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Assessment Calculation of PKL H1.1 by using SPACE Code

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1. Introduction

After development and achieving the license from the regulatory authority, the SPACE[1] code has been in the process of the extension of the capability for the DEC. Some multiple failure accidents have been listed as the mandatory consideration items of the design extension condition (DEC) scenario. The small break LOCA (Loss of Coolant Accident) along with the failure of the high pressure safety injection is one of the mandatory DEC scenarios.

PKL H1.1[2] test is the accident scenario consists of 1% cold leg small break with high pressure safety injection system failure. It has been designed for the counter-part test against LSTF[3]. It includes the state of the high pressure and high temperature for quite long time period. Also it includes the dry-out of the upper part of the fuel during the scenario. PKL H1.1 scenario may be a good assessment problem for the SPACE code.

2. Verification Calculation

2.1 PKL H1.1 Scenario

PKL H1.1 test had been performed as a counter-part test of LSTF. LSTF facility has been designed to single scale pressure so that LSTF pressure ranges up to 150 bar. But the operation pressure of the PKL facility is limited within 50 bar. The conditioning phase is performed before start of test (SoT) for matching and equalizing the key parameters between PKL and LSTF. The key actions for the equalizing are to isolate the steam generators(SG's) and to open break valve for extracting the primary mass inventory. The main focus of the scenario is to see the effectiveness of the accident management (AM) action against the CET(Core Exit Temperature) or PCT(Peak Cladding Temperature) rising. The AM action of the PKL is to open the steam generator dump valve. Opening secondary side valve makes the primary pressure decrease. PKL set the steam generator opening so that the primary hot leg fluid temperature decreases at finite rate as well as the primary pressure decrease. The PKL H1.1 scenario is represented in Fig. 1.

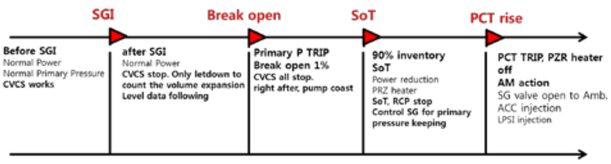

Fig. 1 PKL H1.1 scenario

At the instance of that the primary mass inventory decreases to 90% of steady normal operation, the start of test (SoT) begins. The core power begins to coast-down and pressurizer heater power is changed to high level. Right after SoT, the reactor coolant pump has been quit. After SoT, the primary pressure has been kept within design pressure due to the facility limitation. For the primary pressure keeping, steam generator dump valves are slightly operated and feedwater of loop 1 steam generator has been supplied.

The PCT rises at the end of primary pressure keeping period due to the continuous depletion of the primary mass through the break. After the PCT reaches high trip point, the AM action applied to the ambient dump valve of steam generators. All accumulators are set to work at the injection pressure. The low pressure pumps are set to work.

2.2 SPACE Prediction of PKL H1.1

The PKL facility consists of 4 loops. The pressurizer is connected on loop 2. The core power is set to normal operation level. Additional pressurizer heater is on. Every loop has normal flow rate. The charging and let-down valves are in operation to set the pressurizer level on normal level. Fig. 2 shows the pressure calculation results for the normal operation and break opening period. After the steam generator isolation, both primary and secondary pressure increase slightly. The upper plenum and pressurizer pressure reaches up to high pressure, the break at the cold leg of loop 1 has been open. Right after the break open, primary pressure slightly increases again. It is due to the pump stop and lack of active coolant flows. The reduced coolant flow makes the heat transfer from primary to secondary very small.

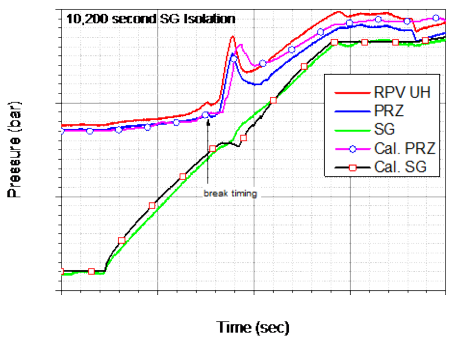

Fig. 2 The pressure trend of the PKL H1.1 before PCT rise

The predicted primary pressure increases and decreases again very rapidly. The pressure decreasing is the result of re-establishment of the natural convection of the primary system. Because that the main core power is still on at normal operation level, the pressure still increases even with the natural convection.

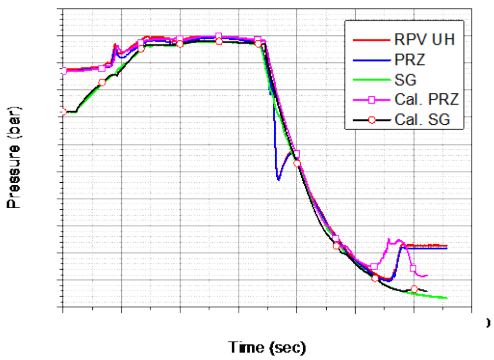

Fig. 3 Pressure trend after PCT rise and AM

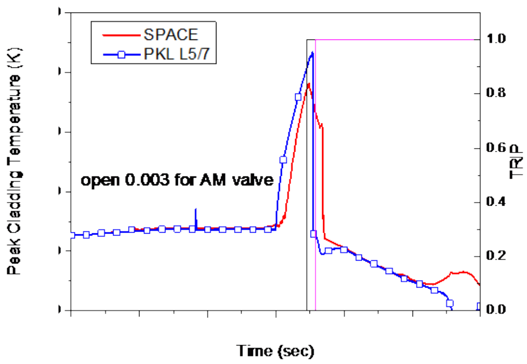

Fig. 4 SPACE prediction about PCT rise and AM action effects

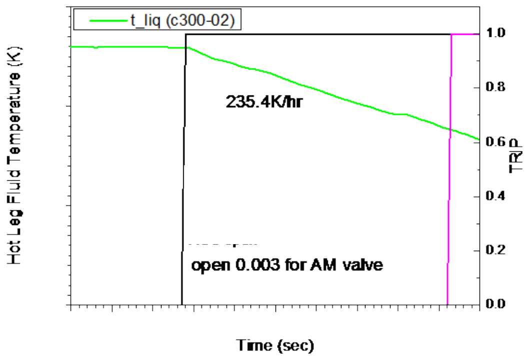

Fig. 5 Hot leg fluid temperature prediction

The pressure trend after PCT rise and accident management is shown in Fig. 3. The PCT rise trend is represented in Fig. 4. The SPACE calculation shows similar PCT rising time. The PKL L5/7 data have been picked up as the PCT. The PKL experiment shows rapid increasing and higher PCT value. The steam generator ambient dump valve is open slightly so that the steam generator pressure is relieved. The AM valve action is designed to decrease the hot leg fluid temperature at the finite rate.

The pressure and PCT trend of SPACE in Fig. 3 and 4 is obtained by keeping the AM valve opening as 0.003 of the normalized valve area for the whole remained period. The hot leg fluid temperature decreasing is shown in Fig. 5. In the Fig. 5, the first trip is on at the moment that PCT becomes a certain trip point. And the second trip is on at the moment that the primary pressure becomes accumulator actuation value due to the indirect pressure decreasing. During the time interval between the first and second trip, the hot leg fluid temperature decreases at the 235.4 K/hr under the condition of constant steam generator AM valve action.

2.3 Controlled AM Valve Action

For the view of the AM valve action, Fig. 6 and 7 shows the hot leg fluid temperature and pressure trend prediction under the condition of controlled AM valve action at a finite rate of hot leg fluid temperature decrease.

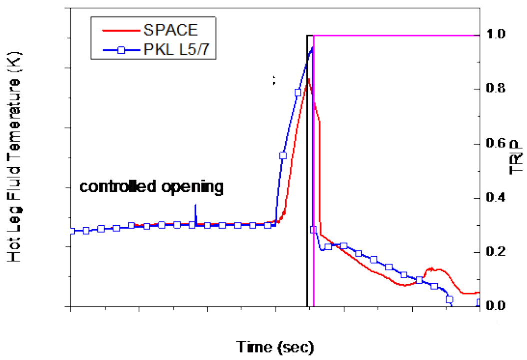

Fig. 6 PCT prediction under the controlled AM valve action

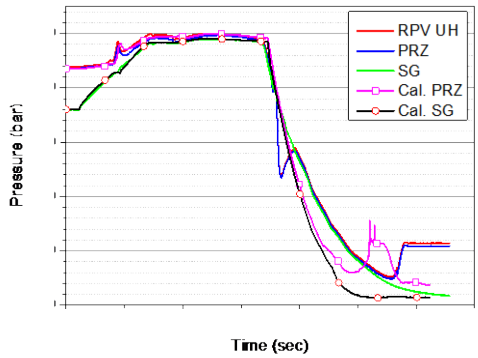

Fig. 7 Pressure prediction under the controlled AM valve action

As shown in Fig. 6, the second trip timing is exactly match the PCT decrease timing of experiment. The PCT, the saturation temperature behavior after the quenching, shows the rapid decreasing trend rather than experiment and the SPACE prediction of the constant AM valve action case (see Fig. 4). It looks that the AM valve action has been ended right after the ACC actuation. The SPACE prediction of pressure shows that the excessive depressurization occurs for the end period of scenario, due to the valve actuation of steam generator dump valve at the hot leg fluid temperature.

3. Conclusions

The SPACE code has been used to predict the PKL H1.1 scenario, which is the small break loss of coolant accident with the high pressure safety injection failure. It is the one of the mandatory DEC scenarios. The primary and secondary pressure of conditioning phase of PKL H1.1 has been predicted and SPACE shows the pressure peak phenomena due to the condition of the coolant flow and natural convection. The PCT behavior after the SoT phase has been well predicted by SPACE code. The AM action timing and the resultant indirect depressurize has been reasonably predicted by the SPACE code. The AM valve actuation logic has been surveyed on the view of the hot leg fluid temperature decreasing rate.

ACKNOWLEDGEMENT

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