# Development of Tritium and Helium Inventory Code for Tritium Storage and Delivery System

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## 1. Introduction

Recently, in Korea, a study on the tritium handling system for recovery which is collected by Wolsong Tritium Removal Facility (WTRF) was initiated. The tritium will be one valuable energy resource in managed tritium storage tank for ITER, but will be one useless source causing occupational exposure if it is leaking from storage tank. Some tritium enters the steel and subsequently decays to helium. This helium can cause the severe deterioration of the mechanical properties of the steel [1]. Therefore the estimation of tritium and helium inventory in stainless-steel used for containing tritium is required. In the previous study, the tritium and helium inventory in the wall supposing that the tritium delivery system is operated without the period of shutdown was evaluated by analytical solutions [2]. The aim of this study was to obtain the tritium and helium inventory in the wall of handling system regarding to the period of shutdown.

## 2. Methods and Results

It is well known the time-dependent diffusion of radioactive material into a wall of which is taken to be a planar sheet with x=0 at the inner surface as shown in Fig. 1.

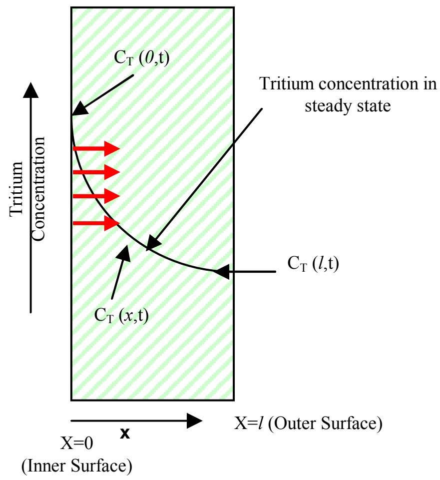


Fig. 1 Tritium diffusion into a wall of stainless steel

The governing equation is described by:

$$\frac{\partial C_T(x,t)}{\partial t} = D\frac{\partial^2 C_T(x,t)}{\partial x^2} - \lambda C_T(x,t) \qquad (1)$$

where λ is tritium decay constant ($sec^{-1}$), α = λ/2, k=λ-α, t is time ($sec^{-1}$), D is diffusion coefficient ($cm^2 \cdot sec^{-1}$), and l is the thickness of the material.

In steady state permeation, the tritium concentration is linear through the sheet. In all calculations in this study $C_T$(l,t) and $C_T$(x,0) are assumed to be zero when the time is zero as the initial condition. The concentration $C_T$(0,t) is set by the tritium gas pressure and temperature, i.e., $C_T(0,t) \equiv C_{ST}$. $C_{ST}$ is the tritium solubility in the surface of stainless steel. Sugisaki et al. derived and suggested the tritium solubility in SUS-316 stainless steel from the experimental data [3].

*2.1 tritium solubility in actual tritium handling system*

$C_{ST}$ depends on the partial pressure of tritium and the temperature at system. Therefore, $C_{ST}$ in operation period is different from $C_{ST}$ in shutdown period as shown in Fig. 2. $C_{ST}$ in operation is about 100 times larger than $C_{ST}$ in shutdown.

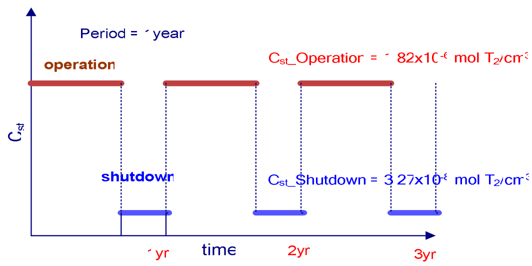


Fig .2 Difference $C_{ST}$ in operation and shutdown period

*2.2 Tritium inventory regarding to shutdown in the tritium handling system*

In previous study, Tritium inventory ($I_{T,F}$) in the wall of the tritium handling facility are derived under assumption that the tritium is continuously. The result is derived as follows [2];

$$I_{T,F}(t) = C_{ST}\left[\begin{array}{l} \dfrac{l}{2} - \displaystyle\sum_{n=1}^{\infty} \dfrac{2\lambda l(1-\cos(n\pi))}{\pi^2 n^2\left(\lambda + \dfrac{Dn^2\pi^2}{l^2}\right)} \\ -\displaystyle\sum_{n=1}^{\infty} \dfrac{2D\pi(1-\cos(n\pi))}{l\left(\lambda + \dfrac{Dn^2\pi^2}{l^2}\right)} \exp\left(-\left(\lambda + \dfrac{Dn^2\pi^2}{l^2}\right)t\right) \end{array}\right] \qquad (2)$$

In this study, the tritium inventory at shutdown time is calculated by subtracting the amount of tritium decaying during shutdown period and adding the small amount of tritium diffused from the surface at shutdown period. And it is supposed the amount of the increasing tritium inventory during operation time is the same as the amount of the increasing tritium inventory applied in previous study [2].

Tritium inventory in the wall depending on the availability of tritium handling system is shown in Fig. 3.

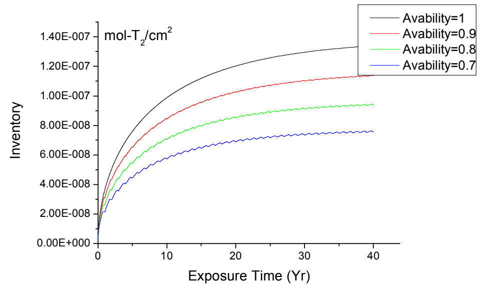


Fig.3 Tritium inventory in the wall depending on the availability of tritium handling system

The tritium inventory at the availability of 1 agrees with tritium inventory under assumption that the tritium is continuously supplied in the previous study. As shown if Fig 3, the tritium inventory is largely effected by the availability of system.

### *2.3 Helium inventory regarding to shutdown in the tritium handling system*

Helium inventory ($I_{He,F}$) in the wall of stainless steel can be obtained and the result is described by;

$$I_{He,F}(t)=C_{ST}\left[\begin{array}{l}\dfrac{l\lambda t}{2}-\dfrac{2\lambda^2 lt}{\pi^2}\displaystyle\sum_{n=1}^{\infty}\dfrac{(1-\cos(n\pi))}{n^2\left(\lambda+\dfrac{Dn^2\pi^2}{l^2}\right)}\\ -\dfrac{2\lambda D}{l}\displaystyle\sum_{n=1}^{\infty}\dfrac{(1-\cos(n\pi))}{\left(\lambda+\dfrac{Dn^2\pi^2}{l^2}\right)}\left(1-\exp\left(-\left(\lambda+\dfrac{Dn^2\pi^2}{l^2}\right)t\right)\right)\end{array}\right] \quad (3)$$

In this study, helium inventory at shutdown time is calculated by adding the amount of tritium decaying during shutdown period. And it is supposed the amount of the increasing helium inventory during operation time is the same as the amount of the increasing helium inventory applied in previous study [2].

Helium inventory in the wall depending on the availability of tritium handling system is shown in Fig. 4

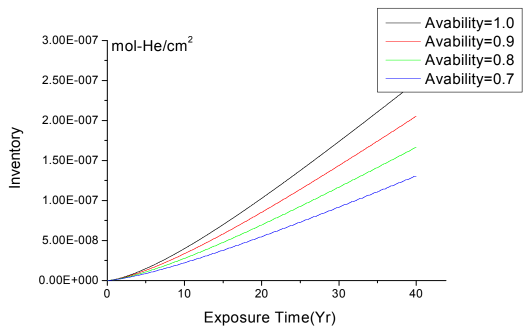


Fig.4 Helium inventory in the wall depending on the availability of tritium handling system

As shown if Fig 4, the helium inventory is largely effected by the availability of system as the case of tritium inventory.

## 3. Conclusions

In this study, the tritium and helium inventory in the wall regarding to shutdown period were estimated. In the previous study [2], the tritium and helium inventory under assumption that the tritium is continuously supplied are overestimated. The tritium and helium inventory are largely effected by the availability of system. Therefore the tritium and helium inventory in the wall of tritium handling system can be estimated reasonably in regard to shutdown period.

## REFERENCES

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