7 Assembly Tooling

7.1 Functions and System Boundaries

7.1.1 Functions

The function of the assembly tooling is to facilitate the on-site handling, preparation, sub-assembly and assembly of the tokamak components.

This tooling includes both standard, commercially available equipment and specially designed, purpose-built tools. Metrology, metallurgy, beryllium control, health physics and occupational safety must also be provided to support the assembly processes, and the equipment required to supply these services is included in the scope of the assembly tooling.

7.1.2 System Boundaries

For the assembly tools, the system boundaries are defined by the scope of the tokamak assembly plan, which is described in the PDD Annex “Assembly Plan”.

The scope of the assembly tooling is to support all aspects of the assembly and installation of the plant equipment not covered by assembly procedures provided within the specific procurement of systems. In particular, it supports the assembly of the tokamak in the pit, as well as the on-site transportation and preparation of the components and sub-assembly units. The subsystems covered include:

- Cryostat and penetrations;
- Bioshield lid;
- Magnet system, comprising;
  - Toroidal field coils and structures;
  - Gravity supports;
  - Poloidal field coils and supports;
  - Central solenoid and supports;
  - Correction coils and supports;
  - In-cryostat feeders;
- Vacuum vessel and ports;
- Thermal shields, comprising;
  - Vacuum vessel thermal shields;
  - Cryostat thermal shields;
  - Transition thermal shields;
- In-vessel components, comprising;
  - Divertor;
  - Blanket modules.
- In-port components, comprising;
  - Cryopumps;
  - Diagnostics;
  - Test blanket modules;
  - Additional heating systems;

and all associated in-cryostat pipework, instrumentation and cabling.

The assembly operations include, for each of the tokamak systems:

- on-site transport of the components between their respective on-site storage areas, their preparation and sub-assembly areas, and their final, installed position in the tokamak pit;
- preparation and sub-assembly operations, and;
- final installation and alignment.

7.2 Requirements

7.2.1 General

The plan for assembling the tokamak, and the associated, integrated package of assembly tools, shall be developed and designed to meet all safety and quality standards, to minimise the overall project cost, and be consistent with the overall construction schedule.

The plan and tooling shall take account of the size, weight and delivery schedule for the component shipments.

7.2.2 Vacuum

The assembly tooling shall be designed, cleaned and operated to ensure meeting the vacuum requirements defined in the vacuum design handbook (VDH).

To achieve and maintain the specified levels of cleanliness will necessitate: physically separating the areas in which the handling, preparation, sub-assembly and assembly operations occur, establishing and maintaining the required level of clean conditions inside these areas, implementing appropriate cleaning procedures for components and tools during transfer to areas with more stringent requirements, and eliminating potential sources of contamination from the controlled areas. The assembly tools shall be designed to meet the material and chemical requirements described below, of the most stringently controlled area in which they will be operated. The efficient cleaning of all tools which will repeatedly move between areas with different requirements shall be considered in their design.

7.2.3 Structural

The assembly tools will be designed in accordance with appropriate codes or standards, and where required, shall be certified to meet ITER site regulatory standards.

It is expected that these design standards will be site specific, and thus will be specified following site selection.

7.2.4 Mechanical

The precision of the adjustment features of the assembly tools shall be sufficient to guarantee achievement of the specified alignment tolerances for the components.

All assembly tools shall incorporate appropriate lifting features to facilitate their handling and on-site installation with appropriate safe rigging.

7.2.5 Electrical

All electrical power and control systems associated with the assembly tools shall be designed, manufactured, installed and tested in accordance with the regulations and standards which apply to the ITER site.

7.2.6 Chemical

The assembly tools shall not contaminate the surfaces of the components which will be exposed to vacuum.

All tools used to handle or machine inside the primary vacuum enclosure (vacuum vessel and ports) shall function without the need of cutting fluids, greases etc. Hydraulic systems which utilise oils for the transmission of power shall be excluded from the vacuum vessel.

Controlled application of cutting fluids, greases etc. is acceptable for tools which will operate in the cryostat (secondary vacuum) provided they are in accordance with the provisions of the VDH, the tokamak and assembly halls, and the hot cell preparation area, but which will be specifically excluded from the primary vacuum enclosure, provided all traces of the contaminant is removed prior to subsequent assembly operations. Hydraulic systems such as jacks, which utilise oils for the transmission of power, may also be used in these tools provided no acceptable mechanical alternative exists. Such systems shall incorporate a high integrity secondary shroud to prevent the spread of oil in the event of component failure.

The procedures, associated tools and chemicals used for cleaning the components, and assembly tools, prior to entry into clean areas shall conform with the requirements of the VDH.

7.2.7 Manufacturing

To minimise the on-site workload and cost, the design and the manufacturing plan for each of the assembly tools shall allow the maximum pre-fabrication and testing at the supplier's shop.

7.2.8 Assembly

The on-site assembly, testing and certification of the assembly tools shall be integrated into the overall machine assembly plan.

7.2.9 Testing

The tools shall be tested to ensure conformity with specification, functionality and reliability and to satisfy the authorities which regulate the operation of equipment, particularly of lifting equipment, at the ITER site. Where possible, all testing should be performed at the supplier’s works.

7.2.10 Instrumentation and Control

Instrumentation and control systems will be required for each of the powered tools, in order to satisfy the regulatory requirements for the ITER site.

The operation of the tools which handle the large components must protect and ensure both the safety of the personnel and the integrity of the components. The control systems for these tools shall be interlocked to prevent incorrect or untimely operation, designed to “fail safe”, and the associated instrumentation systems shall provide redundancy.

7.2.11 Materials

Tools which are introduced into the primary vacuum enclosure shall be fabricated in stainless steel or, for light applications, aluminium alloy. For the remainder of the clean areas, additionally, carbon steel with a surface coating of non-powdering, epoxy paint is an acceptable tool material, provided all of the surfaces which contact the vacuum components are in, or clad with, stainless steel or other vacuum compatible material.

For the tools which are totally excluded from the clean areas, e.g. external, on-site transporters, specific material constraints shall be considered where necessary.

7.2.12 Operation

Personnel safety during the operation of the assembly tooling is a key concern, particularly considering the large size and weight of the components to be handled, and assembled. To minimise, or eliminate, the hazard to personnel associated with the operation of the tools, their design shall integrate appropriate, established safety techniques such as interlocking, “fail-safe” technology, personnel access control, and remote controlled operation.

A training and certification program will be implemented to qualify operators for the large, sophisticated tools.

7.2.13 Maintenance

Any sub-systems of the tools which may require maintaining during their lifetime, shall be designed in such a way as to facilitate such maintenance.

7.2.14 Quality Assurance (QA)

The assembly tools shall be designed, manufactured, tested, commissioned, operated, and maintained in accordance with the ITER QA program and with the appropriate codes and standards.

7.2.15 Reliability

The availability of the assembly tooling shall be consistent with minimising any delay to the tokamak assembly schedule. This requirement shall be met via design, the development and implementation of appropriate maintenance and testing regimes and by the provision of adequate spares.

7.3 Codes and Standards

The assembly tooling design, manufacture, inspection and testing shall be performed in accordance with the appropriate, site-specific codes and standards.