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European Fusion Development Agreement

EFDA NEWSLETTER

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In the internal Pages:

The Report on Safety and Environmental Impact of Fusion approved by the CCE-FU

The CCE-FU (EURATOM Consultative Committee for Fusion) has approved the report on Safety and Environmental Impact of Fusion (SEIF) presented by EFDA at the April meeting in Bruxelles.
This is an integrated report which updated and improved the analysis carried out for the report on the Safety and Environmental Assessment of Fusion Power (SEAFP-1) in 1995. The new results take into account the improvements in data and in the methods of analysis and the changes in materials specifications. The results in the SEIF report confirm once again the attractive safety and environmental characteristics of fusion energy.

EFET, the European Industrial Support to ITER

In 1993 the European Commission issued a call for tender for the European industrial support to the ITER Engineering Design Activities (EDA) being performed by the European ITER Home Team, now represented by the EFDA Close Support Unit in Garching. Following a competitive tendering exercise involving European wide industry groupings with an interest in fusion technology, a Framework Contract covering these industrial support activities was awarded to EFET (European Fusion Engineering & Technology) in April 1994.
EFET is a European Economic Interest Grouping (EWIV) with its administration offices at Framatome Advanced Nuclear Power GmbH in Erlangen, Germany. It brings together major systems engineering companies from seven European countries: Ansaldo Ricerche (Italy), Belgatom (Belgium), Fortum (Finland), Framatome ANP S.A.S. (France), Framatome ANP GmbH (Germany), IBERTEF (Spain) and NNC (United Kingdom).
The Member Companies of EFET jointly cover all the major technology areas required for the design, construction and procurement of the systems and components of the next step fusion device. The range of EFET's expertise covers areas as diverse as superconducting magnets, large mechanical structures, such as the vacuum vessel, and complex remote handling systems required for component inspection and replacement.
Since 1994, throughout the ITER EDA and its extension related to ITER-FEAT, EFDA in Garching has frequently relied on EFET's expertise for the design, assessment and costing of systems and components for the ITER device, including fabricability investigations.
These activities have also included safety, design and cost assessments of ITER as presented by ITER Joint Central Team (JCT) in their design reports at various stages of the ITER project.
EFET is also able to include the specific expertise of third-party industries from Europe when explicitly requested by EFDA, in particular in plasma physics areas.
Within the overall objectives of the European Fusion Programme, EFET has performed significant safety and design studies for future fusion power plant concepts (SEAFP, PPCS).
In addition to contributing to the final design report for ITER-FEAT, EFET is currently participating in the activities for the assessment of the possible European ITER site proposal at Cadarache (F) including related licensing activities.
The application of industrial know-how to the ITER design is very important to the success of the project. By pooling with the expertise and competence of its Members in the field of controlled thermonuclear fusion, EFET is able to provide such know-how and to support the European Fusion Programme in making the next step device an engineering reality.

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The ITER Toroidal Field Model Coil (TFMC) Test Preparations

In 2000 the fabrication of the TFMC was completed by the European Consortium AGAN. The Intercoil Structure (ICS) was delivered in June 2000 to the Toroidal Coil Facility (TOSKA) test site at the Association EURATOM-Forschungszentrum Karlsruhe and the TFMC followed January 11, 2001. The TFMC was assembled with the ICS and set in a vertical position. This arrangement was lifted onto the gravitational support frame and assembled with the auxiliary structure. In the first test campaign this will replace the EU Large Coil Task (LCT) coil and the TFMC will be tested as single coil starting in June 2001 to provide key results until the end of the ITER EDA. Afterwards, in the second campaign until 2002, the TFMC will be tested in the background field of the LCT coil for achieving comparable mechanical stresses of the ITER full size coils.

Before the TFMC arrangement was lifted in the TOSKA vacuum vessel the coil instrumentation (voltage taps, temperature, pressure and flow sensors, displacement transducers, strain gauges) was carefully checked.

The TFMC during lifting procedure in the TOSKA vacuum vessel

The electrical insulation was tested by DC, AC and pulse voltage up to 10 kV.

After the lifting of the arrangement in the TOSKA vacuum vessel a vacuum leak test is performed to assure that the whole arrangement has an overall leak tightness of $5 \cdot 10^{-7}$ mbarl/s.

When this specification is fulfilled, the arrangement will be connected to the cryogenic and the electrical high current supply systems as well as to the data acquisition system. Specific equipment (2 kW refrigerator, 80 t crane, 80 kA power supply with discharge circuit, a modern measuring and control system for the cryogenic supply) was installed and commissioned for previous superconducting coil tests (LCT at forced flow He II operation at 1.8 K, test of the W 7-X prototype coil) in the years before. Two 80 kA current leads were developed and constructed for this test.

“The ITER Central Solenoid Model Coil is a Major Milestone”

The large coils which will generate the major magnetic field components in ITER will all be superconducting. The high currents and long pulse duration would generate too much heating in conventional coils. However, the construction of superconducting coils with the required performance is a major technological challenge, so working prototypes need to be built to prove it can be done.

Dr Robert Aymar, the ITER Director, recently announced the successful testing of a model of the central solenoid coil – the one which sits at the centre of the doughnut and acts as the primary winding of the transformer to drive the plasma current.

But this is no small model.

The test coil is 2 m high, 3.6 m in diameter, carries a current of

Test facility at Naka (Japan) for the model of the ITER central solenoid coil (courtesy of JAERI, Japan)

46000 amperes and produces a field of 13 tesla.

To put that in perspective, the magnets in the biggest hi-fi loudspeakers produce no more than about one tesla, over a volume more than a million times smaller!

The development and testing of this coil is an example of a remarkable international collaboration, involving industry as well as fusion labs. The superconducting strand was produced by companies in the EU, Japan and the USA (with support from the Russian Federation), the conductors were then manufactured by industry in the EU, the magnet was assembled from modules made in Japan and the USA, and the whole assembly was tested on a purpose built facility in Japan.

Dr Aymar says that the successful testing of the coil is “a major milestone of the ITER R&D programme and conveys a strong message about the quality of the ITER collaboration and the strength of industrial involvement”.

Another Step towards Steady-State Tokamaks

The Tore Supra Tokamak at the Association EURATOM-CEA (Cadarache, France) has pioneered the use of superconducting coils to generate its strong toroidal magnetic field. This is an important technology for future machines, since it opens the way to very long plasma pulses, and perhaps even steady state operation. This unique feature of Tore Supra means that it is the right machine for making long pulse experiments. In fact Tore Supra holds the world record of 2 minutes for a hot Tokamak plasma.

The limitation on the plasma performance in these very long pulses is due to heating of the inner surfaces of the machine which define the plasma edge (the "limiter"), and which must absorb most of the injected power. In order to achieve higher performance in long pulses, the physicists and engineers at Cadarache are now working on a major upgrade of the machine called CIEL ("Composants Internes et Limiteur").

This is a prototype of one of the 576 "fingers" which will line the base of the upgraded Tore Supra machine and form the pump limiter. One of the big challenges of the CIEL upgrade is ensuring the reliability of the bonding of every one of the tiles to the copper base material.

The most important new component of CIEL is a "pump limiter" made up of 576 individual fingers. Each finger consists of plasma facing tiles made of a composite of graphite and carbon fibre bonded to a copper substrate which contains a cooling water channel.

This high tech structure has ideal properties for a fusion machine : a refractory, low atomic weight material in contact with the plasma, and a high thermal conductivity substrate which can be water cooled. The bonding of the two uses state of the art techniques developed in collaboration with industry. Prototypes have sustained heat fluxes up to 15 MW/m^2.

The whole set of fingers is designed to be able to support a 15 MW load in steady state. Apertures located under the fingers allow exhaust gas from the plasma to be pumped away. Other elements of the upgrade include improved protection for the remainder of the inner surface of the machine, infrared cameras to monitor the surface temperature of the limiter, and enhanced control systems to allow the long pulses to be operated safely. Full scale plasma operation of the upgraded machine will start in 2002.

The Rise and Rise of High-Power Gyrotrons

Fusion plasmas require many megawatts of heating to reach the temperatures at which fusion reactions occur. Gyrotrons are one of the possible solutions. They are sources of high power, high frequency microwaves which can be absorbed in a very localised region of the plasma. The technique is attractive for various plasma physics reasons, and it also has some significant practical advantages linked to the high frequency of the radiation (which corresponds to a few millimetres wavelength): the radiation can be transported efficiently over large distances and very high power can be transmitted through the small apertures which are permitted in the wall of the plasma vessel.

Gyrotrons use the interaction between a high energy electron beam and radiation in a magnetic field to generate the microwaves. High power is possible because the interaction cavity is large, unlike low power devices which use a fundamental mode cavity. The cavity is carefully designed to support a single high-order waveguide mode which must be converted to a low order mode for transmission to the plasma through waveguides.

A number of years of co-development with industry has led to a solution using an ideal material: diamond. It has very low absorption, high strength and good thermal conductivity. The example here is 80 mm diameter and 1.5 mm thick.

The big problem has always been the severe technological difficulty of making sources which reliably combine high power output, long pulse length and high frequency. For a machine like ITER, the targets are at least 1 MW per gyrotron for many tens of seconds at up to 170 GHz. A practical device also needs an overall efficiency of several tens of percent.

Fusion research has been pushing gyrotron development for over two decades. In this time the progress has been astounding. For example, in 1980 a low frequency (28 GHz) output of 200 kW was an achievement. Today, gyrotrons with 0.5 MW for about 10 s at 100 GHz, and an efficiency greater than 30% are commercially available. Tubes which will meet the ITER requirements are currently in development.

A Fusion Springboard to Commercial Success

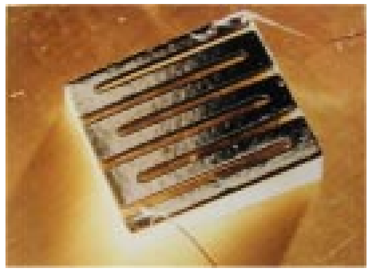
What happens when an SME (Small and Medium sized Enterprise) realises that it has produced a high-tech product of potential value to fusion R&D? This case study shows how the development, encouraged by the fusion community, can be just the beginning.

In the early 1970s, scientists at Queen Mary College (London) were developing a new type of millimetre-wave (short wavelength microwave) detector for use in astronomy. At about the same time, fusion physicists were developing a new plasma diagnostic technique based on the measurement of the millimetre-wave radiation emitted by fusion plasmas. The new detector had exactly the characteristics they were searching for: high sensitivity, large bandwidth and good optical access when built into the liquid helium cryostat used to cool it.

Following successful tests of the detector at UKAEA-Culham, the College started to market the new detector through a small spin-off company, QMC Instruments Ltd.

The company rapidly evolved into the supplier of complete millimetre-wave detector packages to the world's fusion laboratories.

During the 1980s, the new diagnostic was adopted by almost all the world's fusion



The sensitive element in QMC Instruments' detector is a small slice of ultra-pure Indium Antimonide which is cut in a zig-zag pattern and mounted in a liquid helium cryostat at –269 C. Low thermal conductivity wires carry the tiny electrical signals to external room temperature electronics.

experiments, and further evolution of the instrumentation (multi-channel spectrometers with up to 20 detectors) created a lot of business.

At the same time, other requirements of the fusion environment, such as reduced liquid helium consumption to prolong the interval between refills, pushed QMC Instruments into new areas such as the development of sophisticated filters to block unwanted thermal radiation without sacrificing signal. Systems now operate for many weeks without any maintenance.

By the early 1990s, most of the leading fusion laboratories had enough detectors for their needs and the volume of fusion related business began to fall. However, QMC Instruments was able to use the expertise it had acquired to adapt the detectors for non-fusion applications. Today, fusion laboratories account for only a small part of the more than 1 M Euro turnover of QMC Instruments. It sells sophisticated detectors for space applications, laboratory spectroscopy and remote sensing. Recently, new applications have started opening up in biological and medical research. In the words of Sales and Marketing Director, Ken Wood, "By investing in development to satisfy the demands of the fusion community in the early years, we produced much better products which have now found applications in many other areas. We are proud of the contribution we have made to scientific endeavor, but it would never have got off the ground without the impetus provided by the fusion community".

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