion community, analyse the terms of reference of the new infrastructure and hear from representatives of the European Commission how regional funds, and the criteria that apply to them, may be potentially considered to strengthen the financial backbone of their proposal. In order to help all countries during the preparatory stage, F4E has agreed to ask its Governing Board, the body that supervises its activities, to nominate a group of experts to offer guidance. The country delegates were asked to reflect on the information received and to develop jointly with F4E their applications for the infrastructure. In a nutshell the experts have started rolling up their sleeves and the real work is about to start. The activities will reach a crescendo in 2017 with the submission stage and the decision of the EU member states on the location of the facility.





# F4E Director visits Korea and Japan

Exemplifying the international nature of the ITER project and the close and open collaboration between its partners and stakeholders, F4E Director, Johannes Schwemmer, travelled to Korea and Japan.

Upon the invitation of Ki-Jung Jung, Head of the Korean ITER Domestic Agency (KODA), he visited the KODA in Daejeon, South Korea, where individual and joint F4E-KODA ITER projects were discussed. The Director was impressed by KSTAR, or Korea Superconducting Tokamak Advanced Research, the magnetic fusion device being built at the Korean National Fusion Research Institute, which is one of the first research tokamaks in the world to feature fully superconducting magnets and which will study aspects of magnetic fusion energy pertinent to ITER.

Johannes Schwemmer in front of the KSTAR machine nostic components

Hyundai Heavy Industries (HHI), headquartered in Ulsan, South Korea, has been entrusted to deliver four of ITER's Vacuum Vessel sectors and the F4E Director travelled there in order to witness the progress being made and to personally deliver the message that F4E is counting on their speed and efficiency for the completion of the Vacuum Vessel. Indeed, the material handover for sectors 7 and 8 from the European consortium AMW to HHI is very near to a conclusion. He agreed with Cheul-Ho Park, COO of the Industrial Plant & Engineering Division and Senior Executive Vice President of HHI, that HHI is ready to cooperate closely with AMW and exchange the knowledge and experience with the challenging fabrication of the complex Vacuum Vessel openly.

In Japan, Johannes Schwemmer met with Drs Mori, Kurihara, Ishida and Kusama – the top management of the Japanese ITER Domestic Agency QST – in Naka, Japan. The Director discussed issues related to ITER and visited together with ITER Director General Bernard Bigot, the JT-60SA construction site. This was the opportunity to experience the machine up close. He was impressed with the progress that JT-60SA has made while staying within the cost envelope.

The progress of the Broader Approach collaboration was discussed at the Rokkasho Fusion Institute

The Director's next meeting was at Toshiba, the company dealing with the assembly of JT-60SA's Vacuum Vessel, the ITER Toroidal Field (TF) coil cases, and the owner of Mangiarotti – the company which works on the ITER Vacuum Vessel for F4E. Shigenori Shiga, Chairman of the Board of Toshiba Corporation, welcomed him at the headquarters in Kawasaki and assured F4E that Toshiba, having focussed its business units toward the energy sector, fully supports ITER and sees fusion as a key element of their longer term innovation strategy.

At the Toshiba product operations in Yokohama, General Manager Tomohiko Yabu showed Johannes Schwemmer the welding activities on the huge stainless steel coil case components which will be used, partly by F4E, to build ITER's TF coils. The Director was glad to see how the investments in automation, infrastructure and tooling that Toshiba has made optimise the manufacturing process.

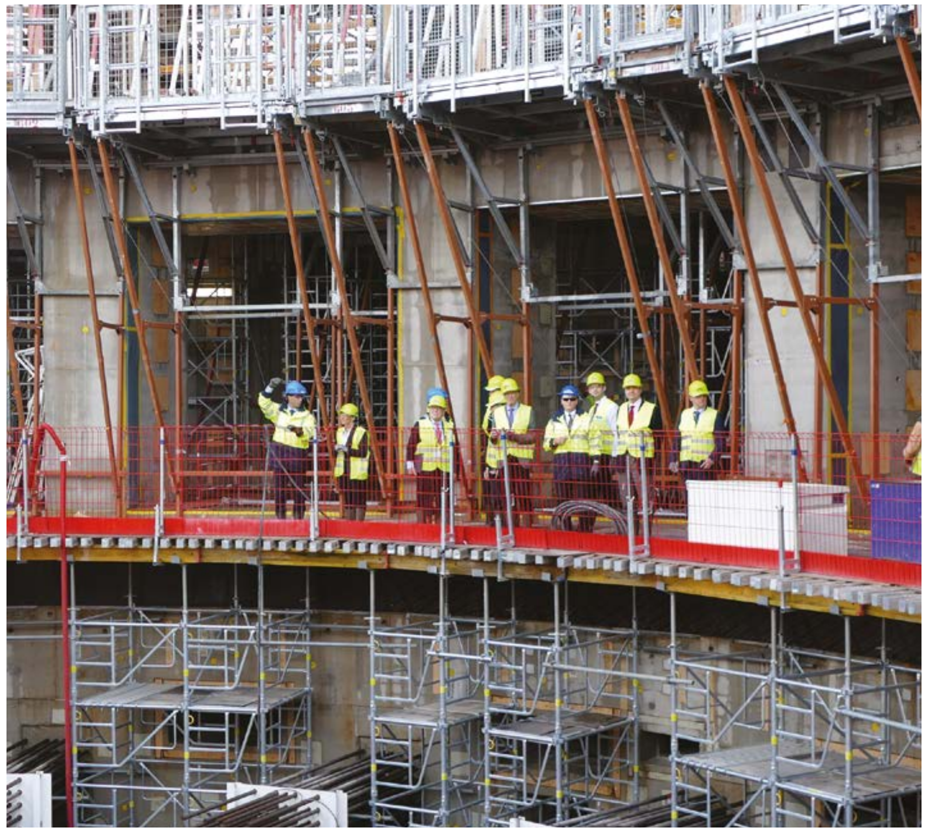
At Rokkasho Fusion Institute, in the very north of the Honshu island, Johannes Schwemmer discussed the Broader Approach collaboration and progress with Kenkichi Ushigusa (Director General), Yoshitaka Ikeda and Shigeru O'hira (Vice-Directors). A visit to the laboratory allowed him to see not only the DEMO research activities, but also the supercomputer HELIOS (one of the IFERC projects) and the impressive progress of installation of the Linear IFMIF Prototype Accelerator (LIPAc). Last but not least, this was an opportunity to understand, over a cup of coffee, how F4E employees and other European researchers live and work in Rokkasho.

Concluding his visit in Asia, Johannes Schwemmer attended the IAEA Fusion Energy Conference, organised by the International Atomic Energy Agency and held in Kyoto.

With the personal high-level contacts firmly strengthened thanks to this trip, the Director facilitates for F4E in the future. *"My meetings have been invaluable in understanding the work being done on the ground", says the F4E Director. "We will use these lessons to further F4E's progress with ITER."*

# Members of the European Parliament witness the progress of ITER and drill deep in the future challenges of the project

In one of the biggest construction sites in Europe counting more than 1000 workers, Members of the European Parliament (MEPs) in full safety gear of hard hats, yellow jackets and work boots are guided through a maze of concrete and steel. F4E, in cooperation with the European Commission, is hosting a visit to the ITER site of a first group of MEPs of the Industry, Research and Energy (ITRE) Committee.



The delegation of Members of the European Parliament during the guided tour at the Tokamak building where the ITER machine will be installed. October 2016.

Inside the Tokamak – C. Moody, F. Zanonato, G. Romero (F4E), G. Thomas (Commission), R. Wilkinson (ITRE Committee), E. Freunde, J. Dalunde (MEPs) and J. Schwemmer (F4E Director) (from left to right)

At the ENGAGE CAD Office reviewing some of the 3D final designs. C. Moody, E. Freund, J. Dalunde, F. Zanonato, M. Poche (MEPs), R. Wilkinson (ITRE Committee) (from left to right).





Kevin Smith, F4E Manager for PF Coils, explains the winding process for the fabrication of the magnets at the PF Coil Building, in the presence of R. Wilkinson (ITRE Committee), R. Darbour (F4E), F. Zanonato, J. Dalunde, M. Poche and C. Moody (MEPs) (from left to right)

Pierre Gavouyere-Lasserre (F4E) explains the contents of a piece of a conductor, one of the "basic elements" of the PF magnets, in the presence of K. Smith (F4E) J. Dalunde, J.M. Filhol (F4E), E. Freund, C. Ehler and C. Moody (MEPs) (from left to right)

The visit was attended by Clare Moody (Socialists & Democrats, UK), Christian Ehler (European People's Party, Germany), Jakop Dalunde, (Greens, Sweden), Flavio Zanonato (Socialists & Democrats, Italy), Eugen Freund (Socialists & Democrats, Austria), and Miroslav Poche (Socialists & Democrats, Czech Republic), rapporteur of the Budgetary Control Committee for the 2015 accounts of the EU Joint Undertakings, including F4E.

The tour on the construction site kicked off at the headquarters of the ENGAGE consortium, the group of companies which has been entrusted with the management of the final design of the buildings and the supervision of the works on-site. The MEPs had the opportunity to discuss with the coordinator of the 3D designs for the technical integration of building infrastructures and systems, a maze of pipes and cables carrying anything from high voltage to all sorts of liquids and gases.

Next on the site tour was the 250-metre long Poloidal Field (PF) coils facility where, due to their impressive diameter and weight, four out of six PF coils of ITER will be manufactured right on site. Following the explanations of the different production stages, MEPs were able to see from close the impressive machinery and tooling used to move objects the size and weight of the PF coils - the largest one being 25 meters high with a weight of 400 tonnes - with extreme accuracy.

The visit continued in the cathedral-high Assembly Hall, where some of the main ITER components will be assembled by special machines before being moved by the 1 500 tonne crane to the adjacent Tokamak building for installation. The visit concluded at the core of the Tokamak building where the donut-shaped reactor will be placed. The ITRE members squeezed through the maze of dense steel reinforcements and forms at the 3.5-metre thick and 30-metre high wall of the "bioshield", which will wrap the ITER device and act as a safety layer between the machine and the building hosting it.

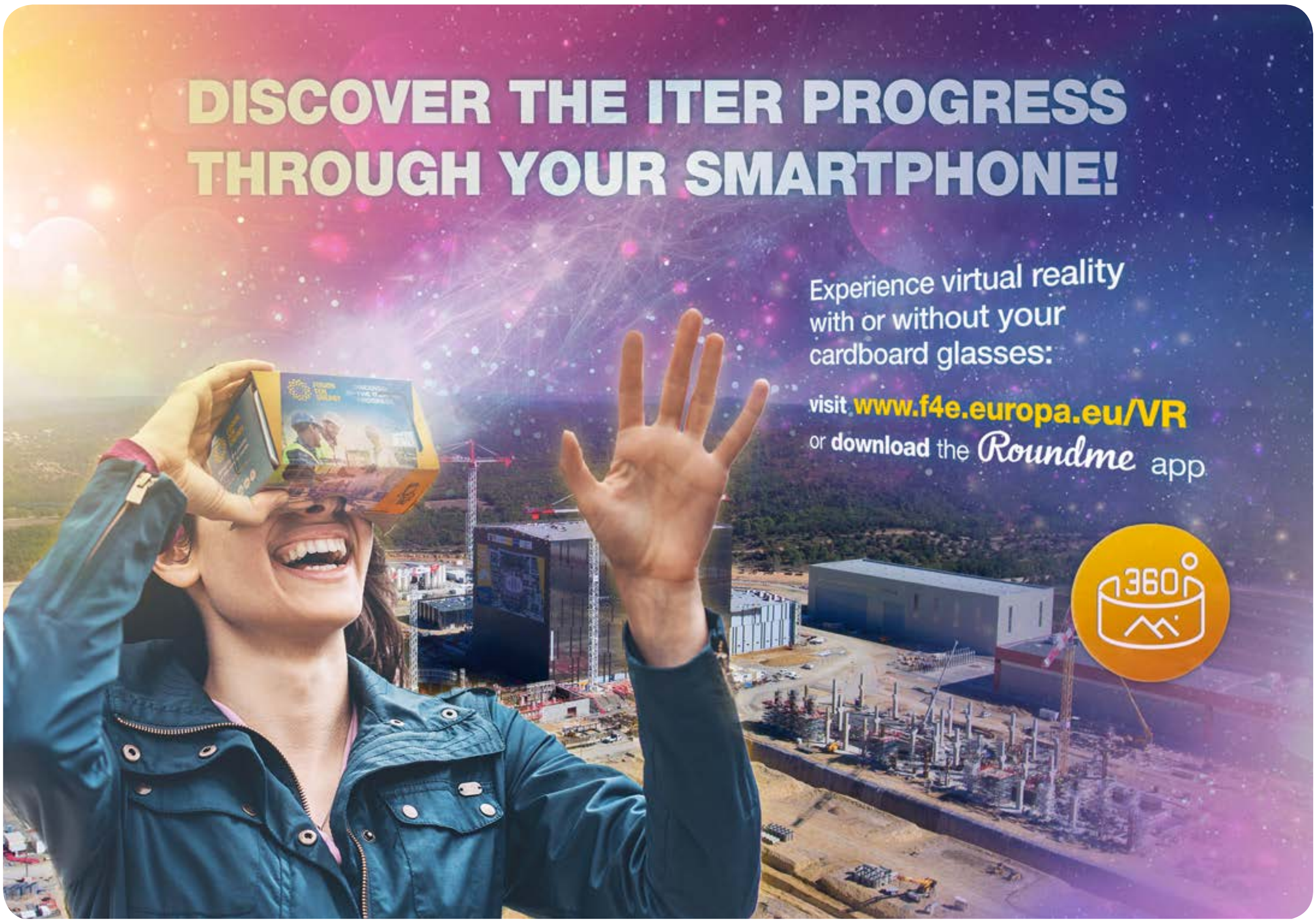
The tour would not have been complete without a visit to the 3D Virtual Reality Room, which allows visitors to enjoy a total immersion inside the machine, examining every detail of the different components and "feeling" their size and complexity.

The presentations by Bernard Bigot, ITER Director General, and Johannes Schwemmer, Fusion for Energy (F4E) Director, covered the benefits of fusion as a potentially limitless, sustainable and safe energy, and the technical achievements and challenges, together with the important changes in the management of the project since 2015. Johannes Schwemmer, presented in more detail the F4E focus on the first plasma components, as well as the turnaround programme for the organisation.

The members of the ITRE committee showed great interest in the project and acknowledged the importance of continuing the quest for fusion and the construction and operation of ITER. They expressed a clear appreciation for the efforts by ITER IO and F4E to improve the management of the project, to prepare the new schedule and put in place the necessary accompanying resources, to ensure a more effective management of the project and Europe's contribution. The exchanges between MEPs and the F4E Director also addressed the role of European fusion laboratories, the benefits for industry and the impact on companies and SMEs. The resources necessary for the next period of the project were also addressed. MEP Christian Ehler stressed the importance of including contingencies in the project, as had been suggested by the independent review panel, in order to avoid some of the errors of the past.

The discussion took place in a very open and frank atmosphere and ITRE members were thankful to the F4E Director and the European Commission representatives for their collaboration and transparency.

MEP Clare Moody joined all other MEPs in thanking F4E for organising this "very informative and interesting day" and added that she was "very pleased to have visited the construction site of this inspirational project."

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