Fusion Engineering and Design 89 (2014) 1524–1528

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Design and R&D activities of TriPla-CA Consortium in support of ITER Tritium Plant development

I. Cristescu[a,*], G. Ana[b], D. Demange[a], R. Michling[a], Alina Niculescu[b], C. Petrutiu[b], T. Pinna[c], S. Welte[a]

[a] Karlsruhe Institute of Technology, Institute for Technical Physics, Tritium Laboratory, 76021 Karlsruhe, Germany
[b] INC-DTCI ICSI Ramnicu Valcea, Romania
[c] ENEA, Frascati, Italy

HIGHLIGHTS

- Several rigs and experimental facilities have been enhanced and developed to carry out R&D for ITER Tritium Plant.
- Wide range of envisaged scenarios for the ITER water detritiation system (WDS) have been experimentally investigated.
- The simulation tool TRIMO++ have been developed and bench marked against experimental data.
- The process based on capture and isotopic exchange on zeolite beds for processing highly tritiated water was investigated.
- The liquid hold-up and the HETP of various types of packing for the cryogenic distillation process have been measured.

ARTICLE INFO

Article history:
Received 16 October 2013
Received in revised form 19 February 2014
Accepted 24 March 2014
Available online 6 May 2014

Keywords:
Tritium processing
Water detritiation
Cryogenic distillation
Highly tritiated water processing

ABSTRACT

The design of ITER tritium processing systems should benefit from experimental data and process validation on experimental facilities that are ITER relevant. TriPla-CA, which is a consortium of four EU laboratories aiming to support tritium relevant activities for ITER design is carrying out R&D and design for ITER Tritium Plant. Several rigs and experimental facilities have been enhanced and developed in order to explore a wide range of envisaged scenarios of some ITER Tritium Plant systems such as water detritiation system (WDS), isotope separation system and highly tritiated water processing. Beside the experimental activities, the enhancement of the relevant software for simulation and design of various tritium processing systems is ongoing. The main achievements concerning the R&D, the mechanical design including the seismic calculations of some ITER WDS components and the main expertize and the hardware available inside the consortium are presented.

1. Introduction

Several experimental rigs and facilities have been developed over the last ten years in support of the R&D program, aiming to provide experimental data and to validate various processes for tritium recovery and separation needed for ITER Tritium Plant. The TRENTA facility from the Tritium Laboratory Karlsruhe (TLK) was developed and installed to investigate appropriate system configuration to process tritiated water in a technical scale relevant to ITER WDS and also to recover tritium from the tritiated waste water produced during laboratory operation [1]. The TRENTA facility consists of two main parts, the WDS and the isotope separation system based on cryogenic distillation. The dedicated process selected for the WDS is the CECE process (Combined Electrolysis and Catalytic Exchange) similar to ITER WDS.

Complementary to WDS activities, two experimental rigs have been developed, aiming to select the technology and also to provide experimental data for processing highly tritiated water that may be generated during ITER operation.

The experimental activities are supported by continuously developing and enhancing relevant software for the simulation and design of various tritium processing systems – this is one of the key activities of TriPla-CA Consortium.

2. Relevant activities for ITER WDS

The assignment of the WDS is to recover tritium from tritiated water and to discharge the decontaminated hydrogen into the

* Corresponding author. Tel.: +49 7247823757; fax: +49 7247822868.
E-mail address: ion.cristescu@kit.edu (I. Cristescu).

http://dx.doi.org/10.1016/j.fusengdes.2014.03.067
0920-3796/

Table 1
Impact of deuterium concentration on the tritium decontamination factor.

Deuterium feeding gas D/(D + H)	Tritium feeding gas T/(H + D + T)	Tritium exhausted gas T/(H + D + T)	DF factor after 8 m of LPCE column
0.143	5.6E−08	1.6E−13	3.3 ± 0.4E+05
0.374	1.1E−07	5.4E−11	2.1 ± 0.1E+03

environment, which shall be oxidized to water before release. The tritium enriched stream in the gas phase from the electrolysis unit shall be partially transferred to ISS for final enrichment and recovery. The CECE process of the WDS consists mainly of two processing steps. First, tritiated water is converted to gaseous hydrogen by the electrolysis unit; secondly, along an isotopic exchange column (LPCE), one part of the generated hydrogen stream is decontaminated and discharged into the environment, whereas the other part is fed to the ISS for final enrichment and recovery.

To control the process in an efficient manner, all tritiated water will be intermediately stored in the holding tanks of WDS, from where the water is constantly fed to the exchange columns or to the electrolysis unit, depending on the tritium content and the operation modes of WDS.

The detailed design of the emergency and holding tanks of 100 m^3 and 20 m^3, respectively, has been completed by the TriPlaCA Consortium. The design of the WDS Emergency and Tritiated Water Holding Tanks have been carried out in compliance with ASME 2007 Section VIII, Division 1 and the seismic calculation of the tanks have been performed in compliance with ASME 2007 Section III–Appendix N – Dynamic Analysis Methods. Several static and dynamic analyses have been performed, using the ANSYS WORKBENCH 13.0 Program, to verify the stress in the tank assembly and anchor bolt design. The main scope of the activities at this stage was to provide a reliable figure for the loads in the Tritium Building where the emergency and holding tanks will be accommodated, and also to ensure the physical integrity of the tanks during earth quake events. It was identified that guide support has to be included on the embedded base plates of the emergency holding tanks, otherwise the share forces exceed the acceptable values.

Since ITER WDS consists of the CECE process and aims to concentrate the tritium for further recovery within the ITER ISS, a side effect is the accumulation of deuterium in the electrolysis system. The deuterium accumulation is unavoidable even during WDS operation with deuterium content at natural level since the CECE technology is one of the most efficient methods to produce heavy water.

In the last years, at the Tritium Laboratory from KIT detailed experimental investigations and process modeling have been conducted in relation to a combined CECE-ISS system, and have focused on evaluating the impact of the deuterium build-up and accumulation in the CECE system. The 8 m LPCE column of the CECE process, employed for detailed experimental investigation and mathematical simulation calibrations, is shown in Fig. 1.

The experimental results and the calculations showed that the increase of deuterium over 30% in the electrolysis system drastically reduces the decontamination factor in the LPCE column, and consequently is a concern for the tritium release into the environment. In Table 1 the decontamination factor measured for the same operation conditions but with significant different deuterium concentrations is shown.

In support of designing the ITER WDS hydrogen discharge system, a prototype oxidation reactor able to oxidase up to 1.8 $m^3 \times h^{-1}$ (scale ~1/80 compared to ITER's operation requirements) has been manufactured, installed and connected to the CECE of the TRENTA facility. The hydrogen discharged from the CECE process was diluted with air stream up to 79 $m^3 \times h^{-1}$ in a dedicated static mixer, before being injected into the Pd based oxidation reactor. The experimental test performed with the installed oxidation

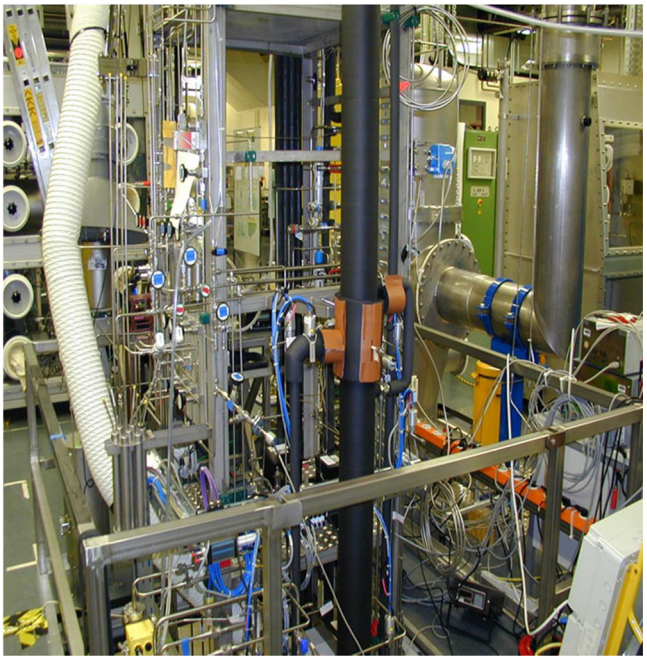

Fig. 1. The 8 m LPCE column of the TRENTA facility.

unit showed efficient hydrogen conversion, as the residual hydrogen concentration in the exhausted gas is about three orders of magnitude smaller than the inlet hydrogen concentration. The efficiency of the oxidizer during startup, warming up of the reactor bed, has also been investigated and the hydrogen content evolution in the exhaust gas during time is shown in Fig. 2. Provision in the operation procedures of the oxidation system shall be implemented according to the safety analysis concerning the impact on ITER ventilation system.

The tritium amount in the CECE process is one of the main safety concerns of the Tritium Plant, the possibilities of incorporating a

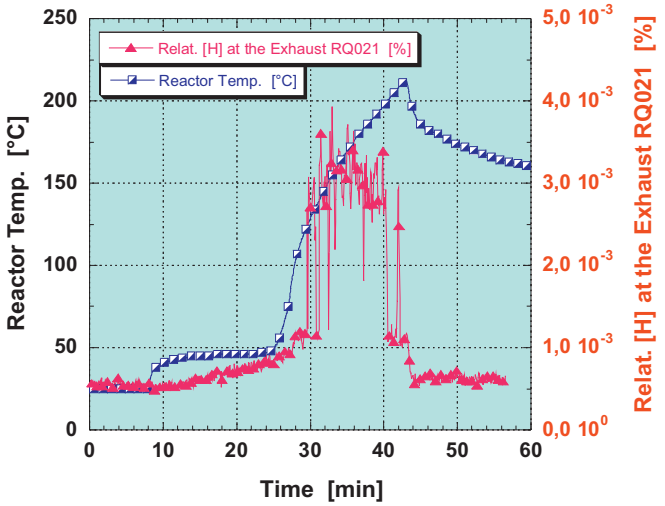

Fig. 2. Hydrogen content in the exhaust gas versus time during warming up of the reactor bed.