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ANALYSIS OF BCL TRANSIENT ECC-BYPASS TEST WITH TRAC-PD2/MOD1 CODE*

by

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As part of the independent assessment of the TRAC-PD2/MOD1 code[1], a calculation for the Battelle Columbus Laboratories (BCL) transient Emergency Core Cooling (ECC) bypass test[2] was performed. The purpose of this calculation was to assess the code's capability to predict the lower plenum refill rate after the initiation of ECC water injection during a postulated large break LOCA in a PWR system.

BCL conducted several ECC bypass tests in their 2/15th-scale model of a typical pressurized water reactor vessel. The test facility consisted of a pressure vessel 2.5m tall with an inside diameter of 0.62m. There was a steam feed line at the top of the upper plenum and a drain line in the lower plenum. The downcomer gap width was 0.0312m with an adjacent core barrel 1.1m long. Two hot legs were simulated by plugs of 0.2m diameter in the downcomer annulus while the four cold legs of 0.102m inside diameter were pipe construction with a 60°-120° orientation. The details of the facility description can be found elsewhere[3].

The simulated transient experiment, ID=29302, involved ramping the steam flow rate down along with the vessel having hot walls. (The facility was made to provide a "hot wall" capability by having thermally thick vessel and core barrel walls). The test was begun by heating the vessel up to an initial temperature of 273.9°C. Initially, the steam flow rate and the lower plenum pressure were maintained at 1.76 kg/s and 2.86 bar, respectively. At 11.2 seconds, the steam flow rate was ramped down to 0.4 kg/s in 13.4 seconds while the ECC water (100°C) was injected at a rate of 22.52 kg/s through three cold legs. The fourth cold leg served as the broken leg. During the transient several key parameters such as lower plenum water level, pressure, and wall surface temperature were recorded.

To simulate the test facility, several TRAC components were used. The test vessel was modeled with the VESSEL module containing nine levels; three in the lower plenum and six along the length of the core barrel. Each level was subdivided into two radial and four (equal) azimuthal zones for a total of 72 cells. The experimental value of steam and ECC water flow rates were specified as boundary conditions at the top of the vessel and three cold legs, whereas the experimental value of containment pressure was imposed at the exit of the broken cold leg.

An additive loss coefficient of 0.5 was also used in the first cell of the broken leg nodalization to obtain the correct pressure drop between the lower plenum and the containment during the steady state ($t < 11s$) portion of the test. This loss coefficient was retained throughout the calculation and is justified since it is used to account for the irreversible losses due to the entrance effects, the presence of full flow drag screen, pitot tube, and thermocouple rake in the broken leg. Finally, three possible methods to model the presence of hot leg plugs were considered, two of which are depicted with respect to the unwrapped downcomer in Figure 1. The third method was to ignore their presence altogether. Therefore, three calculations were performed for Test ID=29302.

Figure 2 shows the comparison between the calculated and measured lower plenum water level and pressure. It is seen that the refill rate is reasonably predicted for all three calculations although they predicted the same pressure overshoot between 12.0 and 18.0 seconds. This pressure overshoot was calculated because TRAC-PD2/MOD1 has only a lumped parameter conduction model for the vessel heat slabs. The heat transfer rate from the vessel wall was, therefore, overpredicted generating more steam and thereby yielding the high pressure prediction.

An analysis of the lower plenum water level (Figure 2) showed two general trends: a continuous refill for the model without hot leg plugs and a periodic refill and bypass for the other two models. For the calculation without the plugs, steam permeated throughout the entire annulus. This set up a predominently co-current flow pattern in the azimuthal cell 5 which aided the water penetration into the lower plenum. The other two models also demonstrated a similar response during the refill periods; however, the flow pattern changed during the bypass stage. As the top two levels of the vessel became essentially filled with water, the period of complete bypass developed and the injected water was removed through the broken leg. The case with the plugs on the cell boundary predicted more water penetration than that with the plugs inside the cell because of the blockage in the azimuthal direction (Figure 1) which forced more flow down into the annulus. These calculations also demonstrated the multidimensional feature of TRAC.

The (TRAC-PD2/MOD1) code predicted the lower plenum filling rate with reasonable accuracy even though three different modeling choices were made for the hot leg plugs. While the hot leg plugs should be modeled from the physical standpoint, further assessment is required to determine the optimum choice.

REFERENCES

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