



DEMO Active Maintenance Facility concept progress 2012



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ABSTRACT

The DEMO Active Maintenance Facility (AMF) would be used for the storage, handling and processing of In-Vessel Components (IVC) throughout their time on site, the only exception being the time that they are installed in the vessel. It is anticipated that all handling operations associated with used components will have to be carried out using remote handling techniques.

During plasma operations the In-Vessel Components are exposed to high levels of neutron activation. This activation results in high radiation dose rates and decay heating. This presents a significant problem for Remote Handling Equipment (RHE) in the AMF. The high dose rates require the equipment to be sufficiently radiation tolerant to allow it to work reliably for long periods. The decay heating requires forced cooling of newly removed IVC's while they are in storage. The duration of the storage is dependent on the decay heating reducing to a level that has been nominally set at <50 °C without active cooling in room temperature air.

This paper summarises the progress made in 2012 on the conceptual design of the AMF and its facilities. The layout and proposed function of the main areas will be described along with the principles applied. The design of the AMF has evolved from a simple representation of the required facilities in 2011 to a concept that can be developed to support maintenance of DEMO.

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1. Introduction

The European Fusion Development Agreement is continuing with the conceptual design of the next generation of fusion device. This device will be a demonstration plant called DEMO. DEMO will show that generation of electricity from fusion is technically and commercially viable and it will need to demonstrate all of the technologies required to construct, operate and maintain a fusion power plant. This work is based on the current conceptual assumptions, not an official DEMO design.

This paper is a summary of the progress made in 2012 of the Active Maintenance Facility (AMF). All of the components and equipment required to maintain the DEMO reactor would be stored, processed or handled in the AMF at some time in their life. Previously the name given to this type of facility has been Hot Cell. Historically, the generally understood function of a hot cell has been limited to the handling of dangerous items remotely, but because of the broader role performed by this building, it was decided to call it the Active Maintenance Facility.

2. Maintenance concept

The design of the maintenance scheme adopted for the In-Vessel Components (IVC) is likely to be one of the biggest influences on the design of the AMF. Other factors to consider would be the durability, the complexity of construction and also the level of activation of the IVCs.

Included in the 2012 work programme was a study of DEMO in-vessel configurations [1]. Its aim was to determine the in-vessel configuration that would be best suited to remote maintenance. From the many ideas examined, a vertical maintenance scheme [2] based on a Multi-Module Segment (MMS) blanket and divertor cassette accessed via the lower port was developed as the most promising configuration, Fig. 1.

The durability of the blanket and divertor will dictate the time between shutdowns. The ability to withstand long periods of operations would increase the availability of the plant. The additional operations time could allow the AMF component processing facilities to be smaller. The time available for completing the work on the used components and prepare for the next shutdown would be increased.

The complexity of the IVC construction would determine how long it would take to process them at the end of their life. This work would be done between shutdowns, so there would be a known fixed duration. Increased complexity in the assemblies would result in a larger processing facility to ensure the work is done on time.

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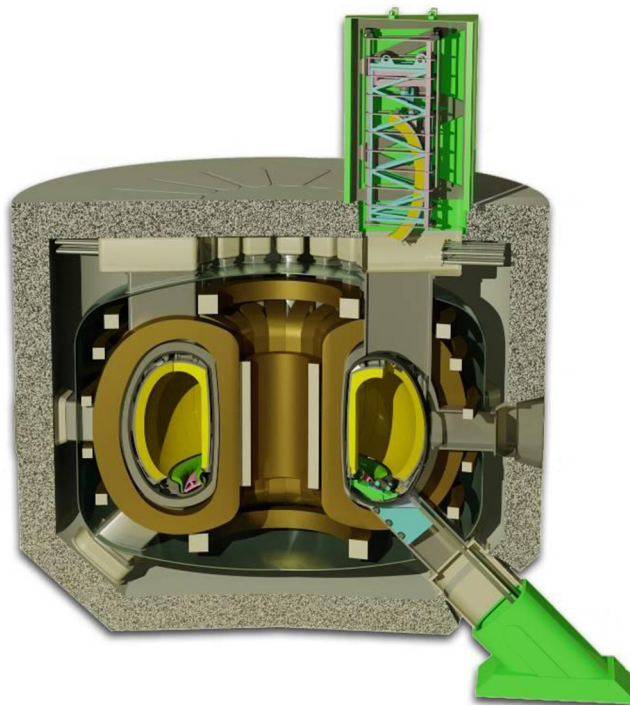


Fig. 1. DEMO vertical maintenance scheme.

During plasma operations, the In-Vessel Components become highly activated. A side effect of this is decay heating [3]. The IVC storage areas would need to be actively cooled until the level of decay heating has reduced to a more manageable level. The time required for active cooling will be taken from the time between shutdowns, reducing the time available for IVC processing. Decay heating has a half life meaning this process cannot be sped up by increasing the level of cooling. The amount of decay heating at 30 days after the reactor is turned off is estimated to be 25 kW for each outer blanket segment and 10 kW for an inner segment and a divertor cassette. After 1 year these values could have reduced to 4 kW and 2 kW, respectively. These estimated values are continuing

to change as the dimensions and composition of the IVCs becomes more detailed.

These component variables are important to understand. For DEMO, the in-service time is currently estimated to be 12 calendar years for the blanket (following the initial “starter” blanket phase) and 5 calendar years for the divertor [4]. These extended operating durations will allow the AMF component processing areas to be a scaled down version of what will be required for a power plant. However, the storage areas would be about the same size. The techniques used for DEMO must be relevant and scalable to those that would be used in a power plant.

To allow a credible concept to be produced, some parameters were required for the maintenance scheme. It is assumed that the vessel has 16 ports that would be used for maintenance. The number of ports being used at the same time could have a large influence on the duration of the shutdown. In parallel to the development of the AMF a study was undertaken to estimate the duration of a shutdown and the parameters required [5]. However because the optimal shutdown had not been established at the time of this work, the worst credible case was selected for the AMF concept. This has 8 ports being used at the same time for the same operations. This would require the largest amount of RH equipment and also have the highest continuous productivity rate (see Fig. 2).

3. AMF design evolution

In 2012, the design of the AMF has evolved from a simple representation of the facilities required to an estimation of the size and layout of a functional concept.

A unidirectional flow for the components has guided the layout of the facilities and how they interact with each other. Where possible, as the components are transported from the vessel they would move through areas of progressively reducing contamination until they reach the waste and recycling facility. New components would take a different route which would minimise the risk of contamination.

Now the concept is beginning to take shape, it has been possible to compare the DEMO AMF with the ITER Hot Cell. In terms of volume, the AMF would be six times larger than the ITER Hot Cell, Fig. 3. This is a comparison of just operational areas of the AMF; the plant and services have not yet been added to the concept.

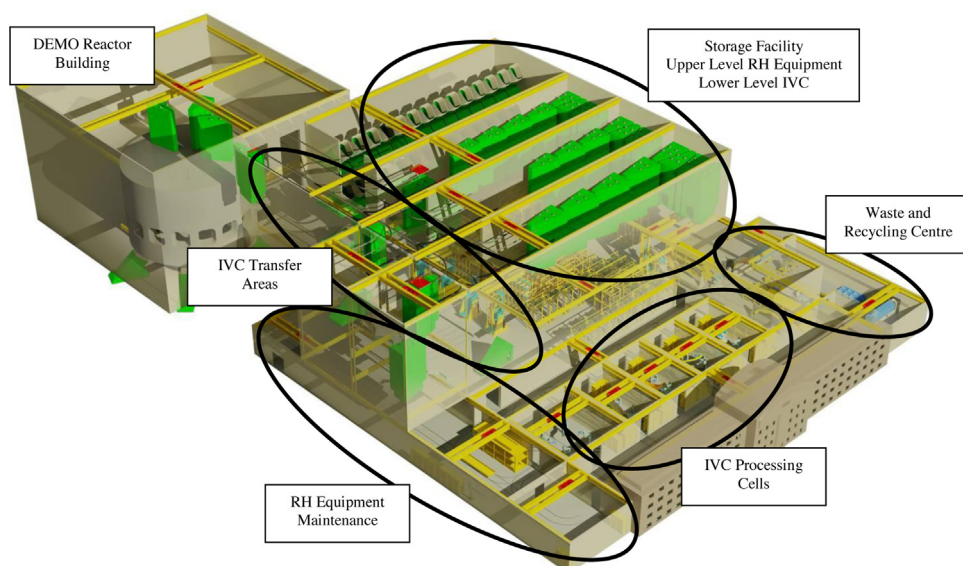


Fig. 2. Overview of the Active Maintenance Facility and reactor building.

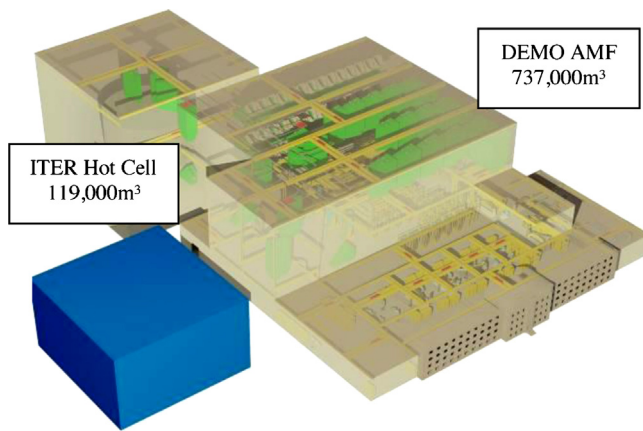


Fig. 3. ITER HCF to AMF size comparison.

4. AMF design characteristics and constraints

The AMF has to support all of the vessel maintenance operations without increasing the duration of the shutdown. On top of this, the AMF must have sufficient capacity to cope with breakdowns and maintenance of its own facilities and equipment.

The work to determine the optimum maintenance strategy was being done in parallel to the development of the AMF; so a worst case maintenance strategy that uses 8 ports in parallel was selected. This would require a large amount of Remote Handling Equipment (RHE) to support it. The blanket handling would require 32 casks and the divertor 42 casks, these numbers include spares. When the casks are not operating they would have to be stored and maintained in the AMF.

The conceptual model is not structurally accurate. The walls and cranes are shown to represent where they would be required. Storage of components or equipment on upper levels would require a lot of support below. Accommodating large support structures would limit the functionality of the lower areas. To support the mass of the RHE for example the supporting structures would have to be reasonably close together compromising the use of overhead cranes.

The current estimate of the decay heating would require the used first wall components to be actively cooled. This cooling would have to be maintained for a period of up to 18 months. This storage facility would be separate to those used for moderately activated items.

The planned operations of DEMO allow significant time between shutdowns for IVC to be processed and RHE to be maintained and prepared for the next campaign. There would be between 6 and 12 years [4] to complete all of the work in the AMF.

Areas where components with high dose rates are worked on have been placed in the middle of the building to help with the shielding.

All areas of the building that activated components pass through should be shielded for radiation. Having un-shielded transfer areas would limit the movement of activated components to certain times of day. This could have a significant impact on productivity and serious consequences if there were a failure in the equipment carrying an activated component in that area.

The transfer bays would be equipped with handling machines. These machines would receive a blanket module as if it were being lowered in to the vessel. As it is transferred to the handling machine it would be loaded in to its storage frame. From here it would be rotated 90° to be stored horizontally. Horizontal storage allows for more efficient use of the space. Simple open frames, Fig. 4, have been used to support the components during storage. The frames

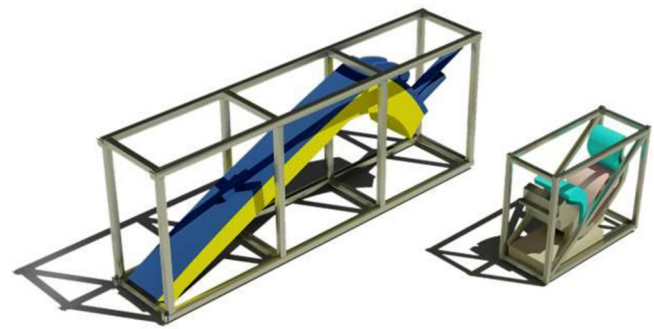


Fig. 4. IVC storage frames.

are simple regular shapes very similar in size to the component. These stacked would allow very efficient use of the space, with 3400 tonnes of IVC's stored in 11,000 m³. Individually the frames have an estimated mass of 3 tonnes for the blanket and 1 tonne for the divertor. The components stored in them are estimated to weigh between 11 tonnes and 37 tonnes.

Processing of the IVCs would be done in cells specifically designed for blankets or cassettes. Each cell would be equipped with RH systems designed for the tasks required to dismantle those components. Multiple pieces of equipment would be used together to form an efficient system. They would be self-contained cells. A cellular approach gives a number of benefits. The productivity of a single cell can be easily quantified and then scaled for a future power plant design. The closure of a cell for routine maintenance or an unexpected breakdown would not affect the operation of the facility as a whole.

Components would be transferred from their storage frames and loaded onto bespoke maintenance fixtures, Fig. 5, as they leave the storage area. These fixtures would be used to transport the components through the dismantling process. The fixtures would be designed to give access to the whole component. Where necessary the fixtures would have joints for turning the component over (see Fig. 6).

Testing and commissioning would be carried out in dedicated areas. Used components would arrive here after maintenance. Part of the maintenance process would be a thorough decontamination, as there should be little or no contamination present in these areas, but components that have been used on the machine would be expected to be radioactive. A separate clean area would be used for new components. The work on new components would be done manually where possible.

A waste and recycling facility has been added. This has been put at the output end of the component processing line. The operation

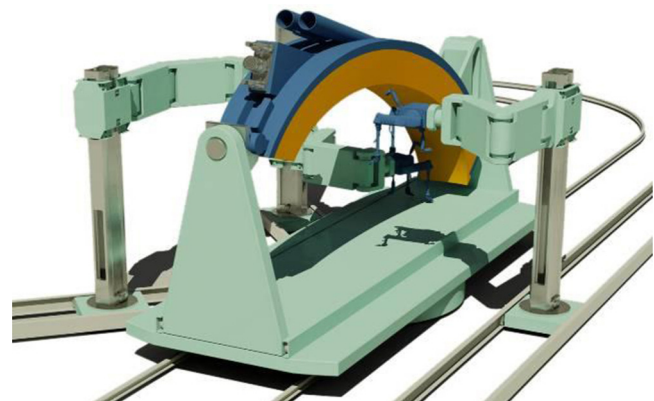


Fig. 5. Blanket processing in-cell RHE.

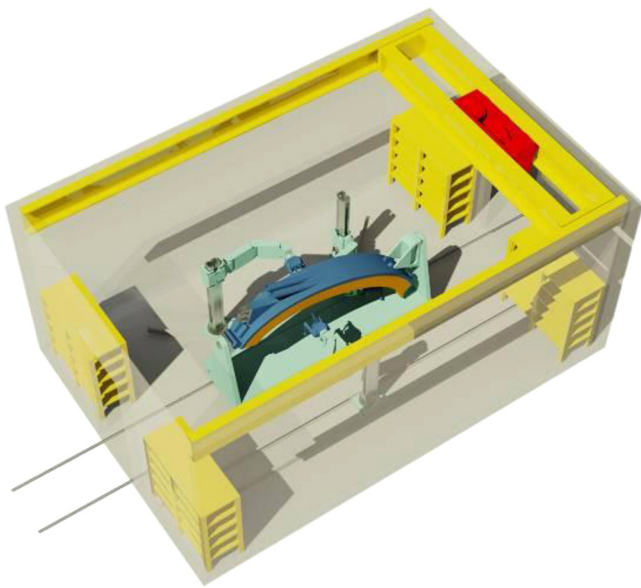


Fig. 6. Blanket module processing cell.

of this facility would also be fully remote. More aggressive dismantling techniques would be employed here as the output would be items sized to fit into transport and storage containers. DEMO would aim to recycle as much material as possible; with only the bare minimum going to waste.

5. AMF capacity

The AMF would be basically divided into two types of area that can be described as storage and productive.

The storage areas will take up the most space in the AMF. The storage areas would have to accommodate all of the vessel components and the RHE required for handling and maintaining them. Component storage facilities would be divided into three different types. For the 128 highly activated IVC's, there would be an actively cooled storage facility. For contaminated components with lower activation components, there would be a passively cooled store. Finally, a clean area is provided for components that are not contaminated or activated.

In addition to the component storage, there would need to be storage areas for RHE. Although the number of casks would be less than the number of components, they are much larger than the components that are transported inside them. With eight upper and eight lower ports operating in parallel, up to 74 casks could be required. The largest cask, for the blanket handling Fig. 7, has an estimated mass of 450 tonnes. More would be required for the transport of ex-vessel components and RHE. The 74 casks required for in-vessel maintenance alone could have a combined mass in excess of 17,500 tonnes [6,7].

There would be two major assemblies requiring transportation in casks: the blankets and the divertor cassettes. Each will have its own basic cask design of which there would be a number of specific configurations. There is unlikely to be enough time to reconfigure and prepare the casks during the shutdown. A set number of casks of each configuration would be available at the start of the shutdown. One or two spares would be needed to ensure minimal delays in the event of a failure.

To store one full set of IVCs will require 11,000 m³ of space. This is based on the components being fitted to simple storage frames. The oblong frames take up the smallest volume possible by being not much larger than the biggest dimension of the component.



Fig. 7. MMS blanket handling cask.

The 8-port in-vessel maintenance strategy could require the AMF to handle a major IVC every 7 h. This is averaged for 160 assemblies being removed and then installed over the shutdown duration of 95 days [5]. Additionally many ancillary components would have to be handled.

6. Conclusions

At the moment, as new tasks are identified, the AMF is only increasing in size. It is likely that a more efficient use of the space would be found but the fact remains that the components being handled and the equipment needed to do this are big. This only increases when enough space for efficient movement and handling in and around the facility is included. Even with the best planning and logistics, there would still be a need to access a component out of sequence.

The type of maintenance scheme and also the number of parallel operations will impact AMF size. More ports, as reported, come with a significant RHE cost increase, less ports would require much more time. The best balance has yet to be found.

It is important that the AMF has enough capacity to stay off the critical path of the shutdown. The long periods of plasma operations between shutdowns for DEMO would allow the component processing areas to be relatively small. Using a cellular approach to design the facilities would allow accurate scaling for a power plant. To fix the AMF storage requirements all of the IVC processing

operations must be completed before the start of the next planned shutdown.

A future power plant will also have to consider the level of decay heating and the time required for it to reduce to manageable levels. This could potentially have a large impact on the storage requirements, possibly doubling it if the cooling time is a significant portion of that available for IVC processing.

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