Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Loading Pattern Risk Assessment for AOA in Domestic WH Type Plants

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1. Introduction

According to the flux mapping data, some of domestic WH type plants have experienced AOA (Axial Offset Anomaly) in several years. AOA is a phenomenon that the axial power distribution is considerably shifted to the bottom of the core compared with the predicted one. The root-cause is known as the deposition of boron compound ($LiBO_2$) in the crud that is accumulated in the upper portion of a fuel assembly [1,2].

At first, by analyzing flux mapping data, we have modeled AOA experienced cycle by 3D depletion code and determined approximately the boron mass deposited in crud. AOA model can be used to evaluate the effects of AOA.

In addition, we need to setup a procedure to assess loading patterns for AOA risk and to give recommendations to the operators, if necessary. As a part of Loading Pattern Risk Assessment, we constructed the AOA prediction system to evaluate whether the selected loading pattern has the higher AOA risk or not. This procedure is described herein and application results are presented.

2. AOA Modeling by 3D Depletion Code [3]

In order to setup the procedure for AOA risk assessment, the analysis of the AOA effect has to be performed for the AOA experienced cycle. As a 3D depletion code, ANC was used. The methodology for AOA model is as follows;

1. Select the assemblies which are suspected to be AOA fuels by analyzing the flux map data.
2. Dummy control rods are inserted into the fuels' upper sections which are observed as flux depressed regions.
3. 3D depletion calculations are performed with inserting dummy control rods. The cross sections and rod steps are changed to adjust the axial offset according to the measured axial offsets.

3. Loading Pattern Risk Assessment of AOA

AOA risk has been increased in domestic 3-loop plants due to high enrichment uranium, low leakage loading pattern, and long-term operation strategy. These factors generally require high critical boron concentration in coolant and high fuel duty. Therefore, to prevent AOA, the critical boron concentration and the fuel duty have to be reduced as low as possible in the loading pattern search stage. Once an appropriate loading pattern is selected, it should be diagnosed for AOA risk by calculating mass evaporation rate from fuel and boron mass deposited in crud.

3.1. Determination of Mass Evaporation Rate

Mass evaporation rate is an indicator of sub-cooled nucleate boiling which is one of the necessary conditions for AOA. High mass evaporation rate means that core has high susceptibility of AOA. In this study, mass evaporation rates were examined for Kori Unit 3 Cycle 16 and 17. For reference, Cycle 16 is an AOA experienced cycle. Figure 1 shows the smaller mass evaporation rates for Cycle 17 than those for Cycle 16. Especially, for the period from BOL to MOL, where critical boron concentrations are high, Cycle 17 has considerably smaller mass evaporation rates than Cycle 16 does.

3.2. Boron Mass Determination by the AOA Prediction System

Corrosion products of coolant system surfaces are released into coolant. The coolant carries the corrosion products into core and they are deposited as porous crud on boiling surface of fuel assemblies. And then, the boron compound believed to be LiBO2 is accumulated into the crud.

The AOA prediction system was constructed to estimate accumulated boron mass in the core. Using ANC and TORC calculation results as input to BOB, BOB can calculate the crud deposit and boron deposit in the core. They are all 3-dimensional codes. The simple data flow taken in this system is shown in Figure 2.

This process was performed for Kori Unit 3 Cycle 16 and 17 and the results were shown in Figure 3. Figure 3 shows approximately same trend with the mass evaporation rates.

From the calculation results of mass evaporation rates, boron mass and other core conditions such as core average temperature, pressure, power, flow rate, and pH control strategy, we could decide that the cycle 17 would have lower AOA susceptibility than cycle 16 at which experienced AOA.

4. Recommendations for Operation

If a core experienced AOA in the previous cycle, the axial power distributions could be severely top-shifted in the early life of current cycle. This will cause high mass evaporation rates in early life of cycle. In this case, it is necessary to control axial offset in early cycle life within a certain criteria. By performing thermo-hydraulic analysis for Kori Unit 3 Cycle 17, the lead control rod insertion is found to be helpful to reduce mass evaporation rates at early high boron concentration conditions. This also makes axial offsets gentle in whole cycle life.

From this evaluation, we recommended that the lead control rod should be inserted in order to control axial offsets within ±3% of predicted values until the critical boron concentration decrease sufficiently.

4. Conclusions

By modeling AOA core and calculating mass evaporation rates and boron mass, we setup the procedure to assess AOA risk for a loading pattern. Based on this methodology, we have been performing loading pattern risk assessments for domestic WH type plants successfully and informed the utility of the assessment result and recommendations.

REFERENCES

[1] Secker, J. R., et al., BOB : An Integrated Model for Predicting Axial Offset Anomaly, Topfuel, May 2001, New Orleans, LA.

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[3] D.I. Chang, et al., AOA Core Modeling in Domestic Plants, KNS, May, 2004

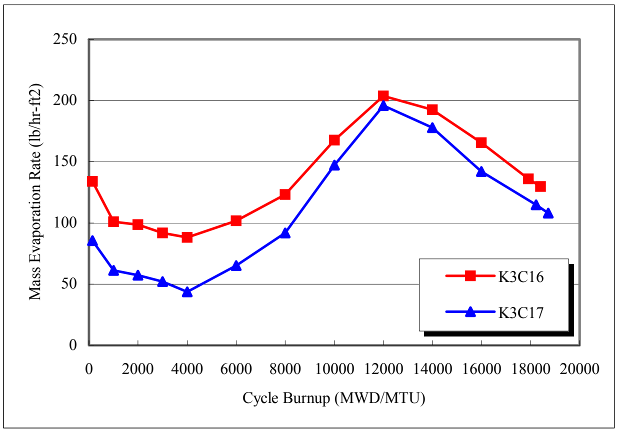

Figure 1. Mass Evaporation Rates versus Burnup for Kori Unit 3

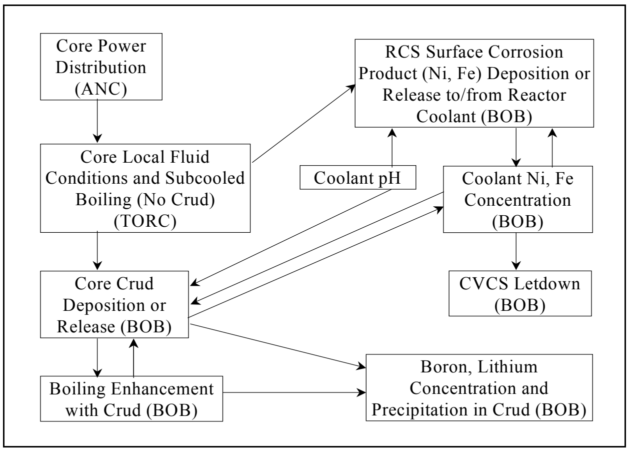

Figure 2. Process Diagram of the AOA Prediction System

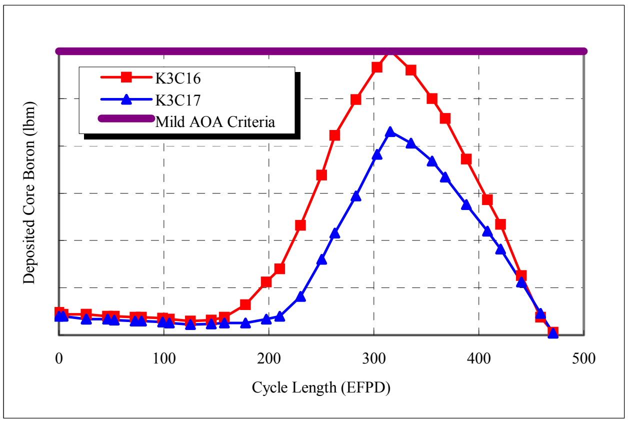

Figure 3. Boron Mass Deposited in Crud versus Burnup for Kori Unit 3