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Effects of Multiple Pipes Break Accident in SMART-P Using RELAP5/SMR Code

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1. Introduction

SMART-P (System integrated Modular Advanced ReacTor) is an integral reactor being developed with indigenous technology and has many key design features that are highly unconventional in comparison to the commercially operating reactors. Such design features include self-pressurizing pressurizer, helically coiled once-through steam generators, PRHRS (Passive Residual Heat Removal System), power operation under natural circulation, and twisted fuel rods of roughly square cross-section.

In SMART-P SAR (Safety Analysis Report) [1], the SBLOCA (Small Break Loss Of Coolant Accident) analysis is restricted to only single pipe break. However, if there are some break accidents at an annular cap or a center cap, multiple pipes break accident is likely to happen in reality due to the dynamic effect from the broken pipe. Accordingly, in licensing review process, thermal-hydraulic behavior of multiple pipes break accident is requested in addition to that of single pipe break accidents such as SI pipe break accident and pressurizer-gas cylinder connection pipe break accident.

The objective of this study is to analyze thermal-hydraulic response for multiple pipes break to support the licensing review in KINS. And the calculation results of multiple pipes break accidents were compared with those of various small break LOCAs to investigate the effects of multiple pipes break.

2. Methods and Results

2.1 Single Pipe Break Accident

The initial steady-state conditions are well agreed with the design values for 103% power operation condition specified in the SMART-P SAR as shown in reference 2 [2].

Two cases of transient analysis were performed for single pipe break accident. One is SI (Safety Injection) pipe break (SI case) and the other is pressurizer-gas cylinder connection pipe break (PRZ case). The former was presented in the reference 2. The break size of pressurizer-gas cylinder connection pipe break is same as the one of SI pipe break whose inner diameter is 25.4mm.

PRZ case shows similar event scenario with SI case. But the specific transient behavior of thermal-hydraulic parameters and system parameters like as water level, coolant inventory, trip activation time, etc. are different in both cases. The event scenarios for two cases are shown in Table 1.

The number of available SI line is two for PRZ case, but one for SI case. So the RAS (Recirculation Activation Signal) of PRZ case is activated earlier than that of SI case. In PRZ case, the gas phase flow is discharged into containment after break initiation. After 7 seconds, the discharge flow changes from gas phase to two-phase. And after 1450 seconds, it changes from two-phase to liquid phase.

But in SI case, liquid phase is discharged into containment after break initiation. Then the discharge flow changes from liquid phase to two-phase. After 46000 seconds, only liquid phase is discharged.

In both cases, there were no core unvovery and fuel temperature increase harming the fuel integrity. And the long term cooling could be maintained.

Table 1. Event scenario for various break accidents

Event	SI Break	PRZ-Gas Cylinder Break	PRZ-Gas Cylinder + SI Line Break	3 SI lines Break	PRZ-Gas Cylinder + 3 SI Line Break
Break Initiation	0.001	0.001	0.001	0.001	0.001
Low Pressurizer Pressure Signal	10.04	3.208	1.969	2.239	0.992
Reactor Trip Signal	11.174	4.334	3.1	3.365	2.12
CEDM Insertion	11.679	4.835	3.605	3.871	2.622
Turbine Trip Loss of Off-Site Power MCP Trip Feedwater Closure PRHRS Activation	14.195	7.347	6.117	6.375	5.141
SI Signal	62.344	48.5	29.568	24.881	15.874
SI Activation	92.354	78.509	59.57	54.886	45.874
Minimum Collapsed Water Level	24170.01 [2.3743m]	1270.013 [2.42m]	632.00 [2.200m]	616.06 [2.06m]	560.01 [1.267m]
SI by RWT Stops	58366.78	29511.04	57834.49	57858.61	57644.74
SI by Sump Recirculation Activation	58366.78	29511.04	57834.49	57858.61	57644.74
End of Calculation	70000	35000	70000	70000	70000

2.1 Multiple Pipe Break Accidents

Three cases of transient analysis were performed for multiple pipe break accidents. One is SI pipe break with pressurizer-gas cylinder connection pipe break (PRZ+SI case), another is simultaneous break of three SI pipes (3SI case), and the other is three SI pipe breaks with pressurizer-gas cylinder connection pipe break (PRZ+3SI case). And only single SI line is available for all the cases.

The event scenarios for these three cases are shown in Table 1. Multiple pipes break accidents show similar event scenarios with single pipe break accident.

Fig. 1 shows the break discharge flow and SI flow for PRZ+SI case. The discharged flow through the SI pipe break is higher than that through pressurizer-gas cylinder connection pipe break until about 10000 sec. But after that time, the discharged flow through pressurizer-gas cylinder connection pipe break becomes higher than that through the SI pipe break. This is due to the differences of void fraction between SI pipe break upstream and pressurizer-gas cylinder connection pipe break upstream.

Fig. 2 shows the break discharge flow and SI flow for 3SI case. This is modeled with one break junction and the break size of this case is three times of single SI pipe break size.

Fig. 3 shows the break discharge flow and SI flow for PRZ+3SI case. In this case, most primary coolant is discharged through SI pipe break due to the break size.

Fig. 4 shows the collapsed water level in the hot side for various cases. There is no core uncovery in 4 cases except for PRZ+3SI case. And the collapsed water level of PRZ+3SI case doesn't recover above the top of MCP suction duct where shutdown cooling system is connected. Though the collapsed water level of PRZ+3SI case maintains below the top of core from 410 sec to 762 sec, the fuel cladding temperature doesn't increase. Because the flow regime is bubbly or slug flow for core uncovery period, not stratified one, thus the fuel integrity can be maintained despite of low collapsed water level.

In all the cases, there was no fuel temperature increase harming the fuel integrity after SI from recirculation sump is activated.

3. Conclusion

The thermal-hydraulic analysis of multiple pipes break accidents was performed using RELAP5/SMR code to support the licensing review in KINS. The simulated events were the combinations of SI pipe break and pressurizer-gas cylinder connection pipe break. Although the minimum collapsed water level is lower and the recovery time of collapsed water level is later in the multiple pipes break accidents compared with various single pipe break accidents, it was verified that there was no fuel temperature increase harming the fuel integrity.

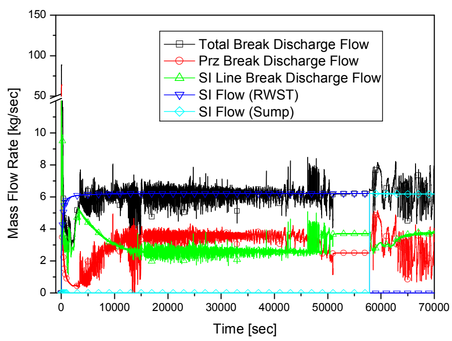

Fig. 1 Break discharge and SI flow transients for PRZ and one SI line breaks

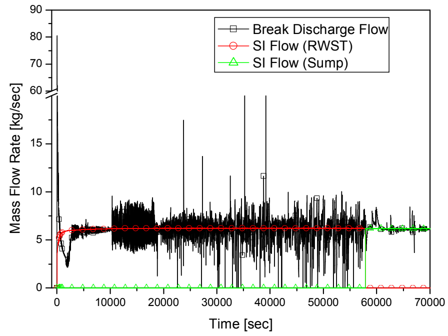

Fig. 2 Break discharge and SI flow transients for three SI line breaks

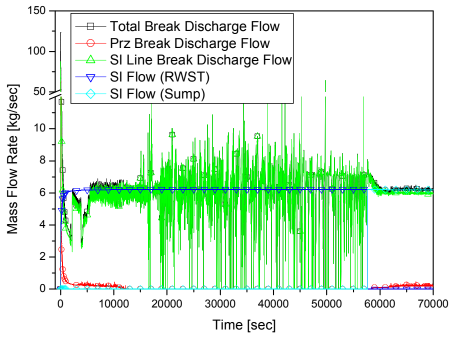

Fig. 3 Break discharge and SI flow transients for PRZ and three SI line breaks

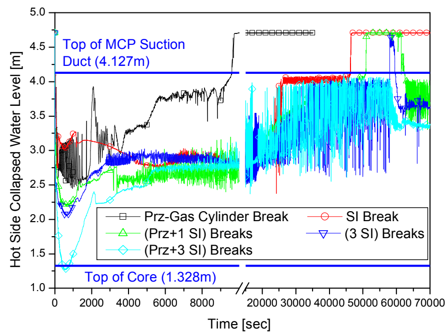

Fig. 4 Hot side collapsed water level transients for various events

REFERENCES

[1] KAERI, SMART-P Safety Analysis Report, 2005.
[2] S. H. Hwang, et. al., Analysis of SBLOCA in SMART-P Using RELAP5/SMR Code, Proceedings of the Korean Society Autumn Meeting, Gyeongju, Korea, 2006. 11.