Requirements of dry storage demonstration for CANDU Spent Fuel

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1. Introduction

As the final management plan for spent nuclear fuel repository is delayed, and recycling technology has not been developed smoothly in most countries, dry storage period of spent nuclear fuel at nuclear power plant by power generation companies is getting very long worldwide. As the decades-long license period approaches the end, countries are preparing test data that will be the basis for safety evaluation to extend the operating period of the existing spent fuel dry storage system. It is an inevitable process to ensure long-term safety.

2. CANDU Spent Fuel Demonstration Project in CANADA

Canada, which developed the CANDU reactor, has developed and operated its own dry storage system early on to solve this problem because the amount of heavy water used in nuclear fuel is very high. Canada also conducted a demonstration project to check the safety of such a dry storage system. The main objectives of this project were to check the integrity of spent fuel and cladding and bundles, check the corrosion resistance of the cladding, check the interaction between the cladding and fission products, and check the leakage of radionuclides.

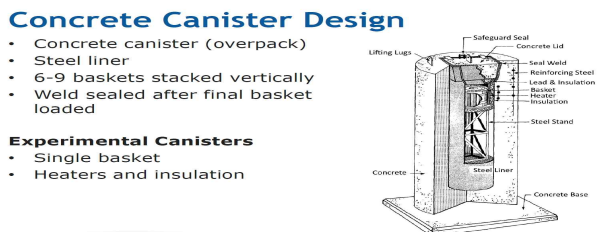

Fig. 1 Dry storage demonstration system in Canada

Canada's CANDU spent nuclear fuel demonstration system is almost similar to Korea's CANDU silo, but the specific specifications are different. However, since the most important spent fuel basket has the same structure including 60 bundles, there are abundant resources that can be directly referenced in the operation plan of the demonstration project in Korea. In addition, Canada has experience in promoting three types of CANDU spent nuclear fuel demonstration project, and since the operation history exceeds 30 years as of 2021, Korea has a lot to learn in terms of long-term operation.

In particular, there are many things to refer to for future demonstration projects in Korea, as the test data for spent nuclear fuel before dry storage operation and test data for spent fuel that has been dry stored for 20 years are the ones in the world. If it is secured jointly with Korea, it will be an invaluable opportunity.

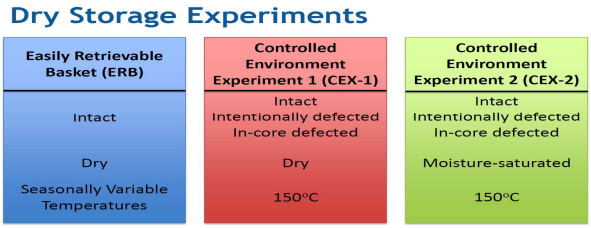

Fig. 2 Summary of Characteristics of Each CANDU Spent Fuel Demonstration Project in CANADA

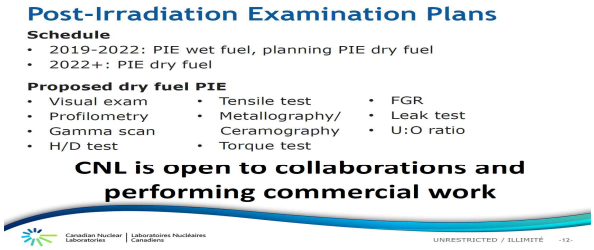

Fig. 3 CANDU Spent Fuel Test Schedule and Test Items in CANADA

3. CANDU Spent Nuclear Fuel Demonstration Direction in Korea

3.1. The need to demonstrate CANDU Spent Fuel

It is important to secure public acceptance by directly demonstrating to the public that the management of spent nuclear fuel in a dry storage environment is safe through a demonstration test of the spent nuclear fuel. Similarly, the United States, Japan, and Canada are promoting demonstration projects for the same purpose.

Among the CANDU spent nuclear fuel dry storage systems, the concrete silo started operation with the goal of 50 years in 1992, and has been in operation for about 30 years so far. Two management options are available by 2040, when the licensing period for the first silo ends.

The first is transportation after securing a centralized storage site, and the second is a failure to secure a centralized storage site and temporary storage for power plant site.

Both options require real-scale demonstration technologies that can be applied to real storage systems before 2040 to secure actual measurement data. Based on this, it is expected that it will be possible to decide whether to transfer to a centralized storage facility or extend the license.

3.2 The objective of demonstration study

The goal is to secure demonstration test technology that proves the soundness of long-term storage of spent nuclear fuel, and to design, manufacture, and operate a demonstration system.

3.3. Definition of Demonstration Technology

The long-term storage demonstration test technology is to compare and verify the engineering factors predicted at the time of designing the spent fuel storage system and the factors of the actual storage system in operation [2,3].

4. Technical requirements of Demonstration test

Due to the recent prolonged dry storage, empirical tests to check the soundness of the spent nuclear fuel, which are the object of storage, and the canister/basket, the storage system, are being actively conducted, mainly in the United States, and the main items of this tests are Gas Sampling, Temperature Evaluation, and SNF Integrity. It is composed of evaluation. The technical requirements for the domestic CANDU spent nuclear fuel demonstration test are the same.

4.1 Gas Sampling (analysis of gases in the system)

The most important process of dry storage is vacuum drying. Recently, incompleteness of vacuum drying has become a big issue, so it is important to measure the moisture inside the storage system through gas analysis. If radionuclides leak from the spent fuel into the storage system, it is detected and the integrity of the spent fuel cladding is checked. It analyzes the amount of gas inside the demonstration system and infer the pressure inside the system.

However, in Korea's CANDU spent nuclear fuel demonstration project, there is no vacuum drying process like in the United States, so it is necessary to perform gas analysis suitable for the Korean situation, such as drying the basket and filling it with air.

4.1 Temperature Evaluation

In a spent fuel storage system, the material properties of major components are deteriorated over a long period of time mainly by temperature, and these weakened material properties can be changed in a dynamic environment (handling, repackaging, transport, external shock, etc.) after storage in the future. It may act as a factor that threatens the integrity of the mechanical structure. Therefore, it is very important to check whether the temperature change value predicted at the time of designing the storage system is different from the measured temperature of each component of the system (outer wall of container, basket, nuclear fuel cladding) during actual storage.

In Korea's CANDU spent nuclear fuel demonstration project, a temperature evaluation system that can reflect the unique characteristics of the CANDU spent nuclear fuel dry storage system such as the temperature distribution inside the basket, the temperature measurement of the nuclear fuel cladding, and the heat flow inside the silo should be prepared.

4.3 SNF Integrity Evaluation

If moisture is present inside the storage system, the corrosion reaction of the spent fuel should be evaluated. In addition, if a problem occurs in the cladding tube and the fission product inside the spent fuel rod leaks into the storage system, it may cause contamination problems inside the repacking facility during the future repacking process, so the soundness of the cladding tube should be evaluated.

Since storage is a temporary management method, it is necessary to evaluate whether or not to secure retrievability, which should not cause any problems, in handling, in the process of transferring the spent nuclear fuel to the final disposal system.

The basis of the spent fuel soundness evaluation method is to compare before storage (t=0), 15 years after storage (t=15), and 30 years after storage (t=30), and predict the behavior for the remaining period by extrapolation Therefore, various experiments on spent nuclear fuel to be stored should be supported.

4. Conclusion

The factor for the demonstration of CANDU spent nuclear fuel are gas sampling and temperature evaluation in the demonstration system. Based on the requirements derived from this thesis in the project, it is planned to establish a demonstration system for CANDU spent fuel in the future and conduct characteristic evaluation.

ACKNOWLEDGE

This work was supported by the Institute of Korea Spent Nuclear Fuel grant funded by the Korea government the Ministry of Trade, Industry and Energy (2021040101002C)

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