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Recent developments on diagnostic integration in ITER

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Introduction

The dynamic nature of diagnostic allocation and integration into ITER to react to safety and operational rules, machine design updates, and diagnostic optimizations, requires a continuous engineering assessment of diagnostic systems' integration. The main drivers for modifications from previous arrangements [1] are i) the elimination of cryostat doors and consequently the replacement of the secondary vacuum boundary, ii) individual systems layout changes, iii) reallocation of Motional Stark Effect (MSE) and Charge Exchange Recombination Spectroscopy (CXRS) optical systems, and iv) integration of new systems (X-ray Spectroscopy Imaging). Integration of equatorial port #11 is presented as an example.

Diagnostic Integration

Diagnostic components are integrated at ITER ports occupying three main areas: the port plug, the interspace and the pit cell [2]. The port plug contains a shielding component at the front end, the "blanket module", intermediate cooled shielding blocks that carry diagnostic components, and a port plug flange which establishes the primary vacuum boundary at the back end (Fig. 1). The interspace area is often occupied by a geodesic frame that supports, or bridges in the pit cell, diagnostic components. The pit cell is an extension of the secondary control volume enveloping the interspace area (Fig. 1) and serves as an intermediate contamination (against Be dust dissemination) and safety (e.g. tritium and port plug cooling water leak) protection barrier between primary vacuum and building.

The direct-coupled diagnostics such as the Neutral Particle Analyzer (NPA), the X-ray Crystal and VUV Survey (XRC-S, VUV-S), and Divertor VUV (D-VUV) diagnostics require a direct vacuum connection to the plasma and extend it behind the port plug flange (primary vacuum boundary), crossing the interspace area up to the pit cell (Fig.1). It is expected that, during operation, Be dust will accumulate along the extended vacuum channels. Optical and some spectroscopy diagnostics such as MSE, CXRS and X-ray Crystal Imaging (XCS-I) respect the primary vacuum boundary by using an optical window at the port plug flange. The microwave diagnostics which make use of wave-guides that penetrate the secondary safety boundary (out of the pit cell) to access the diagnostic room, require provision for a valve at the primary vacuum window location for safety reasons. Although each diagnostic has its own set of requirements and specific component arrangement it is desirable to adopt a common strategy and standard tooling for diagnostic integration, maintenance and refurbishment.

At the port plug level: A modular approach was adopted for all port plugs by tailoring dedicated water-cooled stainless steal shielding modules that are inserted inside the port plug box-like structure. The shielding modules are provided with apertures and grooves where diagnostic components are implemented (Fig. 1). Front end mirrors (slightly oversized) are fixed in pre-shaped surfaces using a thermal mat to ensure good heat transfer to the shielding module. Alignment and image optimization is provided by the subsequent mirrors in the chain where the local environment (i.e. heating by direct radiation flux) is more sympathetic to precision motion components. Microwave antennas (conical shape) are inserted from the blanket module side and recessed from the first wall. A copper thermal mat is foreseen as the simplest effective way to cool such components, using the blanket as a heat sink. Pre-mounted interfaces at the port plug flange ensure the connection to the interspace diagnostic components. Valve/window arrangements with automatic coupling extensions are used to receive the interspace wave-guides extensions. For direct vacuum-coupled diagnostics, a valve/pipe-segment arrangement is also provided for each connection extension. The general rule is that shielding would be sufficient to allow hands-on-access at the port plug flange two weeks after shut down.

At the interspace level: This area is occupied by a geodesic frame that bridges the vacuum and wave guides extensions, and supports some diagnostic components. The interspace frame is fixed against the port plug flange giving a unique reference point to the machine coordinates. In it are inserted the vacuum pipes, wave-guides and extra shielding breaks (probably a stainless steal and polyethylene combination) enveloping the straight vacuum extensions. The vacuum extension pipes are welded to the port plug pipe segments from inside, using a remote welding ‘snake’, and then secured using individual screw locks. The diagnostic chamber containing the detection equipment (gratings, CCD’s, etc) is in most cases attached to the back end of the interspace frame providing stable alignment. A robust flange containing the optical table is bolted against the interspace frame. The vacuum extension pipe passes through the flange opening and is welded against its inside face. An enveloping box is finally welded to a dedicated wedge on the flange (Fig. 1). To ensure a simple strong boundary, access to detection components is not possible from outside. Final alignment is to be done at the hot cell before the diagnostic flange is closed. Requirements for all first vacuum boundary joints to be welded have been worked out.

At the pit cell: At the front end is a bioshield, usually build up from "LEGO-like" concrete bricks that best suit the local distribution of diagnostic components. At the pit cell location there is a transition from the machine to the building reference coordinate system. Diagnostics components that have a link to the machine and are required to sit in this area have to be provided with motion decoupling systems. In the case of the NPA diagnostic, the detection components are located in the pit cell. A double bellows arrangement provides the necessary motion decoupling. The system must be passively aligned before operation. The wave-guide motions relative to the pit cell are taken by individual arrangements of mitre-bends and swivel joints that ensure six degrees of freedom (Fig.1).

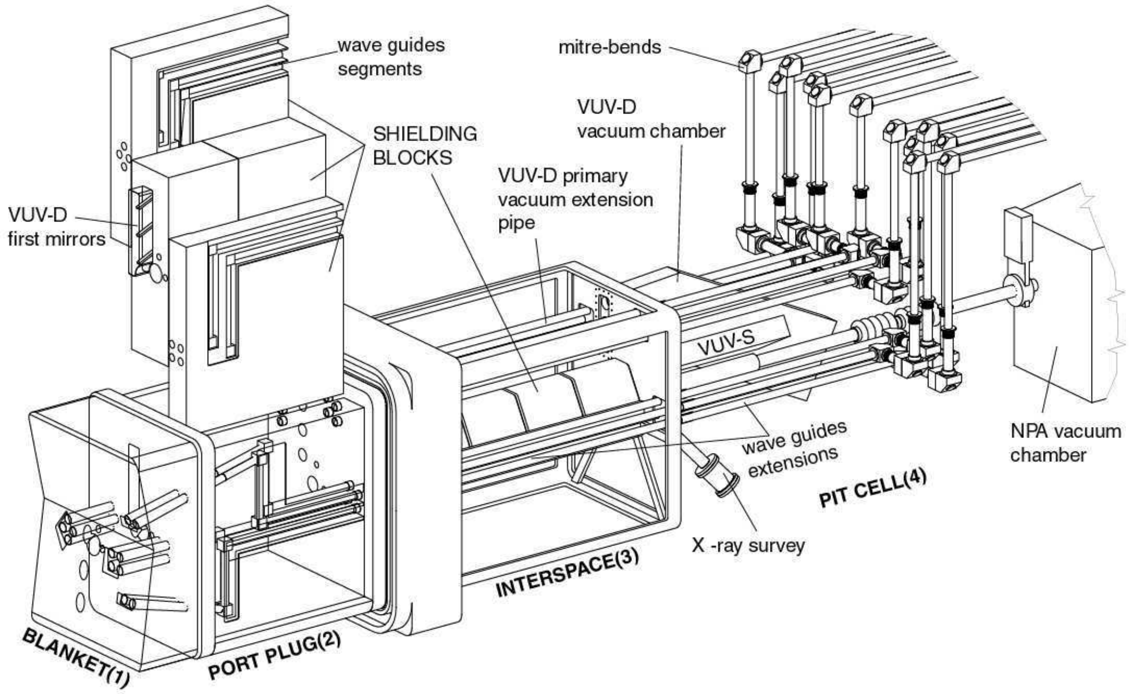

Fig. 1 – Arrangement of diagnostics at equatorial port #11. The port plug (2) carries the blanket module (1) and diagnostic shielding blocks. The interspace frame (3) is fixed to the port plug and is used to bridge diagnostic extensions and support individual vacuum chambers. The pit cell (4) is referenced to the ground and accommodates the bio-shield (not shown) and large diagnostic components (NPA). Dedicated motion decoupling devices (bellows, mitre-bends) are used to take the relative motion between interspace and pit cell.

Maintenance and Refurbishment: Manual access is used at the pit cell to remove diagnostic vacuum boxes, wave-guides along with the flexible joints, and concrete bioshield bricks. Standard orbital cutters enveloped by a shroud are used to cut the vacuum extensions. In this way Be and C dust proliferation is contained. Once access to the back end of the interspace is clear, a cutting ‘snake’ enters inside the tubes and splits them at the port plug flange. Local shrouds and protection caps are inserted to ensure dust retention. The interspace is remotely removed with the remaining pipe segments and wave-guides (and possible with some shielding bricks) by a RH cask and transported to the hot cell. The port plug is also removed and transported in a sealed RH cask [3]. The complete diagnostic chain is maintained at the hot cell. The hot cell is equipped with the necessary RH tools to clean and refurbish the port plug, interspace frame and diagnostic components. Alignment stations are also located at this area and are used for dimensional control and to assist in diagnostic alignment and installation. Provision has been made for the diagnostic chain port plug/interspace/pit cell equipment to be mounted, evacuated and tested at the hot cell.

Conclusions

Diagnostics are heterogeneous systems with different sets of requirements in terms of routing and vacuum boundaries, demanding a rationale for integration in ITER based on the use of common procedures, standard equipment and tools. At the port plug level the diagnostic components are implemented in tailored shielding modules that in turn are placed inside a standard port plug box. At the interspace level a standardized geodesic frame bridges the diagnostic extensions and supports some of the detector chambers. This frame is manipulated by a cask (similar to the port plug one) that contains the necessary tools to fix it at the port plug flange and to perform the alignment and welding of the vacuum extensions. At the hot cell, diagnostics can be maintained, refurbished and aligned making use of the local standard RH equipment (cranes, robot arms, measuring stations, etc.).

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