EUROPE'S CUTTING-EDGE HANDLING SYSTEMS FOR THE ITER ASSEMBLY IN THE PRE-START OF RESEARCH OPERATIONS PHASE

[1]E. RUIZ MORALES, [2]M. BATTAGLIA, [2]E. BRAU, [2]C.-H. CHOI, [1]C. DAMIANI, [1]C. DREMEL, [1]G. DUBUS, [2] A. ENCHEVA, [2]D. HAMILTON, [2]R. HERY, [1]D. LOCKE, [2]J. PALMER, [2]A. SAXENA, [1]C. VAN HILLE, [1]E. VIZIO

[1]Fusion for Energy, Barcelona, Spain
[2] ITER Organization, St. Paul-lez-Durance Cedex, France

Email: emilio.ruiz@f4e.europa.eu

Fusion for Energy (F4E), the European Domestic Agency for the ITER project, is responsible for providing specialized innovative handling machinery to perform assembly tasks during the project's 'Pre-Start of Research Operations' (PRE-SRO) phase. This synopsis presents an overview of these relevant F4E's in-kind procurements and the extended version gives a detailed description of their functional tasks, key aspects of their design and the novel technologies used.

Once the ITER Vacuum Vessel (VV) sectors welding is completed around mid-2030, a 27-month phase will focus on installing in-vessel cables and coils, the blanket system, and divertor cassettes, followed by port plugs and finally cryostat closure in early 2033. Divertor cassettes, blanket modules, and temporary first wall modules are heavy components, each weighing several tons. Their installation necessitates millimetric precision in confined and challenging orientations. For that purpose, three specialized machines will be operated during the final 11 months of assembling for these in-vessel components: the Divertor Assembly Transporter (DAT) delivered by Europe, the In-Vessel Tower Crane, and the Blanket Assembly Transporter (BAT) provided by ITER Organization.

Europe's DAT system includes the radial mover, toroidal movers, and a transport platform to install 54 10-ton divertor cassettes and 3 diagnostic racks through 3 VV ports. It is designed as a simplified version of the nuclear-grade Divertor Remote Handling System (DRHS) [1] – meant to operate during the ITER nuclear phase - with local operator controls. The Radial Mover (RM) transfers cassettes from the transport platform in the port-cell to the VV. It has two specific end-effectors for the different cassette types and another for diagnostic racks. The RM moves the cassette through the port duct along a complex non-straight path, avoiding clashes with duct walls, ceiling and floor using hydraulic and electric motion. Two Toroidal Movers (TM) will install cassettes in their VV location, with one TM designated for cassettes on the right-hand side of the VV port and another for the left side. The two TMs are designed to operate simultaneously to adhere to the 5-month cassette installation schedule. The TMs use water hydraulic actuators to lift cassettes and position them toroidally through a roller-driven system on toroidal rails. Both the TM and RM are compact machines using VTT's innovative digital-valve hydraulic technology and the F4E GENROBOT control system platform with a set of sophisticated operator interfaces offering advanced functionalities for safe and efficient remote and local operations. The DAT is scheduled for delivery to ITER in early 2030. It is presently under preliminary design, with the final design and manufacturing phases scheduled to commence in early 2026. Once delivered at ITER site, it will undergo rehearsals at a test facility to prepare for its deployment in assembly operations.

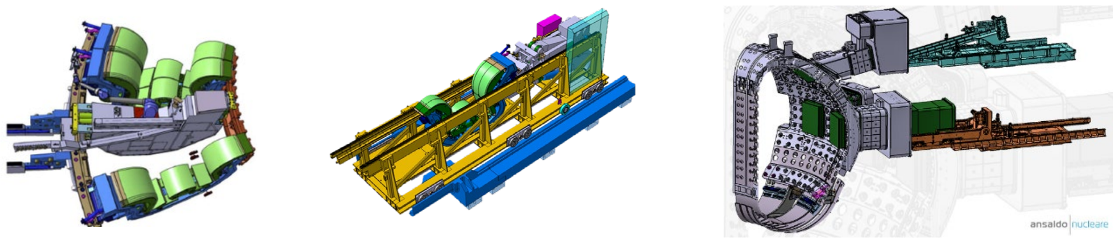

Fig.1: From left to right: The DAT Toroidal Mover, the DAT Radial Mover handling a cassette on the transport platform, The UPP and EPP assembly platforms to the VV

As part of the in-vessel ITER assembly, F4E is also developing systems for the handling and transportation of Equatorial Port Plugs (EPP) and Upper Port Plugs (UPP) that weigh up to 48 tons, utilizing a simplified version of the nuclear-grade Cask & Plug Remote Handling System (CPRHS) [1]. The final design of these systems with reduced functionality was completed in 2024. Currently, three devices—EPP handling, UPP handling, and a single transportation system—are in the manufacturing phase and are scheduled for delivery to ITER in 2026.

It is important to note that the subset of functions performed by the DAT and UPP/EPPs platforms will be validated during assembly. This critical experience will reduce risk and inform the final design of the fully specified and nuclear-grade CPRHS and DRHS. Furthermore, for first assembly, the F4E's In-Vessel Viewing System (IVVS) will be delivered in 2031 as a component (but not as an assembly system) and installed using a dedicated assembly handling and transport system based on the UPP handling system design. The IVVS consists of six nuclear-grade, magnetic and vacuum-compatible units, each equipped with a laser scanning probe on a deployment arm to detect accurately first wall damages during plasma operations.

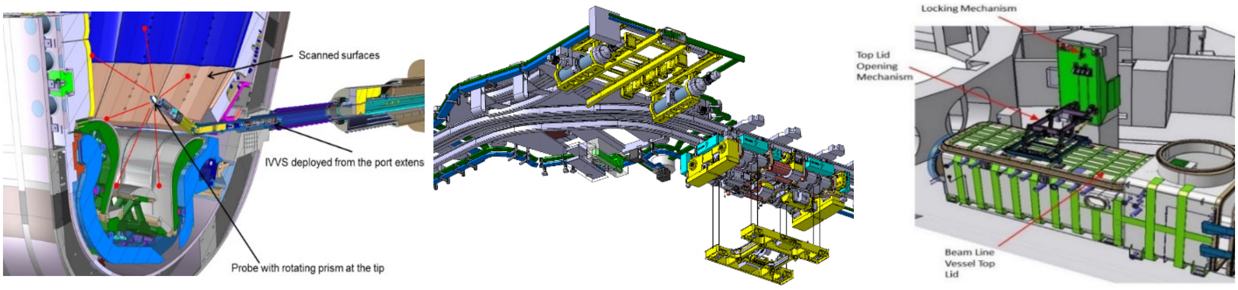

Fig. 2: From left to right: the In-Vessel Viewing System deployed in the Vacuum Vessel, the Crane Trolley approaching a switching point next to the installation hoist, the Top Lid Opening Mechanism docked on a Beam Line Vessel Top Lid

The Neutral Beam cell assembly is the ex-vessel part of the PRE-SRO ITER assembly phase where F4E is responsible for delivering and installing the nuclear-grade Maintenance Crane System (MCS) and the nuclear-grade Top Lid Opening Mechanisms (TLOM) of the Beam Line Vessels. The MCS is a compact crane with a 40-ton capacity, running at the ceiling of the Neutral Beam cell, intended for installing the main components located in the Neutral Beam Cell. It includes permanent parts like the railway, 8 switching points, penetrations, and an installation hoist, along with an installable crane trolley and over 10 lifting frames. The MCS is in the final design phase and the manufacturing contract is expected to be launched in 2026 for a staged delivery from 2029 to 2030. The TLOM provides opening and closing operations of the Top Lid of each Heating Neutral Beam Line Vessel (BLV) weighing 17.4 tons each and having large dimensions (9.6m[L] x 3.5m [W]). The TLOM is located at each side of the HNB vessels mounted to the NB cell building columns. It is under preliminary design and its final design and manufacturing contract is foreseen for 2026 with a delivery date of 2030.

In conclusion, F4E must provide a wide set of cutting-edge machinery with advanced designs and novel technologies to assemble and maintain large and heavy ITER components with millimetric precision. Apart from giving the opportunity to the involved industrial companies to develop products and competence in the fusion assembly and remote maintenance field, this first of a kind equipment may also serve as a standard for other large-scale fusion devices.

References

[1] C. DAMIANI et al, "Overview of the ITER remote maintenance design and of the development activities in Europe", Fusion Engineering and Design 136 (2018) 1117- 1124