

Safety Assessment of Shutdown LOCA for Yonggwang 1&2 and Kori 3&4

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1. Introduction

USNRC Information Notice 95-03 [1] discusses a loss of reactor coolant incident under hot shutdown at Wolf Creek. During the review of Improved Technical Specifications (ITS) of Yonggwang units 1&2 and Kori 3&4 [2], Korean Institute of Nuclear Safety requested an evaluation of operator response times under shutdown loss of coolant accident (LOCA). The issue is raised from the fact that safety injection pumps should be manually operated.

The present approach to resolve the issue is that when the risk from large break (LB) LOCA under shutdown condition is less than under full power, then we have no need to analyze LB LOCA under shutdown conditions. And this makes operator response time under small break (SB) LOCA become more important. As a part of a Periodic Safety Review of Yonggwang 1&2 and Kori 3&4, risk analysis of LB LOCA and safety analysis of SB LOCA are performed.

2. Methods and Results

In this section, the methods and results of risk analysis of LB LOCA and safety analysis of SB LOCA under shutdown conditions are described.

2.1 Risk from Large Break LOCA under Shutdown Conditions

The purpose of this analysis is to show that risk in terms of core damage frequency (CDF) of LB LOCA under shutdown conditions (plant operational modes 3,4) is far less than under full power operation (mode 1), and any design consideration, change of procedure and new safety analysis are not necessary. The risk from LB LOCA can be calculated in terms of core damage frequency as following:

CDF of LB LOCA = Normalized Probability of Large Pipe Break x Fractional Time spent under Particular Operational Mode x Conditional CDF (CCDF) under Particular Operational Mode

The normalized probability of LB LOCA is obtained from the results of Westinghouse plant structural reliability and risk assessment [3]. And the fractional time spent under particular operational mode is estimated from the plant data.

The event tree to calculate a CCDF under mode 1 consists of following event tree headings:

- Accumulator injection
- Low head safety injection
- Low pressure cold leg recirculation
- Containment heat removal
- Low pressure hot leg recirculation

However, under mode 4 the operator has to recognize a symptom of LOCA and realign pipe configuration from residual heat removal mode to safety injection mode hence following event tree headings:

- Recognize symptoms
- Stop residual heat removal
- Low head safety injection
- Low pressure cold leg recirculation
- Low pressure hot leg recirculation

Core damage frequencies of LB LOCA under modes 1, 3 and 4 are calculated through processing above headings and bounding database of the two plants [4] into the SAREX code [5]. The results are summarized in Table 1. It is shown that the 95% values of CDF under modes 3&4 are much smaller than under mode 1.

Table 1. The CDFs from LB LOCA under Mode 3 and 4

Plant Operational Mode		CDF Relative to Mode 1	
		Mean	95%
3		1.50E-3	2.49E-3
4	One RHR Pump Operating before LOCA	9.23E-3	1.56E-2
	Two RHR Pumps Operating before LOCA	4.20E-2	7.11E-2

2.2 Analysis of Small Break Loss of Coolant Accident under Shutdown Conditions

The SB LOCA under mode 3 (more limiting than mode 4) is analyzed using NOTRUMP Evaluation Methodology codes [6,7]. NOTRUMP [6] is a one-dimensional general network code with a number of two-phase features. Among these features are the thermal non-equilibrium in all fluid volumes, flow regime-dependent drift flux calculations with CCFL, mixture level tracking logic in multiple-stacked fluid nodes, and regime-dependent heat transfer correlations. Cladding thermal analyses are performed with the LOCTA-IV [7], which evaluates the fuel, cladding, and the coolant temperature during the hypothetical LOCA.

For the analysis, a break of a 6-inch pipe attached to the RCS cold leg was analyzed since this is the largest branch piping of the reactor coolant system (RCS). Key

parameters for the hot shutdown condition are shown in Table 2. An initial pressure of 1014.7 psia assumed in the analyses is the highest pressure with no accumulator available. The decay heat level is determined based on 50 °F/hr cooldown rate and 120% of the 1971 ANS decay heat. Others are chosen conservatively.

Table 2. Plant Parameters for Hot Shutdown

Parameters	Full Power	Hot Standby/ Hot Shutdown
Reactor Power (MWt)	2830.5	38.5/35.7
% of RTP	102%	1.4%/1.26%
Accident Time(hr)	2.5	4.0
Pressurizer Pressure (psia)	2300	1015/465
Hot Leg Temperature (°F)	620	426/350
Cold Leg Temperature (°F)	554	424/349
Pressurizer Water Level (%)	60	18
SG Pressure (psia)	934	322/134
Peaking Factors	2.6	2.6
FQ	FdH	FdH
	1.65	1.65
K(Z)	top-skewed shape	
SGTP (%)	5	5
ECCS Pumps	Full (Auto)	Full (Manual)
Accumulators	3	0

Following the initiation of the break in the cold leg, there is a rapid depressurization of the RCS. The pressurizer emptied at about 7 seconds, and the hot leg subcooling is lost at about 35 seconds. These two symptoms are used for manual safety injection (SI). Two cases, with SI delay of 10 and 15 minutes, are analyzed for the hot shutdown. The core mixture level reaches a minimum with approximately 1250 seconds as shown Figure 1. Peak clad temperature (PCT) is calculated as 832 °F for the 10 minutes SI delay case and 1530 °F for the 15 minutes SI delay case. Local oxidation is less than 0.1% and rod burst does not occur for both cases.

For break sizes smaller than 5.187 inches, the core experiences no uncover at the time of SI due to the reduction in break flow rate. For 3 and 4 inches breaks, PCTs are calculated less than 600 °F.

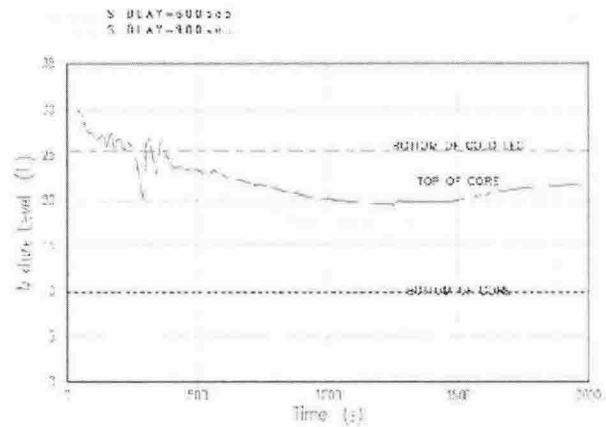


Figure 1. Two-Phase Mixture Level for 6" Cold Leg Break

3. Conclusion

For Yonggwang 1&2 and Kori 3&4, safety of LOCA under shutdown conditions is conservatively estimated. The risk from LB LOCA under shutdown condition is much less than that under full power and it is concluded that safety analysis of LB LOCA under shutdown condition is not necessary, and this made operator response time under SB LOCA become more important. Conservative safety analysis of the bounding 6" SB LOCA under mode 3 demonstrated that the limits of 10CFR50.46 will not be exceeded provided that the operator action establish flow from both a high head and a low head SI pumps within 15 minutes after the appropriate symptoms.

REFERENCES

- [1] USNRC Information Notice 95-03 "Loss of Coolant Inventory and Potential Loss of Emergency Mitigation Functions While in a Shutdown Condition," January 18, 1995.
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