ITER Core Machine Assembly Progress

Abstract

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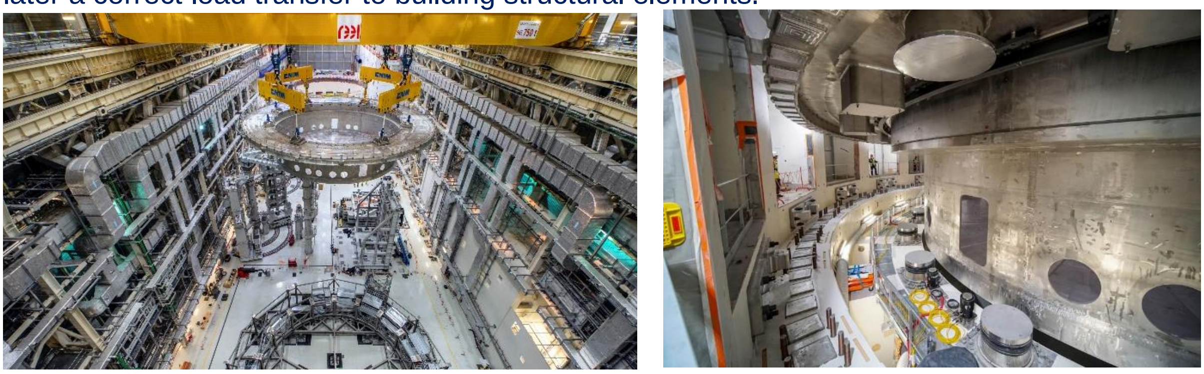
The ITER Tokamak, under construction in Cadarache, Southern France, is a “first of a kind” project and the largest Fusion project at present in the world. Already by the size and the weight of its components, the assembly of this machine is a challenging task.

To achieve the predicted plasma inside the torus through precise magnetic fields, and to accomplish proper distribution of heat loads, all components and systems must be positioned in a very accurate manner with gaps well below normal practical requirements for this size of machines. For that reason, special tools for manipulating and handling of related components were developed. Their performance was proven while performance of first assembling activities. Further to space constraints, multiple internal interfaces, high vacuum standards, and foreign materials exclusion must be respected.

As an example, one of the heaviest single component lifts of the machine assembly program was conducted already four years ago in 2020. The Cryostat base with its approximately 30 m diameter and about 1200 tons weight was located by 2x 750 tons gantry cranes in tandem mode with less than 2.2 mm (x/z directions- positioning tolerance).
Comparable to a space docking stations, for the last final steps before landing, a special engineered and custom-made jacking systems was developed to reach the required position.
The whole lift duration was accompanied by high precision, laser tracker-based metrology and reverse engineering allowing to pass through critical gaps between components with sometimes less than 10 mm.
3D measurements and reverse engineering were used as well for the customization of supporting shims underneath the Cryostat base. It was expected to achieve tight machining tolerances in the range of tens of millimetres between supports and Cryostat base to ensure later a correct load transfer to building structural elements.



Figures 1, 2: Cryostat base while lifting into its final position in the Tokamak pit

In the meantime, many more components were lifted. Most of them arrive in horizontal direction into the assembly hall. Only the move to bring them into an upright position enables further installation activities. That is why, occasionally, floating loads of well above 400 tons could be looked at while up-ending heavy components (figure 3).

Current major steps from assembly point of view are the Vacuum Vessel module preparation. The torus to be built will consist of nine such modules. They are pre-installed in a so-called Sector Sub-Assembly Tool (SSAT) where the vessel segments will be equipped with other components such as the Thermal Shield (TS) and two Toroidal Field (TF) coils, each. The SSAT has on the ground curved rails allowing the rotation of two side arms on which the components are pre-installed (figure 4). While rotating the arms, the TS and the TF coils will be pulled over the vacuum vessel segments. This represents not a new invention, but it is used the first time to perform assembly work in such dimensions within high accuracy.

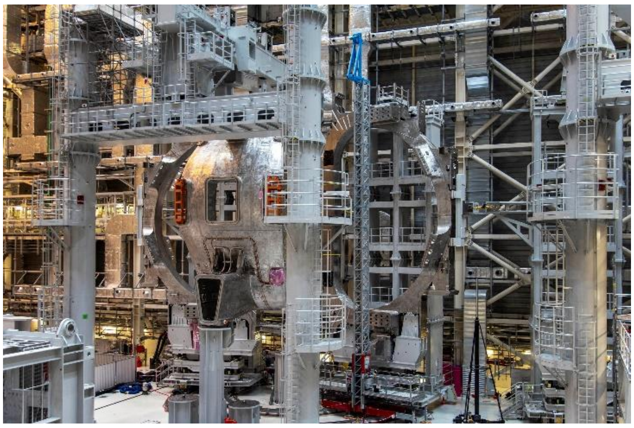



Figure 3, 4: Upending Tool to bring the Vacuum Sector into an upright position & Sector Sub-Assembly Tool with Vacuum Vessel in middle position and Toridal Field coils on rotating arms

Once these modules are sub-assembled, they will be brought, as the Cryostat base before, to their destination in the pit. Flying acrobats, another example of this specific assembly works, called also rope workers, coming into the scene, to engage certain pin connections and lifting accessories between the different lifting devices. These workers are well trained to reach every location where access is normally very limited.

To plan all these activities, a high level of coordination and supervision is needed. The ITER core machine assembly is a joint effort of many partners starting from technical specifications written by IO engineers, transversal work site coordination & supervision by IO and its external supporting partner CMA (Construction Management as Agent) and execution of work in the field by installation contractors (Consortium CNPE-C). Only when all involved entities know what to do at what time and the assembly goals are well-synchronized, the work can be successfully managed in time.

Beside organizational aspects, further explanations on unique assembly solutions, such as the sector module assembly techniques, large-scale lifting and positioning practices as well as superconducting joint installations will be presented in this paper.