



Vol 2003 / 4  
August 5, 2003

# newsletter

EUROPEAN FUSION DEVELOPEMENT AGREEMENT

Issued by the EFDA  
Close Support Unit  
Garching

## News

### New EFDA Leader appointed

Prof. Minh-Quang Tran, head of the "Centre de Recherches en Physique des Plasmas (CRPP)" at the Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, has been appointed the new EFDA leader and will take up the position on October 1st. The decision was taken at the EFDA Steering Committee meeting which took place in Culham (UK) on June 24, 2003.

### ITER Negotiations: P-1 Meeting at Vienna

On 19<sup>th</sup> June 2003 the first Preparatory Meeting (P-1) for ITER Decision Making was held at the IAEA (International Atomic Energy Agency) in Vienna (Austria). At this meeting the Republic of Korea joined Canada, the European Union, Japan, the People's Republic of China, the Russian Federation and the United States of America as a Participant to ITER Negotiations. Each Participant submitted its first indications of position for the various matters addressed in the meeting, as a basis for discussions. At the conclusion of P-1, all of the Participants agreed that substantial progress had been made on the path to the implementation of ITER. The next meeting, P-2, is scheduled to take place at the IAEA in Vienna on 9<sup>th</sup> October.

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### 30<sup>th</sup> EPS Conference on Controlled Fusion and Plasma Physics

The 30<sup>th</sup> European Physical Society (EPS) Conference on Controlled Fusion and Plasma Physics was held, during the week of July 7 - 11, 2003, in St. Petersburg (Russian Federation), a very special and prestigious host for this event since Peter the Great's "Paradise" and "Venice of the North" celebrates this year its 300th anniversary.

For more information on this topic see page 6 and <http://www.ioffe.ru/EPS2003/>.

<http://www.efda.org>



**Dr. Jung-Hoon Han** is presently heading the International Cooperation Unit at the Korea Basic Science Institute in Daejeon, Korea.

**KSTAR** (Korean Superconducting Tokamak Reactor) is a long pulse, superconducting tokamak being designed to explore advanced tokamak regimes under steady state conditions.

**Parameters:**

Major Radius:

1.8 m

Minor Radius:

0.5 m

Plasma Current:

2.0 MA

Pulse Length:

20 sec <  $t_{\text{pulse}}$  < 300 sec

**For more information see:**

<http://www.kbsi.re.kr/2001/english>

<http://www.pppl.gov/kstar/>

**“It was time to make a move ” - Korea joins the ITER project**

**EFDA Newsletter (EN):** Your country officially joined ITER P1 negotiation meeting in Vienna, Austria, on June 19 and plans to join the ITER project as a partner. How long has Korea been working on this decision and has the last push been influenced by China and the US recently joining?

**Jung-Hoon Han (JHH):** Actually we started in 1999, when the Chairman of our research council, Mr. Chae Young-Bok first visited the European Union to be informed about the European fusion programme. The collaboration with the ITER partners was an essential part of the success of the KSTAR project. The last push towards ITER was indeed caused by China and the US. Our country is close to China and since World War II we have had a strong relationship with the US, so I agree that our decision was strongly influenced by the Chinese and the US move.

**EN:** China needs fusion urgently as a future energy source. What role does fusion play in Korea?

**JHH:** Korea has not such a high energy demand as China with its large population. About 40% of our electricity is generated in nuclear power plants. To reduce CO<sub>2</sub> in the long run we have to find an alternative to the use of fossil fuels. Therefore we view fusion as a future generation of electricity producing power plant, replacing or upgrading the existing atomic energy resources one day. From the current point of view it's a very logical step.

**EN:** The Korea Basic Science Institute (KBSI) was established in 1988. It is leading the national fusion R&D programme which designed and constructed the superconducting tokamak KSTAR. What is the history of fusion in your country?

**JHH:** Actually we started in the 1970s with Basic Plasma and Fusion Research at University level; in the 80s and 90s we constructed small-scale fusion research devices like the Snut-79 Tokamak at Seoul National University, KT-1 Tokamak at KAERI and the KAIST Tokamak and the HANBIT Plasma Research Facility at the Korean Basic Science Institute, KBSI, at Daejeon. This institute was established in August 1988 as the first national centre to house various user facilities and to carry out basic science research. KBSI is leading the national fusion R&D programme which is responsible for design and construction of the superconducting tokamak **KSTAR**. The experience gained during the construction and the operation of KSTAR as an international project and, bearing in mind that it is one of the first tokamaks with superconducting toroidal field and poloidal field coils, could be very valuable and represent an important contribution of South Korea to ITER.

**EN:** Several industrial firms like Hyundai and Poscon are already involved in the KSTAR project. Is Korean industry well prepared to take part in the ITER project? What main contributions could they provide?

**JHH:** I have noticed that they have a strong will to join the ITER project. In our country, industry has a relatively short history compared to the European Union, but a good tradition of hard working people. I think, based on the present development level, Korean industry could do some of the conventional parts of ITER.

**EN:** Since June 1996 Korea has had a Cooperation Agreement with the US at government level in the area of Fusion Energy Research and related fields. Does your government plan agreements of similar nature also with the EU?

**JHH:** Yes, actually we are in the process of preparing such an agreement. It has been discussed since 2000 and a Cooperation Agreement between the EU and Korea in the field of fusion has already been drafted. I think this bilateral agreement could be signed by this year or by March next year at the latest.

Interview: D. Lutz-Lanzinger

## ITER

## First ITER NB Injector and the ITER NB Test Facility

A 1 MeV-neutral beam injection system planned for ITER has to operate on the basis of "negative ion technology", i.e. the acceleration and neutralisation of negative rather than positive hydrogen or deuterium ions as on most present NB systems today. R&D is in progress in Europe and in Japan on the two key items: the ion source and the accelerator. In both cases two alternatives are being considered. Such R&D activity should be completed by the middle of 2005.

In the ion source,  $D^-$  ions can be generated either in an arc discharge or in an RF discharge. The arc discharge is produced between tungsten filaments and the source body that acts as the anode. R&D is in progress in Naka, Japan, and in Cadarache, France, where the so called Kamaboko III source, built in Naka, is tested on the MANTIS test bed. The RF discharge is produced with an RF generator; R&D is in progress in Garching, Germany. In both cases small quantities of caesium are introduced into the discharge in order to enhance the production of negative ions. The R&D activity on the RF discharge source is justified, since the presently favoured arc source does not meet all requirements, which are: a negative ion current of 40 A at a current density of 20 mA/cm<sup>2</sup> and a pulse duration up to 1 hour. Further obstacles are the rather limited life time of the arc filaments, resulting in major maintenance effort, and high costs.

The negative ions can be accelerated with two different accelerators. The multi-aperture multi-grid (MAMuG) accelerator, under development in Naka, consists of 5 gaps (four intermediate acceleration grids). In the single aperture, single gap accelerator (SINGAP), under development in Cadarache, a pre-acceleration stage (~40 keV) is followed by a single 1 MeV acceleration stage.

The arc discharge source and the MAMuG accelerator, already developed in Naka for the 500 keV injectors of JT-60 U, were considered the more conservative extrapolations from existing devices, and therefore they are the basis for the ITER NB injector reference design. Both alternatives (the RF source and the SINGAP accelerator) offer significant advantages. The RF source would not need filaments and therefore their replacement (routine maintenance) could be eliminated. The SINGAP accelerator could offer substantial simplification of the accelerator and of the high voltage transmission lines and power supplies. Such design simplifications would also lead to cost saving.

There is a general appreciation within the international NB community, that an ITER-like NB system should be built and tested before the ITER NB system is installed at the ITER site. Such an "ITER-like NB system", should demonstrate high voltage acceleration at ITER relevant currents, to ensure that reliable NB operation is achieved in ITER and to minimise the time required for on-site commissioning. Many elements of the ITER NB system should be tested at essentially full scale and at pulse lengths commensurate with those required for ITER (~1 hour).

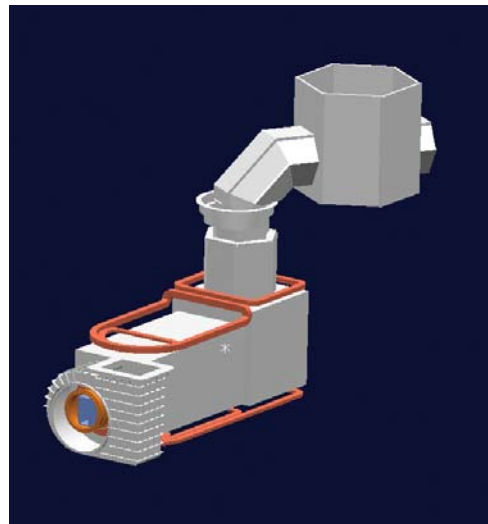
A possible approach to achieve this aim would be to consider the required equipment and all associated auxiliaries as parts of the "first ITER NB injector" to be installed initially at an ITER NB Test Facility and later at the ITER site. A formal agreement on ITER construction and site are necessary preconditions to start procurement. The construction of the first ITER NB injector should be shared between the ITER Partners; the European Union, Japan and the Russian Federation are likely to be involved and discussions are underway with the ITER International Team to prepare for such collaborative development. In the frame of EFDA design activities, the European laboratories are close to starting the preparation for the test facility and to optimise the ITER NB system design.

The ITER Neutral Beam (NB) system consists of two heating and current drive (H&CD) injectors and of one diagnostic neutral beam; space, auxiliaries and services have been foreseen for a third H&CD NB injector.

The energy (1MeV deuterium) and power (16.5 MW per injector) specifications of the ITER NB system significantly exceed those of any NB system currently operating.

Power delivered to the plasma per injector	16.5 MW
Beam energy	1 MeV
Ion species	$D^-$
Accelerated ion current	40 A
Average accelerated ion current density	200 A/m <sup>2</sup>
Current density uniformity over the extraction area	± 10 %
Source filling pressure	0.3 Pa
Pulse length	≤ 3,600 s

*Summary of the design parameters for heating and current drive (H&CD) NB system for ITER.*



## Associations

ENEA (Ente per le Nuove  
Tecnologie, l'Energia e  
l'Ambiente):

<http://www.enea.it/>

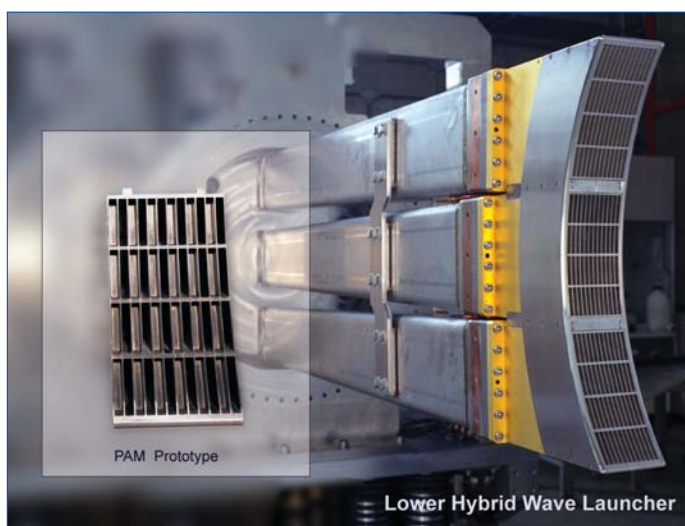
CEA (Commissariat à  
l'Energie Atomique)

<http://www-cad.cea.fr/>

### Lower Hybrid Wave Launcher Prototype at Frascati (Italy)

*The Lower Hybrid (LH) wave is a plasma wave of frequency between the ion and electron cyclotron resonance frequencies. An LH launched from the plasma boundary can accelerate electrons along the field lines and thereby drive current in the plasma. This method, called Lower Hybrid Current Drive (LHCD) has the higher current drive efficiency and is used to control the edge plasma current and access advanced plasma regimes.*

The Frascati Tokamak Upgrade (FTU) is preparing a test, to start in September, which is the first stage of experimental exploration of a new concept considered for the ITER LH wave launcher: the Passive-Active Multijunction (PAM). The PAM is a structure in which the active wave guides are separated by passive wave guides that allow enough space for the cooling system (see photo) and neutron shielding. Since LHCD could contribute to the production of advanced plasma scenarios on ITER, the PAM test is crucial to check the viability of LHCD in steady-state operation. The FTU prototype, developed within a collaboration between the Association Euratom-ENEA and Euratom-CEA, is aimed at verifying the power handling capability of the launcher at ITER relevant densities and magnetic field values (a unique feature of FTU), the coupling flexibility (i.e. the operational range of density in front of the structure) and at validating numerical codes developed for modelling coupling and propagation. Comparing the number of faster than average electrons produced by the PAM with that produced by a conventional grill indicated the effectiveness of the wave launcher. For that purpose, FTU has been equipped with two new fast electron Bremsstrahlung cameras measuring the X-rays generated by the fast electrons produced by lower hybrid waves. The PAM module, which has been successfully characterised in the laboratory during 2002, is presently being assembled on a test bed for testing at high power and will be installed in the tokamak in July. Subsequently, a fully equipped prototype with the cooling system foreseen for ITER will be tested on Tore Supra (Cadarache, France) in long pulse operation.



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**ELM** (edge-localized mode) is an instability that occurs in short periodic bursts during H-mode in divertor tokamaks. It causes transient heat and particle loss into the divertor which enhance erosion. Small ELMs are useful for impurity / density control.

The website

<http://www.oew.ac.at/euratom> presents an overview of the activities of the Association EURATOM-ÖAW

See also:

<http://www.jet.efda.org>

### Association Day on Plasma Physics at Association Euratom-ÖAW

On 20th May 2003 the Association EURATOM-ÖAW organised its annual Association Day on Plasma Physics, which was hosted this year by the Institut für Allgemeine Physik at TU Wien. At this meeting, scientists from Vienna, Innsbruck and Graz presented their current contributions to the EU Fusion Physics Programme.

Dr. Alberto Loarte from EFDA-CSU Garching gave a lecture on strategies and aims of the new European Task Force on Plasma-Wall Interactions. Groups at the Institut für Ionenphysik of Universität Innsbruck and at the Institut für Allgemeine Physik at TU Wien are investigating plasma-wall interaction phenomena and have expressed interest to contribute to the new Task Force and the accompanying technology programme.

In his lecture entitled "JET under EFDA: a cooperative effort", Dr. Bruno Gonçalves from the EFDA-CSU Culham presented an overview of the EFDA-JET Work Programme 2003 and showed the areas of special interest for the Association EURATOM-ÖAW, which are related to mass transport in the edge plasma, **ELMs**, alpha-particle simulation experiments, and fast He-beam spectroscopy.

The afternoon session was opened by a short introduction on general aspects and perspectives of the Sixth EU Framework Programme for research presented by Dr. Christian Seiser from the Austrian Ministry for Education, Science and Culture.

## Associations

### Summer Training Course on the CASTOR Tokamak

Operation of the next step fusion devices, such as ITER, will require a new generation of physicists, which are familiar with all aspects of experimental work on tokamaks. Their practical education can be accelerated substantially by getting them in a direct touch with experimental reality. For that purpose, small-scale experiments can be instrumental. One of those available in Europe is the small but very flexible CASTOR (Czech Academy of Sciences TORus) tokamak routinely operating in the Institute of Plasma Physics in Prague, Czech Republic. The tokamak is equipped with basic diagnostics, a good data acquisition system and a reasonable software package for data processing. Daily, about 50-60 reproducible discharges with the repetition rate comparable to 10 minutes can be easily achieved. The permanent staff is experienced in education and training of Czech as well as foreign students. The Czech and Hungarian Euratom Associations (IPP.CR and HAS) decided to exploit all these benefits and jointly organize the Summer Training Course (SUMTRAIC) on the CASTOR Tokamak. The first run has been successfully performed on June 2-6, 2003, with participation of ten Hungarian students (graduate and post-graduate) and three Hungarian supervisors. Only those students were accepted for participation who passed an exam on a one-semester introductory course on fusion, this way they were already familiar with concepts and theory of fusion.

The first day of the training course was devoted to an introduction of key elements of CASTOR (vacuum, power supplies, diagnostics etc). Several standard shots were done with students as operators and basic experimental data were processed. The following days, the experimental groups have performed topical measurements (focused this time to Langmuir probes, spectroscopy and plasma fluctuations measurements) according to a tentative shot plan. One student of each group was selected to operate the tokamak, another one took care on the particular diagnostics and the remaining students checked and processed data. The last day was dedicated to the discussion of results and the preparation of presentations. The training course was completed on Friday afternoon by a joint workshop, where students presented the main experimental achievements. The next training course is envisaged to be organized in June 2004 in a similar way. Participation from all over Europe is welcome. A web-based fusion education course will be available for interested students well in advance at the homepage of the Hungarian Association.

### Investigations on Chemical Erosion and Hydrocarbon Film Formation at IPP-Berlin

The plasma generator PSI run by the Berlin (Germany) division of Association Euratom-IPP is a stationary high current arc discharge in an axial magnetic field. This facility allows the production of a stationary plasma column of about 2 m in length and 8 cm in diameter. It is used for basic as well as applied research in the field of plasma physics. A number of technical investigations have been conducted in close contact with the EFDA group in Garching (Germany). The problem of chemical erosion of graphite materials being foreseen for ITER has been studied in a joint project. In this context the chemical erosion yield of various **CFC** materials was studied in hydrogen and deuterium discharges. It was observed that with moderate or low flux densities (about  $10^{21}$  ions / $m^2$  s) each hydrogen ion hitting the target has a chance of nearly 10% of releasing a methane molecule (or some other carbon-consisting molecule) from the surface with flux densities of  $2 \cdot 10^{23}$  ions / $m^2$  s the erosion decreases to values of about 0.5%. This is constant with observations on tokamaks (fig. 1, see next page).

For more information on the Institute of Plasma Physics of Czech Republic (ASCR), Association Euratom-IPP-CR, see:

<http://www.cas.cz/en/UFP.html>



### Carbon Fiber Reinforced Material (CFC):

Such materials were chosen for the bottom parts of the ITER divertor vertical target due to their resistance to the high heat fluxes present in that area. However, this important advantage is counterbalanced by other problems, such as erosion and codeposition.

The experimental results described on this page mitigate the problem of erosion. In addition, with respect to film formation the observations made contain a positive message but are less convincing because of lacking knowledge on the ITER divertor conditions.

[http://www.ipp.mpg.de/de/for/bereiche/diagnostik/for\\_ber\\_dia\\_akt.html](http://www.ipp.mpg.de/de/for/bereiche/diagnostik/for_ber_dia_akt.html)

Associations

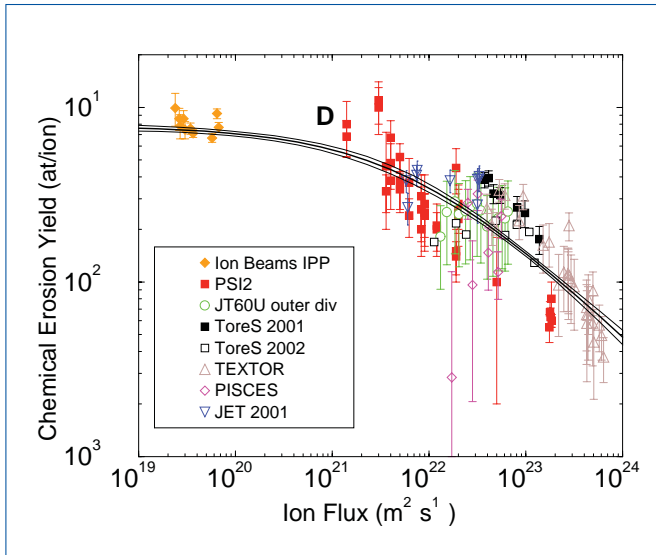


Fig. 1: Chemical erosion yield of graphite as a function of particle flux density

An upgraded version of the plasma generator (PSI-2) was used to study the erosion and deposition behavior of hydrocarbons under conditions similar to that in some areas of the ITER divertor. The hydrocarbons were generated either by chemical erosion of a graphite target or by injections into the plasma through a nozzle. Two processes are at the basis of the two phenomena: deposition of all neutral hydrocarbons which have a high sticking probability and simultaneous erosion of the films by atomic hydrogen. Whereas deposition proved to be nearly independent of the surface temperature, erosion strongly increases with rising temperature.

Therefore there is a critical collector temperature where erosion and deposition are in equilibrium and the thickness of a layer is unchanged. Beyond this temperature erosion prevails and films which have been produced previously are dissolved.

The critical temperature is not a universal quantity but increases with the ratio of hydrocarbon to hydrogen fluxes.

The critical temperatures are inferred immediately as those where the curves cut the temperature scale (fig. 2). This is seen to happen at  $T = 360$  K and  $380$  K wall temperatures. However, the flux ratio requires further investigations. Numerical simulations and additional experiments are under way to assess this issue.

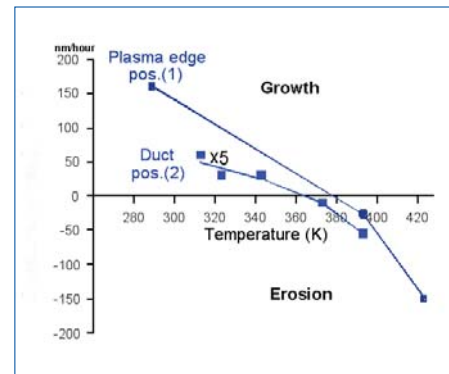


Fig.2: Growth rate of hydrocarbon films vs. surface temperature for the two collectors

(1) close to plasma edge  
(2) at a distance of 0.4 m



V. E. Fortov, winner of the Hannes Alfvén Prize 2003

30<sup>th</sup> European Physical Society Conference on Controlled Fusion

Puschkin, Dostojewski, Achmatowa – Russia’s most important literary figures are closely connected with St. Petersburg, a city having an impressive history not only in cultural matters, but also in the fields of science, industry and trade. About 950 participants from 40 countries in this year’s EPS conference were invited to enjoy the combination of science and great history, staying in the hotel “Saint-Petersburg”, in the city’s heart, directly by the river Neva. In the field of plasma physics 30 plenary speakers were invited. The oral presentations were organized in four parallel sessions and 800 posters were presented. The traditionally awarded Hannes Alfvén Prize 2003 for outstanding contributions to plasma physics went to V. E. Fortov for his seminal contributions in the area of non-ideal plasmas and strongly coupled Coulomb systems and for his pioneering work in the generation and investigation of plasmas under extreme conditions. This conference united for the first time the four sections of the plasma physics division of the European Physical Society with the aim of improving the cooperation and synergetic effects in plasma physics. The 31<sup>st</sup> EPS conference will be held in London (UK).

From left to right: B.V. Kuteev, C.F. Teretschenko, Yu.S. Vasiliev, F. Wagner, E.P. Velikhov



## JET

**25 June 2003: a Special Day at JET**

From the words that P.-H. Rebut (a former director of JET) has written to celebrate the 20th anniversary of the first plasma at JET it is easy to understand that it was a day of great excitement. At that time the machine was such a complex system that all sorts of unexpected problems had to be solved, but over the next few months the current was gradually increased and by October had reached 1 MA.

The fact that JET is still operating and produces huge amount of valuable data is ample evidence of the success of the large team of engineers and scientists that contributed to the project, the construction and the operation of JET.

To mark the occasion, a small exhibition has been organised in the JET K1 Inner Foyer, with photos and memories from some of the people present on Day 1. The Avo meter used on Day 1 was also on show. The full message from P-H Rebut and a selection of photos of Day 1 are available in our public webpage, <http://www.jet.efda.org>.

It was a touching coincidence that the life and work of Dr Derek Robinson FRS, who was the Culham Director and Head of the EURATOM/UKAEA Association before he died in December 2002, was commemorated on the very same day at the Culham Science Centre. Some of the senior representatives of the international fusion community came from all over the world to take part in a daylong seminar.

Well over two hundred colleagues, including many former staff, heard fulsome tributes paid to Derek's work from leaders of the fusion community in Russia, where he had spent a year in 1968 as part of a Culham team confirming Soviet claims for their fusion experiment T-3. This work led to the subsequent development of the tokamak as the main line of fusion research throughout the world.

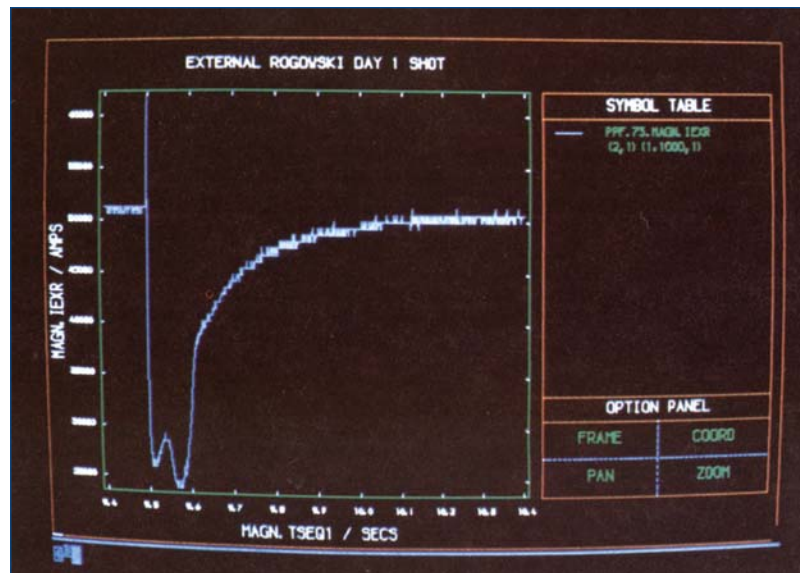
Derek's major input to international research during his career of almost forty years was also recognised by speakers from Japan, China, the USA and mainland Europe, including his role in preparing for ITER. The Associate Leader for JET, Dr Jérôme Paméla, chaired the International Session on future perspectives for fusion and also presented the European contribution, recalling Derek's strong support for JET and his participation over many years in the JET Scientific Council and JET Council.

**Derek Robinson (right) at  
Lev A Artsimovich dacha in 1968**

*(courtesy of Nick Peacock)*

"JET came to life with the first plasma on June 25th 1983 after five years of frantic construction. It was a great day even if a plasma of only a few kA was achieved. At this time all the elements of the machine were not yet tested including the plasma positioning which was not active; nevertheless JET was in operation"

P.-H. Rebut, June 2003



**The first plasma in JET**



## Interview

## More than 30 years for fusion – Michel Huguet leaves ITER Naka

**EFDA Newsletter (E.N.):** You started your scientific career at the Ecole Supérieure d'Electricité in Paris (France) and you complete it as Head of the ITER Joint Work Site at Naka (Japan). The distance between Paris and Naka is about 10 000 km. What were for you the most important milestones along the way?

**Michel Huguet (M.H.):** At the Ecole Supérieure d'Electricité I was still a student. I started work at University for my Doctorate. Basically there are three milestones in my career. The first one was when I left my job at University to join fusion research at the French Atomic Energy Commission (CEA) at Fontenay-aux-Roses in 1969. I was attracted by fusion as a combination of engineering and physics. After having built the tokamak there, the second milestone was when I was asked to join the JET team at Culham in England where I stayed a total of 19 years and became JET Associate Director. At the end of '91, I had to take the most difficult decision: I was offered the position of ITER Deputy Director at Naka, which appeared to be rather difficult and risky for my career because of technical problems and organizational difficulties with ITER. But I wanted to get involved in the design of ITER, and hopefully the construction, and trusted Dr. Rebut, who was the ITER director at that time, and so I went to Naka.

**E.N.:** What feelings do you remember on June 25, 1983, when JET started operation and the operator's note was "first light, a bit of current"?

**M.H.:** This first JET plasma was indeed much publicised, but for the JET team it was just one step within the commissioning of the machine and this had started several months before. But nevertheless it was something significant and I would say the main feeling was relief that the systems were apparently working as expected. But I was much more satisfied a few months later, at the end of 1983, when the first plasma with a current of 1 Million Ampere was achieved. This was for me the real confirmation that the machine was working well.

**E.N.:** The construction schedule for JET was 5 years, that for ITER is foreseen to be 8 years, do you think this schedule will be kept?

**M.H.:** Something that helped JET with its very tight schedule was that, at the time the project was established, we already had manufacturing contracts placed for prototypes of the toroidal field coils and the vacuum vessel. In the case of ITER, after the establishment of the project, about two years will be needed to obtain the license to construct and then, seven years will be required for actual construction. Finally, one more year will be used for commissioning to obtain the first plasma. So the total time to achieve the first plasma is about 10 years. I think for ITER it is still a very tight schedule, but if ITER is given a strong construction team and an effective organization and project control, I don't see why this schedule could not be met.

**E.N.:** Your official work for ITER as Head of the ITER Joint Work Site at Naka ends on June 30. Have you as a French national already been "Japanized" or are you happy to return to your home country?

**M.H.:** Working with the International Team, the Japanese Home Team and the other Home Teams has been stimulating and a very positive experience. For me, the most important part of my work has been the success we have had with the manufacture and testing of the model coils. It has been also very enjoyable for my wife and I to discover Japanese people and culture. But now, after 30 years abroad, I think my wife and I have earned the right to go back to France where our parents, children and grandchildren live. Of course, I will keep in touch with my Japanese friends and colleagues...and I confess that I am taking a lot of technical documents with me to France - so this indicates that I still feel somehow involved in fusion.

Interview: D. Lutz-Lanzinger



**Dr. Michel Huguet (left)** at his farewell party at EFDA/ITER Garching (Germany), together with Dr. Robert Aymar, ITER co-leader (right).

Find a short CV of Dr. Huguet on our Website:

<http://www.efda.org>

**For more information see our EFDA website:**

<http://www.efda.org>

and additionally

<http://www.jet.efda.org>

<http://www.iter.org>

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