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TECHNICAL NOTE

INTRODUCTION TO THE CASK AND PLUG REMOTE HANDLING SYSTEM (IN SUPPORT OF F4E-OMF-1609)

Abstract

Information is presented regarding the Cask and Plug Remote Handling System (CPRHS). This is a novel, remotely operated, electromechanical system designed to provide confinement and transportation of ITER in-vessel components and Remote Handling Systems within the Tokamak and Hot Cell facilities.

An overview of the Cask and Plug Remote Handling System, its various sub-systems , its Control System and related technology is provided.

The (radiation free) operating conditions specific to the ITER Machine Assembly phase is also described. These make possible the presence of operators and, with their assistance, the use of simplified versions of the CPRHS devices for initial installation of in-vessel components.

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1. Cask and Plug Remote Handling System

Due to neutron activation and radioactive contamination during operation of ITER, the maintenance of within its vacuum vessel will require the use of remotely operated equipment. To support this remote maintenance confinement and transportation of in-vessel components and associated Remote Handling Systems is required. This task will be performed by the Cask and Plug Remote Handling System (CPRHS).

The full-specification, nuclear grade, CPRHS is designed to facilitate the removal and reinstallation of the following in-vessel components during the active phase of ITER:

- Upper Port Plugs
- Equatorial Port Plugs
- Blanket First-Wall Panels and Shield blocks (by supporting the Blanket Remote Handling System)
- Divertor Cassettes (by supporting the Divertor Remote Handling System)
- Torus Cryopump
- In-vessel Viewing System

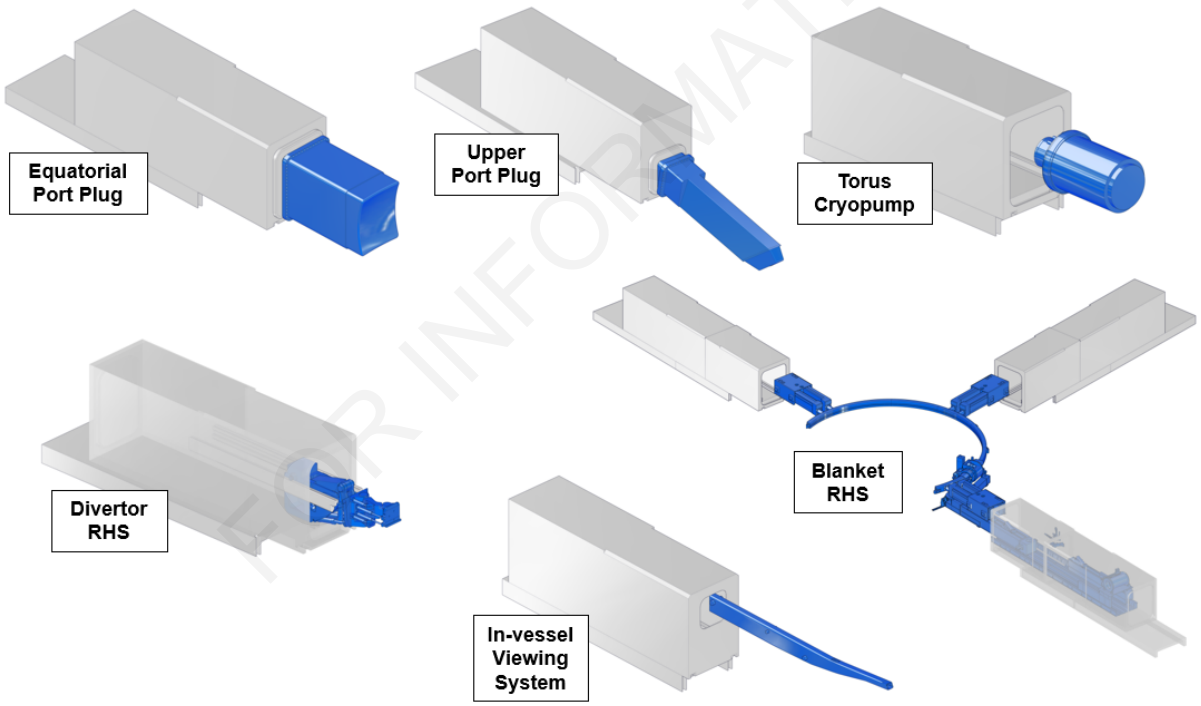

Figure 1: Range of CPRHS variants to support ITER in-vessel maintenance

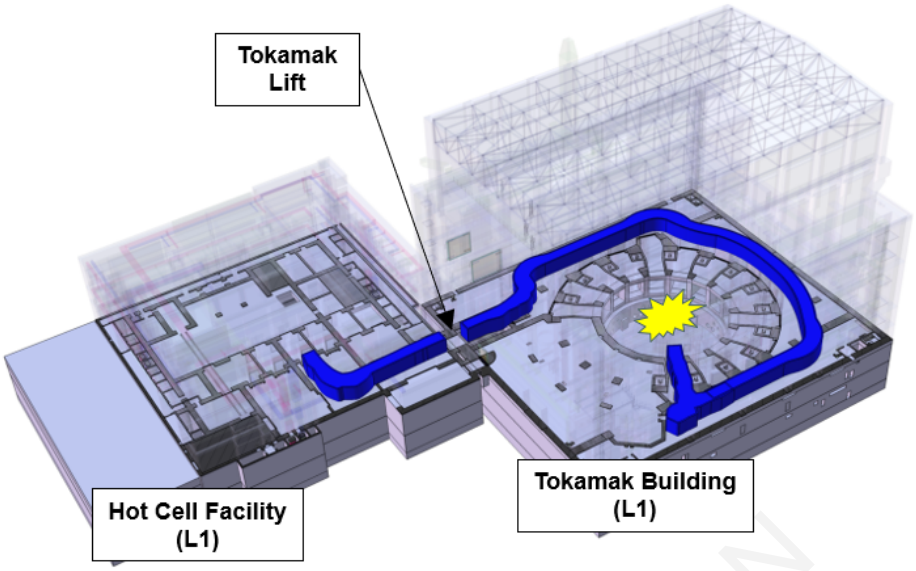

Figure 2: Example of CPRHS trajectory for transportation within the Tokamak and Hot Cell

Each variant of the CPRHS has four main sub-systems operated from an integrated Remote Handling Control System (RHCS):

- Cask Envelope System CES
- Cask Handling System CHS
- Cask Docking System CDS
- Cask Transport System CTS

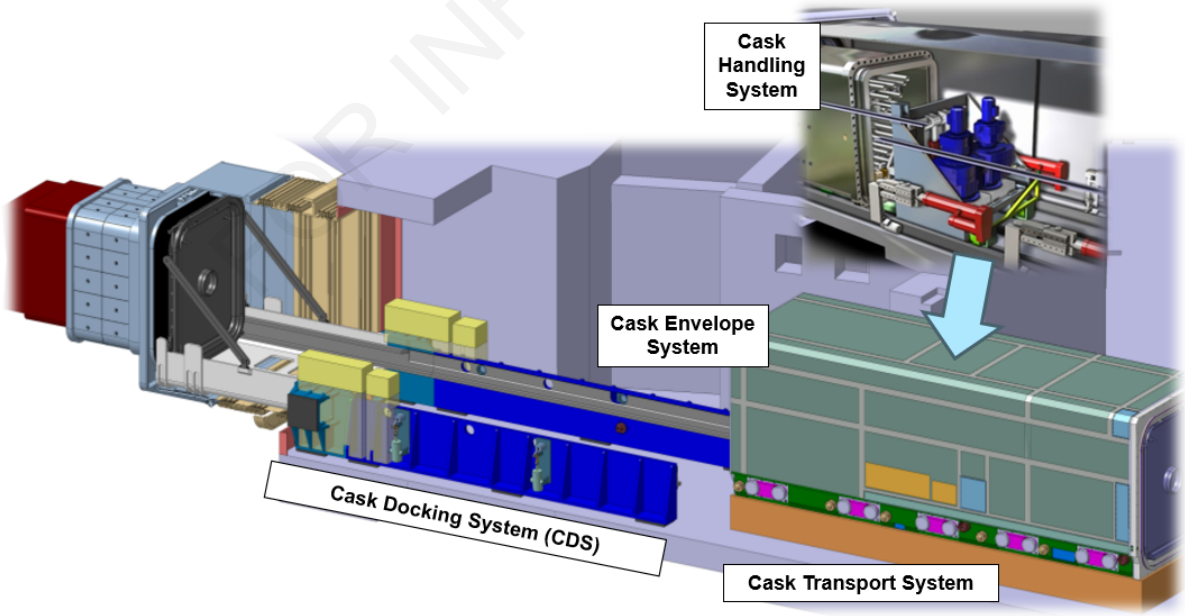

Figure 3: CPRHS main sub-systems within the Tokamak Port Cell

CPRHS operations are also supported with the additional sub-systems:

- Cask Storage System CSS
- Cask Rescue System CRS
- Cask Maintenance System CMS

2. Electromechanical sub-systems

2.1 Cask Envelope System (CES)

The CES provides the nuclear confinement and constraint of the in-vessel components during ITER maintenance. The CES is equipped with a double-door confinement system which allows docking of the Cask to the ITER controlled areas (at the Vacuum Vessel and Hot Cell).

Figure 4: Cask Envelope System & Double Door Mechanism

Each CES is comprised of:

- A nuclear confinement barrier
- Structural support for the in-cask Cask Handling System
- Remote Connector bulkhead – providing all power and signals for CES and CHS operations
- Interfaces with the Cask Docking System (during installation into the Tokamak Port Cells)
- Interfaces with the Cask Transport System (during transportation within the ITER buildings
- Associated I&C to, for example, support double-door operations and maintenance of internal depression

2.2 Cask Handling System (CHS)

The CHS, installed into the CES, ensures the in-vessel component is securely grasped and allows the in-vessel component to be withdrawn into the CES on its supporting rails.

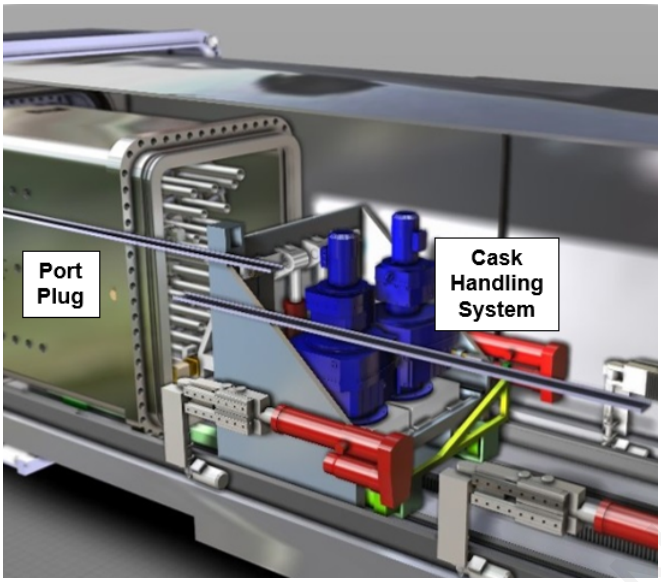

Figure 5: Cask Handling System (embedded into the CES)

Each CHS is comprised of:

- Port Plug gripping features
- Rails to connect to the Vacuum Vessel and support the Port Plug during CES transfer
- Associated I&C to support actuation of the CHS for installation and removal of Port Plugs

2.3 Cask Docking System (CDS)

The CDS consists of a set of rails permanently installed into the Tokamak Port Cells to support and guide the CES during its connection to the Vacuum Vessel during ITER maintenance. Thereafter it provides to the CES the required power and services required to operate the CES and CHS, via a remotely operated multi-connector, during in-vessel component removal and installation. In addition, the CDS supports the Port Cell Equipment which provides services to the Port Plug and Torus Cryopump during ITER plasma operations.

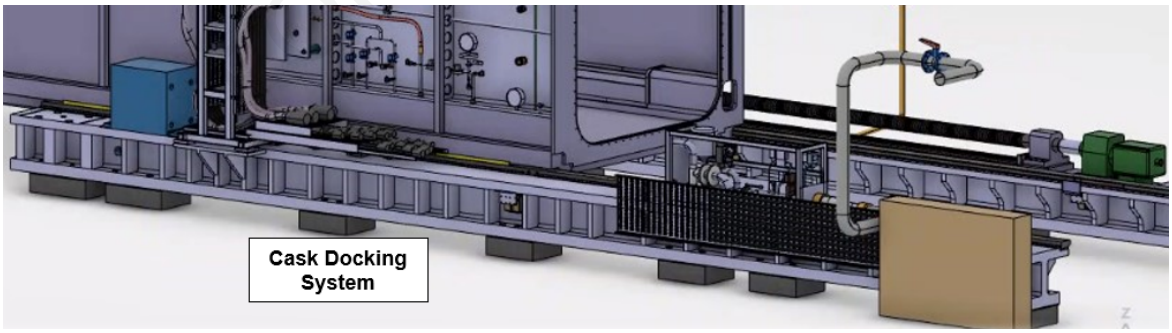

Figure 6: Cask Docking System (Permanent in the Port Cells)

Each CDS is comprised of:

- Structural rails to support the CES during maintenance and Port Cell Equipment during plasma operations
- Remote connector providing all power and services to the CES and CHS
- Connection of the Detritiation System and nitrogen supply for the CES during Port Cell operations

2.4 Cask Transport System (CTS)

The CTS provides the transportation and navigation of the CES between the Tokamak Port Cells and the Hot Cell maintenance areas. This is a semi-autonomous system with on-board navigation, drive, steering and braking to securely delivery the CES to its required location. This is performed within a trajectory accuracy of ±5mm. Communication is provided wirelessly to the RH Control System where man-in-the-loop operations are always maintained. The CTS has on-board power supply, therefore, requires no umbilical for its operational needs.

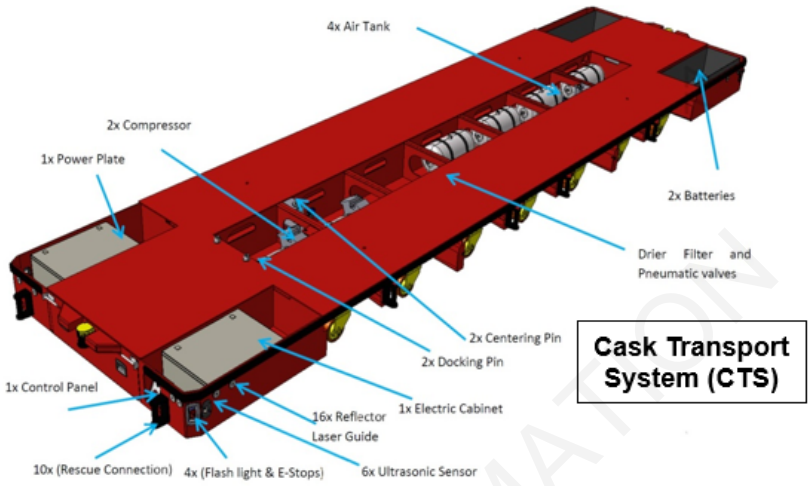

Figure 7: Cask Transport System (Supporting the CES)

Each CTS is comprised of:

- Structural support of the CES during transportation within the ITER buildings
- Navigation to maintain the define trajectory within the ITER buildings
- Drive, braking and steering units
- Wireless communication to the Remote Handling Control System
- On-board batteries for umbilical free operation

2.5 CPRHS for ITER Machine Assembly

Support is also being provided by the CPRHS project for the installation of in-vessel components during the machine assembly phase of ITER. Simplified devices, providing only the functionality required during machine assembly, are in production for the installation of the Equatorial and Upper Port Plugs (EPP & UPP respectively). For the Machine Assembly phase, as there is no nuclear contamination risk, these devices, which are simplified to the maximum extent possible, will provide first installation of the EPP and UPP. The CPRHS for the machine assembly phase currently comprises:

- Machine for support and installation of EPP
- Machine for support and installation of UPP
- Single CTS for the transportation of the above EPP and UPP

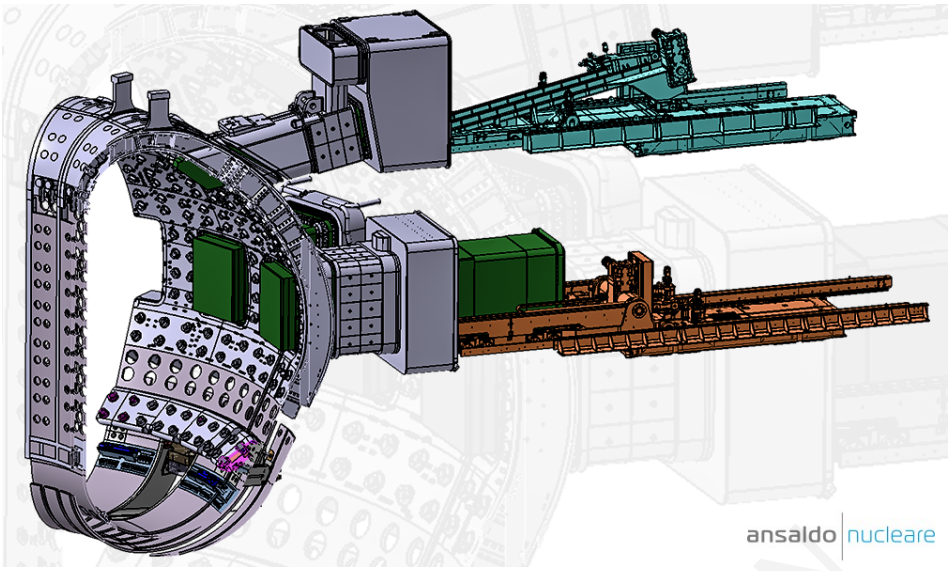

Figure 8: Simplified CPRHS for initial installation of EPP & UPP in production

Operating conditions will differ from those for the ITER Long-term maintenance periods as follows:

- Operator presence will be possible (where occupational health & safety is a factor)
- No radiation will be present
- Ambient temperature will be limited to approximately 30 °C.

The combined presence of both operators and machines during the ITER Machine Assembly phase will require that particular attention is paid to operator safety. Safety features, additional to those required for the final configuration for ITER remote maintenance, will be necessary to achieve compliance with the European Machinery Directive. In this regard CE marking of the Machine Assembly devices, including related hardware, control and safety systems, will be necessary.

Due to the additional requirements coming from the updated ITER Machine Assembly schedule there is, in addition to the simplified CPRHS devices defined in section 2.5, the need for additional devices of the CPRHS to support in the installation of in-vessel components during assembly phase. One requirement is for the CPRHS to support the Divertor Remote Handling System initially installing the Divertor Cassettes.

3. Remote Handling Control System

Each sub-system within the CPRHS, will be operated independently. However, all, with the exception of the devices for ITER machine assembly, will be operated and monitored via a common control system platform, named the CPRHS Remote Handling Control System (RHCS). The need for standardization and consistency across the different ITER Remote Handling (RH) systems, and the applicable regulatory criteria of the final installation, mandate the use of a control system, including software, developed specifically for the purpose. The RHCS architecture is as described below:

- The Low-Level Control System (LLCS), which comprises:
  - "GENROBOT" control software. This implements the generic RH controller functionalities, runs on an industrial computer and interfaces to HLCS applications and to cubicles components over EtherCAT. GENROBOT is highly configurable and

adaptable to any RH application.

- Cubicles, which include the controllers for the CPRHS sub-systems (i.e. control computers with dedicated "GENROBOT" control software)
- The potential for controllers for the BiSS-based multiplexing units for signals and actuators and controllers for the cameras.
- Cables for power and signals from cubicles to the RH devices complemented by connectors, feedthroughs and switching boxes.
- The LLCS includes the electrical system and instrumentation on board the movers.

➢ The High-Level Control System (HCLS) which provides the following set of operator interfaces:

- Command and Control (C&C). This is the primary operator Graphical User Interface (GUI) to remotely control and monitor RH devices. The C&C is interfaced to a Joystick for manually driven motion.
- Operation Management System (OMS). This is to manage, step by step, the operational sequence of RH tasks. OMS provides GUIs for building, executing and analysing RH tasks, and interfaces to the C&C issuing and monitoring operational steps.
- Remote Diagnostic System (RDS). This enables the remote monitoring of the equipment health status to detect degradation, anticipate and diagnose failures through diagnostics and condition monitoring algorithms.
- Virtual Reality (VR). This is to monitor, in real-time and in a 3D graphical environment with augmented reality, the RH equipment in operations. The VR enables the anticipated detection of collision and complements the Viewing System because of the reduced number of camera views in the RH environment.
- Viewing System (VS). This is to display camera views on the monitor displays of the RH work cell.
- The RH Emergency Stop buttons and remote I/O (E-Stop), configured by the ITER RH Supervisory Control System, to set RH devices in a safe state.

➢ The RH networks to connect HLCS applications to LLCS controllers using:

- RH Control and Diagnostic Network (RHCDN): implementing a DDS-based command-reply and data monitoring protocol for C&C, RDA, VR and RH controllers.
- RH Real-Time Network (RH-RTN): to establish a real-time connection between the MA and the MAM.
- Audio-Video Network (AVN): to transfer over IP camera video streams from cameras controllers to monitor displays.

It should be noted that the RH networks are outside the scope of the CPRHS.