Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 6-8, 2026

Analyses of Postulated ATWS Events in the Innovative Small Modular Reactor

Min Seok Lee*, Seok Jeong Park, Ung Soo Kim
Safety Analysis Office, KEPCO-E&C, 269, Hyeoksin-ro, Gimcheon-si, Gyeongsangbuk-do, KOREA
**Corresponding author: mslee@kepco-enc.com*

***Keywords : small modular reactor, anticipated transients without scram**

1. Introduction

Anticipated transients without scram (ATWS) is an accident which the reactor trip system (RTS) fails to initiate a reactor trip in response to an anticipated operational occurrence (AOO). The primary concern during ATWS is over-pressurization of the reactor coolant system (RCS) which could challenge the integrity of the reactor coolant pressure boundary.

The estimated core damage frequency due to postulated ATWS events should be no more than 10^{-5}/year by following the ATWS performance criteria (e.g., there would be analysis to verify that Service Level C limits of the ASME boiler and pressure vessel code [1], 3,200 psig, would not be exceeded, fuel integrity would be maintained, there would be no excessive radioactivity release, the containment would not fail, and long-term shutdown and cooling would be assured) [2].

This work presents the evaluation results of RCS pressurization following a postulated ATWS. Various AOOs from chapter 15 of the safety analysis report (SAR) are considered in the analyses for the innovative small modular reactor (i-SMR).

2. Method of Analysis

The SPACE code [3] is used to evaluate the major thermal-hydraulic behavior of the system. Normal operating conditions and nominal plant design values are assumed to apply the best-estimate analysis method.

A negative moderator temperature coefficient (MTC) is a natural feedback mechanism that reduces core reactivity as coolant temperature increases, leading to a decrease in RCS pressure. Consequently, the highest peak pressure occurs when the MTC is least negative, as this results in higher core power. Fig. 1 shows the MTC changes from the first cycle to the equilibrium cycle including daily load following flexible operating conditions. For conservatism, the least negative MTC values are applied in each fuel cycle.

3. Results and Discussions

3.1 Analyzed AOO Events in SAR Chapter 15

Table I lists the AOOs that lead to RCS pressurization in chapter 15 of i-SMR safety analysis report. During a postulated ATWS, it is qualitatively evaluated that there is no significant loss of RCS inventory or fuel uncovery. Fuel integrity is maintained without any significant fuel heat-up, and the long-term cooling is ensured without metal-water reactions. As a result, a coolable geometry is ensured and containment vessel integrity is maintained. The primary concern in a postulated ATWS is overpressurization, the consequences of which are discussed in the following sections.

3.2 Analyses Results

3.2.1 Loss of Condenser Vacuum and Loss of Normal Feedwater Flow

The LOCV and LONF cause a decrease in heat transfer rate from RCS to secondary system. The RCS temperature increases due to the reduction in heat transfer, and the expansion of the primary coolant leads to increase in the pressurizer pressure. The pressure continue to increase until the reactor trip occurs by the high pressurizer pressure. However, the scram is not

Table I: AOO events in SAR chapter 15

Section	Event
15.2.3	Loss of condenser vacuum (LOCV)
15.2.7	Loss of normal feedwater flow (LONF)
15.3.1	Total loss of reactor coolant flow (LOF)
15.4.3	Single CEA withdrawal event (CEAW)
15.5.1	Pressurizer level control system malfunction (PLCSMF)

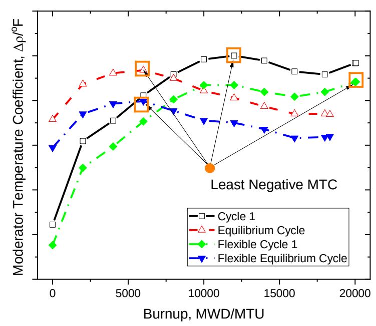

Fig. 1. MTCs from first to equilibrium cycle

inserted into the core due to the postulated ATWS. Primary-to-secondary heat transfer restarts with the opening of secondary passive cooldown system. The negative reactivity feedback effect of MTC reduces the core power level to the point where matches with the heat removal capacity of secondary passive cooldown system. During the transient, RCS pressure is controlled with the opening of safety relief valves, the peak pressure remains below 3,200 psig as shown in Fig. 2 and Fig. 3.

3.2.2 Total Loss of Reactor Coolant Flow

The loss of offsite power (LOOP) results in a simultaneous turbine trip, loss of main feedwater, condenser inoperability, and coastdown of all four reactor coolant pumps. The loss of steam flow and reduced RCS flow lead to a rapid increase in primary coolant temperature. The pressure continue to increase until the reactor trip occurs by the high pressurizer pressure. However, under the postulated ATWS, scram is not inserted. Heat transfer from the primary-to-secondary system is restored through the secondary passive cooldown system. During the transient, RCS pressure is controlled by the opening of safety relief valves, and the peak pressure remains below 3,200 psig as shown in Fig. 4.

3.2.3 Single CEA Withdrawal Event

CEAW event results in an increase in core power, accompanied by corresponding rises in reactor coolant temperature and pressure. The withdrawal of a CEA induces a time-dependent, asymmetric redistribution of core power. However, no significant power or flow mismatches are expected to challenge the core integrity and lead to core damage. As a result, fuel cladding temperature remains below the safety limit of 1,204 °C, preserving fuel integrity. Analysis results show that no reactor trip signal is generated during the transient, and the peak RCS pressure remains below 3,200 psig as shown in Fig. 5.

3.2.4 Pressurizer Level Control System Malfunction

An excess of charging flow over letdown flow results in pressure to increase until the reactor trip occurs by the high pressurizer pressure. However, under the postulated ATWS, scram is not inserted. Primary-to-secondary heat transfer is reduced due to the closure of the main feedwater isolation valves (MFIVs) and main steam isolation valves (MSIVs), which is generated by initiation of secondary passive cooldown system. During the transient, RCS pressure is controlled by the opening of safety relief valves, and the peak pressure remains below 3,200 psig as shown in Fig. 6.

4. Conclusions

Analyses are performed to assess the risk associated with postulated ATWS events. For the purpose of evaluating RCS peak pressure, least negative MTCs are considered for each fuel cycle. From the results, it is found that peak pressures of RCS do not exceed service level C limits of the ASME boiler and pressure vessel code, or 3,200 psig. The safety analyses demonstrate

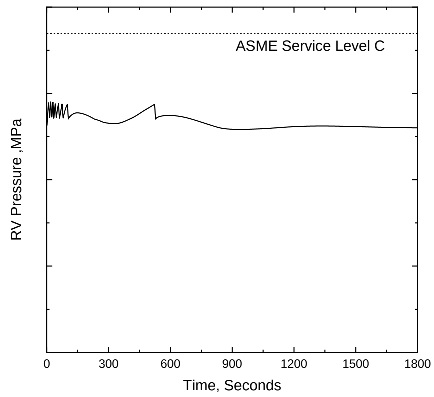

Fig. 2. Loss of condenser vacuum

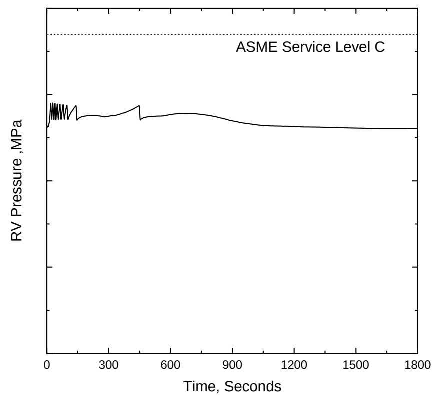

Fig. 3. Loss of normal feedwater flow

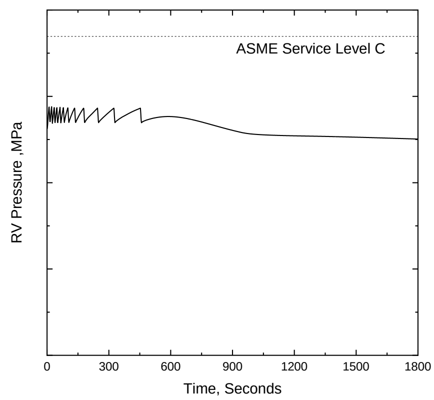

Fig. 4. Total loss of reactor coolant flow

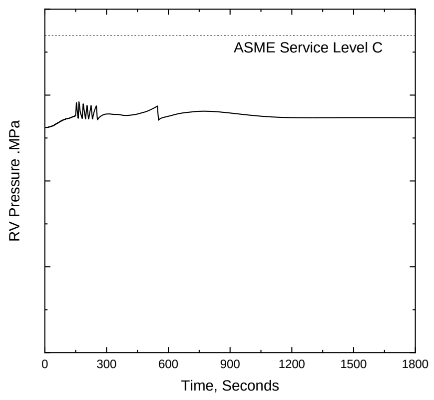

Fig. 5. Single CEA withdrawal event

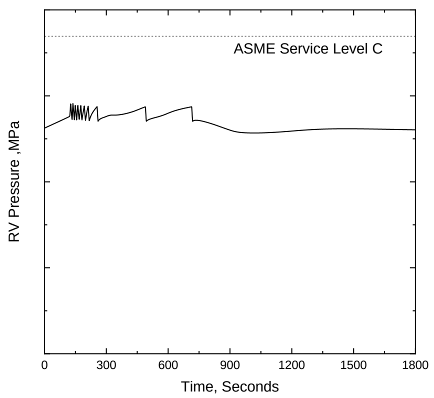

Fig. 6. Pressurizer level control system malfunction

that the applied MTC for the i-SMR effectively limits the increase in RCS temperature to a level where the reduced reactor power matches the heat removal capacity of the secondary passive cooldown system. With the resulting stabilized rise in RCS temperature-and consequently in RCS liquid volume-the pressurizer has sufficient capacity to accommodate the expanded volume. As a result, RCS pressure can be regulated through the opening of safety valves.

After the event of a postulated ATWS, it is determined that none of operator action is needed to reduce RCS pressure, however, reactivity control needs to be achieved by operator with initiation of secondary shutdown system. This system introduces negative reactivity into the core providing an effective means of reactivity control and ensuring long-term safe shutdown.

ACKNOWLEDGEMENTS

This work was supported by the Innovative Small Modular Reactor Development Agency grant funded by the Korea Government (MSIT) (No. RS-2024-00403548).

REFERENCES

[1] ASME BPVC Section III, “Rules for Construction of Nuclear Facility Components,” 2023.
[2] SECY-83-293, “Amendments to 10 CFR 50 Related to Anticipated Transients without Scram (ATWS) Events,” 1983.
[3] KHNP-SQA-안안전-25005, “SPACE 3.3.2 User Manual, SQA Document,” 2025.