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Revision Log

Revision	Description of Changes
0	Initial Issue.

Executive Summary

This white paper is intended to convey to the NRC the design of the SMR-160 Spent Fuel Pool makeup methods. A comparison with the NRC-approved NuScale and AP1000 designs is used to demonstrate SMR-160 conformance with the relevant NRC regulations. This white paper will also provide the opportunity for the NRC to ask any questions on the SMR-160 design. Follow on revisions to this white paper could result from discussions between SMR-160 and the NRC.

Table of Contents

1.0 INTRODUCTION

1.1 Purpose

The purpose of this whitepaper is to give a high-level overview of Holtec's design of the SMR-160 Spent Fuel Pool (SFP) and safety-related makeup methods and discuss the associated regulatory requirements. NuScale and AP1000 designs are also provided for context.

1.2 Objective

The objective of this whitepaper is to obtain feedback from the NRC staff on SFP makeup regulations and understand how they apply to the SMR-160 design.

1.3 Abbreviations

BAS	Boron Addition System (NuScale)
CVCS	Chemical and Volume Control System (SMR-160, AP1000)
DWS	Demineralized Water System
GDC	General Design Criterion
LRWS	Liquid Radioactive Waste System (NuScale)
PCCAWST	Passive Containment Cooling Auxiliary Water Storage Tank (AP1000)
PCCS	Passive Core Cooling System (SMR-160)
PCCWST	Passive Containment Cooling Water Storage Tank (AP1000)
PCMWT	Passive Cooling Makeup Water Tank (SMR-160)
SFP	Spent Fuel Pool
SFPC	Spent Fuel Pool Cooling System (SMR-160)
UHS	Ultimate Heat Sink (NuScale)

2.0 NRC REGULATIONS

10 CFR 50 Appendix A [1] General Design Criteria 61, Fuel storage and handling and radioactivity control, states:

The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, confinement, and filtering systems, (4) with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal, and (5) to prevent significant reduction in fuel storage coolant inventory under accident conditions.

NUREG-0800 Section 9.1.3 Spent Fuel Pool Cooling and Cleanup System [2] Section III. Review Procedures 1.F states:

A seismic Category I, Quality Group C makeup system and an appropriate backup method to add coolant to the spent fuel pool are provided. If the forced-circulation cooling system is *designed to seismic Category I, Quality Group C standards, the backup system need not be a permanently installed system, or Category I, but should take water from a seismic Category I source. Otherwise, the backup system should also be permanently installed, physically separate and independent from the primary makeup system, and designed to seismic Category I, Quality Group C standards. The minimum makeup capacity for each system exceeds the larger of the pool leakage rate assuming spent fuel pool liner perforation resulting from a dropped fuel assembly or the evaporation rate necessary to remove 0.3 percent of the reactor rated thermal power. The design permits initiation of makeup water flow through either system from locations remote from the operating floor surrounding the pool surface. Engineering judgment and comparison with plants of similar design are used to determine that the time necessary to align systems and connect makeup systems not permanently installed is consistent with heatup times or expected leakage from structural damage.*

Regulatory Guide 1.13 Spent Fuel Storage Facility Design Basis [3] Regulatory Position 8, Makeup Water, states:

A Quality Group C, Seismic Category I makeup system should be provided to add coolant to the pool. Appropriate redundancy or a backup system for filling the pool from a reliable source, such as a lake, river, or onsite Seismic Category I water-storage facility, should be provided. If the spent fuel pool cooling system is designed to the requirements of Quality Group C, Seismic Category I, the backup to the makeup system need not be permanently installed or designed to Seismic Category I requirements; however, the backup system should still take water from a Seismic Category I source. The makeup system and its backup should have redundant flowpaths for providing water to the storage pool. The capacity of the makeup systems should exceed the larger of (1) the pool leakage rate, assuming spent fuel pool liner perforation resulting from a dropped fuel assembly, or (2) the evaporation rate necessary to remove 0.3 percent of the rated reactor thermal power.

3.0 SMR-160 SFP DESIGN AND COMPARISON TO OTHER DESIGNS

3.1 SMR-160

The SMR-160 SFP is uniquely located inside containment. The SFP and SFPC system is designed to ensure a minimum water level of at least 10 ft above the top of the active fuel is present during normal operating conditions and accident scenarios. All penetrations in the SFP are safety-related and seismic Category 1, and all besides the Passive Core Makeup Water Tank (PCMWT) balance line are above the minimum water level or have anti-siphon devices to ensure the SFP cannot drain below the minimum water level. Since the PCMWTs are full except during PCCS operation, any issue (e.g., leak) that would connect the SFP and PCMWTs through the balance line would cause the PCMWTs to fill the SFP, not the SFP to drain.

During normal operations, SFP makeup is provided by the nonsafety-related DWS and CVCS systems to maintain a minimum water inventory of approximately 80,500 gallons. The Refueling Water Storage Tank also provides water to flood up the SFP during refueling operations to a minimum water inventory of approximately 232,900 gallons. The cooling portion of the

SMR-160 SFPC system is not designed to seismic Category I, Quality Group C standards, and therefore the water in the SFP is allowed to boil to remove heat upon loss of cooling. Preliminary SFP boiloff calculations demonstrate that makeup to the SFP during bounding SFP decay heat scenarios during both normal operating conditions and refueling is not needed for at least 72 hours to ensure a water level of at least 10 ft above the top of the active fuel is maintained. The SFP safety-related, seismic Category I backup makeup water method includes a permanently installed piping connection from the Passive Core Makeup Water Tanks (PCMWTs) to the SFP. Approximately 145,930 gallons of water are available in the PCWMTs to provide makeup between 72 hours at least 7 days after loss of SFP cooling. Nonsafety-related sources of makeup water may be used after 72 hours if they are available. Additionally, while not currently credited in analyses, a portion of the vapor from SFP boiling will condense on the containment walls and eventually return to the SFP.

If the Passive Core Cooling System (PCCS), which includes the PCMWTs, is needed for core cooling at the same time as a loss of SFP cooling and normal makeup, the PCMWTs will not directly be the source of SFP makeup. During PCCS operation, the opening of Automatic Depressurization Valves opens the Reactor Coolant System to the Containment Structure. The Containment Structure is designed to channel water back to the SFP for eventual long-term cooling by recirculating the water from the flooded containment back through the core via the SFP. Since flooding of containment and recirculation of water through the core will occur within the 72 hours prior to needing SFP makeup water, the SFP level will not drop below the minimum 10 ft above the active fuel. If PCMWTs are needed to provide SFP makeup, technical specifications will direct operators to shut down the plant if PCCS operation would be unavailable.

3.2 NuScale

During normal operations, the NuScale design provides makeup to the SFP via the Demineralized Water System (DWS), Boron Addition System (BAS), or Liquid Radioactive Waste System (LRWS). Additionally, no piping penetrations are present that could drain the SFP below the minimum required water level. The NuScale Spent Fuel Pool Cooling (SFPC) system is not seismic Category I, Quality Group C. NuScale meets the above NRC regulations by citing makeup flow over a weir wall between the SFP and the Refueling Pool (the volumes of which are normally connected within the Ultimate Heat Sink (UHS) pool system of water at elevations above the maximum weir wall height) as the primary SFP makeup source. Additional makeup water is not required for at least 30 days due to the volume of the UHS. A permanently installed, seismic Category I emergency makeup line from the UHS system to the lower portion of the SFP serves as the backup source and can provide makeup at a rate above the maximum anticipated evaporation rate [4]. The NRC finds that the NuScale design conforms with prevention of significant reduction in fuel storage coolant inventory under accident conditions as required by GDC 61 based on the amount of safety-related water available in the UHS for passive cooling of stored spent fuel, the fact that makeup water is not needed for at least 30 days, and that a seismic Category I makeup line is permanently available [5].

3.3 AP1000

The AP1000 design provides makeup to the SFP during normal operations via the DWS and Chemical and Volume Control (CVCS) systems. Connections to the spent fuel pool are at an elevation to preclude the possibility of inadvertently draining the water in the pool to an unacceptable level. The AP1000 SFPC system is not seismic Category I, Quality Group C. To meet the above regulatory requirements, AP1000 cites safety-related makeup flow from the cask washdown pit and, if necessary during the highest anticipated decay heat levels in the spent fuel pool, the cask loading pit, which have sufficient inventory to not need additional makeup for at least 72 hours. The passive containment cooling water storage tank (PCCWST) serves as the safety-related backup source, as needed, and has sufficient inventory to provide makeup for at least 7 days, after which nonsafety-related makeup can be provided. If emergency makeup is needed as a result of a loss of power combined with a seismic event when the plant is being refueled, which would cause high decay heat levels in both the reactor and the SFP, the PCCWST is needed to provide containment cooling and cannot be used for spent fuel pool makeup. In this scenario, cooling water is provided by the nonsafety-related passive containment cooling ancillary water storage tank (PCCAWST). All makeup rates are above the maximum SFP evaporation rate [6]. Based on thermal analysis, the limiting water level maintained during a loss of spent fuel cooling is 1.4 ft above the fuel given safety-related makeup during the first 72 hours and PCCAWST makeup between 72 hours and 7 days. The NRC finds that the AP1000 design also conforms with GDC 61, in part, as safety-related water sources are used to remove SFP decay heat for the first 72 hours when normal SFP cooling is unavailable, and that after 72 hours and before 7 days the SFP credits the use of regulatory treatment of nonsafety systems to provide makeup water to the SFP [7].

4.0 REFERENCES

[1] 10 CFR 50 Appendix A, "General Design Criteria for Nuclear Power Plants".

[2] U. S. Nuclear Regulatory Commission, "NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition - Spent Fuel Pool Cooling and Cleanup System (Section 9.1.3)," Revision 2, March 2007.

[3] U. S. Nuclear Regulatory Commission, "Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis," Revision 2, March 2007.

[4] NuScale Power, LLC, "Final Safety Analysis Report, Part 2 - Tier 2, Chapter 9 Auxiliary Systems," Revision 5, July 2020.

[5] U. S. Nuclear Regulatory Commission, "NuScale Final Safety Evaluation Report, Chapter 9 Auxiliary Systems," August 2020.

[6] Westinghouse, "AP1000 Design Control Document, Tier 2, Chapter 9 Auxiliary Systems, Section 9.1 Fuel Storage and Handling," Revision 19, June 2011.

[7] U. S. Nuclear Regulatory Commission, "NUREG-1793 Final Safety Evaluation Report Related to Certificatoin of the AP1000 Standard Plant Design, Volume 2, Supplement 2," September 2011.