8.8 In Hot Cell Repair/Maintenance Equipment

8.8.1 Function, Basic Configuration and System Boundaries

The hot cell (HC) facility provides space and handling facilities for the following operations on highly radioactive and/or contaminated tokamak in-vessel components and materials;

- Receiving/dust cleaning
- Refurbishment for divertor cassettes, blanket modules, port plugs
- Common storage
- Radwaste processing and storage
- Port plug equipment testing

Configuration
(1) Hot cell docking has to receive transfer casks with radioactive components through an air lock from the tokamak building. Activated dust from delivered components and RH tools is removed in the dust cleaning area. Components before repair/waste processing and after repair are stored in the storage cell.

The docking facility shall be sufficient to provide the required component receiving and dispatching capacity for transfers from the tokamak pit to the HC and transfers from the HC to the VV during a single 8-hour night shift as required to stay within the allowable maintenance times and meet the hot cell throughput capacities.

(2) The HC component repair system performs disassembly, replacement of parts, re-assembly, and inspection/testing. The processing function includes evaluation and segregation of components that must be replaced.

An in-line repair/refurbishment processing strategy has been adopted as it is deemed to minimize storage space requirements and the size of the hot cell.

Processing capacity shall be provided to meet the required replacement schedule.

(3) The HC waste processing and storage system stores solid radioactive materials which have been removed from the tokamak and which will be discarded.

(4) Waste Processing includes cutting, preparation of samples for material evaluation, containerisation of radwaste, and removal of tritium from plasma first-wall component surfaces, if required.

8.8.2 Requirements

8.8.2.1 Environmental Conditions for Hot Cell Repair/Maintenance

Typical operating conditions for in-hot cell repair maintenance are:

- Atmosphere: dry air (in hot cell);
- Pressure: 1 bar absolute;
- Temperature: ~ 40°C
- Radiation < Max 75 Gy/h (surface of blanket module 10^6 s after shutdown)
- Contamination: tritium, activated dust, beryllium;
- Estimated tritium release rates from components are given in Table 8.8-1.

- Magnetic field: zero.

Table 8.8-1 Tritium Release Rate from Components

Component	Tritium release rate
Divertor	1.5 Ci/hr/one divertor cassette
Blanket	0.2 Ci/hr/one blanket module
Limiter	0.4 Ci/hr/limiter
Port plugs	0.4 Ci/hr/eq.port plug, 0.2 Ci/hr/upp.port plug

Components decay heats at 1 month after shutdown are given in Table 8.8-2.

Table 8.8-2 Component Decay Heat 1 Month after Shutdown

Components	Decay heat
Divertor	0.58 kW = 0.166 kW/m^2*3.5m^2/cassette
Blanket	0.75 kW = 0.249 kW/m^2*3m^2/module

8.8.2.2 Maintenance

The main requirements are detailed in Tables 8.8-3, 8.8-4 and 8.8-5 for the storage, radwaste, and equipment repair facilities.

8.8.2.3 Shielding

Sufficient shielding shall be provided by the following facilities to allow hands-on maintenance;

- Port plug equipment testing area
- RH tool repair room

8.8.2.4 Reliability

All hot cell maintenance equipment shall be conservatively designed with factors of reliability to render failure extremely unlikely during the life of the machine.

8.8.2.5 Durability

All hot cell maintenance equipment shall be designed to last the life time of the machine.

8.8.2.6 Access

Man access is required to the following facilities;

- Port plug equipment testing area
- New parts storage room and equipment maintenance room (the door of the common refurbishment cell has to be closed during personnel access)
- RH tool repair room
- Cask docking area and air lock (access precluded when cask transfer and docking operations are occurring)

8.8.2.7 Space and Interface

The hot cell facility shall comply with the following requirements:
- The hot cell facility shall be optimised against cost. It is imperative that the dimensions are kept within a reasonable size.
- The amount of tritiated water generated by the hot cell ADS/VDS plant, as well as by operations inside the hot cell, must be minimised.

8.8.2.8 Occupational Radiation Exposure Limits

In-hot-cell maintenance must comply with the ALARA principles (see the PSR and PDS).

8.8.3 Codes and Standards

- Control system standards:
  - IEC 204-1,1992: Electrical equipment of industrial machines, or
  - ANSI/NFPA 79: Electrical standard for industrial machinery
- Machinery (Robot) safety standard:
  - ISO 10218, 1992 Manipulating industrial robots. Safety, or
  - ANSI/RIA R15.06-1992 Industrial robots and robot systems. Safety requirements
- Pressure vessel structure: ASME section VIII can be applied.
- Welding and inspection: generic at the time of procurement
- Materials: generic at the time of procurement
- Standard control system items: generic at the time of procurement

Table 8.8-3 Hot Cell Throughput Matrix

Equipment	Number	Dimensions (m)	Weight (tonne)	Process	Outlet Level
Blanket Module					
Primary first wall module	421	(1.25-2.0) x (0.7-1.4) x 0.4	2.2-4.6	Dispose/repair	Equatorial
Port Limiter	2	2.1 x 1.7 x 0.4	4.5	Dispose/repair	
Test Blanket Module Frame/shield plug	3	3.5L x 2.1H x 1.7W	40	Dispose/repair	Equatorial
Divertor					
Standard divertor cassette	45	3.4L x2.5H x 0.8W	12	Repair/dispose	Lower
Second divertor cassette	6				
Diagnostics divertor cassette	3				
Pellet Injector	3	6L x 3.5H x 2.4W	35	Repair/dispose	Lower
Cryopump					
Valve of cryogenic pump	10	1.5 x 1.5L	2	Dispose/repair	Lower
Cryopump	10	1.73 x 3.5L	9.5	Dispose	
ICH&CD Module	2	3.5L x 2.1H x 1.7W	40	Dispose/repair	Equatorial
ECH&CD Module	5				
EC launcher	2 (24 windows/ 3 mirrors)	3.5L x 2.1H x 1.7W	40	Dispose/repair	Equatorial
EC launcher	3 (8 windows/ 8 mirrors)	6.15L x 1.3H x 1.3W	13	Dispose/repair	Upper
Neutral Beam Injector					
Neutral beam ion source	3	3.16 x 2.73L	12	Dispose/repair	Equatorial
NB injector filaments, 12 holders-1 NB injector	(6F x 12H) x 3 NB injectors	0.315 x 0.06 x 0.05 (holder sizes)	6 kg/holder	Dispose	
Cesium oven	2x3 Sources	0.15 x 0.3L	5 kg/oven	Dispose	
First shutter actuator	3	2L x 0.4H x 0.3	0.2	Dispose	
Diagnostics					
Equatorial port Diagnostic plug/limiter port plug	6	6.15L x 1.3H x 1.3W	40	Dispose/repair	Equatorial
Divertor port Diagnostic block rack	5	4L x 1.4W x 2.2H	Variety	Dispose/repair	Lower
RH diagnostic plug	2	3.5L x 2.1H x 1.7W	40	Dispose/repair	Equatorial
Upper port diagnostic plug	15	6.15L x 1.3H x 1.3W	13	Dispose/repair	Upper
IVV/GDC Probes	6	Note 1	Note 1	Dispose/repair	Lower

Note 1: Information not yet available

Table 8.8-4 Requirements for Waste Disposal

Equipment	The part to be disposed	Property		
		Material	Dimension of piece (m)	Expected Rate (1/year)
Blanket				
First wall module	4 ~ 6 first walls/module	Be/Cu/SUS	0.4 x (0.7-1.4) x t 0.08	(4 ~ 6) x 429/10 yrs
	Shield block	SUS	(1.25-2.0) x (0.7-1.4) x 0.4	3
Port Limiter	Limiter	Be/Cu/SUS	2.1 x 1.7 x 0.4	2 x 1/2 yrs
Test Blanket Module Frame/shield plug	Test blanket module	Variety	0.6(D) x 1.7(H) x 0.5(W) 0.6(D) x 0.7(H) x 1.3(W)	EU-HT: 7/10 yrs JA-HT: 6/10 yrs RF-HT: 6/10 yrs+1/1 yr
Divertor				
Standard divertor cassette	HHFC* (dome-liner)	W/CFC/Cu	2(L) x 1(H) x 0.8(W)	45 x 3/10 yrs
	HHFC* (inner/outer vert. target)	W/CFC/Cu	1.5(L) x 1(H) x 0.8(W)	2x 45 x 3/10 yrs
Second divertor cassette	HHFC* (dome-liner)	W/CFC/Cu	2(L) x 1(H) x 0.8(W)	6 x 3/10 yrs
	HHFC* (inner/outer vert. Target)	W/CFC/Cu	1.5(L) x 1(H) x 0.8(W)	2x 6 x 3/10 yrs
	Diagnostics	Variety	Note 1	6 x 1/4 yrs
Diagnostics divertor cassette	HHFC* (dome-liner)	W/CFC/Cu	2(L) x 1(H) x 0.8(W)	3 x 3/10 yrs
	HHFC* (inner/outer vert. Target)	W/CFC/Cu	1.5(L) x 1(H) x 0.8(W)	2x 3 x 3/10 yrs
	Mirror assembly	Variety	Note 1	3 x 1/4 yrs
Pellet Injector	Pellet injector	Note 1	Note 1	Note 1
Cryopump				
Valve of cryogenic pump	Valve drive shaft	Variety	φ0.5 x 1	10 x 3/20 yrs
	Valve disk	Variety	φ1.0 x 0.5	10 x 3/20 yrs
	Valve seat	Variety	φ1.0 x 0.1	10 x 3/20 yrs
ICH&CD Module	Faraday shield (front)	Variety	0.6(L) x 2.1(H) x 1.7(W)	2 x 5/20 yrs
ECH&CD Module	Outer valve block assembly		0.5(L) x 2.2(H) x 1.5(W)	Note 1
	Steerable mirror module unit	Variety	Note 1	Equatorial:2x3 mirrorsx5/20 yrs Upper:3x8 mirrorsx5/20 yrs
NB Injector				
Ion Source	Set of grids, etc.	Variety	φ3.16 x 2.73L	Note 1
Filaments, 12 holders (1set)/NB injector	Set of filaments (12 holders/1 NB injector)	Tungsten,etc.	0.315 x 0.06 x 0.05	2
Cesium oven	Cesium oven		φ0.15 x 0.3	2
First shutter actuator	First shutter	SUS/Sm2Co17,etc.	2L x 0.4H x 0.3H	Note 1
Diagnostics				
Equatorial port diagnostic plug /IVT/limiter port plug	Mechanical/electrical/ optical parts	Variety	Note 1	6 x 1/4 yrs
Divertor port diagnostic block	Mechanical/electrical/ optical parts	Variety	Note 1	5 x 1/4 yrs
RH diagnostic plug	Mechanical/electrical/ optical parts	Variety	Note 1	2 x 1/4 yrs
Upper port diagnostic plug	Mechanical/electrical/ optical parts	Variety	Note 1	15 x 1/4 yrs
IVV/GDC Probes	IVV system, etc.	FRP,Al,Glass	(6 m^3, 250 kg)	6 x 1/10 yrs

* HHFC – high heat flux component

Note 1: Information not yet available

Table 8.8-5 Requirements for Repair Operations

Equipment	Maintenance Item	Repair Operation			
		Average Rate	Maximum Rate	Transfer Method	
				Transfer Size (m)	Cask Type
Blanket Module					
Primary first wall module	Replacement of branch pipes	2/yr	20/yr	(1.25-2.0) x (0.7-1.4) x 0.4	Equatorial ports Standard cask
	Replace shear keys	2/yr	20/yr		
	Replace electrical straps	2/yr	20/yr		
	Replace flexible connectors	4/yr	20/yr		
	Test for leaks and flow blockage	2/yr	20/yr		
	Clean surfaces	2/yr	20/yr		
Port Limiter					
Limiter	Replacement of limiter	2/yr	4/yr	2.1 x 1.7 x 0.4	Equatorial ports Standard cask
	Test for leaks and flow blockage	2/yr	4/yr		
	Clean surfaces	2/yr	4/yr		
Test Blanket Module	Replacement, coolant leak/blockage test	1/yr	4/yr	3.5L x 2.1H x 1.7W	Equatorial ports Standard cask
Divertor		(Cassettes)	(Cassettes)		
Standard cassette	Replace all HHF* components	45/3yr	45/yr		
	Replace inner and outer shoes	45/ 10 yr	45/3 yr	3.4 x 2.5 x 0.8	Divertor cask
	Test for leaks and flow blockage	45/3 yr	45/yr		
Second cassette	Replace all HHF* components	6/3 yr	6/yr		
	Replace inner and outer shoes	6/10 yr	6/3 yr		
	Replace and test diagnostics	6/3 yr	6/yr	3.4 x 2.5 x 0.8	Divertor cask
	Test for leaks and flow blockage	6/3 yr	6/yr		
Diagnostics cassette	Replace all HHF* components (different from standard and second cassettes)	3/3 yr	3/yr		
	Remove/reinstall mirror assembly-check alignment	3/3 yr	3/yr	3.4 x 2.5 x 0.8	Divertor cask
	Repair/machine damaged bottom of cassette body	2/3 yr	2/yr		
	Test for leaks and flow blockage	3/3 yr	3/yr		
Pellet Injector	Repair Injector	1/yr	1/yr	6 x 3.5 x 2.4	Note 1
Cryopump					
Valve of cryogenic pump	Valve plug and helico-flex seal replacement	2/yr	2/yr		
	Bellows replacement	1/yr	2/yr	1.5 x 1.5L	Cryopump cask
	Valve drive replacement	1/yr	2/yr		
	Visual inspection of actuator operation, valve stroke and plug alignment	1/yr	2/yr		
Cryopump (non-repair)	Cryopump replacement	-	-	1.73 x 3.5L	-
ICH&CD Module					
	Replacement of Faraday shield	1/10 yr	2/10 yr	3.5L x 2.1H x 1.7W	Equatorial ports Standard cask
	Replace coaxial pipe	1/10 yr	2/10 yr		

* HHF – high heat flux

Note 1: Information not yet available

Table 8.8-5 Requirements for Repair Operations (cont'd)

Equipment	Maintenance Item	Repair Operation			
		Average Rate	Maximum Rate	Transfer Method	
				Transfer Size (m)	Cask Type
ECH&CD Module					
ECH&CD module mirror block assembly (EC launcher)	Replace/repair mirror drive mechanism	1/yr	2/yr	Equatorial:3.5 Lx2.1Hx1.7W Upper:6.15Lx 1.3Hx1.3W	Equatorial ports Standard cask Upper pot Diagnostic cask
	Clean mirror	1/yr	2/yr		
	Repair small mirror leak	1/10 yr	1/3 yr		
	Replace mirror block	1/10 yr	2/10 yr		
Neutral Beam Injector					
NB beam ion source	Ion source replacement	Note 1	Note 1	3.16 x 2.73L	NB cask
NB injector filaments (non-repair)	Filament replacement	2/yr	Note 1	0.315 x 0.06 x 0.05	-
Cesium oven (non-repair)	Cesium oven replacement	2/yr	Note 1	0.15 x 0.3L	-
First shutter actuator	First shutter replacement	Note 1	Note 1	2L x 0.4H x 0.3	
Diagnostics					
Equatorial port diagnostic plug/ limiter port plug	Mechanical repairs and parts replacements	1-2/year	2/year	6.15L x 1.3H x 1.3W	Equatorial ports Standard cask
	Electrical repair and parts replacement	1-2/year	2/year		
	Optical repair and parts replacement	1-2/year	2/year		
	Test for leaks	1-2/year	2/year		
Divertor port diagnostic block rack	Mechanical repairs and parts replacements	4/3 yr	4/yr	4L x 1.4W x 2.2H (TBD)	Divertor cask
	Electrical repair and parts replacement	4/3 yr	4/yr		
	Optical repair and parts replacement	4/3 yr	4/yr		
	Test for leaks	4/3 yr	4/yr		
RH diagnostic plug	Mechanical repairs and parts replacements	Note 1	Note 1	3.5L x 2.1H x 1.7W	Equatorial ports Standard cask
	Electrical repair and parts replacement				
	Optical repair and parts replacement				
	Test for leaks				
Upper port diagnostic plug	Mechanical repairs and parts replacements	Note 1	Note 1	6.15L x 1.3H x 1.3W	Upper port Diagnostic cask
	Electrical repair and parts replacement				
	Optical repair and parts replacement				
	Test for leaks				
IVV/GDC Probes	Replacement of IVV system, etc.	Note 1	Note 1	Note 1	IVV cask

* HHF – high heat flux

Note 1: Information not yet available