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Application of Independent Air-cooled System Installation on Spent Fuel Pool for Decommissioning of Pressurized Water Reactor Kori units 3 and 4

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1. Introduction

Starting with the permanent shutdown of Kori unit 1 in 2017, decommissioning has become the biggest challenge that Korean nuclear society is facing. Now, decommissioning plans for Kori units 3&4 also have to be thoroughly discussed.

When planning for decommissioning of a nuclear power plant, measures to remove spent fuels that emit heat and radiation has to be decided first. In Korea, immediate relocation of the spent fuels is virtually impossible because simply there is no interim or permanent storage in operation. According to a MOTIE's plan in 2021, it will take 20 years for building an interim storage, and 37 years for a permanent storage. Therefore, ideas to safely maintain spent fuels until the storage facilities are ready have been discussed.

Spent fuel pool island (SFPI) concept is one of the most feasible option. This concept is to isolate the existing spent fuel pool (SFP) with some modifications such as installation of an independent dry-cooling system.

In this paper, SFP air-cooled system installation of SFPI concept is reviewed and developed to be applied on Kori units 3&4, the Westinghouse 950 MW pressurized water reactor.

2. Review of Current Cooling System

The SFP Cooling and Cleanup System is composed of two redundant trains. Major cooling components of the primary loop are heat exchangers and cooling pumps. Secondary loop removes heats transferred through the heat exchanger. Component Cooling Water System (CC) and Nuclear Service Cooling Water System (NSCWS) dissipates the heat to the ultimate heat sink.

2.1 System Configuration

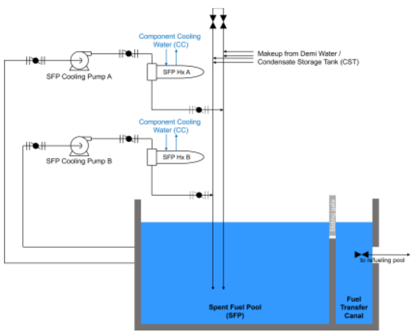

Fig. 1. Schematic diagram of Kori units 3&4 SFP cooling system.

Configuration of the SFP cooling system of Kori units 3&4 in operating condition is shown in Fig. 1. Note that the figure describes only pool side primary loop.

2.2 System Details

The maximum heat load of SFP heat exchanger is 4.83E+07 Btu/h, and pool side and cooling side flow rate is identically 3,500 gpm [1].

Running massive systems like CC and NSCWS would cause more difficulties and schedule delay to the project. Furthermore, capacity of each heat exchanger of CC is 1.77E+08 Btu/h [1]. Hence, this is largely oversized to be used only for cooling SFP in decommissioning phase. Therefore, system modification for sufficient but lighter design is required.

3. Estimated Decay Heat

A study calculated maximum decay heat generated from Kori units 3&4 spent fuels by using ORIGEN of SCALE 6.2 code. The maximum heat generated is 1.06E+07 Btu/h when the most conservative conditions applied; 2,106 spent fuel assemblies spent 5 years for cooling with the average burnup rate of 55,002 MWD/MTU.

More realistic condition is categorizing spent fuels into four groups depending on the cooling time of 5, 10, 20, and 30 years. Assuming the average burnup rate as 50,000 MWD/MTU, estimated decay heat obtained is 6.00E+06 Btu/h [2].

In this study, 1.06E+07 Btu/h heat load is considered as the target heat load of the cooling system to take a sufficient design margin.

4. Case Study

Practices of SFPI concept in decommissioning can be found in the U.S. such as Maine Yankee Nuclear Power Plant, Zion Nuclear Power Station, Connecticut Yankee Nuclear Power Plant, and San Onofre Nuclear Generating Station (SONGS) units 2&3. Although structures, systems, and components (SSCs) of SFP in normal operation was mostly safety-related, SSCs of SFPI were reclassified as non-safety-related [3]. The SFPIs have been successfully completed as the spent fuels were relocated in dry casks of independent spent fuel storage installation (ISFSI).

Decommissioning of SONGS included the latest SFPI that started in 2015. The secondary loop of Independent SFP Cooling System (ISFPCS) used two (2) industrial chillers with 2.4E+06 Btu/h each. Primary / secondary loop flow rate is 883 / 500 gpm. Design base of ISFPCS was to remove heat load of 3.0E+06 Btu/h from 1,318~1,350 irradiated fuel assemblies [4].

5. Application of SFPI cooling system to Kori 3&4

5.1 System Requirements

The maximum SFP temperature shall be lower than 120 ºF (48.8ºC) in normal operation condition [1]. The installed cooling system shall satisfy this requirement.

The cooling system shall remove the maximum heat load of 1.06E+07 Btu/h.

From the case study, it is advisable to reclassify the SSCs of SFPI as non-safety-related.

5.2 Installed Cooling System

Installation of four (4) chillers of which 2.7E+06 Btu/h capacity each is suggested. The schematic diagram of conceptual design is shown in Fig. 2.

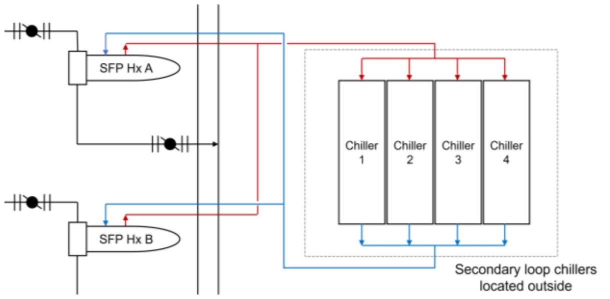

Fig. 2. Schematic diagram of secondary loop of the proposed SFP cooling system.

5.3 Primary Loop Details

The existing heat exchanger capacity and pool water flow rate are 4.83E+07 Btu/h and 3,500 gpm. These are 10 times and 3.96 times greater than those of SONGS. The primary loop components are estimated to provide sufficient heat load capacity in decommissioning. It is reasonable to keep the primary loop as-is without modification.

5.4 Secondary Loop Details

The secondary loop shall allow enough flow rate to transfer the decay heat from the primary loop to the chillers. Finally, the four air-cooling chillers with total capacity of 1.08E+07 Btu/h can completely dissipate heat taken from the secondary loop to the environment.

Furthermore, calculation through ORIGEN shows that decay heat of 30-year-cooled spent fuel was 41.4% of that of 5-year-cooled spent fuel in case of 55,002 MWD/MTU burnup [2]. Hence, required flow rate and number of chillers in operation will be gradually reduced in time.

6. Conclusion

This paper studied application of SFPI air-cooled system on Kori units 3&4. This concept has been adopted in actual decommissioning projects such as SONGS units 2&3, and successfully completed. SONGS case clearly showed that installation of two (2) industrial 2.4E+06 Btu/h air-cooled chillers can be enough to remove the decay heat from 1,350 spent fuel assemblies.

To apply the cooling system to Kori units 3&4, decay heat from 2,106 spent fuel assemblies has to be estimated to decide total capacity of the cooling system. A study using ORIGEN of SCALE 6.2 calculated the amount of decay heat as 1.06E+07 Btu/h when conservative conditions applied.

The conceptual design of SFPI cooling system for Kori units 3&4 suggests similar configuration to SONGS case. To be more specific, installation of four (4) chillers with 2.7E+06 Btu/h capacity each is proposed. Less number of chillers would be operating later because decay heat decreases as time passes. SSCs of the proposed system are classified as non-safety-related.

Further research could be conducted on safety analysis, optimization, and strategy in conjunction with long-term spent fuel management.

ACKNOWLEDGEMENTS

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