Proceedings of the Korean Nuclear Society Spring Meeting
Cheju, Korea, May 1996

FLB Event Analysis with regard to the Fuel Failure

Seung Su Baek, Byung Il Lee, Gyu Cheon Lee, Hee Cheol Kim, and Sang Keun Lee
Korea Atomic Energy Research Institute

Abstract

Detailed analysis of Feedwater Line Break (FLB) event for the fuel failure point of view are lack because the event was characterized as the increase in reactor coolant system (RCS) pressure. Up to now, the potential of the rapid system heatup case has been emphasized and comprehensively studied. The cooldown effects of FLB event is considered to be bounded by the Steam Line Break (SLB) event since the cooldown effect of SLB event is larger than that of the FLB event. This analysis provides a new possible path which can cause the fuel failure. The new path means that the fuel failure can occur under the heatup scenario because the Pressurizer Safety Valves (PSVs) open before the reactor trips. The 1000 MWe typical C-E plant FLB event assuming Loss of Offsite Power (LOOP) at the turbine trip has been analyzed as an example and the results show less than 1 % of the fuel failure. The result is well within the acceptance criteria. In addition to that, a study was accomplished to prevent the fuel failure for the heatup scenario case as an example. It is found that giving the proper pressure gap between High Pressurizer Pressure Trip (HPPT) analysis setpoint and the minimum PSV opening pressure could prevent the fuel failure.

1. Introduction

The FLB event is caused by a break in the main feedwater system. Depending on the break size and location and the response of the main Feedwater system, the effects of a break can vary from a rapid heatup to a rapid cooldown of the Nuclear Steam Supply System (NSSS). Due to the less cooldown effects than the SLB event, the major analysis point of the FLB event was the RCS peak pressure. However, it is found that there exists the possibility of the fuel failure even under the heatup scenario.

2. Objectives

The objectives of this paper is, first, to identify the possibility of the fuel failure for the FLB event and second, to setup the conservative initial conditions for the DNBR aspect of FLB event through the sensitivity studies and finally, to provide the analysis results for the proposed method which prevent the fuel failure. This effort would help to design safer nuclear power plant.

3. Analysis Methods and Results (DNBR Aspect)

The typical C-E plants have been selected to analyze the FLB event under the heatup scenario. The heatup scenario means that the initial conditions of the major physics data are assumed as the values in BOC which increases the RCS temperature, which play major role to decrease the minimum DNBR, rather than those in EOC conditions.

3.1 Possibility of fuel failure in the heatup scenario

The FLB event increases the RCS temperature and pressure due to the loss of subcooled feedwater. The increase of RCS pressure could be culminated by the opening of the PSVs and a reactor trip. The 1000 MWe typical C-E plant HPPT maximum analysis setpoint for harsh environment (HE) events is 2460 psia. The PSV opening setpoint is 2500 ± 40 psia. If PSV opening setpoint was assumed as a minimum value of 2460 psia, the HPPT setpoint and the PSVs opening setpoint are same. The PSV's characteristic of the typical C-E plant is pop open when the pressurizer pressure reaches the opening setpoint. However, the reactor trip on high pressurizer pressure has a delay time. Then, because of the HPPT sensors characteristic, which is identified not as a linear delay but as a First Order Lag (FOL), there exist the cases without reactor trip when the PSVs open and decrease the RCS pressure. This can cause the fuel failure.

3.2 Analyses Methods and Results to minimize the DNBR

In FLB event analyses, it was assumed that PSVs open at the maximum setpoint in case of overpressurization. The loss of subcooled feedwater flow to both steam generators causes increase in steam generator temperature and decrease in liquid inventory and hence water level. The rising secondary temperature reduces the primary to secondary heat transfer and forces a heatup and pressurization of the RCS. As though High Pressurizer Pressure Trip (HPPT) signal occurs, pressurizer pressure increases until PSVs open and the primary pressure will still increase as shown in Figure 1. So, the DNBR margin is allowed not to violate SAFDL in case of overpressurization case.

However, if the minimum PSVs opening setpoint is assumed, RCS pressure decreases without the reactor trip due to the sensors' delay time (FOL) until the PSVs reclose. Because the RCS temperature keeps increasing while the pressure decreases and core power and core flow rate are maintained. the MDNBR occurs around at the time of PSV's reclosure as shown in Figure 6. In this analysis, the Core Protection Calculators (CPCs) low DNBR trip is not credited because the rapid decrease of the pressure while PSVs open is not the CPC design basis. Even though the CPC low DNBR trip is credited, the DNBR will violate the DNB SAFDL.

The plant parameters for minimizing DNBR are as follows ; PSV opening setpoint, break size, pressurizer pressure, initial core flow rate, and core inlet temperature. The sensitivity study was performed about the break size, pressurizer pressure, core inlet temperature and core inlet flow rate.

In cases for minimizing DNBR, it was assumed that PSVs open at the minimum setpoint. Because the lower PSV opening setpoint increases the possibility of PSV opening without HPPT resulting in rapid decreasing of DNBR due to the pressure decrease.

Several break sizes were analyzed with changing the initial PZR pressure. The results of sensitivity studies are summarized in Tables 1, 2, and 3. The resultant minimum DNBR is more limiting for the smaller breaks because of the more increase of the core temperature resulting from the more increase of SG pressure and temperature. As the break sizes increase, the MDNBR increase as of in Figure 3.

The initial PZR pressures of 2000, 2250, 2325 were analyzed to minimize the DNBR. The results are summarized in Tables 1, 2, and 3. As the initial PZR pressure increase, the MDNBR decreases as shown in Figure 2. As shown in Table 4, the major operating parameters of initial core flow rate and core inlet temperature are parametrically studied based on maximum initial pressurizer pressure. Figure 4 and 5 are the results about initial core flow rate and core inlet temperature. Table 5 describes the most conservative initial conditions to minimize DNBR.

As one of the method to prevent the fuel failure on FLB event, the HPP trip setpoint reduction is examined. A lowered HPPT setpoint may help that the reactor trip signal can occur before PSVs open event though the sensor delay time (FOL) exists. From the sensitivity studies, it is found that 10 psi reduction is enough to prevent the fuel failure as shown in Table 7, that is, getting a little pressure gap between HPPT analysis setpoint and the minimum PSV opening pressure can be a method to prevent the fuel failure for this case.

4. Conclusion

This paper announces a new possible process which can cause the fuel failure on the FLB event. The major reason is identified that there is no difference between the minimum PSV opening setpoint and HPPT analysis setpoint. This prevents a proper HPPT, which may result in the fuel failure. The resultant fuel failure for the FLB event with LOOP at the turbine trip is less than 1 percent which is well within the acceptance criteria.

In addition, as though the result is acceptable, considered are the methods to prevent the fuel failure for advanced nuclear power plant design. As an example, this paper shows that a proper gap between the minimum PSV opening pressure and HPP analysis setpoint can trigger the reactor trip before the PSVs open and results in no fuel failure.

5. References

1. Yonggwang Nuclear Units 3&4 Final Safety Analysis Report, 1994, KEPCO.

Table 1. Breaks size

(Initial pressurizer pressure : 2000)

Break size	Rx Trip time	PSV opening time	MDNBR time	MDNBR
0.1	44.12	30.57	47.18	1.5558
0.2	36.98	33.59	39.90	1.6407
0.3	29.76	31.44	32.70	1.6936
0.4	25.05	27.39	27.89	1.7151
0.6	19.10	22.4	21.75	1.6953
0.8	15.55	19.55	18.15	1.6799
1.0	13.20	17.80	15.95	1.6691
1.22	11.35	17.00	14.15	1.6670

Table 2. Break size

(Initial pressurizer pressure : 2250 psia)

Break size	Rx Trip time	PSV opening time	MDNBR time	MDNBR
0.1	44.10	22.85	37.01	1.2918
0.2	37.10	25.09	35.61	1.3788
0.6	19.10	19.55	22.15	1.4657
1.22	11.35	13.00	14.35	1.5095

Table 3. Break size

(Initial pressurizer pressure : 2325 psia)

Break size	Rx Trip time	PSV opening time	MDNBR time	MDNBR
0.1	44.12	15.80	31.65	1.2658
0.2	37.14	17.35	33.05	1.2728
0.8	15.55	15.70	18.55	1.4234
1.22	11.35	11.95	14.35	1.4367

Table 4. Initial Core flow rate and temperature

Initial Pressurizer pressure	Core flow, W	Inlet Temp, Tin	MDNBR
Max.	Min.	Min.	1.2844
Max.	Min.	Max.	1.2300
Max.	Max.	Min.	1.2408
Max.	Max.	Max.	1.1911

Core flow : Min = 95 % of design, Max.= 116 % of design, Inlet Temp.: Min=560°F, Max.=570°F

Table 5. Summary of conservative initial conditions

Parameter	Comments
Core Inlet Temperature (°F)	Maximum (570)
Pressurizer Pressure (psia)	Maximum (2325)
Core Inlet Flowrate (% of design)	Maximum (116)
PSV Opening Pressure	Minimum (2460)
PSV Capacity	Maximum
Scram Rod Worth	-0.3
Loss of offsite Power Time	3 seconds after turbine trip
Break Size (ft^2)	0.1

Table 6. Initial conditions to minimize DNBR in case of reducing HPPT setpoint

CASE	Pressure	Core Temperature	Core Flow Rate
1	Min	Min	Min
2	Nom	Min	Min
3	Max	Min	Min
4	Min	Max	Min
5	Nom	Max	Min
6	Max	Max	Min
7	Min	Max	Max
8	Nom	Max	Max
9	Max	Max	Max
10	Min	Min	Max
11	Nom	Min	Max
12	Max	Min	Max

Table 7. The results of sensitivity studies in case of reducing HPPT setpoint

CASE	Initial DNBR	MDNBR & time (sec)	PSV open time (sec)	HPPT or LSGLT & time (sec)
1	1.7842	1.7619(50.34)	47.97	HPPT(48.4)
2	1.7028	1.6606(26.71)	24.80	HPPT(24.90)
3	1.6756	1.6397(18.92)	17.15	HPPT(17.20)
4	1.7831	1.7831(0.0)	54.85	LSGLT(55.54)
5	1.7106	1.6663(24.41)	22.40	HPPT(22.60)
6	1.6853	1.6457(17.74)	15.70	HPPT(16.00)
7	1.7347	1.7347(0.0)	45.71	HPPT(45.02)
8	1.6407	1.5919(24.12)	22.00	HPPT(22.25)
9	1.6100	1.5670(17.23)	15.20	HPPT(15.45)
10	1.7282	1.7171(50.55)	47.99	HPPT(48.32)
11	1.6295	1.5829(26.55)	24.60	HPPT(24.75)
12	1.6014	1.5583(18.90)	17.00	HPPT(17.15)

(Initial Pressurizer pressure : Min - 2000, Nom - 2250, Max - 2325 psia), (Initial Core Temperature Min - 560, Max - 570 °F), (Initial Core Flow Rate : Min - 95 %, Max - 116 % of Core flow)

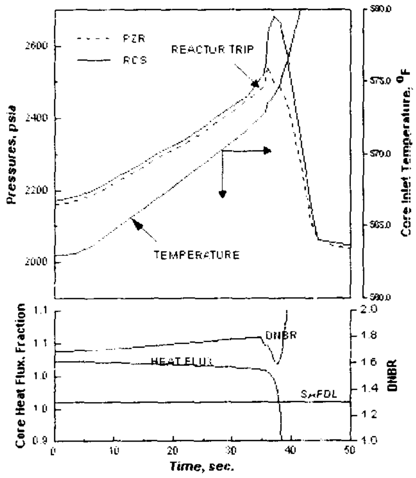

Figure 1. RCS Responses in case of RCS Overpressurization case

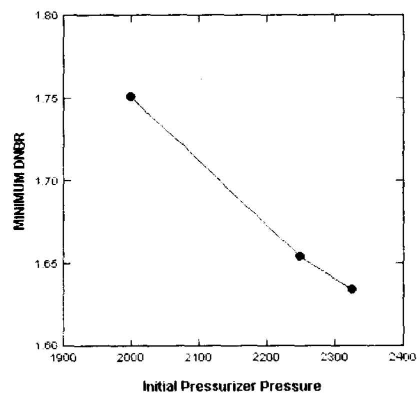

Figure 2. Initial Pressurizer Pressures vs. MDNBR

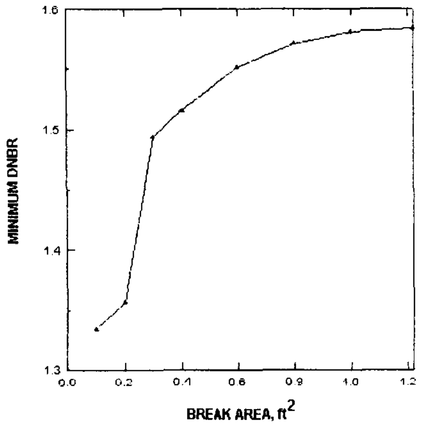

Figure 3. Break Area vs. MDNBR

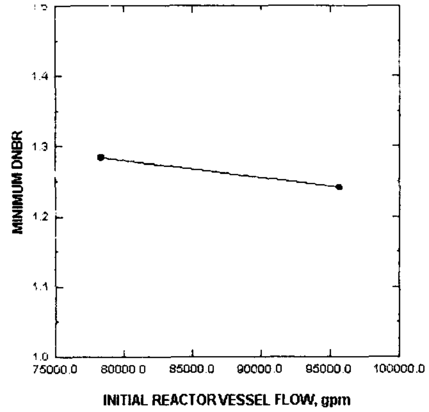

Figure 4. Initial Reactor Vessel Flow vs. MDNBR

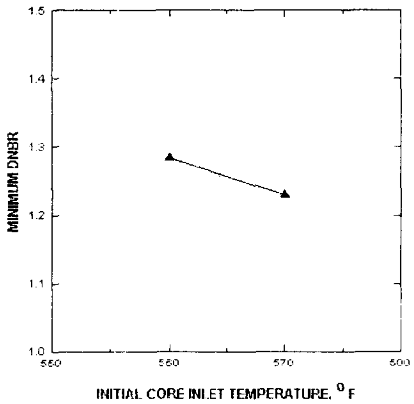

Figure 5. Initial Core Inlet Temperature vs. MDNBR

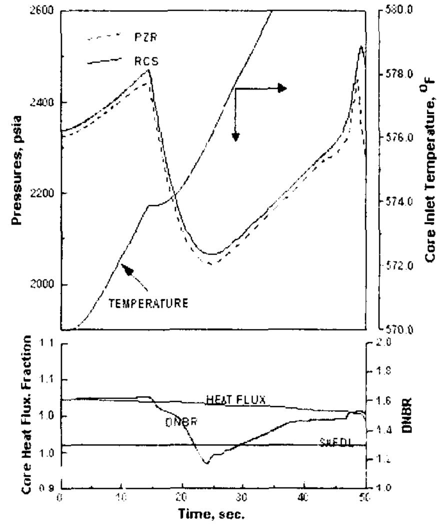

Figure 6. RCS Responses in case of MDNBR Case