RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION 2-7371

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Question 15

There is no discussion of whether cavitation occurs in the vortex chamber or the exit nozzle.

b) Has a calculation been made to determine whether cavitation could occur in the vortex chamber or the exit nozzle? What is the lowest pressure calculated or measured in the vortex chamber and at the throat of exit nozzle? Are the pressures in these areas lower than the vapor pressure so that cavitation would occur?
c) What would be the effects of cavitation, if it occurs, on the SIT flow rates and FD K-factors for both large and small flow periods.

Response

b) Based on the CFD analysis, the vaporous cavitation can occur in the center of the exit nozzle and the discharge tube in both large and small flow mode as shown in Figure RAI-15-1 and Figure RAI-15-3. For example, in Test Case-01-01, the temperature of water is [ ]TS and its saturation pressure of vapor is about [ ]TS. This pressure is consistent with the lowest calculated local pressure for Test Case-01-01 as shown in Figure RAI-15-2 and Figure RAI-15-4. More detailed information for the flow structure and the formation of vaporous cavitation are provided in the Technical Report (Reference 1), "CFD Analysis of Fluidic Device".

c) In the full scale experiment, there were no instruments to detect the cavitation. If it occurs, impacts of cavitation on SIT flow rates and FD K-factors are directly addressed by the full scale test data.
The CAREM, the realistic evaluation methodology for LBLOCA of the APR1400 (Reference 2), uses design requirement values of the FD K-factor for large and small flow injection periods. As described in Section 2.3 of the TR fluidic device design for the APR1400 (Reference 3), the design requirement ranges of the K-factor of the FD and safety injection(SI) line from the SIT-FD nozzle to the direct vessel injection (DVI) nozzle are;

[ ]TS

Among the design requirement ranges of K-factor above, the CAREM determines the most conservative K-factors based on the sensitivity study. Using the conservative K-factor in large flow and small flow mode, LBLOCA calculation was performed and the results have enough margins to meet the acceptance criteria. The detailed results of the K-factor sensitivity study and modeling of the SIT-FD are described in Appendix H of the TR CAREM.

The CFD analysis was specifically performed to confirm the occurrence of cavitation phenomena, a detailed flow structures and its impact related to the performance of the SIT-FD. First, the boundary conditions of the CFD analysis are fixed using the test data, and then the performance of the SIT-FD, K-factor is predicted using the cavitation model. If the CFD results indicate good similarity for measured K-factor, predicted flow structure and cavitation can be justified.

As above mentioned, the SIT flow rates of the test data are used for the boundary conditions of the CFD analysis thus the SIT flow rates should be same with the test data to satisfy the continuity equation in the governing equations of CFD analysis as shown in Figure RAI-15-6.

The CFD evaluated K-factors in some cases deviate from the uncertainty ranges of the test but all cases are similar with the test data as shown in Figure RAI-15-5.

The CFD results show the occurrence of vaporous cavitation in the center of the exit nozzle and the discharge tube in both large and small flow mode as shown in Figure RAI-15-1 and Figure RAI-15-3.

In conclusion, if cavitation occurs in both large and small flow mode, the impacts of the cavitation phenomena are inherently included in the test results, such as the SIT flow rates and FD K-factor.

References for Question 15

1. *APR1400-K-A-NR-14005-P, Rev. 0, "CFD Analysis of Fluidic Device", June, 2014.*
2. *APR1400-F-A-TR-12004-P, Rev. 0, "Realistic Evaluation Methodology for Large-Break LOCA of the APR1400", December, 2012.*
3. *APR1400-Z-M-TR-12003-P, Rev. 0, "Fluidic Device Design for the APR1400", December, 2012.*

TS

Figure RAI-15-1 Iso-surface of void fraction in large flow mode
(Void fraction =0.5)

TS

Figure RAI-15-2 Absolute pressure distribution in large flow mode

TS

Figure RAI-15-3 Iso-surface of void fraction in low flow mode (Void fraction =0.5)

TS

Figure RAI-15-4 Absolute pressure distribution in small flow mode

TS

Figure RAI 15-5 Comparison between the test results and CFD evaluated results for K-factor

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Figure RAI 15-6 Comparison between the test results and CFD evaluated results for mass flow rate

Question 17

Each supply nozzle has a facing angle of [ ]TS with a neighboring control nozzle in the vortex chamber in order to minimize the swirling flow effect.

c) What is the effect of the facing angle uncertainty on the K-factor of large flow period?

Response

c) Table RAI-17-1 shows the results for facing angle sensitivity analysis using the CFD code (Reference 1).

In large flow mode, the maximum difference of CFD evaluated K-factor between the maximum tolerance design and the nominal design is [ ]TS in L1 case. In small flow mode, the maximum difference of K-factor between the maximum tolerance design and the normal design is [ ]TS in S1 case.

As described in the Reference 2, the total uncertainty of K-factor is [ ]TS in the large flow mode, and is [ ]TS in the small flow mode. The CFD evaluated K-factors in small flow mode are within the uncertainty ranges of the test results but the K-factors in large flow mode deviated from the uncertainty ranges.

Meanwhile, the design requirement ranges of the K-factor from the SIT-FD to DVI nozzle are;

[ ]TS

Since the range of the K-factor of the expected SI line from the SIT-FD nozzle to the DVI nozzle is [ ]TS hence the design requirement ranges of the FD K-factor are;

[ ]TS

Among the design requirement ranges of K-factor above, the CAREM (Reference 3) determines the most conservative K-factors based on the sensitivity study. Using the conservative K-factor in large flow and small flow mode, LBLOCA calculation was performed and the results have enough margins to meet the acceptance criteria. The detailed results of the K-factor sensitivity study and modeling of the SIT-FD are described in Appendix H of the TR CAREM.

Therefore, the CFD evaluated K-factors of the maximum tolerance designs in large flow mode satisfy with the design requirement ranges of the FD K-factor.

In conclusion, the facing angle effect originated from the manufacturing tolerance has an insignificant effect on the performance of the SIT-FD.

References for Question 17

1. *APR1400-K-A-NR-14005-P, Rev. 0, "CFD Analysis of Fluidic Device", June, 2014.*
2. *APR1400-Z-M-TR-12003-P, Rev. 0, "Fluidic Device Design for the APR1400", December, 2012.*
3. *APR1400-F-A-TR-12004-P, Rev. 0, "Realistic Evaluation Methodology for Large-Break LOCA of the APR1400", December, 2012.*

Table RAI-17-1 Analysis results for the facing angle sensitivity analysis

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