the interfacial surface area becomes. It is suggested the interphase drag is too small in this calculation, leading to a higher interfacial surface area, a subsequent higher interfacial heat transfer, and a more rapid bubble collapse. An investigation into the way the code treats interphase drag is warranted.

2.2.11 MIT Pressurizer Test ST4

The Massachusetts Institute of Technology (MIT) Pressurizer Test ST4[2.2-18,2.2-19] involved a small-scale, low-pressure pressurizer that was initially partially filled with saturated water. The test was initiated by opening two quick-opening valves, which resulted in the insurge of subcooled water into the bottom of the pressurizer. The accurate calculation of data from this test depends on accurate modeling of steam condensation on the wall as well as interfacial heat transfer between the stratified liquid and the vapor above the liquid.

The experimental apparatus is shown schematically in **Figure 2.2-44**. It consisted of two cylindrical steel tanks: the primary tank, 1.14 m tall and 0.203 m ID, and the storage tank. The primary tank had six windows and was equipped with six immersion heaters with a total power of 9 kW. The storage tank was pressurized with nitrogen to force the liquid into the primary tank.

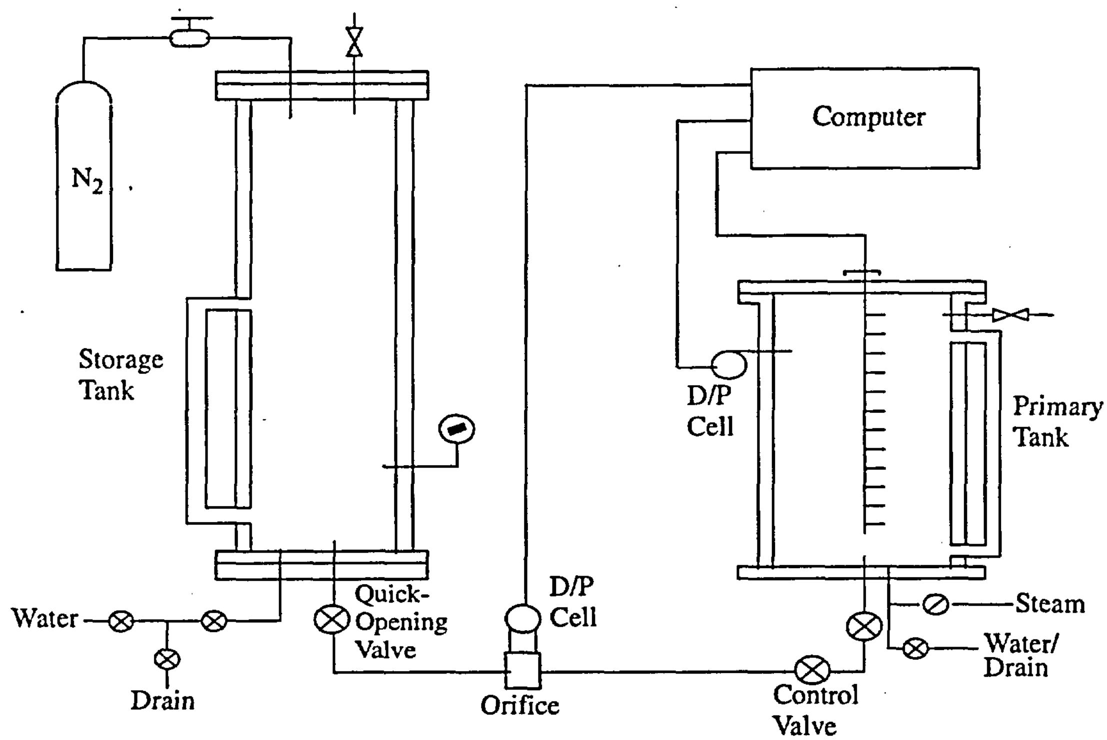

Figure 2.2-44 Schematic of the Experimental Apparatus for the Mit Pressurizer Test

Test ST4 began with the liquid level in the primary tank at 0.432 m from the bottom. The average level rise velocity was 0.0115 m/s over a 41 second time period. The primary tank was modeled with a ten cell pipe, each with a heat slab set at the saturation temperature of the initial pressure. The water and steam in the tank were also set at saturation conditions.. A time-dependent junction fed water at the specified rate from a time-dependent volume to the pipe. The time-dependent volume conditions were those of the

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subcooled water in the storage tank. The initial subcooling as the water entered the tank was 129 K. It was noted that as the liquid level in the pressurizer rose during the subcooled liquid injection, little mixing occurred between the initial saturated fluid in the pressurizer and the incoming highly subcooled liquid. The pressurizer was insulated to diminish energy losses. Calibration tests were used to estimate the losses at 1.1 kW.

The vessel was modelled using 10 fluid cells. A more accurate prediction could be obtained with more cells, however, models of reactor pressurizers usually have less than 10 cells. The water level was initially in cell 4 (the void fraction was 0.22) and reached its maximum value in cell 8 (the void fraction was 0.69). The experimenters did not report on the type and thickness of the insulation covering the vessel. The code model used 8.9 cm of fiber glass insulation. Steady state calculations were performed to adjust the insulation conductivity so that the steady state heat loss agreed with the reported value.

Figure 2.2-45 shows that the calculated rate of pressure rise is close to the measured value. As the cold water was injected into the pressurizer, the pressure increased due to compression of the steam volume. As the pressure increased the saturation temperature also increased. Energy transferred from the vapor to the wall and condensation at the liquid/vapor interface mitigated the pressure rise. The calculated pressure rise was slightly under-predicted. An atypical decrease in the calculated pressure in the MOD3.2 calculation at about 36 seconds was a result of rapid condensation as subcooled liquid droplets entered a saturated steam environment near the top of the pressurizer. It is suspected the problem is associated with the interfacial heat transfer model. However, this behavior was not exhibited in the MOD3.3 calculation.

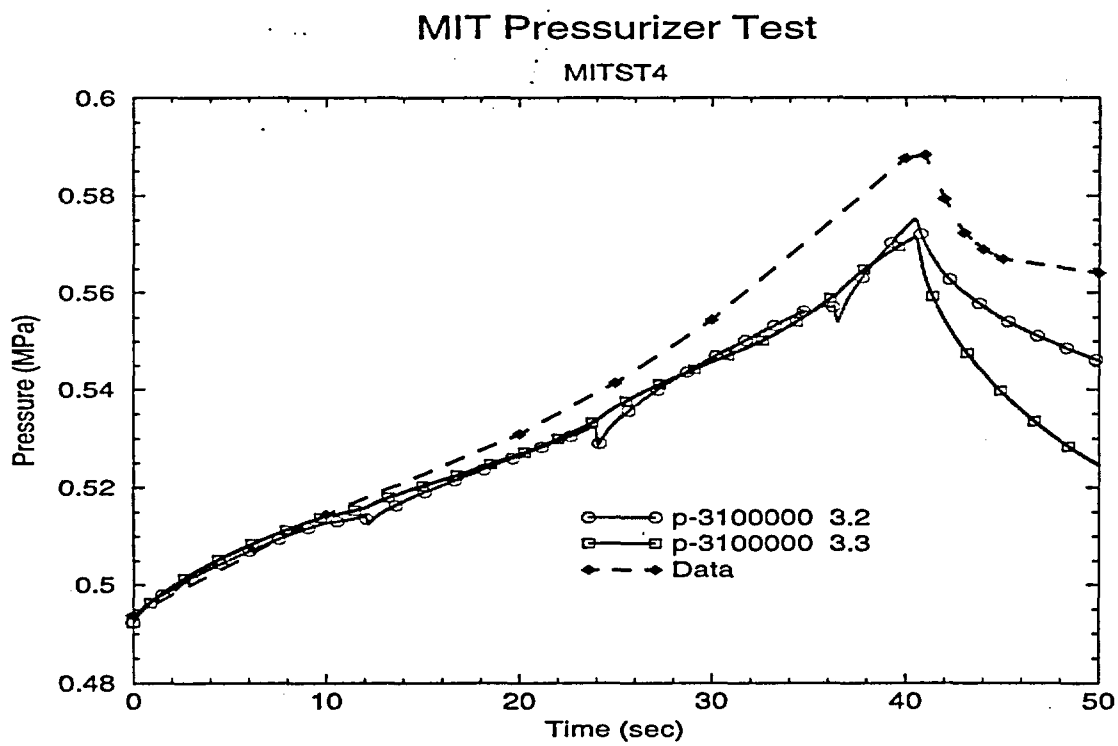

Figure 2.2-45 Measured and Calculated Rate of Pressure Rise for the Mit Pressurizer Test

At about 41 seconds, the flow into the pressurizer was stopped. The pressure response turned over and began to decline. The MOD3.2 calculated pressure did not decline as fast as the MOD3.3 calculated pressure. Differences in the interfacial heat transfer package of the two code versions appear to be a factor in the behavior between the two calculations. The condensation rate calculated by MOD3.2 during this time was much less than that calculated by MOD3.3 as shown in **Figure 2.2-46** (condensation is a negative vapor generation). The smaller condensation rate resulted in a smaller depressurization rate as shown in **Figure 2.2-45.** The MOD3.3 calculated pressure behavior after the flow into the pressurizer was stopped is more typical of the data. Several parameters can affect the calculated response. Thermal stratification in the fluid appears to occur in the experiment as the liquid in the pressurizer moves up. When the flow into the pressurizer is cut off, the pressure responds to the heat removal process at the liquid/vapor interface (which decays rapidly) and the vessel wall. Numerical mixing of the cold and saturated liquid in the calculation resulted in a lower liquid temperature near the interface, thus affecting the calculated condensation/vaporization rate. A finer nodalization would minimize the numerical mixing of the liquid. Use of more optimal noding (both hydrodynamic and wall conduction) would be expected to better predict the response of this test.

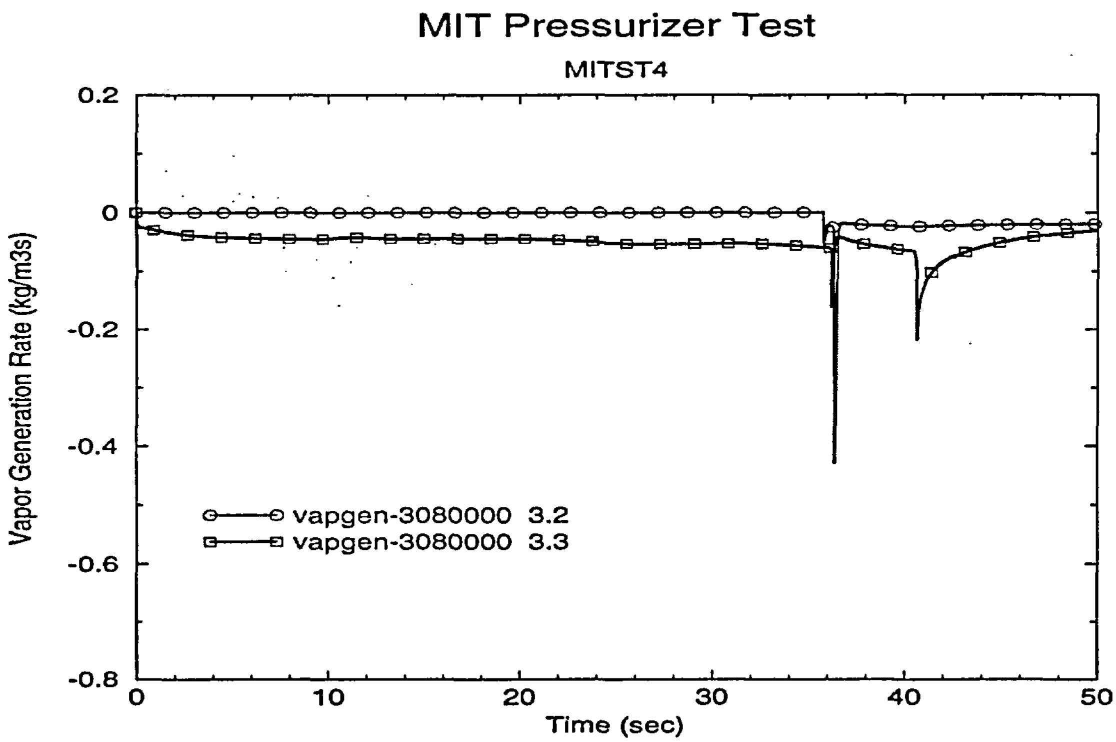

Figure 2.2-46 Calculated Vapor Generation Rate for Volume 3080000, MIT Test ST4

Figure 2.2-47 is a snapshot of the tank fluid and inside wall temperature at 35 seconds into the transient. The water level is at the 0.79 m elevation. The data showed that the initial 0.432 m of saturated water rose with little mixing of the injected subcooled water. The calculation however, showed mixing of the cold and saturated liquid as a result of numerical mixing within the volume boundary. Although the fluid and wall temperature at the intermediate levels misses the actual temperature from the experiment, the trend of the data is represented.

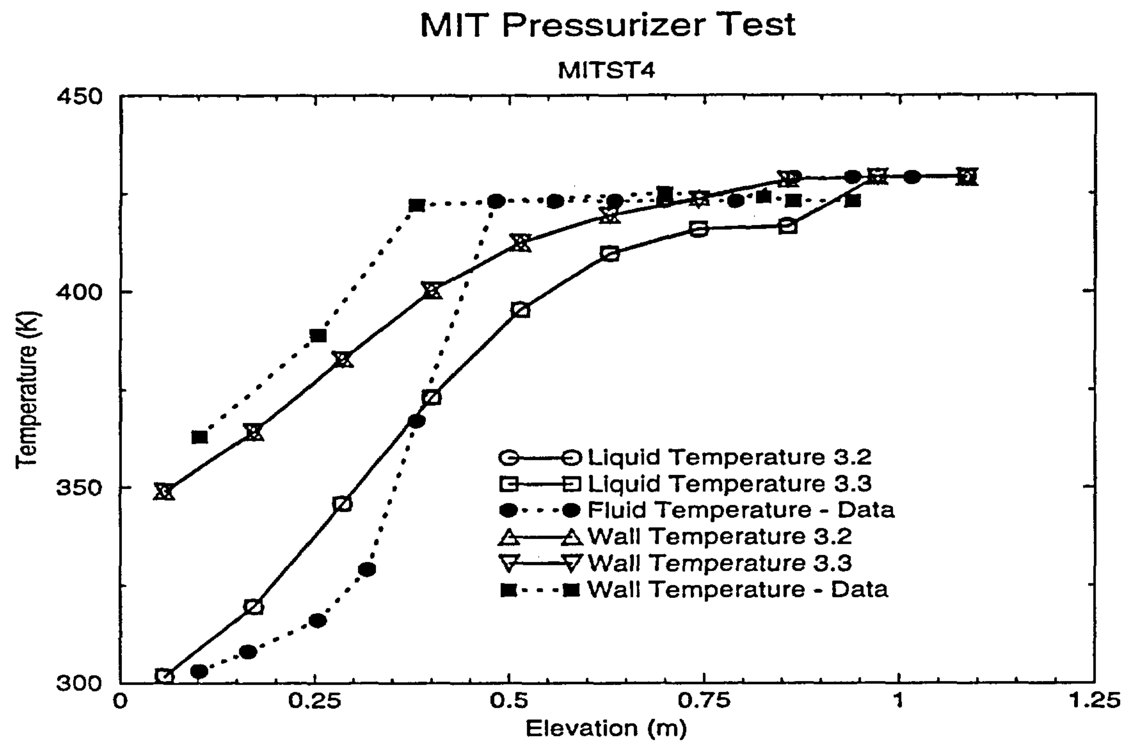

Figure 2.2-47 Tank fluid and Inside Wall Temperature at 35s into the MIT Pressurizer Test

A thermal front tracking model is implemented in the MOD3.3 code version (the t-flag in the volume control flags) that was exercised with this experiment. This feature was included to improve the accuracy of solutions when there is warm fluid appearing above cold fluid in a vertical stack of cells (see Volume I of this manual). **Figure 2.2-48** shows the fluid and wall temperature response at 35 seconds of the MOD3.3 calculation with the thermal front tracking model activated compared to the base case MOD3.3 calculation and data. As observed, the model greatly improved the calculated temperature response. The pressure behavior, with the thermal front tracking model on, is compared with the original calculation and data in **Figure 2.2-49**. The response with the thermal front tracking model on is improved during and after the liquid insurge. After the inflow was stopped, the pressure responded more like the MOD3.2 calculation. Because of the nature of this model, little condensation occurred at the liquid/vapor interface. Additional investigation into the use of the thermal front tracking model for simulating pressurizer behavior appears to be warranted.

2.2.12 FLECHT-SEASET Forced Reflood Tests

Forced reflood test data[2.2-20], Runs 31504 and 31701 from the 161-rod FLECHT-SEASET facility, were used to assess the reflood model at low and high reflood rates. The electrically heated rod configuration was typical of a full-length Westinghouse 17 x 17 rod bundle. The rods had a uniform radial power profile and a cosine axial power profile. The primary component in the test facility was a test section that consisted of a cylindrical, low-mass housing 0.19 m (7.625 in.) inside diameter by 3.89 m (1530.0 in.) long and attached upper and lower plenums. For the tests selected, the flooding water entered

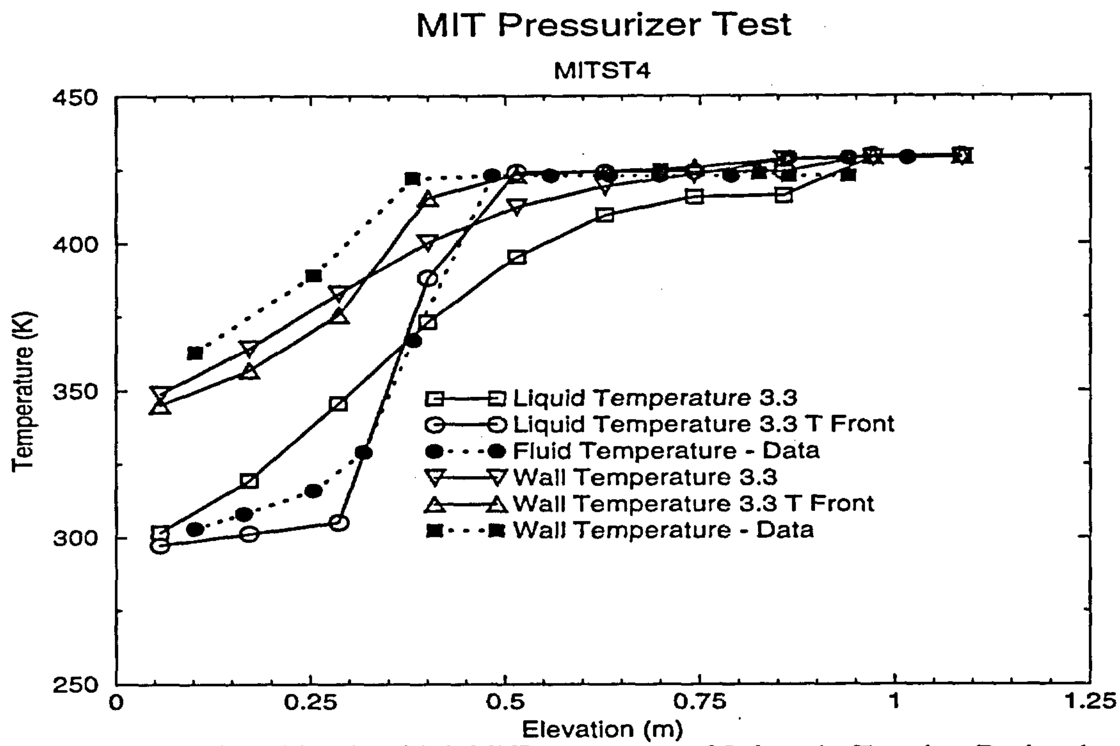

Figure 2.2-48 Tank Fluid and Inside Wall Temperature at 35s into the Transient During the MIT Pressurizer Test with the Thermal Front Tracking Model Active

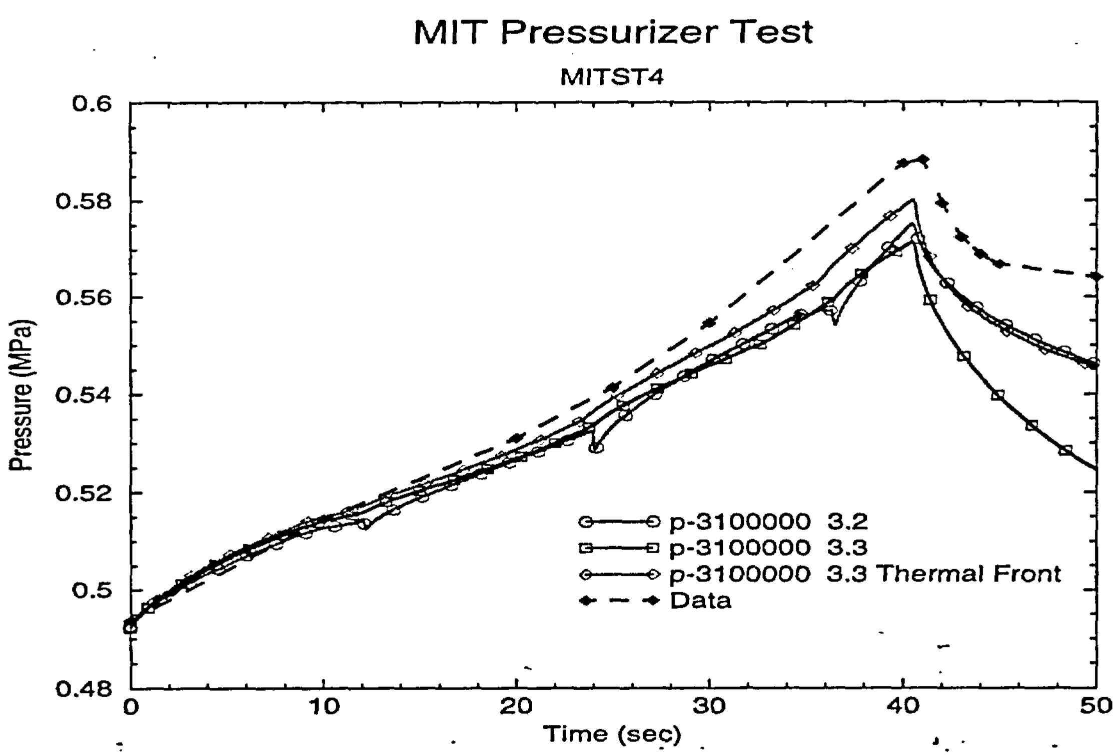

Figure 2.2-49 Measured and Calculated Rate of Pressure Rise for the MIT Pressurizer Test, Thermal Front Tracking Model Active