

Tritium Removal System for Airtight Room in High-flux Advanced Neutron Application Reactor (HANARO) – 12110

Sung Paal Yim*, Jung Hee Lee*, Hyung-Kyoo Kim*, Hoan Sung Jung*,
Cheo Kyung Lee**, Sun Kyun Yoo***
* Korea Atomic Energy Research Institute,
Yusong, Daejeon, Republic of Korea 305-600
** Handong Global University,
Heunghae-eub, Buk-gu, Pohang, Kyungbuk, Republic of Korea 791-708
*** Joongbu University,
Chubu-myun, Geumsan-gun, Chungnam, Republic of Korea 312-702

ABSTRACT

An Airtight room was installed to prevent the diffusion of tritium from the instrument room to other areas in HANARO. It was isolated by a robust structure and the inside was closed tightly. A Tritium removal system located outside the instrument room was connected to the airtight room to lower the tritium concentration when the workers enter the room for maintenance of the instruments. The tritium concentration and the dew point in the airtight room were continuously measured during the operation of the tritium removal system. The data were analyzed by using a model. There was a difference between the measured tritium concentration and the one obtained by the model. It is believed that the difference is due to the change of the generation rate of tritium which would increase as the dew point becomes lower. Based on this assumption, the previous equation was revised to better express the performance of the tritium removal system.

INTRODUCTION

The High-flux Advanced Neutron Application Reactor (HANARO) is a 30 Mw_{th} multi-purpose research reactor generating high neutron flux (fast flux: 2.1×10^{14} n/cm²/s and thermal flux of 4×10^{14} n/cm²/s) at Korea Atomic Energy Research Institute (KAERI). It is the only facility for research and development in the neutron science field and its applications in Korea.

HANARO uses heavy water as a reflector, sometimes called a moderator, and has an instrument room to control the flow of heavy water. The pumps, pipes, valves for circulating heavy water, various instruments for measuring temperature, pressure and flow rate, and heat exchangers for cooling heavy water are installed in the instrument room. Tritium concentration of the instrument room is higher than those in other areas because heavy water containing tritium is released from the connections in pumps, pipes, valves, instrument and heat exchangers. In 2005, to prevent the diffusion of tritium from the instrument room to other area, a part of instrument room, considering that the release of tritium was high, was isolated by a robust structure and the inside was closed tightly. And this area was named 'the airtight room'. Tritium removal system located outside the instrument room was connected to the airtight room to lower the tritium concentration when the workers enter the room for maintenance of the instruments.

Previously Park and Oh [1, 2] estimated the rates of tritium generation in and release from the airtight room. The system performance was also evaluated by measuring and modeling on the tritium removal in the airtight room. According to their investigation, there was a difference between the result from measurement and that from modeling. The measured final tritium concentration was about 10 times higher than the one obtained by the model. They explained that the difference was due to the inhomogeneous mixing of the air in the airtight room during tritium removal.

The tritium concentration and the dew point in the airtight room were continuously measured during the operation of the tritium removal system. The data were analyzed by using the previous model. Based on the analysis, an improved equation is proposed to predict the performance of tritium removal system.

TRITIUM REMOVAL SYSTEM

The tritium removal system consists of compressors, condensers and adsorption beds. The moisture containing tritium in the air of the airtight room is removed first by condensation via compression and then by adsorption onto molecular sieves. The final dew point of the outlet air from the system is less than -70°C . The flow rate of the system is $2.3\text{ m}^3/\text{hr}$. The tritium removal system is shown in Figure 1.



(a) Compressor and condenser



(b) Adsorption bed

Fig 1. Tritium removal system

PREDICTION MODEL

A model was made to predict the tritium concentration of air in the airtight room when the tritium removal system is operating.[2] Volumetric radioactivity balance for the model is shown in Figure 2.

On the basis of the volumetric radioactivity balance, an equation for a change of tritium concentration with time could be expressed as (Eq. 1).

$$V \frac{dc}{dt} = c_{out}L - cL + S_T - cF_S + c_{dru}F_R \quad (Eq. 1)$$

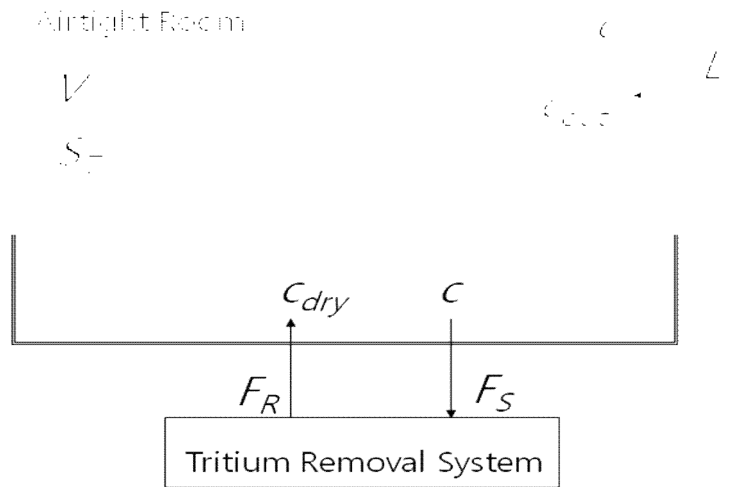


Fig 2. Volumetric radioactivity balance

V : Volume of airtight room, 146 m³

S_T : Tritium generation rate of the airtight room, Bq/hr

c : Tritium concentration of airtight room inside, Bq/m³

c_{out} : Tritium concentration airtight room outside, Bq/m³

c_{dry} : Tritium concentration of air from tritium removal system, Bq/m³

F_S : Intake flow rate of tritium removal system, 138 m³/hr

F_R : Discharge flow rate of tritium removal system, 138 m³/hr

L : leakage rate of airtight room, m³/hr

Here, tritium concentration of air from the tritium removal system is very low and c_{dry} can be ignored. Therefore,

$$V \frac{dc}{dt} = c_{out}L - cL + S_T - cF_S \quad (Eq. 2)$$

In a previous work [2], S_T , tritium generation rate of the airtight room, and L , leakage rate of airtight room were determined by a calculation as follows.

$$S_T = 1.37 \times 10^7 \text{ Bq/hr}$$

$$L = 1.3 \text{ m}^3/\text{hr}$$

Also, c_{out} , tritium concentration airtight room outside, was determined by measurement as follows.

$$c_{out} = 8.25 \times 10^3 \text{ Bq/m}^3$$

When these values are replaced into the (Eq. 2), the equation becomes

$$\frac{dc}{dt} = -0.936c + 93909 \quad (Eq. 3)$$

As the above equation is linear differential equation, the general solution is given as

$$c = 1.00 \times 10^5 + Ce^{-0.936t} \quad (Eq. 4)$$

By using initial condition, constant C can be obtained. When c_0 , initial tritium concentration in airtight room before the operation of tritium removal system, 1.81×10^7 Bq/m³, is replaced in (Eq. 4), the constant C is 1.79×10^7 . Therefore, final solution is expressed as follows.

$$c = 1.00 \times 10^5 + 1.80 \times 10^7 e^{-0.36t} \quad (\text{Eq.5})$$

COMPARISON WITH PREDICTION AND MEASUREMENT

A change of tritium concentration in airtight room with time has been predicted by using (Eq. 5) and it has been compared with measured values. The result is shown in Figure 3.

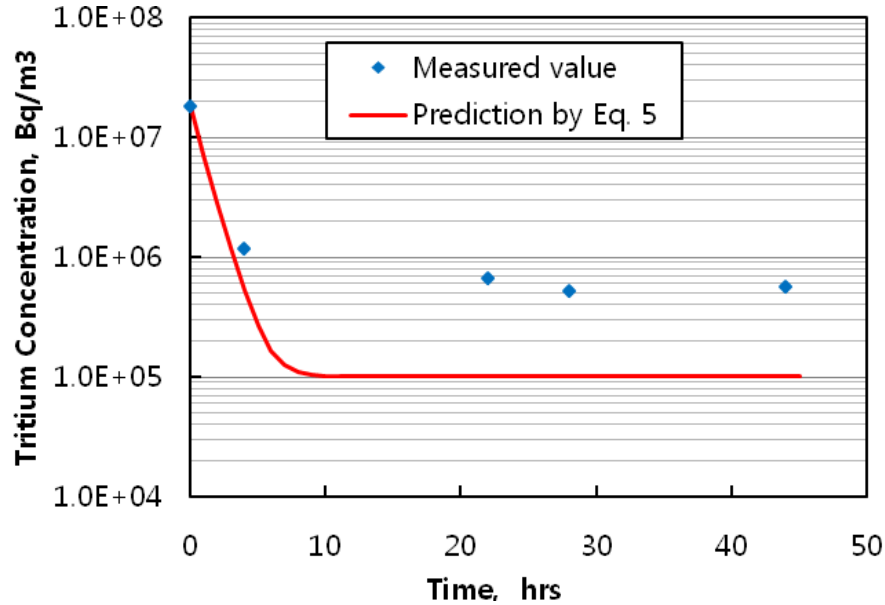


Fig 3. Comparison of prediction by (Eq. 5) and measurement [2]

As shown in Figure 3, there was a difference between the measured values and prediction by (Eq. 5). At steady state, the measured tritium concentration was about 6 times higher than the one obtained by the prediction. It was explained that the difference was due to the inhomogeneous mixing of the air in the airtight room during the removal of tritium.[2] However, it is difficult to understand that the air in the airtight room was not inhomogeneous, even at more than 30 hrs after operating the tritium removal system, because the flow rate of the tritium removal system is high enough to make air in the airtight room homogeneous.

The dew point of the air in the airtight room was measured to confirm the change of amount of moisture in the airtight room over time, when the tritium removal system was operating. The result is shown in Figure 4. The moisture in the air tight room decreased rapidly to less than 0.0051 g/m³ by tritium removal system within 5 hrs. It means that the inside of the airtight room becomes very dry by the tritium removal system. It is believed that generation of tritium in airtight room occurs by vaporization of small amount of water containing tritium leaked from the pumps, pipes, valves and various instruments in the airtight room. Therefore, it is reasonable to believe that vaporization of water containing tritium is influenced by the humidity. Because the tritium generation rate, in previous work [1], was calculated from the data measured at ambient humidity condition, it could be underestimated. However, it is not possible to get the measured data to calculate tritium generation rate at the dry condition. Accordingly, a tritium generation rate was assumed to compare the measured tritium concentration in airtight room with time and the predicted tritium concentration in airtight room with time.

By replacing those assumed S_T values in (Eq. 2), and using the same values of L , c_{out} , c_0 , the following equations were obtained.

When $S_T = 9.0 \times 10^7$ Bq/hr,

$$c = 6.59 \times 10^5 + 1.74 \times 10^7 e^{-0.936t} \quad (Eq.6)$$

Comparison with measured values and predictions by (Eq. 5) and (Eq.6) is shown in Figure 5. Prediction by (Eq. 6) shows very good agreement with measured values. However, more data values would be necessary to assure the validity.

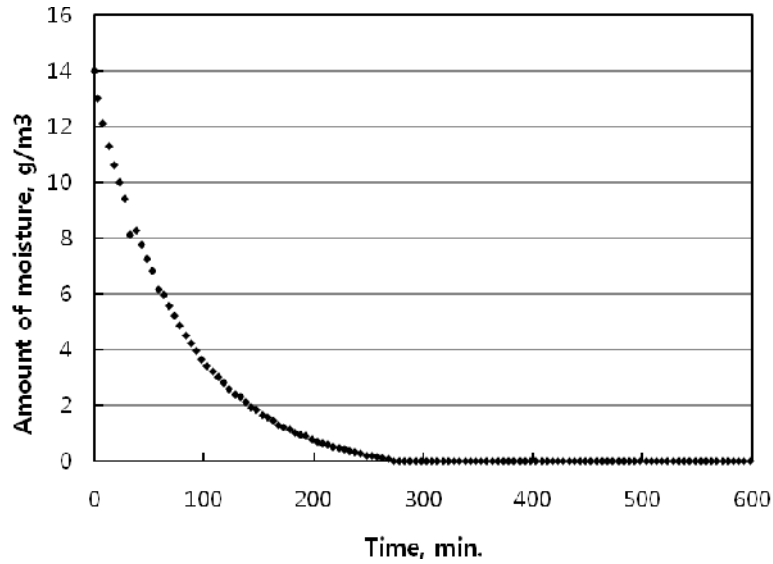


Fig 4. A Change of amount of moisture in airtight room with time

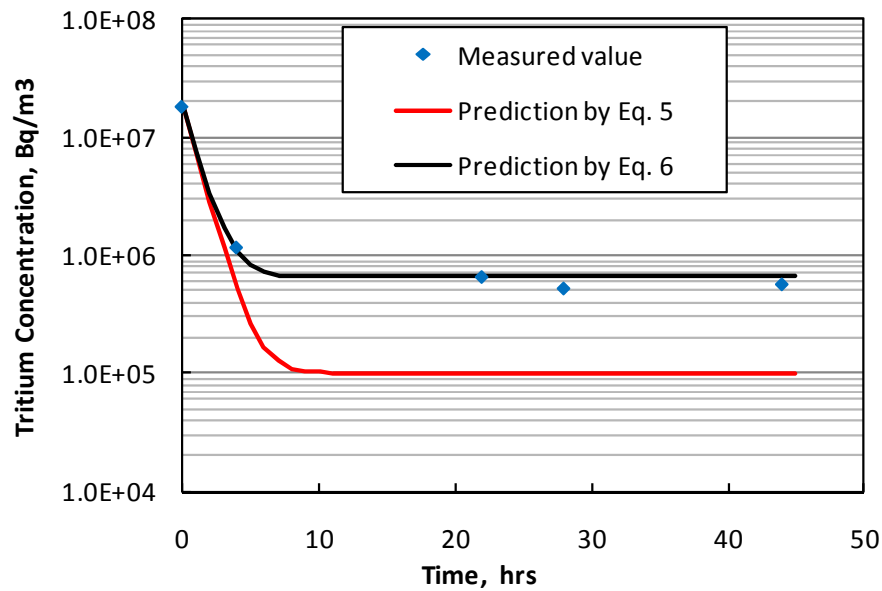


Fig 5. A result of comparison with predictions by (Eq. 5 and 6) and measurement

To more precisely observe the change of tritium concentration, a tritium monitor which can measure the tritium concentration continuously was connected in the airtight room. The data from the tritium monitor are shown in Figure 6. (Eq. 5) and (Eq. 6) were modified to the following (Eq. 7) and (Eq. 8), respectively, because the initial tritium concentration in the airtight room was slightly changed to 1.83×10^7 from 1.81×10^7 Bq/m³.

$$c = 1.00 \times 10^5 + 1.80 \times 10^7 e^{-0.936 t} \quad (Eq. 7)$$

$$c = 6.59 \times 10^5 + 1.76 \times 10^7 e^{-0.936 t} \quad (Eq. 8)$$

As shown in Figure 6, (Eq. 8) is not well fitted with the measured values at the initial stage and a tritium generation rate was again assumed to be 1.6×10^8 Bq/hr. The equation corresponding to the tritium generation rate is expressed as follows.

When $S_T = 1.6 \times 10^8$ Bq/hr,

$$c = 1.17 \times 10^6 + 1.71 \times 10^7 e^{-0.936 t} \quad (Eq. 9)$$

The prediction by (Eq. 9) is shown in Figure 6 and the fit with measured values is very good at the initial stage. However, as time increases, the tritium concentration predicted by (Eq. 9) was slightly higher than those measured by the monitor. Consequently, it can be assumed that the generation rate of tritium at the initial stage is high but decreases with time slowly. Also it means that vaporization of water in airtight room is rapid at the initial stage but becomes slower with time.

It seems that the change of tritium concentration in airtight room could be correctly predicted by using (Eq. 8) and (Eq. 9), although a little difference with measured values still exists.

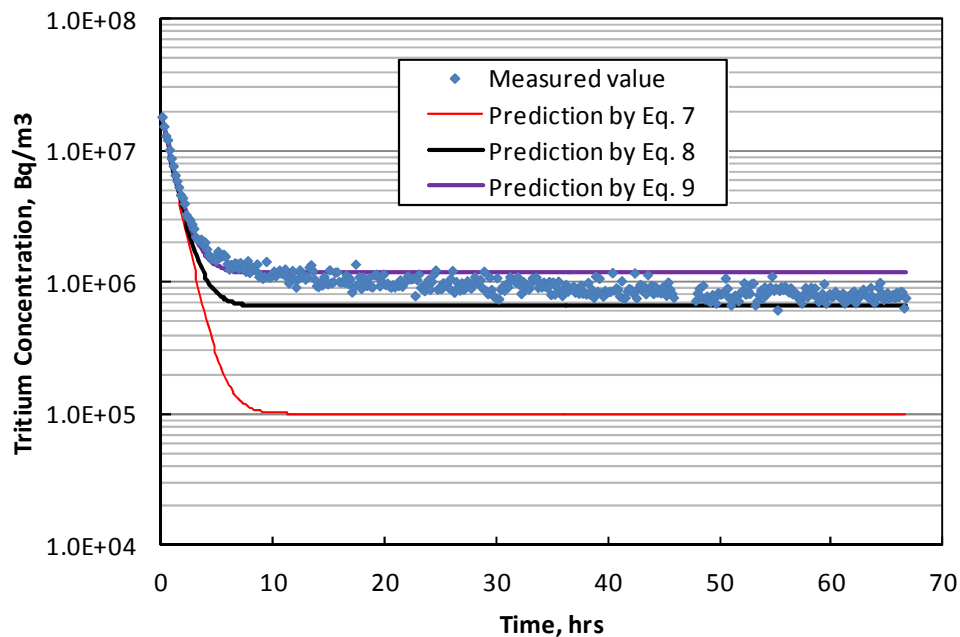


Fig 6. A result of comparison with predictions by (Eq. 7, 8 and 9) and measurement

SUMMARY

It was re-estimated that the change of tritium concentration in an airtight room could be predicted well by using a model and equation proposed in the previous study. It was confirmed

that there was a definite difference between the measured tritium concentration and the one obtained by equation from the model. It is believed that the difference is due to the change of the generation rate of tritium which would increase as the dew point becomes lower. Based on this assumption, the generation rate of tritium was controlled to have higher value and the change of tritium concentration in airtight room could be more correctly predicted. By using the revised equation, the tritium removal system would be operated more effectively.

REFERENCES

1. Jong Hak Park and Soo Yul Oh, "A Measurement of Leakage Rate of Airtight Room," HANARO Internal Memo HAN-TH-CR-033-05-044 (2005)
2. Jong Hak Park and Soo Yul Oh, "Comparison of Prediction and Measurement of Tritium Removal Sytem," HANARO Internal Memo HAN-RR-CR-329-06-003 (2006)