

## **10 Tritium Plant and Detritiation**

### **10.1 Functions, Basic Configuration and System Boundaries**

#### **10.1.1 Functions**

The tritium plant shall be designed to perform the functions described in the DRG1, section 2.7.

#### **10.1.2 Basic Configuration and System Boundaries**

The tritium plant consists of the following sub-systems.

(1) Tokamak fuel cycle systems

- the long term storage system (LTS),
- the fuel storage and delivery system (SDS),
- the tokamak exhaust processing system (TEP),
- the hydrogen isotope separation system (ISS),
- the tritium plant analytical systems (ANS).

(2) Tritium confinement and detritiation systems

- the glovebox atmosphere detritiation system (GDS)
- the normal vent detritiation system (N-VDS)
- the tokamak emergency vent detritiation system (EDS),
- the standby vent detritiation system (S-VDS),
- the standby room air atmosphere detritiation system (S-ADS),
- the tokamak vault air detritiation system (vault dryers),
- the hot cell vent detritiation system (HC-VDS),
- the hot Cell room air atmosphere detritiation system (HC-ADS),
- the water detritiation system (WDS).

(3) Other systems:

- the tritium plant subsystem control systems,
- the room air tritium monitors (process monitors for HVAC isolation and S-VDS),
- the heating ventilation air conditioning systems (HVAC systems) for tokamak, tritium, hot cell, radioactive waste and personnel access control buildings,
- the utility systems,
- the plant exhaust facilities.

All systems are located inside the tritium plant building, except the detritiation systems for the hot cell facility, which is located in the hot cell building. The vault dryer is located in the vault annex in the tritium plant building.

### **10.2 Specific System-Internal Requirements**

#### **10.2.1 Design**

##### **10.2.1.1 Tokamak Fuel Cycle Systems**

#### 10.2.1.1.1 Long Term Storage System (LTS)

The LTS receives T<sub>2</sub> shipping containers, implements accurate measurement ( $\pm 1\%$ ) for tritium quantities, and effects delivery of T<sub>2</sub> gas to, and receipt from the fuel cycle storage and delivery system (SDS). The LTS shall be equipped with a glovebox for long term storage of shipping containers, a load-in/load-out glovebox for tritium quantity measurements and T<sub>2</sub> gas transfers to and from a shipping container. These gloveboxes shall be located in the long-term storage vault for physical protection.

The LTS shall be equipped with an additional glovebox, which contains metal hydride beds to store T<sub>2</sub> recovered from co-deposited layers formed in the tokamak during DT plasma operation.

#### 10.2.1.1.2 Storage and Delivery Systems (SDS)

The SDS provides fuel (T<sub>2</sub> and D<sub>2</sub> containing T) and other gases (Ar, He-3, He-4, Ne, N<sub>2</sub>, and O<sub>2</sub>) to the tokamak fuelling systems, and provides D<sub>2</sub> (containing T) and H<sub>2</sub> to the neutral beam injectors. The fuel gases (T<sub>2</sub> and D<sub>2</sub> containing T) shall be stored by metal hydride beds, and D<sub>2</sub> shall be stored in holding tanks. The system shall be designed to meet the following requirements:

- a) rapid delivery (20 Pam<sup>3</sup>s<sup>-1</sup> per bed) and recovery of fuel,
- b) in-bed calorimetry for rapid tritium quantity measurements ( $\pm 3\%$  in 8-12 h,  $\pm 1\%$  in 24 h),
- c) accurate tritium measurement by using the P-V-T-c method ( $\pm 1\%$ ),
- d) recovery of He-3,
- e) overpressure protection of the metal hydride beds,
- f) future addition of further metal hydride bed(s) with in-bed calorimetry if required.

The fuelling requirements are summarised in DRG-1 1.25. The pumps required for delivery of gases to the gas fuelling system and neutral beam injectors are included in the SDS. The entire SDS shall be placed inside glovebox(es).

#### 10.2.1.1.3 Tokamak Exhaust Processing System (TEP)

The TEP receives the following process streams;

- (a) exhaust gas from the tokamak during normal operation, later stages of pumpdown, wall conditioning (baking and glow discharge cleaning) and co-deposited tritium recovery gas, as well as the neutral beam pumping system exhaust.
- (b) tritiated process gas, purge gas and process vacuum pump exhaust from various tritium systems such as ISS, SDS, and ANS.

The TEP delivers the processed gases (T<sub>2</sub> and DT) to the ISS, SDS, and, following buffer storage to allow decay of gamma activity, when necessary, discharges non-tritiated residual gas to the N-VDS.

The TEP shall be designed to have sufficient capacity to meet the following requirements;

- plasma exhaust for nominal pulse plasma operation (Table 10.2-1)
- overall tritium decontamination factor  $DF > 10^8$
- future expansion for long burn plasma operation scenarios (DRG1 Table 1.2-1) of hybrid operation (burn time 1,000 s, repetition time 4,000 s) and non-inductive

operation I (burn time 3,000 s, repetition time 12,000 s), and the impurity stream from breeder blanket module purge gas tritium recovery.

**Table 10.2-1 Plasma Exhaust Gas Pumping Throughput and Compositions**

Gas Species	He Discharge $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$		$\text{H}_2$ , $\text{D}_2$ and DT Discharges $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$	
	Min	Max	Min	Max
$\text{Q}_2$ (*1)	0	10	200	208
He	200	200	0	22
$\text{C}_x\text{Q}_y\text{O}_z$ (*1), (*2)	0	5	0	5
$\text{Q}_2\text{O}$	0	1	0	1
$\text{O}_2$	0	1	0	1
$\text{CO}_x$	0	5	0	5
$\text{NQ}_3$	0	1	0	1
$\text{N}_2$	0	10	0	10
Ar	0	10	0	10
Ne	0	10	0	10
$(\text{N}_2+\text{Ar}+\text{Ne})$ (*3)	0	10	0	10
Total	200	233	200	253

(\*1) Q is defined as any one or combination of the hydrogen isotopes H, D or T.

(\*2) Organic compounds such as hydrocarbons ( $\text{C}_x\text{Q}_y$ ), aldehydes ( $\text{RCQO}$ ) and acids ( $\text{RCOOQ}$ ).

(\*3) Maximum combined exhaust flow rate for  $\text{N}_2$ , Ar and Ne.

**Table 10.2-2 ISS Feed Stream Throughputs and Compositions**

Stream	Flow Rate		H	D	T	Notes
	$\text{Pa}\cdot\text{m}^3/\text{s}$	Mole/h	at. %	at. %	at. %	
Plasma Exhaust	0 - 220	0 - 176	0 - 100	1 - 100	0 - 50	
NB Exhaust	0 - 50	0 - 84	0 - 100	0 - 100	0 - 1	(1,2)
WDS		280	~ 100	$3 \times 10^{-2}$	$3 \times 10^{-4}$	(1)

Notes: (1) NB exhaust and WDS feed streams are combined before introduction to the ISS.

(2) Based on each NB/DNB injector being regenerated after every 32 nominal pulse cycles (450 s burn and 1,350 s dwell), i.e. one of the three main NB injectors or the DNB will be regenerated after every 8 nominal pulse cycles.

#### 10.2.1.1.4 Hydrogen Isotope Separation System (ISS)

The ISS receives two hydrogen gas streams from the TEP i.e. tokamak exhaust and a combined stream of  $\text{D}_2$  and/or  $\text{H}_2$  from the neutral beam injectors, together with  $\text{H}_2$  from the WDS. The ISS will receive and extract tritium from the breeder blanket purge gas stream, when these modules are installed. The feed stream parameters for the ISS are shown in Table 10.2-2. The ISS shall be designed to produce the following product streams: detritiated  $\text{H}_2$  for environmental discharge (via WDS if required, to meet the ITER tritium efficient target);  $\text{D}_2$ , DT and  $\text{T}_2$  (90%T-10%D) for plasma fuelling; and low-tritium  $\text{D}_2$  for the neutral beam injectors. The target purity of these products is summarised in Table 10.2-3.

The ISS shall be designed to minimise both the tritium and overall hydrogenic inventories. Additionally, the design shall provide overpressure protection (for example by the use of expansion tanks) against such accidental events as coldbox air or helium ingress and failure of loop components such as distillation columns, pumps, heat exchangers and process piping.

**Table 10.2-3 Purity of ISS Product Streams**

Product Streams	Purity
D <sub>2</sub> for plasma fuelling	H < 0.5 at.%
D <sub>2</sub> for neutral beam injectors	H < 0.5 at.%, T < 0.02 at.%
T <sub>2</sub> for plasma fuelling	H < 0.5 at.%, D < 10 at.%
DT for long pulse fuelling	D ~ T ~ 50 at.%, H < 0.5 at.%

#### 10.2.1.1.5 Tritium Plant Analytical System (ANS)

The ANS is installed as an integral part of the ITER tritium plant with the main function of:

- additional verification of the various control processes,
- determination of the concentration for inventory measurements,
- monitoring and additional checks of tritium concentrations,
- additional control of the performance of various processes.

The main task of the ANS is the determination of the composition of the gases processed in the SDS, TEP and ISS (calibration of on-line analytical devices). The analytical requirements of these systems are listed in the Table 10.2-4. Common to all analytical requirements is that the ANS is needed only to determine the composition of various gas mixtures. The ANS shall provide the necessary tools for the acquisition of pressure (P), volume (V), temperature (T) and tritium concentration (c) data for tritium quantity measurement.

**Table 10.2-4 Analytical Requirements for Fuel Cycle Systems**

Gases to be analysed	H <sub>2</sub> , HD, D <sub>2</sub> , HT, DT, T <sub>2</sub> , methane and higher hydrocarbons, nobles gases: He-3, He-4, Ne, Ar, others: N <sub>2</sub> , O <sub>2</sub> , CO <sub>x</sub>
Concentration ranges	0 < H <sub>2</sub> , HD, D <sub>2</sub> , HT, DT, T <sub>2</sub> < 100 % 0 < hydrocarbons < 100 % 0 < He-3, He-4, Ne, Ar < 100 % 0 < N <sub>2</sub> , O <sub>2</sub> < 100 % and various mixtures of the gases mentioned above
Accuracy	< 1% of FS (*1)
Analysis frequency	An average of a few tens of analyses per day
Response time	< 160 s

(\*1) Detection of O<sub>2</sub>, H<sub>2</sub>O in ppm range needed for ISS feeds.

#### 10.2.1.2 Tritium Confinement and Detritation Systems

Process design specifications of the detritation systems required for ITER are summarised in Table 10.2-5.

**Table 10.2-5 Operating Parameters Requirements for Atmosphere Detritation Systems**

System name	Operating throughput m <sup>3</sup> /h	Inlet stream pressure kPa	Inlet max.temp. (°C)	Inlet max. humidity	Decontamination factor DF	Nuclear shielding (*3)	Hydro-carbon cracking (*3)
GDS	150	~ 100	25	< 1,000 ppm	> 100	NR	NR
N-VDS	500	~ 100	25	< 1,000 ppm	> 1,000	R	R
EDS	150	~ 90	Max 300	100 % RH	< 10	NR	NR
S-VDS	3,000	~ 100	35	100 % RH	> 1,000	R	R
S-ADS (*1)	4,500	~ 100	35	100 % RH	> 100	R	R
Vault dryers	22,000 (*2)	~ 100	35	50 % RH	> 100	NR	NR
HC-ADS	4,500	~ 100	< 40	< 10 % RH	> 100	R	R
HC-VDS	600	~ 100	< 40	< 40 %RH	> 1,000	R	R

Notes: (\*1) The S-ADS will be operated for tokamak maintenance to meet the following requirements: flow rate of 2,000 m<sup>3</sup>/h, vacuum vessel internal pressure ~ 0.09 MPa, temp. 35°C, DF < 10 and maximum humidity < 100 ppm.

(\*2) The following assumptions were applied;

Tritium inventory in the TCWS coolant = 1.6 g at the end of ITER life,

Coolant leakage rate = 1%/y of the TCWS coolant holdup,

HTO concentration in the vault air 1 DAC (during maintenance time).

(\*3) R = required; NR = not required. Shielding of filters only.

#### 10.2.1.2.1 Glovebox Atmosphere Detritation Systems (GDS)

The GDS forms a secondary confinement barrier together with the gloveboxes which enclose most of the tritium processing systems. The GDS is a centralised detritation system for gloveboxes located in different rooms on various floors of the tritium plant building. The GDS shall be designed to;

- Reduce tritium permeation and leakage from gloveboxes into rooms (> 99% recovery in 60 min in the case of 100 g T<sub>2</sub> spill event).
- Reduce HTO which is produced by radiolytic reactions between T<sub>2</sub>, H<sub>2</sub>O moisture and O<sub>2</sub>.
- Maintain negative (sub-atmospheric) pressure inside gloveboxes.
- Maintain the tritium concentration at below 1 mCi/m<sup>3</sup> during normal operation.
- Eliminate a risk of hydrogen fire/explosion in the case of a spill of the full inventory of T<sub>2</sub>, DT, and D<sub>2</sub> from a tritium process component such as the metal hydride bed.

#### 10.2.1.2.2 Normal Vent Detritation System (N-VDS)

The N-VDS receives various tritium-bearing exhausts as follows;

- Vacuum pumping exhaust during earlier stage torus pumpdown.
- Leak detection system exhaust.
- Fuel injection systems purge gases (via TEP).
- Torus cryopump pressure relief tank purge gas.
- Fuel cycle subsystem exhaust (via TEP).
- Tokamak emergency vent detritation system (EDS) exhaust.
- Radioactive exhaust from tokamak cooling water system (TCWS).
- Purge gas/air from secondary enclosures.
- Purge gas from tritiated water holding tank systems.
- Air extracted from potentially contaminated rooms to maintain negative room pressure (the relevant HVAC is isolated).

The N-VDS shall be designed to have redundant capacity and operational flexibility to handle the process exhausts listed above (most of them are intermittent, non-steady-state flows). To avoid increasing the amount of tritiated water to be processed by the WDS, the N-VDS condenser shall be designed to separate and recycle the condensate to the TCWS when it receives the TCWS exhaust and the EDS exhaust. Because this subsystem forms the final tritium confinement barrier at any time during ITER operation, safety class power, safety class chilled water and utility gas for the process operation and control shall be provided.

#### 10.2.1.2.3 Tokamak Emergency Vent Detritiation System (EDS)

The EDS is required to start within 3 minutes upon receiving a start signal and to maintain sub-atmospheric pressure ( $< 0.01$  MPa) in the vacuum vessel for the following various bypass events (wet bypass and dry bypass) during plasma operation. The EDS shall be designed to handle vent gas of high temperature (up to  $300^{\circ}\text{C}$ ) and high humidity (steam saturated). The EDS exhaust can be processed by the N-VDS for environmental rejection after detritiation.

#### 10.2.1.2.4 Standby Vent Detritiation System (S-VDS)

The S-VDS is required as an emergency tritium confinement barrier for the tokamak building and the tritium building during various accidental events such as;

- bypass events and fuelling line break events in the tokamak building.
- $\text{T}_2$  gas spill events in the tritium building.

Following occurrence of such an accidental event, the heating ventilation air conditioning system (HVAC system) is isolated and the S-VDS is actuated to maintain negative room pressure ( $-1$  mbar). The S-VDS forms the final tritium confinement barrier, therefore safety class power, chiller and other utilities shall be provided.

#### 10.2.1.2.5 Standby Room Air Detritiation Ssystem (S-ADS)

The S-ADS performs two functions, firstly it provides enhanced room air detritiation for recovery and personnel access into rooms where tritium spill events (as specified by the failure event scenario) have occurred, and secondly, support of tokamak maintenance operations. The S-VDS shall be designed to allow continuous operation for periods exceeding 6 months. During maintenance of the vacuum vessel, dry air will be re-circulated through to the vacuum vessel, in order to promote tritium out-gassing from the first wall. This subsystem shall be designed to be able to add dry  $\text{N}_2$  gas and moisture, to reduce oxygen concentration and static electricity, to minimise the risk of a dust explosion in the vacuum vessel, if such mitigation proves necessary.

#### 10.2.1.2.6 Tokamak Vault Air Detritiation System (Vault Dryers)

Air conditioning of the tokamak vault volumes is performed by a vault air cooler system (maximum heat load in the vault  $\sim 1.2$  MW). The vault dryers shall be designed to achieve tritium concentration of less than 1 DAC HTO in the vault areas

#### 10.2.1.2.7 Hot Cell Vent Detritiation System (HV-VDS)

The HC-VDS is required to maintain negative pressure in the red zone ( $- 3$  mbar) and amber

zone (- 2 mbar) during normal operation, and green zone (-1 mbar) in the case of potential tritium contamination events. The HC-VDS shall be designed to have redundant capacity and operation flexibility for different process throughput to handle both normal operation conditions, and for the tritium contamination event in the green zone rooms. Because this system forms the final tritium confinement barrier in the hot cell building, safety class power, chiller and other utilities shall be provided.

#### 10.2.1.2.8 Hot Cell Room Air Detritiation System (HC-ADS)

The HC-ADS is required to reduce room air tritium concentration to reduce wall contamination by HTO in the red zone rooms. In these rooms, maintenance, storage, testing and waste packing of in-vessel components such as diverter cassettes, blanket modules and shield plugs are performed without any secondary confinement barrier. The maximum estimated tritium evolution rate in the red zone is approximately 20 Ci/h. The HC-ADS capacity is determined as 4,500 Nm<sup>3</sup>/h to achieve an equilibrium HTO concentration of 500 DAC.

#### 10.2.1.2.9 Water Detritiation System (WDS)

The function of the WDS is to recover tritium from tritiated water, and to reduce tritium release into the environment through the rejection of waste water produced by ITER operations. The WDS capacity shall be sufficient to process tritiated water produced through normal operation of the atmosphere detritiation systems. The WDS does not process tritiated waste water generated during any accidental events (in-vessel and ex-vessel loss of coolant events, tokamak vessel bypass events, T<sub>2</sub> gas spill events in the tritium plant building) or any drainage from the TCWS. This tritiated water shall be either stored by holding tanks, or recycled to the TCWS.

The WDS shall be designed to hold tritiated waste water of the following tritium concentration levels;

- High level > 100 Ci/kg water
- Medium level  $1 \times 10^{-3}$  - 100 Ci/kg water
- Low level  $1.6 \times 10^{-6}$  -  $1 \times 10^{-3}$  Ci/kg water
- Low low level <  $1.6 \times 10^{-6}$  Ci/kg water

An emergency holding sump shall be provided capable of holding 400 m<sup>3</sup>, which corresponds to 4 – 6 month operation of the S-ADS and the S-VDS.

The WDS shall be designed to implement frequent assaying of the tritium concentration level in the collected tritiated water, and to distribute the water to the appropriated holding tanks. The holding tanks shall be designed to prevent accumulation of the H<sub>2</sub>-O<sub>2</sub> gas mixture produced by water radiolysis in the holding tanks, by purging this gas through the N-VDS.

#### 10.2.1.3 Other Systems

##### 10.2.1.3.1 Tritium Plant Subsystem Control Systems

The ITER command control and data acquisition and communication system (CODAC) is composed of the supervisory control system and individual dedicated plant control systems to ensure the integrated control of the complete ITER plant. Each tritium plant system shall be

provided with its own local control cubicles (LCCs). Programmable logic controllers (PLCs) will be included in each LCC to implement independent operation and control of each subsystem.

All signals from and to the systems will be made available at the terminal blocks in the LCCs. The LCCs shall provide for the following main functional requirements;

- Real time operation, monitoring and data acquisition.
- Emergency operation and control.
- Safety interlocking.

The key signals from and to the fuel cycle systems and the tritium confinement systems will be inter-linked with CODAC. The soft wired control logic and an independent hard wired alarm and emergency shut-down capability shall be included in the control system.

#### 10.2.1.3.2 Room Air Tritium Monitors

The room air tritium monitors measure the tritium concentration in all rooms specified as green zones, where there is a possibility of tritium contamination at any time. The major function of the monitors is to trigger the HVAC isolation valves (to close) and the isolation valves (to open) of the vent detritation systems (N-VDS, S-VDS and HC-VDS) to confine tritium in the contaminated areas. The tritium monitors shall be placed at strategic detection points such as the HVAC branch exhaust ducts in each room and/or area, and full redundancy of the monitors with safety class power shall be provided. Note that these tritium monitors are HVAC process monitors, which are similar to, but separate from, those in the radiological monitoring and protection system (Chapter 22).

#### 10.2.1.3.3 Heating Ventilation Air Conditioning System (HVAC)

The HVAC forms the tritium confinement barrier together with the N-VDS and S-VDS in the tokamak building and the tritium building, and with HC-VDS in the hot cell, radwaste, and personnel access control buildings. The HVAC emergency isolation valves shall be actuated (within 30 s) to isolate potentially contaminated rooms and /or areas, when the relevant room air tritium monitor signals an excessive tritium concentration. The isolation valve actuators shall have full redundancy and safety class pressurised actuation air. See also chapter 23 (6.2.A.01) tokamak complex, HVAC section 23.2.1.14.

#### 10.2.1.3.4 Electrical Power and Utilities

The electrical power and the utilities such as chilled water, cooling water, compressed N<sub>2</sub> gas and air, required for the tritium plant shall be provided from their load centres located in the tritium plant building.

#### 10.2.1.3.5 Plant Discharge Facilities

Plant discharge facilities for waste water and various process exhaust gases from the tritium plant shall be provided. The waste water collected by the WDS holding tank system shall be rejected to the environment via the ITER low level liquid waste handling facility. Transfer pumps in the WDS holding tank systems will pump the waste water. The process exhaust gases from tritium subsystems, and tokamak vacuum pumping systems and leak detection systems, shall be rejected into the environment through the plant exhaust located above the top of the tokamak building. Continuous monitoring systems shall be provided for these

discharges.

## 10.2.2 Additional Requirements

### 10.2.2.1 Materials

#### 10.2.2.1.1 General

Equipment and piping of the tritium subsystems form the primary tritium confinement boundary. Austenitic stainless steel shall be used for the primary vessels and piping of the tritium subsystems unless use of other material is an essential requirement (for example the electrolysis cells of for highly enriched tritiated water). Tritium contacting materials, other than austenitic stainless steel, shall be qualified for tritium use by long term tritium exposure (> 1 year). This material requirement also applies to the secondary confinement of tritium process equipment.

#### 10.2.2.1.2 Electrical

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 10.2-6 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

#### 10.2.2.2 Mechanical

The maximum operating pressure of the fuel cycle tritium systems is less than 0.38 MPa (except for the NB injector feed line which operates at 0.6 MPa) and the temperature of piping systems is mainly near-ambient. Maximum operating pressure and temperature of the atmosphere detritation systems is approximately 0.1 MPa and 150°C - 500°C. The design of all equipment and piping shall account for normal operating load, i.e. the internal packing load and vessel load at their operating pressure and temperature. All tritium plant systems shall be designed to sustain the seismic loads (SL-0/SL1) earthquakes with 0.05 g peak horizontal and vertical ground acceleration, and SL-2 earthquakes with 0.2 g peak acceleration as defined in the PDS chapter 4.

### 10.2.2.3 Nuclear

The nuclear requirements for the tritium plant design are as follows;

- confinement and minimisation of the tritium release during normal ITER operation,
- confinement and minimisation of the tritium release during all design basis accidents, by minimisation of global tritium inventory and maximisation of segregation of the inventory in different components,
- minimisation of workers tritium exposure during normal operation conditions and for all design basis accidents,
- Provision of gamma delay tanks to receive and delay gamma emitting gas, of sufficient capacity to allow subsequent direct release to the environment.

### 10.2.2.4 Vacuum

To minimize tritium leakage from the tritium systems, the following maximum He leak rate shall be acceptable;

(1) For fuel cycle systems placed in glovebox

- Joints, seals  $< 1 \times 10^{-9} \text{ Pa.m}^3\text{s}^{-1} \text{ (He)}$
- System total leak rate  $< 1 \times 10^{-6} \text{ Pa.m}^3\text{s}^{-1} \text{ (He)}$
- Gloveboxes  $< 0.1 \text{ vol\%/d}$

(2) Atmosphere detritation systems

- System total leak rate  $< 1 \times 10^{-4} \text{ Pa.m}^3\text{s}^{-1} \text{ (He)}$

### 10.2.2.5 Manufacturing

The design shall be based on manufacture using standard and proven components to the greatest extent possible.

### 10.2.2.6 Assembly

The design shall be based on minimising the amount of site assembly, installation and testing work. The systems shall therefore be shop pre-assembled in the largest feasible units, suitably packed and reinforced, for delivery to the ITER site.

### 10.2.2.7 Testing

All shop pre-assembled units shall be fully tested, and if feasible also functionally tested (without tritium) at the supplier's shop.

### 10.2.2.8 Maintenance

The design shall allow planned routine manual maintenance as well as the exchange of faulty parts. Provisions shall be incorporated into the equipment and piping layout design to allow smooth exchange of components and parts without the release of tritium. To this end, the design shall include interface features such as connection rings or flanges to allow attachment of temporary secondary enclosures, such as plastic tents or bags, around the component to be maintained. The design shall be such as to facilitate the installation of these temporary enclosures, as necessary, and to their interface with other tritium infrastructure such as the

normal vent detritation system (N-VDS) and the tritium process monitoring system. All requirements to facilitate in-situ leak testing shall be taken account of in the design.

#### 10.2.2.9 Decommissioning

None of the tritium plant systems is expected to become activated during the lifetime of ITER. However, the exposed surfaces of the plant will become contaminated with tritium and tritium-bearing compounds. These parts shall be designed with decontamination in mind, so that the amount of waste to be disposed of as tritiated material can be minimised.

#### 10.2.2.10 Thermal

The outlet pipes of heated components shall have finned tube sections or other provisions to maintain the outlet temperature below 70°C. Components heated to a temperature of 150°C and above shall be provided with a jacket capable of being evacuated, in order to contain tritium permeating from the hot components, and to limit the heat load to the secondary containment. All surfaces of heated components which are accessible by personnel shall have their accessible surface temperature limited to 60°C to prevent personnel injury.

### **10.3 Codes and Standards**

General ITER specifications, such as safety, including seismic, will be applied. In addition, the following codes and standards shall be applied;

- ASME Section VIII, Division 1, Boiler and Pressure Vessel Code.
- ASME B31.3 Chemical Plant and Refinery Piping.
- ASME Section IX Welding and Brazing Qualification.
- ANSI National Electric Safety Code C2.
- NFPA 70 National Electrical Code.
- NFPA National Fire Code.
- ITER Tritium Plant Numbering System (ANSI/ISA-S5.1 Instrumentation Symbols and Identification).

Note that adjustments to these code selections may have to be made when a specific site has been selected for ITER.