Considerations of Drying System Design for the Dry Storage of Spent Nuclear Fuel

Kyung-Wook Shin*, Byeong-Mok Park, Jae-Hyun Han, Geon-Hui Lee, Gyung-Sun Chae, and Jae-Seok Park
SAE-AN ENGINEERING CO., 184, Gasan digital 2-ro, Geumcheon-gu, Seoul, Republic of Korea
*and9211@sae-an.co.kr

1. Introduction

In the case of Spent Nuclear Fuel(SNF) of domestic the Pressurized Water Reactor (PWR), SNF storage pools reaches sequentially saturation with the beginning at Hanbit nuclear power plant in 2024. In the national basic plan for high-level radioactive waste management, the interim storage facility promotes construction in the site of the permanent disposal facility, adopts the dry storage method considering operation and expansion, economical efficiency. Drying technology of SNF is necessary to store the SNF by the dry storage method. The first trial research for SNF drying from the Pressurized Water Reactor (PWR) is progressing.

The short-term operation is a series of working process within an SNF storage building before the SNF transportation from the storage pool to a dry storage [1]. The processes of short-term operation are SNF loading in cask, cask transfer, cask decontamination, canister internal drainage, canister internal drying and inert gas filling in the canister. Canister internal drying process is the important process to secure the integrity of long-term dry storage of SNF. We conducted the review the design of drying system for the dry storage of SNF from PWR. It is includes the survey of commercialized drying methods and system, related standards, any criteria to complete drying process.

2. Considerations of drying system design

The current drying process is divided into a commercial nuclear fuel vacuum drying system and a force gas dehydration system. Vacuum drying system is relatively simple, and forced gas hydration system has the advantages of short drying time and less heat cycle.

2.1 Drying process

In order to secure the safety of SNF transportation and the long-term integrity of dry storage, the residual water in SNF transportation and storage container should be removed to under the relative standard [2]. The objective of drying process is to remove the residual water in canister to prevent geometric reconfiguration of the packaged SNF, and to prevent canister damage from over-pressurization or corrosion, and to prevent hydrogen induced damage or material corrosion. An evaluating adequate dryness must consider the starting system, the types of water, and water inventory and determine whether the appropriate technology has been applied through the drying process meet the regulatory requirements. Fig. 1 shows the flow diagram to preview the conceptual design of SNF drying process.

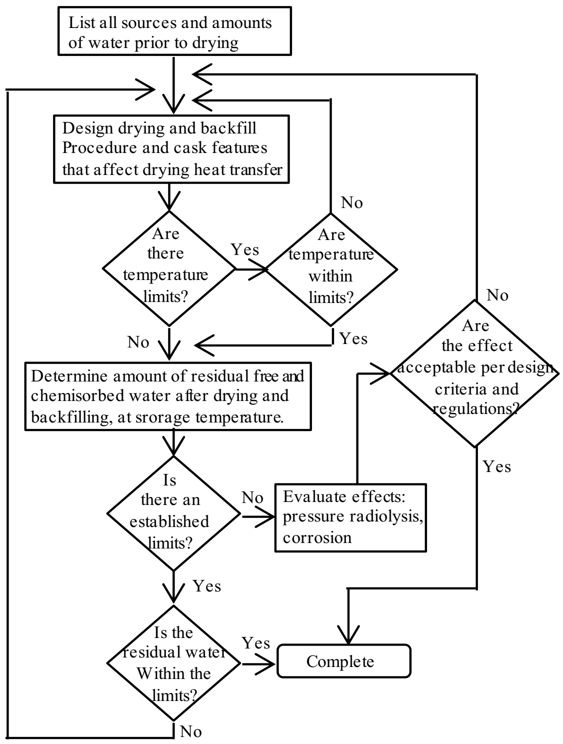

Fig. 1. Flow diagram of SNF drying process.

2.2 Vacuum drying system

Vacuum drying system consists of vacuum pumps, vacuum pipe lines, oil mist filter, gauges, valves, condensers and chiller unit. In vacuum drying process, vacuum drying system connect to the container exhaust and drain connector on the canister lid part, and reduce the container internal pressure to 4.0E-04 Mpa (3 torr) or less. Close the valve in the exhaust system and observe the pressure change for 30 minutes. If it is no change in pressure, the inside of canister complete drying process, and if the pressure increases, the drying operation must repeat. Vacuum drying system is relatively simple than gas circulation, but has some of drawback such as long drying time and ice formation during drying process.

2.3 Forced gas drying system

Forced gas drying system consists of a condensing module, a demoisturizer module, a gas circulator module and a preheater module, which are schematically shown in Fig. 2. The forced gas drying process is effectuated by circulating dry heated inert gas through the storage container loaded with SNF.

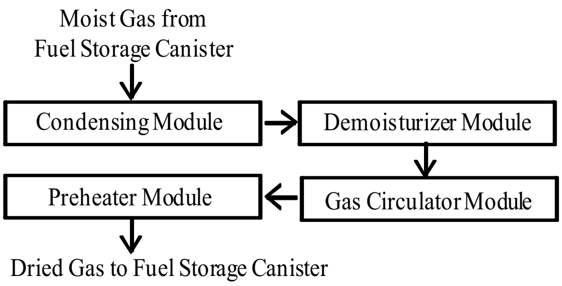

Fig. 2. Flow diagram of forced gas drying process.

The condensing module serves to cool the gas and vapor mixture exiting the canister to a temperature well below its dew point such that water may be extracted from the gas stream. The demoisturizer module receive partially cooled gas exiting the condensing module, progressively chills the recirculating gas to a temperature that is well below the temperature corresponding to the partial pressure of water vapor at 4.0E-04 Mpa (3 torr). The gas circulator module provides the motive energy to circulate the gas, which is sized to provide the pressure rise necessary to circulate gas at the requisite rate. The preheater module serves to add supplemental heat energy to inert gas so as to facilitate rapid conversion of water into vapor form. It also acts to dry enough inert gas before entering the canister.

2.4 Dryness requirement

The U.S. Nuclear Regulatory Commission recommends acceptance criteria that the forced gas dehydration be maintained at a gas vapor pressure of less than or equal to 4.0E-04 Mpa (3 torr).

In the case of the Forced Helium Dehydration system commercialized by Holtec International incorporation, the acceptance criteria is as follows [3].

The partial pressure of the water vapor in the canister will not exceed 3 torr. The limit will be met if the gas temperature at the demoisturizer outlet is verified by measurement to remain ≤ -6.1℃ for ≥30 minutes, or if the dew point of the gas exiting the canister is verified by measurement to remain ≤ -5.06℃ for ≥30 minutes.

3. Conclusion

Canister internal drying process can consider the important process to secure the integrity of long-term dry storage of spent nuclear fuel. We conducted the review the design of drying system for the dry storage of SNF from PWR. It is includes the survey of commercialized drying methods and system, related standards, any criteria to complete drying process. This will be a major issue that can be reflected in the design of the forced gas dehydration under study.

Acknowledgement

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References

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[2] ASTM C1553-16, "Standard Guide for Drying Behavior of Spent Nuclear Fuel[1]", ASTM, 2016.

[3] "Holtec International Final Safety Analysis Report for the HI-STORM 100 Cask System*" 2016.