8.3 Blanket Handling Equipment

8.3.1 Functions, Basic Configuration and System Boundaries

The blanket handling system shall provide the following overall functions:
- Blanket module transportation into and out of the VV
- Blanket module removal from and replacement to the VV wall
- Cooling pipe connection/disconnection
- Bolting for fixing modules by flexible supports
- Leak testing of cooling pipes joints

The blanket RH system consists of the in-vessel transporter (IVT), the blanket transporter, pipe welding/cutting tools, pipe inspection tools, bolting tools, in-cask storage rack, rescue tools, and the control system.
Specific functions, configuration and system boundary are as follows.
The in-vessel transporter (IVT) will provide the functions of transporting and handling blanket modules and tools inside the VV. The IVT is composed of the following elements; vehicle manipulator, blanket handling gripper, articulated rail, rail support device, rail deploying equipment, and umbilical and cable handling equipment.
Vehicle manipulator
- The vehicle manipulator consists of a vehicle travelling along the rail, incorporating a telescopic manipulator capable of accessing all in-vessel areas except the divertor area.

Blanket handling gripper
- A blanket handling gripper, mounted on the end of the telescopic manipulator and providing the functions of gripping a blanket module and temporarily bolting it to the VV wall using the earth strap fixations.

Articulated rail
- Two semi-circular rails, deployable from two RH ports, forming a continuous toroidal rail when installed. As an option, two rails with 100°/80° segmentation, deployable from 2 RH ports.

Rail support device
- Rail support by dedicated supports located in RH ports, which assist in the deployment of the final rail elements.

Rail deploying equipment
- Rail installation by dedicated vehicle manipulator that is inserted into the vessel where it assembles and deploys the rails.

Umbilical and cable handling equipment
- To handle the long complex umbilical during 180° vehicle and manipulator travel.

Bore Tool System
- The blanket bore tool system provides a set of tools to enable the cutting, welding and inspection of the blanket module water cooling pipes.

Bolting tool
- For handling the flexible support bolts for securing blanket modules and likewise the earth strap fixing bolts.
- These tools access blanket modules from the plasma side of the modules.

Blanket transporter
- Transports blanket modules and tools through the remote handling port located at the equatorial level, and delivers them to the IVT.

Rescue tool
- Allows the vehicle manipulator mechanism to be actuated from outside the VV in the

event of a vehicle manipulator locomotion malfunction.

In-cask Storage Rack

- To reduce the docking and transportation duration to and from the tokamak building, an in-cask storage rack provides storage for three modules inside the RH cask.

Control system

Controls all RH devices in such a way that four vehicle manipulators, together with all associated blanket RH handling can operate simultaneously at all four designated VV ports. Control is implemented using local programmable handheld control panels (commissioning and first training) or remotely from the control-room using workstations (normal RH configuration).

8.3.2 Requirements

8.3.2.1 Environmental Conditions during Blanket Maintenance

Typical operating conditions for blanket maintenance are:

- Atmosphere: Nitrogen or dry air
- Pressure: 1 bar absolute
- Temperature: < 50°C (TBD);
- Humidity: ~ 0 % (TBD)
- Gamma radiation dose rates: (10^6 s after DRG1 operation)
  - In-Vessel: Max 470 Gy/hr
  - Inside the remote handling port: (TBC) Sv/h
  - Module contact: ~ 75 Sv/h
  - Between the primary closure plate (in place) and the cryostat: ~ 400 μSv/h
- Contamination: tritium, activated dust (C, Be and W)
- Magnetic field: zero.

8.3.2.2 Maintenance

- The blanket is segmented into 421 modules. There are 30 different kinds of blanket module in terms of configuration, size and weight. These blanket modules are located in all areas of the VV wall, with the exception of the divertor area. Therefore, the blanket remote handling system shall be designed to handle the complete spectrum of module size, shape and location.
- The RH maintenance interface is at the plasma face of the modules, where gripper holes and access holes for cooling pipe cutting/connecting are located, as well as the earth strap bolting and blanket module bolted fixations.
- Maximum payload of the IVT is 4.5 t, corresponding to the maximum module weight.

8.3.2.3 Radiation Hardening

The blanket RH equipment and tools shall be composed of radiation hard components (motors, sensors, lubricant, cables, etc.) with a lifetime of at least 2,160 hours (90 days) continuous operation under a gamma radiation dose rate of 470 Gy/hr. The radiation hardness target lifetime shall be least one order of magnitude higher.

8.3.2.4 Reliability

All RH equipment and RH interface shall be rescueable.

- A live vehicle manipulator will handle the rescue tool to access the damaged vehicle.
- The vehicle manipulator shall incorporate redundant mechanisms to allow the manipulator to be driven from outside the VV.

All RH equipment shall never break confinement barriers including under specified seismic conditions (see the PSR and the DRG1).

8.3.2.5 Lubricant Leak-Free

The blanket RH items involving lubricants such as oil, grease or solid lubricant, must be designed to be leak-free (seals, containers and leak detector, etc.).

8.3.2.6 Decontamination and Maintenance (ex-vessel)

The divertor RH equipment shall be designed in such a way that it can be easily decontaminated in a hot cell, and serviced and repaired by hands-on methods.

8.3.2.7 Standardization

In order to simplify the maintenance of the blanket RH equipment, items such as irradiation hard components (motors, sensors, lubricant, cables, etc.), RH bolts, hooks, RH connectors etc. shall be standardized as much as practical.

8.3.2.8 Access

Four dedicated equatorial RH ports shall be used. The RH equipment and blanket modules shall be transported into of the vacuum vessel through these RH ports.

For transportation of the blanket RH equipment and blanket modules, RH transfer casks shall be used. Therefore, the size of all blanket RH equipment shall be compatible with the RH cask size.

8.3.2.9 Handling

The blanket RH equipment shall include gripping features such as hooks.

8.3.2.10 Materials Compatibility with the VV Interior

All materials shall be compatible with the requirements of the ITER vacuum design handbook.

8.3.3 Codes and Standards

Methods of gamma ray irradiation testing shall be defined and standardized to estimate the results of irradiation tests produced from different facilities.

Industrial codes and standards shall be used as guidelines for the design, manufacturing and testing of the blanket remote maintenance equipment, including the following.

- 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
- 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