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Thermal Analysis for Environmental Qualification of Kori Nuclear power plant unit 3 and 4

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1. Introduction

This paper shows the temperature profiles of safety-related electrical equipment exposed to MSLB inside containment. It must be demonstrated that the LOCA qualification conditions exceed or are equivalent to the maximum calculated MSLB conditions. COPATTA as Bechtel's vendor code is used for the containment pressure and temperature prediction in power uprating project for Kori 3,4 and Yonggwang 1,2 nuclear power plants(NPPs). However, CONTEMPT-LT/028 is used for calculating the containment pressure and temperatures in equipment qualification project for the same NPPs. Power uprating code that is, COPATTA benchmarking study performed in six equipments at saturation temperature and surface temperature. Specially, thermal analysis carefully investigate that view point environmental qualification and NUREG-0588 be mentioned in regard to safety-related heat sink it boundary condition or geometry information.

2. Methodology

2.1 Heat Transfer Coefficient

For heat transfer coefficient to the heat sinks in EQ analysis, the Tagami condensing heat transfer correlation should be used for a LOCA with the maximum heat transfer rate determined at the time of peak pressure or the end of primary system blowdown. A rapid transition to a natural convection, condensing heat transfer correlation should follow. The Uchida heat transfer correlation should be used at all other times when not in the condensing heat transfer mode for both LOCAs and MSLB accidents. The application of these correlations should be as follows:

- Condensing heat transfer
  $q/A = h_{cond}(T_s - T_w)$

Where, q/A = the surface heat flux
h_{cond} = the condensing heat transfer coeffient
T_s = the steam saturation temperature
T_w = surface temperature of the heat sink

- Convective heat transfer
  $q/A = h_c(T_v - T_w)$

Where, h_c = convective heat transfer coefficient
T_v = the bulk vapor temperature

2.2 Heat Sink Condensation

When the containment atmosphere is at or below the saturation temperature, all condensate formed on the heat sinks should be transferred directly to the sump. When the atmosphere is superheated, a maximum of 8 percent of the condensate may be assumed to remain in the vapor region. The condensed mass should be calculated as follows;

- $M_{cond} = X \cdot q/(h_v - h_L)$

where, M_{cond} = mass condensation rate
X = mass condensation fraction (0.92)
q = surface heat transfer rate
h_v = enthalpy of the superheated steam
h_L = enthalpy of the liquid condensate entering the sump region

2.3 Thermal Analysis

According to NUREG-0588, where qualification has been completed but only LOCA conditions were considered, it must be demonstrated that the LOCA qualification conditions exceed or are equivalent to the maximum calculated MSLB conditions. (a) Calculate the peak temperature envelope from an MSLB. (b) The peak surface temperature of the component to be qualified does not exceed the LOCA qualification temperature. (c) If the calculated surface temperature exceeds the qualification temperature, re-qualification testing be performed to appropriate margins, or qualified physical protection be provided to assure that the surface temperature will not exceed the actual qualification temperature. Component thermal analysis may be performed to justify environmental qualification test conditions that are found to be less than those calculated during the containment environmental response calculation. The heat transfer rate to component should be calculated as follows;

- Condensing heat transfer rate
  $q/A = h_{cond}(T_s - T_w)$

where, q/A = component surface heat flux
h_{cond} = condensing heat transfer coefficient is equal to the larger of 4 × Tagami correlation or 4 × Uchida correlation
T_s = saturation temperature
T_w = component surface temperature

- Convective heat transfer

A convective heat transfer coefficient should be used when the condensing heat flux is calculated to be less than the convective heat flux. During the blowdown period, a forced convection heat transfer correlation should be used, as follows;

$$Nu = C(\mathrm{Re})^n$$

Specially, empirical constants, C is dependent on geometry and Reynolds number. This analysis use Churchill and Bernstein correlation [2] for cylindrical geometry as follows;

$$\overline{Nu_D} = 0.3 + \frac{0.62\,\mathrm{Re}_D^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4/\mathrm{Pr})^{2/3}\right]^{1/4}} \qquad ;\ \mathrm{Re}_D < 10^4$$

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$$\overline{Nu_D} = 0.3 + \frac{0.62\,\mathrm{Re}_D^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4/\mathrm{Pr})^{2/3}\right]^{1/4}}\left[1+\left(\frac{\mathrm{Re}_D}{282000}\right)^{5/8}\right]^{4/5} \qquad ;\ 4\times10^5 < \mathrm{Re}_D < 5\times10^6$$

3. Results

Six heat conductors, fan cooler, 3 insulated power cable, valve operator motor and flued head(penetration) representing safety component are additionally considered for thermal analysis. Figure 1, 2 shows COPATTA benchmarking evaluation for fan cooler and power cable. As seen in Figure 1 and 2, CONTEMPT predicts the similar results with COPATTA.

Figure 3, 4 show surface temperatures of related-safety equipment from current analysis. In current analysis, the mass and energy releases for MSLB are regenerated by considering the entrainment effect. As seen in Figure 3 and 4, the surface temperatures in this analysis are lower than those in power uprating analysis. This results from the entrainment effect mainly.

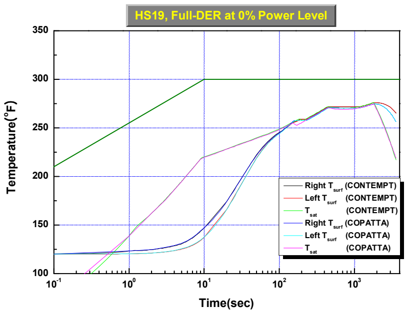

Figure 1. Comparison of surface and saturation temperature (fan cooler, Full Double Ended Rupture, 0% power level)

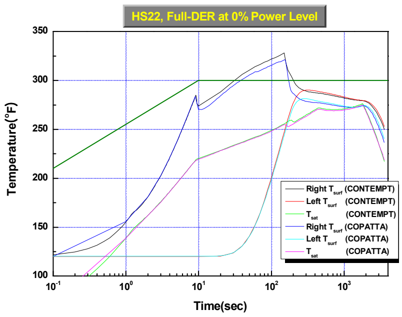

Figure 2. Comparison of surface and saturation temperature (insulated power cable, Full Double Ended Rupture, 0% power level)

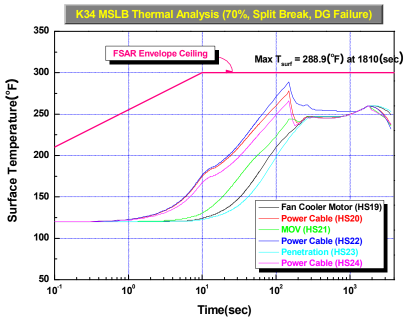

Figure 3. Surface temperature for power level 70% (CONTEMPT, Split break, 1 train Diesel Generator failure)

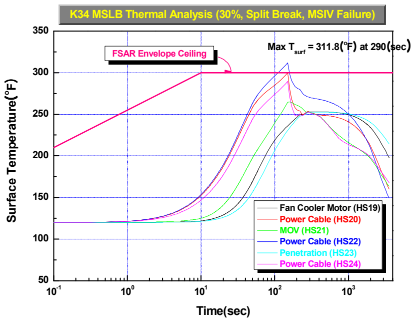

Figure 4. Surface temperature for power level 30% (CONTEMPT, Split break, 1 train Main Steam Isolation Valve failure)

4. Conclusions

In this study, thermal analysis methodology for CONTEMPT is setup. CONTEMPT is modified to be able to simulate the forced convection to meet NUREG-0588. Benchmarking evaluation show CONTEMPT to work well.

Finally, LOCA EQ Envelope is confirmed to be also applied to MSLB.

REFERENCES

[1] NUREG-0588, Appendix B, Rev.1, “Model for Environmental Qualification for LOCA and MSLB inside PWR and BWR Dry Type of Containment”.
[2] Anthony F. Mills, Heat and mass transfer, IRWIN, p.287, 1995