LBLOCA Analyses for 4.5% Power Uprating using KREM

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1. Introduction

KREM [1] is a best-estimate LBLOCA (Large Break Loss-Of-Coolant Accident) evaluation model, which was developed to comply with Regulatory Guide 1.157, 10 CFR 50.46 and their equivalents in Korea. A licensing LBLOCA analysis using KREM was performed for the first time to assess the ECCS (Emergency Core Cooling System) performance of Kori-3/4 and Yonggwang-1/2 under the condition of power uprating by 4.5%.

A break spectrum analysis for 100%, 80%, and 60% DECLG (Double Ended Cold Leg Guillotine) breaks was performed and eighty SRS (Simple Random Sampling) calculations were conducted on the limiting break size.

Another analysis with the same procedure was done for the current operating conditions to evaluate the effect of 4.5% power uprating including 1.5% TDF (Thermal Design Flow) reduction on LBLOCA consequences.

2. Methods and Results

2.1 Methods

KREM is composed of 2 computer codes, RELAP5/MOD3.1/K and CONTEMPT4/MOD5. The RELAP5/MOD3.1/K code analyzes the thermal-hydraulic transient in the RCS including the thermal transient of the fuel rod. The CONTEMPT4/MOD5 code is used to calculate the containment pressure transient which is used as a boundary condition for RELAP5/MOD3.1/K calculation.

As KREM is a best estimate evaluation model, it is necessary to quantify the overall calculation uncertainties. KREM adopted non-parametric statistics for this purpose, in which the confidence level increases as the number of sampling calculations is increased. Twenty-eight uncertainty parameters are selected and eighty input vectors are generated based on the random sampling of the parameters. According to non-parametric statistics, the maximum peak clad temperature, the maximum peak local oxidation, and the maximum core-wide oxidation from eighty SRS calculations are equal to or greater than the ones of 95% probability with 95% confidence level.

Note that not only the number of uncertainty parameters but also the number of SRS calculations was increased from those used in the calculations for the licensing of the evaluation model to accommodate the latest technical findings.

2.2 Calculations for the Uprated Conditions

First of all, calculations for the break sizes equal to 100%, 80%, and 60% of DECLG were conducted. Table 1 lists important input parameters and initial conditions used in the calculations. These input parameters and initial conditions, other than the RCS flow rate, represent the nominal or best estimate conditions of the RCS and associated safety system equipment at the time when the LBLOCA occurs. The RCS flow in the table is the TDF that has been 1.5% reduced from the current value. The input parameters and initial conditions related to the containment were selected to make the containment transient pressure conservatively underestimated.

Table 1. Input parameters and initial conditions

Parameters	After Uprating	Before Uprating
Core power (MWt)	2,900	2,775
Peak linear power (kW/ft)	13.06	12.50
Total peaking factor, F_q^T	2.25	
Control rod drop time (secs)	3.3	
Power shape	Top-skewed	
Fuel assembly array	17×17 RFA	
Acc. water volume (ft^3/each)	1,020	
Acc. gas pressure (psia)	656	
Initial loop flow (gpm)	94,200	95,600
Vessel inlet temperature (˚F)	553.0	556.5
Vessel outlet temperature (˚F)	625.2	620.5
RCS pressure (psia)	2,250	
Steam pressure (psia)	912	950
SG tube plugging level (%)	5 %	

The calculations resulted in peak clad temperatures of 1,746 ˚F, 1,619 ˚F, and 1,511 ˚F for 100%, 80%, and 60% DECLG breaks, respectively. Based on the results, eighty SRS calculations were conducted assuming the break size equal to 100% of DECLG.

Twenty-eight uncertainty parameters were randomly sampled within their 99.9% upper and lower limits to make eighty calculation input vectors. The peak clad temperatures from the SRS calculations are presented in Figure 1. As seen in the figure, the maximum peak clad temperature was calculated to be 1,950 ˚F. Note that RELAP5/MOD3.1/K has some scale biases in the prediction of the ECC water bypass and the steam binding phenomena. However, the evaluation of scale biases could not change the maximum peak clad temperature as the maximum peak clad temperature occurred in early blowdown. Thus, even with 18 ˚F addition to take into account the time step and plot frequency uncertainties, the maximum peak clad temperature is well below the Acceptance Criteria limit of 2,200 ˚F.

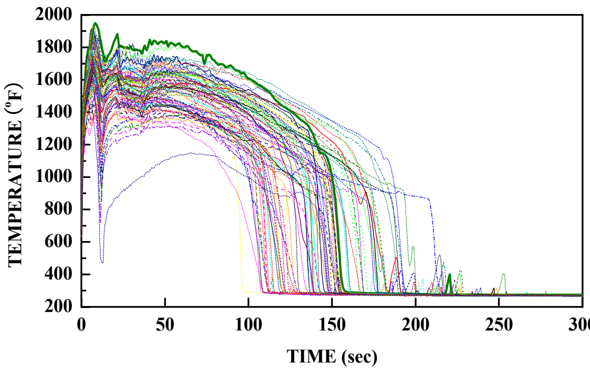

Figure 1. PCTs from eighty SRS calculations

2.3 Calculations for the Current Operating Conditions

Though it is not a licensing requirement, calculations for the current operating conditions were conducted to evaluate the effect of 4.5% power uprating. Just like the case for the uprated conditions, a break spectrum analysis was done first to find out the limiting break size. The initial conditions for the analysis are presented also in Table 1. As seen in the table, the core power and the RCS flow were returned to the currently licensed values. Vessel inlet/outlet temperatures and SG secondary conditions were also changed correspondingly. Not to be surprised, the highest peak clad temperature occurred again in case of a 100% DECLG break. Thus, eighty SRS calculations were performed assuming the 100% DECLG break.

Among the twenty-eight uncertainty parameters, only one parameter, the RCP K-factor, has different upper and lower limits from those for the uprated conditions. After changing the upper and lower limits of RCP K-factor to lower values corresponding to the current RCS flow, a new random sampling of twenty eight uncertainty parameters was done to make eighty calculation input vectors. The maximum peak clad temperature from the SRS calculations, which is compared with that for the uprated conditions in Figure 2, is 1,865 ˚F. From this, the effect of 4.5% power uprating including 1.5% TDF reduction can be estimated to be about 85 ˚F.

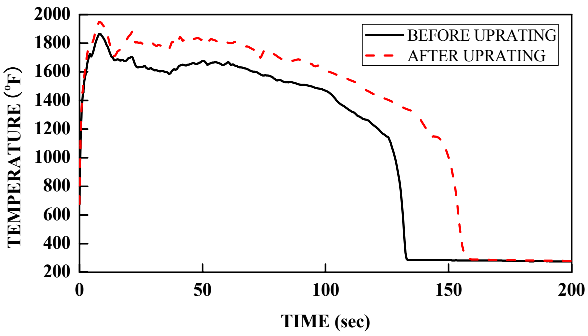

Figure 2 Maximum peak clad temperature comparison

3. Conclusion

A LBLOCA analysis for Kori-3/4 and Yonggwang-1/2 power uprating was conducted using KREM. A break spectrum analysis was performed and the 100% DECLG break was determined to be limiting. eighty SRS calculations assuming the limiting break size were conducted and resulted in the maximum peak clad temperature of 1,950 ˚F. Thus, it is concluded that the ECCS performance of Kori-3/4 and Yonggwang-1/2 has a sufficient margin within the framework of LBLOCA analyses.

The break spectrum analysis and eighty SRS calculations were also conducted for the current operating conditions. From the break spectrum analysis, it was found that the limiting break does not change due to the power uprating. From the SRS calculations, the maximum peak clad temperature of 1,865 ˚F was obtained. Comparing it to the maximum peak clad temperature for the uprated conditions, the effect of 4.5% power uprating including 1.5% TDF reduction was estimated to be about 80 ˚F

REFERENCES

[1] Topical Report for the Realistic Evaluation of Emergency Core Cooling System, TR-KHNP-0002, Rev.0, 2002.