CEFDA03-1098

Task Title: TW3-TDS-MAG: DETAILED ENGINEERING AND MANUFACTURING STUDIES OF THE ITER MAGNET SYSTEM: POLOIDAL FIELD (PF) COIL WINDINGS AND COLD TEST ASSESSMENT

INTRODUCTION

The purpose of this task, started in 2004, is to review the engineering design of critical areas, assess the manufacturing procedures and techniques, layout of the manufacturing facilities and test options, review the fabrication schedule for the production of the ITER coils and their support structures. In particular, the subject of this study contract refers to:

1) Engineering and manufacturing studies of the Poloidal Field (PF) coil winding packs ;

2) Assessment of the cold test options for the Toroidal Field (TF) coils.

CEA is requested to perform this work with industrial participation to assist EFDA and the ITER International Team in the review of some of the critical features of the design, study the manufacturing procedures and tooling required for winding and impregnation of the PF coils, establish the detailed layout of the manufacturing facilities and schedule, and make an assessment of the need for cold testing of the TF coils.
In order to get industrial support for the engineering and manufacturing studies of the PF coils, CEA has placed a contract with the Alstom company in Belfort (France).
The assessment of the cold test options for the TF coils involves participation of the DAPNIA department at CEA-Saclay and of the DRFMC department at CEA-Grenoble, and is carried out in close cooperation with FZK at Karlsruhe (Germany).

2005 ACTIVITIES

DETAILED ENGINEERING STUDIES OF PF WINDINGS

Following the delivery of the draft report by the Alstom company in december 2004, CEA made comments and Alstom delivered a final report in march 2005 [1].

Outline design of the manufacturing line

Alstom studied the possibility to implement a manufacturing line inside the cryogenic buildings. The layout of the buildings showed that an implementation of the different working stations was possible as shown in figure 1. Some areas are available for storage of components or sub-assemblies manufacturing and if needed for handling purposes of the double pancakes.

The design also takes into account surfaces for:

- loading-unloading, which has to be under the crane and isolated from the rest of the building by a wall to prevent from turbulences (when door is open), which could affect the dimensional measurements of the coil.

- warehouse (stock)

- areas for professional support (foremen, quality control, logistics, technical office, …)

- meeting rooms

- social premises (sanitary blocks, locker rooms, eating rooms, …), which are legally required

These areas are located outside the buildings, along one of the long sides, to avoid handling of the double pancakes over them.
The areas dedicated to impregnation shall be separated by a partition wall, in order to be thermally insulated from the rest of the building. For this reason, impregnation stations for double pancakes and for final impregnation are located close to each other.
The assembly and winding-pack impregnation station are put at one end of the building, in order to allow moving out the coils without the need of a heavy crane.
The lifting capacity of the cranes shall be such to avoid handling the double pancakes with their toolings.

A particular attention has been given to temperature control. The area where it should be the narrowest is the winding area, the winding table being manufactured using black steel whereas the conductor jacket will be made of stainless steel. It is proposed to control the temperature in the range ± 5°C, which should allow to limit the error on the largest diameter (24 m for PF3) within ± 0.3 mm. Another possibility would be to manufacture the winding table with stainless steel to avoid temperature control inside the buildings. The proposals are the following:

- no direct sunshine, neither on coils nor winding equipments

- control of temperature at 20°C ± 5°C in the winding areas

- no temperature control in the other areas

- impregnation and curing separated from the rest of the building

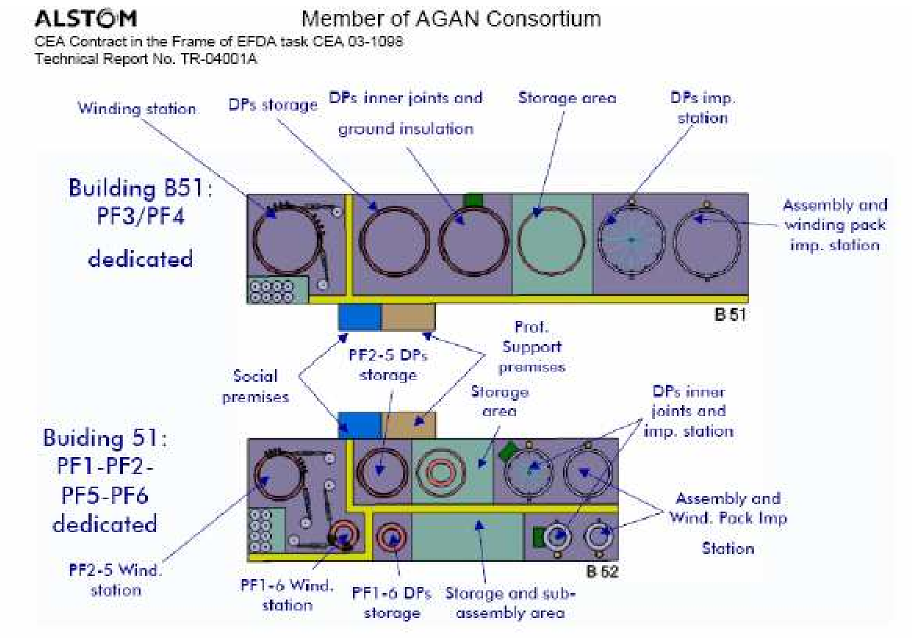

Figure 1: Implementation of the PF coil manufacturing line inside the cryogenics buildings

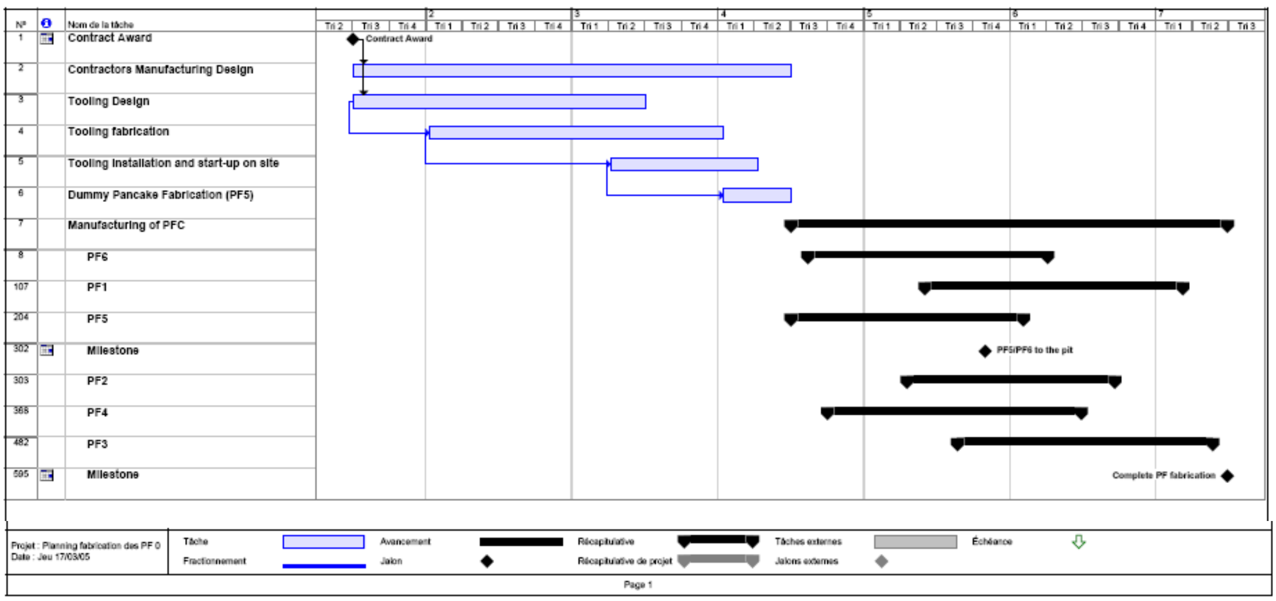

Figure 2: Time schedule for manufacture of the PF coils

Time schedule

A time schedule was built, assuming work in two shifts, 5 days per week. The following hypotheses were taken into account:

- winding speed: 3 m/h for each of the two conductors wound in parallel
- learning curve: longer time for each first two operations than for the following
- start manufacture of a dummy double pancake on the first manufacturing line
- manufacture then the first double pancake on the first manufacturing line
- start manufacture of the first double pancake of a second coil on the second manufacturing line once the first double pancake of the first coil is completed
- start manufacture of the first double pancake of a third coil once the first double pancake of the second coil is completed.

The proposed manufacturing sequence is the following:

- start manufacture of PF5
- manufacture in parallel PF6
- manufacture PF4
- manufacture PF2
- manufacture PF1
- manufacture PF3.

The corresponding time schedule (figure 2) fits within 42 months, including manufacture of a dummy double pancake, which was requested to meet the ITER schedule.

ASSESSMENT OF COLD TEST OPTIONS FOR TF COILS

This work has been reported in an oral presentation at Magnet Technology Conference (MT19) in Genoa [2].

Test objectives

The main aim of cold tests is the reception of the coils before their assembly to form the TF magnet. An extensive set of controls will be performed at different steps of the manufacturing process to check the quality of the manufacture. Nevertheless, the finally achieved properties of the coils can only be derived from tests performed in conditions relevant to operation at 4.5 K. A failure of a coil during operation would cause a major breakdown in the experimental programme and lead to costly repair resulting from a complicated disassembly and reassembly process. It is therefore of prime importance to carefully check all the properties which can be addressed in a component test. The main items to check are:

- the leak tightness of the He circuits
- the electrical insulation of the coils
- the electrical resistance of joints.

Other items are secondary goals of the cold tests:

- electrical properties of the conductor
- mechanical behaviour of the coil
- hydraulic resistance of the conductor
- thermal behaviour of the coil
- instrumentation behaviour
- operation of safety system

Test configuration

Two options can be considered: the test of each coil separately or the tests of coils by pairs. Except the prototype, which should be tested alone, the advantage of testing coils by pair is that it allows time saving on the overall tests and investigation of mechanical behaviour in out-of-plane loading. It is paid by the need of a slightly larger cryostat and of an additional current lead to allow separate coil charging. When testing coils by pair they would be connected adjacent to each other as assembled in the torus.

Testing sequence

A detailed testing sequence has been established in both considered cases: tests of single coils or tests of pairs of coils. The times needed to perform the tests are respectively 58 days for a single coil, 77 days for two coils and less than 3 years for all coils. It is then possible to test all TF coils within 3 years (figure 3).

Testing programme

For each test of a pair of coils, the following tests would be performed:

- room temperature checks (leak checks, high voltage tests, Paschen minimum)
- cooldown
- tests of both coils without current (leak checks, high voltage tests, hydraulic resistance)
- tests of the first coil with current (joint resistance measurements, thermal behaviour, safety system operation, critical properties, mechanical behaviour)
- tests of the second coil with current
- tests of both coils with current (mechanical behaviour)
- warm-up
- final checks at room temperature.

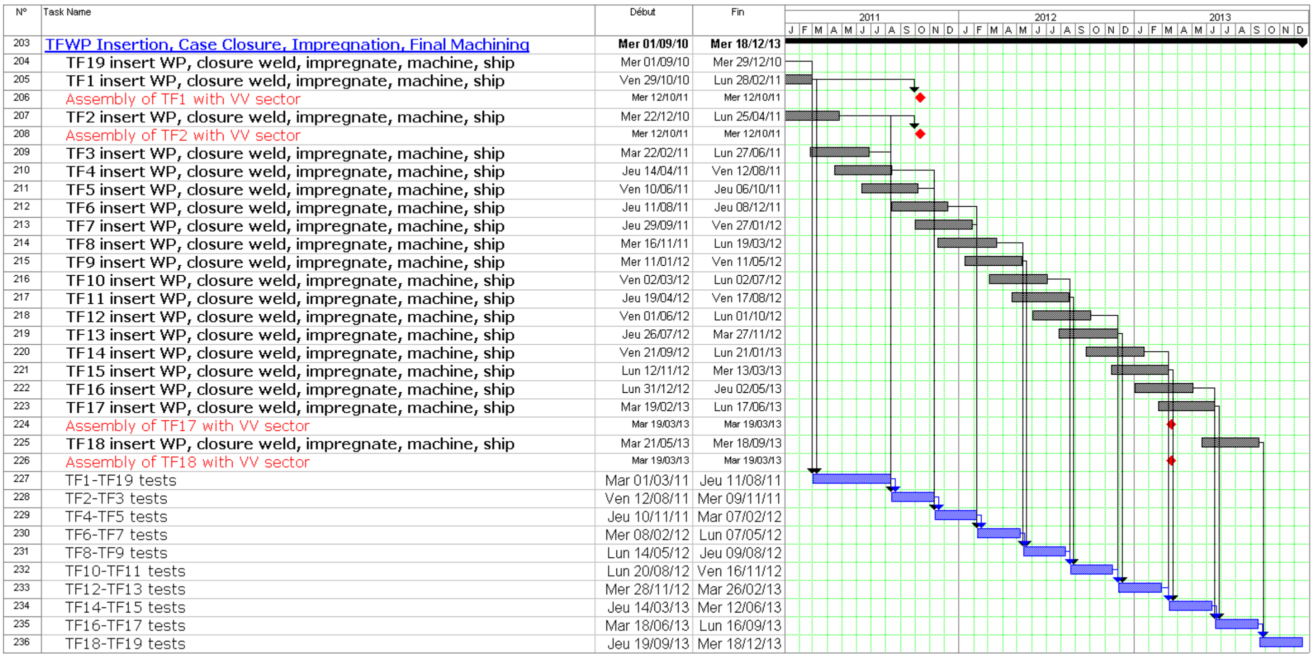

Figure 3: TF coil testing sequence

Outline design of a test facility

An outline design of the test facility has been sketched (figure 4) so as to evaluate the space required and the overall cost. The main components are detailed hereafter.

Cryostat

Housing two TF coils requires a large cryostat. In order to ease the handling of the assembled coils, the proposed design, derived from that of other large existing vessels in Europe, is a parallelepipedic cryostat with a sliding door. This allows installation of the coils on the supporting frame to be performed in an area close to the cryostat and translation of the two-coil assembly into the cryostat by sliding on rails. Easy accessibility to the coils is so provided for the major part of the test preparation and only the final connections to the electrical, hydraulic and instrumentation circuits have to be performed inside the cryostat. No vertical movement is necessary, which simplifies the handling equipment. To meet the working regulations, a maximum magnetic field of 50 mT should be reached in the personal working area, which calls for providing enough distance between the cryostat and the working area so as to limit the need for shielding.

Power supply and dump resistance

Operation at nominal current (68 kA) requires a bipolar 70 kA, ± 15 V power supply with a switching unit similar to the fast discharge unit developed for the ITER magnets operation. Discharge in 11 s is achieved by a dump resistor of 32 mΩ in a single coil test and 88 mΩ in a two-coil test at half current.

Cryogenic refrigerator

A supercritical He cooling circuit will be used for circulating the high mass flow rate with cold circulation pumps. Separate loops are planned for winding and case of the TF coil. A 3 kW (1.6 kW for single coil) refrigerator is needed.

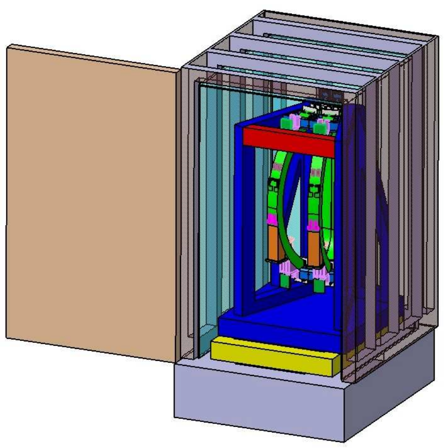

Figure 4: TF coil cold test facility

Construction and cost

Starting in 2008, the construction would be completed in 2010. An estimation of the total construction cost of the test facility gives a capital cost about 25 M€. Operating costs are in the range of 22 M€ for testing all TF coils.

CONCLUSIONS

The engineering study of the PF coils has been completed and Alstom has delivered their final report. An implementation of the manufacturing line inside the cryogenics buildings has been proposed and a time schedule established, which fits with the ITER requirements.

A test of all TF coils by pairs at 4 K has been proposed and a testing sequence established. The test of all coils could be performed within 3 years and fit with the ITER time schedule.

The work carried out in the framework of the task is completed.

REFERENCES

[1] Report on Detailed Engineering studies of PF windings, Task CEA 03-1098, Subtask MAGCEA1, ALSTOM Magnets and Superconductors, TR-041001A, 17/03/05

[2] P. Libeyre et al., Proposals for Cold Testing of the ITER TF coils, Magnet Technology Conference 19, Genoa, 18, 23/09/05

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Task Title: TW5-TDS-QA: EFDA QUALITY ASSURANCE SYSTEM FOR ITER RELEVANT ACTIVITIES

INTRODUCTION

The objective of the 2005 activity is to issue documents describing EFDA Quality Assurance System in order to allow EFDA to act as an ITER project main contractor with respect to French Nuclear Regulation.

2005 ACTIVITIES

The mission of EFDA, with respect to ITER, is to implement all the technical and scientific activities that are part of the European contribution to the design and construction of ITER reactor. This mission can be subdivided as follows:

- Responding to the direct specific requests of ITER, by providing products and services according to ITER specifications. This mission is formalized through ITER task agreements. The specification of such activities is agreed with ITER and the outcome of the activities is transmitted, reviewed and approved by ITER.

- Performing background activities, of general and strategic nature, that enable EFDA to be timely ready for the specific requests of ITER. The specification of these activities is developed internally by EFDA and approved by the EFDA Associate Leader for Technology (EALT). These activities are periodically reviewed with ITER. The outcome of the activities is approved by the EALT and documented and access to the relevant information is granted to ITER in the forms agreed.

In regards with the French Nuclear Regulation, EFDA will act as one of the main suppliers of ITER. The objective of the quality management system developed for EFDA is to ensure ITER that the delivered items fulfil the ITER requirements in the agreed time, by:

- Controlling the EFDA internal activities

- Controlling the supplier's activities.

The control of the EFDA internal activities is made through a set of quality documents based on IAEA Safety series 50-C/SG-Q and compatible with ISO 9001 (2000). A quality manual describes the quality policy and objectives of the EFDA in regards with its mission. Dedicated documents describe the provisions to implement in order to fulfil the IAEA Safety series 50-C/SG-Q:

- Organization and responsibilities. This document describes the organizational structure, functional responsibilities, levels of authority and interfaces for

- managing, performing and assessing the work related to ITER.

- Information, documents and records control. This document describes the rules for identification, preparation, verification, registration, release, archiving, review and approval of documents and records related to ITER.

- Non-conformances Management, corrective and preventive actions. This document describes the provisions for the management of the non-conformance control system.

- Resources management. This document describes the provisions implemented by EFDA to ensure to ensure a proper agreement between the work to be performed and the associated resources (both human and material).

- Audit and control. This documents describes the process to evaluate and improve the EFDA Quality Management System.

- Configuration management and change control. This document describes the provisions implemented to ensure that the outputs of design activities managed by EFDA related to the ITER project are properly controlled.

- Procurement management. This document describes the provisions implemented to ensure that items or services procured by EFDA in support or on behalf of the ITER project are properly controlled so as to ensure they meet established requirements and perform as specified.

The control of the activities of EFDA suppliers is made through three contractual documents dedicated and tailored for each contract placed by EFDA to European industry or laboratories.

- The technical specification defines the object of the contract (the « as specified » configuration of the product)

- The management specification defines the quality requirements to be met by the supplier.

- The contract defines the commercial and legal requirements and provisions that are applicable

These documents are issued by EFDA, reviewed and approved by ITER. They are tailored according to ITER requirements including quality classification.

In order to help European laboratories and industries to develop their own quality management system, some guidance notes have established according to the nature of the work to be performed.

- Quality management in Design contracts
- Quality management in R and D contracts
- Quality management in Manufacture contracts
- Quality management in Integration contracts
- Quality management in Test and Acceptance contracts
- Quality management in Construction contracts

These notes explain the quality provisions to implement in order to bid for ITER.

CONCLUSIONS

The documents were sent to EFDA for approval at the end of november 2005. Minor comments and corrections will be included before April 2006 in order to close the contract.

REPORTS AND PUBLICATIONS

Document Title	Reference
Quality Manual	EFDA/QA 001
Organization and Responsibilities	EFDA/QA 002
Resources Management	EFDA/QA 003
Internal Control and Audit	EFDA/QA 004
Information, documents and records control	EFDA/QA 005
Configuration Management and Change Control	EFDA/QA 006
Procurement management	EFDA/QA 007
Non Conformance management, Preventive and Corrective Actions	EFDA/QA 008
Quality Management in R&D Contracts	EFDA/QA 101
Quality Management in Design Contracts	EFDA/QA 102
Quality Management in Manufacture Contracts	EFDA/QA 103
Quality Management in Integration Contracts	EFDA/QA 104
Quality Management in Tests and Acceptance Contracts	EFDA/QA 105
Quality Management in Construction Contracts	EFDA/QA 106

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