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Development of RETRAN-3D Model to Analyze the Water Discharge through Pressurizer Purge Drain Pipe

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1. Introduction

Some of WEC type nuclear power plants have a loop seal between the pressurizer and pressurizer safety valves. The piping upstream of the Crosby safety valves contains a small water volume in a U-tube piping configuration which acts as a loop seal. The water loop seals provide a protective barrier against corrosive gases which are created in the primary system. But when the safety valves with loop seals open, the thermal/hydraulic piping loads have been shown by safety valve testing to be very large. In order to solve this problem, it is being planned to install the purge drain pipe. This is based on routing the condensate water on the inside surface of the loop seal piping, out of the loop seals and back into the pressurizer. A continuous gravity drain would consist if a drain line between the bottom of each loop seal and the pressurizer. If the reverse flow from the drain line to loop seal is produced at accident condition, it can be threaten the integrity of pressurizer safety valve. In this paper, RETRAN-3D[1] model was developed to investigate the discharge water behavior through pressurizer purge drain pipe during the opening of the pressurizer safety valve at accident condition.

2. Methods and Results

2.1 Purge drain pipe layout

The purge loop seal drain is based on routing the condensate from the loop seals into the pressurizer. A 3/4-inch pipe line is attached to the purge line at the bottom of each loop seal between the loop seal drain line outlet and the loop seal drain valve. Drain pipe provides relatively simple way to remove the water from loop seal. And a significant reduction in safety valve discharge thermal/hydraulic piping loads can be expected since steam instead of subcooled water is being released through the safety valve into the downstream piping. Therefore the number of additional restraints will be reduced.

2.2 RETRAN model

To investigate the water discharge through the purge drain pipe, the RETRAN-3D model was developed as shown in Fig 1. In this figure, the numbers with arrows mean the identification number of junction and the numbers with circle mean the identification number of control volume.

RETRAN-3D model consists of three major parts including the pressurizer, loop seal pipe, and purge drain pipe. To model the pressurizer, the bubble rise model of RETRAN-3D code was used to separate the steam and liquid regions. The loop seal and purge drain pipes were modeled using the normal control volumes and junctions. The fill junction was used to model the boundary conditions, which were generated using the LOFTRAN code. Since the loss of load and turbine trip(LL/TT) show the most limiting results with respect to the peak pressure, the LL/TT have been chosen to generate the boundary condition. The LL/TT analysis was performed using LOFTRAN code based on the conservative initial conditions and assumptions, separately. For the conservatism of RETRAN-3D analysis, the junction loss coefficients were assumed as very small values. This makes the reverse flow through the purge drain pipe to maximize.

The CUPID code[2] is used to analyze the water discharge behavior through purge drain pipe using CFD method. CUPID has been developed by KAERI (Korea Atomic Energy Research and Institute) for multi-dimensional two-phase analysis of LWRs. Fig 2 shows the calculation grid of CUPID for the pressurizer and drain line.

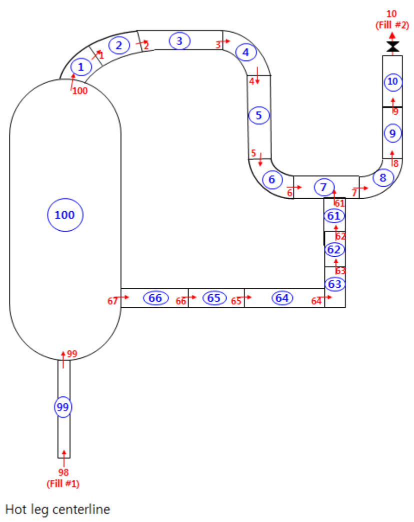

Fig 1. RETRAN model

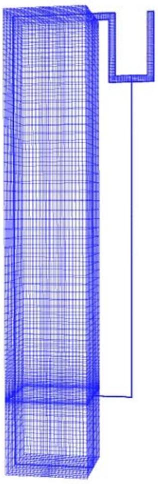

Fig 2. CUPID model

2.3 Calculation results

RETRAN-3D calculation was performed using the Fig 1 model. Fig 3 shows the calculation results of the qualities of important nodes (7, 8, 9 and 10), normalized safety valve discharge flow rate and normalized water level of node 61. The opening setpoint of pressurizer safety valves(PSV) is 2600 psia and the PSV opened at 7.9 seconds and closed at 12 seconds. After the PSV opened, the water level of node 61 was increased and node 61 was filled with water due to the pressurizer insurge. The qualities of nodes 7, 8, 9 and 10 were remained at 1.0 until the PSV closed. This means that no reverse water flow from junction 61 to loop seal line exists and no water discharge occurs through the PSV.

Fig 4 shows the calculation results of flow rates of junctions 6, 7 and 61. Flow rate of junction 61 remains as zero and flow rates of junctions 6 and 7 are equal. Fig 5 shows a void fraction of the PSV flow calculated by CUPID. The void fraction is close to 1.0 even with a conservative assumption that the PSV is opened during 10 seconds. Therefore, the entrainment from the loop seal drain line is not significant.

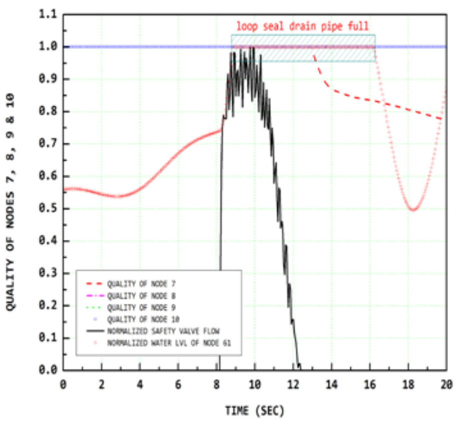

Fig 3. Qualities of nodes 7, 8, 9 & 10

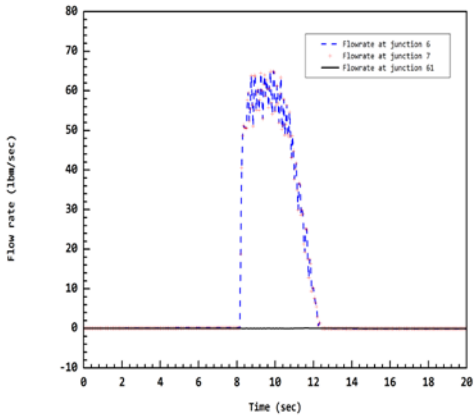

Fig 4. Flow rates of junctions 6, 7 & 61

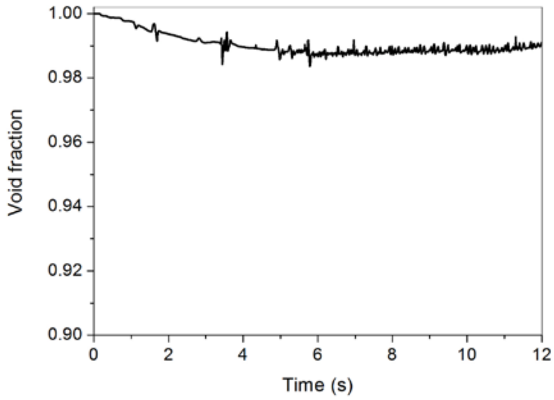

Fig 5. Void fraction of safety valve flow (CUPID)

3. Conclusions

The conservative RETRAN-3D model was developed to investigate the water discharge behavior through PSV. The calculation results showed that no reverse water flow from drain pipe to loop seal is existed and no discharge occurred through PSV during the opening of PSV. Per the results, it is feasible to attach the purge drain pipe at the bottom of loop seal. And no integrity of PSV will be violated by the water discharge through PSV.

REFERENCES

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[2] H. Y. Yoon et al., Recent improvements in the CUPID code for a multi-dimensional two-phase flow analysis of nuclear reactor components, Vol.46, No. 5, pp. 655-666, 2014.