Development of Safety Enhanced Protection Units for Tritium - 11165

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ABSTRACT

A dry type air respirator and a whole body protection unit using adsorbent were developed for enhancing safety. Silica-gel was selected as the adsorbent for the air respirator and protection unit. It was observed that the tritium removal efficiency of 0.98 ~ 0.99 continued for a while by using a proper amount of silica-gel. The dry air passing through the adsorbent could be controlled to have 35 ~ 50% R.H.(Relative Humidity) by humidification. The relative humidity of the air inhaled by the air respirator and the inside air of the whole body protection unit maintained in the range of 25 ~ 45%, respectively.

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 PLWR(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 the 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. [1, 2]

However, because of the disadvantages of the ice packed respirator, such as the decrease of removal efficiency with time, the generation of tritiated wastewater and the slopping of melted water, a safety enhanced protection unit for tritium has been asked for in the nuclear power plants and the HANARO.

In this study, a dry type air respirator and a whole body protection unit using adsorbent were developed for enhancing safety. In the first step, an appropriate adsorbent was selected for the respirator and the protection unit, and the tritium removal efficiency was assessed by using an experimental apparatus. Humidification of dry air through the adsorbent was also conducted to supply the air with proper relative humidity. A dry type air respirator and a whole body protection unit were manufactured based on these experiments, and their performance was evaluated in the laboratory.

ADSORPTION TEST

An adsorption test was performed for the typical adsorbents such as anhydrous calcium sulfate, Zeolite 5A, Zeolite 13X and silica gel. An air, 25±2 °C, 50% R.H (Relative Humidity) was injected in cylindrical column packed with 500 g of adsorbent . The diameter of the column was 100 mm and the flow rate of air was 20 L/min. A change of the dew point of the discharged air was measured with time by using a temperature/dew point meter. The result is shown in Fig. 1.

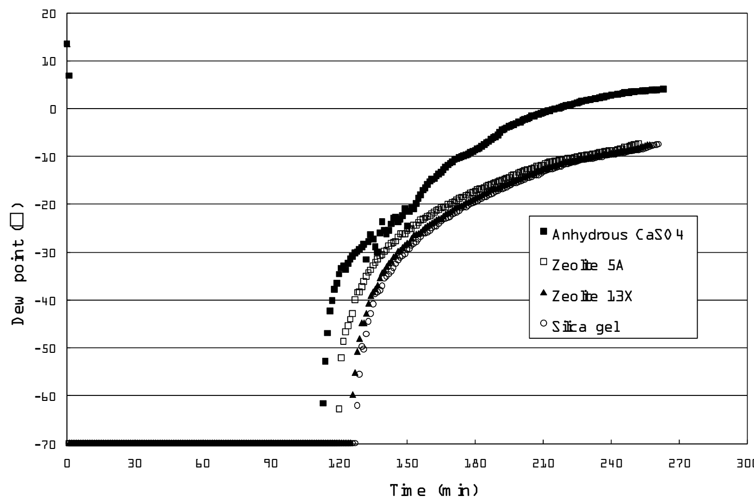


Fig. 1. Break-through curves for several adsorbents

Under the same condition, Zeolite 13X and silica gel had slightly more adsorbed water vapor than anhydrous calcium sulfate and Zeolite 5A did. Similarly, Zeolite 13X and silica gel had ability for adsorption of the water vapor. However, silica gel has the advantages from the viewpoint of the cost and the ease of purchase. Silica gel was selected as the adsorbent for a dry type air respirator and a whole body protection unit. In silica gel column, a change of break-through curves by increase of flow rate of inlet air is shown in Fig. 2. It was observed that the adsorption of water vapor in silica gel rapidly decreases as the flow rate increases from 20 L/min to 60 L/min.

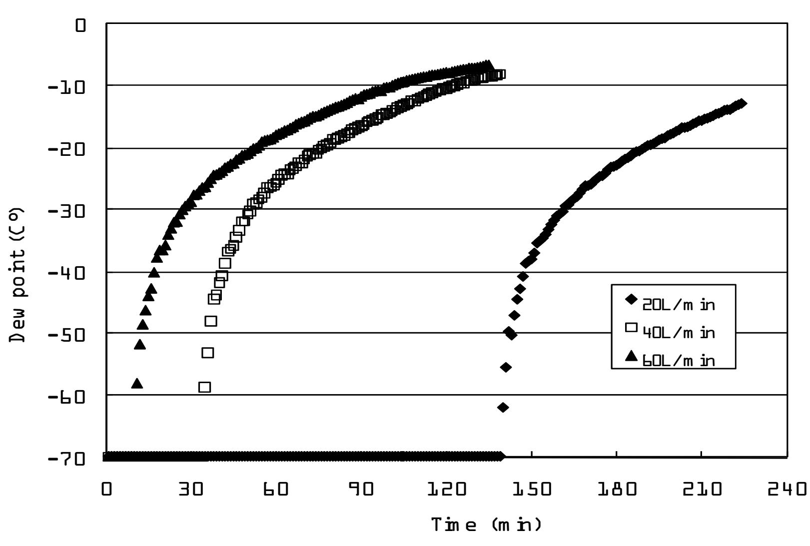


Fig. 2. Change of break-through curves with increase of flow rate of the air in silica gel column

TRITIUM REMOVAL EFFICIENCY OF SILICA GEL

The apparatus to estimate the tritium removal efficiency of silica gel is shown in Fig. 3. The inlet air containing tritiated water vapor was introduced by an air pump into the column packed with silica gel. The inlet air passing through the column packed with silica gel entered the sampling tube. Its temperature and dew point were measured by a temperature/dew point meter connected in the sampling tube. The tritium air monitor with an ionization chamber was also connected to the sampling tube. It took a part of the air from the sampling tube and continuously measured the tritium concentration of the air. The outlet air from the sampling tube and the air from the tritium air monitor were discharged into an area where the tritium concentration was safely controlled.

The tritium removal efficiency of silica gel 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 column packed with silica gel and the outlet air is the air passing through the column packed with silica gel.

The amount of silica gel in the column was 500 g. The specific radioactivity of tritium in the inlet air was 2×10^7 Bq/m^3. The tempearture and relative humidity of the air introduced into the apparatus were 26±1 °C and 55%, respectively. The inlet air was introduced into the the apparatus at a flow rate of 20 L/min.

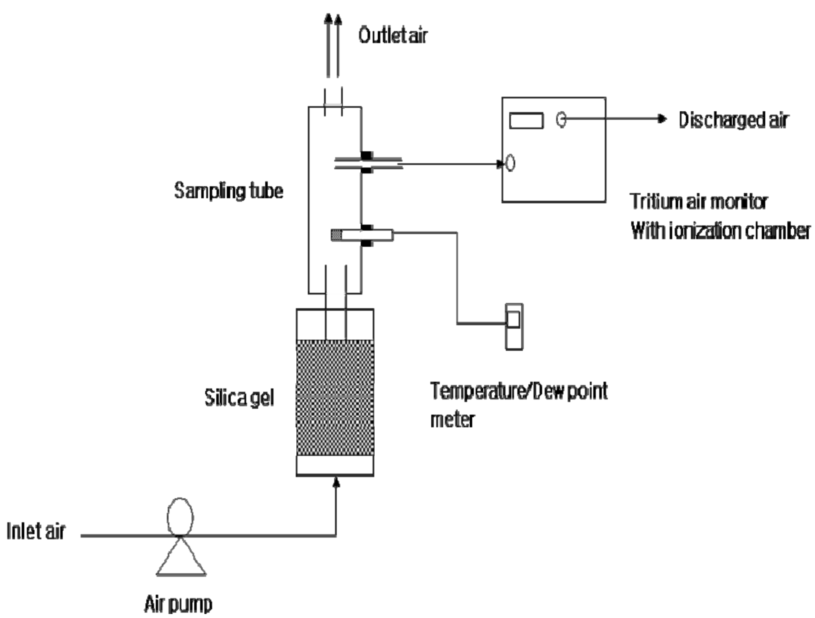


Fig. 3. A schematic of the experimental apparatus

Changes of the tritium removal efficiencies and the dew points with time are shown in Fig. 4. and Fig 5., respectively. The time when the tritium removal efficiency of the silica gel rapidly decreases is very close to the time when the dew point of air from silica gel rapidly increases. From the results, it was known that the tritium removal efficiency of the silica gel has a close relationship with the dew point of air from silica gel. It was confirmed that the tritium removal efficiency of 0.98 ~ 0.99 could be continued for a while by using a proper amount of silica-gel and at a proper air flow rate.

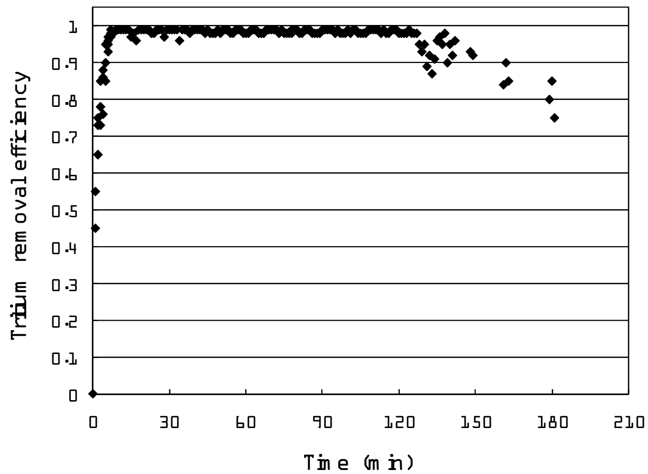


Fig. 4. Change of the tritium removal efficiency with time

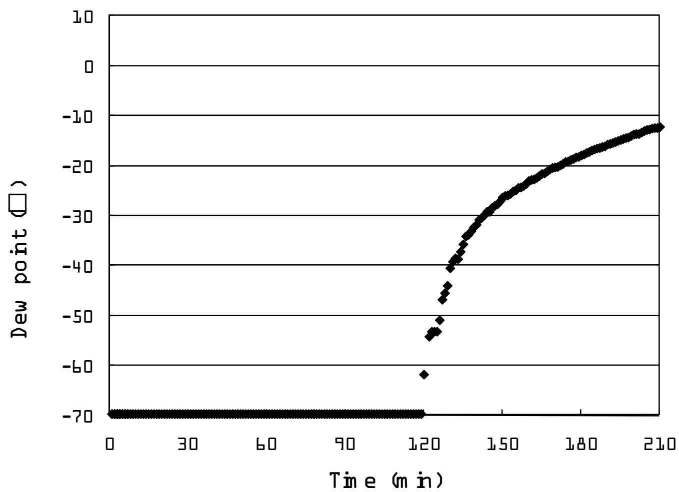


Fig. 5. Change of the dew point with time

CONTROL OF HUMIDITY OF DRY AIR

The air from the column packed with silica gel is very dry and it has to be controlled to be adequate in inhalation. The humidity of dried air from the column packed with silica gel was controlled by passing through a column packed with water saturaed polyuretane foam.

The inlet air containing water vapor was introduced by an air pump into the column packed with silica gel. The dry air from the column packed with silica gel entered the column packed with water saturated polyuretane foam. Its temperature and dew point were respectively measured by a temperature/dew point meter connected in the tube between two columns. The discharged air from the column packed with water saturaed polyuretane foam was wet and its temperature and dew point were respectively measured by another temperature/dew point meter installed in discharged tube. The amount of silica gel in the column was 500 g. The amount of water in the polyuretane foam was 35 g.

The inlet air was introduced into the the apparatus at a flow rate of 20 L/min. The result is shown in Fig. 6.

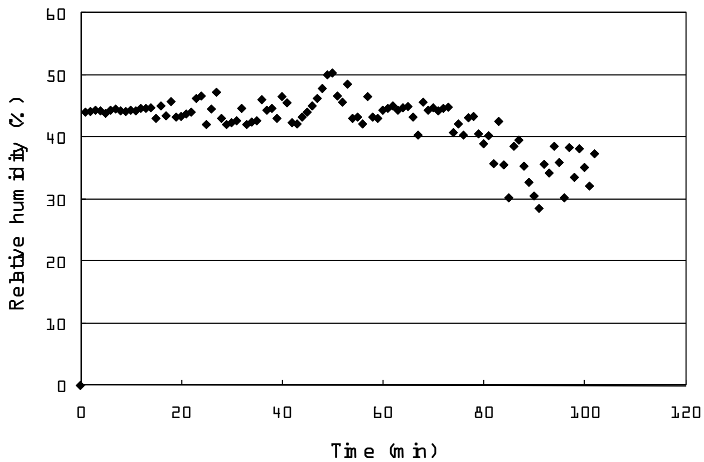


Fig. 6. Relative humidity of air from column packed with water saturated polyuretane foam

The relative humidity of dry air passing through the adsorbent could be controlled to 35 ~ 50% by humidification. It was estimated that the air with 35 ~ 50% R.H. is appropriate for breathing.

DRY TYPE RESPIRATOR AND WHOLE BODY PROTECTION UNIT

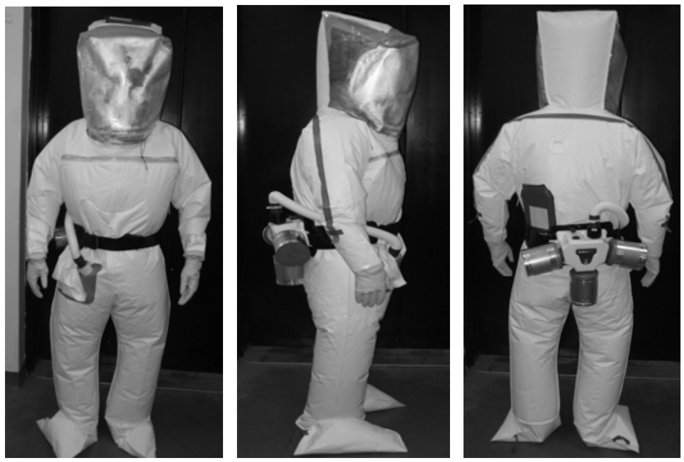
A dry type air respirator and a whole body protection unit for tritium were manufactured based on the previous experiments.

A dry type air respirator consists of two purifiers packed with silica gel, a mask, and a connection hose between the purifier and the mask. The purifier was made of stainless steel and its dimensions are 105 mm in diameter and 100 mm in height. It was packed with silica gel. A HEPA filter was installed in upper part of the purifier inside to remove the particulate from silica gel. A coarse filter was put in between the HEPA filter and silica gel and the other coarse filter in lower part of the purifier to fix the silica gel. Inside of the connection hose, water saturated polyuretane foam was inserted to control the humidity of the air from the purifiers. A dry type air respirator manufactured is shown in Fig. 7.

Fig. 7. A dry type air respirator

A whole body protection unit is required in working areas where the tritium concentration is relatively high. A whole body protection unit manufactured in this study consists of a suit enclosing whole body, an air blower with three purifiers which are same as those of the dry type air respirator and a connection hose between the suit and the air blower. The suit, commercially available, is made of EVA (Polyethylene

–Vinyl Acetate) and its thickness is about 0.24 mm. It has discharge plates to control the flow rate of the discharged air and the pressure of the suit inside. The air blower supplies the purified air to the suit at the flow rate of 60 L/min. Three purifiers attached in the air blower remove the tritium of the inlet air. The connection hose, as well as the connection hose of the dry type air respirator, has water saturated polyuretane foam inside and control the humidity of air from the air blower. A whole body protection unit is shown in Fig. 8.



(a) The front (b) The side (c) the rear

Fig. 8. A whole body protection unit

Performances of the manufactured dry type air respirator and the whole body protection unit were evaluated in the laboratory. As a result, the dry type air respirator and the whole body protection unit manufactured had the tritium removal efficiency of 0.98 ~ 0.99 and the relative humidity of the air inhaled by the air respirator and the inside air of the whole body protection unit maintained in the range of 25 ~ 45%, respectively. The operating time of the dry type air respirator was 2 ~ 4 hrs and that of the whole body protection unit was about 2 hrs.

SUMMARY

A dry type air respirator and a whole body protection unit using adsorbent were developed for enhancing safety. In the first step of this study, silica-gel was selected as the adsorbent for a dry type air respirator and a whole body protection unit. It was observed that the tritium removal efficiency of 0.98 ~ 0.99 continued for a while by using a proper amount of silica-gel. And the dry air passing through the adsorbent could be controlled to have 35 ~ 50% R.H. by humidification. A dry type air respirator and a whole body protection unit manufactured based on the experiments had the tritium removal efficiency of 0.98 ~ 0.99 and the relative humidity of the air inhaled by the air respirator and the inside air of the whole body protection unit maintained in the range of 25 ~ 45%, respectively.

A dry type air respirator and a whole body protection unit developed in this study are currently examined in the HANARO for evaluation purpose, and it is expected that they will be used in the field after implementing some minor problems through cooperation with the workers.

REFERENCES

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2. S. P. YIM, H.S. JUNG, I-C LIM, G-H AHN, C-W. SEOL and C.K. LEE, "Performance Test of Ice Packed Respirator for Tritium Removal," WM2010, Phoenix, March 7-11(2010)