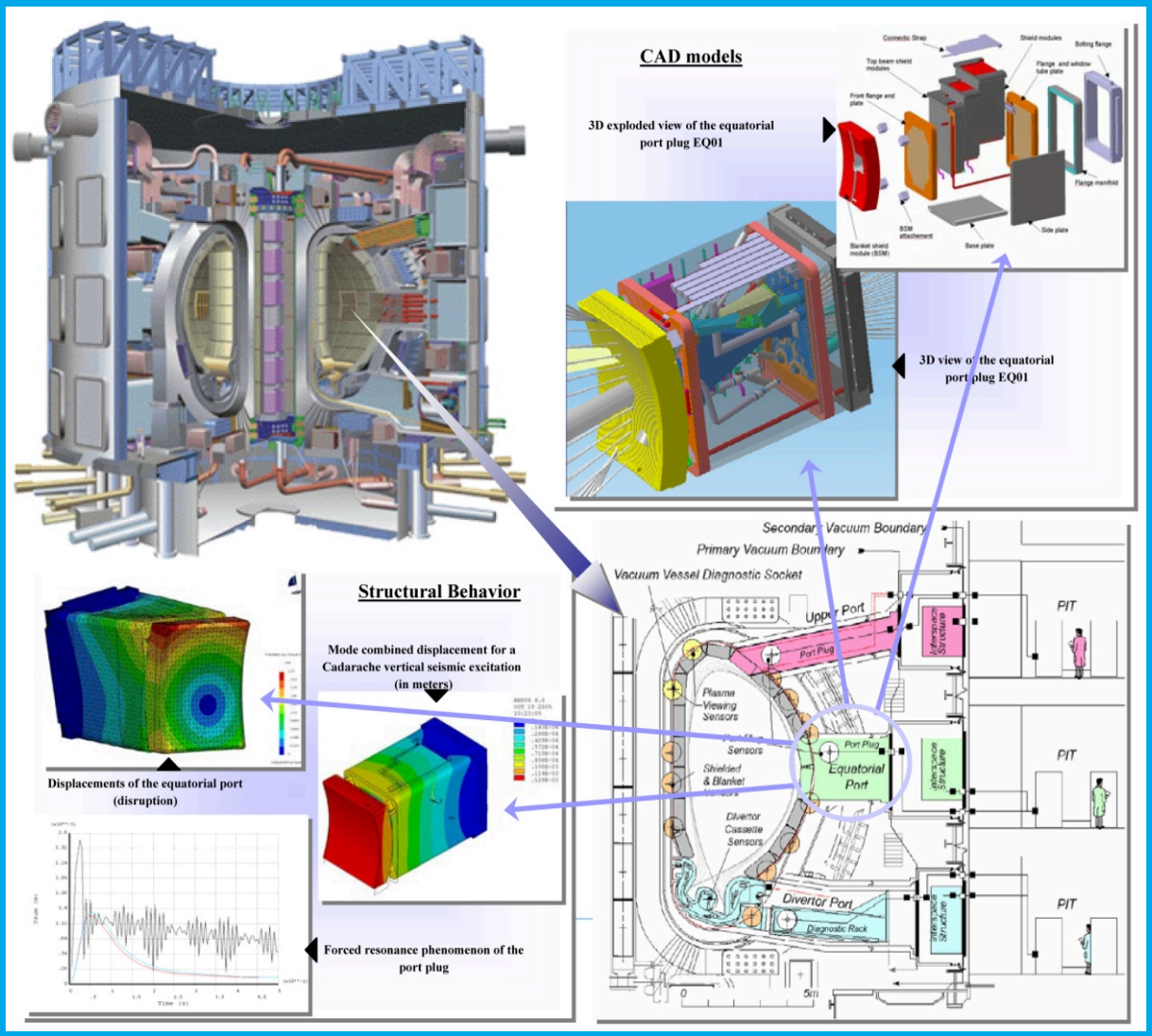
FUSION TECHNOLOGY

Annual Report of the Association EURATOM-CEA 2005

(full report)

Compiled by : Th. SALMON and F. LE VAGUERES



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DSM/DRFC
CEA-CADARACHE
13108 Saint-Paul-Lez-Durance (France)

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Cover: *Most of the ITER diagnostics system are to be integrated in port plugs, which are water-cooled stainless steel structures inserted into the vacuum-vessel ports. The port plug must perform basic functions such as providing neutron and gamma shielding, supporting the first wall armour and shielding blanket material, closing the vacuum vessel ports, supporting the diagnostic equipment. CEA has contributed to the engineering activities (including CAD effort, structural and thermal analyses) on the port plugs and has more particularly focused on the design and diagnostic integration in the representative equatorial port plug EQ01.*

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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 2005 within the frame of the European Technology Programme (both "EFDA" activities and "Underlying Technology" programme). It does not include keep-in touch activities in the frame of Inertial Confinement Energy, reported in a specific issue performed by the European Commission.

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 the Ion Cyclotron Range of Frequencies (ICRF) Antenna developments and to the development of diagnostic components. In particular, concerning diagnostic design for ITER port integration has been studied (see cover).

- Plasma Facing Component (PFC) developments, Vacuum Vessel/Blanket activities and Remote handling studies are carried out inside the field "***Vessel/In-Vessel***". The Vacuum Vessel (VV) studies have mainly focused at welding techniques (hybrid MIG/Laser), and at qualification of inspection methods along the Vacuum Vessel intersector weld.
  On the PFC side, investigations have been performed on material knowledge (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 Euratom-CEA Association has also pursued its R&D program to demonstrate the feasibility of close inspection of the ITER Divertor cassettes and Vacuum Vessel First Wall. The work performed in Remote Handling has been dedicated to improvement of our knowledge on radiation tolerance of electronic components for RH, and to the program called Articulated Inspection Arm (AIA). In 2005 this program included improvement of the knowledge of the single module of the AIA built in 2004, and start of manufacturing of the other modules of the whole arm.

- In the field "***Magnets***", 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 cryogenic tests on ITER magnet structural metals where, in collaboration with FZK, thermal test bench and measurement procedures at 4K, 77K and room temperature have been upgraded and improved.
  On a long term approach, the Euratom-CEA Association has also launched investigations on the possible use of High Temperature Superconductor (HTS) for the 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.
  Within the frame of the Helium Cooled Pebble Bed (HCPB) concept programmes, studies about the development of Li_2TiO_3 pebbles are on going. The main objective of 2005 which was to improve the shape of the Li_2TiO_3 pebbles has been successfully achieved. For this, several batches of 100 grams of Li_2TiO_3 pebbles with the size distribution in the range 0.6 to 0.8 mm have been produced and a revision of the formulation of the extrusion paste (binder and plasticizer content) has been necessary.
  Euratom-CEA maintained significant involvement in the development of structural materials for a fusion reactor, mainly focused at EUROFER in Europe, a reduced activation martensitic steel, from elaboration (internal oxidation method has been investigated), to irradiation effects (Neutron irradiation to 70 dpa at 325°C conducted in the BOR60 reactor of the Russian Research Institute of Atomic Reactors), to modelling of irradiation effect (using Ab-initio defect energy calculations or multi-scale modelling experimental validation by comparison with experimental irradiation in Jannus), without forgetting qualification of fabrication process (tubing process qualification, as well as weldability of homogeneous plate or dissimilar tubes with YAG laser).

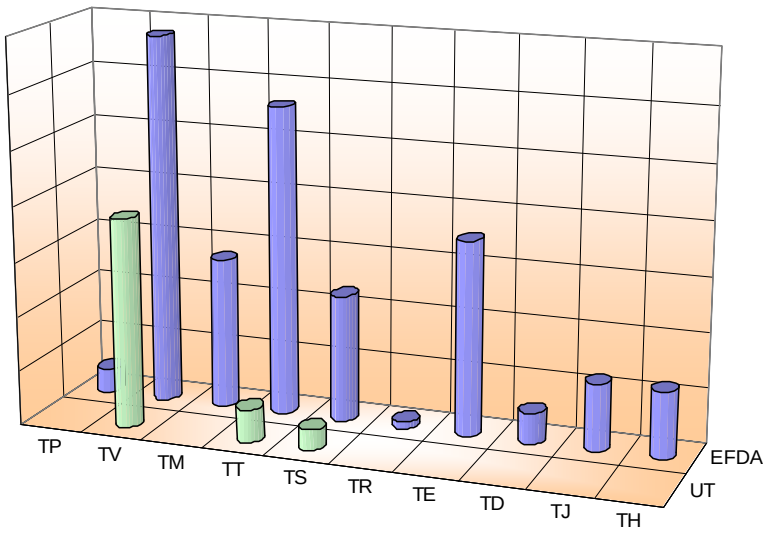
- "***Safety and Environment***" studies realized by Euratom-CEA cover different parts of this topic such as investigation on possible concrete detritition methods, cryogenic experiment on the CEA EVITA facility (in the case of an accidental sequence of coolant ingress into the cryostat), code development and validation : on safety studies on hydrogen mitigation and dust explosion in the vaccum vessel or on prediction of activated corrosion products activities : PACTITER Code, for which validation efforts have been carried on.

- Activities in the field "***System studies***" are dedicated to the Power Plant Conceptual Studies (PPCS). In 2005, activities were dedicated to the reactor model AB, based on a Helium-Cooled Lithium-Lead (HCLL) blanket, especially on the subject of tritium control and management analysis, and on comparison of concepts from the point of view of segmentation and maintenance.

- Activities carried out in the Field "***JET technology***" are devoted to the study of different processes which can be used for tritium removal from carbon materials (a strong effort has been made on a program of laser detritiation associated to remote handling), "Housekeeping" materials, vacuum oil and organic liquids. 2005 activities have also been devoted to the plasma facing component thermo-mechanical modelling, and to the JET diagnostics and divertor enhancement.

Three 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 Material Sciences Division (DSM), which includes the Controlled Fusion Research Department (DRFC) operating Tore Supra and responsible for plasma physics, cryoplant and magnet and plasma facing component activities.



TP : Physics
TV : Vessel/In-Vessel
TM : Magnets
TT : Tritium Breeding and Materials
TS : Safety and Environment
TR : System studies
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

Figure 1 : breakdown of the work carried out by Field

The Euratom-CEA programme in Technology is also completed by specific R&D collaborations with industry in the fields of safety (Technicatome) and with the French National Centre for Scientific Research (CNRS) in the Plasma Facing Component 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 this domain. 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 improve the vision of an electricity producing reactor and will increase the credibility of fusion energy as a genuine energy 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