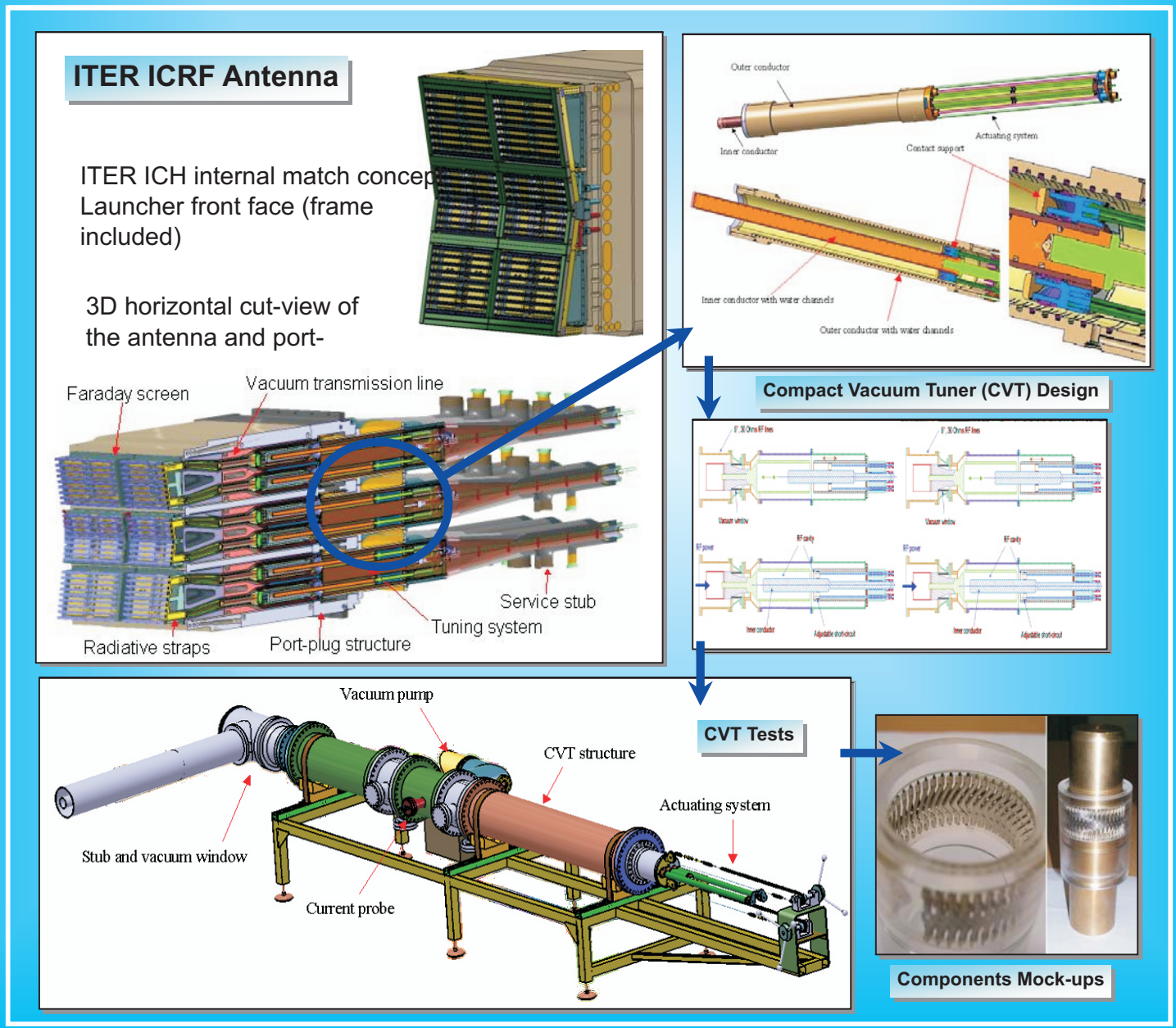
FUSION TECHNOLOGY

Annual Report of the Association EURATOM-CEA 2006

(full report)

Compiled by : Th. SALMON and F. LE VAGUERES



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CEA/DSM/DRFC
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13108 Saint-Paul-Lez-Durance, France

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Cover : *The Compact Vacuum Tuner (CVT) is a high power tuning device to be developed for use in the ITER Ion Cyclotron Heating launcher. As such, it is designed to be compatible with ITER vessel mechanical interface, EM loads, mechanical, thermal, and nuclear specifications. To validate the CVT, dedicated R&D strategy based on mock-ups has been chosen to assess the most critical aspects. Our Association is involved in the CVT design studies and mock-ups.*

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Vessel-In Vessel

Vessel-Blanket and Materials

Plasma Facing Components

Remote Handling

Magnet Structure

Tritium Breeding and Materials

Breeding Blanket

Helium Cooled Lithium Lead (HCLL) blanket

Materials development

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Fusion technology

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Vessel-In Vessel

Vessel-Blanket and Materials

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INTRODUCTION

European research on controlled thermonuclear fusion is carried out in an integrated programme with the objective to develop a safe, clean and economically viable energy source. Part of this programme is under the responsibility of the *European Fusion Development Agreement* (EFDA) which provides a framework covering the activities in the field of technology (both Next Step and Reactor) and the collective use of the Joint European Torus (JET).

This annual report summarizes activities performed by the Euratom-CEA Association in 2006 within the frame of the European Technology Programme (both "EFDA" activities, "Underlying Technology" programme), and also includes keep-in-touch activities in the frame of Inertial Confinement Energy.

This full report is also available on line at "*http://www-fusion-magnetique.cea.fr*". In each section, the tasks are sorted out according to the EFDA main fields: Physics (TP), Vessel/In-Vessel (TV), Magnets (TM), Tritium Breeding and Materials (TT), Safety and Environment (TS), System Studies (TR), JET technology activities (TJ) … The Euratom-CEA Association is involved in all these topics (figure 1).

- Euratom-CEA activities carried out in the field "***Physics Integration***" are mainly linked to heating, current drive and diagnostics. For heating, both Ion Cyclotron Range of Frequencies (ICRF) antenna developments and SINGAP studies have been pursued. Developments on diagnostics, in particular in support to ITER diagnostic design (bolometer, optical design, magnetic sensors, thermocouples, Infra Red fibres for thermography applications, port integration) have been carried out.

- Plasma Facing Component (PFC) developments, Vacuum Vessel/Blanket activities and Remote Handling studies are carried out in the field "***Vessel/In-Vessel***". The Vacuum Vessel (VV) studies have been pursued on welding techniques (hybrid MIG/Laser), and qualification of inspection methods along the Vacuum Vessel inter-sector weld.
  On the PFC side, investigations have been carried out on materials (CuCrZr creep-fatigue studies, neutron effects on material properties of CFC), development and optimisation of Be/CuCrZr joining techniques (HIP), and studies dedicated to the divertor (Carbon Erosion Modelling, Test of Divertor components in FE200).
  The work performed by the Association in Remote Handling has been dedicated to improvement of knowledge on radiation tolerance of electronic components for RH, and to the program called Articulated Inspection Arm (AIA). In 2006 this program included the manufacture of the complete AIA robot, including the deployer and the storage cask. Assembling is now going on in Tore Supra. In 2007, tests in the tokamak environment will be conducted.

- In the field "***Magnets***", the Euratom-CEA Association has devoted a major part of its effort to the studies of advanced Nb_3Sn strands for the Toroidal Field (TF) coils, and the first full size conductor sample was manufactured. The Euratom-CEA Association has also been involved in ITER PF coils studies: a mock-up, representative of the main features of the coil tail has been manufactured, in collaboration with ENEA and fatigue cycled tests at Brasimone (Italy) have been made. On a long term approach, the Euratom-CEA Association has also pursued its investigations on the possible use of High Temperature Superconductor (HTS) for future fusion reactors.

- The Field "***Tritium Breeding and Materials***" includes for a large part reactor relevant activities. Within the frame of Test Blanket Module (TBM), activities mainly concerned the improvement and completion of the TBM engineering design. After a first design step in which the main structure, its functional features, its mounting sequence and manufacturing characteristics were defined, the second step, relied on the optimization of the design and manufacturing of the module as well as its integration to the supporting frame. A planning and list of test requirements for the qualification of the HCLL TBM was defined. A preliminary testing programme for the HCLL TBMs in ITER has been proposed on the basis of the foreseen ITER scenario and of the TBM testing strategy and mock-ups test objectives. Manufacturing of relevant mock-ups are still under progress, and qualification of fabrication processes for TBM have been an important part of 2006 activities.
  Euratom-CEA maintained in 2006 significant involvement in the development of structural materials for a fusion reactor. The main focus has been for EUROFER, a reduced activation martensitic steel, and significant work has been performed on a long term approach for advanced materials, which have been an important part of the activities dedicated to materials, especially improvement of knowledge on SiC/SiC for future fusion power plants.

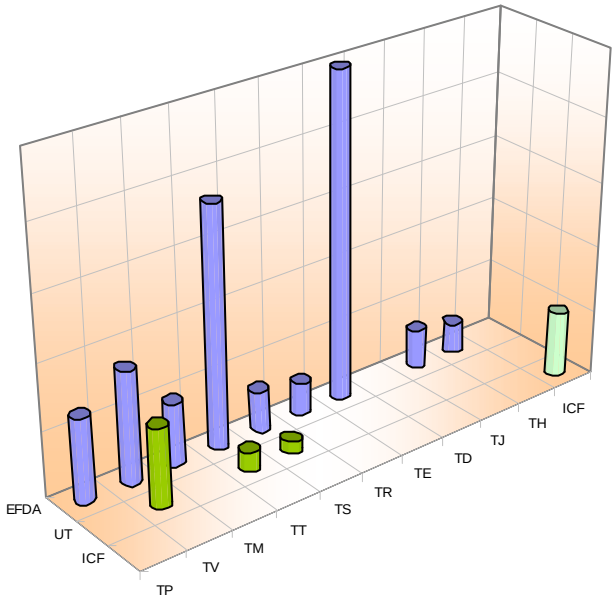
- "***Safety and Environment***" studies realized by Euratom-CEA cover different parts of this topic such as investigation on possible concrete detritition methods, cryogenic experiments on the EVITA facility, dust measurements and removal techniques, code development and validation (safety studies on hydrogen mitigation and dust explosion in the vaccum vessel or on activated corrosion products activities).

- Activities in the field "***System studies***" have been dedicated, in 2006, to conceptual studies for DEMO and future fusion power plants. In that aim, Euratom-CEA has pursued the studies on blanket design from PPCS-model AB, and on DEMO (blanket segmentation and maintenance - remote handling issues ; analysis of current profile control in tokamak reactor scenarios using realistic treatment of current drive efficiencies ; magnet system outline).

- Activities carried out in the Field "***JET technology***" have been devoted to both studies of different processes which can be used for tritium removal from carbon materials and dust characterisation and measurement. 2006 activities have also been devoted to the new diagnostic for thermography analysis which produced infrared images of the in-vessel components showing energy deposited on the divertor, on the top limiter and on the outer limiters during ELMs in JET.

Four specific operational divisions of the CEA, located on four sites (see appendix 5), are involved in the Euratom-CEA fusion activities:

- the Nuclear Energy Division (DEN) , for In-vessel component design (first wall, divertor, blanket, …), neutronics, structural materials and safety activities,
- the Technology Research Division (DRT), for activities dedicated to materials (elaboration, breeding materials) and robotics,
- the Matter Sciences Division (DSM), which includes the Department for Controlled Fusion Research (DRFC) which operates Tore Supra and is responsible for plasma physics and engineering developments , cryoplant and magnet and plasma facing components activities,
- the Life Sciences Division (DSV), for activities related to the impact of tritium contamination on staff.



TP : Physics
TV : Vessel/In-Vessel
TM : Magnets
TT : Tritium Breeding and Materials
TS : Safety and Environment
TR : System studies
ICF : Inertial Confinement Fusion
TE : ITER Site Preparation and activities devoted to ITER future construction in Cadarache
TD : Design Support and Procurement
TJ : JET Technology
TH : Heating Systems Technology Project

EFDA : European Fusion Development Agreement program
UT : Underlying Technology program
ICF : Inertial Confinement Fusion

Figure 1 : breakdown of the work carried out by Field

The Euratom-CEA programme in Technology is also complemented by specific R&D collaborations with the French National Centre for Scientific Research (CNRS), the Ecole Polytechnique, and Universities in the Plasma Facing Components and Inertial Confinement Fusion activities.

Progress in fusion technology is constant over the years and this report once again highlights a number of important steps that have been accomplished in many domains. Euratom-CEA, together with other European Institutions is on the forefront of technological advances which are of prime importance for the success of the ITER construction. On the longer term, progress in technology will gradually improve the vision of an electricity producing reactor and will increase the credibility of fusion energy as a genuine solution for energy production for the future. The authors and the editors should be commended for their dedicated contribution in making this report available.

M. CHATELIER

EUROPEAN FUSION DEVELOPMENT AGREEMENT TECHNOLOGY PROGRAMME