Evaluation on Cooling Performance of Containment Fan Cooler during Design Basis Accident with Loss of Offsite Power for Kori 3&4 Nuclear Power Plant

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1. Introduction

The purpose of this study is to evaluate cooling performance of containment fan cooler units and to review a technical background related to Generic Letter 96-06[1].

In case that design basis accident (DBA) and loss of offsite power (LOOP) occurs, component cooling water (CCW) pumps cannot provide the cooling water source to fan cooler units while fan coolers coast down. Fan cooler units and CCW pumps are restarted by emergency diesel generator (EDG) operation and it takes about 30 seconds. In this scenario, before the EDG restarts and CCW flowrate is restored, heated air in the containment passes through coil of fan cooler units without cooling water source. In this situation, the boiling of water in the fan cooler units may occur. Restarting of CCW pumps may bring about condensation by injected cooling water and water hammer may occur. This thermal-hydraulic effect is sensitive to system configuration, i.e system pressure, containment pressure/temperature, EDG restarting time, etc.

In this study, the evaluation of containment fan cooler units was performed for Kori 3&4 nuclear power plant.

2. Analysis Methodology

To evaluate possibility of the boiling in fan cooler units, GOTHIC ver. 7.2a computer program was used. A simplified boiling analysis model was used to evaluate whether boiling of water occurred in the particular fan cooler units or not. Full modeling of the CCW system was used to estimate the boiling amount and boiling location if boiling occurred.

2.1 GOTHIC Code

GOTHIC (Generation of Thermal-Hydraulic Information for Containments) code[2] is a general purpose thermal-hydraulics computer program for design, licensing, safety analysis of nuclear power plant and other confinement buildings. Two-phase flow in coil tube could be predicted with built-in heat transfer model and built-in fan cooler component is provided.

2.2 Approach Method

To predict the possibility of boiling in a fan cooler units at the DBA and LOOP, base deck of GOTHIC was prepared using the data provided in Kori 3 & 4 Final Safety Analysis Report (FSAR)[3], piping and instrumentation drawing (P&ID) and isometric drawing (ISO DWG)[4]. To model fan coil, heat exchanger part model was used. And heat removal load in FSAR was compared with GOTHIC prediction for heat transfer model validation. As a result, modeling capability of GOTHIC code for fan cooler components showed reasonable prediction.

2.3 Heat Transfer Model

The detailed heat transfer model of fan cooler units is described below. Convection and condensation of heat transfer models were used outside of fan coil. For heat transfer between coil tube and fin, thin film was also considered. For analysis of inside coil, mixed natural convection was used. Nucleate pool boiling of water was considered.

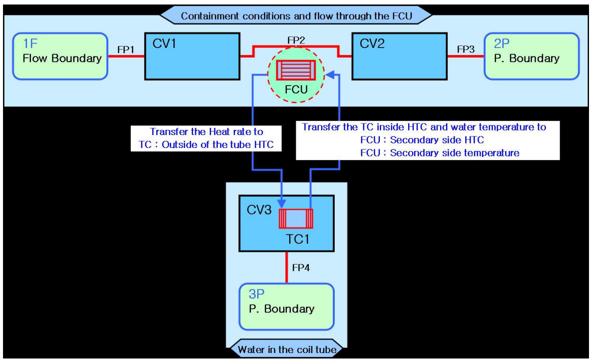

Figure 1. Heat transfer logic between fan coil and heat exchanger part model

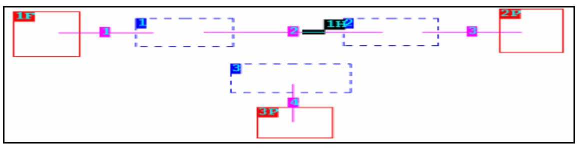
Figure 2. Analysis model of boiling possibility using the GOTHIC code (simplified model)

Figure 3 is nodalization for GOTHIC code to analyze boiling amount and location for whole CCW system. Six banks (#25~#30) were modeled.

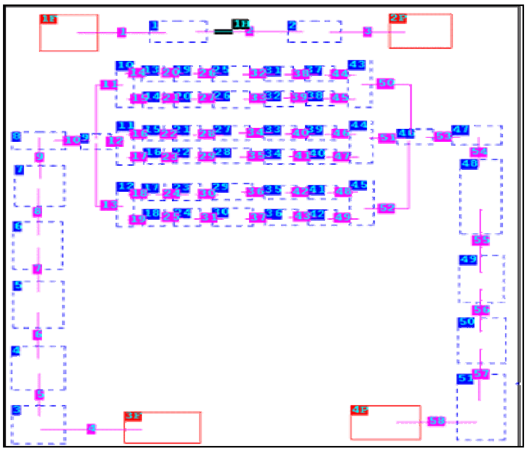

Figure 3. GOTHIC nodalization for boiling amount and location analysis (CCW system model)

Table 1 shows the list of sensitivity analysis. To analyze sensitivity for onset of boiling, various initial conditions, double ended hot leg break (DEHL) and main steam line break (MSLB), are used. The base case is based on the FSAR assumption.

Table 1. Spectrum cases for sensitivity analysis

Case	CCW Flowrate (GPM)	Fan Flowrate (CFM)	Containment Pressure (psia)	Containment Temp. (°F)	Pressure of CCW Pump (psia)	Nodalization
Base	175	5,500	DEHL	DEHL	34.7 @ EL.150.792 ft	Lumped model
Sensitive analysis						
A1(B1)	175	5,500	DEHL×1.02	DEHL×1.02	34.7 @ EL.150.792 ft	Lumped model
A2(B2)	175	5,500	DEHL×1.06	DEHL×1.06	34.7 @ EL.150.792 ft	Lumped model
A3(B3)	175	11,000	DEHL	DEHL	34.7 @ EL.150.79 ft	Lumped model
A4(B4)	175	5,500	54.2	264	34.7 @ EL.150.79 ft	Lumped model
A5(B5)	175	5,500	DEHL-PU	DEHL-PU	34.7 @ EL.150.79 ft	Lumped model
A6(B6)	175	5,500	MSLB	MSLB	34.7 @ EL.150.79 ft	Lumped model
A7(B7)	175	5,500	MSLB×1.02	MSLB×1.02	34.7 @ EL.150.79 ft	Lumped model
A8(B8)	175	5,500	MSLB×1.06	MSLB×1.06	34.7 @ EL.150.79 ft	Lumped model

3. Analysis Results

3.1 Simplified Model

Figure 4 shows possibility of the boiling in fan cooler units. As shown in the figure, onset of boiling in containment fan cooler coil was about 40 seconds.

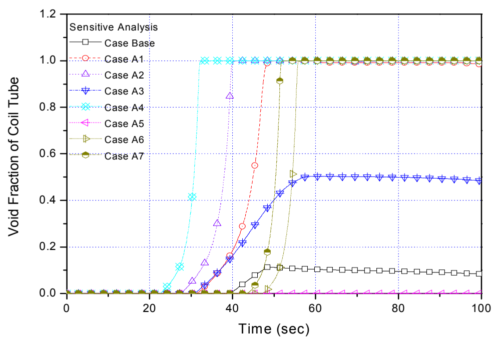

Figure 4. Possibility of boiling analysis (simplified model)

3.2 System Model

Figure 5 shows the results for void fraction of fan cooler unit coil. For base case, onset of boiling was about 40 seconds and boiling in upper coil bank(#25) occurred earlier than in lower coil bank(#26). However, the delivery of rated flow to fan cooler units was about 27 seconds. That means the cooling water is fully provided before onset of boiling in containment fan cooler coil.

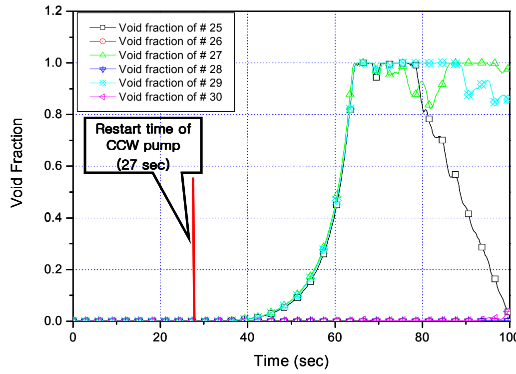

Figure 5. Possibility of boiling analysis(CCW system model)

4. Conclusion

In this study, the evaluation on cooling performance of containment fan cooler was performed using Gothic code. A simplified model for the probability of boiling in fan cooler units and CCW system model for estimating of the boiling amount and boiling location were used. Onset of boiling in containment fan cooler coil was about 40 seconds. As a result of the boiling analysis, boiling of water does not occur before CCW pumps restart and water hammer does not occur during DBA and LOOP for Kori 3&4 nuclear power plant.

REFERENCES

[1] USNRC, Generic Letter 96-06 "Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions", September 30, 1996.

[2] T. L. George et al., "GOTHIC Containment Analysis Package Technical Manual. Version 7.2a", NAI 8907-02 Rev 17, Numerical Applications, Inc., Washington, USA, Jan. 2006.

[3] Final Safety Analysis Report for Kori Unit 3, 4, Korea Electric Power Corporation

[4] KORI Unit 3,4 P&ID, ISO DWG Korea Electric Power Corporation.