Fusion Engineering and Design 87 (2012) 890–895

Contents lists available at SciVerse ScienceDirect

Fusion Engineering and Design

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

Overview of R&D activities on tritium processing and handling technology in JAEA

Toshihiko Yamanishi*, Hirofumi Nakamura, Yoshinori Kawamura, Yasunori Iwai, Kanetsugu Isobe, Makoto Oyaidsu, Masayuki Yamada, Takumi Suzuki, Takumi Hayashi

Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

ARTICLE INFO

Article history:
Available online 3 April 2012

Keywords:
Broader approach
Tritium
Processing
Handling
Analysis
Durability
Safety research

ABSTRACT

In JAEA, the tritium processing and handling technologies have been studied at TPL (Tritium Process Laboratory). The main R&D activities are: the tritium processing technology for the blanket recovery systems; the basic tritium behavior in confinement materials; and detritiation and decontamination. The R&D activities on tritium processing and handling technologies for a demonstration reactor (DEMO) are also planned to be carried out in the broader approach (BA) program by JAEA with Japanese universities. The ceramic proton conductor has been studied as a possible tritium processing method for the blanket system. The BIXS method has also been studied as a monitoring of tritium in the blanket system. The hydrogen transfer behavior from water to metal has been studied as a function of temperature. As for the behavior of high concentration tritium water, it was observed that the formation of the oxidized layer was prevented by the presence of tritium in water (0.23 GBq/cc). A new hydrophobic catalyst has been developed for the conversion of tritium to water. The catalyst could convert tritium to water at room temperature. A new Nafion membrane has also been developed by gamma ray irradiation to get the strong durability for tritium.

1. Introduction

The facility of Tritium Process Laboratory (TPL) in Japan Atomic Energy Agency (JAEA) is a unique laboratory for fusion technology, where we can handle more than 1 g of tritium in Japan [1,2]. Maximum storage amount of tritium is licensed to 22.2 PBq. Now, 11 PBq of tritium (at March 2011) is stored in TPL and used safely in a multiple confinement system for the following R&D since 1988 with a set of valuable data [2]. Recent our missions at TPL are (1) R&D and design activities for ITER; (2) R&D activities toward DEMO plants under BA program [3]; and (3) some fundamental studies on tritium science by some competition budgets. Among the tritium plant of ITER, we undertake 50% of the procurement of the DS (Detritiation System) of ITER [4]. The R&D for ITER-TBM (Test Blanket Module) is also a significant work at TPL for ITER [4]. Under the common strong interests of EU and JA, the R&Ds for tritium technologies toward to the DEMO plant are carried out in the BA program. The following R&Ds are proposed as important, generic, and mutually interested research subjects under the BA program: (1) tritium accountancy technology; (2) basic tritium safety research; and (3) tritium durability test [3]. In this paper, the above recent activities on the tritium technologies at TPL in JAEA are summarized.

2. Introduction of TPL [1,2]

There are 14 glove boxes and 22 hoods at TPL. The experimental components have a leak tight structure for tritium, and the exhaust gas from the components is processed by a tritium removal system. The components are installed in the glove boxes, and the atmosphere of the glove boxes is continually processed by another tritium removal system. One more tritium removal system is also prepared for an accidental tritium release in TPL. All these tritium removal systems are composed of catalytic reactor and molecular sieve beds for removal of the tritium water. The systems have been operated for 26 years with no serious problem. No accidental tritium release occurred over the past 23 years.

The average concentration of tritium in the stack was ~70 Bq/m^3 from March 1988 to March 2011, which is less than ~1/70 of the Japanese regulatory limit. Amount of tritium released from stack is 3.6×10^{11} Bq for HTO, and is 3.0×10^{10} Bq for HT for 20 years. The total amount of tritium released to the environment as the waste water (14 GBq) was ~1/40 of that from the stack. The amount of tritium disposed as solid waste was negligible. Highly contaminated waste water and solids have been stored in TPL.

3. Recent activities for ITER [4]

The DS (Detritiation System) is a key system to ensure the tritium confinement in ITER. The concept of DS of ITER is basically same as that of TPL: catalytic reactor and molecular sieve bed.

* Corresponding author.
E-mail address: yamanishi.toshihiko@jaea.go.jp (T. Yamanishi).

0920-3796/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.fusengdes.2012.02.043

However, recently, the design of the DS was significantly changed. The molecular sieve bed must be regenerated in the case of the saturation, by changing line to another bed. It was found that the reliability of the valves changing the line is not sufficient, so that a part of molecular sieve bed was changed to a scrubber column. The scrubber column is the water and water vapor counter currently exchange column. It has been established in chemical engineering; however, there has been no tritium data. Hence, a series of tritium demonstration tests for a pilot plant scale of the scrubber column of DS of ITER was started at TPL as a R&D task from ITER at TPL. The pilot scale scrubber column has been manufactures and been installed at TPL. The flow rate of the column is 350 m^3/h, which is 1/4 of an actual column of ITER. However, before a series of test runs, TPL has been seriously damaged by the earthquake, and recovering work of TPL has been continued to restart the scrubber tests.

4. Recent activities on tritium technology for BA

4.1. Tritium handling facility [3]

To carry out the above R&D studies, multipurpose RI handling equipment has been designed and manufactured at Rokkasho site (30 m × 50 m × 7 m height). The RI handling equipment at Rokkasho site is the first and quite unique facility in Japan, where tritium, beta and gamma RI species, and beryllium (Be) can simultaneously be used. The amounts of tritium used and stored are 3.7 TBq per glove box (0.37 TBq per hood) and 7.4 TBq, respectively. The amounts of other typical RI species stored are 500 MBq for P-32, ceramics, 915 MBq for Fe-59, and 220 MBq for W-188. Two tritium storage beds are installed into a glove box (nitrogen atmosphere, −40 mm H_2O pressure) as shown in Fig. 1. A detritiation system composed of a catalyst bed and a set of molecular sieve beds (flow rate is 6 m^3/h) is installed to remove tritium in the atmosphere of the glove box. The hydrogen is converted to water vapor with the catalysts bed, and the water vapor is removed with the molecular sieve bed. The detritiation factor of the system is design to be 99.9%. The other detritiation system (flow rate is 2 m^3/h) is operated in the circulation mode to remove tritium in a vessel.

Fig. 1. Photograph of tritium storage bed (7.4 TBq) using ZrCo powder at Rokkasho.

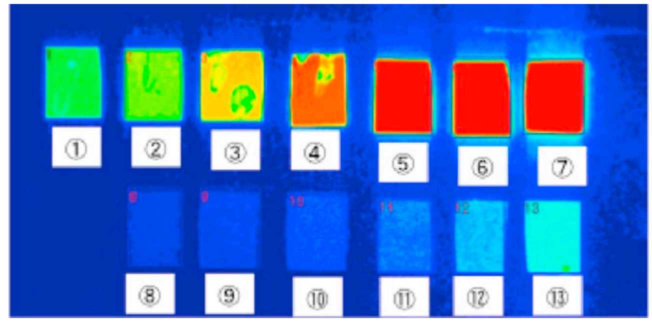

Fig. 2. The result of the IP exposed to the glass plate for 2 days. Tritium concentration on the plate is from 74 kBq/g to 273 MBq/g.

The exhaust gases from the apparatus handling tritium are sent to the vessel. A small amount of gas is also sent to the vessel from the glove box to maintain negative pressure. A hot cell having iron shield with a set of manipulators is installed in a room. Some irradiated samples described above are handled in the cell. In the building a set of Be handling devices (melting, sintering, and treating devises) are installed in a room. An independent ventilation system (frequency of ventilation = 16 times/h, permissible Be concentration = 0.002 mg/m^3) is installed in the room.

4.2. Tritium accountancy technology

The technologies for real-time analysis for hydrogen isotopes, in gas, in liquid and in solid are studied. A large amount of solid waste will also be expected in a demo plant in comparison with ITER, so that it is significant to study a measurement method of tritium inventory in the waste. The calorimeter method measuring decay heat of tritium, which has been studied in several tritium facilities [5], has also been studied in JAEA. A modified calorimeter instrument with larger cells (φ52 mm × 30 mm) and a digital Nanovoltmeter has been designed and been tested at TPL. The sensitivity (0.4 nV/nW) and minimum detective heat (20 nW: 22 MBq) of the instrument have been tested by a series of preliminary runs. The imaging plate (IP) method has also been studied to measure the amount of tritium in the solid waste [6]. The IP consists of a storage film coated with photo-stimulated phosphor (BaFBr:doped Eu^{2+}). The phosphor captures the X-rays induced by b-rays from tritium. The phosphor emits the light by irradiating the laser light, so that we can know the amount of tritium by measuring the intensity of the light. Fig. 2 shows a typical result of IP measurement. In the collaborative studies with Japanese Universities, the IP methods have been tested to measure the concentration of tritium in waste water, and the tritium depth profile in the solid waste [7]. A monitoring method of trace amount of tritium in atmosphere has also been studied in this field with a set of simulation studied of tritium in the environment.

4.3. Basic tritium safety research

It is assumed that an appreciable amount of tritium permeates to a cooling water system. It is required to obtain basic data on the relationship between tritium and materials (F82H, etc.) from the viewpoint of the estimate of the amount of tritium permeation. A series of studies on tritium retention in plasma-facing components such as W are also proposed as a R&D subject for this purpose. It is required to study the tritium behavior in advanced blanket breeder materials from. Several R&D subjects have been carried out by collaborative studies between JAEA and Universities for this purpose. For the tritium behavior (retention and release) in W and F82H, the effect of surface damage has been studied. For the tritium behavior