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Relation between SG Wide Range Level Measurement and TSP Blockage Rate for 3-Loop Plants in Korea

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1. Introduction

Hydrodynamic instability is a potential problem in any fluid system where boiling takes place. Instability, if present in the pressurized water reactor steam generator, will result in periodic oscillation in water level, steam flow, feedwater flow and flow through the circulation loop. Density wave instability is the most common type encountered in the boiling heat exchanger. The density wave instability results from an unfavorable distribution of pressure drop through the circulation loop.[2]

In this paper, hydrodynamic instability is evaluated due to the variation of tube support plate(TSP) flow area. Moreover, this paper shows the relations between SG wide range(WR) level measurements and TSP flow area blockage. If we can develop a correlation for those two parameters, we don't have to take visual inspection of SG TSP every overhaul period.

2. Effect of TSP Flow Area for SG Stability

A reduction of the TSP flow area causes an increase in pressure drop within the two-phase flow zone, which destabilizes the boiling flow through the tube bundle. Although pressure drop in the two-phase zone is also dissipative and thus stabilizing, oscillation in the incoming flow rate does not totally dissipate itself in pressure drop. Pressure drop depends on flow rate and void fraction. An increase in the flow rate will lead to an increase in the pressure drop and a decrease in the void fraction. If the void fraction remains the same then the oscillation can dissipate totally through a complete pressure drop. The decrease in the void fraction reduces the pressure drop, and thus damping of the flow increase is incomplete. The higher the impedance in the two-phase flow zone is, the less damping is, and thus the smaller the stability margin. This feedback between the flow and void can lead to flow oscillation. Figure 1 shows damping factor versus flow area reduction.

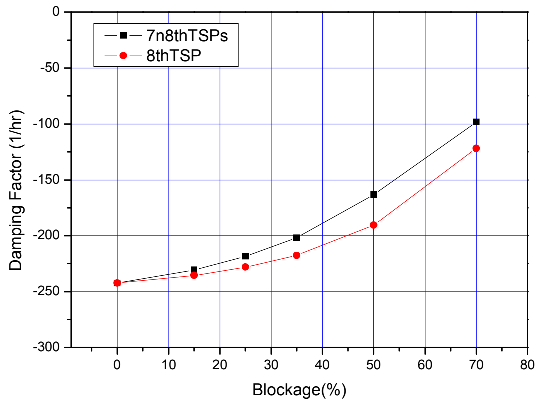

Figure 1. Damping factor vs. TSP flow area blockage

3. Evaluation of SG WR Level Measurements

Figure 2 and 3 show the trend of SG WR range level measurements for the recent 3 fuel cycles. Apparently, SG WR level measurements increase as the fuel burnup goes even though the SG narrow range level measurements maintain almost same setpoint of 50%.

There are two basic reasons for these phenomena possibly. One is the drift of level transmitter. The other is the TSP flow area blockage.

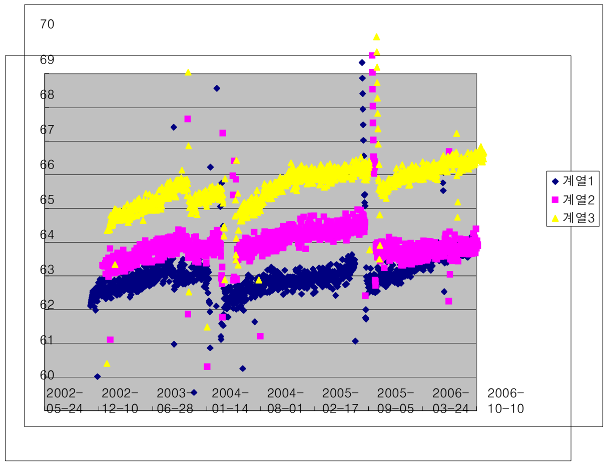

Figure 2. Plant A SG WR level measurements

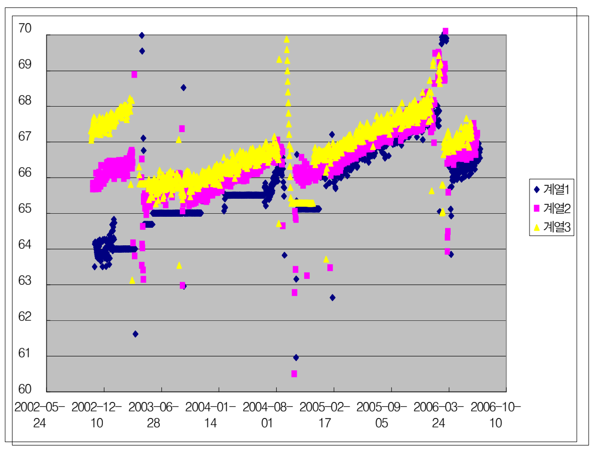

Figure 3. Plant B SG WR level measurements

3.1 Evaluation of SG WR Level Transmitter Drift

The drift data of SG WR level transmitters are evaluated for past 4 fuel cycles at Plants A and B. The number of data is 128 and the mean value is 0.1% which is biased a little bit. This means 0.1% of WR level increase comes from this drift value. Figure 4 shows the probability density of the drift.

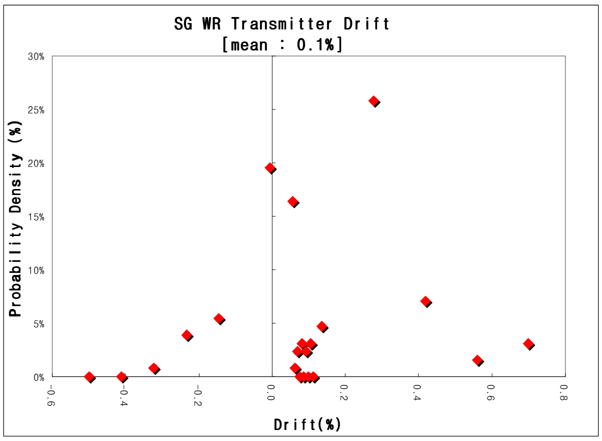

Figure 4. Plants A and B SG WR Transmitter Drift

3.2 Evaluation of SG TSP Flow Area Blockage

There are two key parameters which affect SG WR level increase due to SG TSP flow area blockage. If the TSP flow area blockage proceeds, then the circulation ratio decreases. This makes the downcomer fluid temperature and flow rate decrease. Equation (1) describes the downcomer subcooling effect which affects SG WR level. Equation (2) describes the downcomer flow velocity effect which affects SG WR level. These two effects give positive bias to the SG WR level.

$$\varepsilon_{sub} = \frac{\rho_{dc} - \rho_f}{\rho_{fc} - \rho_{gc}} * \frac{H_{ring}}{H} \qquad (1)$$

where,

ρ_{dc} = downcomer water density

ρ_f = saturated water density at process pressure

ρ_{fc} = water density at calibration condition

ρ_{gc} = saturated gas density at calibration pressure

H = wide range level span

H_{ring} = height of feed ring

$$\varepsilon f_{\upsilon} = \frac{\rho_{dc}\, \upsilon_{dc}^{2}}{2gH(\rho_{fc} - \rho_{gc})} \qquad (2)$$

where, υ_{dc} = downcomer water velocity

g = gravitational constant

Figure 5 shows the total downcomer effects to the SG WR level. From this curve, we can conclude that the WR level increases linearly up to around 40% blockage but it's small amount. If the blockage rate is more than 50%, than the amount of level increase becomes nonlinear and more significant.

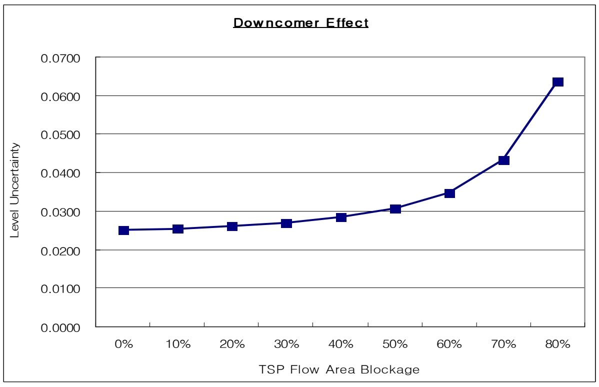

Figure 5. SG WR Level Uncertainty vs. TSP Flow Area Blockage

4. Conclusion

According to the above analyses, we can draw the following conclusions.

1) As a result of the transmitter drift analysis, around 0.1% of SG WR measurements increase during every cycle.

2) For the Plant B, more than one percent of WR level measurements increase possibly due to SG TSP flow area blockage. We can guess around 40% of SG TSP flow area is blocked because up to 40% flow blockage, the amount of level increase is linear.

3) However, this conclusion should be carefully interpreted because a lot of unidentified parameters may exist which makes the level increase. One of those unidentified parameter is the downcomer pressure loss effect. If we investigate this parameter in detail, the estimated TSP flow area blockage may decrease.

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