UPDATE OF ITER ISS-WDS PROCESS DESIGN - 2
TW6-TTFD-TPI-55 (EFDA/06-1511)

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1. Introduction

A Task Force Fuel Cycle has been established at FZK aiming to design the deuterium/tritium system of ITER. The MEdC Association provides support on activities at TLK dedicated to the design of the Tritium Plant Systems.

The ITER Isotope Separation System (ISS) and Water Detritiation System (WDS) are to be integrated in order to reduce potential chronic tritium emissions from the ISS. This is achieved by routing the top (protium) product from the ISS to a feed point near the bottom end of the WDS Liquid Phase Catalytic Exchange (LPCE) Column. This provides an additional barrier against ISS emissions and should mitigate the memory effects due to process parameter fluctuations in the ISS.

During operation of ITER, tritiated water will be produced in various systems. The expected sources are [1], [2], [3]:

- condensate generated from the normal operation of various atmosphere detritiation systems and HVACs.
- tritium process component maintenance,
- condensate from the air coolers in the containment volume (designed to limit overpressures from an ex-vessel coolant leak),
- air detritiation dryers in the containment volume,
- the tokamak cooling water system maintenance drain and the tokamak cooling water system vent gas condensate,
- in-vessel component maintenance drain collected in the hot cell
- condensate from the standby vent detritiation system and the standby atmosphere detritiation system operated during tritium contamination accidents.

The objective of this task was to update the designs of the ITER ISS and WDS as documented in the 2001 FDR (Final Design Report) taken into account the result and the recommendation of the FMEA report [3] and experimental results from ongoing R&D tasks. During the preparation of the Design Description Document package for the final report of ITER 2001 [1], [2] a number of trades off between the Tritium Plant subsystems have been already identified. The design of the strongly interlinked inner deuterium-tritium fuel cycle of ITER need to balance requirements between all subsystems and shall be based upon experimentally proven technologies.

The CATIA V5 software was chosen to create, using the PRM (Project Resource Management) [8], the 3D layouts of plant sites by defining the buildings, the major areas, all the way down in the plant area, the path to the equipment and so on. Subareas for facilities and technological equipments have been created within the plant. The system allows a hierarchical approach including true partition of space with shared boundaries, areas with multi patches, and so on.

2. Process Description

The Combined Electrolysis Catalytic Exchange (CECE) method in combination with Cryogenic Distillation (CD) was chosen for tritium recovery from tritiated water which will be produced during ITER operation. A potential combination of the ITER WDS and of the ITER ISS is shown in Figure 1.

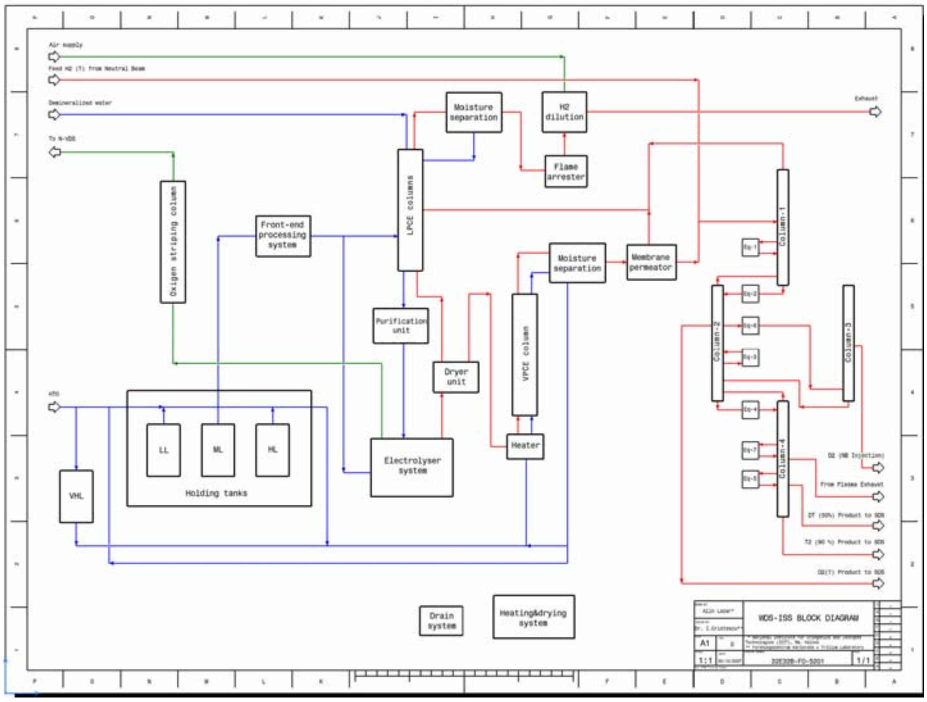

Figure 1. Block diagram of ISS-WDS

The ITER water detritiation plant comprises two subsystems to process and temporary store the quantities of tritiated water: the water detritiation system (WDS) and the tritiated water holding tank system [2]. The tritiated water holding tank system stores the various tritiated water streams according to the tritium concentrations prior to processing. Tritiated water is fed into the LPCE column at heights given by the tritium concentration. At the top of LPCE column natural water is added. Enriched tritiated water is collected in the column boiler from where is sent through a purification unit to the electrolyzer unit. An advanced electrolyzer based on solid polymer electrodes (SPE) was proposed for the ITER WDS to avoid the production of a mixed liquid waste containing high-level tritium concentration (mixture of tritiated water and alkaline solution). The electrolyzer decomposes tritium-enriched water into the tritium-rich H2 gas and O2 gas streams. The mixture is sent to a moister separator and to a membrane permeator for chemical purification and the purified permeate is fed into the ISS column 1 (CD1). The O2 gas stream, which contains a small fraction of HT gas and tritiated moisture (HTO), is sent for purification to the Oxygen Striping Column. Tritiated water with high tritium concentration will be primarily processed within a VPCE column.

Part of the tritium-rich H_2 gas stream is sent to the hydrogen isotope separation system (ISS) for tritium recovery, and the rest of tritium-rich H_2 gas stream is fed to the catalytic isotope exchange tower. The ISS utilizes cryogenic distillation to separate hydrogen isotope mixtures [1]. The ISS of ITER is considered to be the major source for stack releases and in this case it will be in the elemental form (HT). The ITER ISS columns consist of four distillation columns (CD1, CD2, CD3 and CD4). The four cryogenic distillation columns are directly connected and equilibrators (Eq) are employed to split the mixed hydrogen isotopes into H_2, D_2 and T_2, respectively.

Thereby the WDS is employed for detritiation and the ISS is employed for tritium recovery.

3. Plant Layout Design

A 3D layout of the WDS and ISS systems in the building has been developed based on the FDR 2001 report and the recommendation from the reports presented at Tritium Plant Project Team (TPPT) Meeting Cadarache, 8-10 October 2007 [4],[5]. Figure 2 shows vertical views of the major equipment of the ISS and WDS within the building.

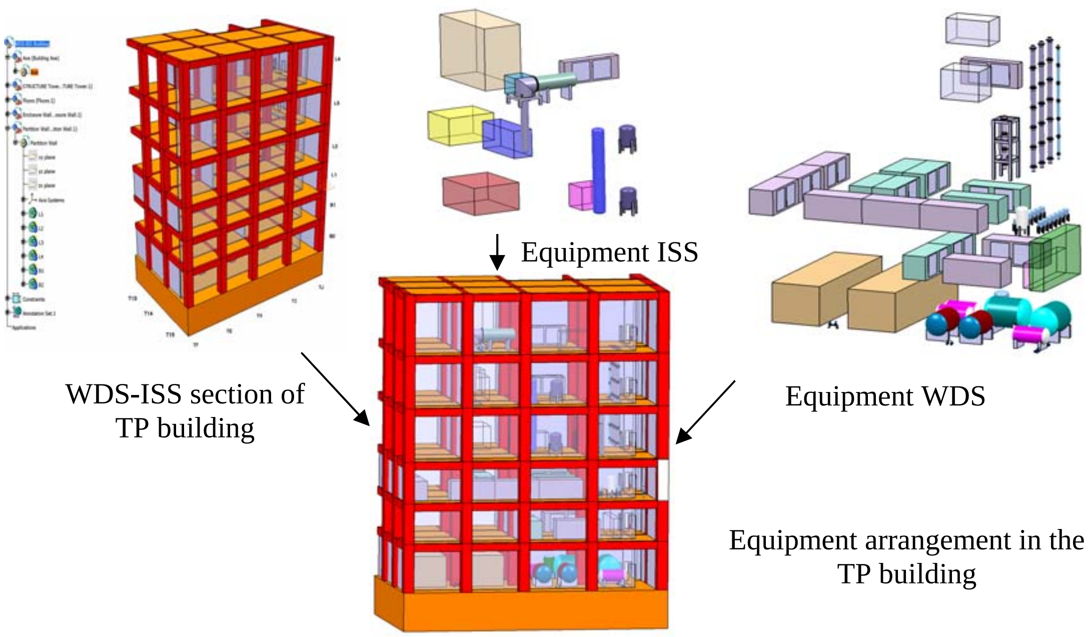

Figure 2. WDS-ISS section of Tritium Plant Building

The designing work involved spaces reservation for the major equipment of ITER ISS-WDS system, analysis of the area/volume allocations and optimization of the general 3D layout of plants and equipment. The arrangement of the constituent process systems has been optimized in terms of minimizing the length of interconnections, and has taken into account provision of adequate space for operation and maintenance, separation of the building areas into zones. The 3D layouts are organized in structures called product tree (skeleton) comprising assemblies, sub-assemblies and parts [8].

Numbering, naming and symbols of components and equipment were chosen according to: ITER-FEAT Tritium Plant Numbering System (Doc. No. 32 OD 0010) [6], ITER_Plant_Identifica_ITER_D_27KSGF_v10 [7], CATIA_V5_E&S_ITER_D_25DD33_v1.0 [8].

The equipment placement into the WDS-ISS layout was done taking into consideration the building constraints [6], [5]:

WDS system:

- B2 (basement level 2) - emergency tanks, L level holding tanks, LL level holding tanks, H level holding, WDS process drain tank.
- B1 (basement level 1) - Tritium monitors for tritiated water, 2 electrolyzer, 2 electrical cabinet-electrolyzer, space reservation for piping connections.
- L1 (Level 1) – 6 electrolyzer, 6 electrical cabinet-electrolyzer, space reservation for collecting vessels.
- L2 (Level 2) - space reservation for LPCE columns & O2 stripping column, Space reservation for VPCE column.
- L3 (level 3) - space reservation for LPCE columns & O2 stripping column, Electrical cabinet for CECE process, hydrogen purification unit.
- L4 (level 4) - space reservation for LPCE columns & O2 stripping column, heating and cooling systems for LPCE columns, H_2 discharge.

ISS system:

- L2 (level 2) - helium buffer tank, H2 expansion tank, space for temporary storage of lower CD cold-box, helium purification unit, helium compressor.
- L3 (level 3) - CD lower cold-box, refrigeration unit, H2 expansion tank, helium purification & gas impurity measurement.
- L4 (level 4) - CD cold-box, ISS Hard shell confinement, Vacuum system, Electrical cabinet for CD system, H_2 discharge.

From the 3D WDS and ISS layouts, plot plans were generated with equipment arrangement for each floor. The plot plans has be send for review to the EFDA CSU Garching /ITER.

4. Collaborative work

Work related to these topics belongs to the task TW6-TTFD-TPI- 55-2 (Art.5.1b) from the EFDA Technology Work program 2006 and was done in collaboration with FZK Association team during the period January 2007 - December 2007.

Part of this work has been performed during the two-month Mobility Secondment of A. Lazar at Forshungszentrum Karlsruhe – Tritium Laboratory, Germany.

5. Conclusions

Development of a Water Detritiation System (WDS) and an Isotope Separation System (ISS), configuration and design of critical components are essential for ITER. ITER needs the WDS&ISS systems to process tritiated water, which was accumulated from operation and also the tritiated water which will be generated during decommissioning. The WDS is based on the Combined Electrolysis Catalytic Exchange (CECE) process and is envisaged to work in combination with the ISS with the aim to recover tritium contained in the processed tritiated water.

The Block diagrams were developed in the Piping and Instrumentation Diagram application from the CATIA V5 software, having as reference the process diagrams from the DDD _32_E report [2], DDD_32_B report [1] and FMEA report [3].

A 3D layout of the WDS and ISS systems arrangement into the building has been developed and plot plans were generated with equipment arrangement for each floor. The plot plans have been sent for review to the EFDA CSU Garching / ITER.

The ITER inputs will be used in a near future for the process design update of the WDS-ISS systems, if required.

References

[1] **Kveton O. K.,** "*Tritium Plant and Detritiation Systems - Hydrogen Isotope Separation System (WBS 3.2B)*".

[2] **Yoshida H.,** "*Tritium Plant and Detritiation Systems Water Detritiation System and Tritiated Water Holding Tank System (WBS 3.2.E)*".

[3] **Rizzello C., Pinna T.,** "*Failure Mode and Effect Analysis for Water Detritiation System of ITER*".

[4] **Cristescu I.,** "*WDS-ISS space allocation*", presented at Tritium Plant Project Team (TPPT) Meeting Cadarache, 8-10 October 2007.

[5] **Beloglazov S.,** "*TP_Layout_ITER_D_28YUVW_v1.0[1]*", presented at Tritium Plant Project Team (TPPT) Meeting Cadarache, 8-10 October 2007.

[6] **Gugla M., Yoshida H.,** "*ITER-FEAT Tritium Plant Numbering System (Doc. No. 32 OD 0010)*"

[7] **Belogazov S., Chiocchio S.,**"*ITER_Plant_Identifica_ITER_D_27KSGF_v1_0*"

[8] **Belogazov S., Caldwell C., Glugla M., Lazar A., Lux M., Wagner R., Weber V.,**"*PRM and Standard Parts Catalogues in CATIA V5 for Tritium containing Systems and Components*"

[9] **Standards,**"*EN ISO 10628*", "*EN ISO 3511*", "*DIN 28401*", "*ASME section VIII, div.1 – Rules for construction of pressure vessels*".