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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 Primary Decay Heat Removal and Secondary Decay Heat Removal systems and facilitate discussion on GDC 57 application to these systems.

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this white paper is to give a high-level overview of Holtec's design of the SMR-160 Primary Decay Heat Removal (PDHR) and Secondary Decay Heat Removal (SDHR) systems, specifically the containment isolation schemes.

1.2 Objective

The objective of this whitepaper is to obtain feedback from the NRC staff on containment isolation regulations and understand how they apply to the SMR-160 PDHR and SDHR designs.

1.3 Abbreviations

AR	Annular Reservoir
LOCA	Loss-of-coolant Accident
PDHR	Primary Decay Heat Removal system
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
SDHR	Secondary Decay Heat Removal system

2.0 SMR-160 PDHR AND SDHR DESIGN

The SMR-160 utilizes a PDHR system to provide safety-related decay heat and sensible heat removal from the Reactor Coolant System (RCS) during non-Loss-of-coolant Accident (LOCA) events. The PDHR system consists of two loops. The PDHR primary loop is part of the reactor coolant pressure boundary (RCPB) and circulates primary coolant from the RCS through the tube side of a heat exchanger. The PDHR secondary loop is a closed system inside and outside containment that circulates demineralized water. The closed system inside containment is formed by the shell side of the primary loop heat exchanger, connected piping, and an expansion tank with a pressure relief valve that relieves to the containment atmosphere. The water then flows through the tubes of a second heat exchanger, which are submerged in the Annular Reservoir (AR). The second heat exchanger and connected piping form the closed system outside containment.

The primary PDHR loop is designed to Quality Group A, seismic Category I as it is exposed to the reactor coolant during normal operations. Normally shut valves on the primary PDHR loop return to the RCS actuate upon receipt of a safety signal to begin PDHR heat removal. The secondary PDHR loop is designed to Quality Group B, seismic Category I, and can accommodate containment temperature and pressure as it is part of the containment boundary. There are no containment isolation valves in the PDHR secondary loop.

The SMR-160 also utilizes a SDHR system to provide safety-related decay heat and sensible heat removal from the RCS during non-LOCA events other than a feedwater or steam line break inside containment. The SDHR system consists of one loop, which is a closed system inside and outside containment that circulates secondary side condensate from the steam generator through a heat exchanger outside containment and returns to the steam generator through the Main Feedwater System. The AR water surrounds the tubes of the SDHR heat exchanger. The steam generator and connected piping comprise the closed system inside containment, while the heat exchanger and connected piping comprise the closed system outside containment. The SDHR loop is designed to Quality Group B, seismic Category I, and can accommodate containment temperature and pressure as it forms the containment boundary. Normally shut valves on the SDHR return to the steam generator actuate upon receipt of a safety signal to begin SDHR heat removal. There are no containment isolation valves in the SDHR loop.

3.0 CLOSED SYSTEM CONTAINMENT ISOLATION REGULATIONS AND GUIDANCE

10 CFR 50 Appendix A [1] General Design Criteria 57, Closed system isolation valves, states:

Each line that penetrates primary reactor containment and is neither part of the reactor coolant pressure boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve.

NUREG-0800 Section 6.2.4 Containment Isolation System [2] Acceptance Criteria 5 states:

Containment isolation provisions for lines in engineered safety feature or engineered safety feature-related systems normally consist of two isolation valves in series. A single isolation valve is acceptable if system reliability can be shown to be greater, the system is closed outside containment, and a single active failure can be accommodated with only one isolation valve in the line. The closed system outside containment should be protected from missiles, designed to seismic Category I and Group B quality standards, and have a design temperature and pressure rating at least equal to that for the containment. The closed system outside containment should be leak-tested unless system integrity can be shown to be maintained during normal plant operations. For this type of isolation valve arrangement the valve is located outside containment, and the piping between the containment and the valve should be enclosed in leak-tight or controlled-leakage housing. If, in lieu of housing, piping and valve are designed conservatively to preclude a breach of piping integrity, the design should comply with SRP Section 3.6.2 requirements. Design of the valve or the piping compartment should provide the capability to detect and terminate leakage from the valve shaft or bonnet seals.

Further, Acceptance Criteria 15 states:

The use of a closed system inside containment as one of the isolation barriers is acceptable if the closed system design satisfies the following requirements:

A. The system does not connect with either the reactor coolant system or the containment atmosphere.

B. The system is protected against missiles and pipe whip.

C. The system is designated seismic Category I.

D. The system is classified Quality Group B.

E. The system is designed to withstand temperatures equal to at least that of the containment design.

F. The system is designed to withstand the external pressure from the containment structure acceptance test.

G. The system is designed to withstand the LOCA transient and environment.

As to the structural design of containment internal structures and piping systems, the protection against loss of function from missiles, pipe whip, and earthquakes is acceptable if 1) isolation barriers are located behind missile barriers; 2) pipe whip was considered in the design of pipe restraints and the location of piping penetrating the containment; and 3) the isolation barriers, including the piping between isolation valves, are designated seismic Category I, i.e., designed to withstand the effects of the safe-shutdown earthquake, as recommended by Regulatory Guide 1.29.

Regulatory Guide 1.141 Containment Isolation Provisions for Fluid Systems [3] endorses requirements and recommendations for containment isolation of fluid systems as specified in ANSI N271-1976 (which has since been superseded by ANSI/ANS 56.2-1984 [4]) subject to stated conditions. However, the standards do not address using a closed system inside containment and a closed outside containment for redundant isolation barriers. ANSI/ANS 56.2-1984 provides criteria for using closed systems (either inside or outside containment) as a containment isolation barrier including, in part, designing to Quality Group B and seismic Category I standards, providing overpressure protection, and providing the capability for leak testing.

4.0 NUSCALE DECAY HEAT REMOVAL SYSTEM

The NuScale Decay Heat Removal System has a similar design to the SMR-160 SDHR system in that it transfers heat from the steam generator to a water source outside containment. The system consists of a closed loop inside containment that includes the steam generator and connected main steam system and feedwater system piping, and a closed system outside containment that includes heat exchanger and connected piping. NuScale requested an exemption to GDC 57 for the Decay Heat Removal System containment penetrations, noting that application of GDC 57 to this system is not necessary to achieve the underlying purpose of the rule. NuScale justifies the exemption request, in part, by stating the closed systems inside and outside containment are redundant containment isolation barriers and meet the underlying purpose of GDC 57 [5]. The NRC determined that the NuScale design accomplishes containment isolation for the Decay Heat Removal System without containment isolation valves outside containment. The closed system inside containment is consistent with NuScale Design-Standard Review Specification 6.2.4 [6] Acceptance Criteria 15 (the same as NUREG-0800 6.2.4 Acceptance Criteria 15) and the closed system outside containment is designed to preclude a breach of integrity. Therefore, the NRC approved the NuScale GDC 57 exemption request [7].

5.0 REFERENCES

[1] 10 CFR 50, App. 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 - Containment Isolatoin System (Section 6.2.4)," Revision 3, March 2007.

[3] U. S. Nuclear Regulatory Commission, "Regulatory Guide 1.141 Containment Isolation Provisions for Fluid Systems," Revision 1, July 2010.

[4] ANSI/ANS 56.2, "Containment Isolation Provisions for Fluid Systems after a LOCA," 1984.

[5] NuScale Power, LLC, "Exemptions, Part 7," July 2020.

[6] U. S. Nuclear Regulatory Commission, "Design-Specific Review Standard for NuScale SMR Design, 6.2.4 Containment Isolation System," June 2016.

[7] U. S. Nuclear Regulatory Commission, "NuScale Final Safety Evaluation Report, Chapter 6 Engineered Safety Features," August 2020.

6.0 APPENDIX A – PDHR P&ID

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7.0 APPENDIX B – SDHR P&ID

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