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Overview of progress on the European DEMO remote maintenance strategy

Oliver Crofts[a,*], Antony Loving[a], Daniel Iglesias[a], Matti Coleman[b], Mikko Siuko[c], Martin Mittwollen[d], Vicente Queral[e], Alberto Vale[f], Eric Villedieu[g]

[a] RACE/UKAEA, Culham Science Centre, Abingdon OX14 3DB, Oxon, UK
[b] EUROfusion Consortium, PPP&T Department, Boltzmannstraße 2, 85748 Garching, Germany
[c] VTT Technical Research Centre of Finland, PO Box 1000, FI-02044 VTT, Espoo, Finland
[d] KIT Institut für Fördertechnik und Logistiksysteme, Gotthard-Franz-Straße 8, Geb.50.38, 76131 Karlsruhe, Germany
[e] CIEMAT Laboratorio Nacional de Fusión, Edif. 66, Avenida Complutense 40, 28040 Madrid, Spain
[f] IST, Instituto Superior Técnico, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
[g] CEA, IRFM, 13108 St Paul lez Durance, France

HIGHLIGHTS

- The remote maintenance strategy is applicable to the range of tokamak and component options currently under consideration in Europe
- The remote maintenance development work is concentrating on the application and limits of the immature technologies that pose the greatest risk to the feasibility of the maintenance strategy
- Position control during the handling of the in-vessel components is one of the areas of high risk and a system is being developed and will be tested prior to concept design to demonstrate the feasibility and capability of a system capable of real time incorporation of changing kinematic data provided by a structural simulator running in parallel
- In-vessel recovery and rescue and the pipe joining technology form two more of the high risk areas where developments are being concentrated

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ABSTRACT

The EU-DEMO remote maintenance strategy must be relevant for a range of in-vessel component design options. The remote maintenance project must provide an understanding of the limits of the strategy and technologies so as to inform the developing plant design of the maintenance constraints. A comprehensive set of maintenance requirements has been produced, in conjunction with the plant designers, against which design options can be assessed.

The proposed maintenance solutions are based around a strategy that deploys casks above each of the vertical ports to exchange the blanket segments and at each of the divertor ports to exchange the divertor cassettes. The casks deploy remote handling equipment to open and close the vacuum vessel, remove and re-install pipework, and replace the in-vessel components.

A technical design risk assessment has shown that the largest risks are common to all of the proposed solutions and that they are associated with two key issues, first; the ability to handle the large blanket and divertor components to the required positional accuracy with limited viewing and position feedback, and second; to perform rapid and reliable pipe connections, close to the blankets, with demonstrated quality that meets the safety requirements.

1. Introduction

The commercial viability of a future fusion power plant (FPP) is heavily dependent on high availability [1]. The EU DEMO reactor design must demonstrate rapid and reliable remote maintenance techniques, and a reasonable availability, compatible with the economic performance of a FPP.

The aim of the current phase of the European DEMO remote maintenance project is to develop a maintenance strategy based on sound remote handling practice and technologies, relevant for a range of in-vessel component design options. At the pre-conceptual design phase the component designs are relatively immature;

* Corresponding author. Tel.: +44 1235 464627.
E-mail address: oliver.crofts@ccfe.ac.uk (O. Crofts).

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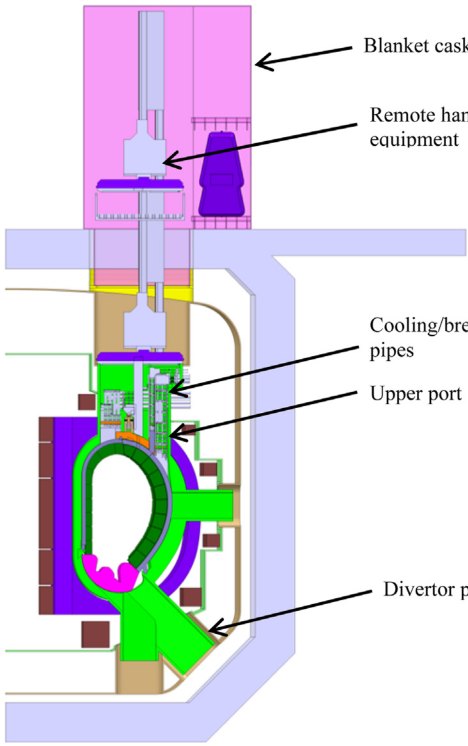

Fig. 1. The proposed maintenance strategy.

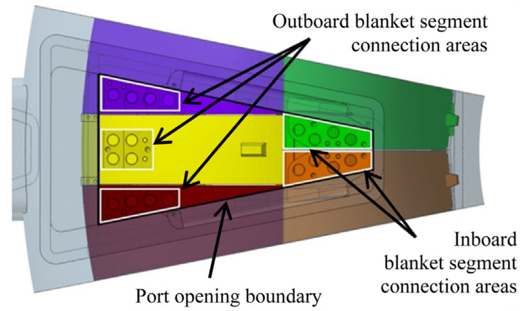

Fig. 2. The vertical port opening showing the vertically accessible areas of the blanket segments.

however the maintenance strategy is being developed in parallel to ensure that the developing plant designs can take into account the maintenance requirements.

The proposed maintenance strategy deploys casks above each of the vertical ports to exchange the blanket segments and at each of the divertor ports to exchange the divertor cassettes. See Fig. 1. The casks deploy remote handling equipment to remove pipework and open the vacuum vessel and then to remove and replace the in-vessel components.

Alternative maintenance solutions for this strategy have been proposed which have varying pipe layouts, vessel opening options and cask deployment arrangements.

2. Maintenance strategy drivers

2.1. Demonstrate technologies

The European DEMO is required to demonstrate the technologies necessary for a commercial fusion power plant [2]. This requires the remote maintenance concept design process to identify the immature technologies that have the greatest threat to the feasibility of the concepts.

This has been undertaken through a technical risk assessment. See Section 3.

2.2. Minimize in-vessel operations

It is vital to minimize the remote handling operations required in or close to the plasma chamber due to the high temperatures and high radiation levels present during maintenance. These conditions make remote operations more difficult due to the limited visual and physical feed-back available for the handling systems. See Section 3.1.3.

Furthermore, the consequences of an unrecoverable failure during in-vessel operations are very severe because they result in high costs and long delays and require extensive rescue equipment to be available. See Section 5.3.

This has driven the requirement for the segmentation of the blankets and divertor cassettes to ensure that at least a small part of each of the in-vessel components is visible through the port opening for the handing connection and service connections. See Fig. 2. Therefore the in-vessel maintenance system requires access to all the vertical and divertor ports.

This allows the handling of the components and service connections to be performed from within the vessel ports, not from inside the plasma chamber where the environmental conditions are significantly more severe. See Section 4.3.

The in-vessel maintenance strategy is discussed in more detail in Section 6.

2.3. Minimize maintenance duration

A fusion power plant must have a high availability to be commercially viable [3], there is therefore a strong cost driver for rapid maintenance operations. DEMO must demonstrate power plant relevant availability, from which a FPP level of availability could be extrapolated. This requires the minimization of the number of in-vessel components. It has also led to proposals to use less mature technologies that have the potential to complete operations faster than more established technologies such as; advanced control algorithms, see Section 3.1 and the use of laser welding. See Section 3.2.

2.4. Small port size

The toroidal field (TF) coils, poloidal field (PF) coils, and the associated inter-coil support structures are permanent components that limit the size of the ports through which the in-vessel components must be exchanged. This in turn limits the size of the in-vessel component handling systems and therefore their load capacity and stiffness. It also limits the space available for removing and replacing pipes and other in-port services and equipment. See Fig. 3.

3. Technical risk assessment

The work to develop a remote maintenance strategy has studied the technical design risks that could impact the performance or feasibility of the remote maintenance systems, and has resulted in several targeted activities being initiated in order to mitigate the risks as far as possible by the time of the concept design review.

The concept design technical risk assessment has shown that the largest risks are common to all of the currently proposed in-vessel component maintenance solutions. The most critical risks are primarily associated with the ability to rigidly handle and control the heavy in-vessel components to a high degree of accuracy,