*Transactions of the Korean Nuclear Society Spring Meeting*
*Jeju, Korea, May 22, 2009*

# The LBLOCA Analysis for APR1400 Power Plants Applying KREM with RELAP5/MOD3.3 Code

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## 1. Introduction

The applicability of KREM methodologies with safety analysis code RELAP5/MOD3.3 is examined and the best estimate analysis of APR1400 LBLOCAs is performed in current study. The analysis results show that the RELAP5/MOD3.3 code reasonably predicts the important phenomena of blowdown, refill and reflood phases of LBLOCA. The sensitivity studies were also done to understand the important phenomena occurred in APR1400. And current study also shows that the ECCS performance of APR1400 has a sufficient margin within the framework of LBLOCA analysis with the application of KREM.

## 2. APR1400 LBLOCA Analysis

### *2.1 Code and Methodology*

KREM realistic evaluation methodology with RELAP5/MOD3.3(Patch 3) is applied for system thermal hydraulics calculation and CONTEMPT4 /MOD5 is used for containment backpressure calculation in current study.

### *2.2 APR1400*

The APR1400 SIS design has several improvements compared with operating plants in responding to LBLOCA. First, a Fluidic Device is installed in safety injection tanks. And safety injection water is injected into the reactor vessel downcomer directly through DVI. Low Pressure Safety Injection Pumps (LPSIPs) are removed with these improvements.

### *2.3 Nodalization and Initial Conditions*

The reactor core is modeled as one hot channel and one average channel with 20 axial levels. The downcomer is divided into 6 azimuthal sectors to accommodate 4 cold legs and 2 hot legs. Four DVI lines are connected to the middle of upper downcomer elevation. Each loop contains modeling of the SIT and high pressure injection ECCSs.

The input parameters and initial conditions related to the containment are selected to determine conservative containment back pressure.

## 3. Analysis and Results

### *3.1 Break Location and Size*

In the large break ECCS performance analysis using the KREM, it is necessary first to determine the limiting break location and size. The Double Ended Cold Leg Guillotine (DECLG) break is determined as a limiting break from sensitivity study of break location on the assumption of one diesel generator fail, which are only 2 of 4 safety injection pumps operated.

The calculations of the break sizes equal to 100%, 80%, and 60% of DECLG were conducted for APR1400. The results show that the highest peak cladding temperature is occurred in the case of 100% break size. Based on the results shown in Fig.1, 124 SRS calculations were performed with assuming the limiting break size of 100% DECLG.

### *3.2 Results for Base Case*

The base case calculation with 100% DECLG and maximum FD k-factor is performed to evaluate thermal and hydraulic appearance occurred in APR1400.
The ECCS water injection flow rates with operating FD on the maximum k-factors shown in Fig.2. The water level of downcomer continuously increase after SIT injection start with some fluctuations also shown in Fig.2. Refill phase is ended because downcomer level increase rapidly and SI water flows into the core around 40seconds.

### *3.3 SRS Calculations*

As the limiting peak clad temperature occurs in the case of 100% DECLG break, 124 SRS calculations are performed assuming 100% DECLG. Twenty-eight uncertainty parameters were randomly sampled within their 99.9% upper and lower limits to make 124 calculation input vectors. The 124 SRS calculations are performed and the third PCT is selected for licensing process. According to non-parametric statistics, the maximum peak clad temperature, the maximum peak local oxidation, and the maximum core-wide oxidation from 124 SRS calculations are equal to or greater than the ones of 95% probability with 95% confidence level.
The PCT result of 124 SRS calculations using input vectors are presented in Fig. 3. Sorting the PCT values in decreasing order and taking the third one results in a majoring PCT exceeding 95% probability with a confidence level of 95%. Hence the final blowdown PCT is peaked from run number 64. The reflood PCT is occurred at 67.1 seconds in run number 83.

### *3.4 Bias Calculations*

It has been found that RELAP5/MOD3.3 has some scale biases in the prediction of the emergency core cooling water bypass, the steam binding, which would cause an adverse effect on the core cooling during reflood. To take into account the effect of the scale biases, independent code runs are conducted for the cases resulting in relatively poor reflood core cooling.

The bias of upper plenum de-entrainment, ECC bypass, and steam generator u-tube droplet break-up are evaluated and the maximum reflood PCT including scale bias is the same as SRS calculation with the bias value of 0K. Hence the evaluation of scale biases could not change the maximum peak clad temperature as the maximum peak clad temperature occurred in early blowdown. Note that it is lower than the majoring one exceeding 95% probability with 95% confidence level, which was determined from 124 SRS calculations.

### *3.5 Final Uncertainty Analysis*

The final majoring PCT exceeding 95% probability with 95% confidence level is well below the acceptance criteria limit of 1478K even with the auto time step control and plot frequency uncertainty of RELAP5, 10K. The maximum clad oxidation is less than 2% and hydrogen generation rate is less than 0.1%. As a results, the ability to remove decay heat generated in the fuel for an extended period of time will be provided. Therefore it is conclude that the ECCS performance of APR1400 has a sufficient margin within the framework of LBLOCA analysis applying KREM.

## 4. Conclusions

An LBLOCA analysis for APR1400 was conducted using KREM with RELAP5/MOD3.3 code.

A break spectrum analysis was performed and 100% DECLG break was determined to be limiting. 124 SRS calculations were also performed and resulted in the maximum peak clad temperature is well below the acceptance criteria limit including plot frequency error. The maximum clad oxidation and hydrogen generation rate are also much less than the acceptance criteria limits. Therefore it is conclude that the ECCS performance of APR1400 has a sufficient margin within the framework of LBLOCA analysis applying KREM with RELAP5/MOD3.3 code.

## REFERENCES

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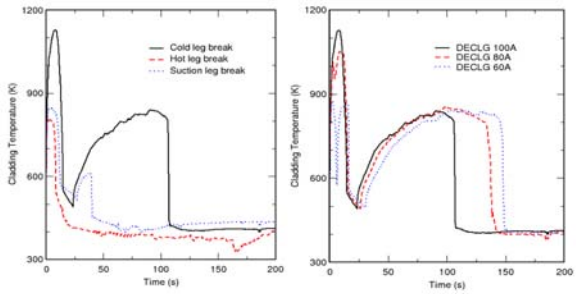


Fig. 1 PCT Comparison for Break Spectrum

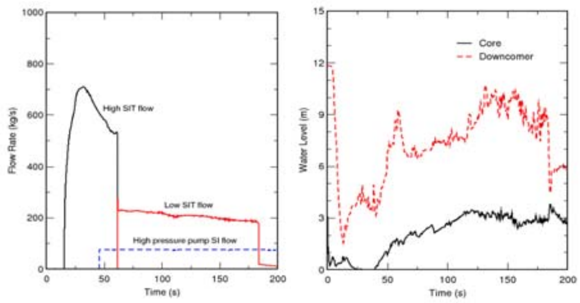


Fig. 7 Results for Base Case Calculations

Fig. 2 Core and Downcomer Water Levels (Base Case)

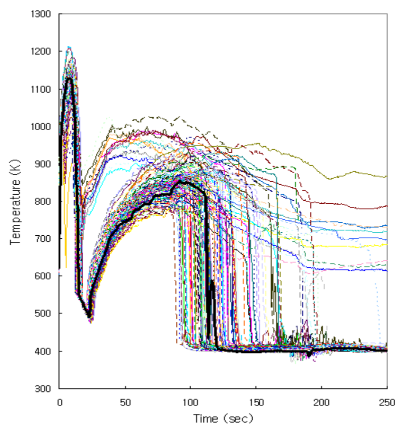


Fig. 3 PCT Results from 124 SRS Calculations