Sensitivity study on critical flow models of SPACE for inadvertent opening of containment spray valve in Shin Kori unit 1

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1. Introduction

SPACE (Safety & Performance Analysis Code for Nuclear Power Plants) has been developed by KHNP with the cooperation with KEPCO E&C and KAERI. SPACE code is expected to be applied to the safety analysis for LOCA (Loss of Coolant Accident) and Non-LOCA scenarios. SPACE code solves two-fluid, three-field governing equations and programmed with C++ computer language using object-oriented concepts [1]. To evaluate the analysis capability for the transient phenomena in the actual nuclear power plant, an inadvertent opening of spray valve in startup test phase of Shin Kori unit 1 was simulated with SPACE [2]. To assess the critical flow models of SPACE, the calculation with several critical flow models were carried out.

2. Analysis model

2.1 SPACE input model

The transient was initiated with the inadvertent opening of isolation valve in the shutdown cooling heat exchanger and the inadvertent opening of the isolation valve of the containment spray in hot shutdown condition. 423 tons of coolant was sprayed in the containment for 37 minutes. Sequential lo-lo flow alarm and pressurizer low level alarm was followed. The RCP trip, the shut off of letdown and the maximum charging flow were taken by operator.

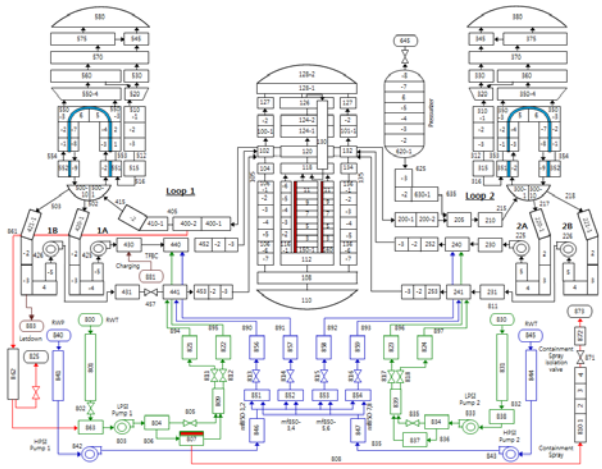

Fig. 1 Nodalization diagram of Shin Kori unit 1

SPACE model for Shin Kori unit 1 is prepared on the basis of the MARS input model [3]. The 2.16 _20150805a version of SPACE code is used in the analysis [1]. The nodalization diagram of Shin Kori unit 1 is depicted in Fig. 1. The plant is modeled with 232 fluid cells, 293 connections between cells and 231 heat structures. The decay heat of 3.59MW was applied conservatively in the calculations. The default critical flow model is Ransom-Trapp(RT) model and user can select Henry-Fauske/Moody (HFM) model, homogeneous equilibrium model (HEM) and Henry-Fauske/HEM (HFH) model critical flow models also. A sensitivity studies on four different critical flow models were performed.

3. Analysis results

3.1 Transient analysis results

The calculation for steady-state condition is performed for 1037 seconds. The transient calculation is performed from 1037 to 3700 seconds when the low pressure safety injection is stopped. The calculated results with SPACE are compared with the measured data in plant. The abrupt decrease of the volume flow rate in shutdown cooling system at 2100 seconds is shown in Fig. 2 and is mainly due to the vapor entrainment resulted from the core uncovery. The recovery of the volume flow rate in shutdown cooling system occurs at 2200 seconds by safety injection. Because the spray flow is overestimated with HFH model as shown in Fig. 3, the flow in shutdown cooling system is underestimated in Fig. 2.

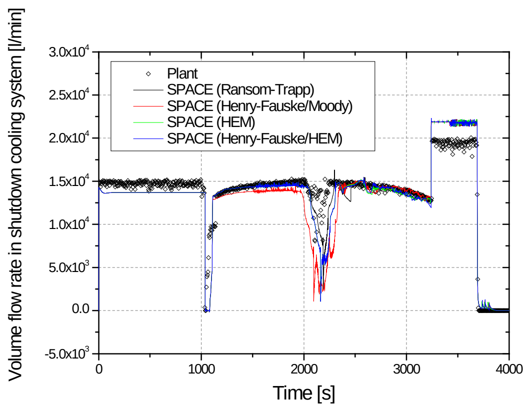

Fig. 2 Volume flow rate of shutdown cooling system

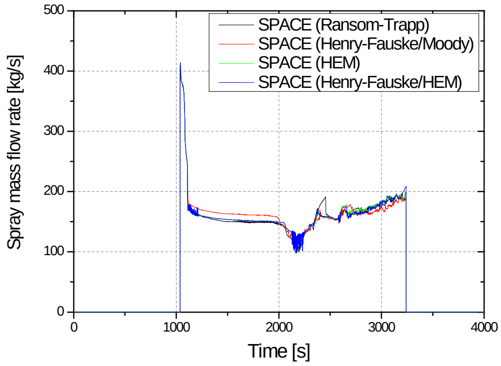

Fig. 3 Transient pressure behavior of pressurizer

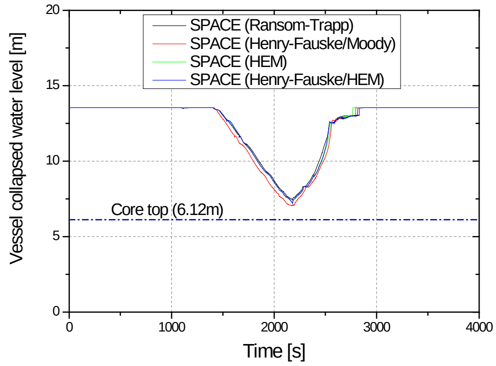

Fig. 6 Collapsed water level in reactor vessel

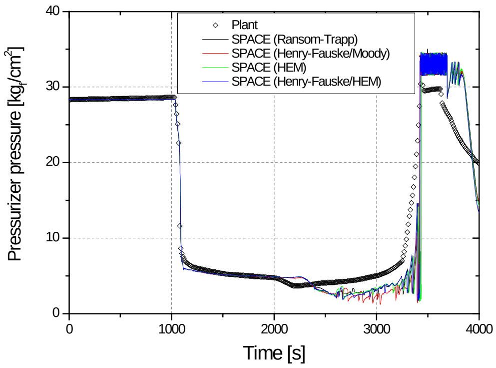

Fig. 4 Transient pressure behavior of pressurizer

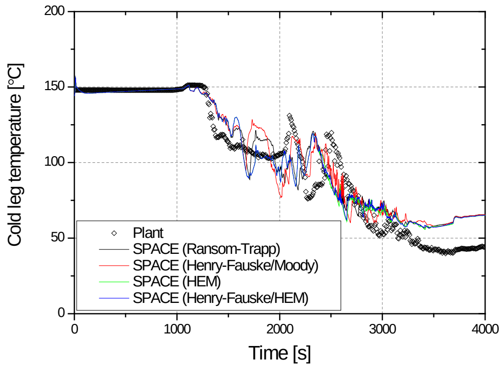

Fig. 7 Transient temperature behavior of cold leg

The pressurizer pressure and level behaviors are well predicted in calculations as presented in Figs. 4 and 5. The difference between calculations and measurement in 2200~3200 seconds seems to be resulted from the two-phase mixing phenomena of safety injection coolant. In Fig. 6, the core collapsed water level is depicted and the deviation of minimum values between critical flow models looks not significant. The calculated cold leg temperature in general shows good agreement with the measured one as presented in Fig. 7.

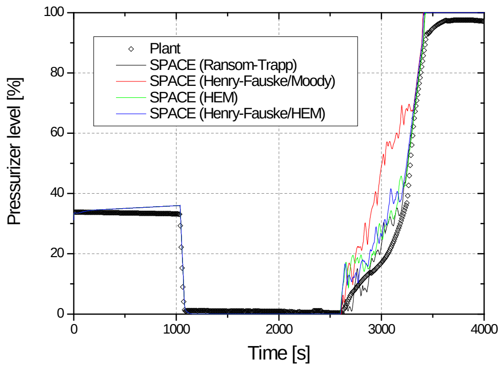

Fig. 5 Collapsed water level of pressurizer

4. Conclusions

The simulations of an inadvertent opening of spray valve of Shin Kori unit 1 with several critical flow models were carried out. The calculated transient behaviors of major reactor parameters with four critical flow models generally show good agreement with the measured.

Acknowledgement

This work was supported by the Nuclear Research & Development of the Korea Institute of Energy Technology and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry and Energy (MOTIE).

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