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# Evaluation of thermal stratification in the S/G and development of preventing device

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## 1. Introduction

In a steam generator the hot water flowing backward through the feed ring or the high-temperature main feedwater remaining in the horizontal pipe is separated from the low-temperature water supplied from the auxiliary feedwater system without any mixture. This is called thermal stratification. The damages to the pipes due to this thermal stratification have a serious effect on the operations and safety of a nuclear power plant. Hence countermeasures need to be taken to address this issue. To this end an experiment is in order, which will devise a way of preventing thermal stratification on the basis of an accurate understanding and prediction of phenomena, and thus proves its effectiveness. Operations and safety, based on the measures resulting from this experiment, must be evaluated, and the specifications for final application to the design are also essential.

## 2. Methods and Results

To formulate a measure to prevent thermal stratification, the governing dimensionless number for the experiment was obtained. On this basis an experiment for verification of thermal stratification was conducted, and then an experiment was conducted to prevent thermal stratification.

### *2.1 Dimensionless number*

The dimensionless number governing thermal stratification in a fluid system with temperature difference is ordinarily expressed as the Richardson number. For thermal stratification is also a type of natural convection taking place inside the pipe. Actually, the flow related to thermal stratification occurs in the pipe, but if a vertical plate is assumed for ease of derivation, the governing equation will be as follows:

$$u^* \frac{\partial u^*}{\partial z^*} = \frac{L}{U_\infty^2} g\beta\Delta T + \frac{\nu}{LU_\infty} \frac{\partial^2 u}{\partial z^{*2}}$$

Here, the dimensionless number is $\frac{L}{U_\infty^2} g\beta\Delta T = \frac{Gr}{\mathrm{Re}^2} = Ri$. Like this the Richardson number is expressed as the duplicate ratio between the Grashof number indicating natural convection and the Reynolds number indicating the inertial force of the flow.

### *2.2 Verification Experiment*

The dimensionless variable made it possible to confirm that the variable, which greatly influences the formation of thermal stratification in the steam generator, is the hot water in the steam generator and the flux of the low-temperature water flowing in through the auxiliary feedwater. An experimental apparatus was made on the similarity with this variable, and the result of a verification experiment based on this apparatus confirmed that thermal stratification occurs in the horizontal feedwater inlet pipe of the steam generator.

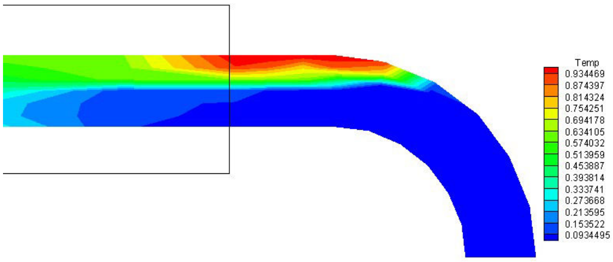


Figure 1. Temperature Distribution, $R_i$ is 72.4 (t=120sec)

### *2.3 Mitigation Experiment A*

A typical mitigating system is the Helix structure. During transient operation the Helix structure not only makes low-temperature water with considerably low flux mix with hot water like a whirlpool in the horizontal water-supply inlet pipe, but also prevents the hot water from flowing backward inside the steam generator. However, as the experimental result showed there was partly a heat island in the upper portion of the curved section adjacent to the horizontal pipe where the Helix structure ends, the soundness of the pipe in the upper part of the curved section was not secured.

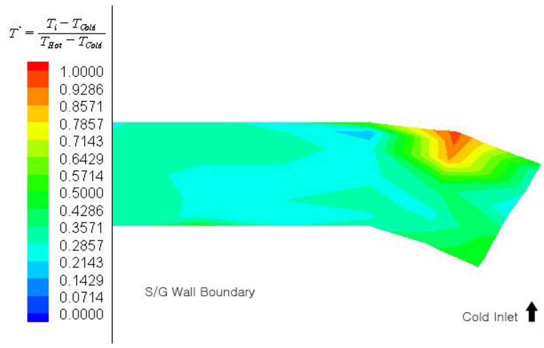


Figure 2. Temperature Distribution, $R_i$ is 72.4 (t=90sec)

### *2.4 Mitigation Experiment B*

The second experiment in mitigation investigated how the minimization of the length of the horizontal feedwater inlet pipe, the place where thermal stratification mostly takes place, and the adjustment of the angle of the pipe would affect the mitigation of thermal stratification. The result of the experiment showed that, when the shape and angle of the horizontal feedwater inlet pipe were adjusted, there was much less thermal stratification than previously, but there was still thermal stratification at the curved section. In particular, an attempt was made to prevent thermal stratification by shortening the length of the horizontal pipe, but thermal stratification did not disappear at the curved section.

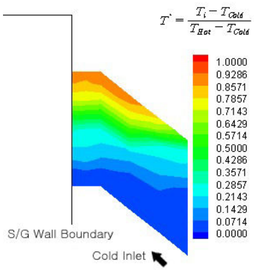


Figure 3. Temperature Distribution, $R_i$ is 72.4 (t=90sec)

## 3. Conclusion

The thermal sleeve, another mitigating system used in existing power plants, can prevent thermal fatigue of the horizontal feedwater inlet pipe caused by thermal stress during operations. It can be the most realistic alternative to existing power plants in terms of costs and effective. There is some concern about FIV, but unlike the safety injection nozzle, it has no cross flow, and since the cause was identified, there is no reason for concern. In particular, if the design would have the curved section wrapped up with the thermal sleeve all the way to the top, it would be more effective.

In addition, in a power plant like KSNP where the main feedwater is separated from the auxiliary feedwater, when low-temperature low-flux auxiliary feedwater flows in, thermal stratification did not occur. Accordingly, new power plants would find it to be the best countermeasure against thermal stratification.

## REFERENCES

[1] United States Nuclear Regulatory Commission, Bulletin No. 88-08, June 22, 1988 "Thermal Stresses in Piping Connected to Reactor Coolant Systems"
[2] R. Magee, et. al., "J. M. Farley Unit 2 Engineering Evaluation of the Weld Joint Crack in the 6, April. 1988, "SI/RHR piping," WCAP-11789
[3] United States Nuclear Regulatory Commission, Bulletin No. 88-08, Supplement 3, April 11, 1989 "Thermal Stresses in Piping Connected to Reactor Coolant Systems"
[4] United States Nuclear Regulatory Commission, Bulletin No. 88-08, Supplement 2, Aug. 4, 1988 "Thermal Stresses in Piping Connected to Reactor Coolant Systems"
[5] Design Report No. Cenc-1940 Revision 01(Z-160-RA-C01-01), 1986, "Design Report For YONG-GWANG Nuclear Power Plant Units 3 And 4 Steam Generators".