Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 30-31, 2008

The Effects of TBS LOCA on the SIS Design for OPR1000

Byung Heon Hwang, Cheol Woo Kim, Eun Kee Kim
Korea Power Engineering Company, Inc., 150 Deokjin-dong, Yuseong-gu, Daejeon, Korea 305-353
bhhwang@kopec.co.kr

1. Introduction

The risk-informed regulation & application (RIR & RIA) based on probabilistic safety assessment (PSA) has been discussed and is under review for the operation, maintenance and design. In the future, the new approach for the design might be applied especially to the loss-of-coolant accident (LOCA). The branch line connected to the main RCS piping is considered as the largest piping to credit the break. This break size is called as a transition break size (TBS).

These new trends in the safety analysis of nuclear power plants reflect the need to eliminate the over-conservatism in design concept and to secure economical efficiency as well as acceptable safety margin. In the design based on the RIR, the TBS LOCA will be the limiting accident for the emergency core cooling system (ECCS) or the safety injection system (SIS) design instead of a large break LOCA (LBLOCA).

In this paper, a study on the TBS LOCA is performed for the Younggwang Nuclear Power Plant Units 5&6 (YGN 5&6), typical plants of OPR1000, for ECCS design optimization by comparing the results of the LBLOCA. This study was conducted as a part of the improvement in plant operation and design technology. The LBLOCA and TBS LOCA analyses were performed for the RCP discharge leg break changing the safety injection (SI) flow rate. The results are compared with those of LBLOCA in terms of peak clad temperature (PCT) to verify the validity of ECCS design changes.

2. Analysis Methods

2.1 Analysis Tool and Methodology

The RELAP5-ME code is used for LOCA analysis, which is used in the KIMERA[1]. It is essentially the same code used in the KREM[2]. RELAP5-ME consists of the RELAP5K computer code linked with the CONTEMP4/MOD5 like the KREM[2], and RELAP5K adopts enhanced mass and energy release models based on RELAP5/MOD3.1/K. The analysis methodology is the same as the KREM which uses the realistic evaluation methodology.

The analysis is carried out with two categories, which are break size and SI flow rate. The break size used in LBLOCA analysis is the double ended area and that for TBS LOCA analysis is 12 inches. The SI flow rate is simulated assuming 50% of the minimum design value in each component such as the safety injection tank (SIT), the low pressure safety injection pump (LPSIP), and the high pressure injection pump (HPSIP).

2.2 Analysis Models and Assumptions

Major models and assumptions of this analysis are summarized as follows:

1. The long term cooling model is not considered.
2. The containment backpressure at each time step is calculated in CONTEMPT4 code and transferred to RELAP5K as a boundary condition.
3. The nominal plant operating parameters are selected as initial conditions.
4. The highest possible core power (102%)
5. Off-site power is unavailable (LOOP).
6. One emergency diesel generator (EDG) failed (single failure).
7. ANS79 decay heat curve with an uncertainty of 2σ is assumed.
8. Modeling of 6 downcomer nodes is used for reactor vessel downcomer.
9. Minimum values of ECCS parameters such as SIT pressure, SI setpoint, and SI flow are used.
10. Safety injection pump (SIP) delay time is a maximum value of 40 sec.
11. The initial containment is in the minimum backpressure condition.
12. The break discharge coefficient (Cd) is 1.0.
13. The Trapp-Ransom critical flow model and the KAERI reflood model are used.

3. Analysis Results

3.1 Comparison of Accident Behaviors

The parameters used in the sensitivity study are 'break size' and 'SI flow rate'. The results of the sensitivity study for these parameters are summarized in Table 1 in terms of PCT. The two peaks of the PCT of TBS LOCA were 500 K and 300 K less than those of LBLOCA because of the smaller break size.

Figure 1 and 2 show the PCT and the reactor vessel water level for LBLOCA and TBS LOCA of the base case in Table 1. The earlier quenching for TBS LOCA appears in Figure 1 due to the smaller break size when compared with LBLOCA. However, no late reheating appears for both cases. The study found out that TBS LOCA is very similar to LBLOCA with a delayed core blowdown, refill and reflood phenomena as provided in Figure 2.

Table 1. Peak Clad Temperature

Event		LBLOCA	TBS LOCA
Base Case *	1st peak	1321K @5.8 ⓝ14	837.1K @2.3 ⓝ15
	2nd peak	941.6K @111 ⓝ15	633.8K @123.6 ⓝ15
Half of HPSIP *	1st peak	1321K @5.8 ⓝ14	837.1K @2.3 ⓝ15
	2nd peak	949.2K @115.9 ⓝ15	624.5K @120.4 ⓝ15
Half of LPSIP *	1st peak	1321K @5.8 ⓝ14	837.1K @2.3 ⓝ15
	2nd peak	943.9K @132 ⓝ15	642.4K @107.6 ⓝ15
Half of SIT *	1st peak	1321K @5.8 ⓝ14	837.1K @2.3 ⓝ15
	2nd peak	963.6K @109 ⓝ14	620.2K @97.1 ⓝ14

* Minimum design flow rate

3.2 Results of SI Flow Change

Figure 3 shows how the PCT of the hottest fuel rod varies when the SI flow rate changes. Because TBS LOCA is similar to LBLOCA, the change of LPSIP flow rate has more influence on PCT.

However, there is no such significant behavior for a higher peak (higher than the first one) or a later peak in all sensitivity cases.

Since HPSIP flow rate is important for the small break LOCA, the sensitivity study for the small break LOCA needs to be performed for the HPSIP flow rate optimization.

Figure 4 shows the PCT of the hottest fuel rod when LPSIP fails to operate. In both cases, there is late reheating the temperatures of which are still below the safety limit (2200 ^{o}F or 1477.6 K) but higher than the first peak during the post-reflood or the post core recovery. However, the late reheating with core uncover is not recommended for the ECCS design due to the possibility of fuel clad failure.

4. Conclusion

A study on the TBS LOCA using the best-estimate analysis methodology was performed to evaluate the effects on the SIS design optimization based on the risk-informed application. The results of LBLOCA and TBS LOCA at the RCP discharge leg for YGN 5&6 were compared by reducing the SI flow rate.

From this study, the following conclusions are introduced.

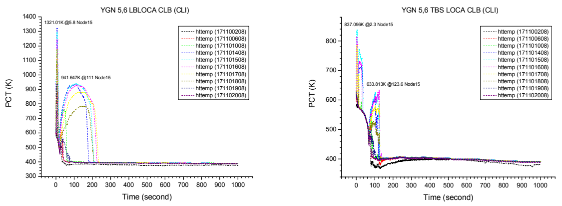
- TBS LOCA regarded as a new design basis shows similar transient behaviors and thermal hydraulic characteristics to those of LBLOCA.
- During TBS LOCA the SIT and LPSIP flow is still important for the emergency core cooling like LBLOCA.
- Because of the smaller break size in TBS LOCA, the blowdown process appears more slowly and the PCT is much lower than that of LBLOCA.
- Since the lower PCT secures more safety margins, the SIS can be efficiently optimized.
- Based on this best-estimate analysis, the current SIS flow rate can be reduced to a half even in LBLOCA.

A further study is required to find the optimized combinations in the SIS by performing statistical analysis on the plant major parameters as well as break size.

REFERENCES

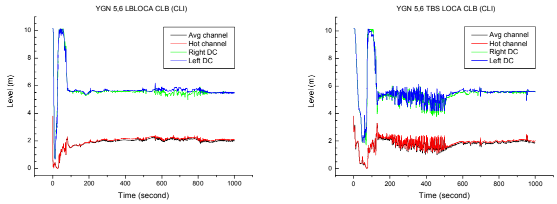
[1] KOPEC, "KOPEC Improved Mass and Energy Release Analysis Methodology," KOPEC/NED/TR /06-005, Rev.0, December 2007.

[2] KHNP, "Topical Report for the Application of KREM to Korea Standard Nuclear Power Plants," TR-KHNP-0010, June 2007.



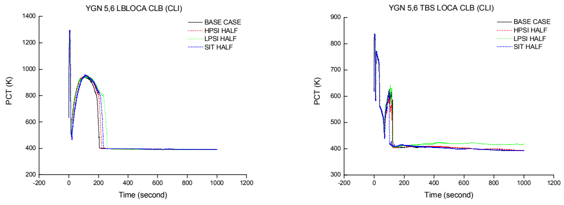
LBLOCA TBS LOCA

Figure 1. Peak Cladding Temperature during LOCA (Base Case)



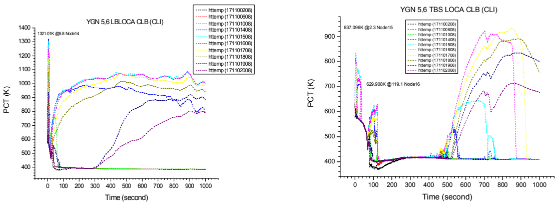
LBLOCA TBS LOCA

Figure 2. Reactor Vessel Water Level during LOCA (Base Case)



LBLOCA TBS LOCA

Figure 3. PCT for Various SI Flow Conditions



LBLOCA TBS LOCA

Figure 4. PCT for all LPSIPs Failed Condition