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Evaluation of Natural Circulation Cooldown for the SMART

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1. Introduction

The SMART (System-integrated Modular Advanced ReacTor) [1] is the reactor which contains core, eight steam generators, pressurizer and four RCPs without pipings (Fig.1). Basically the SMART adopts various proven design concepts of pressurized water reactors and passive safety concept additionally to enhance safety. The PRHRS(Passive Residual Heat Removal System) is the most representative system of the SMART.

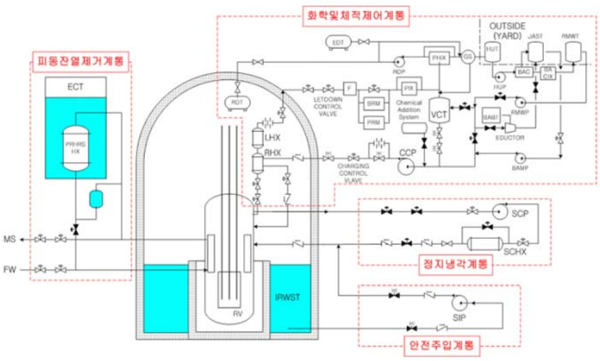

Fig. 1. Schematic diagram of the SMART

This study describes methodology of NCC(Natural Circulation Cooldown) from reactor trip by loss of off-site power to SCS(Shutdown Cooling System) entry conditions and the results performed by MARS-KS code[1]. The NCC analysis was performed in accordance with the requirements of USNRC BTP RSB-5-4[2] and KINS SRP NCC[3]. The requirements specify that safety-grade equipment should be used, and loss of offsite power and single failure should be considered simultaneously for the analysis of NCC.

2. Analysis and Results

2.1 Analytical Model

The MARS-KS code was used for the analysis of the SMART. The condensation heat transfer coefficients in the tube side where condensation heat transfer may occur are Nusselt model(1916) and Shah model(1979) for laminar and turbulent flow, respectively. In order to see the effect of model for the non-condensible gas on the heat transfer the modified MARS-KS code containing the POSTECH condensation heat transfer correlations[4] was also used and the results were compared with those of original MARS-KS code.

Fig. 2 shows a schematic diagram and nodalization of the PRHRS for the SMART. Following loss of flow event due to loss of power to RCPs, the primary and secondary sides of the plant undergo natural circulation cooldown process. The ECTs (Emergency Cooling Tank) in the PRHRS act as the final heat sink during the transient.

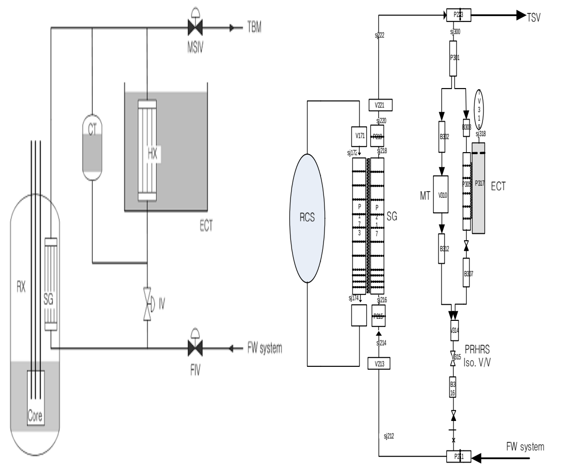

Fig. 2 Schematic diagram and nodalization of PRHRS

2.2 Analysis and Results

The purpose of NCC analysis for the SMART is to evaluate the process of natural circulation cooldown by which the temperature and pressure of RCS reach SCS entry conditions(200 ^{o}C and 2.8 MPa) in accordance with NCC requirements(that is, use of safety class equipment, assumption of LOOP and single failure, maintaining subcooling condition and allowable cooldown rate). In order to satisfy the requirements of subcooling degree and cooldown rate, RCS vent system and safety injection system are actuated intermittently.

The Fig. 3 and 4 show behavior of RCS pressure and temperature during NCC. At 1.2 hr after reactor trip, pressurizer vent valve is open to decrease pressure and subcooling degree. As subcooling degree increases, the vent is closed at 2.56 hr. The reactor inventory is supplemented by injecting safety injection water at 2.43

hr as the pressurizer level decreases below the specified level. The series of depressurization and inventory control using safety injection enables the core exit temperature and RCS pressure to reach SCS entry conditions at 4.96 hr and 6.54 hr, respectively.

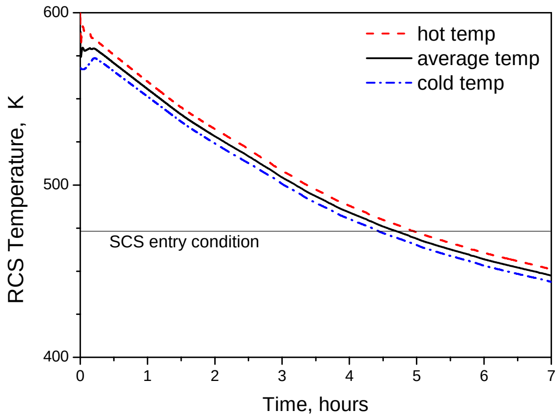

Fig. 3. Behavior of RCS temperature

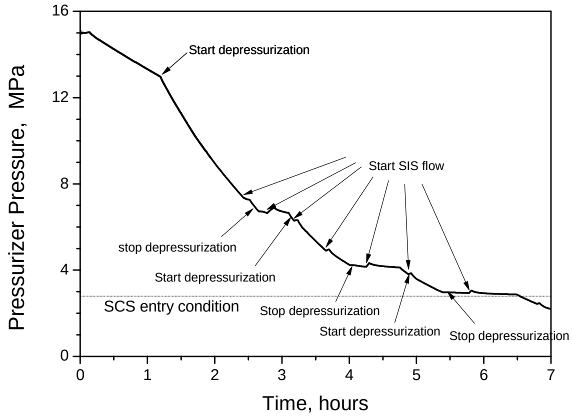

Fig. 4. Behavior of RCS pressure

As mentioned above, the results of MARS-code are compared with those of modified MARS-KS code. The Fig. 5 shows comparison of behavior of RCS pressure during NCC. Fig. 6 shows comparison of behavior of RCS pressure during NCC between MARS-KS code and TASS/SMR-S code.

3. Conclusions

The analysis of NCC for the SMART was performed using MARS-KS code. It is proved from the results that RCS can be brought to SCS entry condition from normal full power operation under requirements of BTP RSB 5-4 and KINS SRP App. 5.4.7-1. The requirements specify that safety-grade equipment, loss of offsite power and single failure should be considered in the analysis.

Despite of singe failure of PRHRS, NCC process was not subjected to any restriction, and NCC process was achieved by use of safety injection system, PRHRS with single failure of one PRHRS, and pressurizer vent system. There are no significant voids except small ones in the upper part of reactor, and subcooling degree was maintained during the whole process of NCC. It is evaluated that NCC process was achieved by original MARS-KS code and modified MARS-KS code within 6.54 hr and 6.39 hr, respectively.

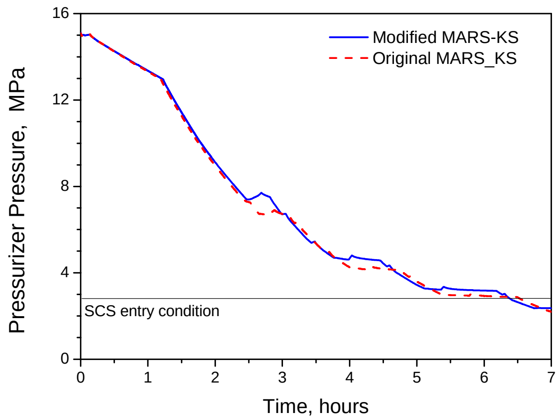

Fig. 5. Behavior of RCS pressure between MARS-KS codes

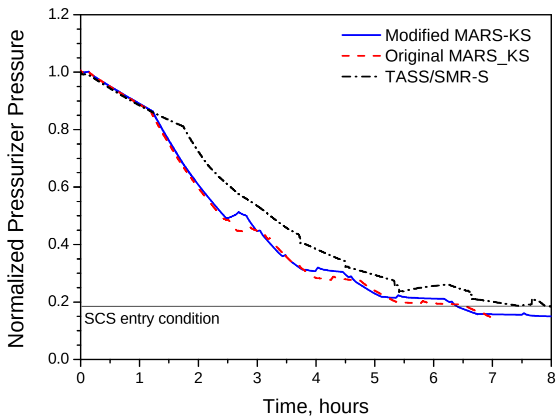

Fig. 6. Behavior of RCS pressure between MARS-KS code and TASS/SMR-S code

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