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Tritium research activities in Korea

Ki Jung Jung[a], Sei-Hun Yun[a,*], Min Ho Chang[a], Hyun-Goo Kang[a], Dongyou Chung[a], Seungyon Cho[a], Hyeon Gon Lee[a], Hongsuk Chung[b], Woo-Seok Choi[b], Kyu-Min Song[c], Chang-Bae Moon[c], Euy Soo Lee[d], Jungho Cho[e], Dong-Sun Kim[e], Hung-Man Moon[f], Seung Jeong Noh[g], Hyunchul Ju[h], Tae-Whan Hong[i]

[a] *National Fusion Research Institute, Yusung-gu, Daejeon 305-333, Republic of Korea*
[b] *Korea Atomic Energy Research Institute, Yusung-gu, Daejeon 305-353, Republic of Korea*
[c] *Korea Hydro & Nuclear Power Central Research Institute, Yusung-gu, Daejeon 305-343, Republic of Korea*
[d] *Dongguk University, Jung-gu, Seoul, 100-715, Republic of Korea*
[e] *Kongju National University, Cheonan, Chungnam, 330-717, Republic of Korea*
[f] *Daesung Industrial Gases Co., Ltd., Danwon-gu, Ansan-si, Gyeonggi-do, 425-090, Republic of Korea*
[g] *Dankook University, Suji-gu, Yongin-si, Gyeonggi-do, 448-701, Republic of Korea*
[h] *Inha University, Nam-gu, Incheon, 402-751, Republic of Korea*
[i] *Korea National University of Transportation, Chungju, Chungbuk, 380-702, Republic of Korea*

HIGHLIGHTS

- NFRI, KAERI and KHNP CRI are major leading group for the ITER tritium SDS design; studying engineering, simulation of hydride bed, risk analysis (on safety, HAZOP), basic study, control logic & sequential operation, and others. KHNP has WTRF which gives favorable experiences for collaboration researchers.
- Supplementary research partners: Five Universities (Dongguk University and POSTECH, Inha University, Dankook University, Korea National Transport University, and Kongju National University) and one industrial company (Daesung Industrial Gases Co., Ltd.); studying on basic and engineering, programming & simulation on the various topics for ITER tritium SDS, TEP, ISS, ADS, and etc.

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ABSTRACT

Major progress in tritium research in the Republic of Korea began when Korea became responsible for ITER tritium Storage and Delivery System (SDS) procurement package which is part of the ITER Fuel Cycle. To deliver the tritium SDS package, a variety of research institutes, universities and industry have respectively taken roles and responsibilities in developing technologies that have led to significant progress. This paper presents the current work and status of tritium related technological research and development (R&D) in Korea and introduces future R&D plans in the area of fuel cycle systems for fusion power generation.

1. Introduction

R&Ds on the ITER tritium SDS have been reported, since Korea became a member of ITER project [1–4]. Those R&D reports were

* Corresponding author.
E-mail addresses: kjjung@nfri.re.kr (K.J. Jung), shyun@nfri.re.kr (S.-H. Yun).

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deeply concerned with the ITER tritium SDS. The R&D scope has been expanded from ITER tritium SDS to the fusion fuel cycle a few years ago, but it does not cover with the whole fuel cycle area. Until now Korea has a restricted R&D scope in the fusion fuel cycle area, nonetheless, researchers in the institutes and the universities are solidifying their banding relationship under the collaboration teamwork.

As a major leading group for the ITER tritium SDS there are three institutes, including NFRI(National Fusion Research Institute, especially ITER Korea), KAERI(Korea Atomic Energy Research Institute) and KHNP CRI(Korea Hydro and Nuclear Power Central Research Institute). There they study in engineering, simulation of hydride bed, risk analysis (on safety, HAZOP), basic study, control logic & sequential operation, and others for calorimetry and tritium usage and etc., basically based on ITER tritium SDS. KHNP has WTRF, so the operation of the tritium removal system in WTRF gives one of favorable experiences for those collaboration researchers.

As of supplementary research partners to the leading group in the fusion fuel cycle study most of university researchers belong to this region: Five Universities (the Dongguk University and POSTECH, the Inha University, the Dankook University, the Korea National Transport University, the Kongju National University), and the only one industrial cryogenic research institute in Korea (Daesung Industrial Gases Co., Ltd.). They are studying on the basic study and engineering approaches on the limited fusion fuel cycle, including hydrogen permeation and protection development, possibility of hydrogen embrittlement for the welding materials having different characteristics, programming & simulation studies on the various topics with ITER tritium SDS, TEP, ISS, and ADS, and the fueling system for the future.

From the next section a series of specific topics being studied in the collaboration team is described as follows:

2. Collaboration works in tritium research

2.1. NFRI

National Fusion Research Institute (NFRI) has not only an authority for all activities with respect to the ITER project in Korea with full responsibility and has a part of responsibility for the tritium R&D, so this institute is one center of excellent for tritium R&D.

In this paper the authors propose a limitation to the recent activities so that three kinds of R&D works are described: 1) Physical property study with DU hydride material, 2) Hydride bed internal study for the heat- and mass-transfer enhancement, and 3) methodology study on the hydrogen gas transfer to the next process, fueling system.

Fig. 1 shows powdered DU hydride after 1 cycle, after 3 cycle, and ten cycles of hydriding/dehydriding steps, respectively. According to Fig. 1 DU material is apt to become a powder which color becomes blackish and a particular as the hydring/dehydriding cycles goes on. After 3 cycles of hydriding & dehydriding most of the DU hydride becomes less than micron size [5].

Fig. 2 shows that the supply of hydrogen isotope gas to fueling system is derived from the metal hydride beds. Not only rapid delivery by heating but also rapid recovery by cooling is key issue. Getting better performance of the metal hydride bed, various shapes of heat transfer enhancing component or geometric designs are applied. In this experiment two small ZrCo beds having different internals like 1) copper foam and 2) copper fin were experimented to compare the heat- and mass-transfer performance. As of result it was revealed that the copper foam type metal hydride bed shows improved performance than the fin type. In addition, uniform heating for the metal hydride bed during desorption is more efficient in copper foam bed case than the copper fin bed [6].

The unit process verification of the SDS was performed using the Depleted Uranium (DU) SPOVE. One of the major functions of the SDS is to deliver the fueling gases to the Fueling System (FS) in the ITER. The main fueling gas is a complex of tritium and deuterium gases and shall be safely handled by tritium compatible equipment. The experimental evaluation of the fueling delivery was performed to satisfy the fueling rate requirements. Fig. 3 is the main results of the proposed operation for the inductive plasma operation [7]. Based on the experimental evaluations, the operating bound of buffer tanks in the SDS was determined within one feasible process design.

2.2. KAERI

Activities in KAERI can be classified as the following two categories: One is for the basic study on hydride bed structure, and the other for the engineering study on load and safety analysis of ITER tritium SDS.

One basic study group on the ITER SDS hydride bed in KAERI supports KO-DA(or ITER KO that means ITER Korea, abbreviation as Korea Domestic Agency comparing with ITER Organization Central Team) with her uranium(depleted uranium) safe handling technology. Fig. 4 shows a glove box at KAERI for the metal hydride bed preparation. The argon in the glove box is pumped through a series of treatment devices, which remove water and oxygen from the gas. The hermetically sealed glove box maintains an argon atmosphere with an H_2O concentration at 0.0 ppm, and O_2 concentration at about 0.0–0.4 ppm. The glove box is kept at a higher pressure of about 1.25-in. H_2O than the surrounding air, so that any microscopic leaks are mostly leaking inert gas out of the box instead of letting air in [8] (see Fig. 5).

This KAERI group also supports ITER KO with her DU hydride bed performance test rig. Fig. 2 shows a rig at KAERI for the DU hydride bed performance test. Metal hydride beds are installed onto the bed performance test rig. The rig is used for a measurement of the hydrogen recovery and delivery rates. Metal powder in the two bed models is activated through several repetitions of hydriding and dehydriding. The amount of hydrogen used for the initial activation and hydriding and dehydriding runs is measured by the hydrogen pressure filled in the loading vessel and the manifold. The control and data acquisition system is provided. The rig is also used to measure an in-bed calorimetry for the tritium accountancy in the bed [8].

The following is concerning to the second research group in KAERI (see Fig. 6): To evaluate the integrity of SDS, load specifications and analyses for dominant load case should be conducted. For the load specification, every single load possible to occur in SDS was generated. Load combinations were made based on the characteristics of each single load and incident/accident scenarios. This structural analysis includes the modal analysis and the seismic analysis for the tritium SDS glove box. The dynamic characteristics of the glove box are obtained through the modal analysis. The seismic response results are calculated for the floor response spectra given in [9]. And the objective of the fire accident analysis for the compartment where the ITER tritium SDS glove boxes are installed is to estimate the integrity of the glove box [10]. Fires in grouped electrical cable trays pose distinct fire hazards within the compartment where the SDS glove boxes are installed. Cable tray fires can occur from various sources. The scenarios of concern include a fire within a cable tray and as exposure fire. Therefore, it is common practice to consider only self-ignited cable fires to occur in power cable trays since they carry enough electrical energy for ignition. In general, electrical cables typically do not carry enough electrical energy for self-ignition. According to NUREG/CR-5384[3.7.1-3], it