*Transactions of the Korean Nuclear Society Spring Meeting*
*Gyeongju, Korea, May 29-30, 2008*

# Tube Plugging Criterion for No. 6 Heater of Ulchin NPP Unit 1 and 2 Based on Its Pressure and Temperature

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## 1. Introduction

Nowadays the nuclear power plants face a problem to reduce operating and maintaining costs to remain competitive without reducing safety. In order to resolve the problem, the maintenance of the secondary side of the plants becomes more important. The thermal efficiency of the power plant affects the power generation cost. As the power plants become older, it is inevitable for the materials of the components to be degraded.

The feed water heater is a kind of heat exchanger which raises the temperature of water supplied from the condenser. The heat source of high-pressure heaters is the extraction steam. If the tube wall cannot withstand the pressure, the feed water flowing inside the tube intrudes to shell side. This forces the thermal efficiency to be low.

The feedwater heater No. 6 of Ulchin NPP Unit 1 and 2 has the carbon steel (TU42C or SA-106 Gr. B in ASME Sec. II Part D) tubes. The characteristics of TU42C at high temperature are excellent. Especially, the strength of TU42C is not changed as temperature rise. However, the carbon steel tubes can be easily degraded due to the severe operating condition. Ulchin NPP Unit 1 and 2 has only two step high pressure heaters, No. 6 and 7. Therefore, the degradation of the high pressure heater tubes of the Units affects the thermal efficiency considerably. The inspection of balance-of-plant (BOP) heat exchanger tubes becomes important to reduce the cost by preventing the lowering thermal efficiency.

The wall thickness of heat exchanger tubes in nuclear power plants are selected to withstand system temperature, pressure, and corrosion. However, tubes have experienced leaks and failures and plugged based upon eddy current testing (ET) results. There are some problems for plugging the No. 6 heater tubes of Ulchin NPP Unit 1 and 2 since the criterion and its basis are not clearly described. For this reason, the criterion for the tube wall thickness of the No. 6 heater is addressed in order to operate the heat exchangers in nuclear power plant without trouble during the cycle.

Many codes and standards are referred to calculate the minimum wall thickness of the heat exchanger tube at a designing stage. However, the codes and standards related to show the tube plugging criteria may not exist currently. In this paper, a method to establish the tube plugging criteria of BOP heat exchangers, which is based on the temperature and pressure, is introduced and the tube plugging criterion for the No. 6 heater in Ulchin NPP Unit 1 and 2. This method relies on the similar plugging criteria used in the steam generator tubes. The tube plugging criteria of steam generator tube may be calculated following USNRC Reg. Guide 1.121.

## 2. Methods and Results

The USNRC Reg. Guide 1,121 based on the safety factors, which is the ratio of the applied stress and the strength of material, mentioned in ASME Sec. III. Using eddy current testing, it is not easy to know the shape of the cross-section of thinned tube. Fortunately, the stresses for the thinning ratio of the eccentric shape and uniform shape are not much different as shown by Fig. 1. In this paper, it is assumed that the thinned shape is uniform.

The steam generator tube plugging criteria depends on the USNRC Regulatory Guide 1.121, Bases for Plugging Degraded PWR Steam Generator Tubes. The Guide 1.121 says the following factors should be considered: 1) the minimum tube wall thickness needed for tubes with defects to sustain the imposed loading under normal and accident conditions, 2) between the inspections, the allowance of degradation and 3) the crack size permitted to meet the leakage limit allowed per the technical specification. The last one is not clearly needed for the tubes of the BOP heat exchangers.

In this paper the maximum stress due to the normal operation condition and thermal gradient is calculated. Then the stress with the safety factors mentioned in ASME Sec. III is compared with the yield strength and tensile strength of tube material at the appropriate temperatures in order to establish the required tube wall thickness. The material properties are given by ASME Sec. II Part D.

The requirements of the Guide for the accident condition are connected with two postulated accidents. They are the steam line break and loss of coolant accidents (LOCA). While the first one can be applicable to establish the tube plugging criteria of the BOP heat exchangers, the second one can not. For considering the first accident condition, the maximum stress due to the design pressure without shell-side pressure is calculated. Then the stress with the safety factors mentioned in ASME Sec. III is compared with the yield and tensile strength of tube material at the design temperatures in

order to establish the required tube wall thickness. The LOCA condition can not be considered directly to the heaters. The steam generator tubes are supposed to be pressed by outside pressure during the LOCA. Observing this fact, the similar condition is adopted for the tubes of heaters in this paper. The minimum wall thickness required for this condition is calculated using well-known formula.

The plugging criteria should include factors for increase in the flaw size between the inspections, which is normally 10% of the installed wall thickness, and for the NDT error, which is also 10% of the installed wall thickness. Including these factors, The tube plugging criteria of the LP feed water heaters of Ulchin NPP Unit 1 and 2 are established as in Table 3.

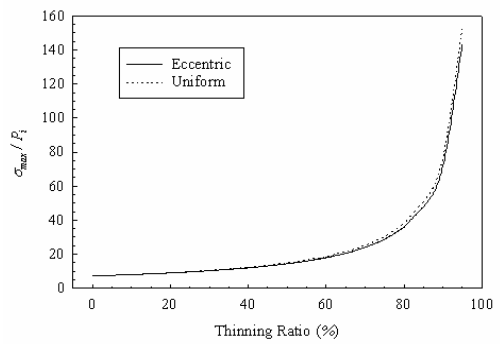


Fig.1. Stresses in the tube with the eccentric and uniform cross-section for the thinning ratio

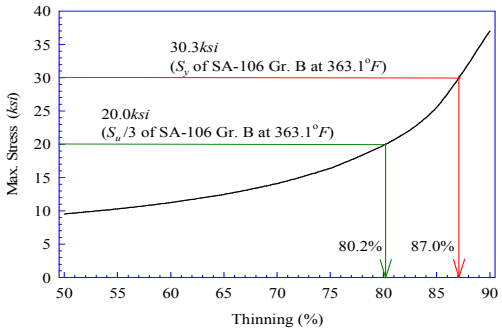


Fig. 2. Minimum wall thickness required for the heater No. 6 of Ulchin NPP Unit 1 & 2 at normal operation.

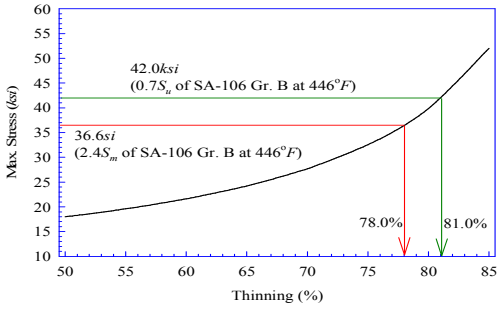


Fig. 3. Minimum wall thickness required for the heater No. 6 of Ulchin NPP Unit 1 & 2 at design condition.

Table 1: Material properties of TU42C

| Material Properties | Unit | TU42C |
|---|---|---|
| Young's Modulus | *psi* | $27.0\times10^{6}$ |
| Poisson's Ratio | · | 0.29 |
| Thm. Exp. Coeff. | $/^{o}F$ | $9.0\times10^{-6}$ |

Table 2: Temperatures of the Heater No. 6

| | Shell/ Tube | Loc | Temp ($/^{o}F$) | Temp I ($/^{o}F$) | Temp II ($/^{o}F$) |
|---|---|---|---|---|---|
| Feed Water Heater No. 6 | Shell | Inlet | 110.0 | 124.0 | 157.0 |
| | | Outlet | 138.0 | | |
| | Tube | Inlet | 250.0 | 190.0 | |
| | | Outlet | 130.0 | | |

Table 3. Plugging criteria for the HP heater No. 6 of Ulchin NPP Unit. 1 & 2

| Condition | Requirement | Criterion |
|---|---|---|
| Normal Operating | $\sigma_{max} \le S_y$ | 87% |
| | $3\sigma_{max} \le S_u$ | 80% |
| Design Condition | $\sigma_{max} \le 2.4S_m$ | 78% |
| | $\sigma_{max} \le 0.7S_u$ | 81% |
| Criterion | Calculated | 78% |

## 3. Conclusion

A method to establish the tube plugging criteria of BOP heat exchangers is introduced based on the USNRC Regulatory Guide 1.121. As an example, the tube plugging criterion for the heater No. 6 of Ulchin NPP Unit 1 and 2 is provided.

## REFERENCES

[1] A. C. Ugral, Stresses in Plates and Shells, McGraw Hills, Inc., 1981.
[2] S. P. Timoshenko and J. N. Goodier, Theory of Elasticity, McGraw Hills, Inc., 3rd Ed., 1970.
[3] C. H. Kent, Thermal Stresses in Thin-Walled Cylinders, Trans. Of ASME, Vol. 53, pp.167-180, 1931.
[4] E. U. Schlunder, Editor-in-chief, Heat Exchanger Design Handbook Vol. 4(Mechanical Design of Heat Exchanger), Hemisphere Publishing Corp., p. 25, 1983.
[5] K. Krzywosz, EPRI Condition Assessment and Inspection Program for Reducing Heat Exchanger Tube Leak, Proceedings of 6th EPRI Balance-of-Plant Heat Exchanger NDE Symposium, 2000.