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# Assessment of Remote Maintenance Schemes for BA DEMO Reactor
# BA原型炉における遠隔保守方式の評価

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Maintenance schemes are one of the critical issues in DEMO design, significantly affecting the configuration of in-vessel components, the size of toroidal field (TF) coil, the arrangement of poloidal field (PF) coils, reactor building, hot cell and so forth. In this presentation, various remote maintenance schemes for DEMO were comparatively assessed based on requirements for DEMO remote maintenance. From the view points of the reliability of inspection on hot cell, TF coil size, stored energy of PF coil and portability of segment, the banana shape segment transport using all vertical maintenance ports would be more probable DEMO reactor maintenance scheme.

## 1. Introduction

Maintenance schemes should satisfy many design requirements and criteria to assure reliable and safe plant operation and to attain reasonable plant availability. Previously, compact DEMO, SlimCS designed by JAEA adopted a horizontal sector transport maintenance scheme taking account of high availability [1-3]. From the view points of support against overturning force of TF coil and sector segmentation, the sector transport using limited number of horizontal maintenance ports (SLH) is a more realistic sector transport maintenance scheme [4]. On the other hands, the sector transport maintenance scheme has disadvantages of larger TF coil and larger maintenance port, which has big impact on medium size DEMO (plasma major radius $R_p$ ~8m), which has been developed by JAEA DEMO design from the aspects of component assessment and systems design for a possible DEMO concept. In order to decide a most probable remote maintenance scheme for DEMO, comparative study of maintenance schemes taking account of not only plant availability but also engineering reliability is important. This presentation describes engineering design of each maintenance schemes and evaluation results of comparison among maintenance schemes.

## 2. Requirements for DEMO remote maintenance

In the remote maintenance for DEMO, top requirement is plant availability and scalability to first power plants. The plant availability depends on not only maintenance time but also reliability of remote maintenance scheme and plasma operation without plasma disruption. Therefore, in this study, the requirements for DEMO remote maintenance scheme determines as follows; 1) Technical feasibility, 2) Reliability of inspection, 3) Consistency with plasma operation and In & Ex-vessel components, 4) Safety and 5) Cost.

## 3. Various remote maintenance schemes

This study roughly categorizes the remote maintenance schemes for a DEMO reactor according to (1) the insertion direction of blanket segments, and (2) blanket segmentation as follows;

Case 1: Sector transport using a Limited number of Horizontal maintenance ports, SLH [4]

Case 2: Horseshoe shape segment transport using Limited number of Horizontal maintenance ports, HLH (Figure 1 (a))

Case 3: Banana shape segment transport using All Vertical maintenance ports, BAV (Figure 1 (b))

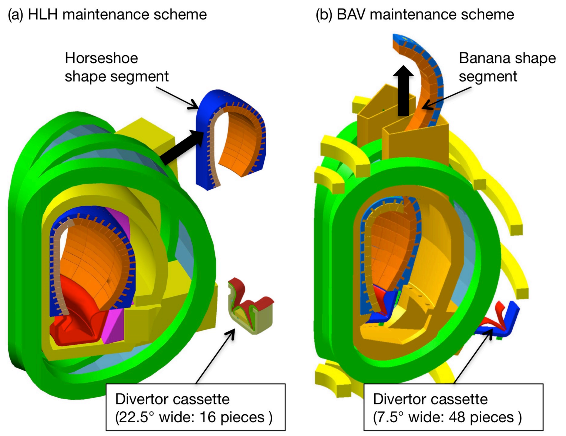


Fig.1. Conceptual view of (a) HLH, and (b) BAV.

Table 1. Comparison among the three maintenance schemes.

| Requirements | | SLH | | HLH | | BAV | |
|---|---|---|---|---|---|---|---|
| 1. Technical feasibility | Weight | | ~500 ton | | ~360 ton | + | ~90 ton |
| | Transferring mechanism | | Non-cooperative ope.<br>Two directions<br>(Tor. and R) | | Non-cooperative ope.<br>Two directions<br>(Tor. and R) | | Cooperative ope.<br>Three directions<br>(Tor. ,R and Z) |
| 2. Reliability of inspection | N. of points | + | BLK: 96, Div: 64 | + | BLK: 96, Div: 64 | | BLK: 320, Div: 192 |
| | Access. to BLK | | Not good | | Not good | + | Good |
| 3. Cons. with plasma and In & Ex-vessel components | TFC size | | 13.7 m | | 13.7 m | + | 11.9 m |
| | Total PFC energy | | 68 GJ | | 68 GJ | + | 27 GJ |
| | Conducting shell | + | Good | + | Good | | Not good |

## 4. Assessment of remote maintenance schemes

### 4.1 *Technical feasibility*

The SLH and HLH maintenance schemes, with a limited number of horizontal maintenance ports, require a bi-directional (Toroidal and radial) transferring mechanism of segment in the vacuum vessel. On the other hands, although the BAV scheme has the advantage of good portability, it has the difficulty of cooperative operation and three-directional (Toroidal, radial and vertical) transferring mechanism of segment in the vacuum vessel.

### 4.2 *Reliability of inspection*

In the case of SLH, HLH and BAV maintenance schemes, the cutting/re-welding/inspection of manifold on the segment must be done on the inside of reactor because of the toroidal segment transfers inside the vacuum vessel. Especially, the BAV scheme has 5 times segment than that of SLH and HLH scheme. Therefore, the way of the cutting/re-welding/inspection of manifold on the segment is key technical issue for BAV maintenance scheme. In contrast, the cutting /re-welding/inspection of manifold on the blanket modules is done in hot cell by remote handling. The banana shape segments have higher accessibility to re-welding and inspection of blanket manifold.

### 4.3 *Consistency with plasma and In & Ex-vessel components*

#### 4.3.1 *TF coil size and PF coil current*

For horizontal sector transport in SLH, the vacuum vessel has large 16 m high horizontal ports, and the TF coils are about 2 m larger than the vertical maintenance scheme (13.7 m). The fabrication of larger TF coil is critical issue for DEMO reactor, and leads to higher construction cost of DEMO reactor.

The PF coil positions are limited by the TF coil size and the maintenance port layout of each remote maintenance scheme. Therefore, the PF coil current in the SLH becomes greater than that in the vertical maintenance schemes. The magnetic stored energy for SLH is more than twice as large as for the vertical schemes, and the SLH has less flexibility for higher elongation range.

#### 4.3.2 *Conducting shell effect for vertical stability*

It is important to design the conducting shell structures which have a high stabilizing effect and a characteristic time long enough to control the plasma position by the feedback control system [5, 6]. The instability growth times of 7.5° and 22.5° conducting shell models are 0.08 and 0.26 s, respectively. The 22.5° conducting shell has good stabilization effect for vertical stability. The 7.5° segment in BAV requires the active conducting shell structure for plasma vertical stability, for example, saddle loops or twin loops structure [7].

## 5. Summary

As shown table 1, various remote maintenance schemes for DEMO were comparatively assessed based on requirements for DEMO remote maintenance. From the view points of the reliability of inspection on hot cell, TF coil size, stored energy of PF coil and portability of segment, the banana shape segment transport using all vertical maintenance ports would be more probable DEMO reactor maintenance scheme, and it has key engineering issues such as in-vessel transferring mechanism of segment, pipe connection and conducting shell design for plasma vertical stability.

## Acknowledgments

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