25 Hot Cell Processing and Waste Treatment

25.1 Functions, Basic Configuration and System Boundaries

The hot cell processing and waste treatment system shall be designed to perform the functions described in DRG1. These are given in more detail below.

25.1.1 Functions

The functions of the hot cell processing system are as follows:
- receive transfer casks with radioactive components from the tokamak building;
- off-load radioactive components into receiving cell;
- on-load, off-load and/or change remote handling (RH) tools of transfer casks;
- load transfer casks with repaired/new components;
- remove activated dust from delivered components and RH tools;
- repair/refurbish components, RH tools and transfer casks;
- test components, RH tools and transfer casks after repair/refurbishment;
- store components, RH tools and transfer casks before and after repair;
- process and store solid radioactive material which has been removed from the tokamak and which will be discarded;
- develop, qualify and test remote handling equipment and procedures to be used for maintenance of tokamak in-vessel components.

The functions of the waste treatment system are as follows:
- process solid and/or liquid waste process streams which are generated by ITER operation, maintenance and decommissioning and which have become contaminated with radioactive materials;
- process toxic and non-toxic non-radioactive solid and/or liquid waste materials, which are generated by ITER operation, maintenance and decommissioning.

25.1.2 Configuration

The hot cell processing and waste treatment system comprises the following major systems:
- the hot cell docking and storage system;
- the hot cell component repair/test system;
- the hot cell waste processing and storage system;
- the low-level radioactive waste processing system;
- the non-radioactive waste processing system.

25.2 Design Requirements

25.2.1 Hot Cell Processing

25.2.1.1 <u>General</u>

25.2.1.1.1 Reliability

All hot cell systems and equipment shall be designed so that the probability of a system or component failure which could contribute more than 1 month of hot cell unavailability is less than 10^{-2}/year.

25.2.1.1.2 Component Receiving Capacity

The common receiving and storage cell with two docking ports shall provide the normal in-vessel component receiving capability for one divertor cassette, two or three blanket modules or any other component that is unloaded from a transfer cask through a divertor or blanket port adapter (port plug, cryopump/cryovalve, divertor diagnostic rack) during a single 8 hour night shift.

Two special docking ports (test tanks) shall allow the tokamak port plug refurbishment from inside the repair/refurbishment hot cell area and hands-on maintenance at the front side of the plugs, including functional testing.

A dedicated docking port for the NB ion source transfer cask shall provide direct-access docking from inside the tokamak NB cell for maintenance operations on NB ion sources.

25.2.1.1.3 Storage Capacity for Tokamak In-Vessel Components

In order to support the process operations a storage space shall be provided. The storage capacity of the receiving/storage cell shall be as follows:

16 divertor cassettes
4 blanket modules
4 upper port plugs or 3 divertor diagnostic racks
4 equatorial port plugs

25.2.1.1.4 Storage Capacity for Remote Handling Tools

The hot cell docking and storage system shall provide sufficient storage/repair capacity for all remote handling tools anticipated to be required during tokamak maintenance. Rotation of the RH tools within the component receiving/storage cell shall correspond to the operational sequence of the component replacement schedule.

25.2.1.1.5 Storage Capacity for Transfer Casks

The remote handling equipment test stand area of the hot cell building shall provide sufficient storage capacity for transfer casks (except for the NB ion source transfer cask) anticipated during tokamak maintenance.

25.2.1.1.6 Repair/Testing Capacity

The hot cell component repair/testing system shall be capable of processing a complete divertor set (54 divertor cassettes) within 6 months (replace all insert parts and testing cassette). Other processing capacity shall be optimised for minimum total cost of storage and processing capacity provided that the tokamak operating schedule is not impacted.

25.2.1.1.7 Waste Processing Capacity

The hot cell waste processing and storage system shall be optimised for minimum total cost of waste storage and processing. The system shall be designed such that the average processing capacity must equal the possible average capacity of waste generation.

25.2.1.1.8 Storage Capacity for Radwaste

The hot cell waste processing and storage system shall provide sufficient storage capacity for properly packaged radwaste for a storage period of six months before shipping it offsite. If required by the Host Party, the size of the storage capacity can be increased to hold all the radwaste generated during ITER operation.

25.2.1.1.9 Layout

All hot cell systems and equipment shall be designed to operate within the hot cell building, and generally within the hot cells. Operation staff of all hot cell systems and equipment must be shielded from radiation and protected from toxic hazards, and able to conduct their work remotely (i.e. by using control and instrumentation systems).
The hot cell building shall be designed in such a way that its operating space can be extended if required.

25.2.1.2 Structural

25.2.1.2.1 Support

All hot cell systems and equipment shall provide sufficient support consistent with applicable codes and standards as well as good engineering practice for high reliability.

25.2.1.2.2 Confinement Compatibility

All hot cell systems and equipment shall be compatible with the structure of the hot cell building for the confinement of tritium, activation products and other hazardous materials for the protection of workers and the public.

25.2.1.2.3 Leak Rate

All hot cell systems and equipment shall designed such that they do not increase building inleakage under negative pressure beyond the design basis of 100% of the room volume per day.

25.2.1.3 Thermohydraulic

25.2.1.3.1 Decay Heat Removal

The decay heat generated inside the hot cells by the components and/or radwaste will passively transfer to the air and shall be removed by the ADS/VDS systems.

25.2.1.3.2 Machinery Heat Removal

Hot cell machinery shall avoid the use of water cooling. Air and nitrogen shall be used as the cooling mediums.

25.2.1.4 Mechanical Requirements

Hot cell equipment shall be designed to be removed from the processing areas and decontaminated so that maintenance activities can be performed "hands-on". All fasteners and other mechanical devices that affect handling and decontamination shall be selected so that equipment can be removed to maintenance area.

25.2.1.5 Electrical

25.2.1.5.1 Voltage

Hot cell equipment voltages shall be in conformance with the IEC-38 standard nominal voltages.

25.2.1.5.2 Radiation Hardening

Electrical equipment and cable insulation shall be able to operate in its radiation environment with no significant degradation due to radiation damage. Insulation lifetime shall be evaluated and a replacement schedule prepared if necessary.

25.2.1.5.3 General Grounding

The hot cell equipment shall be designed to use the building grounding system to ground equipment where required.

25.2.1.6 Nuclear

All hot cell systems and equipment shall be designed with materials which will operate successfully over their full design lifetime and shall not be subject to unacceptable degradation due to gamma fields created by the components and/or radwaste being stored or processed. Equipment which is located inside the hot cells shall be designed to withstand a peak gamma field intensity of 10^2 Gy/h and a lifetime integrated dose of 10^7 Gray.

25.2.1.7 Remote Handling

25.2.1.7.1 Docking Ports and Adapters

The hot cell docking system shall include exchangeable docking port adapters to allow more than one port to be available for in-vessel component receiving during a maintenance campaign such that a port failure does not cause a serious delay to tokamak maintenance operations.

25.2.1.7.2 RH Tool Changes

The hot cell docking and storage system shall provide the ability to change the RH tools of a transfer cask without undocking the cask.

25.2.1.7.3 Rescue System

The design and arrangement of the system shall be such that the hot cell processing equipment can be retrieved into maintenance rooms, decontaminated and repaired.

25.2.1.8 Seismic

Equipment that can impact confinement or release of radioactive material shall be designed to withstand a SL-2 seismic event.

25.2.1.9 Materials

25.2.1.9.1 Hot Cell Equipment

The hot cell equipment shall be designed for long term tritium compatibility. This requirement discourages the use of exposed rubber, plastic, oils, and other materials that become contaminated with tritium. Materials in contact with tritium should be those that have been proven tritium compatible.

25.2.1.9.2 Electrical Insulation

All cables will be made with copper and should have the 15 kV, 6 kV and 0.6 kV rated insulation voltage for 11 kV. Cable insulation should meet the following requirements:

- insulation material XLPE preferred, PVC not accepted;
- max. permissible temperature of conductor:
  - continuous 90°C,
  - under short circuit conditions 250°C;
- acid gas content zero halogen, according to IEC-754;
- fire retardancy according to IEC-332

Table 25-1 IEC Relevant Material

IEC #	Technical Committee	Title
332-1 to 3	SC 20C	Test on electric cables under fire conditions
728	SC 12G	Cable distribution systems
754	SC 20C	Tests on gases involved during combustion of electric cables
840	SC 20A	Test on electric cables 30 kV to 150 kV

25.2.1.10 ADS, VDS and HVAC

25.2.1.10.1 Pressure Differential Control

The hot cell systems and equipment shall be segregated into locations within ventilation groups characterised by tritium release rates, surface contamination zones, and personnel exposure zones. Each ventilation group has a cascading pressure level so that rooms with lower tritium levels leak into rooms with higher tritium levels.

25.2.1.10.2 Air Temperature Limits

The hot cell equipment shall be designed to function with air temperature ≤ 40°C.

25.2.1.10.3 Relative Humidity Limits

Relative humidity limits shall be specified based on a comprehensive trade-off study of a balance between the requirement for the minimisation of tritiated water generated, the derived air concentration (DAC) level of tritium inside rooms, the air leakage rate in the rooms, the requirements for the civil structure (concrete) and the access zones, and the capacity and cost, respectively, of the hot cell building ADS/VDS/HVAC systems and water detritiation system (WDS).

25.2.1.11 <u>Decontamination</u>

25.2.1.11.1 Dust Decontamination

The component receiving/storage cell shall include equipment for removal of dust from components, RH tools, and internal surface of cask at dock prior to storage/repair. The receiving/storage, repair, waste processing and storage, and equipment maintenance rooms shall have equipment (vacuum brush cleaning) for periodic decontamination of walls, floors and equipment in order to minimise dust contamination.

25.2.1.11.2 Tritium Recovery

The waste processing and storage system shall include the possibility to install equipment for recovery of tritium from radwaste containing significant tritium quantities prior to radwaste storage. This facility can be installed after initial tokamak operation when significant tritium inventories are generated (i.e. > 4 years after start up of DT plasma).

25.2.1.12 <u>Assembly</u>

The hot cell building shall act as the staging facility for the initial in-vessel installation operations. During this time, the hot cell building will be used mainly as a Be-controlled area to prepare the in-vessel components and related jigs and fixtures for assembly in the vacuum vessel.

25.2.1.13 <u>Testing</u>

All hot cell systems which use remote handling equipment shall be designed to be used/tested during tokamak assembly, commissioning and non-radioactive maintenance for both practical and development purposes.

25.2.1.14 Instrumentation and Control

25.2.1.14.1 General Instrumentation and Control

All hot cell systems and equipment shall be designed to include all necessary instrumentation and controls for proper system operation and data archiving. The operation of the system shall be independent of any other signal generations and systems.

25.2.1.14.2 Remote Handling Control

Remote handling operations as well as movement of equipment and materials between cells and workstations shall be controlled, monitored, supervised and coordinated by the central control room of the control building.

25.2.1.14.3 CODAC Interface

All hot cell systems and equipment shall be designed to accept supervisory control from the supervisory control system of CODAC, and shall conform to all signal and command protocol standards established by CODAC. The hot cell processing system shall provide status-reporting signals to CODAC.

25.2.1.15 Surveillance and Inspection

Each tokamak component and container with radwaste placed in the hot cell processing system shall be identified by identification tags which can be scanned and which will enable loading information for the component/container into the computer-operated remote handling equipment. The information includes all previous repairs and dimension/position/radiation measurements for that particular component or container.

25.2.1.16 Decommissioning

All hot cell systems and equipment shall be designed such that after removing activated components and radwaste from the processing and storage cells, the surface and equipment of these cells can be decontaminated for "hands-on" dismantling activities.

25.2.1.17 Quality Assurance (QA)

The hot cell processing system shall be designed, manufactured, tested, commissioned, operated, and decommissioned in compliance with the ITER QA programme as it applies to SIC (safety importance class) systems.

25.2.2 Waste Treatment Design

25.2.2.1 General

25.2.2.1.1 Reliability

The waste processing system shall include sufficient storage capacity (both liquid and solid) to ensure that the operation of the ITER facility is not affected by the removal of the waste processing equipment from service for cleaning, maintenance, repair, or modification.

25.2.2.1.2 Processing Capacity and Storage

The waste processing system shall be able to accommodate all contaminated, non-radioactive toxic and non-toxic waste streams during all anticipated modes of plant operation. Waste processing capacity shall be optimised for minimum total cost of storage and processing capacity.

25.2.2.1.3 Layout

The low-level radwaste processing equipment shall be designed to operate within the radwaste building.
The non-radioactive waste processing equipment shall be based on a concept of designated containers, which are periodically collected at a central handling point within the ITER site. Material collected from within the ITER high security boundary will be handled in the site services building.

25.2.2.2 Structural

25.2.2.2.1 Support

The waste processing equipment shall provide sufficient support consistent with applicable codes and standards as well as good engineering practice for high reliability.

25.2.2.2.2 Leak Rate

The low-level radwaste processing equipment shall not increase the building inleakage under negative pressure in low-level radwaste processing rooms to greater than 100% of the room volume per day at a pressure of -1 mbar (access zone B rooms) and at pressure of -2 mbar (access zone C rooms).

25.2.2.2.3 Thermohydraulic

The low-level radwaste processing equipment shall be designed such that decay heat generated by the materials, which are handled or treated by the system, shall be transferred to the air in the radwaste building by passive means. The heated air will be cooled by the building HVAC system.

25.2.2.3 Mechanical

The low-level radwaste, and the toxic waste portions of the non-radioactive waste processing equipment shall be designed to be isolated and decontaminated so that maintenance activities can be performed "hands-on". All containers used in the waste processing systems shall utilise standard lifting, grappling, and stacking features, suitable for operation using mechanised equipment.

25.2.2.4 Electrical

25.2.2.4.1 Voltage

Equipment voltages shall be in conformance with the IEC-38 standard nominal voltages.

25.2.2.4.2 General Grounding

The building grounding systems shall be used to ground equipment where required.

25.2.2.5 Chemical

Materials, which will be subjected to decontamination, must be compatible with chemical cleaning agents, which can be used in order to assist decontamination prior to "hands-on" maintenance activities.
The liquid waste processing system shall render liquid waste chemically inactive including neutral pH.
Processing equipment and containers shall be constructed from materials that are not subject to chemical degradation from anticipated wastes. If necessary, provisions shall be made for neutralisation of chemically aggressive wastes.

25.2.2.6 Material

The low-level radwaste processing system shall be designed for long term tritium compatibility. Materials in contact with tritium should be those that have been proven tritium compatible. Electrical insulation should follow the requirements identified in 25.2.1.9.2.

25.2.2.7 Seismic

The structural loads used to design the waste processing equipment shall be seismic class 0.

25.2.2.8 VDS/HVAC

Consideration shall be given to the possibility of the VDS sharing between the hot cell building and the radwaste building.

25.2.2.9 Instrumentation and Control

25.2.2.9.1 General Instrumentation and Control

The waste processing systems shall be designed to include all necessary instrumentation and controls for proper system operation. The operation of the systems shall be independent of any other signal generations and systems.

25.2.2.9.2 Control Stations and Panels

A control station shall be provided for monitoring, data archiving and coordination of all waste processing activities. Local control panels shall be located near the process equipment for local monitoring, control, and data logging.

25.2.2.9.3 Supervisory Control System Interface

The low-level radwaste processing system shall be designed to accept supervisory control from CODAC, and shall conform to all signal and command protocol standards established by CODAC. The low-level radwaste processing system shall provide status-reporting signals to CODAC.

25.2.2.10 Decommissioning

The waste treatment system shall be used during the ITER decommissioning period. The equipment of the low-level radwaste processing system shall be decontaminated, if necessary, for the "hands-on" dismantling activities. Decontamination liquids shall be drained and rendered to a safe, stable form. Activation products contained in the liquid must be solidified.

25.2.2.11 Surveillance and Inspection

Each container with radwaste or with toxic material shall be identified by identification tags which can be scanned and which will enable loading information for the container into the computer. Tanks containing the tritiated fluids should be inspected periodically in accordance with the equipment maintenance schedule.

25.2.2.12 Quality Assurance (QA)

The waste treatment system shall be designed, manufactured, tested, commissioned, operated, maintained and decommissioned in compliance with the ITER QA programme as it applies to SIC-3 and SIC-4 systems.

25.3 Codes and Standards

Industrial codes and standards should be used as guidelines for the design, manufacturing, testing and operating of hot cell and low-level radwaste processing equipment. Methods of gamma ray irradiation testing must be defined and standardised.
Industrial codes and standards of the host country should be used as guidelines for the design, manufacturing, testing and operating of non-radioactive waste processing equipment.