Sensitivity Analysis According to the Break Loop Location in the MSGTR Accident

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1. Introduction

MSGTR(Multiple Steam Generator Tube Rupture) is defined as an accident in which multiple U-tubes are broken in a single steam generator. KINS(Korea Institute of Nuclear Safety) regulatory guidelines[1] assume an accident in which five U-tubes are broken at the same time. MSGTR accident analysis is conducted with the aim of restricting the release of radioactive substance into the outside atmosphere due to accidents and confirming the design characteristics and the appropriateness of accident management action to prevent nuclear fuel damage in the core. In this study, it was conducted to confirm the difference in the MSGTR analysis results according to the location of the damaged steam generator.

2. Methods and Results

The MSGTR analysis used in this study was performed on Shin-Hanul Units 1 and 2. The unit is the representative unit of the APR1400 type, which received final approval for AMP(Accident Management Program) in January 2025.

2.1 Analysis Code

The application of best estimate analysis methodology is allowed for multiple failure accidents. The RELAP5/Mod3.3[2] computer code, which is the most widely used worldwide, was used for the analysis as a computer program used for best estimate prediction of thermal hydraulic transients in nuclear power plants. RELAP5 is a computational code that can be used in a wide variety of predictions for the physical behavior of the reactor coolant system during the transient period as well as for the thermal hydraulic transients of nuclear and non-nuclear systems, including mixtures of steam, water, non-condensable gases, and solutes. The RELAP5 code used a two-fluid model that applies six governing equations of non-equilibrium and non-homogeneous.

2.2 Boundary Conditions

Table I shows the full power normal operating conditions used in the MSGTR analysis.

Table I: Full Power Normal Operating Conditions

Variables	Design Value
Core Power (MWt)	3,983.0
Cold Leg Temperature (°C)	290.5
Hot Leg Temperature (°C)	323.9
RCS Flow Rate (kg/sec)	20,991
Pressurizer Pressure (MPa)	15.51
Pressurizer water level (%)	50.0
SG Pressure (MPa)	6.89
Steam Flow Rate per SG (kg/s)	1131.2
SG wide water level (%)	77.0

2.3 MSGTR Analysis

After the accident, the pressure and water level of the reactor coolant system decrease due to the loss of inventory. As the pressure of the reactor coolant system decrease, the reactor trips at 136 seconds due to the hot leg saturation temperature reactor trip condition. Turbine trip occurs due to reactor trip, and steam from the steam generator is discharged to the condenser through a turbine bypass valve. After the reactor is tripped, the safety injection signal is generated due to the decompression of the reactor coolant system, and the decompression of the reactor coolant system is stopped due to the safety injection, and the break flow is balanced with the sum of the safety injection flow and the charging flow.

The water level of the steam generator temporarily decrease due to the reactor trip and turbine trip, and then increase again. In particular, the affected steam generator water level increase rapidly due to the break flow rate, generating the main steam isolation signal due to the high water level of the steam generator.

Table II: Event Sequence

Time (sec)	Events
0.00	MSGTR start
136.0	Reactor trip by hot leg sat. temp.
185.0	Safety Injection start
469.0	Aux. feed water injection to the unaffected steam generator
1,747.0	Main steam isolation valve close
2,008.0	Main steam safety valve open and close on affected steam generator

2.4 Sensitivity Results

Figures 1 to 5 show the analysis results as to whether the location of the damaged steam generator is in the loop with hot leg connected to the pressurizer.

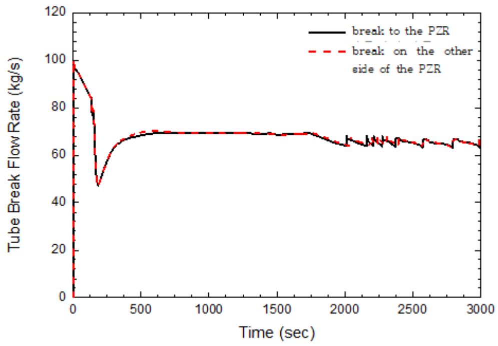

Fig. 1. Steam generator U-tube break flows rates.

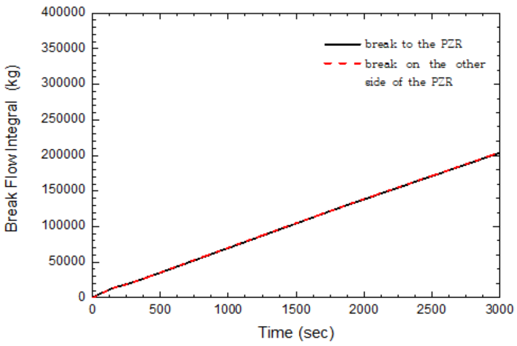

Fig. 2. Integrated steam generator break flow rate.

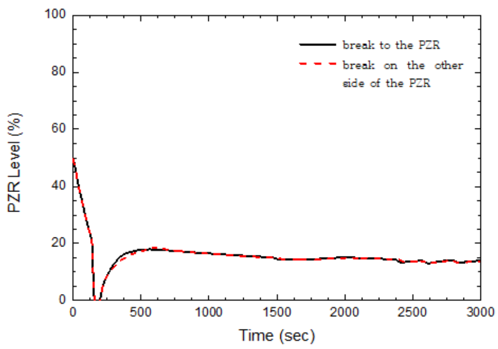

Fig. 3. Pressurizer water level.

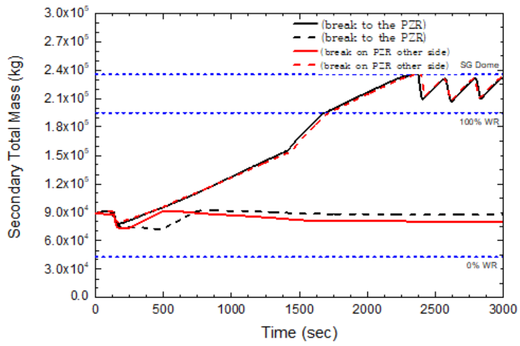

Fig. 4. Steam Generator water level(Invetory).

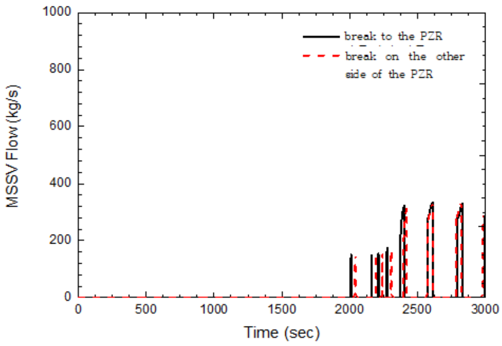

Fig. 5. Main steam safety valve flow rate.

3. Conclusions

In MSGTR accidents, the difference in results was evaluated to be insignificant when the broken loop position was different. In addition, it was evaluated that the difference in results was insignificant even when the location of the broken loop was evaluated differently in other asymmetric broken accidents such as SLB(Steam Line Break) and SGTR(Steam Generator Tube Rupture). A hot leg break connected to a pressurizer is assumed to have a high break flow rate due to the influence of a pressurizer heater, etc., so in general, the break location of an asymmetric break accident is assumed to be in the loop with hot leg connected to a pressurizer, but the difference is insignificant.

REFERENCES

[1] Regulatory Guideline, “16.1 Evaluation of Accidents due to Multiple Failures”, KINS/RG-N16.01, Rev.1, February, 2023.
[2] RELAP5/MOD3.3 Code Manual, ISL, December, 2001.