NuScale Standard Plant
Design Certification Application

Chapter Twenty
Mitigation of Beyond-Design-Basis Events

PART 2 - TIER 2

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 20 MITIGATION OF BEYOND-DESIGN-BASIS EVENTS

On September 9, 2019, the NRC issued the mitigation of beyond-design-basis-events rule (MBDBE), 10 CFR 50.155 (Reference 20.1-9). This rule addresses mitigation of beyond-design-basis events, including remotely-monitored spent fuel pool level instrumentation. In addition, the rule moves requirements for licensees to develop and implement guidance and strategies to maintain or restore core cooling, containment, and spent fuel cooling under circumstances associated with loss of large areas (LOLA) of the plant due to fire or explosion from 10 CFR 50.54(hh) to 10 CFR 50.155(b)(2). Although the MBDBE rule does not apply to NuScale as a design certification applicant, certain provisions of the rule will apply to a COL applicant and COL holder. Chapter 20 describes the features of the NuScale Power Plant with respect to provisions of the MBDBE rule that apply to COL applicants and holders referencing the NuScale design certification.

Section 20.1 addresses the NuScale design's response to beyond-design-basis events (BDBEs), including having remotely-monitored spent fuel pool level instrumentation, and Section 20.2 addresses the NuScale design's response to loss of large areas of the plant due to fire or explosion.

20.1 Mitigation of Beyond-Design-Basis External Events

This section describes the response of the Nuscale design to the assumed damage state of a beyond-design-basis event in 10 CFR 50.155(b)(1), a loss of all alternating current power and loss of normal access to the normal heat sink (LUHS), hereafter referred to as loss of all AC power event. The NuScale design features two functional heat sinks, as described in FSAR Section 9.2.5 and summarized here. During normal operation, the normal heat sink is via the power conversion system, where the condenser transfers heat to the circulating water system. The safety-related sink is the ultimate heat sink (UHS), which is used only if the power conversion system is not available. For the NuScale design, the UHS becomes the heat sink in a loss of all AC power event.

The purpose of the discussion in this section is to address compliance with equipment-related provisions of 10 CFR 50.155 (b)(1), (c), and (e). For the NuScale Power plant, using only safety-related design features, the stored inventory in the Reactor Building pools, and the automatic plant response, the coping duration exceeds 50 days for core cooling and containment, and 150 for spent fuel cooling (Reference 20.1-10).

20.1.1 Not Used

COL Item 20.1-1: Not used.

COL Item 20.1-2: Not used.

COL Item 20.1-3: Not used.

COL Item 20.1-4: Not used.

COL Item 20.1-5: Not used.

20.1.2 Not Used

20.1.3 Mitigation Strategies for a Loss of All AC Power Event

Following a loss of all AC power event concurrent with a LUHS, automatic responses of safety-related equipment establish and maintain the key safety functions of core cooling, containment, and SFP cooling by placing the reactor modules into a safe, stable, shutdown state with passive core and containment cooling. Following the initial, automatic response of safety-related equipment—which requires no operator action and no electrical power (AC or DC)—the reactor modules and the spent fuel pool rely only on the large inventory of the reactor, refueling, and spent fuel pools, which comprise the UHS, to maintain uninterrupted and long-term heat removal. The first 72 hours of a loss of all AC power event are identical to a station blackout, which is described in Section 8.4 of the FSAR.

Core Cooling

The core cooling function is automatically established and passively maintained by safety-related equipment, as follows:

- During a loss of all AC power event, reactor coolant system inventory is preserved by containment isolation that occurs within the first minute of the event.
- The decay heat removal system (DHRS) passively removes decay heat for the first 24 hours of a loss of all AC power event.
- The ECCS cools the core for the remainder of a loss of all AC power event. Reactor coolant water accumulates in the containment vessel (CNV) and passively returns to the reactor vessel by natural circulation after ECCS valves open.
- The reactor modules are partially immersed in the reactor pool, which is part of the UHS. Passive heat removal to the UHS using DHRS and ECCS maintains core cooling for more than 50 days without pool inventory makeup or operator action during that period.

Containment

The containment function is automatically established and passively maintained by safety-related equipment as follows:

- Containment isolation valves (CIVs) and the CNV provide the passive containment function. Without operator action or electrical power, the safety-related CIVs close to isolate the CNV.
- Heat removal to the UHS passively controls temperature and pressure to ensure containment integrity. Peak pressure and temperature conditions for the CNV occur early in the event when the ECCS valves open, and do not challenge containment integrity.

Spent Fuel Pool Cooling

The spent fuel pool cooling function is maintained by submergence of the spent fuel in the UHS.

- The spent fuel pool (SFP), as part of the UHS, communicates with the refueling pool and reactor pool above the SFP weir wall. As such, the pools respond as a single volume during a loss of all AC power event until UHS level lowers below the weir wall.
- The UHS inventory maintains passive cooling of the spent fuel in the SFP for more than 150 days following initiation of a loss of all AC power event without pool inventory makeup or operator action.

Monitoring

- No operator action is required to establish or maintain the required safety functions for at least 50 days following the onset of a loss of all AC power. Therefore, no instrumentation is necessary to support operator actions.
- Although not necessary because of the fail-safe and passive design, monitoring instrumentation (safety display and indication system, SDIS) is maintained in the main control room for at least 72 hours to provide additional assurance that systems have responded as designed (see Table 20.1-1 and Table 20.1-2).
- Although sufficient UHS level exists for at least 50 days, UHS level monitoring, which includes SFP level, is assured for at least 14 days using installed equipment and dedicated backup battery power supplies (see Table 20.1-3).

The installed equipment relied on to ensure core cooling, containment, and SFP cooling is safety-related and has sufficient capacity and capability to perform those functions for at least 50 days. Beyond the installed-equipment coping duration, only a small amount of water (approximately 28 gpm) added through a gravity-fed piping system would maintain the remaining pool inventory. Monitoring is not relied on for the mitigation strategies and guidelines, but installed instrumentation provides at least 72 hours of module and at least 14 days of UHS monitoring as a supplementary capability. Therefore, the installed-equipment coping capability provides adequate time to obtain offsite assistance and resources, if needed and no preplanned offsite resources are required for a NuScale Power Plant to respond to a loss of all AC power event.

COL Item 20.1-6: Not used.

COL Item 20.1-7: Not used.

20.1.4 Spent Fuel Pool Instrumentation

The purpose of the spent fuel pool instrumentation (SFPI) requirements at 10 CFR 50.155(e) is to ensure that information about the SFP is provided to decision makers to enable resource prioritization for event mitigation and recovery actions. The SFPI requirements are not intended to support mitigation action but rather, to provide information. Use of SFPI is not necessary for the NuScale design to respond to an event; however, the instrumentation is available for at least 14 days following an event. The MBDBE SFPI requirements require licensees to provide reliable means to remotely monitor wide-range water level for each SFP at its site until five years have elapsed since all of the fuel in that SFP was last used in a reactor vessel for power generation.

20.1.4.1 Design Bases

The design of the four (4) UHS level instruments meets the guidance of NEI 12-02 (Reference 20.1-5). The design basis functions of the pool level instrumentation are to provide plant personnel with a reliable wide-range water level indication of the UHS level until the UHS level decreases below the SFP weir when the RFP and reactor pool inventory is separate from the inventory in the SFP and reactor pool relative to the following water levels:

- Level 1 - level that is adequate to support operation of the normal pool cooling systems (See Table 9.2.5-1, Relevant Ultimate Heat Sink Parameters, Minimum level for SFPCS and RPCS suction penetrations),
- Level 2 - level that is adequate to provide substantial radiation shielding for a person standing on the operating deck (See Table 9.2.5.1, Relevant Ultimate Heat Sink Parameters, Minimum level to support radiation shielding),
- Level 3 - level where stored fuel remains covered and actions to implement make-up water should no longer be deferred (See Table 9.2.5-1, Relevant Ultimate Heat Sink Parameters, Top of spent fuel rack).

During refueling, the NPM is disassembled in the RFP area to allow transferring of new and spent fuel to and from the reactor core. When an NPM is disassembled, the water level in the RFP area will be monitored to ensure the fuel in the reactor is covered during an ELAP event.

The UHS level instruments are designed to withstand external hazards; such as seismic, flooding, high winds (including applicable missiles) extreme temperatures, and snow and ice; without loss of capability to perform their monitoring function.

The UHS instruments are designed to withstand the effects of and to be compatible with the environmental conditions associated with the expected conditions in the Reactor Building during normal operations and an ELAP event.

The UHS level instruments and their power supplies are physically and electrically separated and independent.

20.1.4.2 Description

Two (2) wide-range water level instruments are provided for both the SFP and the reactor pool, for a total of four (4) instruments. The wide-range instruments encompass the elevations from the top of the fuel storage racks to near the operating deck. The pool water level instrumentation is consistent with the guidance of NEI 12-02, Revision 1 (Reference 20.1-5).

Instruments

Two (2) permanent wide-range instruments monitor the level of the SFP. Two permanent wide-range instruments are also installed to monitor the UHS water level, one in the RP area and one in the RFP area. The instruments transmit signals to the main control room. All four of these instruments are capable of monitoring Levels 1 and

2. The two (2) SFP level instruments are capable of monitoring Level 3, when the RP water level is below the weir wall elevation. The two (2) level instruments in the RP and RFP areas are capable of monitoring the level of the water above the fuel in the reactor core when the NPM is disassembled in the RFP during refueling.

Arrangement

The two (2) SFP level instruments are arranged in opposite corners of the SFP. The two (2) UHS level instruments are located in the one (1) in the RFP area and the other instrument is located in the RP area. The separation of these instruments is adequate to provide protection from missiles that may be generated within the reactor building from affecting the instruments simultaneously. Protection from external missiles is provided by the Reactor Building structure.

The instrument cables are also separated to provide protection against a single missile damaging both trains.

Mounting

The four (4) UHS instruments are seismically mounted such that the instruments will maintain their design configuration during and following an SSE (Seismic Category I).

Qualification

The four (4) UHS instruments and associated cabling are environmentally qualified to operate following a BDBEE in the following environmental conditions:

- SSE seismic event (Seismic Category I)
- Concentrated borated water environment,
- Temperature of approximately 212 degrees Fahrenheit and 100 percent relative humidity,
- Boiling water or steam environment,
- Radiological conditions existing from a normal refueling with a freshly discharged fuel batch that remains covered with SFP water (Level 3).

Independence

The four (4) UHS level instruments are both physically and electrically independent.

Power Supplies

The power to the four (4) UHS level instruments is supplied by the highly reliable DC power system (EDSS) with interface through the plant protection system (PPS). Power to the redundant level instruments is from separate bus sources such that the loss of one supply will not result in a loss of power supply function to both divisions of UHS level instrumentation. Additionally, a dedicated battery-powered backup power supply for each level instrument ensures that each instrument is capable of providing level indication for at least 14 days. The dedicated backup power supply is isolated from faults on the normal power supply and provides an alternate source of power independent from the plant AC and DC power systems. Batteries are designed for easy replacement to power UHS monitoring level instruments indefinitely.

Accuracy

The instrument channels are designed to maintain the minimum accuracy following a power interruption or change in power source without recalibration.

Testing

The permanently installed UHS level instruments are designed such that testing and calibration can be performed in-situ.

Display

The four (4) UHS level instruments transmit signals to the main control room and the remote shutdown panel, and are immediately available to the operators following an event. The instrument signals also initiate high or low level alarms, both locally and in the main control room.

Programs

COL Item 20.1-8: A COL applicant that references the NuScale Power Plant design certification will develop procedures, training, and a qualification program for operations, maintenance, testing, and calibration of ultimate heat sink level instrumentation to ensure the level instruments will be available when needed and personnel are knowledgeable in interpreting the information as addressed in Nuclear Energy Institute (NEI) 12-02, Revision 1, Industry Guidance for Compliance with NRC Order EA-12-051, "To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation."

Safety Evaluation

The four (4) UHS level instruments are designed to withstand and be protected from natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis and seiches without loss of function.

These instruments are also designed to accommodate or be protected from the effects of the postulated environmental conditions, including missiles, pipe whipping, and jet impingement.

The instruments and associated cabling is protected by both physical and electrical separation such that a failure in one channel will leave the other channel functional.

20.1.5 References

20.1-1 Not used.

20.1-2 Not used.

20.1-3 Not used.

20.1-4 Not used.

20.1-5 Nuclear Energy Institute, Industry Guidance for Compliance with NRC Order EA-12-051, "To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," NEI 12-02 Revision 1, August 2012.

20.1-6 Not used.

20.1-7 Not used.

20.1-8 Not used.

20.1-9 *U.S. Code of Federal Regulations*, "Mitigation of Beyond-Design-Basis Events," Part 50, Chapter 1, Title 10, "Energy," (10 CFR 10.155).

20.1-10 NuScale Power LLC, "Mitigation Strategies for Extended Loss of AC Power Event," TR-0816-50797-NP, Revision 3.

Table 20.1-1: Core Cooling Parameters(1)

Function	Parameters for Assuring Function is Established	Parameters for Assuring Function is Maintained
RCS inventory control	RPV water level	None(2)
	Containment isolation valve positions	
Reactivity control	Neutron flux	None(2)
	Core inlet temperature	
	Core exit temperature	
	Reactor trip breaker status	
	CVCS containment isolation valve positions	
DHRS decay heat removal	Core exit temperature	Spent fuel pool level(3)
	DHRS valve positions	
	MSIV positions	
	MSIV bypass isolation valve positions	
	FWIV positions	
	Spent fuel pool level(3)	
ECCS decay heat removal	ECCS valve positions	Spent fuel pool level(3)
	Containment water level	
	RPV water level	
	Core exit temperature	
	Spent fuel pool level(3)	

(1) Monitoring is not relied on for the mitigation strategies and guidelines, but installed instrumentation provides at least 72 hours of module monitoring, and at least 14 days of UHS monitoring as a supplementary capability.

(2) By design, once these functions are established, they are maintained indefinitely.

(3) Spent fuel pool level provides indication of UHS level when UHS level is above the SFP weir.

Table 20.1-2: Containment Parameters(1)

Function	Parameters for Assuring Function is Established	Parameters for Assuring Function is Maintained
Containment isolation	Containment isolation valve positions	None(2)
Containment heat removal	Wide range containment pressure	Spent fuel pool level(3)
	Spent fuel pool level(3)	

(1) Monitoring is not relied on for the mitigation strategies and guidelines, but installed instrumentation provides at least 72 hours of module monitoring, and at least 14 days of UHS monitoring as a supplementary capability.

(2) By design, once these functions are established, they are maintained indefinitely.

(3) Spent fuel pool level provides indication of UHS level when UHS level is above the SFP weir.

Table 20.1-3: Spent Fuel Pool Parameters[1]

Function	Parameter for Assuring Function is Established	Parameter for Assuring Function is Maintained
Spent Fuel Pool Cooling	Spent fuel pool level	Spent fuel pool level

(1) Monitoring is not relied on for the mitigation strategies and guidelines, but installed instrumentation provides at least 14 days of UHS monitoring as a supplementary capability.

20.2 Loss of Large Areas of the Plant due to Explosions and Fires

NRC regulation 10 CFR 50.155(b)(2) requires licensees to develop and implement guidance and strategies to maintain or restore core cooling, containment, and spent fuel cooling under the circumstance associated with the loss of large areas of the plant due to explosion or fire (LOLA). The strategies (Reference 20.2-3) that are required to be addressed are: (i) fire fighting; (ii) operations to mitigate fuel damage; and (iii) actions to minimize the radiological release.

Technical Report TR-0816-50796 (Reference 20.2-1) documents an assessment evaluating the NuScale Power Plant response to a LOLA event using the guidance in Nuclear Energy Institute (NEI) 06-12 (Reference 20.2-2). The report defines LOLA criteria and identifies the design features that meet those criteria and expected combined license (COL) applicant requirements.

The analysis was performed using the three phases recommended in NEI 06-12 (Reference 20.2-2): Phase 1 - Enhanced Fire Fighting Capabilities; Phase 2 - Measures to Mitigate Damage to Fuel in the Spent Fuel Pool; and Phase 3 - Measures to Mitigate Damage to Fuel in the Reactor Vessel and to Minimize Radiological Release.

This section describes the results of the assessment with no Security Related Information.

20.2.1 Phase 1 - Enhanced Fire Fighting Capabilities

The firefighting response to a LOLA event includes the operational aspects of responding to explosions or fire including items such as prearranging for the involvement of outside organizations, planning and preparation activities (e.g., pre-positioning equipment, personnel, and materials to be used for mitigating the event), and developing procedures and training for the event.

The fire protection system includes an underground yard fire main loop. Hydrants are provided on the yard fire main loop in accordance with the National Fire Protection Association at intervals up to 250 feet and located on each side of the Reactor Building. The lateral to each hydrant is controlled by an isolation valve. There are several connections in the yard main that can support supplying the yard main using a portable diesel-driven pump and several valves that can isolate damaged section(s) when required. The fire protection system is described in more detail in Section 9.5.1.

COL Item 20.2-1: A COL applicant that references the NuScale Power Plant design certification will develop enhanced firefighting capabilities in accordance with 10 CFR 50.155(b)(2). The enhanced firefighting capabilities should address the expectation elements listed in Section 4.1.3 of the Technical Report TR-0816-50796 (Reference 20.2-1).

20.2.2 Phase 2 - Measures to Mitigate Damage to Fuel in the Spent Fuel Pool

Additional spent fuel cooling strategies are not required, in accordance with the guidance in NEI 06-12 (Reference 20.2-2).

20.2.3 Phase 3 - Measures to Mitigate Damage to Fuel in the Reactor Vessel and to Minimize Radiological Release

The only mitigating strategy required for the NuScale Power Plant is release mitigation. Standpipes and hose connections are located in each stairway and exit corridor. Hydrants are located in yard areas at least 100 yards from the Reactor Building (RXB). Portable external pump and supporting equipment should be located more than 100 yards from the RXB. The NuScale design will successfully support supplying the underground fire water ring main using a portable diesel-driven pump. External water sources available for makeup to the yard fire main loop are the fire protection supply tank and the fire protection alternative supply tank, which contain at least 300,000 gallons of water. The portable pump and supporting equipment (e.g., diesel fuel), as well as flexible hoses and supporting equipment, should be located at least 100 yards from the RXB. The COL applicant will determine the estimated flow rate of the portable equipment. If the yard fire main loop is intended to be used for reactor mitigation strategies, the capability to isolate other structures is included due to several connections and valves that can ensure isolation of broken sections of the main.

COL Item 20.2-2: A COL applicant that references the NuScale Power Plant design certification will provide a means for water spray scrubbing using fog nozzles and the availability of water sources, and address runoff water containment issues (sandbags, portable dikes, etc.) as an attenuation measure for mitigating radiation releases outside containment.

20.2.4 References

20.2-1 NuScale Power, LLC, "Loss of Large Areas Due to Explosions and Fires Assessment," (Security Related Information), TR-0816-50796-P, Revision 1.

20.2-2 Nuclear Energy Institute, "B.5.b Phase 2 & 3 Submittal Guideline," NEI 06-12, Revision 3, September 2009.

20.2-3 U.S. Nuclear Regulatory Commission, “Developing Mitigating Strategies/Guidance for Nuclear Power Plants to Respond to Loss of Large Areas of the Plant in Accordance with B.5.b" of the February 25, 2002, Order, Commission Letter, February 25, 2005.