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# Requirements for qualification of manufacture of the ITER Central Solenoid and Correction Coils

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## HIGHLIGHTS

- A manufacturing line is installed for the ITER Correction Coils.
- A manufacturing line is under installation for the ITER Central Solenoid.
- Qualification of the manufacturing procedures has started for both manufacturing lines and acceptance criteria set.
- Winding procedure of Correction Coils is qualified.

## ARTICLE INFO

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## ABSTRACT

The manufacturing line of the ITER Correction Coils (CC) at ASIPP in Hefei (China) was completed in 2013 and the manufacturing line of the ITER Central Solenoid (CS) modules is under installation at General Atomic premises in Poway (USA). In both cases, before starting production of the first coils, qualification of the manufacturing procedures is achieved by the construction of a set of mock-ups and prototypes to demonstrate that design requirements defined by the ITER Organization are effectively met. For each qualification item, the corresponding mock-ups are presented with the tests to be performed and the related acceptance criteria. The first qualification results are discussed.



## 1. Introduction

The design of the ITER magnet system [1] includes a 4.1 m Ø, 13.2 m high Central Solenoid (CS) made of 6 coils [2], a set of 18 Toroidal Field (TF) coils, a set of 6 Poloidal Field (PF) coils and 3 sets of 6 Correction Coils (CC) each [3]. The CC, distributed symmetrically around the tokamak and inserted between the TF and the PF coils, are respectively the 2.6 m × 7 m Bottom Correction Coils (BCC), the 6.8 m × 7.2 m Side Correction Coils (SCC) and the 2.6 m × 7 m Top Correction Coils (TCC). All coils are superconducting using cable-in-conduit conductors but they do not use the same superconductor. Whereas the CS uses a superconducting 45 kA $Nb_3Sn$ conductor, operating up to 13 T, the CC use a 10 kA NbTi operating up to 5 T. Following the award of contracts by the respective domestic agency the selected suppliers have installed dedicated manufacturing lines at their premises. The CS manufacturing line (Fig. 1) is under installation at General Atomic (GA) in Poway (USA) [4]. The installation of the CC manufacturing line (Fig. 2) has been completed in 2013 at ASIPP in Hefei (China) [5]. Before starting the production of the

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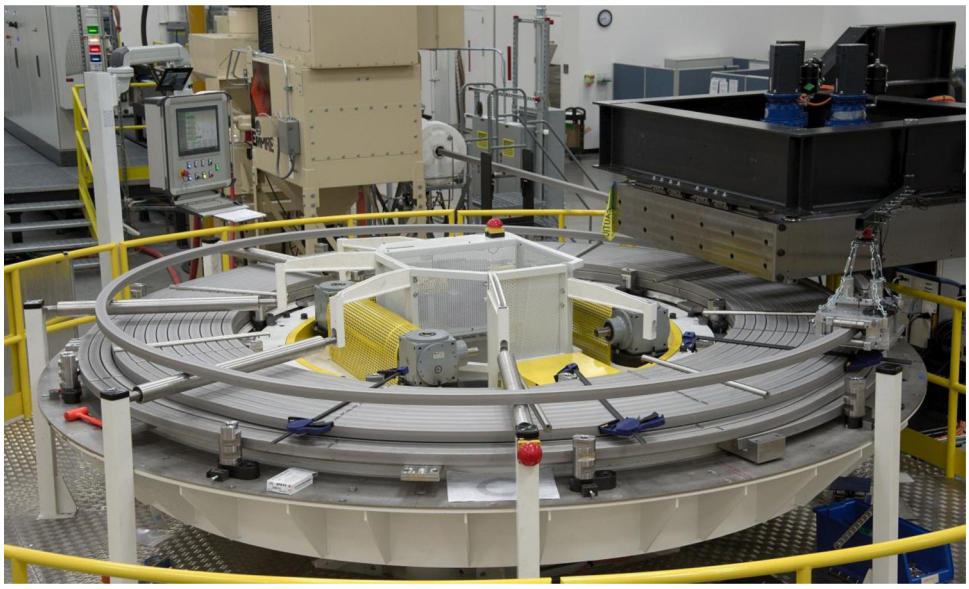

**Fig. 1.** ITER CS winding line at GA (Poway, USA).

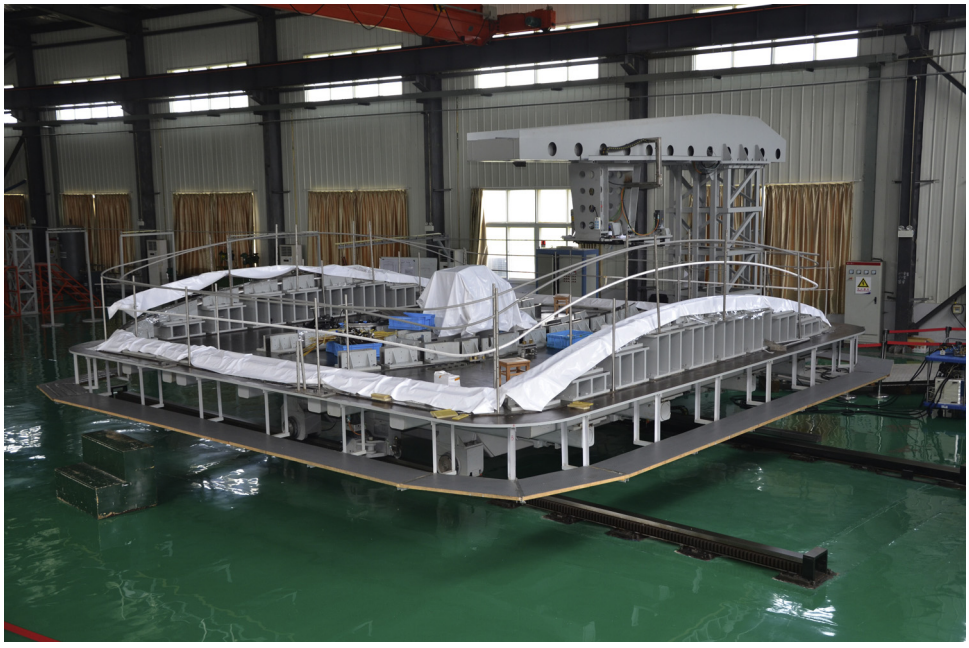

**Fig. 2.** ITER CC winding line at ASIPP (Hefei, China).

real coils, it is of prime importance that the manufacturing processes are fully qualified. This is achieved by the production of prototypes to be tested. This paper concentrates on the qualification of CS and CC manufacturing processes, describing the requirements, the different mock-ups and prototypes, the tests to be performed and the acceptance criteria. The first results are presented and discussed.

## 2. Coil manufacturing procedure

### 2.1. CS manufacture

As the maximum length of one unit of conductor is 920 m, it is not possible to wind one CS module with a single conductor length. Each CS module is made of six hexapancakes and one quadpancake, connected with each other by interpancake joints. As the conductor uses $Nb_3Sn$ superconducting strands, a reaction heat treatment at 650 °C has to be performed according to supplier schedule. The selected process is the wind and react route, which implies installation of the electrical insulation after the heat treatment. Glass-polyimide tapes wrapped around the conductor and impregnated with epoxy resin are used for the turn insulation. The ground insulation includes a set of interleaved sheets of polyimide and glass cloth. Impregnation and curing of the whole module insulation (turn, pancake and ground) are achieved in a single step. The six modules are stacked upon each other at the ITER site, keyed by a set of insulated pins, and assembled with its stainless steel structure made of nine independent subsets of tie-plates connected to keyblocks to form the complete CS. The structure is tightened in order to apply a vertical precompression preventing relative

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