Analysis of vacuum drying for canister with spent nuclear fuel

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1. Introduction

Spent fuel in the wet storage has to be transferred to the dry storage due to limitation of wet storage capacity and longer operation of nuclear power plant. In general drying process is required to store the wet spent fuel in dry storage system because oxidation composition could be bad effect of fuel cladding and long-term integrity of fuel cladding could not be guaranteed. There are two types of drying process. One is vacuum drying. Vacuum drying process is used widely because drying system is very simple. The other is forced dehydration drying. It is based on drying of forced convection using circulating of very dried gas.

In vacuum drying, residual water in canister could be indirectly figured out by pressure rise of vaporization. The exact amount of water could not be directly measured. To find out how much residual water is remained during drying process, analytical calculation of vacuum drying process was performed.

2. Concept of modeling

Vacuum drying is based on pressure change in canister due to vacuum pump and water evaporation. The modeling of vacuum drying process is consisted of 2 parts. One is pressure evacuation by vacuum pump and the other is pressure increase by water evaporation. Calculation process of pressure change at each time step was shown in Fig.1.

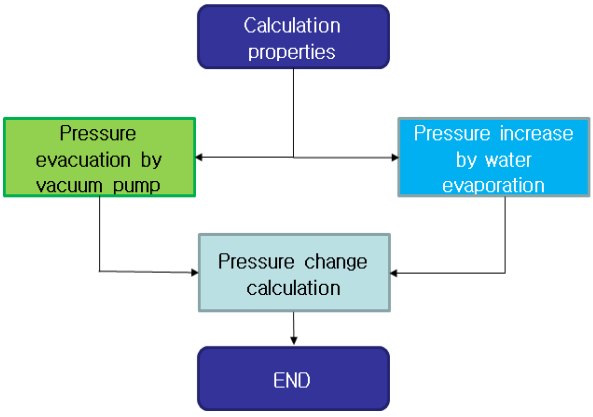

Fig. 1. Calculation process of pressure change at each step

Calculation program was made by C++ code. Pressure change, residual water, water evaporation rate could be acquired from the results of calculation.

3. Results and discussion

Assumptions of calculation are below as

- Temperature inside canister was constant.
- Residual water only naturally evaporated.
- Initial pressure is 101.325kPa.
- Initial residual water at bottom was 50g.

To check the effect of residual water, case with residual water and case without water were compared. Required time until pressure was less than 0.4 kPa (3 Torr) is 111 s for result without water and is 35907 s for result with water. It took much longer time for vacuum drying of case with residual water.

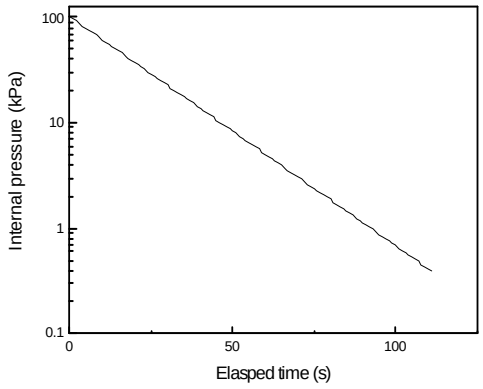

Fig. 2. Result of pressure change without residual water

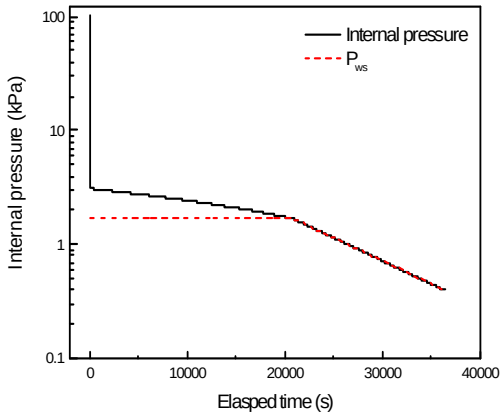

Fig. 3. Result of pressure change with residual water

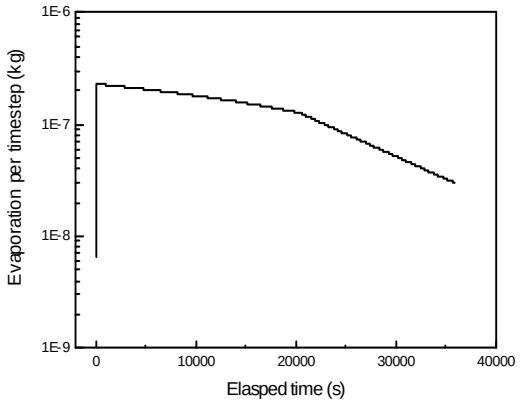

Fig. 4. Result of evaporation per time step with residual water

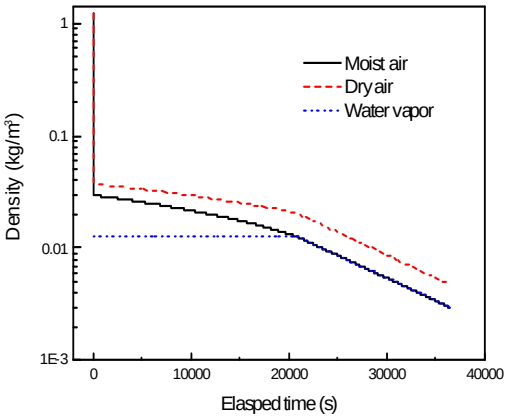

Fig. 5. Result of pressure and water vapor saturation pressure with residual water

In case with water, water evaporation rate was 2.995E-08 kg/s and final residual water 3.23E-03 kg when pressure reached 0.4 kPa.

The effects of temperature inside canister were compared. Temperature range is from 15°C to 90°C. The results were listed Table 1. As the temperature increased, evaporation rate increased

Table 1. The effect of initial temperature on required time

Initial Temp. (°C)	Required time(s)
15	35907
30	29931
45	28817
60	28453
75	27998
90	27689

3. Conclusions

The calculation program of vacuum drying was developed to analyze analytically vacuum drying process of transfer/storage canister or cask with spent nuclear fuel. This program was based on pressure increase by natural evaporation of residual water and pressure decrease by vacuum pump. The effect of residual water and temperature on vacuum drying was compared. As the temperature increased, required time for vacuum drying decreased due to faster evaporation of residual water.

REFERENCES

[1] ASHRAE Handbook-Fundamentals (SI) Chanper 5, 6, 2005
[2] Vacuum pump manual, Pfeiffer Vacuum Gmbh