KHNP Response to Request for Additional Information No. 2-7371

Question 1

Please provide the following documents referenced in the topical report (TR) APR1400-Z-M-TR-12003-P, Rev. 0:
a) Data Base of Fluidic Device Performance Verification Experiment, KAERI/THETA-FD2, Rev.1 (2012)
b) Quality Assurance Manual, APR1400 Fluidic Device Verification Experiment (2003)
c) Quality Assurance Procedures, APR1400 Fluidic Device Verification Experiment (2003)
d) FD Performance Repeatability Experimental Procedure, FD-EP-01 (2004)

Response

The above documents are separately attached as PDF files.
Attachment A. FD Database Report-P.pdf
Attachment A. FD Database Report-NP.pdf
Attachment B. FD Quality Assurance Manual-NP.pdf
Attachment C. FD Quality Assurance Procedures-NP.pdf
Attachment D. FD Experimental Procedure-P.pdf
Attachment D. FD Experimental Procedure-NP.pdf

Question 2

TR section 4.2 describes four (4) cases of tests carried out to verify the performance of the VAPER SIT with test conditions summarized in Tables 4.2-1 through 4.2.5.

a) Are the numbers of test cases sufficient to cover the application range of SIT?
b) What are the ranges of the applicability of the SIT-FD test results in terms of SIT pressure, RCS pressure, temperature, dissolved nitrogen, (other parameters?) etc.?

Response

a) The test cases presented in the topical report with the basis of the above parameters are sufficient to cover the SIT-FD application range. In the early phase of APR1400 SIT-FD, the basic design parameters were determined through the tests conducted at a small scale test facility of [ ]TS Then, the full-scale tests were conducted with the purpose of final design confirmation. In conducting the full scale tests, [ ]TS were considered as the major parameters that affected the performance of the SIT-FD.

b) The applicable ranges of the VAPER SIT-FD test results are provided in Table RAI-2

Table RAI-2 Test range and plant operation range

[ ]TS

1) [ ]TS psig is the initial SIT pressure in Case-01-04 Test.
2) [ ]TS psig corresponds to 95% of plant operation pressure of [ ]TS psig.
3) [ ]TS psig is the RCS pressure which corresponds to the pressure difference of [ ]TS psig between SIT nominal pressure ([ ]TS psig) and RCS pressure.
4) As described in the answer to the APR1400-RAI-16, the two-phase flow formed by the air through the empty stand pipe causes higher pressure drop across the FD than the two-phase flow formed by the evolution of dissolved nitrogen when the gas quality is the same. As described in topical report Section 5.2, the maximum nitrogen gas flow rate is

much smaller than the air flow rate during the period of [ ]^{TS} seconds. Therefore, the VAPER test results cover the range of dissolved nitrogen gas up to the saturated dissolution of nitrogen with respect to its effect on the FD K-factor.

Question 3

Figure 4.3-1 shows the water level changes in the SIT and the stand pipe for Case-01 tests. Section 4.3.1 states that the base elevation of the SIT water level is the bottom of the SIT, and the base elevation of the stand pipe water level is [ ]$^{\text{TS}}$ mm higher than the top surface of the FD. As a result, the base elevation of the stand pipe water level is [ ]$^{\text{TS}}$ mm higher than that of the SIT water level.

a) Does this mean that the SIT water level shown in Figure 4.3-1 must subtract [ ]$^{\text{TS}}$ mm in order to have direct comparison with the stand pipe water level (having the same reference base elevation)?
b) What is the reason for not using the same reference base elevation on the same figure?

Response

a) Yes. We can subtract [ ]$^{\text{TS}}$ *mm from the SIT water level to have the same base elevation with the stand pipe water level. The following two figures show the locations of the pressure tabs for the measurements of SIT and stand pipe water levels.*

b) The water levels were measured using differential pressure transmitters. The pressure impulse lines of the transmitters were connected to the bottom of the SIT for the SIT water level, and to the bottom part of the stand pipe for the stand pipe water level. The actual locations to which the pressure impulse lines were connected were used as the base elevation for each water level. There is no special reason for not using the same base elevation.

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Figure RAI-3 Pressure Tab Locations for SIT and Stand Pipe Water Level Measurements

Question 4

Figure 4.3-2 shows comparison of the water level changes in the SIT and the standpipe for various test cases. Why does Case-02-01 have the stand pipe water level higher than the stand pipe elevation?

Response

The stand pipe used for Case-02 Tests was [ ]$^{\text{TS}}$ higher than the stand pipe used for other test cases. The pressure tab located in the upper part of the stand pipe was moved [ ]$^{\text{TS}}$ higher in Case-02 Tests, and the SIT water level was also increased by the height increased in the stand pipe to maintain the same SIT water inventory for large flow period.

Question 5

Section 4.3 describes the FD test results with time-averaged FD K-factors for various test cases summarized in Table 4.3-1. Figure 4.3-6 depicts FD K-factors as a function of time for only the base case of each of the four test cases.
For test cases 02, 03, and 04, please provide the test results for all cases similar to Figure 4.3-5 for test case-01.

Response

The following three figures show the FD K-factor as a function of time for Cases-02, -03, and -04 Tests:

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Figure RAI-5-1 Pressure Loss Coefficient (K-factor) of the Fluidic Device (Case-02 Tests)

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[redacted]

Figure RAI-5-2 Pressure Loss Coefficient (K-factor) of the Fluidic Device (Case-03 Tests)

TS

[redacted]

Figure RAI-5-3 Pressure Loss Coefficient (K-factor) of the Fluidic Device (Case-04 Tests)

Question 6

Figure 4.3-11 shows the variation of air temperature in the upper region of the VAPER SIT for test Case-01-01.
a) Provide a figure showing the pressure variation on the SIT tank for the same case.
b) Provide plots for the temperature and pressure variation for all other test cases.

Response

a&b) The air temperature in the SIT was measure only for Case-01 Tests. The following two figures show the air temperature and the SIT pressure for Case-01 Tests.

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Figure RAI-6-1 Variation of Air Temperature in the Upper Region of the VAPER SIT (Case-01 Tests)

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Figure RAI-6-2 Variation of SIT Pressure (Case-01 Tests)

Question 7

Section 4.4 describes uncertainty evaluation. In Equations 4.4-1 and 4.4-2, it appears that a simplification is made such that (∂Y/∂x)=Y/X. Justify this simplification.

Response

The Equations are obtained not by the simplification, but by the partial derivatives of Equations 4.3-1 and 4.3-2 as follows:

$$W_{SI}(t) = \rho_{wtr} A_{SIT} \frac{h_{SIT}(t) - h_{SIT}(t+\Delta t)}{\Delta t}$$

$$\frac{\partial W_{SI}(t)}{\partial \rho_{wtr}} = A_{SIT} \frac{h_{SIT}(t) - h_{SIT}(t+\Delta t)}{\Delta t} = \frac{W_{SI}(t)}{\rho_{wtr}}$$

$$\frac{\partial W_{SI}(t)}{\partial A_{SIT}} = \rho_{wtr} \frac{h_{SIT}(t) - h_{SIT}(t+\Delta t)}{\Delta t} = \frac{W_{SI}(t)}{A_{SIT}}$$

$$\frac{\partial W_{SI}(t)}{\partial \Delta h_{SIT}(t)} = \rho_{wtr} A_{SIT} \frac{1}{\Delta t} = \frac{W_{SI}(t)}{h_{SIT}(t) - h_{SIT}(t+\Delta t)}$$

$$K_{FD} = \Delta P_{FD} \frac{2\rho_{wtr} A_{Pipe}^2}{W_{SI}^2}$$

$$\frac{\partial K_{FD}}{\partial \Delta P_{FD}} = \frac{2\rho_{wtr} A_{Pipe}^2}{W_{SI}^2} = \frac{K_{FD}}{\Delta P_{FD}}$$

$$\frac{\partial K_{FD}}{\partial \rho_{wtr}} = \Delta P_{FD} \frac{2A_{Pipe}^2}{W_{SI}^2} = \frac{K_{FD}}{\rho_{wtr}}$$

$$\frac{\partial K_{FD}}{\partial A_{Pipe}} = \Delta P_{FD} \frac{2\rho_{wtr} \cdot 2A_{Pipe}}{W_{SI}^2} = 2\frac{K_{FD}}{A_{Pipe}}$$

$$\frac{\partial K_{FD}}{\partial W_{SI}} = \Delta P_{FD} 2\rho_{wtr} A_{Pipe}^2 \frac{(-2)}{W_{SI}^3} = -2\frac{K_{FD}}{W_{SI}}$$

$$\left(\frac{\partial K_{FD}}{\partial W_{SI}}\right)^2 = \left(-2\frac{K_{FD}}{W_{SI}}\right)^2 = \left(2\frac{K_{FD}}{W_{SI}}\right)^2$$

Question 8

Section 4.4 provides an uncertainty evaluation, including the effects on the SIT water injection flow rate and FD K-factor of water density, SIT cross-sectional area, and the SIT water level changes within a time interval.

a) Why are uncertainties of other elements, such as the facing angle between the supply nozzle and control nozzle, and DP across the FD measurement (on K-factor calculation) not considered?

b) What are the bases of the uncertainty value assigned to each element, and the sensitivity of each element on the injection flow rate and K-factor?

Response

a) In the early phase of APR1400 SIT-FD, the facing angle was determined through the tests conducted at a small scale test facility of [ ]^{TS}. The full-scale VAPER SIT-FD was manufactured based on that facing angle. The effect of facing angle would be insignificant because the manufacturing tolerance of the facing angle is [ ]^{TS}, thus the uncertainty of the facing angle was not considered.

The uncertainty of the DP measurement across the FD is considered in the first term of RHS in topical report Eq. 4.4-2. As described in topical report Section 4.4, the elemental systematic uncertainty of the DP measurement is [ ]^{TS}.

b) The uncertainty of the water density was determined to cover the density difference between the lowest density at [ ]^{TS} and the highest density at [ ]^{TS}. The above densities cover the whole range of the density in all test cases.

The uncertainty of the SIT cross-sectional area was determined based on the dimensional inspection report provided by the manufacturer of VAPER SIT.

The uncertainties of the SIT level change, DP across the FD was determined based on the on-site calibration results.

The uncertainty of the piping cross-sectional area was set to have the same uncertainty with the SIT cross-sectional area because the dimensional inspection report was not provided.

The references [2] and [3] in the topical report define the sensitivity of the each elemental uncertainty as the partial derivative terms in Equations 4.4-1 and 4.4-2, such as $\frac{\partial K_{FD}}{\partial \Delta P_{FD}}$, $\frac{\partial K_{FD}}{\partial \rho_{wtr}}$, $\frac{\partial K_{FD}}{\partial A_{Pipe}}$, $\frac{\partial K_{FD}}{\partial W_{SI}}$.

Question 9

Section 4.4 determines the total uncertainty of FD K-factors as shown in Figure 4.4-3, and the average total uncertainty of [ ]^{TS} for the large and small flow rate periods, respectively.

a) How are these total uncertainty values combined with the K-factors in Table 4.3-1?
b) In the safety analyses, what are the values of the FD K-factors used for the large and small flow periods, respectively?

Response

a) The uncertainty is not included in the FD K-factors in topical report Table 4.3-1. The systematic uncertainty of the FD K-factor is calculated by the uncertainty propagation equation of Eq. 4.4-2 in topical report. The random uncertainty is calculated by multiplying a coverage factor (t_{95}) to the standard deviation for thirteen FD K-factors presented in Table 4.3-1. The value of [ ]^{TS} was used for the coverage factor, which corresponds to the degree of freedom of twelve (number of K-factors minus one) and 95% confidence level.
As described in topical report Section 4.6, the final FD K-factor of the VAPER tests is obtained by combining the mean value of the thirteen FD K-factors in Table 4.3-1 and the total uncertainty. In case of the large flow injection period, the mean value is [ ]^{TS} and the total uncertainty is [ ]^{TS}. As a result, the final large flow FD K-factor of the VAPER tests has the range of [ ]^{TS}. In case of the small flow injection period, the mean value is [ ]^{TS} and the total uncertainty is [ ]^{TS}. As a result, the final large flow FD K-factor of the VAPER tests has the range of [ ]^{TS}.

b) The safety injection tanks with fluidic device (SIT-FD) are mainly activated during a Large-Break Loss-of-Coolant Accident (LBLOCA).
The CAREM, the realistic evaluation methodology for LBLOCA of the APR1400, 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, the design requirement ranges of the total pressure loss coefficient (K-factor) of the FD and safety injection(SI) line form 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(total pressure loss coefficient of the FD and safety injection(SI) line form the SIT-FD nozzle to the direct vessel injection (DVI) nozzle) based on the sensitivity study. The determined K-factors (total pressure loss coefficient of the FD and SI line form the SIT-FD nozzle to the DVI nozzle) for large and small flow injection periods are;

[ ]TS

The detailed results of the K-factor sensitivity study and modeling of the SIT-FD are described in Appendix H of the TR CAREM.

For small break LOCA (SBLOCA), large flow is injected from SIT-FD during relatively larger breaks and the transient ends before small flow injection phase begins. The FD K-factor of [ ]TS is used for large flow injection phase, based on VAPER test results.

Question 10

Figure 4.3-1 and 4.3-2 show the flow rate turning point (around 30 seconds) when the SIT water level (after subtracting [ ]^{TS}) is close to the stand pipe level.

a) In all tests do the flow rate turning points (switching from large to small flow rate) occur when the SIT water level decreases to the stand pipe elevation?
b) What are the variations of the SIT water level from the stand pipe elevation observed in these test?
c) In the LOCA safety analyses, what is the criterion used to determine the flow rate turning or switchover from the large-flow injection phase to the small-flow injection phases so that the corresponding K-factors can be used?
d) How is the variation or uncertainty of the SIT water level for flow rate switching accounted for in the safety analyses?

Response

a&b) Table RAI-10 shows the Flow Rate Turning Time (Column [A]) and the difference between SIT water level and top elevation of stand pipe height at the flow rate turning time (Column [E]). The flow rate turning time corresponds to the time when the stand pipe water level starts to decrease abruptly.
Column [B] is the SIT water level at the flow rate turning time. Column [C] is the length (or height) of stand pipe. ΔH in Column [D] is the elevation difference from the reference elevation of SIT water level (SIT bottom) to the elevation at the bottom of the stand pipe. ΔH is [ ]^{TS}.
The SIT water level at the flow rate turning time is, on average, [ ]^{TS} higher than the top of the stand pipe. The standard deviation for the difference (Column [E]) is [ ]^{TS}.

c)

( )^{TS}

The results of SIT-FD model assessment against VAPER tests show that the SIT-FD model described above reasonably predicts flow rate turning time from large flow injection phase to small flow injection phase. The details of SIT-FD model assessments are described in Appendix H of TR CAREM.

d)

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Table RAI-10 SIT Water Level at Flow Rate Turning Time

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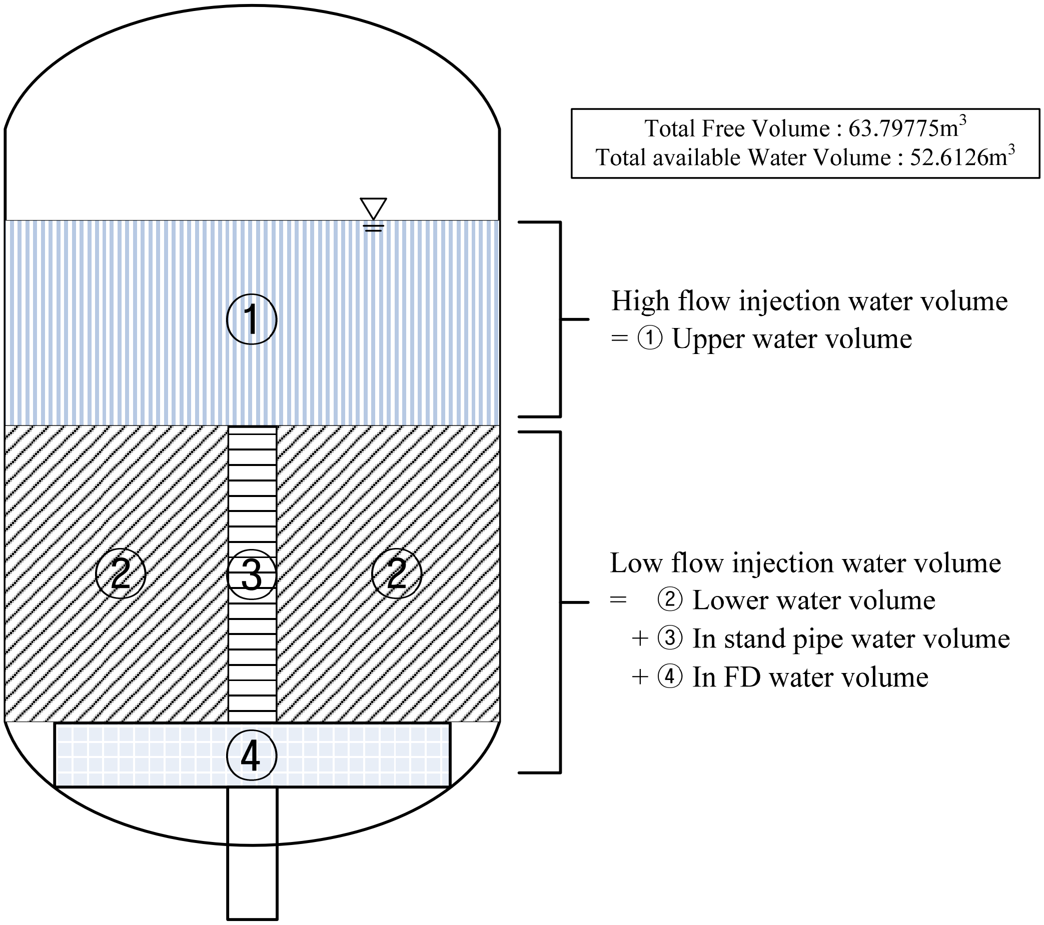

Figure RAI-10 A schematic diagram of the SIT-FD

Question 11

Section 4.1.3 states that the pressure of the stock tank is kept to be an atmospheric pressure condition during the experiment. During a LOCA, the RCS pressure will fluctuate during the transient.
What is the effect of dynamic RCS pressure fluctuations on the K-factors? Is there additional uncertainty due to this dynamic pressure fluctuation effect and how is the uncertainty, if any, accounted for?

Response

As can be seen from the Case-01-04 test result, the FD K-factor was not affected when the pressure difference between SIT and RCS was reduced to about [ ]^{TS}. Rapid pressure transient of RCS occurs in large flow period, and a swirling flow in the fluidic device does not appear during that period. Therefore, the effect of system pressure on the FD K-factor has similarity to the effect of system pressure on the discharge coefficient of venture device, which is insignificant as generally accepted.
The rate of change in the pressure difference between SIT and RCS might affect the FD K-factor. Figure RAI-11 shows the typical pressure difference change calculated by RELAP 5/MOD3 for APR1400 LBLOCA, and the pressure difference changes obtained from the VAPER tests (Case-01-04 and Case-01-04). The effect of the pressure difference change of APR1400 is covered by the VAPER tests.
Therefore, we determined that the K-factor would not be affected by the RCS dynamic pressure fluctuation, and the uncertainty due to this pressure fluctuation was not considered.

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Figure RAI-11 Changes in the pressure difference between SIT and RCS

Question 12

Test Case-01-04 has the initial SIT tank pressure of [ ]^{TS}, which is about [ ]^{TS} of the initial SIT pressure of [ ]^{TS} psig for all other test cases. Section 4.3.3 states that as indicated in Table 4.3-1, Case-01-04 test showed that the pressure loss coefficient of the FD was not dependent on pressure difference between the SIT and the RCS. However, Table 4.3-1 shows that the time-averaged FD K-factor of [ ]^{TS} for the large-flow phase for Case 01-04 is lower than all other cases with K factor of [ ]^{TS}.
Please clarify the statement that the FD K-factor was not dependent on the SIT-RCS pressure difference.

Response

In order to examine the effect of the pressure difference between SIT and RCS on the FD K-factor, we should compare the test results which have the same test conditions except the pressure difference between SIT and RCS. That is, the FD K-factor of Case-01-04 should be compared with the FD K-factors of Case-01-01, Case-01-02, and Case-01-03.
The average difference between the FD K-factor of Case-01-04 and the other three FD K-factors is [ ]^{TS}. The standard deviation of the three FD K-factors of Case-01-01, Case-01-02, and Case-01-03 is [ ]^{TS}, and the 't' value of t-distribution with 95% confidence level is [ ]^{TS}. As a result, the random uncertainty for the three FD K-factors is [ ]^{TS}.
The average difference of [ ]^{TS} between Case-01-04 and the other three test cases is less than half of the random uncertainty of [ ]^{TS}, thus it falls within the uncertainty range with sufficient margin. Therefore, we can conclude that the FD K-factor is not dependent on the SIT-RCS pressure difference.

Question 13

Figure A-5 of Appendix A of the TR, titled "Drawing of the SIT and FD of the VAPER Facility," shows the drawing of the discharge pipe connected to the exit nozzle, with the inside diameter of the discharge pipe of [ ]^{TS} mm. This appears to be contrary to the statement in Sections 4.1.3 and 5.1 that the inner diameter of the discharge pipe line of the VAPER test facility is [ ]^{TS} mm, which is also different from the diameter of the SI discharge line ([ ])^{TS} of the APR1400.

a) Do figures in Appendix A represent the dimensions for the VAPER test facility or the APR1400 design?
b) Are the drawings of the exit nozzle drawing and discharge pipe in Figures A-4 and A-5 representing VAPER facility or APR1400?
c) What are the exit nozzle dimensions for the VAPER facility and APR1400?

Response

a) Figures A-1 to A-4 in Appendix A of the TR represent the dimensions for the VAPER test facility. But, figures A-5 represents neither the VAPER test facility nor the APR1400 design. Figure A-5 was inadvertently included in the report. The TR will be revised replacing this figure with the correct figure, which represents the dimension for the VAPER test facility.

b) Figures A-5 represents neither the VAPER test facility nor the APR1400 design. Figure A-4, which is a correct figure, represents the VAPER test facility. Figure A-5 was inadvertently included in the report. The TR will be revised replacing this figure with the correct figure, which represents the dimension for the VAPER test facility.

c) Figures RAI-13-1 shows the discharge tube of the VAPER SIT-FD. Figure RAI-13-2 and RAI-13-3 show the exit nozzle and discharge tube of the APR1400 SIT-FD. Major dimensions of each of the exit nozzle and discharge tube are presented in Table RAI-13.

Table RAI-13 Dimensions of exit nozzles and discharge tubes of VAPER SIT-FD and APR1400 SIT-FD

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Figure RAI-13-1 Drawing of Discharge Tube of VAPER SIT-FD

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Figure RAI-13-2 Drawing of Exit Nozzle of APR1400 SIT-FD

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Figure RAI-13-3 Drawing of Discharge Tube of APR1400 SIT-FD

Question 14

Section 4.3.4 provides a calculation of air discharge from the SIT, and shows the inception of air discharge at around [ ]^{TS} for Test Case-01. It also provides the average values of the FD K-factor for the periods of [ ]^{TS} seconds, [ ]^{TS} seconds, and [ ]^{TS} seconds, from the evaluation of the case 01-01 test at the small flow condition, which shows a variation of about [ ]^{TS}. It then concludes that the difference among the FD K-factor averaged over different time periods would be primarily due to random unsteadiness of the swirling flow inside the vortex chamber of the FD, and the FD K-factor was not sensitive to the amount of air discharge flow rate for the period of [ ]^{TS} seconds. Please explain how KHNP arrived at this conclusion?

Response

Short term random fluctuations are expected due to very short fluctuations in turbulent flow and instrument noise. A short term fluctuation of the SIT water level measurement results in an amplified short term time variation of the FD K-factor.

The FD K-factor is inversely proportional to the square of the SI water injection flow rate (Eq. 4.3-2 in TR), and the SI water injection flow rate is proportional to the time derivative of the SIT water level (Eq. 4.3-1 in TR). As a result, the FD K-factor is inversely proportional to the square of the time derivative of the SIT water level, and a subtle change in the SIT water measurement is amplified in the FD K-factor calculation, thus causing the time variation of the FD K-factor.

The random error in the SIT water level measurement randomly affects the FD K-factor calculation throughout the whole period of the SI water injection.

Figure RAI-14 shows the small flow FD K-factors of Case-01 tests (Case-01-01, 01-02, and 01-03), which are averaged for ten seconds. The time averaged FD K-factors show a periodicity, but the periodicity has still random characteristics (i.e., the times of the peaks and valleys are different among the tests). As a result, the time variation of the FD K-factor is not wholly related with the short term random fluctuation, but also related with a long term fluctuation. We presumed that it would be the unsteadiness of the swirling flow inside the vortex chamber.

Comparing the K-factors for a period of [ ]^{TS} *seconds and* [ ]^{TS} *seconds during which the air discharges throughout an empty stand pipe, there is not a noticeable change in the FD K-factor. As a result, we can conclude that FD K-factor is not sensitive to the amount of air discharge flow rate for the period of* [ ]^{TS} *seconds.*

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Figure RAI-14 Averaged FD K-factors of Case-01 tests

Question 15

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

a) Has cavitation been observed in the vortex chamber or exit nozzle during large flow and small flow injection phases in any of the tests? If cavitation was not observed in the tests, does it mean cavitation did not occur, or it might have occurred but was not detected because no means was provided to detect cavitation?
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

a) Cavitation was not detected because no means was provided to detect cavitation in all the cases of VAPER tests.

b&c) KHNP will provide CFD analysis results which include a cavitation effect on the SIT-FD performance (FD K-factors) and a series of sensitivity analysis to support for a validation of CFD methodology.

Question 16

Section 5.2 discusses the effect of dissolved nitrogen gas on the FD K-factor. It concludes that the maximum mass and volumetric flow rate of nitrogen gas are much smaller than the air discharge flow rate during the period of [ ]TS seconds, and as a result, the evolution of dissolved nitrogen gas does not materially affect the FD K-factor.

Since the air discharge is the discharge of covered air when the standpipe is emptying, which is different from the evolution of the dissolve nitrogen in the SIT water, how can it be used as a comparison for the dissolved nitrogen coming out of SIT water?

Response

In case that the evolution of dissolved nitrogen occurs, it is mixed with SI water and two-phase flow is formed. For the same mass flow rate, we expect that the pressure drop in two-phase flow is higher than that in single-phase flow. In case that a gas quality is low, the pressure drop increases with an increase in the gas quality. In case that a flow path is the same, the pressure drop increases with an increase in the migration length of the two-phase flow in the flow path.

The throat of the FD exit is the place where the pressure reaches its minimum. Therefore, the region near the FD exit is the most vulnerable place to the gaseous cavitation due to the evolution of dissolved nitrogen. On the other hand, in case that the air flows into the FD vortex chamber, two-phase flow starts to be formed from the exits of supply nozzle and control nozzle. That is the two-phase flow migrates whole through the vortex chamber and discharge tube. As a result, the two-phase flow formed by the air through an empty stand pipe has longer migration length. Thus, the air flow causes higher pressure drop than the evolution of dissolved nitrogen when the gas quality is the same for both cases. As described in topical report Section 5.2, the maximum nitrogen gas flow rate is much smaller than the air discharge flow rate during the period of [ ]TS seconds. Therefore, we expect that the evolution of dissolved nitrogen gas does not materially affect the FD K-factor.

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.

a) How is this facing angle of [ ]TS determined to be appropriate?
b) What is the manufacturing uncertainty of this facing angle?
c) What is the effect of the facing angle uncertainty on the K-factor of large flow period?

Response

a) In the early phase of APR1400 SIT-FD, the basic design parameters were determined through the tests using a small scale test facility of AEA Technology in U.K. Tests were conducted for two FDs which have the facing angles of [ ]TS. Based on the test results, the facing angle of [ ]TS was selected as a basic design parameter.

b) The manufacturing tolerance or uncertainty of the facing angle is [ ]TS.

c) KHNP will provide CFD analysis results which include a facing angle effect (under a manufacturing tolerance band) on the SIT-FD performance (FD K-factors) and a series of sensitivity analysis to support for a validation of CFD methodology.

Question 18

Since the FD verification test results are applicable to the specific FD design configuration, what process will be used to assure that no changes are made to the APR1400 SIT/FD design configuration?

Response

SIT-FD (FD) design is followed by configuration control process as follows. KAERI produced the Full Scale Test results as stated in the topical report and performed an internal QA process during design confirmation. The final FD design in U.S. will be provided to KHNP from KAERI, and then KHNP will provides the final FD design to the manufacturer, Doosan Heavy Industry (DHI), after KHNP's internal QA process. DHI will perform its internal QA process at manufacture stage. Configuration Control for the FD design will be properly maintained since each organization performs own internal QA process. KHNP is responsible for all the processes The main parameters of the SIT-FD such as SIT water volume, K-factor for large and small flow period will be described in ITAAC. Figure RAI-18 is shows a draft ITAAC for the FD design.

Table RAI-18 A draft ITAAC for the FD design

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