Design of Tritium Storage and Delivery System Based on ITER FDR

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1. Introduction

Tritium used in ITER (International Thermonuclear Experimental Reactor) will be supplied by external sources. About 120 g of tritium shall be supplied from SDS (Storage and Delivery System) during a short DT burn pulse of 450 sec. The SDS is one of the subsystems of TP (Tritium Plant), which is also essential for the long burn pulse operation of the tokamak beyond the initial hydrogen phase, as tritium will be produced from DD reactions. The main purpose of the SDS is to store and supply the gases needed for operation of ITER and to provide the necessary infrastructure for short and long term storage of large amounts of tritium.

In this study, the design requirements and specifications of the SDS adaptable to the present ITER design configuration of the FDR (Final Design Report) are described.

2. Design Description

2.1 Interface

A schematic of ITER fuel cycle is shown in figure 1. The SDS supplies the hydrogen isotopes and the pure gases such as helium, nitrogen, argon and neon to FS (Fuelling System) and NBI (Neutral Beam Injection) for the various purposes. The hydrogen isotopes are recycled through the ISS (Isotope Separation System) and the insufficient tritium is made up by external sources through the LTS (Long Term storage System). The ANS (ANalytical System) is for the determination of the composition of the gases handled in the SDS, ISS and TEP (Tokamak Exhaust Processing system).

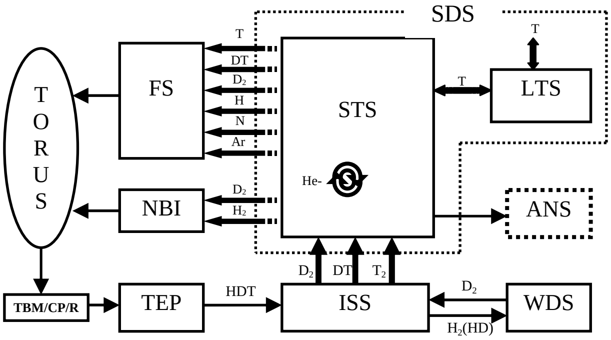

Figure 1. Interfaces among the SDS and other systems in ITER fuel cycle

2.2 Function

The SDS has the following major functions.

- ◦ Storage of tritium and deuterium.
- ◦ Measurement and determination of tritium inventories.
- ◦ Preparation and delivery of deuterium and deuterium/tritium mixtures for fuelling.
- ◦ Supply inactive gases needed for operation.
- ◦ Handling of incoming and outgoing tritium shipments and transfers to/from the fuel cycle.
- ◦ Extraction and collection of the He-3 decay product.

2.3 Requirement

The main tasks of the SDS are the supply of the hydrogen isotopes and of the pure gases for various fuelling purposes. The impurity gases of nitrogen, argon and neon for the FPSS (Fusion Power Shut-down System) shall be also supplied by SDS.

The capacities of the gases supplied from SDS to FS and NBI are summarized in table 1.

Table 1. Demands of gases supplied by SDS.

Gas	Supply Capacity	Purity Specification
Nitrogen	5 std m^3/month	Ultra-high purity
Helium	5 std m^3/month	Ultra-high purity
Deuterium	5 std m^3/month	Ultra-high purity
Hydrogen	25 std m^3/month	Laboratory Grade
Argon	10 std m^3/month	Laboratory Grade
Neon	10 std m^3/month	Laboratory Grade

The primary containment of the SDS shall be fully tritium compatible. The overall leak rate of any component of SDS shall be less than 10^{-9} Pam^3/s. The overall leak rate of the whole primary system of SDS shall be less than 10^{-8} Pam^3/s. The maximum operating pressure shall be 0.25 MPa(a). Primary process components and pipe work shall be located in glove boxes with leak rates smaller than 0.1vol%/h. All primary volumes heated to temperature higher than 150 ^oC shall be surrounded by evacuated outer vessels. Tritium or hydrogen permeated through the heated primary containment shall be collected and the heat losses into the glove box shall be minimized. Single components such as metal getter beds, reservoirs, pipes, etc., shall be dimensioned so that the tritium inventory in a single component is smaller than 100 g. Separation of single components from the other components must be possible, e.g. by valves.

3. Subsystems and Configuration

The SDS is divided into three subsystems of STS, LTS and GBC, which fulfill different functions.

3.1 STS (Short Term Storage and Delivery System)

The STS receives from the ISS and stores 90% T_2, 50% DT and 98% D_2. 20 ZrCo beds and 11 reservoirs are used for the storage and buffering. Three batteries of ZrCo are installed for T_2, DT and D_2 gases, respectively. 9 ZrCo beds are installed in the T_2 battery, 8 in the DT battery and 3 in the D_2 battery. The tritium content in the ZrCo beds is measured by calorimetry with around 1% accuracy.

Two glove boxes are designed for the STS. One glove box of 30 m^3 is prepared for the temporary storage of primary or secondary containments. The other is for the vessel of D_2 supplied to the NBI. The metal bellows pumps are installed to transfer T_2, DT and D_2 to the FS and NBI. The spiral vane pumps are used to evacuate the STS. A circulation pump is operated for the He-3 recovery and a He-3 purifier with SAES material is used. An expansion reservoir of 1 m^3 is provided for the overpressure protection. 4 purifiers are also installed for the purification of the helium, neon, argon and hydrogen respectively.

3.2 LTS (Long Term Storage and Transfer System)

The LTS (Long Term storage System) has a storage capacity of up to 1 kg of tritium. 10 ZrCo beds is installed in the long term storage system. These ZrCo beds have a simpler design than the ZrCo beds of the main part of STS. In-bed accountancy is not required for these beds. In this system, pump for the tritium transfer is not required.

Four glove boxes in LTS are designed for the various functions as an LTS vault, a load in/out box, a tritium storage vault and a dismantling box.

Table 2. Components of the SDS.

Component	Quantity	
	STS	LTS
ZrCo Storage Beds	20	10
Purifiers	5	2
Vessels	11	2
Pumps	18	-
Glove Boxes	2	4
Heaters	46	12
Calorimeter	20 (in-bed)	-
Valves & Rupture Discs	596	123
Instruments	674	83
Lines	325	74

3.3 GBC (Gas Bottle Compound)

The gas bottle compound supplies inactive and pure gases required for tokamak fuelling and conditioning, such as helium, nitrogen, neon, argon, protium, deuterium, etc. For the fusion power shut-down, some gases are supplied from the GBC. The GBC is located outside of the tritium building.

4. Conclusion

The design of the SDS based on the ITER FDR is performed, and the design requirements and component specifications are studied. The SDS comprises three subsystems of STS, LTS and GBC, which fulfill different functions. In the further study, the fast and stable delivery of tritium will be considered in the design of the SDS, and the calorimeter for the tritium storage beds will be designed and tested.

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