System Code Analysis of MSGTR Mitigation with Passive Auxiliary Feedwater System

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I. Introduction

A Multiple Steam Generator Tube Rupture (MSGTR) is a Design Extension Condition (DEC) accident that occurs when two or more U-tubes in an SG fail simultaneously. In the case of MSGTR, the discharge flow through the tube rupture is higher than that of SGTR, so the accident proceeds quickly. Appropriate operator action is required to prevent the leakage of radioactive materials to the outside through the opening of the Main Steam Safety Valve (MSSV) and to mitigate the accident successfully.

According to the Emergency Operation Guidelines (EOGs) related to the SGTR, key operator actions for MSGTR mitigation include followings: (1) Reactor Coolant Pump (RCP) manual trip and restart, (2) steam discharge to the condenser and Reactor Coolant System (RCS) temporary-cooldown using Steam Bypass Control System (SBCS) manual control with the Main Steam Isolation Bypass Valve (MSIBV) opening, (3) RCS depressurization for pressure balance of Pressurizer (PZR) and affected SG using the PZR aux-spray, and (4) RCS controlled-cooldown using Atmospheric Dump Valve (ADV) of the unaffected SG.

Authors performed RELAP5/MOD 3.3 analysis of MSGTR for a 1,000 MWe Pressurized Water Reactor (PWR) in Reference [1], and evaluated operator actions. It was found that the MSGTR could be appropriately mitigated by operator actions and furthermore, the time required for key operator actions were derived through various sensitivity analyses.

The existing EOG based on the active safety system may vary as the passive safety system is adopted. In South Korea, the Passive Auxiliary Feedwater System (PAFS) was developed as an advanced design feature to completely replace the active Auxiliary Feedwater System (AFWS) [2]. The PAFS is operated by condensation and natural circulation of condensed steam by gravity and reduces the operator actions for reactor safety. The PAFS is installed in the advanced PWR 1,000MWe under development.

Operator actions to mitigate MSGTR may differ if PAFS is installed instead of AFWS. Therefore, in this study, a system code analysis was performed on how accident mitigation proceeds during MSGTR due to the installation of PAFS instead of AFWS. The reference plant is a 2-loop 1000 MWe PWR and the analysis was performed using RELAP5/MOD3.3 [3].

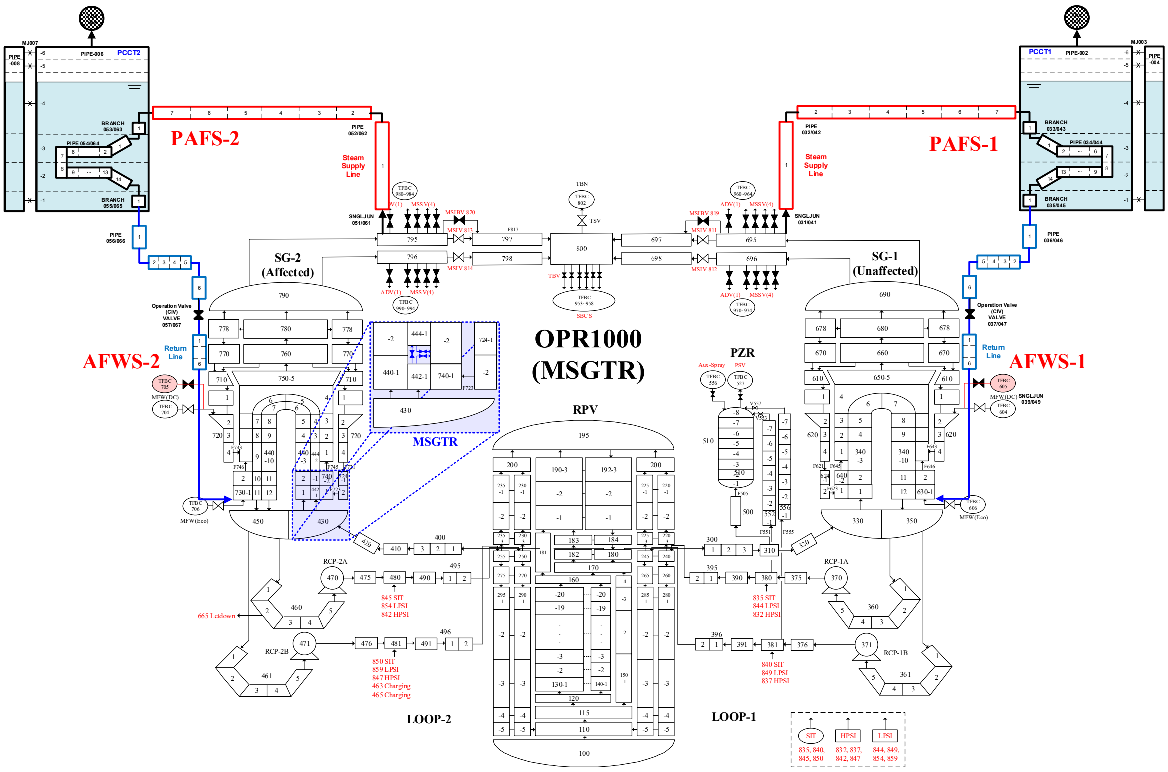


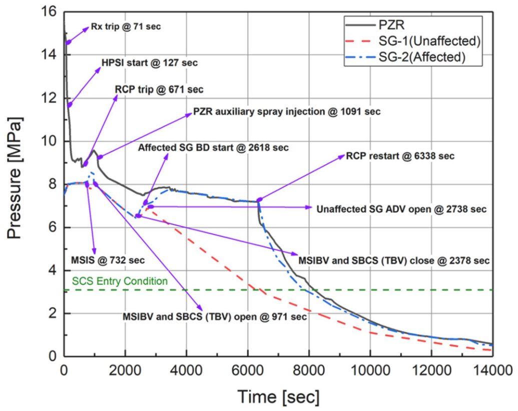
Fig. 1. RELAP5 nodalization for MSGTR analysis (AFWS or PAFS)

II. MSGTR Simulation with AFWS or PAFS

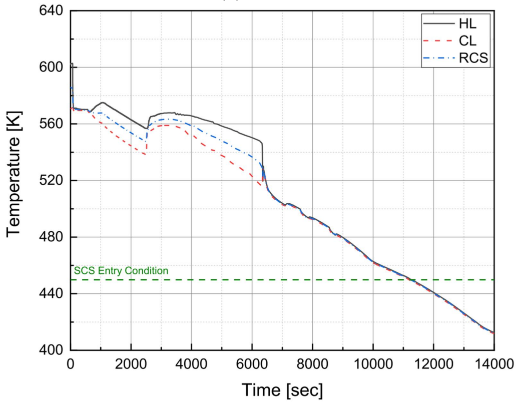
MSGTR analyses were performed based on the OPR1000 nodalization as shown in Fig. 1. It consists of RCS, secondary side, and safety systems such as AFWS or PAFS. Also, it includes PZR Pressure Control System (PPCS), PZR Level Control System (PLCS), Feedwater Control System (FWCS), SBCS, etc. Additionally, PZR aux-spray and MSADV were added.

In the case of PAFS, steam from the main steam line is injected into the Passive Cooling Heat eXchanger (PCHX). The steam is condensed by heat transfer from the PCHX to a Passive Condensate Cooling Tank (PCCT). Condensate is supplied to the SG economizer through the feedwater line. The PAFS model is connected to main steam line in Fig. 1 instead of AFWS.

Figure 2 shows the MSGTR simulation using AFWS. The RCS is cooled by various operator actions referred in the introduction and reaches the Shutdown Cooling System (SCS) entry condition within 4 hours.



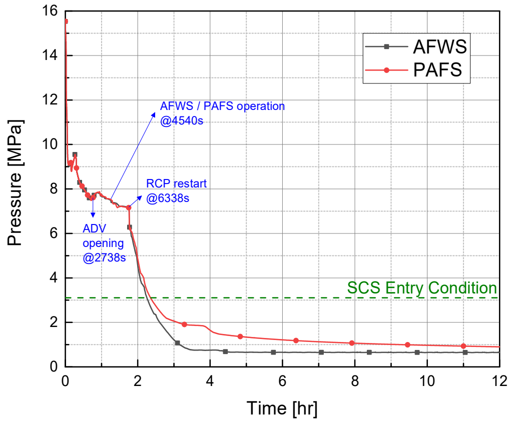
(a) Pressure



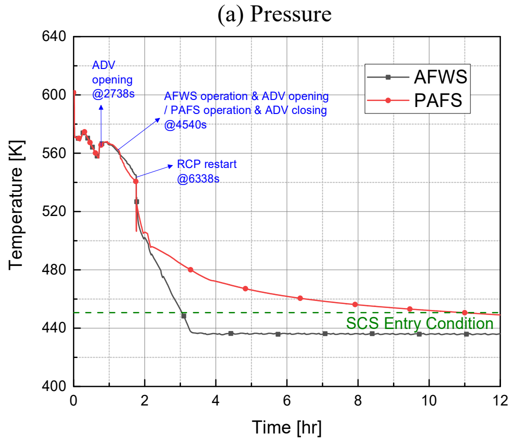
(b) Temperature

Fig. 2. MSGTR Simulation results with AFWS [1]

Figure 3 presents the MSGTR simulation results, comparing PAFS and AFWS. During PAFS operation, the ADV was closed to ensure PAFS. RCS pressure and temperature exhibit the same behavior before PAFS or AFWS are activated. In the case of PAFS, it can be confirmed that the RCS temperature decreases slowly compared to controlled-cooldown using ADV, but reaches the SCS entry condition after about 12 hours.



(a) Pressure



(b) Temperature

Fig. 3. MSGTR Simulation results with PAFS

III. Conclusions

In this study, we analyzed how operator actions can be changed during MSGTR when PAFS is installed instead of active AFWS for 1,000 MWe PWR using RELAP5/MOD3.3. The overall operator actions were similar, but it was confirmed that controlled-cooldown using ADV should be stopped during PAFS operation. The reduction in operator actions is the advantage of PAFS. The results of this study can be used to develop the accident mitigation strategies.

ACKNOWLEDGEMENT

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