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Assessment on the Reactor Containment Cooling Capability of Kori Unit 1 Under LOCA Conditions with Loss of Offsite Power

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1. Introduction

The fan cooler system is designed to remove heat from containment under postulated accident conditions. During a postulated LOCA concurrent with a Loss of Offsite Power (LOOP), the Component Cooling Water (CCW) pumps that supply cooling water to the fan cooler and the fan that supplies containment air to the fan cooler will temporarily lose power. Then, the high temperature steam in the containment atmosphere will pass over the fan cooler tubing without forced cooling water flow. In that case, boiling may occur in the fan cooler tubes causing steam bubbles to form and pass into the attached CCW piping creating steam voids. Prior to the CCW pumps restart, the presence of steam and subcooled water can induce the potential for water hammer. As the CCW pumps restart, the accumulated steam condenses and the pumped water can produce a water hammer when the void closes. The hydrodynamic loads caused by such a water hammer event could challenge the integrity and the function of the fan cooler and associated CCW system.

With respect to this phenomena, the United States Nuclear Regulatory Commission (USNRC) issued the Generic Letter (GL) 96-06, which requests an assessment of the possibility of boiling and water hammer in the cooling water system [1].

The objectives of this study are to develop a analysis method for predicting the thermal hydraulic status of containment fan cooler and then to assess the containment fan cooler of Kori Unit 1 using the developed model under a LOCA with LOOP.

2. Analysis Method

The GOTHIC 6.1b [2] was used to analyze thermal hydraulic response of CCW in containment fan cooler of Kori Unit 1. Based on the review of fan cooler system design, an analysis model which predicts the extent and location of resulting steam region as well as the likelihood of boiling in the tubes was developed using GOTHIC 6.1b general features and its own component model.

2.1. Review of fan cooler system design of Kori Unit 1

Kori Unit 1 power plant has 4 fan cooler units, which were located at 86 ft level in containment. Each fan cooler unit contains 2 coil banks and each coil bank is consists of 2 cooling tube assembly [3].

The CCW system that plays a role of transferring heat from containment air to the seawater is a closed-loop system. It is composed of pumps, heat exchangers, surge tanks, chemical mixing pots, piping and valves. The surge tanks are located at 70 ft level in auxiliary building and are pressurized to 20 psig by nitrogen gas.

2.2. Input and analysis model

Fig. 1 is a schematic of the GOTHIC model of the fan cooler unit and corresponding CCW pipe. Nodes 20 to 23 represent the cooling tubes. Nodes 16 to 19 and 24 to 27 are the inlet and outlet header on the coil tubes respectively. Nodes 1 to 15 and 28 to 42 represent the inlet and outlet piping inside containment, respectively. And nodes 43 and 44 represent containment atmosphere.

Geometrical information was obtained from the cooler design specifications and piping layout drawings.

The initial pressure boundary conditions were based on the static head relative to the surge tank and remain constant until the CCW pump restarts at 30 seconds.

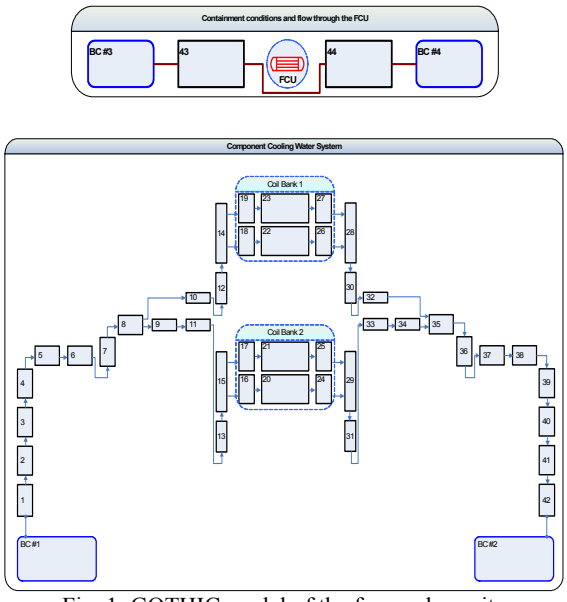

Fig. 1. GOTHIC model of the fan cooler unit

2.3. Analysis conditions

The analysis conditions are summarized in Table 1. The temperature and pressure of containment in base case (case A1) are based on those of Double Ended Hot Leg (DEHL) LOCA which is the design basis accident, in which conventional 6 % conservatism was considered.

Table 1 Analysis conditions (/coil banks)

Case	Fan flow (CFM)	CTMT T (°F)	CTMT P (psia)	CCW P (psia)
A1	15,500[1)]	DEHL·1.06	DEHL·1.06	34.7 at EL. 70 ft
A2	15,500	254.7[3)]	50.1[3)]	34.7 at EL. 70 ft
A3	29,000[2)]	DEHL	DEHL	34.7 at EL. 70 ft
A4	15,500	DEHL	DEHL	34.7 at EL. 70 ft
A5	15,500	270[4)]	57.7[4)]	34.7 at EL. 70 ft

[1)]Fan flow at accident operation condition
[2)]Fan flow at normal operation condition
[3)]Peak values on DEHL LOCA
[4)]Design values on Kori Unit 1 containment

3. Analysis Results

In order to verify the developed model, normal and accident operation conditions of fan cooler system are simulated with the model and their results are compared with those of the Final Safety Analysis Report (FSAR) data. As shown in Table 2, the calculated results are well agreed with the FSAR data.

Table 2. Verification analysis results

	FSAR	GOTHIC
Exit temp. of containment air (NO)	88 °F	88.2 °F
Exit temp. of CCW (NO)	89 °F	89.4 °F
Exit temp. of CCW (AO)	185 °F	184.6 °F
NO : Normal operation AO : Accident operation		

Fig. 2 and 3 represent the void fraction of A1 analysis, which is predicted inside regions of coil tubes and piping respectively. Voiding in the regions inside coil tubes begins about 26 second after the accident but voiding in the inlet and outlet piping does not occur.

In the cases A2 to A4, the CCW inside the fan cooler tubes does not boil because of the surge tank pressure. This means that although the containment conditions maintain the peak temperature and pressure of DBA, CCW does not boil during transient time interval and therefore the integrity of fan cooler system is not challenged by the water hammer event.

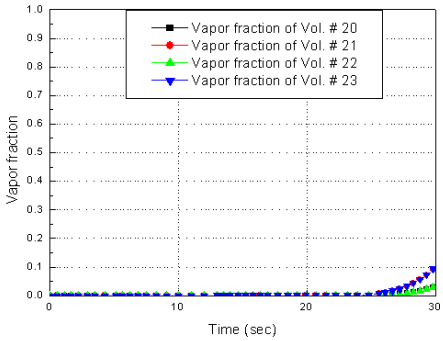

Fig. 2. Analysis results (Case A1, coil tubes)

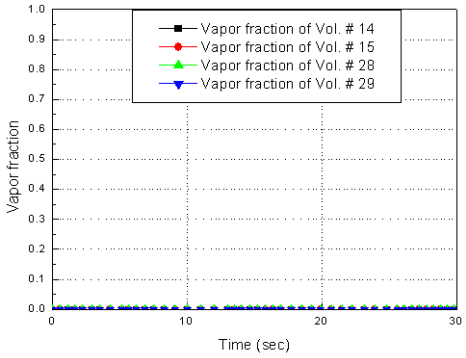

Fig. 3. Analysis results (Case A1, piping)

The case A5 is the most conservative analysis in order to examine the boiling behavior of cooling water inside fan cooler unit. The results are depicted in Fig. 4. Most of the piping is filled with steam as the water boils in the regions of coil tubes.

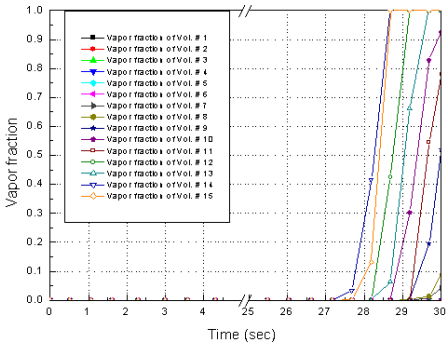

Fig. 4. Analysis results (Case A5, inlet piping)

4. Conclusion

To analyze the thermal hydraulic response of containment fan cooler system, analysis model was developed with GOTHIC 6.1b code. And then Kori Unit 1 fan cooler system was assessed under DBA with LOOP conditions.

The analysis results show that voiding in the regions inside of the cooling tubes occurs but the extent is not distinctive. And inlet and outlet piping regions are full of the cooling water during the transient interval. Based on these results, it can be concluded that the fan cooler system of Kori Unit 1 will maintain the integrity under DBA coincident concurrent with LOOP conditions.

REFERENCES

[1] USNRC, Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions, 1996.
[2] T.L.George et al., GOTHIC Containment Analysis Package Technical Manual-Version 6.1b, NAI, 2001.
[3] Kori Unit 1, Final Safety Analysis Report, KHNP.