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A Study on Applicability of RELAP5/MOD3.1K to UPI Plant

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1. Introduction

The RELAP5/MOD3.1K code is currently licensed to the Large Break Loss of Coolant Accident (LBLOCA) analysis for Westinghouse design 3 loop plants [1].

As an effort to extend the code application to Kori Unit 1, which equipped with Upper Plenum Injection (UPI), UPTF test 20 was assessed to develop an appropriate noding for UPI plant. In this study, the multi-channel noding for upper plenum was developed.

2. UPI Phenomena and Upper Plenum Modeling

The UPTF is a full-scale simulation of the primary system of a 1300 MWe pressurized water reactor nuclear power plant designed by Siemens [2]. The purpose of UPTF test 20 was to investigate the steam, water, and UPI flow interaction in the upper plenum during reflood phase of LBLOCA. This test included subcooled ECC injection into the upper plenum simultaneously with saturated steam and water flow from a simulated reactor core. There were three test phases, each phase with a different combination of steam and water flow to parametrically study core steam flow and distribution.

The test results show major water delivery to the core in a very local region, rapid formation of an upper plenum water pool, 100% condensation efficiency with 80% in the upper plenum and 20% in the core, and significant storage of water in the hot legs. The pool is uniform except for the region above the penetration zone, which indicates water levels about twice as high. The phenomena in the upper plenum and tie plate region were multidimensional, water down-flow from the upper plenum to the core occurred in discrete region below the injection locations. Outside these down-flow regions, a two-phase mixture of steam and water flowed from the core to the upper plenum. [3] Specifically, the injected water impinges on the upper plenum structure. After impingement, it can breakup into droplets or thin liquid film. Some water can deflect into other structures. It can flow partially as a thin liquid film on a structure surface or spread into droplet. Some water can deflect into other structures. It may impinge on the secondary structure and spread in the upper plenum space [4].

The UPTF upper plenum structures are consist of 61 guide tubes, 8 support columns, and open space as shown in figure 1. Guide tube may play an important role on ECC behavior in UPTF upper plenum. ECC water injected into the upper plenum impinges on the first array of guide tubes and flow down to the upper core plate. Some water passed the first array may impinge next array of guide tube. ECC water injected into the upper plenum is nearly impossible to pass guide tube without impingement as shown in Figure 1. Figure 2 shows UPTF conceptual breakthrough locations based on test data. Most of ECC water falls down through guide tube region as shown in Figure 2. In this figure, upper plenum may grouped three radial and four azimuthal regions. The first radial region is free space from injection nozzle to the first guide tube. In this region, there is no ECC impingement on guide tube. The second region is located between first and third region. The third region is central region where ECC water cannot reach. ECC breakthrough location is azimuthally within the 1/4 of upper plenum. This is a guideline for modeling UPTF upper plenum using RELAP5K.

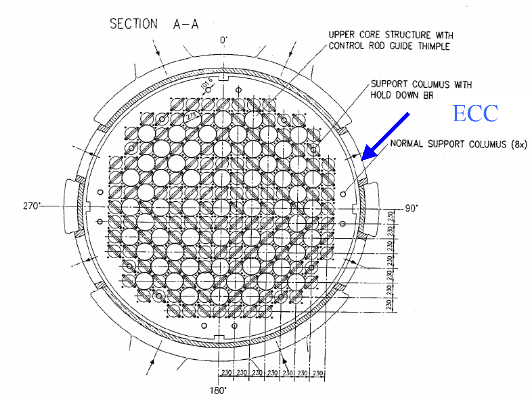

Figure 1. UPTF Upper Plenum Structures

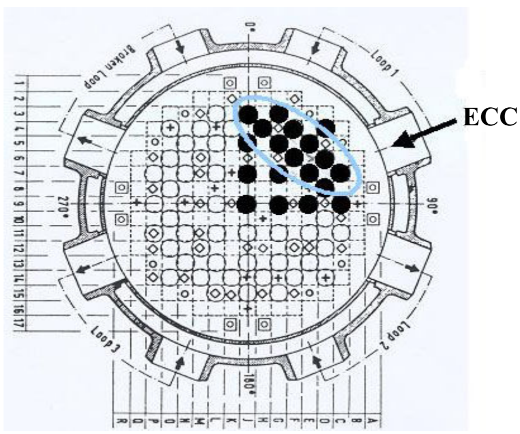

Figure 2. Conceptual Breakthrough Location

The noding for upper plenum consists of fifteen channels and four axial nodes according to the guideline. The first region modeled 4 sub-channels with open space. The second channels with 8 sub channels with open space and guide tubes. The third channel consists of 3 channels with hot assembly, guide tube, and open space. Each channel was connected using cross flow junctions. Loops and ECCS is connected in first region. The same noding as upper plenum is applied dummy fuel region. Core is modeled with 9 sub-channels to model non-uniform steam injection rate, guide tube and hot assembly channels are merged into each region. Downcomer is modeled with 8 channels according to loop arrangement. Intact and broken loop hot legs, steam generator, pump simulators, cold legs, and ECCS are also modeled. The ECC water is injected into the upper plenum through the hot leg of loop 1. Detailed noding for upper plenum is shown in Figure 3.

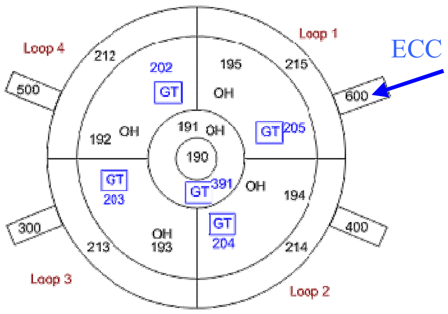

Figure 3. Upper plenum Noding

3. Results

RELAP5/MOD3.1K calculation for UPTF test 20 was performed with base noding developed in section 2. Test results show that the ECC water injected into the hot leg penetrates into the tie plate immediately after start of ECC injection. This penetration continued through the test.

Figure 4 and figure 5 show upper plenum liquid level and integrated hot leg mass flow rate, RELAP5K well predicted test results. Figure 6 shows down flow locations, RELAP5K well predicted ECC breakthrough location within 1/4 of upper plenum. In this study, RELAP5K that is one dimensional thermal hydraulic computer code can predict multidimensional phenomena of UPI test in the upper plenum. This is mainly due to the detail noding for upper plenum and well group the sub-channel. That is, each channel has one flow direction, up or down-flow.

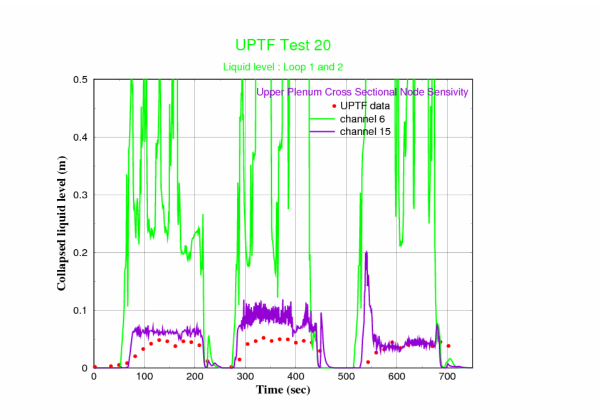

Figure 4. Upper Plenum Liquid Level

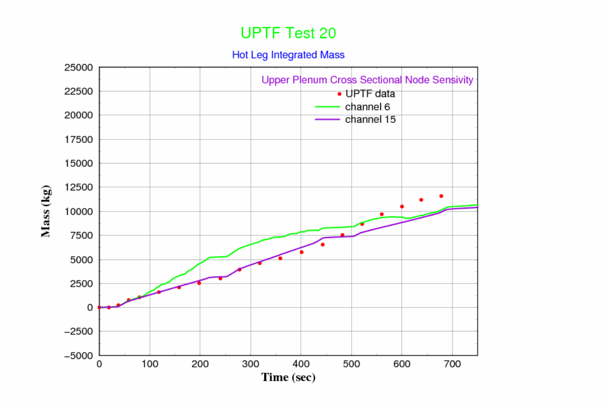

Figure 5. Integrated Hot Leg Mass Flow Rate

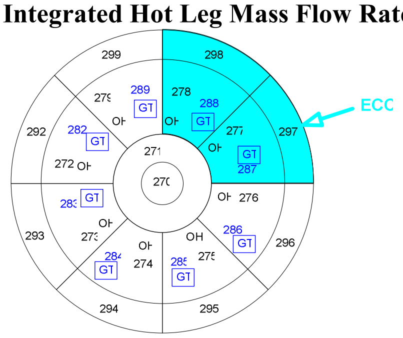

Figure 6. Down Flow Location and Area

4. Conclusion

RELAP5/MOD3.1K calculation for UPTF test 20 was performed to assess the applicability of this code for the UPI plant. Through the comparison with test data, RELAP5/MOD3.1K well predict upper plenum level, down-flow location, and hot leg mass flow rate as shown in test results. The Multi-channel noding developed in this study will be applied to Kori Unit 1 and CCTF with UPI type.

As a conclusion, RELAP5/MOD3.1K can be used for UPI plant LBLOCA analysis.

Acknowledgement

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REFERENCES

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