8.2 Divertor Handling Equipment

8.2.1 Functions, Basic Configuration and System Boundaries

The divertor remote handling equipment has the following functions and basic configuration:

1) Cassette multi-functional mover (CMM)
The cassette multi-functional mover (CMM) implements the radial transport of components along the inclined RH ports in a cantilevered configuration. It includes a common tractor and a set of changeable end-effectors designed to accommodate the various component requirements. End-effector changeover is an automatic operation performed in the hot cell after cask docking.
2) Cassette toroidal mover (CTM)
The cassette toroidal mover (CTM) implements the toroidal transport of cassettes from the RH port location to their final assembly location inside the vacuum vessel. In addition, it performs RH operations such as cassette locking, inspection and possibly, some rescue operations. It is introduced into the vacuum vessel using the CMM end-effector for second cassette handling.
3) Manipulator arm (MAM)
The MAM is a dextrous manipulator arm (including associated tools and tools boxes) capable of performing RH operations in-vessel and inside the connection duct. The MAM can be incorporated into and work in conjunction with, the CTM, the tractor of the cassette multi-functional mover (CMM), possibly the CMM end-effector for second cassette locking (inboard support only), and the cassette toroidal movers.
4) Bore Tool System
The divertor bore tool system implements the cutting, welding and inspection of the divertor cassette water cooling pipes routed along the 18 divertor ports.
5) Divertor rails
The toroidal rails, in conjunction with the cassette supports, implement the alignment and attachment of the cassette, and secure it to withstand the loads imposed during plasma operation. During cassette handling, the toroidal rails guide and support the cassette toroidal mover inside the vessel.
6) Control system
Control is implemented both locally using local programmable handheld controllers (commissioning and first training) and remotely from the control-room using workstations.

The in-vessel ITER divertor RH equipment includes the following:

- The cassette multi-functional mover (CMM), consisting of:
  - The CMM tractor and umbilical
  - The end-effector for standard cassette handling
  - The end-effector for second cassette handling
  - The end-effector for central cassette handling
  - The end-effector for second cassette locking
- The cassette toroidal movers (CTM) and umbilical
- Manipulator arms (MAM)
- Pipe bore tools
- Control system

8.2.2 Requirements

8.2.2.1 Environmental Conditions during Divertor Handling

- Gas: Nitrogen or dry air
- Pressure: ~ 1 bar
- Temperature: < 50°C (TBD)
- Humidity: ~ 0 % (TBD)
- Gamma radiation dose rates: (10^6 seconds after DRG1 operation)
  - in-Vessel: Max 470 Gy/hr
  - inside the duct: $5x10^4$ μSv/h (temporary value to be reevaluated by NAG when design of ports is fully defined)
  - cassette contact: ~ 75 Sv/h (TBD)
  - between the primary closure plate (in place) and the cryostat: ~ 130 μSv/h (without penetration. Shielding reinforcement of the RH port is on-going, temporary value to be reevaluated by NAG when design of ports is fully defined)
- Contamination: tritium, activated dust (C, Be and W)
- Magnetic field: zero

8.2.2.2 Maintenance

Components to be handled;

a) Standard cassette:
- Weight: ~ 11.2 t
- Related RH operations: locking/securing-unlocking of the supports, cassette handling and positioning, pipe cutting, welding and inspection

b) Central (or diagnostic) cassette:
- Weight: ~ 12.9 t
- Related RH operations: locking/securing-unlocking of the supports, cassette handling and positioning, pipe cutting, welding and inspection

c) Second cassette:
- Weight: ~ 11.2 t
- Related RH operations: locking/securing-unlocking of the supports, cassette handling and positioning, pipe cutting, welding and inspection

d) Diagnostic rack:
- Weight: ~ 5 t
- Related RH operations: locking/securing-unlocking of the supports, connections, handling and positioning

e) Primary closure plate:
- Weight: ~ 5 t
- Related RH operations: flange bolting/securing-unbolting, lip seal cutting, welding, inspection and plate handling and positioning, pipe cutting, welding and inspection

f) Cassette toroidal mover:
- Weight: ~ 3 t
- Related RH operations: handling and positioning, umbilical installation and connection

Expected number of replacements

One full divertor over the ITER lifetime: ~ 4.
One instrumented cassette or one diagnostics cassette over the ITER lifetime: ~ 4.
One non-instrumented cassette over the ITER lifetime: ~ 4.

- The time needed for replacement operations shall be:
  For the entire divertor < 6 months.
  For one cassette < 8 weeks.

8.2.2.3 Radiation Hardening

The divertor RH equipment and tools shall be composed of radiation-hard components (motors, sensors, lubricant, cables, etc.) the life times of which are at least 1,000 hours (40 days) in continuous operation under a gamma radiation dose rate of 470 Gy/hr for the CTM and of $5x10^4$ μSv/h for the CMM.

8.2.2.4 Reliability

All RH equipment and divertor RH interfaces (rails, supports, pipes) shall be rescueable All RH equipment and divertor RH interfaces shall not breach confinement barriers including operation under specified seismic conditions (see the PSR and the DRG1).

8.2.2.5 Lubricant Leak-Free

Leak-free lubricant systems are required. The materials, lubricants and level of cleanliness involved in the manufacturing of the RH equipment shall be compatible with the requirements of the ITER vacuum design handbook.

8.2.2.6 Decontamination

It shall be easy to decontaminate the RH equipment.

8.2.2.7 Standardisation

All the remote handling equipment shall be standardised to the greatest extent practicable. This shall include items such as radiation-hard components (motors, sensors, lubricant, cables, etc.), RH bolts, hooks, RH connectors and other RH elements.

8.2.2.8 Access Requirements

The 3 divertor RH ports, together with the 2 hot cell ports and the related divertor RH equipment shall be capable of parallel operation (that is, operating at all 3 ports at any given time).

The divertor bore tools shall be compatible with the internal geometry of the curved divertor cooling pipes.

8.2.2.9 Space/Interfaces

The maximum step between 2 adjacent divertor high heat flux components inside the vessel should not exceed 4 mm.

All supports should be locked and secured.

8.2.3 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
- 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