ID: 032

A Study of the Maintainability of the Lower (Divertor) Port & Divertor Cassette

UK Atomic Energy Authority

A Wilde[1], W Brace[2], C Gliss[3], S Jimenez[1], G Keech[3], A Loving[1], C Shaw[1], T Tremethick[1], C Vorpahl[3], J H You[4]

[1] RACE, UKAEA, Culham Science Centre, Oxfordshire, OX14 3DB, United Kingdom
[2] VTT Technical Research Centre of Finland, Tampere, Finland
[3] EUROFusion PMU, Boltzmannstr.2, Garching 85748, Germany
[4] Max Planck Institute of Plasma Physics, Garching, Germany

ABSTRACT

- The EU DEMO project aims to prove that fusion power can be developed into a commercially viable power source.
- This requires that the plant has suitably high availability that can be extrapolated to a commercial power plant (i.e. plant downtime for maintenance needs to be minimised) whilst meeting the relevant safety standards (IAEA, regulator, and good practice).
- Thus, maintainability becomes mission critical for DEMO, and is design defining.

The DEMO divertor cassette has evolved through several differing baselines; During the course of this evolution, the engagement between integration, component design and maintenance teams has led to various lessons being learned and the development of design features which are required in the divertor cassette, and several key learnings on the maintainability of the divertor cassettes and the impact on the lower port in general.

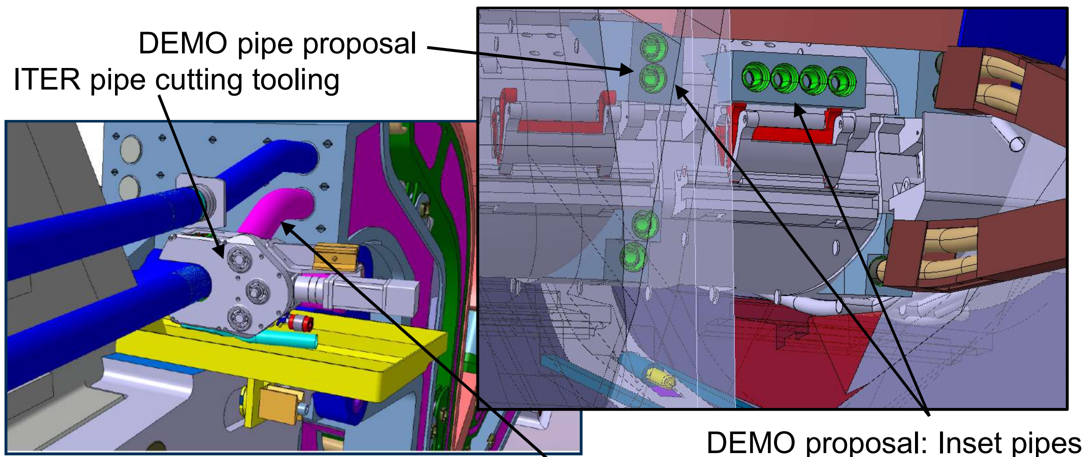
1: BACKGROUND

The DEMO divertor cassette is a Eurofer box, water-filled & pressure-retaining, and is stiff compared to ITER (which was designed as a large spring). As a result of this difference between ITER and DEMO divertors, it is necessary for a compliant element (spring) to be used between divertor & VV.

In ITER, pipe connections pass through the VV to the divertor; pipes cannot be easily replaced. DEMO radiation levels mean pipes will need replacing.

All maintenance activities will be done remotely without possibility of human intervention (up to 200Gy/hr dose rates in ports; up to 2000Gy/hr in-vessel).

Minimising contaminated and activated waste is of course a high priority.



2: CHALLENGES

FIXATIONS

Each of the divertor cassettes expands thermally and deflects under ferromagnetic / disruption loads. The different movements between the divertor cassette (hot) and VV (relatively cool) gives a differential expansion of around 12.5mm. Loads into the VV will be very high unless compliance is provided.

Divertor fixations will be needed to resist forces identified above; fixations will consist of an inboard fixation (passive, no RM interaction needed) and an outboard fixation (active, RM access needed, with compliant element which RM needs to compress to install or remove divertor cassette).

In operational conditions, forces required in fixations need to resist potential disruption and ferromagnetic loads. In the installation (cold) condition the fixation needs to still provide sufficient force to hold the divertor cassette against possible seismic events. RM loads to operate the fixation at installation conditions (and provide handling clearance) are currently unknown.

PIPES & SERVICES

Pipes will need to be replaced during the life of the plant, so they need to be within the port; this means a sufficiently large area of the divertor needs to be visible to fit the pipes. For lateral divertor cassettes, this is challenging.

Tight space constraints in DEMO mean that an in-bore laser welding system is proposed. This enables tighter packing density of pipes and minimizes cutting & welding durations. Pipes will need alignment features to enable use of this system: Alignment cuffs are expected to be around ø160mm for a DN80 pipe.

Differential thermal expansion will also happen in pipes. This is expected to be around 16mm. Compliance is therefore needed in pipes as well, sufficient to accommodate the 12.5mm of divertor movement and 16mm of pipe expansion.

During installation (welding) and removal (cutting) of pipes, pipe location needs to be controlled, and forces applied to accommodate compliance.

3: RM PREFERENCES

PIPE MODULES

Early RM studies identified that much as 60-70% of the divertor replacement duration could be spent cutting, removing, replacing & welding pipes.

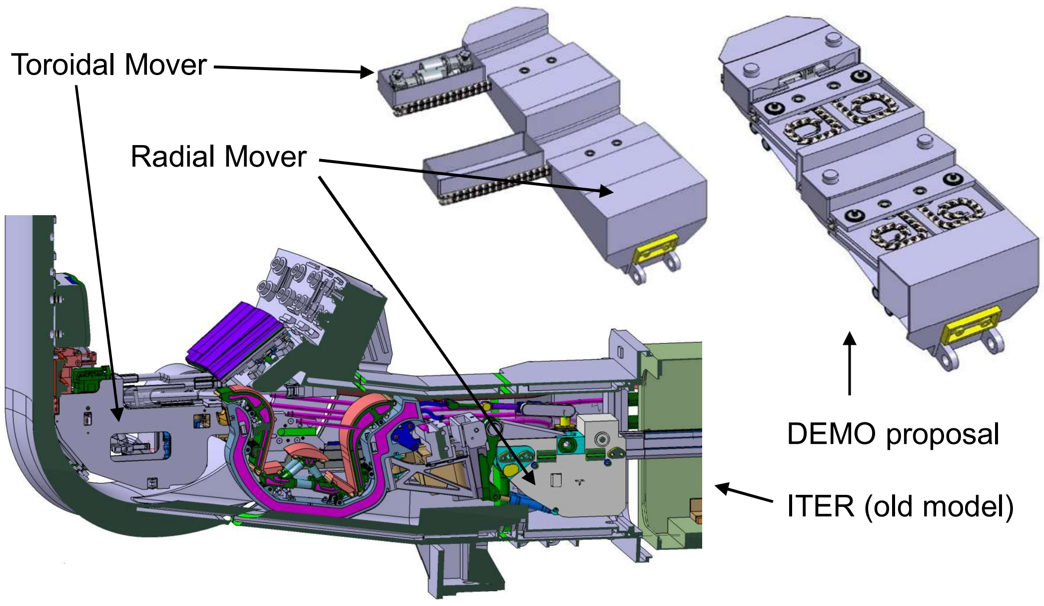
This has been reduced by developing the SJS system, and "bundling" pipes into pipe modules to be handled & cut / welded as a group – one per cassette.

DIVERTOR HANDLING

Basic RM principles of handling a component from under its CoG (rather than a cantilevered lift) massively reduces space implications & handling costs.

For DEMO, using this principle, the proposed toroidal movers are <10% the volume and mass of the divertor cassette. In ITER, where a cantilevered lift must be used due to insufficient space, the CTM is larger than the divertor cassette and weighs more. Similar is seen with the radial movers.

By minimising the time RM equipment spends in high radiation, the reliability of the RM equipment can be maximised, and contaminated waste minimised.



4: RM OPERATIONS

PIPE MODULES

Handling pipe modules is far more challenging (each pipe end needs accuracy of ~0.5mm radially and ~0.1mm axially) but brings significant savings to maintenance durations. Removal kinematics are complex and require space.

DIVERTOR

300-400mm space is required locally under the divertor for this operation.

The first movement of the divertor is expected to be to take the weight of the divertor off the inboard fixation (to avoid sliding motions) then outboard and down into clearance, before a toroidal movement into the centre of the port.

CONCLUSIONS

Handling space under the divertor enables significant improvements in maintenance durations and feasibility. This space is limited & localised.

Handling pipes as pipe modules also enables significant improvements in maintenance durations and feasibility, but requires consideration of making & breaking connections in the port (particularly where pipes exit the VV).

A little space, intelligently allocated, can make a lot of difference early in the project; not doing so will lead to major cost increases, maintenance duration increases, and project risks.

RACE

EUROfusion

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-20 under grant agreement No. 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

VTT

IPP Max-Planck-Institut für Plasmaphysik