Performance Test of Ice Packed Respirator for Tritium Removal - 10117

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ABSTRACT

The tritium removal efficiency of an ice packed respirator was estimated in HANARO. Ice cubes of about 500 g were packed in a container of the respirator. Air containing tritiated water vapor with a specific radioactivity of $1 \times 10^5 \sim 4 \times 10^6$ Bq/m^3 was passed through the packed bed of ice cubes in the container at a flow rate of 20 L/min. The specific activity of tritium in the air passing through the packed bed of ice cubes in the container was measured by a tritium air monitor with an ionization chamber and bubbling method. The experimental results show that the tritium removal efficiency of the ice packed container used in the respirator was about 0.9 within one hour, and it decreased with time.

INTRODUCTION

The research reactor HANARO(High-Flux Advanced Neutron Application Reactor) in the Republic of Korea and the CANDU(Canadian Deuterium Uranium) type nuclear power plants generate tritium much more than PHWR(Pressurized Light Water Reactor) type nuclear power plants because they use heavy water as a moderator and/or coolant while PHWRs use light water.

Usually, tritium exists in the form of tritiated water vapor in air and it is harmful if the air containing tritiated water vapor is inhaled. Therefore, the air containing tritiated water vapor must be purified for safe inhalation by a proper method or tool.

An ice packed respirator developed by engineers working in KEPCO(Korea Electric Power Company, its name is now KHNP, Korea Hydro and Nuclear Power company) has been widely used in the CANDU type nuclear power plants and the HANARO in the Republic of Korea. Its main part is a container packed with ice cubes. It is known that tritiated water vapor in the air exchanges isotopes with the water on the surface of ice cubes and removed from the air when the air containing tritiated water vapor passes through the packed bed of ice cubes in the container. However, the tritium removal efficiency of the ice packed respirator has not been clearly evaluated yet. [1]

This study was performed to estimate the tritium removal efficiency of the ice packed respirator which is currently used in HANARO.

EXPERIMENTALS

Ice packed respirator

An ice packed respirator consists of a container packed with ice cubes, a mask, and a connection hose between the container and the mask. Fig. 1 shows the ice packed respirator. The main part of the ice packed respirator is the ice packed container. When inhaling air, the inlet air containing tritium in the form of tritiated water vapor enters the container through the inlet tubes installed in the container. It passes through the packed bed of ice cubes. At this time, the tritiated water vapor in the air is removed from the air. The clean outlet air passing through the container is finally inhaled. As time passes, ice cubes melt and the melted water falls down to the lower part of the container. This melted water includes tritium in the water removed from the air. Figure 2 shows a skematic of an ice cube container.

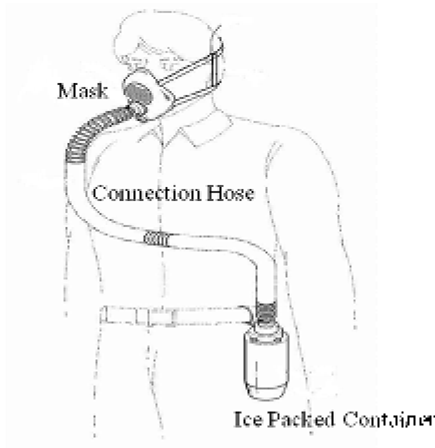

Fig. 1. An ice packed respirator (from Ref. [2])

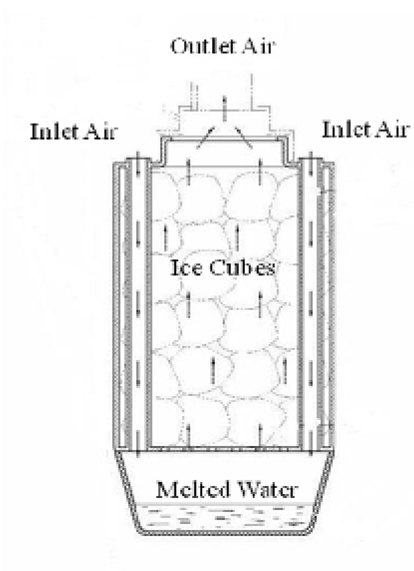

Fig. 2. An ice packed container (from Ref. [2])

Test Method

The apparatus to estimate the tritium removal efficiency of ice packed respirator is shown in Fig. 3. The inlet air containing tritiated water vapor was introduced by an air pump into the ice packed container. The inlet air passing through the packed bed of ice cubes in the container entered the sampling tube. Its temperature and dew point were respectively measued by a temperature/dew point meter connected in the sampling tube. The tritium air monitor with an ionization chamber was also connected in the sampling tube. It sucked a part of the air from the sampling tube and continuously measued the tritium concentration of the air. The air from the tritium air monitor flowed into the air bubbler filled with demineralized water. The bubbled water was periodically sampled, and its tritium concentration was analyzed by a liquid scintillation detector. The outlet air from the sampling tube and the air from the air bubbler were discharged into an area where the tritium concentration was safely controlled.

The tritium removal efficiency of ice packed container is expressed as follows:

$$\text{Removal efficiency} = 1 - \frac{\text{Specific activity of tritium of outlet air, Bq/m}^3}{\text{Specific activity of tritium of inlet air, Bq/m}^3}$$

where the inlet air is the air introduced into the ice packed container and the outlet air is the the air passing through the ice packed container.

The amount of ice cubes in the container was 500 g, and the size of an ice cube was about 3 cm x 4 cm x 2 cm. The weight and temperature of an ice cube was about 25 g and -25 °C, respectively. The specific radioactivity of tritium in the inlet air was in the range of $1 \times 10^5 \sim 4 \times 10^6$ Bq/m^3. The tempearture and relative humidity of the air introduced into the apparatus were 25 °C and 50%, respectively. The inlet air was introduced into the the apparatus at a flow rate of 20 L/min.

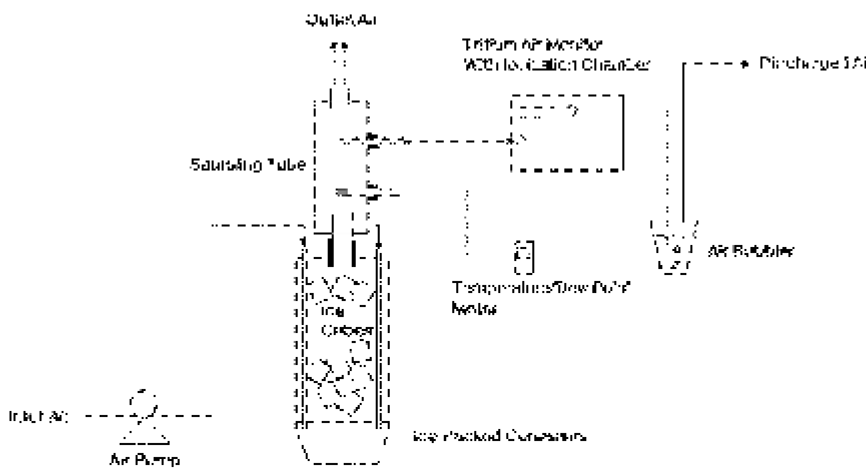

Fig. 3. A Schematic of the experimental apparatus

RESULTS AND DISCUSSION

The tritium removal efficiency of the ice packed container measured by tritium air is shown in Fig. 4. It shows that the tritium removal efficiency of the ice packed container is about 0.9 until one hour and it changes with time. The low removal efficiencies until about 20 minutes may be caused by a slow response of the monitor. A change of removal efficiency measured by the bubbling method is shown in Fig. 5. The removal efficiency measured by the bubbling method means an average value during the measuring time. It shows that the tritium removal efficiency of the ice packed container is about 0.95 within 30 minutes and 0.9 within 1 hour, and it decreased with time continuously. Until now, it has been known that the tritium removal efficiency of an ice packed container reaches 0.98~0.99. However, as a result of this study, that number is considered to be slightly overestimated.

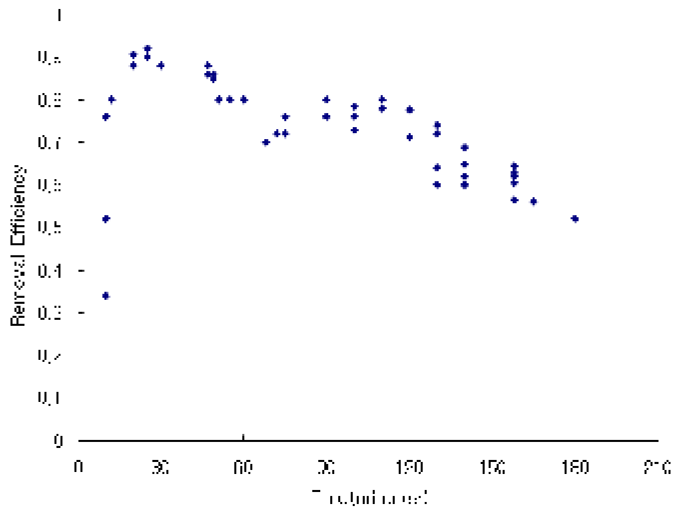

Fig. 4. A change of removal efficiency for tritium of the ice packed container measured by a tritium air monitor

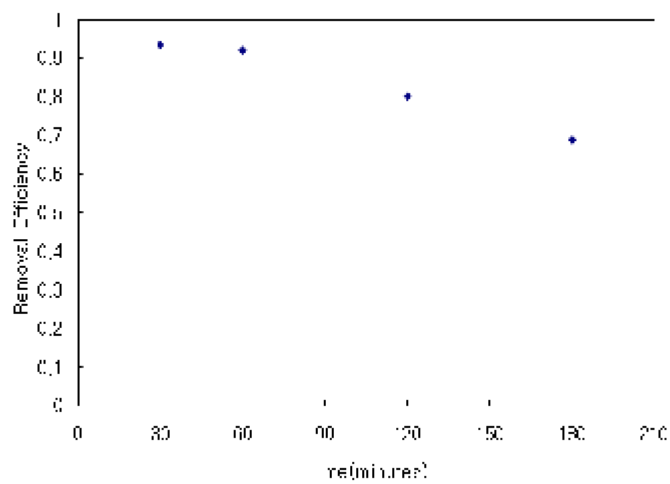

Fig. 5. A change of removal efficiency for tritium of the ice packed container measured by a bubbling method

Changes of temperatures and dew points of outlet air passing through the ice packed container are shown in Fig. 6. The temperature of the outlet air was almost constant at around 20 °C. The temperature was about 5 °C lower than that of the inlet air introduced in the ice packed container. The dew point was less than 5 °C until 30 minutes but slowly increased with time. Assuming the tritiated water vapor in the inlet air was removed by only condensation due to the difference of dew points between the inlet air and the oulet air of the ice packed container, by calculation, the removal efficiency of the ice packed container revealed no more than 0.5. Therefore, it can be confirmed that the tritiated water vapor in the air exchanged isotopes with the water on the surface of the ice cubes. However, it is not clear whether the exchanged tritium penetrated into the ice or not.

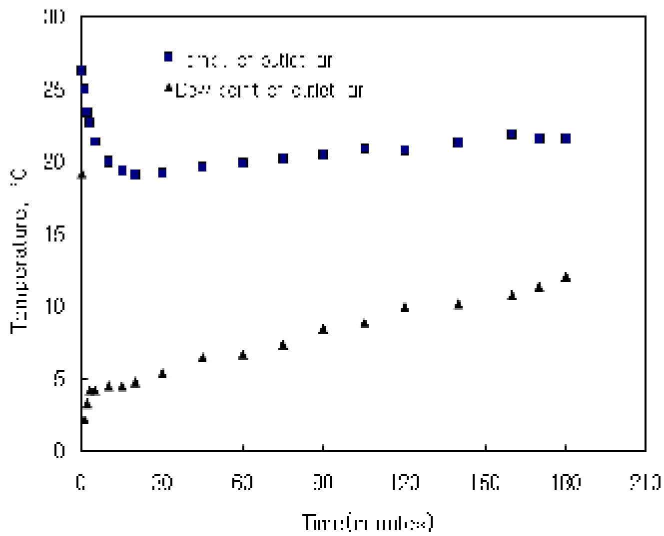

Fig. 5. Changes of temperature and dew point of the outlet air

A change in the amount of melted water in the ice packed container is shown in Fig. 6. The melted water from the ice cubes proportionally increased with time. It assumes that melting of the ice cubes affected the decrease of removal efficiency of the ice packed container with time.

The melted water included tritium removed from the inlet air and existed in the form of tritiated water. Therefore, it was handled with care as radioactive waste. Because the water slopped around in the lower part of the container when a worker moved, it sometimes caused trouble for inhalation due to the blocking of the inlet tubes.

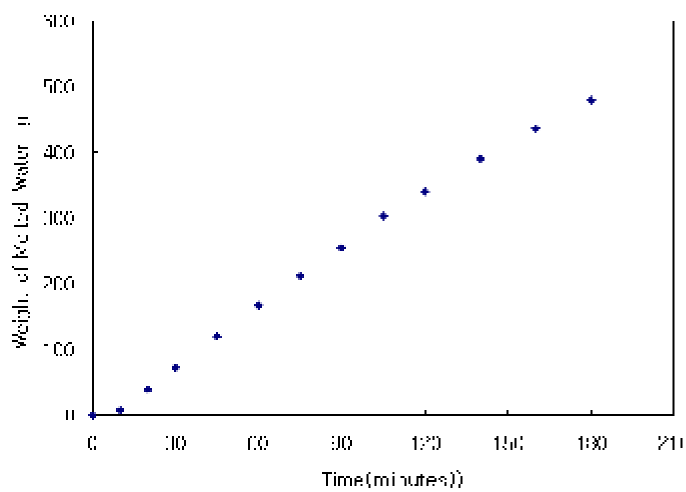

Fig. 6. A change in the amount of melted water in the ice packed container

SUMMARY

It was estimated that the tritium removal efficiency of an ice packed respirator was about 0.9 within one hour and decreased with time. Although it didn't reach 0.98 as it had been known until now, it can be sufficient to use under a controlled condition. At present, in HANARO, the ice packed respirator is being used under an air condition containing tritium at a range of $3 \times 10^5 \sim 3 \times 10^6$ Bq/m^3. However, working time limit of the respirator is not specified. Therefore, based on the result of this study, it is desirable that the working time of the ice packed respirator be limited to no more than one hour.

To use the ice packed respirator more properly, at present, the effects of specific activity of tritium, the flow rate of the inlet air, and the size of ice cubes on the removal efficiency of the ice packed respirator is being evaluated in detail. In addition, some efforts have been made to improve the disadvantages of the ice packed respirator, such as the generation of tritiated wastewater and the slopping of melted water. Furthermore, an attempt is currently being made to develop the respirator with a high tritium removal efficiency which doesn't use ice cubes.

REFERENCES

1. G. W. CHOI, H. S. PARK, and D. J. KIM, "Development of the High Efficiency Respirator for H-3 Protection," KRISS/SS-020/2005 (2005)
2. W. C. KIM, "Respirator for Tritium Self-Protection," KR Patent 10-0659783 (2006)