Pressurizer Heater and Safety Valve Test for SPACE code

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1. Introduction

The Korea nuclear industry has been developing a thermal-hydraulic analysis code for safety analysis of PWR(pressurized water reactor). The new code is named SPACE(Safety and Performance Analysis Code for Nuclear Power Plant). In this paper, the pressurizer heater model and safety valve for SPACE code is tested. The SPACE code input for pressurizer is developed and simulations are performed. Calculations were performed with and without heater and safety valve model and results are compared to confirm effectiveness of heater and safety valve.

2. Description of SPACE Code

2.1 General Description of SPACE Code

The SPACE code is an advanced system thermal hydraulic analysis code with two-fluid, three-field analysis capability. The SPACE code has many component models required for modeling a PWR, such as reactor coolant pump, safety injection tank, etc. The programming language used in the new code is C++, for new generation of engineers who are more comfortable with C/C++ than old FORTRAN language.

2.2 Pressurizer Heater Model

The SPACE pressurizer heater model includes proportional heater, backup heater and control system input heater. The electric power input for proportional heater is function of pressurizer pressure. The user specifies pressure versus electric power in form of data table. The backup heater is ON/OFF controlled by trip input. The pressurizer heaters are turned off if liquid level falls below cutoff level. The heat capacity of the heater is taken into consideration when calculating heat transfer to water. When using control system heater input, heat capacity of the heater is ignored since control system logic can include time delay logic. The sum of proportional, backup and control system heater power is distributed among pressurizer cells. The heat is only transferred to liquid portion of the pressurizer fluid.

2.3 Safety Valve Model

The pressurizer safety valve is modeled using TFBC + valve. The TFBC hydro-component includes pressure sink and valve. Two types of valves can be used to model a safety valve: pressure or time. Pressure valve operates depending on pressure of the upstream cell. It can be used to model hysteresis effect of different open and closing pressure. The time valve also allows different setpoints for opening and closing the valve. However, it does not support partial valve opening as function of upstream cell pressure. For this paper, time valve is used for pressurizer safety valve.

3. Calculation Methods and Results

3.1 SPACE Nodalization

The RCS of PWR expand or contract as a result of power mismatch between core power generation and steam generator power removal. This expansion or contraction leads to increase or decrease of RCS pressure. In this paper, pressure increase and decrease is simulated by heating and cooling close volume of water. The C100 in Fig.1 contains large amount of water. Heating or cooling is done through heat structure attached to C100. The pressurizer is connected to C100 via surge line, C505. C600 is the safety valve.

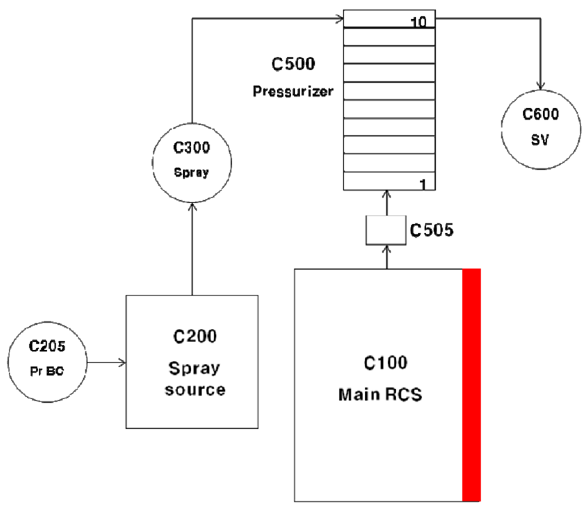

Fig. 1. SPACE nodalization.

3.2 Results

First, RCS depressurization through cooling is calculated. Without pressurizer heaters, the pressurizer pressure falls to about 14MPa at 200 sec(Fig.2). With the pressurizer heater, the pressure remains above 15MPa, showing that pressurizer heater is keeping pressure high. The pressure fluctuates as backup heater is turned ON and OFF. Fig. 3 shows electric power input for pressurizer heaters. The proportional heater is turned ON throughout the transient, but the capacity is not enough to retain pressure. The backup heater, with much larger capacity, cycles ON and OFF, increasing pressure when ON, and pressure decreasing when OFF.

RCS pressurization is calculated by heating the RCS. Without pressure safety valves, the pressurizer pressure increases to about 18MPa at 200sec(Fig.4). With the pressurizer safety valve, the maximum pressure is limited to about 16.5MPa. The pressurizer pressure fluctuates as the safety valve opens and closes. The pressurizer level for 4 cases are shown in Fig. 5. The pressurizer collapsed water level decreases for depressurization transient, and increases for pressurization transient. From these results, we can conclude that pressurizer heater model and safety valve model work as intended, reducing pressure change during RCS transients.

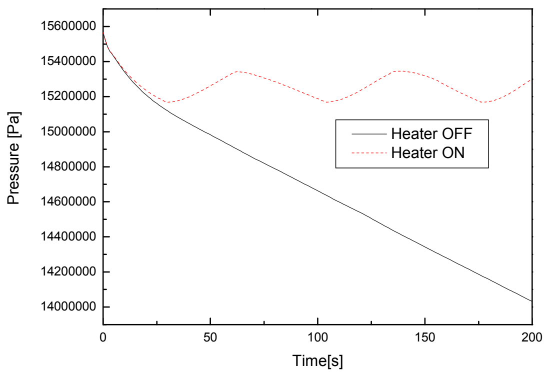

Fig. 2. Pressurizer pressure vs. time during depressurization

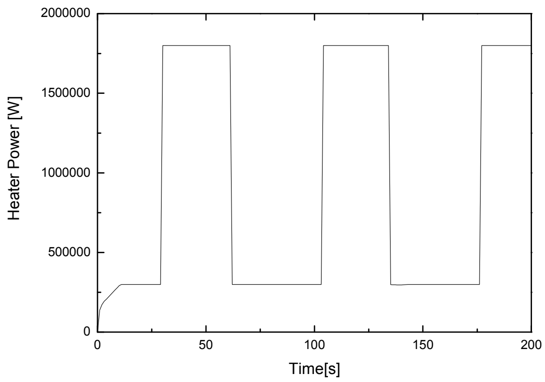

Fig. 3. Heater electric power vs. time during depressurization

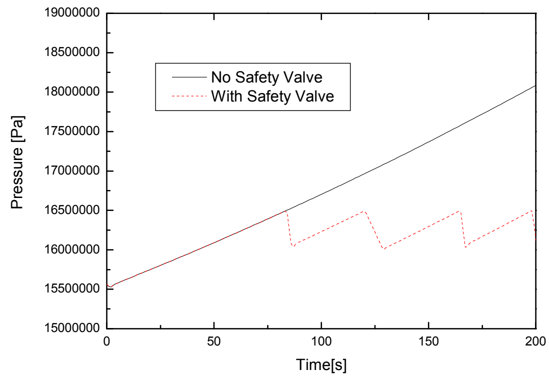

Fig. 4. Pressurizer pressure vs. time during depressurization

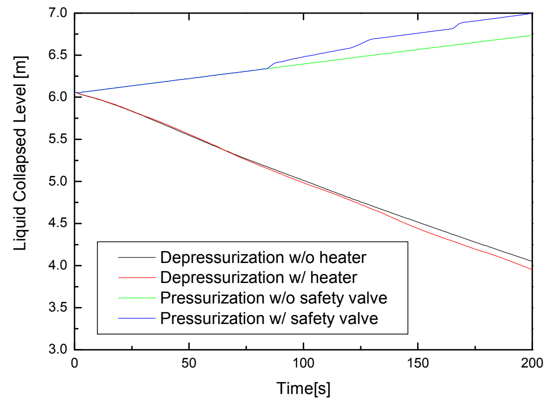

Fig. 5. Pressurizer level vs. time

4. Conclusions

The pressurizer heater model and safety valve model for SPACE code is tested. The SPACE code input for pressurizer is developed and simulations are performed. Calculations were performed with and without heater and safety valve model and results are compared to confirm effectiveness of heater and safety valve. The results show that pressurizer heater model and safety valve model work as intended, reducing pressure change during RCS transients.

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