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Improving the start-up behavior of a gas separation membrane for tritium removal system

トリチウム除去用気体分離膜の始動時分離特性の改善

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A tritium removal system using gas separation membrane for dehumidification has been proposed and developed. It is indicated the start-up transient phenomenon of gas separation performance. To improve the start-up behavior, we focus on the application of PID control and keeping the polymer membrane in a dry state during shout-down period. As the results, the gas separation performance for dehumidification in the start-up period was improved by keeping in a dry state in the apparatus during a shout down period. This experimental result shows that the amount of water absorbed in polymer membrane play an important role to suppress the start-up transient phenomenon.

1. Introduction

The most widely used atmospheric tritium removal technique is oxidation of tritiated hydrogen to water by catalytic oxidation reactors, followed by adsorption process on a molecular sieve bed [1]. For the processing of a large volume of air contained with tritium, tritium removal system using a hollow-fiber-type polyimide membrane has been developed and demonstrated with the performance of tritium recovery [2]. Since the polyimide material absorbs water, a part of absorbed tritium is released at the start-up period when tritiated water is absorbed in the membrane.

To improve the start-up behavior of gas separation membrane, we focus on the application of a standard proportional-integral-differential (PID) control technique and some preservation methods after operation. In this paper, from a viewpoint of practical use, we discuss with the behavior of the dew point at the start-up period in comparison with few methods.

2. Experimental apparatus

A schematic diagram of a gas separation membrane apparatus is shown in Fig. 1. The experimental apparatus consists of a compressor, condensers, a membrane module, two mass flow controllers, a pressure regulator, various sensors and mass flow meter. A hollow fiber type polyimide membrane module (UM-XC5, UBE industry Ltd.) was used as membrane separator. The shape of the membrane module is outer diameter of 90 mm, and a length of 710 mm. The gas flow in the membrane module was a counterflow type. The experiments were operated at room temperature. The feed flow rate was 6 Nm^3/h. The gas pressure was 0.8 MPa at the feed side of membrane module and atmospheric pressure at the permeated side. The water vapor concentration in the feed gas was about 800 ppm. The pressure of permeated side was almost atmospheric pressure. A part of dried gas was refluxed to the permeated side of the membrane in order to control the dew point in the dried gas. Then, the mass flow controller (FC2) was automatically controlled by PID control. The maximum flow rate of FC2 was 3 Nm^3/h. The dew point in dried air was measured by an electrical capacitance hygrometer (Moisture Image Series 1, GE sensing Co.). After the experimental operations, the apparatus was left to stand as it is, or was kept at constant pressure of 100 Pa by a scroll pump.

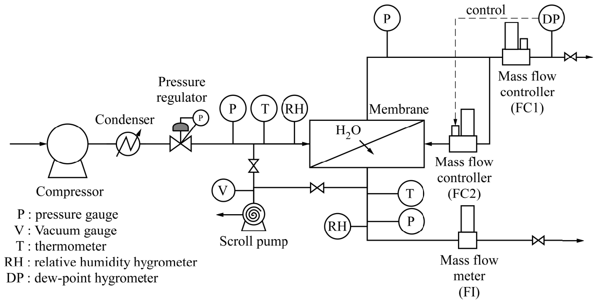

Fig.1. A schematic diagram of membrane separator

3. Results and discussion

3.1 *Effect of PID control in the start-up phase*

Figure 2 shows the comparison of normal

operation and PID controlled operation at the start-up phase. In this study, the target dew point was determined at -70^{o}C. The initial dew point before the operation was more than -30^{o}C. In the case of normal operation without PID control, it took 15 hours to reach the target dew point, when the purge flow rate was set at 1.2 Nm^3/h. Whereas, in the case of PID control operation, the time to target dew point was reduced to 5 hours by controlling the purge flow rate. The application of PID control on the membrane gas separation could result in shorter the start-up period.

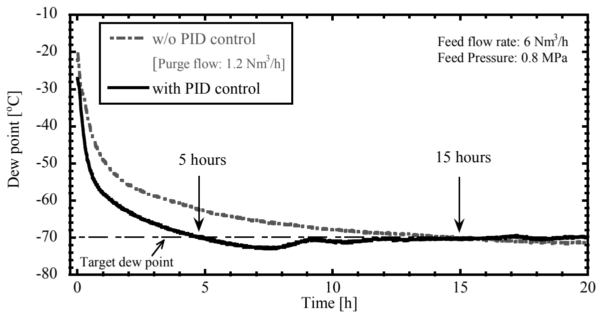

Fig.2. Comparison of normal operation and PID controlled operation at the start-up phase.

3.2 *Effect of preserve condition after operation*

Figure 3 shows the behavior of the start-up phase without PID control. The preserve conditions after operation were atmospheric condition (0.1 MPa) or vacuum condition of 100 Pa. In the case of atmospheric condition the permeated flow rate increased at the start-up period. It would indicate that the water content in the polyimide material decreased with decreasing with the dew point. Then the permeated flow rate was kept at a constant flow rate when the dew point became to be less than -40^{o}C. In the case of vacuum condition, the initial dew point was less than -50^{o}C even at the start-up phase. Whereas the permeated flow rate was not changed. It means that the polyimide material becomes dry state. Therefore, the permeated flow rate is kept at constant even at the start-up period. The time to target dew point was 8 hour. It took longer time than the time in the case of applying PID control as shown in Fig 2. However, the time to reach the target dew point is of no importance, but the total amount of released water from apparatus should be minimized.

These experimental results are summarized in Table I in addition to the result of the combination of PID control and vacuum condition in the shut down period. The amount of released water at start-up period was minimized by combining vacuum condition and PID control. In this case, although the time to low dew point took 8 hours, the released water was reduced one-tenth of combination of atmospheric preserve and uncontrolled conditions. These results show that to improve the start-up period is required not only the PID control but also the vacuum condition.

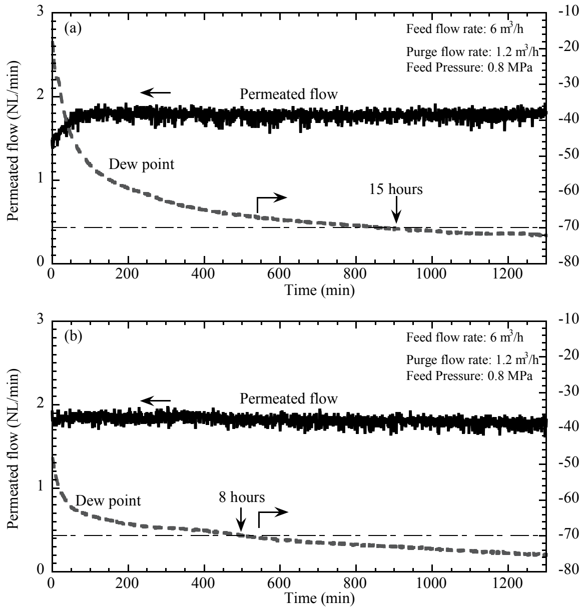

Fig.3. The behavior of the start-up phase without PID control as compared with the preserve conditions: (a) atmospheric condition, (b) vacuum condition.

Table I. Summary of experimental results

Condition in a shut-down period	Atmospheric condition		Vacuum condition at 100 Pa	
Purge flow	Constant: 1.2 Nm^3/h [Uncontrol]	PID control	Constant: 1.2 Nm^3/h [Uncontrol]	PID control
Initial dew point [^{o}C]	-23.1	-27.1	-45.7	-53
Time to dew point of -70^{o}C [hour]	15	5	8	8
Released water vapor from apparatus [mol]	0.12	0.025	0.016	0.014

4. Summary

To improve the start-up behavior of the gas separation membrane for dehumidification, we focus on the application of PID control and keeping the polymer membrane in a dry state during shout-down period. It is found that the amount of water absorbed in polymer membrane play an important role to suppress the start-up transient phenomenon.

References

[1] “Safe handling of tritium” Technical Reports Series No. 324, IAEA, Vienna, (1991) 34.

[2] T. Hayashi, K. Okuno, T. Ishida, et al.,: Fusion Eng. Des. **39-40** (1998) 901.