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# Forced Circulation Drying Test for Removing Residual Water

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## 1. Introduction

To maintain the integrity of spent nuclear fuel when storing spent nuclear fuel by dry type, canister water is drained to the outside, and the remaining water is physically bound to the canister, and spent fuel must then be dried and stored in an inert gas atmosphere.

Methods for removing residual water from dry storage system canisters include vacuum drying and forced circulation drying. The degree of drying that can be approved in the case of forced circulation drying involves as follows: The dew point temperature at the canister outlet should be maintained below -5 °C for more than 30 min, or the temperature at the dehumidifier should be maintained below -6 °C for more than 30 min [1].

The aim of the present paper is to evaluate signs appearing that residual water inside the canister dried well. To do so, a forced circulation drying system and small-sized canister were designed and fabricated. Forced circulation drying tests were conducted using our forced circulation drying system and canister.

## 2. Forced Circulation Drying Test

### *2.1 Description of the Forced Circulation Drying Test Equipment*

The forced circulation drying system comprises a small-sized canister, a helium circulation pump, a heater, a condenser, and a flow controller. Three small-sized canisters of lengths 50 cm (65 ℓ), 100 cm (130 ℓ) were used for a drying test. The bodies of the small-sized canisters were made of stainless steel and each had a diameter of 40.6 cm and a thickness of 1.27 cm. The lid of the canister had a water inlet and drain port, and there was a port for installing a pressure gauge to measure pressure.

### *2.2 Forced circulation Drying Test*

The forced circulation drying test was performed thirteen times in total according to the following procedure:

- Connect the extended hose connected to the inlet of the forced circulation drying test equipment to the inlet of the canister lid
- Fill 130 g water through the outlet port
- Connect the extended hose connected to the outlet of the forced circulation drying test equipment to the outlet of the canister lid
- Adjust the water to the desired test temperature
- Adjust the pressure of the canister to 0.5 kg/cm$^2$ using helium gas
- Set the heater temperature (these tests: 200 °C)
- Set the flow rate of the circulation pump (these tests: 30 m$^3$/hr)
- Start the measuring equipment
- Start the test by turning on the forced circulation drying test equipment
- When the dew point temperature reaches - 5 °C, maintain that state for 9 min
- End the test by turning off the forced circulation drying test equipment
- Unscrew the small-sized canister lid bolts
- Open the lid and check the water remaining in the canister

Fig. 1. Forced Circulation Drying Test Equipment

### *2.3 Test Results and Discussion*

(1) Test using a 65 liter canister

A forced circulation drying test using a 65 liter canister was conducted for three cases (water temperature: 30 °C, 35 °C, 40 °C). Table 1 presents the test results.

Table 1. Test results using a 65 liter canister

| Test | | Temp. of water (°C) | Water(After Test) Weight(g) | | Drying Time (min) |
|---|---|---|---|---|---|
| | | | Dry | Residual | |
| 65 litter | 1 | 30 | 129 | 1 | 59 |
| | 2 | 35 | 128 | 2 | 52 |
| | 3 | 40 | 129 | 1 | 47 |

In the case of Test 1, the dew point temperature was measured at - 5 °C after 59 min of drying test time. 129 g of 130 g of water in the canister had dried, and 1 g of water remained.

In the case of Test 2, the dew point temperature was measured at - 5 °C after 52 min of drying test time. 128 g of 130 g of water in the canister had dried, and 2 g of water remained.

In the case of Test 3, the dew point temperature was measured at - 5 °C after 47 min of drying test time. 129 g of 130 g of water in the canister had dried, and 1 g of water remained.

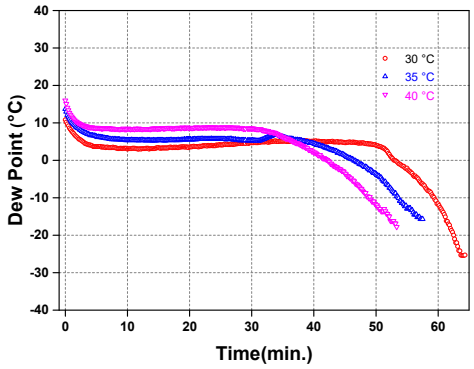


Fig. 2. Dew-point temperature change (65 liter)

(2) Test using a 130 liter canister

A forced circulation drying test using a 130 liter canister was conducted for four cases (water temperature: 25 °C, 30 °C, 35 °C, 40 °C). Table 2 presents the test results.

In the case of Test 4, the dew point temperature was measured at - 5 °C after 86 min of drying test time. 129 g of 130 g of water in the canister had dried, and 1 g of water remained.

In the case of Test 5, the dew point temperature was measured at - 5 °C after 64 min of drying test time. 129 g of 130 g of water in the canister had dried, and 1 g of water remained.

In the case of Test 6, the dew point temperature was measured at - 5 °C after 59 min of drying test time. 129 g of 130 g of water in the canister had dried, and 1 g of water remained.

In the case of Test 7, the dew point temperature was measured at - 5 °C after 53 min of drying test time. All of the water in the canister had all dried.

Table 2. Test results using a 65 liter canister

| Test | | Temp. of water (°C) | Water(After Test) Weight(g) | | Drying Time (min) |
|---|---|---|---|---|---|
| | | | Dry | Residual | |
| 130 litter | 4 | 25 | 129 | 1 | 86 |
| | 5 | 30 | 129 | 1 | 64 |
| | 6 | 35 | 129 | 1 | 59 |
| | 7 | 40 | 130 | None | 53 |

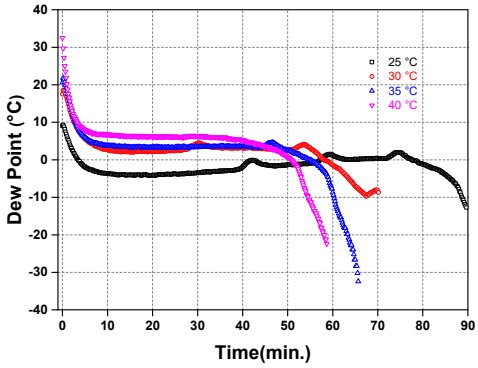


Fig. 3. Dew-point temperature change (130 liter)

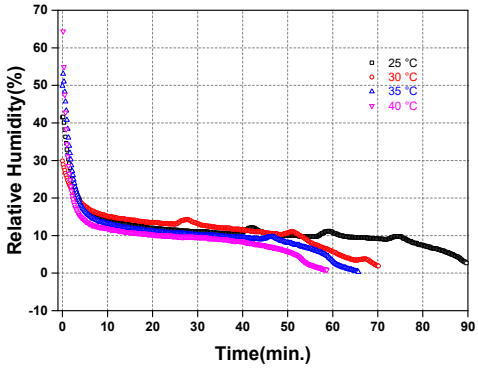


Fig. 4. Relative humidity change (130 liter)

## 3. Conclusion

A forced circulation drying system and small-sized canister were designed and fabricated, and used to conduct forced circulation drying tests to evaluate whether the drying of residual water inside the canister was adequate. The main results of our study are as follows:

- When the water temperature was low, drying time was long.
- When the volume of a canister was small, drying time was short.
- When the forced circulation drying progressed smoothly inside the canister, the dew point temperature in the canister decreased at the beginning of drying (approximately 5 min) and then continued to rise slightly, and when drying was completed, the dew point temperature rapidly decreased to approximately - 5 °C.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] Dry Storage Handbook, 2015 Edition. Fuel Performance in Dry Storage. ANT International, Molnlycke, Sweden.