applicant conducted four series of full-scale performance verification tests at the Valve Performance Evaluation Rig (VAPER) test facility at the Korea Atomic Energy Research Institute (KAERI) to confirm the operational principles of the fluidic device, and examine the performance of the SIT-FD. The full scale test facility, VAPER, consists of the SIT installed with the FD, a compressed air supply system, SIT water discharge pipe line and associated valves, SIT water supply and recirculation system, stock tank, and a data acquisition and control system as shown in Figure 4.1-1, “Schematic of the VAPER Facility,” of the topical report (Reference 1). The SIT of the VAPER facility was manufactured to have the same inner diameter, height, and volume of the APR1400 SIT. The stock tank, which receives the discharged contents of the SIT during the tests, is kept at atmospheric pressure. No scaling analysis was needed.

Two series of tests, identified as the Case-01 series and the Case-02 series, correspond to the standard FD tests; that is, the FD in these two series of tests has almost the same geometrical dimensions as the FD of the APR1400, but the Case-02 series has a slightly higher stand pipe than the Case-01 series in order to examine the effect of the stand pipe height on FD performance. The other two series of tests, identified as the Case-03 series and the Case-04 series, are sensitivity tests to evaluate the effects of manufacturing tolerances. The details of the test objectives, test apparatus, and test results for these tests are described in Section 4, “Performance Verification Tests,” of the topical report (Reference 1).

Three Case-01 tests were performed at the reference test conditions, shown in Table 4.2-1, “Reference Test Conditions for the Performance Verification Tests of the VAPER SIT,” of the topical report, (Reference 1), in order to check the repeatability of the test results. One additional Case-01 test was performed at approximately half of the reference pressure in order to evaluate the reliability of the pressure drop characteristics of the FD. The test conditions of Case-01 tests are summarized in Table 4.2-2, “Test Conditions of ~~Case-02~~ Tests,” of the topical report (Reference 1). A total of four tests were performed as a part of the Case-01 series.

Case-01

Three Case-02 tests were also performed at the reference test conditions to check the repeatability of the tests. Case-02 tests utilized a stand pipe which was approximately 12.87 inches higher than the stand pipe in Case-01. The test conditions for Case-02 are summarized in Table 4.2-3, “Test Conditions of Case-02 Tests,” of the topical report (Reference 1). A total of three tests were performed as a part of the Case-02 series.

In addition, three Case-03 and three Case-04 sensitivity tests were performed at the reference test conditions to ensure repeatability of the tests. Case-03 tests utilized vortex chamber height reduction and Case-04 tests utilized vortex chamber height reduction as well as control nozzle width enlargement to assess the effect of maximum expected manufacturing tolerances. A total of three tests were performed as a part of the Case-03 series and a total of three tests were performed as a part of the Case-04 series.

Overall, these tests were performed with the objective of confirming the following characteristics:

the measured FD K-factor. In RAI 2-7371, Question 17 (ML14100A668); the NRC staff inquired about how the facing angle uncertainty of the nozzle design in the FD might affect the FD K-factor. The CFD analysis (Reference 2) also analyzed the effect of this manufacturing tolerance by varying the nominal facing angle. The applicant showed that the APR1400 design requirement range for the SIT-FD K-Factor bounded the CFD results. The staff evaluated the CFD analysis on the effect of the manufacturing tolerance of the facing angle and confirmed that the design requirements for the APR1400 SIT-FD, bound the computational results. RAI 2-7371, Question 17 is resolved and closed.

The staff evaluated the full scale testing results and confirmed that the performance of the SIT-FD during large and small flow injection phases behaves as intended by the applicant's design. The results of these tests showed that a large flow rate manifests when the tank water level is above the standpipe; and when the water level in the tank falls below the inlet of the standpipe, the injection flow rate decreases significantly. The accompanying CFD analysis qualitatively confirms vortex formation inside the FD as well as cavitation effects during large and small flow injection phases. The staff's evaluation concludes that the design requirements of the APR1400 SIT-FD bound all full-scale experimental and computational results of the applicant's test program, and that cavitation is inherently accounted for in the full-scale testing. The staff's evaluation also confirmed the design principle of passive flow control by the fluidic device.

3.1.3 Effect of Dissolved Nitrogen

Fluid in the SIT of the APR1400 is in contact with nitrogen and over time nitrogen will dissolve and diffuse throughout the liquid phase. In the limiting case, water becomes saturated with nitrogen at equilibrium. A potential impact of dissolved gas on the performance of the fluidic device thus exists. As the fluid particles move through the fluidic device, subject to a pressure drop, the dissolved nitrogen gas will emerge out of solution and potentially affect the flow resistance of the fluidic device.

The applicant utilized compressed air as the cover gas and liquid water as the injection fluid. The staff noted that there was no attempt to test dissolved gas in equilibrium with the injection liquid. However, to evaluate the effect of dissolved nitrogen gas on the FD K-factor, the applicant provided an estimate of the dissolved nitrogen flow rate out of solution during the whole injection period. First, the applicant calculated the solubility of nitrogen in the SIT water for SIT water temperatures of 0 degrees Celsius (°C) (32 degrees Fahrenheit (°F)) and 40 °C (104 °F) using the empirical correlation from "Prediction of Nitrogen Solubility in Pure Water and Aqueous NaCl Solutions up to High Temperature, Pressure, and Ionic Strength," (Reference 5). The staff noted that boron solubility was ignored in the applicant's analysis. The applicant assumed that the nitrogen gas content in the SIT water reaches the equilibrium state of the solubility given by the empirical correlation during the fast pressure transient process across the FD. Using data obtained from Case-01-01 data, the mass release rate of nitrogen from solution was computed over time for two different temperatures of 0 °C (32 °F) and 40 °C (104 °F). Due to the ~~lower SIT water temperature~~ during the large flow rate period, the mass release rate of nitrogen gas was larger during this time compared to the small flow rate period. In the experiments, it was observed that the air discharged through the empty stand pipe had little

higher nitrogen gas solubility in water