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Core Shroud Blowdown Load Calculation During Recirculation Suction Line Break by TRACG Analysis for Dresden Nuclear Power Station, Units 2 and 3, and Quad Cities Nuclear Power Station, Units 1 and 2

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3.0 Analytical Model Description

An input base deck was prepared for use with TRACG from an existing base deck for LaSalle.

The nodalization used was a result of sensitivity studies carried out to evaluate the effect of azimuthal and axial nodalization on the computed blowdown load. One sensitivity study consisted of adding an additional axial level in the break region. The result of the study was a negligible difference in the calculated force, which can be seen in Figure 3-2 for a case with twelve azimuthal cells, and 100% break flow area and friction.

The increased nodalization provided a more accurate representation of the pressure distribution near the break region, as can be seen in Figure 3-3.

Plane view - 2 rings, 14 azimuthal segments

Elevational view - 15 axial levels

Figure 3-1. TRACG Nodalization of RPV for Quad Cities/Dresden

Figure 3-3. Vessel Pressure for axial level 4 at t=2.0 seconds (normalized with respect to pressure at 0°).

Thus, the use of 14 azimuthal sectors provided a more accurate assesment of the blowdown force.

In addition to the nodalization, the base deck included proportional simulation of jet pumps and feedwater flow in the azimuthal sectors. Other RPV components, such as the steam separators, guidetubes, and external recirculation loops, were also modeled along with the jet pumps in the TRACG base deck.

The TRACG code uses a multi-dimensional two-fluid model for the reactor thermal hydraulics; it solves the conservation equations for mass, momentum, and energy for the gas and liquid phases. The code closes the conservation equations with an extensive set of basic models consisting of constitutive correlations for shear and heat transfer at the gas/liquid interface and the wall; these correlations are based on a single flow regime map used throughout the code. A three-dimensional formulation is used for the vessel component, while the rest of the components (e.g. pipes, tees, valves) are modeled in one dimension. The code also includes a control system model capable of simulating the major BWR control systems (e.g. recirculation flow, pressure).[3-1]

[3-1] J.G.M. Andersen, et.al., "TRACG Model Description - Licensing Topical Report," NEDE-32176P, February 1993.

4.0 Analytical Model Qualification

The TRACG analytical model has been used for many plant applications including LOCA, BWR transients, and ATWS events, and has been systematically qualified. The qualification process included comparisons to separate effects tests, BWR component performance tests, several integral system effects tests, and several BWR plant tests. Therefore, the overall TRACG analytical model is already well qualified. A sensitivity study has been performed on the portion of the model that has been implemeted to calculate the lateral blowdown load, and is already described in Section 3. The two primary parameters that significantly affect the calculation of the lateral blowdown load on the core shroud are the critical flow rate through the broken suction line and the circumferential flow resistance of the jet pumps; they are discussed below.

4.1 Critical Flow

The critical flow model in TRACG has been compared with the data from the Marviken reactor vessel, PSTF test facility, and Edwards test. All these comparisons show an excellent agreement between the TRACG prediction and the test data. Figure 4-1 shows the comparison between the TRACG prediction and Marviken Test 15. The Marviken Test 15 had 31 K subcooling. During the subcooled blowdown period, the TRACG overpredicts the test results. Overall the deviation from the test data is less than 20 % for all periods.

Figure 4-1. Comparison of TRACG Blowdown Flow Rate to Marviken Test 15.

5.0 Results

The results of the TRACG analysis are provided in this section for the blowdown load, moment, and moment arm acting in the 0°-180° and 90°- 270° planes on the shroud section above the H5 weld. In addition, the results are also provided for the force, moment, and moment arm acting on the complete shroud assembly.

For the force and moment, the critical time period is that below five seconds, when subcooled blowdown occurs, and when the highest load is placed on the shroud. Once two-phase blowdown begins, the load decreases significantly. It should also be noted that the acoustic wave response is not accurately modeled in this analysis and the initial 0.5 to 1.0 second in each of the figures should be ignored. Although TRACG can assess the acoustic response, it would require a calculation time step on the order of one microsecond, the use of which was not feasible for the present analysis. In addition, the TRACG code has not been qualified extensively for calculation of the acoustic wave response due to a recirculation line break.

Figure 5-1 shows the pressure distribution as a function of elevation at 0° and 180°. This shows that depressurization near the suction nozzle causes the force imbalance accross the shroud.

Figure 5-1. Variation of Pressure with Vessel Elevation at t=2.0 seconds