TRITIUM BEHAVIOR INTENTIONALLY RELEASED IN THE ROOM

Kazuhiro Kobayashi, Takumi Hayashi, Yasunori Iwai and Toshihiko Yamanishi,
R. Scott Willms* and R. V. Carlson*

Tritium Engineering Laboratory, Directorates of Fusion Energy Research,
Japan Atomic Energy Agency, Tokai-mura, Ibaraki-ken, 319-1195, Japan. E-mail: kobayashi.kazuhiro@jaea.go.jp
** Los Alamos National Laboratory, Los Alamos, NM 87545, USA*

To construct a fusion reactor with high safety and acceptability, it is necessary to establish and to ensure tritium safe handling technology. Tritium should be well-controlled not to be released to the environment excessively and to prevent workers from excess exposure. It is especially important to grasp tritium behavior in the final confinement area, such as the room and/or building. In order to obtain data for actual tritium behavior in a room and/or building, a series of intentional Tritium Release Experiments (TREs) were planned and carried out within a radiologically controlled area (main cell) at Tritium System Test Assembly (TSTA) in Los Alamos National Laboratory (LANL) under US-JAPAN collaboration program. These experiments were carried out three times. In these experiments, influence of a difference in the tritium release point and the amount of hydrogen isotope for the initial tritium behavior in the room were suggested. Tritium was released into the main cell at TSTA/LANL. The released tritium reached a uniform concentration about 30 ~ 40 minutes in all the experiments. The influence of the release point and the amount of hydrogen isotope were not found to be important in these experiments. The experimental results for the initial tritium behavior in the room were also simulated well by the modified three-dimensional eddy flow analysis code FLOW-3D.

I. INTRODUCTION

In a future fusion reactor of high safety and acceptability, safe confinement of tritium will be one of the key issues for realizing a fusion reactor, the tritium should be well-controlled with limited release to the environment and minimal worker exposure. Tritium will be handled under a multiple confinement system in a fusion reactor and each level of confinement will have its own detritiation system [1]. This concept of the multiple confinements has been successfully adopted in tritium facilities in the world [2,3]. The Tritium Process Laboratory (TPL) of Japan Atomic Energy Agency (JAEA) is a facility licensed to handle 22.2 PBq of tritium, which also has multiple confinement systems [4], and since its foundation it has been accumulating safety experiences for more than 20 years without any accidental tritium release into the rooms or into the environment [5]. A room and/or a building will be important as a final confinement barrier of tritium to the environment. However, only a few reports are available for the case when a room is the final barrier [6], [7].

In TPL/JAEA, in order to understand the tritium behavior in a room, the Caisson Assembly for Tritium Safety study (CATS) was installed in 1998. CATS consists of a Caisson and a glove box. CATS, 12 m^3 of leak-tight box was the experimental apparatus used to simulate a room. The data of the tritium behavior in the simulated room had been accumulated using the CATS [8-10]. A simulation code has been developed by modifying the code FLOW-3D [11-13].

In order to obtain data for the actual tritium behavior in a room and/or building, a series of intentional tritium release experiments were planned and carried out within the main cell at TSTA/LANL under US-JAPAN collaboration program.

This paper discusses the influence of different release points and the amount of hydrogen isotope on the initial tritium behavior in a room. The experimental results were also compared with the simulation code.

II. EXPERIMENTAL

II. A. Experimental Apparatus

Fig. 1 shows an artistic view of the radiological controlled area (main cell) of TSTA/LANL (solid bold line area). The volume of the main cell is about 3000 m^3 (~29 x ~12 x ~8.5 m). The area is normally at a negative pressure of approximately 27 Pa relative to ambient atmospheric pressure. There are two tritium release points. One is at the corner in the main cell. Another one is at the center in the main cell. The tritium released into the main cell was measured by eight ion chambers. Three water bubbler systems are also installed to measure the HTO concentration.

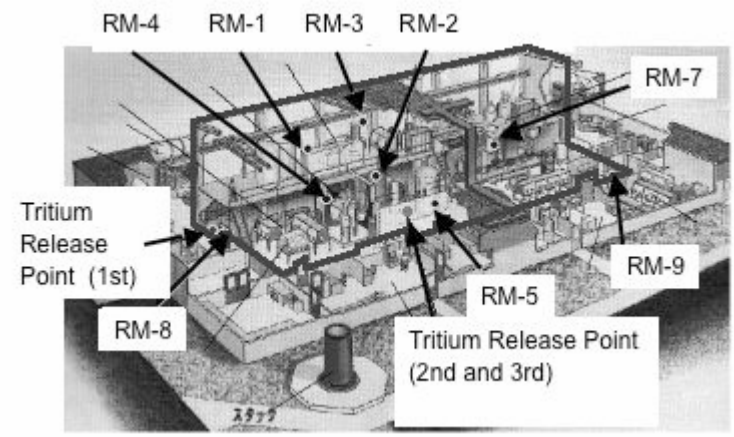

Fig. 1. Artistic view of radiological controlled area (main cell) of TSTA/LALN

II. B. Experimental Method and Conditions

TABLE I shows the experimental conditions of the three TREs at TSTA/LANL. The differences in the experiment from the 1st to the 3rd are the tritium release points and the amount of released hydrogen isotope. Tritium released from the corner of the main cell in the 1st TRE and from center of the main cell in the 2nd and 3rd TREs. The amount of the released tritium in the TREs was 37 GBq of pure tritium gas or tritium gas with 4L of D_2 with less than 1% tritiated water, respectively. In the 1st and the 2nd TREs, the tritium was released from a stainless steel container (4.5 cm^3, 8 kPa) with a N_2 purge. In the 3rd TRE, the tritium was diluted in the stainless steel container (2 L, 202 kPa) with 4L of D_2 and was released with a N_2 purge.

TABLE I. Experimental Conditions of TRE

Tritium Release Experiment (TRE)	1st	2nd	3rd
Release gas species	T_2 gas		T_2 gas with 4L of D_2
Released T amount	37 GBq (with less than 1% HTO)		
Volume of the main cell	3000 m^3		
Release point	Corner	Center	
Atmospheric pressure	78 kPa		

The experimental method was as follows. The first, the main cell was isolated by stopping the ventilation system, and then the tritium sample was automatically released into the main cell. The tritium profiles were measured by eight ion chambers and by three bubbler systems. Five hours after the tritium release, the ventilation system was started and the activity was discharged to TSTA stack.

II. C. Computer Code and Simulation Analysis Condition

In order to simulate the tritium behavior in the room, a computer analysis code was developed by improving a three dimensional eddy flow analysis code, Flow-3D by Flow Science Inc.. In the analysis code, K-e two equations eddy flow model was adopted by adding a low Reynolds flow model, such as the Launder-Sharma model, in order to handle actual rather lower ventilation flows. Moreover, the actual tritium release behavior was expressed by using a residence time function equation. The mesh size of calculation was adjusted to be smaller around the tritium release point and the ventilation inlet ducts. More details were provided in the previous papers [11,12]. Fig.2 shows a schematic view of the simulated the main cell at the TSTA/LANL used by the modified Flow-3D code.

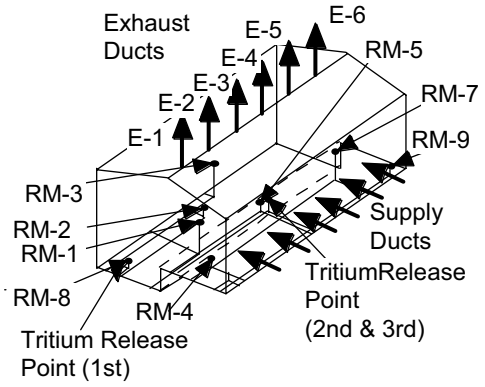

Fig. 2. Schematic view of simulated the main cell in the TSTA/LANL by modified Flow-3D

III. RESULTS AND DISCUSSION

III.A. Initial Tritium Behavior and Detritiation Behavior in the Main Cell at TSTA/LANL

Figs. 3 and 4 show the results of the initial tritium behavior in the main cell at TSTA/LANL for 2nd to 3rd TREs, respectively.

The released tritium dynamically driven by the residual air flow in the main cell. The released tritium was quickly detected at the nearest tritium monitor from the tritium release point. In the 1st TRE, the tritium level of RM-8 increased quickly to about 150 MBq/m^3 just after tritium released [7]. In the 2nd and 3rd TREs, the tritium level of RM-5 increased quickly to about 170 MBq/m^3 and 400 MBq/m^3, respectively. All of the tritium concentrations reached a uniform value of about

10 MBq/m^3 in 30 ~ 40 minutes in the all of TREs. The results of 1st TRE and fig. 3 are the difference in the tritium release point. Each tritium monitor responded to the passing plume. However, the time to reach a uniform value in the tritium levels in the main cell was almost same. The results of figs. 3 and 4 show the difference in the amount of hydrogen isotope. In the case when 4L of D_2 was released with 37 GBq of tritium (Fig. 4), the tritium level in RM-5 increased about 3 times higher than in the 2nd TRE (Fig. 3) just after the tritium release. However, the time to reach the uniform value in the tritium levels in the main cell did not change drastically by comparison to the 1st and 2nd TRE. This means that a 370 TBq (about 1 g of tritium) tritium release was simulated to the main cell (3000 m^3) and the initial tritium behavior in the main cell was almost identified to the 37 GBq release.

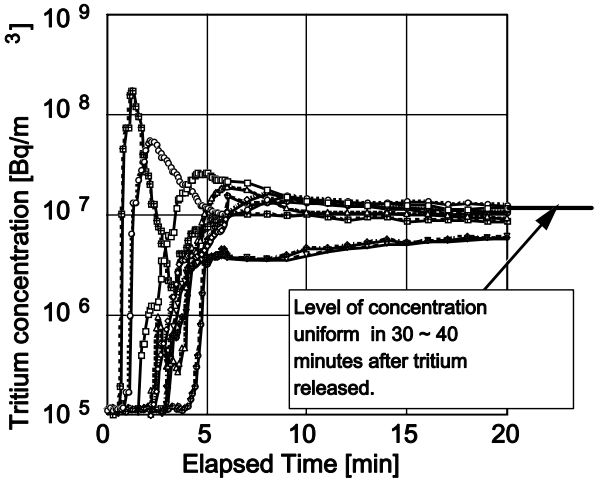

Fig. 3. Initial tritium behavior in the main cell (2nd TRE)

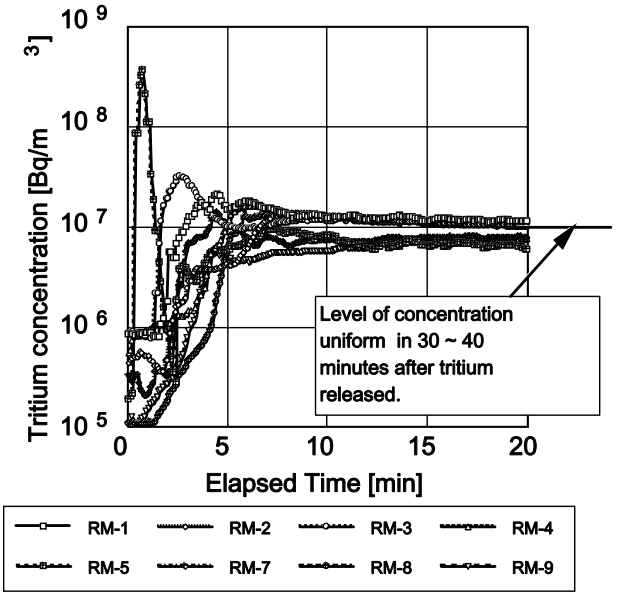

Fig. 4. Initial tritium behavior in the main cell (3rd TRE)

Five hours after the tritium released, the ventilation system was started to remove the tritium in the main cell. The ventilation system was used 18,000 m^3/h stack blower in the TSTA/LANL. Fig. 5 shows the detritiation behavior in the main cell for the 3rd TRE. Since the released tritium was almost tritium gas with less than 1% tritiated water, the tritium contamination in the main cell was negligible. The tritium activity quickly dropped to background levels within 1 hour after the ventilation system started, and also all of tritium monitors decreased uniformly. It was found that it could be evaluated as the perfectly mixed flow even in the actual room. The detritiation behavior of the 1st and 2nd TREs were similar.

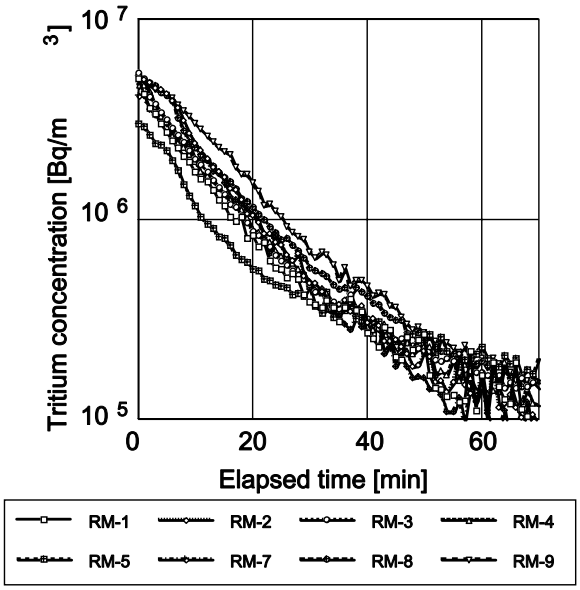

Fig. 5. Detritiation behavior in the main cell (3rd TRE)

III.B. Simulation for Initial Tritium Behavior in the Main Cell at TSTA/LANL

The initial tritium behavior in the main cell at TSTA/LANL was evaluated by using the modified FLOW-3D code. Fig. 6 shows the results of the simulation for the initial tritium behavior during the 3rd TRE. Since the tritium was released in the main cell after ventilation stopped, the released tritium was migrated by the residual air flow. The experimental result for the initial tritium behavior was evaluated by considering residual air flow in the main cell in the simulation code. The result of the simulation was in good agreement with the result of 3rd TRE as shown in Figs. 6 and 4. The modified FLOW-3D code can be used to predict the tritium behavior in a room during any tritium release event.

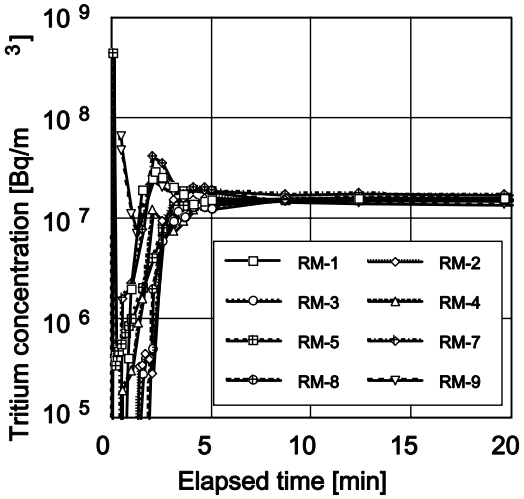

Fig. 6. Calculated initial tritium behavior in the main cell (3rd TRE)

IV. CONCLUSION

Three TREs were carried out safely and data for the tritium behavior in an actual room was accumulated.

1. Released tritium migrated dynamically on the residual air flow in the main cell and reached a uniform value after 30 ~ 40 minutes in all TREs. In the TREs of difference in tritium release point (center and corner), the time to reach uniform value was almost the same. In the TRE for which tritium was co-released with 4L of D_2, the initial tritium behavior did not change drastically compared to the another TREs.
2. During detritiation, the released tritium was quickly removed to background levels within 1 h after the ventilation system started. All the tritium monitors decreased uniformly, indicating that a perfectly mixed flow model could be used in the room.
3. The initial tritium behavior in the main cell at TSTA/LANL was evaluated by using the modified FLOW-3D code. The results of the simulation were in good agreement with the result of TREs.

ACKNOWLEDGMENTS

The authors wish to thank Dr. H. Takatsu and Dr. T. Nishitani for their continuous support and encouragement on this study. The authors also wish to thank all TPL/JAEA staff and TSTA/LANL staff for their help to perform experiments.

REFERENCES

1. ITER EDA Documentation Series No.24, ITER Technical Basis, IAEA, Vienna (2002).
2. T. BUXTON, et al., Final Safety Analysis Report for Tritium Systems Test Assembly at the Los Alamos National Laboratory, *TA-21-155, ESA-TSE,* Los Alamos National Laboratory (1996).
3. P. SCHIRA, E. HUTTER, G. JOURDAN, R. D. PENZHORN, "The Tritium Laboratory Karlsruhe; Laboratory Design and Equipment," *Fusion Eng. and Des.,* **18**, 19 (1991).
4. Y. NARUSE, Y. MATSUDA, K. TANAKA, " Tritium Process Laboratory at the JAERI", *Fusion Eng. and Des.,* **12**, 293 (1990).
5. M. YAMADA, T. YAMANISHI, W. SHU, et al., "Operation Results on Safety Systems of Tritium Process Laboratory in Japan Atomic Energy Research Institute ", *Fusion Sci. and Technol.*, **41**,593 (2002).
6. J. R. BARTLIT, J. L. ANDERSON, R. A. JALBERT, et al., " Dispersion and removal of Tritium Released into the Main Cell of TSTA", *Proc. Of 13 the SOFE,* Knoxville, TN, U.S.A., 798 (1989).
7. T. HAYASHI, K. KOBAYASHI, Y. IWAI, et al., "Tritium Behavior Intentionally Released in the Radiological Controlled Room under the US – JAPAN Collaboration at TSTA/LANL", *Fusion Technol.*, **34**, 521 (1998).
8. T. HAYASHI, K. KOBAYASHI, Y. IWAI, et al., "Tritium Behavior in the Caisson, a Simulated Fusion Reactor Room", *Fusion Eng. Des.*, **51-52**, 543 (2000).
9. K. KOBAYASHI, T. HAYASHI, Y. IWAI and M. NISHI, "Results of Experimental Study on Detritiation of Atmosphere in Large Space", *Fusion Eng. Des.*, **58-59**, 1059 (2001).
10. K. KOBAYASHI, T. HAYASHI, Y. IWAI, et al., "Tritium Behavior Study for Detritiation of Atmosphere in a room", *Fusion Sci. Technol.*, **41**, 673(2002).
11. Y. IWAI, T. HAYASHI, T. YAMANISHI, et al., "Simulation of Tritium Behavior After Intended Tritium Release in a Ventilated Room", *J. Nucl. Sci. Technol.*, **38**, 63 (2001).
12. Y. IWAI, T. HAYASHI, K. KOBAYASHI AND M. NISHI, "Simulation Study of Intentional Tritium Release Experiments in the Caisson Assemby for Safety study at the TPL/JAERI", *Fusion Eng. Des.*, **54**, 523 (2001).
13. Y. IWAI, T. HAYASHI, K. KOBAYASHI AND M. NISHI, "Case Study on Unexpected Tritium Release happened in a Ventilated room of Fusion Reactor", *Fusion Sci. Technol.*, **48**, 460 (2005).