# Adsorption Characteristics of an Atmospheric Detritiation Dryer

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## 1. Introduction

As fusion research facilities and power plants are sure to require a large atmospheric-detritiation system (ADSs) to mitigate the tritium releases and to recover the heavy water vapor. The best available technology for these systems is the oxidized-and-adsorb process, where tritiated species are converted to tritium oxide (HTO) and adsorbed onto an atmospheric-detritiation dryer (ADD) [1-4].

Conventional ADDs use synthetic zeolites as the adsorbent and rely on a thermal–swing cycle. This permits a continuous detritiation of a gas by using multiple desiccant beds, each bed being regenerated following a period of moisture removal (adsorption). The performance of a desiccant dryer depends on the simultaneous transfer of the mass and energy between the flowing gas and solid desiccant. In designing a fixed bed dryer and preparing an advanced dryer control, it is necessary to quantify the bed utilization and dynamic behavior against inlet humidity and flow rate. In this study, a quantitative evaluation based on an adsorption test was carried out to evaluate the adsorption characteristics and the operating performance of an atmospheric detritiation dryer.

## 2. Experimental

A series of regeneration/adsorption cycles was performed using a bench-scale dryer described in Figure 1. The dryer was loaded with 1.6mm (nominal) of a Linde 13X molecular sieve. Each test consisted of regenerating a 10cm long by 1.1cm diameter bed to a known condition, followed by an adsorption using moisture stream with a constant humidity. The bed was vertical and gas flowed downward during the adsorption and regeneration.

Constant humidity was used during each adsorption test. CEM (Control-Evaporation-Mixing, Bronkhorst Hi-Tec. Co.) system was applied to supply the carrier gas adjusted with a constant humid condition. The defined quantity of the liquid can be mixed with the carrier gas and vaporized in the CEM system as seen in Table 1. Capacitance–type hygrometers from Michell Instruments with Cermet sensors monitored the inlet and outlet of the dryer bed.

The outlet humidities expressed as a dew-point temperature were automatically recorded through the interface with a computer.

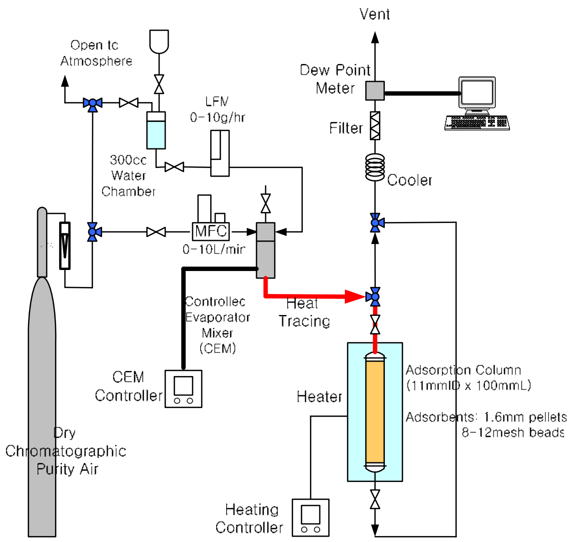


Figure 1. Schematic representation of the experimental apparatus for evaluating performance of a detritiation dryer.

Table 1. Humidity conditions by using the liquid delivery system with vapor control.

| Water flow (g/hr) | Dry air flow (L/min) | Absolute humidity ($gH_2O$)/g dry air) | Relative humidity (%) | | | Dew point (℃) |
|---|---|---|---|---|---|---|
| | | | 15℃ | 25℃ | 35℃ | |
| 0.1 | 1.0 | 0.0015 | 13.01 | 7.25 | 4.22 | -11.02 |
| 0.2 | 1.0 | 0.0029 | 25.97 | 14.46 | 8.41 | -3.06 |
| 0.3 | 1.0 | 0.0044 | 38.87 | 21.64 | 12.59 | 2.05 |
| 0.4 | 1.0 | 0.0058 | 51.72 | 28.79 | 16.75 | 6.11 |
| 0.5 | 1.0 | 0.0073 | 64.51 | 35.91 | 20.89 | 9.35 |
| 0.6 | 1.0 | 0.0088 | 77.24 | 42.99 | 25.01 | 12.05 |
| 0.7 | 1.0 | 0.0102 | 89.92 | 50.04 | 29.11 | 14.38 |
| 0.8 | 1.0 | 0.0117 | - | 57.06 | 33.19 | 16.42 |
| 0.9 | 1.0 | 0.0131 | - | 64.05 | 37.26 | 18.25 |
| 1.0 | 1.0 | 0.0146 | - | 71.01 | 41.3 | 19.9 |

## 3. Results and Discussion

### *3.1 Effect of Air Flow Rate*

Figure 2 shows that a breakthrough appears earlier at a higher air flow rate. On the other hand, the breakthrough curves are a little steeper at a higher air flow rate. In general, if the flow rate is decreased or the bed length increased, the breakthrough curve becomes steeper. The driving force for an adsorption, as well as regeneration, is the difference in the water vapor pressures in air and at the desiccant surface. The amounts of water vapor passing during each adsorption step to reach a breakthrough were estimated to be about 0.2g $H_2O$/g adsorbent by time-integrating the outlet water vapor content and multiplying it by the air flow-rate.

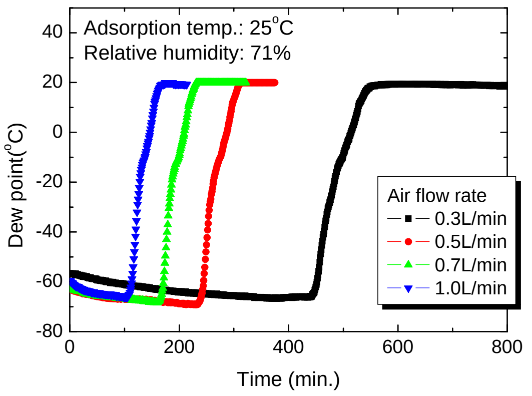


Figure 2. Breakthrough curves for water vapor adsorption on molecular sieve 13X bed at different humidity.

*3.2 Effect of Humidity*

Figure 3 shows that a breakthrough appears earlier and the breakthrough curves are steeper at a higher humid condition. That is to say that a breakthrough zone which creates a mass transfer from a fluid to an adsorbent becomes narrower due to a higher driving force.

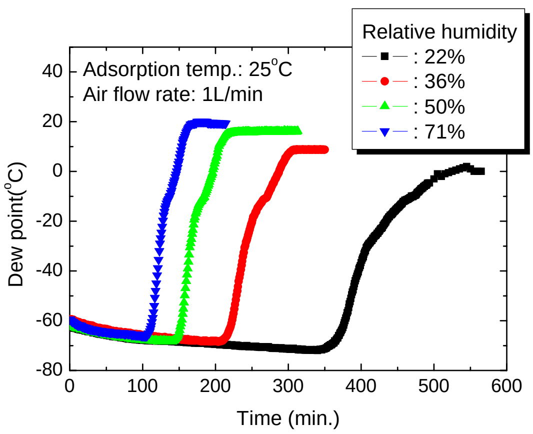


Figure 3. Breakthrough curves for water vapor adsorption on molecular sieve 13X bed at different inlet humidity.

*3.3 Effect of Adsorption Temperature*

The breakthrough appears earlier at a higher temperature condition as seen in Figure 4. This tendency is thought that an increasing adsorption temperature increases the temperature difference of the air stream through the adsorption column. The average amount of water vapor breaking during the adsorption through the fixed bed was estimated to be about 20 wt.% as a breakthrough capacity at the normal humidity conditions.

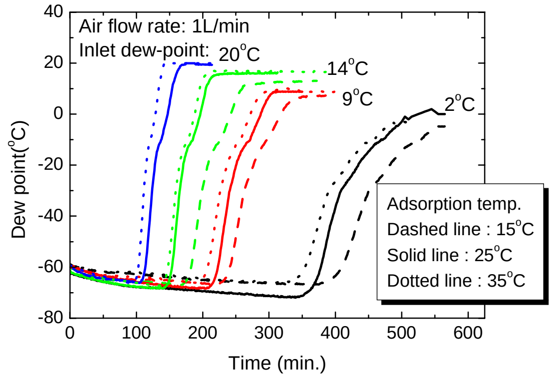


Figure 4. Breakthrough curves for water vapor adsorption on molecular sieve 13X bed at different humidity and adsorption temperature.

## 4. Conclusion

A small scale technique was used to study the adsorption characteristics of an atmospheric detritiation dryer. In an isothermal fixed bed adsorption system for a constant inlet humidity and flow rate of air stream, the breakthrough patterns were obtained to quantify the adsorption performance of the water vapor on synthetic zeolites.


## Acknowledgement

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