§5. Study on Polymer Membrane Type Dehumidifier for Tritium Removal

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1) Introduction

In future DD experiments for LHD, it is important to establish the removal technique of tritium produced in vacuum vessel by DD reaction. In this collaborative study, the acquirement of dehumidify characteristics for a membrane type dehumidifier and theoretical study was done for achievement of high performance dehumidify compared to molecular sieve method. Simulation study using perfect mixture model performed in the last fiscal year was performed. However, the simulative and experimental estimations of the water recovery ratio from the membrane could not be agreed with each other. Therefore, in this fiscal year, critical factor of this disagreement was considered and analyses using alternative simulation were attempted and discussed.

2) Model

There are many simulation models proposed for analyzing gas separation behavior using a membrane type dehumidifier. It is well known that the combination of counter-flow and cross-flow model is the most ideal model. However, some specific parameters related to membrane are required and some of them are hard to determine. To avoid these problems, we adopted the model of two component mixture gases. Fig. 1 shows schematic drawing of gas stream inside of a membrane module. In this figure, F_f [mol/s] is supply mixture gas flow rate, and x_f, x_o and x_p

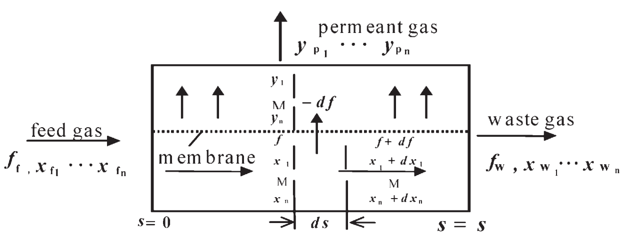

Fig.1 Schematic drawing of membrane module for the model.

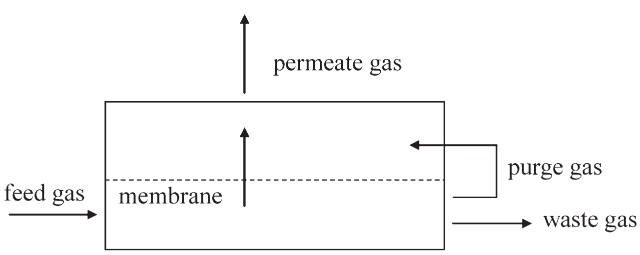

Fig.2 Schematic drawing of membrane module in NIFS.

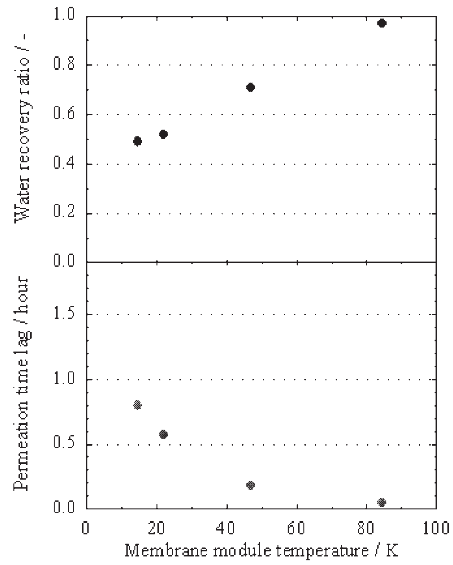

Fig.3 Dependence of water permeation on membrane module temperature.

are, respectively, mole fraction of inlet, high pressure outlet and low pressure outlet gas stream of each component. The gas component for outlet side was expressed by the following equation,

$$y_p = \frac{(\alpha-1)(\phi+x_f)+1-\sqrt{\{(\alpha-1)(\phi+x_f)+1\}^2-4\phi(\alpha-1)\alpha x_f}}{2\phi(\alpha-1)}$$

In this equation, ϕ is an operation factor, and explained in the following equation;

$$\phi = \gamma + \theta - \gamma\theta,$$

where, θ is a cut rate and γ is a pressure ratio. And α is ideal separation factor of gas described by the ratio of permeation factors. On the other hand, the membrane module studied in NIFS could not be described as Fig. 1 but Fig.2: a part of feed-through gas was introduced into permeant gas as purge gas.

3) Results and discussion

The effects of the temperature of membrane module and cut rate on the membrane dehumidifier in NIFS were estimated and discussed using this model. Fig.3 shows the experimental results of recovery ratio and time lag from feed to permeate as a function of temperature obtained from the same membrane type as that in NIFS. However, the cut rate in this model was quite different from that in NIFS, since the flow rate of purge gas was taken account to the latter. More than 99% of water recovery ratio was achieved by the membrane module in NIFS, while approximately 50% was done by that in Shizuoka University. This would be mainly reasoned by the increase of permeation rate on the membrane surface of the lower pressure side due to the introduction of purge gas into the lower pressure side. Therefore, taking the effects of purge gas into consideration, alternative analyses with considering the module temperature dependence will be studied in the future works.