FTP/P7-31

Critical Design Factor for Sector Transport Maintenance in DEMO

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Background

Maintenance is a critical issue for fusion DEMO reactor because the design conditions and requirements for DEMO maintenance scheme are different from ITER.

Difference between ITER and DEMO remote maintenance

- **Replacement components** ITER：several/each DEMO：overall/each
- **Irradiation**
  - ✓ Dose rate ITER：0.5kGy/hr DEMO：Shutdown※：~300kGy/hr, 1 month later：~30kGy/hr
  - ✓ Decay heat

DEMO (SlimCS) P_f: 3GW 2FPY

Devices	Permissible dose (Accumulation dose)	Operation time※
Motor	10-80MGy	33-266hr
Imaging fiber	2-5MGy	6-16hr
Location sensor	10-30MGy	33-99hr

Focus of this research:

- critical design factors and key engineering issues on the **sector transport maintenance** scheme **considering three different maintenance schemes** based on sector transport
- a feasible maintenance scenario option considering **handling of decay heat** in sector transport maintenance

Summary

Critical design factors:

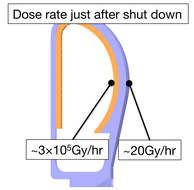
- How to support an enormous turnover force of the TF coils
  -> **By limiting the number of maintenance ports**, an enormous turnover force of the TF coils can be supported.
- The transferring mechanism of sector in the vacuum vessel
  -> the wheeled plat-form considered the radiation resistance was proposed.
- Maintenance scenario under the high decay heat
  - After the cooling down time of **one month**, each sector of SlimCS would be allow to transport to the hot cell facility **only by gas-cooling**.
  - Considering plant availability, **additional cooling system in cryostat** would be required for **unexpected interruption** during RM such as trouble of cooling pipe handling and sector transport.

Sector transport maintenance scheme

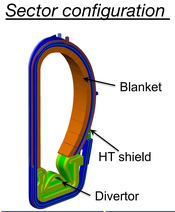
~ Three different maintenance schemes ~

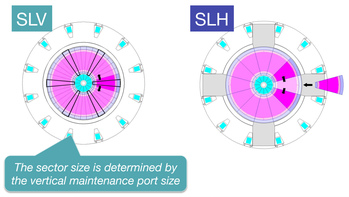
Advantages of sector transport maintenance

- Low risk of development of RH devices
  NO need for complex handling system in VV
  →w/o the use of sophisticated RH devices (e.g. servomotor) in high radiation environment
- High plant availability
  Minimum N of manifolds
  →leads to minimum N of cutting/re-welding points, short maintenance time

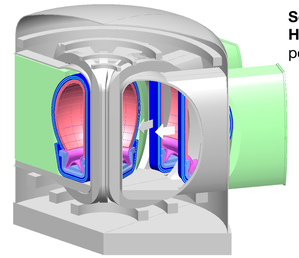


Sector configuration





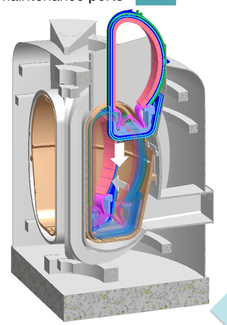
	SAH	SLV	SLH
Maintenance port	All ports	Limited	
Direction	Horizontal	Vertical	Horizontal
N. sector (N. manifold)	+ 12 (minimum)	36	+ 12 (minimum)
Sector weight	~700ton	~200ton	~500ton
Support against T-O force (Critical issue ①)	– Ex. support (Cryostat/Building)	+ Independent (Inter-coil structure)	+ Independent (Inter-coil structure)
Sector transport (Critical issue ②)	+ One direction (R)	Two directions (Tor. and Z)	Two directions (Tor. and R)
Pipe cutting/ re-welding points	+ Outside of vacuum vessel	Inside of vacuum vessel	Inside of vacuum vessel



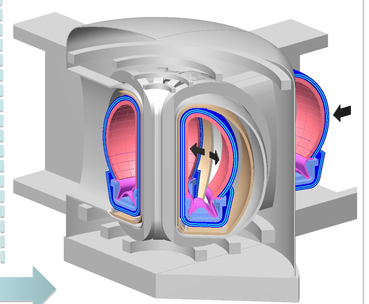
Sector transport using **A**ll **H**orizontal maintenance ports SAH

All port / Maintenance port / Limited

Sector transport using **L**imited number of **V**ertical maintenance ports SLV



Sector transport using **L**imited number of **H**orizontal maintenance ports SLH



Vertical / Pull/Insert direction / Horizontal

Common critical issue

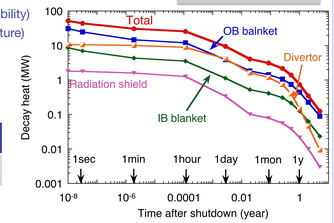
Feasible maintenance scenario considering decay heat

Critical issues on transport to hot cell

- During the sector transport, all coolant needs to be tentatively removed
  ➔how long cooling time in reactor (trade-off with plant availability)
  ➔how to remove the decay heat (material allowable temperature)
- Tritium removal from reactor components
- Prevention of diffusion of radioactive dust
- Induced radioactivity

	Stop	1 day	1 month	3 month	6 month	1 year
Total (MW)	55	11.4	3.1	2.2	1.4	0.7

SlimCS (P_f: 3GW) FW (W Thickness=0.2mm) 2 FPY



Y. Someya, K Tobita, Estimation of decay heat in fusion DEMO reactor, Plasma and Fusion Research **7** (2012) 2405066.

Shut down
•Primary cooling system -> Maintenance cooling system
≈ 1 month later (Tritium removal from sector)
•Sector is kept at 40°C
Start (N_2 gas-puffing)

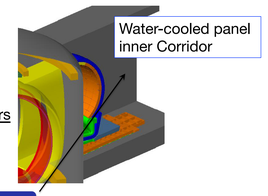
Cryostat / Hot cell

11hr
•Cooling stop on replaced sector
•Cutting of coolant pipes

18hr
•Port cover removal (Cutting of lip-seal on maintenance port)

3hr
•Pull out (including wheeled plat-form insert)
•Sector transport (velocity: 1.6m/min)
•Sector transport and installation
•Cooling

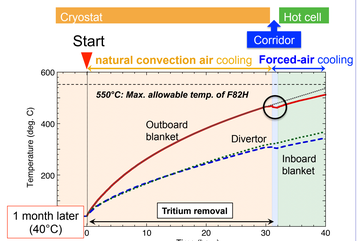
Total: 32hours



forced-air cooling

Tritium release can be suppressed by temperature drop.

Temperature evolution of components by 1D heat conduction analysis



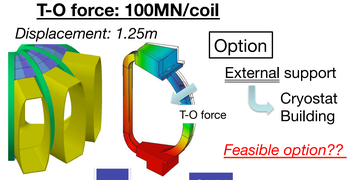
- Temp. of sector would NOT exceed the max. allowable temp. of F82H (550°C), when the cool down time is one month in which the sector is kept at 40°C.
- Sector should be transported to hot cell within 40 hours in the case the cool down time is one month

Critical issue ①

How to support enormous turnover forces of the TF coils

T-O force: 100MN/coil

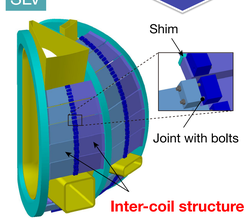
SAH *Displacement: 1.25m*



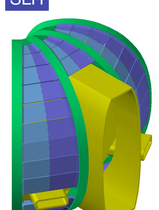
Option: External support → Cryostat Building

Feasible option??

SLV



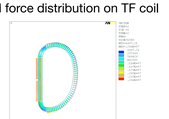
SLH



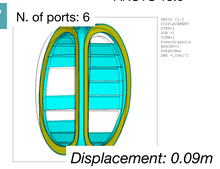
Structural analysis by FE analysis

Analysis code: ANSYS 13.0

EM force distribution on TF coil

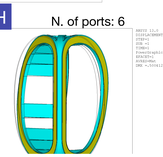


SLV N. of ports: 6



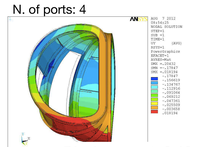
Displacement: 0.09m

SLH N. of ports: 6



Displacement: 0.50m

N. of ports: 4



Displacement: 0.18m

By limiting the number of maintenance ports, sufficient inter-coil structure supporting T-O forces can be installed.

Critical issue ②

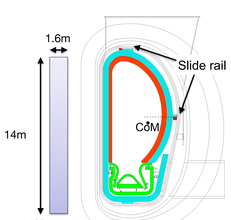
Sector transport in reactor

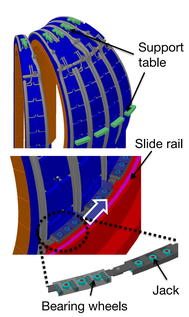
The limited number of maintenance ports maintenance schemes require the **two direction** transferring mechanism of sector in the vacuum vessel.

Key design factor:
feasibility of the sector transferring mechanism **considering the radiation resistance**

SLV

CoM, lower than the slide rail to avoid overturning



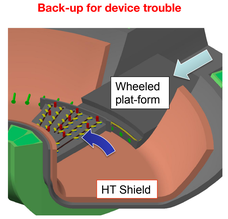


Bearing wheels and Jack (maximum load rating of 30 ton/jack)

SLH

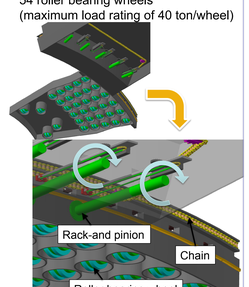
The sector is transferred with the wheeled plat-form

Trans. mechanism in T direction:
Rack-and pinion + Chain
Back-up for device trouble



The driving source of sector transport could be arranged in behind the gamma shield.

54 roller bearing wheels (maximum load rating of 40 ton/wheel)

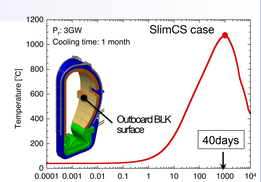


Discussion ~In the case of TROUBLE~

The severest trouble case in remote maintenance:
Sector stop in the reactor after cutting of coolant pipes

Cooling system: only natural convection air cooling

The max. temp of OB BLK surface increases to ~1100°C at ~40 days after maintenance start.

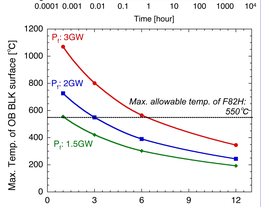


In SlimCS case, necessary cooling time is

P_f=3GW >6month
P_f=2GW >3month
P_f=1.5GW >1month

Trade-off with plant availability

In order to keep bellow 550°C allowable temp. of F82H



Review of core configuration including additional cooling system in cryostat would be required for severe trouble case on RM