Sensitivity Test of 1-D Analysis for MSLB in 3rd ATLAS Domestic Standard Problem (DSP-03)

J. Kim[a*], J.J. Kim[b], J.S. Lee[c], H.H. Son[d], T.W. Ha[e], J.I. Kim[f], J.S. Huh[a], Y.S. Park[a], B.U. Bae[a], K.H. Kang[a], K.Y. Choi[a]
[a] *Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong, Daejeon 305-353, Korea*
[b] *KEPCO E&C*
[c] *KINS*
[d] *Department of Nuclear Engineering, Hanyang University*
[e] *School of Mechanical Engineering, Pusan National University*
[f] *DOOSAN Heavy Industry*
**Corresponding author: jongrok@kaeri.re.kr*

1. Introduction

KAERI (Korea Atomic Energy Research Institute) has been operating an integral effect test facility, the ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) for accident simulations of advanced pressurized water reactors (PWRs). As an integral effect test database for major design basis accidents has been accumulated, a Domestic Standard Problem (DSP) exercise using the ATLAS was proposed in order to transfer the database to domestic nuclear industries and to contribute to improving safety analysis methodology for PWRs. This exercise aims at effective utilization of integral effect database obtained from the ATLAS, establishment of cooperation framework among the domestic nuclear industry, better understanding of thermal hydraulic phenomena, and investigation of the possible limitation of the existing best-estimate safety analysis codes. As the DSP exercise, 100% Guillotine Break of Steam line without LOOP at zero power condition (~8%) [1] was determined.

In this paper, the activity for sensitivity test of 1-D analysis for SLB transient experiment is described. Six domestic organizations (KEPCO E&C, KINS, Hanyang University, Pusan National University, DOOSAN Heavy Industry, and KAERI) joined and done the 1-D analysis using MARS-KS in an open calculation environment. This group modified the input decks (node modification, combination of models, and etc.) to predict thermal hydraulic phenomena in the ATLAS system. This group also analyzed the sensitivity by modifications to suggest some guide lines for users who makes input deck.

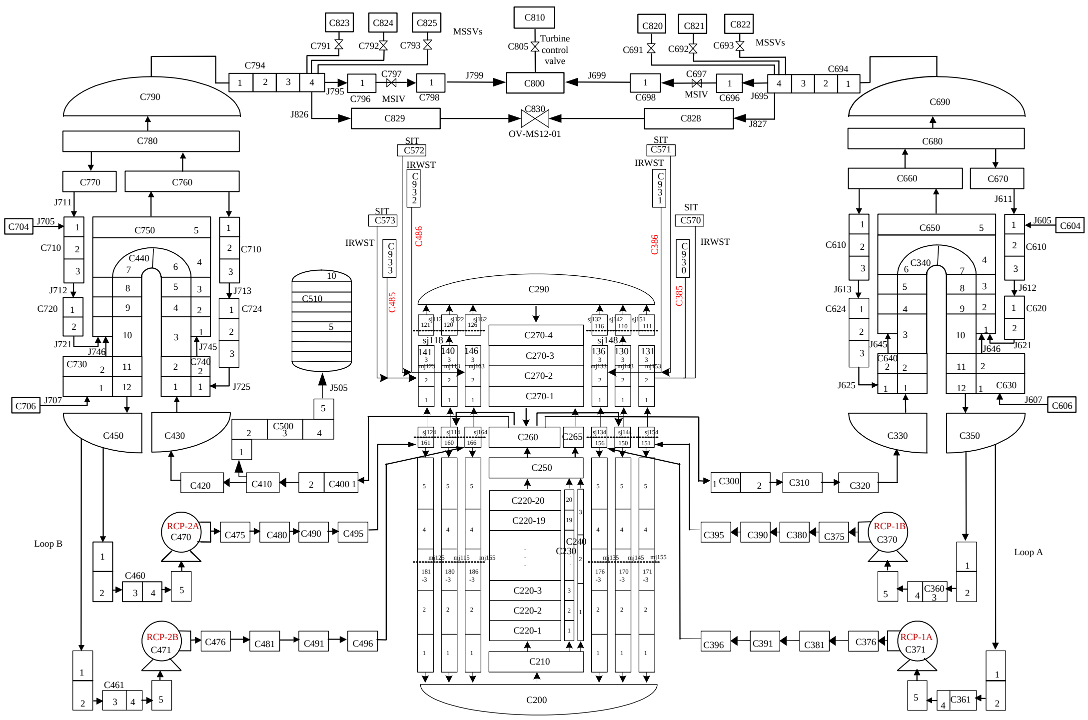


Fig. 1. ATLAS Standard Nodalization

2. Calculation result and findings

2.1 Critical Flow Model

2.1.1 Critical Flow Model

Overall analysis results of Henry Fauske, Modified Henry Fauske and Moody Critical Flow Model are similar but when pressure is increase in SG and PZR, the pressure of Moody model is larger than other two models. Henry Fauske and Modified Henry Fauske are better than Moody model in analysis.

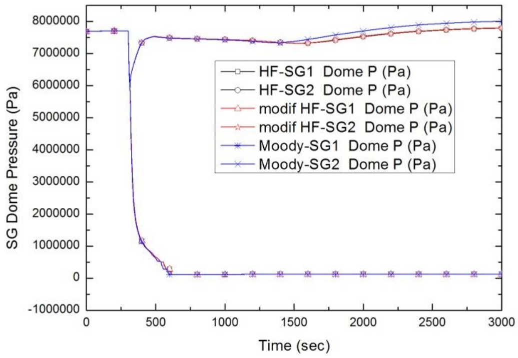
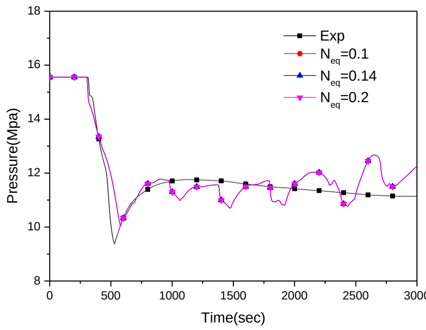


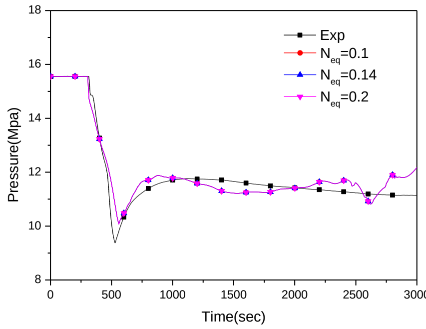
Fig. 2. SG Dome Pressure for Sensitivity Study for Critical Flow Model

2.1.2 Discharge Coefficient and Thermal Non-equilibrium factor

In the default critical flow model of MARS-KS, Henry-Fauske critical flow model was used and this model is considerably affected by the discharge coefficient (C_d) and thermal non-equilibrium factor (N_{eq}). Therefore, the sensitivity study was performed to find out the optimal C_d and N_{eq} values. Considering the results of primary pressure and core outlet temperature, the discharge coefficient and thermal non-equilibrium factor were set to 1.0 and 0.14, respectively.



(a) C_d=0.90



(b) C_d=1.0

Fig. 3. Primary Pressure for Sensitivity Study for C_d and N_{eq}.

2.2 Nodalization

2.2.1 Steam Line

In steam line nodalization sensitivity study, volume quantity of 694 Component (SG 1) was revised from 4 to 8 and 12. Sensitivity study analyses only SG dome, PZR pressure and SG water level because this factor affect reactor trip, RCP trip, MSIS, SIP, Aux-Feedwater and decay power control. As many as volume quantity increase, pressure are lowered. This difference is caused by SG internal flow difference, so SG internal node of MARS-KS needs subdivision to correct this problem.

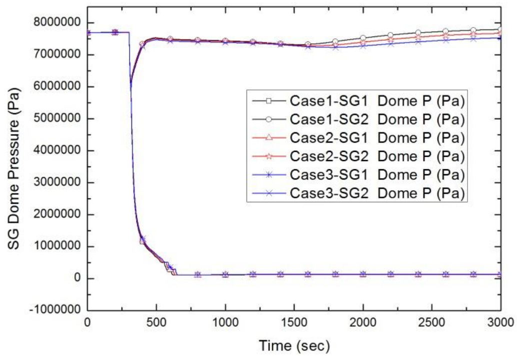
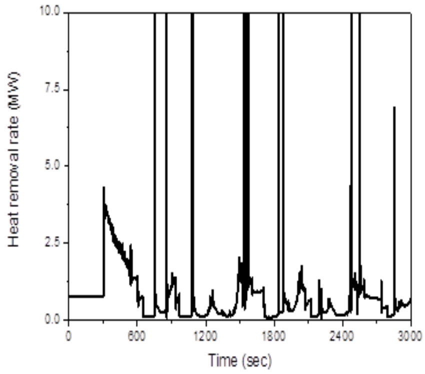


Fig. 4. SG Dome Pressure for Sensitivity Study for Steam Line Nodalization

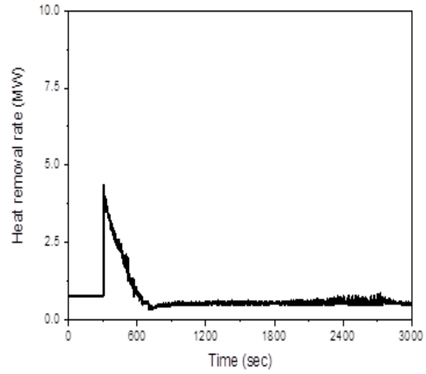
2.2.2 Secondary-side Tube Bundle in the SG Steam Line

After the MSLB, the coolant of SG-1 is finally depleted and, however, auxiliary feedwater (AFW) is continuously fed into the secondary side of the steam generators. Thereafter, the heat transfer at the lower part of the steam generator tube bundle is unrealistically oscillated. To modify this unrealistic oscillation, two ways were applied.

From first way, it was found that the use of fine meshes for the SG bottom region improves the result to a great extent. The components 630, 640, 730 and 740 are divided into five equal-sized volumes instead of one volume in the base input. In addition, options 65 and 75 were applied for a smooth transition of boiling flow regimes. These modifications resulted in a more realistic heat transfer in the steam generator



(a) Coarse meshes



(b) Fine meshes and options

Fig. 5. SG-1 Heat Transfer Rate

From second way, it was concluded that inconsistence of hydraulic volume considerably lumped and miss-selection of option or model can promote instability of void fraction in lower side adjacent to economizer of the SG. It is considerable because heat removal in the affected SG occurs mainly at the lower side in terms of long-term cooling. Moreover, as the AFW is supplied from downcomer not the economizer, the phenomenon that the AFW is trapped in the economizer before evaporation is locally significant. In this region, therefore, sensitivity analysis was conducted with 4 volume 630 component, selection of option 18 (void model). In addition, CCFL model was partially applied at the region that backflow of steam occurs consistently after AFW injection.

Fig. 6. shows separate effects for each sensible parameter. In all cases, the initial pressure peak of pressurizer occurred early than experiment. In addition, LPP signal was not actuated in case of base-case and selection of option 18. It means that heat transfer on the boundary of U-tubes is more sensitive for partitioning hydraulic volumes and Counter Current Flow Limit (CCFL) model between water and steam. However, when the option 18 was correlated with the case of volume partition, it mitigated the thermal oscillation at the U-tubes which is the heat transfer boundary.

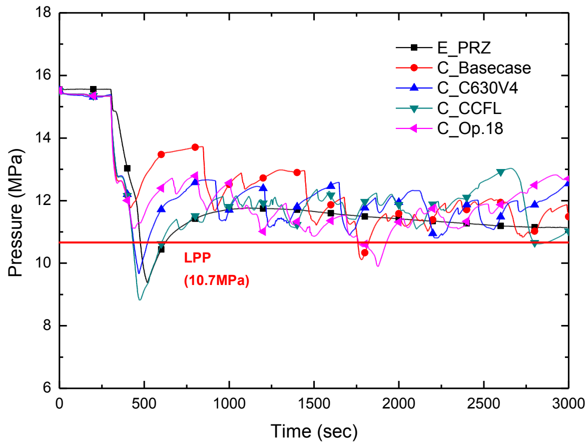


Fig. 6. Pressurizer pressure

2.3 Separator Performance

It was assumed that separators at experiment were operated under the worst condition. To model the separator, VOVER parameter was changed to 1.0. Although this correction is not consistent with the experiment, the overall effects of separator performance on the system behaviors with significant change. The depletion time is similar to the experiment because the break flow including more droplets discharges compared to base calculation until the depletion. Therefore, the core inlet and outlet temperatures show a good agreement with measured data. The results indicate the separator performance is very important for the system behaviors.

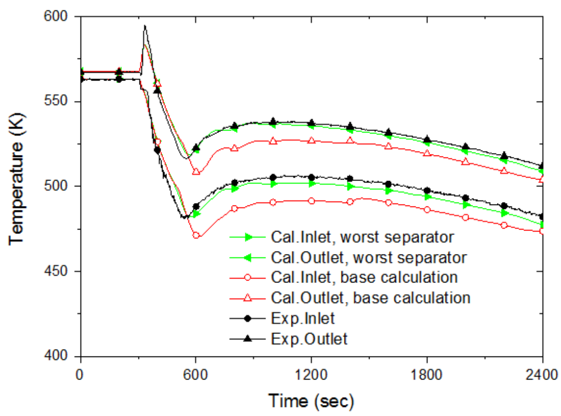


Fig. 7. Comparison of core inlet and outlet temperatures; separator sensitivity calculation

3. Conclusions

Some sensitivity tests of 1-D analysis for SLB transient experiment were done as activity of DSP-03. Several modifications using modified nodalization, combination of models and options were applied and analyzed. From each sensitivity test, some guide lines for users who makes input deck suggested.

REFERENCES

[1] K. H. Kang et al., Test Report on the Guillotine Break of the Main Steam Line Accident Simulation with the ATLAS, KAERI-TR-4790, 2012.