8.5 Viewing/Metrology Equipment

8.5.1 Function, Basic Configuration and System Boundaries

The main function of the viewing system is to allow a quick in-vessel inspection to look for possible damage to plasma-facing components.

For such an inspection, the system is described in Table 8.5-1 and the following.

Table 8.5-1 Viewing/Metrology Equipment - Summary Description

Category / Item	Requirement
Port allocation	Located at 3 Divertor ports out of 6 divertor ports allocated for the viewing/metrology equipment, probe travel horizontal (inclined).
Performance of IVV cask	---
First and second confinement barriers	cask constitutes part of the confinement barriers, and therefore has to comply with PSR.
Extending system and container	The probe heads are quickly exchangeable without opening the vacuum boundary. An extending system and associated container are provided in the vessel for this purpose. The container selects one of the probes and a deployment system extends the probe.
Performance of viewing/metrology	---
Resolution for viewing	1 mm (The distance to the object is from 500 mm to 8,000 mm)
Accuracy for metrology	(+/-) 0.5 mm
Viewing time	10 min (FDR)
Metrology time	8 hours (FDR)
Viewing time required for first image	10 min (FDR) after cooldown
Viewing area	Under study (For divertor < 100 % (TBD), For blanket < 100% (TBD))
Glow discharge system	To be installed in the IVV cask
Snake robot system	To be installed in the IVV cask
Small cylindrical shield plugs	To be installed in the IVV cask

(1) Port allocation
Every 3rd divertor port out of 18 needs viewing/metrology equipment for complete coverage, i.e. a total of 6 ports is allocated for the 3 pieces of viewing/metrology equipment. First the viewing/metrology equipment head protrudes into the vacuum chamber through a hole at the junction of the divertor and the blanket. Following a first inspection, the 3 pieces of viewing/metrology equipment travel to the other 3 ports and perform inspections.
(2) Performance
Viewing resolution is to be within 1 mm and the allowable time for inspection of an entire

sector (defined as the area viewed by one probe) is 10 min. Further requirements are quick global viewing and real time observation. Accuracy of the metrology is within (+/-) 0.5 mm, with an allowable duration of 8 h for performing metrology activities in one probe sector.
(3) Interface with integrated systems
Viewing/metrology equipment consists of an IVV cask which is modular and, as well as the in-vessel viewing/metrology system, also integrates the glow discharge system, the snake robot system and the small cylindrical shield plugs.

The IVV cask configuration allows the selection of one of the systems (inspection system, viewing system, plug, etc.) contained in it, for deployment into the vacuum vessel. Space constraints do not allow linear insertion and deployment of the probes, and therefore the deployment system must be compatible with insertion along a curved trajectory.

The viewing/metrology equipment connections with its external supporting service unit includes channels for heat removal, power and signals, as well as a structural interface. The diameter of the probe and its external deployment tube are limited to 150 and 300 mm respectively.

8.5.2 Requirements

8.5.2.1 Environmental Conditions for Viewing/Metrology

Viewing/metrology equipment has to be operated under conditions of intense gamma radiation, high heat flux and magnet flux. The components are required to withstand these conditions.

Table 8.5-2 Environmental Conditions for Viewing/Metrology

Category/Item	Requirement
Environmental condition	**---**
After an off-normal event	Media: vacuum, dose/flux: 5-8 T, temp.: 120°C (baking 240°C), magnetic field: on, radiation level: less than 3 x 10^4 Gy/h
Between plasma operation campaigns	Media: vacuum, dose/flux: 5-8 T, temp.: 120°C (baking 240°C), magnetic field: on, radiation level: less than 2.5 x 10^3 Gy/h
During in-vessel maintenance intervention and rescue operation	Media:N_2, dose/flux: 3 x 10^4 Gy/hr, temp.:50°C, magnetic field: off

8.5.2.2 Maintenance

IVV hardware elements shall be designed to operate for the required in-service duration. This includes periodical maintenance. The double door at one end of the IVV cask shall be able to dock with the cryopump cask. The double door shall be capable of supporting the delivery of tools, replacement of parts, the dispatch of fully suited workers, and other such maintenance activities.

8.5.2.3 Hands-on

IVV hardware elements shall be designed to be maintained by a standard robotic arm and its tools. Access inside the IVV cask by fully suited personnel shall only be required for rescue purposes.

8.5.2.4 Reliability

The IVV system design shall include an analysis of failure modes and effects and specify corrective actions in response to failures. Failure rates for primary mechanism components shall be less than 10^{-6} over the plant life. The failure rate for any malfunction requiring personnel access for repair, shall be less than 10^{-6} per annum.

8.5.2.5 Durability

The IVV system shall be designed to be compatible with the environmental conditions described in 8.5.2.1 and for its operations.

8.5.2.6 Access

Inside the IVV cask, there shall be enough space to perform maintenance and rescue activities.

8.5.2.7 Space

The IVV cask that installs IVV modules shall be located in the pit at the divertor level.

8.5.3 Codes and Standards

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 & inspection: generic at the time of procurement
- Materials: generic at the time of procurement
- Standard Control system items: generic at the time of procurement