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ITER vacuum vessel, in-vessel components and plasma facing materials

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ABSTRACT

The vacuum vessel (VV) design is being developed in more detail considering manufacturing and assembly methods, and cost. Incorporating manufacturing studies being performed in cooperation with ITER Parties, the regular VV sector design has been nearly finalized. Design of the neutral beam (NB) ports including duct liners has been developed.

Design of the in-wall shielding has been developed in more detail considering the supporting structure and the assembly method. Additional ferromagnetic inserts to be installed in the outboard midplane region will minimize the maximum ripple and the toroidal field flux line fluctuation.

Detailed studies were carried out on the ITER vacuum vessel to define appropriate codes and standards in the context of ITER licensing in France.

The blanket module design has progressed in cooperation with participant teams. Fabrication of mock-ups for qualification testing is under way and the tests will be performed in 2007–2008.

The divertor activities have progressed with the aim of launching the procurement according to the ITER project schedule.

1. Introduction

Design improvements and additional R&D of ITER vessels and in-vessel components have progressed to fix interfaces and define technical specifications. The procurement specifications for long lead-time items are under preparation. Review of the design requirements and the current design is now going on before start of the procurement of ITER components.

2. Vacuum vessel

The main components that make up the vacuum vessel (VV) are the main vessel, the port structures and the VV supporting system. The VV is a torus-shaped double wall structure with shielding and cooling water between the shells [1,2]. The basic vessel design is an all-welded structure. Only the inner shell serves as the first confinement barrier. The VV components need to be designed and manufactured consistent with an accepted code or standard. The RCC-MR code is expected to be used for the ITER VV. The VV is divided into nine toroidal sectors joined by field welding using splice plates at the central vertical plane of alternate ports. The final welding is performed in parallel at three locations between 120° sectors. The VV has upper, equatorial, and lower port structures (including local penetrations located mainly at the lower level of the machine) (see Fig. 1). At the upper level, there are 18 ports of a similar design. At the equatorial level, there are 14 regular equatorial ports and three ports for the neutral beam injection (NB ports). There is one “blind” port. At the lower level, there are five ports for divertor cassette replacement and/or diagnostics (the divertor RH/diagnostic ports), and four ports for vacuum pumping (the cryopump ports). Between these ports, there are local penetrations for the divertor piping, the in-vessel viewing and glow discharge systems.

Detailed design is progressing on the main vessel and ports for the procurement specification document to start the call for tender in 2008. The regular VV sector design has been nearly finalized.

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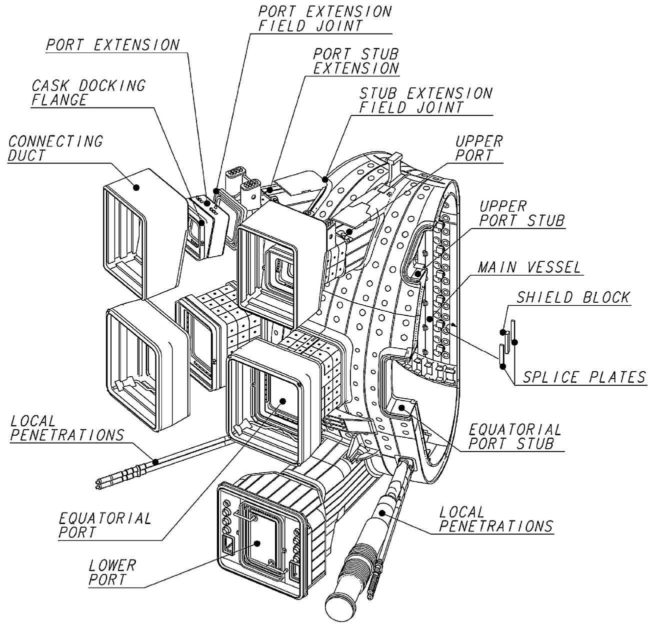


Fig. 1. ITER vacuum vessel and ports.

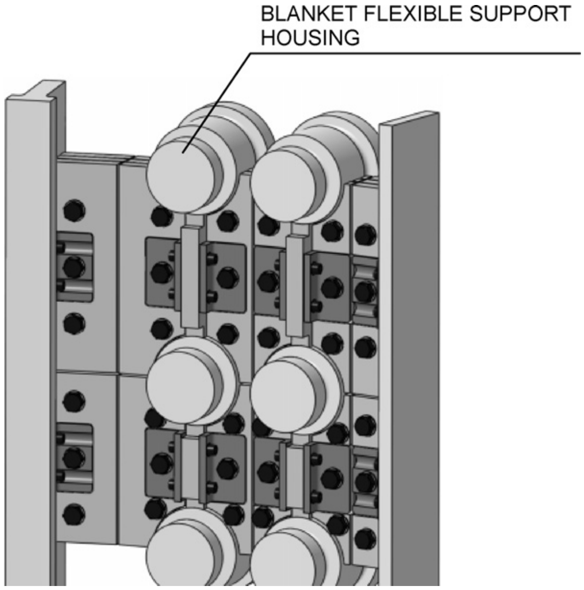


Fig. 3. Supporting structure of the in-wall shielding.

Design of the NB ports including duct liners under heat loads of the neutral beams has been developed.

2.1. In-wall shielding

The space between the double walls will be filled with shield structures (see Fig. 2) mainly made of an austenitic stainless steel containing 1–2% weight boron to improve the neutron shielding efficiency. The shielding structures occupy 55–60% of the in-wall space. A ferritic stainless steel (SS 430) is used as the shielding material in the shadow of the TF coils in the outboard area to reduce the toroidal field ripple. These plates fill up to 60% of the volume between the shells. This steel has a high saturated magnetization at about 1.5 T. The shield blocks are fixed by bolts to the ribs to withstand the mechanical forces (see Fig. 3) [2,3]. The gaps between the shield blocks and between the blocks and the ribs are minimized to avoid excessive neutron streaming.

The ferromagnetic insert was previously not included in the outboard midplane region between equatorial ports due to irregularity caused by the tangential ports for neutral beam injection. The absence of the ferromagnetic inserts in the midplane causes a relatively large ripple (~1%) in a limited region of the plasma and the toroidal field flux lines fluctuate ~10 mm due to the large ripple in the FW region. It is difficult to achieve the same configuration when including the additional ferromagnetic insert in each toroidal location due to the constraint of the supporting structure of the shield blocks. Therefore, the same volume of ferromagnetic insert is added in every sector but with different shapes between regular sectors and NBI sectors (see Fig. 4) [4]. The volume of the additional ferromagnetic insert is adjusted to make the magnetic configuration toroidally cyclic as much as possible to minimize the effect of lower mode error fields.

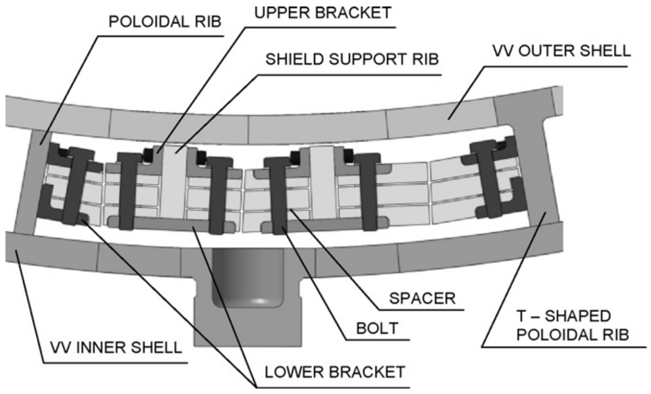
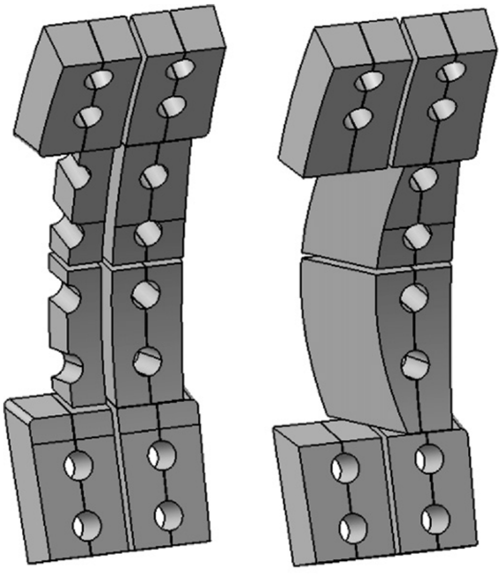


Fig. 2. Layout of the in-wall shielding.



(Regular port region) (NB port region)

Fig. 4. Additional ferromagnetic inserts between equatorial ports.