The Effect of Fan Cooler Operating Units on the Containment Mass and Energy Release and Integrity for the Main Steam Line Break Event for APR 1400

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1. Introduction

Generally, the local Pressure and Temperature (P/T) increase inside containment can threaten the integrity of containment structure and engineering safety features. The Reactor Containment Fan Cooler (RCFC) plays an important role in maintaining the containment condition on the normal operation.

In the event of Main Steam Line Break (MSLB), the Mass and Energy (M/E) released to the containment can be affected by the atmospheric conditions of the containment. Operating units of the RCFC will affect the containment back pressure and M/E release.

In this study, the evaluation of MSLB M/E release analysis and resultant containment the P/T depending on operating units of the RCFC are performed for APR 1400.

2. Overview

2.1 MSLB Overview

The MSLB is the event that the secondary steam line is broken and the steam is discharged into the containment. The High Containment Pressure (HCP) trip signal is generated because of the containment pressurization by steam and the containment isolation system is performed by HCP. The Main Steam Isolation Valves (MSIVs) and Main Feedwater Isolation Valves (MFIVs) are closed following the Main Steam Isolation Signal (MSIS) by HCP. Since the liquid inventory in the affected steam generator flash into the steam and is discharged to the containment atmosphere, the affected SG level decreases.

2.2 RCFC Design and Operation

In the containment, 4 RCFCs are located in the top of building. These 4 RCFCs are arranged in two pairs, with one RCFC of each pair normally operating. Each cooler has a cooling coil assembly installed on three sides of the RCFC unit, a fan with a two-speed motor. It is designed to remove heat and water vapor and to provide proper mixing of the air for achieving a uniform containment atmosphere. On normal operation, 2 RCFCs are operated and up to 4 RCFCs can be operated.

RCFC is non-safety system. So it is not required to operate after a MSLB event. However, manual provisions are made to operate the RCFC from the emergency power supply.

3. Result and Discussion

3.1 Analysis Method

The SGN-III program [1] is used to evaluate the released M/E and the CONTEMPT-LT/028 program [2] is used to calculate the P/T during the MSLB. The SGN-III program makes M/E data through thermodynamic system analysis and the CONTEMPT-LT calculates the containment the P/T using the M/E data produced by SGN-III. In terms of M/E release, the conservative methodology is applied to the analysis and the limiting initial conditions are selected to maximize the M/E release.

Table I shows the initial conditions used to perform M/E analysis. The primary pressure and core inlet temperature are assumed maximum value to transfer the energy to affected steam generator. The steam generator level is assumed maximum value to have more energy. The break size is selected on sum of two steam line area to release the maximum M/E.

Table II shows the initial conditions used to perform P/T analysis. The P/T analysis is carried out on the limiting containment initial conditions to increase containment P/T. The containment pressure and temperature are assumed maximum value and the containment free volume is minimum value to increase the P/T. The RCFC is not required since it decreases the containment P/T.

The sensitivity study on MSLB is performed on the 102% and 75% power levels which are selected the limiting cases for the peak pressure and temperature of the containment, respectively.

Since the RCFC is non-safety class component, its safety function is not credible on the peak P/T analysis during the MSLB. However, in terms of M/E release, the operation of RCFC on the event before containment isolation is intended to increase the M/E release because it decreases the back pressure.

Figure 1 shows the normalized RCFC cooling capacity data. It varies depending on the temperature of the containment atmosphere and the operating units. The M/E release is evaluated with the same initial conditions except changing RCFC cooling capacity.

Table I: Limiting initial condition on M/E analysis

Parameter	Conservative Value
Power Level	102%, 75%
Primary Pressure	Maximum
Core Flow Rate	Minimum
Core Inlet Temperature	Maximum
Steam Generator Level	Maximum
Break Size*	9.134 ft^2 (steam line size)

*Choking status will be formed at the steam generator nozzle.

Table II: Limiting initial condition on P/T analysis

Parameter	Conservative Value
Containment Pressure	Maximum
Containment Temperature	Maximum
Containment Humidity	Minimum
Containment Free Volume	Minimum
RCFC operation	N/A

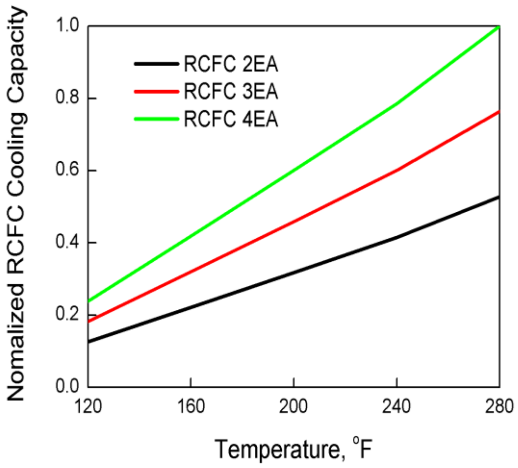

Fig. 1. RCFC cooling capacity

3.2 Results of M/E Analysis

Figures 2 and 3 show the break mass and energy flow by changing the RCFC`s operating units during the MSLB (102, 75% power level).

Table III shows the event chronology for 75% power level on 2 RCFCs operation. At the beginning, the RCFC is operating and stopped by containment isolation at about sixty seconds. The reactor trip is occurred by HCP and turbine stop valve is closed. The steam generators are isolated by MSIS. The break mass flow rapidly decreases as the unaffected steam generator is isolated. The break flow continues to decrease due to the continuous pressure drop of the affected SG and has a constant trend as the affected steam generator pressure is similar with containment back pressure.

Figures 4 and 5 present the back pressure for 75% and 102% power level. The break mass flow is determined by the pressure difference between the affected steam generator and containment back pressure. In figures 2 and 3, the break flow considering the 4 RCFCs operation (green line) shows slightly higher value than the others, because it reduces the more containment pressurization by its higher cooling capacity and expands the pressure difference. In figures 4 and 5, the 2 RCFCs back pressure (black line) has higher value than other because the 4 RCFCs more remove heat and depressurize the containment during RCFC operation (60 seconds).

In figure 2, the break mass flow differences are occured at around 440 seconds although the RCFC operated in sixty seconds. Before the 440 seconds, critical flow (Moody critical flow [3]) is formed because of the large difference between the affected steam generator pressure and back pressure. Thus, the black and red line have same results. However, the green line has different value with other in the early time. The black line and red line indicate that the reactor trip is occurred by HCP at the same time, but the green line have delayed reactor trip time as the 4 RCFCs further decrease the pressure of the containment. Thus, it has other value although critical flow is formed.

After that, the affected steam generator pressure continuously decreases and the critical flow cannot be built following the small pressure difference. At this time, the break mass flow is calculated by Darcy equation [1] in the subcritical phase following the pressure difference. As a result, the all cases show the different M/E release and it may affect the containment the P/T.

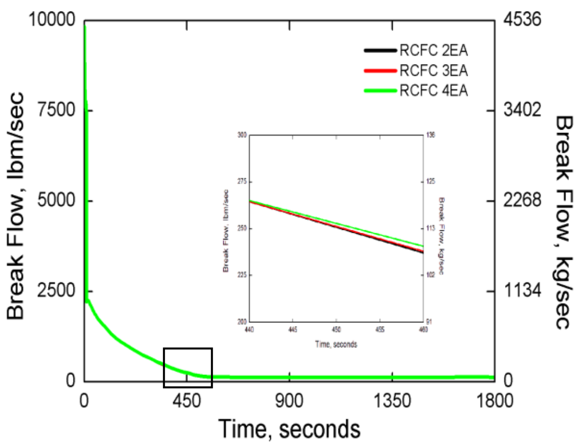

Fig. 2. Break flow at 75% Power level

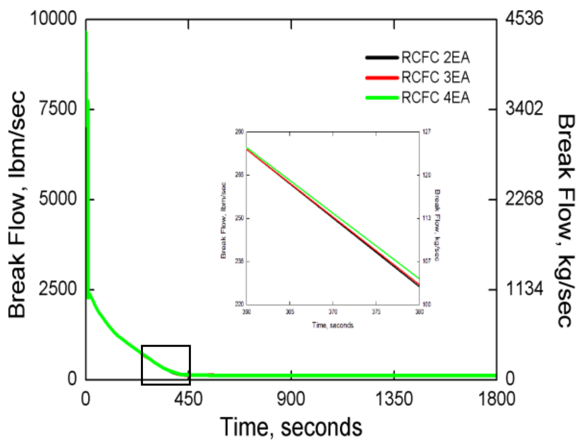

Fig. 3. Break flow at 102% Power level

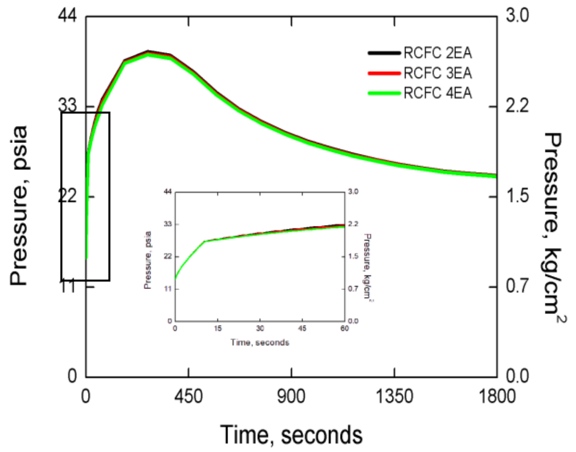

Fig. 4. Back pressure at 75% Power level

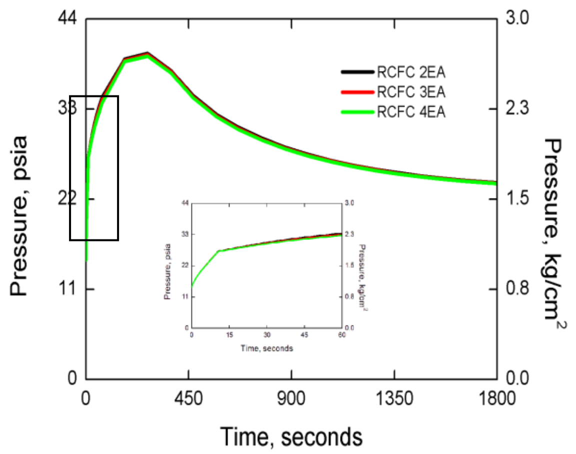

Fig. 5. Back pressure at 102% Power level

Table III: Event chronology on 75% power level and 2 RCFCs

Time (sec)	Event
0.0	Break Occurs
3.87	Containment Pressure Reaches Reactor Trip Analysis Setpoint Containment Pressure Reaches Main Steam Isolation Signal (MSIS) Analysis Setpoint
5.02	High Containment Pressure Reactor Trip Signal
5.12	Reactor Trip Breakers Open Turbine Admission Valves Closed
10.22	Main Steam Isolation Valves Closed
60.0	RCFCs isolated
125.75	Start Containment Spray Injection Peak Containment Temperature, (336.18 °F)
340.0	Peak Containment Pressure, (62.909 psia)
1800.0	End of Blowdown

3.3 Results of the P/T Analysis

Figures 6,7,8 and 9 show the resultant P/T of containment atmosphere during the MSLB. In terms of containment P/T analysis, the RCFC is not required because it cool down the containment. Thus, the containment P/T for sensitivity study depend only on released M/E. The peak pressure was found at 75% power level and the peak temperature was calculated at 102% power level. The P/T suddenly increase due to the steam from the break at the beginning of the event. And then, the containment pressure slowly increases due to the M/E release decreased by closure of MSIVs following MSIS. The containment spray system is activated around 126 seconds by High-High Containment Pressure (HHCP) signal to mitigate the high containment P/T. In respect to containment temperature, the spray system has significant effect for decreasing the temperature, the temperature drastically drops after it is activated. Thus, the peak temperature occurs immediately, right before the spray operation. Consequently, the containment pressure behavior considering 2 RCFCs (black line) shows the lower value than the behavior considering 4 RCFCs (green line), but the difference is very small.

Table IV summarizes results of the peak P/T for all cases. At the same core power such as each 102% and 75% power levels, it is confirmed that the peak P/T of the containment relevant to RCFC operating unit is almost equal and its value is below the design value of containment (60 psig [4]).

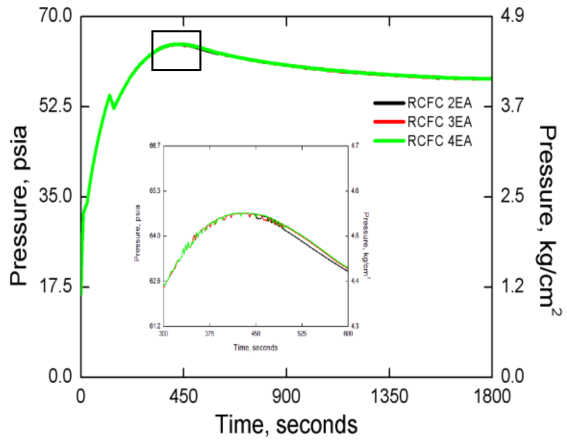

Fig. 6. Containment pressure at 75% power level

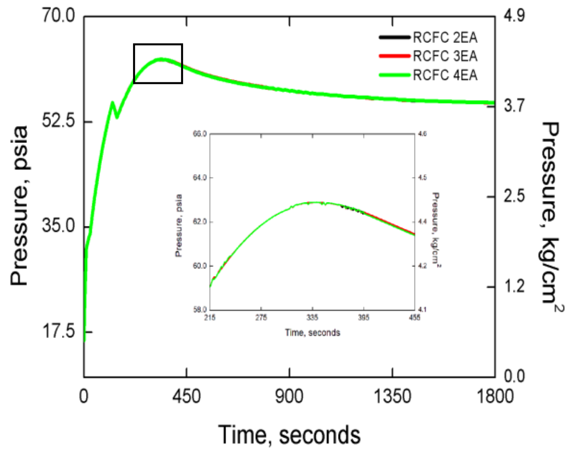

Fig. 7. Containment pressure at 102% power level

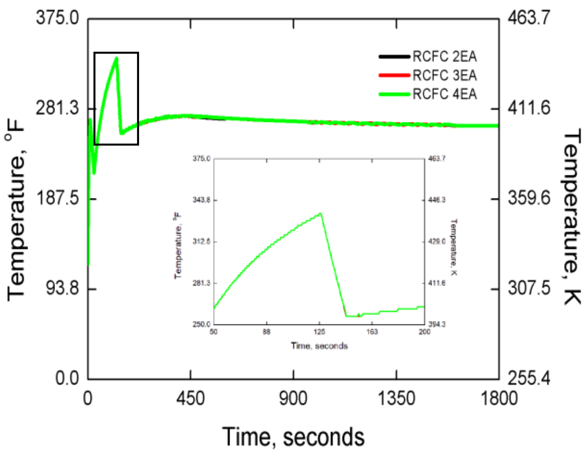

Fig. 8. Containment temperature at 75% power level

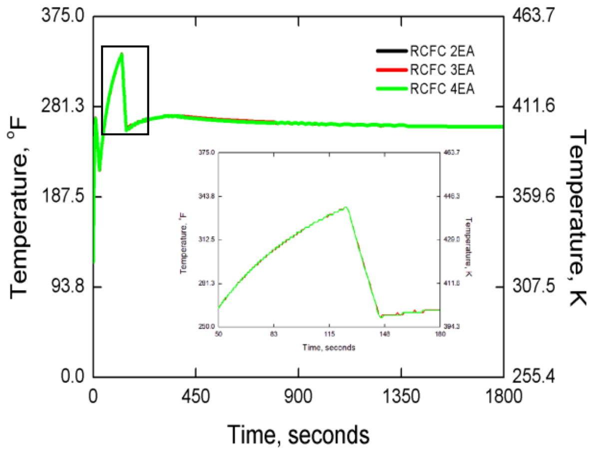

Fig. 9. Containment temperature at 102% power level

Table IV: Containment P/T

Parameter	102% Power			75% Power		
RCFC Operation Units	2EA	3EA	4EA	2EA	3EA	4EA
Peak Pressure (psia)	62.909	62.909	62.914	64.673	64.673	64.683
Peak Temperature (°F)	336.18	336.18	336.08	334.05	334.05	334.04

4. Conclusions

From the results of the evaluation of the RCFC effect on the M/E release and resultant the P/T analysis for the MSLB for APR 1400, the M/E release are minor differences and the resultant peak P/T has negligible differences. Therefore, it is clearly confirmed that the effect of the number of RCFC operation units on MSLB event is insignificant and the integrity of containment design is sufficiently satisfied with standard safety.

REFERENCES

[1] Description of the SGNPV Digital Computer Code Used in Developing Main Steam Line Break Mass/Energy Release Data for Containment Analysis, SGNIII-MOD1," Nuclear Power Systems, C.E. Inc., February 1988.
[2] CONTEMPT-LT/028, "A Computer Program for Prediction of Containment Pressure and Temperature Response to a LOCA," Idaho National Engineering Laboratory, February 1979.
[3] F. J. Moody, "Maximum Flow Rate of a Sing1e Component, Two-Phase Mixture", Trans, ASME, Series C. Vol. 87, February 1965, P. 134.
[4] "Shin-kori Nuclear Power Plant Unit No.3 and 4, Final Safety Analysis Report (FSAR)"

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